# Applications Handbook
# Technical Notes

# Applications Handbook

The Applications Handbook (HW/BK/0005 | 9 Jan. 2024) comprises technical notes for Curtiss-Wright products.

All controlled documents contained in the Applications Handbook are issued by date. The following is a list of the controlled documents contained in the Applications Handbook and their issue dates.

| Technical note title | Issue date \| reference number |
|---|---|
| Using the KAD/ETH/101 | 13 Oct. 2022 \| TEC/NOT/054 |
| Using the KAD/VID/103 | 29 Dec. 2017 \| TEC/NOT/055 |
| Using the KAD/CBM/102 | 29 Dec. 2017 \| TEC/NOT/056 |
| Overview of SNMP and using third party SNMP tools | 29 Dec. 2017 \| TEC/NOT/058 |
| KAD/TDC/107 cable assembly using ACD/CJB/002 reference junction block | 29 Dec. 2017 \| TEC/NOT/059 |
| Using the KAM/TCG/102 | 12 Jan. 2023 \| TEC/NOT/060 |
| Using the KAD/UAR/102 | 26 Jun. 2023 \| TEC/NOT/062 |
| Grounding and shielding of the Axon and Acra KAM-500 | 7 Dec. 2022 \| TEC/NOT/063 |
| Using the KAM/MEM/103 | 2 Sep. 2019 \| TEC/NOT/064 |
| Using the KAD/SWI/101 | 29 Dec. 2017 \| TEC/NOT/065 |
| Using the KAD/DEC/103 | 31 Jul. 2017 \| TEC/NOT/066 |
| IENA and iNET-X packet payload formats | 10 Feb. 2023 \| TEC/NOT/067 |
| Network MCS in KSM-500 | 29 Dec. 2017 \| TEC/NOT/068 |
| Xbar Switches - Filtering and Forwarding | 29 Dec. 2017 \| TEC/NOT/069 |
| Using the KAD/DSI/003/B | 6 Oct. 2022 \| TEC/NOT/071 |
| Time and leap seconds | 7 Dec. 2023 \| TEC/NOT/072 |
| Using the KAD/VID/106 | 27 Aug. 2019 \| TEC/NOT/073 |
| Using DAS Studio 3 to configure the KAD/CBM/103 | 29 Dec. 2017 \| TEC/NOT/074 |
| Using DAS Studio 3 to configure the KAD/EBM/102 | 26 Apr. 2023 \| TEC/NOT/075 |
| Using the KAD/HBM/102 | 13 Dec. 2023 \| TEC/NOT/076 |
| Using shunting processes in Ethernet systems | 3 Sep. 2019 \| TEC/NOT/077 |
| Using the KAD/UBM/104 | 29 Dec. 2017 \| TEC/NOT/078 |
| Using the KAD/UBM/103 | 26 Jun. 2023 \| TEC/NOT/079 |
| Visualization effects while reconstructing time waveforms from sampled data | 8 Mar. 2018 \| TEC/NOT/081 |
| Analog modules specifications explained | 23 Jan. 2023 \| TEC/NOT/082 |
| Using the KAM/MEM/113 | 27 Apr. 2023 \| TEC/NOT/083 |
| Using the KAM/WSI/104 | 27 May 2020 \| TEC/NOT/084 |
| Using the KAM/TCG/105 and KAM/TCG/106 | 14 Jun. 2021 \| TEC/NOT/085 |
| Using the KAD/ABM/103 | 24 Jun. 2021 \| TEC/NOT/086 |
| Using the AXN/ABM/401 | 13 Jan. 2023 \| TEC/NOT/087 |
| Using DAS Studio to configure the AXN/ENC/402 | 30 Mar. 2023 \| TEC/NOT/089 |
| Using the AXN/TCG/401 | 14 Mar. 2023 \| TEC/NOT/091 |
| AXN capabilities and FAQ | 8 Aug. 2023 \| TEC/NOT/092 |

See “Revision histories” on page 645 for details of any revisions to technical notes since the last release of the Applications Handbook.

## Obsolete documents

The following technical notes are obsolete and have been removed from the Applications Handbook.

| Technical note title | Obsolete date \| reference number |
|---|---|
| Bridge balancing and shunt calibration | 2 Feb. 2012 \| TEC/NOT/002 |
| MIL-STD-1553 and the MSB/001/B | 29 Nov. 2011 \| TEC/NOT/005 |
| ARINC-429 and the KAM/ARI/001 | 28 Nov. 2011 \| TEC/NOT/007 |
| Accuracy on KAM-500 modules | 28 Nov. 2011 \| TEC/NOT/017 |
| CAIS and KAM-500 | 28 Nov. 2011 \| TEC/NOT/021 |
| Fiber channel | 28 Nov. 2011 \| TEC/NOT/028 |
| XML | 28 Nov. 2011 \| TEC/NOT/031 |
| Using Ethernet for data transmission | 4 Jul. 2017 \| TEC/NOT/032 |
| CompactFlash | 28 Nov. 2011 \| TEC/NOT/033 |
| Ethernet data acquisition networking | 28 Nov. 2011 \| TEC/NOT/034 |
| Capturing Asynchronous IRIG-106 PCM Streams | 28 Nov. 2011 \| TEC/NOT/036 |
| Using the KAD/ETH/001/B | 10 Jan. 2017 \| TEC/NOT/038 |
| Using the KAM/MEM/003/B | 10 Jan. 2017 \| TEC/NOT/039 |
| SSR-500 recorder data formats and storage | 8 Sep. 2014 \| TEC/NOT/050 |
| Using recorders | 20 Aug. 2012 \| TEC/NOT/057 |

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# Table of contents

Chapter 1

# Strain gages and ideal bridges

TEC/NOT/001

This paper introduces the basics of strain gage theory and the terminology used. It examines how these gages can be used in a variety of ways with Wheatstone bridges, focusing on how strain can cause a change in resistance, which in turn causes a voltage change across the bridge that can be measured. Also, the relationship between the output voltage and the change in resistance is described for the more popular bridge configurations.

The following topics are discussed:



## 1.1 Stress and strain

The following figure displays a piece of metal fixed at one end and attached to a dangling mass at the other.

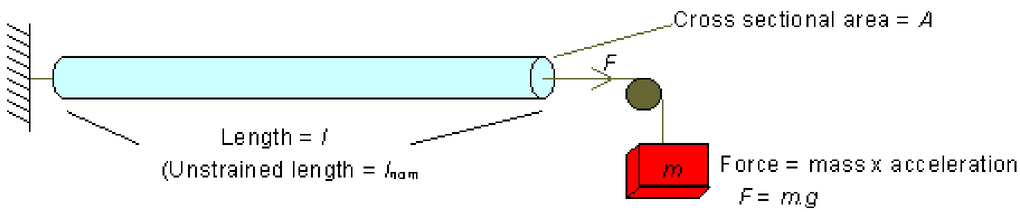



*Figure 1-1: A beam under stress*

The mass (m) causes a force (F), which places the beam under stress ($\sigma$), causing the beam to increase in length ($l_{nom} \rightarrow l$).

$$Stress \Rightarrow \sigma \equiv \frac{F}{A}$$

In this paper, "≡" denotes "equal by definition" and the subscript "nom" denotes "the unstrained/unstressed or nominal condition".

Strain is a measurement of the fractional change in length and is defined as:

$$Strain \Rightarrow \varepsilon \equiv \frac{l - l_{nom}}{l_{nom}}$$

For certain materials, there exists a small elastic range where the strain is linear with respect to stress. In particular Hooke's law states:

$$\varepsilon \cong \frac{\sigma}{E}$$

where *E* is Young's modulus.

If, as in the previous figure, the force is perpendicular to the cross-section and positive, then the force is said to be uniaxial and tensile. If the force is negative, then it is said to be compressive. If the force acts along the cross section, then it is said to be shear stress (see the following figure).

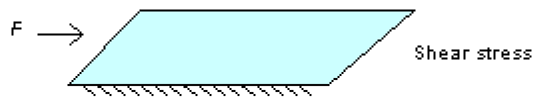



*Figure 1-2: Shear stress*

Typical strains are in the order of parts per million (ppm) and it is common to use the term $\mu\varepsilon$ (micro-strain) defined as follows:

$$\mu\varepsilon \equiv \varepsilon \cdot 10^6 = \frac{l - l_{nom}}{l_{nom}} \cdot 10^6$$

## 1.2 Strain and fractional change in resistance

The following figure exaggerates how the shape of a piece of metal changes with strain.

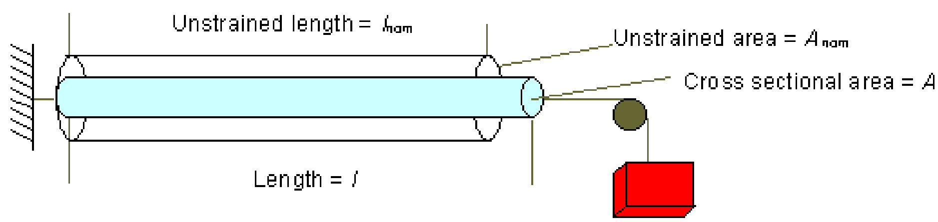



*Figure 1-3: How the shape of a cylinder changes when stretched*

The resistance of a piece of metal is proportional to its length ($l$) and inversely proportional to its cross sectional area ($A$). The volume ($V$), which remains constant, is a product of length and area ($V=l.A$). In other words:

$$R \propto \frac{l}{A}$$

The constant of proportionality is $\rho$, the material resistivity:

$$R = \frac{\rho l}{A} = \rho\frac{l}{V/l} = \rho\frac{l^2}{V}$$

Because strain is defined as a fractional change in length, the resistance (which is a function of length as just shown) can be used as a means of measuring strain.

The fractional change in resistance ($\delta$) can be defined as:

$$\delta \equiv \frac{R - R_{nom}}{R_{nom}}(\Omega/\Omega)$$

Substituting the equation for *R* above (and canceling *V* and the resistivity constant) this becomes:

$$\delta = \frac{l^2 - l_{nom}^2}{l_{nom}^2} = \left(\frac{l}{l_{nom}}\right)^2 - 1$$

From the definition of strain $\varepsilon$:

$$\varepsilon \equiv \frac{l - l_{nom}}{l_{nom}} = \frac{l}{l_{nom}} - 1 \Rightarrow \frac{l}{l_{nom}} = \varepsilon + 1$$

Combining the last two equations gives a formula for fractional change as a function of strain:

$$\delta = (\varepsilon + 1)^2 - 1 = 2 \cdot \varepsilon + \varepsilon^2$$

For very small strains the second order term is sometimes ignored:

$$\delta \cong 2 \cdot \varepsilon$$

Hence the nominal gage factor ($F_G$) of 2 used for strain gages.

Even if the gage factor is not 2 (or is not even linear) it must be known (from manufacturers data sheets) or deduced (from experience or calibration). The rest of this paper, apart from a short discussion of errors, assumes the gage factor is known and concentrates on measuring $\delta$.

## 1.3 Sources of error in the gage

The following sources of error are evident in strain gage systems:

- The bridge itself
- The measurement equipment

This section looks briefly at some of the errors that can exist in the bridge itself due to bonding and temperature. Other application notes look at errors in the measurement equipment.

### 1.3.1 Temperature errors

Strain gages on airplanes are rarely kept at a constant temperature. To measure the resistance, current is applied, which causes power dissipation (heating) in the gage.

Sometimes referred to as pseudo-strains, heating causes the following types of errors:

- As the gage, bonding and member change temperature, they expand or contract at different rates. In other words, with a constant stress the strain changes.
- The resistivity of the gage (and hence its resistance) changes with temperature.

These errors can be somewhat compensated for with a known gage, current, type of bonding and material by measuring the temperature. However this is not always practical.

Certain gages when used with specific current, bonding and material are designed to self compensate.

In bridge circuits advantage is often taken of the fact that the absolute resistance values of bridge arms is less important than the ratio (see “1.4 The Wheatstone bridge and Poisson’s ratio” on page 4) so that gages can have compensation arms (bonded perhaps at right angles to the strain being measured).

### 1.3.2 Bonding errors

Great care must be taken when bonding gages to a structure.

If the gage is not parallel to the strain being measured, this causes an error. For example, even being out by 2.5° causes approximately 0.1% gain error.

If the gage is not flat, it appears shorter with respect to the direction of strain, thus causing a gain error.

If the bonding material is not of the correct type and thickness, the heat dissipation will not be as expected and hence a strain error will be induced on the gage.

## 1.4 The Wheatstone bridge and Poisson’s ratio

The bridge has two sides (left and right) and four arms (see the following figure).

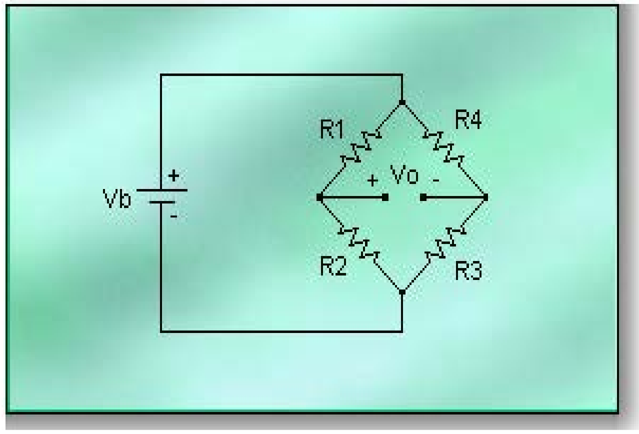



*Figure 1-4: The Wheatstone bridge*

On the left hand side, $R1$ and $R2$ act as a resistor divider so $V_{0+}$ can be calculated as:

$$V_{0+} = V_b \frac{R2}{R1 + R2} = V_b \frac{1}{1 + (R1)/(R2)}$$

Similarly for the right hand side $V_{0-}$:

$$V_{0-} = V_b \frac{R3}{R3 + R4} = V_b \frac{1}{1 + (R4)/(R3)}$$

$V_0$ = $V$+ minus $V$- is therefore:

$$V_0 = V_b \cdot \left( \frac{1}{1 + (R1)/(R2)} - \frac{1}{1 + (R4)/(R3)} \right)$$

If the ratio on one side equals that on the other ($R2/R1 = R4/R3$), the output voltage ($V_0$) is 0V. The fact that the ratios determine the output enables compensation gages to be used to compensate for bonding and temperature errors.

In the previous figure, if $R2$ was a gage, $R1$ could be used to compensate for some of the errors. However, to do this it should ideally be of the same type and bonded as close as possible to $R2$. It must be bonded perpendicularly to $R2$ so as not to cancel out $R2$ altogether.

The following figure exaggerates how the perpendicular gage experiences a strain of opposite polarity, but of smaller magnitude. This ratio of the transverse magnitudes is known as Poisson's ratio ($\nu$) and for most metals is approximately 0.3.

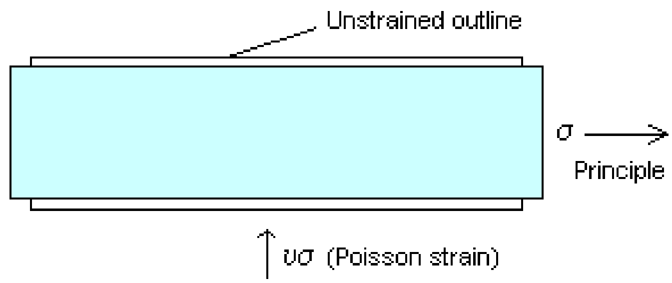



*Figure 1-5: An illustration of transverse strain*

Sometimes the compensation gage can be mounted so that the strain is the same magnitude but of opposite sign, as with bending beams as displayed in Figure 1-6 on page 6.

## 1.5 Resistance as a function of fractional change

Previously in this paper, the fractional change in resistance for a resistor was defined as:

$$\delta \equiv \frac{R - R_{nom}}{R_{nom}}$$

This can be rewritten as:

$$R = R_{nom} \cdot (\delta + 1)$$

In the analysis which follows, resistance values of active gages are replaced with the above equation.

In particular, a Poisson gage, when used, is written as:

$$R = R_{nom} \cdot (-\nu\delta + 1)$$

where $\nu$ is the Poisson ratio, and the negative sign indicates strain in the opposite direction to the principle axis.

The following figure illustrates the use of Poisson compensation and “opposed” compensation as used on bending beams.

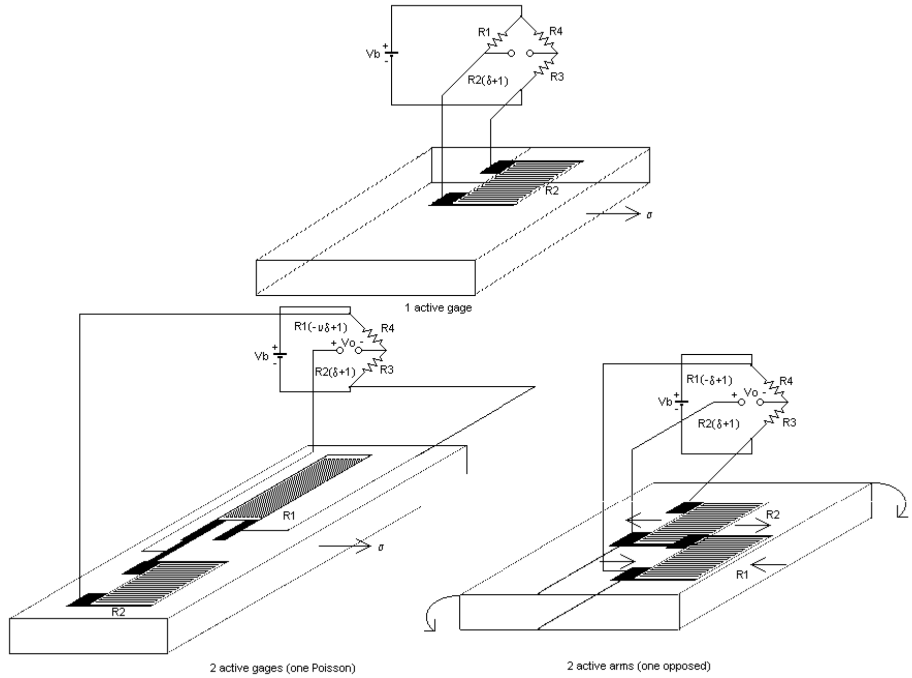



*Figure 1-6: An uncompensated gage and two types of compensation*

In the next section, the output voltage ($V_0$) as a function of the fractional change ($\delta$) is examined. The inverse function, $\delta$, is as important a function of $V_0$.

Knowing the output voltage of a bridge, how is the fractional change causing it, and hence the strain, calculated?

The analysis is carried out using the two active arms with Poisson as shown in the previous figure. One reason for this is the equations for the single gage can be got by setting $\nu$=0 and for the opposed configuration by setting $\nu$=1.

## 1.6 Equations for two active gages, one of which is Poisson

The following figure displays two active gages, one of which (*R*1) is mounted perpendicular to the uniaxial stress and hence experiences a transverse (Poisson) strain. An amplifier with a gain (*G*) is also displayed.

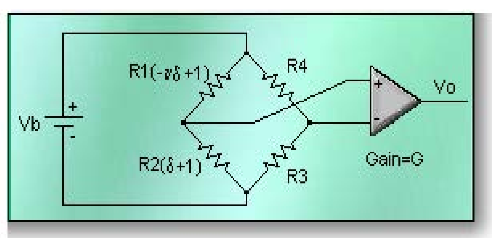



*Figure 1-7: Bridge with two active arms (one Poisson) and amplifier*

The output voltage of the amplifier is defined as:

$$V_0 = G \cdot V_b \cdot \left( \frac{1}{1 + \frac{R1_{nom}}{R2_{nom}} \cdot \frac{(-\nu\delta + 1)}{(\delta + 1)}} - \frac{1}{1 + \frac{R4}{R3}} \right)$$

Given a bridge that is balanced in the unstrained condition (that is, $R1_{nom}/R2_{nom} = R4/R3 = 1$), the equation becomes:

This is the relationship between $V_0$ and $\delta$. For small $\delta$ this is almost linear and the sensitivity (*S*) can be defined as:

$$V_0 = G \cdot V_b \cdot \left(\frac{(\delta + 1)}{2 + \delta \cdot (1 - \nu)} - \frac{1}{2}\right) = G \cdot V_b \cdot \frac{\delta \cdot (1 + \nu)}{2 \cdot \delta \cdot (1 - \nu) + 4}$$

$$S \equiv Limit \frac{V_0}{\delta}\bigg|_{\delta \to 0} \Rightarrow S = \frac{G \cdot V_b \cdot (1 + \nu)}{4}$$

From the last two equations, to get the relationship between δ and $V_0$:

$$\left(V_0 = S \cdot \frac{\delta}{1 + 0.5 \cdot \delta \cdot (1 - \nu)}\right) \Rightarrow \frac{V_0}{S}(1 + 0.5 \cdot \delta \cdot (1 - \nu)) = \delta$$

Bringing the terms with $\delta$ to the left gives:

$$\delta \cdot \left(\frac{V_0}{2 \cdot S}(1 - \nu) - 1\right) = -\frac{V_0}{S}$$

Therefore,

$$\delta = \frac{1}{\frac{S}{V_0} - \frac{(1 - \nu)}{2}}$$

A Maclaurin (or Taylor about 0) series expansion gives:

$$\delta = \frac{1}{S}\left(V_0 + 2(1 - \nu) \cdot V_0^2 + 4 \cdot (1 - \nu)^2 \cdot V_0^3 + 8 \cdot (1 - \nu)^3 \cdot V_0^4 + \ldots (2 - 2 \cdot \nu)^{n-1} \cdot V_0^n\right)$$

These equations have been derived for seven types of bridge as shown in the following table. If the left-hand side arms are swapped with the right-hand side then multiply the sensitivity by -1. If the top arms are swapped with the bottom arms, again multiply the sensitivity by -1.

Table 1-1: Bridge types

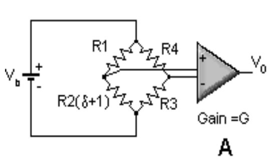
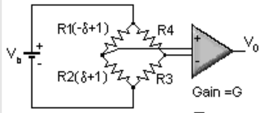
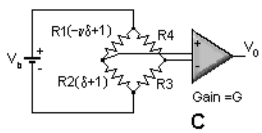
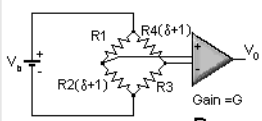
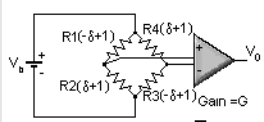
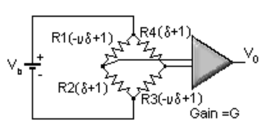
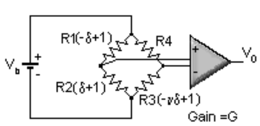
| Topology | Description | Sensitivity | Vo(δ) | δ(Vo) |
|---|---|---|---|---|
|  | One active gage in uniaxial tension or compression | $S = \frac{G \cdot V_b}{4}$ | $V_0 = S\frac{\delta}{1 + 0.5 \cdot \delta}$ | $\delta = \left(\frac{S}{V_0} - \frac{1}{2}\right)^{-1}$<br>$\delta = \frac{1}{S}\sum_{n=1}^{\infty} 2^{n-1} \cdot V_0^n$ |

Table 1-1: Bridge types

| Topology | Description | Sensitivity | Vo(δ) | δ(Vo) |
|---|---|---|---|---|
| <br>B | Two active gages with equal and opposite strains, typical of bending beam arrangement | $S = \frac{G \cdot V_b}{2}$ | $V_0 = S \cdot \delta$ | $\delta = \frac{1}{S}V_0$ |
| <br>C | Two active gages in uniaxial tension or compression, one mounted perpendicular (Poisson=*n*) | $S = \frac{G \cdot V_b \cdot (1+\nu)}{4}$ | $V_0 = S\frac{\delta}{1 + 0.5 \cdot (1-\nu) \cdot \delta}$ | $\delta = \left(\frac{S}{V_0} - \frac{1-\nu}{2}\right)^{-1}$<br><br>$\delta = \frac{1}{S}\sum_{n=1}^{\infty}(2-2 \cdot \nu)^{n-1} \cdot V_0^n$ |
| <br>D | Two active gages, for example, used on opposite sides of column with low temperature gradient | $S = \frac{G \cdot V_b}{2}$ | Same as Type A above | Same as Type A above |
| <br>E | Four active gages, paired in equal and opposite uniaxial tension or compression | $S = G \cdot V_b$ | Same as Type B above | Same as Type B above **(LINEAR)** |
| <br>F | Four active gages, in uniaxial tension or compression, two mounted perpendicular (Poisson=*n*) | $S = \frac{G \cdot V_b \cdot (1+\nu)}{2}$ | Same as Type C above | Same as Type C above |
| <br>G | Four active gages, Poisson pairs at equal strain but opposite sign, for example, beam | Same as Type F above | Same as Type B above | Same as Type B above **(LINEAR)** |

## 1.7 Straight line approximations

How important are the higher coefficients? The following table lists the approximate errors (in ppm) for assuming first, second, third or fourth order fits, for δ as a function of $V_0$, for various values of mΩ/Ω:

Table 1-2: Error calculated in respect of expected value

| δ=mΩ/Ω | me | 1st order | 2nd order | 3rd order | 4th order |
|---|---|---|---|---|---|
| 100,00 | 50,000 | -50,000 | -2750 | -150 | 8 |
| 50,000 | 25,000 | -25,000 | -600 | -20 | -0.25 |
| 10,000 | 5,000 | -5000 | -25 | 0 | 0 |

These errors are calculated with respect to the expected value. In bipolar applications, the range is twice either extreme so the errors with respect to full range is halved:

- With a 10-bit A/D system, one count corresponds to 977ppm (≈ 0.1%)
- With a 12-bit A/D system, one count corresponds to 244ppm (≈ 0.025%)
- With a 16-bit A/D system, one count corresponds to 61ppm

## 1.8 Conclusion

This paper introduced the basics of strain gage measurement using Wheatstone bridges. Equations were given relating the voltage measured on a bridge to the fractional change in resistance, which in turn is a function of strain.

While some of the sources of errors within the gage itself were briefly discussed, the assumption was made that the excitation and gain circuitry were free from errors.

## 1.9 References

A series of technical notes on strain gages are available from:


Measurements Group INC.

P.0. Box 2777

Raleigh

North Carolina 27611

USA

Applied Measurement Engineering

Charles P Wright

Prentice Hall

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Chapter 2

# IRIG-B

**TEC/NOT/003**

This paper introduces the IRIG-B time code format. In particular the physical layer, word definitions and some format types are discussed.

The following topics are discussed:



## 2.1 Overview

Many different time formats have evolved to provide for correlation of multiple devices (sources of data usually) and multiple recordings.

In October 1956, the Tele-Communications Working Group (TCWG) of the Inter-Range Instrumentation Group (IRIG) undertook the task of standardization of time code formats. In 1960, IRIG-104-60 was released. The current release is IRIG-104-98.

The IRIG time codes are continuously transmitted in well-defined cycles. At one part of the cycle, a reference marker indicates the time being transmitted. IRIG time codes are referenced by a four-digit number (see the following figure). This paper focuses on IRIG-B, although other code formats are also discussed.

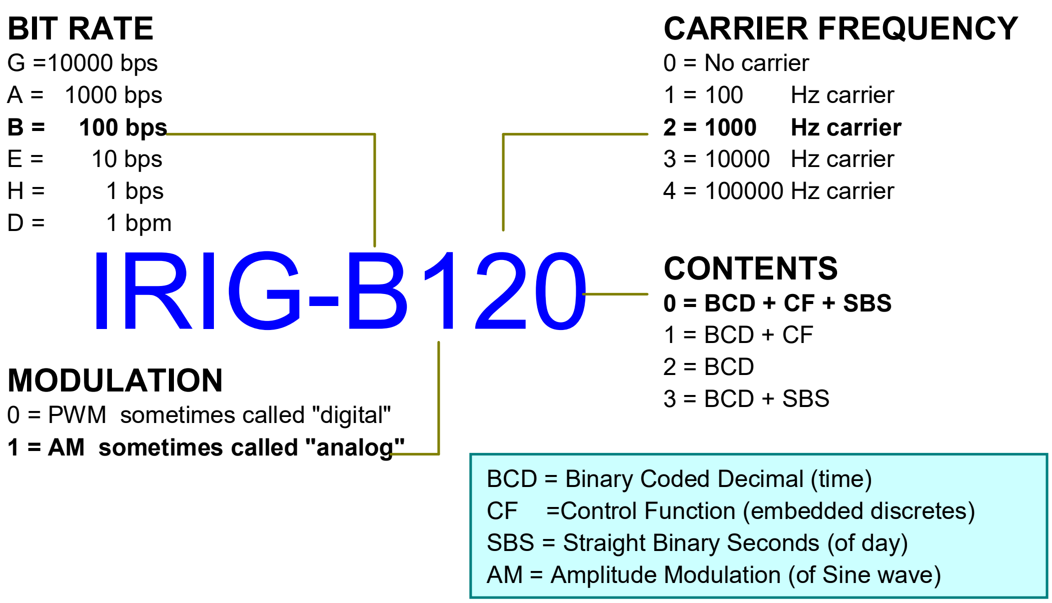


*Figure 2-1: IRIG-104-70 / IRIG-200-70 time code formats*

For IRIG-104-70, four formats were standardized with respect to format B (B000, B003, B120 and B123); others were added in IRIG-104-98.

## 2.2 The physical layer

Because the IRIG time code formats evolved from many formats already in place and because the time can be transmitted in many ways (or stored on tape), the physical layer does not form part of the definition.

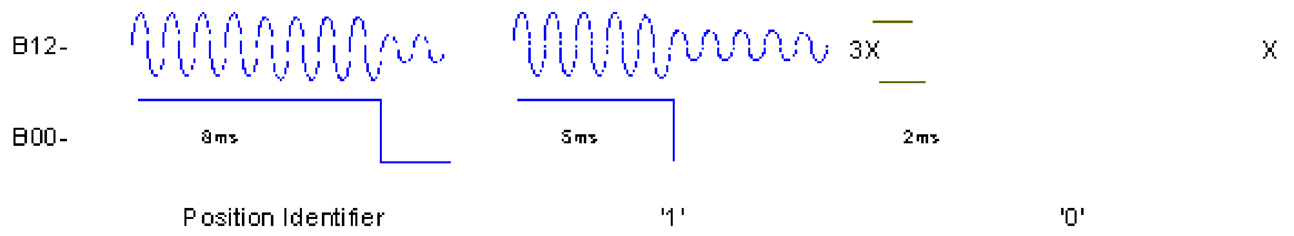


*Figure 2-2: The three type of bits used in IRIG-B*

In general one IRIG-B transmitter (generator) transmits a single-ended signal (with respect to the transmitters reference ground) that can be connected to many receivers (readers or translators*). The receivers are generally differential-ended if the distances involved are more than a few meters.

*A translator is often referred to as a reader (receiver) that displays or retransmits the time (perhaps in another code format).

## 2.3 Defining a frame

The following figure shows an IRIG-B frame.

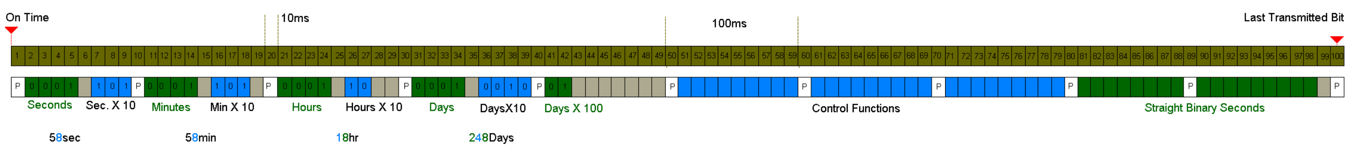


*Figure 2-3: One-second frame of IRIG-B time code format*

A frame is 1 second long. Least Significant Bits (LSBs) are transmitted first. The midpoint between two consecutive Position Identifiers indicates the start of a frame and the point of time referenced in the frame.

## 2.4 Conclusion

In this paper some of the nomenclature associated with IRIG-B was introduced. The different types of IRIG-B format were also discussed.

## 2.5 References


Datum Handbook of Time Code Formats, Datum Inc., 9975 Toledo Way, Irvine, California 92630-1819, USA

IRIG STANDARD 200-95, IRIG Serial Time Code Formats, Telecommunications and Timing Group, Range Commanders Council, Published by: Secretariat, Range Commanders Council, U.S. Army White Sands Missile Range, New Mexico 88002-5110

Chapter 3

# MIL-STD-1553

TEC/NOT/004

This paper introduces the MIL-STD-1553 bus, focusing on its physical layer, as well as word definitions and message types.

The following topics are discussed:



## 3.1 Overview

Introduced in the mid 1970s, MIL-STD-1553 Aircraft Internal Time Division Command/Response Multiplex Data Bus is a military standard (currently in revision B) that became one of the key components used today for the integration of avionics systems.

The following figure illustrates the key elements of MIL-STD-1553. The bus consists of a Bus Controller (BC), which commands up to 31 Remote Terminals (RT address 0 to 30) to transmit or receive. Data transfer is via a 1 Mbps, transformer coupled, command response bus. The bus is dual redundant in the sense that only one bus is used at a time. The other bus is used if a remote terminal fails to respond.

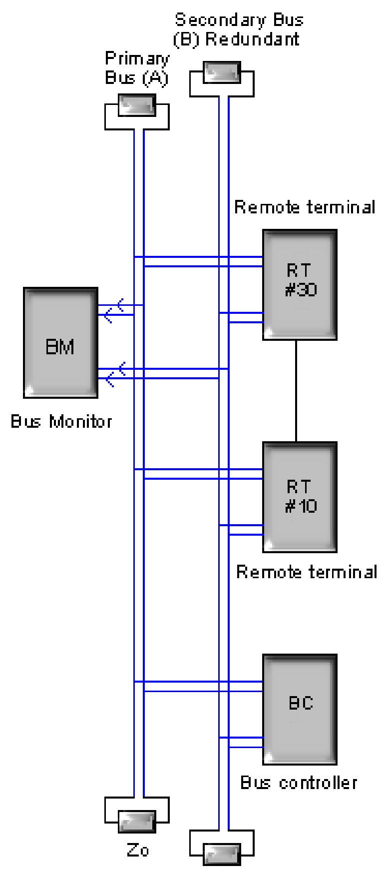


*Figure 3-1: Overview of MIL-STD-1553 bus*

Any number of bus monitors (BMs) such as the KAD/MSB/001 can be connected to the bus. BMs cannot transmit on the bus. Data is sent in 20-bit words organized into various types of messages as discussed in "3.2 The physical layer" on page 14.

## 3.2 The physical layer

The MIL-STD-1553 bus is twisted shielded pair, transformer coupled (see the following figure) for one half of the dual redundant busses.

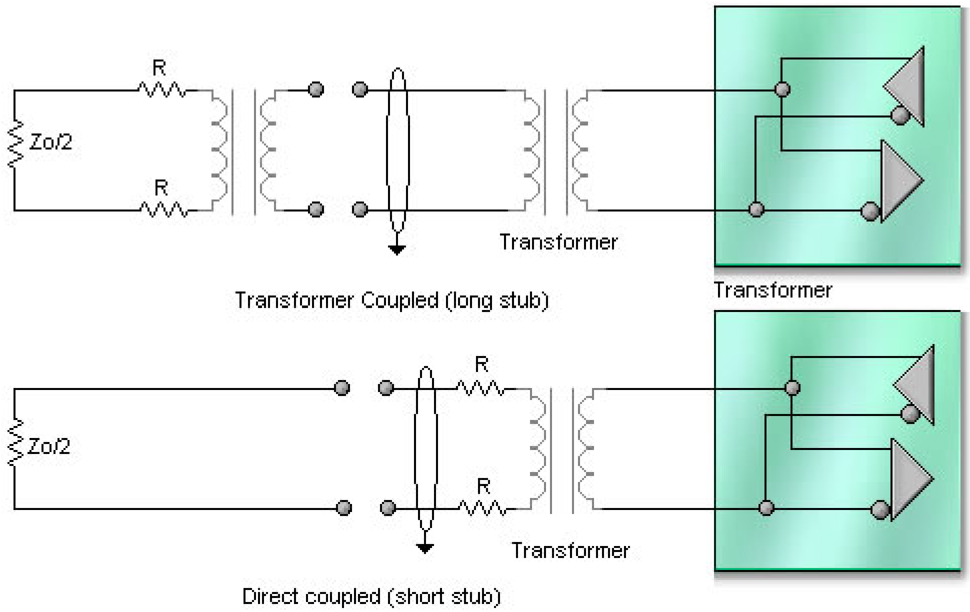


*Figure 3-2: Transformer Coupled and Direct Coupled stubs*

The high/low voltage levels are typically greater than ±10V line-to-line on the bus. Data is transferred at 1 Mbps in 20-bit words; the code used is BI∅-L (with illegal synchronization bits as described in “3.3 Word definition” on page 14).

## 3.3 Word definition

There are three types of word available on a MIL-STD-1553 (see the following figure).

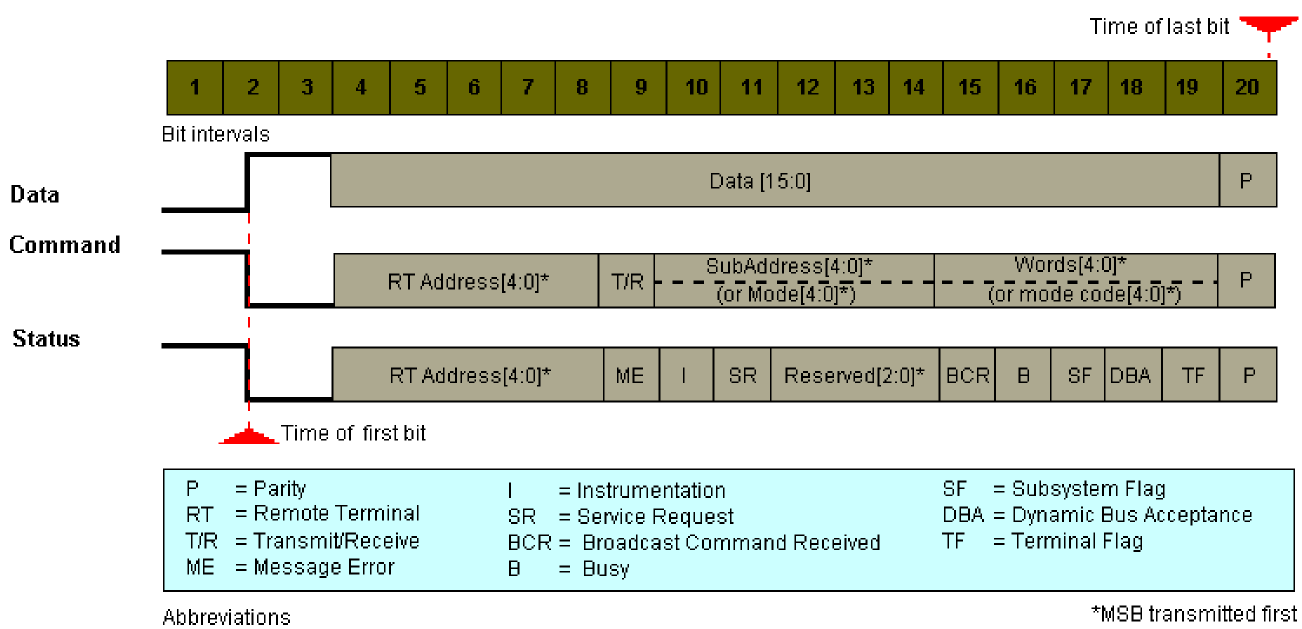


*Figure 3-3: Word definitions of MIL-STD-1553*

A word is always 20 µs long. The last bit transmitted is a parity bit (odd). The first bit transmitted is a synchronization bit that is illegal (in the sense that the bit interval is 3 µs as opposed to 1 µs for other bits).

The synchronization bit differentiates a data word from a non-data word (command or status). Occasionally (but not always), the instrumentation bit in the status word is used to differentiate a status word (I = 0) from a command word (I = 1). However, this reduces the number of available RT addresses by 50%. While command/status words are usually determined from the context in which they are received, some other rules that can be used are:

- Two consecutive non-data words must be commands (see RT-to-RT(s) in Figure 3-4 on page 16).
- If the reserved bits are zero (often the case), any set to 1 indicates a command word.
- An RT address of 31 decimal (1F hex, 11111 binary) always indicates a broadcast command.
- The first non-data word after the predefined time-out period can be assumed to be a command.

The time at which a word appears is determined by the mid-point of the sync-bit. The response time of a remote terminal is the time from the midpoint of the last bit of the last word received to the midpoint of the synchronization bit of the status word. Physically, this cannot be less than 2 µs and is usually specified as between a minimum and a maximum response time.

Words[4:0] represents the number of data words (for non-mode commands), 1 to 31 decimal with 0 meaning 32 decimal.

## 3.4 Message types

All data transfer is in messages that are always initiated by a command from the bus controller (BC). See the following figure.

When commanding a particular remote terminal (RT) to transmit or receive, the RT[4:0] bits of the command words are used to identify the RT in question. When broadcasting, the BC can command all busses to receive by setting the RT address to 31 decimal (1F hex, 11111 binary).

Only one device can transmit at a time. When a remote terminal transmits, the data is always preceded by a status word. If only one RT receives data (the data is not broadcast), the RT sends a single status word to acknowledge the transfer.

The SubAddress[4:0] specified in a command identifies what to transmit or receive.

Mode commands are short messages with either no data or just one data word. A mode command is identified by a SubAddress[4:0] = 00000 bin or 11111 bin. Many mode codes are defined as part of the standard being used (A or B) and others can be defined for a particular application. All RTs must accept all the mode codes defined for a particular application.

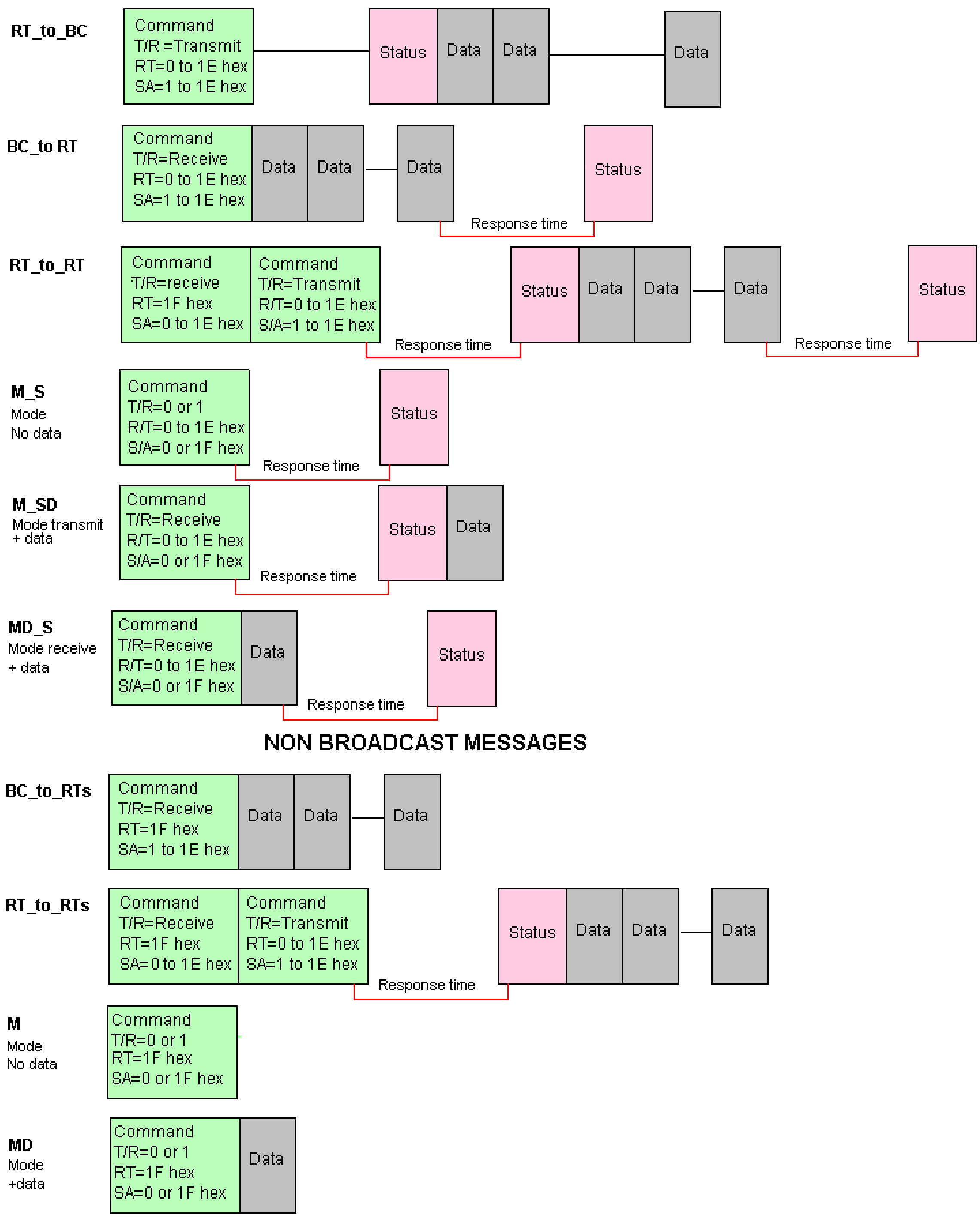


*Figure 3-4: The 10 MIL-STD-1553 message types*

| | |
|---|---|
| **RT_to_BC** | Remote terminal to bus controller |
| **BC_to_RT(s)** | Bus controller to remote terminal(s) |
| **RT_to_RT(s)** | Remote terminal to remote terminal(s) |
| **M_S** | Mode command to remote terminal |
| **M_SD** | Mode command (transmit) to remote terminal with single data word |

| | |
|---|---|
| **MD_S** | Mode command (transmit) to remote terminal with single data word |
| **M** | Broadcast mode without data word |
| **MD** | Broadcast mode with data word |

## 3.5 Dynamic change of bus control

There can be only one BC at a time. However the BC may relinquish control to a capable RT, which then becomes the new BC, hence the Dynamic Bus Acceptance (DBA) bit in the status word.

This has implications for bus monitoring. Messages must be defined not only by the receiving RT but also by the transmitting RT in case either becomes BC.

## 3.6 Conclusion

In this paper, some of the nomenclature associated with MIL-STD-1553 was introduced. The different types of words and messages were also illustrated.

## 3.7 References

MIL-STD-1553 Designer's Guide

ILC Data Device Corporation®

105 Wilbur Place

Bohemia

New York 11715-2482

Military standards:

MIL-STD-1553 A

MIL-STD-1553 B

MIL-STD-1553 Multiplex Applications Handbook

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Chapter 4

# ARINC-429

TEC/NOT/006

This paper introduces the ARINC-429 bus. In particular the physical layer and word definition are discussed.

The following topics are discussed:



## 4.1 Overview

The first revision of the ARINC-429 Mark 33 Digital information Transfer System (DITS) was generated on 11 April 1978. The current specification is ARINC-429-10.

Components connected to the busses are Transmitter (source), Receiver (sink) or Transmitter and Receiver. All data is transmitted over a single, twisted pair in one direction only.

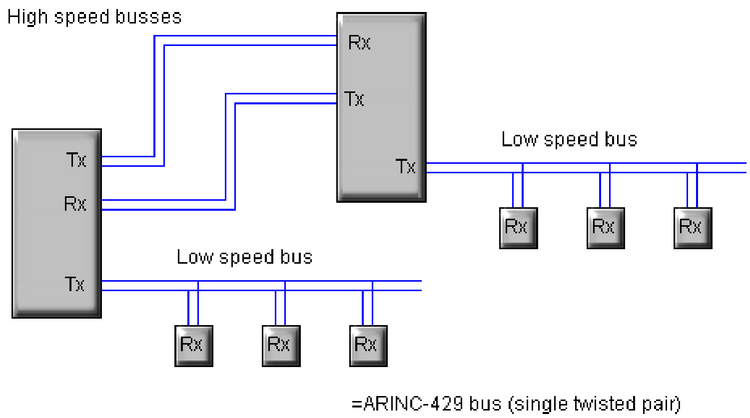


*Figure 4-1: An example ARINC-429 architecture*

A transmitter (Tx) may transmit (only) to up to 20 Receivers (Rx). If a Receiver is required to acknowledge reception of data, another ARINC-429 is required in the opposite direction.

Data is sent in single words identified by one of 255 Labels and a 2-bit Source/Destination identifier.

## 4.2 The physical layer

Data is transmitted in a bipolar return to zero (RZ) format. This is a trilevel code as illustrated in the following figure.

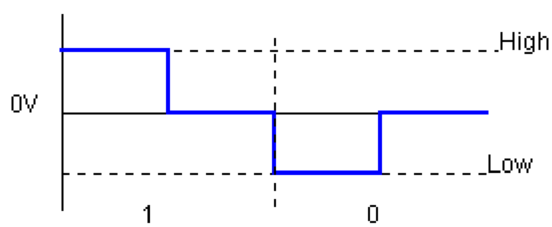


*Figure 4-2: ARINC-429's bipolar, RZ code*

For a transmitter, the high (low) voltage must be +10V ±10% (-10V ±10%). A receiver must be specified to a minimum of ±5V. The transmitter output impedance is 75Ω (±5Ω ) and should correspond to the transmission line characteristics.

There are two bit-rates associated with ARINC-429. The high speed bus is 100 kbps and the low speed bus is between 12 and 14.5 kbps. Only one data rate is allowed per bus.

ARINC-429 also specifies the data rate tolerances and rise and fall times.

## 4.3 Word definition

The general format of an ARINC-429 word is as shown in the following figure.

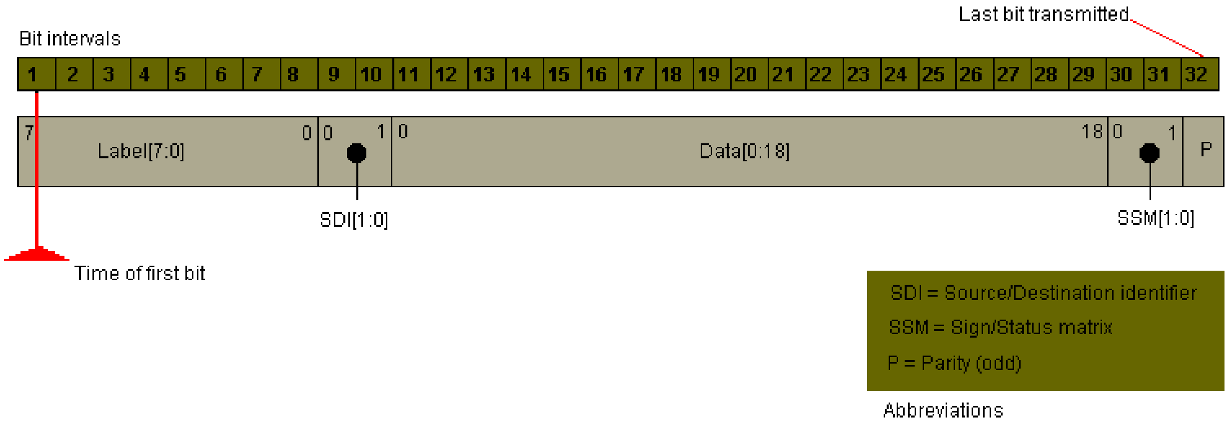


*Figure 4-3: Generic word definition for ARINC-429*

The 8-bit label identifies the parameter being transmitted.

The main purpose of the Source/Destination Identifier (SDI) bits is to direct data words to a particular receiver. The SDI bits are not used with certain types of data.

The Sign/Status Matrix (SSM) bits are used to indicate minus, south and so on for certain types of data, the word type for AIM (Acknowledge, ISO alphabet No. 5 and Maintenance) data and the status of the transmitter. For binary data, bit 29 (Data18) is used to indicate sign.

There are five types of data words:

- Binary
- BCD subset of ISO Alphabet No. 5
- Discrete
- Maintenance
- AIM

Also, file transfer is supported.

## 4.4 Conclusion

In this paper some of the nomenclature associated with ARINC-429 was introduced. The generic word definition was also discussed.

## 4.5 References


An Overview of ARINC-429

AIM USA Inc.

4547 Gateway Circle

Dayton

Ohio 45440

Standards

ARINC-429-10

Chapter 5

# Panavia

TEC/NOT/008

This paper introduces the Panavia bus, focusing on its physical layer as well as word definition and tag sequence.

The following topics are discussed:



## 5.1 Overview

Mainly used on the Tornado, Panavia is a single-source (Tx) single-sink (Rx) architecture (see the following figure). All data is transmitted over two twisted pairs in one direction only. One twisted pair is for data (NRZ-L) and the other is for a (64 kHz) data clock.

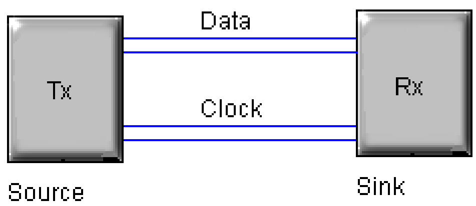


*Figure 5-1: The Panavia bus transmits point-to-point in one direction*

Data is sent in 32-bit words, each identified by one of 32 5-bit tags.

## 5.2 The physical layer

Data is transmitted in a Non Return to Zero-Level (NRZ-L) format with a data clock. The last 6 transmitted bit periods on the data line are *clocks* (illegal NRZ-L bits). The three types of bit are illustrated in the following figure.

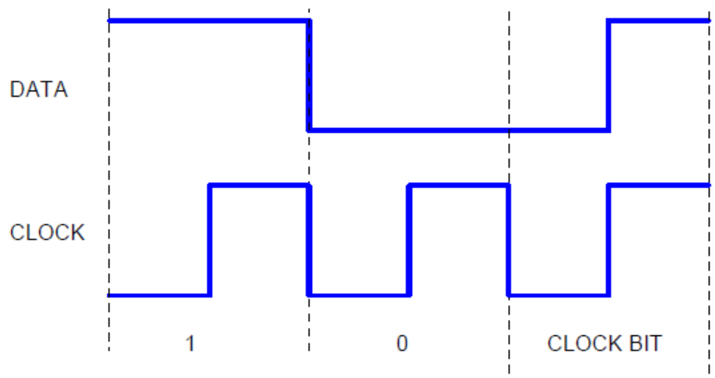


*Figure 5-2: The Panavia code for 1, 0 and clock*

Data transfer is at 64 kHz, and for a transmitter the high voltage must be between +3.5 and 5.5V.

## 5.3 Word definition

The following figure illustrates the bit definition of a Panavia word.

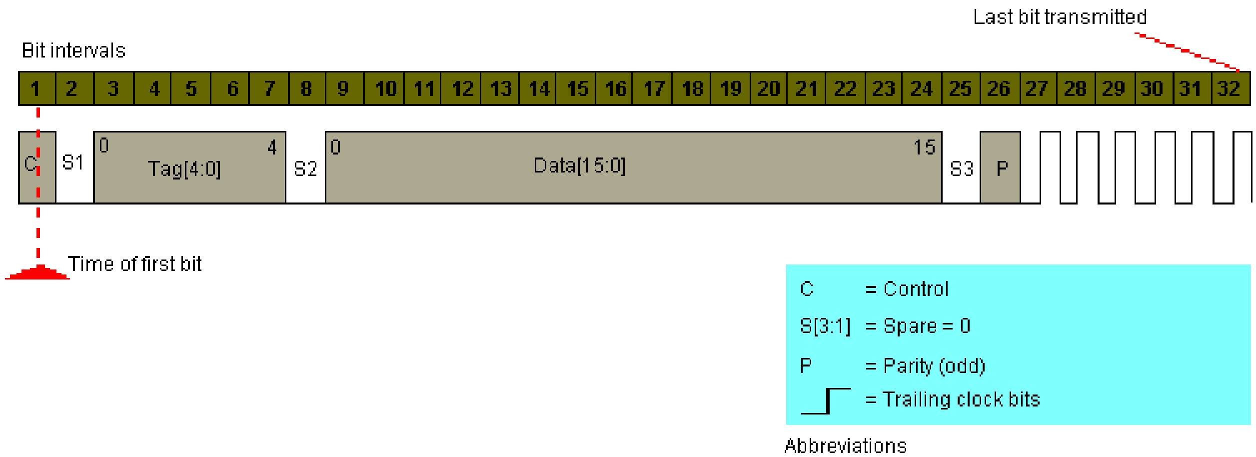


*Figure 5-3: Word definition for Panavia*

The 5-bit tag identifies the parameter being transmitted. Tags can start at 0 decimal and end with 31 decimal. Tags are transmitted in a sequence and must increase then wrap around.

## 5.4 Conclusion

In this paper, some of the nomenclature associated with Panavia was introduced. The generic word definition was also discussed.

# Chapter 6

# Panavia and the KAD/PBM/001

TEC/NOT/009

This paper outlines the key features of the KAD/PBM/001 with respect to Panavia bus monitoring. It is recommended that *TEC/NOT/008 - Panavia*, be read first. For a list of error codes and output register definitions, refer to the *KAD/PBM/001* data sheet.

The following topics are discussed:



## 6.1 The physical layer

The KAD/PBM/001 monitors up to eight Panavia busses. The following figure displays the receiver circuit internal to the KAD/PBM/001.

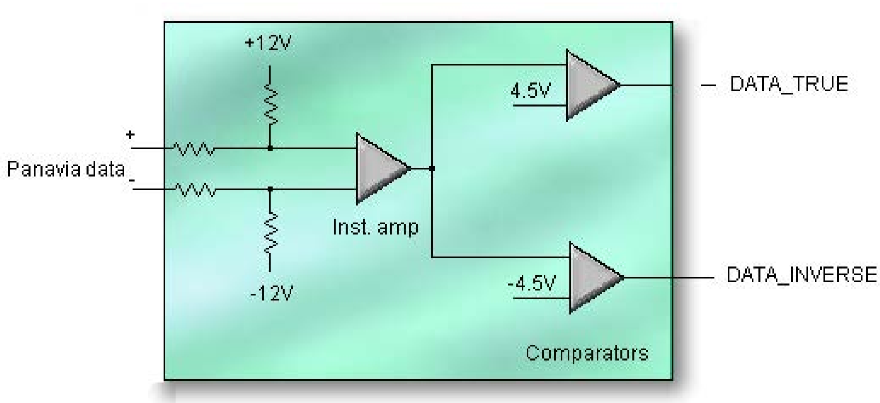


*Figure 6-1: One of eight receivers on the KAD/PBM/001 (same circuit used for clock)*

The thresholds for High and Low are +4.5V and -4.5V respectively. As per the Panavia specification, the shields for each bus must be connected to the GND pin of the KAD/PBM/001.

## 6.2 Bit detection circuitry

Each of the eight busses has a separate independent bit detection circuit.

The true/complement output of the receiver is sampled at 25 times the selected bit-rate. The output of the bit detection circuitry is: 1, 0, clock or bad. The following figure displays patterns used for determining good 1, 0 or clock.

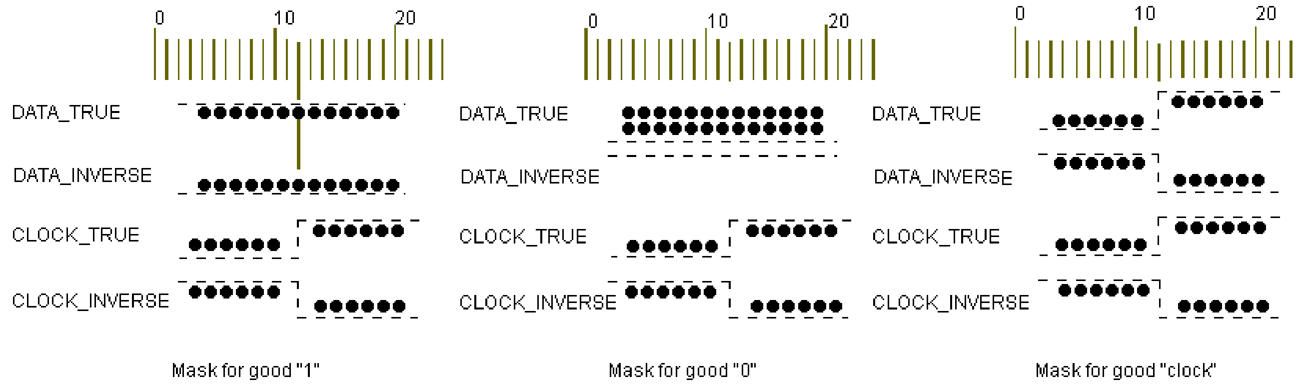


*Figure 6-2: Masks for 1, 0 or clock*

The gradation displayed in the previous figure represents 25 samples per bit period. The KAD/PBM/001 is tolerant of jitter because data is not checked either side of an expected transition (indicated by the absence of dots).

The bit detector outputs a bad indication if one of the three masks is not met after a 1, a 0 or a clock has been received. In other words a 1, a 0, a clock or a bad is clocked into the serial to parallel register of the word detection circuitry every bit period.

## 6.3 Word detection circuitry

Each bus has a separate word detection circuit. A word is considered found when three clock bits follow at least eight good 1s or 0s.

This circuit checks that there is precisely the correct number of good bits, the spare[3:1] bits are 0 and the parity is correct. The Tag[4:0] and control bit along with 3 bits indicating the bus are used to address a trigger list. The trigger list assigns one of 256 identifiers (IDs) to each word along with flags for invalid tag, control bit error and also returns the next expected tag for sequence checking (if enabled).

The output of the word detection circuitry consists of the following:

| | |
|---|---|
| **Flags** | Indicating invalid tag, control bit error, parity error, not enough bits or sequence error (when the tag was not the expected tag). |
| **Traffic[15:0]** | All the bits in the word received except the tag[4:0], control, spare[3:1] and parity. |
| **ID[7:0]** | One of 512 IDs based on bus[2:0], tag[7:0] and control bit. |
| **Time[47:0]** | The binary coded decimal (BCD) time, to hours of day, with ms resolution, at the midpoint of the first bit received. |
| **Word[15:0]** | The (valid) word counter for each bus when the word arrived. |

Because the data transfer is word based (not messages or frames), there is no protocol tracking on the KAD/PBM/001. A received word either has errors or it does not.

## 6.4 Error reporting, word counting and time tagging

The errors detected by the bit detection and word detection circuitry are combined into a 4-bit code. This code can be part of the report parameter from the KAD/PBM/001, along with 3 bits indicating the bus on which the fault was recorded (see the *KAD/PBM/001* data sheet).

All errors are also reported/logged via the snarfer along with the time that it occurred and the traffic following.

When a valid word is received, a word counter is incremented for each bus. This is a 16-bit binary counter that resets at FFFF hex. This parameter can be read for each of the eight busses from the KAD/PBM/001.

The following three binary coded decimal (BCD) time words are associated with time tagging:

| | | |
|---|---|---|
| **High time** | 00:00 | ➔23:59 Hrs:Mins |
| **Low time** | 00.00 | ➔59.99 seconds |
| **Micro time** | 0000 | ➔9999 *s |

## 6.5 Parsing

In the KAD/PBM/001 parser, triple buffering of words and tags is used for each bus as shown in the following figure.

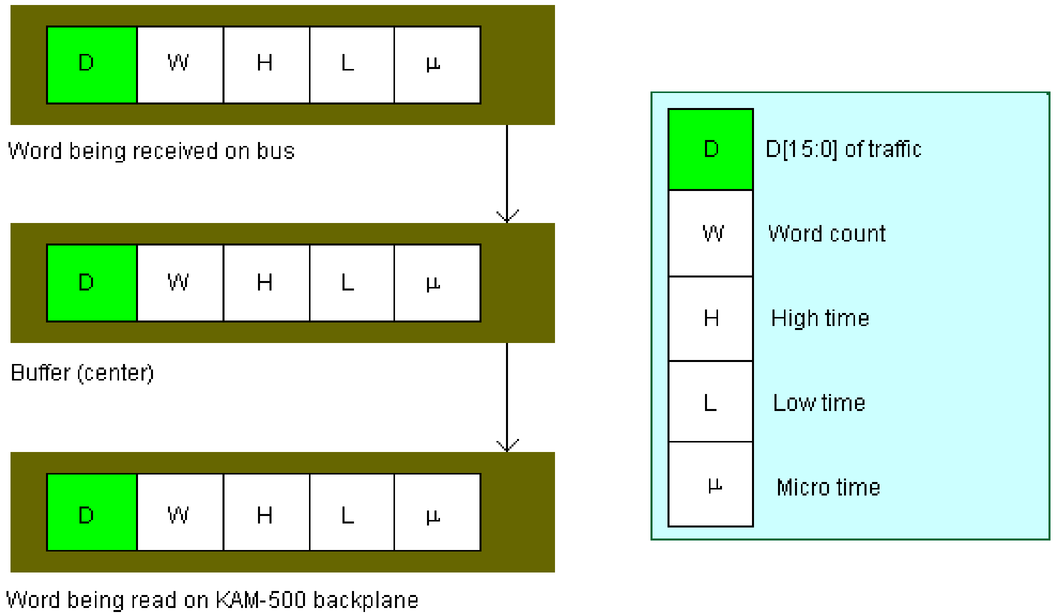


*Figure 6-3: Triple buffering of traffic and associated tags*

Time tags and a word count are added to each word received, and stored in separate buffers for each of the eight busses. As soon as a word is received with no errors, the complete buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped bit is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the contents of the center buffer (if new) are transferred to the read buffer. If no new word has been received, the stale flag is set. A center and read buffer exist for every ID (1024).

## 6.6 Snarfing

One disadvantage of parsing is that data can be lost (skipped). One solution is to store all traffic (or selected traffic) and tags in a FIFO as shown in the following figure.

In the snarfer, all traffic (words) are first tagged with High, Low and Micro time and the word count, for that bus, when the word arrived.

Traffic and tags are then filtered (removed) according to user-defined filters depending on the word ID and how full the FIFO is (empty to ¼, ¼ to ½, ½ to ¾, or ¾ to full). Only the traffic words and Low time tag are allowed through (see the following figure).

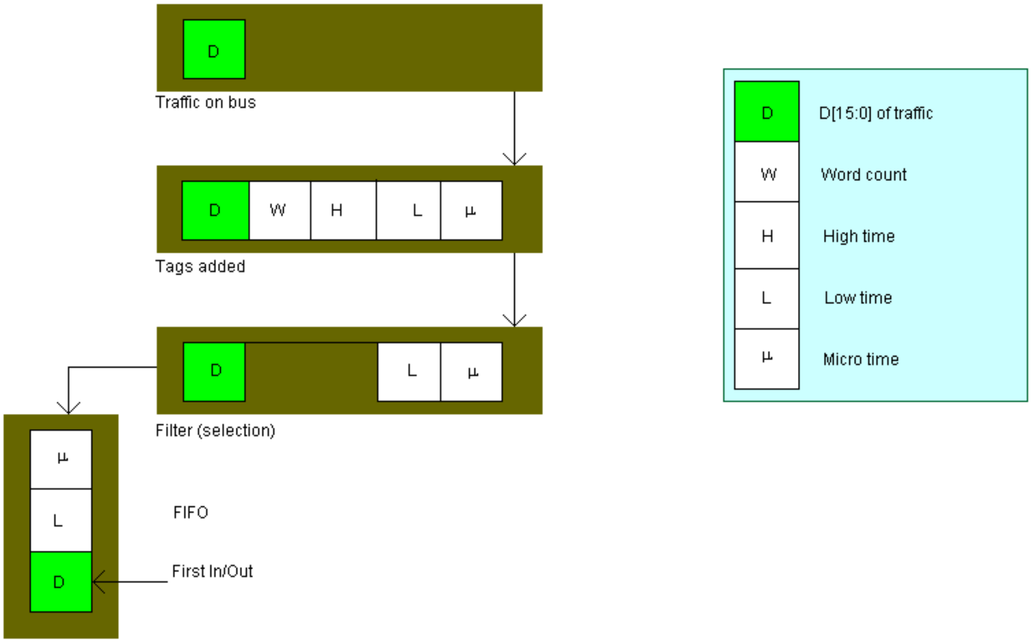


*Figure 6-4: Snarfing*

If an error occurs, an error code, all traffic, the word count and the three time tags of each command word are sent to the FIFO.

A single FIFO (16K deep) is shared between all eight busses. A content identifier is added to each traffic or tag word, identifying the type of parameter (data Hi/Lo, Time Hi/Lo/µ, word count, error or FIFO full/empty) and the bus the traffic was received on.

## 6.7 Conclusion

Key features of the KAD/PBM/001 include:

- Eight valid word counters, one for each bus.
- A 48-bit binary coded decimal (BCD) timer that counts to hours of the day with 1 µs resolution. The timer is used to tag data to 1 µs resolution and is typically seeded from an IRIG-B module (KAM/TCG/001) in the same chassis.
- Valid words defined and identifiers are assigned (one of 256 IDs) using all the bits of the tag and bus number. Multiple words can be mapped to any ID.
- Parsing of traffic from up to 256 word identifiers (IDs). Added to each parsed message is the word count and time when the word arrived. The parser provides stale and skipped indication for each word.
- Snarfing of traffic and tags into a FIFO 16K words deep. A content identifier is added to each word entering the FIFO to identify the type of word (Data Hi/Lo, High/Low/Micro Time, Error, FIFO full/empty) and the bus it appeared on 0-7. The filtering (data selection) into the FIFO is based on both the ID and how full the FIFO is. This allows the user to ensure that the FIFO never fills and any data removed is determined before hand.
- Parsing and snarfing even with 100% utilization of all busses.

Chapter 7

# Thermocouples

TEC/NOT/010

This paper outlines temperature measurement using thermocouples. In particular the concepts of reference junctions and firmware compensation are discussed.

The following topics are discussed:



## 7.1 Overview

In 1821, Thomas Seebeck discovered that a junction of two dissimilar metals produced a thermoelectric voltage (thermal emf) that was a function of the temperature of the junction.

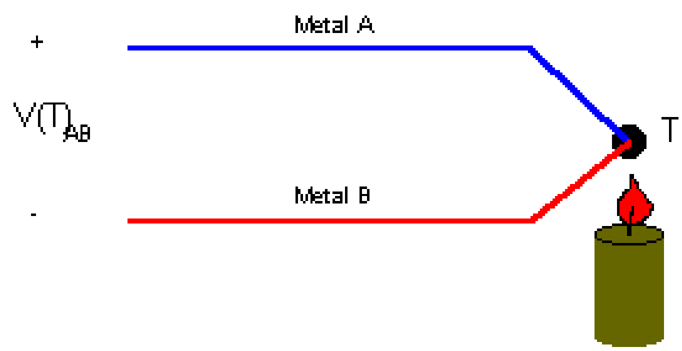


*Figure 7-1: The Seebeck (thermoelectric) voltage*

This method is still popular as a means of measuring temperature because it is relatively inexpensive, rugged, can be made into many shapes and has a wide temperature range (-276 to 1500°C).

## 7.2 Thermocouple theory

The Seebeck voltage is due to different valency levels in different metals. Electrons drop from the higher valency level to the lower until enough charge (voltage) builds up to stop the flow of electrons. This voltage is the thermoelectric voltage. One important corollary of this is the *Law of Intermediate Metals* that states that a third metal (for example a wire to a voltmeter) can be placed between two metals and does not affect the voltage produced if the temperature at each end is the same.

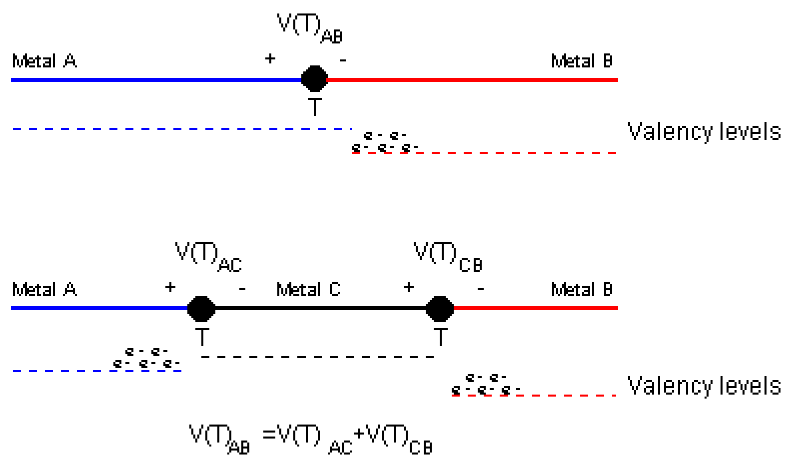


*Figure 7-2: An illustration of the Law of Intermediate Metals*

The following figure illustrates the thermal emfs produced about the circuit connecting a thermocouple probe to an ideal instrumentation amplifier.

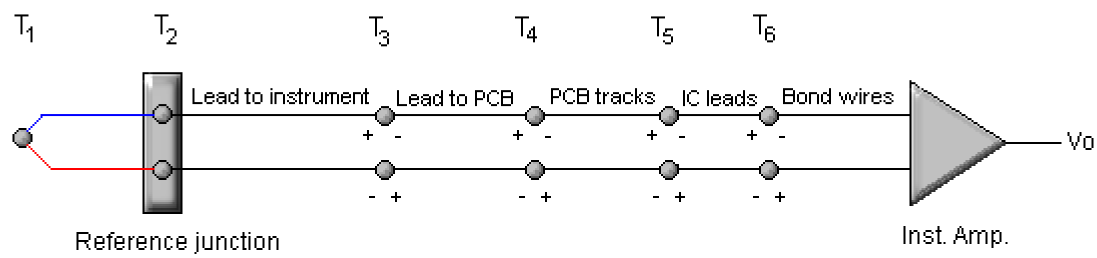


*Figure 7-3: A thermocouple connected to an amplifier via a reference junction block*

Because the metals used from the reference junction to the IC leads (inclusive) are usually of similar metals (copper), and at low temperature (-45° to +85°C), the thermal emfs produced are small. More importantly, providing the leads are kept close together at the same temperature, the thermal emfs produced are the same and cancel out.

Electrically the circuit is as shown in the following figure and the *Law of Intermediate Metals* can be used to remove metal C.

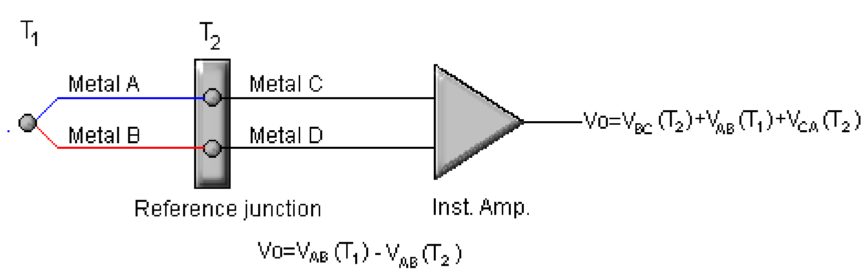


*Figure 7-4: Summing the voltages about the thermocouple loop*

---

**NOTE:** The net voltage produced is the voltage A and B produce at temperature $T_1$ (the measurand temperature) minus the voltage that A and B would produce at $T_2$ (the temperature of the reference junction).

In other words:

$$Eq1 \Rightarrow V_0 = V(T_{meas}) - V(T_{ref})$$

The voltage produced for a pair of metals is a non-linear function of the temperature of the junction. The function is so non-linear that an eighth-order polynomial can still have 0.5°C errors for certain metals and ranges. For this reason, the National Bureau of Standards (NBS) has drawn up thermocouple tables for the voltage produced about a loop for various combinations of metals. These tables of voltage versus temperature assume the reference junction is at a known fixed temperature (the Ice Point).

In other words:

$$V_{NBS}(T) = V(T) - V(0°)$$

This can be rewritten as:

$$V(T) = V_{NBS}(T) + V(0°)$$

Putting this in equation I:

$$V_0 = [V_{NBS}(T_{meas}) + V(0°)] - [V_{NBS}(T_{ref}) + V(0°)] = V_{NBS}(T_{meas}) - V_{NBS}(T_{ref})$$

Finally:

$$T_{meas} = V_{NBS}^{INVERSE}(V_0 + V_{NBS}(T_{ref}))$$

If $V_0$ and $T_{ref}$ are known, $T_{meas}$ can be obtained by using the NBS table to convert temperature to voltage and voltage to temperature.

---

**NOTE:** In Curtiss-Wright's KAD/TDC/002, a full 65536 point table, from temperature to voltage, and another 65536 point table, from voltage to temperature, is downloaded to EEPROM for any type of thermocouple.
The reference junction ACC/CJB/001 has a linear temperature sensor for measuring $T_{ref}$.

## 7.3 Types of thermocouples

The American Institute for Standards (ANSI) has approved letters for some types of thermocouples. The following table displays the composition and range for some of the more popular types.

Table 7-1: Some popular thermocouple combinations and their ANSI designation

| Type | Composition | Range (ºC) | Range (mV) | Sensitivity at 0ºC (µV/ºC) |
|---|---|---|---|---|
| **J** | Iron Vs.<br>Copper-Nickel | -210<br>+760 | -8.096<br>+42.922 | 50 |
| **K** | Nickel-Chromium Vs.<br>Nickel-Aluminum | -270<br>+1370 | -6.458<br>+54.807 | 39 |
| **E** | Nickel-Chromium Vs.<br>Copper-Nickel | -270<br>+1000 | -9.835<br>+76.358 | 59 |
| **T** | Copper Vs.<br>Copper-Nickel | -270<br>+400 | -6.258<br>+20.869 | 39 |
| **S** | Platinum Vs.<br>Platinum-10% Rhodium | +1760 | 18.612 | 5 |

The following figure graphs the output voltage (mV) versus the junction temperature (°C) from tables produced by the NBS.

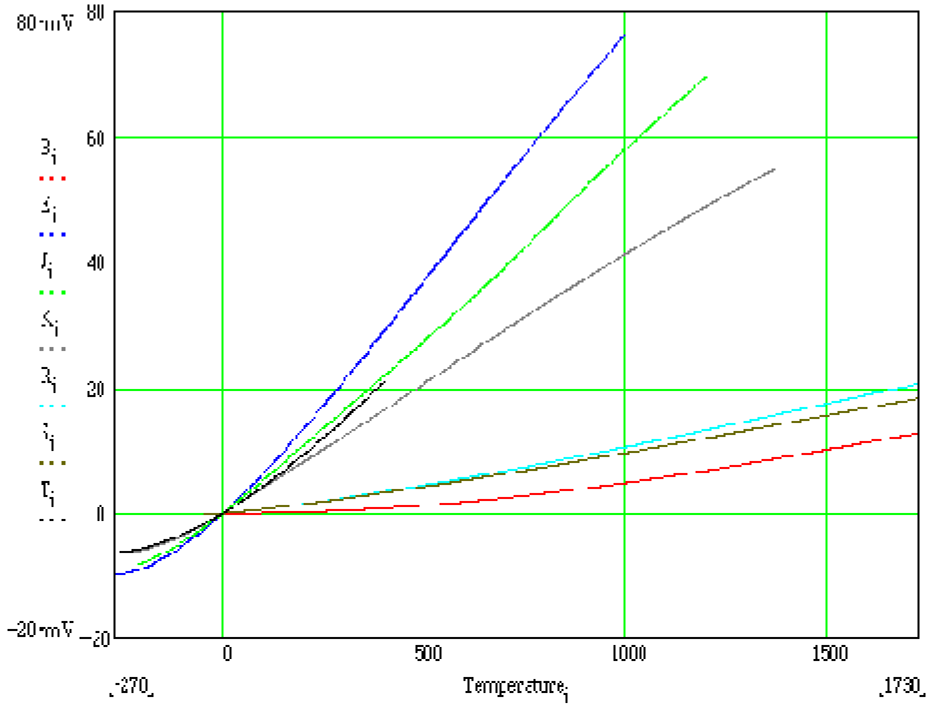


*Figure 7-5: Voltage versus temperature for various types of thermocouples*

Usually, errors from thermocouple to thermocouple of the same type are at least 0.5°C and are typically 1.5°C.

## 7.4 Design considerations

To reduce any noise pickup and to make it common mode, thermocouple wires should be shielded and twisted. A current return path for bias currents from the instrumentation amplifier must be provided as shown in the following figure.

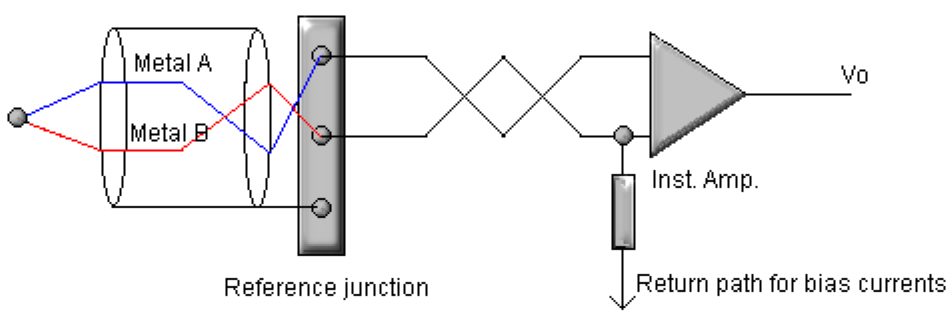


*Figure 7-6: Twisting and shielding and return paths for amplifier bias currents*

The return resistor should be large to reduce resistor divider effects; current loops when the thermocouple probe is not isolated. If it is too large, the bias currents (approx. 20 nA) cause a common mode voltage and the wires present a high impedance, making them susceptible to noise pickup.

---

**NOTE:** In the KAD/TDC/002, a 10 kW return resistor is provided for each channel.

## 7.5 Conclusion

In this paper, temperature measurement using thermocouples was introduced.

Thermocouples are self-powered, rugged, inexpensive, come in various shapes and can be used for a wide range of temperatures.

However they are non-linear, have a low voltage output and require a reference junction (and the measurement of the junction temperature).

## 7.6 References


*The Temperature Handbook*

Omega Engineering, Inc.

P.O. Box 2669

Stamford

CT 06907-0047

USA

Omega.com

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Chapter 8

# Synchros

TEC/NOT/011

This paper introduces angle and angular velocity measurement using synchros.

The following topics are discussed:



## 8.1 Overview

Synchros have been available since the 1930s. They are electromechanical devices consisting of a stator with three windings and a rotor with one winding. The rotor carries an ac signal and induces a different ac signal on each of the stator windings depending on the angle.

By monitoring the signals on the stator windings, the angle (and hence angular velocity) can be deduced. This method is robust and is arguably the most accurate way of measuring angle.

## 8.2 Synchro theory

Synchros are cylindrical and resemble small ac motors as illustrated in the following figure. The size of a synchro is specified by rounding the diameter to the nearest tenth of an inch.

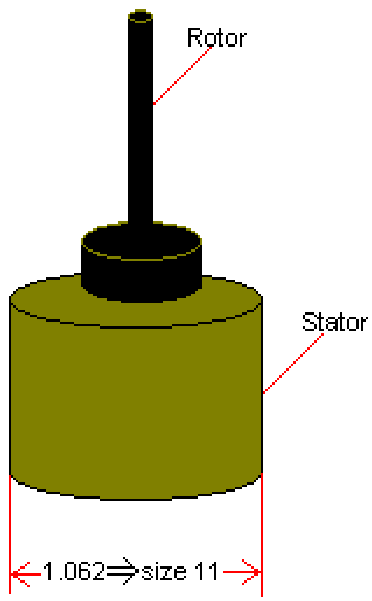


*Figure 8-1: A typical synchro outline*

An exploded view of a synchro is shown in the following figure.

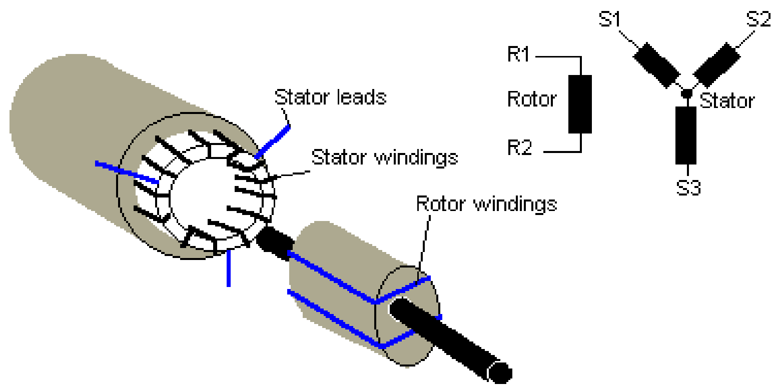


*Figure 8-2: Exploded view of synchro*

An ac signal (typically 60 or 400 Hz) is applied to the rotors (usually via carbon brushes), inducing a voltage on the stator leads that is a function of the shaft angle ($\theta$). In particular, if the voltage on the rotor is:

$$R = A \cdot Sin(360° \cdot t \cdot 60Hz)$$

The signals that appear across the stator terminals are:

$$V_{s1-s3} = K \cdot Sin(360° \cdot t \cdot 60Hz) \cdot Sin(\theta)$$

$$V_{s3-s2} = K \cdot Sin(360° \cdot t \cdot 60Hz) \cdot Sin(\theta + 120°)$$

$$V_{s2-s1} = K \cdot Sin(360° \cdot t \cdot 60Hz) \cdot Sin(\theta + 240°)$$

These voltages are known as synchro format voltages and are graphed in the following figure for a shaft angle ($\theta$) of 15°. Essentially there are three equations with two unknowns (*K* and $\theta$), where *K* is a gain factor that may vary with time and temperature and from synchro to synchro. To solve for two unknowns, two equations are normally sufficient. However when the shaft angle ($\theta$) is 0°, the amplitude of the voltage $V_{S1\text{-}S2}$ is 0 and therefore cannot be used so instead the other two are used.

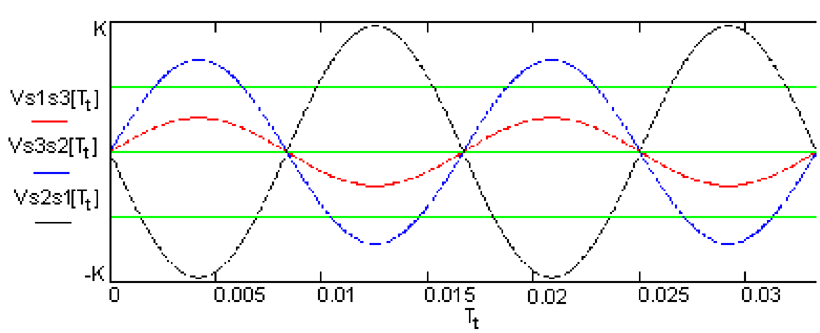


*Figure 8-3: Synchro format voltages for a shaft angle of 15º*

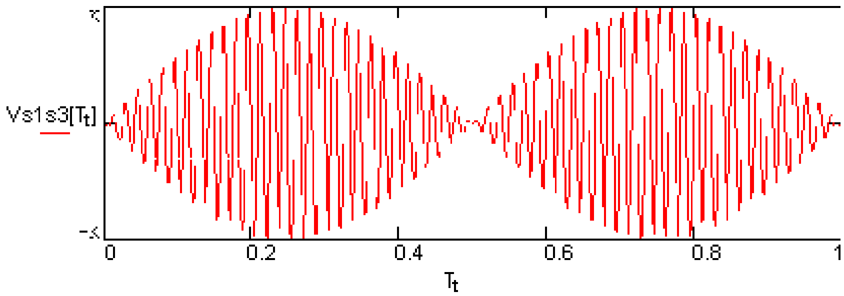


*Figure 8-4: One of the three synchro format voltages for a 360º/sec. angular velocity*

## 8.3 Conclusion

This paper described basic synchro theory, and examined angle and angular velocity measurement using synchros.

## 8.4 References


*Synchro & Resolver Conversion*

Analog Devices

Two Technology way

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Norwood

Massachusetts 02062-0280

USA

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Chapter 9

# Piezoelectric effect and charge amplifiers

TEC/NOT/012

This paper introduces force and pressure measurement using piezoelectric devices. In particular the piezoelectric effect is discussed along with circuits used to measure this effect (charge amplifiers).

The following topics are discussed:



## 9.1 Overview

In 1880 the Curie brothers discovered the piezoelectric effect as illustrated in the following figure. Piezo comes from the ancient Greek verb Piezein - to press.

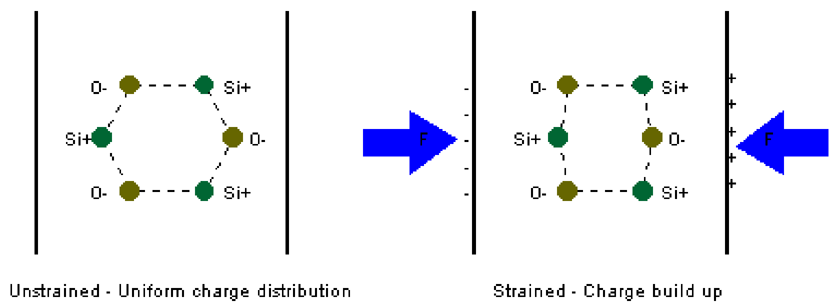


*Figure 9-1: Illustration of piezoelectric effect*

In crystals, such as quartz or tourmaline, all the molecules are arranged, and thus become deformed under pressure, in the same way.

These crystals are highly directional (no *Poisson type* effects), thermally stable, produce highly repeatable results and have a very large dynamic range.

However, the signal produced requires a charge amplifier (compared to the voltage output of a strain gage or thermocouple for example). This paper is concerned with the considerations and design aspects of charge amplifiers. In particular, unless the device has very high input impedance, the charge will *leak-away* and the device will have limited applications for dc signals.

Walter Kistler (founder of Kistler AG) patented the charge amplifier, as it is known to the industry today.

## 9.2 In-line charge converters

Because piezoelectric devices are charge-based, they are more susceptible to cabling and moisture variations. Often, the sensor can have the charge-to-voltage signal conditioning built in. Also some manufacturers supply in-line charge amplifiers that can be placed near the sensor. Both these methods are illustrated in the following figure along with a popular method of supplying power to these devices (constant current) and decoupling the signal returned.

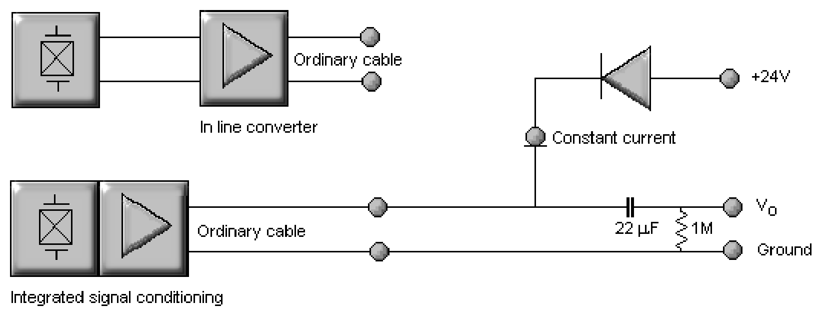


*Figure 9-2: Integrated and in-line signal conditioning techniques*

In-line charge amplifiers are available from Kistler, Endevco, PCB Piezotronics and others. The KAD/ADC/006 from Curtiss-Wright can be connected to six such devices.

## 9.3 Voltage mode charge conversion

The sensor can be modeled as a charge source in parallel with a capacitance as shown in the following figure. The charge is a function of the force or pressure being measured.

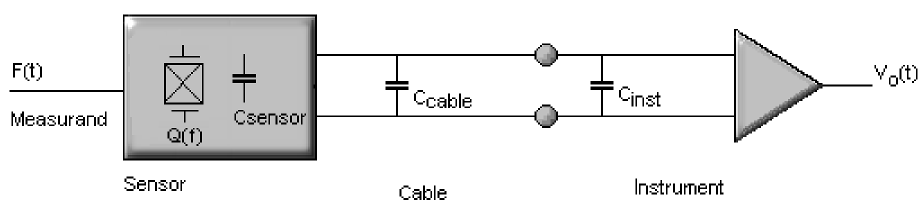


*Figure 9-3: Voltage mode charge conversion*

The transfer function for such a circuit is:

$$V_0(t) \propto \frac{Q(t)}{C_{sensor} + C_{cable} + C_{inst}}$$

To minimize the effects of variations of the sensor cable and stray capacitance within the instrument, $C_{inst}$ must be made as large as possible, which in turn requires greater amplification. This circuit is rarely used and is shown here for completeness only.

## 9.4 Charge mode charge conversion

An alternative is the circuit shown in the following figure.

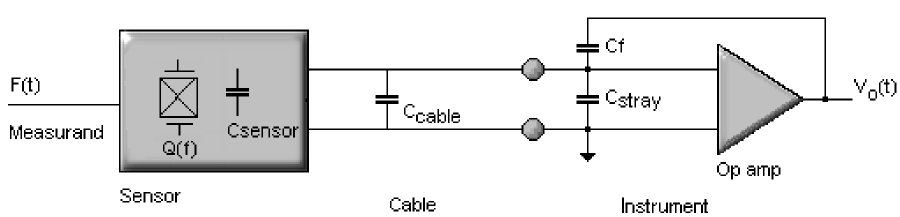


*Figure 9-4: Charge mode charge conversion*

The transfer function for such a circuit is:

$$V_0(t) \propto \frac{Q(t)}{C_f} \cdot \frac{1}{1 + \frac{1}{G_{op-amp}}\left(\frac{C_{sensor} + C_{cable} + C_{stray}}{C_f}\right)} \approx \frac{Q(t)}{C_f}$$

In other words, if the operational amplifier has a high negative open-loop gain ($G_{\text{op-amp}}$), variations in cable, sensor and stray capacitance have a negligible effect. However, great care must still be taken with connectors and the shielding of tracks.

A variation of this circuit (including high resistance returns for op-amp bias currents) is used on the KAM/CDC/001.

## 9.5 Conclusion

Piezoelectric sensors were introduced along with various methods of interfacing to them. In particular in-line charge converters (as used on the KAD/ADC/006) or charge mode amplifiers (as used on the KAM/CDC/001).

## 9.6 References


Applied Measurement Engineering

Charles P. Wright

Prentice Hall

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# Chapter 10

# 3-phase power monitoring

**TEC/NOT/013**

This paper examines the nomenclature and techniques used for AC power monitoring. In particular, the root-mean-square (RMS) values for voltages and currents, active power, apparent power, and power factor are outlined.

The following topics are discussed:



## 10.1 Overview

Electrical generators consist of a rotor that induces a voltage on stator windings as it rotates (ignoring solar power and batteries). For aircraft applications, the generator may be part of a main engine assembly or a dedicated motor. Often there is a backup mechanism in the event of failure.

This rotation causes an alternating voltage, or current, to be induced on the stator (hence AC). These AC signals can be thought of as sine waves:

$$V = A_v \cdot Sin(2 \cdot \pi \cdot f \cdot t)$$

$$I = A_I \cdot Sin(2 \cdot \pi \cdot f \cdot t + \phi)$$

where *A* is the amplitude, *f* is the frequency of rotation and $\phi$ is the phase angle between the current and voltage.

A 3-phase generator has three sets of windings, equally spaced (at 120°) about the stator. Each has a voltage induced on it. Each voltage lags or leads the next one by 120°.

If the generator is connected to a purely resistive load (no inductance or capacitance), the phase angle (between voltage and current) is 0°. If the generator is connected to an ideal inductor or capacitor, the phase angle is ±90°.

In all three cases, the devices have voltages across them and current through them but only the resistor is dissipating power. In the following figure, the phase angle is 45° (not 0 or ±90°) so it is not purely resistive, capacitive or inductive.

This paper outlines the measurement of voltages and currents and the actual power being dissipated.

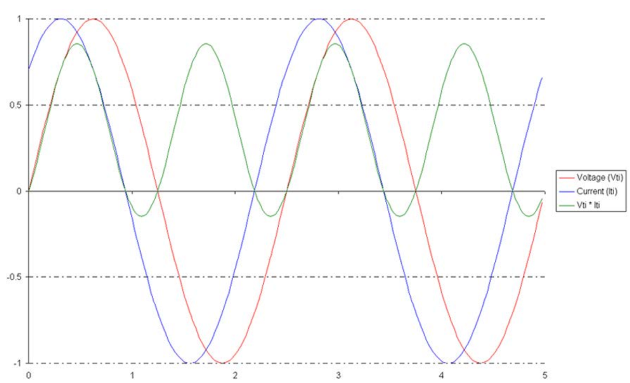

*Figure 10-1: Normalized voltage and current for a phase angle of +45° and their product*

## 10.2 Amplitude, average and root-mean-square

The following figure shows a sine wave with an offset. The equation for this is:

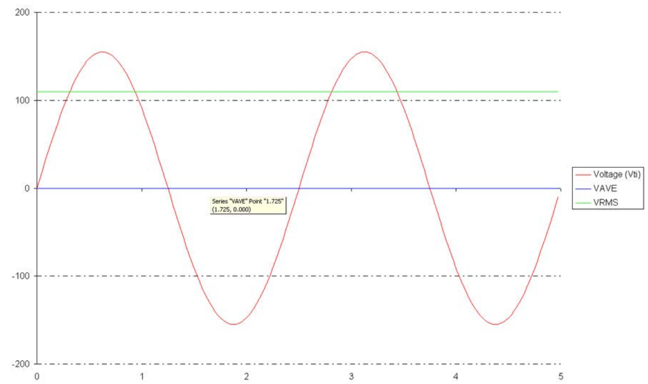


*Figure 10-2: Graph of 110$V_{rms}$ at 400 Hz*

| | |
|---|---|
| The **frequency** is - | **400 Hz** |
| The **period** (1/frequency) is - | **2.5 ms** |
| The **maximum** value ($V_{max}$) is - | **157V** |
| The **minimum** value ($V_{min}$) is - | **-155V** |
| The **peak-to-peak** difference ($V_{p\text{-}p}$= $V_{max}$-$V_{min}$) is - | **312V** |
| The **amplitude** ($V_{p\text{-}p/2}$) is - | **156V** |

If a large number of values (for example, $N$ = 2,048) samples ($V_i$) are taken over an integral number of periods, the average or mean value can be calculated as follows:

$$V_{avg} = \frac{1}{N}\sum_{i=1}^{N} V_i = 1V$$

Similarly, the RMS (root-mean-square) value is:

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} V_i^2} \cong 110V$$

If a DC voltage of $V_{rms}$ is connected across a resistor ($R$), the power dissipated is:

$$Power_{Dissipated} = \frac{V_{rms}^2}{R}$$

This is the same as the average power dissipated if $V(t)$ is connected across the same resistor. In other words, $V_{rms}$ squared equals the average of $V(t)$ squared.

For a sine wave (with no offset):

$$Amplitude = V_{max} = -V_{min} = V_{p-p/2} = V_{rms} \times \sqrt{2}$$

$$V_{rms} = (Amplitude)/(\sqrt{2})$$

## 10.3 Active power, apparent power and power factor

The active power is a measure of the power dissipated in the load. If a large number of values (for example *N* = 2,048) samples for the voltage ($V_i$) and the current ($I_i$) are taken over an integral number of periods, the average or mean value for the power can be calculated as follows:

$$P_{active} = \frac{1}{N}\sum_{i=1}^{N} V_i \cdot I_i$$

The average power is called active and the RMS power is called apparent:

$$P_{apparent} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (V_i \cdot I_i)^2}$$

The power factor is defined as the ratio between active and apparent:

$$Power\_\text{factor} = \frac{Active}{Apparent}$$

For a sine wave (with no offset):

$$Active\_power = V_{rms} \times I_{rms} \times Cos(\phi)$$

$$Apparent\_power = V_{rms} \times I_{rms}$$

$$Power\ factor = Cos(\phi)$$

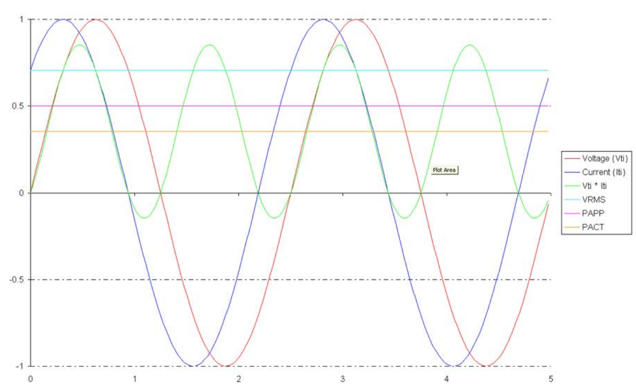


*Figure 10-3: Normalized voltage and current for a phase angle of +45° and their product*

## 10.4 Three-phase power monitoring

The following figure displays star and delta connection schemes for three-phase power distribution.

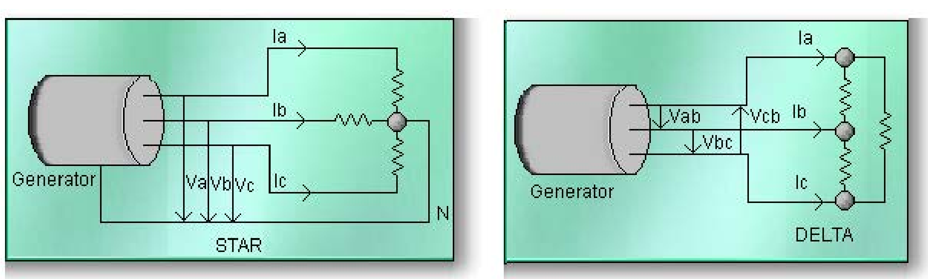


*Figure 10-4: Star and delta connections for three-phase power*

For balanced loads, the:

- voltage across each of the loads for a delta connection is √3 times that of a star connection
- current through each of the loads for a star connection is √3 times that of a delta connection

There are six connections to be made when monitoring three-phase power. There is one signal for each of the voltages and one for each of the currents. Usually a transformer is used to isolate the instrumentation equipment from the power and to produce a much (1/20) attenuated voltage.

Various sensors (Hall effect, resistor in series) can be used to produce a voltage representing the current.

## 10.5 Power monitoring and the KAD/ADC/008

Curtiss-Wright's KAD/ADC/008 accepts six single-ended voltage signals (three voltage plus three current). Each signal is connected to a separate A/D and all channels are sampled at the same time. The KAD/ADC/008 measures the period of the signal connected to channel 0 and uses a positive-going-zero-crossing to start (and later to stop) computation of the various parameters.

The maximum, minimum, amplitude, average, RMS, active power, apparent power, and power factor are calculated using the formulae in sections “10.2 Amplitude, average and root-mean-square” on page 42 and “10.3 Active power, apparent power and power factor” on page 43. There is no assumption made that the wave is sinusoidal.

At least 2,048 A/D readings are taken for each channel. If a DC signal is attached to a channel, the algorithm updates every 65,536 samples.

The ACC/TRF/001 is an external transformer that can be used to isolate and attenuate three voltages.

When programming the KAD/ADC/008, the relationship between the input voltage levels and the voltage and current being measured (scaling) should be specified.

## 10.6 Conclusion

In this paper, some of the nomenclature associated with power monitoring was introduced along with some formulae for deriving parameters such as maximum, minimum, amplitude, average, rms, active power, apparent power and power factor.

Chapter 11

# Linear variable differential transformers

TEC/NOT/014

This paper introduces Linear Variable Differential Transformers (LVDTs), its uses and the signal conditioning required. The following topics are discussed:



## 11.1 Overview

From the early part of the twentieth century, differential transformers have been used in control applications. However, it was not until the 1940s that their use in instrumentation systems became popular. In 1946 Herman Schaevitz published a paper entitled The Linear Variable Differential Transformer.

LVDTs are used to measure mechanical displacement. As illustrated in the following figure, two secondary coils are wound around a movable core, around which is also wound around a primary coil. The primary coil is connected to an AC excitation.

In the midpoint (null position), the voltage induced on both secondary coils is the same. As the core moves up (or down), the voltage on each becomes larger or smaller.

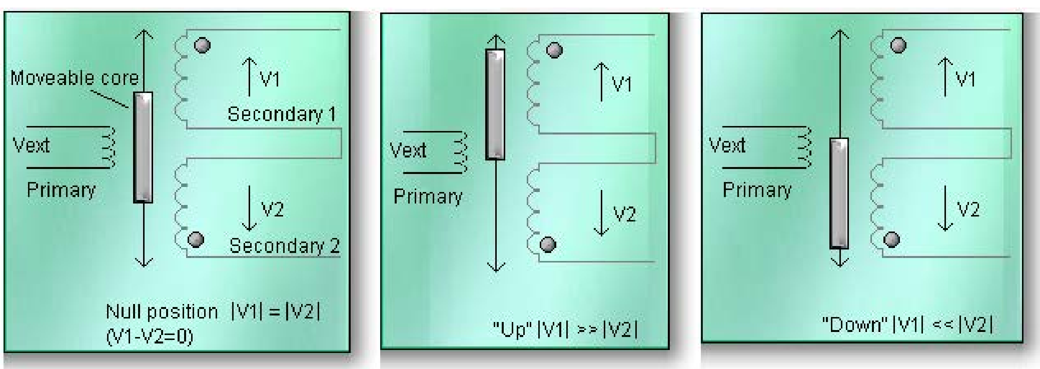


*Figure 11-1: Illustration of a full-bridge LVDT*

LVDTs operate on the principle that the position of the core may be deduced by observing the voltage(s) induced on the secondary coils. This paper examines various methods of doing just that.

This paper also examines the half-bridge LVDT. The analysis that follows also holds for Rotational Variable Differential Transformers (RVDT) where the coils are wound around a circular movable core so that the device can be used for rotational (angular) measurement.

## 11.2 Full-bridge LVTD basics

In general the excitation voltage to the primary can be represented as a sine wave with no dc component:

$$V_{ext}(t) = A_{exc} \cdot Sin(2 \cdot \pi \cdot f)$$

Often the excitation frequency ($f$) is chosen so that it is many times (>10) greater than the bandwidth of the movement being measured, so as to simplify the signal conditioning circuitry. If so, the analysis can be simplified using root-mean-square (rms) values as:

$$V_0 = V_{rms_{\sec 1}} - V_{rms_{\sec 2}} \cong P \cdot V_{rms_{ext}} \cdot S + V_{rms_{ext}} \cdot O$$

where *P* is the position of the core, and *S* is the sensitivity of the LVDT as specified by the manufacturer (for example 2.4 mV / V / inch).

*S·P* is the voltage induced on the secondaries as a function of core position and *O* is the voltage induced irrespective of core position.

If the LVDT manufacturer has designed the device so that the difference in the primaries is zero at the mid-point (null position), the equation becomes:

$$V_0 \cong P \cdot V_{rms_{ext}} \cdot S$$

In other words, by knowing the excitation and the sensitivity of the LVDT, the position (*P*) can be deduced from the rms value of the output voltage.

## 11.3 Compensating for variations in the excitation

In the previous section, it was stated that for an LVDT designed to output 0V difference in the null-position, the position (P) of the core can be deduced from the rms of the output voltage using:

$$V_0 \cong P \cdot V_{rms_{ext}} \cdot S$$

If the excitation voltage varies with lead resistance, temperature or aging, it should be measured accurately and the position (*P*) can be deduced from the ratio:

$$P \cong \frac{V_0}{V_{rms_{ext}}} \frac{1}{S}$$

This circuit is shown in the following figure and is the principle used on Curtiss-Wright's KAM/LDC/001.

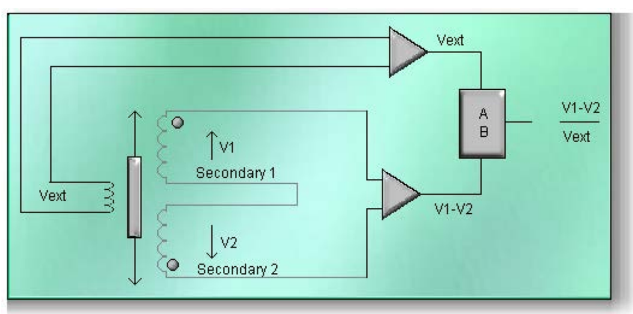


*Figure 11-2: Ratiometric full-bridge LVDT circuit*

The circuit used assumes that a frequency has been chosen such that the phase difference between the primary and secondary is 0° (or 180° by swapping lines).

## 11.4 Half-bridge LVTD basics

In a full-bridge LVDT, the voltage induced on each secondary varies with core position. In a half-bridge LVDT circuit, the inductance of two coils varies with core position (analogous to resistance change in a potentiometer).

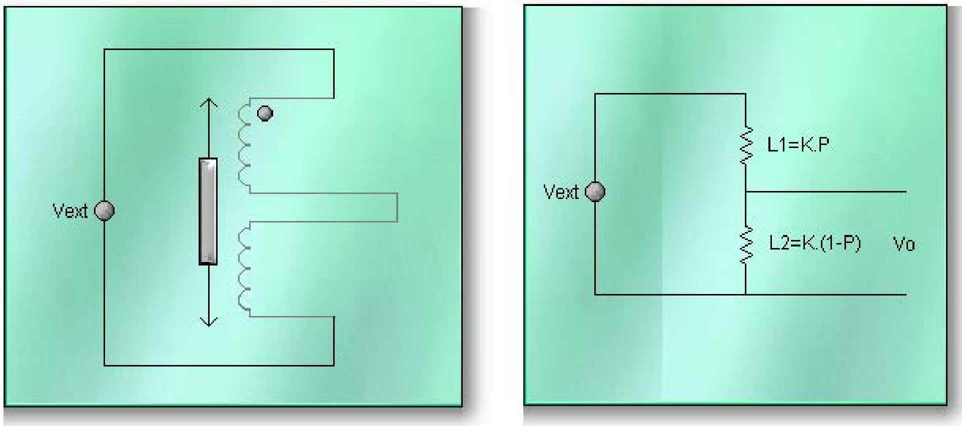


*Figure 11-3: Illustration of half-bridge LVDT*

The output voltage (rms) for this device can be approximated by:

$$V_0 \cong V_{rms_{ext}} \frac{L1}{L1 + L2} = V_{rms} \cdot P$$

This is similar to the equation for the full-bridge LVDT, so the ratiometric circuitry used on the KAD/LDC/101 can also be used.

## 11.5 Conclusion

In this paper, some of the uses of the Linear Variable Differential Transformer (LVDT) and the signal conditioning required were introduced.

## 11.6 References

*LVDT Signal Conditioning Techniques*, Jackson Szczyrbak, Principal Engineer, Schaevitz Products. Dr Ernest D.D. Schmidt, Director of Technology, Sensors, Lucas Control Systems

*AD698 and AD598 data sheets*, Analog Devices, One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106 USA

In 1946, Herman Schaevitz published a paper entitled The Linear Variable Differential Transformer.

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# CVSD modulation of audio signals

TEC/NOT/015

This paper introduces Continuously Variable Slope Delta (CVSD) modulation.

The following topics are discussed:



## 12.1 Overview

This paper introduces CVSD modulation as a method of transmitting audio signals in PCM systems. In particular CVSD is discussed as a variation of Sigma-Delta (ΣΔ) modulation wherein the Delta (Δ) varies as a function of the signal being encoded. Also the issue of reproducing the audio signal is briefly discussed.

Quite often it is desirable to record (or transmit) the pilot's (and co-pilot's) voice along with the instrumentation data to ease synchronization and reduce the number of, or simplify, the storage devices or transmitters required.

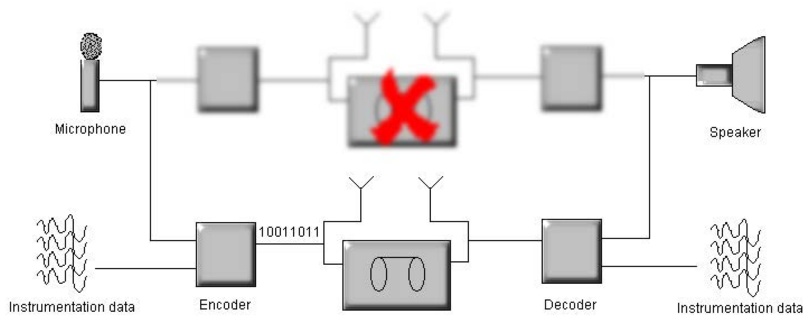


*Figure 12-1: Embedding audio signal in instrumentation data*

How many bits per second are required?

- Telephone quality transmissions require 8-bit samples at approximately 8 ksps or 64 kbps.
- Compact disk quality transmissions require approximately 10 times this bit-rate (16-bit samples at approximately 40 ksps).
- Compression algorithms always require less bits but require processing and may be less tolerant of bit-errors.

One approach is to take advantage of the fact that audio signals have no DC component and that it is the size and rate of change that is of particular interest.

What follows is an introduction to Sigma-Delta (ΣΔ) modulation and then CVSD modulation (encoding).

## 12.2 Sigma-delta (ΣΔ) modulation

Sigma-Delta (ΣΔ) modulation is based on the fact that the signal has no DC component and simply transmits a 1 or a 0, depending on whether the signal has increased or decreased since the last sample. The encoder and decoder adds (or subtracts) a Delta **(**Δ**)** from a running value which is compared to the next sample depending on whether a 1 or a 0 is transmitted.

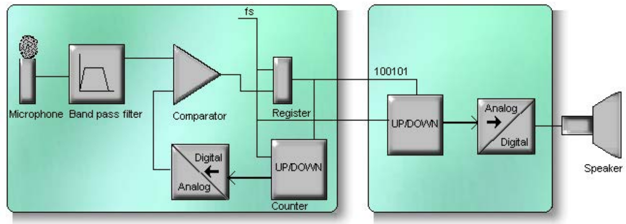


*Figure 12-2: Basic implementation of Sigma-Delta (ΣΔ) encoder/decoder system*

The maximum rate of change for a sine wave of amplitude *A* and frequency *f* is at the zero crossing. If the signal is being sampled at a rate $f_s$ then the maximum change in one sample period is:

$$S_{max} = 2 \cdot \pi \cdot A \cdot \frac{f}{f_s}$$

If telephone quality (8-bit) audio is required, the Delta **(Δ)** must be $1/2^8$ times the A/D input range, and signal frequencies up to 8 kHz are expected. Assuming the signal is close to the rail of the A/D (that is, the A/D range = ±A) then:

$$\Delta = \frac{2 \cdot A}{2^8} > 2 \cdot \pi \cdot A \cdot \frac{8000}{f_s} \Rightarrow 643kHz$$

In other words, for telephone quality, Sigma-Delta (ΣΔ) modulation requires compact disk quality bit-rates. At first, this may appear like a step backwards. However it is worth noting that if the amplitude was typically a quarter of the maximum (or less) and the frequency was typically 1 kHz (or less), then telephone quality would be obtained at a bit-rate of 32 kHz.

## 12.3 CVSD modulation

In a CVSD system the Delta (Δ) varies depending on the recent rate of change of the input signal. In particular, if the last three outputs from the encoder are 1 then this indicates that the signal is increasing faster then 1Δ per sample, so the Delta (Δ) is increased until a 0 is output.

As the smallest Delta (Δ) can be smaller than 1/256th of the input range (on the KAD/VDC/001 it is 1/1024), the CVSD modulator can have better dynamic performance then an 8 x 8 kbps system for slow or small signals.

However, for fast or large signals, the dynamic performance may not be as good as an 8 x 8 kbps system (hence the KAD/VDC/001 should not be used for tone or phase signals).

A quantitative analysis of CVSD modulation is beyond the scope of this paper, however the following statements may help:

In IRIG-106-98 Chapter 5, the following statement appears:

A qualitative test of CVSD with a tactical aircraft intercom system (ICS) yielded the following results:

- intelligible robotics sounding audio at 12 kbps
- good quality audio at 16 kbps
- audio quality did not significantly improve as the bit rate was increased above 32 kbps

In application note 607 from Intersil (see “References” on page 51) the following appears:

CVSD has better intelligibility then PCM when random bit errors are introduced during transmission.

## 12.4 CVSD and the KAD/VDC/001

The KAD/VDC/001 continuously samples two audio streams at a constant rate. Both channels need not be sampled at the same rate. The samples (comparator outputs) are then sent to a programmable serial-to-parallel converter. For each channel the bits per word (10/12/14/16) must be specified.

**NOTE:** A 16-bit word means that the comparator results of 16 samples are stored in one word. For example, 4 x 12-bit words would have exactly the same information as 3 x 16-bit words.

Words are therefore generated at a constant rate; there is an integral number of words per acquisition cycle (major-frame). Data sampling is simultaneous with respect to the acquisition cycle; the serial-to-parallel converter starts a new word at the start of an acquisition cycle.

While the Acra KAM-500 PCM encoders enable data to be inserted in a PCM stream at any location, Chapter 5 of IRIG-106-98 strongly recommends that digitized audio words be evenly spaced in PCM streams.

## 12.5 CVSD Decoding

Many telemetry ground stations have CVSD-to-audio cards; one implementation is illustrated in the following figure.

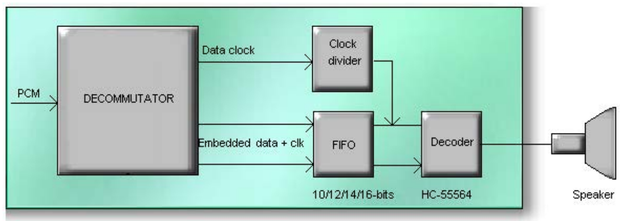


*Figure 12-3: Key blocks required for CVSD demodulation*

The CVSD data PCM decommutator is marked as an embedded stream and therefore gets clocked out in bursts one word long. If data is evenly spaced (in time) in the PCM stream, then the data can be clocked into a simple one word deep FIFO.

The data is clocked out of the FIFO at a rate determined by the formula:

$$f_s = \mathrm{PCM\_BIT\_RATE} \cdot \frac{\mathrm{CVSD\_BITS\_PER\_FRAME}}{\mathrm{TOTAL\_BITS\_PER\_FRAME}}$$

Interfacing to these cards can be made simpler if the following rules (as recommended by IRIG-106-98 Chapter 5) are followed when defining the PCM frame:

- Space the CVSD words evenly (in time) throughout the data, this eases time correlation and FIFO design.
- Transmit the oldest sample bit first, this simplifies FIFO design.
- Ensure BIT_RATE/$f_s$ is an integer, this simplifies the clock divider design.

The Acra KAM-500 allows users to follow these recommendations or not.

## 12.6 Conclusion

CVSD is a form of Sigma-Delta (ΣΔ) modulation where the Delta (Δ) changes depending on the signal. It enables digitization of audio signals at bit-rates as low as 9600 bps, therefore allowing the signals to be embedded among instrumentation data without a significant bandwidth cost. With each KAD/VDC/001 two audio channels can be thus encoded.

## 12.7 References


IRIG-106-98 Chapter 5

Application note 607

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Chapter 13

# Power dissipation - a worked example

TEC/NOT/016

This paper provides a worked example of the issues involved in calculating power dissipation.

The following topics are discussed.



## 13.1 Introduction

This paper discusses some of the issues involved in calculating power dissipation with respect to a typical system. Power dissipation is calculated using coefficients for radiation and convection and is compared to an actual system. Finally, some of the factors to be considered are discussed.

## 13.2 Configuration

The configuration used was as follows:

| | |
|---|---|
| KAM/SYS/13U | 13 user-slot system with power supply, and PCM encoder/controller |
| KAM/ADC/005 × 7 | 8 × 7 (= 56) fully-programmable differential-ended analog channels |
| KAM/MSB/001 × 2 | 2 dual redundant MIL-STD-1553 bus monitor modules |
| KAD/UAR/001 × 1 | 8 RS-232/422 (V.20) bus monitor channels |
| KAD/ADC/001 × 1 | 32 single-ended analog channels |
| KAD/ADC/009 × 2 | 8 × 2 (16) fully programmable bridge channels[1] |

1. For this analysis, each of the 16 channels are connected to a 350Ω full-bridge with 10V (±5V) across each bridge.

The system was powered using a 28V supply and mounted on an insulator (therefore with no conduction cooling) in a black room at an ambient temperature of 26.1°C.

## 13.3 Power consumption

The power consumption of the system should be as follows:

| | | |
|---|---|---|
| KAM/SYS/13U | 5.1 × 1 | 5.1W |
| KAD/ADC/005 | 2.0 × 7 | 14.0W |
| KAD/MSB/001/B | 1.0 × 2 | 2.0W |
| KAD/UAR/001 | 0.6 × 1 | 0.6W |
| KAD/ADC/001 | 1.6 × 1 | 1.6W |
| KAD/ADC/009 | 2.9 × 2 | 5.8W[1] |
| Bridges (external) | $(10^2 / 350) \times 16$ | 4.6W |

| | | |
|---|---|---|
| Bridges (internal) | (10/350) × (7-5) × 2 × 16 | 1.8W |
| Total (excluding DC/DC losses) | | 35.5W |
| Total (including DC/DC losses) | 35.5 × 1.2 | 42.6W |
| Total power consumed internally | 42.6 - 4.6 | 38.0W |

1. This figure excludes the power consumed due to the bridges.

For an actual system with the above configuration the total was measured to be:

| | | |
|---|---|---|
| Total (including DC/DC losses) | 28V × 1.46A | 40.9W |

This is about 4% from the estimated value.

**NOTE:** The margin of error can be higher due to variations from module to module, external connections, power efficiency and so on.

## 13.4 Power dissipation

The ambient (air) temperature is measured to be 26.1°C and the case temperature of the KAM/SYS/13U settled at 54.1°C.

The power radiated from an Acra KAM-500 can be approximated using the equation:

$$P_{rad} = \theta_{rad} \cdot \left(T_{KAM}^{4} - T_{surface}^{4}\right)$$

where:

| | |
|---|---|
| $P_{rad}$ | Radiated power |
| $T_{KAM}$ | Case temperature of an Acra KAM-500 (degrees Kelvin) |
| $T_{surface}$ | Equivalent black surface temperature (degrees Kelvin) of the surrounding enclosure (assumed to be ambient) |
| $\theta_{rad}$ | Radiation coefficient (5.78 x $10^{-9}$ for a vertical SYS/13U) |

This gives:

$$P_{rad} = 5.78 \times 10^{-9} \cdot (327.25^{4} - 299.25^{4}) = 19.9W$$

Heat transfer due to natural convection in still air, at sea level, from an Acra KAM-500 can be approximated using the equation:

$$P_{conv} = \theta_{conv}(T_{KAM} - T_{AMB})^{1.25}$$

where:

| | |
|---|---|
| $P_{conv}$ | Natural convection heat transfer |
| $T_{KAM}$ | Case temperature of an Acra KAM-500 (°C) |
| $T_{ambient}$ | Ambient air temperature surrounding the housing (°C) |
| $\theta_{conv}$ | Convection coefficient (0.21 for a vertical SYS/13U) |

This gives:

$$P_{conv} = 0.21 \cdot (54.1 - 26.1)^{1.25} = 13.5W$$

In this analysis it is assumed that the heat loss due to conduction is negligible because the unit is mounted on an insulator.

| | |
|---|---|
| The total power dissipated (according to the above equations) is therefore 19.9 + 13.5 | = 33.4W |
| The total power actually dissipated in the SYS/13U is (40.9 - 4.6) | = 36.3W |

## 13.5 Analysis of theory vs. practice

| | |
|---|---|
| The estimated total power consumption is | 42.6W |
| The actual total power consumption is | 40.9W (42.6W - 4%) |
| The estimated power dissipation for the measured temperatures is | 33.4W |
| The actual power dissipated internally is | 36.3W (33.4W + 9%) |

## 13.6 The maximum ambient temperature for the system

If the equations in section 16.1.3 are used with a KAM/SYS/13U case temperature of 85°C and an ambient temperature of 60°C, the following power can be dissipated:

$$P_{rad} = 5.78 \times 10^{-9} \cdot (358.15^4 - 333.15^4) = 23.9W$$

$$P_{conv} = 0.21 \cdot (85 - 60)^{1.25} = 11.7W$$

This total (35.6W) is slightly higher than the total at room temperature (33.4W) even though the Delta ($T_{KAM}$ - $T_{ambient}$ = 25°C) is smaller.

This indicates that the ambient still-air temperature can reach 60°C and the case temperature will not exceed 85°C.

## 13.7 Notes

- As a rule of thumb, the KAM/SYS/13U case temperature increases by 0.8°C per watt of power dissipated in a warm ambient environment (approximately 50°C).
- For smaller Acra KAM-500 units, the power radiated and convected decreases, as does the amount of power that needs to be dissipated.
- At high altitude (unpressurized), the rate of convection decreases. However ambient temperature may also be lower.
- In a small sealed enclosure, convection effectively ceases. Cooling then depends on conduction and radiation.
- The rate of airflow past an Acra KAM-500 is important in determining the normal real rate of convection cooling. The above example is based on still-air (worst case).
- In most applications, an additional amount of power is dissipated via conduction as an Acra KAM-500 is typically mounted to a metal support frame.

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Chapter 14

# Digital filtering

TEC/NOT/019

This paper introduces analog filters and their application to flight test instrumentation (FTI).

The following topics are discussed:



## 14.1 Overview

This paper compares analog filters with the type of digital filter used in Acra KAM-500 modules. It is not intended to be an exhaustive explanation of filtering and sampling theory. The most commonly used FTI techniques and their advantages and disadvantages are qualitatively discussed. This paper shows why digital filtering can provide superior performance to both traditional analog and switched-capacitance filters.

Most transducers used in FTI produce an analog signal that is related to a measurement of interest in some predefined way. For example, Wheatstone bridges formed from strain gages produce signals (on the order of tens of millivolts), which are proportional to the mechanical strains, and therefore the forces some structural members of an aircraft undergo.

Analysis of such signals using modern techniques requires that the data be acquired and stored in digital form. To accomplish this the signal is typically converted to a voltage (if not already so), amplified, offset added and then sampled at regular intervals.

This process necessarily requires the signal to be filtered. The filtering removes the unwanted portion of the signal while preserving the portion of interest. Without this filtering there is the chance that the sampled signal will be aliased and falsely show characteristic not really present in the original signal.

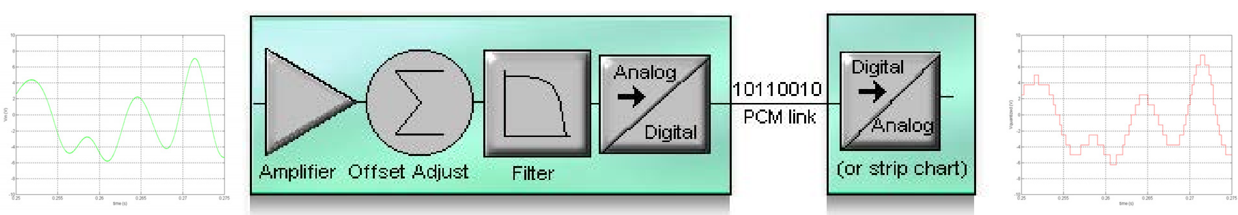


*Figure 14-1: An FTI channel*

The primary design goal of this filter is to remove the unwanted components of the signal as completely as possible without distorting the portion of the signal of interest. There are three major areas where this design goal may be compromised:

1. The attenuation (reduction of amplitude) characteristic of the filter that reduces the unwanted portion may also affect the signal of interest.
2. The delay through the filter circuit of each component frequency that makes up the desired signal may be different. This shifting distorts the captured signal's time characteristics. For example, a signal used to modulate a carrier may be phase aligned to the carrier before passing through the filter but have an unwanted time offset afterward.

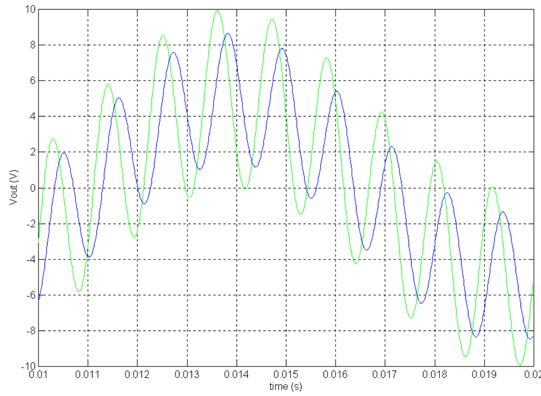


*Figure 14-2: Time offset before and after filtering*

3. Converting a signal from analog to digital introduces uncertainty (quantization noise) because of finite resolution of the device used to convert the signal. This noise is always present in analog design, but it can be greatly reduced if a digital filter with oversampling and downsampling is used.

This paper will show that using digital filters minimizes or completely eliminates all three of these errors and is, therefore, the best choice.

The analog and digital approaches are very similar. Both have amplifiers and filters before the analog-to-digital conversion. They differ only in that the digital system's additional filtering and fine-tuning of gain and offset is carried out after the analog-to digital-conversion. This significantly simplifies the amplification, offset and in particular the filtering before the A/D. This paper describes the merits of this method.

## 14.2 Reproducing the signal

The best way to analyze both digital and analog filtering methods is to compare the captured signal to the original. Any difference can be considered an error.

If a slow-moving sine wave (here, slow means the frequency is less than half the sampling rate) is input to the system discussed in the previous section, the reproduced signal is seen to be a series of steps as the output attempts to follow the input. The size of these steps depends on the resolution of the A/D (the errors caused by this are discussed in “14.4 Quantization noise” on page 60).

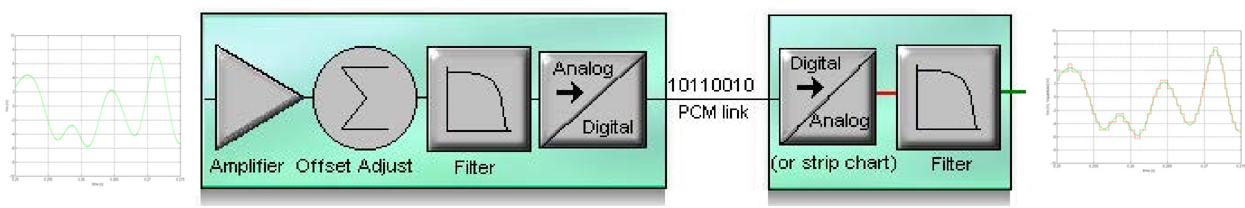


*Figure 14-3: Slow signal input into digital filter*

For a slow moving sine wave the output appears to follow the input. The following figure shows what happens if a fast sine wave is connected (fast means the frequency is more than twice the sampling rate).

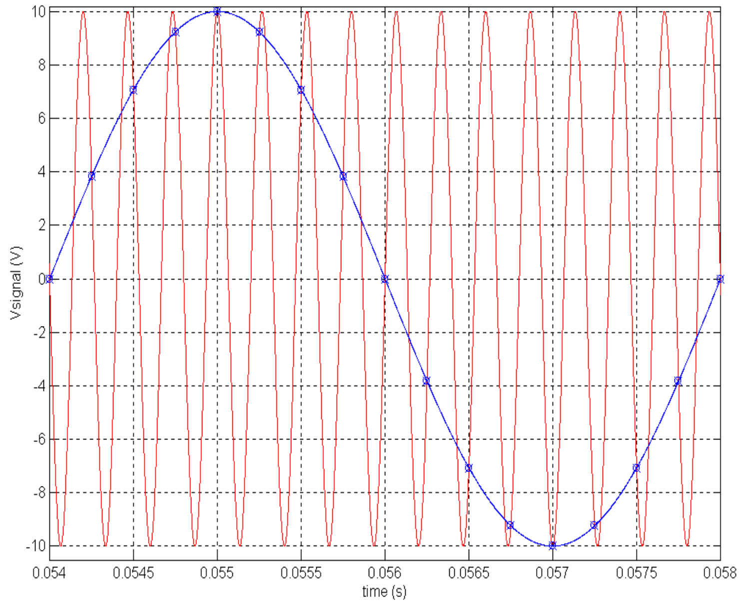


*Figure 14-4: Aliasing due to undersampling*

The fast sine wave will be reproduced as a slower sine wave. In 1928 H. Nyquist working in Bell telephone laboratories in New York studied this phenomenon and reached the following conclusions for all signals (not just sine waves).

If a signal is sampled at twice the bandwidth of the signal, then the signal can be reproduced exactly.

For low-pass signals this can be paraphrased as:

Assume a perfect filter that does not attenuate sine waves below half the sampling rate, but removes sine waves above half the sampling rate. With one of the filters before the A/D and one after the D/A then:

The filtered signal can be sampled and reproduced exactly* even at each point in time between the samples.

*There will be an error due to the step size of the A/D and D/A which is discussed in “14.4 Quantization noise” on page 60.

These filters are called anti-aliasing (or pre-sample) filters and in FTI are usually low-pass (in that they pass lower frequencies only). The crux of the problem is that the ideal filters discussed above do not exist. Real-life filters are a series of compromises with respect to attenuation, time distortion, power consumption and PCB (Printed Circuit Board) space. The next section discusses some of these trade-offs with respect to analog filters.

## 14.3 Analog filters

One method of designing analog filters is to use the Sallen-Key low-pass circuit in the following figure *(a)*. At very low frequencies the capacitors act as open circuits and the filter behaves like the voltage follower in the following figure (b). At very high frequencies the capacitors behave as short circuits and the inputs (and therefore output) becomes 0V.

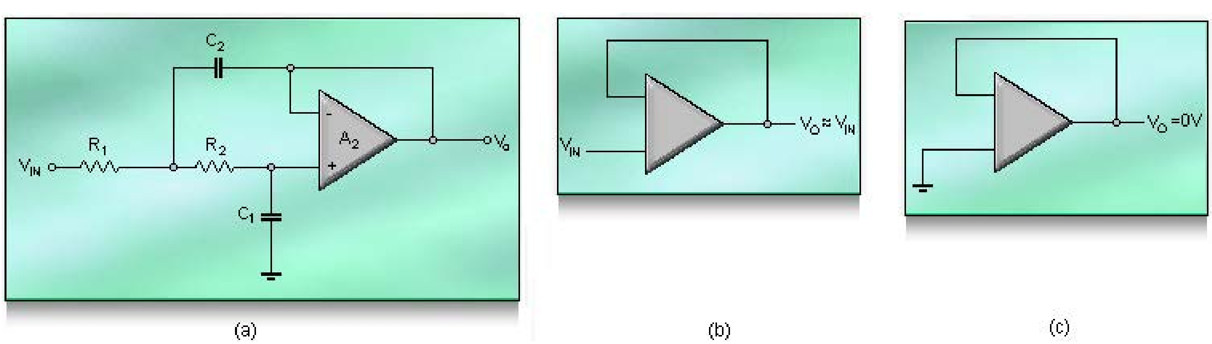


*Figure 14-5: (a) Unity-gain Sallen Key 2-pole filter (b) Behavior of filter for very low frequencies (c) Behavior of filter for very high frequencies*

This circuit is called a 2-pole low-pass filter. A 2-pole filter must have at least two capacitors. Other types such as 4, 6 or 8-pole filters can be made by cascading two, three or four of these blocks. In FTI, Butterworth and Bessel (Thomson) filters are often used. The attenuation as a function of frequency and the delay as a function of frequency for both Butterworth and Bessel filters are shown in the following figure.

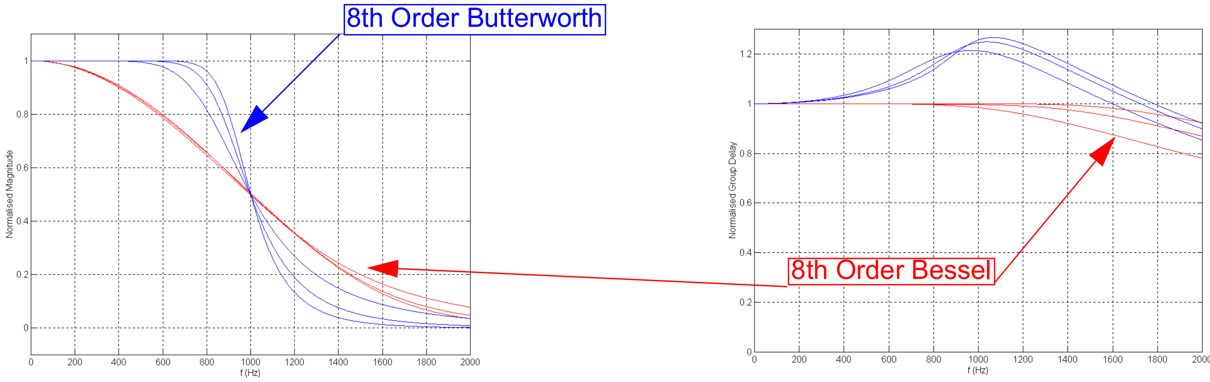


*Figure 14-6: Normalized amplitude response and group delay for 4th, 6th and 8th order Bessel and Butterworth low-pass filters*

The Butterworth filter has the flattest amplitude response for lower frequencies of any analog filter, however different frequencies are delayed by different amounts causing shape distortion. The Bessel filter has a more consistent delay than any other analog filter type (less shape distortion) but has poor attenuation (it rolls off too slowly thus attenuating signals of interest) in the passband.

A real-life illustration of both of these types of distortion is graphed in “14.7 Conclusions” on page 63.

With analog filters there is a trade-off between amplitude attenuation in the pass-band and shape distortion. Analog filters use capacitors, which means that the characteristics vary from channel to channel and with temperature. Higher order analog filters require even more power and PCB space than lower order filters and introduce more components in the signal path, thus increasing offset, gain, linearity and reliability concerns.

## 14.4 Quantization noise

Before looking at digital filtering it is worthwhile looking at the effects of the finite step-size of the A/D in more detail. The following figure shows a random signal with no frequency components above 1000 Hz. The signal is sampled at 4000 Hz using a 4-bit A/D.

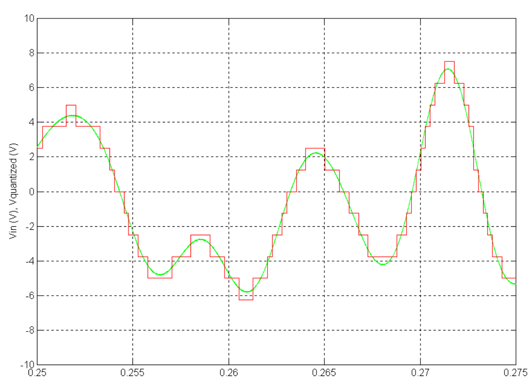


*Figure 14-7: Band-limited random signal sampled with a 4-bit A/D at 4000Hz*

Allowing for delays in the system the difference between the original signal and the captured signal is as shown in the following figure. This error is due to the finite step size of the 4-bit A/D. For a 4-bit A/D the step size is 1.25V for a range of ±10V (20/16), this means a worst-case error of ±0.625V.

This error has frequency components of up to half the sampling rate. However, if the same signal is sampled with the same A/D operating at, for example, eight times faster than before and then digitally filtered and downsampled [2], then the error will be reduced by the same factor (that is, 1/8). It is important to emphasize here that the traditional analog approach yields the large error (that is, it does nothing to reduce this noise) and the digital approach yields the small error (that is, it significantly reduces this noise).

Another advantage to over-sampling the signal is that real-life noise components above the signal bandwidth (Dither) cause the A/D to toggle between levels rather than return a constant value for slow signals. These components are removed by the filter after the D/A, but in the meantime, have helped provide a more accurate capture of the signal.

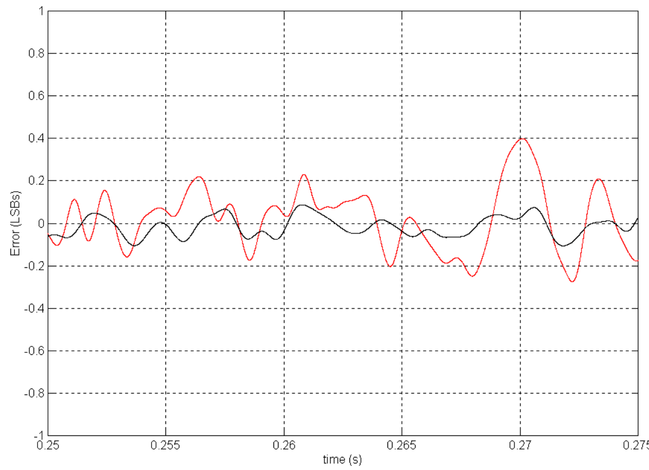


*Figure 14-8: Quantization errors with a 4-bit A/D at 4000 Hz and the error from the same A/D at 32 kHz with dither added and filtering after the A/D*

Another advantage is that non-linearities (variations in step-sizes) are reduced by filtering after the A/D.

## 14.5 Digital filtering

Digital filters are implemented after a signal has been sampled. They are mathematical calculations performed on a data series with known and controllable properties. They are not subject to component tolerances. Digital filters can be constructed that are equivalent to analog filters, but the converse is not always true. That is, some digital filters cannot be reproduced with analog circuits.

The following figure shows a generic FIR (Finite Impulse Response) filter. Outputs are calculated by multiplying past inputs by certain coefficients.

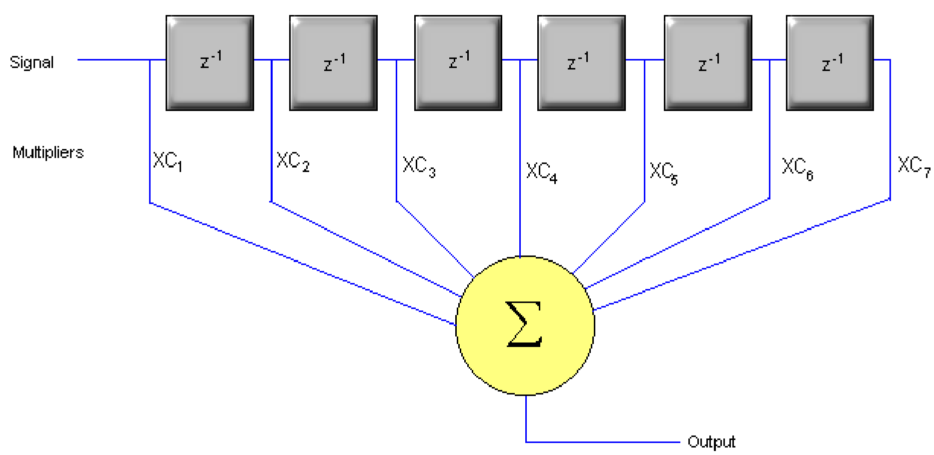


*Figure 14-9: Generic FIR filter*

Digital filters may be implemented with digital signal processors, lookup tables, or other digital circuitry. A couple of practical concerns are the speed at which the filter calculation can be performed and the precision of coefficients and results.

In Acra KAM-500 modules, signals are sampled many times faster than specified by the user. This over-sampling has the advantage of removing some of the quantization noise as discussed in “14.4 Quantization noise” on page 60. More importantly, the constraints on the analog anti-aliasing filter are much reduced and so it will not typically suffer from the problems of a higher order multi-stage design.

A simple, fixed, second-order anti-aliasing filter is usually sufficient so the problem with noise of cascaded stages is eliminated. When using an oversample-and-decimate approach the cutoff point of this filter may be fixed thus eliminating the noise and inconvenience associated with altering the passive components of the filter.

The digital filter used in Acra KAM-500 modules is a 31-tap half-band filter (sometimes called a Kaiser filter). The following graphs show that it has flatter pass-band response than the flattest (Butterworth) analog and a more consistent delay then the most consistent (Bessel) analog filter.

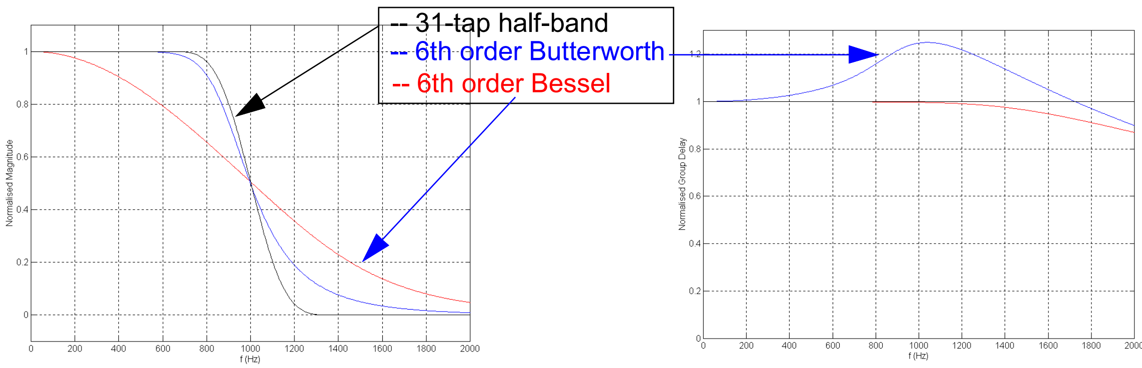


*Figure 14-10: Normalized amplitude response and group delay for a 6th order Butterworth, bessel and a 31-tap half-band filter*

## 14.6 Switched Capacitor Filters (SCFs)

In “14.3 Analog filters” on page 59, analog filters built around a Sallen-Key building block were discussed. The statevariable method uses the integrator building block shown in the following figure (a). This integrator can be approximated by the switched capacitor circuit in the following figure (b) where capacitors are charged and discharged through MOSFET switches. Adding this scheme to an active filter allows the adjustment of the resistance and hence the cutoff of the filter by only changing the frequency of a reference clock signal used to switch the MOSFET.

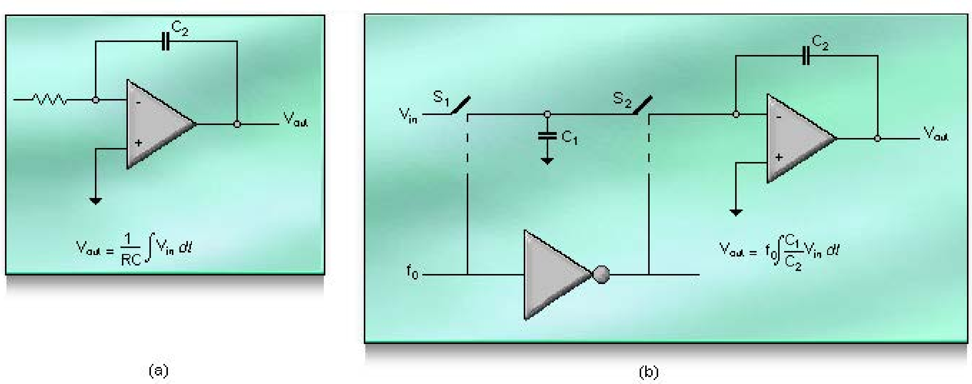


*Figure 14-11: (a) Conventional integrator (b) Switched capacitor integrator*

This approach uses a minimum number of components, and is very flexible and accurate in terms of adjusting the cutoff frequency. ICs typically have 5th order Bessel or Butterworth responses.

However, after much experimentation with these devices, Curtiss-Wright decided to stop using them in 12-bit systems for the following reasons:

- Harmonics of the noise caused by high-speed switching was very difficult to remove. Ideally a filter would be added before and after the switched capacitor filter (SCF).
- Power consumption per channel due to high-speed switching is almost 125 mW per channel.
- DC offsets, non-linearities and drifts were in the order of 0.1% which is not consistent with a 12-bit system.
- Significant PCB space is required as multiple channels cannot share the resource.

- The SCFs are sampling devices and need anti-aliasing filters. To allow cutoff frequencies more than a decade (10x) apart, multiple SCFs need to be cascaded (just like the FIR filter in “14.5 Digital filtering” on page 61). However, in the case of SCFs that means doubling the errors, PCB space, and power consumption.

## 14.7 Conclusions

In this paper the following points were demonstrated:

- Sampling at twice the highest frequency component of a signal means that it can be reproduced at the sampling points to within ±1/2 LSB.
- If the reproduced signal is passed through a filter then it can be reproduced even between the sample points to within ±1/2 LSB.
- Signals above half the sampling rate appear as slower frequencies (much like stage coach wheels in old western movies) and as such must be removed before sampling.
- These components are traditionally removed using either a 6th-order Butterworth or 6th-order Bessel analog filter.
- To maximize the amount of signal pass-band, these filters should have cutoff points set as a function of the sampling rate (not easy for active filters).
- Butterworth filters have strong attenuation in the stop-band and little attenuation in the pass-band. However, signal delay varies with frequency thus causing shape distortion. See Figure 14-12 on page 63.
- Bessel filters have less delay distortion then any analog filter. However, they have weak attenuation in the stop-band and significant attenuation in the pass-band. See Figure 14-12 on page 63.
- Switched capacitor filters cannot be used in 12-bit systems where power and space are at a premium.

Digital filters offer the following advantages:

- The 31-tap half-band filter has a flatter amplitude response than the flattest analog filter (Butterworth) (see the 900 Hz component in the following figure).

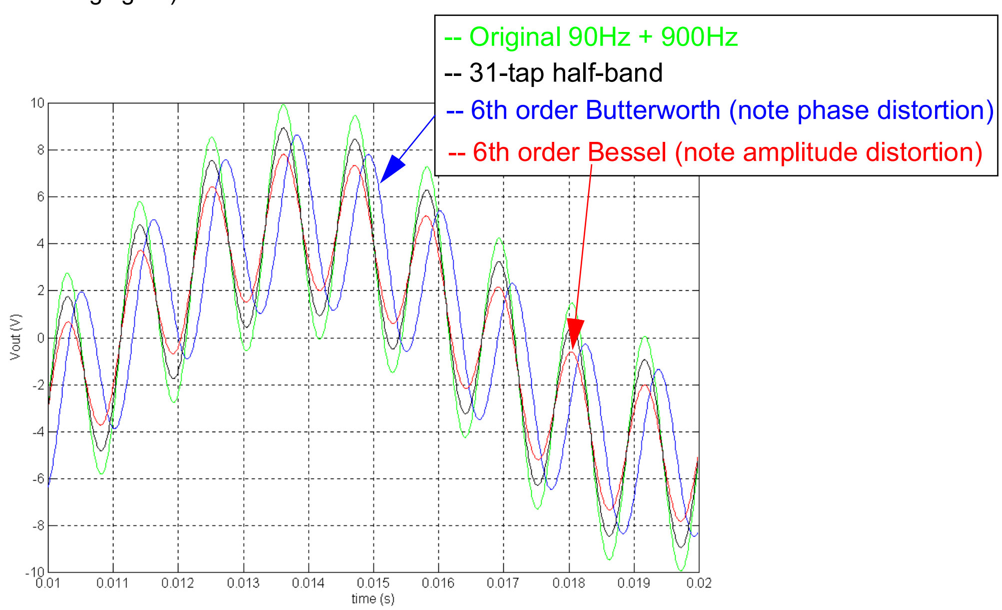

*Figure 14-12: A sum of 90 Hz and 900 Hz components passed through a half-band, Butterworth and Bessel filter*

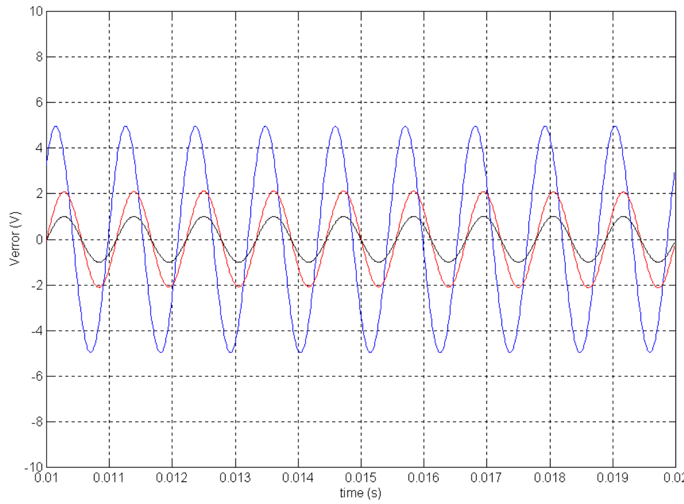


*Figure 14-13: Time and amplitude distortions through a half-band, Butterworth and Bessel filter*

It can be clearly seen in the previous figure that the digital filter has no time distortion and the least amplitude distortion of all three types of filters. As stated above, this is the design goal of the filtering, and so digital filters are the best choice to accomplish this goal.

- The 31-tap half-band filter has less delay variation than the most consistent analog filter (Bessel).
- Over-sampling and decimating digital filters significantly improves accuracy by reducing quantization noise and non-linearity errors.
- Channel-to-channel response matching of digital filters is exact compared to 5% variations with active analog filters and 0.5% variations with switched capacitor filters.
- Digital cutoff frequencies are an exact function of the final sampling rate. Therefore they are optimum and programmable.
- Doing the filtering and fine-tuning of gain and offset after the A/D means there are considerably fewer components (sources of error) in the signal path.
- Savings in PCB space gained with digital filters and smaller package sizes of today's A/Ds allow good channel density to be achieved with a dedicated A/D for each channel. This eliminates the errors associated with analog multiplexers.

## 14.8 References

For a detailed mathematical treatment of the issues involved with sampling and digital signal processing see:

[1] Digital Signal Processing - A Practical Approach

Emmanual C. Ifeachor, Barrie W. Jervis

Addison-Wesley Publishing Company

[2] Discrete-Time Signal Processing

Alan V. Oppenheim, Ronald W. Schafer, John R. Buck

Prentice Hall Publishing

[3] A Basic Introduction to Filters - Active, Passive, and Switched-Capacitor

National Semiconductor

Application Note 779

Kerry Lacanette

April 1991

To experiment with A/Ds and filters including the three types discussed in this paper or to reproduce the graphs used:

The MatLAB software package from The MathWORKS® Inc.

# An introduction to resistance temperature detectors

TEC/NOT/023

CURTISS-WRIGHT

This paper introduces temperature measurement using Resistance Temperature Detectors (RTD). The following topics are discussed:



## 15.1 Introduction

In 1871, Sir William Siemens proposed a thermometer comprising a metallic conductor as the thermometric medium, whose resistance changes with temperature. He chose platinum as the element for the resistance thermometer. Platinum does not oxidize at high temperatures and has a relatively uniform change in resistance with temperature over a large range. The Platinum Resistance Temperature Detector is still used today as an interpolation standard from the oxygen point.

## 15.2 Overview

An RTD is a general term for any device that senses temperature by measuring the change in resistance of a material. The resistivity ($\rho$) of a material is directly proportional to its resistance (R),

$$R = \rho(l/A)$$

where l is the length of the wire and A is the cross sectional area. The resistivity of a material is also dependant on temperature. The resistance of a metal increases with temperature and at higher temperatures, atoms move more rapidly and are arranged in a less orderly fashion, as shown in the following figure, creating a larger interference to the flow of electrons. If the temperature change is gradual, the resistivity of a metal increases almost linearly with temperature. That is,

$$\rho_T = \rho_0(1 + \alpha\Delta T)$$

where $\rho_0$ is the resistivity at some reference temperature (such as 0°C or 20°C), $\rho_T$ is the resistivity at a temperature $\Delta$T above the reference temperature, and $\alpha$ is the temperature coefficient of resistivity

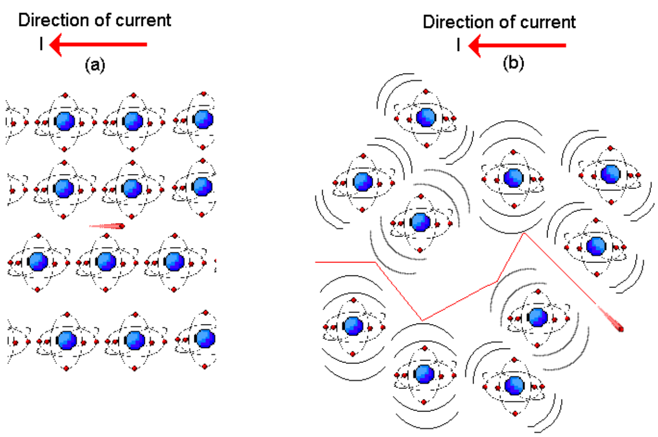


*Figure 15-1: (a) Atoms in a metal; (b) Atoms in a metal at higher temperature*

All metals produce a positive change in resistance for a positive change in temperature, which is, of course, the main function of an RTD. System error is minimized when the nominal value of the RTD resistance being used is large, that is, a metal wire with a high resistivity. The lower the resistivity of a metal, the more material is required. The following table lists the resistivities of common RTD materials.

Table 15-1: Metal Resistivities

| Metal | | Resistivity Ω m |
|---|---|---|
| **Gold** | **Au** | 2.349 x $10^{-8}$ |
| **Silver** | **Ag** | 1.591 x $10^{-8}$ |
| **Copper** | **Cu** | 1.664 x $10^{-8}$ |
| **Platinum** | **Pt** | 1.059 x $10^{-7}$ |
| **Tungsten** | **W** | 5.491 x $10^{-8}$ |
| **Nickel** | **Ni** | 6.842 x $10^{-8}$ |

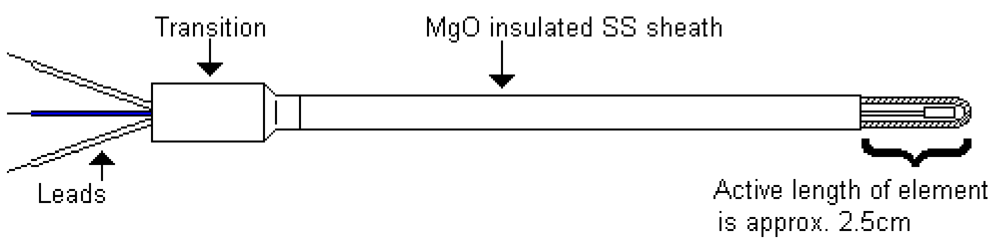


*Figure 15-2: Resistance temperature detectors*

An RTD probe is an assembly composed of a resistance element, a sheath, lead wire and a termination or connection. There are several very important details that must be specified in order to properly identify the characteristics of an RTD:

- Material of resistance element (platinum, nickel, and so on)
- Temperature coefficient
- Nominal resistance
- Temperature range of application
- Physical dimensions or size restrictions
- Accuracy

Resistance thermometers can be used for a wide variety of industrial applications. A high electrical output can be obtained by using the RTD with many types of simple resistance bridges. This high output can then be fed directly into recorders, temperature controllers, transmitters, or digital readouts, which can be calibrated to read very precise increments of temperature over wide dynamic ranges.

## 15.3 RTD specifications

The Resistance-Temperature (R-T) curves of pure metals, namely platinum and nickel, over definite spans, are relatively linear making them ideal materials for the elements in resistance thermometers. RTDs can also be constructed from copper or nickel/iron. Each metal has a different a-coefficient and operating range. An RTD's a-coefficient must be matched to its instrumentation or an error of several degrees may occur.

Platinum is by far the most popular metal used due to its linearity with temperature. The R-T relationship of some common RTD materials are illustrated in the following figure, where the y-axis is the normalized resistance with respect to resistance at 0°C (32°F), x-axis is the temperature.

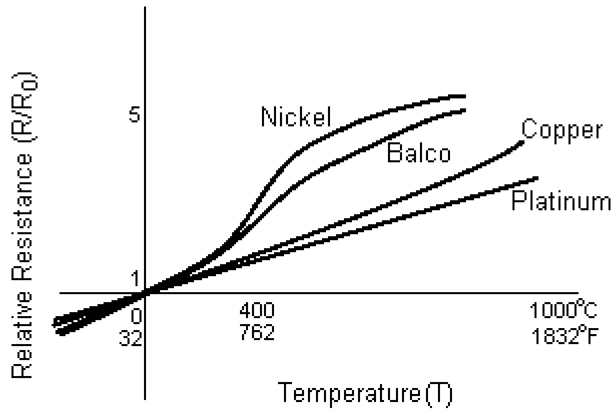


*Figure 15-3: Resistance-Temperature relationship for some RTD materials*

The temperature coefficient of an element is a physical and electrical property of the material. This is a term that describes the average resistance change per unit of temperature from ice point to the boiling point of water. Different organizations have adopted different temperature coefficients as their standard. Laboratory resistance temperature detectors of pure platinum, fully annealed and strain free have been chosen as the International Standard of Temperature Measurement from liquid oxygen [(LO2)-182.97°C] to the melting point of antimony [(Sb) + 630.5°C]. Platinum resistance wire has been generally acknowledged as the standard for accuracy and repeatability in a temperature sensor; it is the standard interpolation device between critical temperatures from -259°C to 631°C. Temperature coefficient: 0.003915 W°C-1 and 0.00385 W°C-1. (0.00385 or DIN standard has been adopted as the World and USA standard.) The following table compares several RTD materials.

Table 15-2: RTD material specifications

| Material | Temp Range (°C) | ~T.C.%/°C at 25°C |
|---|---|---|
| Platinum | -200 to +850 | 0.39 |
| Nickel | -80 to +320 | 0.67 |
| Copper | -200 to +260 | 0.38 |
| Nickel-Iron | -200 to +260 | 0.46 |

Specifications for temperature range are different for thin film, wire wound and glass encapsulated types. The usual nominal resistance of platinum RTDs is 100W at 0°C. Unfortunately, standards are not identical worldwide, which presents a problem when an RTD, built to one standard, is used with an instrument designed to a different standard. In addition, manufactured tolerances must be considered. Not only do they vary with the manufacturer and the standard, but the tolerances are also affected by the manufacturing process itself.

The DIN and American standards are the most commonly available. The following table describes the most common standards for platinum RTDs.

Table 15-3: Standards for RTDs

| Organization | Standard | Alpha Average Temp. Coefficient of Resistance | Nominal Resistance (W) at 0°C |
|---|---|---|---|
| British Standards Association | B.S. 1904: 1984 | 0.003850 | 100 |
| Fachnormenausschuss Elektrotechnik in Duetschen | DIN43760-1980 | 0.003850 | 100 |
| U.S. Department of Defense | MIL-T-24388 | 0.00392 | 100 |
| International Electronical Commission | IEC 751: 1983 | 0.003850 | 100 |

Table 15-3: Standards for RTDs (continued)

| Organization | Standard | Alpha Average Temp. Coefficient of Resistance | Nominal Resistance (W) at 0°C |
|---|---|---|---|
| Japanese Standard (Joint Industrial Standards) | JIS C1604-1981 | 0.003916 | 100 |

RTDs come in 2-, 3- and 4-wire probes. The most commonly used RTD is the 3-wire probe, which allows for the compensation of loop resistance by introducing a third wire, known as a reference wire, that is equal in length and size to the two wires connecting the RTD to the readout device. This third wire bypasses the RTD at its junction to one of the other two wires, and allows the readout device to automatically subtract the lead resistance from the overall resistance of the circuit.

Offering even greater potential for accuracy is the 4-wire RTD, which uses two reference wires. The system, however, must be designed to accommodate this design.

In 1826, forty-five years before RTDs, T.J. Seebeck discovered that when wires of different metals are fused at one end and heated, a current flows from one to the other. The electromotive force generated can be quantitatively related to the temperature and hence, the system can be used as a thermometer - known as a thermocouple.

When choosing whether to use a thermocouple or an RTD in a design, the conditions to which the temperature component will be exposed must be considered. RTDs are extremely precise for temperatures below 524°C, and can be more accurate than a thermocouple; however, the reliability of RTDs in service above 524°C is poor. In addition, an RTD's R-T relationship is more linear than the thermocouple's EMF-to-temperature ratio.

For almost all other requirements, however, thermocouples are preferable to RTDs. First, due to its ability to withstand extreme bending and vibration, the thermocouple is more durable than the RTD. Thermocouples also have a wider temperature range (that is, -162°C to 2300°C), as opposed to the RTD's range of -210°C to 524°C. While in theory RTD elements are good for temperatures well in excess of 524°C, in practice, contamination of the element (and thus, loss of accuracy) is common. The following table illustrates the advantages and disadvantages of using RTDs as opposed to thermocouples.

Table 15-4: Comparison of thermocouples and platinum RTDs

| | Thermocouple | Platinum RTD |
|---|---|---|
| Economics | Probe is cheaper. | Probe is more expensive. |
| | 2-wire transistor can be used in the field if *home run* cables are lengthy, thereby keeping system cost down. | System cost can be lower because RTDs use ordinary copper leads for extension wire. |
| Operations | Non-linear output signal. | Linear output signal. |
| | Small size-fast response. | Limited size. |
| | Higher temperature range. | Lower-use temperature range. |
| | Point sensing. | No point sensing. |
| Reliability | More reliable with vibrations and at high pressures (in excess of 10,000 PSIG) and high temps (in excess of 4000°F). | Not as reliable to shocks and vibrations, and poor stability in high temperatures. |
| Maintenance | More rugged. | Less rugged. |
| | Not as vulnerable to contamination. | More vulnerable to contamination. |
| Sensor accuracy | =±2°F or 3/8 of 1% of reading. | More accurate, ±0.1% with compensating loop. |
| General overall system accuracy | Approx. ±0.75% of reading measured temperature. | Approx. ±0.5% of the measured temperature. |
| Installation methods | Equal. | Equal with one additional wire. |

Table 15-4: Comparison of thermocouples and platinum RTDs (continued)

| | Thermocouple | Platinum RTD |
|---|---|---|
| Wiring methods | Two-wire, thermocouple material. | Three-wire minimum, copper wire. |
| Terminations | Same. | Same. |
| Monitoring equipment | Readily available. | Readily available. |
| | Monitors sensor output only and compensates for cold junction temperature. | Sends power to field sensor before sensor can be monitored. |
| | Reads sensor output only (for temperature). | Interprets lead wire resistance change as temperature change if 3- or 4-wire systems are not used. |

RTDs offer stable output within broad temperature ranges, can be recalibrated for verifiable accuracy, are stable over the long term, follow a more linear curve than thermocouples, have high sensitivity, and provide accurate reading over narrow temperature spans. The KAD/ADC/019/100 and KAD/ADC/013/B modules have been designed to take temperature samples from RTDs. This was a specification set out by the customer, which was duly incorporated into the above-mentioned modules.

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Chapter 16

# Evolution of pulse code modulation

TEC/NOT/024

This paper describes the evolution of Pulse Code Modulation (PCM). The following topics are discussed:



## 16.1 Overview

PCM is the process of sampling an analog signal's amplitude at fixed intervals, converting the amplitudes into discrete levels (quantization) and assigning digital codes to represent those levels. This paper outlines the development of wireless communication from Guglielmo Marconi’s demonstration of the wireless telegraph in 1895, the use of amplitude and frequency modulation and mechanical commutators evolving into electronic switches and multiplexors. In particular, it discusses the development of the different methods used in communications: Stage I, mechanical commutators; Stage II, the introduction of the integrated circuit; and Stage III, Acra KAM-500.

## 16.2 History

Telemetry comes from the Greek and Latin words for distance and measurement. It is based on the studies of James Clerk Maxwell, who developed the mathematical theory of electromagnetic waves, and Heinrich Hertz, who devised an apparatus for generating and detecting them.

Guglielmo Marconi, recognizing the possibility of using these waves for a wireless communication system, gave a demonstration of the wireless telegraph, using Hertz's spark coil as a transmitter for Amplitude Modulation (AM) in 1895. AM (see the following figure) is the modulation method used in the AM radio broadcast band. In this system, the intensity or amplitude of the carrier wave varies in accordance with the modulating signal. The frequency components of the modulating signal are translated to occupy a different position in the spectrum. It is essentially a multiplication process in which the time functions that describe the modulating signal and carrier are multiplied together.

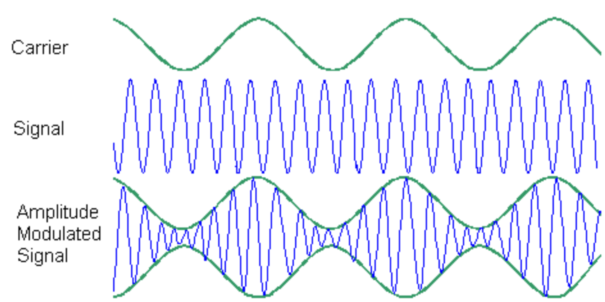


*Figure 16-1: Amplitude Modulation*

In 1906, the transmission of music and speech became possible with the work of Reginald Fessiden and Ernst F.W. Alexanderson. However, it was not until Major Edwin H. Armstrong invented the superheterodyne radio receiver in 1918 that long-range radio reception became practicable. To this day almost all radio receivers are of this type.

Twenty-seven years later, in 1933, Armstrong was granted patents on a Frequency Modulation (FM) system that he promoted as a superior alternative to the established AM broadcasting service. In FM, the frequency of the carrier wave is varied in such a way that the change in frequency at any instant is proportional to another signal that varies with time (see the following figure). Its principal application is also in radio, where it offers increased noise immunity and decreased distortion over the AM transmissions at the expense of greatly increased bandwidth.

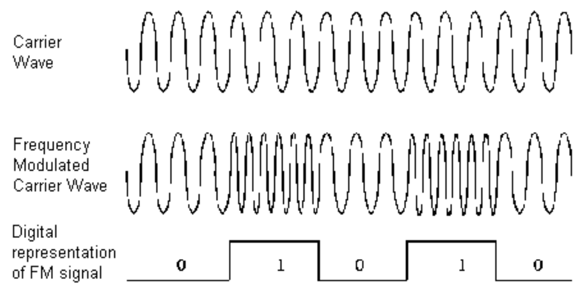


*Figure 16-2: Frequency Modulation*

## 16.3 Sampling

In 1928, Harry Nyquist developed criteria for the correct reception of telegraph signals transmitted over discrete channels in the absence of noise. Much of Nyquist's early work was applied later to the transmission of digital data over discrete channels. He introduced a sampling theorem, which states that a signal can be completely recovered from knowledge of its samples taken at a rate of 2W samples per second for a band-limited signal with a bandwidth of W Hertz.

An important feature of the sampling process is the conservation of time. That is, the transmission of the message sampled engages the transmission channel for only a fraction of the sampling interval on a periodic basis, and in this way some of the time intervals between adjacent samples are cleared for use by other independent message sources on a time-shared basis, giving rise to Time Division Multiplexing (TDM).

This method of transmission was first broadcast via mechanical commutators (see stage I of the following figure). A commutator was originally a rotating mechanical switch with many contacts used for sequentially switching voltages. Early telemetry systems used two synchronized units (called a commutator and decommutator) to pass analog voltage samples through a link between the units. Commutators can be connected in series and driven at different speeds to allow channels to be sampled at different rates. Modern telemetry systems use electronic switches and multiplexors. This strategy required some way of knowing where in a sequence of data a given point would be. One solution to this problem was to introduce a synchronization pattern, which in turn could also be used to calibrate the gain and offset of the receiver.

Faster signals were connected more often to the commutator, giving rise to the term super-commutation for signals sampled more than once per periodic rotation of the main commutator. Slower signals were connected to a second (or third) commutator, which revolved at a slower rate than the main commutator, giving rise to sub-commutation.

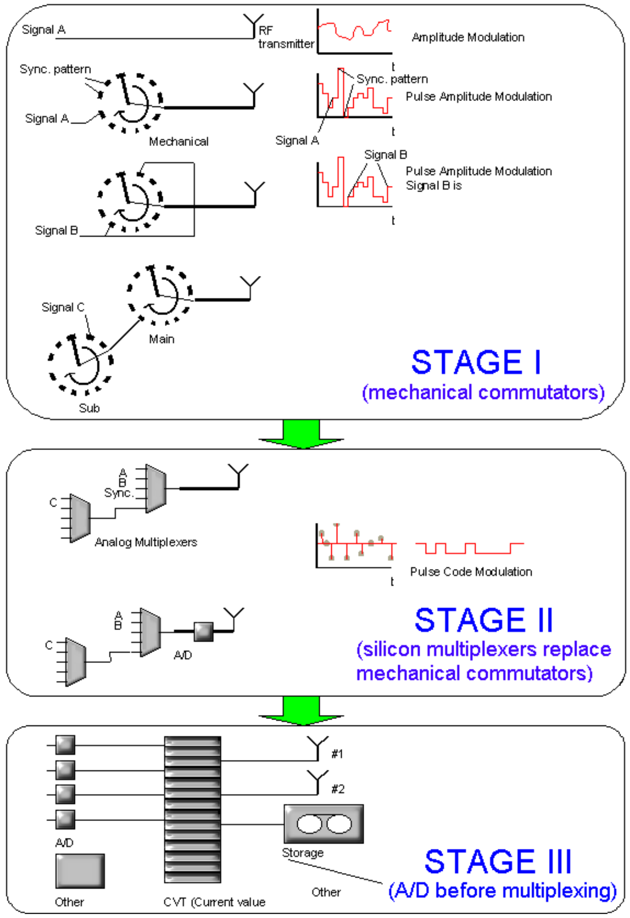


*Figure 16-3: The evolution of communication technology*

## 16.4 Digital communication

In 1948, the theoretical foundations of digital communications were laid by Claude Shannon in a paper entitled, *A Mathematical Theory of Communication*. Shannon's paper was received with immediate and enthusiastic acclaim. Prior to the publication of Shannon's 1948 classic paper, it was believed that increasing the rate of information transmission over a channel would increase the probability of error; the communication theory community were taken by surprise when Shannon proved that this was not true, provided that the transmission rate was below the channel capacity.

Many developments in the method of communication took place during Stage I (see the previous figure) of the communication technology evolution. All of these methods, however, were improved significantly by the introduction of the integrated circuit in 1958 by Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor Corp. This development in technology was the beginning of Stage II.

In 1939, The English inventor Alec H. Reeves developed PCM for the digital encoding of speech signals. The technique was developed during World War II to enable the encryption of speech signals. A full-scale, 24-channel system was used in the field by the United States military at the end of the war. It was used to transmit information over long distances with hardly any interference or distortion. With built in mathematical redundancy and error checking of the received signal, offering higher noise rejection and response speed, PCM had become the most important form of pulse modulation. However, PCM had to await the discovery of the transistor and the subsequent development of large-scale integration of circuits for its commercial exploitation.

PCM is the process of sampling an analog signal’s amplitude at fixed intervals, converting the amplitudes into discrete levels (quantization) and assigning digital codes to represent those levels. This process is sometimes referred to as analog to digital (A/D) conversion. The higher the sample rate, the greater the number of quantization levels, and therefore the closer the representation of the digital codes will be to the original analog signal.

The number of quantization levels depends on the number of bits in the digital code used to represent the signal's amplitude. If a 4-bit binary code was used, then there would be 16 quantization levels. The analog signal would be sampled and assigned codes of the form: 0101, 0111, 1100 and so on. The difference between the original analog signal amplitudes and the assigned discrete levels is called quantization noise. The greater the number of quantization levels, the smaller the quantization steps, which results in lower quantization noise. Quantization may be linear (using a uniform step size) or non-linear.

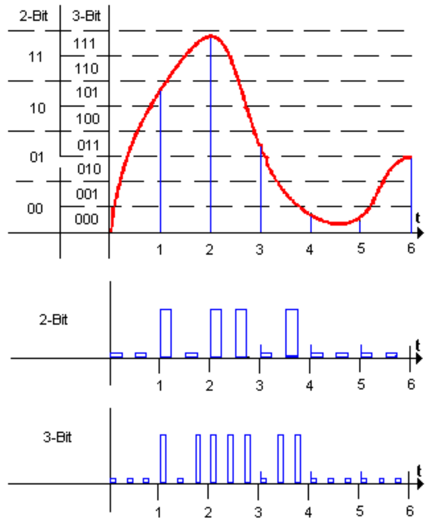


*Figure 16-4: Pulse code modulation*

In 1996, Stage III of the communications technology evolution brought with it large advances in the methods of PCM transmission, by repositioning the A/D converters, which were placed after the circuit's combinational logic in STAGE II. The quality of the incoming signal is heightened with the A/D converters placed before the logic. This method protects the signal from deteriorating through the multiplexers before being sampled. This leads to a more improved approximation of the original signal.

This technology has been implemented within the Acra KAM-500 system, which is used in over 25 countries in the most demanding applications and harshest of environments including aircraft flight test, vehicle crash test, and turbine telemetry.

## 16.5 References

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Chapter 17

# Dictionary of telemetry terms

TEC/NOT/026

This paper defines some terms commonly used in telemetry. The following topics are discussed:



## 17.1 Definitions

### 17.1.1 Basic terms

#### Barker Codes

A selection of bits to be used as frame sync words so as to minimize the probability of false lock. For more information, see the *Reference* section of *Applications Handbook*.

#### Hamming Code

A method by which extra bits can be added to a word so as to detect one (or more) bit errors (and possibly fix them).

#### IRIG

Inter-Range Instrumentation Group of the Range Commanders Council (RCC).

#### Pulse Amplitude Modulation (PAM)

Pulse modulation in which a voltage is sampled periodically and transmitted as an analog signal whose amplitude is proportional to the sampled voltage. Because PAM is susceptible to transmission noise, it has been replaced by PCM in most telemetry applications. For more information, see *TEC/NOT/024, Evolution of Pulse Code modulation (PCM)*.

#### Pulse Code Modulation (PCM)

Pulse modulation in which a signal is sampled periodically, converted to a digital value, and transmitted as a serial binary code. For more information, see *TEC/NOT/024 - Evolution of Pulse Code modulation (PCM)*.

#### Telemetry

The science of gathering information at some remote location and transmitting the data to a convenient location to be examined and recorded.

#### Time Division Multiplexing (TDM)

A process by which two or more channels of information are transmitted over the same link by allocating a different time interval for the transmission of each channel.

### 17.1.2 Serial transmission

#### Bandwidth

The frequency range occupied or required by a signal; the frequency range containing useful information. PCM signals contain harmonics that are usually removed by pre-modulation filtering to reduce the bandwidth needed for telemetry transmission or tape recording. However, insufficient bandwidth may result in the loss of essential information and prevent the recovery of PCM encoded data.

#### Bit Error Rate (BER)

Probability of a bit being received incorrectly. Every data link has a theoretical minimum error rate depending on the noise present. A reasonable encoder/decoder system linked via copper would have a BER of 10-9. BERs are specified for encoders, data links (especially radio), bitsyncs and decoders.

Another popular expression (especially among bit sync suppliers is that the bit-rate is within 1 dB of theory. This means that the error rate, when plotted in dBs versus noise, is within 1 dB of the theoretical best case graph.

#### Bit-rate

The number of PCM output bits transmitted in 1s, such as 2 Mbps. The bit-rate must be stable in order for the PCM decoder to regenerate the bit clock needed to determine the logic level of each data bit in the PCM code.

#### Bit synchronizer

Responsible for recovering *clean* clock and data from a (usually noisy) PCM stream.

#### Decoder

Typically comprises a bitsync and frame synchronizer and outputs (to DPR, A/D status) for selected parameters. Decoders can be considered low-end ground stations. Ground stations have decoder modules included.

#### PCM code

Any of several encoding schemes used to convert a parallel digital value into a serially transmitted sequence of binary ones and zeros such that a PCM receiver can decode and recover the original digital value. For more information, see *TEC/NOT/024 - Evolution of Pulse Code Modulation*.

#### Signal to Noise Ratio (SNR)

At any point in an electronic circuit, device or transmission system, the ratio of one parameter of a desired signal to the same or a corresponding parameter of the noise. In broadcast communication the signal-to-noise ratio is often quoted in decibels.

#### Synchronization pattern

A pattern of ones and zeros that are chosen because they are easy to distinguish from randomly occurring data words. The pattern is used to synchronize the PCM decoder so that it can accurately locate the positions of the data words in the PCM stream. Appendix C of IRIG 106-96 lists recommended PCM synchronization patterns.

#### Manchester encoding

Popular name for BIØ-L. For more information, see the *Reference* section of *Applications Handbook*.

#### Pre-modulation filtering

The use of filters to limit the bandwidth or frequency spectrum of the PCM signal before sending it to a telemetry transmitter or data link. Appendix A of IRIG 106-96 describes frequency considerations for telemetry systems.

### 17.1.3 Data structures

#### Channel

A signal that carries data information, such as temperature. This term normally refers to a specific data input or output of the PCM encoder/decoder system as well as the associated data word(s) in the frame format.

#### Checksum

A word sometimes added at the end of a frame, which is the sum of the data already sent. For example in an 8-bit system the last word would be a modulo 256 addition of the data in the words already sent.

#### Commutation

The process of sampling data channels. Channels can be sampled at different rates to accommodate different data bandwidths. A normal channel is sampled once each minor-frame. Channels can also be sampled at multiples (super-commutation) and submultiples (sub-commutation) of the minor-frame rate.

#### Commutator

Originally a rotating mechanical switch with many contacts used for sequentially switching voltages. Early telemetry systems used two synchronized units (called a commutator and decommutator) to pass analog voltage samples through a link between the units. Commutators can be connected in series and driven at different speeds to allow channels to be sampled at different rates. Modern telemetry systems use electronic switches and multiplexors.

### Current value table (CVT)

Usually a dual ported ram (DPR) in which the latest values of parameters received are stored in predefined locations.

### Decommutator

Finds the sync word and subsequent data words.

### Dynamic format switches

Decoders capable of dynamic format switching can be set up to find a format identifier which identifies the correct format to use so as to decommutate the rest of the frame.

The bits/word, words/minor frame and minorframes/major frame may change as determined by the format identifier. Usually the new format definition would take effect as of the next word but it could also take effect as of the next frame.

Dynamic format switching is useful in applications where the demands change as the test progresses or in the event of an error or failure.

### Frame Alternating Component (FAC)

In an FAC format, every second syncword is inverted. This may be useful in applications where slow signals are being sampled and it is possible that signals could take the value of the syncword. FAC can be used together with SFID and URC.

### Frame Code Complement (FCC)

FCC is one method of sub-frame identification whereby the syncword is the last (first) minor-frame inverted. This method has the advantage that no extra words in the format are required to identify the major-frames. The disadvantage is that a complete major-frame may be lost before sync is achieved.

### Frame synchronization strategy

The method by which synchronization within a major-frame is achieved. To define the frame sync strategy, the following information must be given:

(a) The syncword (usually the Barker code)

(b) The syncword mask (some bits in the syncword may not have to match)

(c) The syncword error tolerance (allowable mismatches in the syncword)

(d) The bits per minor-frame

(e) The sub-frame-sync-strategy (in case there are FCC is being used)

(f) The matches to check allowed (usually 1) 1 to 16

(g) The matches to lock allowed (usually 0, that is, no check state) 0 to 15

(h) The misses to search allowed (usually 1) 1 to 16

(i) The misses to loss allowed (usually 0 that is, no search) 0 to 16. The frame synchronizer powers up in the LOSS state. After finding the syncword to within the specified tolerance (SYNCWORD ERROR TOLERANCE) in the correct place, a given number of times consecutively (MATCHES TO CHECK) it moves into the state check. Then after the required MATCHES TO LOCK it moves into lock.

If it misses the syncword while in lock MISSES TO SEARCH times then it goes into SEARCH. If while in search it misses the syncword MISSES TO LOSS times then it goes into loss again.

If a match is found in SEARCH then return to LOCK.

If a miss is found in CHECK then return to LOSS.

If the bit-sync reports a loss condition then the frame sync may be programmed to go to LOSS.

The user should have the choice of whether or not to consider data in SEARCH and CHECK stages valid.

It is a good idea to start looking for the sub-frame identifier while in check.

### Format identifier

A word, typically less than 16 bits long, located in the PCM stream which identifies the format being decommutated (used only with dynamic format switching).

### Frame structure

The PCM output is arranged into a data structure consisting of one or more frames. Each frame starts with a synchronization pattern followed by the data channel words. The synchronization pattern enables the PCM decoder to locate the beginning of each frame. When there are many data channels, the PCM output is structured into a major-frame comprising two or more minor-frames. Complex frame formats (Class II) may use several different formats indicated by a frame format identification word.

### Major-frame

One complete cycle of data sampling in which all parameters are sampled at least once. A major-frame contains enough minor-frames to sample every parameter.

### Major-frame pulse

A pulse, typically one bit long, which goes high while the first bit of the major-frame is being transmitted. See also minor-frame pulse and word pulse.

### Matches to lock

See frame synchronization strategy.

### Matches to search

See frame synchronization strategy.

### Minor-frame

The number of bit intervals starting with a frame synchronization pattern and continuing to the occurrence of the next synchronization pattern. A frame count word is usually included to identify each frame. The simplest PCM format contains one minor-frame.

### Misses to loss

See frame synchronization strategy.

### Misses to check

See frame synchronization strategy.

### Normal commutation

A channel is sampled exactly once in each and every minor-frame.

### Parity

Even or odd parity can be added to each word as extra security against bit errors.

### Parameter

Any signal included in the PCM stream.

### Parser

A parser stores traffic, with tags, from a message (MIL-STD-1553) or frame (IRIG-106 PCM) in a receive buffer. If a message has been received with zero errors it is loaded into the input buffer of a double buffered Current Value Table (CVT) one message wide. After the last parameter of interest has been read the complete message is loaded into the output buffer.

### Pre modulation filter

Used primarily with radio links, the filter is usually a sixth order low pass filter whose 3dB point is chosen so as to limit the bandwidth required to send the PCM signal.

### Snarfer

A snarfer stores all traffic and tags from a bus in a FIFO. For example in a FIFO 16 words deep, each word has 16 bits for traffic and seven bits for content identification.

### Subcommutation

A channel is sampled one or more times in each major-frame, but not in every minor-frame.

### Sub-frame

One cycle of the parameters from a commutator whose rate is a submultiple of the minor-frame rate. A sub-frame occupies the same word in each minor-frame. A sub-frame has a depth of four if it is repeated every four minor-frames. Note: A format may have many minor-frames yet have no sub-frames.

### Sub-Frame identification (SFID)

SFID is one method of sub-frame identification whereby one sub-frame (usually the first after the syncword) contains a word in each location unique to that minor-frame. The simplest, and most usual, method is a sub-frame counter which starts at the minor-frame count and counts down.

This method has the disadvantage that extra words in the format are required to identify the minor-frames. The advantage is that a minor-frame can be identified immediately.

### Supercommutation

A channel is sampled two or more times in each minor-frame.

### Synchronous embedded data

Data from another stream which is included in the format after synchronization.

Example one: A slow PCM stream is merged into unused bits of another stream after it has been decommutated so that selected parameters can be merged into certain, CC.

A standard decoder would then be capable of handling this embedded stream.

Example two: An encoder sequentially reads a FIFO containing data from an RS-232 receiver. The system transmitting the data does so only after receipt of the major-frame pulse, thus guaranteeing synchronization. A format may have many minor-frames yet have no sub-frames. See also asynchronously embedded data.

### Unique Recycling Code (URC)

URC is one method of sub-frame identification whereby one word (usually the first after the syncword) in the first (last) minor-frame contains a unique pattern to identify the minor-frame. This method has the disadvantage that an extra word in the format is required to identify the minor-frames and extra precautions must be taken to ensure that the URC can not appear elsewhere in the sub-frame, also a complete major-frame can be lost before sync is achieved.

### Word

A digital or binary value appearing in the PCM output and occupying a specific time interval. Numeric values are usually expressed in binary or 2's complement format.

### Word length

The number of bits in a PCM output word. (Note: Synchronization patterns are counted as one word and are typically twice as long as the average data word.) All words for a particular data channel are the same length. Many PCM systems have fixed word lengths for all channels, such as all words being 12 bits long. Other PCM systems support variable word lengths, in which each data channel can have an independently defined word length.

## 17.1.4 Class II data structures

### Fragmented word

A word divided into segments that occupy various locations in the same minor-frame. For example, a 64-bit floating-point data word could be divided into four segments of 16 bits.

### Format change

The frame format may change with regard to structure, word length or location, commutation sequence, sample interval, or minor-frame boundaries, and may not have a definable major frame length. The current format structure is indicated by a frame format identification (FFI) word placed in a fixed position in every minor-frame.

### Asynchronous embedded format

A secondary data stream inserted into specified word positions in the major frame. The internal data structure of the embedded format is independent of the major-frame.

### Asynchronous data merge

Data, such as serial RS-232 and parallel MIL-STD-1553 messages, are inserted into specified word positions in the major-frame. To aid in recovering the data, flag bits indicating stale and overflow conditions are appended to each data word.

### Tagged data format

A format with fixed length containing a stream of data words, or blocks of words, with associated identifiers (tags). The stream may contain alternating tag and data words, or blocks of MIL-STD-1553 bus data.

## 17.2 References


http://tecnet0.jcte.jcs.mil/RCC/manuals/106-01/

http://www.lancaster.sparta.com/otis/IRIG_Files/IRIG_Chapter4.htm

# IRIG 106-96 Chapter 4

TEC/NOT/027

This paper describes the IRIG 106-96 Chapter 4 standard. The following topics are discussed:



## 18.1 Overview

IRIG Standard 106-96 covers all aspects of Frequency Modulation (FM) and Pulse Code Modulation (PCM) telemetry, including transmitters, receivers, and tape recorders. Chapter 4 of IRIG Standard 106-96 is the primary telemetry standard used throughout the world by both government and industry.

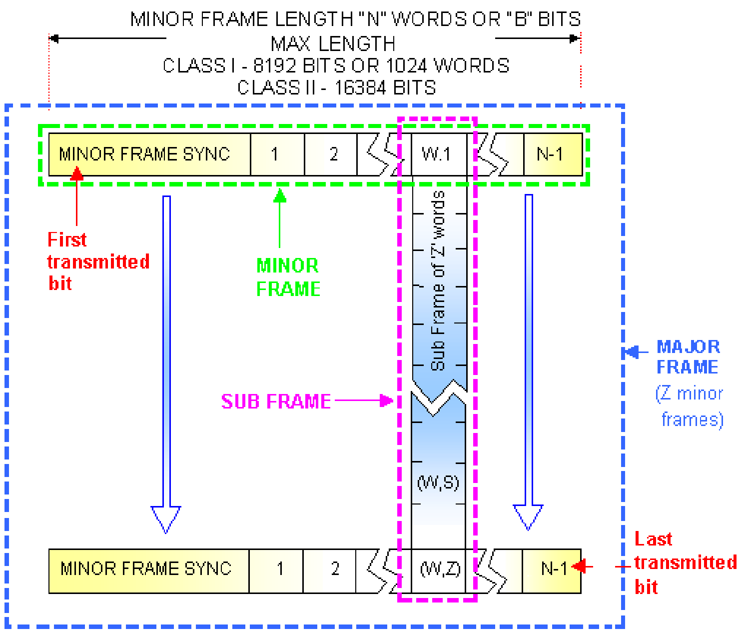


*Figure 18-1: PCM frame structure*

This is one of many comprehensive standards prepared by the Telemetry Group of the Range Commanders Council (RCC) to foster the compatibility of telemetry transmitting, receiving, and signal processing equipment at member ranges. Owing to its success as a proven standard and its wide support by telemetry equipment manufacturers, most commercial data acquisition systems also use the same IRIG standard PCM formats and definitions.

Because IRIG 106-13 concentrates on defining the essential data structures and serial codes, rather than the content of the data, it has become a recognized standard for PCM telemetry systems used worldwide.

### 18.1.1 Background

Rapid advances in digital technology, combined with its universal application to many fields, make it difficult to create standards that don't, just as rapidly, become obsolete. Serial data transmission, for example, is an essential element of the telecommunications and computer industries. As a result, industries have independently developed their own standards. Even within the telemetry industry, the many military and commercial aerospace programs, and the usual demand for secrecy, have discouraged the development of international telemetry standards.

### 18.1.2 PCM

PCM telemetry is a way of acquiring data in one location, converting the data samples to digital words, encoding the data in a serial digital format, and transmitting it to another location for decoding and analysis. PCM systems are less susceptible to noise than analog systems, and the digital data is easier to transmit, record, and analyze.

Telemetry systems are used to acquire data parameters in one location and encode them for transmission over a serial data link, such as a microwave transmitter of fiber optic cable. At the second location, the serial data is received and decoded to recover the individual data parameters. When making large numbers of measurements, it is desirable to squeeze the data into one signal or data link in order to simplify the transmission and recording.

Early telemetry systems transmitted analog voltages using a commutator (rotary switch) at one end and a synchronized decommutator at the other end. The words commutator and decommutator are still used though most telemetry systems today use electronic switches and send digital data.

The following figure shows the basic elements of a modern PCM telemetry system. A PCM encoder converts the input data signals into a serial data format suitable for transmission. At the receiving end, a PCM decoder (or PCM decommutator) converts the serial data back into individual output data signals.

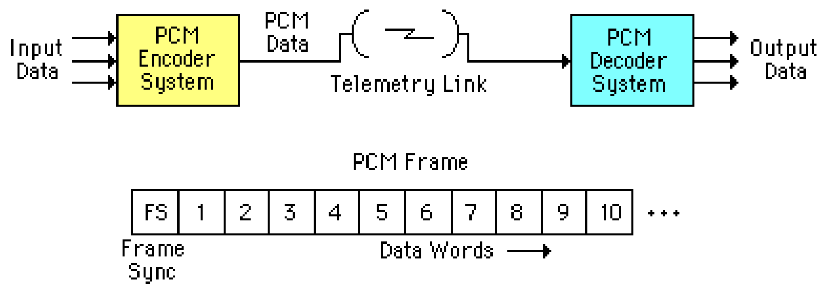


*Figure 18-2: Basic elements of PCM system*

The simplest PCM frame consists of a frame synchronization word followed by a string of data words. The frame repeats continually to provide new data samples as the input data changes. Frame synchronization enables the PCM decoder to easily locate the start of each frame.

The following table provides a summary of relevant PCM specifications.

| Specification | Class I | Class II |
|---|---|---|
| Class format support | Class I (simple formats) supported on all ranges | Class II (complex formats) requires concurrence of range involved |
| Binary bit representation (PCM codes) | NRZ-L, NRZ-M, NRZ-S, RNRZ-L (per Appendix D), BiØ-L, BiØ-M, BiØ-S | Same as Class I |
| Bit rate | 10 bps to 5 Mbps | 10 bps to > 5 Mbps |
| Bit rate accuracy and stability | 0.1% | Same as Class I |
| Bit jitter | ±0.1 bit | Same as Class I |
| Bit numbering | Most significant bit is bit number 1 | Same as Class I |
| Word length (data) | 4 to 16 bits | 4 to 64 bits |
| Fragmented words | Not allowed | Up to eight segments each; all segments of a word must be located in the same minor frame |
| Word numbering | First word after synchronization is number 1. Following words are numbered sequentially within each minor frame | Same as Class I |
| Frame structure | PCM data is formatted into fixed length frames containing a fixed number of equal duration bit intervals | Same as Class I |
| Binary bit representation (PCM codes) | NRZ-L, NRZ-M, NRZ-S, RNRZ-L (per Appendix D), BiØ-M, BiØ-M, BiØ-M | Same as Class I |

| Specification | Class I | Class II |
|---|---|---|
| Bit rate | 10 bps to 5 Mbps | 10 bps to > 5 Mbps |
| Minor frame length | Up to 8192 bits or 1024 words including sync word | Up to 16384 bits including sync word |
| Minor frame composition | Minor frame synchronization pattern, data words, and sub-frame synchronization if used | Same as Class I plus other words such as frame format identifiers |
| Minor frame synchronization | Minor frame sync pattern is 16 to 33 bits long | Same as Class I |
| Transmitted frame counter (optional) | Binary count located in fixed word position increments to indicate minor frame number. Can use sub-frame ID counter | Same as Class I |
| Major frame length | Up to 256 minor frames | Same as Class I |
| Minor frame numbering | First minor frame in each major frame is number 1 | Same as Class I |
| Subcommutation (sub-frames) | Parameters may be sampled at submultiple rates (1/D) where D is an integer between 2 and Z, the number of minor frames in each major frame | Same as Class I |
| Sub-frame synchronization (sub-frame ID counter) | Standard method is to use a Sub-frame ID counter, a binary count located in a fixed position in every minor frame and which increments or decrements at the minor frame rate and is reset to max or min count at the start of each major frame | Same as Class I |
| Supercommutation | Parameters may be sampled at a multiple of the minor frame rate (supercom) or at a multiple of the sub-frame rate (supercom on a sub-frame); samples must be evenly spaced | Samples should be as evenly spaced as practical |
| Format change | Not allowed | Frame structure is specified by frame format identification word in every minor frame |
| Asynchronous embedded format | Not allowed | Up to two embedded formats per major frame; embedded formats must occupy same word locations in every minor frame |
| Tagged data formats | Not allowed | Alternating tag and data, or MIL-STD-1553 data blocks |

| Specification | Class I | Class II |
|---|---|---|
| Time words | Standardized time format uses three 16-bit words designated high order time, low order time and microsecond time. It is recommended that the time words be inserted before the first data word in the minor frame. For PCM word sizes other than 16 bits, the data must be inserted into the PCM stream as 48 contiguous bits with zeros added at end to fill any unused bits | Same as Class I |
| Asynchronous data merge | Regarded as Class II feature | External sequential data (such as RS-232) can be inserted into the PCM frame format in fixed word positions |

### 18.1.3 IRIG PCM codes

The only codes allowed by IRIG 106-96 for PCM bit streams are: NRZ-L, NRZ-M, NRZ-S, RNRZ-L, BiØ-L, BiØ-M, and BiØ-S. For tape recording PCM data, the only permissible codes are: RNRZ-L, BiØ-L, BiØ-M, and BiØ-S (see the *Reference* chapter of *Applications Handbook*).

Randomized NRZ-L code (RNRZ-L) is not illustrated since it is derived from NRZ-L code by using the randomizer circuit defined in Chapter 6 and Appendix D of IRIG 106-96. Despite its name, RNRZ-L is not truly random because it is completely predictable. The main advantage of RNRZ-L code is that it prevents the occurrence of long strings of consecutive ones or zeros that would make it difficult to decode or record the PCM signal. It is also a low bandwidth code for economical PCM tape recording.

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**NOTE:** Bi-phase codes can be derived from NRZ codes by inverting the level for the last half of each interval.

## 18.2 Conclusion

This paper gave an overview of the IRIG 106-96 Ch. 4 standard. It described the basic structure of a PCM frame and the elements of a PCM system. It outlined a brief summary of PCM specifications and listed the PCM codes used worldwide in industry and government systems.

## 18.3 References


1. IRIG STANDARD 106-99, Telemetry Standards, January 1999, Prepared by: Telemetry Group, Range Commanders Council, Published by: Secretariat, Range Commanders Council, U.S. Army White Sands Missile Range, New Mexico 88002-5110

2. FAS Military Analysis Network - EC - 18 ARIA

http://www.fas.org/man/index.html

http://www.fas.org/man/dod-101/sys/ac/index.html

Chapter 19

# Rules of PCM placement

TEC/NOT/035

This paper outlines some useful rules for PCM placement. This paper describes rules about slow read rates, interleaving threads, minimum word size, master/slave operation and multiple PCM streams.

The following topics are discussed:



**NOTE:** PCM Placer software utility follows "0.2 Rule 1: Bus monitors - do not interleave threads from the same module" on page 1 and "0.3 Rule 2: Master/slave operation" on page 1. We recommend using PCM Placer if multiple PCMs are used or if the bit-rate is higher than 6 Mbps.

## 19.1 Rule 1: Bus monitors - do not interleave threads from the same module

Bus monitor modules need to read all required parameters from a particular MIL-STD-1553 message at once. It takes time to transfer all these over the Acra KAM-500 backplane. For best results, place parameters from a single MIL-STD-1553 message adjacent to each other, in ascending order, in the same minor frame.

Table 19-1: Threads example on a PCM frame

| | | | | | | |
|---|---|---|---|---|---|---|
| MSG_0_1_D0 | MSG_0_1_D1 | MSG_0_1_thi | MSG_0_2_D3 | MSG_0_2_D23 | MSG_0_2_tlo | Syncword |
| | | | MSG_0_2_D3 | MSG_0_2_D23 | MSG_0_2_tlo | Syncword |
| MSG_0_1_D0 | MSG_0_1_D1 | MSG_0_1_thi | MSG_0_2_D3 | MSG_0_2_D23 | MSG_0_2_tlo | Syncword |
| | | | MSG_0_2_D3 | MSG_0_2_D23 | MSG_0_2_tlo | Syncword |

## 19.2 Rule 2: Master/slave operation

We recommend placing parameters from slaves later in the frame.

When placing parameters in the master PCM stream, time must be allowed to transmit a parameter from a slave to the master.

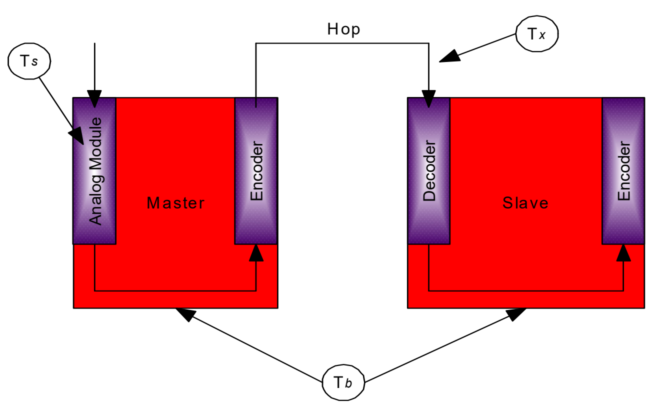


*Figure 19-1: Elements contributing to the delays encountered in a signal as it moves through an Acra KAM-500 chassis*

See "Types of delays" on page 86 for further details.

## 19.3 Rule 3: Minimum word size

The minimum word transmit time is 500 ns for the KAD/BCU/101. Therefore at 16Mbps the minimum word size is 8 bits (16 Mbps x 500 ns = 8 bits).

See “Table 19-3: Minimum word transmit time per encoder module” on page 87 for a list of the minimum word sizes per encoder module.

## 19.4 Rule 4: Multiple PCM streams - acquisition cycles must agree

### 19.4.1 Rule 4.1

All the major frames of the PCM streams must fit into the acquisition cycle, so the rule is:

(BitsPerMajorFrame1) / (BitRate1) = N* (BitsPerMajorFrame2) / (BitRate2)

with N being an integer.

### 19.4.2 Rule 4.2

If the same parameter is on two different PCM streams you must place them at the same time position.

For example, P1 stream 1 at 16 bits fixed transmission wordIndex = 8, FrameIndex = 0, BitRate = 2 Mbps.

P1 stream 2 at 16 bits fixed transmission wordIndex = 4, FrameIndex = 0, BitRate = 4 Mbps.

## 19.5 Rule 5: Read delay after start of acquisition cycle

Some older modules such as KAD/ADC/009/S1 or KAD/ADC/006 cannot be read for 16 µs after the start of an acquisition cycle while accessing setup information.

For example, at 8 Mbps the parameter must be transmitted after bit 128 (8 Mbps x 16 µs = 128 bits).

See Table 19-4 on page 87 describing the read delay per module.

## 19.6 Rule 6: Slow read rate

Older modules can be read at 500 ksps, in other words a gap of 2 µs is required. So if data is read from one of these modules only, 500 ksps is the maximum sampling rate available.

However during that gap, data can be read from other modules. This is called interleaving reads. An example of interleaving is displayed in the following table.

In order to allow and support interleaving, it helps to try to place parameters from the same sampling groups in different slots consecutively in the PCM stream.

Table 19-2: Interleaving example on a PCM frame

| | | | | | | |
|---|---|---|---|---|---|---|
| ADC_J3_Ch0 | ADC_J4_Ch0 | ADC_J5Ch0 | ADC_J3Ch1 | ADC_J4Ch1 | ADC_J5Ch1 | Syncword |
| ADC_J3_Ch0 | ADC_J4_Ch0 | ADC_J5Ch0 | | | | Syncword |
| ADC_J3_Ch0 | ADC_J4_Ch0 | ADC_J5Ch0 | ADC_J3Ch1 | ADC_J4Ch1 | ADC_J5Ch1 | Syncword |
| ADC_J3_Ch0 | ADC_J4_Ch0 | ADC_J5Ch0 | | | | Syncword |

See Table 19-5 on page 87 for a list of the worst-case read rates per module.

## 19.7 Appendix

### 19.7.1 Types of delays

Considering Figure 19-1 on page 85, there are three types of delay which are described as follows:

$T_s$ – The sourcing delay due to filter characteristics. This delay is dependent on the type of source module, the sample rate and module configuration.

$T_b$ – A delay associated with transferring the data over the backplane of a chassis. This delay is constant for all chassis.

$T_x$ – A delay associated with transferring a sample via PCM from chassis to chassis. This delay varies from link to link depending on the bit-rate used to transfer the data and the amount of data sent.

Table 19-3: Minimum word transmit time per encoder module

| Module | Minimum word transmit time (μs) |
|---|---|
| KAD/ENC/106 (no PMF) | 0.375 |
| KAD/BCU/101 | 0.5 |
| KAD/BCU/001 | 1 |
| KAD/ENC/005/B | 1 |
| KAD/ENC/004 | 0.5 |
| KAD/ENC/005 | 0.5 |

Table 19-4: Read delay per module

| Module | Read delay (μs) |
|---|---|
| KAD/MDC/001 | 3289 |
| KAD/SDI/001 | 2000 |
| KAD/ADC/001 | 72 |
| KAD/ADC/009 | 16 |
| KAD/ADC/019 | 16 |
| KAD/ADC/005 | 16 |
| KAD/ADC/006 | 16 |
| KAD/CDC/001 | 16 |
| KAD/LDC/001 | 16 |

Table 19-5: Worst-case read rates per module

| Module | Read rate (μs) |
|---|---|
| KAD/ADC/003 | 2.5 |
| KAD/ADC/009 | 1.75 |
| KAD/ADC/019 | 1.75 |
| KAD/ADC/005 | 1.75 |
| KAD/ADC/006 | 1.75 |
| KAD/CDC/001 | 1.75 |
| KAD/LDC/001 | 1.75 |
| KAD/ADC/001 | 1 |

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Chapter 20

# Using the KAD/ADC/008

TEC/NOT/037

This technical note discusses the following topics:



## 20.1 Introducing the KAD/ADC/008

The KAD/ADC/008 is a monitor for 3-phase power lines. It allows many parameters associated with 3-phase power supplies to be easily measured and embedded in an Acra KAM-500 data output stream (PCM, Ethernet etc.). The AC parameters measured include: maximum, minimum, amplitude, average and root-mean-square (RMS) for both voltages and currents; active and apparent power, together with the power factor for each phase. In order to maximize the accuracy of these calculations, the KAD/ADC/008 converts all voltages and currents into the digital domain.

The physical interface of the KAD/ADC/008 comprises six single-ended input channels: three of these are for the three voltages of the 3-phase power supply. The other three channels are for measurement of the three currents of the 3-phase power supply.

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**NOTE:** All six channels measure voltages. Therefore, a current transformer and resistor circuit is used to generate a voltage proportional to the current for the three current phase channels.

The KAD/ADC/008 simultaneously over-samples all six channels at 125 ksps. Various algorithms are performed to calculate each of the measurements. In fact, 40 different parameters associated with 3-phase power supplies are measured/calculated. A summary of these parameters is provided below with each of the parameters discussed in detail in Table 20.4 on page 93.

- Maximum (× 6 - for each channel Ch0 –> Ch5)
- Minimum (× 6 - for each channel Ch0 –> Ch5)
- Amplitude (× 6 - for each channel Ch0 –> Ch5)
- RMS (× 6 - for each channel Ch0 –> Ch5)
- Average (× 6 - for each channel Ch0 –> Ch5)
- Active power (× 3 - Phase 0 –> 2)
- Apparent power (× 3 - Phase 0 –> 2)
- Power factor (× 3 - Phase 0 –> 2)
- PERIOD (× 1 - Measured for 3-phase power supply)

In the calculations for any of the above parameters, the KAD/ADC/008 does not assume a sinusoidal shape but instead calculates these values based on all sample points. The KAD/ADC/008 assumes that the three phases are synchronous and assumes that the inputs are bipolar.

The algorithm used in the KAD/ADC/008 defines the start of each period as the time of the positive-going-zero-crossing of channel 0. The KAD/ADC/008 defines the end of each period as the time of the next positive-going-zero-crossing of channel 0. This crossing must be more than 50 ms after the first crossing. Over each period, each of the parameters listed above are calculated for the module. The processing algorithm is a hard-wired state machine with no microcode or forbidden states.

The KAD/ADC/008 has two analog gain ranges: ±1V and ±10V. The accuracy of the measurement of the KAD/ADC/008 when either range is chosen is ±0.25% of the full-scale range (FSR). Any FSR (up to a max. of ±10V) can be specified for the module. Digital gain is used on the module to map the analog range used (±10V or ±1V) to the chosen range. It should be noted that using digital gain decreases the accuracy of the card. For example, with a selected range of ±2V the module operates with an analog range of ±10V and a digital gain of 5. A digital gain of 5 means that the accuracy of the module may be increased to approximately 1%.

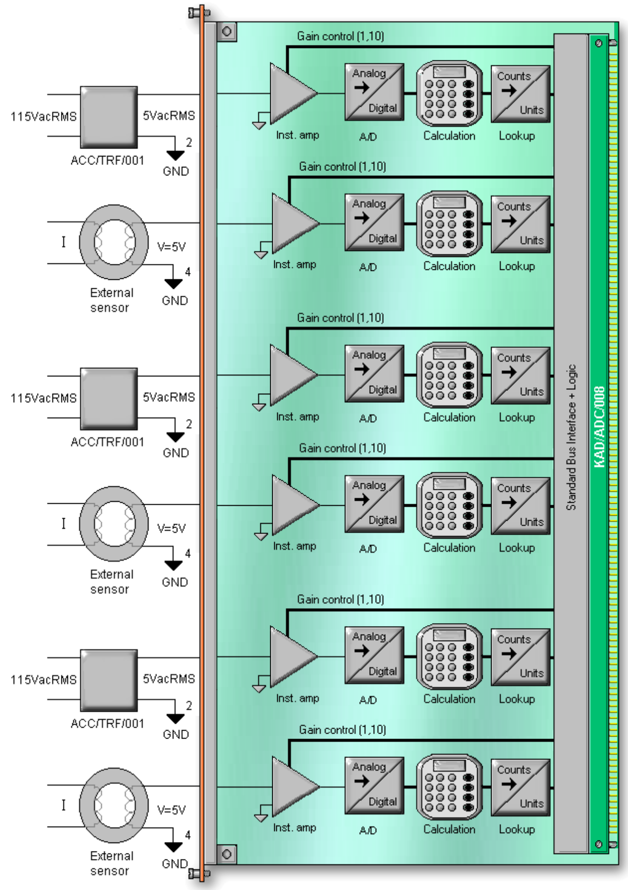



*Figure 20-1: KAD/ADC/008 – 3-phase power monitor*

## 20.2 Using transformers

When measuring or monitoring a power supply, it is desirable, if possible, to isolate the measurement from the power supply itself, so that the power supply does not get shorted or open-circuited during a fault condition. It is best to use a voltage-to-voltage transformer to measure each of the voltages of the 3-phase power supply, and to use a current-to-current transformer to measure each of the currents of the 3-phase power supply.

The ACC/TRF/002 from Curtiss-Wright is a six-channel voltage-to-voltage transformer for variable frequency supplies from 200 Hz to 900 Hz in a rugged housing, which is designed for use with the KAD/ADC/008. The ACC/TRF/002 has a primary-to-secondary-turns ratio of 20.9:1. This means that a $115V_{rms}$ input to the ACC/TRF/002 produces a $5.5V_{rms}$ output. This is fed directly to the voltage channel input of the KAD/ADC/008.

Similarly, the legacy ACC/TRF/001/B can be used with the KAD/ADC/008 and has a primary-to-secondary-turns ratio of 19.6:1 with a typical output of a 5.87 $V_{rms}$.

As previously noted, both the ACC/TRF/001/B and the ACC/TRF/002 can be used with the KAD/ADC/008, however the ACC/TRF/002 is recommended for new programs. Refer to the respective data sheet for more information.

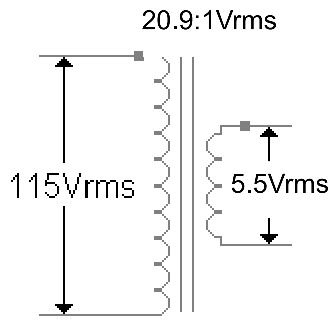



*Figure 20-2: Voltage transformer for a single channel of the ACC/TRF/002*

The 5.5$V_{rms}$ input to the KAD/ADC/008 is approximately 14.14$V_{p-p}$ or ±7.07V. The ADC voltage range for a voltage channel with 115$V_{rms}$ input and using the ACC/TRF/002 should set the input voltage range to be greater than ±7.07V. It is advisable to leave some headroom so that clamping does not affect readings. A range of ±10V is typically used.

It is recommended to use a current transformer to measure the current of each phase. Curtiss-Wright does not manufacture current transformers for use with the KAD/ADC/008. One significant reason for this is because the rated temperature and current may vary greatly from application to application. Rated current is one of the key specifications for any current transformer. Other important requirements for the current transducer are accuracy specifications, temperature specifications, and size.

Curtiss-Wright suggests choosing a current transformer that meets the specifications required for a particular application. The CR Magnetics 8400 family of transformers may provide a suitable solution. The CR 8459 is a transformer which can measure large current loads. It's rated current is 200$A_{rms}$. The CR 8459 can be used to measure current accurate to 0.2%. However, the CR 8459 is only specified over the temperature range -25°C to 66°C. If a -40°C to 85°C temperature range is required CR Magnetics also provide custom military specification current transformers. CR Magnetics can be contacted directly via their web site (www.crmagnetics.com).

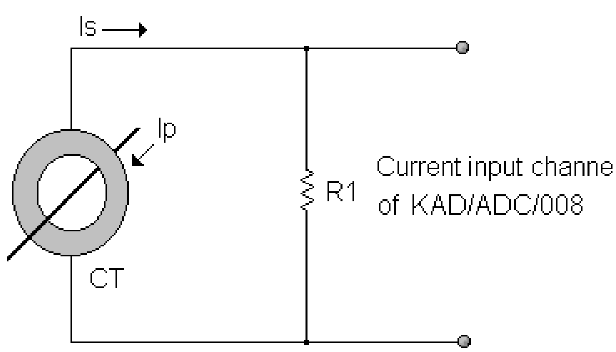



*Figure 20-3: Current transformer external connection to the KAD/ADC/008*

With current transformers the primary current carrying wire is fed through a current transformer. The induced secondary current is proportional to the primary current. Their relationship is given by:

$$I_S = \frac{I_P}{N}$$

where:

- $I_S$ is the induced secondary current
- $I_P$ is the primary current
- $N$ is the turns ratio (secondary turns / primary turns)

The voltage input to the KAD/ADC/008 is:

$$V_I = I_S \times R_1$$

where:

- $V_I$ is the induced voltage dropped over the burden resistor $R_1$

In current transformer applications, it is necessary to place a burden resistor across the output of the transformer. From a design standpoint, the primary function is to limit the output voltage so that the transformer is not allowed to saturate. From a circuit design point of view, the burden resistor is used to adjust the output of the transformer to the desired output for the particular circuit. In reality, both these criteria must be dealt with.

Instead of designing current transformers to operate with a given burden resistor value we suggest the following approach:

1. Select a current transformer that has the mechanical specifications required and meets maximum current, temperature, and accuracy specifications.
2. Specify the maximum voltage that can be measured by the acquisition circuit.
3. Specify or calculate the saturation voltage of the transformer at the desired frequency.
4. Calculate the maximum current in the secondary circuit of the transformer.
5. Using the minimum of the acquisition voltage (from 2) and saturation voltage (from 3) and the maximum secondary current (from 4) calculate the burden resistor.
6. Calculate the power dissipated by the burden resistor.

For many current transformers, it is best to keep voltage dropped over the resistor relatively small (circa 1V is fine from most current transformers). For this, the best accuracy may be obtained from the KAD/ADC/008 if the current channel is configured on the ±1V range as this uses a digital gain of 1, hence the accuracy of the module will be 0.25%. Generally, it is best to choose a resistor so that the peak voltage induced is less than 1V – say 900 mV.

From the equations above $R_1$ can be calculated as follows:

$$R_I = \frac{N \times V_I}{I_P}$$

If the ±1V range on the KAD/ADC/008 is chosen, it is important to choose $R_1$ so that the peak primary current induces a voltage less than ±1V.

$$R_I < \frac{N}{I_{p-p}}$$

where $I_{p-p}$ is the peak primary current.

It is also important that the resistor is chosen with a power rating in excess of the power absorbed by the resistor. The average power absorbed by the resistor is:

$$P_{R1} = \frac{I^2_{P-RMS}}{N^2} R_1$$

It should be noted that for large currents (~100A) and/or small turns ratio (~50) the power consumed by the resistor can be quite large. For example an RMS current of 100A passed once though a current transformer with a turns ratio of 50 would cause a 5Ω resistor connected across the secondary coil to be heated by 20W. This is a large power rating for a resistor and would melt standard resistors.

## 20.3 Example

What are the specifications of a resistor required to monitor the following 3-phase power supply?

- the maximum RMS primary current is $100A_{rms}$.
- the required temperature range is –10°C to 50°C
- an overall accuracy of better than 1% is required

Curtiss-Wright suggests using a CR 8459 current transformer from CR Magnetics. Verify that this is a suitable choice and choose a resistor to give optimal accuracy.

### 20.3.1 Check that the transformer meets the peak current of the supply

The rated current for the CR 8459 is $200A_{rms}$. This is greater than the required 100A maximum rms current. Hence the CR 8459 is suitable from this point of view. The accuracy of the CR 8459 is 0.2% (for loads > 40A).

### 20.3.2 Choose a resistor for optimal accuracy

The CR 8459 has 2000 secondary turns. Assuming that the primary wire is passed straight through the core, then the turns ratio is 2000:1. Assuming the primary current is approximately sinusoidal then the peak primary current is:

$$I_{P-PK} = \sqrt{2} \times I_{rms-MAX} = 141.1A$$

Hence the resistor *R* should be chosen so that

$$R_1 = \frac{N \times V_I}{I_P}$$

Choose $R_1$ so that the peak primary current $I_{p\text{-}p}$ induces a voltage within the ±1V range of the KAD/ADC/008.

$$R_1 < \frac{N}{I_{p-p}} < \frac{2000}{141.4} < 14.14\Omega$$

Assuming a 10Ω resistor, the power consumed by the resistor is given by:

$$P_{R1} = \frac{I_{P-rms}^2}{N^2} R_1 = \frac{100^2}{2000^2} 10 = 25mW$$

Hence choose a resistor that is rated to handle at least 25 mW of power. Any standard resistor will probably suffice.

### 20.3.3 Accuracy

Use a 10Ω burden resistor with the CR 8459 current transformer.

The KAD/ADC/008 is configured on the ±1V range. The primary current is $100A_{rms}$ or $\pm 141.4A_{p\text{-}p}$. Using a 10Ω burden resistor and 2000:1 turns ratio this results in ±141.4 × 10 / 2000 = ±0.707 volts generated across the burden resistor. Hence 70% of the FSR of the KAD/ADC/008 is used so the accuracy should be approximately 0.36%.

In the above example, the accuracy of the CR 8459 current transformer is approximately 0.2%.

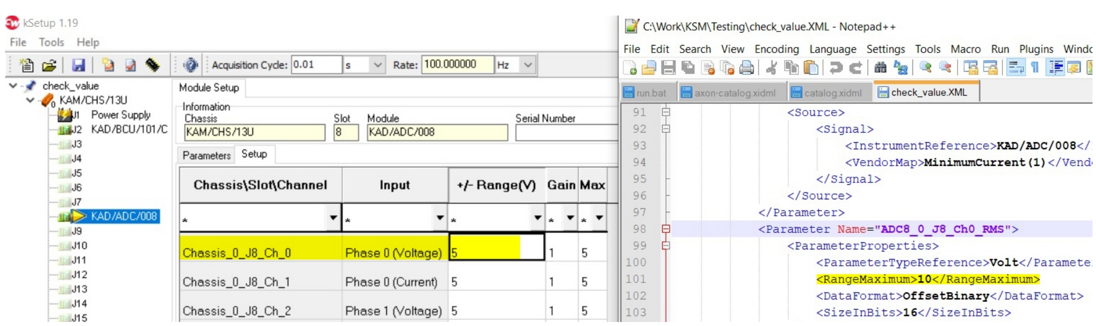
Adding the two errors yields an overall accuracy of the sensor and acquisition to be better than 0.6% which is better than the overall requirement of 1%.

## 20.4 Output registers

The KAD/ADC/008 simultaneously measures/calculates 40 different parameters associated with 3-phase power supplies. A detailed description of each of these parameters is provided in the following table.

---

**WARNING:** In KSM-500 GUI, the VRANGE value that you enter is doubled when you save and open the XidML2.4 task file. As shown in this example, if VRANGE = 5 in KSM-500, then in the task file it shows as RangeMaximum=10.




Therefore if the range from the XidML2.4 task file is to be used for processing data, you must adjust the equation for the range in your processing software accordingly.

Table 20-1: Output registers

| REGISTER | Notation (default name in KSM-500) | Description |
|---|---|---|
| **CALCULATED PARAMETERS FOR ALL CHANNELS** | | |
| **Maximum** | ADC8_X_JY_Ch0_MAX<br>ADC8_X_JY_Ch1_MAX<br>ADC8_X_JY_Ch2_MAX<br>ADC8_X_JY_Ch3_MAX<br>ADC8_X_JY_Ch4_MAX<br>ADC8_X_JY_Ch5_MAX | The maximum value of the analog input is measured for each of the six channels. This value is displayed in six different registers as shown in the notation column. The maximum value is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range ($V_{RANGE}$) can be set by the user. MAX is calculated with 12 bits of resolution and is represented in OFFSET BINARY notation by the bits R[15:4]. Bits R[3:0] are reserved for future use.<br>R[15:4] = $\left(\frac{V_{MAX} + V_{RANGE}}{2 \times V_{RANGE}}\right) \times 4096$<br>Example: Setting $V_{RANGE}$ = 5 in KSM-500 (±5V analog range) then an $8V_{p-p}$ input with +0.5V of offset has a maximum at 4.5V. This maximum is represented by code 9.5 / 10 × *4096 = 3891. When read as a 16-bit register this will be represented as 62256. |
| **Minimum** | ADC8_X_JY_Ch0_MIN<br>ADC8_X_JY_Ch1_MIN<br>ADC8_X_JY_Ch2_MIN<br>ADC8_X_JY_Ch3_MIN<br>ADC8_X_JY_Ch4_MIN<br>ADC8_X_JY_Ch5_MIN | The minimum value of the analog input is measured for each of the six channels. This value is displayed in six different registers as shown in the notation column. The minimum value is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range ($V_{RANGE}$) is user-definable. MIN is calculated with 12 bits of resolution and is represented in OFFSET BINARY notation by the bits R[15:4]. R[3:0] are reserved for future use.<br>R[15:4] = $\left(\frac{V_{MIN} + V_{RANGE}}{2 \times V_{RANGE}}\right) \times 4096$<br>Example: Setting $V_{RANGE}$ = 5 in KSM-500 (±5V analog range) then an $8V_{p-p}$ input with +0.5V of offset has a minimum at -3.5V. This minimum is represented by code 1.5 / 10 × 4096 = 614. When read as a 16-bit register this will be represented as 9824. |
| **Average** | ADC8_X_JY_Ch0_AVG<br>ADC8_X_JY_Ch1_AVG<br>ADC8_X_JY_Ch2_AVG<br>ADC8_X_JY_Ch3_AVG<br>ADC8_X_JY_Ch4_AVG<br>ADC8_X_JY_Ch5_AVG | The average value of the analog input is measured for each of the six channels. This value is displayed in six different registers as shown in the notation column. The average value is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range ($V_{RANGE}$) can be set by the user. AVG is calculated with 16 bits of resolution and is represented in OFFSET BINARY notation by the bits R[15:0].<br>R[15:4] = $\left(\frac{V_{AVG} + V_{RANGE}}{2 \times V_{RANGE}}\right) \times 65536$<br>Example: Setting $V_{RANGE}$ = 5 in KSM-500 (±5V analog range) then a $8V_{p-p}$ input with +0.5V of offset has an average of +0.5V. This average is represented by code 5.5 / 10 × 65536 = 36045. |

Table 20-1: Output registers

| REGISTER | Notation (default name in KSM-500) | Description |
|---|---|---|
| **Amplitude** | ADC8_X_JY_Ch0_AMP<br>ADC8_X_JY_Ch1_AMP<br>ADC8_X_JY_Ch2_AMP<br>ADC8_X_JY_Ch3_AMP<br>ADC8_X_JY_Ch4_AMP<br>ADC8_X_JY_Ch5_AMP | The amplitude of the analog input is measured for each of the six channels. This value is displayed in six different registers as shown in the notation column. The amplitude value is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range ($V_{RANGE}$) can be set by the user. *AMP* is calculated with 12 bits of resolution and is represented in OFFSET BINARY notation by the bits R[15:4]. R[3:0] are reserved for future use.<br>R[15:4] = $\left(\frac{V_{MAX} - V_{MIN}}{2 \times V_{RANGE}}\right) \times 4096$<br>Example: Setting $V_{RANGE}$ = 5 in KSM-500 (±5V analog range) then a $8V_{p\text{-}p}$ input with +0.5V of offset has an amplitude of +8V. This amplitude is represented by code 8/10 × 4096 = 3277. When read as a 16-bit register this will be represented as 52432. |
| **RMS** | ADC8_X_JY_Ch0_RMS<br>ADC8_X_JY_Ch1_RMS<br>ADC8_X_JY_Ch2_RMS<br>ADC8_X_JY_Ch3_RMS<br>ADC8_X_JY_Ch4_RMS<br>ADC8_X_JY_Ch5_RMS | The RMS of the analog input is measured for each of the six channels. This value is displayed in six different registers as shown in the notation column. The RMS value is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range ($V_{RANGE}$) is user-definable. Root-mean-square is calculated with 16 bits of resolution and is represented in OFFSET BINARY notation by the bits R[15:0].<br><br>$V_{rms}$ = SQRT ((DC_rms)^2 + (AC_rms)^2)<br><br>R[15:0] = $\left(\frac{V_{RMS}}{V_{RANGE}}\right) \times 65536$<br>Example: Setting $V_{RANGE}$ = 5 in KSM-500 (±5V analog range) then a $8V_{p\text{-}p}$ input with +0.5V of offset has a $V_{rms}$ as follows:<br><br>$V_{pp}$ = 8V<br>DC_rms = 0.5<br>AC_rms = $V_p$ / SQRT(2) = $V_{pp}$ / (2 × SQRT(2)) = 8/ (2 × SQRT(2)) = 2.8284<br><br>$V_{rms}$ = SQRT (0.5^2 + (2.8284)^2) = SQRT (0.25 + 8) = SQRT (8.25)<br>$\frac{\sqrt{8.25}}{5} \times 65536 = 37648$ |

Table 20-1: Output registers

| REGISTER | Notation (default name in KSM-500) | Description |
|---|---|---|
| **Calculated parameters for pairs of channels** | | |
| **Active power** | ADC8_X_JY_Ph0_ACTPW<br>ADC8_X_JY_Ph1_ACTPW<br>ADC8_X_JY_Ph2_ACTPW | The active power is calculated for each pair of inputs (Ch0 and Ch1; Ch2 and Ch3; Ch4 and Ch5). In the calculation of the active power: Ch0, Ch2 and Ch4 should represent the voltage inputs; and Ch1, Ch3 and Ch5 should represent the current inputs for each of the three phases Ph0, Ph1 and Ph2.<br>This active power is displayed in three different registers as shown in the notation column. The active power is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range for each of the voltage and current channels can be set by the user. Let $V_{RANGE-V}$ be the range of the voltage input (Ch0, Ch2 or Ch4) and $V_{RANGE-I}$ be the range of the current input (Ch1, Ch3 or Ch5).<br>ACTIVE power is calculated with 16 bits of resolution and is represented in OFFSET BINARY notation by the bits R[15:0].<br>$$P_{ACTIVE} = \frac{1}{N}\sum_{i=1}^{N} v_i \times i_i$$<br>R[15:0] = $\left(\frac{P_{ACTIVE} + (V_{RANGE-V} \times V_{RANGE-I})}{2 \times (V_{RANGE-V} \times V_{RANGE-I})}\right) \times 65536$<br>Example: Assume Ch0 has $V_{RANGE-V}$ = 5V and an 8$V_{p-p}$ input with +0.5V of offset is connected. Assume Ch1 has $V_{RANGE-I}$ = 5V and an 8$V_{p-p}$ input with +0.5V of offset is connected. Both channels have a frequency of 400 Hz and Ch1 is delayed by 10°. The Active power should be approximately 8.13W.<br>This amplitude is represented by code (8.13 + 25) / 50 × 65536 = 43424 |
| **Apparent power** | ADC8_X_JY_Ph0_APPPW<br>ADC8_X_JY_Ph1_APPPW<br>ADC8_X_JY_Ph2_APPPW | The apparent power is calculated for each pair of inputs (Ch0 and Ch1; Ch2 and Ch3; Ch4 and Ch5). In the calculation of the apparent power Ch0, Ch2 and Ch4 should represent the voltage inputs and Ch1, Ch3 and Ch5 should represent the current inputs for each of the three phases Ph0, Ph1 and Ph2.<br>This apparent power is displayed in three different registers as shown in the notation column. The active power is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The input voltage range for each of the voltage and current channels is user-definable. Let $V_{RANGE-V}$ be the range of the voltage input (Ch0, Ch2 or Ch4) and $V_{RANGE-I}$ be the range of the current input (Ch1, Ch3 or Ch5).<br>Apparent power is calculated with 16 bits of resolution and is represented in OFFSET BINARY notation by the bits *R*[15:0].<br>$$P_{APP} = V_{RMS} \times I_{RMS}$$<br>R[15:0] = $\left(\frac{P_{APP}}{V_{RANGE-V} \times V_{RANGE-I}}\right) \times 65536$<br>Example: Assume Ch0 has $V_{RANGE-V}$ = 5V and an 8$V_{p-p}$ input with +0.5V of offset is connected. Assume Ch1 has $V_{RANGE-I}$ = 5V and an 8$V_{p-p}$ input with +0.5V of offset is connected. Both channels have a frequency of 400 Hz and Ch1 is delayed by 10°. The Active power should be approximately 8.25W.<br>This amplitude is represented by code 8.25 / 25 × 65536 = 21627 |

Table 20-1: Output registers

| REGISTER | Notation (default name in KSM-500) | Description |
|---|---|---|
| **Power factor** | ADC8_X_JY_Ph0_PF<br>ADC8_X_JY_Ph1_PF<br>ADC8_X_JY_Ph2_PF | The power factor is calculated for each pair of inputs (Ch0 and Ch1; Ch2 and Ch3; Ch4 and Ch5). In the calculation of the power factor Ch0, Ch2, and Ch4 should represent the voltage inputs and Ch1, Ch3, and Ch5 should represent the current inputs for each of the three phases Ph0, Ph1, and Ph2.<br>This apparent power is displayed in three different registers as shown in the notation column. The active power is always measured over the sample period as calculated by the KAD/ADC/008 and displayed in the PERIOD register.<br>The power factor is calculated with 16 bits of resolution and is represented in OFFSET BINARY notation by the bits *R*[15:0]. Power factor will be in the range -1 to +1.<br>$PF = \frac{P_{ACT}}{P_{APP}}$<br>R[15:0] = $\left(\frac{PF+1}{2}\right) \times 65536$<br>Example: Assume Ch0 has $V_{RANGE-V}$ = 5V and an 8$V_{p-p}$ input with +0.5V of offset is connected. Assume Ch1 has $V_{RANGE-I}$ = 5V and an 8$V_{p-p}$ input with +0.5V of offset is connected. Both channels have a frequency of 400 Hz and Ch1 is delayed by 10°. The Active Power should be approximately 8.13W.The Apparent Power should be approximately 8.25W. The power factor should be (8.13 / 8.25) = 0.985.<br>This amplitude is represented by code (0.985+1) / 2 × 65536 = 65044 |
| **Calculated for channel 0 only** | | |
| **PERIOD** | ADC8_X_JY_PERIOD | The PERIOD is calculated for Ch0 only. The PERIOD is defined as the average time between positive going zero crossings for Ch0 and this channel. PERIOD is calculated with 16 bits of resolution and is represented in OFFSET BINARY notation by the bits *R*[15:0]. PERIOD is calculated with respect to 100 ms.<br>R[15:0] = $\left(\frac{T_{PERIOD}}{0.1}\right) \times 65536$<br>Example: For a 400 Hz input at Ch0 the PERIOD will be 2.5 ms. This will be represented by 2.5e-3 / 0.1 × 65536 = 1638 |

## 20.5 Calculating the parameter from the measured count

Each of the 40 different parameters measured/calculated by the KAD/ADC/008 is represented as a 16-bit count. To convert a count into a voltage, current, power, or period the appropriate equation as shown below should be used. It is up to the user to calculate the primary voltages and currents based on the transformer used in their application.

Maximum voltage

$$V_{max} = \frac{R[15:0] \text{ x } V_{range}}{32768} - V_{range}$$

Minimum voltage

$$V_{min} = \frac{R[15:0] \text{ x } V_{range}}{32768} - V_{range}$$

Average voltage

$$V_{avg} = \frac{R[15:0] \times V_{range}}{32768} - V_{range}$$

Voltage amplitude ($V_{p\text{-}p}$)

$$V_{amp} = V_{max} - V_{min} = \frac{R[15:0] \times V_{range}}{32768}$$

RMS voltage

$$V_{rms} = \frac{R[15:0] \times V_{range}}{65536}$$

Active power (no assumption is made that the wave is sinusoidal)

$$P_{active} = \frac{R[15:0] \times V_{range\text{-}v} \times V_{range\text{-}I}}{32768} - (V_{range\text{-}v} \times V_{range\text{-}I})$$

Apparent power

$$P_{app} = \frac{R[15:0] \times V_{range\text{-}v} \times V_{range\text{-}I}}{65535}$$

Power factor

$$PF = \frac{R[15:0]}{32768} - 1$$

PERIOD

$$T_{period} = \frac{R[15:0] \times 100ms}{65536}$$

In each of the formulae *R*[15:0] is the register being read from the module in 16-bit mode.

Example: to calculate $V_{MAX}$ use the ADC8_X_JY_ChZ_MAX register where *R*[15:0] appears in the formula.

Example: to calculate $T_{PERIOD}$ use the ADC8_X_JY_PERIOD register where *R*[15:0] appears in the formula.

At least 2048 A/D readings are taken for each channel. If a DC signal is attached to a channel, the algorithm updates every 65,536 samples.

The ACC/TRF/002 is an external transformer that can be used to isolate and attenuate three voltages.

When programming the KAD/ADC/008, the relationship between the input voltage levels and the voltage and current being measured (scaling) should be specified.

## 20.6 Conclusion

In this paper, some of the nomenclature associated with power monitoring was introduced along with some formulae for deriving parameters such as maximum, minimum, amplitude, average, RMS, active power, apparent power and power factor.

# Using the KAD/BIT/101

TEC/NOT/045

The KAD/BIT/101 is a continuous built-in test module that monitors the Acra KAM-500 system using window functions to ensure that it is operating correctly.

This paper specifically describes window functioning, window strategy and the different outputs used to display the results of the window functions.

This paper discusses the following topics:

## 21.1 Features of the KAD/BIT/101



**Backplane power monitoring** - the five KAM chassis backplane voltages are captured within 1% accuracy and provided as five different 16-bit parameters, which are updated at 1 Hz.

**Thermal monitoring** - two thermocouples are located on the top block and on the printed circuit board of the module. Accuracy of this standard component is 1.5% FSR (3ºC) and has a range of -55 ºC to 125 ºC.

**Acquisition cycle monitoring** - a 32-bit counter captures the tick length of the acquisition cycle and verifies against a stored Current Value Table.

**Backplane address checksum** - a 16-bit register and adder monitors the address and data lines on the backplane.

**Format checking** - by reading the format (0 – 14) at the beginning (reset) of the acquisition cycle, the KAD/BIT/101 verifies the format via the Current Value Table.

**Power-on counter** - non-volatile RAM stores the number of power resets that occur.

**Time-on counter** - a continuous power-on duration counter increments every five minutes.

**Error reporting** - when an error occurs, the error code is time-tagged and placed in a FIFO on the KAD/BIT/101. Errors can then be presented over the backplane as 16-bit parameters or be transmitted in a 20-character message over an RS-422 output stream. Available bit-rates are 9.6 kbps and 115 kbps.

**Status reporting** - KAD/BIT/101 monitors the status parameter of bus monitors, memory modules, and verifies that analog inputs are within programmed voltage thresholds.

**Window functions** - you can store up to 120 window functions on the KAD/BIT/101 for continuous monitoring. All parameters on the backplane are available for error reporting via the KAD/BIT/101. Each window function has a user-specified ID for reference in the RS-422 stream or the KAD/BIT/101 status parameter.

Errors are presented in a 16-bit parameter on the backplane, including the status of the error FIFO (empty or overwritten). These window errors can also be transmitted over an RS-422 stream.

**Dedicated TTL/LED outputs** - eight output pins are dedicated to driving four LEDs or four TTL discretes. The status of these outputs are reflected as 4 bits in the KAD/BIT/101 status register.

**Dedicated 'Dolls Eye' indicator outputs** - the four status bits can be routed to drive four BITE indicators. Appropriate voltage and 40 ms pulses are incorporated into the module.

**RS422 stream outputs** - 20 character stream

"$E<ERR_COUNT>,<PARAMTER-ID>,<WINDOW_FCT-ID>,<STS_OUT>, <SKIPPED><CR><LF>"

**Slave chassis functionality** - the KAD/BIT/101 can monitor module status parameters on a slave chassis but cannot monitor the backplane voltages in a chassis where the module is not populated.

**NOTE:** Each KAM/CHS/13U/D chassis has a continuous +/-12 VDC across the backplane, therefore only one KAD/BIT/101 module is needed for each KAM/CHS/13U/D chassis. The KAM/CHS/13U/B and KAM/CHS/13U/C chassis each require two KAD/BIT/101 modules to monitor the +/-12 VDC backplane voltage due to the dual +/-12 VDC power supplies.

## 21.2 Defining window functions

Using window functions, you can monitor specific bits in any parameter available on the backplane. If thresholds or bit characteristics are met or exceeded, you can turn on an externally connected LED or ‘Dolls Eye’ indicator, or send a TTL pulse high, as defined in the window strategy. These voltages are supplied via the external connector on the KAD/BIT/101.

You can configure up to 120 window functions; each window function can check up to 32 parameter inputs with an output of four-bits. The outputs of all of the window functions are logically ORed together to produce a four-bit result.

The following figure shows two examples of window functions. Window Function 1 is used to check an internal power parameter of the KAD/BIT/101 and Window Function 120 is used to check a parameter from another module.

The output of window Function 1 is 0001 because the value of the input parameter is not above 2. The output of Window Function 120 is 0010 because the value of the input parameter is not equal to 65535.

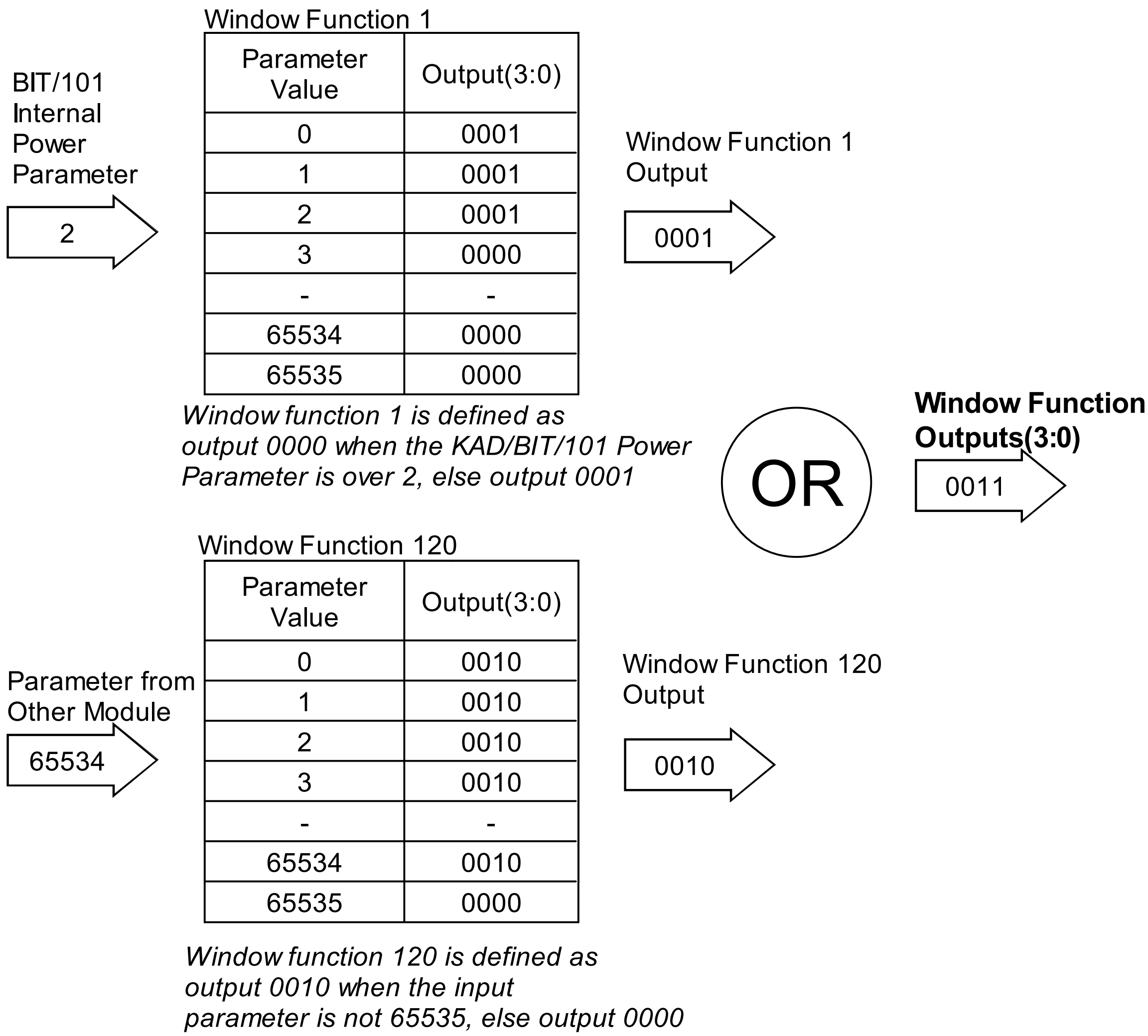



*Figure 21-1: Example of two window functions*

You can define window functions on the following Window Functions tab.

![CURTISS-WRIGHT]

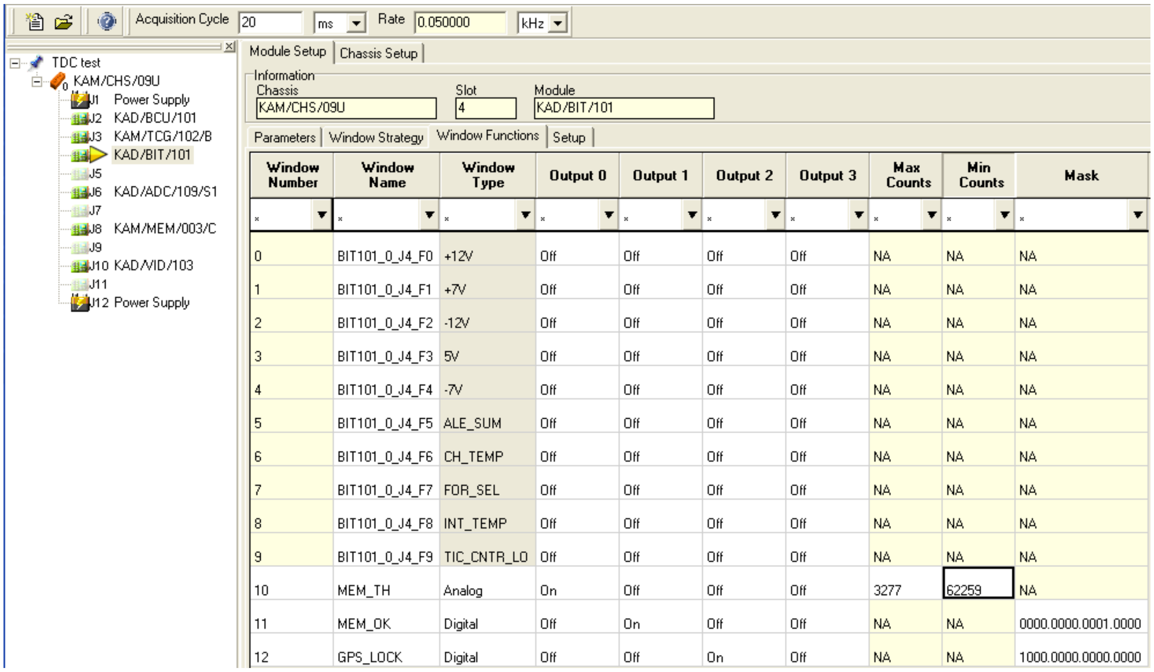



*Figure 21-2: Window Functions tab*

On the Window Functions tab, are default window functions for operations such as backplane power monitoring, backplane format monitoring, and measurement of internal/top block chassis temperature.

In addition to the default window functions, you can also manually define window functions. When defining window functions, you can do the following:

- Define types of window function
- Set specific outputs to be enabled (if the parameter determined is within the defined threshold or mask)
- Set threshold limits of an analog signal in raw counts
  (0 to 65535 for 16-bit parameters)
- Define masking strategies for digital parameters

To add a window function click **Add** at the bottom of the Window Function tab or right-click anywhere on the tab.

## 21.3 Defining window strategies

You can define up to 32 window strategies for a single KAD/BIT/101. You can place a single parameter in multiple window strategies and therefore use multiple window functions.

The following Window Strategy tab enables you to assign one or more parameters to a window function.

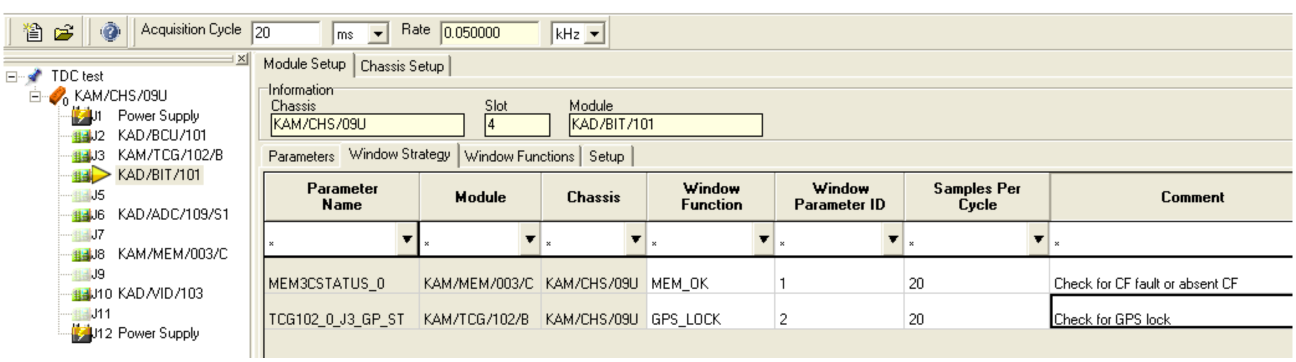



*Figure 21-3: Window Strategy tab*

The Window Strategy tab enables you to do the following:

- Assign parameters to window functions
- Define window functions to be assigned to specific parameters
- Define window parameter IDs
- Define the update rate per acquisition cycle
- Add comments if needed

To add a strategy, click **Add** at the bottom of the Window Strategy tab or right-click anywhere on the tab. When you click **Add**, the following Window strategy parameter selection screen displays.

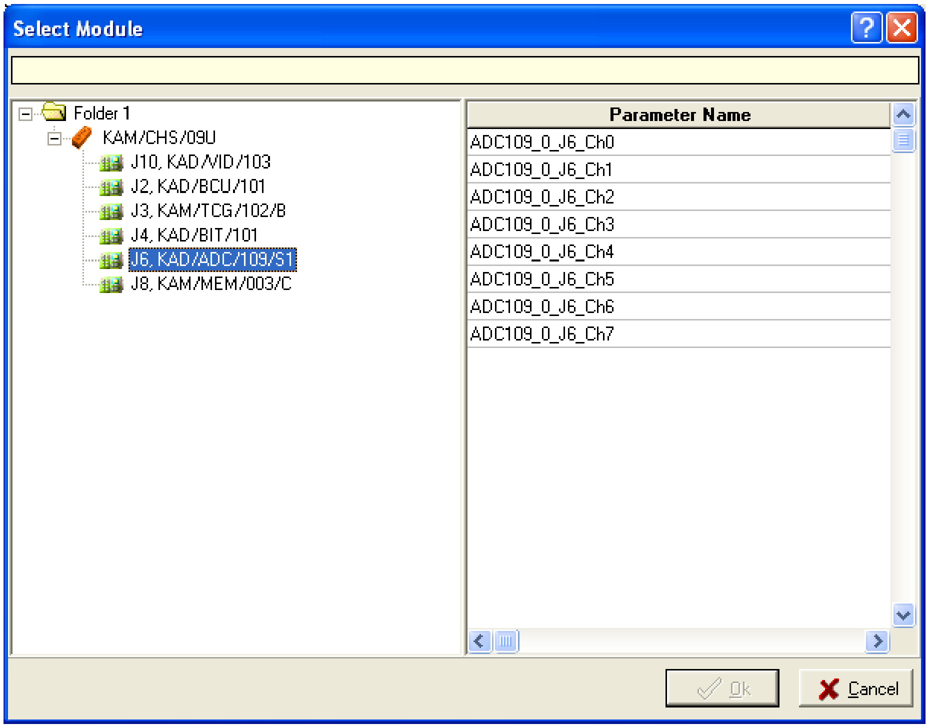



*Figure 21-4: Window strategy parameter selection window*

After adding a specific parameter, you can assign to it a pre-defined window function via a drop-down menu. If no window functions have been defined, the drop-down menu is empty. For information on defining window functions, see "21.2 Defining window functions" on page 100.

## 21.4 Configuring output channels

You can configure four output channels for the KAD/BIT/101. Each output channel can power an LED or a 'Dolls Eye' indicator, or trigger a TTL event.

You can configure output channels on the following Setup tab.

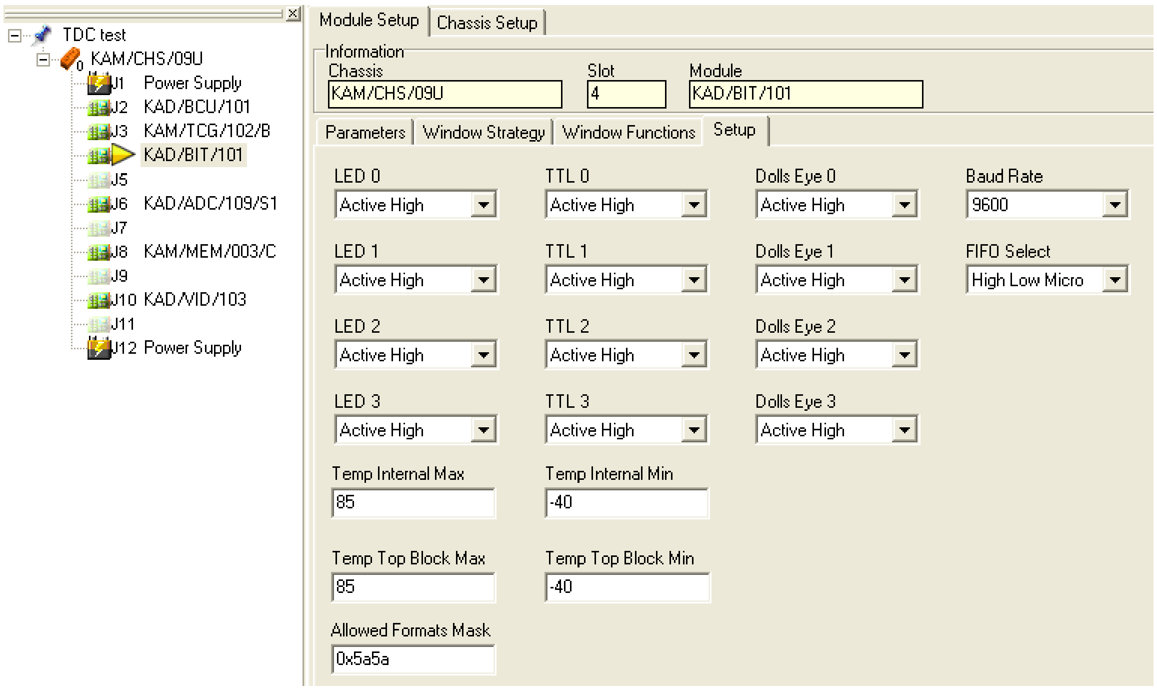



*Figure 21-5: Configuration of output channels on the Setup tab*

On the Setup tab you can do the following:

- Set each output channel to Active High or Low
- Set the Baud Rate for the output RS-422 error stream
- Determine the FIFO time tag
- Set the maximum and minimum temperature for the top block and chassis
- Set the allowed backplane format mask for advanced users

**NOTE:** When an output channel is active, as defined in the window function output column, all four output channels are active. You can define the active state on the Setup tab.

## 21.5 Monitoring analog thresholds

In this section, consider a basic analog input signal is being monitored which has an input voltage rage of ±10V. If the voltage exceeds ±9V, it is possible to trigger circuitry external to the Acra KAM-500. The trigger takes the form of a basic TTL (5 VDC) signal, Active High.

To generate a pulse on the KAD/BIT/101, which can be used to trigger external equipment, use an output on the module set to **high** when a certain event happens. As shown in the following figure, when the analog input voltage exceeds ±9V then Output 0 will be set to **active high**. The figure shows a window function added and named ADC_TH_9V. The first output channel is active if the thresholds are exceeded.

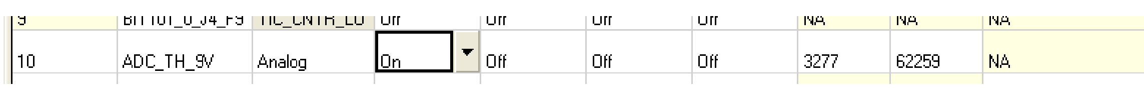



*Figure 21-6: Analog window function*

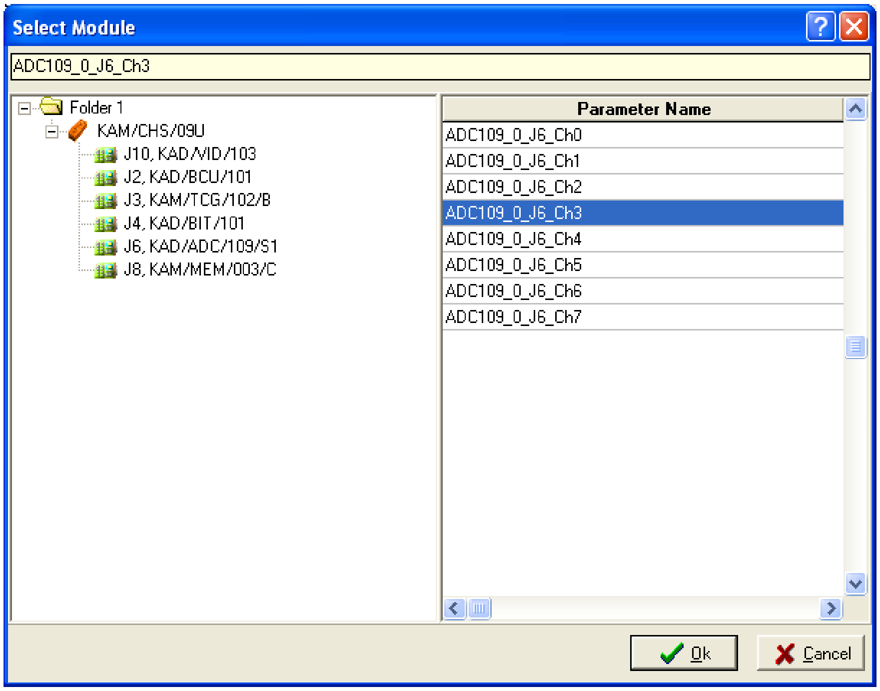
As mentioned, the threshold is ±9V over an input range of +/- 10V. This equates to a minimum count of 3277 and a maximum count of 62259.

A ±10V range equates to a 20V Full Scale Range (FSR). Therefore, 20V = 65536 counts and 0V = 32768 counts, that is, no offset.

A 1V change on the input causes a change (65536 / 20 = 3277) in counts. This implies that -9V = 0 - 9V = 32768 - 9 (3277) = 3277 and that +9V = 0 + 9V = 32768 + 9 (3277) = 62259.

To add a window strategy which monitors a threshold:

1. On the Windows Strategy tab, click **Add**.
2. Select the third channel of the ADC/109.



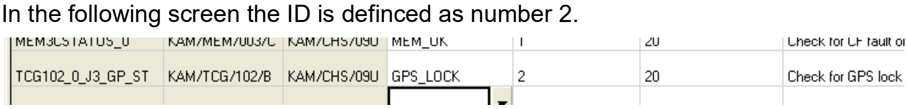

3. Assign a window function to the parameter and define an ID.
4. Save the changes.
5. Program the Acra KAM-500 chassis for the new function to take effect.

## 21.6 Monitoring specific register bits

You can monitor specific register bits of a module, for example the status register. Using the KAD/TCG/102 GPS receiver and clock generator as an example, if bit number 15 in this 16-bit status register is logic 1, we can power an LED external to the Acra KAM-500 to indicate the receiver has GPS lock. If GPS lock is lost, the LED turns off.

To add a window strategy which monitors a specific register bit:

1. On the Window Functions tab, click **Add**.
2. Define the window function characteristics which includes the required masking of the register (Bit 15).
3. On the Window Strategy tab, click **Add**.
4. Assign the window function added in step 1 and define an ID.
   In the following screen the ID is definced as number 2.




5. Save the changes.
6. Program the Acra KAM-500 chassis for the new strategy to take effect.

## 21.7 Monitoring the fullness of a KAM/MEM/00x CompactFlash® card

The memory module sends its current status to the backplane via a 16-bit word. This status register contains vital information for monitoring and logging parameters. The following table displays the status register bits found in MEM3STATUS, as detailed in the *KAM/MEM/003* data sheet.

Table 21-1: Status register bits

| Register | Bits | Bit Definition | MSB |
|---|---|---|---|
| **MOD_STS** | R[15:9] | Binary 0 - 7F hex indicates how full the CompactFlash card is. | R(15) |
| | R[8] | 1 when CompactFlash card is full. | |

Table 21-1: Status register bits (continued)

| Register | Bits | Bit Definition | MSB |
|---|---|---|---|
| | R[7] | 1 while logging | |
| | R[6] | 1 if logging or logged at least once | |
| | R[5:0] | Error codes | R(5) |

The Most Significant Bits (MSBs) of the status register (R[15:9] - see the previous table) indicate how full the CompactFlash is.

When the CompactFlash is empty, R[15:9] = 0000 000 = 0 Dec. = 0 hex. When the CompactFlash is full, R[15:9] = 1111 111 = 127 Dec. = 7F hex. For an intermediate range, if R[15:9] = 1001 100 = 76 dec = 4C hex.

By dividing the decimal amount of the intermediate measurement by the decimal amount when full, you can deduce the CompactFlash is about 60% full (76 dec / 127 dec = 0.598).

You can extract 16-bits from the memory module status register for a memory percentage full indicator. Once this percentage reaches a threshold, for example 90%, you can activate an output channel such as an LED.

When the memory module is logging, the last five bits are zero (0) via the error codes stated in the memory module's data sheet. The Least Significant Bits (LSBs) in this 16-bit configuration constitute an error in the percentage full count. If the 9 error code bits were all 1s, this would convert to 511 decimal. If all 16 bits were logic HI, we can calculate the error involved with the extra LSBs; 1111 1111 1111 1111= 65535 dec. The maximum error represented by this configuration is 511 / 65535 = 0.78%. Therefore the error is minimal for this application.

**Example - 90% full indication**

If you want to drive an LED output when the CompactFlash is 90% full, define an analog threshold as a window function and assign it to the memory module status under window strategies.

You can define the threshold depending on the desired error of the application:

For a 90% full indication, R[15:9] = 1110 010 = 114 decimal (114/127 = 89.7%), applying the full 16-bits of the MEM status register equates to a minimum count of 58368 (1110 0100 0000 0000) and a maximum count of 65535 (full count = 100%) (see the following figure).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | MEM_90_FULL | Analog | Off | Off | Off | On | 65535 | 58368 | NA |

*Figure 21-7: Setup for a window strategy*

In the example given on Page 105, the output channel 4 is active, and therefore the LED, if set to Active High on the Setup tab, lights when the CompactFlash is 89.7% full.

## 21.8 Monitoring the CompactFlash fault/full bit

As stated, the memory module provides error codes and CompactFlash fullness through its status register. R[5:0] defines the error codes for testing purposes, but generally these are all LO (0VDC) signifying that correct logging is occurring.

If required, you can monitor a specific bit from this register, for example the fault/full bit (R[4]). The following figure displays the specific window function required for this application.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | MEM_OK | Digital | Off | On | Off | Off | NA | NA | 0000.0000.0001.0000 |

*Figure 21-8: Example of a window function*

You must then define a window strategy as usual. For more information, see "21.6 Monitoring specific register bits" on page 104.

**NOTE:** The second output channel is enabled. Therefore when the specific bit transitions from 0 to 1, the output channel number two will be active. If required, you can define characteristics of the output channels on the Setup tab. For more information, see "21.4 Configuring output channels" on page 102.

## 21.9 References

See the *KAD/BIT/101* data sheet.

Chapter 22

# Using the KAD/EBM/101

TEC/NOT/046

The KAD/EBM/101 is a Fast Ethernet (10/100Mbps), single-port bus monitor that filters and parses Ethernet traffic. It monitors all network traffic or only traffic that is specifically addressed (or broadcast) to it.

This paper discusses the following topics:



## 22.1 Connecting the KAD/EBM/101 to a network

### 22.1.1 IP address overview

All nodes on an Ethernet network have an IP (Internet Protocol) address. The KAD/EBM/101 requires an IP address primarily to work in non-promiscuous mode, when data is being sent directly to it. The IP address is also used to ping the KAD/EBM/101 to verify its existence on the network (see “22.5.2 Testing the connection between PC and the KAD/EBM/101” on page 118).

IP addresses beginning with 192.168.X.X are reserved worldwide for private networks so this range is a good one to use.

Almost any other option is available, and the best solution depends on the network that you are connecting the KAD/EBM/101 to. For example, if an IP address of 192.168.0.103 is to be assigned, in hexadecimal, the address 192.168.0.103 reads as: C0 A8 00 67. In binary, this address is: 11000000 10101000 00000000 1100111.

---

**NOTE:** As IP and MAC addresses are stored internal to the KAD/EBM/101 after system programming, a hard-wired IP address is not required for the KAD/EBM/101. For more information, see “22.2 Ethernet packet structure” on page 109.

### 22.1.2 Wiring the KAD/EBM/101 connector interface

The following figure shows the location of the pins on a KAD/EBM/101 module.

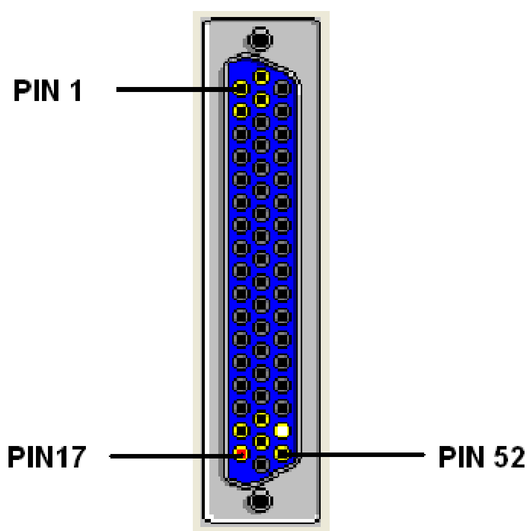
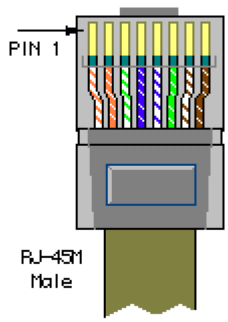



*Figure 22-1: KAD/EBM/101 connector pin locations*

## 22.1.3 Wiring the PC Ethernet interface

The KAD/EBM/101 is designed to interface to a standard 100BaseT Ethernet connection. The following figure shows the standard connections for an RJ-45 Ethernet connector.

| Crossover Cable | |
|---|---|
| RJ-45 PIN | RJ-45 PIN |
| 1 Rx+ | 3 Tx+ |
| 2 Rx- | 6 Tx- |
| 3 Tx+ | 1 Rx+ |
| 6 Tx- | 2 Rx- |




| Straight Through Cable | |
|---|---|
| RJ-45 PIN | RJ-45 PIN |
| 1 Tx+ | 1 Rx+ |
| 2 Tx- | 2 Rx- |
| 3 Rx+ | 3 Tx+ |
| 6 Rx- | 6 Tx- |

*Figure 22-2: Standard Ethernet cable connections*

The corresponding pins on the KAD/EBM/101 are shown in the following table.

Table 22-1: KAD/EBM/101 receive/transmit pins

| Pin | Name | Comment |
|---|---|---|
| 1 | RX A+ | Receive for Ethernet bus |
| 2 | RX A- | Receive for Ethernet bus |
| 18 | TX_A+ | Transmit for Ethernet bus |
| 19 | TX_A- | Transmit for Ethernet bus |

**NOTE:** The KAD/EBM/101 has a single Ethernet bus.

You can connect the KAD/EBM/101 directly to a PC or switch using a crossover cable, or to a hub using a straight-through cable. The corresponding pin connections are shown in the following table.

Table 22-2: Pin connections for connecting to a PC

| Crossover | | Straight-through | |
|---|---|---|---|
| KAD/EBM/101 pin | RJ-45 pin | KAD/EBM/101 pin | RJ-45 pin |
| 1 | 3 | 1 | 1 |
| 2 | 6 | 2 | 2 |
| 18 | 1 | 18 | 3 |
| 19 | 2 | 19 | 6 |

**NOTE:** This document focuses on wiring the KAD/EBM/101 to a network. For a comprehensive guide on wiring an Acra KAM-500 system, see the *Acra KAM-500 Databook*.

## 22.2 Ethernet packet structure

Before the KAD/EBM/101 can effectively capture traffic from the network, you must classify parser flows in the software configuration. The KAD/EBM/101 extracts packets from the bus containing user-defined criteria in the form of data word offsets from the beginning of the Ethernet packet. The 16-bit word offsets contain information such as IP or MAC addresses, port numbers, TCP or UDP protocol, and length.

It is essential that you understand the structure of the Ethernet packet to fully comprehend how the KAD/EBM/101 parses the packets.

The KAD/EBM/101 parser enables you to extract specific data words from the captured packet similar to a MIL-STD-1553 message. All protocol layer information is parsed and presented as 16-bit parameters, starting from data word zero (0). The Ethernet Preamble and the Start Frame Delimiter is discarded. Typically, data of interest lies in the proprietary layer (see the following figure).

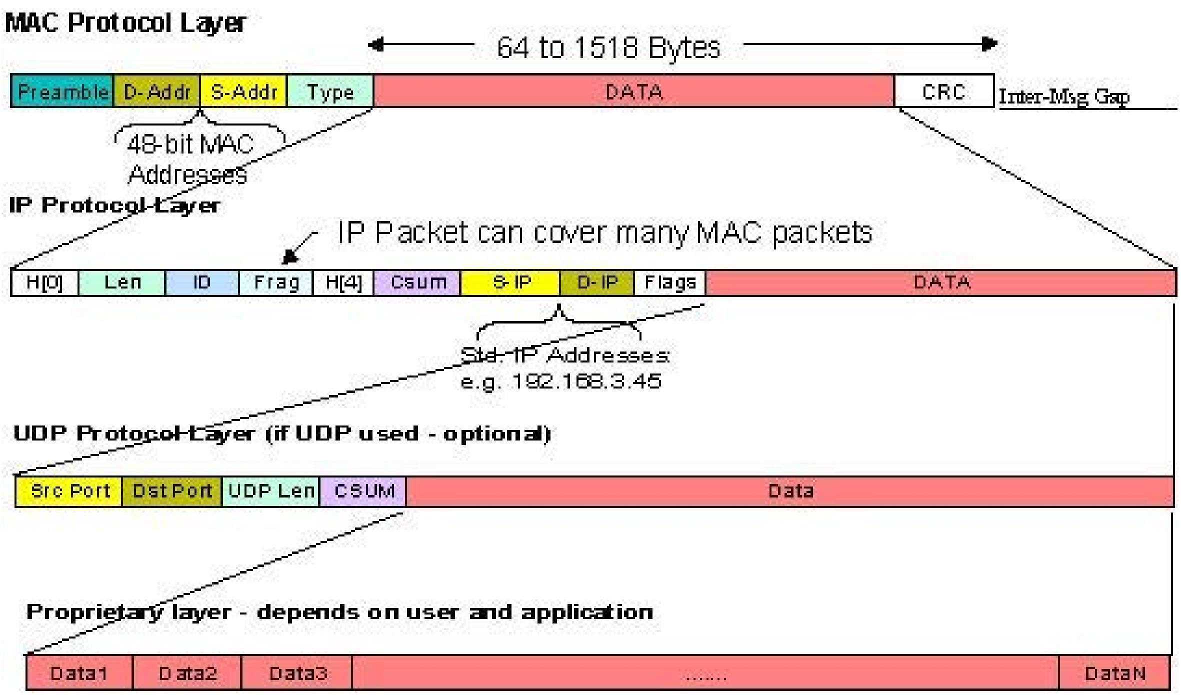



*Figure 22-3: Ethernet frame Structure*

The KAD/EBM/101 uses information in the protocol layers (see the previous figure), to place specific packets into the designated parser slot. The proprietary layer contains a flexible payload, the size of which can be set by you or the application.

If the KAD/EBM/101 monitors a general Ethernet packet, the parser splits the data into 16-bit data words following the Ethernet preamble (see the following table).

Table 22-3: KAD/EBM/101 data word offsets

| Data word # | Description | Comments |
|---|---|---|
| 0 | Destination MAC address, Word 0 (MSW) | |
| 1 | Destination MAC address, Word 1 | |
| 2 | Destination MAC address, Word 2 (LSW) | |
| 3 | Source MAC address, Word 0 (MSW) | |
| 4 | Source MAC address, Word 1 | |
| 5 | Source MAC address, Word 2 (LSW) | |
| 6 | Protocol type | IP = 0800h |

Table 22-3:  KAD/EBM/101 data word offsets (continued)

| Data word # | Description | Comments |
|---|---|---|
| | IP header | |
| 7 | Bytes in data payload or type of payload | Depends if 802.3 or Ethernet II packet |
| 8 | Total packet length | |
| 9 | Packet ID # | |
| 10 | Fragment offset | Only for fragmented packets |
| 11 | Time to live (1 byte) / IP protocol (1 byte) | xx11h for UDP and xx06h for TCP |
| 12 | Header checksum | |
| 13 | Source IP address, Word 0 (MSW) | |
| 14 | Source IP address, Word 1 (LSW) | |
| 15 | Destination IP address, Word 0 (MSW) | |
| 16 | Destination IP address, Word 1 (LSW) | |
| 17 | Source port | |
| 18 | Destination port | |
| 19 | Length of header in bytes | |
| 20 | Checksum | |
| | Data payload | |
| 21 | Data 0: (IENA Key) | Typically 001Fh |
| 22 | Data 1: (IENA Size) | Number of words in IENA data payload |
| 23 | Data 2: (IENA Time Word 0) | Straight binary microseconds |
| 24 | Data 3: (IENA Time Word 1) | Straight binary microseconds |
| 25 | Data 4: (IENA Time Word 2) | Straight binary microseconds |
| 26 | Data 5: (IENA Status) | Fixed at 7F00h |
| 27 | Data 6: (IENA Sequence) | Continuously increments |
| 28 | Data 7: (IENA Data Word 0) | |
| 29 | Data 8: (IENA Data Word 1) | |
| 30 | Data 9: (IENA Data Word 2) | |
| | … | |
| n | Data n - 21: (IENA Data Word m) | |
| n+1 | Data n - 20: (IENA End) | Typically FFFFh |
| n+2 | CRC Word 0 | |
| n+3 | CRC Word 1 | |

For example: A UDP packet from a KAD/ETH/001, KAD/ETH/101 or KAD/BCU/105 module contains an IENA transport data payload in the proprietary layer. The IENA packet structure (see the following figure) can be correlated with data word 21 and higher (see Table 22-3 on page 109).

| KEY | SIZE | TIME | STATUS | SEQ_NUM | DATA | END |
|---|---|---|---|---|---|---|
| (1 word) | (1 word) | (3 words) | (1 word) | (1 word) | (1 to 65,527 words) | (1 word) |

*Figure 22-4: IENA packet structure*

# 22.3 Using kSetup to configure the KAD/EBM/101

To configure the KAD/EBM/101, you can use kSetup (version 1.2.2 or higher). kSetup is included in the KSM-500 suite of tools.

## 22.3.1 Defining KAD/EBM/101 module settings

After creating a task in kSetup and adding the appropriate hardware for the application, select the KAD/EBM/101 module from the hardware hierarchy.

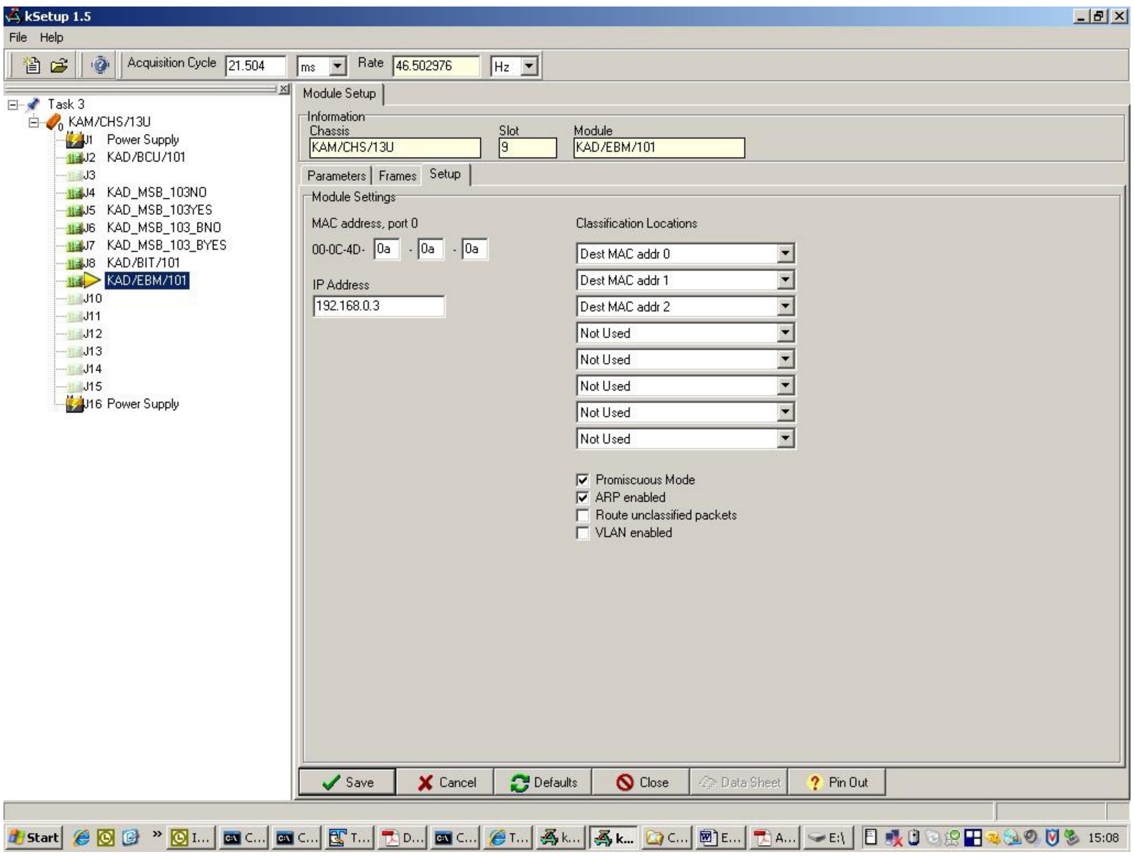



*Figure 22-5: KAD/EBM/101 module Setup tab*

### 22.3.1.1 Defining IP and MAC addresses

The KAD/EBM/101 requires the designation of an IP and MAC address. These are defined on the Setup tab of the KAD/EBM/101 module.

In the **IP Address** field, define an IP address for the KAD/EBM/101; 192.168.0.103 is used in the example displayed in Figure 22-5 on page 111.

Curtiss-Wright's EBM modules have been designated the first 6 hex numbers (3 bytes) of the MAC address (00-0C-4D). On the Setup tab, in the **MAC address, port #** field, insert the last 6 hex numbers (3 bytes) of the MAC address.

**NOTE:** Word 0 (see Table 22-3 on page 109), is the prefix of an IP or MAC address. For example, if we wanted to parse packets from the 48-bit MAC address 01-02-03-04-05-06, the 16-bit words would be broken down by the parser according to the following:
MAC 01-23-45-67-89-AB:

01-23 › MAC addr word 0
45-67 › MAC addr word 1
89-AB › MAC addr word 2.

#### 22.3.1.2 Specifying classification locations

You can also use the Setup tab to define classification locations. The purpose of these classification locations is to set filtering criteria for the packets. Using drop-down menus, you can select any 8 of the 16-bit data words in the protocol layer to define filtering criteria for a single flow.

The classification schema are based on the 16-bit data words available in the protocol layers of the Ethernet packets (see Table 22-3 on page 109).

---

**NOTE:** The KAD/EBM/101 module can also be used as part of a Multi-Chassis Scheduler on a networked Acra KAM-500 systems. For details of this configuration, refer to *TEC/NOT/068 - Network MCS in KSM-500*.

### 22.3.2 Other settings on the Setup tab

Other settings located on the Setup tab include:

- **Promiscuous Mode**. If this field is selected, the KAD/EBM/101 monitors all traffic on the port regardless of MAC address destinations. If not selected, all traffic is discarded, other than the traffic addressed to the KAD/EBM/101's MAC address, including broadcast traffic.
- **ARP enabled**. If this field is selected, the KAD/EBM/101 responds to ARP/PING packets. If not selected, the KAD/EBM/101 is transparent on the bus even though the ARP/PING packet is captured.
- **Route unclassified packets**. If this field is selected, all unparsed (unclassified) packets are available in parser slot 254. If not selected, all unparsed packets are discarded.
- **VLAN enabled**. If this field is selected, the parser skips over Virtual Local Area Network packet headers to classify the IP protocol. Typically, VLAN enabled is not selected on UDP networks.

### 22.3.3 Defining flows and payloads

You can configure up to 254 unique flows per KAD/EBM/101. A flow is defined to be a parser slot that captures packets based on user-defined criteria for each classification location. For example, if two classification locations are defined as Source IP Addr 0 and Source Port Number, the first flow can capture all packets with an IP address 192.168.x.x coming from IP port 0x03FF (1023 dec) while the second flow captures all packets from source port 0x0402 (1026 dec) regardless of IP address. This example is illustrated in the following figure.

Parameters | Frames | Setup

| Bus | Flow | Frame Name | Source IP Addr 0 | Source Port no | Not Used | Not Used |
|---|---|---|---|---|---|---|
| x | x | x | x | x | x | x |
| 0 | 254 | Frm_0_J15_0 | | | | |
| 1 | 255 | Frm_0_J15_1 | | | | |
| 0 | 0 | Example_Flow_1 | 192.168 | 03FF | xxxxxxxxxxxxxxxx | xxxxxxxxxxxxxxxx |
| 0 | 1 | Example_Flow_2 | x.x | 0402 | xxxxxxxxxxxxxxxx | xxxxxxxxxxxxxxxx |

*Figure 22-6: Sample flows*

---

**NOTE:** Classification locations are shown at the header of each column and the default flow 254 is available for a *capture all* operation. Flow 255 on Port 1 is unavailable at this time for the KAD/EBM/101.

#### 22.3.3.1 Adding flows

After specifying classification locations, you can define a flow (parser slot) on the Frames tab (see the previous figure).

To add a flow, right-click the **Frames** tab and select **Add Frame** as shown in the following figure. To remove a flow, right-click on the **Frame** and select **Remove Frame**.

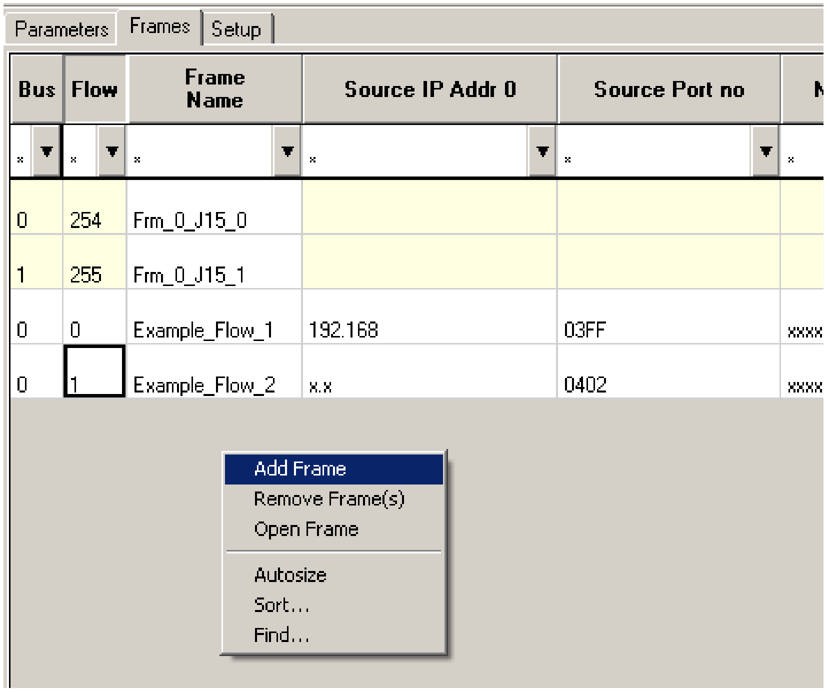



*Figure 22-7: Adding a flow*

After adding a flow, designate a quantity to at least one classification location; use x for don't care. Then, complete the flow number (Flow) and the flow name (Frame Name).

#### 22.3.3.2 Defining payloads

To specify the data payload for a flow, click **Edit** (on the right of the flow). When you click **Edit**, the data payload window populates. To add payload data words, right-click in the data payload window and select **Add Datawords**.

---

**NOTE:** The index starts at zero and correlates to the first 16-bit word after the preamble of the Ethernet packet, see Table 22-3 on page 109.

A timestamp is given for each packet arriving on the bus for each data flow. This timestamp occurs at the beginning of the first received bit of the packet.

Also included is the Info register, which informs you whether the parser buffer has been updated with a new packet according to the flow specification: a Stale and Skipped bit, which are standard on all Curtiss-Wright bus monitors.

To populate the parameters for PCM placement or other Acra KAM-500 sinks, click **OK**, and then click **Save** at the bottom of the Setup tab.

## 22.4 Using DAS Studio 3 to configure the KAD/EBM/101

In this example, the configuration consists of a chassis, a KAD/BCU/140 controller, and a KAD/EBM/101 module. With the KAD/EBM/101 module in context, click the **Settings** tab to show the following screen.

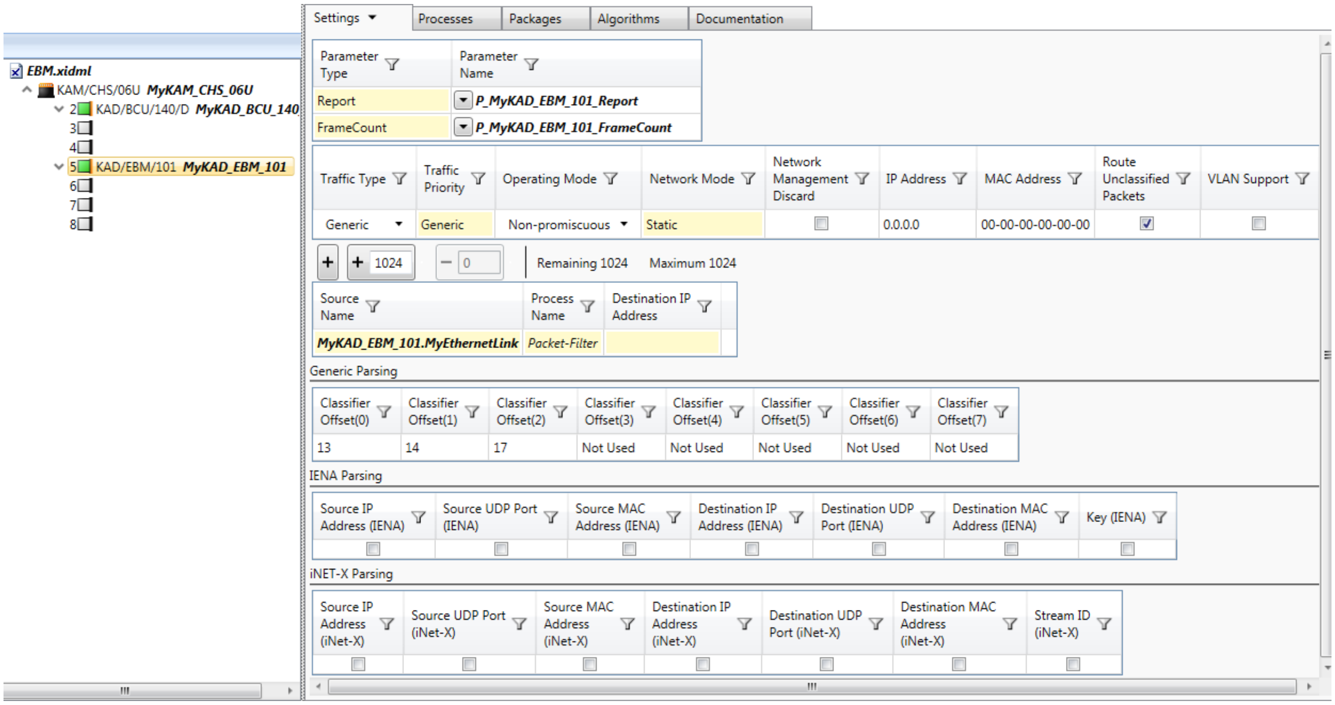



*Figure 22-8: Settings tab with KAD/EBM/101 in context*

Table 22-4: Settings tab descriptions

| Setting | Description |
|---|---|
| Parameter Type: Report | Use this parameter to know if the KAD/EBM/101 is connected to an Ethernet link. Refer to the *KAD/EBM/101* data sheet for further details. |
| Parameter Type: Frame Count | Use this parameter to know if the KAD/EBM/101 is parsing Ethernet frames on the Ethernet link. Refer to the *KAD/EBM/101* data sheet for further details. |
| Traffic Type | Use Generic when parsing 3rd party Ethernet traffic. This technical note only covers the Generic option. The other options are used for a Multi-Chassis Scheduler (MCS) on a networked Acra KAM-500 system. Refer to the *DAS Studio 3 User Manual* for further details. |
| Traffic Priority | Enables you to select IENA or INET-X for the MCS while also using the same KAD/EBM/101 to parse 3rd party Ethernet traffic. |
| Operating Mode | If Promiscuous is selected, the KAD/EBM/101 monitors all traffic on the port regardless of MAC address destinations.<br>If Non-promiscuous is selected, all traffic is discarded, other than the traffic addressed to the KAD/EBM/101's MAC address, including broadcast traffic. |
| Network Management Discard | Disable this setting if you want to ping/ARP the module.<br>When selected, the KAD/EBM/101 requires the designation of an IP and MAC address. |
| IP Address | Enables you to define an IP address for the KAD/EBM/101. |
| MAC Address | Enables you to define a MAC address for the KAD/EBM/101. |
| Route Unclassified Packets | If selected, all unparsed (unclassified) packets are available in parser slot 254.<br>If not selected, all unparsed packets are discarded. |

Table 22-4: Settings tab descriptions (continued)

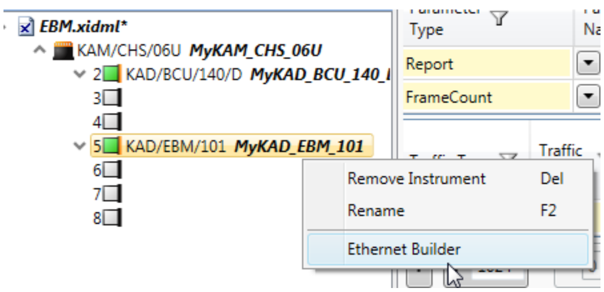
| Setting | Description |
|---|---|
| VLAN Support | If selected, the parser skips over Virtual Local Area Network packet headers to classify the IP protocol. Typically, this setting is not enabled on UDP networks. |

The other fields (see the following figure) in the Settings tab are used for a MCS on a networked Acra KAM-500 system (refer to the *DAS Studio 3 User Manual* for details). The settings in the Generic Parsing pane are automatically populated when using Etheret Builder (see the following section).

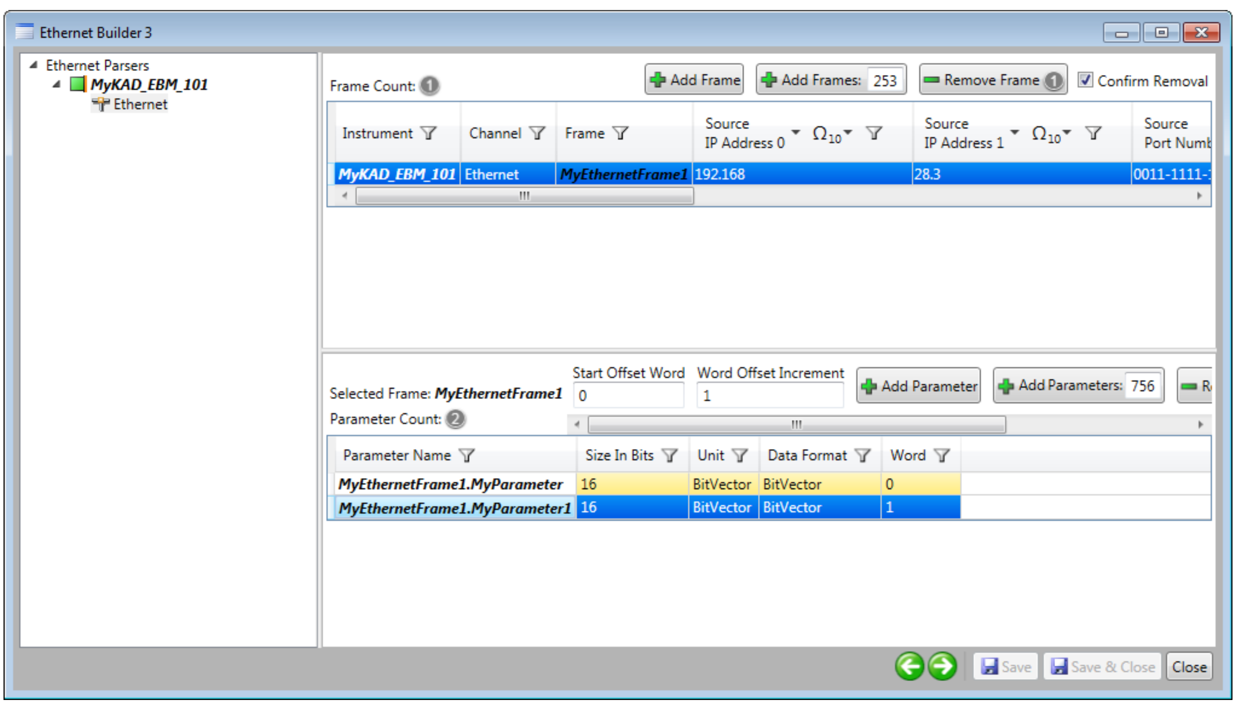
## 22.4.1 Using the Ethernet Builder application

Ethernet Builder is used to configure the classifications and flows when a 3rd party Ethernet frame is required to be parsed.

1. To start the application, right-click the **KAD/EBM/101** node in the Navigator and click **Ethernet Builder**.




The **Ethernet Builder 3** dialog box opens.

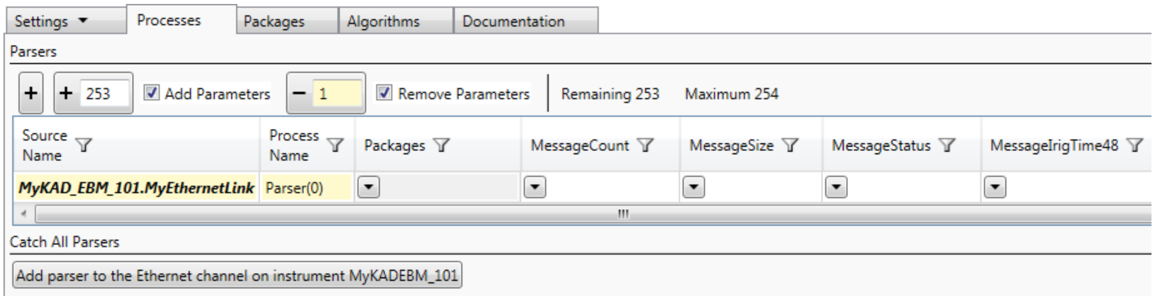



2. For more information, see “Ethernet Builder” in the “Applications” chapter of the *DAS Studio 3 User Manual*.

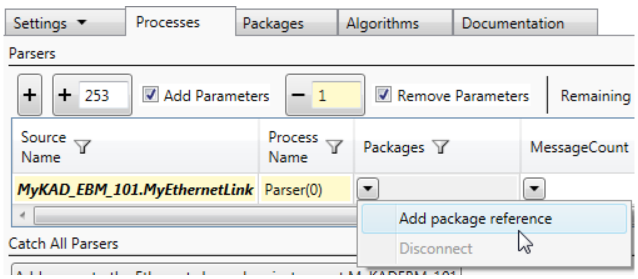
### 22.4.2 Creating a parser process

Use the Processes tab to read package tags. Package tags are associated information such as microsecond time of sync bit transition, message count, response time and package errors. To read a package tag, you must first create a new parser process.

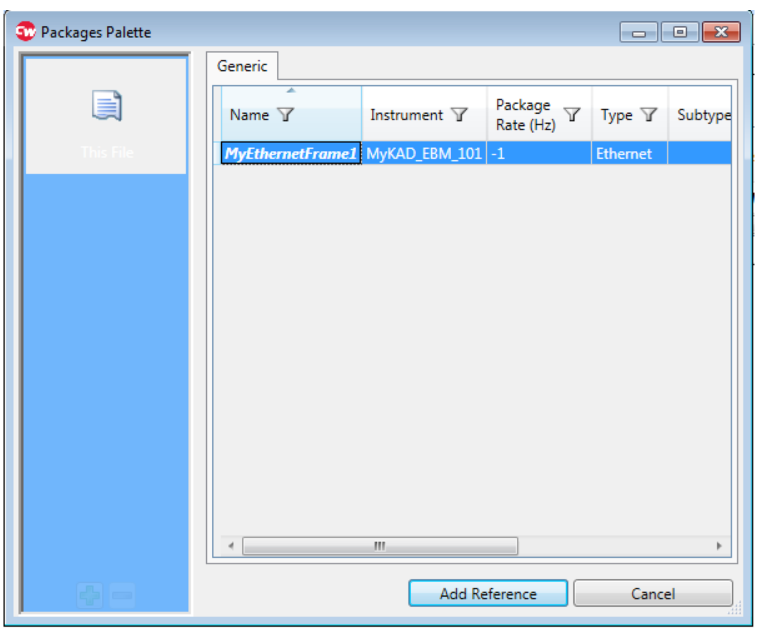
1. With the **KAD/EBM/101** module in context, click the **Processes** tab.



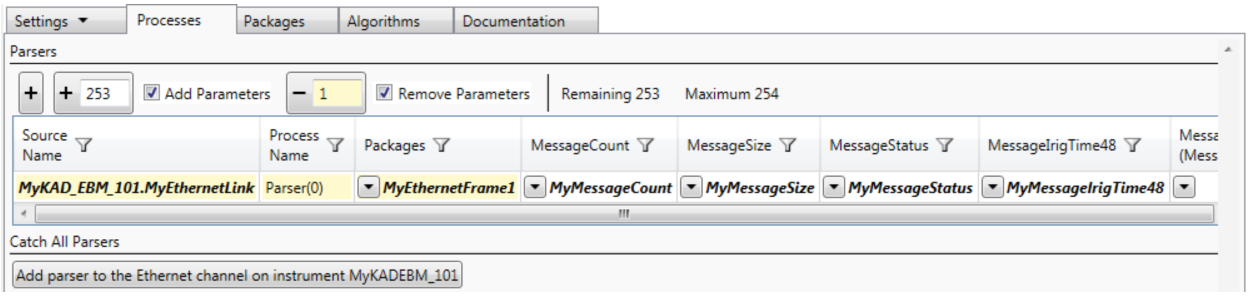

2. In the **Packages** drop-down menu, click **Add package reference**.




The **Packages Palette** dialog box opens.



3. Select **MyEthernetFrame1** and the click **Add Reference**.




All the tag parameter fields are now populated. Refer to the *KAD/EBM/101* data sheet for parameter defintions.

**NOTE:** A timestamp is given for each packet arriving on the bus for each data flow. This timestamp occurs at the beginning of the first received bit of the packet. Also included is the Message Info register, which informs you whether the parser buffer has been updated with a new packet according to the flow specification: a Stale and Skipped bit, which are standard on all Curtiss-Wright bus monitors.

## 22.5 Configuring and testing the network

This section describes setting up and testing network connections on a Windows XP operating system. The steps for other Windows operating systems are similar to the procedures shown here.

### 22.5.1 Setting up the PC on the network

If ARP is enabled on the KAD/EBM/101 in kSetup (see Figure 22-5 on page 111), the KAD/EBM/101 responds to ARP and PING packets.

Likewise, if Network Management Discard in DAS Studio 3 is not selected, the KAD/EBM/101 responds to ARP and PING packets.

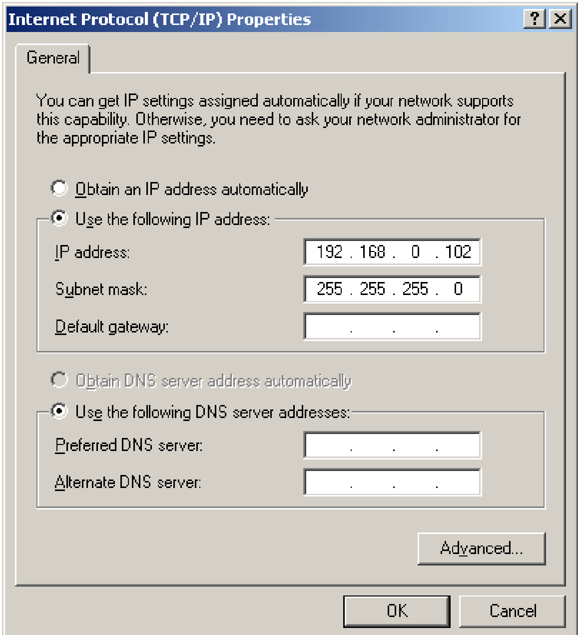
To "see" the KAD/EBM/101, the PC must be on the same network as the Acra KAM-500. Not only must they be physically connected through the switch or hub, but they must share the same network address section of their IP, which you must manually configure.

Also, make sure the KAD/EBM/101 port is connected to the uplink port when using a hub; smart switches might need software configuration to enable the KAD/EBM/101 to see all packets moving through the switch on its particular port.

Do the following to configure an IP address:

1. Click **Start**, **Control Panel**.
2. Open **Network Connections**.
3. Under **LAN or High-Speed Internet**, double-click the **Local Area Connection** that the Acra KAM-500 is connected to.
4. Click **Properties**.
   The Local Area Connection Properties window opens.

5. Select **Internet Protocol (TCP/IP)** and then click **Properties**.
   The Internet Protocol (TCP/IP) Properties window opens.



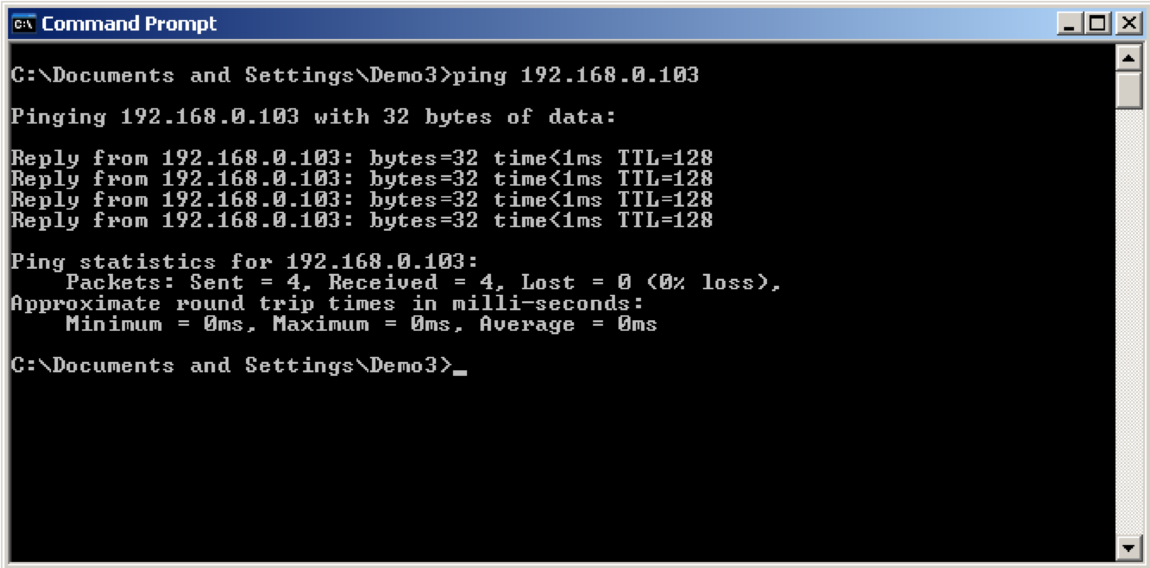

6. Select the **Use the following IP address:** radio button.
7. In the **IP address** field, insert an appropriate IP address.
   This IP address must have the same network address as the KAD/EBM/101. Typically, the network address is determined by the first two or three bytes of the IP address. Using the earlier example where the KAD/EBM/101 was set up for IP address 192.168.0.103, then the network address for this could be 192.168.0. The node address must be unique (that is, the one or two bytes that are not the network address). So in this example we could set the PC address to 192.168.0.102.
8. In the **Subnet mask** field, insert details for the network address.
   If only the first two bytes are the network address, then the mask would be 255.255.0.0. If the first three are the network address then the mask would be 255.255.255.0.
9. Click **OK**.
   If required, re-boot the PC.

### 22.5.2 Testing the connection between PC and the KAD/EBM/101

If the KAD/EBM/101 is not parsing correctly after it has been configured, check whether the KAD/EBM/101 is receiving packets. Do this by pinging the KAD/EBM/101 through a switch/hub via a PC NIC.

To ping the KAD/EBM/101:

1. Click **Start**, **Run**.
2. Type **cmd** and click **OK**.
3. At the C:\ prompt, type ping, followed by the IP address of the KAD/EBM/101.
   If the PC is able to connect to the KAD/EBM/101, you get a response similar to that displayed in the following figure.




If the ping determines that the PC can communicate with the KAD/EBM/101, the KAD/EBM/101 has been successfully configured and is able to receive packets.

### 22.5.3 Troubleshooting

If the PC is unable to communicate with the KAD/EBM/101, you get a response similar to that displayed in the following figure.

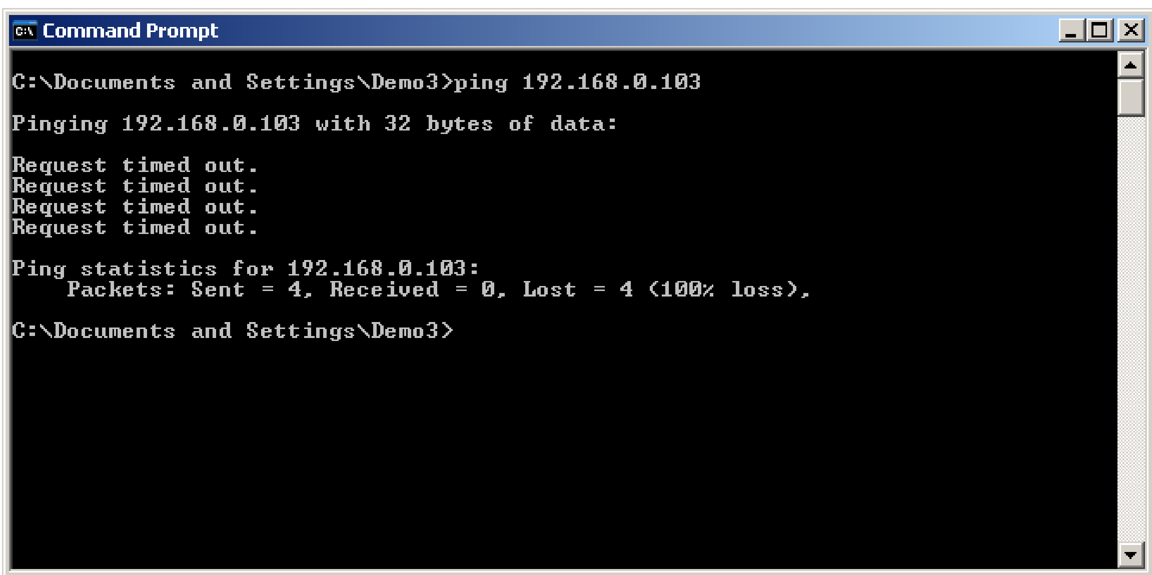



*Figure 22-9: Example of unsuccessful ping*

If the PC cannot communicate with the KAD/EBM/101, check the wiring and power to the KAM-500. If there is a problem with the network configuration, you get a response similar to that displayed in the following figure.

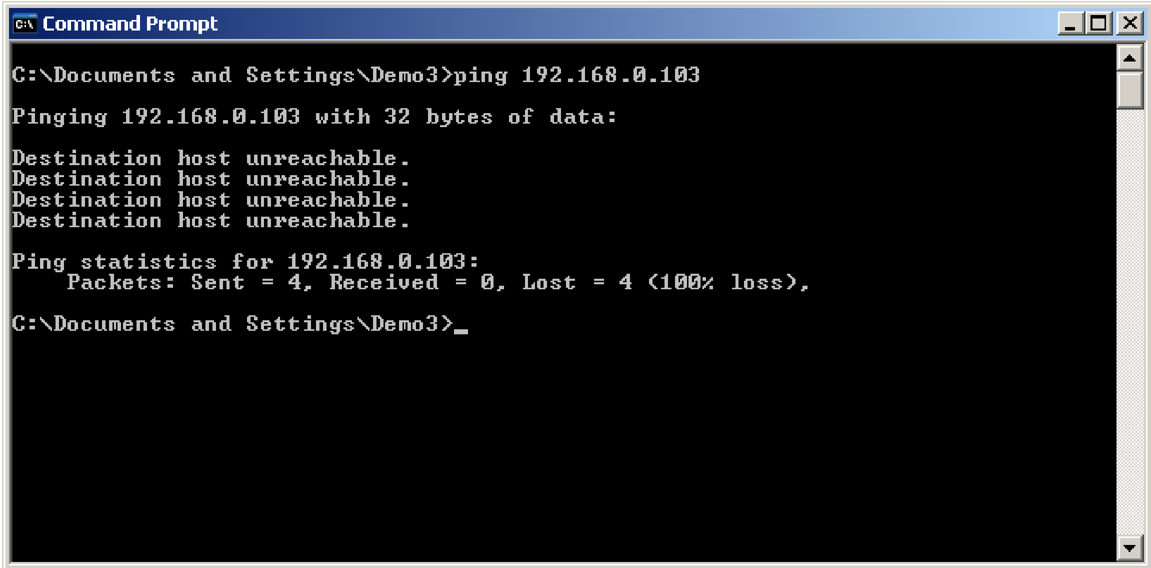



*Figure 22-10: Example of unsuccessful ping*

The response displayed in the previous figure suggests that the PC and the hardware are not on the same network by subnet reference. Check for errors or typos in the configuration of both.

# Using the KAD/DSI/002

TEC/NOT/047

The KAD/DSI/002 can monitor up to 24 differential or single ended, discrete channels. Eight of these channels (channels 0 to 7) act as special function counters, with multiple functions possible for each counter.

This paper describes how to set up the KAD/DSI/002 including details of counter settings and event tagging options. It is divided into the following sections:


- "23.1 Physical interface details" on page 121
- "23.2 Setting threshold voltages" on page 121
- "23.3 Special function registers" on page 125
- "23.4 Event tagging" on page 127


## 23.1 Physical interface details

All 24 channels have an identical physical interface as shown in the following figure.

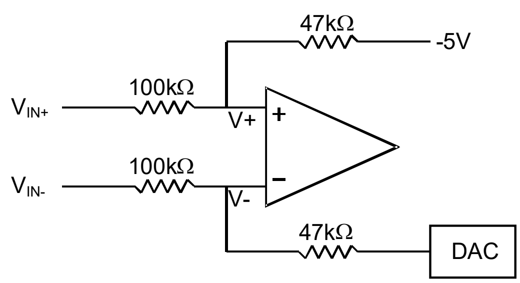



*Figure 23-1: Physical interface of a channel*

## 23.2 Setting threshold voltages

When $V_+$ is greater than $V_-$, the comparator output for each channel switches from logic 0 to logic 1. Therefore, the threshold voltage ($V_T$) can be defined as the point where $V_+$ is equal to $V_-$.

From the superposition theorem:

$$V_+ = \left(\frac{47}{147}\right)(V_{IN+}) + (-5)\left(\frac{100}{147}\right)$$

and

$$V_- = \left(\frac{47}{147}\right)(V_{IN-}) + (V_{DAC})\left(\frac{100}{147}\right)$$

At the threshold voltage, $V_+$ is equal to $V_-$. Therefore, the condition required for the output to switch from logic 0 to logic 1 is the following:

$$V_{IN+} - V_{IN-} > \left(\frac{100}{47}\right)(V_{DAC} + 5)$$

The above equation also expresses the relationship between the threshold voltage for each channel and the $V_{DAC}$ (Voltage across the Digital-to-Analog Converter) as outlined in the following table.

Table 23-1: Relationship between $V_{DAC}$ voltages and threshold voltages for the KAD/DSI/002

| $V_{DAC}$ (V) | Threshold ($V_T$) | $V_{DAC}$ (V) | Threshold ($V_T$) |
|---|---|---|---|
| -7.350 | -5.000 | 0.000 | 10.638 |
| -7.000 | -4.255 | 0.500 | 11.702 |
| -6.500 | -3.191 | 1.000 | 12.766 |
| -6.000 | -2.128 | 1.500 | 13.830 |
| -5.500 | -1.064 | 2.000 | 14.894 |
| -5.000 | 0.000 | 2.500 | 15.957 |
| -4.500 | 1.064 | 3.000 | 17.021 |
| -4.000 | 2.128 | 3.500 | 18.085 |
| -3.500 | 3.191 | 4.000 | 19.149 |
| -3.000 | 4.255 | 4.500 | 20.213 |
| -2.500 | 5.319 | 5.000 | 21.277 |
| -2.000 | 6.383 | 5.500 | 22.340 |
| -1.500 | 7.447 | 6.000 | 23.404 |
| -1.000 | 8.511 | 6.500 | 24.468 |
| -0.500 | 9.574 | 6.750 | 25.000 |

Expressed another way, $V_{IN+}$ must be greater than $V_{IN-}$ by the threshold voltage ($V_T$), which is equal to the following:

$$V_T = \left(\frac{100}{47}\right)(V_{DAC} + 5)$$

KSM-500 software (used to configure the KAD/DSI/002 module) allows you to specify the threshold, in volts, for each channel as shown in the following figure.

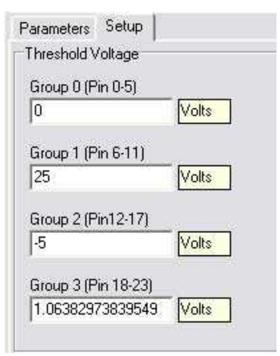



*Figure 23-2: Channel threshold settings*

After the threshold voltage has been specified using the software, the DAC (Digital-to-Analog Converter) is set automatically.

### 23.2.1 Channels per DAC

There are four DACs on a KAD/DSI/002, spread between the 24 input channels. Each DAC controls the threshold voltage for a group of six channels as shown in the following table.

Table 23-2: Channels per DAC

| DAC | Channels |
|---|---|
| DAC1 | Channels 0 to 7. |
| DAC2 | Channels 8 to 15. |
| DAC3 | Channels 16 to 23. |
| DAC4 | Channels 24 to 31. |

### 23.2.2 Examples of threshold settings

The following examples outline suitable threshold settings which correspond to various electrical inputs for the KAD/DSI/002. Recommended electrical inputs for particular threshold settings are also covered.

#### 23.2.2.1 When both inputs are connected to defined voltages

When $V_{IN+}$ and $V_{IN-}$ are switched between known voltages, that is, never left floating, each input behaves according to the following principle:

$V_{IN+}$ must be greater than $V_{IN-}$ by an amount greater than, or equal to, the threshold voltage in order to read a logic 1 for that channel.

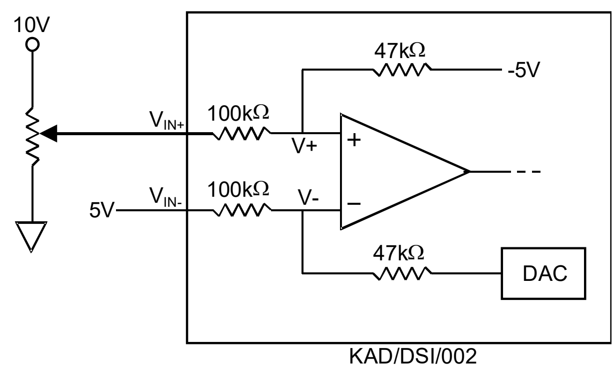



*Figure 23-3: Threshold settings when both inputs are connected to defined voltages*

Therefore, when a KAD/DSI/002 channel is connected as shown in the previous figure, the comparator outputs logic 0 when:

$$V_{IN+} \leq 5V + V_T$$

The comparator outputs a logic 1 when:

$$V_{IN+} > 5V + V_T$$

Therefore, if the threshold voltage is set to 0V, the comparator output switches from logic 0 to logic 1 when the input voltage ($V_{IN+}$) is greater than 5V.

Also, should the threshold voltage be set to, say 4V, the comparator output switches from logic 0 to logic 1 when the input voltage ($V_{IN+}$) is greater than 9V.

### 23.2.2.2 When setting a channel for 0V/Open

You can set the KAD/DSI/002 input channel to read a 0V/Open discrete signal (see the following figure).

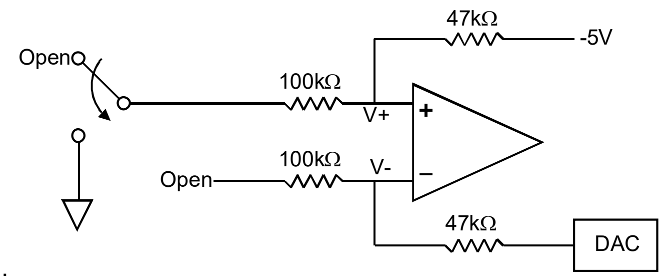



*Figure 23-4: Threshold settings for 0V/Open*

To set up a channel for 0V/Open, leave the negative input pin floating. This ensures that $V_-$ floats to whatever the $V_{DAC}$ is set to. When the switch is in the Open position, $V_+$ and $V_{IN+}$ float to -5V. When the switch is in the 0V position, $V_+$ increases to approximately -3.4V due to the voltage divider at the input (see the following figure).

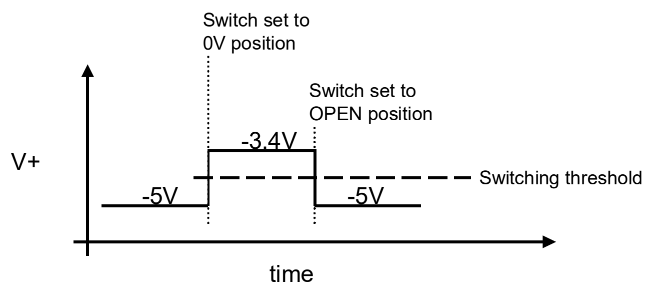



*Figure 23-5: Position of switches relative to switching threshold voltage*

You should set the $V_{DAC}$ to a value between -3.4V and -5V (typically, in the middle of this range—approximately -4.2V). According to Table 23-1 on page 122, the threshold should be set to approximately 1.7V.

The group of six channels which the channel belongs to should be set with a threshold of 1.7V. To achieve this, the software automatically sets the DAC to the appropriate voltage (in this case, -4.2V). If you are setting up the module through the XID, XML or XidML files, you can set the DAC voltage directly in the syntax.

### 23.2.2.3 When setting a channel for 28V/Open

You can set the KAD/DSI/002 input channel to read a 28V/Open discrete signal (see the following figure).

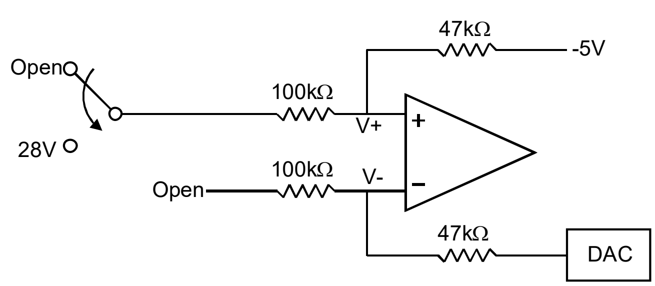



*Figure 23-6: Threshold settings for 28V/Open*

To set up a channel for 28V/Open, leave the negative input pin floating. This ensures that $V_-$ floats to whatever $V_{DAC}$ is set to. When the switch is in the Open position, $V_+$ floats to -5V. When the switch is in the 28V position, $V_+$ increases to approximately 5.55V due to the voltage divider at the input.

Therefore, the DAC voltage should be set to a value between -5V and 5.55V. Typically, you could choose somewhere in the middle of this range, that is, 0V. According to Table 23-1 on page 122, the threshold value in the software is to be set to approximately 10V.

#### 23.2.2.4 When setting a channel for 28V/0V

You can set the KAD/DSI/002 input channel to read a 28V/0V discrete signal (see the following figure).

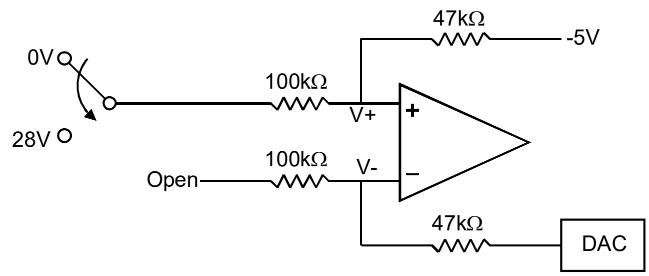



*Figure 23-7: Threshold settings for 28V/0V*

To set up a channel for 28V/OV, leave the negative input pin floating. This ensures that V- floats to whatever $V_{DAC}$ is set to. When the switch is in the 0V position, $V_+$ is approximately -3.4V. When the switch is in the 28V position, $V_+$ increases to approximately +5.55V.

Therefore, the DAC voltage should be set to a value between -3.4V and +5.55V. Typically, you could select somewhere in the middle of this range, that is, +1V. According to Table 23-1 on page 122, the threshold value in the software is to be set to approximately 12V.

#### 23.2.2.5 Other options

All examples given here involve the floating of the negative input. However, it is possible to leave the positive input floating (in which case $V_+$ always floats to -5V) and connect the negative input to the discrete signal (such as 0V/Open or 28V/0V).

When left unconnected, the negative input pin floats to the DAC output voltage, which can be set between -7.35V and 6.75V, with 3.663 mV steps. That is, 12-bit DAC in the range ±7.5V; however not all of the range is usable.

## 23.3 Special function registers

The first eight channels of the KAD/DSI/002 are connected to special function registers, which you can configure on a channel-by-channel basis to read the following:

- The number of clock cycles between events on a channel
- The number of events on a channel in a defined clock period
- The number of events since the register was previously read
- The time elapsed since the register was previously read
- The number of events updated on a sample since power-up
- The total number of clocks on the channel
- Each time the register is read
- The total number of events on a channel

The following figure shows how these registers can be set in the software.

Parameters | Setup

| Parameter Name | Mode | Type | Output | Edge | Clock | Protocols | Comment |
|---|---|---|---|---|---|---|---|
| DSI2_0_J7_CTR0 | COUNTER_0 | PERIOD | BCD | Rising | 1s | None | |
| DSI2_0_J7_CTR1 | COUNTER_1 | FREQUENCY | BIN | Falling | 1ms | None | |
| DSI2_0_J7_CTR2 | COUNTER_2 | EVENT_SINCE | BCD | Rising | N/A | None | |
| DSI2_0_J7_CTR3 | COUNTER_3 | ELAPSED | BIN | Falling | 125ns | None | |
| DSI2_0_J7_CTR4 | COUNTER_4 | COUNT | BCD | Rising | 125ns | None | |
| DSI2_0_J7_CTR5 | COUNTER_5 | TIMER | BIN | Falling | 125ns | None | |
| DSI2_0_J7_CTR6 | COUNTER_6 | READ | BCD | N/A | N/A | None | |
| DSI2_0_J7_CTR7 | COUNTER_7 | EVENT | BIN | Rising | N/A | None | |
| DSI2_STAT_HI_0_J7 | STATUS[23-12] | N/A | N/A | N/A | N/A | None | |
| DSI2_STAT_LO_0_J7 | STATUS[11-0] | N/A | N/A | N/A | N/A | None | |
| DSI2_TAG_EV_0_J7 | TAG_EVENT | N/A | N/A | N/A | N/A | None | |

*Figure 23-8: Register settings in kSetup*

You can set the output of each special function register to display in BINary (BIN) or Binary Coded Decimal (BCD). You can also configure each special function register to count on either rising or falling edges of a signal.

### 23.3.1 PERIOD

This register type counts the number of clock cycles between events on a channel. To gain optimum resolution for the period measurement, select the clock frequency for the register.

To measure a signal which typically has a period of two seconds, configure the channel to measure PERIOD, with a clock time of one millisecond (ms), that is, the frequency is equal to 1 kHz. Therefore, whenever you read the special function register, expect to read a PERIOD value of 2000 (meaning that 2000 × one-millisecond clock is equal to a two-second period).

Set the period measurement clock to any value between 125 nanoseconds (ns) and one second. The register counts from 0 to 65535 (or to 9999 for BCD mode), and stays there when the maximal value has been reached.

### 23.3.2 FREQUENCY

This register type counts the number of events on a channel, in a defined clock period. To gain optimum resolution for the frequency measurement, select the clock frequency for the register. To measure a signal which has a frequency varying between 500 Hz and 2.5 kHz, configure the channel to measure frequency, with a clock time of one second, that is, frequency is equal to 1 Hz.

Therefore, whenever you read the FREQUENCY register, expect to read a period value of somewhere between 500 and 2500 events, since that is the number of events on that channel between one-second clock periods.

Similarly, should you set the clock frequency on the channel to be 10 Hz, that is, the clock period is equal to 100 ms, then expect to read values between 50 and 250 events whenever you read the FREQUENCY register.

You can set the frequency measurement clock to any value between 125 ns and one second. Setting the clock period to one second means that any frequency result is in Hertz. The register counts from 0 to 65535 and stays at 65535 when the maximal value has been reached.

### 23.3.3 EVENT_SINCE

This register type counts the number of events since the register was previously read. Thus, events on the channel increment the counter, and the counter is cleared each time it is read. The register counts from 0 to 65535 and stays at 65535 when the maximal value has been reached.

### 23.3.4 ELAPSED

This register type counts the time elapsed since the register was previously read. Clock pulses on the channel increment the counter, and the counter is cleared each time it is read. The register counts from 0 to 65535 (or to 9999 for BCD mode), and stays there when the maximal value has been reached.

### 23.3.5 COUNT

This register type counts the number of events since power-up. The register counts from 0 to 65535 (or to 9999 for BCD mode), incrementing each time an event updates on a sample, and rolls back to 0 after the maximal value has been reached.

### 23.3.6 TIMER

This counter increments using a pre-selected clock. In this mode, the register counts the total number of clocks on the channel since the last event. As per period measurement, the clock period may be set at any value between 125 ns and one second. The register counts from 0 to 65535 (or to 9999 for BCD mode), and stays there when the maximal value has been reached.

### 23.3.7 READ

This register type counts each time the register is read. The register counts from 0 to 65535 (or to 9999 for BCD mode), incrementing each time it is read, and rolls over to 1 after the maximal value has been reached.

### 23.3.8 EVENT

This register type counts the total number of samples since the last event on a channel. The register increments when every sample is read on the channel counting up to 65535 (or to 9999 for BCD mode), and resets to 1 on a new event.

### 23.3.9 STATUS

All 24 channels may be sampled to give a snapshot of whether they are logic 1 or logic 0 at any time. The status of the 24 channels is available to read typically as 2 × 12-bit STATUS words, with 12 of the status values in each of the 12-bit words.

## 23.4 Event tagging

You can configure the last 16 channels as event tagging channels. The range of each counter is programmable as is voltage threshold and sensitivity to the rising and falling edge. Events are triggered when the channel has either a rising or falling edge. You can use the last 16 of the 24 channels for event tagging.

Event tagging means that every time an event occurs on a channel, a 48-bit word is generated for that event. This 48-bit word contains the following information:

- Status of Channels 7 to 23 inclusive (16 bits)
- Lo Time (16 bits)
- Micro Time (16 bits)

Lo Time and Micro Time are the time stamps for when the event happened.

48-bit event tag words are stored in an event buffer which is 1K deep. This buffer must be read frequently so that it does not overflow.

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Chapter 24

# Format select

TEC/NOT/048

This paper discusses the following topics:



## 24.1 Overview

Format select enables different sampling strategies to be loaded into the hardware simultaneously and to switch between them.

Having multiple format select settings enables different test configurations to be set up for the stages of landing, take off and flutter tests.

---

**NOTE:** Using multiple format selects occupies space in the EEPROM. See “24.4.2 Encoder/controller module” on page 130.

Format select can also be used in calibration or test configurations. For example, format select can be used in pseudo shunt calibration, using the adjust voltage Vadj of the bridge modules as shown in the following figure. This gives a known deflection on all selected channels (if set to non-zero value).

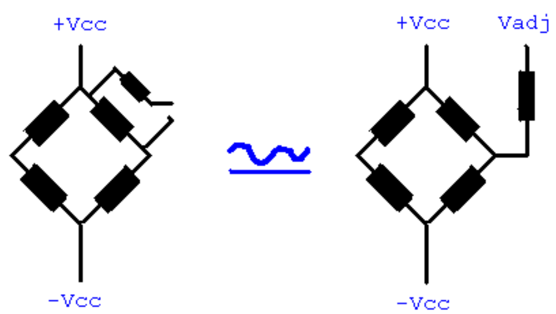


*Figure 24-1: Pseudo shunt calibration using format select*

## 24.2 Wiring for format select

The KAD/ENC/004, KAD/BCU/001 and KAD/BCU/101 modules have four format select lines. These are buffered TLL inputs (pulled to GND if not connected).

FORMAT ID 0 - 13 are available for use; 14 and 15 are reserved.

By setting this format select, the controller, the PCM transmitters and some modules use different EEPROM addresses. Format select is acting like an offset in the EEPROM address on the Acra KAM-500.

## 24.3 Bus monitors and format select

Most bus monitor modules do not support format select, that is, for any format select chosen, bus monitors use the EEPROM content from FMT_0 (format select 0). To transmit data from different messages on a different format select, you must set up all messages and data words for each format select and then transmit what you want into the PCM.

**For example:**

With the MIL-STD-1553 modules, we want to look at messages A, B and C in format 0, and we want to look at messages A, C and D in FMT_7.

To do this, A, B, C and D must be defined for FMT_0 and FMT_7 in the module setup. However, in the PCM for FMT_0, you transmit A, B and C; and in the PCM for FMT_7, you transmit A, C and D.

The modules in the following table must use format select as described in this section.

Table 24-1: Bus monitors which use EEPROM from FMT_0

| | | | |
|---|---|---|---|
| MSB/001 | MSB/003 | PBM/001 | ARI/001/B |
| MSB/001/B | MSB/003/B | PBM/002 | UAR/002/B |
| MSB/002 | FBM/001/B | SBM/001 | UAR/002/C |
| MSB/002/B | ARI/001 | FBM/001 | UAR/102 |

**NOTE:** If you want to use format select, and your bus monitor is not listed above, contact Curtiss-Wright support (acra-support@curtisswright.com).

# 24.4 Format select for sink modules

## 24.4.1 Memory module

You can use MEM/003 or MEM/004 in FMT_0 only.

## 24.4.2 Encoder/controller module

Both the encoder and controller have address space dedicated to format select. A single format can spill over format select boundaries, if it is large enough.

Overlapping issues are difficult to assess because the number of instructions is dynamic and depends on configuration.

The programmer KUP detects formats overlapping in EEPROM. If this error is reported, you must then leave room between the various formats in the EEPROM.

The KAD/ENC/004, KAD/BCU/001 and KAD/BCU/101 family PCM transmitter uses 65536 16-bit EEPROM words per format select.

**For example:**

The KAD/BCU/101/B PCM transmitter uses 65536 16-bit EEPROM words per format select. If there is a 16-bit PCM in your setup with 800 words/minor frames × 256 minor frames = 204800 words per major frame, this PCM word structure is stored in the EEPROM, taking two 16-bit words per PCM words, so the PCM will take 204800 × 2 = 409600 words.

Therefore, PCM would require 409600/65536 = 7 format select EEPROM space.

Therefore, you must use FMT_0 and FMT_7 instead of using FMT_0 and FMT_1.

**NOTE:** If the PCM is a 10-bit fixed PCM, each 10-bit word could need up to three address locations.

The KAD/ENC/004 (or higher controller revision) will not normally run into format select overruns unless there is something called paging. Paging occurs when the acquisition cycle (major frame duration for PCM) does not divide exactly by 1 microsecond. This causes the instruction set to repeat until the overall cycle divides exactly by 1 microsecond. A large number of pages can cause the format select region to overflow.

## 24.4.3 Analog modules

The bridge modules KAD/ADC/009, KAD/ADC/014, KAD/ADC/109 and KAD/ADC/114, can change the adjust voltage using multi-format. Only the adjust voltage of the modules must be changed during format select. All other module setup information must remain the same.

**NOTE:** The KAD/ADC/005 family can only address from FMT_0 to FMT_7. The KAD/ADC/105 family has the same capabilities as the KAD/ADC/005 over 14 formats.

Chapter 25

# Power estimation

TEC/NOT/049

This technical note discusses the following topics:



## 25.1 Power estimation overview

To make an accurate estimation of power drawn by an Acra KAM-500 chassis, the configuration must be known.

### 25.1.1 Chassis

A chassis can hold a number of modules, each drawing current on the available power lines: 5V, ±7V and ±12V. These lines are supplied via DC/DC converters from the Power Supply Unit (PSU). The PSU is externally supplied on 28V.

### 25.1.2 Modules

Each module draws current on the above mentioned power lines. The current drawn by a module is found in the General specifications section of the respective data sheet. This consumption varies depending on factors such as the sampling frequency for KAD/ADC/xxx modules, the output/input rate for bus modules or the excitation driven at the output of a module. The power drawn by a module is the sum of the power used on each power supply line.

## 25.2 Limitations

### 25.2.1 Power lines

Each PSU has limited current available per power line. Therefore the sum of current used on each line must be checked against the total current available on the PSU of the chassis. The total current available per line can be found in the PSU data sheet.

### 25.2.2 Imbalanced power lines

When selecting modules, the current drawn between the positive and negative lines of the 7V and 12V supply should be kept as balanced as possible. If that ratio is greater than 7:1, DC/DC stability can be compromised and the total power available cannot be achieved.

**NOTE:** When an imbalance reaches 7:1, the voltage on the opposite line may vary within ±10%. This variation will affect other modules in the chassis, such as modules that need to draw current on this line or a KAD/BIT/101 monitoring power lines, and will generate constant errors.

### 25.2.3 Power available

Because of PSU internal wiring limitations, we recommend keeping the total power ($P_{total}$) dissipated below 56W for the KAM/PSU/012 and 81W for the KAM/PSU/012/B.

## 25.3 DC/DC converter efficiency charts

The following two figures represent the DC/DC converter efficiency used on the KAM/PSU/012 and KAM/PSU/012/B of the Acra KAM-500 chassis.

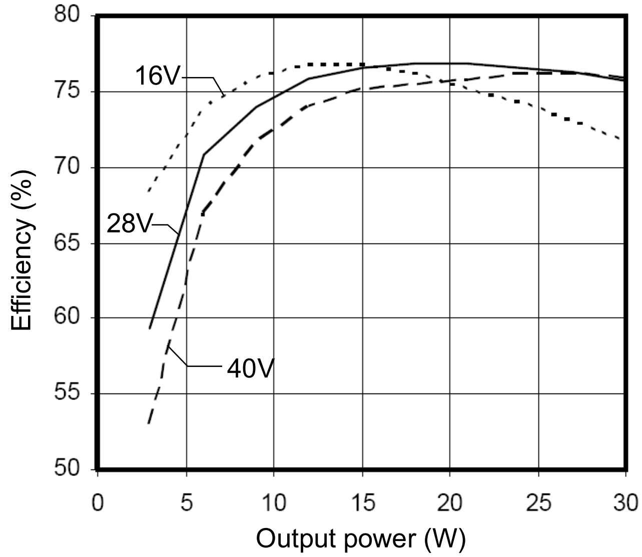


*Figure 25-1: 5V DC/DC converter efficiency for the KAM/PSU/012 and KAM/PSU/012/B*

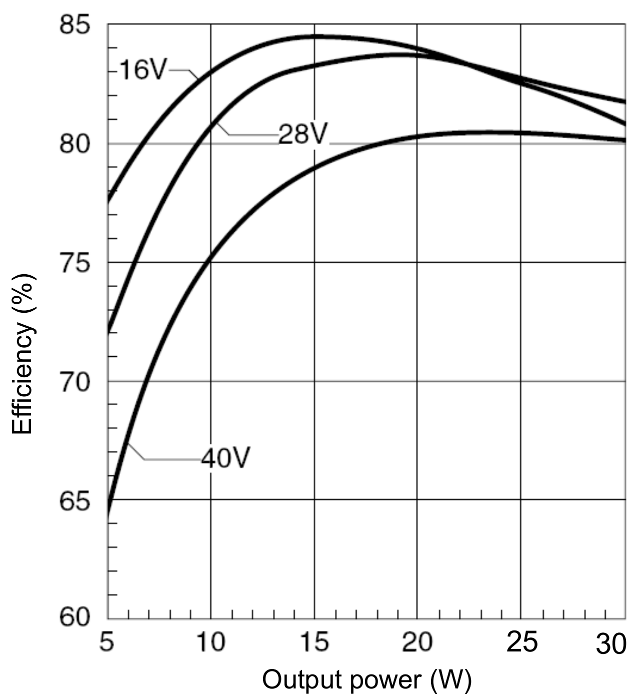


*Figure 25-2: 7V/12V DC/DC converter efficiency for the KAM/PSU/012 and KAM/PSU/012/B*

## 25.4 Example of power estimation[1]

| Slot | KAM/CHS/13U | 5 | 7 | -7 | 12 | -12 | Excitation | Exc 7V | Exc -7V | Exc 12V | Exc -12V | Conditions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | KAM/PSU/012[1] | 4000 | 4000 | | 2500 | | | | | | | |
| 2 | KAD/BCU/101/B | 782 | 0 | | 0 | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | KADDSI/003/B | 264 | 0 | | 32 | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | KAD/ENC/106 | 231 | 0 | | 103 | | | | | | | |
| 7 | KAD/UAR/102 | 165 | 0 | | 0 | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | KAD/ADC/106/B | 170 | 0 | | 95 | 45 | 6 x 3.6 mA x 2.5 | 0 | | 54 | 0 | With 3.6 mA on 6 channels and 2.5 DC/DC efficiency |
| 11 | KAD/ADC/109/B/S1 | 160 | 60 | 50 | 80 | 60 | 8 x (10V / 350R) | 228 | 228 | 0 | 0 | With 10V over 350R bridge on 8 channels |
| 12 | KAD/ADC/109/B/QB350 | 170 | 40 | 40 | 70 | 40 | 8 x 14.5 mA | 116 | 116 | 0 | 0 | With 14.5 mA over 350R bridge on 8 channels |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| | External excitation | | | | 12 | | | | | | | With 12V on a 1K load |
| | Current per module (mA) | 1942 | 100 | 90 | 392 | 145 | Current per excitation (mA) | 344 | 344 | 54 | 0 | |
| | Total current per line (mA) | 1942 | 444 | 434 | 446 | 145 | | | | | | |
| | Total current (mA)[2] | 1942 | 878 | | 591 | | | | | | | |
| | Power used (W) | 9.71 | 6.146 | | 7.092 | | | | | | | |
| | Efficiency[3] | 0.67 | 0.72 | | 0.72 | | | | | | | |
| | Power on DC/DC (W)[4] | 14.493 | 8.5361 | | 9.85 | | | | | | | |
| | | | | | | | | | | | | |
| | Total power on 28V (W)[5] | 32.88 | | | | | | | | | | |
| | Current on 28V (A)[6] | 1.1742 | | | | | | | | | | |

1. PSU output current for KAM/PSU/012. Check the KAM/PSU/012/B datasheet for limitations on 5V, ±7V and ±12V power lines
2. Check lower than PSU output current
3. Derived from the efficiency charts (Figure 25-1 and Figure 25-2)
4. For each line, the power is divided by the DC/DC efficiency factor
5. The total power is the sum of the power consumed per DC/DC
6. This current is the total power / 28V

1. Contact Curtiss-Wright support (acra-support@curtiss-wright.com) to request a copy of the above TSR-U-023 spreadsheet.

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Chapter 26

# Ethernet frames, Wireshark® and FAT32

TEC/NOT/051

This paper explains how a network recorder operates. The following topics are discussed:



## 26.1 Overview

An Ethernet network recorder can capture data stored in Ethernet frames and write them to a file using the Wireshark Packet CAPture (PCAP) file format. This paper outlines the process of packing data samples in Ethernet frames for transmission across an Ethernet networked data acquisition system.

The PCAP file format is a flexible and efficient means of recording networked data which can then be processed and viewed on a range of open and closed applications. During a recording session, multiple PCAP files may be created. These PCAP files are then stored in a FAT32 file system.

## 26.2 Encapsulating data in Ethernet frames

Packet encapsulation is the process where sampled data is packetized to be transmitted. The TCP/IP model has four abstraction layers and is an accepted alternative to the seven-layer OSI (Open System Interconnect) reference model. Each abstract layer attaches a descriptive header—this header contains specific information required to correctly route the data and unpack the data when it reaches its intended destination.

In summary, packet encapsulation creates a packet by prepending a header to the data and passing the packet onto the next abstract layer. The following figure illustrates the packetization process and displays several Ethernet frames consecutively transmitted on the wire.

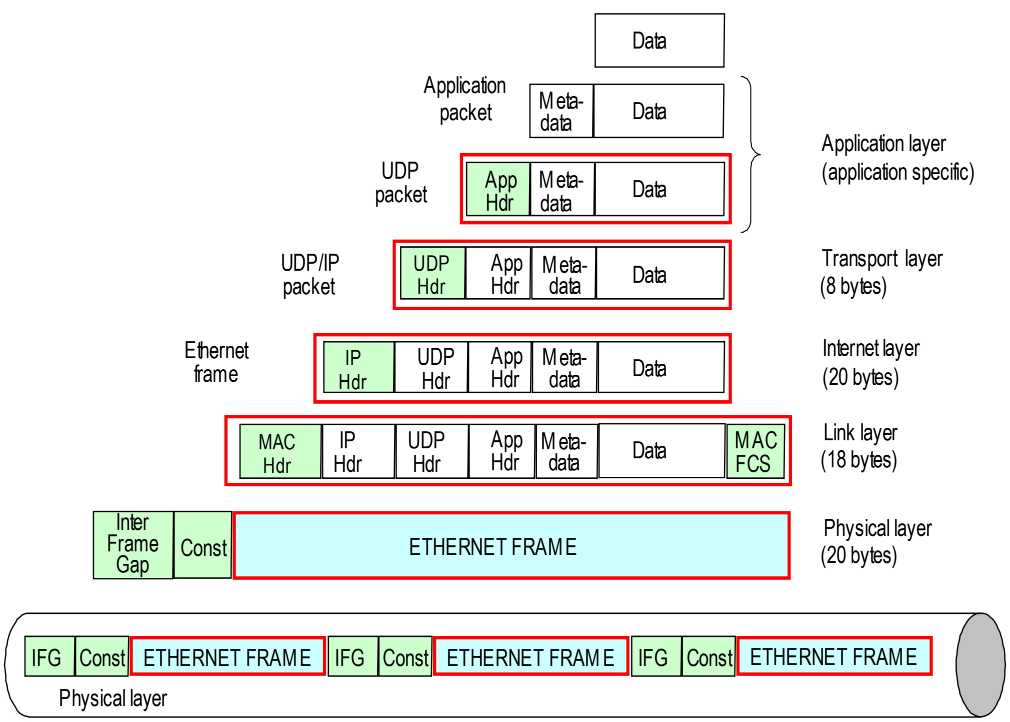


*Figure 26-1: Packet encapsulation*

The Application layer gathers data to be transmitted, and prepends the associated metadata in the application header. Typically, the application header contains information such as sequence numbers and time stamps.

**NOTE:** This paper assumes a generic Application layer similar to IENA iNET-X or RTP as compared in “26.5.2 Existing Application layer protocols” on page 143. For more information on the Application layer used in the SSR-500 recorder, see *TEC/NOT/067 - IENA and iNET-X packet payload formats*.

The application packet is then passed to the Transport layer where the User Datagram Protocol (UDP) header is added. The UDP header contains source and destination port numbering.

To correctly route the data to its destination, the Internet layer prepends the Internet Protocol (IP) header, which provides the necessary logical source IP address and destination IP address.

The Link layer creates the Ethernet frame by prepending the MAC (Medium Access Control) header, which contains the source and destination hardware address, and appends the MAC Frame Check Sequence (FCS).

**NOTE:** Ethernet requires networked devices to have both a logical system-wide unique IP address and a unique hardware MAC address. Both the logical and hardware addresses are required to route data to its destination.

Finally, the Ethernet frame is transmitted over the Physical layer. The Physical layer (see the previous figure) imposes an Inter-Frame Gap (IFG), that is, the duration of 96-bit times of the physical link. For example, the duration of 96-bit times on a 100BaseT (100 Mbps twisted pair link) is 960 ns. Following the IFG, there is a constant preamble and Start Of Frame (SOF) delimiter, signaled before the Ethernet frame is transmitted over the link. On high-speed links, the IFG and SOF are not easily observed using an oscilloscope.

### 26.2.1 Packetization efficiency

As described in “26.2 Encapsulating data in Ethernet frames” on page 135, each layer adds additional header overhead to the data to be transmitted over the network. Since bandwidth is a finite resource, it is important to maximize the packetization efficiency of the data to be transmitted.

Assuming a generic Application layer adds a 16-byte overhead, the total overhead to transmit each packet is 82 bytes, as summarized in the following table.

Table 26-1: Example: packet encapsulation overhead (82 bytes)

| Abstract encapsulation layer | Layer overhead (bytes) |
|---|---|
| Application layer | 16 |
| Transport layer – UDP | 8 |
| Internet layer – IPv4 | 20 |
| Link layer – Ethernet MAC | 18 |
| Physical layer | 20<br>12 bytes of an Inter-Frame-Gap 96-bit times (12 bytes), and lasts 960 ns on 100 Mbps link<br>7 bytes of preamble, for example 10101010…<br>1-byte Start Of Frame (SOF) delimiter |

If every 2-byte sample is to be transmitted in a single packet, the total bandwidth required to transmit a sample is 84 bytes. The packing efficiency of carrying 2 bytes of data can be calculated as follows:

Packing efficiency = data transmitted / (overhead + data transmitted)

2.4% ≈ 2 bytes / (82 bytes + 2 bytes)

This is clearly an inefficient use of bandwidth. However, if 512 samples of the same parameter are transmitted in a single Ethernet frame, the total bandwidth required to transmit these samples is 1106 bytes.

Using the same formula, packing more samples into a single Ethernet frame greatly improves packing efficiency. This is described in the following example:

$$93\% \approx (512 \times 2 \text{ bytes}) / (82 \text{ bytes} + (512 \times 2 \text{ bytes}))$$

The following figure illustrates how packing efficiency increases with the number of 2-byte samples carried within the packet. By packing more samples into a single Ethernet frame, there is greater packing efficiency and therefore better bandwidth management. However, there is an upper limit to the number of samples that can be contained in a single packet; this is described in "26.2.2 Ethernet frame sizes and fragmentation" on page 137.

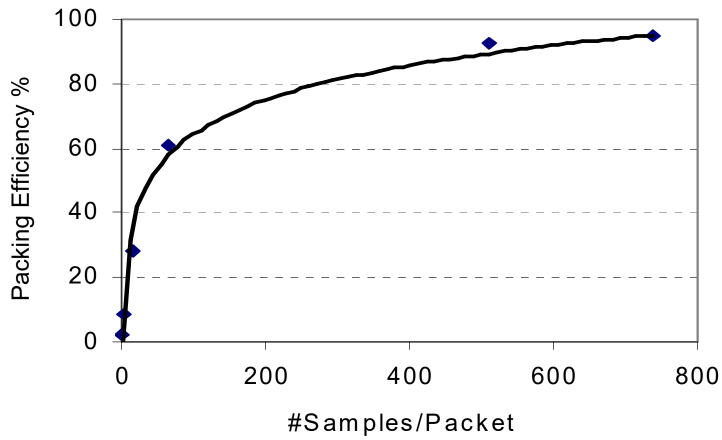


*Figure 26-2: Packing efficiency with number of samples per packet*

### 26.2.2 Ethernet frame sizes and fragmentation

Ethernet frames are subject to certain rules imposed by the IEEE 802.3 Ethernet standard. Valid Ethernet frames must be sized between 64 bytes and 1518 bytes. Ethernet frames that are outside this range may be either discarded or fragmented by the switch, router, or network interface card. (Frames that are less than 64 bytes are known as runts while frames greater than 1518 bytes are known as giants.)

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**NOTE:** Some routers and switches allow Ethernet frames of 1,522 bytes (this includes the 4-byte VLAN 802.1q tagged Ethernet frames).

IP fragmentation occurs when the size of the IP packet exceeds the Maximum Transmission Unit (MTU) on the network link. The MTU is the maximum sized packet that is allowed to be transferred across the network link. IP packets transmitted over Ethernet have an MTU of 1,500 bytes.

Fragmentation should be avoided for the following reasons:

- Fragments may arrive out of order and complicate reassembly of the data.
- Fragments may be lost, rendering all other fragments for the frame useless.
- The process of fragmenting and reassembly of the data takes time.

It is generally accepted that, excluding the Link layer overhead, the IP packet may not exceed 1,500 bytes (inclusive of the IP header overhead). The maximum number of samples (S) that can be packed into a single unfragmented packet can be calculated as follows:

$$S \times \text{SampleSize} = 1{,}500 \text{ bytes} - (\text{IP} + \text{UDP} + \text{generic application overhead})$$

Assuming a 16-byte generic application header overhead is:

$$S \times 2 \text{ bytes} = 1{,}500 - (20 \text{ byte IP} + 8 \text{ byte UDP} + 16 \text{ byte application header})$$

then,

$$S = 728 \text{ samples}$$

### 26.2.3 Packetization delay

As discussed in "26.2.2 Ethernet frame sizes and fragmentation" on page 137, it is clear that the more samples there are contained in a single packet, the greater the efficiency of the bandwidth. However, there is a trade-off in terms of packetization delay (see the following figure).

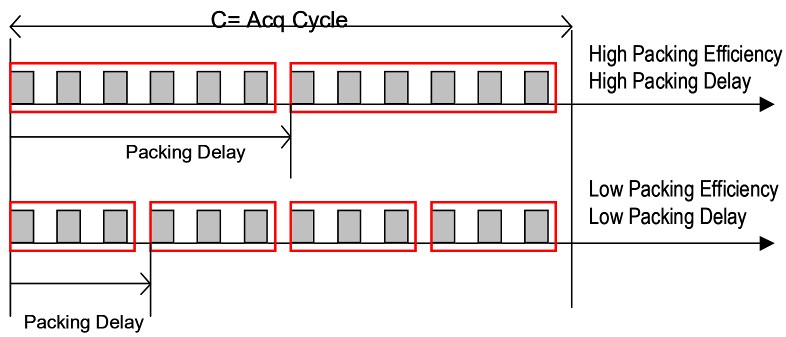


*Figure 26-3: Trade-off of packing efficiency against packing delay*

For example, in order to pack 512 two-byte samples of a single parameter sampled at 1,024sps (samples per second) into one packet (to achieve 93% bandwidth packing efficiency), the first sample in the packet would be 500 ms old before the packet is transmitted. A delay of 500 ms may not be a problem if the data is being stored for analysis, however if the data is being viewed in real-time, a delay of even 250 ms can be significant.

## 26.3 Recording Ethernet frames as Wireshark PCAP files

Known previously as Ethereal, Wireshark is a widely used network protocol analyzer. It is an open source software project, and is released under the GNU General Public License (GPL).

Wireshark non-intrusively reads and captures live packet data on physical networking technologies including Ethernet, IEEE 802.11, PPP/HDLC, ATM, Bluetooth, USB, Token Ring, Frame Relay and Fibre Distributed Data Interface (FDDI).

WinPCAP, the Wireshark packet-capturing engine, is the industry-standard tool for link layer network access and enables the capture of Ethernet frames. Filters can be used to capture only packets that are of interest, for example, packets with a given destination IP address.

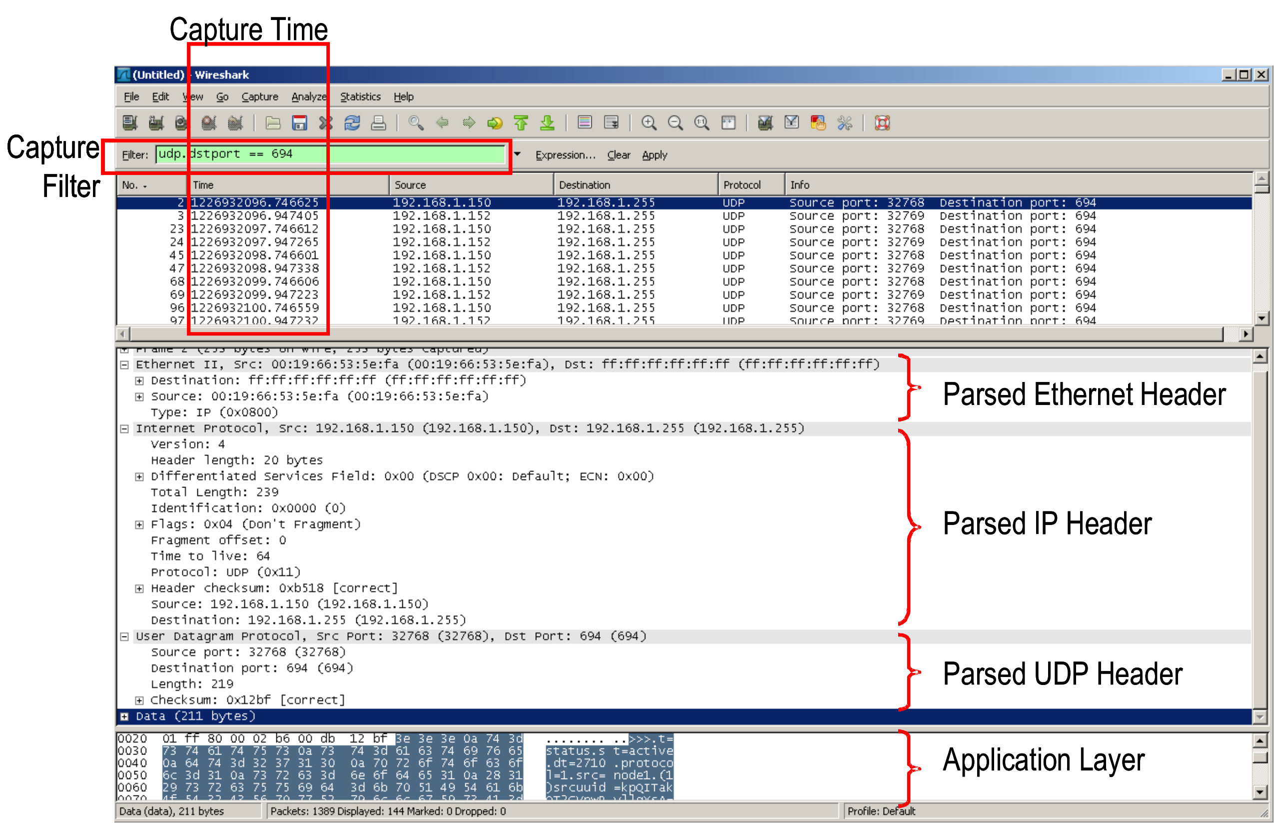


*Figure 26-4: Wireshark packet capturing and filtering*

The previous figure illustrates how a filter has been applied to display only UDP packets whose destination port number is 694. When a packet meeting this criterion is received, its capture is time stamped. Wireshark dissects the Link, Internet, and Transport encapsulation layers. The physical layer IFG, preamble, and SOF delimiter need not be recorded since these are constant for all Ethernet frames that are captured. Moreover, the network interface stack removes the 4-byte Ethernet FCS for valid error-free Ethernet frames.

Wireshark offers a number of options for recording to file by generating a new capture file every N minutes, N megabytes or N packets. In Record mode, Wireshark writes the captured packets using the PCAP file format. PCAP files are designed to support recording on a number of different networking technologies including Ethernet, FDDI and Token Ring. The PCAP file format is stable (last revision 1998) and is not expected to change in the future. It is supported and used on a range of open and closed network recording and analysis tools.

The following figure illustrates the format of PCAP files. Each PCAP file has a 24-byte Global header containing global information describing the recording session, followed by zero or more records for each captured packet. Each captured packet is prepended with a 16-byte packet header.

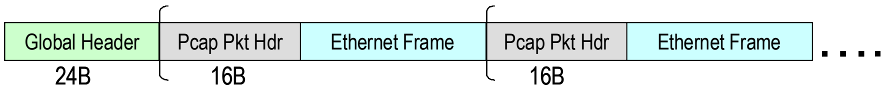


*Figure 26-5: PCAP file format*

The Global header contains basic metadata on the packet capture recording session (see the following table) while the PCAP packet header records the length and capture time of the packet (see Table 26-3 on page 139).

Table 26-2: Global header

| Field name | Length (bytes) | Description |
|---|---|---|
| Magic number | 4 | Used to detect the file format and the byte ordering. The writing application writes 0xa1b2c3d4 (using its native byte ordering format) to this field.<br>The reading application reads either 0xa1b2c3d4 (identical) or 0xd4c3b2a1 (swapped). If the reading application reads the swapped 0xd4c3b2a1 value, it indicates that all the following fields must also be swapped. |
| Version major:minor | 2:2 | The version number of this file format (current version is 2.4). |
| This zone | 4 | The correction time, in seconds, between UTC and the local time zone of the following packet header time stamps. For example, if time stamps are in UTC, this zone is simply 0; if time stamps are in Central European time, such as Amsterdam or Berlin (which is UTC + 1:00), this zone must be -3600. |
| Sig flags | 4 | The accuracy of the capture timestamp. Not supported in most PCAP-compatible tools. |
| Snap length | 4 | To capture the entire Ethernet frame, this is typically set to 65535. |
| Network | 4 | Data link layer type, for example 1 for Ethernet. This can be various types such as Token Ring or FDDI. |

Table 26-3: PCAP packet header

| Field name | Length (bytes) | Description |
|---|---|---|
| Ts Sec | 4 | The date and time when this packet was captured. This value relates to seconds since January 1, 1970 00:00:00 UTC. |
| Ts USec | 4 | The time, in microseconds, when this packet was captured, as an offset to ts_sec. |
| Incl Len | 4 | The number of bytes of packet data actually captured and saved in the file. |
| Orig Len | 4 | The length of the packet, as it appeared on the network when it was captured. |

### 26.3.1 PCAP time stamp

The granularity of a PCAP time stamp is microseconds. This has sufficient accuracy to record packet capture times. The inter-arrival time between consecutively captured packets is at least 6720 ns, calculated as the sum of a minimum sized Ethernet frame of 64 bytes or 512 bits (including the Link, Internet, and Transport layers), fixed IFG of 96-bit times (or 960 ns on a 100 Mbps link), preamble and SOF of 64 bits.

### 26.3.2 PCAP storage efficiency

As seen in "26.3 Recording Ethernet frames as Wireshark PCAP files" on page 138, when storing packets in the Wireshark PCAP file format an additional 16-byte overhead is imposed to record each packet; the total overhead to store a single packet is 74 bytes. This includes the PCAP packet (16 bytes), generic application header (16 bytes), UDP transport header (8 bytes), IP internet header (20 bytes), and 14 bytes MAC link layer header (excluding the MAC FCS). The PCAP file format does not record the physical layer constants such as the preamble, SOF, or the IFG.

If each 2-byte sample is stored in a single packet, the total memory required to record a single sample is 76 bytes. The efficiency of storing 2 bytes of data can be calculated as follows:

Storage efficiency = (data stored) / (storage overhead + data stored)

2.6% ≈ 2 bytes / (74 bytes + 2 bytes)

This is clearly an inefficient use of memory. However, if 512 samples of the same parameter were to be recorded in a single Ethernet frame, the total memory required is 1,098 bytes. By packing more samples into one frame, storage efficiency is vastly improved.

Storage efficiency = (data stored) / (storage overhead + data stored)

93% ≈ (512 × 2 bytes) / (74 bytes + (512 × 2 bytes))

Despite the overhead imposed to support the PCAP file format, the storage efficiency is comparable to the packing efficiency (see the following figure).

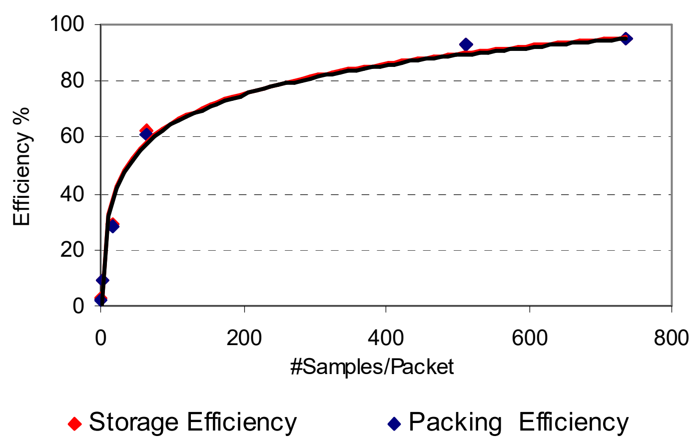


*Figure 26-6: Comparison of storage efficiency and packing efficiency*

## 26.4 Storing PCAP files in a FAT32 file system

The File Allocation Table (FAT) system is particularly suited to solid-state memory cards, and is a convenient way of sharing data between operating systems. The maximum file size supported on FAT32 systems is just under 4 GB with a maximum partition size of 2 TB.

The first sector of the FAT system (see the following figure) is the Reserved Region. This sector contains information about the file system and includes the following:

- Bytes per sector (512 - 4,096)
- Number of sectors per cluster
- Number of root directories
- Number of sectors per FAT

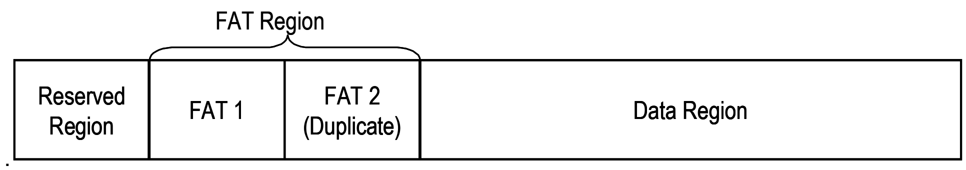


*Figure 26-7: FAT32 partition layout*

After the Reserved Region is the FAT Region, which records the files or directories contained in the Data Region. The FAT region typically contains two copies of the FAT. A duplicate copy (see FAT2 in the previous figure) is for redundancy checking and error recovery in case FAT1 becomes corrupt. The duplicate copy is rarely used.

The FAT records which files or directories occupy which parts of the Data Region. The Data Region is divided into clusters. The FAT contains one entry for each cluster.

Each FAT entry, which represents part of a file, contains the number of the next FAT entry in the file; the end of the file is marked by a FAT entry containing a special END value (see the following figure). In this way, the FAT defines individually linked lists of clusters in the Data Region used by files.

Directories are stored in the same way as files. Unused clusters and bad (physically damaged) clusters are recorded as special FAT entry values.

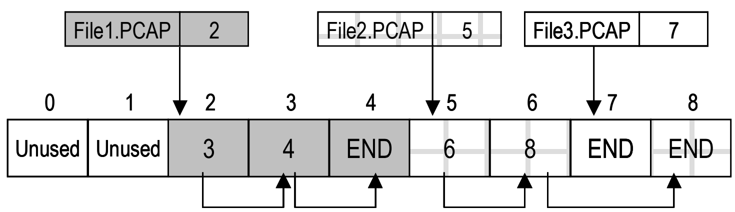


*Figure 26-8: Linked list FAT32 overview*

Each entry in a FAT32 system is 32 bits long (although only 28 bits are actually used). The upper four bits are usually zero but are reserved and should be left untouched.

The FAT contains one entry for each cluster. For historical reasons, clusters are numbered from 2; the first two table entries of the FAT are unused. Files are stored as whole clusters, so the space occupied in the volume is a multiple of the cluster size. This means that, if the clusters are 32 KB in size, up to 32 KB can be wasted at the end of every file. Data should be stored in large files: a 1-KB file takes up 32 KB of disk space, with 3,100% wastage; whereas a 31,969 KB file takes 32,000 KB which is 0.1% wasted space.

## 26.5 Appendix

### 26.5.1 Encapsulation header overhead

Table 26-4: Transport layer - UDP (8 bytes)

| Field Name | Length (bytes) |
|---|---|
| Source port | 2 |
| Destination port | 2 |
| Length | 2 |
| Checksum | 2 |

Table 26-5: Internet layer - IPv4 (20 bytes)

| Field Name | Length (bytes) |
|---|---|
| Version | 4 bits |
| Header length | 4 bits |
| Type Of Service (TOS) | 1 |
| Total length | 2 |
| ID fragment | 2 |
| IP flags | 3 bits |
| Fragment offset | 13 bits |
| Time To Live (TTL) | 1 |
| Protocol | 1 |
| Header checksum | 2 |
| Source IP address | 4 |
| Destination IP address | 4 |
| **Options:** The IP header may additionally carry header extension options, as indicated by the header length. | |

Table 26-6: Link layer - basic Ethernet MAC frame (18 bytes)

| Field Name | Length (bytes) |
|---|---|
| Destination MAC address | 6 |
| Source MAC address | 6 |
| Type/length | 2 |
| Trailer Frame Check Sequence (FCS) | 4 |

Table 26-7: Link layer - Ethernet MAC Frame with 802.1Q tags (22 bytes)

| Field Name | Length (bytes) |
|---|---|
| Destination MAC address | 6 |
| Source MAC address | 6 |
| Tag | 4 |
| Type/length | 2 |
| Trailer Frame Check Sequence (FCS) | 4 |

Table 26-8: Physical layer - 100Mbps Fast Ethernet (20 bytes)

| Field Name | Length (bytes) | Description |
|---|---|---|
| Inter-Frame Gap (IFG) | 12 | There is a mandatory idle gap between successive Ethernet frames. This is typically 96 bits (12 bytes), which amounts to an interval of 960 ns on a 100 Mbps link. |
| Preamble | 7 | |
| SOF | 1 | |

### 26.5.2 Existing Application layer protocols

A number of Application layer protocols have been developed for the specific requirements of telemetry data. These include: IENA (AirBus), Chapter 10 (IRIG 106), TmNS Data Message Protocol (iNET-X), and the iNET-X packet structure. In addition the Real-time Transport Protocol (RTP) that is commonly used for the transmission of real-time data is briefly described.

#### 26.5.2.1 IENA - Airbus

The IENA Application layer protocol partitions logical groupings of data into packet streams. An IENA Key field in the Application header uniquely identifies each packetized group of data. The IENA Key is mapped to a metadata description of the payload contents to facilitate decoding of the received data. IENA defines structures and placement rules that indicate how data can be placed in the packet. These structures may be Positional, Standard or Message type. A packet may contain multiple data structures, however all structures must be of the same type.

#### 26.5.2.2 Chapter 10 – IRIG-106

Chapter 10 is part of the IRIG-106 Telemetry standards. The focus of Chapter 10 is on-board and ground-based recording for which a number of packetized data formats have been defined (for example general and data source specific data formats including, Analog, Discrete, ARINC-429, Video, and Ethernet). The Chapter 10 standard is revised every two years with a release due in 2009. Chapter 10 files consist of a Setup Record followed by data stored in structures known as data specific packets interleaved with time packets. Data packets have three elements: a header; body; and optional trailer. The data packet header has fixed header fields including a Channel ID (analogous to the IENA key) that is used to associate packets from the same source. Following the header, the data is prepended with a Data header.

#### 26.5.2.3 iNET-X and TmNS

The TmNS protocol from iNET-X is in the standards definition phase. It is an ongoing process and subject to future protocol revisions. As of January 2009, only the Application layer header has been fully defined. The approach taken was to identify the elements in the Application layer header that encompass the merits of each of the existing protocols, IENA and Chapter 10. The Application payload consists of Packages that are partitioned subsets of data. It is expected that Packages will have a fixed Package header with the possibility of source specific Package header extensions.

iNET-X packets use the standard iNET-X TmNS Application layer packet structure and are compatible with iNET-X packets. However, iNET-X packets have an additional 4-byte extension field, called the iNET-X Payload Information Field, appended directly following the standard iNET-X header. The iNET-X Payload Information Field contains Curtiss-Wright-specific metadata to facilitate decoding and decommutation of the iNET-X payload.

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**NOTE:** For more information on the iNET-X packet structure and the packetization rules, see *TEC/NOT/067 - IENA and iNET-X packet payload formats*.

#### 26.5.2.4 Real-time Transport Protocol (RTP) - IETF

The RTP protocol is an open-standard protocol that is published by the Internet Engineering Task Force (IETF) defined in the RFC 3550 (Standard 64) document. RTP was originally defined for multimedia applications with real-time transport requirements. Profiles define the rules and packetization structures for different data types in the RTP payload. To date, there is no profile defined that specifically targets telemetry applications.

### 26.5.2.5 Application layer protocol comparison

These protocols are compared in the following table. There is a notable difference in the terminology used between the different protocol implementations. To unify these terms, the descriptive field (far left column) relates a generic term to a specific protocol term.

Table 26-9: Comparison of existing application layer protocols

| **Descriptive Field** | | **IENA**<br>**Airbus** | **Chapter 10**<br>**IRIG 106** | **iNET-X**<br>**iNET-X with Curtiss-Wright header extension** | **RTP**<br>IETF RFC 3550 Standard 64 | **Common** |
|---|---|---|---|---|---|---|
| Packet Header | Version | X | √ | √ | √ | NO |
| | Timestamp | √ - 48bits | √ - 48bits | √ - 64bits | √ - 32bits | YES |
| | Sequence Number | √ | √ | √ | √ | YES |
| | Stream Identifier | √ - IENA Key | √ - Channel ID | √ - Stream Identifier | √ - Synchronization Source Identifier | YES |
| | Status/Flags | √ - Key status, Application status | √ - Packet Flags | √ | √ - Padding, Marker, Extension | YES |
| | Length/Size | √ | √ - Packet Length/Data length | √ | X | YES |
| | Data Block Type | X – inferred from Key | √ - Data Type | √ - Payload Type | √ - Payload Type Identifier | NO |
| | Optional Header Extension | X | √ - Secondary header (Time, Reserved, Header Checksum) | √ | √ | NO |
| | Other Fields | None | None | None | Optional multiplexing facilities | N/A |
| Payload Data (Blocks) | Payload Types | √ - General | √ - Data type specific | √ - General and Data Type specific | √ - General and Payload specific | YES |
| | Packet Body Format | √ - Positional or Standard/Message | √ - Channel specific data + Intra-packet | √ - Blocks | √ - General and Payload specific | YES |
| | Multiple Data Blocks | √ | √ | √ | TBD for Telemetry | YES |
| | Block Header | √ - Standard (Param ID); Message (Param ID Length)<br>For Standard (D) and Message (Q) type Param ID followed by Time | √ - Intra-packet time, header. Data | √ - Dependent on Payload Type - Bit-aligned, Video, Placed, Parser-aligned, Error/Event | TBD for Telemetry | NO |
| | Fixed Length Blocks | X – Message types not fixed length | √ - Unclear, assumed to be fixed from Data Length in Packet Header | X | TBD for Telemetry | NO |
| | Block Padding | X | Optional - Filler bits in Intra-packet | √ | TBD for Telemetry | NO |

Table 26-9: Comparison of existing application layer protocols (continued)

| **Descriptive Field** | | **IENA**<br>**Airbus** | **Chapter 10**<br>**IRIG 106** | **iNET-X**<br>**iNET-X with Curtiss-Wright header extension** | **RTP**<br>IETF RFC 3550 Standard 64 | **Common** |
|---|---|---|---|---|---|---|
| Packet Trailer | Padding | Optional | Optional - Filler | X | Optional | NO |
| | Trailer | √ - End Field 0xDEAD | √ - Header Checksum | X | X | NO |
| Packing Rules | Payload Filling Method | √ - Fill to max size or max delay | X – Not specified | √ - Fill to max size or max delay | TBD for Telemetry | NO |

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# Using the KAD/ARI/001

TEC/NOT/052

The KAD/ARI/001 is an ARINC-429 bus monitor combining the capabilities of an all-pass/selected-pass monitor, a coherent message parser and an error-detection function on a single module. This paper explains how to set up the KAD/ARI/001 for monitoring ARINC-429 traffic and is divided into the following sections:


- “27.1 Introducing ARINC-429” on page 147
- “27.2 Features of the KAD/ARI/001 in relation to ARINC-429 bus monitoring” on page 149
- “27.3 Using kSetup to configure the KAD/ARI/001” on page 150
- “27.4 Troubleshooting” on page 156
- “27.5 References” on page 156


## 27.1 Introducing ARINC-429

ARINC-429 is the standard for the predominant avionics data bus used on most high-end commercial and transport aircraft.

Connected to the busses is a transmitter (source), a receiver (sink), or a transmitter and receiver (see the following figure). All data is transmitted over a single, twisted pair in one direction only.

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**NOTE:** The first revision of the ARINC-429 mark 33 Digital Information Transfer System (DITS) was generated on 11 April 1978. The current specification is ARINC-429-10.

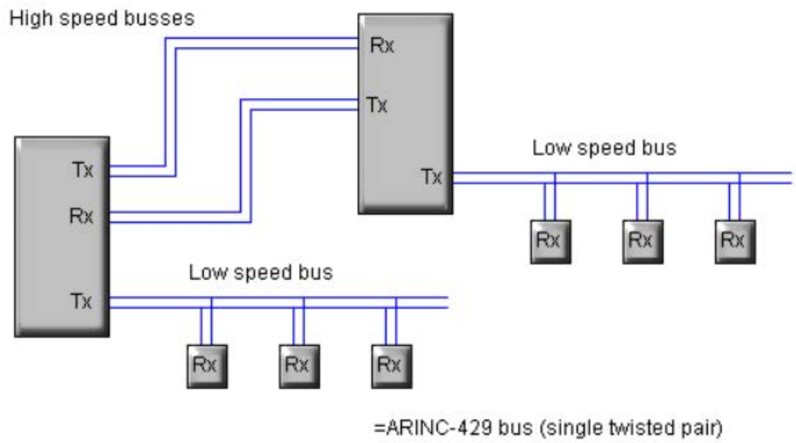


*Figure 27-1: An example of ARINC-429 architecture*

A transmitter (Tx) may transmit to up to 20 Receivers (Rx). If an Rx is required to acknowledge reception of data, another ARINC-429 Tx is required in the opposite direction.

Data is sent in single words identified by one of 255 Labels and a two-bit source/destination identifier.

### 27.1.1 Physical layer

Data is transmitted in a bipolar Return-to-Zero (RZ) format. This is a trilevel code (see the following figure).

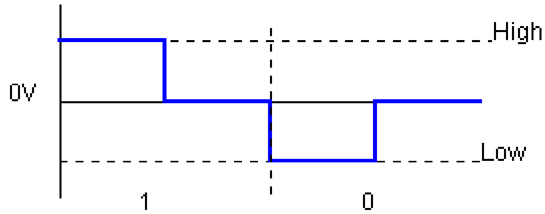


*Figure 27-2: ARINC-429's bipolar, RZ code*

For a Tx, the high (low) voltage must be +10V ±10% (-10V ±10%). A receiver must be specified to a minimum level of ±5V. The Tx output impedance is 75Ω (±5Ω) and a suitable 75Ω cable should be used.

Typically, there are two bit-rates: the high speed bus is 100 kbps and the low speed bus is between 12 and 14.5 kbps. Only one data rate is allowed per bus.

ARINC-429 also specifies the data rate tolerances and rise and fall times.

### 27.1.2 Word definition

The following figure illustrates the generic format of an ARINC-429 word.

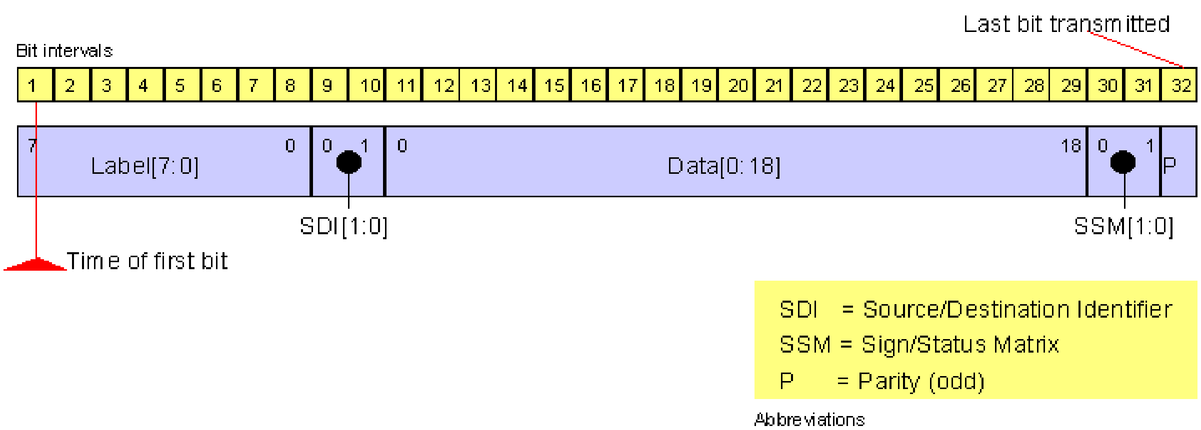


*Figure 27-3: Generic word definition for ARINC-429*

As shown in the previous figure, the eight-bit Label identifies the parameter being transmitted.

The main purpose of the Source/Destination Identifier (SDI) bits are to direct data words to a particular Rx. The SDI bits are not used with certain types of data.

The Sign/Status Matrix (SSM) bits are used to indicate plus or minus, north, south, east or west and so on for certain types of data, the word type for AIM (Acknowledge, ISO alphabet No. 5 and Maintenance) data and the status of the Tx. For binary data, bit 29 (Data18) is used to indicate sign.

There are five types of data words:

- Binary
- BCD subset of ISO Alphabet No. 5
- Discrete
- Maintenance
- AIM

Also, file transfer is supported.

## 27.2 Features of the KAD/ARI/001 in relation to ARINC-429 bus monitoring

### 27.2.1 Physical layer

The KAD/ARI/001 monitors up to eight ARINC-429 busses. The following figure displays the Rx circuit internal to the KAD/ARI/001.

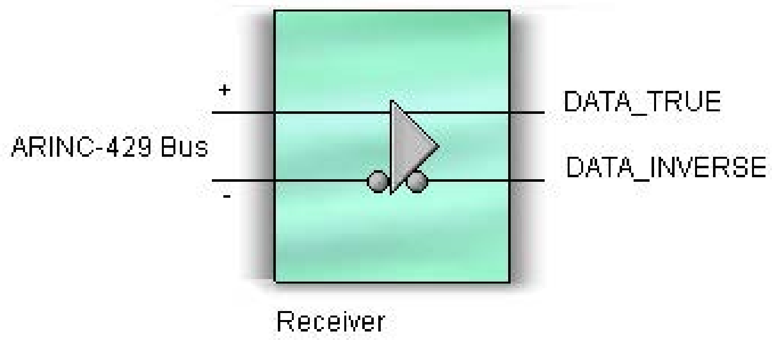


*Figure 27-4: One of eight receivers on the KAD/ARI/001*

For exact threshold levels for high and low signals, see the *KAD/ARI/001* data sheet. The Rx components are third-party products certified for ARINC-429 operation. Any combination of busses can be programmed to monitor high (100 ksps) or low speed (13.25 ±10%) operation.

As per the ARINC-429 specification, the shields for each bus must be connected to the GND pin of the KAD/ARI/001.

### 27.2.2 Bit detection circuitry

Each of the eight busses has a separate independent bit detection circuit. The true/complement output of the Rx is sampled at 20 times the selected bit-rate. The output of the bit detection circuitry is 1,0, Hi-Z or bad.

The bit detector outputs a bad indication if one of the three masks is not met after a 1 or a 0 has been received. In other words, every bit period, a 1, a 0, a Hi-Z or a bad is clocked into the serial-to-parallel register of the word detection circuitry.

### 27.2.3 Word detection circuitry

Each bus has a separate word detection circuit. A word is considered found when two Hi-Z bits follow at least eight good 1s or 0s.

This circuit checks that there is precisely the correct number of good bits and that the parity is correct. The Label[7:0], SDI[1:0] and SSM[1:0], along with three bits indicating the bus, are used to address a trigger list. The trigger list assigns one of 1,024 identifiers (IDs) to each word along with flags for invalid Label, SSM and SDI. For details of the time tag words, refer to the *KAD/ARI/001* data sheet.

As the data transfer is word based (not messages or frames), there is no protocol tracking on the KAD/ARI/001. A received word either has errors or it does not.

### 27.2.4 Error reporting, word counting and time tagging

The errors detected by the bit detection and word detection circuitry are combined in a four-bit code. This code can be part of the report parameter from the KAD/ARI/001, along with three bits indicating the bus on which the fault was recorded (for details of bit definition, see the *KAD/ARI/001* data sheet).

All errors are also reported/logged along with the time that it occurred and the traffic following.

When a valid word is received, a word counter increments for each bus. This is a 16-bit binary counter that resets at FFFF hex. This parameter can be read for each of the eight busses from the KAD/ARI/001. For details of the time tag words, refer to the *KAD/ARI/001* data sheet.

### 27.2.5 Parsing

The following figue illustrates the triple buffering of words and tags used for each bus in the KAD/ARI/001 parser.

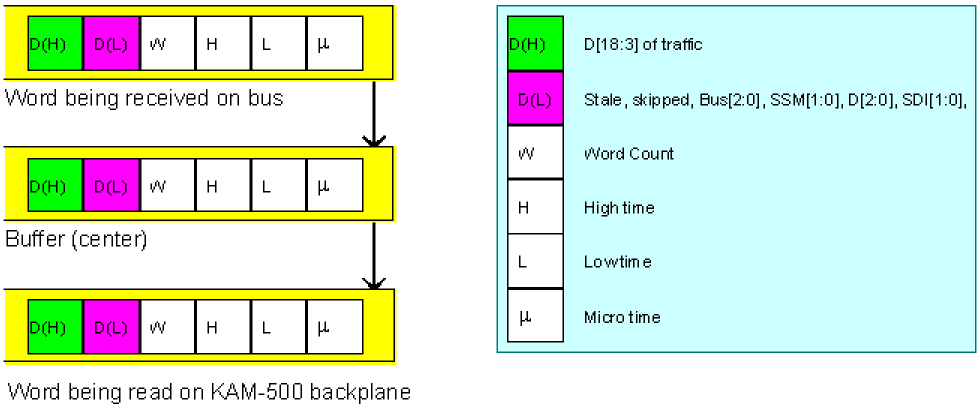


*Figure 27-5: Triple buffering of traffic and associated tags*

Time tags and a word count are added to each word received and stored in separate buffers for each of the eight busses. As soon as a word is received with no errors, the complete buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped flag is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the contents of the center buffer (if new) are transferred to the read buffer. If no new word has been received, the stale flag is set. A center and read buffer exist for every ID (1,024).

### 27.2.6 General features of the KAD/ARI/001

- Eight valid word counters, one for each bus.
- A 48-bit BCD timer that counts to hours of the day with 1 µs resolution. This timer is used to tag data to 1 µs resolution and is typically seeded from an IRIG-B module—for example KAM/TCG/102—in the same chassis.
- Valid words are defined and assigned IDs using all the bits of the Label, SDI and SSM. Multiple words can be mapped to any ID.
- Parsing of traffic from up to 1,024 IDs. Added to each parsed message is the word count and time when the word arrived. The parser provides stale and skipped indication for each word.
- Parsing even during 100% utilization of all busses, at high speed.

## 27.3 Using kSetup to configure the KAD/ARI/001

The KAD/ARI/001 has eight busses and can coherently parse traffic and tags for up to 4,095 words per bus. You must use kSetup software to configure the KAD/ARI/001 according to your requirements. kSetup is included in the KSM-500 suite of tools.

### 27.3.1 Default parameters

To view parameters for the KAD/CBM/102, select the module in the Task Explorer pane of kSetup.The Parameters tab (see the following figure) displays a list of fixed module parameters. For more information on using kSetup, contact Curtiss-Wright support (acra-support@curtiss-wright.com).

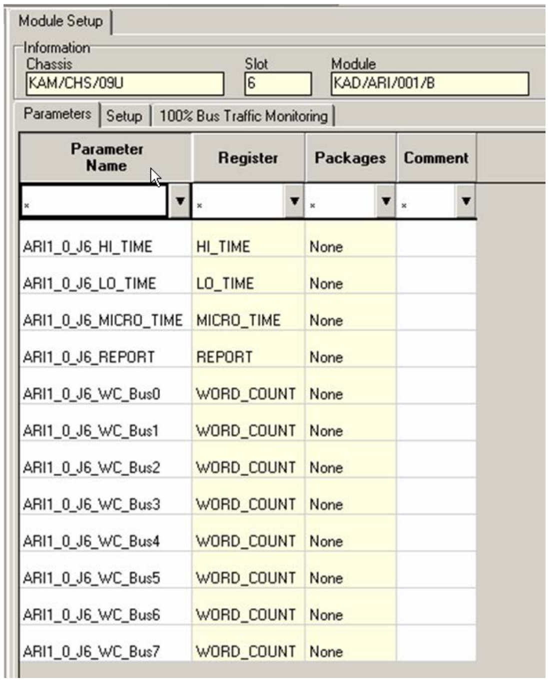


*Figure 27-6: Parameter settings*

To edit parameters for the KAD/ARI/001, select the module in the Task Explorer pane of kSetup. On the Parameters tab, complete the fields described in the following table.

Table 27-1: Parameter settings

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter. |
| Register | Output register that stores values relating to the word count, parser or snarfer; for more information on register definitions, see the *KAD/ARI/001* data sheet. |
| Packages | The package of data in the PCM after the parameter is placed; by clicking on package after placing the parameter in the PCM, the transmission details of that parameter is displayed. |
| Comment | User-defined text relating to the parameter. |

### 27.3.2 Configuring busses

On the Setup tab (see the following figure), you can define settings for Time Server and Parity as well as defining settings for any of the eight busses.

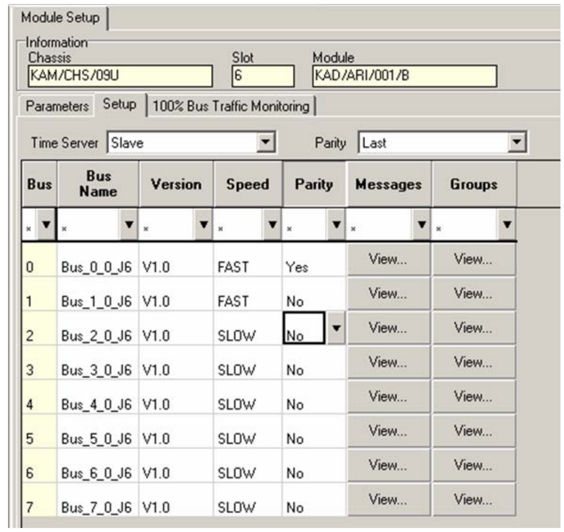


*Figure 27-7: Bus settings*

#### 27.3.2.1 Defining Time Server settings

In the Time Server field (see the following figure), the following settings are available:

- Slave - configures the KAD/ARI/001 to be seeded with system time; all time tags reported by the KAD/ARI/001 are based on the system time.
- Excluded - configures the KAD/ARI/001 so that it is not time seeded; time increments from 0 the instant the system is powered up.

#### 27.3.2.2 Defining bus settings

To define bus settings, complete the fields described in the following table.

Table 27-2: Bus settings

| Field name | Description |
|---|---|
| Bus | Number of the bus; read-only. |
| Bus Name | Name of the bus; package corresponding in the XidDML file is changed accordingly. |
| Version | Version of the bus. |
| Speed | FAST refers to 100 KBit/s. SLOW refers to 12.5 KBit/s. |
| Parity | Parity check; if YES is selected, the module checks the parity bit coming from the ARINC-429 message. |
| Messages | Click View to load the message definition; for more information, see “27.3.3 Defining messages” on page 154. |
| Groups | Not used. |

#### 27.3.2.3 Defining parity status

The parity status (see Parity field in the following figure) affects the bit setting on the module register. Figure 27-9 on page 153 and Figure 27-10 on page 153 illustrate the formats of Parity First and Parity Last.

For information on bit settings, see the *KAD/ARI/001* data sheet.

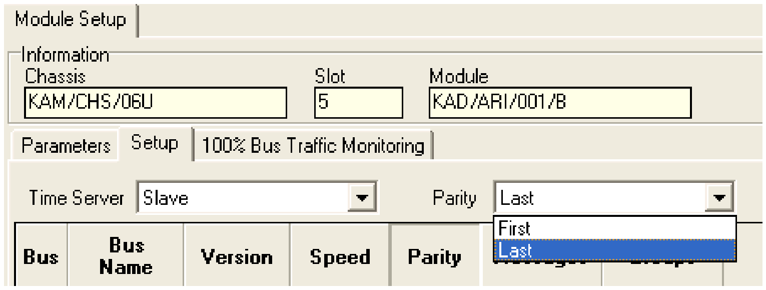


*Figure 27-8: Parity settings*

**NOTE:** Parity first is typically used when you want to transmit the ARINC parameter to a 12-bit fixed PCM.

| | Parity | SSM | | Data | | | | | | | | | | | | | | | | | | | SDI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ARINC Bit | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Bit | 0 | 1 | 0 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 1 | 0 |
| Data (bin) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Data (hex) | 1 | 3 | | 4 | | | 3 | | | | C | | | | 3 | | | | C | | | | 0 | |

| | Parity | SSM | | Data Bits 18 to 10 | | | | | | | | | Bus | | | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data Bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data (bin) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Data (hex) | F | | | | 0 | | | | F | | | | 0 | | | |

Data_Hi (Parity First)

| | Data Bits 9-0 | | | | | | | | | | SDI | | MT | S | Sk | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data Bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data (bin) | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | X | 0 | 0 |
| Data (hex) | F | | | | 0 | | | | F | | | | 0/4 | | | |

Data Low (Parity First)

*Figure 27-9: Parity First (bit level)*

| | Parity | SSM | | Data | | | | | | | | | | | | | | | | | | | SDI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ARINC Bit | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Bit | 0 | 1 | 0 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 1 | 0 |
| Data (bin) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Data (hex) | 1 | 3 | | 4 | | | 3 | | | | C | | | | 3 | | | | C | | | | 0 | |

| | SSM | | Data Bits 18 to 5 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data Bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data (bin) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| Data (hex) | E | | | | 1 | | | | E | | | | 1 | | | |

Data_Hi (Parity Last)

| | Data Bits 4 to 0 | | | | | SDI | | MT, S, Sk | | | Bus | | | R | | Parity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data Bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data (bin) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | X | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Data (hex) | E | | | | 0 | | | | 8/0 | | | | 1 | | | |

Data Low (Parity Last)

*Figure 27-10: Parity Last (bit level)*

# 27.3.3 Defining messages

You can specify the data characteristics of messages (see the following figure) to be monitored by each bus of the module. To view or edit the data characteristics of a message, click View to the right of a bus on the Setup tab.

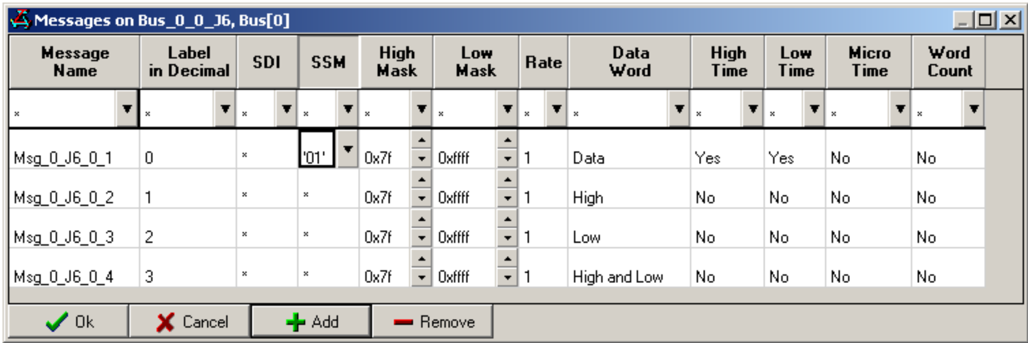


*Figure 27-11: Message settings*

The settings for messages are described in the following table.

Table 27-3: Message settings

| Field name | Description |
|---|---|
| Message Name | When adding a message, the monitoring parameters are automatically created; the parameters are named <bus>:<message>$<type>; type depends on the DataWord choice. |
| Label in Decimal | Message matching this label is to be captured; to view the label in a different format such as hexadecimal or octal, right-click the label value. |
| SDI | Message matching this value is to be captured; wild cards allowed. |
| SSM | Message matching this value is to be captured; wild cards allowed. |
| High Mask | 23-bit payload as a 23-bit word: SSM[1:0]Data[18:0]SDI[1:0]; Figure 27-12 on page 155 shows the result of selecting Mask values to adjust the payload. |
| Low Mask | Payload setting; see High Mask. |
| Rate | Not used. |
| Data Word | Selecting a data word changes the ARINC monitoring registers:<br>High - just the DATA_HI word is captured; creates a parameter called <Bus>:<Message>$dh.<br>Low - just the DATA_LO word is captured; creates a parameter called <Bus>:<Message>$dl.<br>High & Low - both DATA_LO and DATA_HI are captured as two 16-bit words; as Ethernet modules only support parameter transmission up to 16 bits, this mode should be used if DATA_HI or DATA_LO is not sufficient.<br>All - DATA_LO and DATA_HI are captured as a single 32-bit word; creates a parameter called <Bus>:<Message>. |
| High Time | If set to YES, the appropriate time tag word to the corresponding message is captured as a parameter called <bus>:<message>$th. |
| Low Time | If set to YES, the appropriate time tag word to the corresponding message is captured as a parameter called <bus>:<message>$tl. |
| Micro Time | If set to YES, the appropriate time tag word to the corresponding message is captured as a parameter called <bus>:<message>$tu. |
| Word Count | If set to YES, the Word Count word is captured as a parameter called <bus>:<message>$wc. |

**NOTE:** The default setting for an SDI or an SSM field is a wild card, that is, *. If the * wild card is set for SDI, data words are directed to the Rx with all the following IDs 00, 01, 10 and 11. For SSM, the sign and status for all data corresponding to 00, 01, 10, 11 is active.

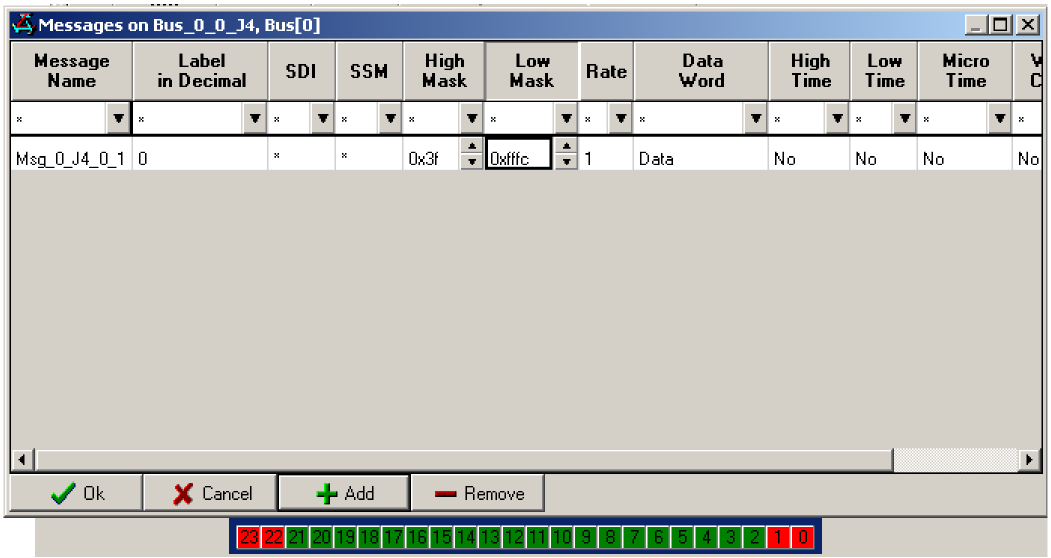


*Figure 27-12: Using High Mask and Low Mask to set payload*

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**NOTE:** The payload adjustment shown in the previous figure can only be used under PCM.

### 27.3.4 Defining bus traffic settings

To define bus traffic monitoring settings on the 100% Bus Traffic Monitoring tab, complete the fields described in the following table.

Table 27-4: Bus settings

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter; if #Word is greater than 1, the parameter name is appended with a number. |
| Active | If set to YES, snarfer data is made available. |
| #Words | You can read the snarfer multiple times in an acquisition cycle; by increasing the number of instances of the snarfer word, you can place data irregularly in the PCM frame, which allows you to save some PCM bandwidth. |
| Mode | If set to snarfer (see the following figure), 32-bit word mode; if set to snarfer16, 2x16-bit consecutive word mode. |
| Comment | User-defined comment relating to the parameter. |

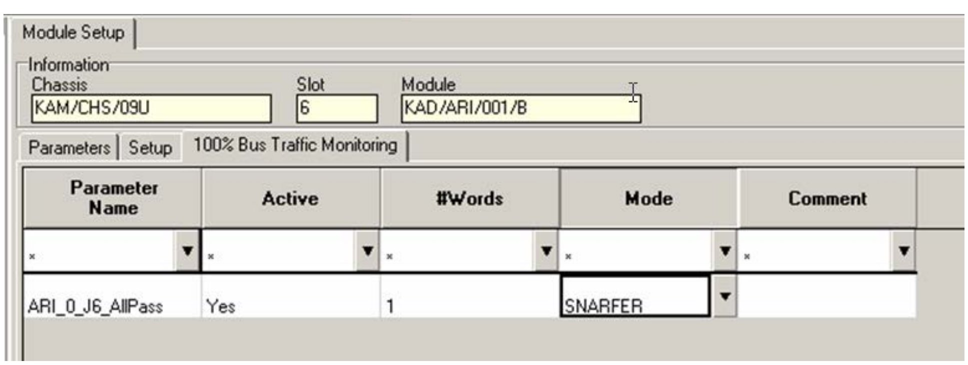


*Figure 27-13: 100% Bus Traffic Monitoring Settings tab for the KAD/ARI/001*

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**NOTE:** For further information on the snarfer, contact Curtiss-Wright support (acra-support@curtiss-wright.com).

## 27.4 Troubleshooting

The common issues are

- The bus +/- is physically inverted.
- The wrong bus is being parsed.
- The bus speed is wrongly set.
- The message is defined in KSM-500 in decimal but it’s defined by the avionics in octal.

## 27.5 References

An Overview of ARINC-429

AIM USA Inc.

4547 Gateway Circle

Dayton

Ohio 45440

Standards

ARINC-429-10

Chapter 28

# Using the KAD/BCU/105

TEC/NOT/053

This paper introduces the KAD/BCU/105 module, how to set it up using KSM-500 software, how to configure the module IP address, 1588 synchronization and its application.

This paper discusses the following topics:



## 28.1 Overview

The KAD/BCU/105 is a full-duplex 100BaseTX Ethernet Acra KAM-500 backplane controller, programmer and packet generator.

### 28.1.1 Controller

- Must be placed in slot J2
- Can be placed in any Acra KAM-500 chassis
- Can program and control any Acra KAM-500 module

### 28.1.2 Programmer

- Programs the chassis via Ethernet
- Can be PING / ARP, IP is user-assigned
- IP v4 protocol is supported
- Factory-programmed with a unique MAC address

### 28.1.3 Packet generator

- Generates packets which are compliant with the published IENA standard (UDP compliant)
- Can transmit packets at different rates; can transmit packets of different sizes to different destinations such as multicast, unicast and or broadcast
- Minimal latency; when all parameters values in an IENA packet are present in the Current Value Table (CVT), the IENA packet is transmitted

## 28.2 Using KSM-500 to configure the KAD/BCU/105

To configure the KAD/BCU/105, kSetup and kProgram software are required.

### 28.2.1 Setting parameters

Both default parameters and fixed data parameters can be set. To view and or set parameters for the KAD/BCU/105, select the module in the Task Explorer pane of kSetup.

#### 28.2.1.1 Default parameters

The following figure shows the default parameters listed on the Parameters tab. The Mode, Value, Bit Size and Packages values for all default parameters are factory-set and cannot be edited. You can however edit names in the Parameter Name column. Double-click a Parameter Name field to insert the desired name. For details of register definitions described as Mode in kSetup, see the *KAD/BCU/105* data sheet.

#### 28.2.1.2 Fixed data parameters

To add fixed data or to remove a fixed data, right-click and select the desired option. To edit values for the new parameter, double-click on the relevant field in the Value column and insert a 16-bit hexadecimal value.

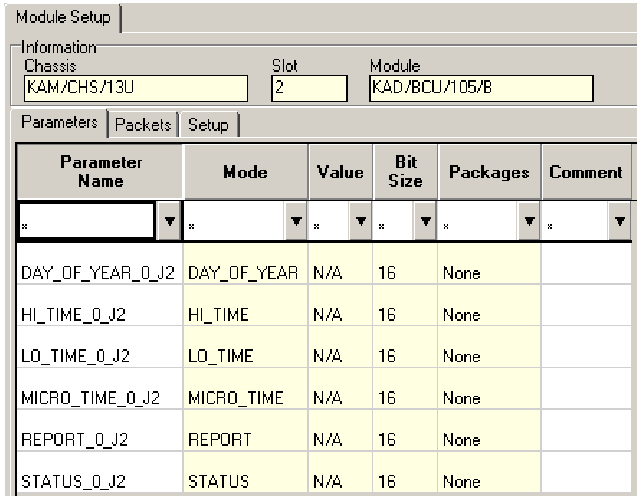


*Figure 28-1: Default parameters*

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**NOTE:** The time registers cannot be transmitted into the IENA packets. However, this is not required as IENA has a 48-bit time stamp.
Curtiss-Wright recommends placing the REPORT parameter into an IENA packet (for information, see "28.2.2.3 Placing parameters in packets" on page 160). The REPORT parameter has important information such as the synchronization status. The REPORT parameter cannot be read over the Acra KAM-500 system, that is, it is not available for any other sink such as a KAM/MEM/103.

## 28.2.2 Adding IENA packets

You can add or remove IENA STANDARD packets on the Packets Tab (see Figure 28-2 on page 159). You can also edit Packet Names, Packets per Acquisition Cycle, Destination IP Address, Destination Port and Mac Address fields for any packet. For details of the IENA packet description, see "Appendix 2: IENA specification" on page 10.

To add a packet, right-click on the spreadsheet, select **Add Packet** then select **IENA STANDARD** and complete the fields described in the following table.

Table 28-1: Adding/removing packets

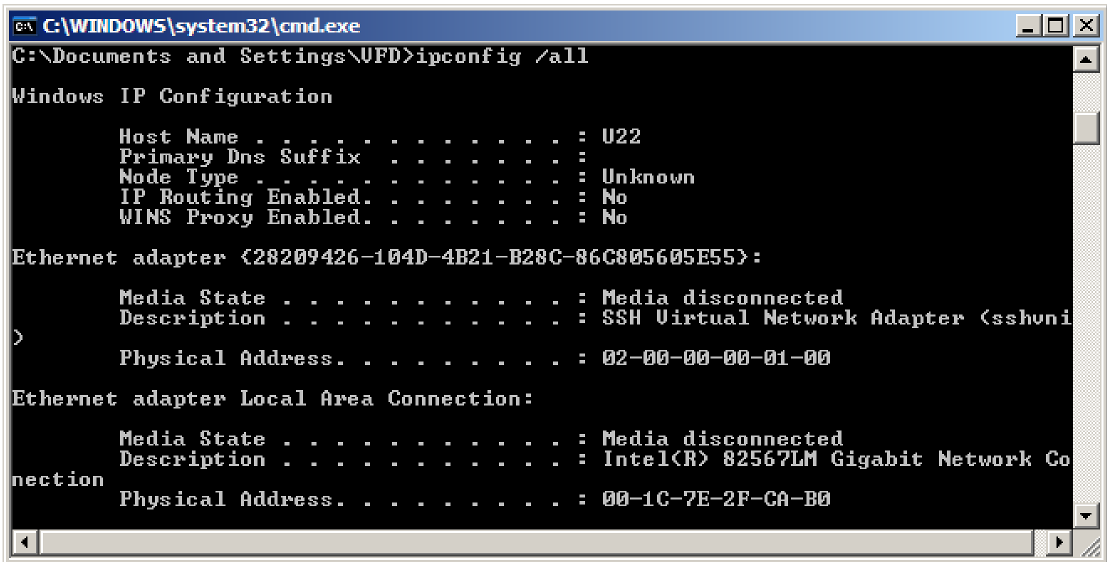
| Field name | Description |
|---|---|
| Packet Name | Name which identifies packet being transmitted |
| Packet Type | IENA STANDARD is the only packet type supported; double-click IENA STANDARD to open the packet setup definition |
| Packets per Acquisition Cycle | The number of packets per acquisition cycle; this number drives the sampling rate for the parameters transmitted into this packet |
| Destination IP Address | The destination IP address can be unicast, broadcast or multicast |
| Destination Port | The destination port can be any value between 0 to 65535 except what is specified in RFC 1700 (see "Appendix 1: Well known ports" on page 166); ensure your decommutation PC firewall allows UDP packets to be received on this port |
| MAC Address | The destination MAC address; when a multicast IP address is used, this field is automatically generated by the software and is read-only |

---

**NOTE:** When using a multicast destination IP address on a network distributed system, the KAD/BCU/105 reports an event on the REPORT parameter on bit 7: Unexpected Ethernet frame received. This bit is set because the KAD/BCU/105 receives multicast packets coming from other sources.

Always create a packet with an instance of one for Packets per Acquisition Cycle. XidML doesn't include the concept of acquisition cycle. For example, if you only create a packet with 512 for packets per acquisition cycle, after closing kSetup, the number of acquisition cycle is multiplied to 512 and the packets per acquisition cycle changes to one.

To determine the MAC address used by your laptop, type **IPConfig/all** in a Windows command prompt. IPConfig returns the MAC address as Physical Address. In the example below, the Physical Address is 00-1C-7E-2F-CA-B0.




## 28.2.2.1 Configuring IENA packets

To configure an IENA packet, double-click an IENA STANDARD cell in the Packet Type column on the Packets tab (see the following figure).

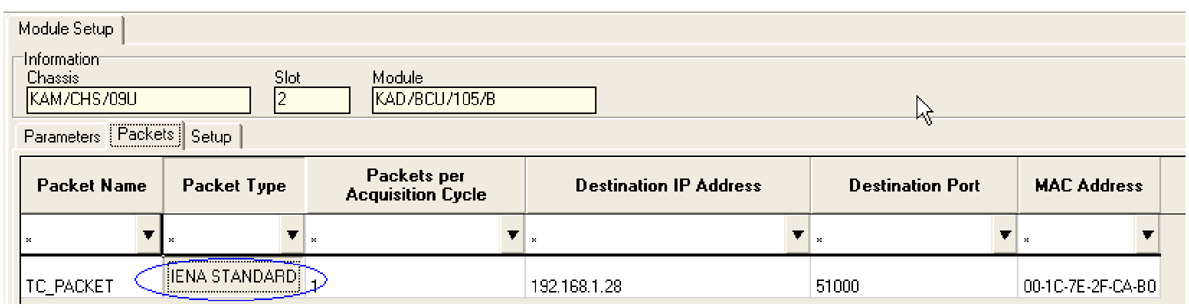



*Figure 28-2: Configuring IENA packets*

## 28.2.2.2 Editing IENA keys

To edit the IENA Key or IENA End key, double-click the Key cell or the End cell (see the following figure).


*Figure 28-3: Editing IENA keys*

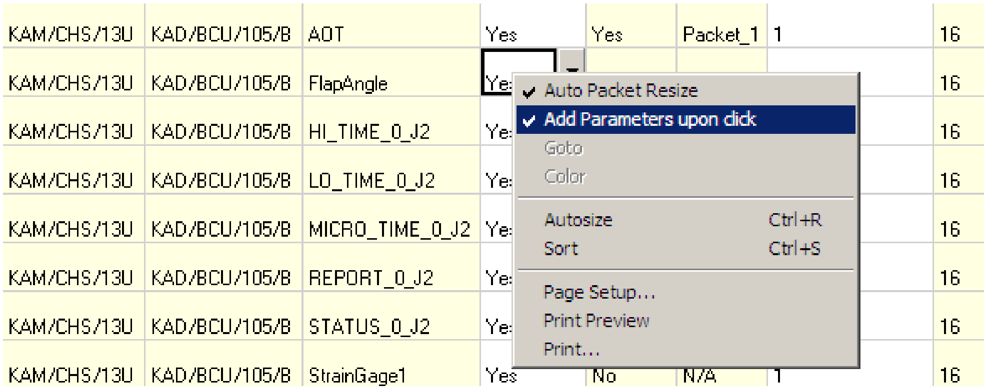
**NOTE:** To modify the IENA Key or the IENA End, ensure Add Parameters upon click is not selected (for Add Parameters option, see the following figure).
The IENA key must be unique for each IENA packet type generated.
The IENA End has the same value for all the packets coming from the module.

### 28.2.2.3 Placing parameters in packets

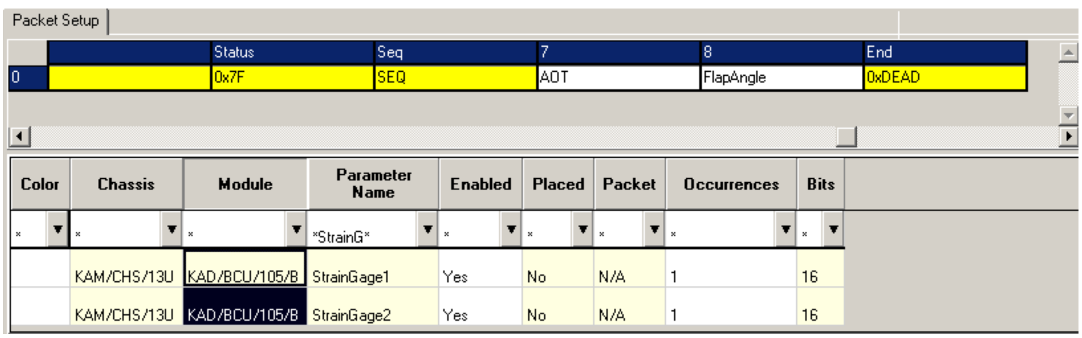
You can manually place parameters in a packet if you want to specify the position of that parameter in the packet. For subsequent placements, each additional parameter is placed to the right of its predecessor.

To manually place a parameter, do the following:

1. On the Packet Setup tab, right-click and ensure **Auto Packet resize** and **Add Parameters upon click** are checked.




2. For the packet concerned, click on the spreadsheet to select a parameter.
3. Click on the byte to the right of the location you wish to place the parameter.
   For example, to place StrainGauge1 and StrainGage2 to the right of the FlapAngle parameter: Select StrainGauge1 and StrainGage2 then click on 0xDEAD.




4. Complete the fields described in the following table.

Table 28-2: IENA packet settings

| Field name | Description |
|---|---|
| Color | Not available |
| Chassis | Chassis label from where the parameter comes from; read-only field |
| Module | Module label from where the parameter comes from; read-only field |
| Parameter Name | Name of the parameter; read-only field |
| Enabled | Set to No prevents you from placing the parameter in the packet |
| Placed | Set to Yes when the parameter is placed into a packet |
| Packet | Packet label where the parameter is placed |
| Occurrences | Number of occurrences of the parameter in the packet; this number drives the parameter sampling rate; the same number of occurrences is recommended for all the parameters within the same packet |
| Bits | Number of source bits for the parameter |

### 28.2.3 Setting up the KAD/BCU/105

After IENA packets have been configured, you can set up the KAD/BCU/105 to transmit the newly configured packets. When setting up the module, you must specify the Module IP address, Module Port and Time to live per packet. This information is required before it is possible to assign the IP address of the module.

On the Setup tab, complete the fields described in the following table.

Table 28-3: Module setup

| Field name | Description |
|---|---|
| Module IP address | When set, the module can be pinged; for details of pinging the module, see “28.3.1 Testing the connection between PC and the KAD/BCU/105” on page 162 |
| Module Port | Any value between 0 to 65535, except what is specified in RFC 1700 (see “28.6.1 Appendix 1: Well known ports” on page 166); ensure your programming PC firewall allows this port |
| Time to live (s) | An advanced configuration field which determines how long a packet from the module ‘lives’ in the network, in the event that it does not reach its destination |

---

**NOTE:** The Module IP Address field does not assign the IP address for the KAD/BCU/105; this field is used only to program the chassis. For information on assigning the IP address, see “Assigning the IP address” on page 6.

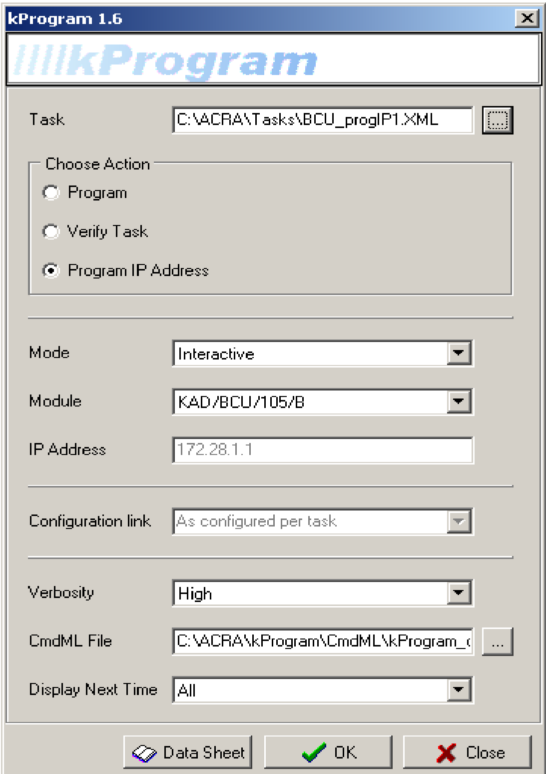
## 28.3 Assigning the IP address

If the KAD/BCU/105 top block pin 7 is connected to BVDD, the KAD/BCU/105 assumes a default hard-wired IP address—239.0.0.0 is used, as it is an administratively scoped IP multicast address.

To assign the IP address for KAD/BCU/105, do the following:

1. Launch kProgram.
2. In the **Task** field, browse for the task file required.
3. Select the **Program IP address** radio button.

4. In the **CmdML File** field, select the xidML file with the KAD/BCU/105 module IP address that you want to assign to.
   After the xidML file is selected, the IP Address field displays the IP address taken from the xidML file.




5. Click **Ok**.
6. Connect IP_ASSIGN (pin 7) to BVDD (pin 4) and then click **OK** onscreen.
7. Disconnect IP_ASSIGN (pin 7) from (pin 4) BVDD and click **OK** onscreen.
8. To verify the new IP address, click **Yes**.

---

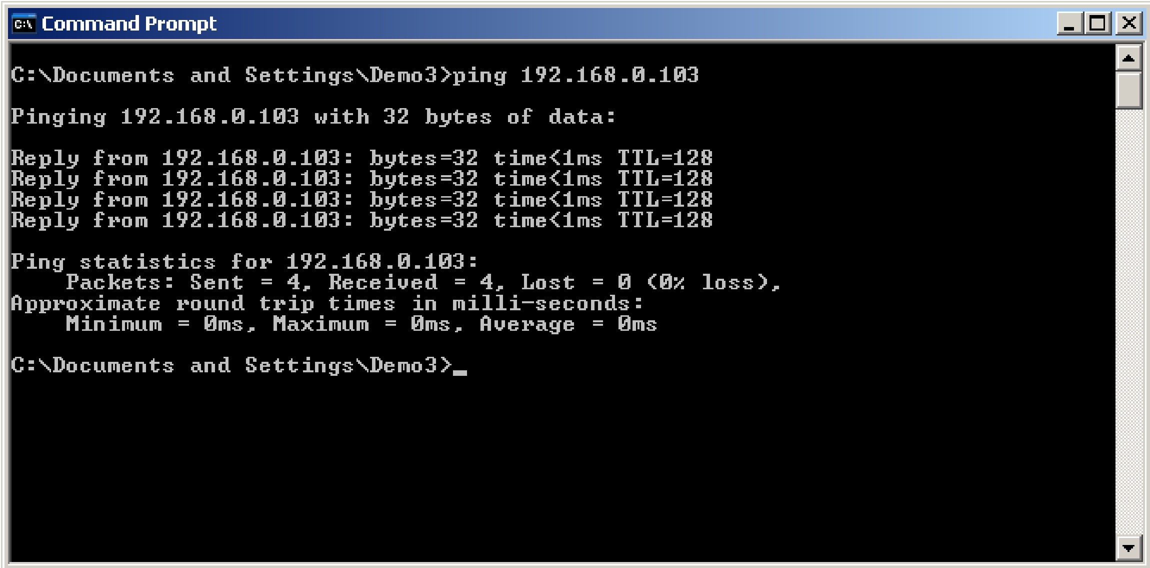
**NOTE:** Ensure the PC being used to assign the KAD/BCU/105 IP address uses the same subnet as the newly assigned module IP address. This is necessary for when kProgram prompts you to perform a test on the IP address.
The KAD/BCU/105 has auto-crossover capability; it operates either with a straight through or a crossover cable without being preset to do so.

### 28.3.1 Testing the connection between PC and the KAD/BCU/105

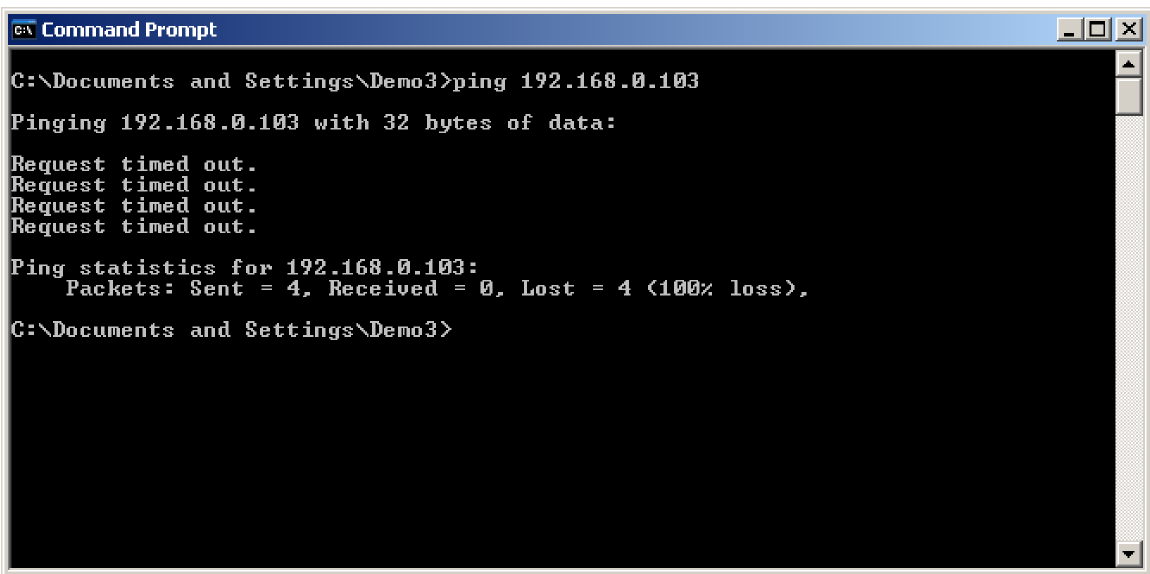
Before programming the unit, check the connection between the PC and the KAD/BCU/105. You can do this by pinging the module from the Windows command prompt.

To ping the KAD/BCU/105, do the following:

1. Click **Start**, **Run**.
2. Type **cmd** and click **OK**.
3. At the C:\ prompt, type **ping**, followed by the IP address of the KAD/BCU/105.
   If the PC is able to connect to the KAD/BCU/105, you get a response similar to that displayed here.




If the ping determines that the PC can communicate with the KAD/BCU/105, the module has been successfully configured and is able to receive packets. If there is a problem and the PC is unable to communicate with the Acra KAM-500 chassis, the response is similar to that shown here.




If a ping has not been successful, make the following checks:

- Check that the correct IP address is being used in the ping command
- Check that the pinging PC is on the same subnet as the KAD/BCU/105
- Power down the Acra KAM-500 chassis and check the wiring

### 28.3.2 Programming the KAD/BCU/105

When the ping has determined that a connection between the PC and the KAD/BCU/105 is established, use kProgram to program the KAD/BCU/105. For information on using kProgram, see the *kProgram* data sheet.

## 28.4 1588 Synchronization

Synchronization is achieved via an external IEEE 1588 Precision Time Protocol (PTP) v1 source. A 1588 grandmaster such as the NET/SWI/002 is necessary to achieve synchronization. For more information on IEEE 1588, see "28.6.3 Appendix 3: Introduction to IEEE 1558" on page 166.

NOTE: To get the most from networked Acra KAM-500 data acquisition systems, it is essential that IEEE 1558-compatible Ethernet switches are used.

### 28.4.1 Alignment of distributed acquisition cycles

It is possible to synchronize packets from multiple Data Acquisition Units (DAUs) if acquisition cycles are aligned according to the following criteria:

- The start of an even second must coincide with the start of an acquisition cycle; this implies that all acquisition cycles must divide evenly into two seconds
- Acquisition cycles must be a multiple of 125 ns long
- Acquisition cycles must be greater than 100 µs long

The following figure shows different DAUs with different acquisition cycles—this illustrates how they should look after synchronization.

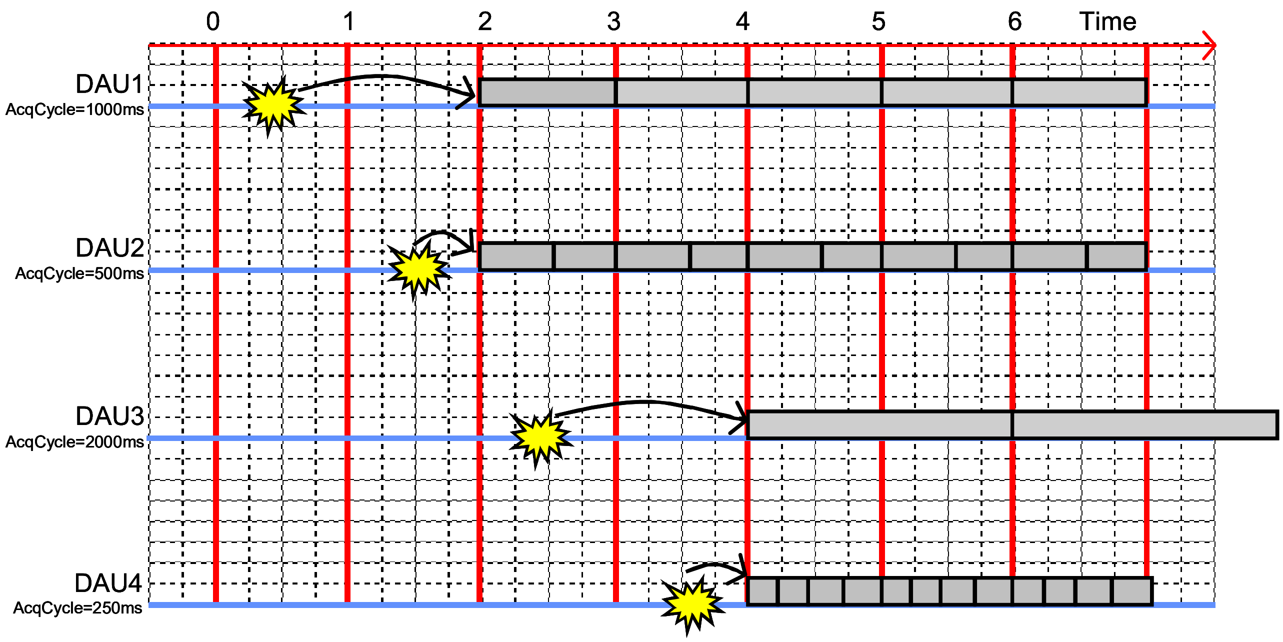



*Figure 28-4: DAU acquisition cycles after* synchronization

When two or more controllers synchronize to a grandmaster, their even second boundaries happen at the same time. As acquisition cycles are aligned to these boundaries, acquisition cycles of the same length start at the same time, even though they are on different DAUs (for possible acquisition cycle frequencies, see the *KAD/BCU/105* data sheet).

### 28.4.2 Clock adjustment algorithm

There are two mechanisms by which the KAD/BCU/105 can adjust its clock to eliminate the offset between its clock and the clock in the grandmaster.

If the magnitude of the offset is greater than 500 µs, the KAD/BCU/105 calculates the correct time as the current clock value plus the offset, and sets its clock to that value. There is a residual error of a few microseconds, due to the time taken to do the calculation, which is calculated and corrected when more PTP messages are received.

An offset less than 500 µs is corrected by adjusting the clock speed until the offset is eliminated. When the KAD/BCU/105 eliminates the offset, it does not suffer from the residual error of the previous method. However, there is a limit to how much the clock speed can be adjusted, so this is only suitable for small adjustments.

## 28.5 Applications

### 28.5.1 Single chassis system

In a single chassis system, a time code generator module, for example KAD/TCG/102, or a real-time clock module, for example KAD/RTC/003, can be used to seed the time into the Acra KAM-500 chassis. The time in the IENA output from the KAD/BCU/105 is derived from the time code generator module or the real-time clock module.

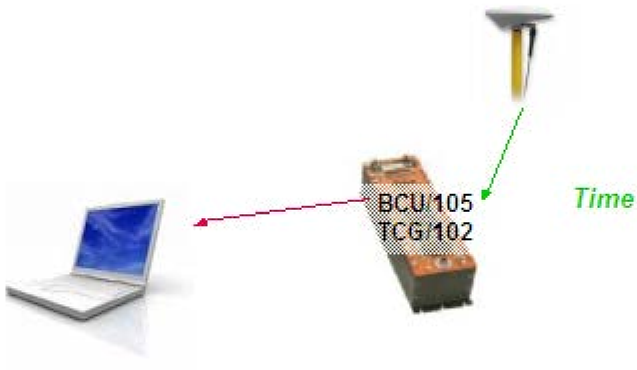



*Figure 28-5: Single chassis system*

### 28.5.2 Distributed system

In a distributed system, to synchronize the chassis with the KAD/BCU/105, an IEEE 1588 v1 grandmaster is necessary. The NET/SWI/002 can act as a grandmaster and has a GPS input to seed the time to the PTP packets.

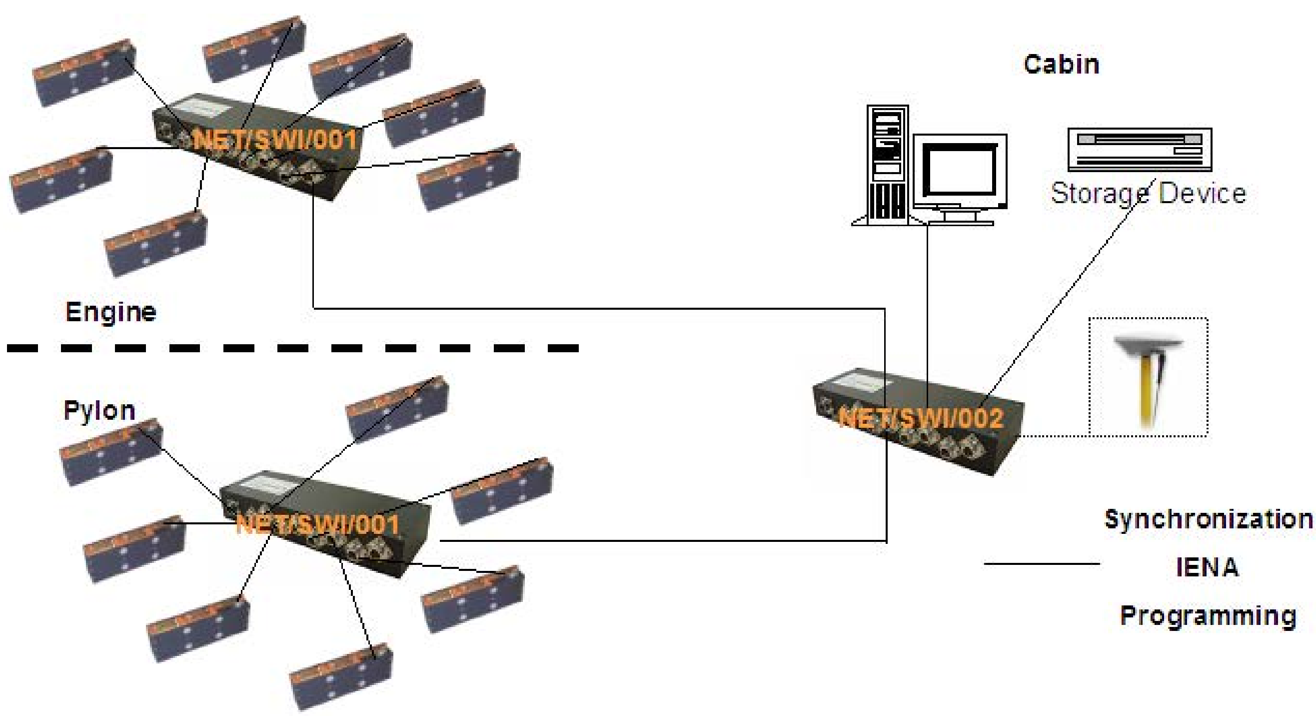



*Figure 28-6: Distributed system*

## 28.6 Appendix

### 28.6.1 Appendix 1: Well known ports

For a list of well known port numbers, refer to http://www.iana.org/assignments/port-numbers.

### 28.6.2 Appendix 2: IENA specification

IENA packets have different types such as IENA STANDARD or messages. The KAD/BCU/105 supports only IENA STANDARD packets. The IENA STANDARD packet is the payload of a UDP datagram.

#### 28.6.2.1 IENA data header

The following table shows the IENA data header fields with corresponding size and description. You must define the Key value for each additional IENA STANDARD packet created.

Table 28-4: IENA data header fields

| Field | Size | Description |
|---|---|---|
| Key | 16 bits | Key in IENA STANDARD packet indicates the type of data in the packet and how data is structured within that packet; this key is a user input |
| Size | 16 bits | Number of data words in the packet; automatically calculated by the module when packet is built |
| Time | 48 bits | Time of sampling of first data sample in packet in straight binary microseconds |
| Status | 16 bits | Reserved |
| Seq | 16 bits | Value that increments for each packet of a given key |

#### 28.6.2.2 IENA data footer

The following table shows the size and description of the IENA data footer end field. Once the value is changed, the change applies to all IENA STANDARD packets defined in the module setup.

Table 28-5: IENA data footer end field

| Field | Size | Description |
|---|---|---|
| End | 16 bits | This is a constant value; a typical value for this is 0xDEAD |

### 28.6.3 Appendix 3: Introduction to IEEE 1558

IEEE 1588 provides fault-tolerant synchronization for different clocks in the same network. IEEE 1588 involves minimal bandwidth consumption, processing power and setup; this is accomplished by use of PTP. PTP synchronizes all clocks within a network by adjusting clocks to the highest quality clock.

IEEE 1588 defines value ranges for the standard set of clock characteristics. The grandmaster clock algorithm determines which clock is the highest quality clock within the network. The grandmaster clock then synchronizes all other clocks (slave clocks) in the network. If the grandmaster clock is removed from the network, or is determined by the grandmaster clock algorithm to no longer be the highest quality clock, the algorithm then redefines what the new grandmaster clock is and adjusts all other clocks accordingly. No administrator input is required for this readjustment as the algorithm provides fault-tolerant synchronization.

Bidirectional Multicast Communication is used by the slave clocks to synchronize to the IEEE 1588 grandmaster clock. The grandmaster sends a sync packet, containing the grandmaster's clock value at the time the sync packet was sent. As there may be delays between the time when the grandmaster reads its clock to build the packet and when the packet is sent, this timestamp may be approximate. The grandmaster may therefore also send a follow-up packet containing the exact time that the sync packet left the grandmaster.

The following figure shows an example of the 1588 sequences.

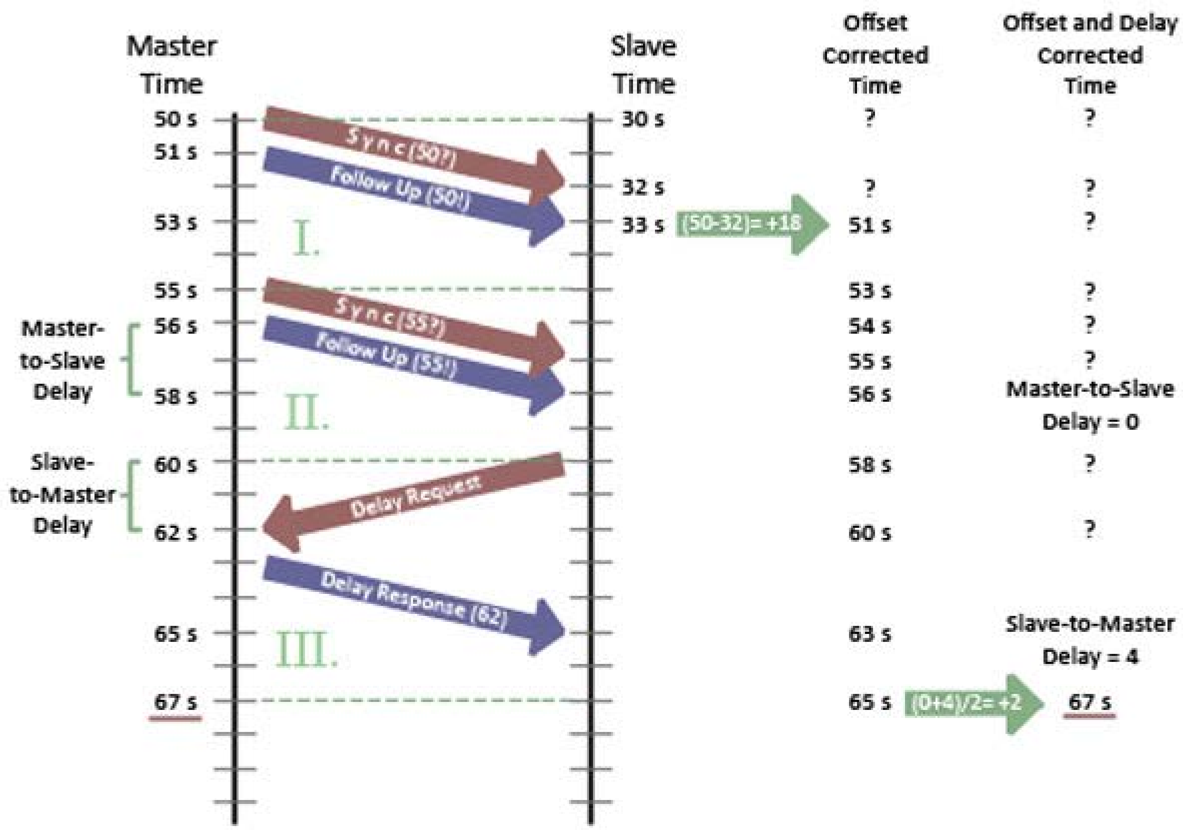



*Figure 28-7: 1588 packets sequence*

The delay between master and slave sync packets, and vice versa, implies that IEEE 1588 operates on the assumption that network propagation delay is symmetrical. It is because of this assumption that a slave can determine and readjust for the propagation delay. To do this, the slave creates a delay request packet and timestamps it upon departure. The master clock then timestamps the packet upon receipt and sends it back to the slave, a delay response packet. The network propagation delay is then determined by finding the delay between these timestamps.

The sending and receiving process of the synchronization packets allows the slave clock to accurately measure the offset between the slave's own clock and the master clock.

Standard methods of clock adjustment implementation are not outlined by IEEE 1588; it provides only a standard protocol for the exchange of messages between clocks. The benefit of this is that clocks from different manufacturers are able to synchronize with each other.

#### 28.6.3.1 1588 PTP packet formats

This section outlines PTP packet formats for the standard message header, sync/delay requirement, follow-up and delay response.

## PTP standard message header

| | 0 | | | | | | | | 1 | | | | | | | | 2 | | | | | | | | 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 0 | PTP version | | | | | | | | | | | | | | | | Version Network | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | Subdomain | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | Message Type | | | | | | | | Source comm tech | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | source uuid | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | Source Port | | | | | | | | | | | | | | | | Sequence id | | | | | | | | | | | | | | | |
| 32 | Control | | | | | | | | Reserved =00 | | | | | | | | Flags | | | | | | | | | | | | | | | |
| 36 | Reserved = 00 00 00 00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## PTP sync and delay_req

| | 0 | | | | | | | | 1 | | | | | | | | 2 | | | | | | | | 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 38 | Origin ts (sec) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 42 | Origin ts (nsec) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 46 | Epoch number | | | | | | | | | | | | | | | | Current UTC offset | | | | | | | | | | | | | | | |
| 50 | "00 | | | | | | | | GM Comm tech | | | | | | | | | | | | | | | | | | | | | | | |
| 54 | GM Clock UUID | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 58 | GM Port ID | | | | | | | | | | | | | | | | GM Seq ID | | | | | | | | | | | | | | | |
| 62 | "00 | | | | | | | | "00 | | | | | | | | "00 | | | | | | | | GM Clock Stratum | | | | | | | |
| 66 | GM Clock ID | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 70 | "00 | | | | | | | | "00 | | | | | | | | GM Clock Variance | | | | | | | | | | | | | | | |
| 74 | "00 | | | | | | | | GM Preferred | | | | | | | | "00 | | | | | | | | GM Boundary | | | | | | | |
| 78 | "00 | | | | | | | | "00 | | | | | | | | "00 | | | | | | | | Sync interval | | | | | | | |
| 82 | "00 | | | | | | | | "00 | | | | | | | | Local Clock Variance | | | | | | | | | | | | | | | |
| 86 | "00 | | | | | | | | "00 | | | | | | | | Local Steps Removed | | | | | | | | | | | | | | | |
| 90 | "00 | | | | | | | | "00 | | | | | | | | "00 | | | | | | | | Local Clock Stratum | | | | | | | |
| 94 | Local Clock ID | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 98 | "00 | | | | | | | | Parent Comm Tech | | | | | | | | | | | | | | | | | | | | | | | |
| 102 | Parent UUID | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 106 | "00 | | | | | | | | "00 | | | | | | | | Parent Port Field | | | | | | | | | | | | | | | |
| 110 | "00 | | | | | | | | "00 | | | | | | | | Estimated Master Variance | | | | | | | | | | | | | | | |
| 114 | Estimated Master Drift | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 118 | "00 | | | | | | | | "00 | | | | | | | | "00 | | | | | | | | UTC Reasonable | | | | | | | |

## PTP follow-up

| | 0 | | | | | | | | 1 | | | | | | | | 2 | | | | | | | | 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 38 | "00 | | | | | | | | "00 | | | | | | | | Associated Seq ID | | | | | | | | | | | | | | | |
| 42 | Precise Origin ts (sec) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 46 | Precise Origin ts (nsec) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

PTP_delay_resp

| | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| | 0 1 2 3 4 5 6 7 | 8 9 10 11 12 13 14 15 | 16 17 18 19 20 21 22 23 | 24 25 26 27 28 29 30 31 |
| 38 | Delay Receipt ts (sec) | | | |
| 42 | Delay Receipt ts (nsec) | | | |
| 46 | "00 | Req Source Comm Tech | | |
| 50 | Req Source UUID | | | |
| 54 | Req Source Port ID | | Req Source Seq ID | |

Table 28-6: PTP terms

| Field name | Description |
|---|---|
| Version PTP | Value of the PTP standard implemented by the clock issuing the message |
| Version Network | Version number of the network specific portions of the PTP standard implemented by the clock issuing the message |
| Subdomain | Value of the subdomain from the default data set; may have two functions in an implementation<br>Can act as a magic number to increase confidence that the message is a PTP event or PTP general message<br>Can act as a unique identifier distinguishing event or general messages in a given subdomain |
| Message Type | Event messages - Sync or Delay_Req have a value of 0x01<br>General messages - Delay_resp, Follow-up or Management messages value 0x02 |
| Source Communication Technology | Value of the port_communication_technology of the source port data set issuing the message |
| Source UUID | Value of the port_uuid_field of the port data set issuing the message |
| Source Port UUID | Value of the port_id_field of the port data set of the port issuing the message |
| Sequence Id | Event messages - the value of the last_sync_event_sequence or the port data set issuing the message<br>General - last_general_event_sequence_number of the port data set issuing the message |
| Control | ControlField enumeration<br>PTP_SYNC_MESSAGE =0<br>PTP_DELAY_REQ_MESSAGE =1<br>PTP_FOLLOWUP_MESSAGE =2<br>PTP_DELAY_RESP_MESSAGE =3<br>PTP_MANAGEMENT_MESSAGE =4<br>Reserved 5-255 |
| Flags | MSB is bit 15<br>(15-7) Reserved<br>(6) PTP_SYNC_BURST: In a delay_Req message is true if the sender is requesting a burst of sync messages; in a sync or follow-up message is true if this is part of such a burst<br>(5) Parent stats<br>(4) PTP_EXT_SYNC – external timing of the default data set<br>(3) PTP_ASSIST – clock_followup_capable default data set<br>(2) PTP_BOUNDARY_CLOCK<br>(1) PTP_LI_59 – leap_59 of global properties data set<br>(0) PTP_LI_61 – leap_61 of global properties data set |

#### 28.6.3.2 PTP message intervals

The most complex specification deals with how often slave clocks issue Delay_Req messages:

- Randomized to reduce network and master clock processing loads
- Randomization is first over multiple sync intervals and second within the selected interval

From section 7.11 of the PTPv1 standard, the following timing rules apply for the various messages:

Given the constants:

- Sync_interval = {1,2,4 … etc}
- PTP_SYNC_INTERVAL_TIMEOUT = 2 ^ sync_interval
- PTP_SYNC_RECEIPT_TIMEOUT = 10 x 2 ^ sync_interval
- PTP_DELAY_REQ_INTERVAL = 30
- PTP_RANDOMIZING_SLOTS = 18
- AVERAGING_INTERVAL = PTP_SYNC_INTERVAL_TIMEOUT x PTP_DELAY_REQ_INTERVAL

### 28.6.4 SYNC

Table 28-7: SYNC

| | |
|---|---|
| On receipt | Processed at a rate of no less than one per PTP_SYNC_INTERVAL_TIMEOUT |
| On transmission | The clock sends a sync message within PTP_SYNC_INTERVAL_TIMEOUT/(2 x PTP_RANDOMIZING_SLOTS) |

### 28.6.5 FOLLOW_UP

Table 28-8: FOLLOW_UP

| | |
|---|---|
| On receipt | Processed at a rate of no less than two per PTP_SYNC_INTERVAL_TIMEOUT |
| On transmission | The clock sends a sync message within PTP_SYNC_INTERVAL_TIMEOUT/PTP_RANDOMIZING_SLOTS after sending the sync message |

### 28.6.6 DELAY_REQ

Table 28-9: DELAY_REQ

| | |
|---|---|
| On receipt | Processed at an average rate of no less than (PTP_RANDOMIZING_SLOTS-2) messages per PTP_SYNC_INTERVAL_TIMEOUT over the AVERAGING_INTERVAL |
| On transmission | Within PTP_SYNC_INTERVAL_TIMEOUT/ PTP_RANDOMIZING_SLOTS after the event requiring the issuance of the Delay_Req |

### 28.6.7 Frequency of DELAY_REQ

When required for the delay computation, a clock issues the Delay_Req within a time window *T* where:

A clock generates two random numbers *R* and *Q*

R is in the range 2 to PTP_DELAY_REQ_INTERVAL, that is, 2 - 30

Q is in the range 2 to PTP_RANDOMIZING_SLOTS, that is, 2 - 18

The window occurs in the time interval P, beginning the Rth receipt after the generation of R, of a sync message form the current master clock.

Within the time interval P, the window T is a closed interval Qx∆T to (Q+1)x∆T

The time window width ∆T is the PTP_SYNC_INTERVAL_TIMEOUT/ PTP_RANDOMIZING_SLOTS

### 28.6.8 DELAY_RESP

Table 28-10: DELAY_RESP

| | |
|---|---|
| On receipt | Processed at an average rate of no less than (PTP_RANDOMIZING_SLOTS-2) messages per PTP_SYNC_INTERVAL_TIMEOUT over the AVERAGING_INTERVAL |
| On transmission | Within PTP_SYNC_INTERVAL_TIMEOUT/ (2xPTP_RANDOMIZING_SLOTS) after the event requiring the issuance of the Delay_Resp |

## 28.7 Glossary

**IP address**

The address of a device attached to an IP network (TCP/IP network). Every client, server and network device must have a unique IP address for each network connection. The format of an IP address is a 32-bit numeric address, written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

**IP subnet addressing**

Routers, or gateways, are used to separate networks. The router breaks the network into multiple subnets. This result may seem familiar as Class A, B, and C addresses have a self-encoded or default subnet mask built in; class A network address - 255.0.0.0: class B network address - 255.255.0.0: class C network address - 255.255.255.0.

**MAC address**

A hardware address which uniquely identifies each node of a network. In IEEE 802 networks, the Data Link Control (DCL) layer of the OSI reference model is divided into two sublayers—the Logical Link Control (LLC) layer and the Media Access Control (MAC) layer. The MAC layer interfaces directly with the network medium. Consequently, each different type of network medium requires a different MAC layer.

**Port**

A number used, in conjunction with the IP address, to indicate one end of an ethernet conversation. Some port numbers are reserved for particular services. The port number identifies what type of port it is. For example, a server listening for HTTP traffic listens on port 80. Port numbers range from 0 to 65536, but only port numbers 0 to 1024 are reserved for privileged services and designated as well known ports. For more information, see http://www.iana.org/assignments/port-numbers.

**Switch**

A device that can route data only to the nodes (and links) for which the data is intended. Using a switch eliminates the possibility of collisions on a node link. Also, as long as the total bandwidth available to data leaving the switch is the same as, or greater than, the total bandwidth of data entering the switch, there is no data loss.

**UDP**

User Datagram Protocol. An unreliable connection-less transport protocol which doesn’t provide a guarantee that packets will arrive, or that they will arrive in the order in which they were sent. UDP is widely used for streaming audio and video, voice over IP (VoIP) and videoconferencing.

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Chapter 29

# Using the KAD/ETH/101

TEC/NOT/054

The KAD/ETH/101 is a full-duplex, fast Ethernet module. It can be used to program an Acra KAM-500 chassis or transmit data from an Acra KAM-500 chassis. This technical note describes how to set up the KAD/ETH/101 for programming and decommutating using a PC and is divided into the following sections:



## 29.1 Introducing the KAD/ETH/101

The KAD/ETH/101 is a full-duplex, 100BaseTX Ethernet Acra KAM-500 programmer and packet generator.

### 29.1.1 Programmer

The Acra KAM-500 chassis is programmed via proprietary protocol over UDP. The KAD/ETH/101 module has a factory-programmed, unique MAC (Media Access Control) address. The IP address for the module must be manually assigned (see "29.5.4 Assigning the KAD/ETH/101 IP address" on page 179 for details).

### 29.1.2 Packet generator

The KAD/ETH/101 generates data in IENA packets. The IENA format is a published standard and consists of an IENA application layer, consisting of a header and payload, transported over UDP as shown in the following figure. For more information on IENA data header fields, see "29.6.2.1 IENA data header" on page 183.

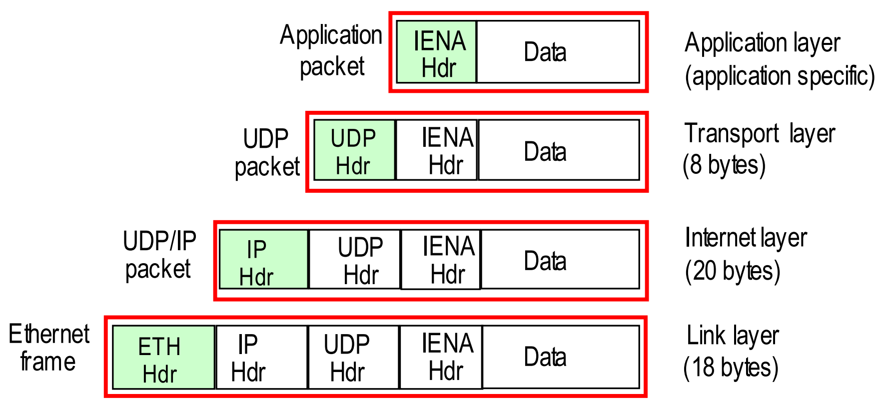



*Figure 29-1: Packet encapsulation*

The packet generator can transmit packets at varying rates as well as transmit packets of different sizes to different destinations, such as multicast and/or unicast and/or broadcast. When all parameter values in an IENA packet are present in the Current Value Table (CVT), the IENA packet is transmitted.

## 29.2 Wiring the KAD/ETH/101

You must wire the following elements on every KAD/ETH/101 module:

- The Ethernet interface (both Tx± and Rx± lines)
- The KAD/ETH/101 to KAD/BCU/101 programming interface (if Acra KAM-500 system programming via Ethernet is required)

**NOTE:** If the PC being used has auto-MDIX functionality, the KAD/ETH/101 may be connected to the PC through an ACC/ASY/023/C or ACC/ASY/024 cable, by using a straight-through or cross-over cable. Without this functionality, a cross-over cable or a straight-through cable with hub is required. Alternatively, the connection may be made as per the wiring guide (see the following table).

Table 29-1: KAD/ETH/101 to PC port RJ-45 wiring (cross-over)

| KAD/ETH/101 pin | PC port RJ45 pin |
|---|---|
| 1 (RX_A+) | 1 (Tx+) |
| 2 (RX_A-) | 2 (Tx-) |
| 18 (TX_A+) | 3 (Rx+) |
| 19 (TX_A-) | 6 (Rx-) |

### 29.2.1 KAD/ETH/101 to KAD/BCU/101

The KAD/ETH/101 transfers data to the KAD/BCU/101 via its programming lines. There are two programming busses designated, that is, bus A and bus B. Bus A is for all chassis whose chassis ID is 31 or less. Bus B is for all chassis whose chassis ID is 32 or greater.

The chassis ID is determined by pins 4-7, 37, and 38 on the KAD/BCU/101. When using a single chassis in stand-alone mode, these pins should be left open circuit, resulting in a chassis ID of 0. This is programmed via bus A.

For a single chassis, bus B can be ignored. The corresponding connections are outlined in the following table.

Table 29-2: Module connections

| KAD/ETH/101 | | KAD/BCU/101 | |
|---|---|---|---|
| **Pin** | | **Pin** | |
| 6 | PROG_A+ | 25 | PROG_DATA+ |
| 7 | PROG_A- | 26 | PROG_DATA- |

The programming bus should have 120Ω terminations at each end. The programming lines are internally terminated in the KAD/ETH/101. The 120Ω resistor on the KAD/BCU/101 (see the following figure) can be used to terminate the bus; this resistor is permanently connected to PROG_DATA+ internally. To connect to PROG_DATA-, connect pin 27 (PROG_DATA_TRM+) to pin 26 (PROG_DATA-).

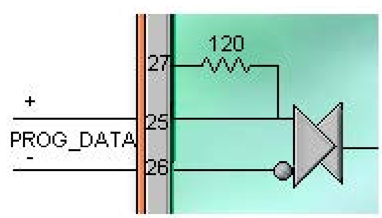



*Figure 29-2: Termination resistor on the KAD/BCU/101*

## 29.3 Connecting the Acra KAM-500 chassis to a PC

The Acra KAM-500 chassis may be connected directly to a PC using a cross-over cable, or may be connected to a hub using a straight-through cable. The goal is to create a network in which the programming PC is one node and the Acra KAM-500 chassis is another node.

## 29.4 Connecting the PC and the Acra KAM-500 chassis to a network

For a PC to recognize the Acra KAM-500 chassis, the PC must be on the same network as the chassis. Not only must they be physically connected, but they must share the same network address section of their IP address.

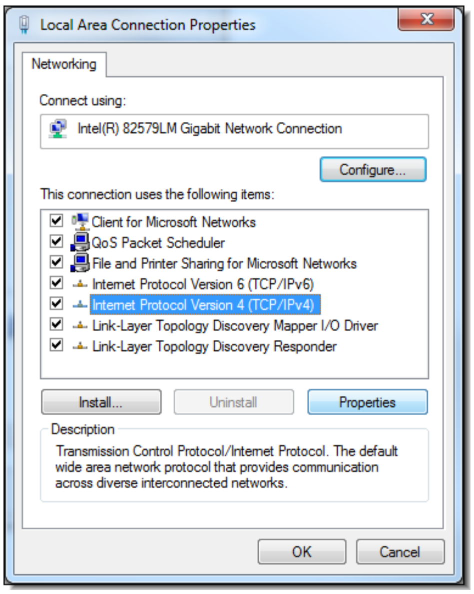
You can manually configure the IP address of the PC through Windows. For details on configuring the IP address for the KAD/ETH/101, see "29.5.4 Assigning the KAD/ETH/101 IP address" on page 179.

---

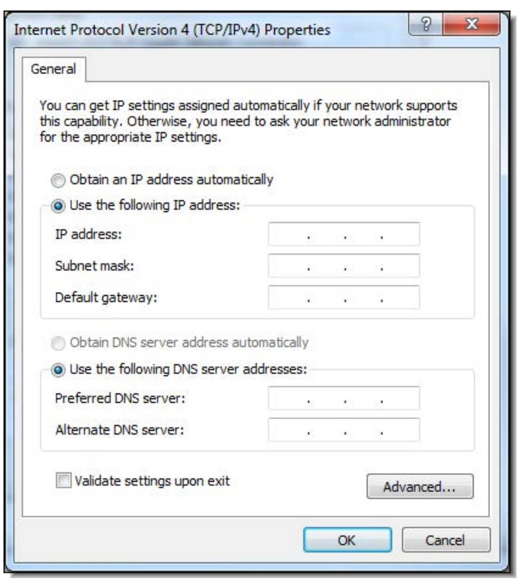
**NOTE:** The following procedure assumes your operating system is Windows 7.

To set up the network, do the following:

1. Click **Start**, **Control Panel**.
2. Click **Network and Sharing Center**.
3. Double-click the **Local Area Connection** that the Acra KAM-500 is connected to.
4. Click **Properties**.
   The Local Area Connection Properties window opens.




5. Select **Internet Protocol Version 4 (TCP/IPv4)** and then click **Properties**.
   The Internet Protocol **Version 4** (TCP/IPv4) Properties dialogue box displays.




6. Select the **Use the following IP address:** radio button.

7. In the **IP address:** field, insert the appropriate IP address.
   This IP address must have the same network address as the Acra KAM-500 chassis. Typically, the network address is determined by the first two or three bytes of the IP address. For example, if the chassis IP address was set to 192.168.0.3, then the network address for this might be 192.168.0. The node address—the one or two bytes that are not the network address—must be unique. So in this example we could set the PC address to 192.168.0.2.
8. In the **Subnet mask** field, insert details for the network address.
   If only the first two bytes are the network address, then the mask would be 255.255.0.0. If the first three are the network address then the mask would be 255.255.255.0.
9. Click **OK**.
   If required, re-boot the PC.

## 29.5 Using KSM-500 to configure the KAD/ETH/101

To operate the KAD/ETH/101, an IENA STANDARD packet must be created containing appropriate parameters and destination details. The module must be configured to communicate over a network by assigning it an IP address and establishing communication paths between it and the specified destinations of each packet.

When unicast packets are being used, it is important to correctly configure the target device MAC address when creating the IENA packet. This is because most switches use the MAC address rather than the IP address to determine how they route packets between ports. If an invalid target MAC address is used by the KAD/ETH/101, the switch may dump (delete) the packet or broadcast it to all ports.

When multicast packets are being used, KSM-500 software automatically assigns the corresponding destination MAC address for the IENA packets.

To configure the KAD/ETH/101, kSetup and kProgram software are required. kSetup and kProgram are included in the KSM-500 suite of tools.

### 29.5.1 Defining packets

You can add or remove IENA STANDARD packets on the Packets tab. You can also edit Packet Names, Packets per Acquisition Cycle, Destination IP Address, Destination Port and Mac Address fields for any packet.

| Packet Name | Packet Type | Packets per Acquisition Cycle | Destination IP Address | Destination Port | MAC Address |
|---|---|---|---|---|---|
| * | * | * | * | * | * |
| TC_PACKET | IENA STANDARD | 1 | 192.168.1.28 | 51000 | 00-1C-7E-2F-CA-B0 |
| PT100_PACKET | IENA STANDARD | 10 | 238.0.0.100 | 50001 | 01-00-5E-00-00-64 |
| WING_PACKET | IENA STANDARD | 16 | 238.0.0.101 | 50001 | 01-00-5E-00-00-65 |
| ACCEL_PACKETS | IENA STANDARD | 512 | 192.168.1.29 | 52001 | AA-23-45-71-43-AF |

*Figure 29-3: IENA STANDARD packets*

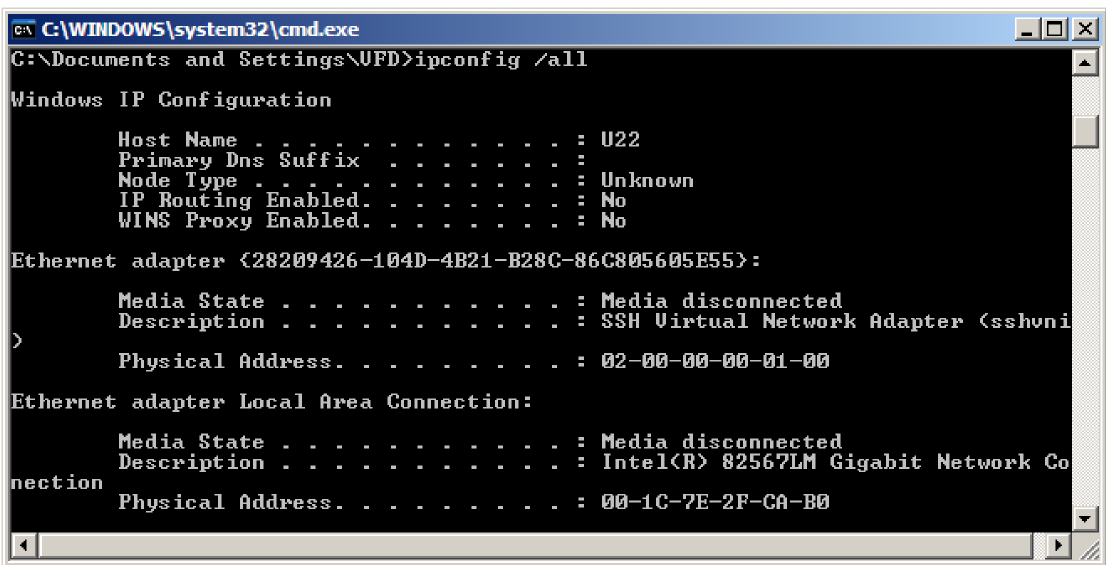
To add a packet, right-click on the spreadsheet, select Add Packet then select IENA STANDARD and complete the fields described in the following table.

Table 29-3: Adding/removing packets

| Field name | Description |
|---|---|
| Packet Name | Name which identifies packet being transmitted. |
| Packet Type | IENA STANDARD is the only packet type supported; click IENA STANDARD to open the packet setup definition. |
| Packets per Acquisition Cycle | The number of packets per acquisition cycle; this number drives the sampling rate for the parameters transmitted into this packet (the sampling rate of a given parameter is calculated by multiplying the number of occurrences of that parameter within a packet, by the number of packets per acquisition cycle, by the frequency of the acquisition cycle). |
| Destination IP Address | The destination IP address can be unicast, broadcast, or multicast. |
| Destination Port | The destination port can be any value between 0 to 65535 except what is specified in RFC 1700 known as the well known ports (see “29.6.1 Appendix 1: Well known ports” on page 182); ensure your decommutation PC fire wall allows UDP packets to be received on this port. |
| MAC Address | The destination MAC address; when a multicast IP address is used, this field is automatically generated by the software and is read-only. |

**NOTE:** Always create a packet with an instance of one for Packets per Acquisition Cycle. XidML doesn’t include the concept of acquisition cycle. For example, if you create a packet with 512 for packets per acquisition cycle, after closing kSetup, the number of acquisition cycles is multiplied to 512 and the packets per acquisition cycle changes to one.

**NOTE:** To know the MAC Address used by your PC, type IPConfig /all under a DOS CMD window. IPConfig refers to it as Physical address. In the example below, the MAC Address is 00-1C-7E-2F-CA-B0.




## 29.5.2 Configuring IENA packets

You can configure IENA packets on the Packets tab (see the following figure). For details of the IENA packet description, see “29.6.2 Appendix 2: IENA specification” on page 183“. To configure an IENA packet, double-click an IENA STANDARD cell in the Packet Type column on the Packets tab.

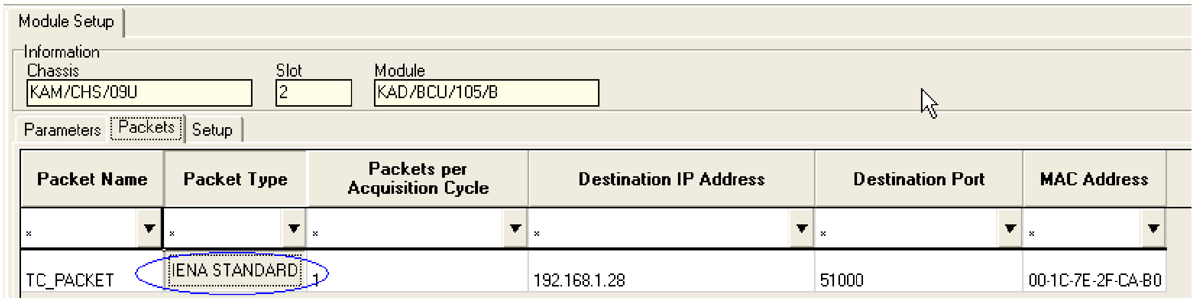



*Figure 29-4: Configuring IENA packets*

### 29.5.2.1 Editing IENA keys

To edit the IENA Key or IENA End key, double-click the Key cell or the End cell (see the following figure).


*Figure 29-5: Editing IENA keys*

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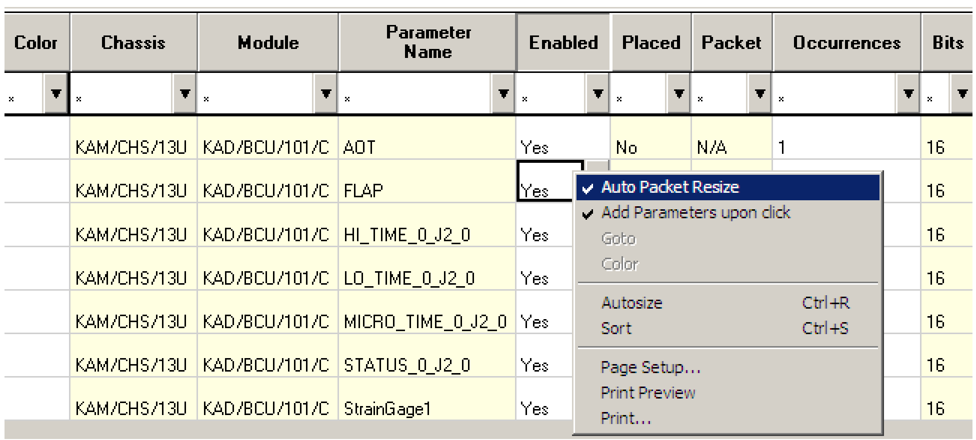
**NOTE:** To modify the IENA Key or the IENA End key, ensure Add Parameters upon click is not checked (see the previous figure).
The IENA key must be unique in a network distributed system.
The IENA End key has the same value for all the packets coming from the module.

### 29.5.2.2 Placing parameters in packets

You can manually place parameters in a packet if you want to specify the position of that parameter in the packet. For subsequent placements, each additional parameter is placed to the right of its predecessor.

To manually place a parameter, do the following:

1. On the Packet Setup tab, right-click and ensure Auto Packet resize and Add Parameters upon click are checked.




2. For the packet concerned, click on the spreadsheet to select a parameter.
3. Click on the byte to the right of the location you wish to place the parameter.
4. Complete the fields described in the following table.

Table 29-4: IENA packet settings

| Field name | Description |
|---|---|
| Color | Not available. |
| Chassis | Chassis label from where the parameter comes from; read-only field. |
| Module | Module label from where the parameter comes from; read-only field. |
| Parameter Name | Name of the parameter; read-only field. |
| Enabled | Set to No prevents the user from placing the parameter in the packet. |
| Placed | Set to Yes when the parameter is placed into a packet. |
| Packet | Packet label where the parameter is placed. |
| Occurrences | Number of occurrences of the parameter in the packet; this number drives the parameter sampling rate; the same number of occurrences is recommended for all the parameters within the same packet. |
| Bits | Number of source bits for the parameter. |

### 29.5.3 Setting up the KAD/ETH/101

After IENA packets have been configured, you can set up the KAD/ETH/101 to transmit the newly configured packets (for information on setting up IENA packets, see Figure 29-4 on page 178). When setting up the module, you must specify the Module IP address, Module Port and Time to live per packet.

On the Setup tab, complete the fields described in the following table.

Table 29-5: Module setup

| Field name | Description |
|---|---|
| Module IP address | When set, the module can be pinged; for details of pinging the module, see “29.5.5 Testing the connection between PC and the KAD/ETH/101” on page 180. |
| Module Port | This can be any value between 0 and 65535. We recommend that well known ports as specified in RFC1700 are not used. Section “29.6.1 Appendix 1: Well known ports” on page 182 lists some of the more commonly used well known port numbers. Ensure that your logging device supports this port and that it is not blocked by any fire walls in the test system. |
| Time to live (s) | An advanced configuration field in the IP header, which determines how long a packet from the module *lives* in the network, in the event that it does not reach its destination. Each switch that a packet passes through as it travels through the network can decrement this field. A switch can dump a packet if its time to live is 0. |

**NOTE:** The Module IP Address field does not assign the IP address for the KAD/ETH/101; this field is used only to program the chassis.

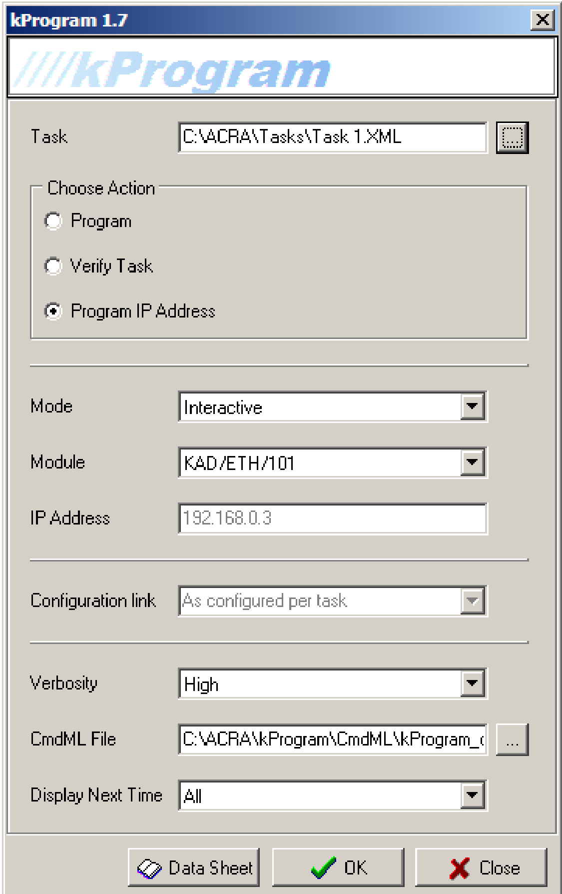
### 29.5.4 Assigning the KAD/ETH/101 IP address

If pin 39 is connected to GND, the KAD/ETH/101 assumes a default hard-wired IP address—224.0.0.3 is used, as it is an administratively scoped IP multicast address.

You must use kProgram to assign the IP into the module.

1. Launch kProgram.
2. In the **Task** field, browse for the task file required.
3. Select the **Program** IP address radio button.

4. In the CmdML File field, select the xidML file with the KAD/ETH/101 module IP address that you want to assign to.
   After the xidML file is selected, the IP Address field displays the IP address taken from the xidML file.




5. Click **OK** and follow the on-screen instructions.

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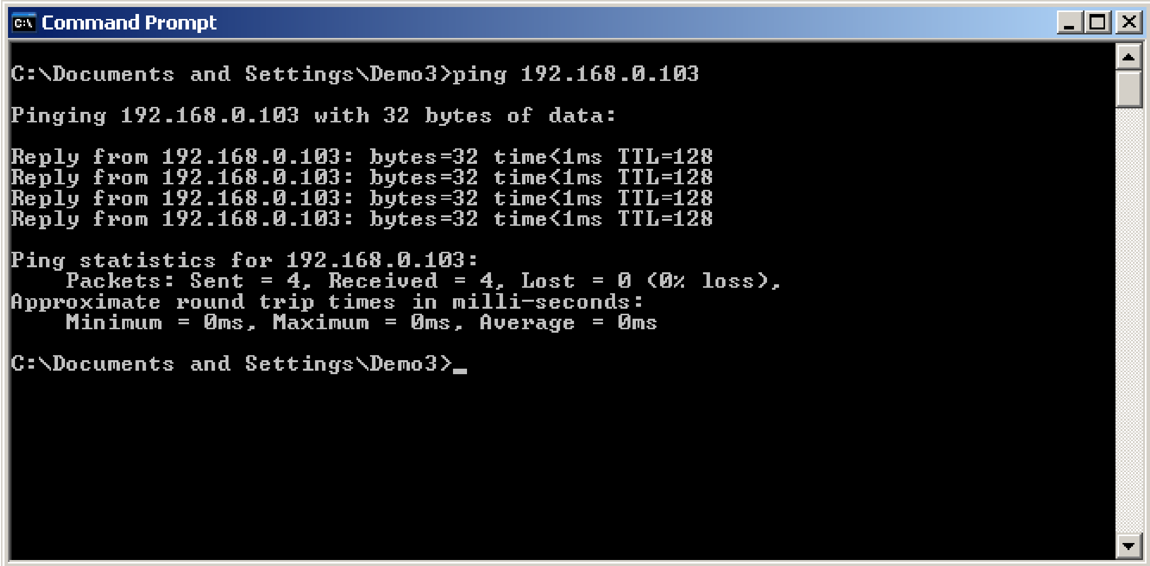
**NOTE:** Ensure the PC used to assign the KAD/ETH/101 uses the same subnet as the newly assigned KAD/ETH/101 module IP address. This is necessary should you want to use kProgram to perform a test on the IP address.

### 29.5.5 Testing the connection between PC and the KAD/ETH/101

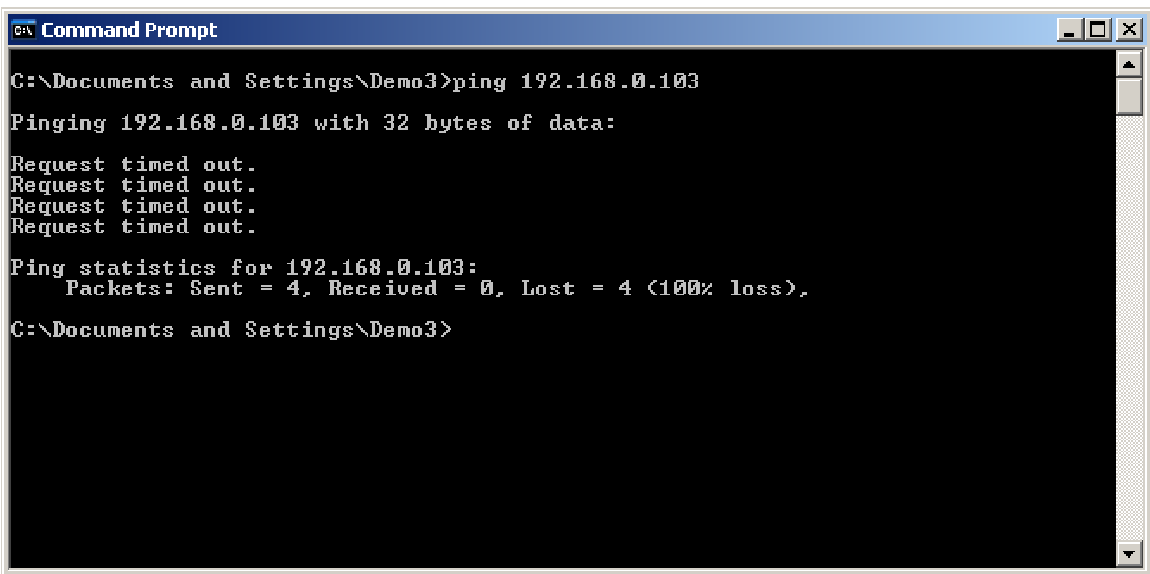
Before programming the unit, check the connection between the PC and the KAD/ETH/101. You can do this by pinging the module from the command prompt.

To ping the KAD/ETH/101, do the following:

1. Click **Start**, **Run**.
2. Type **cmd** and click **OK**.
3. At the C:\ prompt, type ping, space, followed by the IP address of the KAD/ETH/101.
   If the PC is able to connect to the KAD/ETH/101, you get a response similar to that displayed below.




If the ping determines that the PC can communicate with the KAD/ETH/101, the module has been successfully configured and is able to receive packets. If there is a problem and the PC is unable to communicate with the KAD/ETH/101, the response is similar to that shown in the following figure.




If a ping has not been successful, make the following checks:

- Check that the correct IP address was used in the ping command.
- Check that the pinging PC is on the same subnet as the KAD/ETH/101.
- Power down the Acra KAM-500 chassis and check the wiring and power to the chassis.

### 29.5.6 Programming the KAD/ETH/101

When pinging has determined that a connection between the PC and the KAD/ETH/101 is established, use kProgram to program the KAD/ETH/101.

To program the module, do the following:

1. Launch kProgram.
2. In the **Task** field, browse for the task file required.
3. Select the **Program** radio button.
4. Click **OK**.

For information on using kProgram, contact Curtiss-Wright support (acra-support@curtisswright.com).

# 29.6 Appendix

## 29.6.1 Appendix 1: Well known ports

The following table lists some well known port numbers and specifies the server process associated with its contact port. For a complete listing of well known ports refer to: http://www.iana.org/assignments/port-numbers

Table 29-6: Well known ports

| Port Number | Description |
|---|---|
| 1 | TCP Port Service Multiplexer (TCPMUX). |
| 5 | Remote Job Entry (RJE). |
| 7 | ECHO. |
| 18 | Message Send Protocol (MSP). |
| 20 | FTP -- Data. |
| 21 | FTP -- Control. |
| 22 | SSH Remote Login Protocol. |
| 23 | Telnet. |
| 25 | Simple mail transfer table (SMTP). |
| 29 | MSG ICP. |
| 37 | Time. |
| 42 | Host Name Server (Nameserv). |
| 43 | WhoIs. |
| 49 | Login Host Protocol (Login). |
| 53 | Domain name system (DNS). |
| 69 | Trivial file transfer protocol (TFTP). |
| 70 | Gopher Services. |
| 79 | Finger. |
| 80 | HTTP. |
| 103 | X 400 Standard. |
| 108 | SNA Gateway Access Server. |
| 109 | POP2. |
| 110 | POP3. |
| 115 | Simple File Transfer Protocol (SFTP). |
| 118 | SQL Services. |
| 119 | Newsgroup (NNTP). |
| 137 | NetBios Name Service. |
| 139 | NetBIOS Datagram Service. |
| 143 | Interim Mail Access Protocol (IMAP). |

Table 29-6: Well known ports (continued)

| Port Number | Description |
|---|---|
| 150 | NetBIOS Session Service. |
| 156 | SQL server. |
| 161 | SNMP. |
| 179 | Border gateway protocol (BGP). |
| 190 | Gateway Access Control Protocol (GACP). |
| 194 | Internet Relay Chat (IRC). |
| 197 | Directory Location Service (DLS). |
| 389 | Lightweight directory access protocol (LDAP). |
| 396 | Novell Netware over IP. |
| 443 | HTPPS. |
| 444 | Simple Network Paging Protocol (SNPP). |
| 445 | Microsoft-DS. |
| 458 | Apple QuickTime. |
| 546 | DHCP Client. |
| 547 | DHCP Server. |
| 563 | SNEWS. |
| 569 | MSN. |
| 1080 | Socks. |

### 29.6.2 Appendix 2: IENA specification

IENA has different types such as IENA STANDARD or messages. The KAD/ETH/101 supports only IENA STANDARD. The IENA STANDARD packet is the payload of a UDP packet.

#### 29.6.2.1 IENA data header

The following table shows the IENA data header fields with corresponding size and description. You must define the Key value for each additional IENA STANDARD packet created.

Table 29-7: IENA data header fields

| Field | Size | Description |
|---|---|---|
| Key | 16 bits | Key in IENA standard indicates the type of data in the packet and how data is structured within that packet; this key is a user input. |
| Size | 16 bits | Number of data words in the packet; automatically calculated by the module when packet is built. |
| Time | 48 bits | Time of sampling of first data sample in packet in straight binary microseconds. |
| Status | 16 bits | Reserved. |

Table 29-7: IENA data header fields (continued)

| Field | Size | Description |
|---|---|---|
| Seq | 16 bits | Value that increments for each packet of a given key. |

#### 29.6.2.2 IENA data footer

The following table shows the IENA data footer end field and its size and description. Once the value is changed, the change applies to all IENA STANDARD packets defined.

Table 29-8: IENA data footer end field

| Field | Size | Description |
|---|---|---|
| End | 16 bits | This is a constant value; a typical value for this is 0xDEAD. |

## 29.7 Glossary

**IP address**

The address of a device attached to an IP network (TCP/IP network). Every client, server and network device must have a unique IP address for each network connection. The format of an IP address is a 32-bit numeric address, written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address.

**IP subnet addressing**

Routers, or gateways, are used to separate networks. The router breaks the network into multiple subnets. This result may seem familiar as Class A, B, and C addresses have a self-encoded or default subnet mask built in; class A network address - 255.0.0.0: class B network address - 255.255.0.0: class C network address - 255.255.255.0.

**MAC address**

A hardware address which uniquely identifies each node of a network. In IEEE 802 networks, the Data Link Control (DLC) layer of the OSI reference model is divided into two sublayers—the Logical Link Control (LLC) layer and the Media Access Control (MAC) layer. The MAC layer interfaces directly with the network medium. Consequently, each different type of network medium requires a different MAC layer.

**Port**

A number used, in conjunction with the IP address, to indicate one end of an Ethernet conversation. Some port numbers are reserved for particular services. The port number identifies what type of port it is. For example, a server listening for HTTP traffic listens on port 80. Port numbers range from 0 to 65536, but only port numbers 0 to 1024 are reserved for privileged services and designated as well known ports. For more information, see http://www.iana.org/assignments/port-numbers.

**Switch**

A device that can route data only to the nodes (and links) for which the data is intended. Using a switch eliminates the possibility of collisions on a node link. Also, as long as the total bandwidth available to data leaving the switch is the same as, or greater than, the total bandwidth of data entering the switch, there is no data loss.

**UDP**

User Datagram Protocol. An unreliable connection-less transport protocol which doesn't provide a guarantee that packets arrive, or that they arrive in the order in which they were sent. UDP is widely used for streaming audio and video, voice over IP (VoIP) and video conferencing.

Chapter 30

# Using the KAD/VID/103

TEC/NOT/055

This technical note discusses the following topics:



## 30.1 Overview

The KAD/VID/103 module is a video encoder module that converts one of three composite video (CVBS) inputs or one S-Video input into digital video and compresses it using an MPEG-4 encoding scheme. The module also accepts analog audio inputs and compresses them using an Adaptive Differential Pulse-Code Modulation (ADPCM) encoding scheme.

The video and audio are then placed into an MPEG-2 transport stream, which is output onto the Acra KAM-500 backplane.

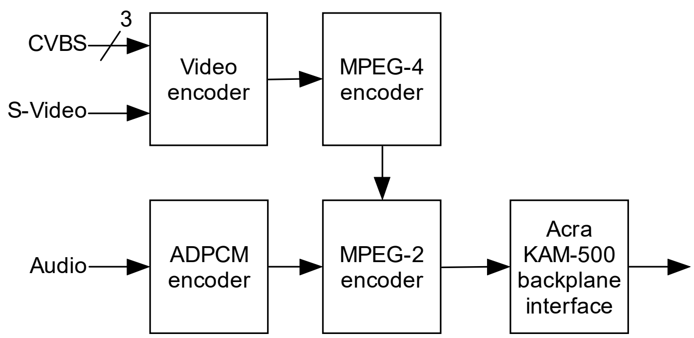



*Figure 30-1:* KAD/*VID/103's compression of audio/video input*

## 30.2 Compression methods

The KAD/VID/103 automatically compresses video and has an option to compress audio.

### 30.2.1 Video compression

The KAD/VID/103 compresses video using the MPEG-4 Simple Profile technique. This method encodes each received frame as either an I-frame (**I**ntra coded) or a P-frame (**P**redicted) depending on the module settings.

#### 30.2.1.1 I-frames

I-frames take all the information in the received picture and encode it using a lossy compression scheme to create a reference frame. This reference frame can be thought of as a stand-alone frame, that is, it does not need any information from other frames in the video stream to be viewed. This means that each I-frame is an accurate representation of the received analog picture.

#### 30.2.1.2 P-frames

P-frames encode only the changes from the previous frame. This means that P-frames need information from previous frames to be viewed. This results in a reduction of bandwidth needed to encode a moving picture. However, if the picture were to change quickly, an accurate representation would not be displayed until the next I-frame was processed.

#### 30.2.1.3 Group Of Pictures (GOP)

I-frames and P-frames are grouped together in a GOP. The setting used for GOP determines the image quality and bandwidth.

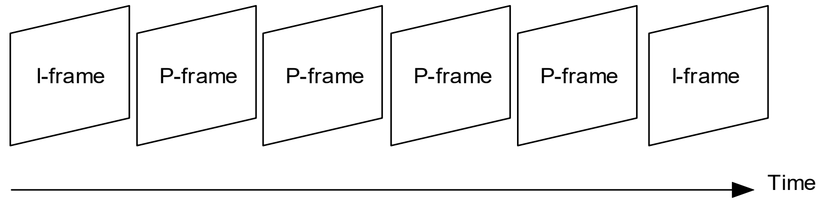



*Figure 30-2: GOP with P-frame to I-frame ratio of 5:1*

### 30.2.2 Audio compression

The KAD/VID/103 compresses audio using ADPCM. This uses an encoding philosophy similar to that used by MPEG-4 Simple Profile. ADPCM encodes the difference between a predicted sample and the current audio sample. The bit-rate for audio is fixed at 64 kbps per channel.

### 30.2.3 Video and audio encoding

The MPEG-4 video and ADPCM audio are then encoded in an MPEG-2 transport stream. An MPEG-2 transport stream is a fixed length (188 bytes) packet.

These packets are then fragmented into 16-bit words, which are output onto the Acra KAM-500 backplane on a FIFO basis. From there they can be inserted in a PCM frame, a UDP packet, logged to a memory module, or a combination of all three.

## 30.3 Setting up the KAD/VID/103

### 30.3.1 Hardware setup

The KAD/VID/103 occupies two slots in an Acra KAM-500 chassis and has two 52-way connectors as shown in the following figure.

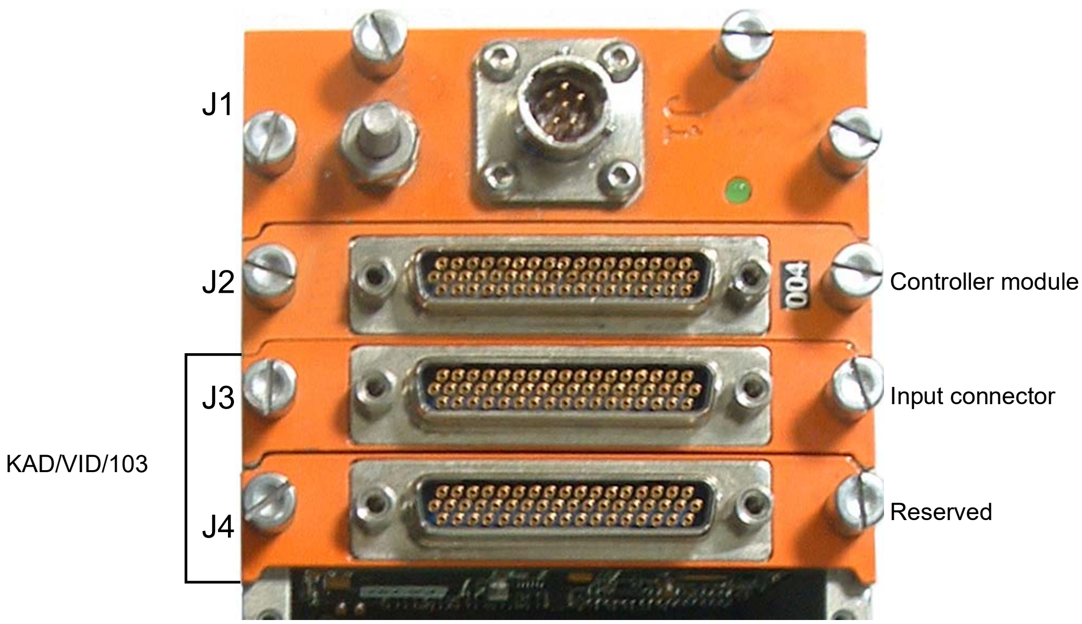



*Figure 30-3: Positioning for a KAD/VID/103 module in a chassis*

The connector nearest the controller module contains the I/O pins; the other connector is an interface for programming and debug and should not be used. When using the setup software, the connector that is furthest from the controller module determines the location of the module, in this case slot J4.

#### 30.3.1.1 Pinout connections

Pinout connections are described in the following table.

| Connection | Description |
|---|---|
| CVBS_0_IN<br>CVBS_1_IN<br>CVBS_2_IN | These input connections allow up to three independent composite video sources to be connected.<br><br>**NOTE:** The KAD/VID/103 can only process one video input at a time. |
| Y_IN<br>C_IN | These two input connections are used for component (S-Video) inputs. Y_IN corresponds to luminance; C_IN corresponds to chrominance. |
| CAM_2_GENLOCK_OUT<br>CAM_3_GENLOCK_OUT | Composite video waveforms output a regular sync pulse (every 64µs for PAL, every 63.5µs for NTSC) that can be used to synchronize multiple video inputs. When a video source is connected to CVBS_0_IN, its output waveform is available on both GENLOCK outputs. This allows up to two other composite video sources connected to CVBS_1_IN and CVBS_2_IN to be synchronized with the CVBS_0_IN input. |
| AUDIO_RIGHT_IN<br>AUDIO_LEFT_IN | These are the inputs for audio. |
| CAM_SEL_BIT_0<br>CAM_SEL_BIT_1<br>CAM_SEL_BIT_2 | If Input Select is set to CONNECTOR, these three inputs can be used to select the input video source.<br><br>**NOTE:** These connections are internally pulled high; they must be tied to ground as shown in the following table to select the various inputs. |

Camera selection

| CAM_SEL_BIT [2:0] | | | Selected Input |
|---|---|---|---|
| GND | GND | GND | Outputs a simple test pattern |
| GND | GND | NC[1] | CVBS_0_IN |
| GND | NC | GND | CVBS_1_IN |
| GND | NC | NC | CVBS_2_IN |
| NC | GND | GND | Y_IN, C_IN |

1. NC = not connected.

### 30.3.2 Software setup

The KAD/VID/103 can be configured using kSetup.

#### 30.3.2.1 Parameters tab settings

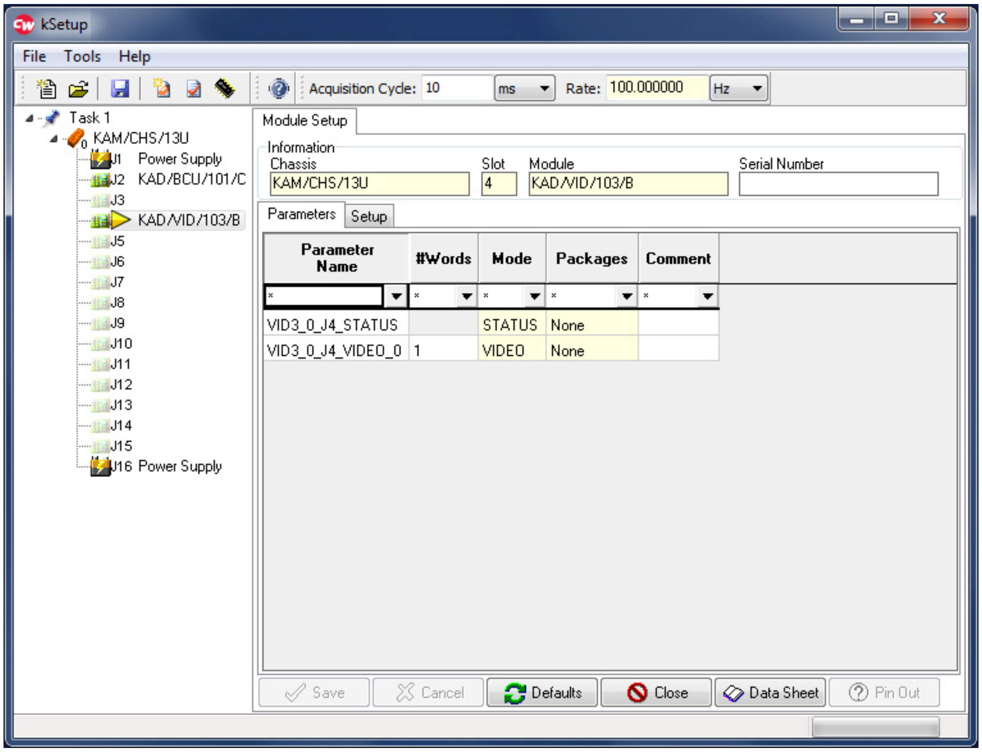



*Figure 30-4: Parameters tab in kSetup*

The Parameters tab has two Mode settings; the STATUS word and the VIDEO word. They are described in the following table.

| Mode | Description |
|---|---|
| STATUS | This word relates the status of the module. Three bits of the status word are defined.<br><br>**NOTE:** The KAD/VID/103 STATUS word definitions are as follows:<br>R(2) - Built-in self test passed.<br>R(1) - Audio input signal connected.<br>R(0) - Video input signal connected. |
| VIDEO | It is possible to specify more than one data word from the KAD/VID/103. The amount of video words specified should be chosen so as to optimize available bandwidth. For example, 10 video words placed at 10:1 commutation in the frame is equivalent to 1 video word placed at 100:1 commutation—the advantage lies in the fact that 10:1 commutation is usually easier to achieve than 100:1 commutation. |

### 30.3.2.2 Setup tab settings

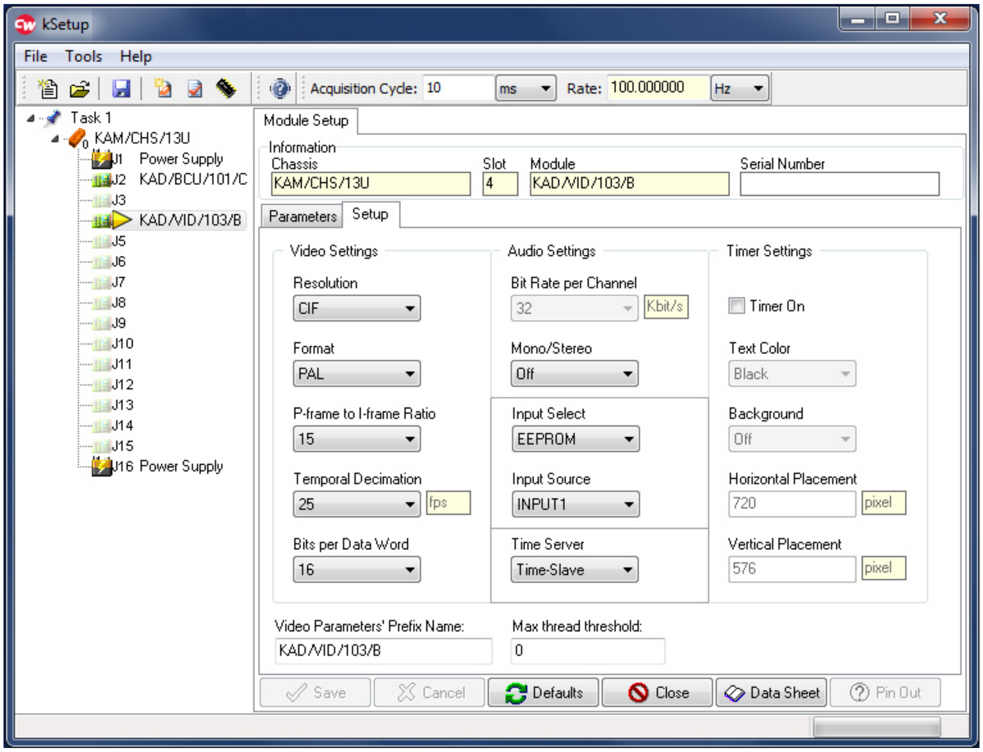



*Figure 30-5: Setup tab in kSetup*

The Setup tab covers video, audio and timer settings, which are described in the following table.

| Setting | Description |
|---|---|
| Resolution | Determines the resolution of the displayed image. For details of options available, see " Resolution options for the KAD/VID/103" on page 190. |
| Format | Determines the input format; PAL (Europe and Asia) or NTSC (the Americas). This setting must match the video source. |
| P-frame to I-frame Ratio | Determines the ratio of P-frames to I-frames in the output video. Allowed values range from All (all I-frames) to 1800' (1 I-frame to every 1,800 P-frames).<br>A higher P-frame to I-frame ratio reduces the amount of bandwidth needed for a given video application. However, the video stream takes longer to recover should any bit errors occur. We recommend using an initial setting of 5:1 and experimenting from there. |
| Temporal Decimation | Determines the number of frames per second (fps) displayed in the video output. This setting can be used as a crude method to reduce bandwidth. For example, displaying 12.5fps uses just over half the bandwidth needed to display 25fps. |
| Bits per Data Word | Determines the number of bits that the video words use; allowed values are 12 or 16 bits. We recommend that 16 bits is used whenever possible. If 12-bit words are to be used, ensure that there is an even number of video words defined in the parameters section. |
| Bit Rate per Channel | This is fixed at 32 kbps per channel. |
| Mono/Stereo | Determines which audio channels (if any) are to be used. |
| Input Select | There are up to three camera inputs. The module acts as a multiplexer so you can switch between cameras. The active channel can be pre-set in the EEPROM during configuration, or it can be read from the configuration of several pins on the connector. Use this option to select which method the module should use to select the camera input. |

| Setting | Description |
|---|---|
| Input Source | If Input Select is set to EEPROM this option specifies the video source. For details of options available, see " Input source options" on page 190. |
| Time Server | This determines the time source for the KAD/VID/103. If Time-Slave is selected, the KAD/VID/103 gets its time from an IRIG source (such as a KAD/BCU/xxx or a KAM/TCG/xxx module). If Free-Running is selected, then the KAD/VID/103 counts its own time from power on, with no reference to outside clocks. |
| Timer On | The KAD/VID/103 can display BCD time in the video output. Checking this box enables this option. |
| Text Color | Determines the timer text color. |
| Background | Determines the background shading of the timer. |
| Horizontal Placement/ Vertical Placement | Determines the location of the timer in x y co-ordinates in pixels from the top-left corner of the screen. |
| Video Parameter's Prefix Name | Enables multiple words of video to be transmitted over Ethernet. For more information, see "30.3.2.3 Prefixing of the video parameter name" on page 190. |
| Max thread threshold | Advance option. Use 0 by default for the compiler to manage the video words on the backplane. |

#### Resolution options for the KAD/VID/103

| Option | Resolution settings (in pixels) |
|---|---|
| CIF | 352 × 288 (PAL)<br>352 × 240 (NTSC) |
| 2CIF | 704 × 288 (PAL)<br>704 × 240 (NTSC) |
| D1 | 704 × 576 (PAL)<br>704 × 480 (NTSC) |

#### Input source options

| Option | Description |
|---|---|
| TEST | Outputs a simple test pattern |
| INPUT1 | Channel 1 composite |
| INPUT2 | Channel 2 composite |
| INPUT3 | Channel 3 composite |
| YC | YC input (S-video) |

### 30.3.2.3 Prefixing of the video parameter name

The video parameter enables video to be transmitted over Ethernet. To enable multiple words of video to be transmitted over Ethernet, the video parameter is prefixed with its parameter name (see the Video Parameter's Prefix Name field in "Figure 30-5: Setup tab in kSetup" on page 189). To allow for more optimized backplane scheduling, we recommend using this naming convention rather than using one video word (and increasing the number of occurrences in the packet). For example, if the parameter name in the Parameters tab is VID3_0_J14_VIDEO_0, to enable multiple words of video to be transmitted over Ethernet, use VID3_0_J14_VIDEO in the Video Parameter's Prefix Name field.

## 30.3.3 Using video

There is no inherent difference between video data and other types of Acra KAM-500 data, except that video data generally uses far greater bandwidth. Video bandwidth (or MPEG-4 bit-rate) for a PCM stream can be calculated as follows:

MPEG-4 bit-rate = number of video words × number of bits per video word × commutation × number of minor frames × frame rate (bps)

A similar approach can be used to calculate the bandwidth for placement in a UDP packet or logging to a memory module (for example a KAM/MEM/103). The MPEG-4 bit-rate needed depends on the application (see the following table for guidelines).

Optimal KAD/VID/103 settings

| Resolution | Frame rate (fps) | | Bit-rate (bps) (minimum to maximum) |
|---|---|---|---|
| | PAL | NTSC | |
| CIF | 1 | 1 | 64k - 100k |
| CIF | 12.5 | 15 | 750k - 1.0M |
| CIF | 25 | 30 | 1.0M - 1.5M |
| 2CIF | 12.5 | 15 | 1.0M - 1.5M |
| 2CIF | 25 | 30 | 2.0M - 2.5M |
| D1 | 12.5 | 15 | 2.0M - 2.5M |
| D1 | 25 | 30 | 4.0M - 4.5M |

**NOTE:** If audio is to be used in the application, up to 64 kbps (32 kbps per channel) extra bandwidth is required.

The KAD/VID/103 is unique amongst Acra KAM-500 modules in that it does not support different sample rates. If video data is being sent to more than one destination in the system (such as a PCM frame, a UDP packet or a memory module) it must be sampled at the same rate by the destination modules. kProgram does not flag this as an error.

### 30.3.3.1 Using video in PCM

Video data can be used in a PCM frame like any other type of data. The KAD/VID/103 is optimized to read and transmit two MPEG-2 packets (376 bytes, 188 video parameters) at a time. Thus to ensure minimum delay, no more than 188 video parameters are read at a time.

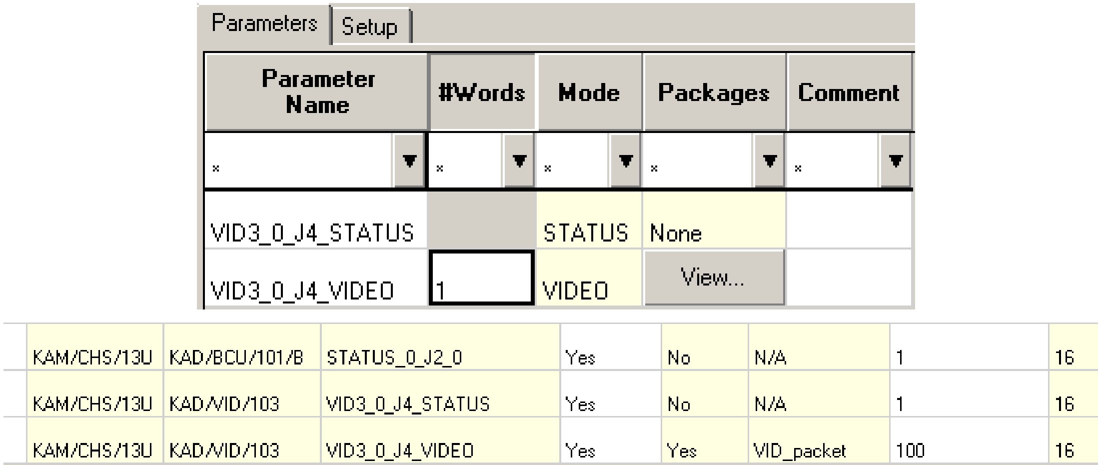
As video data generally uses more bandwidth than other data, we recommend placing the video data prior to placing any other data from the system and placing the first video word as close as possible to the beginning of the frame to ensure reliable operation.

### 30.3.3.2 Using video over Ethernet

Video data can be placed in a UDP packet created by a KAD/ETH/xxx or networked KAD/BCU/xxx module. However, due to the different transmission mechanisms between Ethernet packets and PCM frames, care has to be taken when using video over Ethernet.

The KAD/VID/103 outputs the video words onto the backplane in an order which is transparent. This poses no problem when using PCM—each parameter is always read at a specific time by the controller module and then placed in a specific location in the PCM frame. However, when sampling using Ethernet, the UDP packet is not transmitted until it is *full*. This means that video parameters can appear out of order. Consequently, the MPEG-2 transport stream makes no sense to a decoding device. There are three methods to get around this constraint:

- Use only one video word and transmit it as many times as necessary in the UDP packet (see setup required in “Figure 30-6: Transmitting one video word many times in a UDP packet” on page 192).
  The disadvantage with this method is that the task may not compile due to timing considerations.



| Parameter Name | #Words | Mode | Packages | Comment |
|---|---|---|---|---|
| * | * | * | * | * |
| VID3_0_J4_STATUS | | STATUS | None | |
| VID3_0_J4_VIDEO | 1 | VIDEO | View... | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| KAM/CHS/13U | KAD/BCU/101/B | STATUS_0_J2_0 | Yes | No | N/A | 1 | 16 |
| KAM/CHS/13U | KAD/VID/103 | VID3_0_J4_STATUS | Yes | No | N/A | 1 | 16 |
| KAM/CHS/13U | KAD/VID/103 | VID3_0_J4_VIDEO | Yes | Yes | VID_packet | 100 | 16 |

*Figure 30-6: Transmitting one video word many times in a UDP packet*

- Place the video parameters in a PCM frame to force the ordering in the UDP packet (even if the PCM frame is not going to be used).
  If this method is to be used, ensure video parameters do not occur more than 188 times in a single packet. The disadvantage with this method is that it uses up PCM bandwidth.
- Use the Video Parameter's Prefix Name field to allow multiple words to be transmitted over Ethernet. For more information, see "30.3.2.3 Prefixing of the video parameter name" on page 190.

### 30.3.3.3 Using video with a memory module

Video data can be logged to a memory module like any other type of data. The following two constraints apply:

- Video parameter names must follow the syntax <optional_ label>VIDEO<optional_label>.
- Video words must be sampled at the same rate in the memory module as in the PCM frame (see setup required in the following figure).

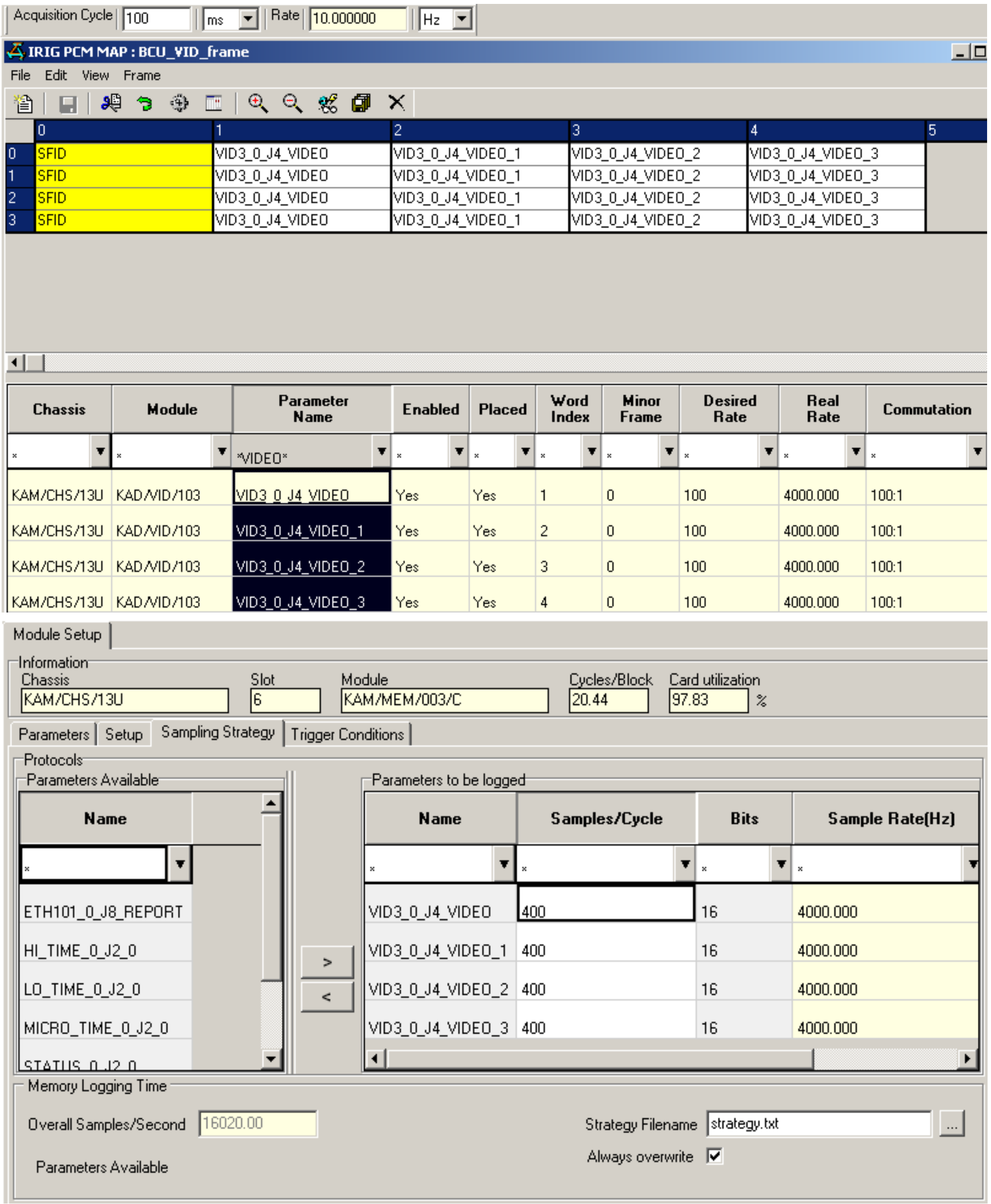


*Figure 30-7: Logging video data to a memory module at the same rate as it is sampled in PCM*

## 30.4 Viewing KAD/VID/103 data

The data from the KAD/VID/103 can be viewed in real-time using gVideo, GS Works 8, or at a later date by using a memory module.

### 30.4.1 Using gVideo

gVideo can be used to decompress up to four separate video streams in one incoming PCM stream. The decompressed video streams can be viewed through either hardware (GTS/VID/001 PCI board) or software (Mplayer).

Mplayer is a third party program ([http://www.mplayerhq.hu/](http://www.mplayerhq.hu/)) with several limitations. It does not support audio and it shows a noticeable latency in the end display. If a system contains a sink module, for example a memory module, that is used to sink video data then gVideo does work but Mplayer is not displayed. To get around this limitation, remove the sink module from the task to be used with gVideo. Due to these limitations we recommend using a GTS/VID/001 module.

**TIP!** Avoid placing the KAD/VID/103 status word in the video PCM stream as this degrades gVideo's performance.

#### 30.4.1.1 Main tab settings

When gVideo is launched the Main tab displays.

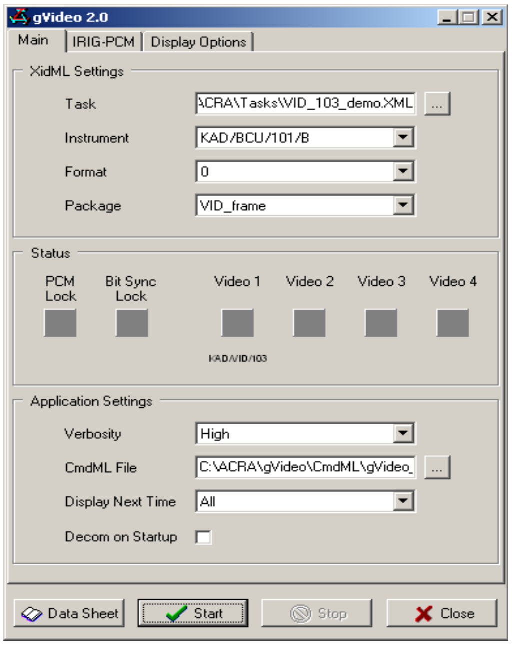



*Figure 30-8: gVideo Main tab settings*

Settings on the Main tab are described in the following table.

| Setting | Description |
|---|---|
| Task | Specifies the XidML file that defines the system configuration. |
| Instrument | Specifies the sink module that is supplying the video data. |
| Format | Specifies the particular system format. |
| Package | Specifies the package (PCM frame, UDP packet) name containing the video data. |
| Status | Indicates the system status when gVideo is running: green indicates status OK; red indicates a problem.<br><br>**NOTE:** It is possible to have PCM lock (green) but no video (red) as shown in the following figure. This indicates a problem with the MPEG-4 bit stream (such as a the MPEG rate being too low). |

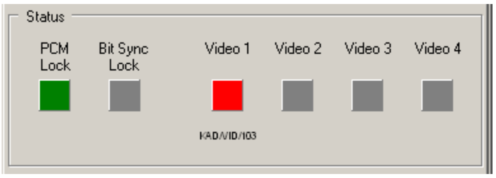



*Figure 30-9: PCM frame in lock with no readable video stream*

### 30.4.1.2 IRIG-PCM tab settings

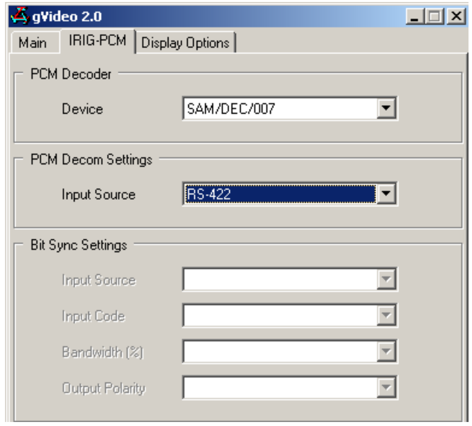



*Figure 30-10: gVideo IRIG-PCM tab settings*

Settings on the IRIG-PCM tab are described in the following table.

| Setting | Description |
|---|---|
| Device | Specifies the device (SAM/DEC/007/C, GTS/DEC/001, GTS/BSC/001) to be used to decommutate the video data. |
| Input Source | Specifies the electrical signaling protocol (RS-422, TTL) that is used to transmit the PCM stream. |

### 30.4.1.3 Display Options tab settings

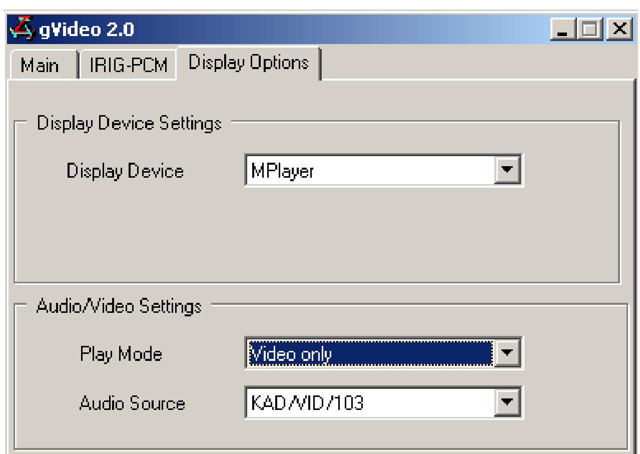



*Figure 30-11: gVideo Display Options tab settings*

Settings on the IRIG-PCM tab are described in the following table.

| Setting | Description |
|---|---|
| Display Device | Specifies the method to be used (Mplayer, GTS/VID/001) to view the video stream. |
| Play Mode | Specifies the data to be decommutated: Video and audio; Video only; or Audio only. |
| Audio Source | If audio is required, specifies the name of the KAD/VID/103 module which is supplying the audio stream. |

**NOTE:** gVideo is now an obsolete product.

## 30.4.2 Using GS Works 8

Video data is treated the same as other types of Acra KAM-500 data by GS Works 8.

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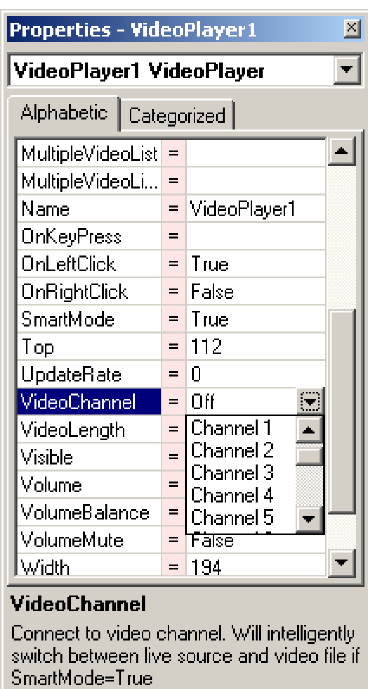
**NOTE:** To view video using GS Works 8, the ffdshow codec must be installed. Download **ffdshow-20041012.exe** from the following link (newer versions of the codec do not work with GS Works 8): http://sourceforge.net/project/showfiles.php?group_id=53761&package_id=59355&release_id=274595

After installing the codec, do the following to view video in GS Works 8.

1. Open GS Works 8 and follow the Start Wizard to load the data you want to view.
2. Click the **Display Builder** button on the dashboard to open the **Display Builder** window.
3. On the **Data Displays** tab, drag the **Analysis Window** icon to the desktop.
4. On the **ActiveX Controls** tab, drag the **VideoPlayer** icon to the **Analysis** window.


5. Right-click the **VideoPlayer** window and select **Properties**.
6. In the **Properties** window, scroll to the **VideoChannel** field and select the channel corresponding to the KAD/VID/103 output from the drop-down menu.




The video stream displays in the VideoPlayer.

## 30.4.3 Using a memory module

As with any data, video data can be logged to a memory module for later viewing. Ensure that the KAD/VID/103 parameters are named <label>VIDEO<label> for correct operation.

Once the video data has been logged to a CompactFlash® card, it can be extracted using kFlashCardXID. The output format must be Video (MPEG-2 Transport Stream) as shown in the following figure.

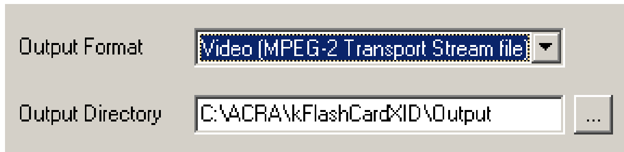



*Figure 30-12: Selecting video output format in kFlashCardXID*

The video is extracted as a transport stream file (<filename>.ts) to the specified output directory. This transport stream file can then be viewed by MPEG viewing software such as VLC (http://www.videolan.org/vlc/).

# 30.5 Troubleshooting

## 30.5.1 Only a blue screen is displayed

This means the KAD/VID/103 is operating correctly but it is not receiving a video stream.

- Ensure the correct 52-way connector is being used (see “30.3.1  Hardware setup” on page 186).
- If camera selection is through the connector ensure the correct pins are grounded (see CAM_SEL_BIT_0, CAM_SEL_BIT_1, and CAM_SEL_BIT_2 described in “30.3.1.1  Pinout connections” on page 187).
- If camera selection is through EEPROM ensure the camera is connected to the correct input (see Input Select described in “30.3.2.2  Setup tab settings” on page 189).
- Ensure the camera is working.

## 30.5.2 gVideo (or GS Works 8) is in PCM lock but no video is displayed

This usually means there is either a problem with the KAD/VID/103 video data, or with destination modules.

- Ensure the correct output format is selected (PAL or NTSC) (see Format described in “30.3.2.2  Setup tab settings” on page 189).
- Ensure the MPEG bit-rate is adequate for the application. For information, see “30.3.3  Using video” on page 191.
- If more than one destination module is being used in the system, ensure that the KAD/VID/103 data is sampled at the same rate in each destination module. For information, see “30.3.3  Using video” on page 191.
- If a sink module (such as a memory module) is being used to sink video data, remove the sink module from the XidML task that gVideo uses. For information, see “30.3.3  Using video” on page 191.

## 30.5.3 The clock is not visible

- Ensure Timer On is enabled (see Timer On described in “30.3.2.2  Setup tab settings” on page 189).
- If CIF resolution is selected, the location of the timer may need to be altered; we recommend (x, y) = (100, 100). For information, see Horizontal Placement/Vertical Placement described in “30.3.2.2  Setup tab settings” on page 189.

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Chapter 31

# Using the KAD/CBM/102

TEC/NOT/056

The KAD/CBM/102 is a CAN (Controller Area Network) bus monitor, a coherent message parser and an error-detection function within a single module. This paper explains how to set up the KAD/CBM/102 for CAN bus monitoring and is divided into the following sections:



## 31.1 Introducing CAN bus traffic

It is essential to understand the structure of CAN bus traffic to fully comprehend how the KAD/CBM/102 monitors it.

### 31.1.1 The physical layer

The physical layer is a differential two-wire interface with CANH and CANL wires for each bus. Bit encoding used is Non-Return to Zero (NRZ) encoding (with bit-stuffing).

The use of NRZ encoding ensures compact messages with a minimum number of transitions and high resilience to external disturbance. Cable length depends on the data rate used (40 meters for 1 Mbps).

The CAN bus uses the following drive voltages:

- High - 2.75 to 4.5 volts
- Low - 0.5 to 2.25 volts
- Differential - 1.5v to 3.0 volts

### 31.1.2 Word definition

A CAN network can be configured to work with two different message (frame) formats: CAN 2.0 A (standard/base frame format) or CAN 2.0 B (extended frame format). The following two figures show the structure of the two formats.

The only difference between the two formats is the bit length supported for the identifier (ID). CAN 2.0 A supports a length of 11 bits for the ID; CAN 2.0 B supports a length of 29 bits for the ID—this comprises the 11-bit ID and an 18-bit extension (IDE). The IDE bit is transmitted as dominant in the case of an 11-bit frame, and transmitted as recessive in the case of a 29-bit frame.

CAN controllers that support CAN 2.0 B messages are also able to send and receive messages in CAN 2.0 A. All frames begin with a Start-Of-Frame (SOF) bit which denotes the start of the frame transmission. For definitions of fields shown in the following two figures, see Table 31-1 on page 200.

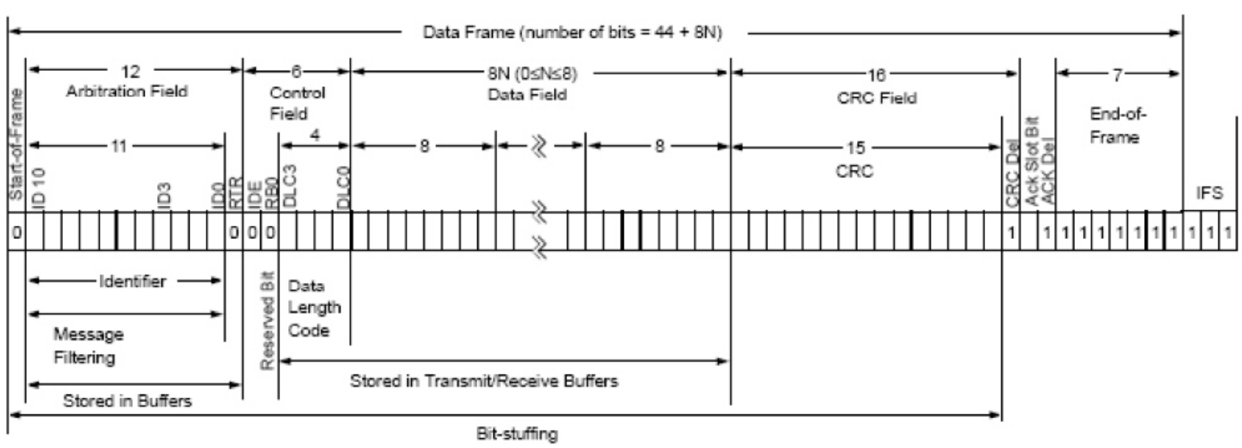



*Figure 31-1: CAN 2.0 A*

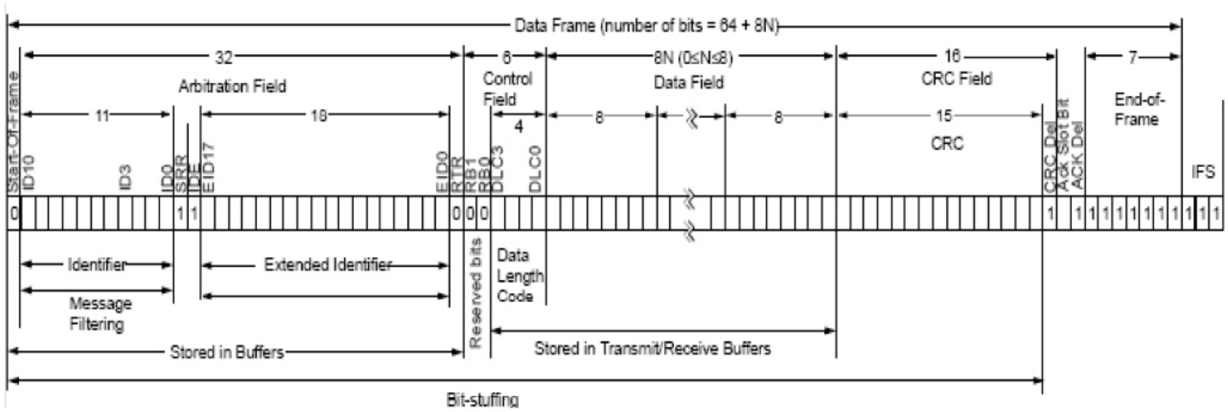



*Figure 31-2: CAN 2.0 B*

Table 31-1: Frame format fields

| Frame format field | Description |
|---|---|
| ID (Identifier) / IDE (Extended IDentifier) | CAN2.0 A—11 bits; CAN2.0 B—29 bits |
| SSR | Substitute remote request - CAN2.0 B (masked by default) |
| RTR | Remote transmission request - CAN 2.0 A |
| DLC (Data Length Code) | Number of data bytes to be transmitted (0 to 8 bytes) |
| Data field | Data to be transmitted |

# 31.2 Features of the KAD/CBM/102 in relation to CAN bus monitoring

## 31.2.1 Parsing

Like other Curtiss-Wright bus monitors, the KAD/CBM/102 uses a triple buffer for parsing. The following figure shows the triple buffering of words and tags used for each bus in the KAD/CBM/102 parser.

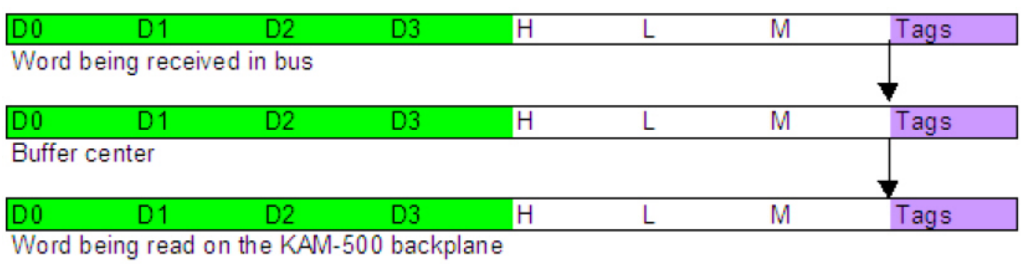



*Figure 31-3: Triple buffering of traffic and associated tags (abbreviations defined in table below)*

Table 31-2: Traffic definitions

| Abbreviation | Definition |
|---|---|
| D0, D1, D2, D3 | Traffic |
| H | High time |
| L | Low time |
| M | Micro time |

### 31.2.2 Skipped and Stale flag settings

Time tags and a word count are added to each word received and stored in separate buffers for each of the four busses. As soon as a message is received with no errors, the complete buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a Skipped flag is set and the message is lost.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the content of the center buffer (if new) is transferred to the read buffer. If no new message has been received, the Stale flag is set. A center and read buffer exist for every message.

## 31.3 Using kSetup to configure the KAD/CBM/102

The KAD/CBM/102 has four busses and can coherently parse traffic and tags for up to 126 complete messages per bus. You can use kSetup software to configure the KAD/CBM/102 according to your requirements. kSetup is included in the KSM-500 suite of tools.

### 31.3.1 Setting parameters

To set parameters for the KAD/CBM/102, select the module in the Task Explorer pane of kSetup. On the Parameters tab (see the following figure), complete the fields described in Table 31-3 on page 201.

For more information on using kSetup, contact Curtiss-Wright support (acra-support@curtisswright.com).

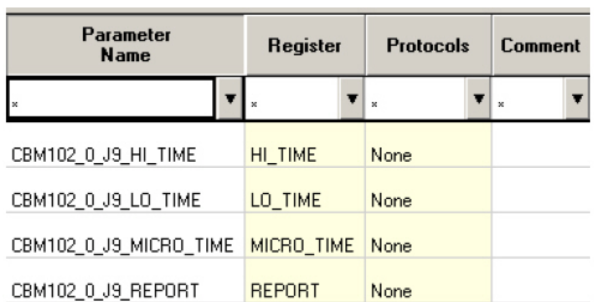



*Figure 31-4: Standard parameter settings on the Parameters tab of kSetup*

Table 31-3: Parameter settings

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter |
| Register | The Report register is useful to transmit when monitoring message problems; for details of register definitions, see the *KAD/CBM/102* data sheet |
| Protocols | When the parameter is placed in a PCM frame, click on the Package button to display transmission details |
| Comment | User-defined text relating to the parameter |

### 31.3.2 Defining messages

The first four default messages parse any messages received on a bus (similar to a snarfer). If they're used as transmitted parameters, the corresponding parameter must be sampled fast enough to ensure that all messages in the bus are parsed. Also, the ground station should have the ability of decommutating such a parameter.

You can edit message characteristics or add new messages on the Messages tab (see the following figure).

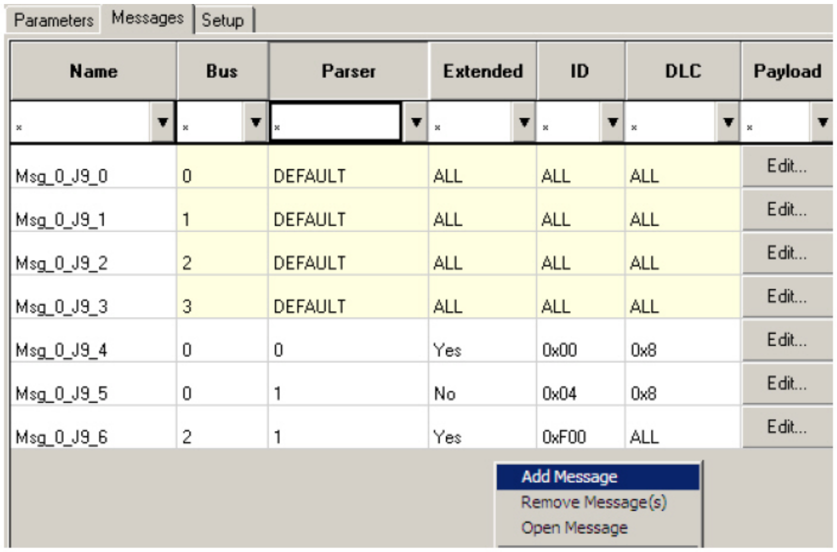



*Figure 31-5: Adding messages*

To add a new message, do the following:

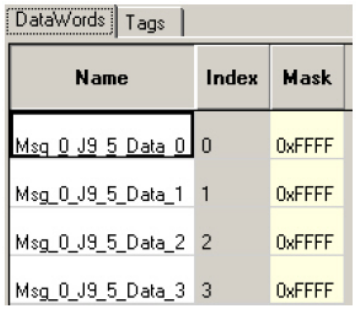
1. Right-click the spreadsheet and select **Add Message** (see the previous figure).
2. In the **Name** column, select the name of a bus.
3. Complete the fields described in the following table.

Table 31-4: Message settings

| Field name | Description |
|---|---|
| Name | Name of the bus; package corresponding in the XidML® file will be changed accordingly |
| Bus | Bus number from 0 to 3 |
| Parser | Parser identifier; must be unique across all messages and within the following ranges:<br>Bus 0: 0 to 126<br>Bus 1: 128 to 254<br>Bus 2: 256 to 382<br>Bus 3: 384 to 510 |
| Extended | If No is selected, the message to be parsed must be CAN2.0A (11 bits CAN ID)<br>If Yes is selected, the message to be parsed must be CAN2.0B (29 bits CAN ID) |
| ID | CAN ID in hexadecimal |
| DLC | Data Length Code corresponds to the number of data bytes to be transmitted (0 to 8 bytes or ALL)<br>ALL is a wildcard on the DLC; if the ALL wildcard is used, any message with the same CAN ID is parsed |
| Payload | Message DataWords and tags (see “31.3.2.1 Defining payload settings” on page 202) |

### 31.3.2.1 Defining payload settings

To edit DataWords for a message, click Edit (on the right of the message). After clicking Edit, the DataWords tab displays default DataWords (see the following figure). Double-click any DataWord to edit the name.



| Name | Index | Mask |
|---|---|---|
| Msg_0_J9_5_Data_0 | 0 | 0xFFFF |
| Msg_0_J9_5_Data_1 | 1 | 0xFFFF |
| Msg_0_J9_5_Data_2 | 2 | 0xFFFF |
| Msg_0_J9_5_Data_3 | 3 | 0xFFFF |

*Figure 31-6: DataWord settings*

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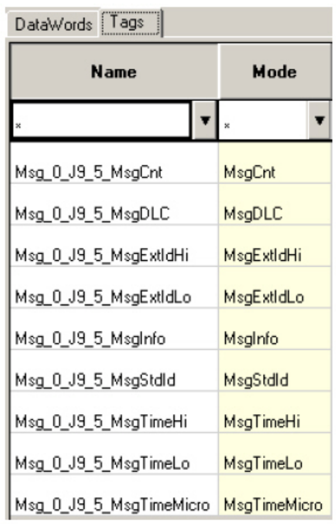
**NOTE:** The CAN bus is described in bytes. The KAD/CBM/102 concatenates two bytes in one 16-bit parameter.

On the Tags tab, default parameter names are displayed. Double-click to edit any tag parameter name.



| Name | Mode |
|---|---|
| Msg_0_J9_5_MsgCnt | MsgCnt |
| Msg_0_J9_5_MsgDLC | MsgDLC |
| Msg_0_J9_5_MsgExtIdHi | MsgExtIdHi |
| Msg_0_J9_5_MsgExtIdLo | MsgExtIdLo |
| Msg_0_J9_5_MsgInfo | MsgInfo |
| Msg_0_J9_5_MsgStdId | MsgStdId |
| Msg_0_J9_5_MsgTimeHi | MsgTimeHi |
| Msg_0_J9_5_MsgTimeLo | MsgTimeLo |
| Msg_0_J9_5_MsgTimeMicro | MsgTimeMicro |

*Figure 31-7: Tag settings*

Values in the Mode column are read-only. For details of parameter descriptions, see the *KAD/CBM/102* data sheet.

### 31.3.3 Setting baud rates

On the Setup tab (see the following figure), you can set CAN bus baud rates for each bus.

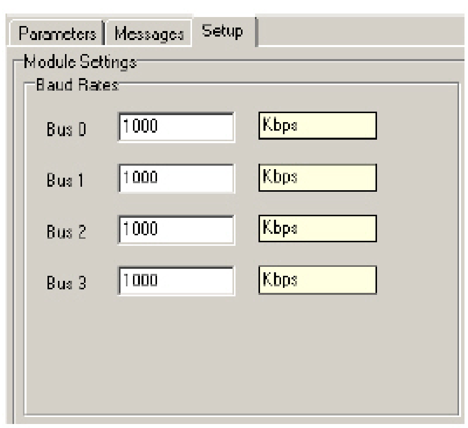



*Figure 31-8: Setting baud rates*

For information on baud rates supported, see the *KAD/CBM/102* data sheet.

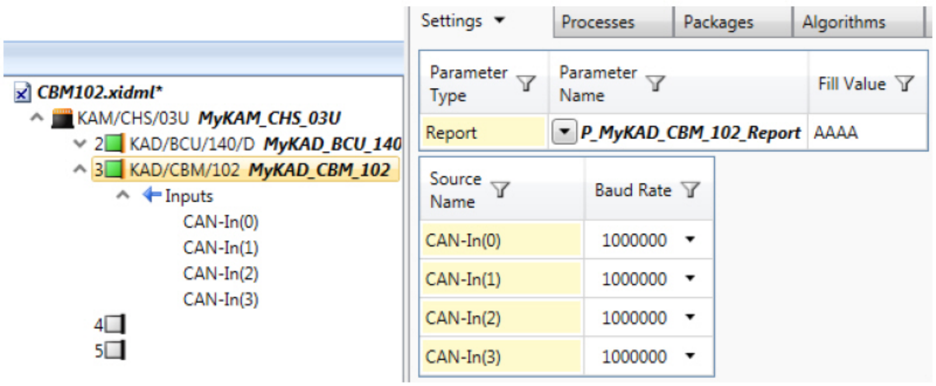
## 31.4 Using DAS Studio 3 to configure the KAD/CBM/102

The KAD/CBM/102 has four busses and can coherently parse traffic and tags for up to 126 complete messages per bus. You can use DAS Studio 3 software to configure the KAD/CBM/102 according to your requirements.

### 31.4.1 Adding messages with the CAN-Bus Builder

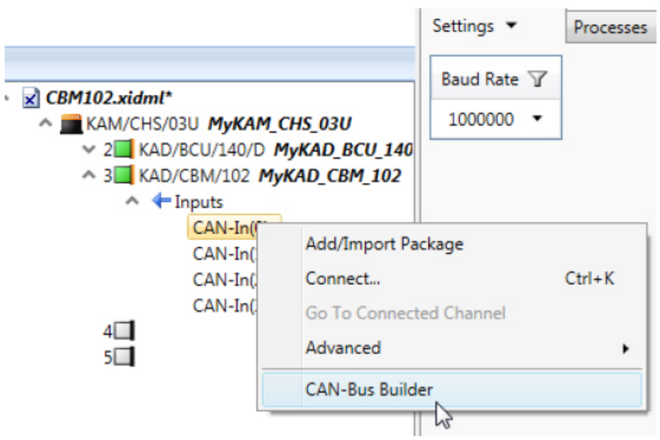
In the following example, the configuration consists of a chassis, a KAD/BCU/140 controller, and a KAD/CBM/102 module.

1. With the **KAD/CBM/102** module in context, click the **Settings** tab.

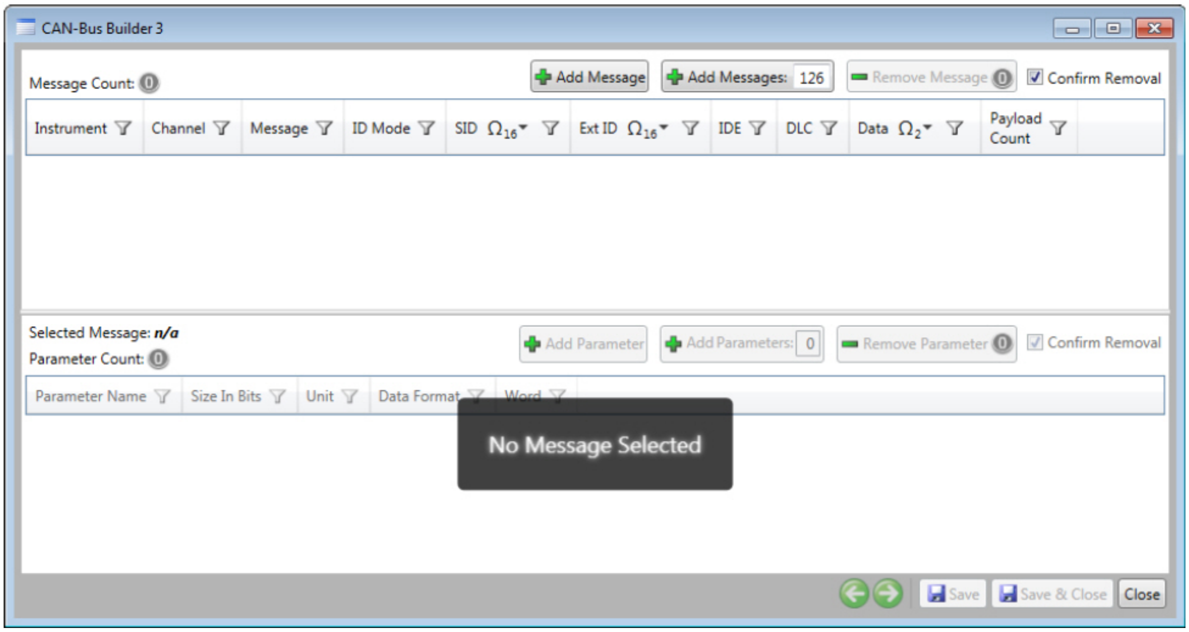



The **Settings** tab contains the **Report** parameter, the fill value, and the configuration of the baud rate for each of the four buses. Refer to the *KAD/CBM/102* datasheet for further details on these fields.

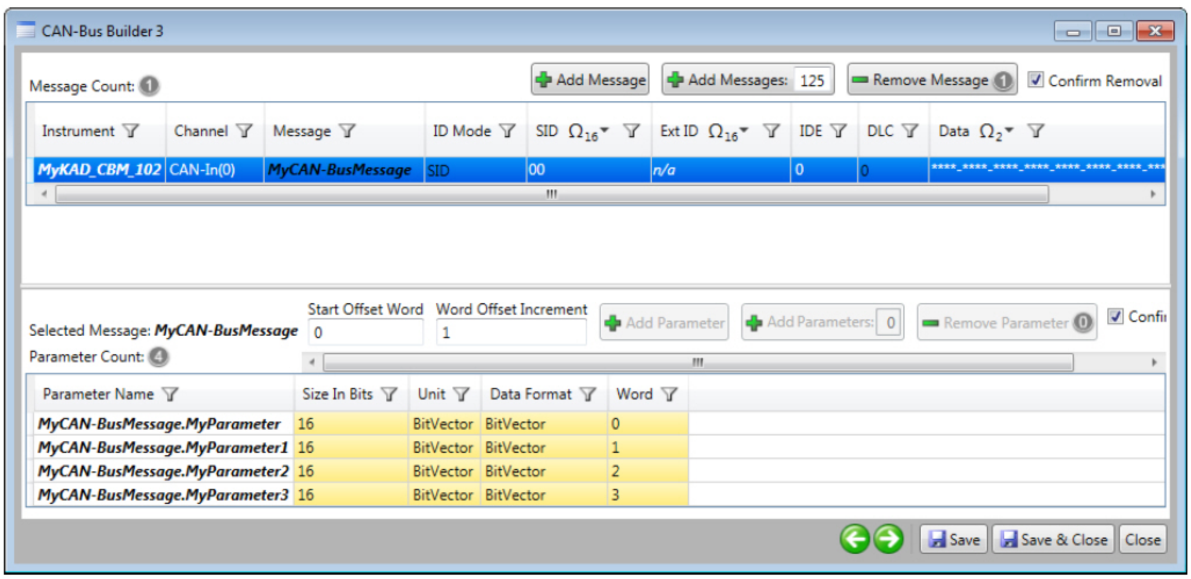
2. Right-click one of the **CAN-In** busses and then click **CAN-Bus Builder**.



The **CAN-Bus Builder 3** dialog box opens.




3. To add messages for parsing, type the number of messages in the **Add Messages** field and then click **Add Messages**.

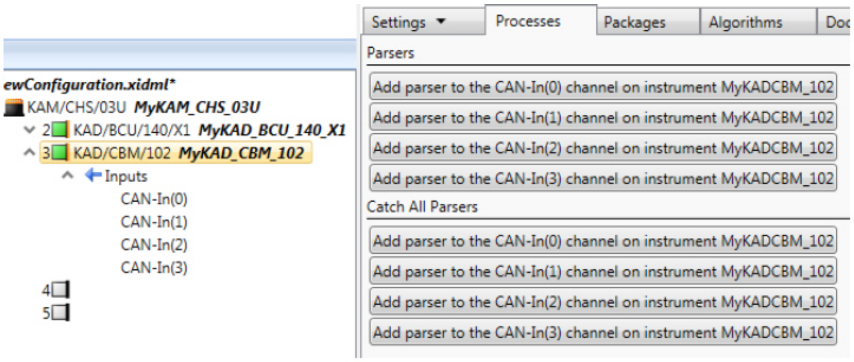



4. To add parameters to a message, type the number of parameters in the **Add Parameters** field and then click **Add Parameters**.
   For more information, see “CAN-Bus Builder” in the “Applications” chapter of the *DAS Studio 3 User Manual*.

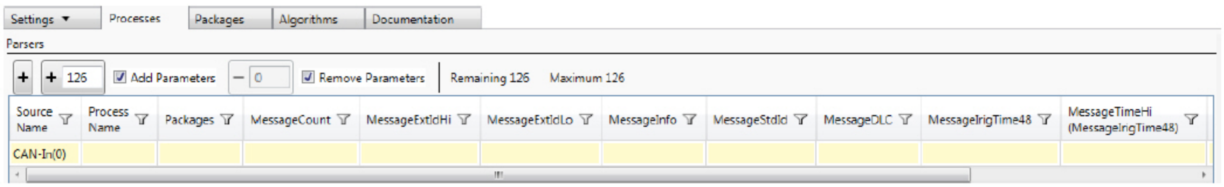
## 31.4.2 Creating a parser process

Use the Processes tab to read package tags. Package tags are associated information such as message count and time when the last bit of the message was received by the module. To read a package tag, you must first create a new parser process.

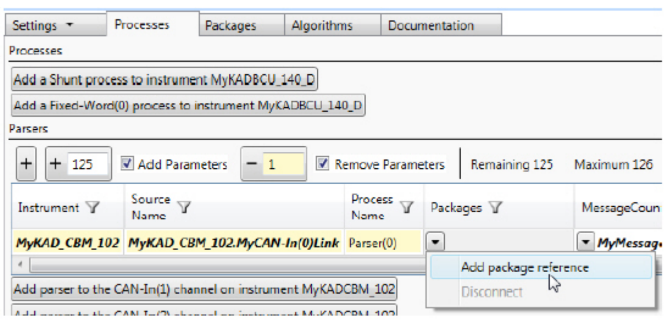
1. With the **KAD/CBM/102** module in context, click the **Processes** tab.



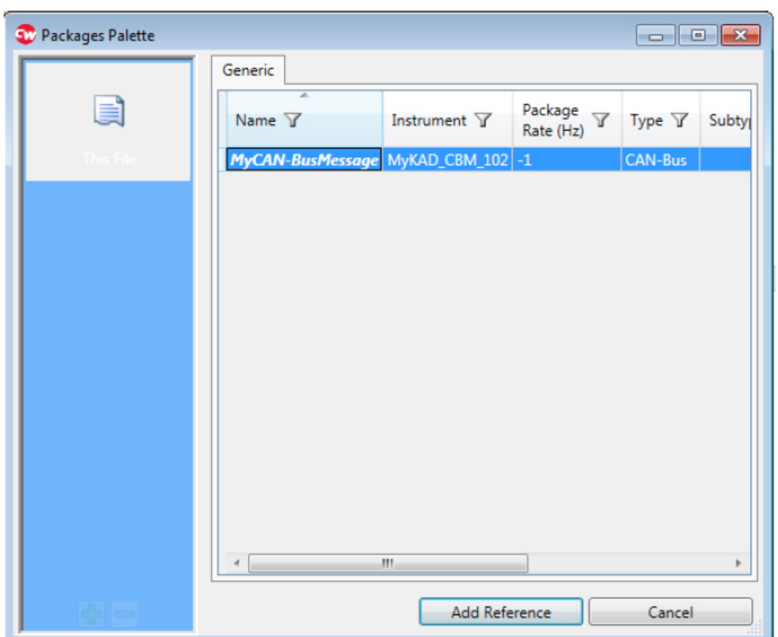

2. In the **Parsers** pane, click **Add parser to the CAN-In(0) channel on...** button to show all supported parser parameters. Refer to the *KAD/CBM/102* data sheet for the bit definitions of each parameter.



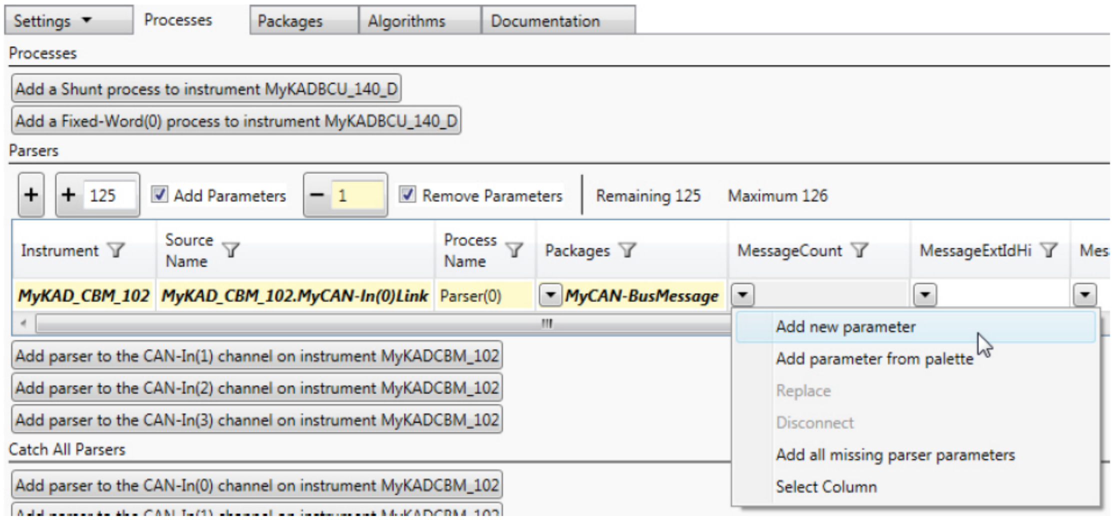

3. In the **Packages** drop-down menu, click **Add package reference**.



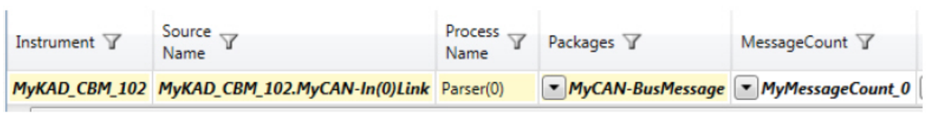

4. In the **Packages Palette** dialog box, select the message to which the parser parameters will be added and then click **Add Reference**.



5. In the **MessageCount** drop-down menu, click **Add new parameter**.




The message count parameter for the message defined is now available to be transmitted to any sink modules.

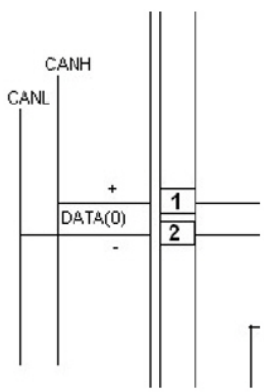



For more information, see the “Processes tab” chapter of the *DAS Studio 3 User Manual*.

# 31.5 Troubleshooting

## 31.5.1 The module is not parsing as expected

1. Ensure CANH is correctly wired to DATA+ and CANL is correctly wired to DATA- as shown in the following figure.




2. Ensure the baud rate is set appropriately (see “31.3.3 Setting baud rates” on page 203 for details).
3. Ensure the CAN bus ground is connected to the Acra KAM-500 ground (GND). See *TEC/NOT/063 - Grounding and shielding of the Acra KAM-500*.
4. Ensure the CAN bus being monitored does not require an acknowledgment before transmitting CAN data.
   The KAD/CBM/102 is silent, meaning it only monitors and does not transmit or acknowledge.

**NOTE:** 120-ohms termination is not needed as the KAD/CBM/102 monitors only CAN bus traffic.

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Chapter 32

# Overview of SNMP and using third party SNMP tools

TEC/NOT/058

There are a number of open standard network protocols that can be used to discover, manage, and debug networked based Flight Test Instrumentation (FTI) systems. One such protocol is Simple Network Management Protocol (SNMP), which is a standard IP network protocol that can be used to interrogate, query, and configure SNMP-enabled devices such as the NET/REC/XXX or SSR/CHS/XXX recorder, or the KAD/BCU/140 Ethernet controller. You can also carry out other tasks such as turning on recordings and setting Events via SNMP.

To describe how SNMP operates and how it can be used to interact with SNMP-enabled Curtiss-Wright devices, this paper is divided into the following sections:



## 32.1 Overview of the SNMP

SNMP is a simple but powerful protocol that can be used to discover (GET) and configure (SET) information in SNMP-enabled devices. SNMP is a component of the Internet Protocol Suite as defined by the Internet Engineering Task Force (IETF). It consists of a set of standards for network management, including an application layer protocol, a database schema, and a set of data objects. SNMP exposes management data in the form of variables on the managed systems, which describe the system configuration. Variables on the network end node can then be read (GET) or configured (SET) by a remote station. The end node is controlled by the remote computer. In addition, an end node may be configured to set a trap (TRAP) for key events without the need for polling.

SNMP uses an extensible and customizable Management Information Base (MIB) to describe the variables that may be accessed in the FTI device including the structure, interpretation and read/write attributes of the supported variables. The MIB contains global variables that are common to all networked FTI devices.

In networked FTI, SNMP may be used to monitor and remotely configure network nodes such as:

- Data Acquisition Units (DAUs)
- Switches
- PTP Grandmasters
- Network Recorders

Each of these classes of device has a set of specialized discoverable variables that are also described in the MIB.

An SNMP-managed network consists of three key components as shown in the following figure:

- **Network Management System (NMS):** A software application that monitors and controls managed devices in the networked FTI system. NMSs provide the bulk of the processing and memory resources required for network management. There may be one or more NMSs managing the network. The NMS uses User Datagram Protocol (UDP) port 162 for SNMP.
- **Managed device:** A managed network node (DAU, switch, PTP Grandmaster, network-recorder etc.) that contains an SNMP agent. Managed devices collect and store management information and make this information available to NMSs via the SNMP protocol.
- **Agent:** A piece of software which handles SNMP requests that resides in the managed device. An agent has local knowledge of management information and translates that information into a form compatible with SNMP. The agent uses UDP port 161 for SNMP.

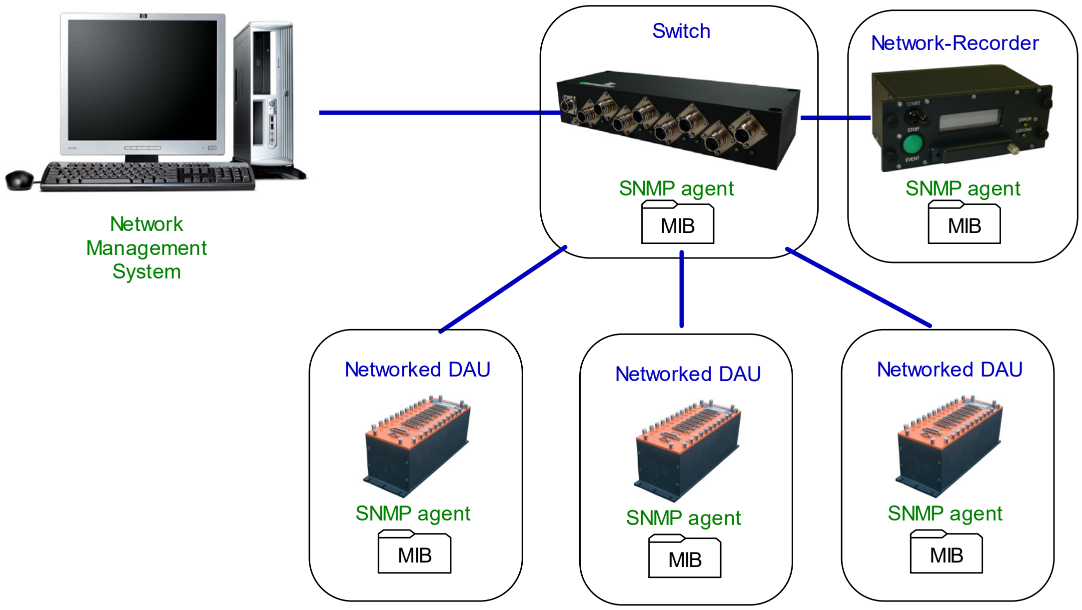


*Figure 32-1: An SNMP-managed network*

The SNMP protocol is a request-response protocol whereby the NMS issues queries and configures commands via SNMP to the managed device, for example the SNMP messages described in Table 32-1 on page 211 and the SNMP-enabled DAU as shown in the following figure. (See the Microsoft® TechNet SNMP web page for an overview on this topic.)

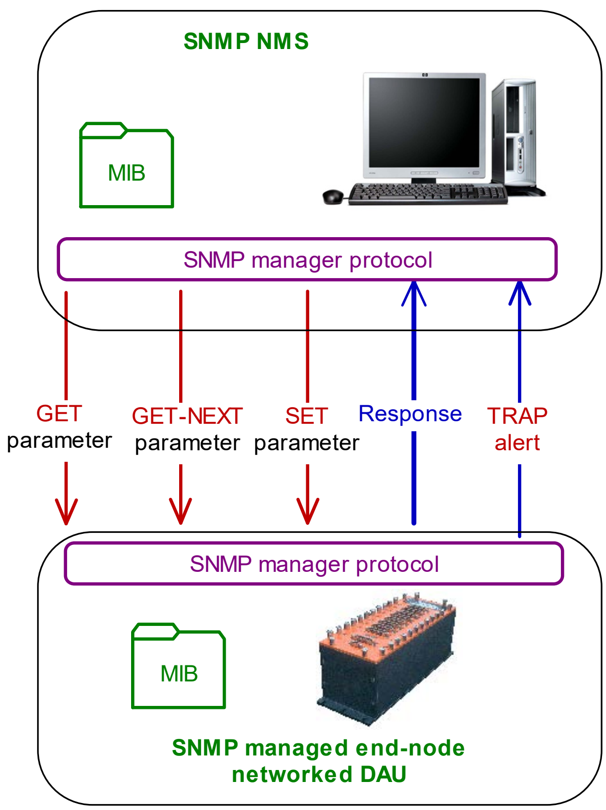


*Figure 32-2: SNMP messages in action*

Table 32-1: SNMP messages

| SNMP version | SNMP command | Description of messages used by the NMS |
|---|---|---|
| V1 | GET | Retrieves the value of one or more object instances from an agent. For example, GET EventNumber. |
| V1 | GETNEXT | Retrieves the value of the next object instance in a table or a list within an agent. For example, GETNEXT NextEventNumber. |
| V1 | SET | Sets the values of object instances within an agent. For example, SET IPAddress. |
| V1 | TRAP | Asynchronously informs the NMS of a significant event. For example, TRAP TemperatureExceedsThreshold. |
| V2c | GETBULK | Efficiently retrieves large blocks of data. |

### 32.1.1 Comments on SNMP usage

It is clear that SNMP is a powerful protocol for reconfiguring and querying devices for key settings. However, there are some caveats that must be considered before it is implemented.

- Although TCP transport is possible, SNMP typically runs over UDP, which is a connectionless protocol that does not provide packet delivery acknowledgments or retransmit lost packets. Therefore, there can be no guarantee that commands/messages issued by SNMP are correctly propagated through the network. To mitigate this, each SNMP-SET operation should be safeguarded by a subsequent SNMP-GET operation to verify the success of the SET.
- SNMP allows the NMS to potentially configure critical variables that alter the devices' configuration and operation. Care should be taken when determining the variables that can be set via SNMP. These variables should not interrupt packet switching, data acquisition or allow the device to enter an unstable state. Such critical variables are protected from accidental SNMP SETs using the locking mechanism described in "32.5.2 Setting protected variables using SNMP with Curtiss-Wright devices" on page 223.
- There are several flavors of the SNMP protocol. As currently specified, SNMPv2 is incompatible with SNMPv1 in two key areas: message formats and protocol operations. SNMPv2c messages use different header and Protocol Data Unit (PDU) formats from SNMPv1 messages. SNMPv2c also uses two protocol operations that are not specified in SNMPv1. However, RFC1908 defines two possible SNMPv1/v2c coexistence strategies: proxy agents and bilingual network-management systems.
- SNMPv1 and SNMPv2c pose a security risk in that packet sniffing can be used to monitor auto-discovery advertisements. Although this has been addressed in SNMPv3 through the introduction of encryption techniques, SNMPv3 has a significantly larger footprint and consumes onerous processing resources.

## 32.2 MIBs

SNMP is a protocol and does not define which information or variables are managed. The variables accessible via SNMP are organized in hierarchies with meta-data (type and variable description). The variables accessible via SNMP are described by MIB files. MIBs describe the structure of the management data of a device subsystem using a hierarchical namespace containing Object IDentifiers (OID) as shown the following figure. Each OID is unique and identifies a variable that can be read or set via SNMP. The following types of managed objects exist:

- Scalar objects define a single object instance.
- Tabular objects define multiple related object instances that are grouped in MIB tables.

One can either access the hierarchy solely via dot-delimited numbers, dot-delimited strings, or a combination of both. For example, the three object identifiers below are all equivalent:

```
.1.3.6.1.4.1.33698.10.21.0
.iso.org.dod.internet.private.enterprises.acra.recorder.controlMethod.0
.iso.org.dod.internet.private.enterprises.33698.10.21.0
```

**NOTE:** A full listing of the values that can appear in the OID node that comes after *enterprises* can be found at: http://www.iana.org/assignments/enterprise-numbers

A useful feature of the NMS is its ability to perform a MIB or SNMP walk whereby the walk can retrieve a sub-tree of the available variable hierarchy from a specified OID branch and the values returned to the NMS. The MIB walk is achieved using SNMP-GETNEXT messages. For example, by instructing an SNMP walk to start at .iso.org.dod.internet.private.enterprises.acra the variables in the acra subtree can be listed, ignoring any variables which might exist under any of the nodes which are not highlighted in the following diagram:

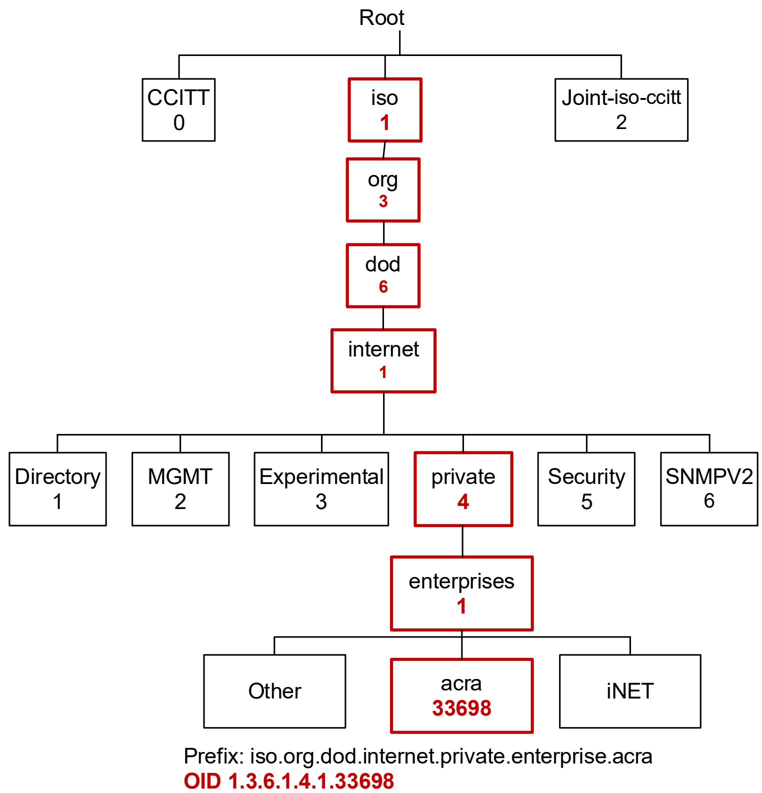


*Figure 32-3: OID hierarchy*

## 32.2.1 Reading the MIB file

The MIB file describes the managed objects or variables and their properties that can be accessed via SNMP. The Abstract Syntax Notation One (ASN.1) is a standard formal and flexible notation used to describe data structures for representing, encoding, transmitting and decoding data. ASN.1 provides a set of formal rules for describing the structure of objects that are independent of machine-specific encoding techniques and is a precise, formal notation that removes ambiguities.

The MIB file is written using the Structure of Management Information (SMI) notation, which is an adapted subset of the ASN.1.

SMI subdivides into the following three parts:

- **Module definitions**: Describes information modules. An ASN.1 macro, MODULE-IDENTITY, is used to concisely convey the semantics of an information module.
- **Object definitions:** Describes managed objects. An ASN.1 macro, OBJECT-TYPE, is used to concisely convey the syntax and semantics of a managed object.
- **Notification definitions:** (aka *traps*) Describes unsolicited transmissions of management information. An ASN.1 macro, NOTIFICATION-TYPE, concisely conveys the syntax and semantics of a notification.

### 32.2.1.1 Example of reading the MIB file

The following is an extract from the Acra MIB. All variables (or managed objects) and their hierarchy are described in the MIB. The managed object hierarchy and its mapping to OID is described in the MIB. For example, the following line indicates that the Acra sub-tree (belonging to the Curtiss-Wright Acra Business Unit, formerly ACRA CONTROL Ltd.) is associated with an OID value of 33698 under the enterprises branch:

```
acra OBJECT IDENTIFIER ::= { enterprises 33698 }
```

This is the trunk of the main Acra tree. It starts out with defining the main subtree **acra** as under the enterprises node and identified as sub-node 33698. So, the full path so far is `iso.org.dod.internet.private.enterprises.33698`.

Navigating into the Acra sub-tree, the following hierarchy is in place:

```
devices OBJECT IDENTIFIER ::= { acra 1 }
settings OBJECT IDENTIFIER ::= { acra 2 }
...
recorder OBJECT IDENTIFIER ::= { acra 10 }
...
```

Therefore, to reach the Acra recorder sub-tree, the OID is:

```
iso.org.dod.internet.private.enterprises.acra.recorder
1  .3  .6  .1       .4      .1          .33698.10
```

The MIB also defines the managed objects that may be accessed via SNMP. By way of illustration, using an SNMP variable definition within the MIB, consider the variable defined as the `controlMethod`. This `controlMethod` variable is used with the NET/REC/XXX and SSR/CHS/XXX products to configure how a recorder is to be controlled. Three control methods are possible locally using the front panel START/STOP and EVENT buttons (`local, 0`); using SNMP commands over the network (`network, 1`); or remotely using discrete I/O signals (`remote, 2`). The `controlMethod` object has an `integer` value with three possible values relating to the three control methods. This variable has `read-write` access so SNMP-SET and SNMP-GET commands can be used to retrieve and modify the value of this variable. The default value, `DEFVAL`, is `network`, as seen in the following code:

```
controlMethod  OBJECT-TYPE
SYNTAX     INTEGER {
local (0),
network (1),
remote (2)
}
MAX-ACCESS read-write
STATUS     current
DESCRIPTION
"Method of controlling the recorder.
Only the control method listed in this variable shall control the recorder
with the exception that the controlMethod variable itself shall always be
modifiable with SNMP.
(0) local - controlled by front panel,
(1) network - controlled over the network via SNMP,
(2) remote - discrete I/O signal controlled from cockpit."
DEFVAL  { network }
::= { recorder 21 }
```

The final entry in this MIB entry is the location of the variable within the MIB hierarchy. In this case the `controlMethod` variable is located at subtree index 21 within the recorder branch of the MIB:

| iso | org | dod | internet | private | enterprises | acra | Recorder | ControlMethod |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 10 | 21 |

The final part of the OID indicates whether the variable is a scalar object, a tabular object, or an array object. Scalar variables describe a single object instance, whereas tabular variables describe multiple related instances. For example, `controlMethod` is scalar, because there is only one variable in the recorder which determines how the recorder is controlled. The description of an Ethernet port (`iso.org.dod.internet.mgmt.mib-2.interfaces.ifTable.ifEntry.ifDescr`) is tabular because a device may have multiple Ethernet ports.

In the OID for a scalar variable, the final part of the OID is 0. In a tabular OID, the final part is the index, with 1 indicating the first item in the table. So, for example, a switch with eight ports would have variables `...ifEntry.ifDescr.1 to ...ifEntry.ifDescr.8` giving descriptions of the eight ports.

Since `controlMethod` is scalar, the index value is 0.

The syntax of the path for this OID is:

```
.iso.org.dod.internet.private.enterprises.acra.recorder.controlMethod.0
.1.3.6.1.4.1.33698.10.21.0
```

The MIB sections list out in great detail the hierarchy under the acra subtree; time, devices, settings, identification, and so on. It's not necessarily in the order above. Nor are all the sections actually supported by all actual devices. Since all the sections are similar, only some example subtree sections are discussed below.

### Settings subtree section

The Settings section is where most of the important variables are defined. One of the most common uses of SNMP is to set the IP address.

```
ipSetVar OBJECT-TYPE
        SYNTAX   IPSetVarType
        ACCESS   read-write
        STATUS   current
        DESCRIPTION
"Combined MAC address, IP address and IP mask"
        ::= { settings 1 }
```

In this case, we are looking at the ipSetVar node, which shows the MAC, IP address and IP mask together in one variable. It can be accessed by the full path of `.iso.org.dod.internet.private.enterprises.33698.2.1.0`.

In a recorder, you might want to increment the Event number, by setting the `triggerRemoteEvent` variable. To do this, you have to go through the triggers node:

```
.iso.org.dod.internet.private.enterprises.33698.3.10.1.0
-- Triggers
recorderTriggers OBJECT IDENTIFIER ::= { triggers 10 }
triggerRemoteEvent OBJECT-TYPE
SYNTAX INTEGER (0..1)
ACCESS read-write
STATUS current
DESCRIPTION
"Event increment variable, writing 1 to this variable will increment the event
number reading from this variable returns the current event number"
DEFVAL { 0 }
::= { recorderTriggers 1 }
```

### Time subtree section

```
Subtree under acra.time
ptp2           OBJECT IDENTIFIER ::= { time 9 }
```

Since time is subtree acra.13, then ptp2 is subtree acra.13.9.

Ptp2 doesn't show up on all devices, even networks switches; the NET/SWI/004/EM1, for example, does not support PTPv2, and therefore does not have any variables in the Ptp2 subtree.

### Device Identifiers section

This section lists every device Curtiss-Wright supports with SNMP, as of the time the version of the MIB file was released. To see the description, look at the entries under acra.devices.

**NOTE:** Devices from Acra use the acra.devices OIDs to specify an identifier for each device type. A more descriptive variable, which lists version numbers, is in: `.iso.org.dod.internet.mgmt.mib-2.system.sysDescr.0`.

## 32.3 SNMP and the MIB in action

To demonstrate SNMP in action, the example of SNMP as shown in the following figure is described. Consider a system comprised of an NMS and an SNMP-enabled DAU, where the DAU has a hypothetical SNMP-Trap variable for temperature. The NMS sends an SNMP-GET message to the DAU to retrieve the value for the temperature threshold variable as defined in the MIB supported by the DAU. The DAU's own SNMP-Agent interprets the received SNMP-GET message containing the OID of the temperature threshold variable. In this way, the DAU SNMP-Agent can retrieve the desired variable value and return the appropriate response to the requesting NMS. Should the NMS choose to reconfigure the temperature threshold variable on the DAU, the NMS sends an SNMP-SET message to the DAU. However the temperature threshold variable must have read/write attributes so that it can be reconfigured. The SNMP-Agent continuously monitors its current temperature over time. When the DAU detects that the current temperature exceeds the newly defined temperature threshold, the DAU can send an SNMP-Trap to the trap listener in the NMS to warn it of the occurrence of this event.

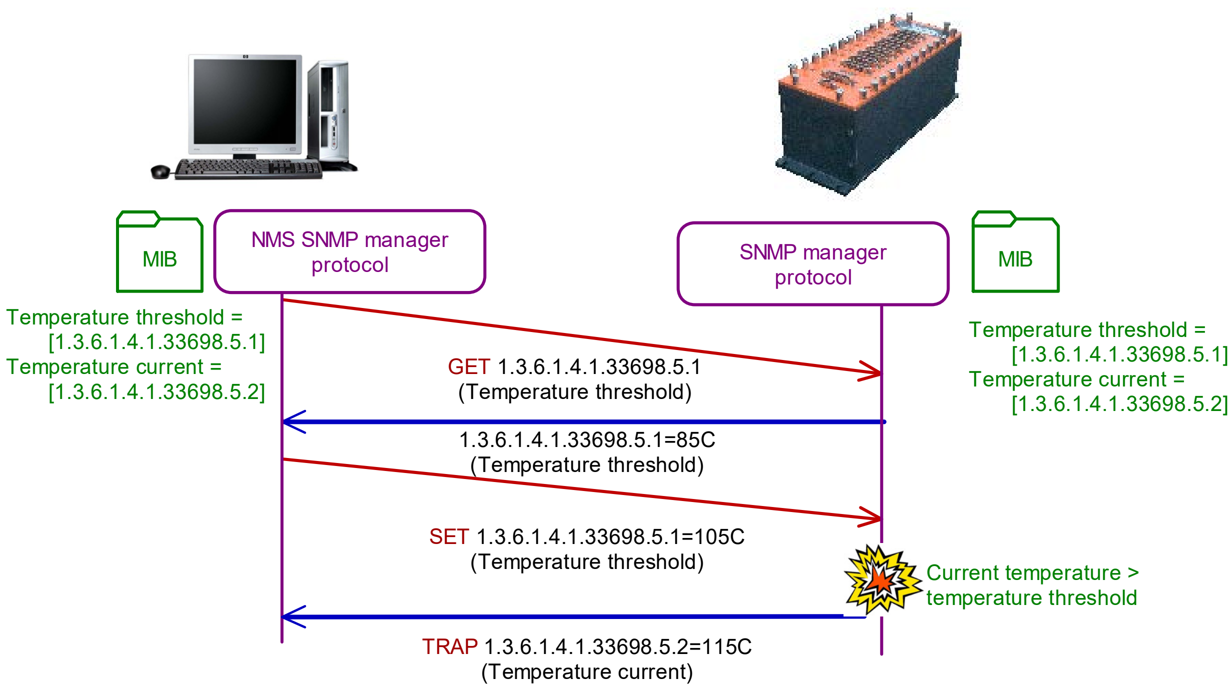


*Figure 32-4: SNMP example*

## 32.4 SNMP software

There is much free and commercial SNMP software available to perform SNMP tasks including:

- Network Monitoring Software - Loriot Pro, free and commercial versions available.
- OpManager – ManageEngine, commercial version.
- NetDecision – NetMechanica, commercial version.
- Network Management Tools – SimpleSoft, commercial version.
- MIB Browser and SNMP Manager - iReasoning, commercial.
- Net-SNMP- free C/C++ open source API and binary.
- Netsnmpj - java open source implementation available on SourceForge.
- JMIBBrowser - java open source implementation available on SourceForge.
- Frameflow MIB Browser -Frameflow is a good way of exploring the SNMP hierarchy to get a feel for the structure. It allows read-only access, so you cannot accidentally change important values.
- kSNMP - This is a Curtiss-Wright in-house generated software program created to add a GUI interface to the SNMP settings. It has been superseded by DAS Studio 3, but is still of value to KSM-500 users. Contact Curtiss-Wright support (acra-support@curtisswright.com) for more information.

- DAS Studio 3 - This is the main Curtiss-Wright software used to control and query all Curtiss-Wright hardware, including DAUs, switches, and recorders. It provides a GUI interface to the entire system. For SNMP devices, it allows access to the normal control variables as well as more advanced features like filtering or X-Bar setup. Contact Curtiss-Wright support (acra-support@curtisswright.com) for information.

### 32.4.1 Installation and setup of Net-SNMP

This section describes using the Net-SNMP open source utility to perform SNMP tasks with Curtiss-Wright devices.

1. Download and install the Net-SNMP library according to the library's instructions.

---

**NOTE:** The latest Net-SNMP library can be downloaded here: http://www.net-snmp.org/download.html, which points to http://sourceforge.net/projects/net-snmp/files/.

2. Ensure that the appropriate MIBs are installed in the correct location for Net-SNMP to access them (contact Curtiss-Wright support [acra_support@curtisswright.com] for the latest files). To add the Acra MIB, the iNET MIB and any other relevant MIBs to Net-SNMP, first copy the MIBs to the following directory:

```
<installation root>:\NetSNMP\share\snmp\mibs
```

3. Then register the newly added MIBs by modifying the following config file:

```
<installation root>:\NetSNMP\etc\snmp\snmp.conf
```

4. Add the following lines to the config file:

```
mibs +BRIDGE-MIB
mibs +EtherLike-MIB
mibs +ACRA-MIB
mibs +TMNS-MIB
```

   ACRA-MIB is Curtiss-Wright’s Acra MIB and TMNS-MIB is the iNET MIB.

5. The config file should now contain the following:

```
mibdirs C:/NetSNMP/share/snmp/mibs
persistentDir C:/NetSNMP/snmp/persist
tempFilePattern C:/NetSNMP/temp/snmpdXXXXXX
mibs +BRIDGE-MIB
mibs +EtherLike-MIB
mibs +ACRA-MIB
mibs +TMNS-MIB
```

### 32.4.2 Using Net-SNMP

The Net-SNMP utility can be run from the command line to:

- Retrieve information from an SNMP-capable device, either using single requests (`snmpget, snmpgetnext`), or multiple requests (`snmpwalk, snmptable, snmpdelta`).
- Manipulate configuration information on an SNMP-capable device (`snmpset`).
- Retrieve a fixed collection of information from an SNMP-capable device (`snmpdf, snmpnetstat, snmpstatus`).
- Convert between numerical and textual forms of MIB OIDs, and display MIB content and structure (`snmptranslate`).

In this section, only the basic SNMP-SET and SNMP-GET commands are described.

The basic syntax for SNMP-SET commands is as below:

```
snmpset [Version] [Community][Agent] [OID] [Type] [Value]
```

| Field | Typical values | Description |
|---|---|---|
| Version | -v 2c | Specifies SNMP version to use. All Curtiss-Wright devices support SNMPv2c. |

| Field | Typical values | Description |
|---|---|---|
| Community | -c public | SNMP Version 1 or 2c specific command line field. The “community string” allows the authentication of clients, in effect a type of password, which is transmitted in clear text. |
| Agent | 192.168.28.1 | IP address of the managed device. Be sure the NMS is on the same subnet. |
| OID | OID in text | OID of the target variable, for example: `.iso.org.dod.internet.private.enterprises.acra.recorder.controlMethod` |
| Type | i | One of i, u, t, a, o, s, x, d, b, U, I, F, or D<br>i: INTEGER<br>u: unsigned INTEGER<br>t: TIMETICKS<br>a: IPADDRESS<br>o: OBJID<br>s: STRING<br>x: HEX STRING<br>d: DECIMAL STRING<br>b: BITS<br>U: unsigned int64<br>I: signed int64<br>F: float<br>D: double |
| Value | 1 | The appropriate value associated with the preceding type. |

For example:

```
snmpset -v 2c -c public 192.168.28.1 .iso.org.dod.internet.private.enterprises.acr
a.recorder.controlMethod.0 i 2
```

(as a single line, with no line break) is the command line used to issue an SNMP-SET command to a NET/REC/001 with an IP address of 192.168.28.1 to change the setting of the `controlMethod` variable to an integer value of 2, where a value of 2 is mapped to the remote control. Similarly, the SNMP-GET command has a similar format:

```
snmpget -v 2c -c public 192.168.28.1 .iso.org.dod.internet.private.enterprises.acr
a.recorder.controlMethod.0
```

Following are some more examples.

**Get the system name**

```
snmpget -v 2c -c public 192.168.28.4 .iso.org.dod.internet.mgmt.mib-2.system.sysName.0
```

might return `SNMPv2-MIB::sysName.0 = STRING: Left Wing DAU`.

**Change the system name**

```
snmpset -v 2c -c public 192.168.28.4 .iso.org.dod.internet.mgmt.mib-2.system.sysName.0 s
The_System_Name
```

which will return `SNMPv2-MIB::sysName.0 = STRING: The_System_Name`.

**Change the IP address on a KAD/BCU/140/x module**

1. Verify the current IP address with ping or Wireshark® (below), and use it for the steps below.
2. Run these SNMP commands: (Note, copy/paste into a command shell may not work correctly; for example the '-' character may be replaced by a Unicode dash symbol.) This example shows changing from 192.168.28.1 to 192.168.28.5:
   a. Set the BCU module to Change IP Address mode.
      `snmpset -v 2c -c public 192.168.28.1 iso.org.dod.internet.private.enterprises.acra.settings.enableFailSafeIPSet.0 i 1`
   b. Show a hex string with the current MAC address, current IP address and current IP Mask.
      `snmpget -v 2c -c public 192.168.28.1 .iso.org.dod.internet.private.enterprises.acra.settings.ipSetVar.0`
      Example return value: HEX-STRING: 00 00 0C 4D 8D 61 FA **C0 A8 1C 01** 00 00 00 00 FF FF FF FF
   c. Change the IP Address. The example below sets it to 192.168.28.05 (C0A81C05 HEX).
      `snmpset -v 2c -c public 192.168.28.1`

```
.iso.org.dod.internet.private.enterprises.acra.settings.ipSetVar.0 x
00000C4D8D61FAC0A81C0500000000FFFFFFFF
```

d. Verify the IP address has been changed.

```
snmpget -v  2c -c public 192.168.28.5 .iso.org.dod.internet.private.enterprises.acra.
settings.ipSetVar.0
```

e. Exit Change IP Address mode.

```
snmpset -v 2c -c public 192.168.28.5 .iso.org.dod.internet.private.enterprises.acra.
settings.enableFailSafeIPSet.0 i 0
```

3. Ping the new IP address to test it.

**Change the IP address on a NET/SWI/003**

1. Verify the current IP address with ping or Wireshark, and use it for the steps below.
2. Run these SNMP commands: (Note, copy/paste into a command shell may not work correctly; for example the '-' character may be replaced by a Unicode dash symbol.)
   a. `snmpset -v 2c -c public <OLD_IP_ADDRESS> .iso.org.dod.internet.private.enterprises.acra.settings.enableFailSafeIPSet.0 i 1`
   b. `snmpset -v 2c -c public <OLD_IP_ADDRESS> .iso.org.dod.internet.private.enterprises.acra.settings.ipSetVar.0 x 00000C4DAC7A00<NEW_IP_ADDRESS_IN_HEX>00000000FFFFF`
   For example: `00000C4DAC7A00C0A81C0500000000FFFFFFFF`
   Don't change any other characters. They are the MAC address and masks.
   c. `c.snmpset -v 2c -c public <NEW_IP_ADDRESS> .iso.org.dod.internet.private.enterprises.acra.settings.enableFailSafeIPSet.0 i 0`

**Finding SNMP variables**

The command `SNMPWALK` recursively goes through the entire tree or subtree, depending on the starting location. For example, `snmpwalk -Of -v 2c -c public 192.168.28.4` displays the full MIB address and value of each valid SNMP variable. Whereas `snmpwalk -Of -v 2c -c public 192.168.28.4 .iso.org.dod.internet.mgmt.mib-2` displays only the MIB-2 tree.

## 32.5 Appendix - Curtiss-Wright SNMP support

This section lists a subset of the variables supported by Curtiss-Wright devices including the NET/REC/XXX and SSR/CHS/XXX recorders and the NET/SWI/XXX family of products.

The attributes for each of the variables is indicated:

- SET: the value of the variable may be modified via SNMP-SET command.
- GET: the value of the variable may be retrieved via SNMP-GET command.
- NA: the variable is not accessible as it is used to implement a structure on the MIB hierarchy.

Table 32-2: Public sub-tree: .iso.org.dod.internet.mgmt.mib-2

| Variable name | Attributes | Description |
|---|---|---|
| `.system` | NA | |
| `.system.sysDescr` | GET | Returns a string containing the name and version identification of the device. For example, on the NET/SWI/004, this returns: “NET/SWI/004 Mar 12 2010 TIC/V/038  A00 TIC/V/037 1600 FWA/W/001 1.02”. |
| `.system.sysObjectID` | GET | Returns one of the values under Devices in the Acra MIB, listed below, identifying the device. |
| `.system.sysName` | GET/SET | This is a string, which you may set. By default, this is left blank. For example, sysName may be “MyCockpitNetworkRecorder”. |
| `.system.sysLocation` | GET/SET | This is a string, which you may set. By default, this is left blank. For example, sysLocation may be “Cockpit”. |

Table 32-2: Public sub-tree: .iso.org.dod.internet.mgmt.mib-2

<table>
<tr><td>.system.sysServices</td><td>GET</td><td>Return an integer whose bits indicate what parts of the network stack the device mainly works with. Bit 0 represents the physical layer (layer 1), up to bit 6 for the application layer (layer 7).<br>The NET/SWI/004 returns 72, implying Application level (PTP) and Transport level (switching).</td></tr>
<tr><th>Variable name</th><th>Attributes</th><th>Description</th></tr>
<tr><td>.interfaces</td><td>NA</td><td></td></tr>
<tr><td>.interfaces.ifNumber</td><td>GET</td><td>Number of supported Ethernet interfaces. The NET/SWI/004 is an 8-port Ethernet switch and as such reports back a value of 8. This normally coincides with the number of entries in .interfaces.ifTable, but an SNMP walk does not depend on this.</td></tr>
<tr><td>.interfaces.ifTable</td><td>NA</td><td>Table of ifEntry structures, giving information about the interfaces.<br>These contain the following information:
<table>
<tr><th>Table variable name</th><th>Attributes</th><th>Description</th></tr>
<tr><td>.ifEntry.ifIndex.n</td><td>NA</td><td>Where n is the index. Returns the index value, n.</td></tr>
<tr><td>.ifEntry.ifDescr.n</td><td>GET</td><td>Description of the interface, for example onboard Ethernet.</td></tr>
<tr><td>.ifEntry.ifType.n</td><td>GET</td><td>Returns a value indicating the type of interface. The value returned is the one specified for all Ethernet-like interfaces regardless of speed.</td></tr>
<tr><td>.ifEntry.ifSpeed.n</td><td>GET</td><td>Returns the speed of the interface in bits per second.</td></tr>
<tr><td>.ifEntry.ifPhysAddress.n</td><td>GET</td><td>MAC address of the interface.</td></tr>
<tr><td>.ifEntry.ifOperStatus.n</td><td>GET</td><td>Indicates whether interface n is operating. Values that may be returned are: up; down; testing; unknown; dormant; notPresent; or lowerLayerDown.</td></tr>
</table></td></tr>
</table>

Table 32-2: Public sub-tree: .iso.org.dod.internet.mgmt.mib-2

<table>
<tr><td>.ip</td><td>NA</td><td></td></tr>
<tr><td>.ip.ipAddrTable</td><td>NA</td><td>The table of addressing information relevant to this entity's IP addresses. An interface may have multiple IP addresses or none, so the number of entries in this table is not necessarily the same as that in .interfaces.ifTable.
<table>
<tr><th>Table variable name</th><th>Attributes</th><th>Description</th></tr>
<tr><td>.ipAddrEntry<br>.ipAdEntAddr.n</td><td>GET</td><td>The IP address to which this entry's addressing information pertains.</td></tr>
<tr><td>.ipAddrEntry<br>.ipAdEntIfIndex.n</td><td>GET</td><td>The index value, which uniquely identifies the interface to which this entry is applicable. The interface, identified by a particular value of this index, is the same as the value of RFC 1573's ifIndex. That means its value ranges between 1 and the value of ifNumber. The value for each interface must remain constant at least from one re-initialization of the entity's network management system to the next re-initialization.</td></tr>
<tr><td>.ipAddrEntry<br>.ipAdEntNetMask.n</td><td>GET</td><td>Returns the Netmask, indicating which bits of the IP address refer to the local subnet.</td></tr>
</table></td></tr>
<tr><td>.host</td><td>NA</td><td></td></tr>
<tr><td>.host.hrSystem.hrSystemDate</td><td>GET</td><td>Return the module’s notion of the current local date and time of day, as a DateAndTime structure defined in RFC2579.</td></tr>
</table>

### 32.5.1 Acra sub-tree: .iso.org.dod.internet.private.enterprises.acra

Curtiss-Wright’s MIB identification string is ACRA-MIB.

**NOTE:** This section describes only a subset of the SNMP managed variables that are available across the Curtiss-Wright product families. For more details on SNMP-managed variable support for a specific device, refer to the corresponding data sheet and supporting documentation for that device. If you still require information on specific variables, contact Curtiss-Wright support (acra-support@curtisswright.com).

The following data types are defined in the Acra MIB:

- `IPSetVarType`**:** A combination of Interface index, MAC address, IP address, IP mask, and Gateway IP address. This is used when setting these variables on a device. The packet to set this information may be broadcast. Each of these fields must be set since normal point-to-point communication may not be possible if some or all of these fields are not correctly set.
- `acraDeviceType`**:** Used in conjunction with the variable `.identification.networkNodeType` and is described in the following table. The enumerated possible values for the device type are as follows:
  - Null
  - Network device
  - DAU
  - Recorder
  - Time master

Table 32-3: Public sub-tree - .iso.org.dod.internet.private.enterprises.acra

| Variable name | Attributes | Description |
|---|---|---|
| .devices | NA | Defines values that indicate the type of device returned by system.sysObjectID above. Object IDs are generated based on the type number of the device. For a specific device the OID is `.iso.org.dod.internet.private.enterprises.acra.devices.<type number>.0`<br>At present the MIB defines values for NET/REC/001, SSR/CHS/001, NET/REC/002 and NET/SWI/004. |
| .settings | NA | Returns one of the values under Devices in the Acra MIB, listed below, identifying the device. |
| .settings.ipSetVar | GET/SET | Combined MAC address, IP address, netmask and Gateway IP address. These are sent in a single SNMP packet as explained above under `.IPSetVarType`. |
| .settings.serial | GET/SET | Serial number of the device. This is a string with a maximum size of 16 characters. |
| .settings.factoryConfig | GET | Read-only, indicates whether the module is in Factory Mode. |
| .settings.enableFailSafeIPSet | GET/SET | Enable or disable write access to `ipSetVar` or related variables. The IP address can only be changed if this is set to 1. The host should reset this value to 0 when the IP address has been changed. However, if the host fails to do so, it reverts to 0 when the device is power cycled or if the variable is not updated and if no operation which depends on it, such as setting the IP address, occurs for five minutes. |
| .triggers | NA | This sub-tree is used for variables that trigger events. |
| .triggers.recorderTriggers | NA | Sub-tree containing variables which trigger events on the NET/REC/XXX. |
| .triggers.recorderTriggers<br>.triggerRemoteEvent | GET/SET | Writing 1 to this variable increments the event number and causes an event packet to be recorded. |
| .recorder | NA | |
| .recorder.wrapAround | GET/SET | Controls whether the recording stops when the CompactFlash card is full, or whether the oldest data is overwritten. |
| .recorder.nextEventNumber | GET/SET | Reads or sets the number of the next Event record. |
| .recorder.streamSpeed | GET | Current filtered Ethernet packet speed (bytes). |
| .recorder.currentFileName | GET | Indicates the name of the file currently being written to by the recorder. |
| .recorder.recMode | GET | Indicates the current mode of the recorder. This may have the following values:<br>• `idle`: Result of stop or mount.<br>• `record`: Record command was received.<br>• `dismounted`: Media is dismounted (this value is not used in the NET/REC/001/02, as mounting is automatic).<br>• `notReady`: Mode used when recorder is being configured or other times when functional control of the recorder is not available.<br>• `mediaNotPresent`: Media not present.<br>• `mediaFull`: Media full.<br>• `mediaLocked`: Media is write-protected. |

Table 32-3: Public sub-tree - .iso.org.dod.internet.private.enterprises.acra

| Variable name | Attributes | Description |
|---|---|---|
| .recorder<br>.recorderMulticastGroupsTable | NA | Table of Multicast IP groups that the recorder should join. This allows the recording of multicast data, which would otherwise be blocked by a switch. Elements contain the following:<br><br>**Table variable name** / **Attributes** / **Description**<br>`.groupIndex.n` / GET / Return the index value, *n*.<br>`.IPAddress.n` / GET/SET / Multicast IP address. |
| .recorder.recCommand | GET/SET | Issues a command to the recorder, or returns the last command issued. Command values are:<br>• `noCommand`: Returned when `recCommand` is read, if no command has yet been received.<br>• `record`: Starts the recording function.<br>• `stop`: Stops recording function.<br>• `mount`: Mount the media for read/write access (this value is not used in the NET/REC/001, as mounting is automatic).<br>• `dismount`: Dismount the media in preparation for removal. Recorder must be in the idle state for this command to be valid. (This value is not used in the NET/REC/001; in the stopped state you can remove the media without dismounting.) |
| .recorder.controlMethod | GET/SET | Select or read whether the recorder is controlled by its front panel, by SNMP, or by another interface. The `controlMethod` variable remains available via SNMP even if the local or external method is selected, but other control functions are no longer available. Values of this variable are:<br>• `local`: Controlled by the front panel.<br>• `network`: Controlled over the network via SNMP.<br>• `external`: Controlled from the cockpit over some other interface. |
| .recorder.erase | GET/SET | Erases the recording media. Set to true to start erase. Recorder sets this value to false when the erase process is complete. |
| .recorder.defaultFileSize | GET/SET | Default PCAP file size in megabytes or zero to set it automatically based on the media size. |
| .recorder.freeSpaceWarningLimit | GET/SET | Free space warning limit in megabytes or zero to disable blinking warning. |
| .display | NA | Controls the front panel display of the recorder. |
| .display.brightness | GET/SET | Returns or sets the display brightness, as a percentage of the full brightness level. |
| .time | NA | |
| .time.curLeapSeconds | GET/SET | Reads or sets the number of leap seconds since the start of the PTP epoch. |
| .time.curYear | GET/SET | Reads or sets the current year. If the device is synchronized to IRIG, or another time source that does not provide year information, this defines the current year. If the device synchronizes to GPS or PTP, this variable is updated with information from the GPS or PTP source. |

Table 32-3: Public sub-tree - .iso.org.dod.internet.private.enterprises.acra

| Variable name | Attributes | Description |
|---|---|---|
| .time.ptpSyncReliabilityLevel | GET/SET | Reads or sets the definition of "in synch" when synchronizing to a time master. If the PTP stack calculates the current error as having a magnitude, in nanoseconds, less than or equal to this, then the device is considered in synch.<br>In a recorder, this controls the "time reliable" and "time unreliable" event packets recorded on foot of information gathered by the PTP stack. |
| .time.ptpSyncError | GET | Reads the most recently calculated error in the local clock, that is, the last calculated error relative to the PTP Grandmaster. The value is an integer number of nanoseconds.<br>In the NET/SWI/004, which synchronizes to IRIG or GPS rather than to PTP, this gives the synchronization error relative to the time master in use.<br>If the device is not currently in synch with a time master, the value 999999999 (a nanosecond short of 1 second, and the maximum legal value of a PTP nanoseconds field) is returned. |
| .time.timeReliable | GET | Reads whether the current time is considered reliable. This returns 1 if the device is receiving time information and the `.ptpSyncError` value ≤ the<br>`.ptpSyncReliabilityLevel` value, 0 otherwise. |
| .time.timeMode | GET/SET | Indicates the current source of time information. Values that can be returned are:<br>• `LocalFreeRunning`: Not willing to be synchronized to anything.<br>• `PTPSlave`: Synchronizes to a PTP grandmaster.<br>• `LocalTimeNoPTP`: Synchronizes to a non-network time source (for example, GPS or IRIG) but does not do PTP.<br>• `LocalTimePTPGrandmaster`: Synchronize to a non-network time source, and serves out the time as a PTP Grandmaster.<br>• `Automatic`: This is not yet supported. The device should use the Best Master Algorithm to compare any PTP Grandmaster with the available non-network time source. It becomes master if it has a better clock, otherwise it is a PTP slave. |

### 32.5.2 Setting protected variables using SNMP with Curtiss-Wright devices

The use of SNMP to access and modify configuration settings on devices should be used with care and be protected against accidental or inadvertent modification. SNMP configurable variables that affect the operation of a device are considered to be critical variables. These critical variables are protected by a simple 2-step locking mechanism. To illustrate this locking mechanism, consider the variable `ipSetVar` that is used to modify the IP address of a given device using SNMP.

#### 32.5.2.1 STEP 1: Unlock access to the critical variable

In the Acra MIB, there is an `enableFailSafeIPSet` variable located within the Settings branch.

| iso | org | dod | internet | private | enterprises | acra | Settings | EnableFailSafeIPSet |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 2 | 4 |

This variable is described in the MIB as follows:

```
enableFailSafeIPSet OBJECT-TYPE
SYNTAX INTEGER { disable(0), enable(1) }
ACCESS read-write
STATUS current
```

```
DESCRIPTION
"Enable/disable IP settings"
DEFVAL { disable }
::= { settings 4 }
```

To unlock access to any critical variable, the variable `enableFailSafeIPSet` must be first enabled. The command used by Net-SNMP to SET this variable to enable is:

```
snmpset -v2c -c public 192.168.28.1. iso.org.dod.internet.private.enterprises.acra
.settings.enableFailSafeIPSet.0 i 1
```

The following figure illustrates the dissected Wireshark output of the SNMP SET command.

```
⊟ Simple Network Management Protocol
    version: v2c (1)
    community: public
  ⊟ data: set-request (3)
    ⊟ set-request
        request-id: 5
        error-status: noError (0)
        error-index: 0
      ⊟ variable-bindings: 1 item
        ⊟ 1.3.6.1.4.1.33698.2.4.0:
            Object Name: 1.3.6.1.4.1.33698.2.4.0 (iso.3.6.1.4.1.33698.2.4.0)
            Value (Integer32): 1
```

*Figure 32-5: Dissected SNMP SET Command to Unlock Critical Variable Access*

#### 32.5.2.2 STEP 2: Modify the critical variable

Once the critical variable has been unlocked, the IP address can be modified. The IP Address variable is located in the Settings subtree of the Acra MIB.

| iso | org | dod | internet | private | enterprises | acra | Settings | ipSetVar |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 2 | 1 |

This variable is described in the MIB as follows:

```
ipSetVar OBJECT-TYPE
        SYNTAX  IPSetVarType
        ACCESS  read-write
        STATUS  current
        DESCRIPTION
"Combined MAC address, IP address and IP mask"
        ::= { settings 1 }
```

The command used by Net-SNMP to SET the IPAddress variable is:

```
snmpset -v 2c -c public 192.168.28.1 .iso.org.dod.internet.private.enterprises.acr
a.settings.ipSetVar.0 s 01000c4d000000c0a80402ffffff00cc09d7b02
```

where the string is a combined MAC address, IP address, and IP mask value.

**NOTE:** This setting value takes effect if and only if the `enableFailSafeIPSet` variable has been set to enabled, unlocking access to this protected variable.

The following figure illustrates the dissected Wireshark output of the SNMP SET command.

```
⊟ Simple Network Management Protocol
    version: v2c (1)
    community: public
  ⊟ data: set-request (3)
    ⊟ set-request
        request-id: 6
        error-status: noError (0)
        error-index: 0
      ⊟ variable-bindings: 1 item
        ⊟ 1.3.6.1.4.1.33698.2.1.0: 01000c4d000000c0a80402ffffff00c09d7b02
            Object Name: 1.3.6.1.4.1.33698.2.1.0 (iso.3.6.1.4.1.33698.2.1.0)
            Value (OctetString): 01000c4d000000c0a80402ffffff00c09d7b02
```

*Figure 32-6: Dissection SNMP SET command to set the IP address variable*

To further safeguard these protected critical variables, the `enableFailSafeIPSet` times out after five minutes of inactivity and returns to a disabled state.

## 32.6 Troubleshooting

1. Ensure the NMS (desktop PC) is on the same IP subnet.
2. Ensure proper command formatting.
3. Use ping to ensure the device is connected.
4. Use `snmpwalk -Of -v 2c -c public <IP ADDRESS>` to test basic SNMP functionality. If it returns with full character descriptions of the various OIDs and their values then Net-SNMP should be working correctly.
5. Use Wireshark to view what is actually happening on the Ethernet port.
6. Contact Curtiss-Wright support (acra-support@curtisswright.com) for further support.

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Chapter 33

# Cable assembly using ACD/CJB/002 reference junction block

**TEC/NOT/059**

This technical note describes how to wire an ACD/CJB/002 for use with specific thermocouple modules such as the KAD/TDC/107. This technical note is divided into the following sections:



## 33.1 Tools required

You will need the following for the cable assembly:

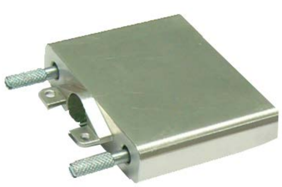
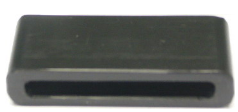
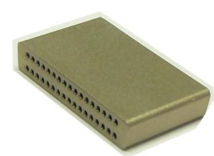
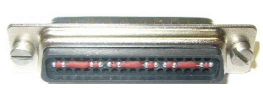
- ACD/KIT/001 (must be ordered separately)
- Crimp tool
- Flat-tip screwdriver
- Nut-locking solution

---

**NOTE:** We recommend always using a nut-locking solution on the clamp bar assembly screws.

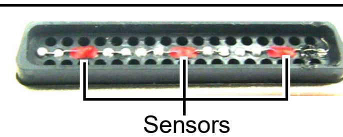
## 33.2 Parts required

The ACD/CJB/002 is comprised of the following parts.

| | | | |
|---|---|---|---|
|  Back shell |  Insulator A |  Insulator B |  Aluminum block |
|  Rubber grommet |  CON/KAD/010 connector |  Connector cover |  Clamp bar |
|  Contacts |  Two M2 screws |  Four M2.5 screws |  Two UNC 4-40 screws |

---

**WARNING:** The sensors on the CON/KAD/010 connector can be easily damaged. Do not touch or scratch the sensors with the insertion tool when inserting pins into the connector.



## 33.3 Assembly overview

All the connector parts are bevelled; that is, one face is wider than the other. Before cable assembly, ensure all parts are oriented as shown in the following figure.

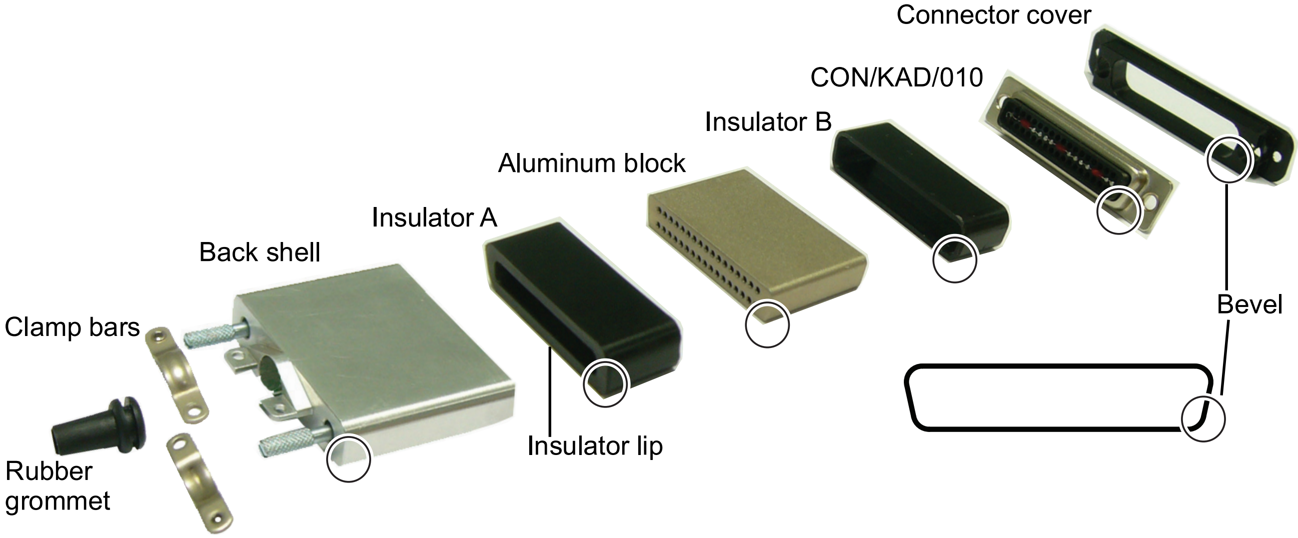
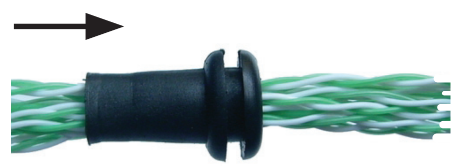
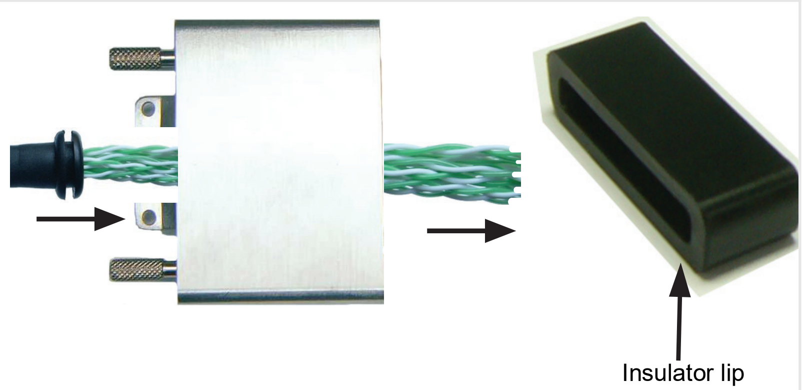



*Figure 33-1: Parts placement*

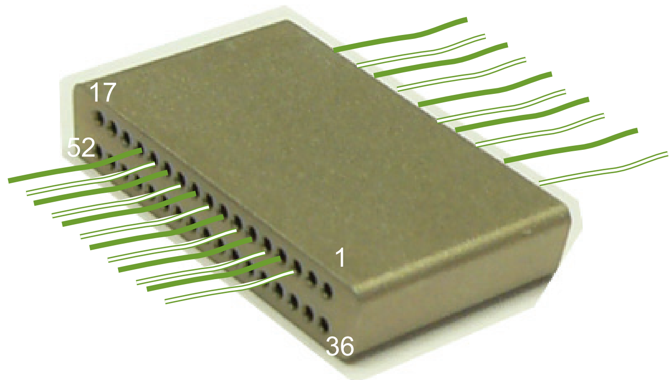
## 33.4 Cable assembly

The following cable assembly uses a KAD/TDC/107 module as an example.

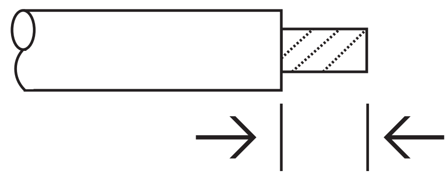
<table>
<tr>
<td>
1. Gather the number of wires you will need for the module type.<br>
WARNING: At this point DO NOT crimp any of the wires; crimped wires will not pass through the aluminum block.<br>
2. With the rubber grommet oriented as shown, insert the wires through the rubber grommet.
</td>
<td></td>
</tr>
<tr>
<td>
3. Insert the wires through the back shell.<br>
4. With the insulator lip orientated as shown, insert the cables through the insulator A.
</td>
<td>
</td>
</tr>
</table>

5. Insert the wires through the aluminum block.

   **NOTE:** The example shown is for a KAD/TDC/107. To determine which pins to use and for pin descriptions, see the respective data sheet connector pinout table.




6. Strip 0.12 in. (3 mm) of insulation from the end of each wire.
7. Adjust the crimping stop point to match the wire diameter.

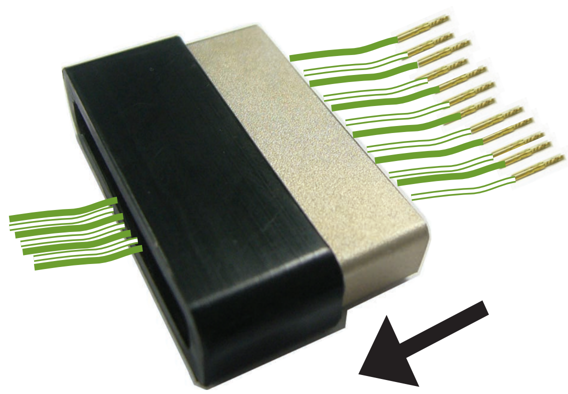


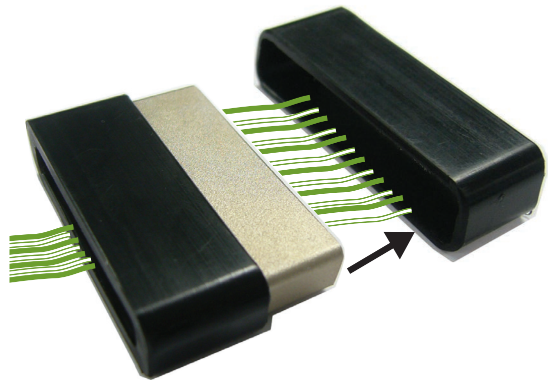
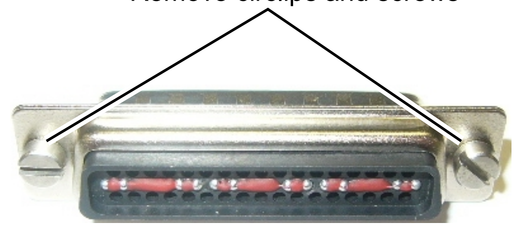
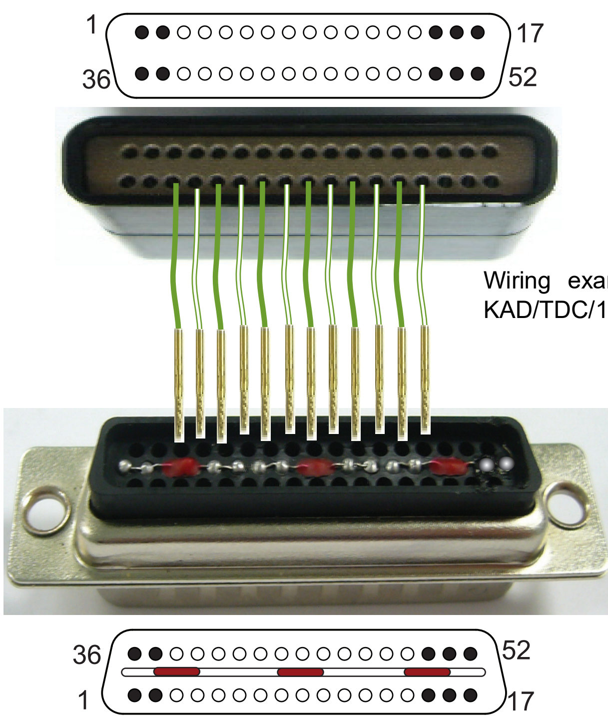

8. Insert the contact into the locator (if required).
9. Insert the stripped end of the wire into the contact crimp pot.
10. Squeeze the handles firmly to crimp the contact to the wire.

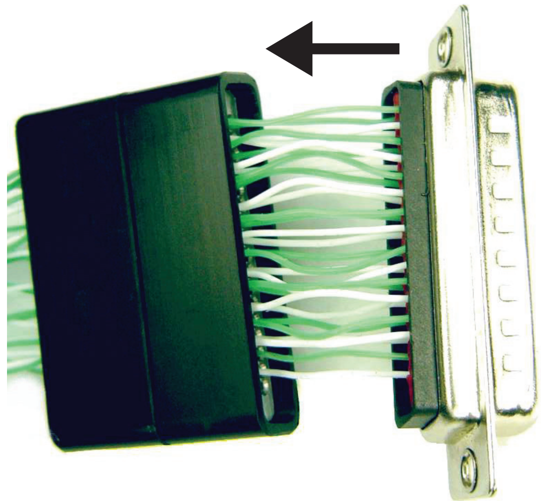
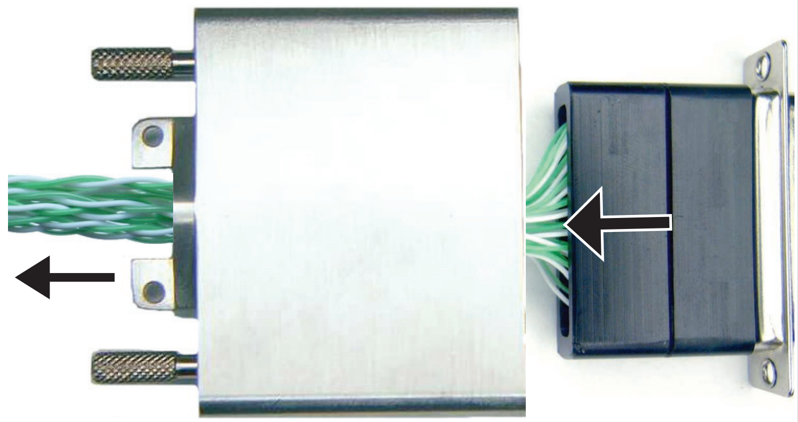
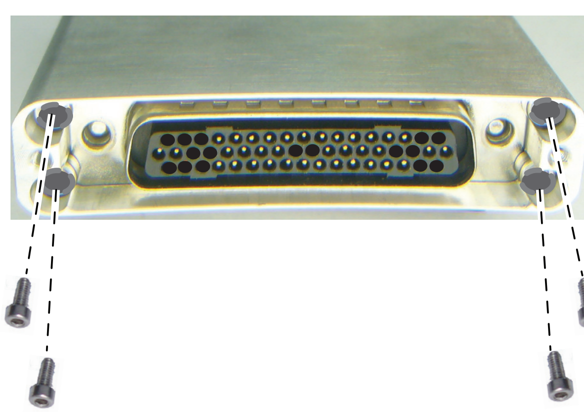
    **WARNING:** The tool will not release if crimping is incomplete.

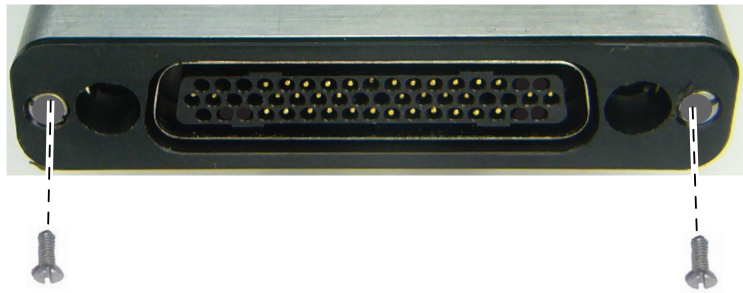
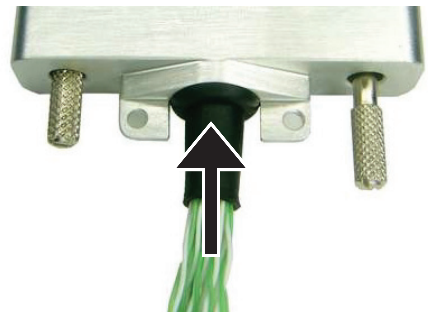
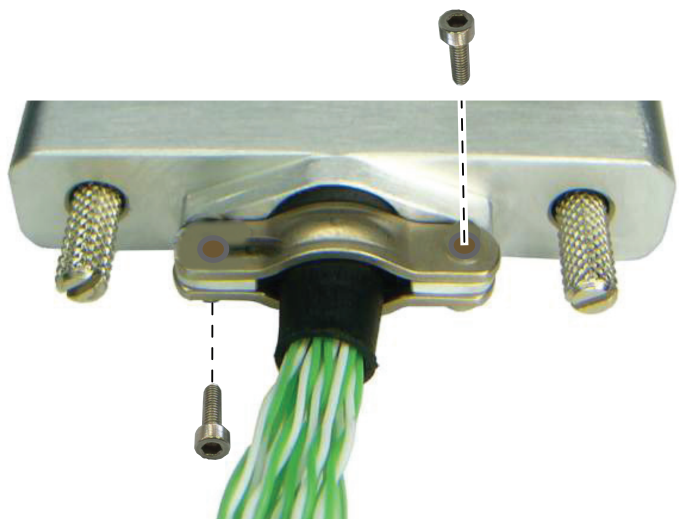
11. Repeat for the other wires to be crimped.
12. Before resuming cable assembly, check all wires for damage, frayed insulation, or loose contacts.

13. Insert the aluminum block into insulator A.



| | |
|---|---|
| 14. Insert the wires through insulator B.<br>15. Then insert the aluminum block into insulator B. |  |
| 16. Remove and discard the two circlips and screws from the CON/KAD/010 connector. (Skip this step if there are no screws attached to the CON/KAD/010 connector that shipped.) |  |
| 17. Ensure the block and connector are correctly aligned before inserting pins into the connector.<br>18. Using the insertion tool, insert pins 38 to 49 (for KAD/TDC/107) from the aluminum block to the connector.<br>19. Then insert pins 3 to 14 (for KAD/TDC/107).<br><br>**NOTE:** Make sure the wires are not twisted between the block and the connector.<br><br>**WARNING:** The middle row of the connector is populated with the temperature sensors; touching or scratching the sensors with the insertion tool can damage the sensors.<br><br>**NOTE:** Unused connector holes can be filled with un-crimped pins; this should be completed at this stage of assembly. |  |

| | |
|---|---|
| 20. Insert the CON/KAD/010 connector into the block/insulator assembly. |  |
| 21. Insert the block/insulator/CON/KAD/010 assembly into the back shell. Keep the wires taut on the other side of the back shell.<br>**WARNING:** If the assembly is correctly oriented but does not slide easily into the back shell, then most likely a wire is caught between the assembly and the inside wall of the back shell. Keeping the wires taut helps to avoid this. |  |
| 22. Ensure the block/insulator/CON/KAD/010 assembly is fully inserted as shown here. |  |
| 23. Secure the connector to the backshell with four M2.5 screws.<br>**NOTE:** Do not exceed tightening torque of 0.4 Nm. |  |

| | |
|---|---|
| 24. Secure the connector cover with two M2 countersunk screws.<br>**NOTE:** Do not exceed tightening torque of 0.25 Nm. |  |
| 25. Secure the rubber grommet to the backshell. |  |
| 26. Secure the clamp bar to the backshell with two UNC 4-40 screws.<br>**NOTE:** Do not exceed tightening torque of 0.4 Nm.<br>**NOTE:** If using small gauge thermocouple wire, you may need to reverse one of the clamp bars in order to properly hold the wire. This may cause the grommet to be deformed.<br>27. Apply nut-locking solution to both screws. |  |

Chapter 34

# Using the KAM/TCG/102

TEC/NOT/060

The KAM/TCG/102 is a combined GPS and IRIG input module. This technical note introduces the KAM/TCG/102 module and describes how to set it up, as well as troubleshoot GPS. This paper is divided into the following sections:

## 34.1 Overview of the KAM/TCG/102



The KAM/TCG/102 module comprises a GPS receiver, a GPS reader, and an IRIG reader which decode incoming signals. For more information, see the *KAM/TCG/102* data sheet.

### 34.1.1 Key features of the KAM/TCG/102

- Synchronizes with IRIG-B or GPS
- Interfaces to an onboard L1 GPS receiver or to an external National Marine Electronics Association (NMEA) stream
- Accepts and generates analog and digital IRIG-B
- Time is maintained from an external battery during power-down
- GPS navigation information available
- Secondary time source input

## 34.2 Setting up the KAM/TCG/102 using KSM-500

kSetup software can be used to configure the KAM/TCG/102. kSetup is included in the KSM-500 suite of tools. Features to be configured are described in "34.2.3 Setup tab setting" on page 237. If NMEA messages are required to be parsed, refer to "34.2.2 Setting NMEA Messages" on page 235.

## 34.2.1 Setting parameters

The Parameters tab (see Figure 34-1 on page 234) displays all parameters available from the module. To select parameters from the KAM/TCG/102, select the module in the Task Explorer pane of kSetup. From the Parameters tab, complete the fields described in Table 34-1 on page 234. For more information on using kSetup, contact Curtiss-Wright support (acra-support@curtisswright.com).

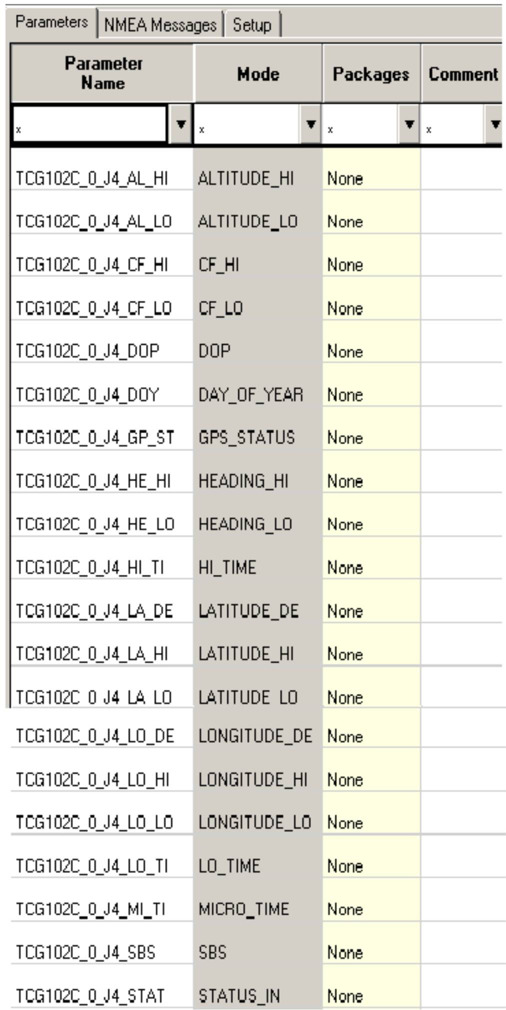



*Figure 34-1: Parameters tab in kSetup*

Table 34-1: Parameters tab settings

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter. |
| Mode | Time or navigation data such as position, altitude, velocity and heading. For more information on the Mode column values, see the Parameter definition table in the *KAM/TCG/102* data sheet. |
| Packages | When you place the parameter in a PCM frame, you can double-click a Packages cell. A window displays the transmission details in the PCM frame, such as the transmission rate. |
| Comment | User-defined text relating to the parameter. |

## 34.2.2 Setting NMEA Messages

When GPS is used, the NMEA Messages shown in Figure 34-2 on page 235 are available.

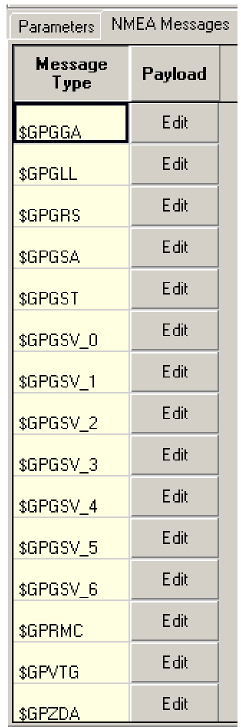



*Figure 34-2: NMEA Messages tab in kSetup*

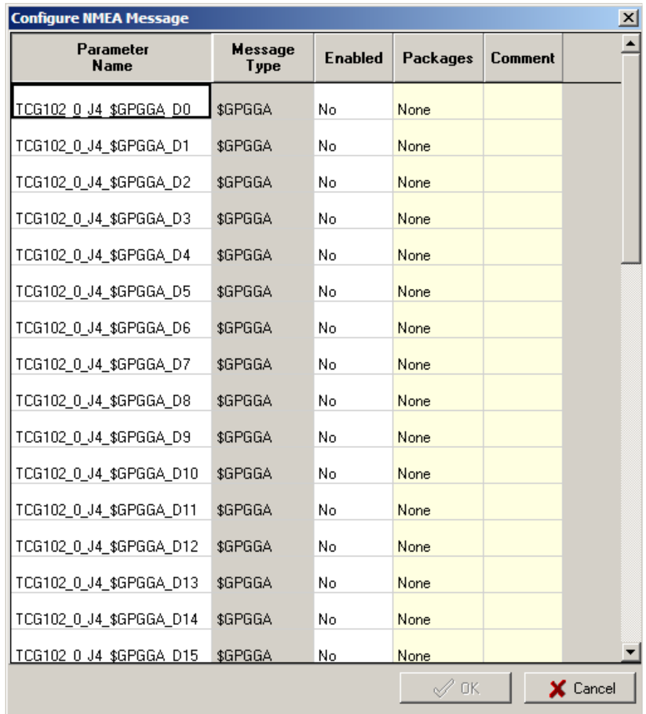
Table 34-2: NMEA Messages tab settings when GPS is used

| Field name | Description |
|---|---|
| Message Type | A read only field representing the NMEA messages. |
| Payload | Clicking an Edit button activates words from the NMEA messages (see Figure 34-3 on page 236). |

For more information on NMEA message definition, see the *KAM/TCG/102* data sheet.

### 34.2.2.1 Defining Payload settings

To define payload settings, click an Edit button (see Figure 34-2 on page 235). When the Configure NMEA Message window displays (see Figure 34-3 on page 236), complete the fields described in Table 34-3 on page 236.



Configure NMEA Message

| Parameter Name | Message Type | Enabled | Packages | Comment |
|---|---|---|---|---|
| TCG102_0_J4_$GPGGA_D0 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D1 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D2 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D3 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D4 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D5 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D6 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D7 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D8 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D9 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D10 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D11 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D12 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D13 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D14 | $GPGGA | No | None | |
| TCG102_0_J4_$GPGGA_D15 | $GPGGA | No | None | |

OK Cancel

*Figure 34-3: Payload settings*

Table 34-3: Configure NMEA Messages settings when GPS is used

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter. |
| Message Type | A read only field representing the NMEA messages. |
| Enabled | If set to Yes, the word from the message is available for transmission.<br>If set to No, the word from the message is not available for transmission. |
| Packages | When you place the parameter in a PCM frame, you can double-click a Packages cell. A window displays the transmission details in the PCM frame, such as the transmission rate. |
| Comment | User-defined text relating to the parameter. |

**NOTE:** The data words from the NMEA message read the full NMEA messages. The first data word for $GPGGA has the following result: $G.
You can select up to 41 data words from any NMEA message. An NMEA message may be less than 82 characters. As stated in the NMEA 0183 specification version 3.01, the maximum number of characters is 82, consisting of a maximum of 79 characters between start of message "$" or "!" and terminating delimiter <CR><LF> (HEX 0D and 0A).

## 34.2.3 Setup tab setting

Fields on the Setup tab (see Figure 34-4 on page 237) allow you to configure available settings for the KAM/TCG/102. For more information on Setup definition, see the *KAM/TCG/102* data sheet.

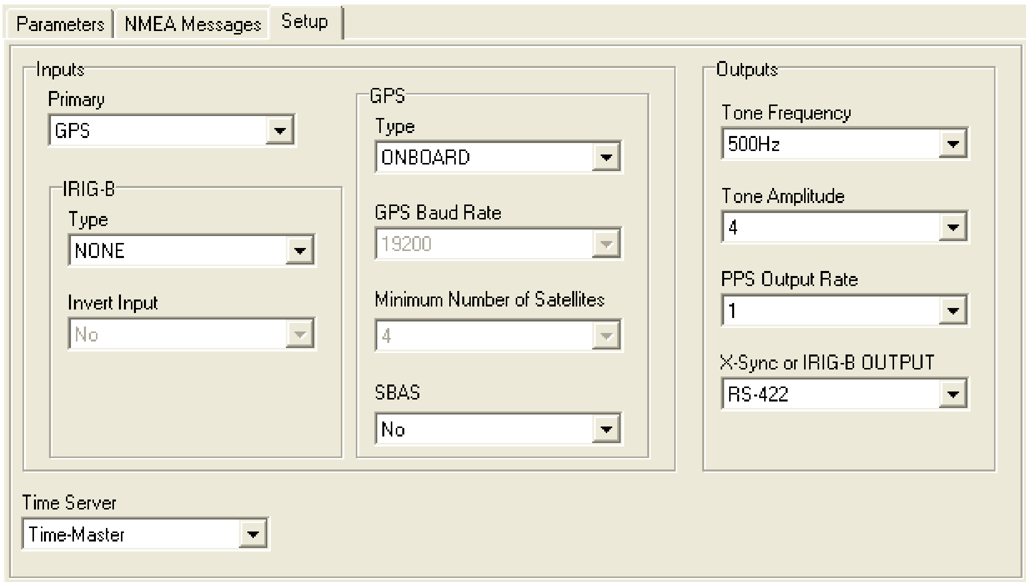



*Figure 34-4: Setup tab in kSetup*

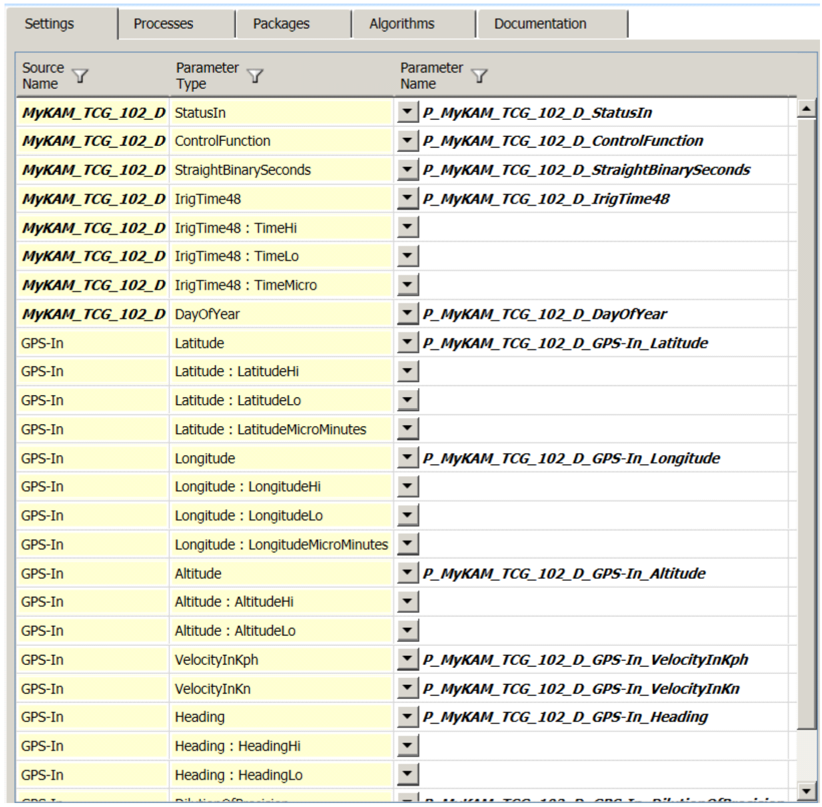
# 34.3 Setting up the KAM/TCG/102 using DAS Studio 3

You can use DAS Studio 3 software to configure the KAM/TCG/102. Features that can be set up include configuring channels, setting messages, and adding data words to messages. More information on these settings can be found in the “Setting up packages” and “Setting up datalinks” sections of the *KAM/TCG/102* data sheet.

DAS Studio 3 is used to create a configuration file which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

## 34.3.1 Settings tab settings

The Settings tab as shown in Figure 34-5 on page 238, shows available parameters for the module. The parameters shown in the Settings tab are defined in the *KAM/TCG/102* data sheet.



Settings | Processes | Packages | Algorithms | Documentation

| Source Name | Parameter Type | Parameter Name |
|---|---|---|
| MyKAM_TCG_102_D | StatusIn | P_MyKAM_TCG_102_D_StatusIn |
| MyKAM_TCG_102_D | ControlFunction | P_MyKAM_TCG_102_D_ControlFunction |
| MyKAM_TCG_102_D | StraightBinarySeconds | P_MyKAM_TCG_102_D_StraightBinarySeconds |
| MyKAM_TCG_102_D | IrigTime48 | P_MyKAM_TCG_102_D_IrigTime48 |
| MyKAM_TCG_102_D | IrigTime48 : TimeHi | |
| MyKAM_TCG_102_D | IrigTime48 : TimeLo | |
| MyKAM_TCG_102_D | IrigTime48 : TimeMicro | |
| MyKAM_TCG_102_D | DayOfYear | P_MyKAM_TCG_102_D_DayOfYear |
| GPS-In | Latitude | P_MyKAM_TCG_102_D_GPS-In_Latitude |
| GPS-In | Latitude : LatitudeHi | |
| GPS-In | Latitude : LatitudeLo | |
| GPS-In | Latitude : LatitudeMicroMinutes | |
| GPS-In | Longitude | P_MyKAM_TCG_102_D_GPS-In_Longitude |
| GPS-In | Longitude : LongitudeHi | |
| GPS-In | Longitude : LongitudeLo | |
| GPS-In | Longitude : LongitudeMicroMinutes | |
| GPS-In | Altitude | P_MyKAM_TCG_102_D_GPS-In_Altitude |
| GPS-In | Altitude : AltitudeHi | |
| GPS-In | Altitude : AltitudeLo | |
| GPS-In | VelocityInKph | P_MyKAM_TCG_102_D_GPS-In_VelocityInKph |
| GPS-In | VelocityInKn | P_MyKAM_TCG_102_D_GPS-In_VelocityInKn |
| GPS-In | Heading | P_MyKAM_TCG_102_D_GPS-In_Heading |
| GPS-In | Heading : HeadingHi | |
| GPS-In | Heading : HeadingLo | |

*Figure 34-5: Settings tab showing available parameters*

**NOTE:** To see module settings, the module must be in context in the Navigator. Refer to the *DAS Studio 3 User Manual* for more information.

The Settings tab as shown in Figure 34-6 on page 239, shows available settings for the module. These settings are defined in the *KAM/TCG/102* data sheet.

**NOTE:** At the time of writing this technical note, DAS Studio 3.3.3 was the current release. In that release, NMEA messages in ASCII form cannot be parsed.

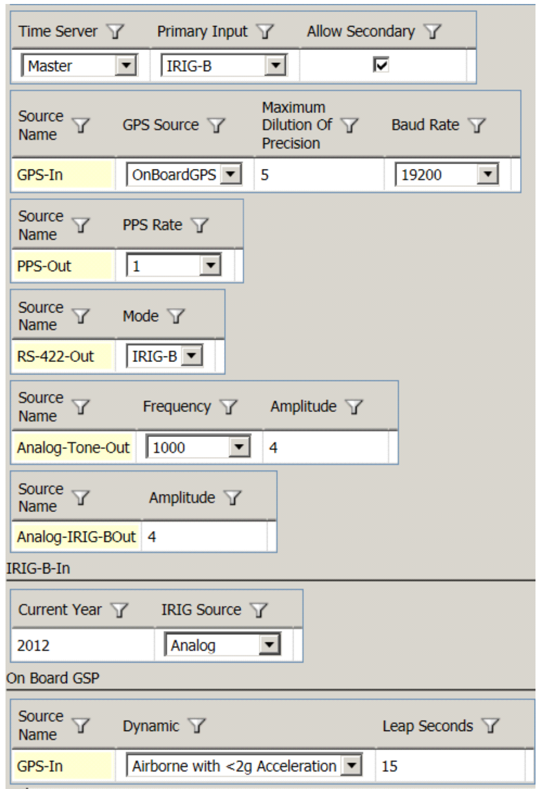



*Figure 34-6: Settings tab showing available settings*

# 34.4 Example configurations

## 34.4.1 External GPS receiving RS-422

The setup for an external GPS receiving RS-422 at 19,200bps is shown in Figure 34-7 on page 239, Figure 34-8 on page 240, and Figure 34-9 on page 240.

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**NOTE:** For all sample configurations below, it is assumed that the secondary input IRIG is not used.

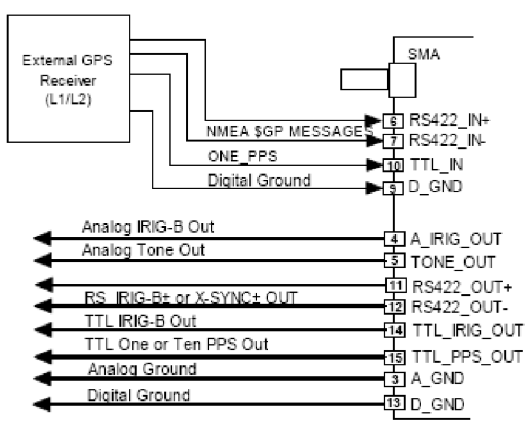



*Figure 34-7: Setup for external GPS receiving RS-422*

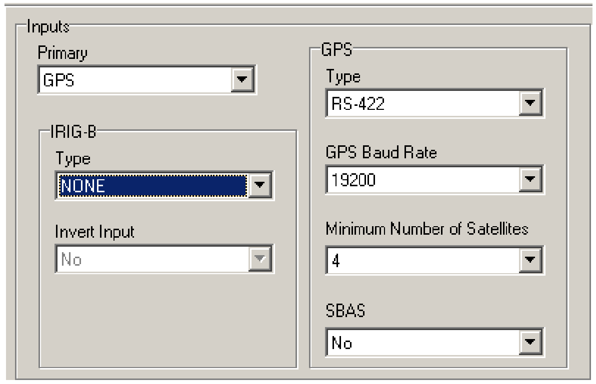



*Figure 34-8: Example of setup for external GPS receiving RS-422 in kSetup*

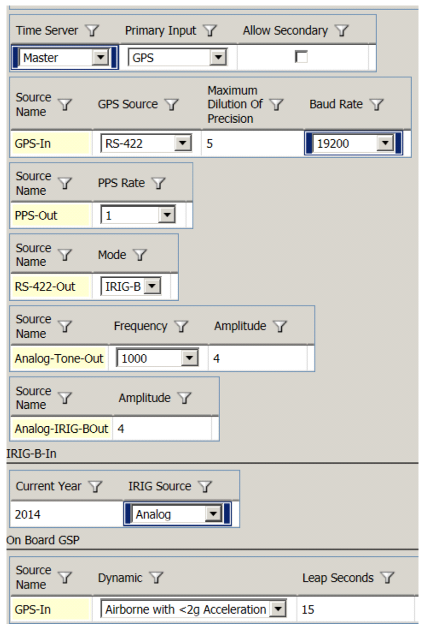



*Figure 34-9: Example of setup for external GPS receiving RS-422 in DAS Studio 3*

## 34.4.2 Active GPS antenna

The setup for an active GPS antenna is shown in Figure 34-10 on page 241, Figure 34-11 on page 241, and Figure 34-12 on page 242.

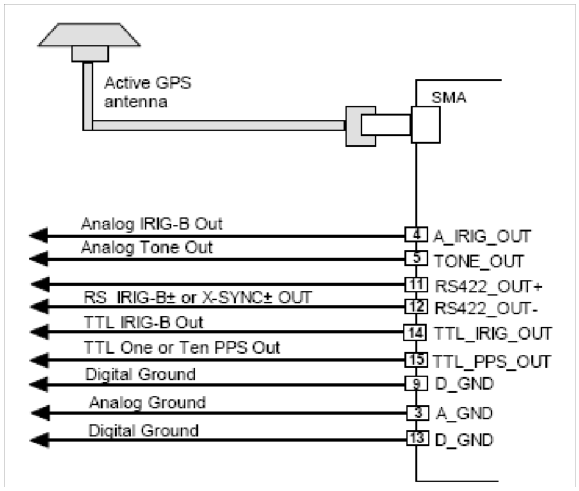



*Figure 34-10: Setup for active GPS antenna*

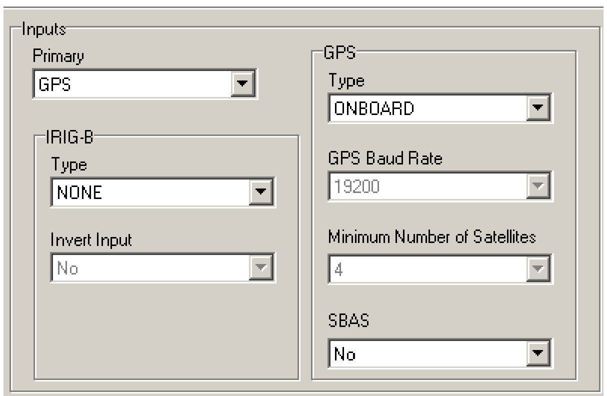



*Figure 34-11: Example of setup for active GPS antenna in kSetup*

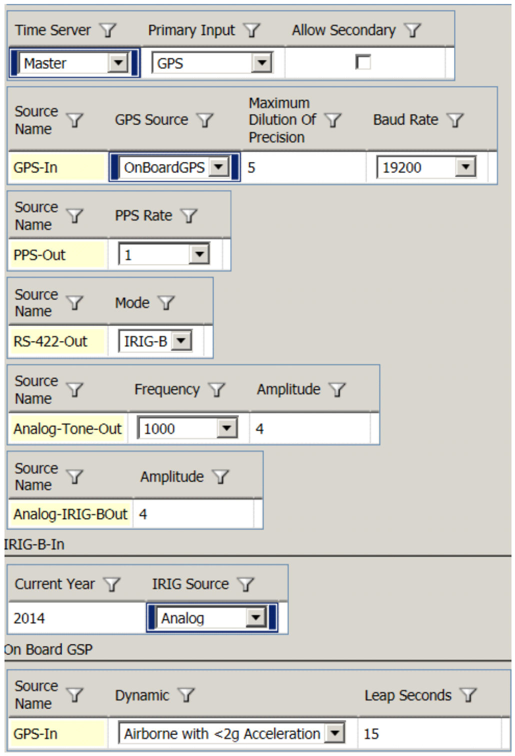



*Figure 34-12: Example of setup for active GPS antenna in DAS Studio 3*

## 34.4.3 External GPS receiver using RS-232 and TTL

The setup for an external GPS receiver using RS-232 at 19,200bps and TTL is shown in Figure 34-13 on page 242, Figure 34-14 on page 243, and Figure 34-15 on page 243.

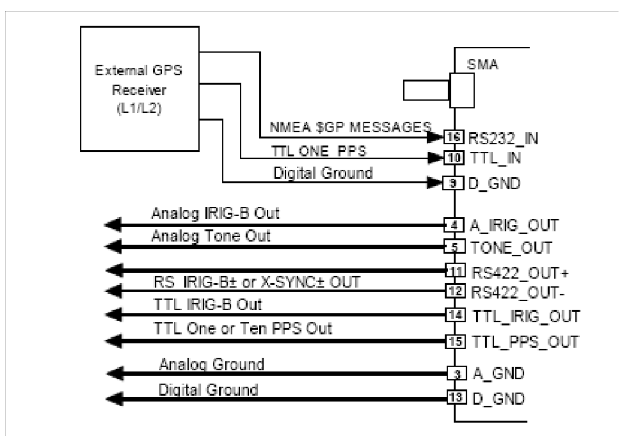



*Figure 34-13: Setup for external GPS receiver using RS-232 and TTL*

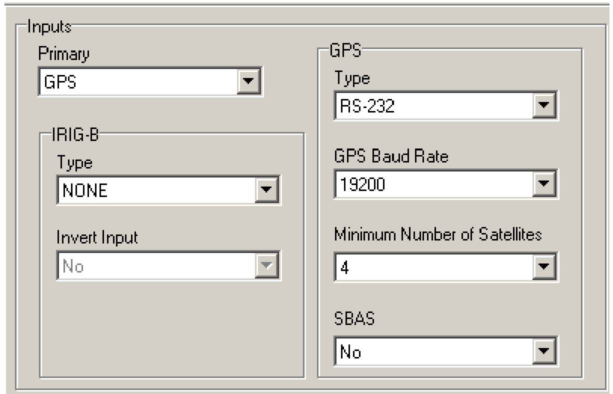



*Figure 34-14: Example of setup for external GPS receiver using RS-232 and TTL in kSetup*

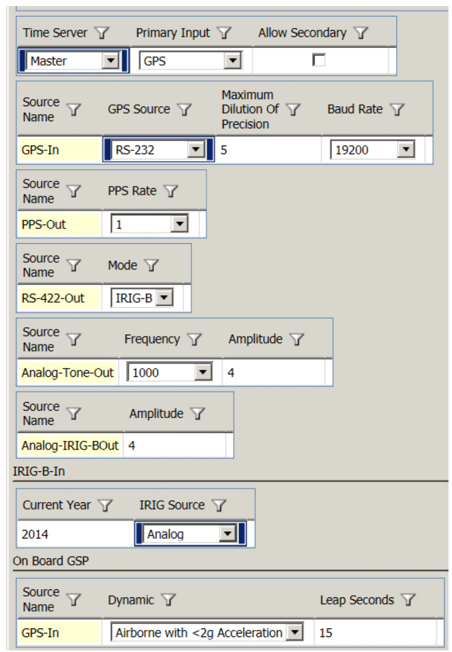



*Figure 34-15: Example of setup for external GPS receiver using RS-232 and TTL in DAS Studio 3*

## 34.4.4 Analog IRIG-B input

The setup for an analog IRIG-B input is shown in Figure 34-16 on page 244, Figure 34-17 on page 244, and Figure 34-18 on page 245.

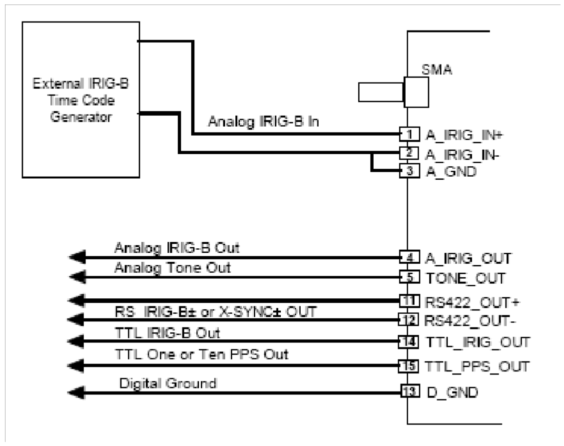



*Figure 34-16: Setup for analog IRIG-B input*

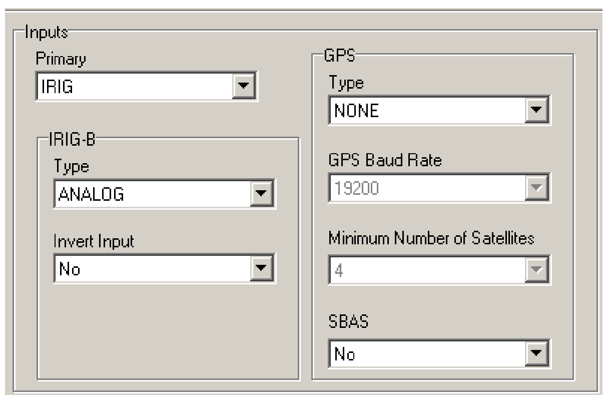



*Figure 34-17: Example of setup for analog IRIG-B input in kSetup*

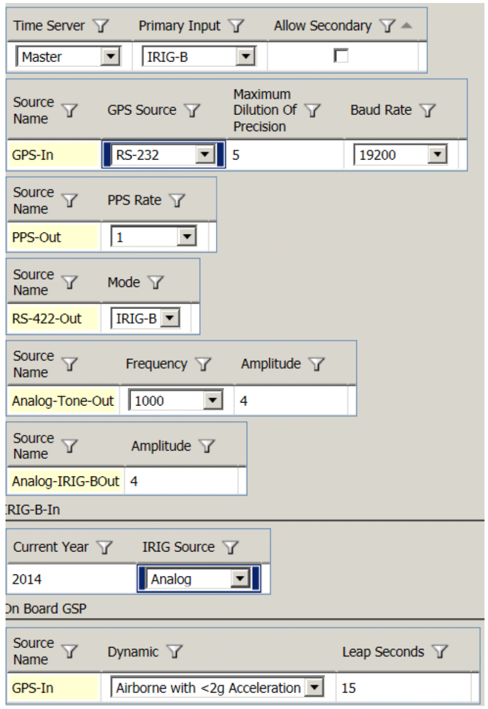



*Figure 34-18: Example of setup for analog IRIG-B input in kSetup DAS Studio 3*

## 34.4.5 Digital IRIG-B input

The setup for a digital IRIG-B input is shown in Figure 34-19 on page 245, Figure 34-20 on page 246, and Figure 34-21 on page 246.

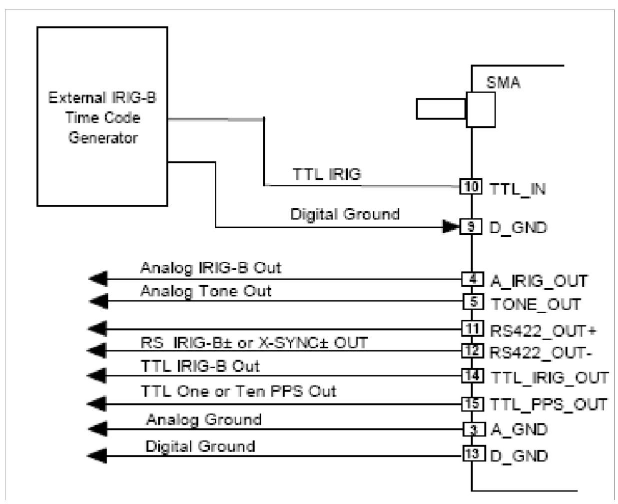



*Figure 34-19: Setup for digital IRIG-B input*

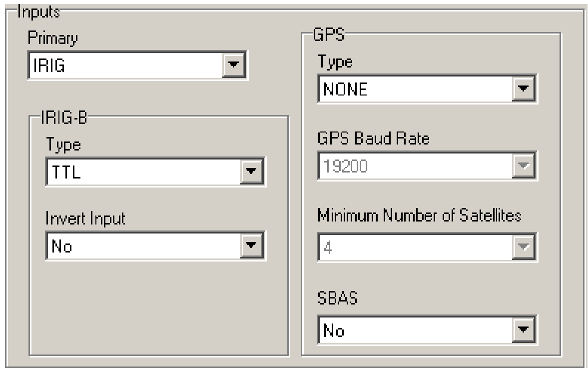



*Figure 34-20: Example of setup for digital IRIG-B input in kSetup*

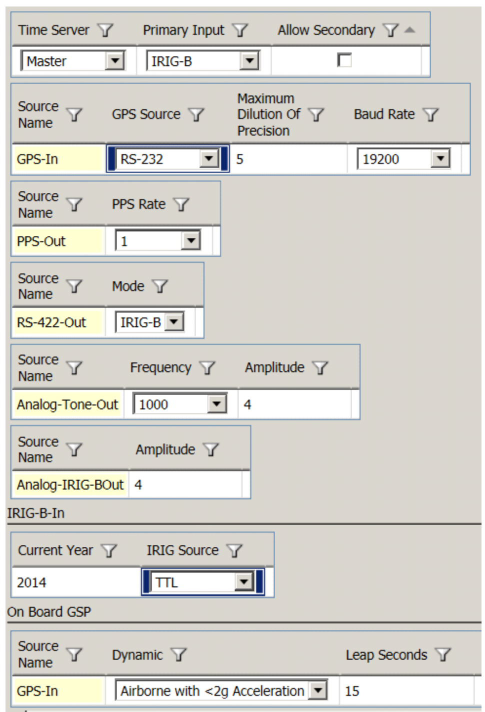



*Figure 34-21: Example of setup for digital IRIG-B input in DAS Studio 3*

## 34.4.6 RS-422 IRIG-B input

The setup for a RS-422 IRIG-B input is shown in Figure 34-22 on page 247, Figure 34-23 on page 247, and Figure 34-24 on page 248.

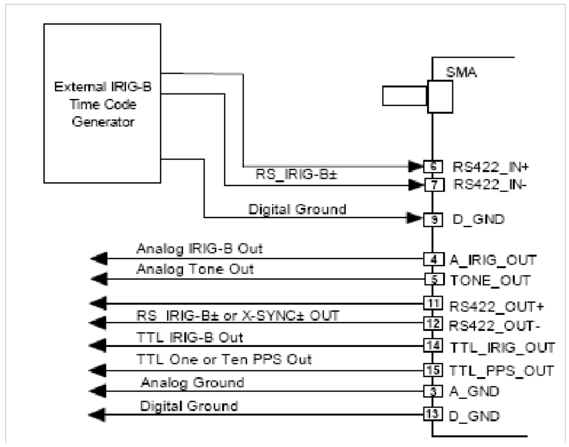



*Figure 34-22: Setup for RS-422 IRIG-B input*

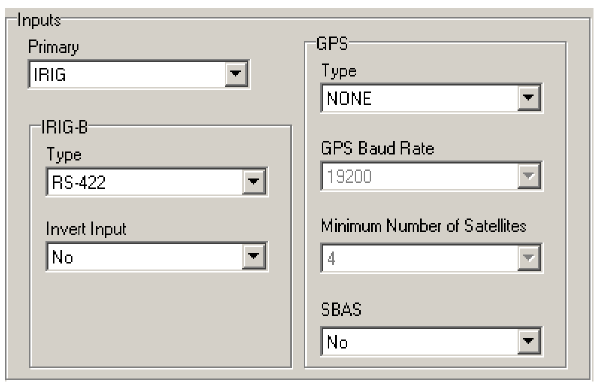



*Figure 34-23: Example of setup for RS-422 IRIG-B input in kSetup*

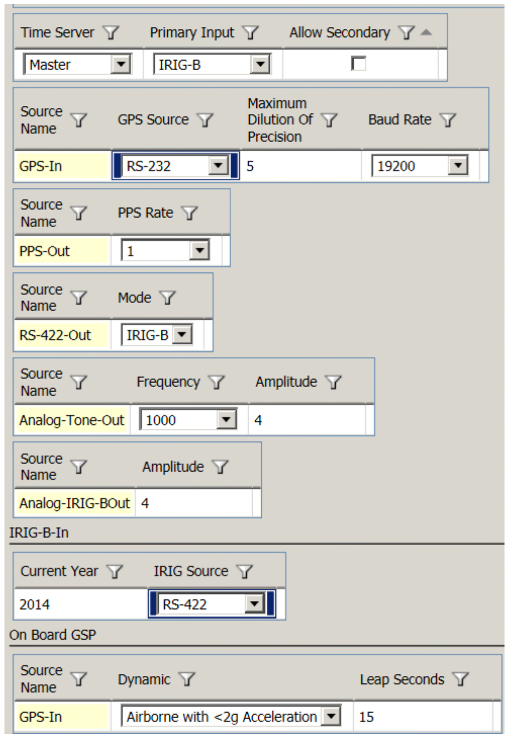



*Figure 34-24: Example of setup for RS-422 IRIG-B input in kSetup DAS Studio 3*

For GPS antenna recommendations, see the *KAM/TCG/102* data sheet.

# 34.5 Troubleshooting GPS

## 34.5.1 GPS not in lock

Check the StatusGPS parameter. This parameter provides information on the current GPS status, such as GPS lock, Dilution of Precision (DOP) in and out of range, and number of satellites in use.

---

**NOTE:** Bit 15 of the StatusGPS parameter defaults to 0, which indicates the module does not have GPS lock. Bit 15 is only set to 1 when the GPS receiver has achieved GPS lock.

If bit 15 remains at 0, the module is unable to achieve GPS lock and there are problems with satellite coverage. This may be due to poor satellite coverage or issues with the GPS antenna or cabling.

If bit 15 is set to 1 (GPS lock) but the position is incorrect, check bit 11. If bit 11 of the StatusGPS parameter is set to 1, this indicates that the DOP figures are out of range. The actual DOP figures can be read from the DilutionOfPrecision parameter.

Also, check the number of satellites in view (StatusGPS[7:4]) and the number of satellites in use (StatusGPS[3:0]). If the number of satellites in view is less than four, try the other troubleshooting hints in this section.

---

**NOTE:** The antenna must be connected before powering up the Acra KAM-500 chassis with the KAM/TCG/102.

## 34.5.2 Multipath errors

A multipath environment exists if GPS signals arrive at the antenna directly from the satellite and also from reflective surfaces, for example water or building walls (see Figure 34-25 on page 249).

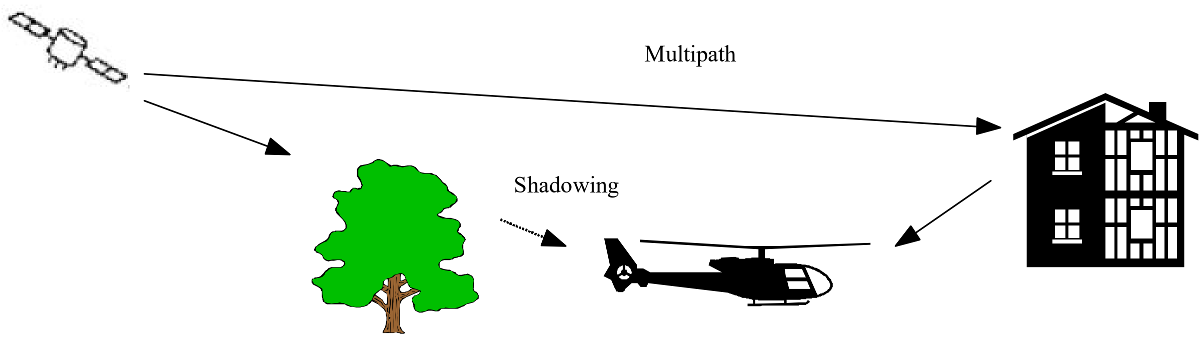



*Figure 34-25: Multipath environment*

If there is a direct path in addition to the reflected path available, the receiver can usually detect the situation and compensate to some extent. If there is no direct line of sight, but only reflections, the receiver is not able to detect the situation.

Under multipath conditions, range measurement to the satellite provides incorrect information to the navigation solution, resulting in less accurate positioning. If there are few satellites in view, the navigation solution might be wrong by several hundred meters.

Location of the antenna close to a vertical metal surface can be harmful owing to the fact that metal is an almost perfect reflector. When mounting an antenna on top of a reflective surface, the antenna should be mounted as close to the surface as possible. Then, the reflective surface acts as an extension of the antennas ground place and not as a source multipath.

## 34.5.3 Antenna shortcomings

Although GPS can work with a weak signal, to have a reliable GPS system the antenna selection and location should be considered carefully as inappropriate selection and poor location degrades GPS performance. Factors which degrade the GPS performance include the following:

- Inadequate gain of the GPS antenna
- Poor directivity of the GPS antenna
- Improper orientation of the antenna to the sky
- Poor matching of antenna, cable, and receiver impedance
- Poor noise performance of the input stage of the antenna amplifier

For more information on getting the most from the antenna, see the *KAM/TCG/102* data sheet.

# 34.6 Tips

Battery drift

The data sheet states a drift of 3ppm when acting as a generator. What is the drift when not powered-up and an external battery is connected?

The drift does not change when powered with an external battery. However, the module shows a jump in time when the module is powered up with a battery connected. It is not a constant jump and increases with the number of power-ups.

Pulses Per Second (PPS)

No more then one PPS should be used with the KAM/TCG/102 as the Phase Locked Loop has been designed to work with one PPS only.

GPS input in relation with IRIG-B output

What delay in time, if any, exists in the KAM/TCG/102 between a received RF GPS input and the derived modulated IRIG-B output?

The internal circuitry of the module compensates for any known fixed delays between the GPS input and the IRIG-B output. This means that the latency is as defined on the data sheet to within one microsecond.

NMEA

The following NMEA messages GGA, GSV, ZDA, GSA, GLL are the minimum required for the KAM/TCG/102 to function. These NMEA messages and one PPS are sufficient for the KAM/TCG/102 to synchronize time with the Acra KAM-500.

Circular Error Probable (CEP)

The error quoted for CEP takes into account any glitch that might happen due to reflections or generally corrupted reception. In practice, 99% of the time, the accuracy remains around 2.5m but a glitch can happen giving a sample up to 22m of accuracy.

Since parameters from the KAM/TCG/102 are updated every second, such a sample can be easily spotted and discarded.

DOP

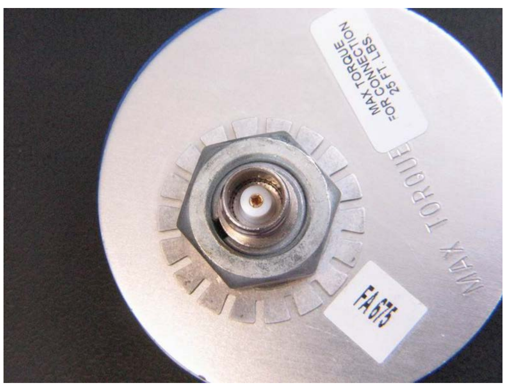
DOP is a unitless value that indicates when the satellite geometry provides the most accurate results. It's the mathematical representation of the quality of the navigation solution, based on the geometry of the satellites used in the calculation. DOP is mainly controlled by the number of visible satellites and their relative positions in the sky. Satellites spread over the sky give better results (lower DOP).

The most commonly used DOP is Position Dilution Of Precision (PDOP). It's a combination of Horizontal Dilution Of Precision (HDOP) and Vertical Dilution Of Precision (VDOP). A PDOP of one indicates an optimum satellite constellation and high quality data. The quality of the data decreases as the PDOP value increases.

A PDOP with a value in excess of eight is considered poor. A point calculated with PDOP of 30 may be off by more than 150 meters from its true location.

RFE/AEG/001

There are no special accessories required to mount this antenna; it is shipped complete for mounting. The antenna in this series is hard-mounted through a unique single hole feed structure and includes gaskets to prevent air and water leaks. The mounting is a through hole 5/8-18UNC-2A thread.




## 34.7 References

ASCII code reference can be found under http://nemesis.lonestar.org/reference/telecom/codes/ascii.html

NMEA reference: http://www.gpsinformation.org/dale/nmea.htm

Chapter 35

# Using the KAD/UAR/102

TEC/NOT/062

The KAD/UAR/102 parses (coherently extracts specific bytes) and snarfs (sends all data to a FIFO) up to four RS-232/422/485 channels. This paper introduces the RS-232/422/485 channels and outlines how to configure the KAD/UAR/102 module. This paper discusses the following topics:



## 35.1 RS-232/RS-422/RS-485 overview

This section introduces RS-232/422/485, focusing on the physical layer and the bit definition.

### 35.1.1 Physical layer

RS-232 is single ended, so the difference voltage is relative to ground. RS-422 and RS-485 are differential ended, so the difference voltage is between the positive and negative terminals. RS-422 and RS-485 are nominally independent of ground, but if the ground potential differs by too much between end nodes, then no data is received.

The RS-232, RS-422 and RS-485 logic 0 is less than -200 mV. Logic 1 is more than 200 mV (see the following figure).

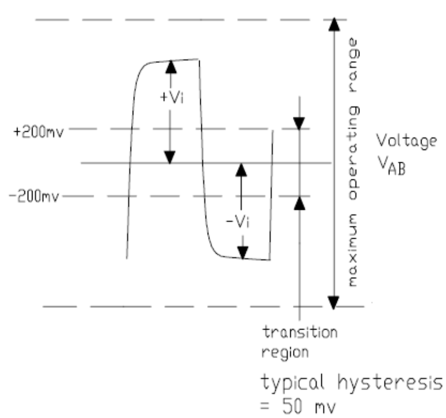



*Figure 35-1: Differential input*

RS-422 and RS-485 require a termination at the end of the transmission line (see the following figure).

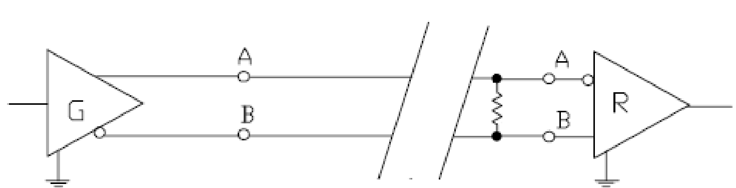



*Figure 35-2: Termination differential input*

## 35.1.2 Bit definition

A data word can be either seven or eight bits in length. A parity bit can be placed at the end of each data word (see the following figure).

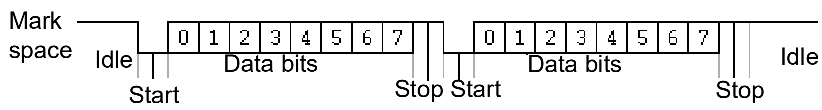



*Figure 35-3: Serial bit definition*

# 35.2 KAD/UAR/102 and the serial link

This section outlines the key features of the KAD/UAR/102 with respect to the serial link monitoring. Like other Curtiss-Wright bus monitors, the KAD/UAR/102 uses a triple buffer for parsing.

## 35.2.1 Parsing

The following figure illustrates the triple buffering of data words (green) and time message tags (white) used for each bus in the KAD/UAR/102's parser. These data words and message tags are described in Table 35-1 on page 252.

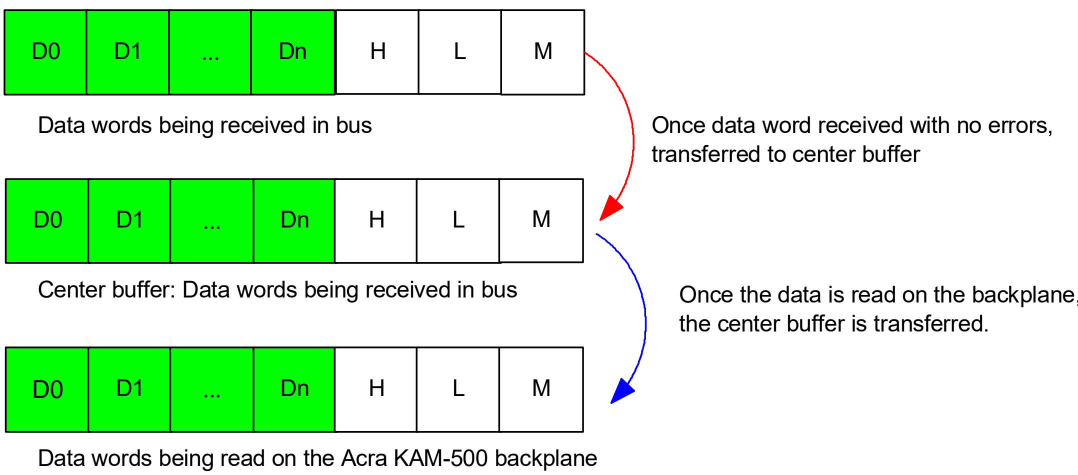



*Figure 35-4: Triple buffering of traffic and associated message tags*

Table 35-1: Data word and message tag descriptions

| Data word/message tag | Description |
|---|---|
| D0, D1, D2, Dn | Traffic with n<512. |
| H | High time. |
| L | Low time. |
| M | Micro time. |

Time message tags are added to each message received and stored in separate buffers for each of the four busses. As soon as a message is received with no errors, the complete buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped flag is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the contents of the center buffer (if new) are transferred to the read buffer. If no new data word has been received, the stale flag is set. A center and read buffer exist for every message ID (parser slot).

Skipped and stale bits can be found in the MsgInfo register. Refer to the *KAD/UAR/102* data sheet**.**

## 35.3 Overview of the KAD/UAR/102

The KAD/UAR/102 is an RS-232, RS-422, or RS-485 universal asynchronous bus monitor, a coherent message parser and an error-detection function on a single module. The KAD/UAR/102 also has snarfer capability for each of the four busses.

In the parser, a total of up to 126 complete messages are triple buffered so that the stale indication is message-wide. Each message can be up to 512 characters (bytes) long (including start and stop characters). Each message is tagged to 0.1 ms resolution; a message is considered found when up to eight specific bytes are received. The end of a message is determined by a user-defined stop character or specific number of data words. A message is not updated if any sequence is incorrect. The snarfer stores all data from each bus in a separate FIFO 2K data words deep.

### 35.3.1 Key features

- Four independent input channels
- Bit-rates from 300 bps to 1,000,000 bps
- 7/8 bits per data word with odd/even or no parity
- Programmable start sequence (one to eight characters)
- Programmable stop sequence (one character or by fixed length)
- Locks on idle time
- Parses up to 126 strings (messages) per module
- Up to 512 characters (bytes) per message; minimum of nine characters (bytes) per message
- Time tagging (±0.1 ms)
- Message wide stale (skipped) indication
- FIFO is 2K data words deep per channel
- Two bits for FIFO full/empty

## 35.4 Setting up the KAD/UAR/102 using KSM-500

You may use kSetup software to configure the KAD/UAR/102. kSetup is included in the KSM-500 suite of tools. Some configuration features that are needed to set up the KAD/UAR/102 include configuring channels, setting messages and adding data words to messages. This information is summarized in the “Setting up packages” and “Setting up datalinks” section of the *KAD/UAR/102* data sheet.

### 35.4.1 Setting parameters

The Parameters tab (see the following figure) displays all the parameters available from the module. To set parameters for the KAD/UAR/102, select the module in the Task Explorer pane of kSetup. On the Parameters tab, complete the fields described in the following table. For more information on using kSetup, contact Curtiss-Wright support (acra-support@curtisswright.com).

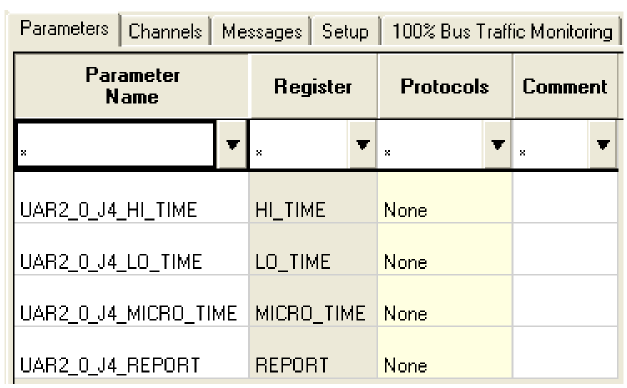



*Figure 35-5: Parameters tab in kSetup*

Table 35-2: Parameters tab settings

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter. |
| Register | The Report register is useful to transmit when monitoring message problems; for details of register definitions, see the *KAD/UAR/102* data sheet. |

Table 35-2: Parameters tab settings (continued)

| Field name | Description |
|---|---|
| Protocols | When the parameter is placed in a PCM frame, click on the Package button to display transmission details. |
| Comment | User-defined text relating to the parameter. |

### 35.4.2 Configuring channels

You must configure channels for both parsing and snarfing. On the Channels tab (see the following figure), complete the fields described in the following table.

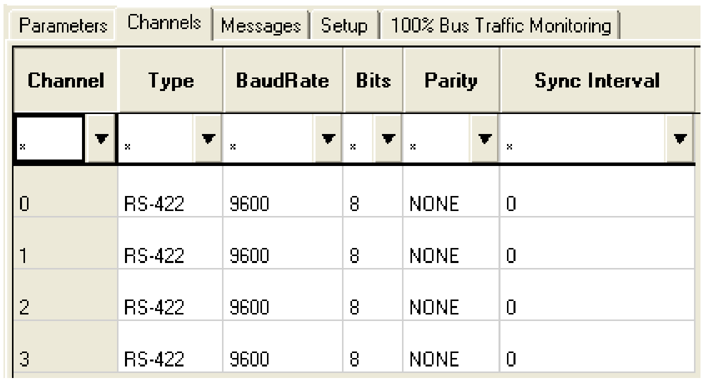



*Figure 35-6: Channels tab in kSetup*

Table 35-3: Channels tab settings

| Field name | Description |
|---|---|
| Channel | Read-only field; the bus for which the physical definition must be configured. |
| Type | RS-232, RS-422 or RS-485. |
| BaudRate | Baud rates supported by the module. |
| Bits | Bits per data word: 7 or 8. |
| Parity | Parity of the data word: None, Even or Odd. |
| Sync Interval | Idle time between consecutive characters required before starting new message; 2 to 63ms. |

**NOTE:** When setting Type, the pinout for RS-232 is different than the pinout for RS-422/RS-485.
When setting BaudRate, a channel can also use a non-standard baud rate. You can define non-standard baud rates (tolerance of ±2%) provided the relationship between the highest non-standard baud rate (f1), and the other non-standard baud rate (fNS), obeys the following: fNS = f1 / N (where N is an integer greater than or equal to 2 and less than 4095).
When setting Sync Interval, idle time can be used when there's no unique start sequence on a message. For more information on Sync Interval, see “35.6 Common errors and scenarios for configuring messages” on page 259.

## 35.4.3 Setting messages

It is necessary to configure messages if you want to use the KAD/UAR/102 to parse data. On the Messages tab (see the following figure), complete the fields described in the following table.

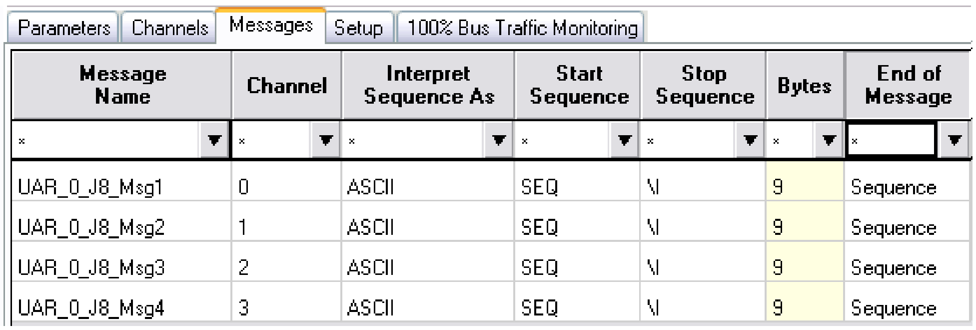
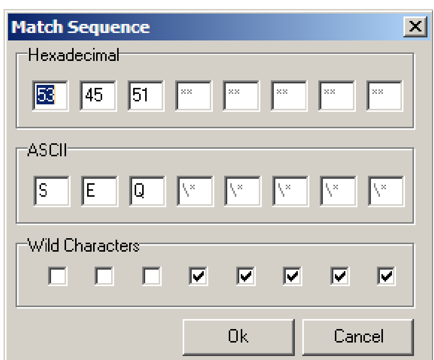



*Figure 35-7: Messages tab in kSetup*

Table 35-4: Messages tab settings

<table>
<tr><th>Field name</th><th>Description</th></tr>
<tr><td>Message Name</td><td>Label for the message name. Select the message name and type the new message name.</td></tr>
<tr><td>Channel</td><td>Channel to parse. Select the channel from 0 to 3.</td></tr>
<tr><td>Interpret Sequence As</td><td>The module can parse hexadecimal or ASCII data stream. Select between ASCII and Hex.</td></tr>
<tr><td>Start Sequence</td><td>Start sequence to parse the data stream. If you right-click a message and select Edit Start Sequence, the Match Sequence dialog box displays.<br>


<br>0 to 8 bytes can be defined in the Start Sequence. If 0 byte is used, Sync Interval on the Channels tab has to be configured. For more information, see “35.7 References” on page 264.</td></tr>
<tr><td>Stop Sequence</td><td>Parses the data stream. Right-click on the message and select Edit Stop Sequence.<br>Stop Sequence is only used when End of Message is set to Sequence. Stop Sequence can only be set up with one byte.</td></tr>
<tr><td>Bytes</td><td>Number of bytes in the full message including the start sequence. Complete this field only when End of Message is set to Length. For more information, see “35.6 Common errors and scenarios for configuring messages” on page 259.</td></tr>
<tr><td>End of Message</td><td>You can parse on the message length or on a stop sequence. For more information, see “35.6 Common errors and scenarios for configuring messages” on page 259.</td></tr>
</table>

### 35.4.3.1 Adding data words

To add data words on the parser, double-click a message on the Messages tab and then click Add. For examples of data words, see the following figure. On the Data tab, complete the fields described in the following table.

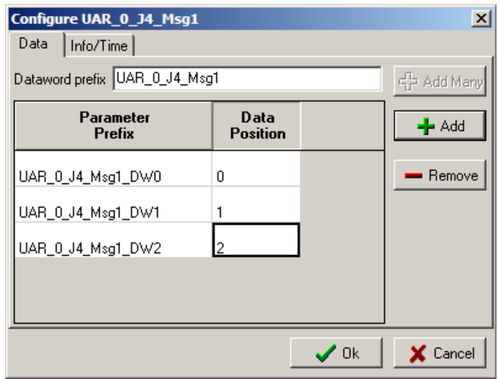



*Figure 35-8: Adding data words*

Table 35-5: Data word settings

| Field name | Description |
| --- | --- |
| Parameter Prefix | Parameter name. |
| Data Position | Position of the data word in the message.<br><br>If the data position is an even number, the data word is read as:<br>Data N (even) R[15:8] The 7/8 bits of byte M in serial stream. R(15) is the Last Bit Transmitted (LBT).<br>Data N (even) R[7:0] The 7/8 bits of byte M+1 in serial stream. R(15) is the LBT.<br><br>If the data position is an odd number, the data word is read as:<br>Data N (odd) R[15:8] The 7/8 bits of byte M in serial stream. R(15) is the LBT.<br>Data N (odd) R[7:0] The 7/8 bits of byte M-1 in serial stream. R(15) is the LBT.<br>See Figure 35-12 on page 260 and Figure 35-15 on page 260 for an example of data position. |

**NOTE:** If the start sequence is defined, the first data words contain the start sequence. These specific odd/even registers are used to differentiate between a little/big endian. The odd/even registers facilitate the decommutation depending on whether UNIX or Microsoft is used on the ground station.
The KAD/UAR/102 can parse up to 512 bytes per message per bus. This length includes the bytes used for the start sequence and the end sequence (if it is used).
Data words are only updated when the sequence is correct. Data words are not refreshed until a valid message appears. At power-up, data words have a random value until a valid message arrives. If Length is selected as the End Sequence, add a number of data words less than or equal to the Length, otherwise kProgram generates an error.
For a data word example, see the previous figure.

### 35.4.3.2 Adding Info/Time message tags

Because the serial stream is asynchronous to the Acra KAM-500, some message tags are available (see the following figure). For bit definitions of these registers, see the *KAD/UAR/102* data sheet.

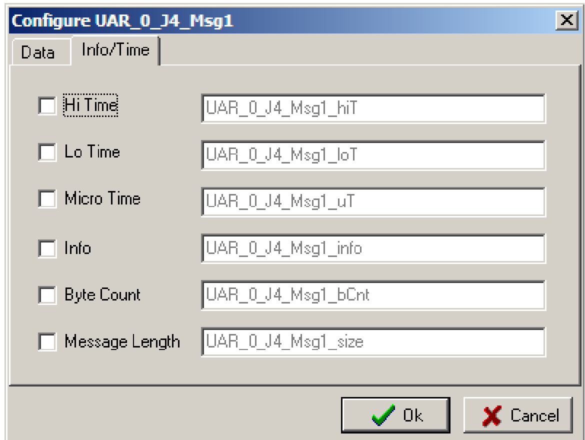



*Figure 35-9: Available Info/Time message tags*

The serial stream is asynchronous to the Acra KAM-500 so it does not pick up the time and message info automatically. These settings can be added to the stream as extra time/info about the messages.

## 35.4.4 Reviewing Setup tab requirements

Time Server: Legacy. Must remain at default setting of Slave.

## 35.4.5 Defining snarfer settings

If configuring the KAD/UAR/102 to snarf as well as parse, you must define settings on the 100% Bus Traffic Monitoring tab as well as the Channels tab. For information on Channel tab settings, see “35.4.2 Configuring channels” on page 254.

To define snarfer settings on the 100% Bus Traffic Monitoring tab (see the following figure), complete the fields described in Table 35-6 on page 258.

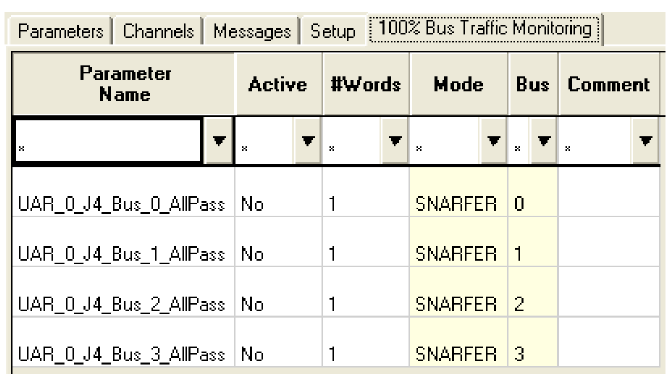



*Figure 35-10: 100% Bus Traffic Monitoring tab in kSetup*

Table 35-6: 100% Bus Traffic Monitoring tab setting

| Field name | Description |
|---|---|
| Parameter Name | You can edit any parameter name. |
| Active | If active, all snarfer parameters from the module are made available for transmission. |
| #Words | Allows an irregular PCM frame placement to ensure you get the best possible bandwidth from the PCM. |
| Mode | Read-only field. For bit definition, see the *KAD/UAR/102* data sheet. |
| Bus | Read-only field. The bus to be snarfed. |
| Comment | User-defined text relating to the parameter. |

# 35.5 Setting up the KAD/UAR/102 using DAS Studio 3

You may use DAS Studio 3 software to configure the KAD/UAR/102. Some configuration features that are needed to set up the KAD/UAR/102 include configuring channels, configuring messages, and adding data words to messages. This information is summarized in the “Setting up packages” and “Setting up datalinks” section of the *KAD/UAR/102* data sheet.

## 35.5.1 About the Settings tab

The Settings tab (see the following figure) displays settings available for configuring the KAD/UAR/102. On the Settings tab, complete the fields described in Table 35-7 on page 258. For information on using the other tabs, that is Processes, Packages, Algorithms, and Documentation, see the *DAS Studio 3 User Manual*.

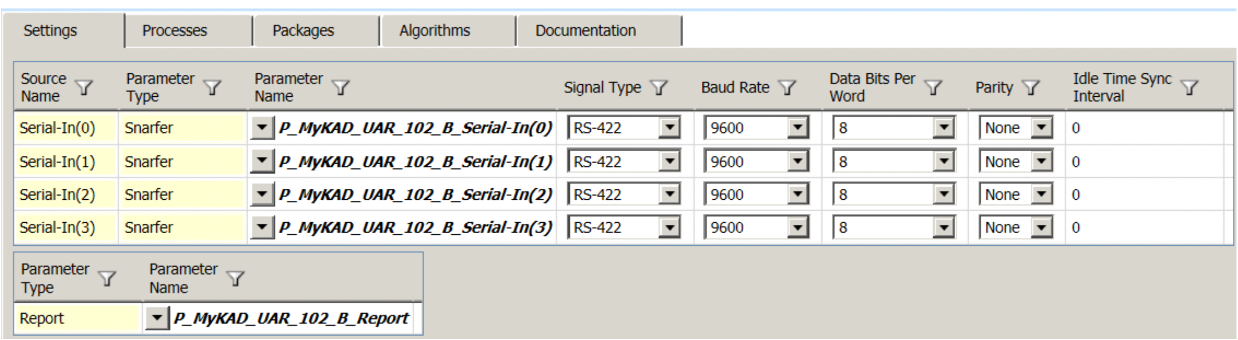



*Figure 35-11: Settings tab in DAS Studio 3*

Table 35-7: Settings tab features

| Field name | Description |
|---|---|
| Source Name | Read-only field; displays the bus for which the physical definition must be configured. |
| Parameter Type | Read-only field; displays the snarfer function being configured. |
| Parameter Name | Snarfer parameter name. |
| Signal Type | For information, see the “Instrument Settings” section of the *KAD/UAR/102* data sheet.<br>**NOTE:** This field is applicable for snarfing and parsing. |
| Baud Rate | For information, see the “Instrument Settings” section of the *KAD/UAR/102* data sheet.<br>**NOTE:** This field is applicable for snarfing and parsing. |
| Data Bits Per Word | For information, see the “Instrument Settings” section of the *KAD/UAR/102* data sheet.<br>**NOTE:** This field is applicable for snarfing and parsing. |
| Parity | For information, see the “Instrument Settings” section of the *KAD/UAR/102* data sheet.<br>**NOTE:** This field is applicable for snarfing and parsing. |

Table 35-7: Settings tab features (continued)

| Field name | Description |
|---|---|
| Idle Time Interval | For information, see the “Instrument Settings” section of the *KAD/UAR/102* data sheet.<br>**NOTE:** This field is applicable for snarfing and parsing. |
| Parameter Type | Read-only field; the Report register is useful to transmit when monitoring message problems. For details of register definitions, see the *KAD/UAR/102* data sheet. |
| Parameter Name | Name of the parameter to be transmitted. |

**NOTE:** When setting Signal Type, the pinout for RS-232 is different than the pinout for RS-422/RS-485.
When setting Baud Rate, a channel can also use a non-standard baud rate. You can define non-standard baud rates (with a tolerance of ±2%) provided the relationship between the highest non-standard baud rate (f1), and the other non-standard baud rate (fNS), obeys the following: fNS = f1 / N (where N is an integer greater than or equal to 2 and less than 4095).
When setting Sync Interval, idle time can be used when there is no unique start sequence in a message. For more information, see “35.6.6 Parsing messages without a unique start sequence” on page 263.

### 35.5.2 Serial Builder applications

The Serial Builder application is used to add and configure messages and parameters on RS-232, RS-422 and RS-485 serial bus monitor modules for the mode parser of a module. For more information, see the “Serial Builder” section in the *DAS Studio 3 User Manual*. For information on package tags, see the “Processes Tab - Process Register Editor and Viewer” section in the *DAS Studio 3 User Manual*.

## 35.6 Common errors and scenarios for configuring messages

### 35.6.1 Common errors

If the bus +/- is physically inverted, swap the connections referring to the pinout of the data sheet and retransmit.

If the wrong bus is being parsed, compare the channel on the Channels tab to the physical connection, referring to the pinout on the data sheet.

If the baud rate is set incorrectly, change the setting (see “35.4.2 Configuring channels” on page 254).

If the Serial link ground is not connected to the Acra KAM-500 ground (GND), refer to the pinout on the data sheet and make the connection.

If termination is not present or double termination is incorrectly used, refer to the pinout of the data sheet and make the connection.

### 35.6.2 Parsing messages with less than nine bytes

To parse a message, the message must have at least nine bytes. The snarfer can parse any data stream size in bytes.

If a message is five bytes on the bus and the user programs the KAD/UAR/102 with a length of nine bytes, the module parses the message but it also parses the next message. The KAD/UAR/102 continues parsing until it receives the full message length that it has been configured with. This may affect the next message on the bus, because as soon as the parser identifies a valid start sequence received, it ignores everything else after it.

**NOTE:** If using a KAD/UAR/102/C, the minimum message length is 4 bytes (rather than 9 bytes).

### 35.6.3 Optimizing parsing

Parsing can be likened to performing a search on a text or binary file. To optimize parsing, you must configure the Start Sequence and Stop Sequence fields with the most information possible as described in the following example.

Two different messages are defined in the bus: Message A (MSGA) - ABCDEFGHI\I; and Message B (MSGB) - ABTUVWXYZ\I. If for one message, the Start Sequence is defined as AB, the KAD/UAR/102 uses the same ID (parser slot) to store the message (see Figure 35-12 on page 260). In this case, the data words for the module return the following:

DW0 = AB

DW2 = CD or TU

DW4= EF or VW

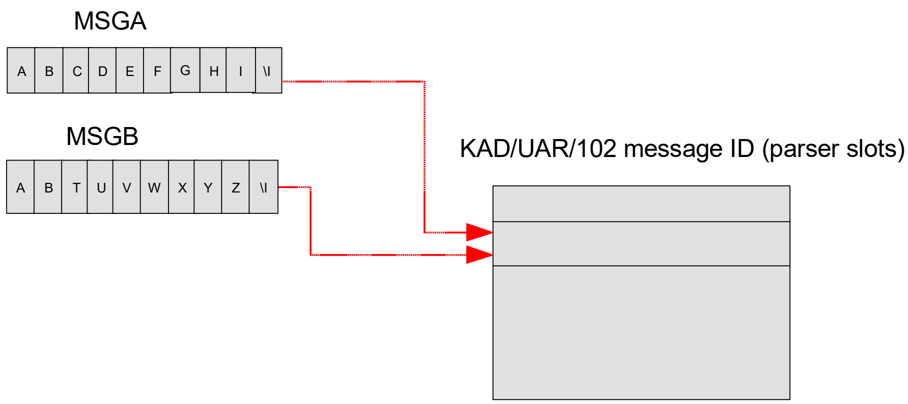



*Figure 35-12: Using the same message ID (same parser slot for two different messages)*

For the following example, the Start Sequence for both messages is defined:

MSGA has a Start Sequence defined as ABC. MSGB has a Start Sequence defined as ABT. Both messages have a Stop Sequence defined as \I (see the following figure).

Parameters | Channels | Messages | Setup | 100% Bus Traffic Monitoring

| Message Name | Channel | Interpret Sequence As | Start Sequence | Stop Sequence | Bytes | End of Message |
|---|---|---|---|---|---|---|
| MSGA | 0 | ASCII | ABC | \I | 9 | Sequence |
| MSGB | 0 | ASCII | ABT | \I | 9 | Sequence |

*Figure 35-13: Defining Start Sequence and Stop Sequence fields with KSM-500*

| Instrument | Channel | Package | Parsing Mode | Bytes Per Package | Start Sequence Format | Start Sequence | Stop Sequence Format | Stop Sequence |
|---|---|---|---|---|---|---|---|---|
| MyKAD_UAR_102_B | Serial-In(0) | MSGA | Start/Stop Sequence | n/a | ASCII | ABC | ASCII | \I |
| MyKAD_UAR_102_B | Serial-In(0) | MSGB | Start/Stop Sequence | n/a | ASCII | ABT | ASCII | \I |

*Figure 35-14: Defining Start Sequence and Stop Sequence fields with DAS Studio 3*

In this example, the KAD/UAR/102 uses a unique message ID to store each message (see the following figure).

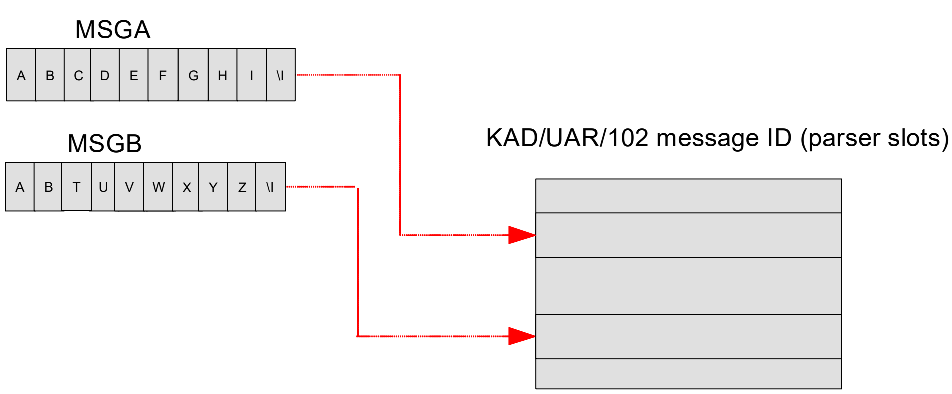



*Figure 35-15: Using a unique message ID (different parser slots for two different messages)*

In this case, the data words for the module return the following:

MSGA

DW0 = AB

DW2 = CD

DW4 = EF

MSGB

DW0 = AB

DW2 = TU

DW4 = VW

### 35.6.4 Using End of Message values to stop parsing

Parsing of the string can be stopped by using the Length and Sequence values in the End of Message field (see the following figure and Figure 35-17 on page 261). Length and Sequence values are not used by the module to determine the parser slot (Message ID).

In the following example, MSGA and MSGB both use the same Start Sequence value but with a different length (defined in the Bytes field); both messages use the same parser slot (Message ID) in the module.

MSGA: ABCDEFGHI

MSGB: ABCDVWXYZ

---

**WARNING:** The module may inadvertently put data words from MSGA into MSGB or vice versa.

Parameters | Channels | Messages | Setup | 100% Bus Traffic Monitoring

| Message Name | Channel | Interpret Sequence As | Start Sequence | Stop Sequence | Bytes | End of Message |
|---|---|---|---|---|---|---|
| MSGA | 0 | ASCII | ABCD | \I | 6 | Length |
| MSGB | 0 | ASCII | ABCD | \I | 7 | Length |

*Figure 35-16: Setup of two messages with different lengths using KSM-500*

In the following example, MSGA and MSGB both use the same Start Sequence value but with a different Stop Sequence value; both messages use the same parser slot (Message ID) in the module.

MSGA: ABCDEGHIF

MSGB: ABCDWXYZE

---

**WARNING:** The module may inadvertently put data words from MSGA into MSGB or vice versa.

Parameters | Channels | Messages | Setup | 100% Bus Traffic Monitoring

| Message Name | Channel | Interpret Sequence As | Start Sequence | Stop Sequence | Bytes | End of Message |
|---|---|---|---|---|---|---|
| MSGA | 0 | ASCII | ABCD | F | 9 | Sequence |
| MSGB | 0 | ASCII | ABCD | E | 9 | Sequence |

*Figure 35-17: Setup of two messages with different Stop Sequence values using KSM-500*

| Instrument | Channel | Package | Parsing Mode | Bytes Per Package | Start Sequence Format | Start Sequence | Stop Sequence Format | Stop Sequence |
|---|---|---|---|---|---|---|---|---|
| MyKAD_UAR_102 | Serial-In(0) | MSGA | Start/Stop Sequence | n/a | ASCII | ABCD | ASCII | F |
| MyKAD_UAR_102 | Serial-In(0) | MSGB | Start/Stop Sequence | n/a | ASCII | ABCD | ASCII | E |

*Figure 35-18: Setup of two messages with different Stop Sequence values using DAS Studio 3*

## 35.6.5 Setting variable lengths

Some messages have a variable length. As shown in the following example, the parser cannot differentiate between different message lengths that use the same stop sequence.

MSGA instance 1: ABXYZxywzF

MSGA instance 2: ABXYxywzF

| Message Name | Channel | Interpret Sequence As | Start Sequence | Stop Sequence | Bytes | End of Message |
|---|---|---|---|---|---|---|
| * | * | * | * | * | * | * |
| MSGA | 0 | ASCII | AB | F | 9 | Sequence |

*Figure 35-19: Incorrect setup of variable length (as seen in KSM-500)*

| Instrument | Channel | Package | Parsing Mode | Bytes Per Package | Start Sequence Format | Start Sequence | Stop Sequence Format | Stop Sequence |
|---|---|---|---|---|---|---|---|---|
| MyKAD_UAR_102 | Serial-In(0) | MSGA | Start/Stop Sequence | n/a | ASCII | AB | ASCII | F |

*Figure 35-20: Incorrect setup of variable length (as seen in DAS Studio 3)*

If the message is defined as shown in Figure 35-19 on page 262, then the data words for the module return the following:

MSGA:

DW0: AB

DW2: XY

DW4: Zx or xy

DW6: yw or wz

DW8: zF or Fr (with r being a random byte)

**WARNING:** This type of message cannot be parsed properly. For this case, the snarfer must be used by setting up 100% Bus Traffic Monitoring (see the following figure).

Parameters | Channels | Messages | Setup | 100% Bus Traffic Monitoring

| Parameter Name | Active | #Words | Mode | Bus | Comment |
|---|---|---|---|---|---|
| * | * | * | * | * | * |
| UAR_0_J5_Bus_0_AllPass | Yes | 1 | SNARFER | 0 | |
| UAR_0_J5_Bus_1_AllPass | Yes | 1 | SNARFER | 1 | |
| UAR_0_J5_Bus_2_AllPass | Yes | 1 | SNARFER | 2 | |
| UAR_0_J5_Bus_3_AllPass | Yes | 1 | SNARFER | 3 | |

*Figure 35-21: Active field set to Yes on 100% Bus Traffic Monitoring tab in kSetup (KSM-500)*

| Source Name | Parameter Type | Parameter Name | Signal Type | Baud Rate | Data Bits Per Word | Parity | Idle Time Sync Interval |
|---|---|---|---|---|---|---|---|
| Serial-In(0) | Snarfer | P_MyKAD_UAR_102_B_Serial-In(0) | RS-422 | 9600 | 8 | None | 0 |
| Serial-In(1) | Snarfer | P_MyKAD_UAR_102_B_Serial-In(1) | RS-422 | 9600 | 8 | None | 0 |
| Serial-In(2) | Snarfer | P_MyKAD_UAR_102_B_Serial-In(2) | RS-422 | 9600 | 8 | None | 0 |
| Serial-In(3) | Snarfer | P_MyKAD_UAR_102_B_Serial-In(3) | RS-422 | 9600 | 8 | None | 0 |

| Parameter Type | Parameter Name |
|---|---|
| Report | P_MyKAD_UAR_102_B_Report |

*Figure 35-22: Snarfer parameters set using DAS Studio 3*

## 35.6.6 Parsing messages without a unique start sequence

Some messages don't have a unique Start Sequence value defined (see the following figure).

| Message Name | Channel | Interpret Sequence As | Start Sequence | Stop Sequence | Bytes | End of Message |
|---|---|---|---|---|---|---|
| MSGA | 0 | ASCII | | F | 9 | Sequence |

*Figure 35-23: No Start Sequence*

The Sync Interval is used when there is no Start Sequence value defined (see the following figure) because the messages in the physical bus do not have a unique start sequence. The Sync Interval can also be used if the value of the Start Sequence is also defined in the message payload.

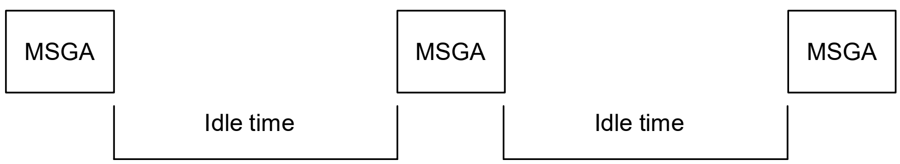



*Figure 35-24: Different instances of a message with a defined Sync Interval (idle time)*

The Sync Interval can be set to a specific time (see the following figure).

| Channel | Type | BaudRate | Bits | Parity | Sync Interval |
|---|---|---|---|---|---|
| 0 | RS-422 | 9600 | 8 | NONE | 12 |

*Figure 35-25: Channel tab setup with a Sync Interval of 12 ms using KSM-500*

| Source Name | Parameter Type | Parameter Name | Signal Type | Baud Rate | Data Bits Per Word | Parity | Idle Time Sync Interval |
|---|---|---|---|---|---|---|---|
| Serial-In(0) | Snarfer | P_MyKAD_UAR_102_Serial-In(0) | RS-422 | 9600 | 8 | None | 12 |

*Figure 35-26: Settings tab with a Sync Interval of 12 ms using DAS Studio 3*

## 35.6.7 Using wildcards in Start Sequence

The KAD/UAR/102 can parse messages with a wilcard in Start Sequence. This feature is supported in DAS Studio's Serial Builder using the Start Sequence Format to Hex (see the following figure). Wilcard is for a whole byte, therefore two wildcards are necessary '**'

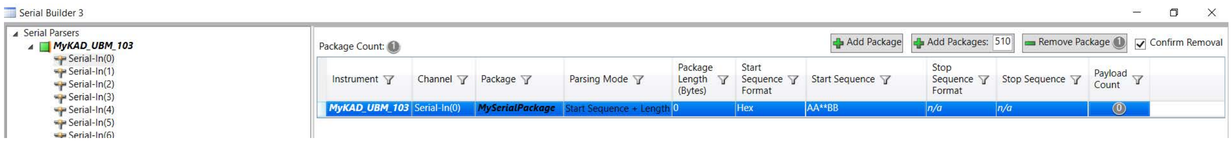



*Figure 35-27: Wildcard in Start Sequence example in DAS Studio*

In KSM-500, right-click a message, then click **Edit start sequence**, and then select the appropriate byte to wildcard check boxes.

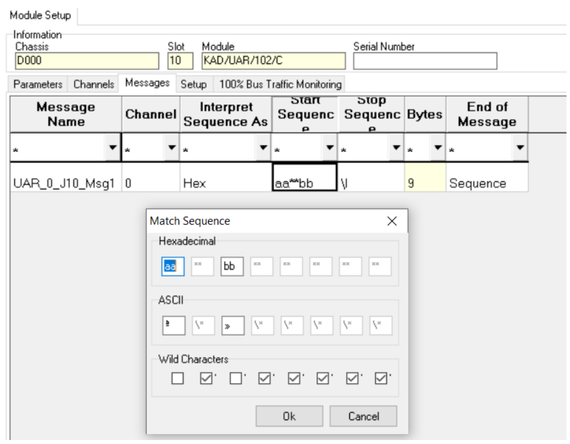



*Figure 35-28: Wildcard in Start Sequence example in KSM-500*

## 35.6.8 Data word examples

Consider a stream with ABCDEFGHI:

Data position 0: DW0 is AB

Data position 1: DW1 is BA

Data position 2: DW2 is CD

Data position 3: DW3 is DC

Data position 4: DW4 is EF

Data position 5: DW5 is FE (and so on)

# 35.7 References

ASCII code reference can be found under http://nemesis.lonestar.org/reference/telecom/codes/ascii.html.

Chapter 36

# Grounding and shielding of the Axon and Acra KAM-500

TEC/NOT/063

This technical note describes the recommendations for grounding and cable shielding of the Acra KAM-500. This information is also applicable to Axon products.

This paper discusses the following topics:



## 36.1 Axon/KAM-500 isolated grounds

The Axon/KAM-500 has the following three grounds:

- **GND**: Axon/KAM-500 internal electrical ground
- **CHASSIS**: Axon/KAM-500 mechanical ground
- **POWER**(-): 28V return

---

**NOTE:** All three grounds are isolated from one another inside the Axon and KAM-500 chassis.

### 36.1.1 GND

GND is the internal zero volt line that all Axon/KAM-500 modules reference. All input and output signals on Axon and KAM-500 modules are referenced to this potential. The GND reference signal is normally taken out to the connector on the top of each Axon and KAM-500 module and is usually pin 51. The GND connection is also available on the Axon/KAM-500 Power Supply Unit (PSU) connectors.

### 36.1.2 CHASSIS

CHASSIS is the signal name for a connection to the physical Axon/KAM-500 chassis (metal work). CHASSIS is also known as mechanical ground. The Axon and KAM-500 top blocks, connector frames, and the ground mounting bolt on the PSU are at CHASSIS potential.

The standard connector on Axon and KAM-500 modules has a pin connected to CHASSIS (this pin is typically pin 52 of the top-block connector). The connector frame and jackposts are also at CHASSIS potential. Most KAM-500 chassis PSU connectors also have a CHASSIS pin, which means that the backshell frame is connected to CHASSIS via the top-block connector as shown in the following figure. This is specially useful when connecting cable shields.

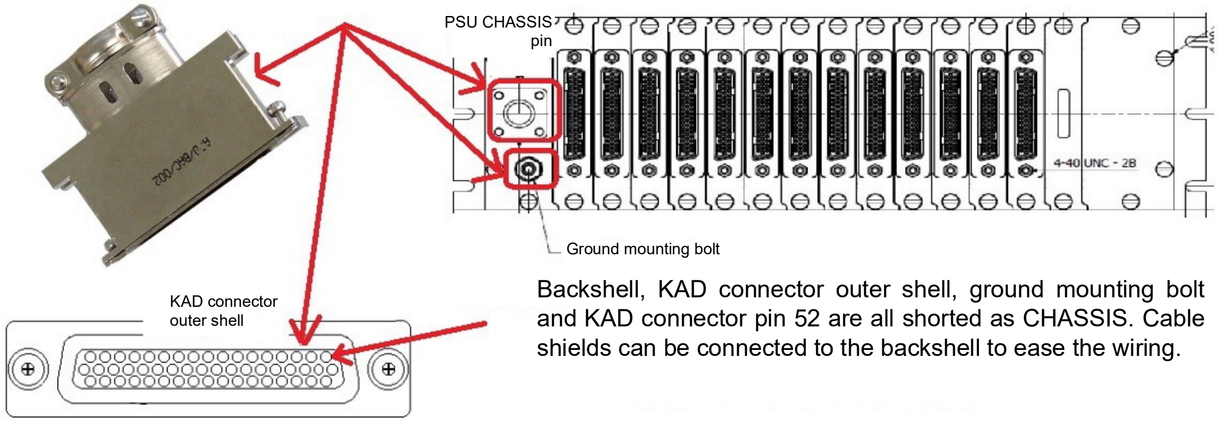



*Figure 36-1: Chassis connections on KAM-500*

### 36.1.3 POWER(-)

POWER(-) is the return line for the 28V Axon/KAM-500 power supply. The POWER(-) pin is not connected to the CHASSIS line nor GND line within the Axon/KAM-500.

To improve EMC, it is recommended to be run as a twisted pair with the 28V supply line.

POWER(-) must be referenced to the external star point (airframe, or chassis). This can be done at the source of supply (for example battery or generator).

Both Axon and KAM-500 PSU are compliant with the EMC standards listed in the *Environmental Qualification Handbook for Axon Products* and *Environmental Qualification Handbook (Acra KAM-500)* respectively without the need for shielding on the power lines.

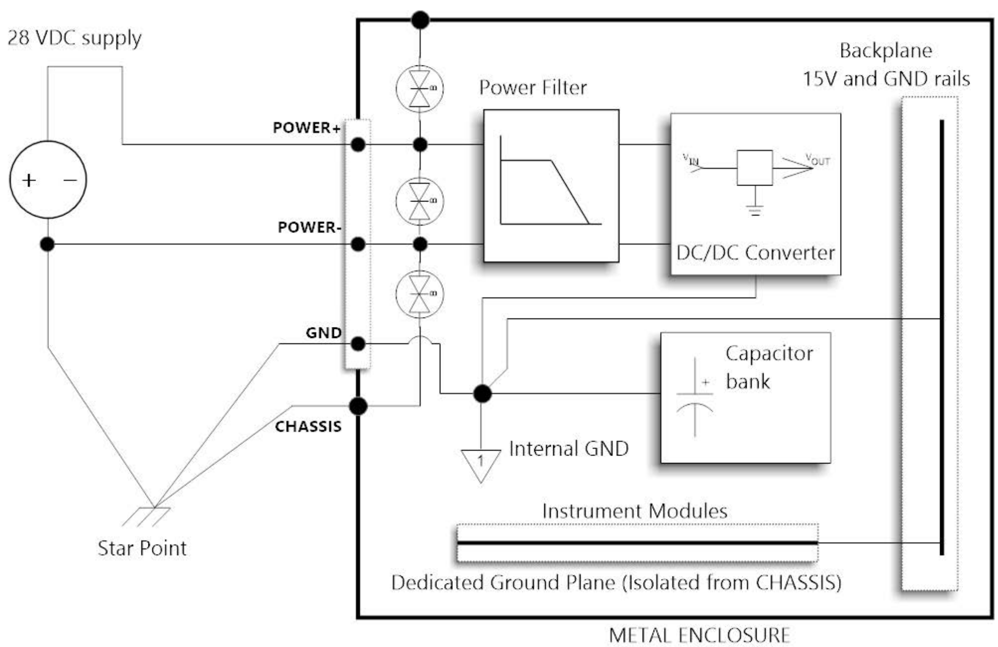



*Figure 36-2: Power supply and backplane connections for Axon (KAM-500 is similar)*

## 36.2 Axon/KAM-500 chassis bonding and grounding

As a general recommendation, each isolated ground signal should be connected to the main star point on the aircraft or vehicle using a low impedance connection. Hence the GND pins on the Axon and KAM-500 PSU connector, the CHASSIS pin on the PSU connector (if available) and the POWER (-) pin on the PSU connector should be connected directly to the star point.

The following figure shows an example of connecting a star point to POWER(-), GND, and CHASSIS. It shows the ideal or lab condition grounding scheme, however actual aircraft applications may differ from this grounding scheme due to installation issues such as the distance between the power supply, the Axon/KAM-500, and the airframe, which may act as CHASSIS.

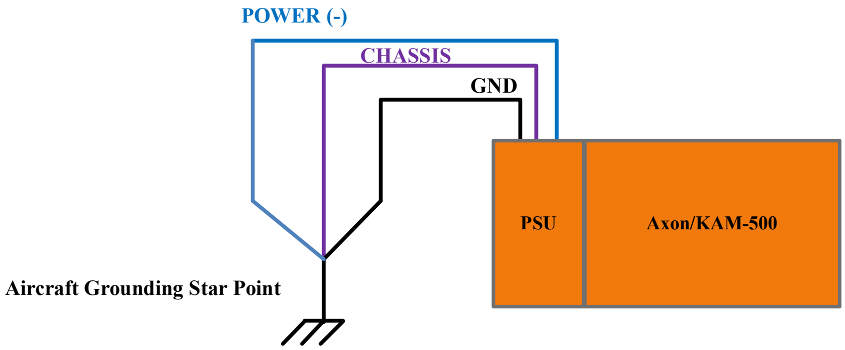



*Figure 36-3: Axon/KAM-500 ideal grounding scheme*

Because POWER(-) is carrying return current, it must not be combined with GND or CHASSIS ahead of the star point. Shorter cables are better because they have lower impedance and less chance of Radio Frequency (RF) noise pickup.

For the CHASSIS connection to the star point, it is recommended to use the ground mounting bolt on the PSU with a short braided cable instead of the CHASSIS pin. Braided cable has lower high-frequency impedance than single wires.

The chassis mounting bolts may be used for bonding, if they make good electrical contact (< 50 mΩ) with both the mount and the Axon/KAM-500 chassis. The unpainted base of the Axon is also very suitable for chassis bonding.

To keep GND from floating relative to CHASSIS, they should be joined together. Join at only one point to prevent ground loops. A convenient place, that does not overly expose the internal GND to the external environment, is inside the PSU connector backshell using the GND pin.

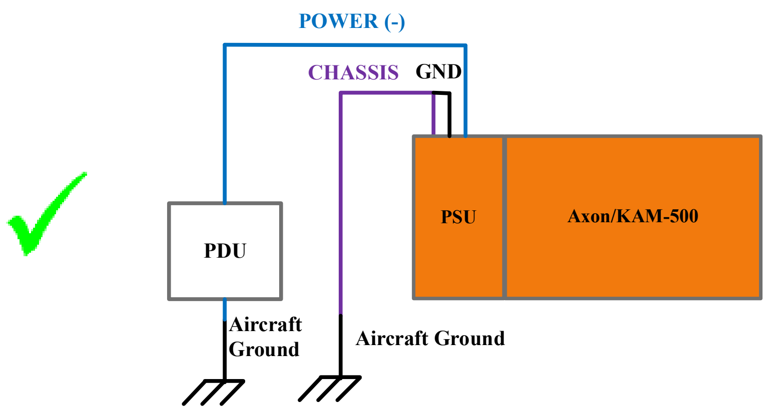



*Figure 36-4: GND referenced to CHASSIS*

## 36.3 Validating grounding

After connecting the grounds, measure the resistance between each GND point, CHASSIS point and POWER (-) on each Axon/KAM-500 to the star point. The resistance should be below 50 mΩ. Ground validation on aircraft is critical for data measuring equipment especially in distributed systems.

## 36.4 Cables and shielding

The intention of using a shielded cable is to create a continuous conductive shield envelope (Faraday cage) for the signal lines, incorporating the cable shield, cable clamp, backshell, connector, and top-block.

It is recommended to use metal backshells.

All cables should be shielded with the shields connected to the Axon/KAM-500 CHASSIS, through the connector backshells.

If the backshells have shield terminations then these should be used, otherwise the backshell cable clamp can be used for the electrical connection if it is clamped directly onto the cable shield braid or ferrule.

An alternative method of connecting a cable shield to an Axon/KAM-500 module is to use a short pig-tail and take this from the cable shield to the CHASSIS pin on the Axon/KAM-500 connector. This method is acceptable but not recommended as it may result in a short length of unscreened signal cable and a discontinuity in the shield envelope. A single wire also has higher RF impedance than a clamped backshell due to its lower cross-sectional area.

In many analog sensor applications, connecting only one end of the shield may give better EMC results, for instance when the predominant noise comes from a difference in the potential between the signal source and the Axon/KAM-500 CHASSIS.

To avoid ground loops, the sensor case and cable shield may have to be insulated from the airframe. For instance, as shown in the following figure, accelerometers may need to be used with insulated bases when mounted on metal airframes to avoid creating a second current path to the Axon/KAM-500 module through the airframe.

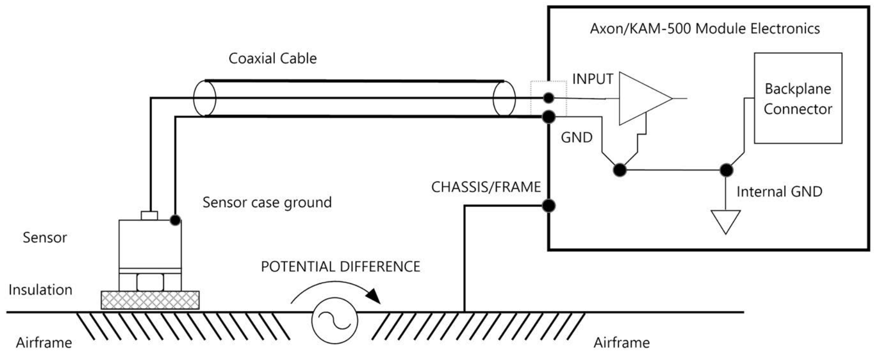



*Figure 36-5: Insulating sensor case and cable shield*

Most high-speed Ethernet or bus monitor cable shields should be connected to CHASSIS at each end of the cable run. The standard cable should be shielded twisted pair. Differential signals should be paired with their other half and single-ended analog signals should be paired with their own ground reference/returns.

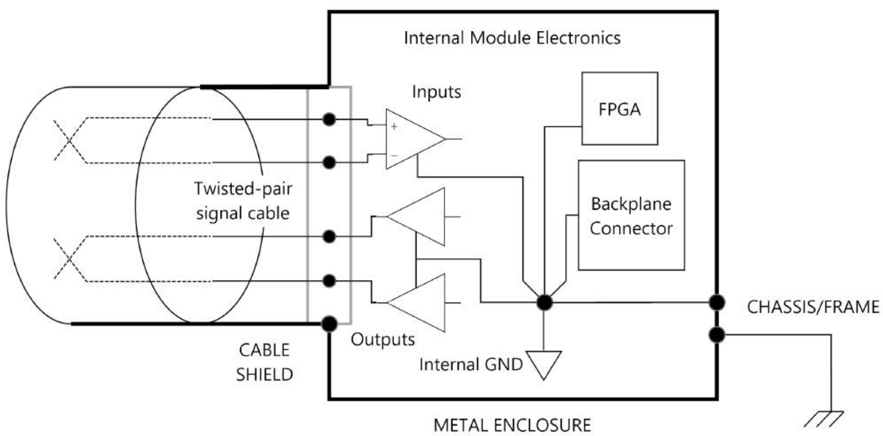



*Figure 36-6: Cable shield and chassis create RF envelope*

When using sensors powered with an isolated external power supply, the ground of the external power should be referenced to Axon/KAM-500 GND. When possible, use KAM-500 internal power supply levels such as ±12V or +5V (available in KAM/PSU/012 and KAM/PSU/011 power supply units). Refer to the power supply unit data sheet for voltage levels and maximum current available.

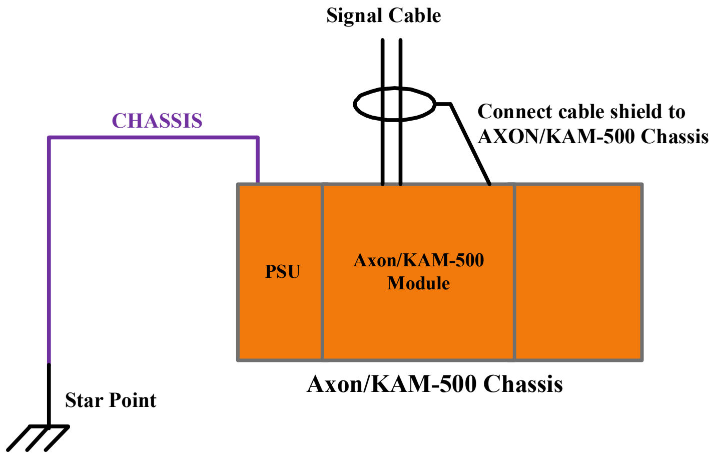



*Figure 36-7: Shielding*

Curtiss-Wright recommends the use of twisted pairs with an overall foil shield. Wires should ideally be silver plated.

Coaxial cable signals such as a GPS or video are a special case. The cable shield is considered to be chassis potential but internally the signal reference is Axon/KAM-500 GND. For these signals it is necessary to make a link between GND and CHASSIS relatively close to the cable connector. See "36.7 Co-axial Radio Frequency interfaces" on page 270.

### 36.4.1 Transient protection

Where a ground connection is required for transient protection devices, these devices should be connected to Axon/KAM-500 CHASSIS and not the Axon/KAM-500 GND. In this configuration, CHASSIS both shields the Axon/KAM-500 electronics from transients and provides a low impedance path to the article star point for such transients.

## 36.5 Incorrect configurations

### 36.5.1 Incorrect Axon/KAM-500 grounding

POWER(-) must not share a common cable to the star point as shown in the following figure.

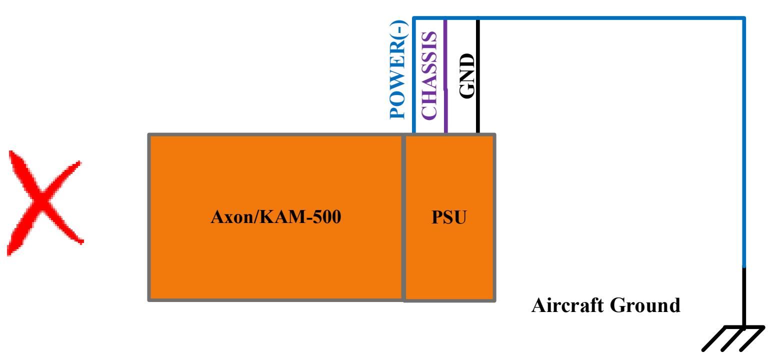



*Figure 36-8: Do not use CHASSIS connection as Power Return*

## 36.6 Grounding for multiple Axon/KAM-500 chassis

When more than one Axon/KAM-500 is used, each Axon/KAM-500 should be connected to the star point using individual cables. Shared cables should not be used. No two chassis should share common cables for the GND, POWER(-) or CHASSIS signals.

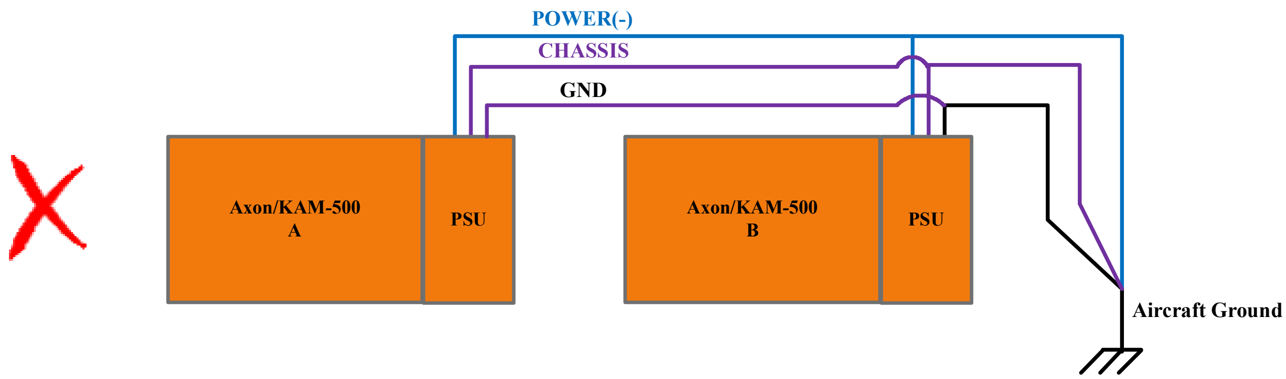



*Figure 36-9: Do not share or daisy-chain*

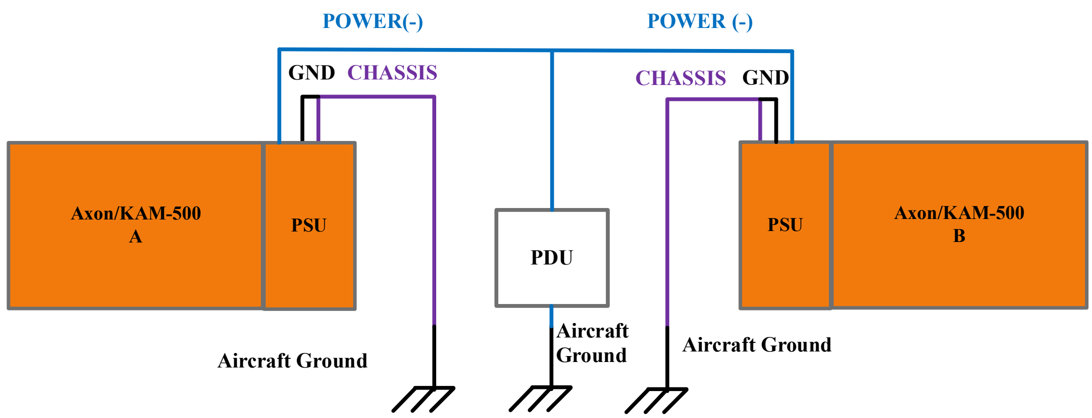



*Figure 36-10: How to ground two chassis: Ideally each ground (Power(-), CHASSIS, GND) should have its own connection to the star point*

## 36.7 Co-axial Radio Frequency interfaces

When co-axial cable is used to interface an Axon/KAM-500 module to an external antenna (for example GPS) the cable shield behaves as both an RF signal ground and a transient protection ground. That is, any transients are conducted by the cable shield, whilst the cable shield also provides a signal return path to the antenna/transmitter.

### 36.7.1 Axon modules

In Axon RF modules such as the AXN/TCG/401, CHASSIS and GND are connected together in the module itself, since the co-axial cable shield is providing both RF ground and transient protection grounding functions. This introduces the risk of creating ground loops in the aircraft/test article wiring unless care is taken with the wiring design. See the following figure.

If a link between CHASSIS and GND is present at the RF module, then ideally these signals should not be linked anywhere else. Otherwise some Ground currents may find a path through the chassis and vice versa.

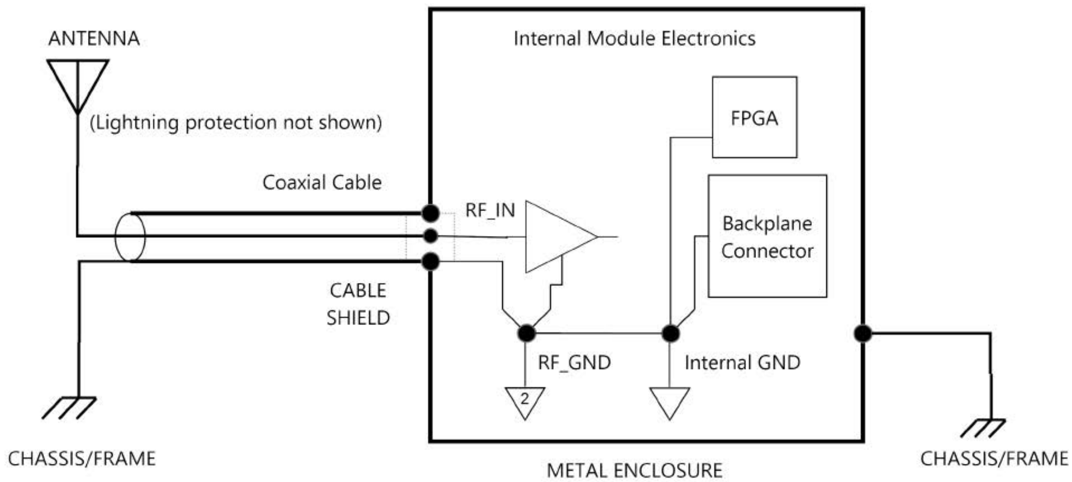



*Figure 36-11: Axon grounding with AXN/TCG/xxx module and GPS antenna*

### 36.7.2 Acra KAM-500 Modules

In KAM-500 modules with coaxial input signals such as GPS, wireless or video, both CHASSIS and GND must be connected together as close to the module as possible. Since the co-axial cable shield is providing both RF ground and transient protection grounding functions, an electromagnetic loop with the grounding star point will be created if this is not performed, potentially reducing the sensitivity of the GPS receiver and providing an EMI antenna for noise from the KAM-500.

This introduces the risk of creating ground loops in the aircraft/test article wiring unless care is taken with the wiring design. If CHASSIS and GND are connected together near the RF module, this should ideally be the only such connection between CHASSIS and GND.

---

**NOTE:** This technical note does not cover lightning arrestors or other safety devices, which would normally be required for external antennae.

## 36.8 Glossary

**Chassis**

The metal enclosure of the Axon/KAM-500. Any element at the same electrical potential as the chassis, such as screws in direct metal-to-metal contact, is said to be at CHASSIS potential.

**Distributed system**

Application in which more than one KAM-500 or AXON are synchronized and data from different Data Acquisition Units (DAUs) is being gathered at the same time.

**EMC**

ElectroMagnetic Compatibility

**EMI**

ElectroMagnetic Interference

**Faraday cage**

A conductive enclosure with limited apertures, such that radiated RF energy inside is not detectable outside, and vice versa.

**Frame**

The metal frame of the aircraft external to the Axon/KAM-500, if one exists, or the conductive path to the star point or ground plane provided in lieu of one. The Axon/KAM-500 chassis should be electrically bonded to the frame.

**Ground**

A common reference point for all electrical signals in a circuit.

**Ground loop**

An unwanted current flowing between ground reference points in two separate devices at different ground potentials.

**Lightning arrester**

A lightning arrester (also called lightning diverter) is a device used on electric power systems and telecommunication systems to protect the insulation and conductors of the system from the damaging effects of lightning.

**Loop antenna**

A loop formed by a wire or other conductor that can pick up RF energy, intentionally or not.

**PDU**

Power Distribution Unit

**Shield**

A conductive layer around a cable that encloses signal carrying wires. The shield is used to couple any incoming or outgoing EMI and conduct it to CHASSIS, thus attenuating any interference to the enclosed signal carrying wires and ensuring that any noise from the enclosed signal carrying lines does not adversely affect nearby equipment.

**Star point**

The star point is a common point for all grounds on the aircraft or vehicle. It is the designated reference point for all voltages and signals. (Note: In the case of a metal airframe the star point can be the whole airframe, because of the low impedance of the metal airframe structures.)

**STP (Shielded Twisted Pair)**

STP is used in noisy environments where the shield around each of the wire pairs, plus an overall shield, protects against excessive electromagnetic interference. Contrast with UTP.

**Transient protection devices: see Lightning Arrester**

**UTP - (Unshielded Twisted Pair)**

A pair of wires that are twisted around each other to minimize interference. Contrast with STP.

## 36.9 Related documentation

| DOCUMENT | DETAILS |
|---|---|
| DOC/DBK/001 | *Acra KAM-500 Databook*, “Equipment Interface” chapter. |
| Tutorial MT-031 | Analog Devices |
| Tutorial MT-095 | Analog Devices |

Chapter 37

# Using the KAM/MEM/103

TEC/NOT/064

The KAM/MEM/103 is a memory module which supports logging data to removable CompactFlash® memory cards. This document introduces the KAM/MEM/103 and outlines how to set it up using kSetup and DAS Studio 3.

This paper discusses the following topics:



## 37.1 KAM/MEM/103 overview

The KAM/MEM/103 can store data on a CompactFlash card from any combination of data sources in an Acra KAM-500 system. The KAM/MEM/103 is designed to be used with a wide range of CompactFlash cards. Approved cards are listed in the *KAM/MEM/103* data sheet (as higher density CompactFlash cards become available, Curtiss-Wright approves them for use). Data storage can be triggered by a combination of discrete bits and analog signal levels. The KAM/MEM/103 saves data to a FIFO in blocks of 32,768 × 16-bit words. To read or erase the data, remove the CompactFlash card and insert it into a standard off-the-shelf CompactFlash card reader. Data can then be extracted using kFlashcardXID software.

---

**NOTE:** As with KAM/MEM/x03 modules, the KAD/MEM/004 can be used where physical access to the CompactFlash card is restricted. Initialization and data extraction are possible across Ethernet. For more information, see the *KAD/MEM/004* data sheet.

### 37.1.1 Key features of the KAM/MEM/103

- Supports removable solid-state memory cards
- Supports Type I & II removable CompactFlash cards (CompactFlash cards can be read with a USB card-reader or a PCMCIA adapter)
- Programmable event size
- Designed to support high-speed CompactFlash cards up to 128 GB
- Logs data at up to 2 Msps
- Recording trigger function

## 37.2 Setting up the KAM/MEM/103 using KSM-500

kSetup is included in the KSM-500 suite of tools. When setting up a KAM/MEM/103, you can set sampling rates for parameters, configure the triggering conditions and create stamp marks called headers.

### 37.2.1 Setting parameters

To set parameters, first select the KAM/MEM/103 in the Task Explorer pane of kSetup. The Parameters tab in kSetup (see the following figure) displays the parameter available for the KAM/MEM/103.

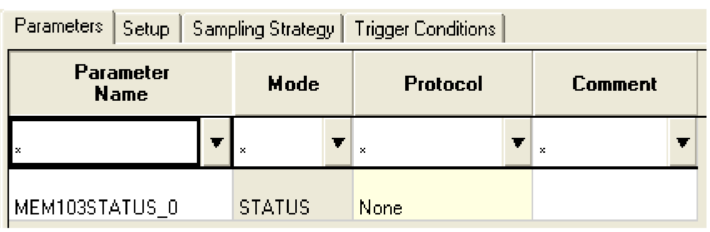



*Figure 37-1: Parameters tab in kSetup*

For information on using kSetup, see the *kSetup* data sheet.

The Parameters tab contains only one parameter when the KAM/MEM/103 is selected in the Task Explorer pane. The MEM103STATUS parameter, which is used to monitor the status of the KAM/MEM/103, is a 16-bit status register. This parameter provides information regarding error codes (bits 0 to 5), the status of the KAM/MEM/103 (bits 6 to 8 which indicate whether the KAM/MEM/103 is full, recording data or idle), and how full the CompactFlash card is (bits 9 to 15). For more information on the MEM103 STATUS parameter, see the *KAM/MEM/103* data sheet.

**NOTE:** The recording bit (bit 7) of the MEM103STATUS parameter is refreshed after the first block is written to memory. Therefore if the acquisition cycle rate is slow, and the number of samples per cycle is low, it may take several seconds to save the first block and update this bit.

However, when both the acquisition cycle rate and the number of samples per cycle are high, the transition from low to high logical level may be too fast to be seen. For example, it takes 0.2 seconds to fill up the first block when logging 16 samples per parameter from 100 parameters, at an acquisition cycle of 100 Hz. Similarly, when logging 16 samples per parameter from 30 parameters, at an acquisition cycle of 10 Hz, it takes 6.8 seconds to fill up the first block.

### 37.2.2 Setup tab settings

On the Setup tab, you can define Header Setup options. When defining Header Setup options, you can set up to four 16-bit hexadecimal values as shown in the following figure.

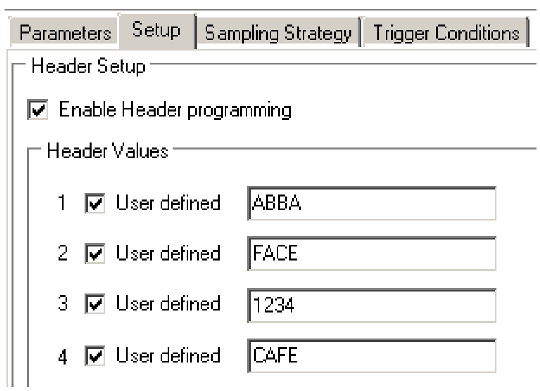



*Figure 37-2: Header Setup options available when a memory module is selected in the Task Explorer pane*

Alternatively, if a time code module, such as the KAM/TCG/102, is selected in the Task Explorer pane, you can select time parameters (see the following figure). Headers are saved to the CompactFlash card as each block is logged. Each header is displayed when extracting events from the CompactFlash card. For information on extracting events, see the kFlashcardXID data sheet.

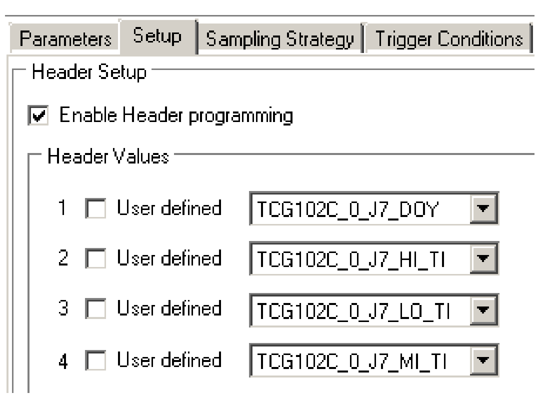



*Figure 37-3: Header Setup options available when a a time code module is selected in the Task Explorer pane*

**NOTE:** Parameters from time code modules, selected as headers, cannot be added to the parameters to be logged list (on the Sampling Strategy tab).

**WARNING:** Headers can be changed only by reprogramming the KAM/MEM/103. If you see different headers on extracted data, it is a sign that the KAM/MEM/103 has been reprogrammed.

### 37.2.3 Sampling Strategy tab settings

On the Sampling Strategy tab (see the following figure), you can configure data to be logged on a KAM/MEM/103. This is done by setting the parameters to be logged and the desired numbers of samples per cycle (depending on the acquisition cycle).

On the Sampling Strategy tab, first use the > button to select the parameters you want to log. Then complete the fields described in the following table.

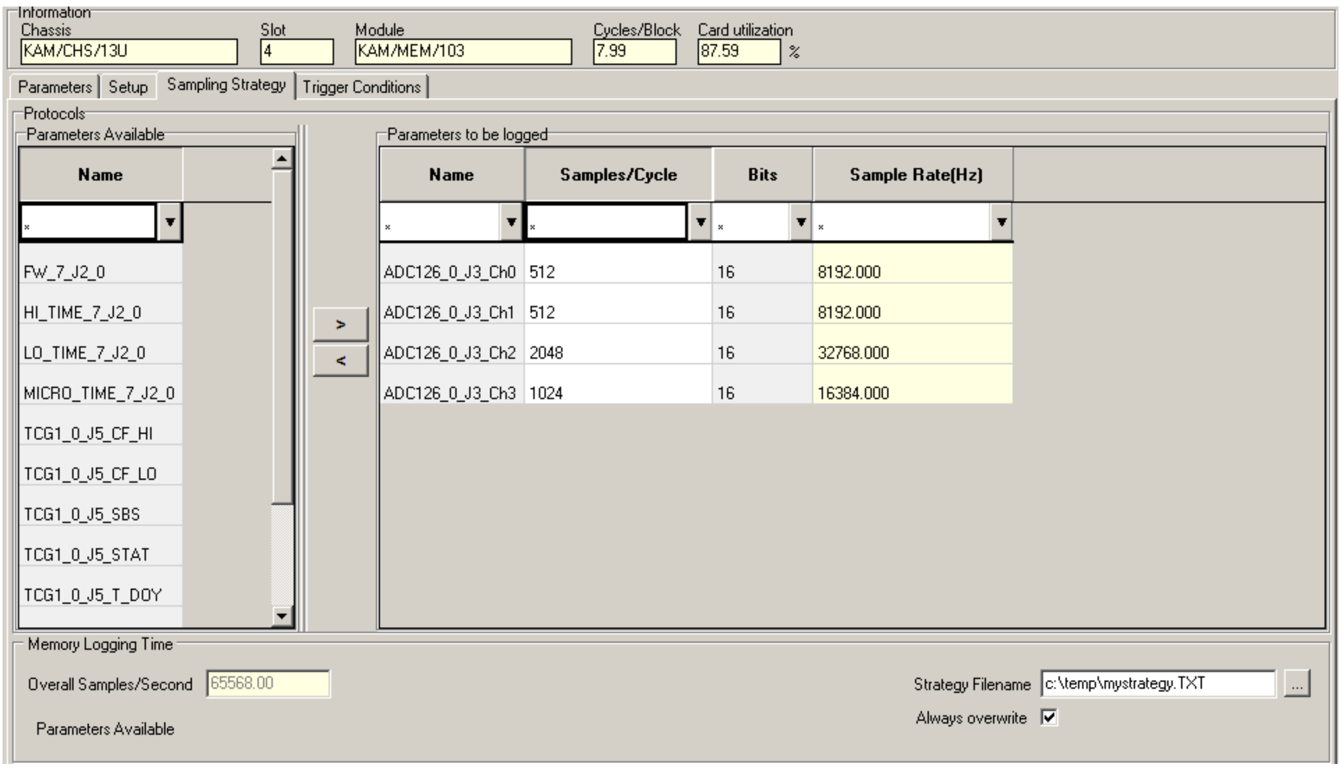



*Figure 37-4: Sampling Strategy in kSetup*

Table 37-1: Sampling Strategy tab fields

| Field name | Description |
|---|---|
| Parameter Name | Read-only label for parameter selected from the Parameters Available list. |
| Samples/Cycle | Number of samples per acquisition that you want to log. |
| Bits | Read-only. The number of bits of the parameter to be stored. |
| Sample rate (Hz) | Rate at which parameters are stored in the KAM/MEM/103. To modify this, change the number of samples per cycle in the Samples/Cycle field. |
| Overall Samples/Second | Number of samples per second the KAM/MEM/103 logs. For information on the maximum sampling rates of the CompactFlash card used, see the *CompactFlash cards* data sheet. For information on constraints, see “37.2.3.1 Other fields” on page 276. |
| Strategy Filename | Important system file which must be stored in a secure location. This file is required for recovering data from the CompactFlash card. The strategy file documents the layout of data logged to the CompactFlash card and is created after verifying the task file. For details of the strategy file format, see the *kFlashAPIXID* data sheet. |
| Always Overwrite | Ensures the previous strategy file is overwritten when you click Verify on the kWorkbench screen. |

**NOTE:** The value set in the Samples/Cycle field defines the sampling rate of a parameter. The KAM/MEM/103 stores only 16-bit parameters transferred over the backplane. A 32-bit parameter is transferred as 2 × 16-bit backplane transfers. Ensure that the value set in the Overall Samples/Second field does not exceed the maximum sampling rate.

During initialization, using kFlashcardXID, you can upload the strategy file to the CompactFlash card. For details, see the *kFlashcardXID* data sheet.

#### 37.2.3.1 Other fields

Other fields on screen include Cycles/block and Card utilization.

The value in the Cycles/block field is the number of acquisition cycle being stored in a 32-kilosample block. The number of words to be stored in one acquisition cycle is the sum of the value in the Samples/Cycle field for all parameters to be logged. The equation is (32,768 - 16) / (number of samples to be stored in one acquisition cycle + 2 words for the sync word).

The value in the Card utilization field shows the card utilization to be used according to all the parameters you want to store. As the KAM/MEM/103 stores an integer number of acquisition cycle in a 32-kilosample region, a remainder is present.

Data is stored on two 32k word buffers before being written to the CompactFlash card. Data for at least two acquisition cycles must be written to the buffer before it is written to the CompactFlash card. Each buffer has space for 32,752 (32,768 - 16) 16-bit words. Hence the maximum number of samples to be transferred per acquisition cycle is 16,376 samples / acquisition cycle.

For large amounts of data per second, we recommend setting a fast acquisition cycle. For example, to achieve 500 ksps, the slowest acquisition cycle is 500,000 / 16,373 = 30.5 cycles/second.

When more than 16,376 samples per acquisition cycle are being logged to the KAM/MEM/103, you see an error during verification similar to the one shown in the following figure.

ACRA ERROR: Module KAM/MEM/103 has a invalid value of <number greater than 16376> for 'number of parameters in acq cycle'. Max value allowed is 16376

*Figure 37-5: Sample error message displayed during verification*

In the event you see this error message, we recommend either reducing the number of parameters, lowering the number of samples per acquisition cycle, or setting a faster acquisition cycle.

### 37.2.4 Trigger Conditions tab settings

A key feature of the KAM/MEM/103 operation is the memory trigger function. This allows you to define when, and under what conditions, the logging of data begins.

If triggering is used with the KAM/MEM/103, you may set two triggers (Trigger A and Trigger B); each of these triggers have their own individual settings tab in kSetup. To set triggers as analog or digital triggers, select the Use Triggers field (see the following figure) on the Trigger setup tab and then complete the appropriate fields described in the following table.

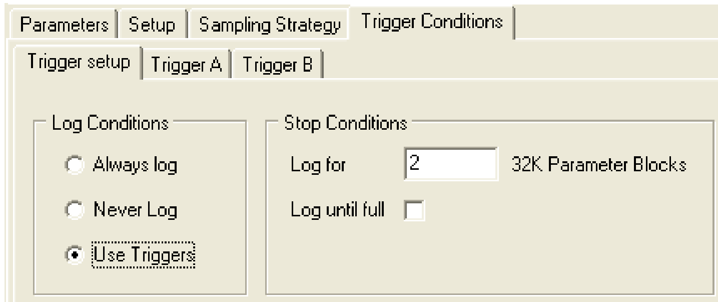



*Figure 37-6: Trigger Conditions tab in kSetup*

Table 37-2: Trigger setup

| Field name | Description |
|---|---|
| **Log Conditions** | |
| Always log | Start logging data as soon as the system powers on. |
| Never Log | Do not log under any circumstances. |
| Use Triggers | Start logging according to the trigger setup and stop conditions. |
| **Stop Conditions** | |
| Log for | Number of 32k parameter blocks to be logged.<br>2 is the minimum number of blocks, that is, the minimum size of an event is 64k (2 × 32k) samples. |
| Log until full | When a trigger condition is met, the KAM/MEM/103 logs data to the CompactFlash card until the card is full or the system powers off. If you select this option, the last block being logged may be lost or corrupted. |

When Always log is set, the KAM/MEM/103 continuously logs the amount of blocks set in the Log for field and stop logging only when the trigger conditions are no longer met. The following two figures show the stop conditions using the minimum number of blocks.

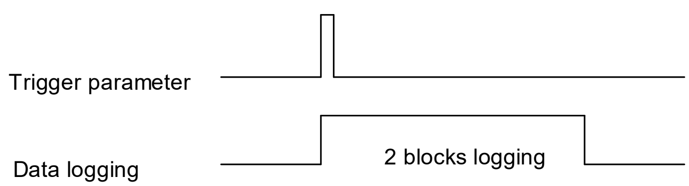



*Figure 37-7: Example of stop logging using 2 as the minimum number of blocks and a pulse as the trigger*

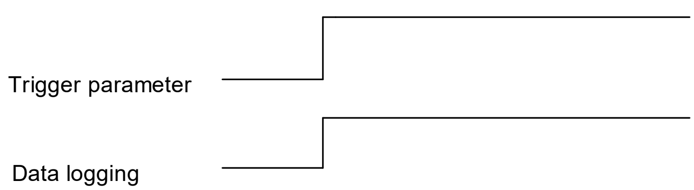



*Figure 37-8: Example of logging using 2 as the minimum number of blocks and the trigger remaining active*

If the number of cycles per block and the length of the acquisition cycle is known, it is possible to calculate the minimum logging time. For example, if Log conditions is set to Use Triggers, the Log for field is set to 10 blocks, the acquisition time is 10 ms, and the Cycles/Block is 9.5, then the minimum logging time can be calculated using the following formula:

Logging time = (blocks to log) × (cycles / block) × acquisition cycle = 10 × 9.5 × 0.01 = 950 ms

After this time, if the trigger conditions are still met, the KAM/MEM/103 keeps logging for the same amount of time indefinitely until the trigger condition is removed or the CompactFlash card is full.

**NOTE:** The minimum number of blocks that can be recorded after triggering is two and the maximum log time is 65,535, that is 4 GB. Therefore, for a 32-GB CompactFlash card, if more than 4 GB of data is logged, the KAM/MEM/103 records a new event at this time (despite the active trigger condition).

#### 37.2.4.1 Setting the trigger condition with an analog representation

In the example shown in the following figure, channel 0 of the analog module acts as the trigger to start logging data when its input is between 50,000 and 60,000 in decimal.

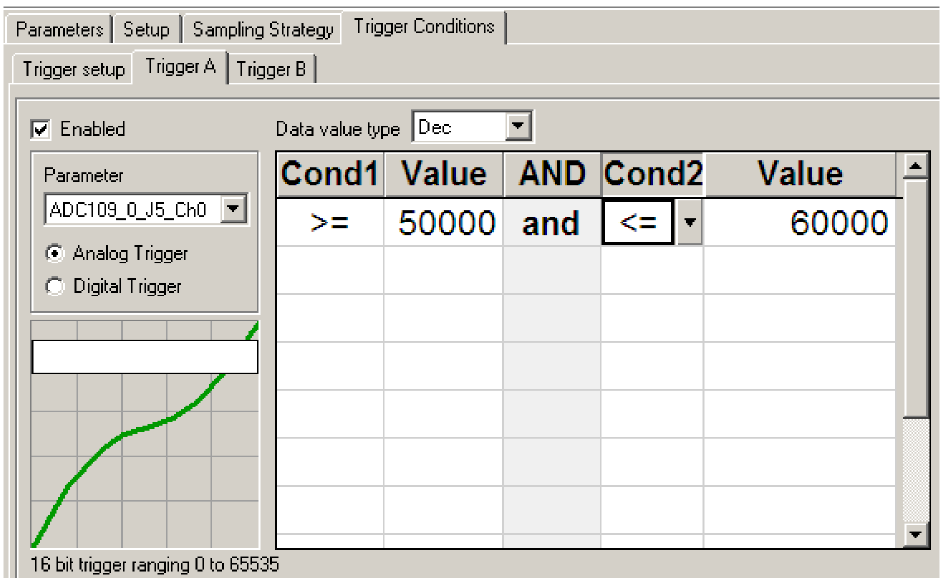



*Figure 37-9: Analog trigger settings*

#### 37.2.4.2 Setting the trigger condition with a digital representation

The digital trigger continuously compares, bit by bit, the value of the parameter set as trigger, with the trigger binary mask. The digital trigger is activated once conditions defined are reached. In the example shown in the following figure, a parameter (LO_TIME) from the backplane controller module (KAD/BCU/xxx) is used as a trigger parameter.

**NOTE:** LO_TIME represents seconds and centiseconds (R[15:0] BCD 00.00-59.99 seconds). Therefore, in this example, triggering starts at five seconds and any centiseconds. The KAD/MEM/103 starts logging data every minute after the first five seconds, if Log until full (on the Trigger setup tab) is not selected, or continuously after the first five seconds, if Log until full is selected).

Although the bits of the digital trigger bit mask are ANDed by default, they can be ORed by selecting OR Bits together as shown in the following figure.

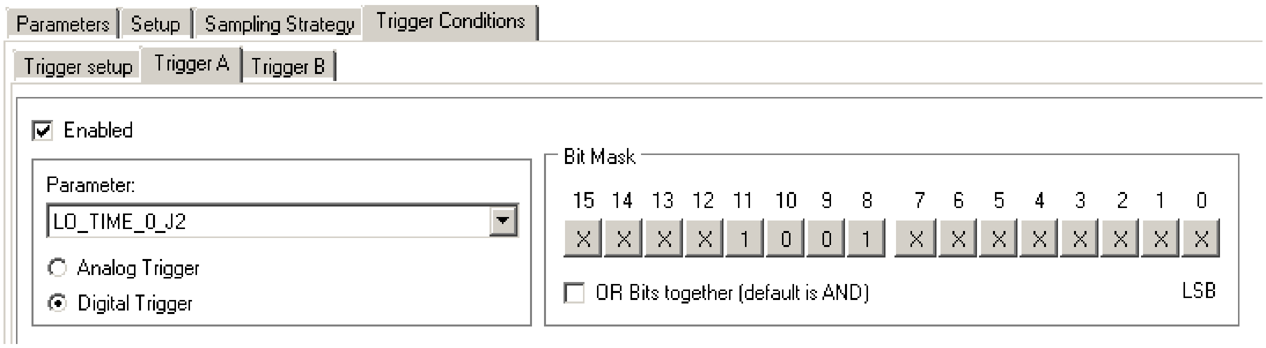



*Figure 37-10: Digital trigger settings*

### 37.2.4.3 Triggering recommendations

The results of both triggers (Trigger A and Trigger B) are ANDed together to determine when logging is to start. Therefore, both triggers must be active for logging. In the scenario where both triggers are disabled, they are set to always produce a combined inactive result. In the scenario where one trigger is enabled, the disabled trigger is set to always produce an active result. Therefore, when the enabled trigger is active, the combined trigger results are active.

Due to the digital filter delay present in all analog modules, we recommend you always use an analog trigger in combination with a parameter taken from a digital module (that has no filter delay) such as the encoder module or a KAM/TCG/102, in order to avoid false triggers and therefore undesired events.

Backplane controller modules such as the KAD/BCU/xx1 and KAD/BCU/105 have a status register, which incorporates a MEM_TRIGGER bit. The MEM_TRIGGER bit can be used to trigger the KAM/MEM/103. This bit is tied to a physical pin on the KAD/BCU/xx1, enabling you to trigger the KAM/MEM/103 externally by means of a switch. For information on the pin connection and register definition, see the respective *KAD/BCU/xxx* data sheet.

---

**NOTE:** Only 16-bit parameters can act as triggers.
The KAD/BCU/140 does not have a MEM_TRIGGER pin.

## 37.3 Setting up the KAM/MEM/103 using DAS Studio 3

When setting up a KAM/MEM/103, you can set sampling rates for parameters, create stamp marks called headers and create Bit Mask Alarm processes.

### 37.3.1 Setting parameters

To set parameters, first select the KAM/MEM/103 in the Navigator and then click the **Settings** tab. The Settings tab displays parameters that are available for the KAM/MEM/103 as shown in the following figure.

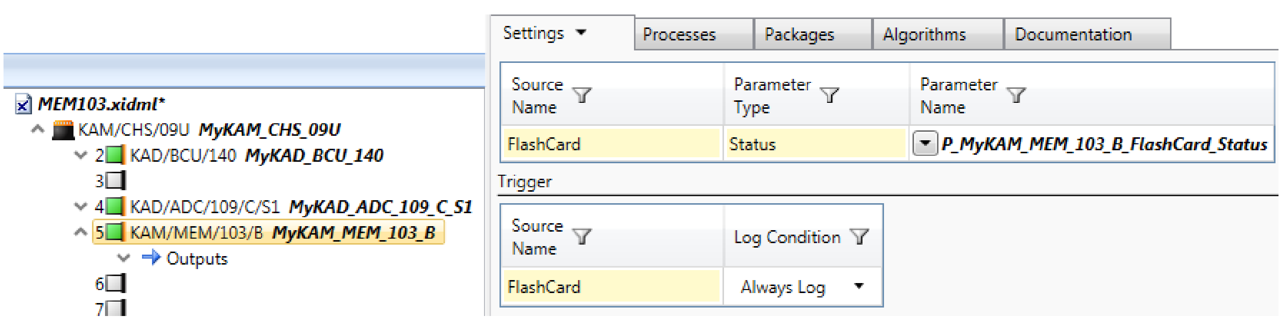



*Figure 37-11: Settings tab in DAS Studio 3*

The Settings tab contains only one parameter when the KAM/MEM/103 is selected in the Navigator. The Status parameter, which is used to monitor the status of the KAM/MEM/103, is a 16-bit status register. This parameter provides information regarding error codes (bits 0 to 5), the status of the KAM/MEM/103 (bits 6 to 8, which indicate whether the KAM/MEM/103 is full, recording data or idle), and how full the CompactFlash card is (bits 9 to 15). For more information on the MEM103 STATUS parameter, see the *KAM/MEM/103* data sheet.

**NOTE:** The recording bit (bit 7) of the Status parameter is refreshed after the first block is written to memory. Therefore, if the acquisition cycle rate is slow, and the number of samples per cycle is low, it may take several seconds to save the first block and update this bit.

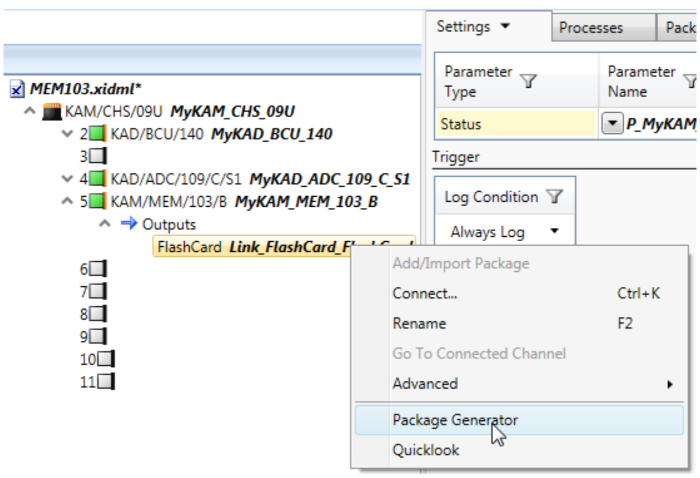
However, when both the acquisition cycle rate and the number of samples per cycle are high, the transition from low to high logical level may be too fast to be seen. For example, it takes 0.2 seconds to fill up the first block when logging 16 samples per parameter from 100 parameters, at an acquisition cycle of 100 Hz. Similarly, when logging 16 samples per parameter from 30 parameters, at an acquisition cycle of 10 Hz, it takes 6.8 seconds to fill up the first block.

## 37.3.2 Parameters to be logged

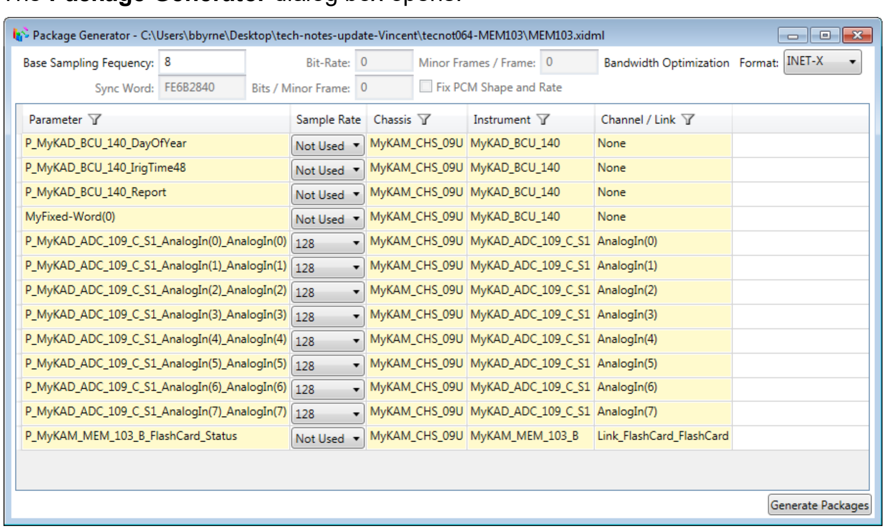
There are two ways you can define parameters that are to be logged to the CompactFlash card: using Package Generator or using Add/Import Package.

### 37.3.2.1 Using Package Generator

1. Expand the **KAM/MEM/103** node and then expand the **Outputs** node.
2. Right-click the **FlashCard** link node and then click **Package Generator**.



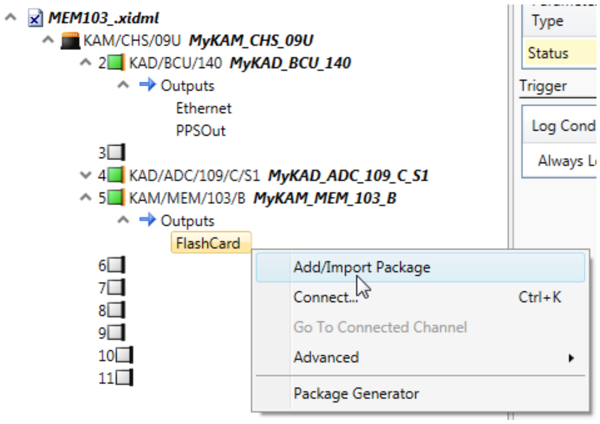

The **Package Generator** dialog box opens.



3. Select the **Sample Rate** for each parameter to be logged to the CompactFlash card and then click **Generate Packages**. For further details, refer to the *DAS Studio 3 User Manual*.

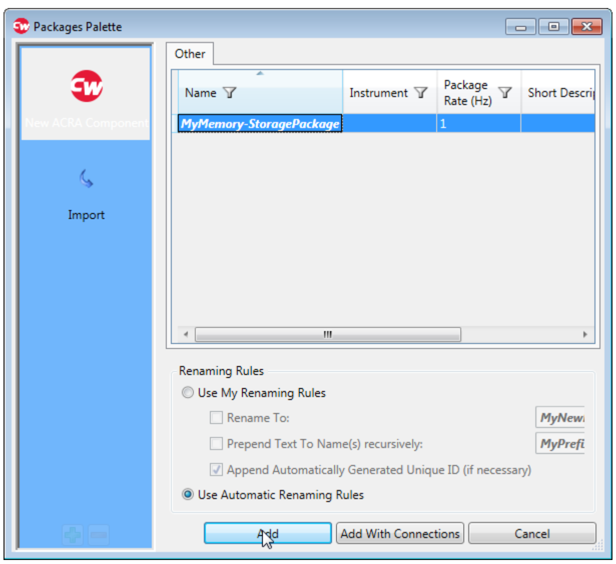
#### 37.3.2.2 Using Add/Import Package

1. Expand the **KAM/MEM/103** node and then expand the **Outputs** node.
2. Right-click the **FlashCard** link node and then click **Add/Import Package**.

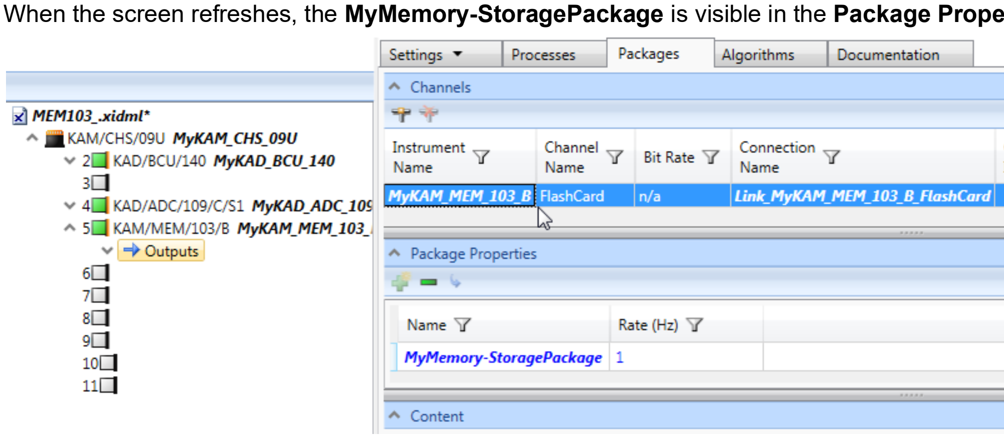



The **Packages Palette** opens.

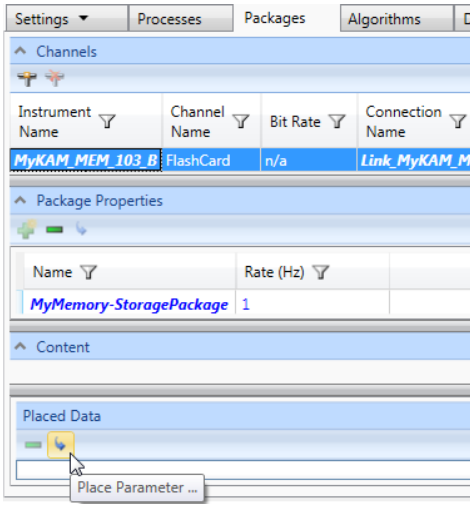
3. Select **MyMemory-StoragePackage** and then click **Add**.




4. With **KAM/MEM/103 Outputs** still in context, click the **Packages** tab and then click the **MyKAM_MEM_103_B** row in the **Channels** pane.
When the screen refreshes, the **MyMemory-StoragePackage** is visible in the **Package Properties** pane.

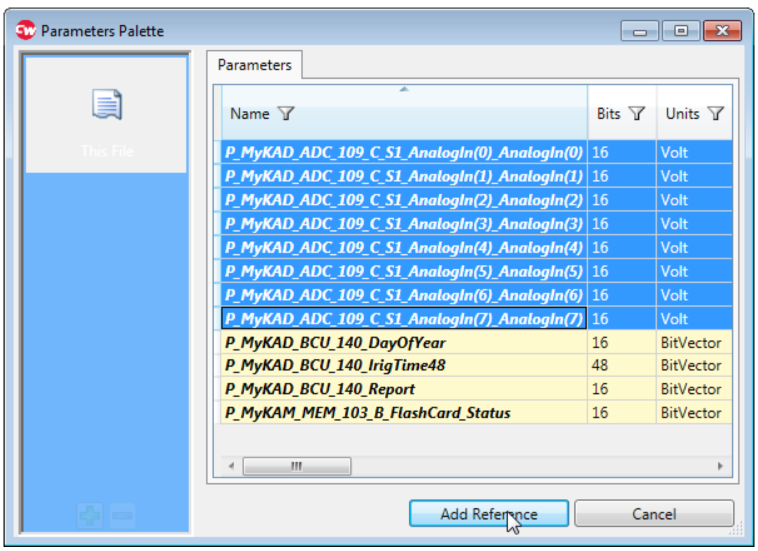


5. In the **Placed Data** pane, click the **Place Parameter** button.




The **Parameters Palette** dialog box opens,

6. Select the parameters you want to be logged to the KAM/MEM/103 and then click **Add Reference**.
   Refer to the *DAS Studio 3 User Manual* for details on adding packages and parameters.




**NOTE:** A strategy file will be created in the MEM_Strategy folder after compilation/programming in the location where DAS Studio 3 is installed.
The strategy file is required for recovering data from the CompactFlash card. It documents the layout of data logged to the CompactFlash card and is created after verifying the task file. For details of the strategy file format, see the kFlashAPIXID data sheet.

### 37.3.2.3 Tips for logging data at a high rate

The KAM/MEM/103 is limited to 16 kilosamples per acquisition; this section provides a work around for this limitation.

The number of words to be stored in one acquisition cycle is the sum of the value in the Actual Rate field for all parameters to be logged divided by the acquisition cycle. The acquisition cycle in DAS Studio 3 is the lowest package rate.

The equation is: (32,768 - 16) / (number of samples to be stored in one acquisition cycle + 2 words for the sync word)

As the KAM/MEM/103 stores an integer number of acquisition cycle in a 32-kilosample region, a remainder is present.

Data is stored on two 32k-word buffers before being written to the CompactFlash card. Data for at least two acquisition cycles must be written to the buffer before it is written to the CompactFlash card. Each buffer has space for 32,752 (32,768 - 16) 16-bit words. Hence the maximum number of samples to be transferred per acquisition cycle is 16,376 samples / acquisition cycle.

For large amounts of data per second, we recommend setting a fast acquisition cycle. For example, to achieve 500 ksps the slowest acquisition cycle is 500,000 / 16,373 = 30.5 cycles/second.

When more than 16,376 samples per acquisition cycle are being logged to the KAM/MEM/103, you see an error during verification similar to the following.

```
97000 06/12/2016 08:54:07.0200: Failed to generate for module
KAM/MEM/103/B - Failure in set_mem_acqu_cycles_per_block -
Cannot log 16386 words to memory in a single acquisition cycle,
maximum allowed is 16376 for channel FlashCard on instrument
MyKAM_MEM_103_B
```

*Figure 37-12: Sample error message displayed during verification*

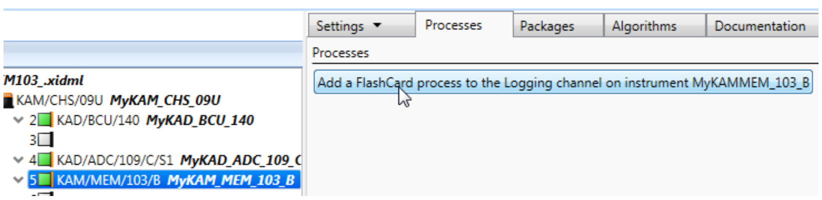
In the event you see this error message, we recommend either reducing the number of parameters, lowering the number of samples per acquisition cycle, or setting a faster acquisition cycle.

To ensure you do not exceed the writing speed of the CompactFlash card being used. calculate the overall sampling rate being written to the KAM/MEM/103. For maximum sampling rates for supported CompactFlash cards, refer to the *CompactFlash cards* data sheet.

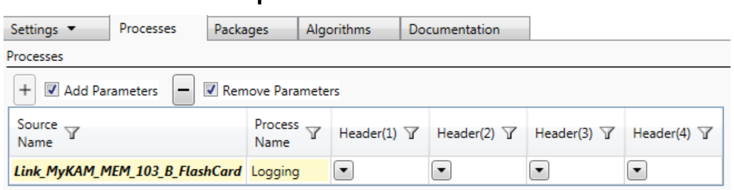
### 37.3.3 Headers

This section describes how to create stamp marks called headers. Headers are saved to the CompactFlash card as each block is logged. Each header is displayed when extracting events from the CompactFlash card. For information on extracting events, see the *kFlashcardXID* data sheet.

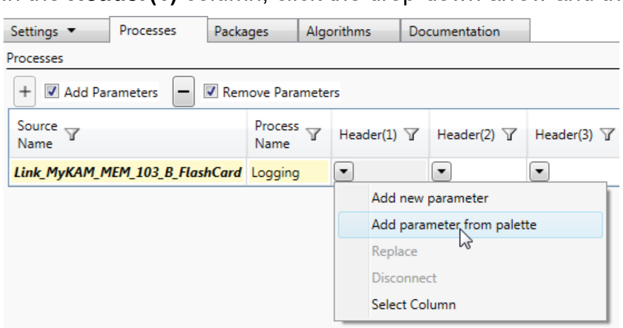
1. With the **KAM/MEM/103** in context, click the **Processes** tab.



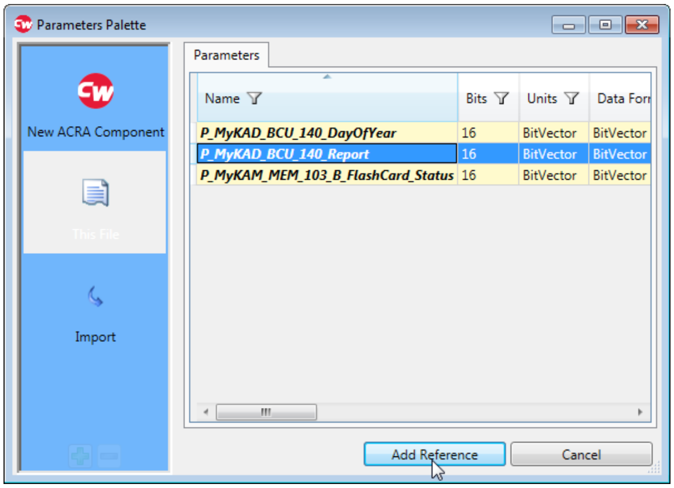

2. Click **Add a FlashCard process to**...




3. In the **Header(1)** column, click the drop-down arrow and then click **Add parameter from palette**.



4. In **Parameter Palette**, click the **This File** library button.




5. Select a parameter and then click **Add Reference**.
Refer to the “Processes tab” chapter in the *DAS Studio User Manual* for further details.

---

**NOTE:** Parameters selected as headers, cannot be added to MyMemory-StoragePackage.

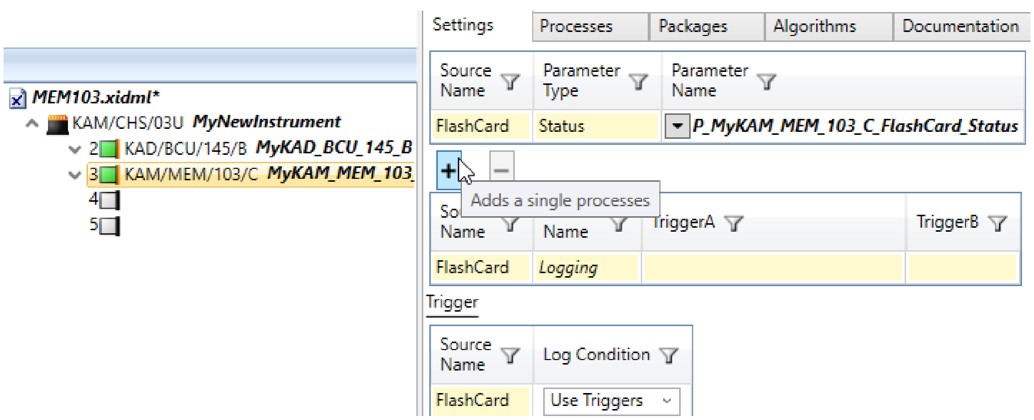
---

**WARNING:** Headers can be changed only by reprogramming the KAM/MEM/103. If you see different headers on extracted data, it is an indication that the KAM/MEM/103 has been reprogrammed.

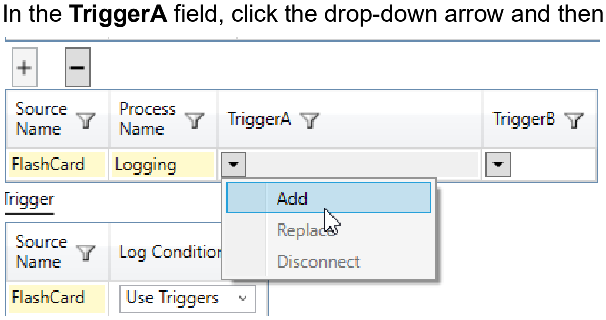
## 37.3.4 Creating a Bit Mask Alarm process

This section describes how to add a trigger.

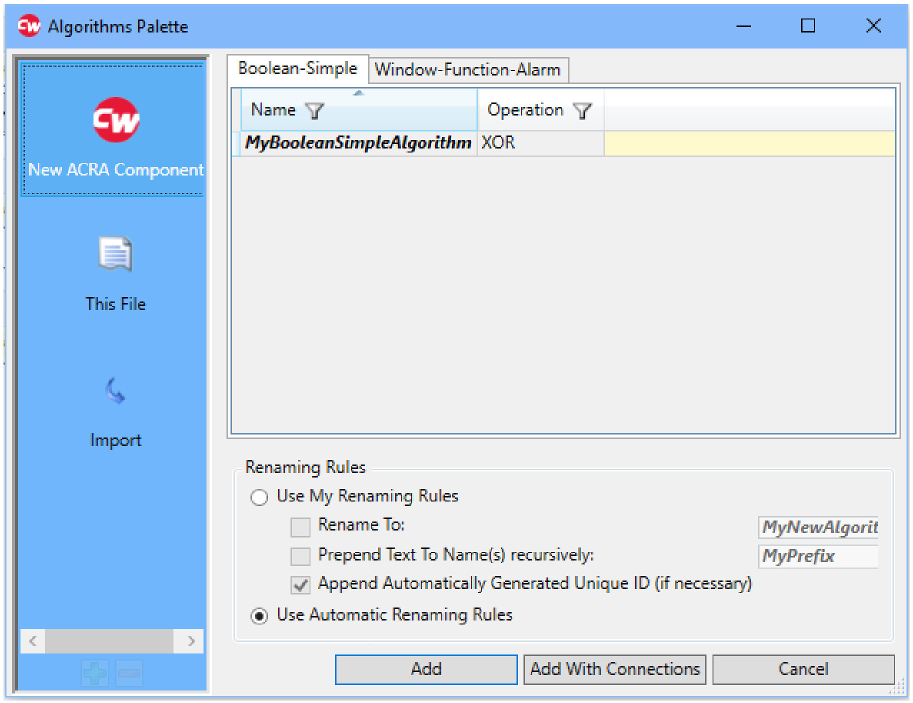
1. With the **KAM/MEM/103** in context, on the **Settings** tab click **+** to add a process.



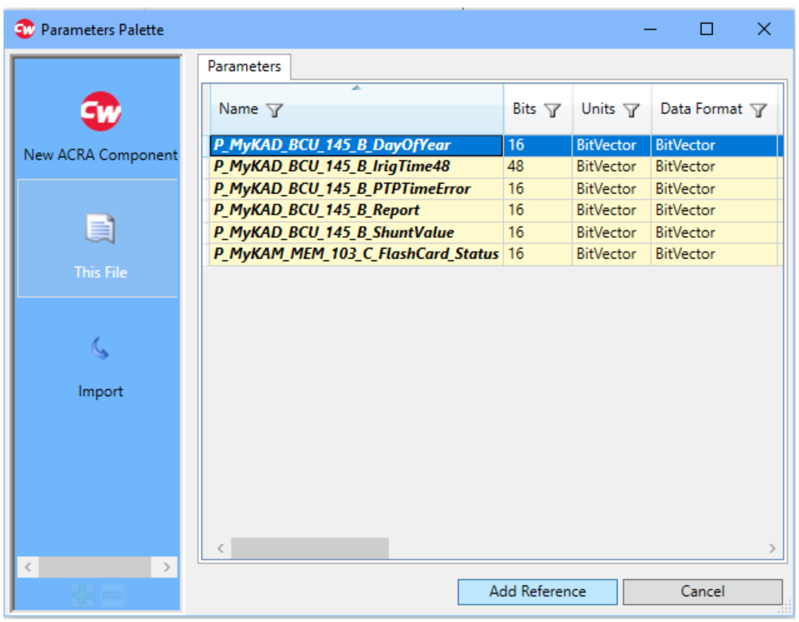

2. In the **TriggerA** field, click the drop-down arrow and then click **Add**.



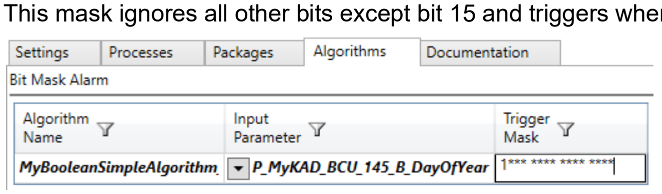
3. The **Algorithms Palette** opens.
   Select the **Boolean-Simple** or **Windows-Function-Alarm** tab and then click **Add**.




4. The **Parameters Palette** opens.
   Click the **This File** library, select the parameter you want to trigger and then click **Add Reference**.




5. On the **Algorithms** tab, in the **Trigger Mask** field, type 1*** **** **** ****.
   This mask ignores all other bits except bit 15 and triggers when bit 15 is 1.



## 37.4 CompactFlash card overview and the KAM/MEM/103

CompactFlash cards are removable mass storage devices. The history of these memory cards is closely linked to the widespread distribution of digital photographic cameras. The KAD/MEM/103 is designed to support high-speed CompactFlash cards up to 128 GB.

As higher density CompactFlash cards become available, they can be used with the KAM/MEM/103 without the need for hardware or software upgrades.

### 37.4.1 Viewing data

The CompactFlash card requires initializing, using kFlashcardXID or kFlashAPIXID, before you can begin logging or viewing data. For more information, see the *kFlashcardXID* data sheet.

To view data logged to the CompactFlash card, the different applications which can be used are described as follows:

- GS Works: the CompactFlash card can be used as a standard source for GS Works; for more information, see the *GS Works* data sheet.
- kFlashcardXID: initializes CompactFlash cards and extracts logged data; for information on the different output files, see the *kFlashcardXID* data sheet.
- kFlashAPIXID: allows you to extract the data in a specific format that kFlashcardXID doesn't support. The *kFlashAPIXID* data sheet details the different functions provided by the API and describes the structure of Curtiss-Wright data.

---

**NOTE:** kFlashAPIXID is provided with the kFlashcardXID installation; kFlashAPIXID is recommended for software developers only.

### 37.4.2 Care of CompactFlash cards

The CompactFlash card should be considered as a hard disk. We recommend using the Windows Chkdsk utility or the Scandisk (for earlier versions of Windows) utility from time to time. If a file system error occurs on the CompactFlash card, Windows can repair it before problems potentially occur during data acquisition.

If Chkdsk or Scandisk identifies file system problems on a CompactFlash card, format the card using Windows FAT file system. When formatting the CompactFlash card for the KAM/MEM/103, use Windows FAT32 file system.

## 37.5 Troubleshooting and tips

### 37.5.1 Hot swapping not allowed

CompactFlash card hot swapping is not allowed. The KAM/MEM/103 retrieves the CompactFlash card’s size at power-on. Therefore, it is important to power on the Acra KAM-500 system with the CompactFlash card inserted. Similarly, to avoid data loss and/or corruption, power should be off before extracting the CompactFlash card from the KAM/MEM/103.

### 37.5.2 Restrictions

Multiple formats are not supported in KAM/MEM/003, KAD/MEM/004, KAM/MEM/004, and KAM/MEM/103. Only Format select 0 is supported.

kSetup supports only one KAM/MEM/103 card per Acra KAM-500 chassis, which can be placed in any user-slot.

### 37.5.3 Maximum logging rate

The maximum rate for recording to the CompactFlash card is 2 Msps, however not all CompactFlash cards support this rate. The maximum logging rate depends on the manufacturer of the CompactFlash card and on the card’s capacity. For information on logging rates, see the *KAD/MEM/103* data sheet.

### 37.5.4 Boot-up time

The CompactFlash card has a controller, which manages data storage and retrieval, defect handling and diagnostics, power management, and clock control. Boot-up time depends on the CompactFlash card (for details, see the *CompactFlash Cards* data sheet).

### 37.5.5 Always log

The Always log option (on the Trigger setup tab) is not recommended when using the KAM/MEM/003, the KAM/MEM/003/B, the KAM/MEM/003/C, and the KAM/MEM/004. These modules start storing even if the CompactFlash card boot-up has not finished, and corruption of the first block in the event occurs.

We recommend that you use a trigger with the modules mentioned. Alternatively, to request a module upgrade, contact Curtiss-Wright support (acra-support@curtisswright.com).

### 37.5.6 Extraction and initialization benchmarks

For extraction and initialization benchmark details, see the *kFlashcardXID* data sheet.

---

**NOTE:** Extraction time is strongly dependent on the USB CompactFlash card reader used.

### 37.5.7 Networked systems and time synchronization

In a networked data acquisition system, all chassis with network controllers, for example KAD/BCU/105 and KAD/BCU/140, synchronize their internal clocks with the PTP Grandmaster on a 2-second time boundary (for more information, see a *KAD/BCU/xxx* data sheet). Synchronization can imply an abrupt time adjustment that happens once after power-on and once every time the KAM/MEM/103 synchronizes with a time master.

If a KAM/MEM/103 is present in the system, and Always Log is set, the adjustment in time results in the loss of data for the length of an acquisition cycle of data at the time of adjustment, and a subsequent cycles of invalid data sometime after the adjustment.

### 37.5.8 Associated software

The following table displays software available for use with all memory modules produced.

Table 37-3: Memory module history

| Module | Software required for module setup | Software required for: Initialization | Software required for: Extraction | Comments |
|---|---|---|---|---|
| KAM/MEM/003 | KSM-500<br>KSMv2 | KSMv2 | KSMv2 | Supports Type I CompactFlash cards only.<br>Supports FAT16 only.<br>The first block logged may corrupt if Always log is set. |
| KAM/MEM/003/B | KSM-500<br>KSMv2 | KSMv2 | KSMv2 | Supports Type I and II CompactFlash cards.<br>The first block logged may corrupt if Always log is set. |
| KAM/MEM/003/C | KSM-500<br>KSMv2 | kFlashcardXID | GS Works<br>kFlashAPIXID<br>kFlashcardXID | Supports CompactFlash cards up to 8 GB in size.<br>The first block logged may corrupt if Always log is set. |
| KAM/MEM/003/D | KSM-500 | kFlashcardXID | GS Works<br>kFlashAPIXID<br>kFlashcardXID | Supports CompactFlash cards up to 128 GB in size.<br>Always log option fixed. |
| KAM/MEM/003/E | DAS Studio 3 or KSM-500 | kFlashcardXID | GS Works<br>kFlashAPIXID<br>kFlashcardXID | Added knurled head captive screw. |
| KAM/MEM/103 | KSM-500 | kFlashcardXID | GS Works<br>kFlashAPIXID<br>kFlashcardXID | Supports Type I and II CompactFlash cards.<br>Maximum logging rate of 2 Msps. |

Table 37-3: Memory module history

| Module | Software required for module setup | Software required for: | | Comments |
|---|---|---|---|---|
| | | Initialization | Extraction | |
| KAM/MEM/103/B | DAS Studio 3 or KSM-500 | kFlashcardXID | GS Works<br>kFlashAPIXID<br>kFlashcardXID | The /B revision corrects an issue where the KAM/MEM/103 fails to start logging correctly with a KAD/BCU/105 in an X-SYNC slave chassis. |
| KAM/MEM/103/C | DAS Studio 3 or KSM-500 | kFlashcardXID | GS Works<br>kFlashAPIXID<br>kFlashcardXID | The /C revision corrects an issue where the KAM/MEM/103 fails to start logging correctly with a KAD/BCU/140/C. |
| KAD/MEM/004 | KSM-500 | kFlashcardXID | GS Works (using raw file only)<br>kFlashAPIXID<br>kFlashcardXID | The first block logged may corrupt if Always log is set.<br>For information on using raw files, see the *kFlashcardXID* data sheet. |
| KAD/MEM/004/B | DAS Studio 3 or KSM-500 | kFlashcardXID | GS Works (using raw file only)<br>kFlashAPIXID<br>kFlashcardXID | Always log option fixed.<br>The /B revision corrects problems with capacity reporting at power-on and initialization at high temperatures. |

## 37.6 Frequently asked questions

**Question**: “After querying the CompactFlash card with kFlashcardXID, I don't see any event stored”.

**Answers**:

- Ensure the trigger was applied correctly. For this, you just need to monitor the memory status and check whether the logging bit is set correctly.
- As the KAM/MEM/103 needs to log at least a block (32,768 × 16-bit words) before saving data to the CompactFlash card, you may not have waited long enough. Time to fill a block = cycles/block × cycle frequency.
- Curtiss-Wright guarantees only the correct operation of CompactFlash cards validated and approved for use with the KAM/MEM/103. For more information, see the *KAM/MEM/103* data sheet.

**Question**: “When using Windows Explorer to browse files on the CompactFlash card, why do I see only a readme.txt file and a strategy file?”

**Answer**: From the KAM/MEM/003/C onwards, data is logged directly on the CompactFlash card, that is, Windows FAT 32 is not used. The memory module doesn't have a file controller, that is, a microprocessor, to allow such file management. Data logged on the CompactFlash card cannot by viewed using Windows Explorer. A backup copy of the contents of the CompactFlash card can be created using kFlashcardXID.

**Question**: “Why does Curtiss-Wright provide an API to extract the data instead of providing the data format on the CompactFlash card?”

**Answer**: The API is intended for use by software developers. The main reason for using the API is that Curtiss-Wright may change the data format on CompactFlash cards used with future memory modules. Using an API makes any future changes transparent to customers using Curtiss-Wright memory modules. The structure of the data logged on the CompactFlash card is described in the *kFlashcardXID* data sheet.

## 37.7 Further reading

The following documents are related to this technical note:

*CompactFlash cards* data sheet

GS Works data sheet

*KAD/BCU/101*, *KAD/BCU/105,* and *KAD/BCU/140* data sheets

*KAM/MEM/103* data sheet

*kFlashcardXID* data sheet

*kFlashAPIXID* data sheet

*KSM/STE/002* data sheet

*DAS Studio 3* data sheet and *DAS Studio 3 User Manual*

*TEC/NOT/039 - Using the KAM/MEM/003/B*

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# Using the KAD/SWI/101

TEC/NOT/065

This technical note discusses the following topics:



## 38.1 KAD/SWI/101 overview

The KAD/SWI/101 is a four-port 100BaseTX Ethernet switch. The internal routing table is fixed, therefore incoming packets on the three ingress (DAU) ports are forwarded to the egress (aggregator) port. The KAD/SWI/101 transparently supports IEEE 1588v1 Precision Time Protocol (PTP) messages.

The KAD/SWI/101 can be used in the following applications:

- As a lower tier switch in a system where synchronization is provided by a NET/SWI/004 PTP Grandmaster.
- As a stand-alone switch in a system consisting of an Acra KAM-500 and a third party Ethernet source.

## 38.2 KAD/SWI/101 software

The KAD/SWI/101 is supported by DAS Studio 3. As the internal routing table is fixed, no setup is required. Four status registers are available (one for each Ethernet port), which indicate the number of packets passed on each port. These registers reset to 0 every second.

## 38.3 KAD/SWI/101 as a lower tier switch

The KAD/SWI/101 can be used to aggregate data from up to three KAD/BCU/140 modules and send this data to a NET/SWI/004. Synchronization is achieved using PTP packets originating from the NET/SWI/004. Programming is accomplished via the console port of the NET/SWI/004.

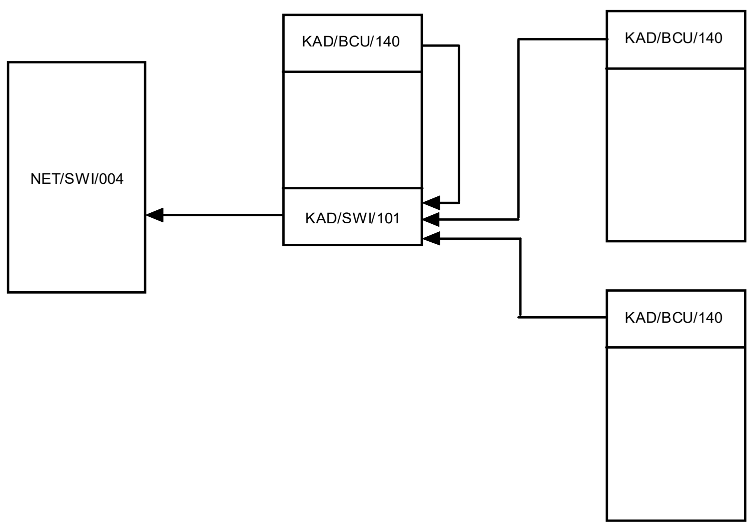



*Figure 38-1: KAD/SWI/101 in a NET/SWI/004 PTP time synchronized system*

**NOTE:** The maximum number of KAD/SWI/101 switches (or any Curtiss-Wright switches) that can be cascaded is two.

## 38.4 KAD/SWI/101 as a stand-alone switch

The KAD/SWI/101 can be used to aggregate data from an Acra KAM-500 and a third party Ethernet source and send this data to another network node.

Synchronization is achieved using an Acra KAM-500 time module in the chassis containing the KAD/SWI/101; a KAM/TCG/102/D is the most suitable as its IRIG-B outputs can be used to achieve system synchronization. This assumes that the third party Ethernet source accepts IRIG-B synchronization.

---

**NOTE:** Ensure that the KAM/TCG/XXX module is set as Time Master in DAS Studio 3 setup.

Programming is accomplished through the spare DAU port of the KAD/SWI/101.

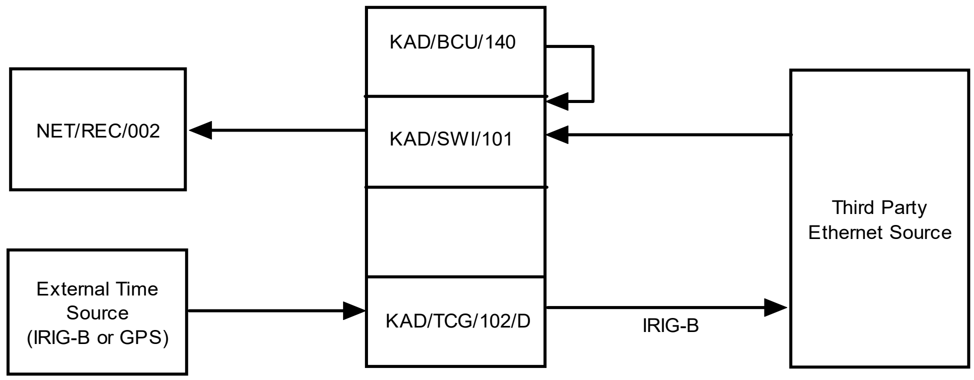



*Figure 38-2: Using the KAD/SWI/101 with a third party Ethernet source*

---

**NOTE:** The KAD/SWI/101 has neither an IP nor a MAC address so does not respond to Ping or ARP requests, however it does forward Ping or ARP requests. Therefore network nodes connected to the KAD/SWI/101, that are capable of responding to such requests, do respond.

Chapter 39

# Using the KAD/DEC/103

TEC/NOT/066

This technical note discusses the following topics:



## 39.1 KAD/DEC/103 overview

The KAD/DEC/103 is a dual PCM decommutator that can accept two independent PCM streams. Data from each stream is individually parsed into a minor frame buffer from which it can be read coherently over the backplane.

The KAD/DEC/103 has two modes of operation: synchronous and asynchronous, which are described in section "39.2 KAD/DEC/103 in synchronous mode" on page 293 and section "39.4 KAD/DEC/103 in asynchronous mode" on page 298.

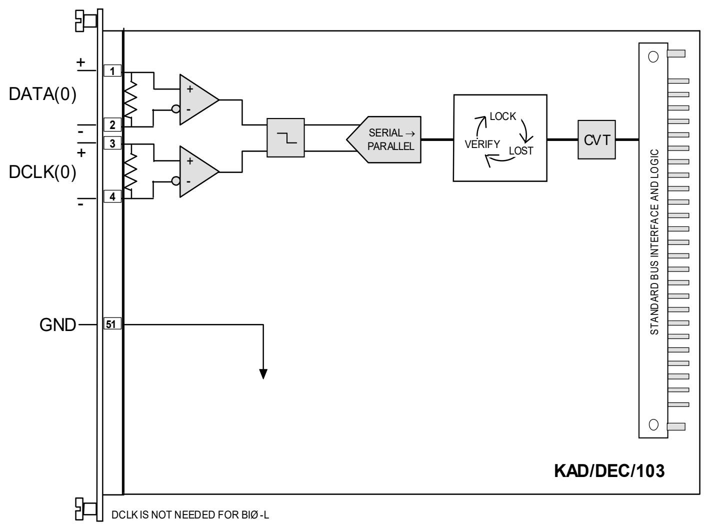



*Figure 39-1: KAD/DEC/103 overview*

**NOTE:** The KAD/DEC/003 has the same functionality as the KAD/DEC/103. However, the access rate in the backplane of the KAD/DEC/103 is faster. Also, for synchronous operation in a distributed Acra KAM-500 chassis, the maximum inter-chassis bit-rate for the KAD/DEC/003 is 3.2 Mbps, using NRZ-L PCM code; whereas the KAD/DEC/103 is limited to 8 Mbps.

## 39.2 KAD/DEC/103 in synchronous mode

The KAD/DEC/103 can merge two PCM streams in a distributed acquisition system with a star configuration. In a typical distributed acquisition system where each Acra KAM-500 chassis operates synchronously, the KAD/DEC/103 runs in synchronous mode. Data is decommutated by the decoder before it is read over the backplane.

### 39.2.1 Operation

Using the KAD/DEC/103 in synchronous mode means each Acra KAM-500 system is operating synchronously. An X_SYNC connection is required for this, as explained in the "Equipment interface" section of the *Acra KAM-500 Databook***.**

In chassis ID 0, the bus controller module (KAD/BCU/101 in this example), provides X_SYNC to all the slave chassis to allow synchronization. X_SYNC is a proprietary Curtiss-Wright protocol through an RS-422 line at 1 Mbps using BIØ-L.

#### 39.2.1.1 Setup in KSM-500

In a master/slave system, the task file in kSetup is similar to that shown in the following figure.

All chassis in a master/slave system must be represented in the same task file.

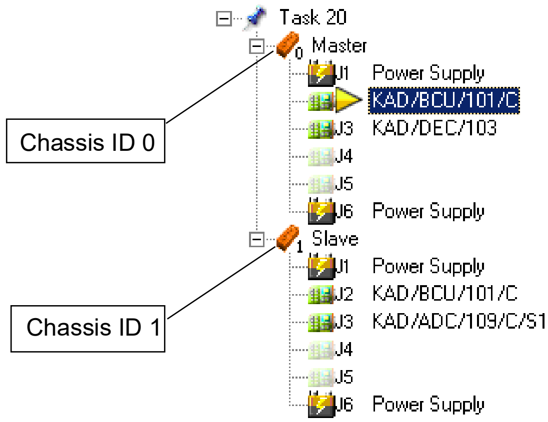



*Figure 39-2: Example master/slave task in kSetup*

---

**NOTE:** In kSetup, the chassis ID increments automatically for each new chassis added in the system. You can edit the ID by double-clicking on the chassis itself.

### 39.2.2 Bus setup

The KAD/DEC/103 has two busses. Bus setup allows an incoming PCM to be connected to the KAD/DEC/103 bus. To display options for bus setup, as shown in the following figure, double-click KAD/DEC/103. On the tabs displayed, complete the fields described in the following table.

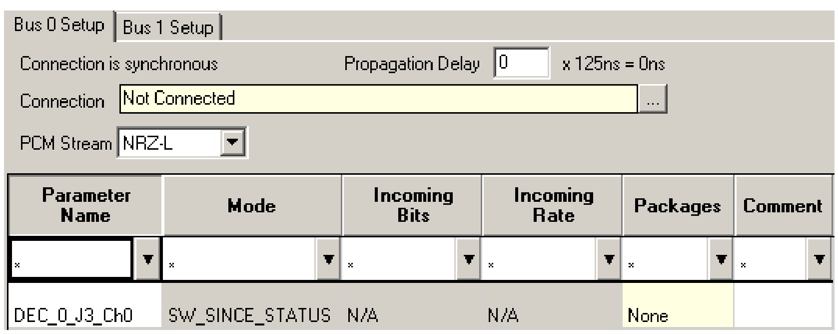



*Figure 39-3: Bus setup*

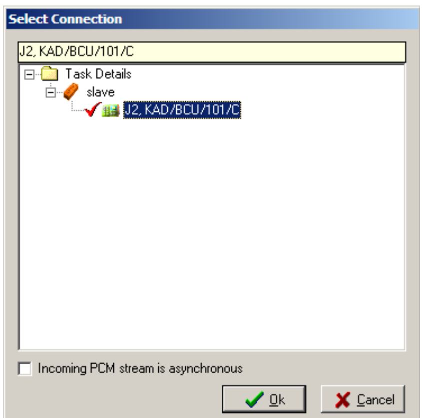
Table 39-1: Parameter settings on Bus setup

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter. |
| Mode | Read only field. Refer to the output registers from the module data sheet for further information on the register column. The status indicates the lock from the incoming PCM. It is vital to check if an issue is seen on a parameter from the incoming PCM. |
| Incoming Bits | Not available in synchronous mode. |
| Incoming Rate | Not available in synchronous mode. |
| Packages | When the parameter is placed in a PCM frame, click the Packages cell to display transmission details. |
| Comment | User-defined text relating to the parameter. |

**NOTE:** The KAD/DEC/103 status register checks the lock for all the incoming minor frames. To ensure you get lock for all the minor frames in the major frame, we recommend transmitting this status register at the minor frame rate of the incoming PCM. In synchronous mode, the status of the bus controller module, such as the KAD/BCU/101, must be checked to ensure X_SYNC is also in lock.

#### 39.2.2.1 Connection

1. Click the browse button ... beside the **Connection** field.
   This allows the PCM encoder modules in a slave chassis to be connected in order to merge incoming PCMs streams from a slave chassis.
   The following dialog box opens indicating which incoming PCMs to merge with the KAD/DEC/103 bus.




2. Select the PCM encoder module on the appropriate slave chassis, in this example KAD/BCU/101, as shown in the following figure.


#### 39.2.2.2 Propagation delay

The propagation delay is the delay associated with the cable length used between the KAD/DEC/103 and the PCM encoder module. kSetup already compensates by setting a transparent default of 20 meters. Using a value greater than the real cable length for the propagation delay does not affect the master/slave operation.

In a standard Cat 4 cable, the propagation delay is 7 ns per meter.

X_SYNC cable length should also be taken into account when calculating the propagation delay as shown in the following example.

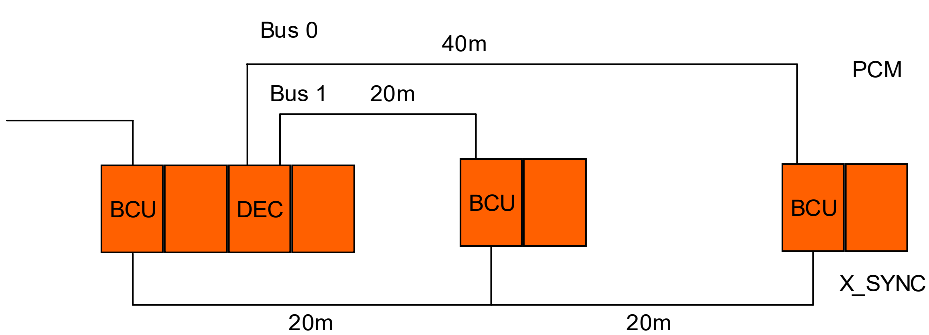



*Figure 39-4: Example of a star master/slave PCM system*

Consider a star master/slave PCM system with two slave chassis (see the previous figure).

Propagation Delay Bus 0: 40m PCM + 40m X_SYNC = 80m, 80m × 7 ns per meter = 560 ns.

Propagation Delay Bus 0 should be set to 560 / 125 = 5.

Propagation Delay Bus 1: 20m PCM + 20m X_SYNC = 40m, 40m × 7 ns per meter = 280 ns.

Propagation Delay Bus 0 should be set to 280 / 125 = 3.

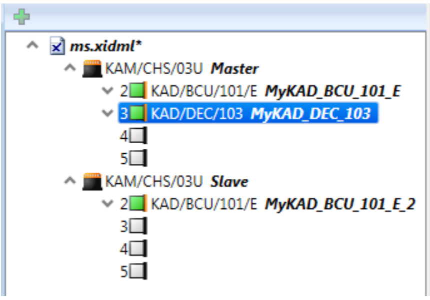
---

**NOTE:** Using the propagation delay with a long cable could cause the KAD/DEC/103 to read the wrong minor frame, that is, it could read the wrong parameter.

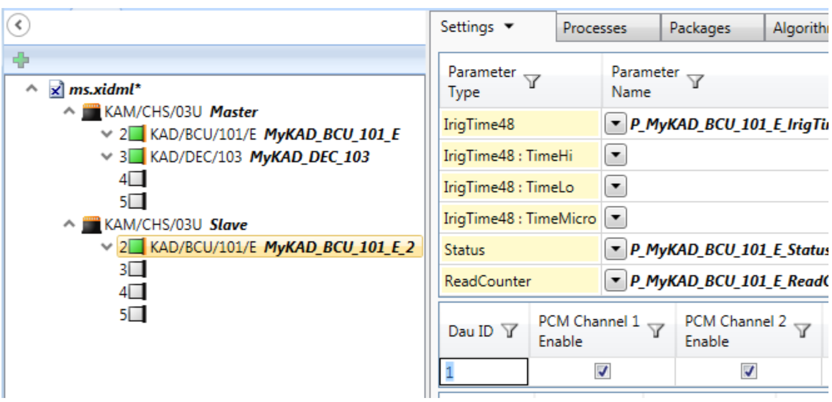
#### 39.2.2.3 Setup in DAS Studio 3

All chassis in a master/slave system must be represented in the same XidML task file. For identification purposes, rename the chassis to Master/Slave. Then assign DAU IDs to each controller to identify the source of traffic.

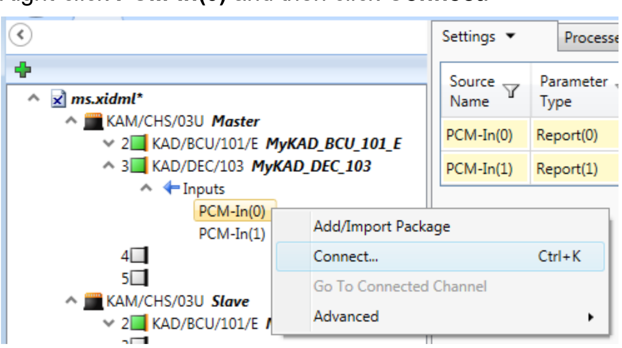
1. Configure your task file with two chassis each containing a controller module (for example KAD/BCU/101).
2. Add a KAD/DEC/103 to the first master chassis as shown below.




3. In the Navigator, click the **KAD/BCU/101** module in the **Slave** chassis and set the DAU ID to 1. (The DAU ID on the KAD/BCU/101 in the master chassis should be left at the default 0.)

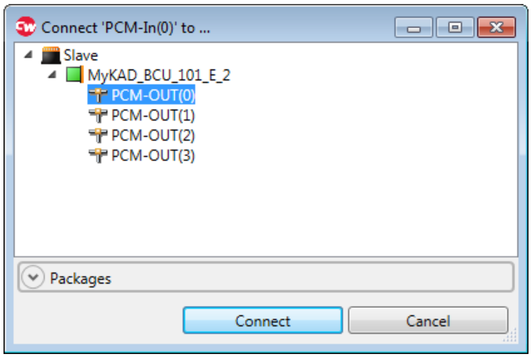



4. In the Navigator, double-click the **KAD/DEC/103** node to expand it and then double-click the **Inputs** node to expand that.
5. Right-click **PCM-In(0)** and then click **Connect**.

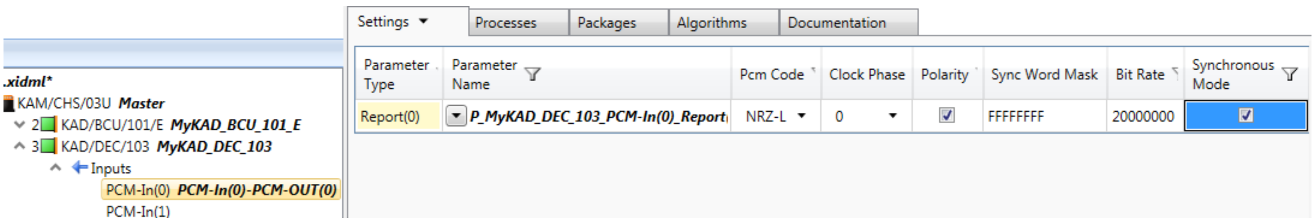



The **'Connect PCM-In'** dialog box opens allowing you to connect a PCM-OUT option.

6. On the **Slave**, KAD/BCU/101, select **PCM-OUT(0)** and then click **Connect**.




7. On the KAD/DEC/103 **Settings** tab, ensure **Synchronous Mode** is enabled.
(The **Bit Rate** setting can be ignored as this is automatically calculated by the Multi Chassis Scheduler (MCS) during compilation.)




8. In the KAD/BCU/101 of the Master DAU, build your PCM frame. (Refer to the *DAS Studio 3 User Manual*.)

---

**NOTE:** The KAD/DEC/103 report register checks the lock for all the incoming minor frames. To ensure you get lock for all the minor frames in the major frame, we recommend transmitting this status register at the minor frame rate of the incoming PCM. In Synchronous Mode, the status of the bus controller module, such as the KAD/BCU/101, must be checked to ensure X_SYNC is also in lock.

#### 39.2.2.4 PCM Stream

NRZ-L or BIØ-L can be selected as the PCM Stream. BIØ-L allows only DATA± to be wired.

## 39.3 Tips and troubleshooting in synchronous mode

### 39.3.1 Slave PCMs

KSM-500 and DAS Studio 3 software build the PCM frame between the slave chassis and the KAD/DEC/103 automatically. Care must be taken when transmitting a parameter from the slave into the master PCM. For details, see *TEC/NOT/035 - Rules of PCM placement*.

### 39.3.2 Daisy chain PCMs

We do not recommend the use of PCM daisy chain configuration, that is, placing a KAD/DEC/103 in synchronous mode in a slave chassis.

### 39.3.3 Status

In BIØ-L, the lock bit in the status remains at 1 if the KAD/DEC/103 goes out of lock. It is essential to check if the bit *Sync word since last read* is also set to 1.

### 39.3.4 Bus controller module and KAD/DEC/103 status

It is important to check if the KAD/DEC/103 status is in lock. It is also important to check if the bus controller module status has X_SYNC lock. The X_SYNC status not being in lock could cause the KAD/DEC/103 to go out of lock. If you don't transmit the KAD/DEC/103 status at the PCM incoming minor frame rate, you may not see the KAD/DEC/103 going out of lock.

### 39.3.5 RS-422

Great care must be taken when grounding (GND) a master/slave system. The PCM encoder module-to-KAD/DEC/103 connection is made via RS-422. If the GND is floating, you may damage the KAD/DEC/103 or PCM encoder RS-422 driver. For details, see *TEC/NOT/063 - Grounding and shielding of the Axon and Acra KAM-500*.

### 39.3.6 Out of lock

Check the KAD/DEC/103 lock and the bus controller module lock.

Ensure X_SYNC is correctly connected. Check the following with a multimeter from the master X_SYNC cable:

- that the 120 ohms between X_SYNC+ and X_SYNC- is present.
- that infinite ohms exist from X_SYNC+ and GND.
- that infinite ohms exist from X_SYNC- and GND.

Check, with an oscilloscope, X_SYNC± from the last slave getting X_SYNC. You should see a BIØ-L stream at 1 Mbps. Note that lots of AAAA in hexadecimal are transmitted so your oscilloscope may display 500 kbps.

Ensure PCM is correctly connected. Check with a multimeter from the KAD/DEC/103 cable that the DATA± and DCLK± are all connected to the PCM encoder module.

Check with an oscilloscope DCLK± and DATA± coming from the PCM encoder module.

Try to reprogram the system. This ensures the chassis ID from the slave chassis is still correct. If two chassis are set to chassis ID 0, the parameters become corrupt.

## 39.4 KAD/DEC/103 in asynchronous mode

When decommutating data from an encoder running asynchronously, data is parsed into a coherent buffer. All parameters that are read are guaranteed to be from the same minor frame.

### 39.4.1 Operation

Support for asynchronous PCM stream collection is based on the understanding that the source of the PCM stream is another Curtiss-Wright PCM encoder system.

However, support for PCM streams, which originate from third party PCM systems is possible when the frame from the third party PCM source is duplicated with a dummy Acra KAM-500 system, which emulates the third party source.

This process is described in the following steps:

1. Define a dummy Acra KAM-500 system in a new task. Build a frame on the dummy system to represent your asynchronous PCM frame from the third party PCM source.
2. Connect the PCM output of the dummy system to the appropriate bus input of the KAD/DEC/103 PCM decoder module in the main (merger) Acra KAM-500 acquisition system.
3. Transmit the asynchronous parameters on your Acra KAM-500 system, which includes PCM words, which have been merged from the asynchronous third party system.

---

**NOTE:** The KAD/DEC/103 decodes only minor frames, so there can be only one minor frame per major frame. You cannot use an SFID to reconstruct major frames in hardware. Thus, major frame reconstruction must take place at the ground station. If the size of the major frame is less than the maximum number of words per minor frame (4,096 words), we could define the entire major frame as one minor frame to help in capturing it. However, some unique syncword must be defined. Sub (super) commutated data must be processed on the ground station for proper reconstruction. A way around for a sub-commutated parameter is to mimic the major frame into one minor frame.

#### 39.4.1.1 Example of emulating a third party source using KSM-500

##### Step 1: Defining a dummy Acra KAM-500 system representing the asynchronous PCM frame

Consider the following PCM:

- All data words are 10 bits long.
- The sync word is 20 bits, Barker code.
- Eight words per minor frame.
- Two minor frames per major frame.

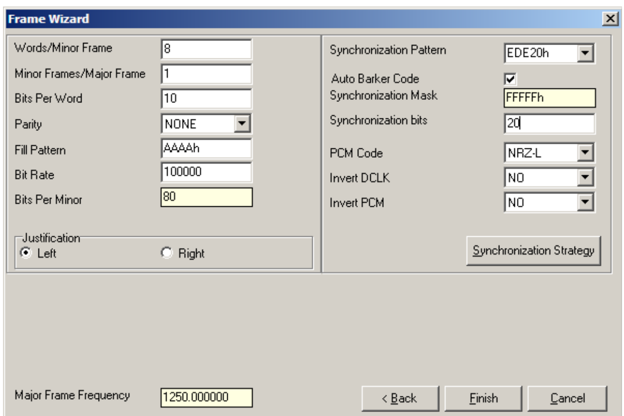
- The baud rate is 100 kbps.

See the PCM representation displayed in the following figure.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SYNC1 | SYNC2 | SFID | A | B | C | E | A |
| SYNC1 | SYNC2 | SFID | A | B | D | | A |

*Figure 39-5: PCM system representation*

1. Create a dummy task using a PCM encoder module.
2. Generate parameters from the PCM encoder module which contain fixed data.
3. Rename the parameters **A1, B, CD, E** and **A2**.
4. In the task file, double-click the **PCM encoder module** and click **Frame Builder**.
5. Build the frame setup as in the following figure.

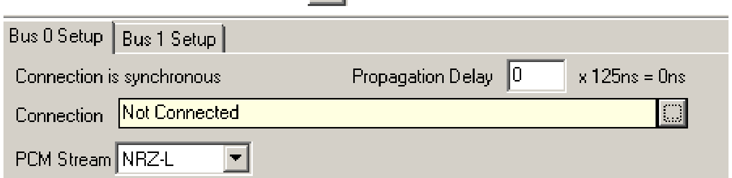



6. Place the parameters in the PCM to represent the asynchronous PCM as shown in the following figure.

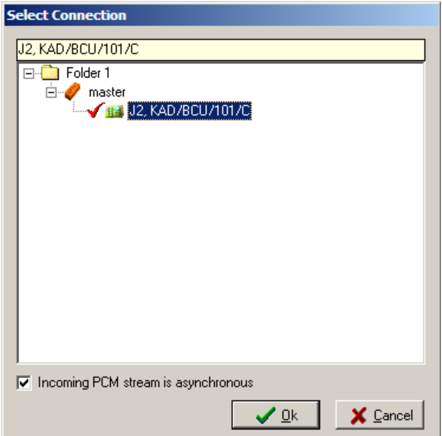
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 | SFID | A1 | B | CD | E | A2 | SYNCWORD | |

## Step 2: Connecting the main Acra KAM-500 to the asynchronous PCM frame

1. On your physical system task, double-click the **KAD/DEC/103** to display bus setup options, then click the browse button beside the **Connection** field ... .



2. Select the Incoming PCM stream is asynchronous field check box. Select the dummy task created in step 1 and select the corresponding dummy PCM encoder module, KAD/BCU/101 in this example.




3. Click **Ok** to make any parameter set up in the dummy PCM available to the KAD/DEC/103 as a parameter as shown in the following screen.

| Parameter Name | Mode | Incoming Bits | Incoming Rate | Packages | Comment |
|---|---|---|---|---|---|
| * | * | * | * | * | * |
| A1 | ASYNCHRONOUS | 10 | 1250 | None | |
| A2 | ASYNCHRONOUS | 10 | 1250 | None | |
| B | ASYNCHRONOUS | 10 | 1250 | None | |
| CD | ASYNCHRONOUS | 10 | 1250 | None | |
| DEC_0_J3_Ch0 | SW_SINCE_STATUS | N/A | N/A | None | |
| E | ASYNCHRONOUS | 10 | 1250 | None | |
| SYNC_3_0_0 | ASYNCHRONOUS | 10 | 1250 | None | |
| SYNC_3_0_1 | ASYNCHRONOUS | 10 | 1250 | None | |
| WORD_3_0_2 | ASYNCHRONOUS | 10 | 1250 | None | |

#### Step 3: Transmitting the asynchronous parameters from your Acra KAM-500 system

All parameters (or any subset of those parameters) created on the KAD/DEC/103 can be placed in any sink module such as a KAM/MEM/103, PCM encoder, or an Ethernet transmitter.

The parameters appearing in the stream should be sampled at a frequency equal to, or greater than, the frequency at which they appear, to ensure they are all recorded. If the parameter is sampled at a lower rate, then values are skipped. Respectively, the parameter is stale if the frequency is higher.

### 39.4.1.2 Example of emulating a third party source using DAS Studio 3

#### Step 1: Defining a dummy Acra KAM-500 system representing the asynchronous PCM frame

Consider the following PCM:

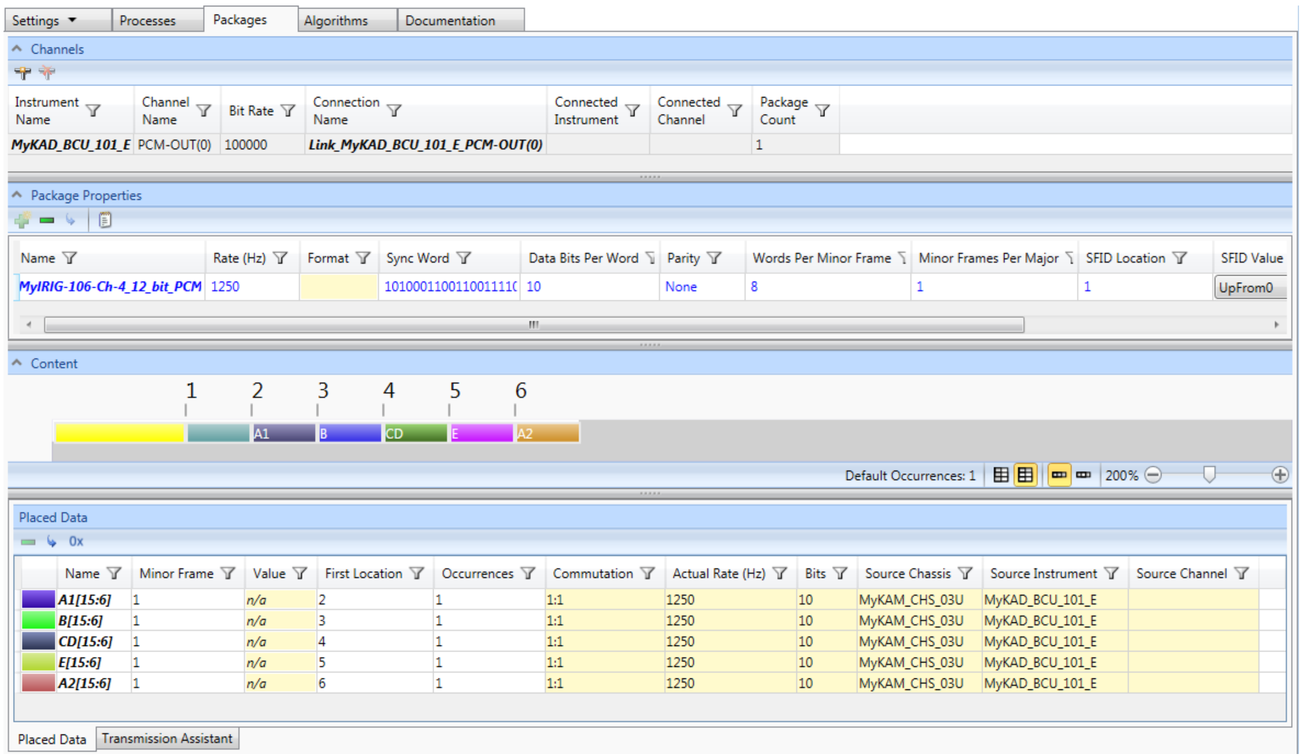
- All data words are 10 bits long.
- The sync word is 20 bits, Barker code.
- Eight words per minor frame.
- Two minor frames per major frame.
- The baud rate is 100 kbps.

See the PCM representation displayed in the following figure.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SYNC1 | SYNC2 | SFID | A | B | C | E | A |
| SYNC1 | SYNC2 | SFID | A | B | D | | A |

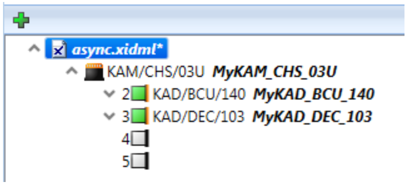
*Figure 39-6: PCM system representation*

1. Create a dummy task using a PCM encoder module.
2. Generate parameters from the PCM encoder module, which contain fixed data. (Refer to the DAS Studio 3 User Manual to set up fixed data.)
3. Rename the parameters **A1, B, CD, E** and **A2**.
4. Set up the PCM as shown in the following screen.

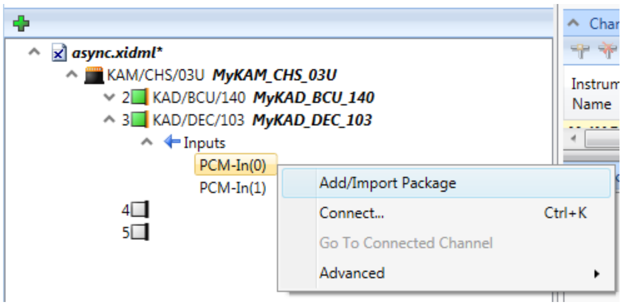


Connecting the main Acra KAM-500 to the asynchronous PCM frame

1. Create a configuration XidML file (for example async.xidml) with the following instruments.

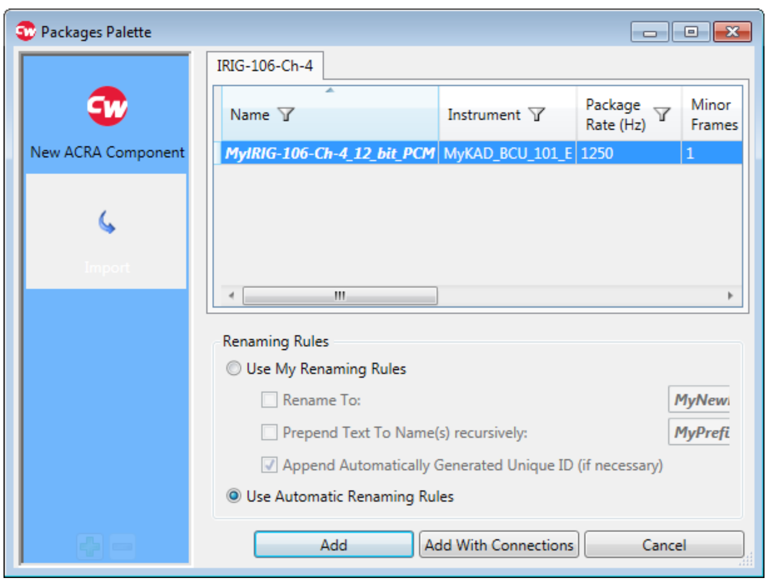



2. In the Navigator, double-click the **KAD/DEC/103** node to expand it and then double-click the **Inputs** node to expand that. In this example, channel 0 [PCM-In(0)] on the KAD/DEC/103 is used to decommutate the third party PCM from the dummy.xidml which we defined in the previous Step 1 section.
3. Right-click **PCM-In(0)** and then click **Add/Import Package**.

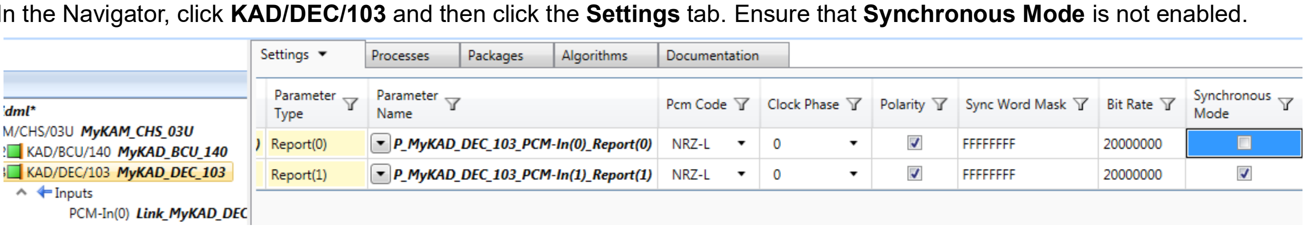



The **Packages Palette** opens.

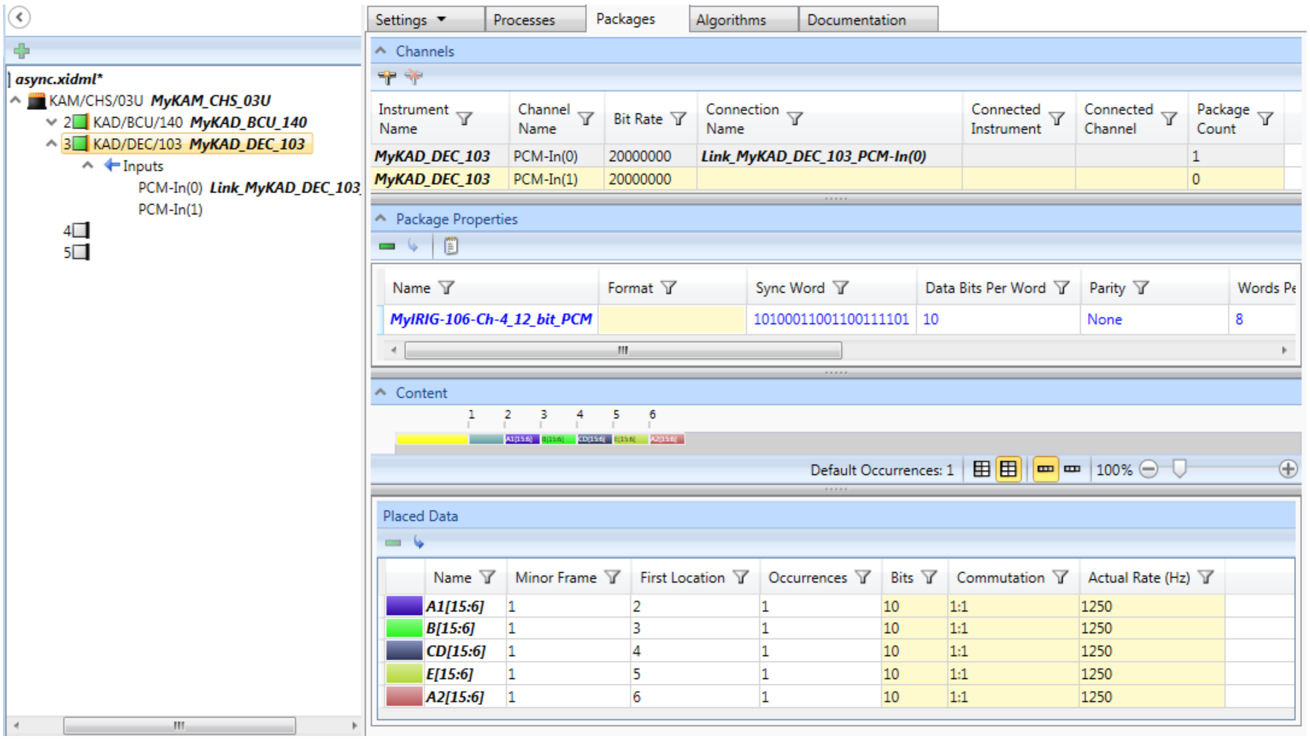
4. Click the **Import** library button and then browse to the dummy.xidml file.




5. Select the PCM package and click **Add With Connections**.
6. In the Navigator, click **KAD/DEC/103** and then click the **Settings** tab. Ensure that **Synchronous Mode** is not enabled.



7. Now click the **Packages** tab.
The package and parameters that were defined in the dummy.xidml are now shown in the **Package Properties** and **Content/Placed Data** panes.




## Transmitting the asynchronous parameters from your Acra KAM-500 system

All parameters (or any subset of those parameters) created on the KAD/DEC/103 can be placed in any sink module such as a KAM/MEM/103, PCM encoder, or an Ethernet transmitter.

The parameters appearing in the stream should be sampled at a frequency equal to, or greater than, the frequency at which they appear, to ensure they are all recorded. If the parameter is sampled at a lower rate, then values are skipped. Respectively, the parameter is stale if the frequency is higher.

# 39.5 Tips for operating in asynchronous mode

## 39.5.1 Parameter subset

You can use all of the parameters from an asynchronous stream, or any subset of those parameters.

## 39.5.2 Placing asynchronous parameters

Asynchronous parameters can be placed anywhere in the main system's major frame. You can also transmit them through Ethernet or store them into a memory module.

## 39.5.3 Coherency

Samples from an asynchronous stream are *minor frame coherent*. In other words, samples from a frame have been sampled simultaneously, and samples from subsequent frames are also sampled simultaneously at subsequent time intervals. The KAD/DEC/103 Current Value Table (CVT) is updated only when all parameters of interest from a particular minor frame have been read.

The KAD/DEC/103 is a bus monitor in asynchronous mode. Like all the bus monitors, it uses a triple buffer.

## 39.5.4 Rate

Asynchronous parameters should be read slightly faster than the rate at which they arrive to ensure no loss of data, otherwise this leads to occasional stale data.

### 39.5.5 Status

Stale and skipped data can be identified by reading the STATUS words from the KAD/DEC/103.

Ensure that the KAD/DEC/103 is in lock, there are no errors and a synchronization word was received since the last read. If the KAD/DEC/103 is receiving data correctly, the status word displays a 6xxx in hexadecimal.

Chapter 40

# IENA and iNET-X packet payload formats

TEC/NOT/067

This paper discusses the following topics:



## 40.1 Overview

This paper describes the packet header structures and payload structures for both IENA and iNET-X application layer packetization protocols.

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**NOTE:** There is significant commonality regarding the creation and placement of the payload in both iNET-X and IENA application layer packets, the sections describing the IENA packetization formats are for illustrative purposes since the payload specific details have been discussed in the corresponding iNET-X section.

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**NOTE:** To better understand this paper, see “40.6 Recommended reading” on page 326.

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**NOTE:** The notation used in this document is the standard bit ordering and numbering convention used in networking known as *standard big-endian network byte order*. That is, the most significant octet is transmitted first; the left-most bit of the entire field is the most significant bit.

## 40.2 Transmitting data

The backplane controller packs the acquired data from each of the user-modules into the packet payload. The controller then encapsulates the payload of acquired data as either iNET-X or IENA packets which are subsequently encapsulated and transmitted as UDP/IP packets. The following two figures illustrate the complete UDP/IP-encapsulated iNET-X and IENA packet structures respectively.

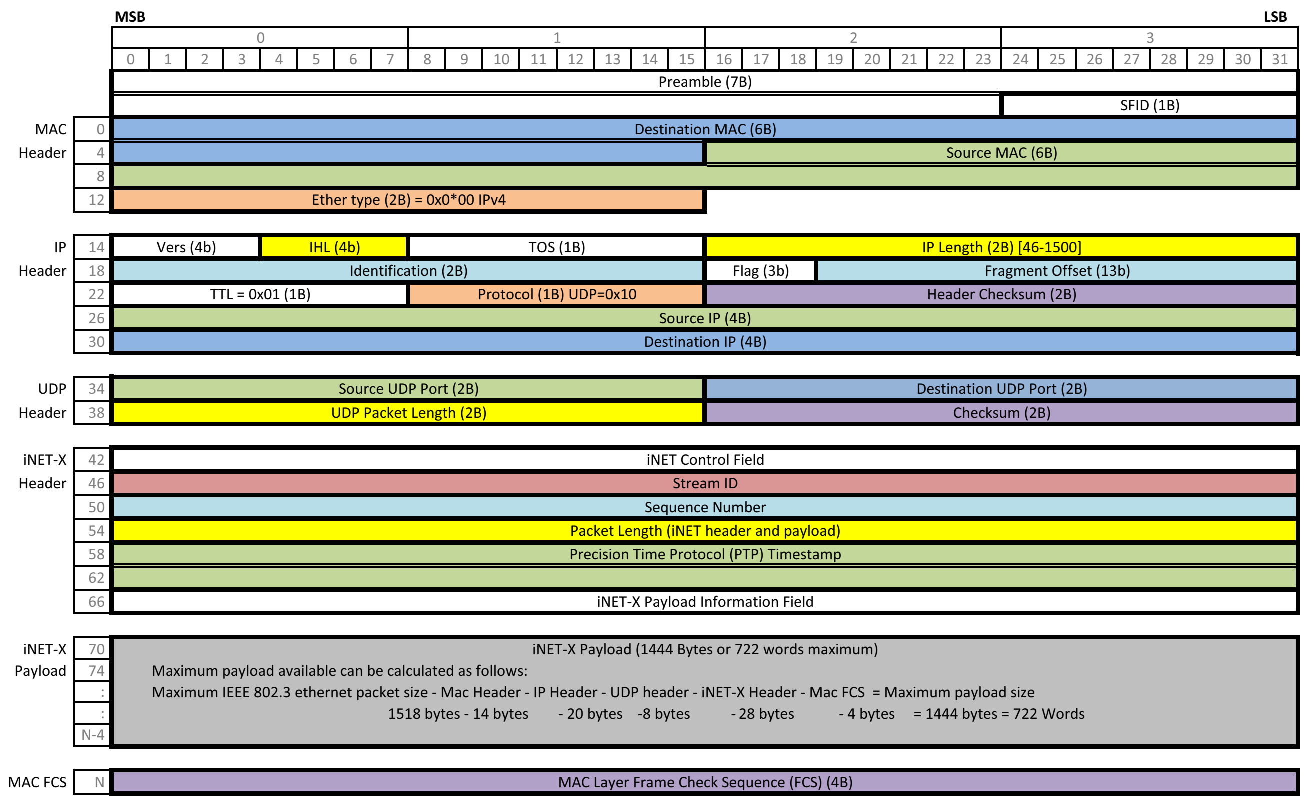


*Figure 40-1: iNET-X packet structure*

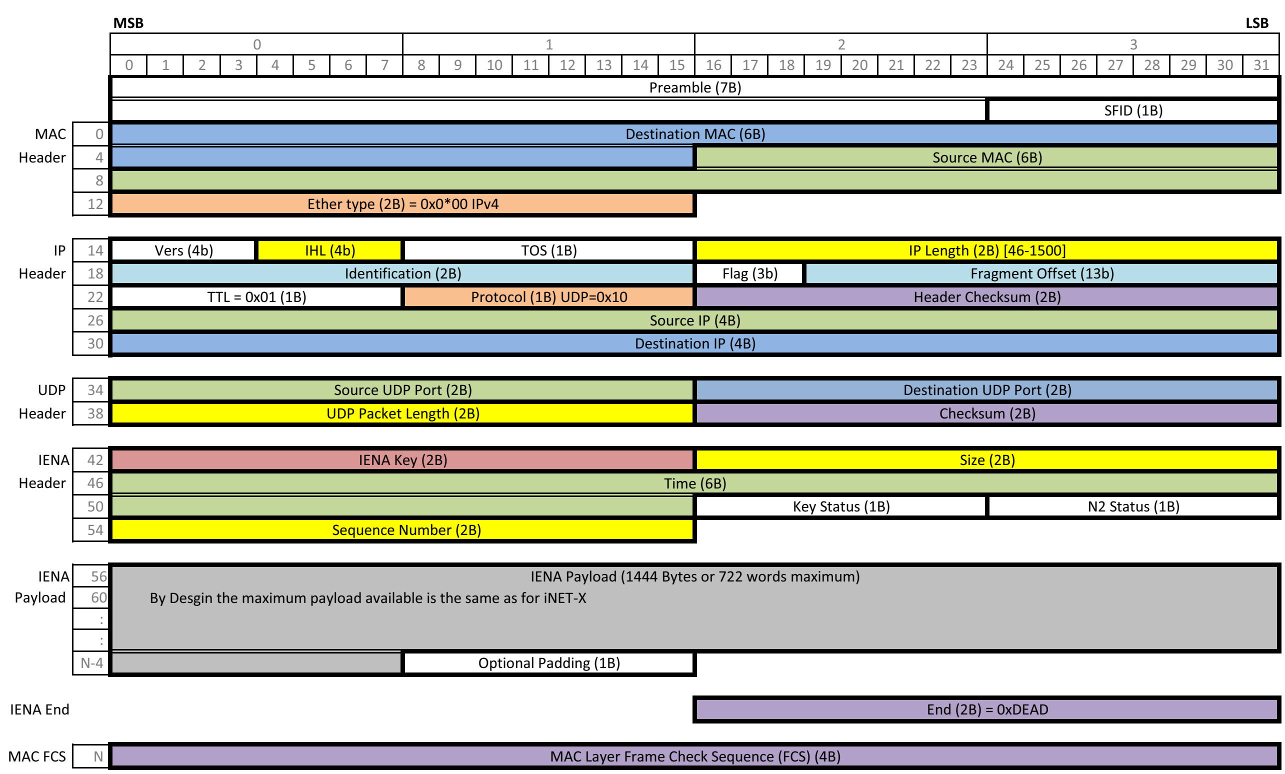


*Figure 40-2: IENA packet structure*

### 40.2.1 Packetization rules and recommendations

The following table outlines the packetization rules and recommendations for both IENA and iNET-X packet structures.

Table 40-1: iNET-X and IENA packetization rules and recommendations

| Recommendation | iNET-X | IENA |
|---|---|---|
| Each packet stream carries a Stream ID. | iNET-X Stream ID (32 bits). | IENA Key (16 bits). |
| A Data Acquisition Unit (DAU) may transmit more than one packet stream. | Recommended. | Recommended. |
| It is recommended that the packet stream is transmitted as multicast. | Recommended. | Recommended. |
| The Stream ID/IENA Key is system-wide unique. | Recommended. | Recommended. |
| All packets for a given stream contain one type of parameter (that is, messages and parameters are not mixed in the one packet payload). | Recommended. | Recommended. |
| Supported payload structures. | iNET-X defines the following payload structures:<br>Placed<br>Block<br>Bit-aligned<br>Parser-aligned<br>Event | IENA defines three basic payload structures however only the Positional type is supported.<br>Other types not currently supported:<br>Message<br>Standard |
| Parameter placement rules. | No restrictions, but recommended as having contiguously placed samples. This applies to Placed payload structures. | Positional type payloads must adhere to strict parameter sample interleaving rules. |
| The placement of parameters is fully described by XidML. | Recommended. | Recommended. |
| Fragmentation support:<br>Large payloads exceeding the Maximum Transmission Unit (MTU) of 1500 bytes incurs an onerous packetization and reassembly delay thereby increasing the end-to-end latency. | Fragmentation is not supported by the INET-X standard. | IP layer fragmentation is allowed as part of the IENA standard but it is not recommended. |
| Packetization latency:<br>The latency from sensor to display should not exceed real-time limits. A typical value of 50ms is recommended. | Recommended. | Recommended. |

## 40.3 iNET-X packet header

iNET-X packets use the standard iNET application layer packet structure as shown in the following figure and are therefore fully compliant and compatible with iNET systems. iNET-X packets have an additional 4-byte extension field, called the iNET-X Payload Information field, appended directly following the standard iNET header.

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**NOTE:** For more information on iNET, go to http://www.inetprogram.org/default.aspx.

The iNET-X Payload Information field contains Curtiss-Wright-specific metadata to facilitate decoding and decommutation of the payload.

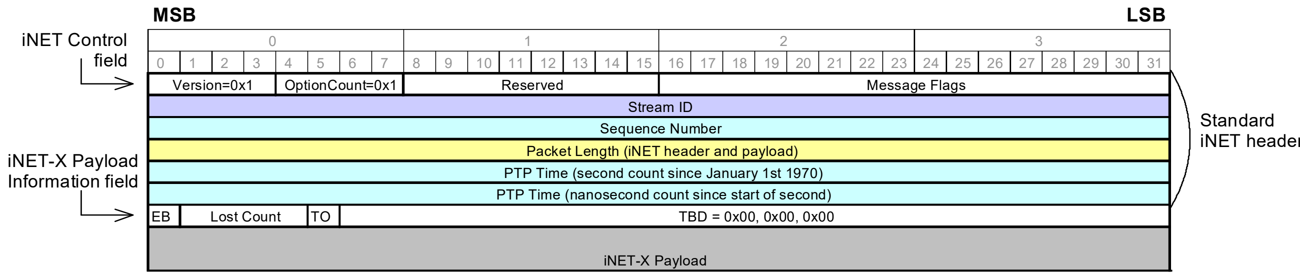


*Figure 40-3: iNET packet header*

The iNET packet header contains the following elements:

- iNET Control field (32 bits):
  - Bits [0:3] Version: identifies the version of the iNET application layer protocol. The version supported is Version1.
  - Bits [4:7] OptionCount: specifies the number of 32-bit words in the application defined extension field. The value in this field is 0x1, since iNET-X packets comprise a single 32-bit application defined extension field, called the iNET-X Payload Information field, following the standard iNET header.
  - Bits [8:15] Reserved: to be defined and is reserved for future use.
  - Bits [16:31] Message Flags: contains the following fields:
    - Message Fragmentation flags.
    - Message Simulated Data flag.
    - Message Time Synchronization flag.
    - Message Health flag.
    - End of Data flag.

---

**NOTE:** These Message flags are not currently supported in iNET-X.

- Stream ID (32 bits): points to a unique (system wide) metadata package description in the XidML. The package description describes the format, structure, and data contained in the iNET-X packet payload.
- Sequence Number (32 bits): increments by one for each packet generated and transmitted with a given Stream ID.
  - A sequence number value of 0 occurs when:
    - The DAU controller is powered on.
    - After the DAU has been programmed.
    - The sequence number has incremented to the maximum value and has wrapped around back to 0.
- Packet Length (32 bits): is the length of the complete iNET-X packet in bytes including the iNET header, iNET-X Payload Information field, the payload, and any padding in the packet. Padding is used when the length of the iNET-X packet does not fall on a 32-bit boundary.
- PTP Time (64 bits): is the timestamp associated with the oldest unit of data in the payload. In the case of analog data, the timestamp relates to the earliest sample contained in the payload. For bus monitor data, the timestamp relates to the first and earliest bit or message captured on the bus. The time is TAI and the format used is unsigned Precision Time Protocol (PTP) version 1 format using PTP epoch where:
  - Bits [0:31] Time = second count since January 1st 1970.
  - Bits [32:63] Time = nanosecond count since start of second.
- iNET-X Payload Information field (32 bits): contains Curtiss-Wright-specific packet metadata. The iNET-X Payload Information field comprises the following fields:
  - EB (Bit 0): Error Bit: the acquired data is validated for parity and bit errors. The EB is used to indicate the integrity of the payload.
    - EB = 1 if there is one or more errors associated with the data (such as bits or messages) contained in the payload.
    - EB = 0 if there are no errors associated with the payload.
    - LostCount (Bits [1:4]): when the First In First Out (FIFO) or buffer is filled with acquired data at a faster rate than iNET-X packets are being generated, data is lost. When this occurs, the Drop Count field indicates the number of iNET-X packet payloads lost due to the buffer becoming saturated.
  - TO (Bit 5): Timeout: iNET-X supports an Aperiodic Transmission (No Transmit When Empty) function to make efficient use of network bandwidth and recording media resources. However, on asynchronous busses during periods of low data rates, the buffer or FIFO may fill slowly. To ensure iNET-X packets are periodically generated to facilitate real-time analysis and processing, during periods of low data rates there is a timeout associated with the data, thereby guaranteeing that a packet is generated.
    - TO = 1 if the iNET-X packet is generated and transmitted as the result of a timeout occurring.

- TO = 0 if the iNET-X packet is generated as a result of the FIFO or buffer being filled to a predefined maximum size.
- Bits [6:31]: Reserved: to be defined and is reserved for future use.

**NOTE:** When the timeout is reduced from the default value, a higher packetizer rate may be required to ensure that each packet can timeout and still be read.

### 40.3.1 iNET-X payload formats

iNET-X defines the following payload formats which are suitable for a variety of acquired data types:

- Bit-aligned
- Placed
- Block
- Parser-aligned
- Event

The iNET-X payload format implemented is a feature of the appropriate user module.

The key attributes of iNET-X packets are summarized in the following table.

Table 40-2: iNET-X payload structure overview

| iNET-X packet payload type | Examples | Example products | Max payload length | PTP timestamp | Notes and metadata elements |
|---|---|---|---|---|---|
| Bit-aligned | Continuously Variable Slope Delta (CVSD) audio | SSR/CHS/00X built-in VDC | N x 4 bytes, not exceeding 1,444 bytes | Time tag of first bit in the payload | • iNET-X packet type: bit-aligned.<br>• Timeout: if applicable, for example 10ms.<br>Data type: string representation of the data type, for example CVSD audio.<br>• Target packet size in bytes, for example N x 32-bit. |
| Placed | Analog samples, synchronous PCM, and any periodic acquisition | SSR/ADC/126 | Fixed and constant length, not exceeding 1,444 bytes | Time tag of oldest sample in the payload | • iNET-X packet type: placed.<br>• For each parameter:<br>- Format: for example offset binary, 2's complement and so on.<br>- Range: maximum, minimum with respect to SI units.<br>• Parameter placement should always start on a 16-bit boundary.<br>• If more than 16-bit, that is 24-bit, must be extended by N x 16-bit. |
| Block | MPEG-2 transport stream video | SSR/VID/106 | N x block length in bytes, not exceeding 1,444 bytes | Time tag of oldest block in the payload | • iNET-X packet type: block.<br>• Timeout: if applicable, for example 10ms.<br>• Data type: string representation of the data type, for example video.<br>• Bytes per block, for example 188.<br>• Target packet size: integral number of blocks, for example 7. |
| Parser-aligned | MIL-STD-1553, ARINC-429, PCM | SSR/MBM/101<br>SSR/ABM/102<br>SSR/ABM/103<br>SSR/PBM/104<br>SSR/CBM/105 | Variable, not exceeding 1,444 bytes | Time tag of first message in the payload | • iNET-X packet type: Parser-aligned.<br>• Timeout: if applicable, for example 10ms.<br>• Data type: string representation of the data type, for example MIL-STD-1553, ARINC-429, PCM.<br>• Target packet size in bytes. |

Table 40-2: iNET-X payload structure overview (continued)

| iNET-X packet payload type | Examples | Example products | Max payload length | PTP timestamp | Notes and metadata elements |
|---|---|---|---|---|---|
| Event, Status, Error | SSR locally or remotely generated pilot event markers and traps | SSR/CHS/00X NET/REC/00X KAD/BIT/102 | Variable, not exceeding 1,444 bytes | Time tag of event | • iNET-X packet type: event.<br>• For each event type, an enumeration and string. |

## 40.3.2 iNET-X placed packet format

Placed iNET-X packet structures are designed to cater for tailored packet payloads where parameters are placed at specific locations in the payload as shown in the following figure. This approach is analogous to the placement of parameters in a PCM frame. The format and structure of these placed packets must be described in full, in XidML, for individual parameters and samples to be located and extracted from the packet.

The placement of parameters and/or samples in the iNET-X payload is not restricted or constrained by placement rules. However, the locations of the placed parameters must be fixed and constant for each iNET-X packet generated, with a given stream ID for a given configuration.

Analog samples for multiple channels may be placed contiguously in the payload. Where there are multiple channels of analog data, the number of samples for each analog channel contained in the payload must be an integral number of the lowest common denominator of samples. For example, consider Channel 1 has N samples (lowest common denominator); every other channel must contain Z x N samples, where Z ≤ 1.

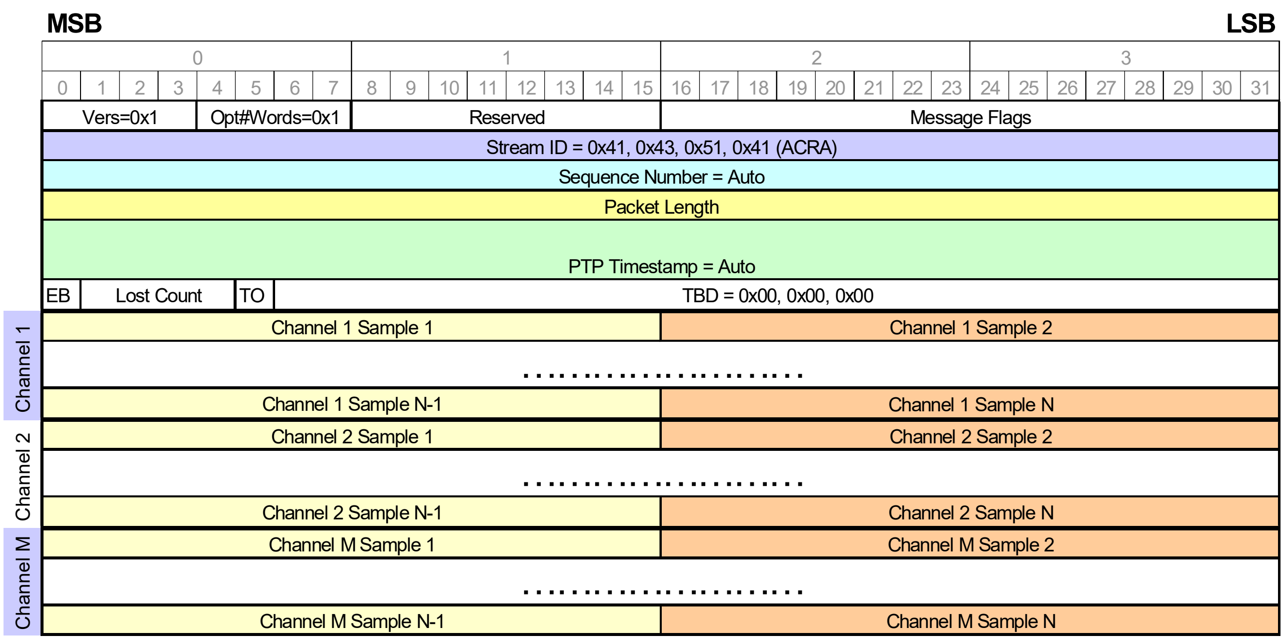


*Figure 40-4: Example of iNET-X payload packet format*

### 40.3.2.1 Example - iNET-X placed packet for analog data

Consider an analog module with four input analog channels. The analog parameters are sampled at the start of an even second and at even intervals of time thereafter. The analog data is packetized in a placed iNET-X analog packet and may contain data for one or more analog channels, where each channel may be sampled at equal or differing rates. Samples for each channel are placed contiguously in the analog packet.

Consider sampling four channel parameters at different rates (as shown in the following table) and packetized in a placed iNET-X packet called MyAnalogPacket.

Table 40-3: Analog module sampling configuration and packetization in MyAnalogPacket

| Parameter name | Rate (ksps) | Occurrences per packet | First channel-sample byte offset from start of Ethernet frame |
|---|---|---|---|
| MyChannel #1 | 2 | 100 | 68 |
| MyChannel #2 | 4 | 200 | 268 |
| MyChannel #3 | 1 | 50 | 668 |
| MyChannel #4 | 1 | 50 | 768 |

MyAnalogPacket contains a total of 400 samples per packet and packets are generated 20 times per second, as shown in the following figure.

The placed iNET-X packet, MyAnalogPacket, contains contiguously placed samples for each of the four channels. The first sample of the analog data is located at an offset of 68 bytes from the start of the Ethernet frame. The PTP timestamp in the iNET-X packet header relates to the sampling instant of the first (earliest) sample contained in the payload. The sampling instant of subsequent samples is calculated by adding the channel-sampling interval to the PTP timestamp. The format of the generated analog packets is stored in the XidML file.

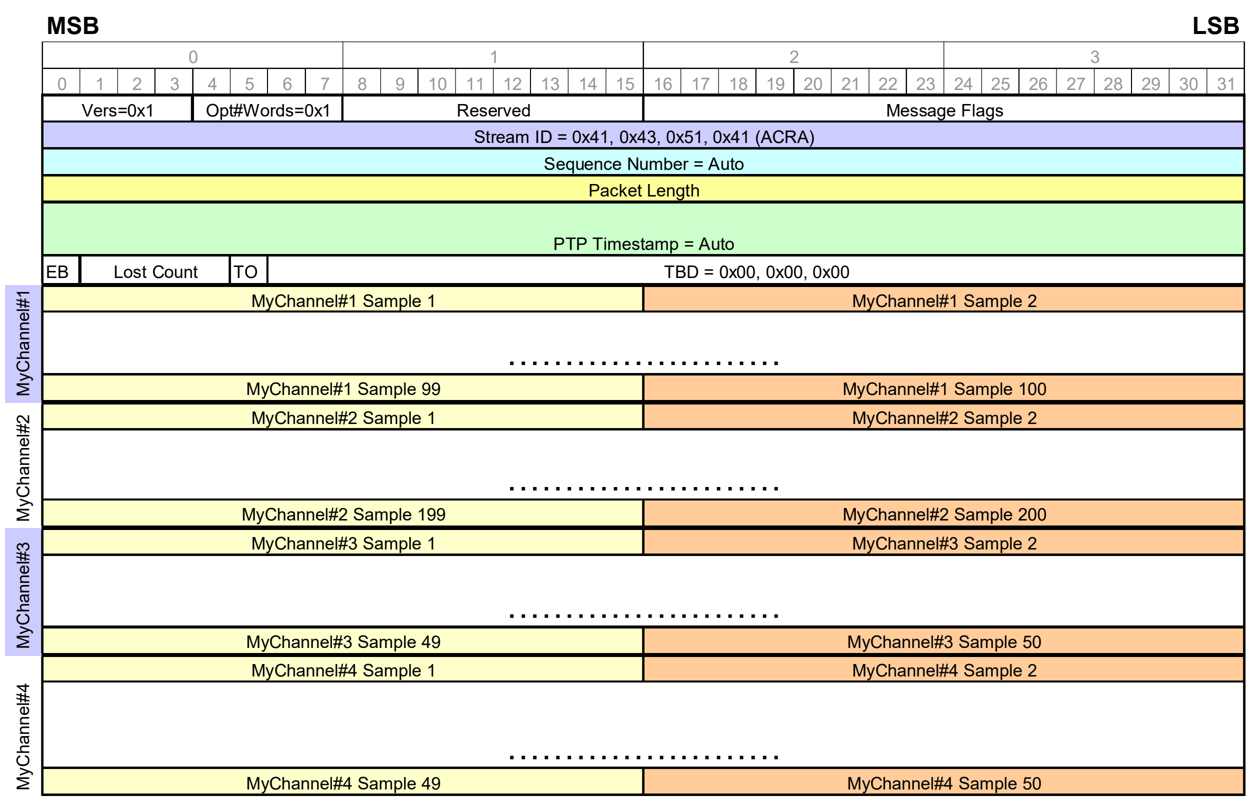


*Figure 40-5: 400 analog samples for four channels at different rates in a single iNET-X placed packet*

The analog packet transmission properties are described in the following table.

Table 40-4: MyAnalog packet transmission properties

| Transmission property | Value |
|---|---|
| Analog payload size (bytes) | 800 (400 samples x 2 bytes) |
| Total Ethernet frame length (bytes) | 874 MAC header 14 bytes + IP 20 bytes + UDP 8 bytes + iNET-X 28 bytes + analog data + MAC Frame Check Sequence (FCS) 4 bytes |
| Packet rate (packets per second) | 20 |
| Total number of parameter samples | 400 |
| Total bit-rate (kbps) | 139.8 |

### 40.3.3 iNET-X bit-aligned packet format

The iNET-X bit-aligned packet format is suited to bit-aligned data streams such as audio CVSD (as opposed to word-aligned or frame-aligned data types). Moreover, this raw packing structure can be applied to any data type stored in a FIFO. The PTP timestamp in the iNET-X packet header refers to the acquisition instant of the first bit placed in an empty FIFO.

#### 40.3.3.1 Example - iNET-X bit-aligned packet format for synchronous CVSD audio data

CVSD encodes voice audio at 1 bit per sample; audio sampled at 64kHz is encoded at 64kbps. The application payload format for CVSD audio data is the same as that used for PCM bit-stream data.

The CVSD packet transmission properties are described in the following table and indicate the packetization structure of 8,000 CVSD, 1-bit, audio samples in a single packet to maximize the storage efficiency. The structure of the iNET-X MyCVSD audio packet is shown in the following figure.

Table 40-5: MyCVSD audio packet transmission properties

| Transmission property | Value |
|---|---|
| CVSD packet payload size (bytes) | 1,000 (8,000 x 1-bit samples) |
| Total Ethernet frame length (bytes) | 1,074<br>MAC header 14 bytes + IP 20 bytes + UDP 8 bytes + iNET-X 28 bytes + CVSD audio bit-stream data + MAC FCS 4 bytes |
| Packet rate (packets per second) | 8 |
| Total number of bytes per packet | 1,000 |
| Total bit-rate (kbps) | 68.7 |

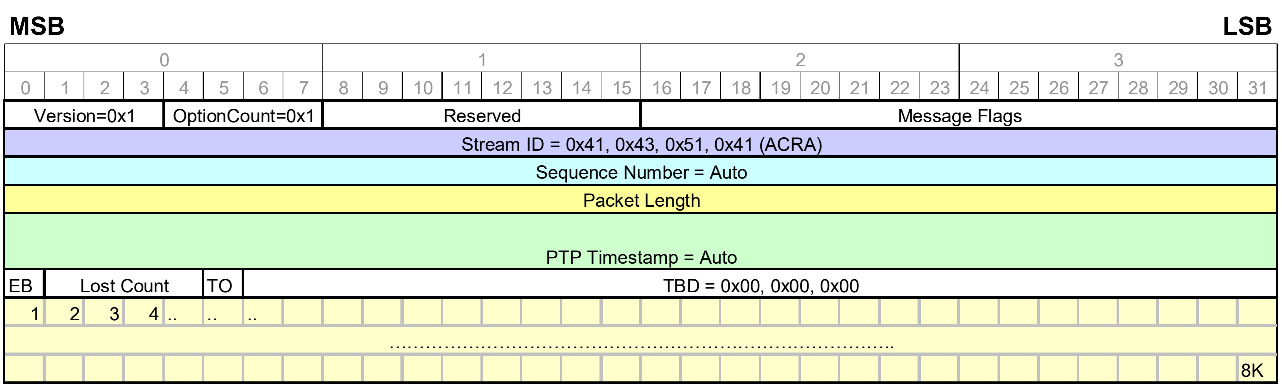


*Figure 40-6: MyCVSD bit-aligned iNET-X packet*

## 40.3.4 iNET-X block packet format

The iNET-X block packet format is suited to constant bit-rate data types such as MPEG-2 transport stream video data. An iNET-X block packet consists of an integral number of blocks of data, where each block consists of M words. For example, using MPEG-2 transport stream data, a maximum of seven transport stream chunks can be stored in the payload as shown in the following figure. The PTP timestamp in the iNET-X packet header refers to the acquisition instant of the first block of data in the payload.

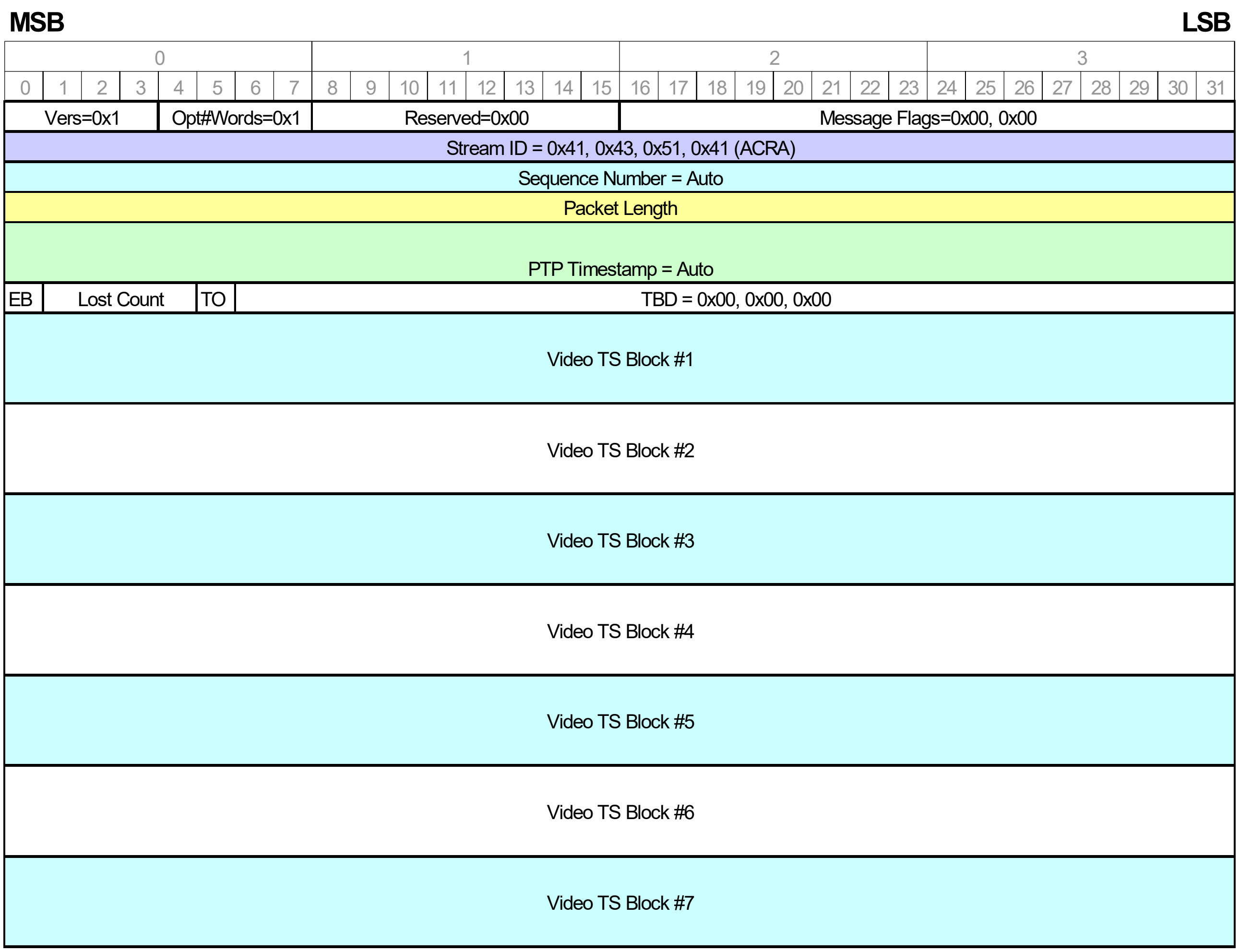


*Figure 40-7: iNET-X block packet structure*

### 40.3.4.1 Example - iNET-X block packet format for MPEG-2 transport stream video

Consider an MPEG-4 compression module that embeds the MPEG-4 video in an MPEG-2 transport stream. An MPEG-2 transport stream partitions the MPEG-4 video data into a continuous flow of transport stream chunks where each chunk is 188 bytes. iNET-X block video packets contain an integral number of MPEG-2 transport stream chunks.

If the target encoding bit-rate is 1Mbps, seven transport stream chunks can be stored in each Ethernet frame (7 x 188 bytes = 1,316 bytes of video data in the payload). To achieve a bit-rate of approximately 1Mbps, then 95 packets per second are required to capture the video data. However, to ensure no video data is lost in the event that the video bit-rate exceeds 1Mbps, the video packet storage/transmission rate is rounded up to 100 packets per second.

The video packet transmission properties are described in the following table. The video packet structure is shown in the following figure.

Table 40-6: MyVideo iNET-X block packet transmission properties

| Transmission property | Value |
|---|---|
| Video packet payload size (bytes) | 1,316 (7 x 188-byte transport stream chunks) |
| Total Ethernet frame length (bytes) | 1,390 (MAC header 14 bytes + IP 20 bytes + UDP 8 bytes + iNET-X 28 bytes + video data + MAC FCS 4 bytes) |
| Packet rate (packets per second) | 95, rounded up to 100 |
| Total number of transport stream chunks per packet | 7 |
| Total bit-rate (Mbps) | 1.1 |

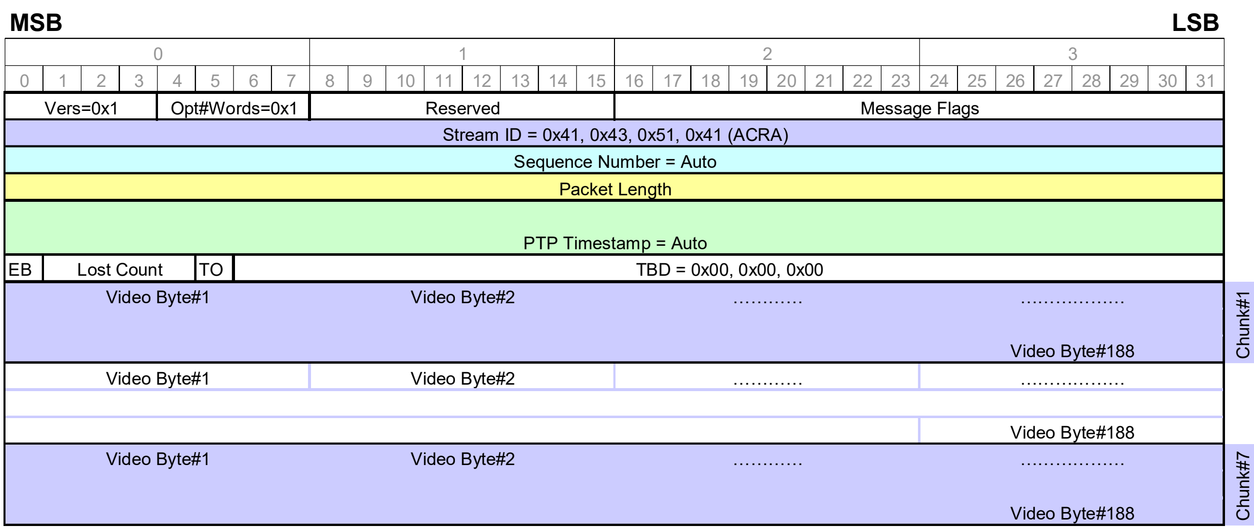


*Figure 40-8: MyVideo iNET-X block video packet*

## 40.3.5 iNET-X parser-aligned packet format

There is a diverse range of avionic bus technologies for which traffic may be captured, for example, MIL-STD-1553, PCM, or ARINC-429. The generalized iNET-X payload structure for parser-aligned packets is shown in the following figure.

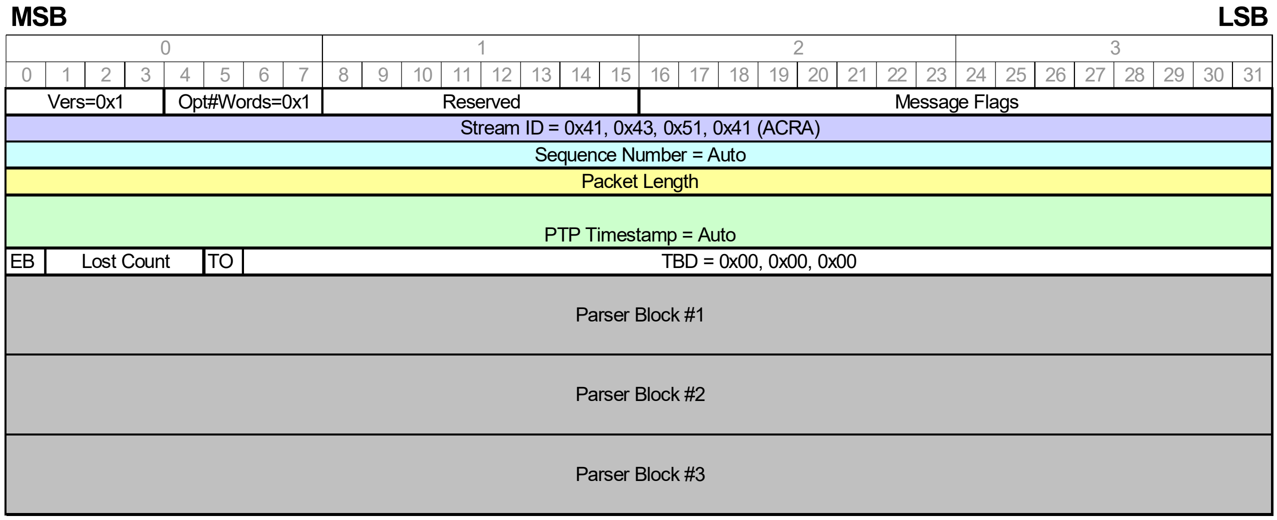


*Figure 40-9: Generalized parser-aligned iNET-X packet*

As messages are captured on the bus, they are formatted in a parser block. Each parser block begins with a 4-byte parser information word, followed by a 4-byte elapsed time tag and the message data shown in the following figure.

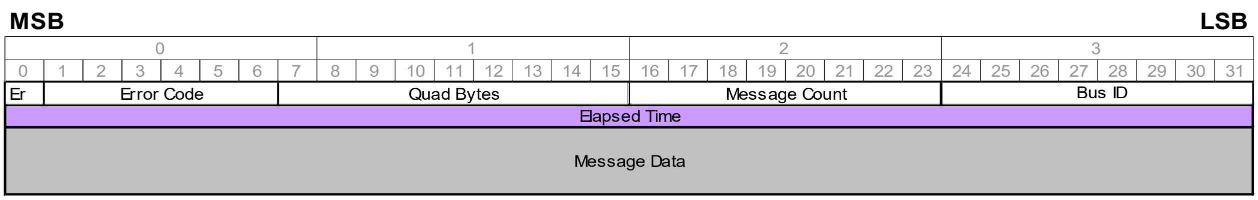


*Figure 40-10: iNET-X parser block*

A parser block consists of the following fields:

- Parser information word (4 bytes): metadata providing information about the health and status of the message.
  - Er (Bit 0): indicates that an error occurred.
  - Bits [1:6]: TBD.
  - Quad bytes (Bits [7:15]): number of quad bytes. This relates to the length of the parser information word, elapsed time tag, and the message data and padding (N x 4 bytes). For example, a 4-byte message captured from a given bus has a quad-byte value of 3, that is 12 bytes that includes 4 bytes parser information word, 4 bytes elapsed time, and 4 bytes bus message data.
  - Message count (Bits [16:23]): message counter. This is a message counter that relates to the messages contained in the payload. The message counter increments for each message contained in the packet payload and continues to increment across consecutive packets. The message counter resets and wraps around to 0 once it has reached the maximum message count of 0xFF.
  - Bus ID (Bits [24:31]): bus number.
- Elapsed time (4 bytes): time tag as an unsigned offset in nanoseconds that is added to the base PTP timestamp in the iNET-X header.
- Message data (N x 4 bytes): captured bus traffic, padded if necessary to end on 4-byte boundary.

## 40.3.5.1 Example iNET-X parser-aligned packet format for ARINC-429

Consider an eight-channel ARINC-429 bus monitor where traffic captured on each of the ARINC-429 busses is placed in an iNET-X parser-aligned packet (see the following figure) where each bus has its own unique Stream ID.

As the ARINC messages arrive they are tagged with a 4-byte parser information word and a 4-byte elapsed time word, followed by the 4-byte ARINC message. The parser information word identifies properties of the ARINC-429 message (such as the message counter and the ID of the bus on which the message was received) and marks the health of the message using an error bit and error code. The PTP timestamp in the iNET-X packet header is fixed when the packet is opened for writing and is used as the base timestamp for the whole packet. The PTP timestamp for each ARINC message in the packet can be calculated by adding the elapsed time to this base timestamp. Directly following the elapsed time field is the ARINC-429 message.

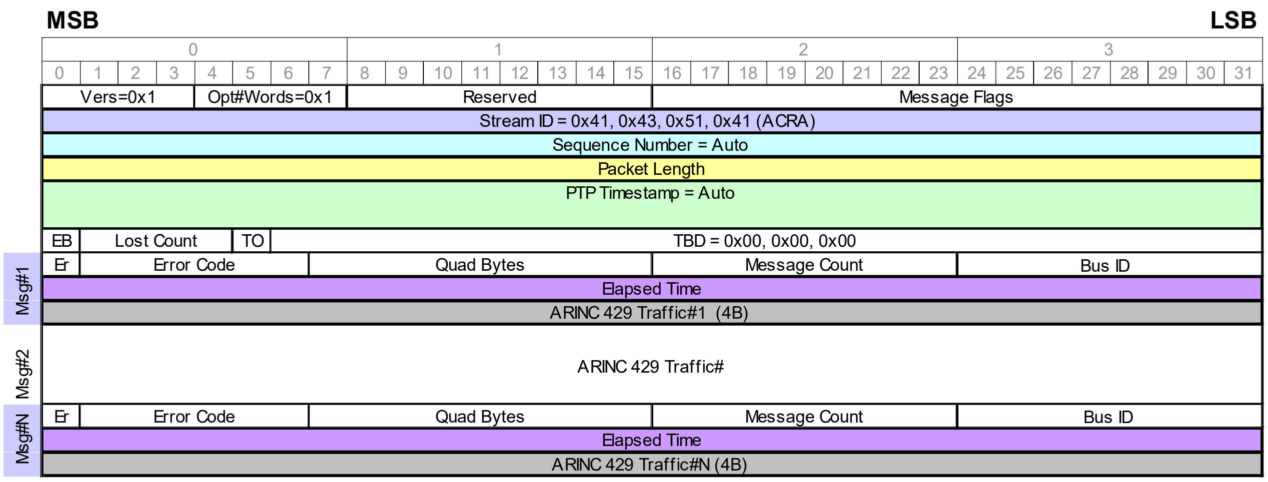


*Figure 40-11: ARINC-429 iNET-X parser-aligned packet*

For example, to facilitate real-time processing, the minimum payload size of an ARINC-429 packet is given as 1,008 bytes for a given default high-speed bus bit-rate of 100kbps, allowing for 84 ARINC 12-byte blocks to be carried in a single packet. This results in a maximum packet rate of 34 packets per second since the traffic on the bus may be asynchronous. The transmission properties for a 100kbps ARINC bus are summarized in the following table.

Table 40-7: MyARINC packet transmission properties

| Transmission property | Value |
|---|---|
| ARINC-429 packet payload size (bytes) | 1,008 bytes (84 ARINC message blocks of 12 bytes per ARINC block) |
| Total Ethernet frame length (bytes) | 1,082 bytes (MAC header 14 bytes + IP 20 bytes + UDP 8 bytes + iNET-X 28 bytes + ARINC-429 data + MAC FCS 4 bytes) |
| Packet rate (packets per second) | 34[1] |
| Total number of ARINC messages per packet | 84 ARINC blocks |
| Total bit-rate (kbps) | 294.3 |

1. 84 ARINC-429 messages per packet × (32 data bits + 4 inter message gap bits) = 3024 ARINC-429 bits on the bus to fill one packet
100kbps bus speed / 3024 bits on the bus per full Ethernet packet = 33.06 (rounded to 34) packets per second

## 40.3.6 iNET-X parser-aligned packet structure for MIL-STD-1553 bus monitoring

As MIL-STD-1553 messages arrive, the MIL-STD-1553 protocol tracker logic identifies them and maps them to corresponding transaction identifier codes, as in the following table.

Table 40-8: Transaction identifier codes

| Message type | Mnemonic | Transaction ID |
|---|---|---|
| Bus Controller to Remote Terminal | BC → RT | 0x00 |
| Remote Terminal to Bus Controller | RT → BC | 0x01 |
| Remote Terminal to Remote Terminal | RT → RT | 0x02 |
| Mode Code without Data | M → S | 0x03 |
| Mode Code with Data (R) | MD → S | 0x04 |
| Mode Code with Data (T) | M → SD | 0x05 |
| **Broadcast** | | |
| Bus Controller to Remote Terminals | BC → RTS | 0x06 |
| Remote Terminal to Remote Terminals | RT → RTS | 0x07 |
| Mode Code without Data | M | 0x08 |
| Mode Code with Data (R) | MD | 0x09 |
| **Messages without Status reply** | | |
| Bus Controller to Remote Terminal | BC → RT | 0x10 |
| Remote Terminal to Bus Controller | RT → BC | 0x11 |
| Remote Terminal to Remote Terminal | RT → RT | 0x12 |
| Mode Code without Data | M → S | 0x13 |
| Mode Code with Data (R) | MD → S | 0x14 |
| Mode Code with Data (T) | M → SD | 0x15 |
| Remote Terminal to Remote Terminal | RT → RTS | 0x17 |

Only valid MIL-STD-1553 transactions are stored in the packet (see the following figure). If an error occurs, only the parser information word and elapsed time tag are written to the iNET-X packet; the message is then dumped. The error bit and error code (see Table 40-10 on page 319), which are set in the parser information word, indicate the cause of the error.

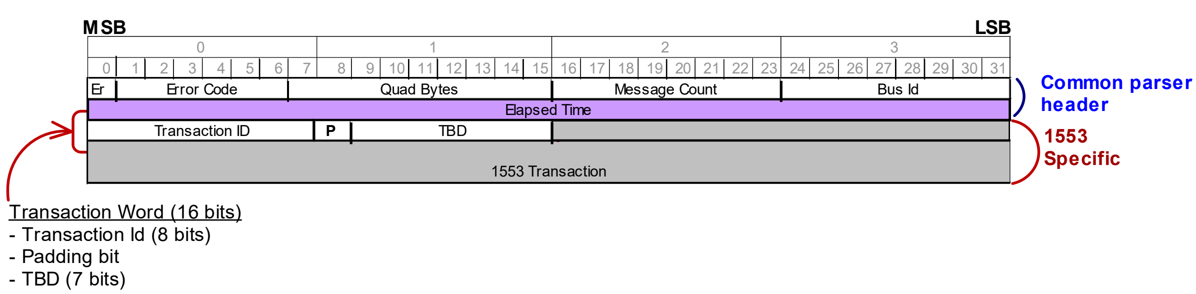


*Figure 40-12: MIL-STD-1553 transaction iNET-X parser-aligned packet*

In the case where a remote terminal is off-line but it is still desirable to capture data sent to it, you can set options to include Accept Rx Message With No Status and Accept Tx Message With No Status. In such a scenario, the parser information word indicates an error but the 1553 traffic is still captured.

The transaction identifier may be used to indicate when response times are carried in the iNET-X parser-aligned block. The MIL-STD-1553 standard specifies a minimum response time of 4µs and a maximum response time of 12µs. However, the bus controller waits up to 20µs before determining a timeout has occurred. The granularity of response time on the 8MHz bus can be measured to a resolution of 125ns. When a timeout occurs, the response time is set to 0xFF.

In order to facilitate the decoding and decommutation of the MIL-STD-1553 parser-aligned iNET-X packets, the first word of a MIL-STD-1553 transaction is the transaction word where:

- Transaction word (2 bytes): metadata providing protocol tracking information, health, and status of the message.
  - Transaction ID (Bits [0:7]): see Table 40-8 on page 317
  - P (Bit 8): bit to indicate if the parser message has been padded to fall on a 4-byte boundary
  - TBD (Bits [9:15]): TBD

Where a MIL-STD-1553 transaction does not fall on a 32-bit boundary, the MIL-STD-1553 parser-aligned message is padded. In MIL-STD-1553 the maximum number of padding words (16-bit) possible in a single transaction is one. Therefore a single bit is sufficient to indicate if a transaction message has been padded. The following two figures illustrate individual MIL-STD-1553 BC ⟶ RT transactions, with and without padding.

<table>
<tr><td colspan="16">MSB</td><td colspan="16" align="right">LSB</td></tr>
<tr><td colspan="8">0</td><td colspan="8">1</td><td colspan="8">2</td><td colspan="8">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td></tr>
<tr><td>Er</td><td colspan="6">Error Code</td><td colspan="9">Quad Bytes=6</td><td colspan="8">Message Count</td><td colspan="8">Bus ID</td></tr>
<tr><td colspan="32">Elapsed Time</td></tr>
<tr><td colspan="8">Transaction ID: RT->BC</td><td>P=0</td><td colspan="7">TBD</td><td colspan="16">Cmd=TX</td></tr>
<tr><td colspan="16">Response</td><td colspan="16">Status</td></tr>
<tr><td colspan="16">Data#1</td><td colspan="16">Data#2</td></tr>
<tr><td colspan="16">Data#3</td><td colspan="16">Data#4</td></tr>
</table>

*Figure 40-13: MIL-STD-1553 transaction iNET-X parser-aligned message without padding*

<table>
<tr><td colspan="16">MSB</td><td colspan="16" align="right">LSB</td></tr>
<tr><td colspan="8">0</td><td colspan="8">1</td><td colspan="8">2</td><td colspan="8">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td></tr>
<tr><td>Er</td><td colspan="6">Error Code</td><td colspan="9">Quad Bytes=7</td><td colspan="8">Message Count</td><td colspan="8">Bus ID</td></tr>
<tr><td colspan="32">Elapsed Time</td></tr>
<tr><td colspan="8">Transaction ID: BC->RT</td><td>P=1</td><td colspan="7">TBD</td><td colspan="16">Cmd=RX</td></tr>
<tr><td colspan="16">Data#1</td><td colspan="16">Data#2</td></tr>
<tr><td colspan="16">Data#3</td><td colspan="16">Data#4</td></tr>
<tr><td colspan="16">Data#5</td><td colspan="16">Response</td></tr>
<tr><td colspan="16">Status</td><td colspan="16">Padding</td></tr>
</table>

*Figure 40-14: MIL-STD-1553 transaction iNET-X parser-aligned message with padding*

The following figure demonstrates the iNET-X parser-aligned payload structure for MIL-STD-1553 with the following three parsed MIL-STD-1553 transactions in the payload:

- BC ⟶ RT: With four data words transferred.
- RT ⟶ RT: With five data words transferred.
- RT ⟶ BC: With four data words transferred.

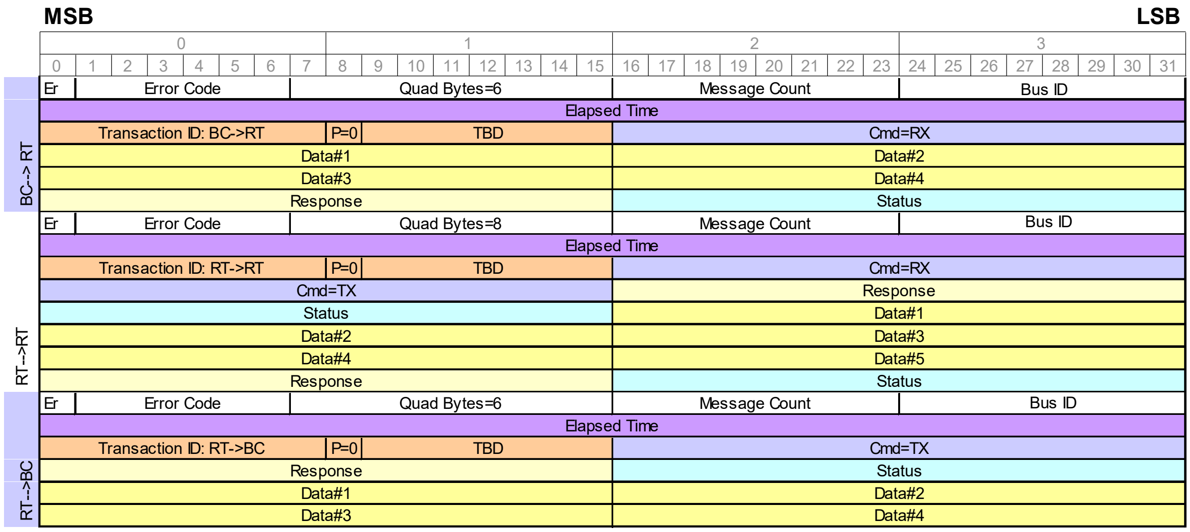


*Figure 40-15: iNET-X parser-aligned payload for multiple MIL-STD-1553 transactions*

For example, the MIL-STD-1553 bus has a peak bit-rate of 1Mbps. However, the messages and transactions transmitted are variable in length and asynchronous. If it is assumed that the mean MIL-STD-1553 transaction is 14 bytes long (comprising of a command, response, data words, and a status word), the iNET-X parser block structure encapsulating this transaction is therefore 24 bytes (including the MIL-STD-1553 transaction ID, parser information word and the elapsed time). In this case, each iNET-X parser-aligned packet may contain up to 60 parser blocks in the payload (that is, 60 parser blocks x 24 bytes per block which results in 1440 bytes of payload, or 840 bytes of MIL-STD-1553 bus data). To ensure that no data is lost on the bus, packets are generated at a rate of 150 packets per second.

The transmission properties for a 1Mbps MIL-STD-1553 bus are summarized in the following table.

Table 40-9: MyMIL-STD-1553 packet transmission properties

| Transmission property | Value |
|---|---|
| MIL-STD-1553 packet payload size (bytes) | 1440 bytes (60 MIL-STD-1553 parser blocks of 24 bytes per block where each block contains 14 bytes of MIL-STD-1553 bus data) |
| Total Ethernet frame length (bytes) | 1514 bytes MAC header 14 bytes + IP 20 bytes + UDP 8 bytes + iNET-X 28 bytes + MIL-STD-1553 data + MAC FCS 4 bytes |
| Packet rate (packets per second) | 150 |
| Total number of MIL-STD-1553 transactions per packet | 60 transactions assuming 14 bytes per transaction |
| Total bit-rate (kbps) | 1816.8 |

Table 40-10: Error codes

| Error code | Description | Error code | Description |
|---|---|---|---|
| $0_{16}$ | Reserved for future use. | $20_{16}$ | Expected STS was a data word. |
| 116 | Data word did not have enough bits. | $21_{16}$ | Expected STS was invalid. |
| $2_{16}$ | Data word had bit error. | $22_{16}$ | Expected STS had incorrect RT. |
| $3_{16}$ | Data word had parity error. | $23_{16}$ | Expected STS had contiguous traffic. |
| $4_{16}$ | Non-data word did not have enough bits. | $24_{16}$ | Expected STS timed out. |
| $5_{16}$ | Non-data word had bit error. | $25_{16}$ | Expected STS had no contiguous data word. |

Table 40-10: Error codes (continued)

| Error code | Description | Error code | Description |
|---|---|---|---|
| $6_{16}$ | Non-data word had parity error. | $26_{16}$ | Reserved for future use. |
| $7_{16}$ | Reserved for future use. | $27_{16}$ | Reserved for future use. |
| $8_{16}$ | Expected data word was non-data word. | $28_{16}$ | Reserved for future use. |
| $9_{16}$ | Expected data word did not have contiguous word. | $29_{16}$ | Reserved for future use. |
| $A_{16}$ | Expected last data word was not last. | $2A_{16}$ | Reserved for future use. |
| $B_{16}$ | Expected mode data word was non-data word. | $2B_{16}$ | Expected Tx CMD of RT to RT(s) had different number of words than Rx CMD. |
| $C_{16}$ | Expected mode data word has contiguous traffic. | $2C_{16}$ | Expected Tx CMD of RT to RT(s) had same RT as Rx CMD. |
| $D_{16}$ | Reserved for future use. | $2D_{16}$ | Expected Tx CMD of RT to RT(s) had contiguous traffic. |
| $E_{16}$ | Reserved for future use. | $2E_{16}$ | Second CMD in RT-RT was not a TX. |
| $F_{16}$ | Reserved for future use. | $2F_{16}$ | Reserved for future use. |
| $10_{16}$ | Expected first CMD was a data word. | $30_{16}$ | Reserved for future use. |
| $11_{16}$ | Reserved for future use. | $31_{16}$ | Reserved for future use. |
| $12_{16}$ | Reserved for future use. | $32_{16}$ | Reserved for future use. |
| $13_{16}$ | Reserved for future use. | $33_{16}$ | Reserved for future use. |
| $14_{16}$ | Reserved for future use. | $34_{16}$ | Reserved for future use. |
| $15_{16}$ | Expected first CMD had contiguous traffic. | $35_{16}$ | Reserved for future use. |
| $16_{16}$ | Expected first CMD was Rx with no contiguous data word. | $36_{16}$ | Reserved for future use. |
| $17_{16}$ | Expected first CMD was Mode with no contiguous data. | $37_{16}$ | Reserved for future use. |
| $18_{16}$ | Expected second STS of RT to RT was data word. | $38_{16}$ | Reserved for future use. |
| $19_{16}$ | Expected second STS of RT to RT had incorrect RT. | $39_{16}$ | Reserved for future use. |
| $1A_{16}$ | Expected second STS of RT to RT had contiguous traffic. | $3A_{16}$ | Reserved for future use. |
| $1B_{16}$ | Expected second STS of RT to RT timed out. | $3B_{16}$ | Reserved for future use. |
| $1C_{16}$ | Reserved for future use. | $3C_{16}$ | Reserved for future use. |
| $1D_{16}$ | Reserved for future use. | $3D_{16}$ | Reserved for future use. |
| $1E_{16}$ | Reserved for future use. | $3E_{16}$ | Reserved for future use. |
| $1F_{16}$ | Reserved for future use. | $3F_{16}$ | Reset occurred since last read. |

Tx = transmit; STS = status; CMD = command.

## 40.3.7 iNET-X Event packets

The format and structure of an Event packet is shown in the following figure. The recorded errors and events are listed in Table 40-12 on page 325 in the Appendix.

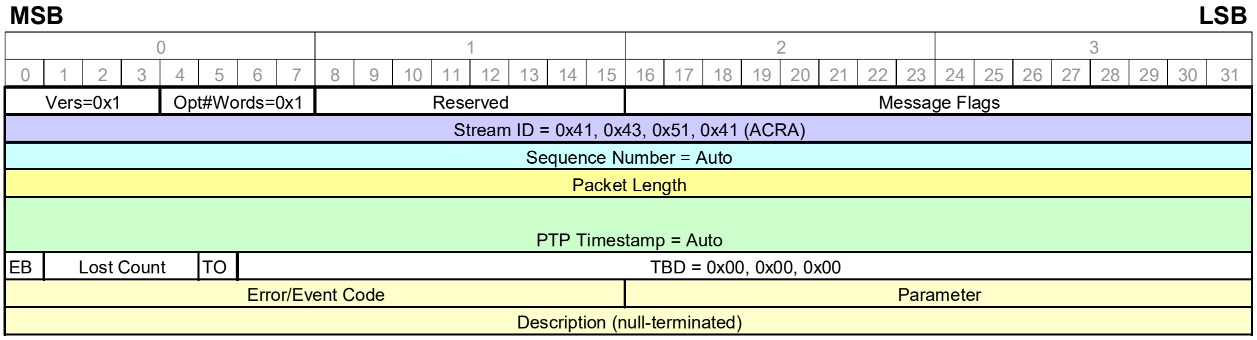


*Figure 40-16: iNET-X Event packet*

# 40.4 IENA packetization

IENA is the application layer protocol developed by Airbus that defines the packet header and packetization rules for the transmission of acquired data as UDP/IP packets. Similar to iNET-X, IENA partitions logical groupings of data into packet streams, each uniquely identified by an IENA Key. The IENA standard defines the application layer IENA header, shown in the following figure, and payload structures.

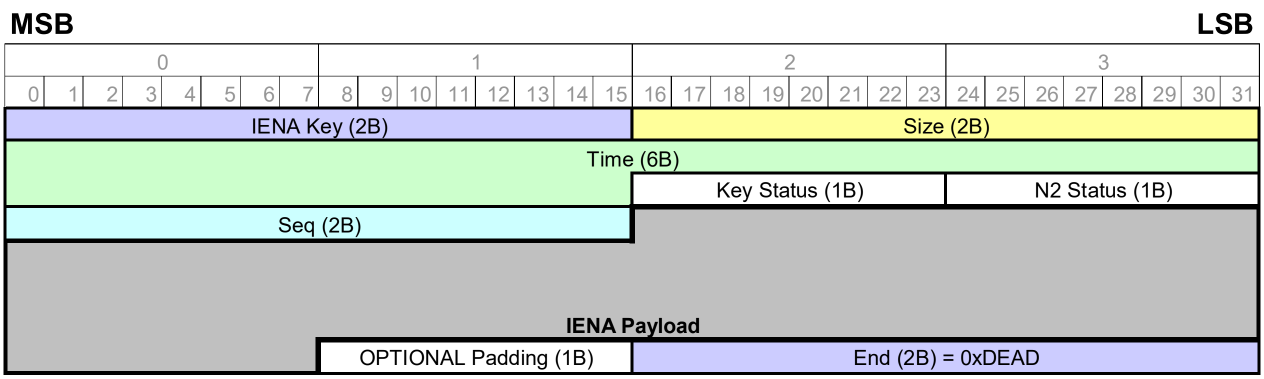


*Figure 40-17: IENA packet header*

The IENA packet header contains the following elements:

- IENA Key (16 bits): Points to a unique (system wide) metadata package description in the XidML. The package description describes the format, structure, and data contained in the IENA packet payload.
- Size (16 bits): The length of the complete IENA packet in 16-bit words including the IENA header, the payload, padding, and the IENA Trailer field. Padding is used when the length of the IENA packet does not fall on a 16-bit boundary. The valid range for the Size field is therefore 8 to 32753, which is the maximum possible payload size.
- Time (48 bits): The time of the current year in microseconds since the 1st January.
- Key Status (8 bits): This field is reserved for future use.
- N2 Status (8 bits): This field is specific to Airbus equipment and is not used. This fields has a default value of 0x00.
- Sequence Number (16 bits): Increments by one for each packet generated and transmitted with a given IENA Key and wraps around back to 0. The valid sequence number range is 0 to 65535.
- Padding (8 bits): The IENA standard specifies that packets must be 16-bit word aligned, therefore to achieve alignment it may be necessary to pad the IENA payload to fall on a 16-bit boundary.
- Trailer End field (16 bits): This is specified as being a unique value for all keys where the default value is 0xDEAD.

## 40.4.1 IENA payload formats

The IENA standard defines three main payload structures. These are called:

- Positional - This payload structure is analogous to the iNET-X placed payload structure in that parameters and samples are placed within the payload.
- Standard - This is similar to the Positional type however samples for a given parameter are placed contiguously in the payload and a 2-byte Parameter Identifier describes each contiguous block of samples.
- Message - This payload structure is designed for asynchronous variable length data sets where each message has an associated Message Identifier and timestamp.

Curtiss-Wright products only support the positional type of IENA payload structure. Other IENA payload structures are not described in this technical note.

## 40.4.2 IENA

An IENA packet contains a standard IENA layer header and footer. Between these, the data field contains one or more parameters of a specified type. For the KAD/ABM/103 each ARINC-429 message can be formatted as either a D Type or N Type IENA parameter. In both cases, the 16-bit parameter ID for each parameter is composed by combining the bus ID (for channels 0 to 23) with the label and SDI fields from the received message. As shown in the following figure, these fields appear in the message from MSB to LSB in the order SDI[1:0], bus ID[4:0], and label[7:0]. The MSB is always equal to 0.

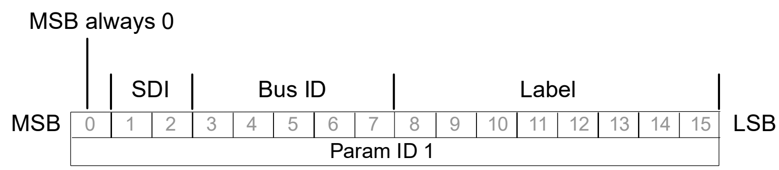


*Figure 40-18: Parameter ID from received message*

As shown in the following figure, D Type parameters consist of a 16-bit parameter ID, a 16-bit delay field, and the 32-bit ARINC-429 message. The delay field indicates the difference in microseconds between the timestamp in the IENA packet's header and the received timestamp for the specific message contained in the parameter. ARINC-429 messages use 8 bytes per N Type parameter.

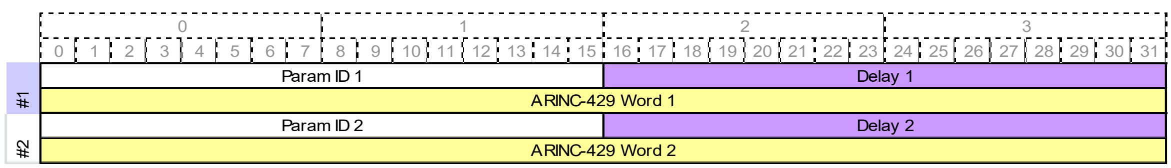


*Figure 40-19: D Type IENA parameter for ARINC-429*

As shown in the following figure, N Type parameters include the 16-bit parameter ID and the 32-bit message, but the delay field is omitted and the only timestamp is that of the packet, which relates to the first packetizer message. ARINC-429 messages use 6 bytes per N Type parameter.

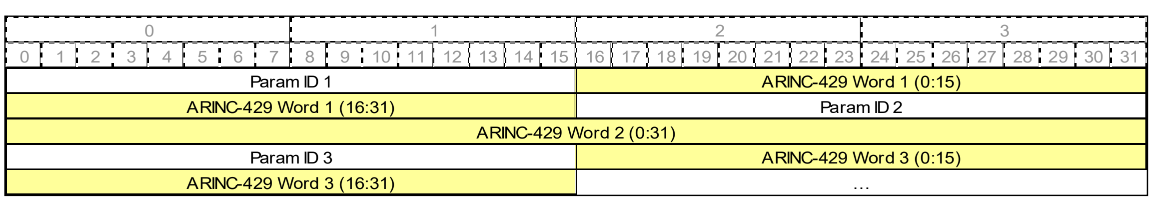


*Figure 40-20: N Type IENA parameter for ARINC-429*

### 40.4.2.1 IENA positional payload formats

Only the Positional type payload structure is supported, the following subsections provide applied examples of the positional payload structure for use with packetizer and placed parameter payloads. There are a number of rules that govern the placement of parameters within the positional payload structure:

- Length of the parameters: All parameters within the payload are an even number N bytes long where 2 ≤ N ≤ 14.

- All parameters must have the same length.
- The length of the parameters can be determined from the IENA Key status field (that is, N/2)
• Number of parameters in the pattern: The positional payload interleaves parameter samples in a block pattern. The first block pattern contains the first sample for all parameters in the payload, the second block pattern contains the second sample for all parameters, and so on.
• The metadata file: This describes the name of the parameter and the location of each parameter in the pattern. Subsequent sample locations can be inferred knowing the sampling rate and the number of samples for a given parameter in the payload.

The following figure illustrates the interleaved sample placement in block patterns where each parameter is 16 bits wide, that is, N = 2.

| Block Pattern #1 | | | | Block Pattern #2 | | | | Block Pattern …. | | | | Block Pattern #x | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | B1 | C1 | D1 | A2 | B2 | C2 | D2 | A.. | B.. | C.. | D.. | Ax | Bx | Cx | Dx |

*Figure 40-21: IENA positional payload format*

The previous figure illustrates the positional payload structure where each parameter is 2 bytes long, each block pattern contains a single sample for four parameters, and there are X number of these block patterns repeated in the payload. The XidML file is used to specify the location of the parameters in the block.

### 40.4.2.2 IENA positional packet format for analog

Although IENA positional types specify interleaved placement rules for the parameters, this restriction is not enforced. The following figure illustrates the interleaved placement of the parameter samples while Figure 40-23 on page 324 illustrates the payload structure for contiguously placed parameter samples.

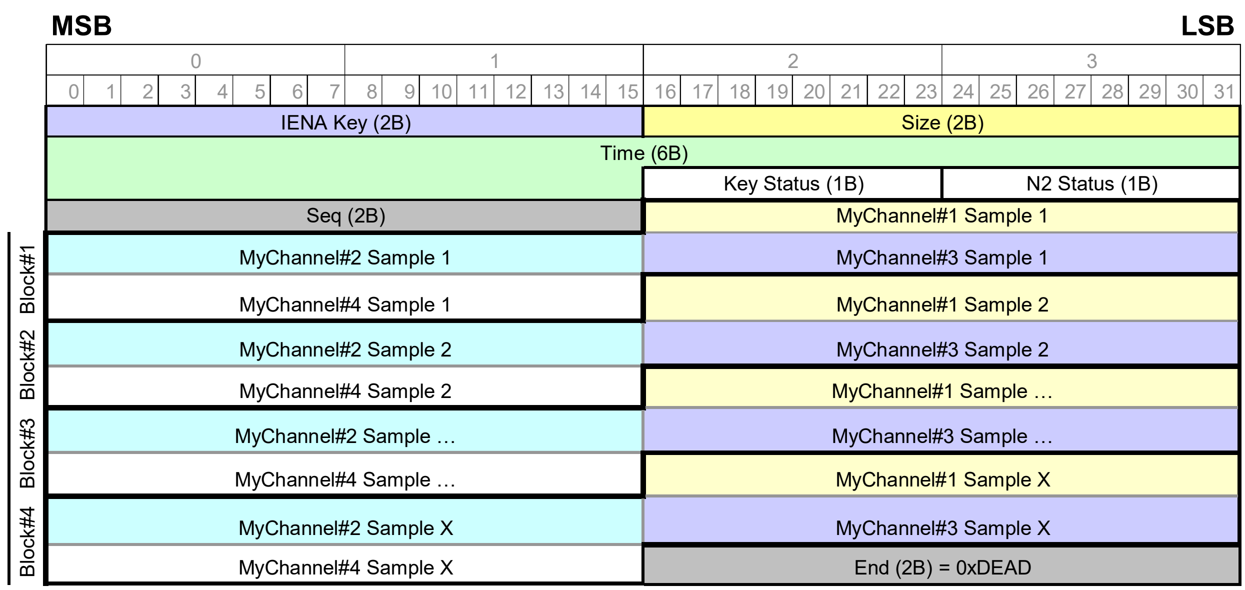


*Figure 40-22: IENA interleaved positional placed packet structure*

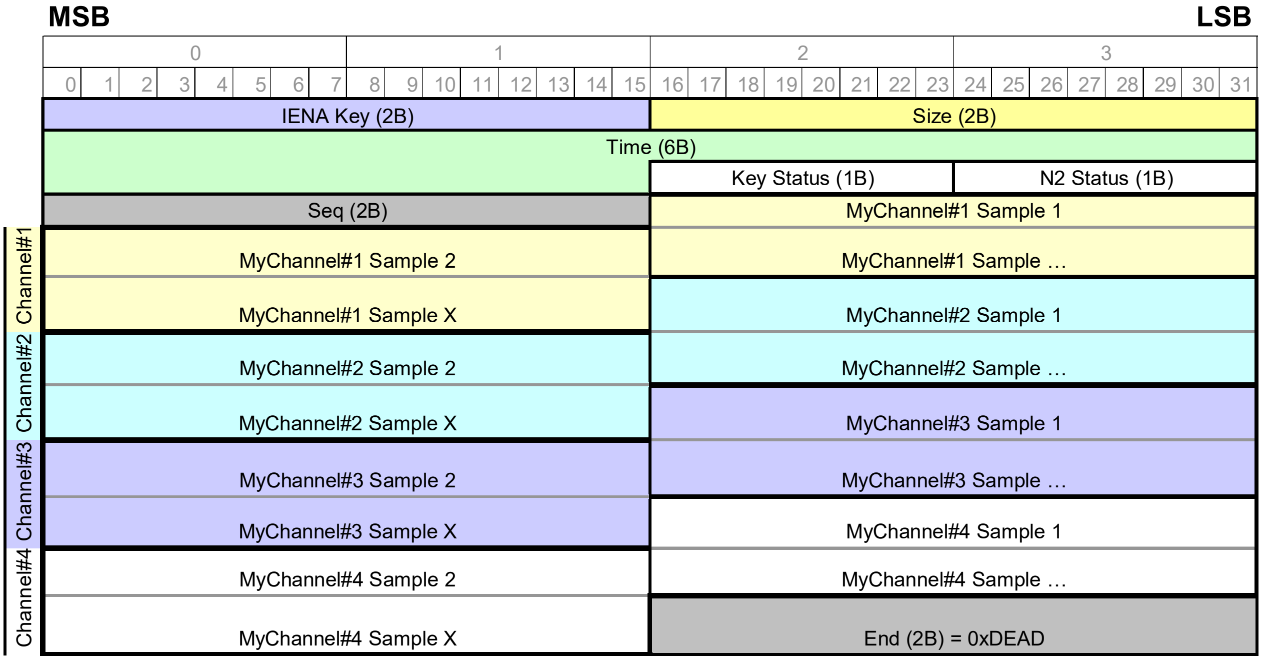


*Figure 40-23: IENA contiguous positional placed packet structure*

## 40.5 Appendix

Table 40-11: Parser-aligned MIL-STD-1553 Transaction Identifier codes

| Message with Status (S) reply | Mnemonic | Transaction ID |
|---|---|---|
| Bus Controller to Remote Terminal | BC ⟶ RT | 0x00 |
| Remote Terminal to Bus Controller | RT ⟶ BC | 0x01 |
| Remote Terminal to Remote Terminal | RT ⟶ RT | 0x02 |
| Mode code without data | M ⟶ S | 0x03 |
| Mode code with Data (receive) | MD ⟶ S | 0x04 |
| Mode code with Data (transmit) | M ⟶ SD | 0x05 |
| **Broadcast messages** | **Mnemonic** | **Transaction ID** |
| Bus Controller to Remote Terminals | BC ⟶ RTs | 0x06 |
| Remote Terminal to Remote Terminals | RT ⟶ RTs | 0x07 |
| Mode code without data | M | 0x08 |
| Mode code with Data (receive) | MD | 0x09 |
| **Messages without Status (S) reply** | **Mnemonic** | **Transaction ID** |
| Bus Controller to Remote Terminal | BC ⟶ RT | 0x10 |
| Remote Terminal to Bus Controller | RT ⟶ BC | 0x11 |
| Remote Terminal to Remote Terminal | RT ⟶ RT | 0x12 |
| Mode code without data | M ⟶ S | 0x13 |
| Mode code with Data (receive) | MD ⟶ S | 0x14 |
| Mode code with Data (transmit) | M ⟶ SD | 0x15 |

Table 40-12: Event and error codes

| | Name | Error/Event code | Parameter | Description Zero terminated ANSI text |
|---|---|---|---|---|
| **Event** | Event Pressed | 0x100 | Event number | EVENT PRESSED |
| | Event Start | 0x101 | Event number | EVENT START |
| | Event Released | 0x102 | Event number | EVENT RELEASED |
| | Start | 0x103 | Event number | START |
| | Stop | 0x104 | Event number | STOP |

Table 40-12: Event and error codes (continued)

| | Name | Error/Event code | Parameter | Description Zero terminated ANSI text |
|---|---|---|---|---|
| **Remote Event** | Remote Event Pressed | 0x200 | Event number | REMOTE EVENT PRESSED |
| | Remote Event Start | 0x201 | Event number | REMOTE EVENT START |
| | Remote Event Released | 0x202 | Event number | REMOTE EVENT RELEASED |
| | Remote Start | 0x203 | Event number | REMOTE EVENT START |
| | Remote Stop | 0x204 | Event number | REMOTE EVENT STOP |
| **Error** | Packet Dropped | 0x800 | Number of packets dropped | PACKET(S) DROPPED |
| | PTP Grandmaster Lost | 0x900 | Event number | GRANDMASTER LOST |
| | PTP Time Reliable | 0x901 | Event number | TIME RELIABLE |
| | PTP Clock Jumped | 0x902 | Event number | CLOCK JUMPED |
| | PTP Time Unreliable | 0x903 | Event number | TIME UNRELIABLE |

## 40.6 Recommended reading

To better understand this paper, read the documents listed in the following two tables.

Table 40-13: Data sheets

| Document | Description |
|---|---|
| KAD/ADC/126 | Accelerometer ADC (current excitation, programmable analog gain, 25kHz b/w) - 4ch at 100ksps. Explains the electrical interface, possible sampling rates and configuration. |
| SSR/CHS/001 | Ethernet multi-role recorder (CompactFlash®, voice connector) - 4 user-slots. Explains the STOP/START switch, LCD display and power consumption. |
| KAD/MBM/101 | Dual redundant MIL-STD-1553 bus packetizer Explains the electrical interface, possible sampling rates and configuration. |
| KAD/VID/106 | H.264 video encoder (analog video input) - 1ch Explains the electrical interface, possible sampling rates and configuration. |
| DAS Studio 3 | Explains the graphical user interface to set up the SSR/CHS/00X. |

Table 40-14: Technical notes

| Document | Description |
|---|---|
| *TEC/NOT/051 - Ethernet frames, Wireshark® and FAT32* | Explains the rationale for large Ethernet frames that are close to but not exceeding 1500 bytes. Describes the FAT32 file system on the CompactFlash card. |

**NOTE:** For more information on XidML, go to http://www.xidml.org.

Chapter 41

# Network MCS in KSM-500

TEC/NOT/068

This document describes MCS (Multi-Chassis Scheduler) over Ethernet in KSM-500 where PCM is used for real-time telemetry in an Ethernet system.

This technical note discusses the following topics:



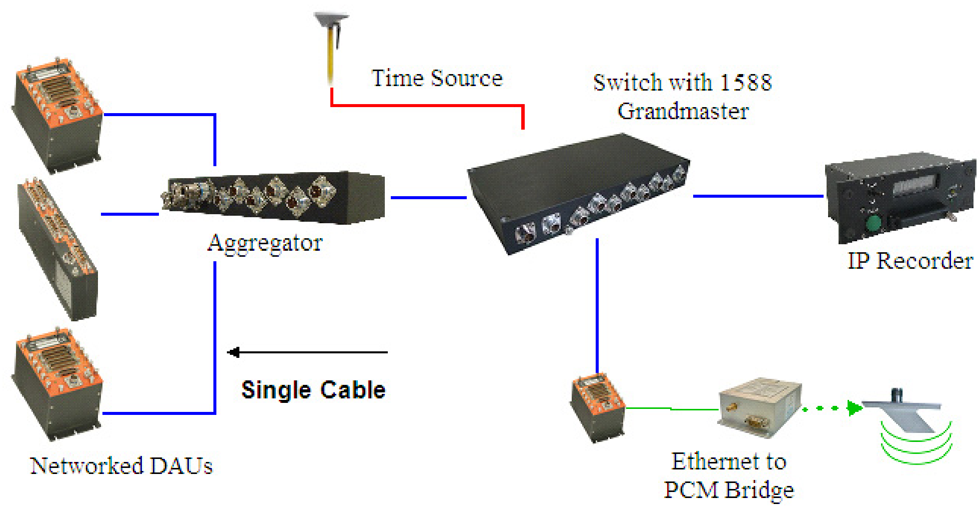


*Figure 41-1: Networked FTI system*

## 41.1 KSM-500 for network configurations

The MCS is a system scheduler that enables you to transparently create parameters to an Ethernet parsing DAU module from any available DAU in a networked system.

The following figure illustrates a kSetup example that has two Ethernet based DAUs, DAU1 and DAU2, with KAD/BCU/140s connected to a switch (not represented in the GUI) and one DAU which is used as the Ethernet to PCM bridge, ETH2PCM_BRIDGE.

The Ethernet to PCM bridge DAU must contain:

- An Ethernet bus monitor (KAD/EBM/102 in the following figure), which is used to capture packets from an aggregator port of the switch.
- A PCM encoder (KAD/ENC/106 in the following figure), which is used to create a PCM frame in which parameters from any DAU, parsed by the Ethernet bus monitor, can be transmitted.

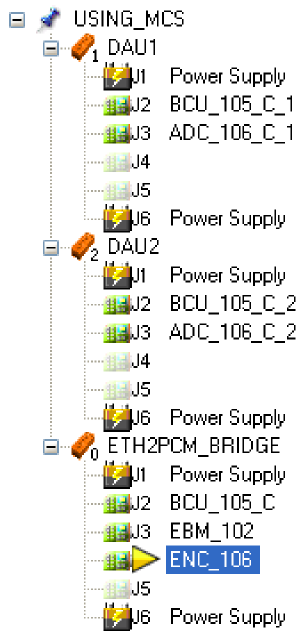


*Figure 41-2: Example of a network data acquisition system in kSetup*

Ethernet packets can still be created and transmitted from each stand-alone DAU but if there is no Ethernet bus monitor in that DAU then these packets can only contain parameters from the transmitting DAU, as there is no link to other DAUs. Usually these packets are sent to an IP recorder, such as a NET/REC/001, a real time monitoring PC or any device connected to the aggregator port of the switch.

The Ethernet to PCM bridge DAU allows you to transmit parameters from any existing DAU present in the network system over the PCM transmitter.

For the PCM transmission of any parameter in the network, the Frame Builder on the PCM encoder setup (KAD/ENC/106 in the previous figure) can be used. The MCS takes into account the parameters from other chassis that are available to the PCM encoder through the MCS, and allows them to be placed in the encoder's PCM frame.

Frame Builder displays all the parameters available in the system as illustrated in the following figure.

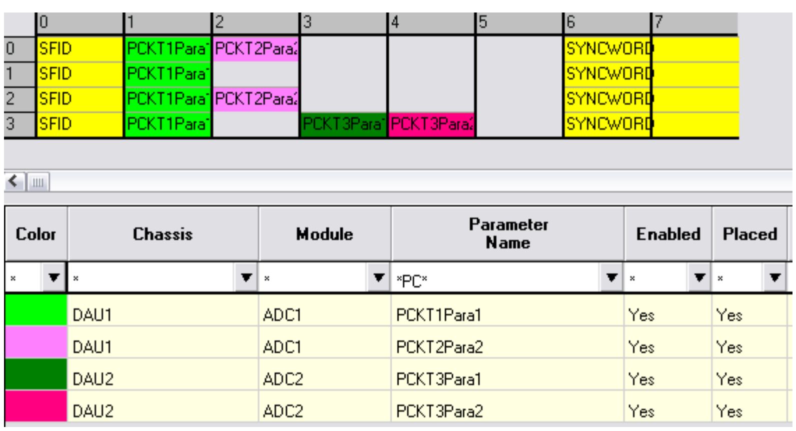


*Figure 41-3: Example of Frame Builder displaying all the parameters in the different chassis*

When Verify or Program are selected, the MCS transparently creates inter-chassis Ethernet packets containing the desired parameters from other DAUs. These inter-chassis packets are then parsed by the Ethernet bus monitor which renders all the parameters available for transmission over a PCM frame.

## 41.2 Module support

The MCS supports any Ethernet controller, such as the KAD/BCU/105 or KAD/BCU/140, and any Ethernet transmitter, such as the KAD/ETH/101. It also supports any Ethernet bus monitor, such as the KAD/EBM/101/B or KAD/EBM/102. It supports any PCM transmitter, memory module or ARINC transmitter on the receiver chassis.

## 41.3 How the MCS works

In Figure 41-2 on page 328, the MCS automatically creates packets to transfer parameters from DAU1 and DAU2 to the ETH2PCM_BRIDGE DAU for those placed in the PCM. It automatically sets up the Ethernet bus monitor accordingly.

### 41.3.1 Ethernet packets automatically built for the MCS

By default, the packets are transmitted to the Ethernet bus monitor using its unicast IP address. However, if needed, the MCS can transmit multicast packets to the Ethernet bus monitor to allow the switch, for example NET/SWI/003, to filter out the MCS packets. See “41.4.1  GUI options added to kSetup for the MCS” on page 332 for more details.

The packets are IENA packets with a unique key per packet. The key starts from FFFE in hexadecimal and then decrements, skipping any IENA keys that have already been defined in the XidML so that they are always unique.

There are one or more packets created for each parameter sampling rate group from each chassis.

For example, assuming an acquisition cycle of 1 Hz, if there is only one parameter at 50 Hz from DAU1 placed in the PCM frame then the MCS creates a packet from DAU1 containing that single parameter, that is one occurrence per packet. The packet is then sent 50 times per second to achieve the 50 Hz sampling rate needed by the PCM frame.

Another example would be if you have one hundred 5 Hz parameters from DAU2 placed in the PCM frame. In this case, the MCS creates a packet from DAU2 containing those 100 parameters. This packet is sent five times per second to achieve the 5 Hz sampling rate. Note that the number of occurrences of a parameter in a packet is one.

A single packet is created for multiple parameters that are placed in the PCM at the same rate, from the same chassis.

If the packet is too small, that is less than 64 bytes, dummy parameters (fixed data) are automatically appended.

If the packet is too long, the MCS creates multiple packets each with unique IENA keys. This occurs when there are more than 722 (by default) parameters at the same rate from the same chassis. The limit of 722 words per packet is set to avoid packet fragmentation (after 1,500 bytes), which is not recommended as it further complicates data reconstruction.

### 41.3.2 How to setup the Ethernet bus monitor for MCS

The MCS automatically sets up the Ethernet bus monitor according to the packets created by the MCS, as explained in “41.3.1 Ethernet packets automatically built for the MCS” on page 329.

The Ethernet bus monitor parses all the MCS packets using the IENA key and IP source classifications. It then defines the packet positions of the data words, which are the parameters going to the PCM frame.

If multiple Ethernet bus monitors are in the Ethernet to PCM bridge chassis, use kSetup to define the Ethernet bus monitor that should be used for the MCS. See “41.4.1  GUI options added to kSetup for the MCS” on page 332 for more details.

## 41.3.3 Example MCS packets

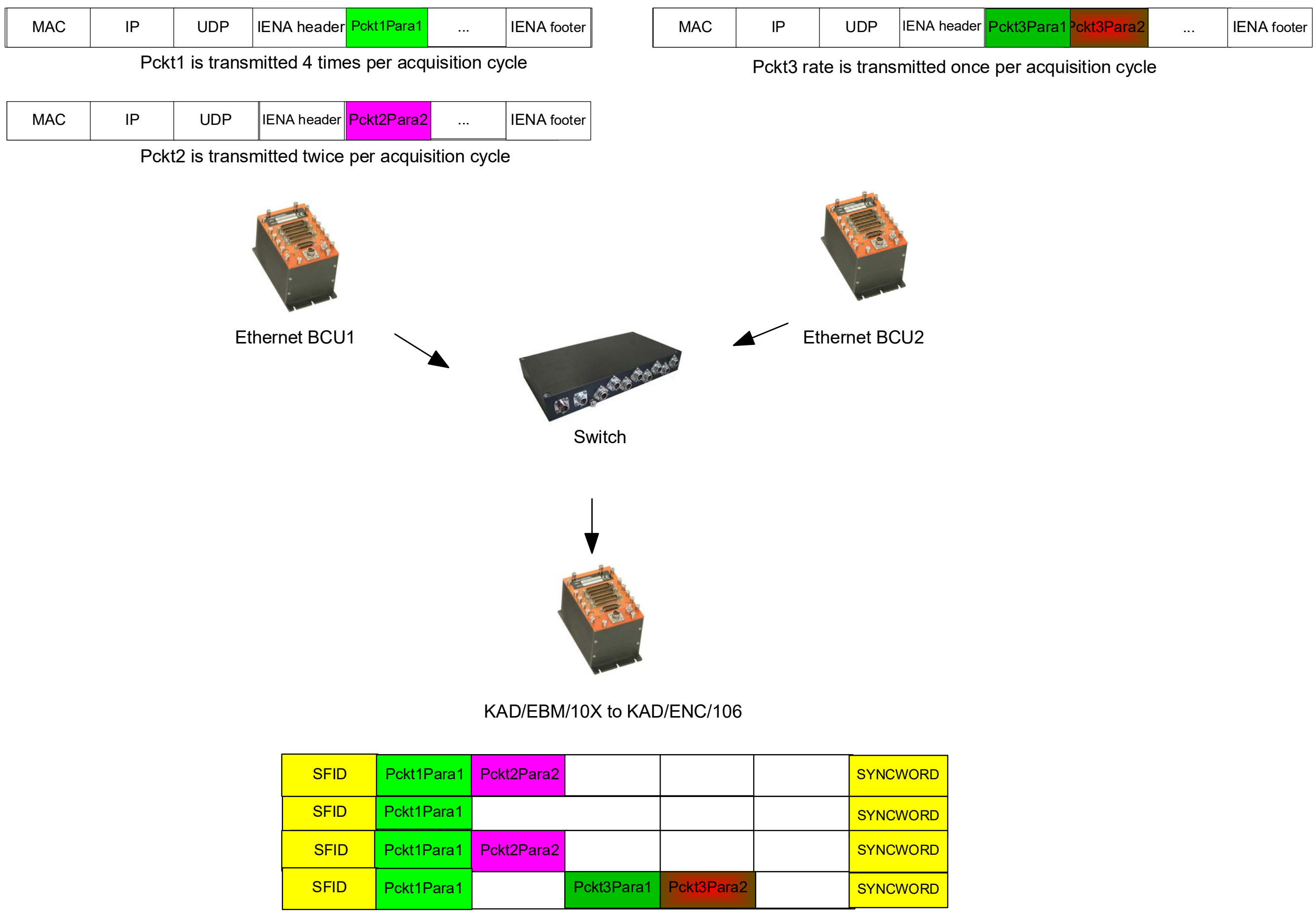


*Figure 41-4: Example of a network MCS*

See Pckt3 in the previous figure. This packet shows that parameters from the same chassis, at the same rate, are grouped in the same packet.

The packets created by the MCS have the same rate as the parameters transmitted in the PCM, that is occurrences of one are used for all the parameters used by the MCS.

If the packet is less than 64 bytes, dummy parameters are inserted in the packet.

## 41.3.4 Delays associated

This section provides simplified descriptions of underlying algorithms used in MCS within KSM-500.

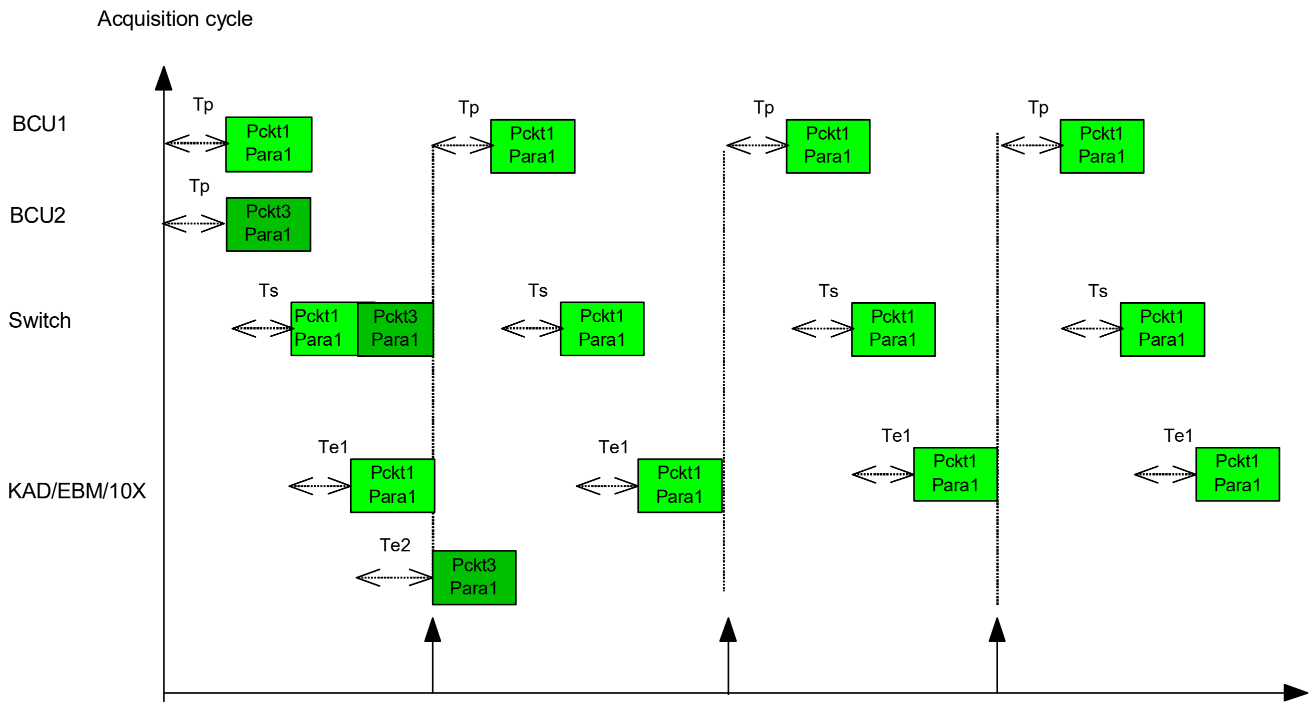


*Figure 41-5: Graph representing the delay associated*

Tp is controlled by the MCS, see the previous figure. The MCS can transmit packets to the Ethernet to PCM bridge at a specific time depending on the PCM deadline. Tp is in the order of microseconds.

Ts is mostly known except the jitter. It's a store and forward switch. The delay is twice the packet length at 100 Mbps. Tp is also dependent on the bandwidth of the traffic coming from the different ingress ports as this queues to the aggregator port. Ts is in the order of microseconds.

Te is known. An Ethernet bus monitor uses a triple buffered input so there may be up to two packet delays at the input.

## 41.3.5 Notes on network efficiency

The packets created by the MCS are not efficient for a network data acquisition system. For recorders, it's recommended to use long packets, not fragmented packets. You should optimize the packets by using parameters occurrences rather than packet rate.

However, because the PCM used by telemetry has a small bandwidth, the MCS does not have much of an effect on the overall network efficiency. For example, a PCM at 4 Mbit/s using an Ethernet to PCM bridge increases the network bandwidth by approximately 8Mbit/s.

## 41.3.6 Notes on PCM placement

All the parameters placed in the PCM are internally sourced by the Ethernet bus monitor when the MCS is used. The Ethernet bus monitor follows the same rules for PCM placement as other bus monitors. PCM placement rules that are specifically applicable for the MCS over IP network are:

- To not interleave parser slots from the same bus module. In Figure 41-2 on page 328, the KAD/EBM/102 in the Ethernet to PCM bridge DAU is an Ethernet bus monitor. Each parameter at the same rate from the same DAU is parsed by one parser slot from the KAD/EBM/102. Therefore you should place slave parameters from the same DAU at the same rate in a horizontal, sequential placement in the PCM frame. This limits the overhead needed when accessing these parser slots.
- To place a networked DAU parameters later in the PCM frame. There is a delay associated with transferring a parameter from a networked DAU to a PCM frame in an Ethernet to PCM bridge DAU. Therefore, parameters from the networked DAUs should be placed furthest away from the beginning of the PCM frame. This allows time for the parameter to be sampled, transmitted over Ethernet, parsed by the Ethernet bus monitor and become available to the PCM transmitter. See "Delays associated" on page 330.

Thread threshold on the Ethernet bus monitor can be used in case of a compilation issue. This advanced field allows the compiler to interleave data words from different messages on the same module. This helps compilation if the rules of PCM placement are not followed. The smaller the number used for the thread threshold the better the flexibility on the backplane, but more transfers (overhead) on the backplane are added.

# 41.4 Appendix

## 41.4.1 GUI options added to kSetup for the MCS

The MCS can be configured with different settings to make it as flexible as possible:

- The Prohibit/Allow implicit packets transmission setting determines if the module is to be used to transmit/receive MCS packets. This is useful if there are multiple Ethernet transmitters or bus monitors in the same chassis. Also, if there are Ethernet bus monitors in the task, other than the Ethernet to PCM bridge DAU, then they need to be prohibited from being used by the MCS. If they are not prohibited then a parameter could pass through the bus monitor and therefore pass through an extraneous DAU rather than go directly to the Ethernet to PCM bridge DAU.
- Multicast destination IP address can be used to filter out MCS traffic, for example, when using a NET/SWI/003 and you don't want MCS traffic going to a network recorder. If this field is left blank then the unicast IP address of the bus monitor is used as the destination for the MCS packets. If a multicast IP address is entered in the field for the Ethernet bus monitor, all MCS packets to that bus monitor use this new destination IP address. If a multicast IP address is entered in this field for a transmitter then this is used for all MCS packets going from this transmitter to the bus monitor. The setting on the transmitter takes precedence over the setting on the bus monitor.
- Max payload size is the maximum packet size used by the MCS. By default this is 722, which is the maximum size of an unfragmented IENA packet in networks with a Maximum Transmission Unit (MTU) of 1,500 bytes. The same precedence and usage rules apply as those of the multicast destination IP address. This option can be used to reduce latency. It can also make it easier to schedule the backplane transfers of a DAU that is supplying parameters for the MCS over Ethernet or an Ethernet to PCM bridge DAU, if there are problems during compilation.

The following screenshot shows how these settings appear in the Setup tab of Ethernet transmitters and bus monitors:

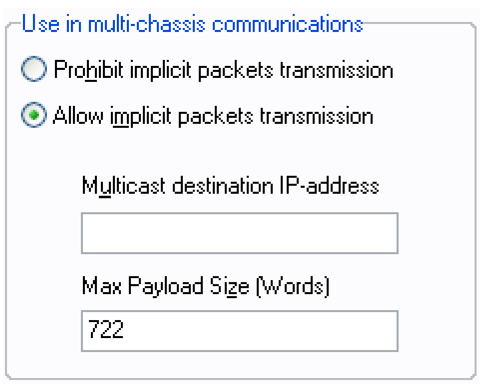


*Figure 41-6: Setup tab of the Ethernet transmitters and bus monitors associated to the network MCS*

### 41.4.2 Connections example

Using a NET/SWI/004 as reference, the different DAUs and recorders should be connected as in the following figure.

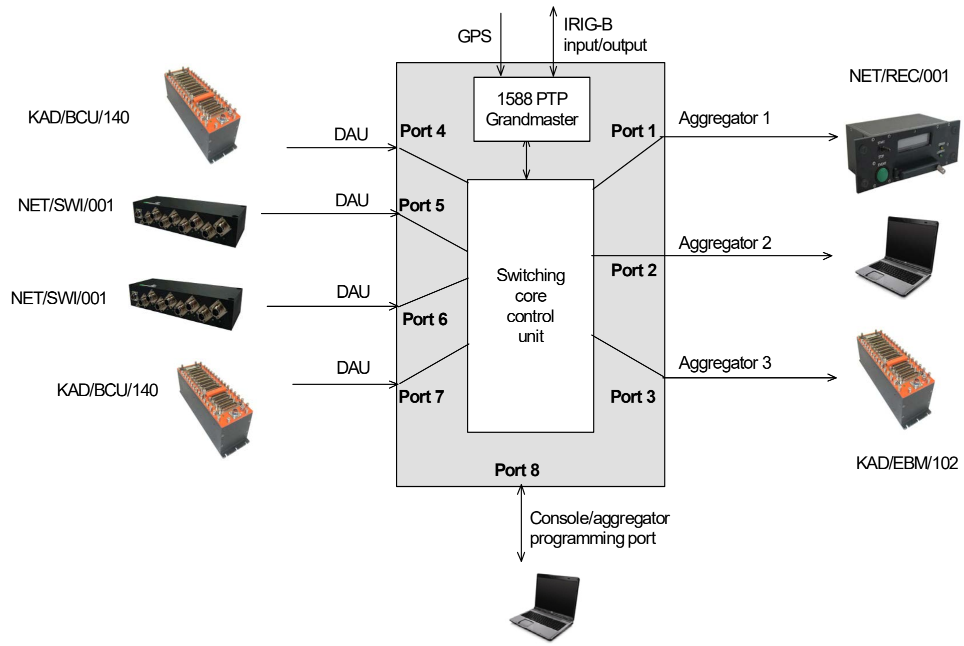


*Figure 41-7: NET/SWI/004 connection example*

All DAUs are connected to DAU ports. The Ethernet bus monitor is connected to an aggregator port.

**NOTE:** Note that the bus monitor module must be located in the same DAU as the PCM encoder. These two modules could be located in a dedicated Ethernet to PCM bridge chassis or in one of the DAUs. The network recorder and/or monitoring PC are connected to an aggregator port.

## 41.5 Glossary of terms

**DAU**: Data Acquisition Unit

**IP**: Internet protocol. The network layer protocol OSI stack. The IP layer provides logical IP source and destination addresses for packets that are transmitted across the network.

**MCS**: Multi-Chassis Scheduler. Part of the compiler that transparently looks after cross-chassis configurations.

**PCM**: Pulse Code Modulation. The primary way analog signals are converted into digital form by taking samples of the waveforms from 8 to 192 thousand times per second (8 to 192 kHz) and recording each sample as a digital number from 8 to 24 bits long.

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# Xbar Switches - Filtering and Forwarding

TEC/NOT/069

Switches are a critical component in any networked FTI data acquisition system in order to allow the forwarding of data from the Data Acquisition Unit (DAU) to the target destination devices such as the network recorder, Ethernet-to-PCM gateway or ground station.

This paper describes the fully interconnected Xbar switch fabric technology implemented in the Curtiss-Wright Xbar switch product family. The Xbar technology is designed to meet the reliability and performance requirements of FTI equipment whilst providing full flexibility and configurability to meet any topological requirements.

This paper discusses the following topics:



**NOTE:** It is assumed that the reader is familiar with network switching and the Simple Network Management Protocol (SNMP). To better understand this paper, see "42.6 Recommended reading" on page 357.

## 42.1 Overview of network switches

In an FTI network of distributed peer DAUs, the switch is a key component that allows data to be transmitted to and from different nodes in the network. Switches are comprised of a number of ports to which DAUs may be connected or which can be used to interconnect other switches. In general, connections in the switch utilize point-to-point full-duplex Ethernet links. The most important task of the switch is to reliably and quickly forward and route packets to their destination. Quite often the terms routing and forwarding are used interchangeably. There is in fact a subtle relationship between the two, see "42.1.0.1 Routing" on page 335 and "42.1.0.2 Forwarding" on page 335 for more details.

#### 42.1.0.1 Routing

Routing is the mechanism of looking up a routing table to determine the best path for a packet from a given sender to reach its destination through intermediate routers. There are two forms of routing, static and dynamic.

- **Static routing:** Suitable for small networks whereby the number of routes is limited and can be manually configured.
- **Dynamic routing:** More suited to larger networks with complex topologies that may change over time. This is an adaptive form of routing which determines the network topology using routing protocols, which are then used to automatically and periodically generate and populate routing tables. Routing tables contain information derived from routing algorithms.

Routing protocols communicate routing information about the connected devices between neighboring routers. The routing table maps an IP address prefix to the next hop address prefix. This is, in essence, a Layer-3 topological view of the network and is optimized for detecting and adapting to changes in the topology.

#### 42.1.0.2 Forwarding

Forwarding is the mechanism of passing or forwarding a packet from one port or interface in the switch to the appropriate egress interface by looking up the forwarding table. Although it is possible to supplement the forwarding table with extra information that is typically found in the routing table, such as next hop information, forwarding statistics, and QoS metrics, it is more common for the routing and forwarding tables to be kept separate. In this way, the routing tables can be used to generate compact and efficient forwarding tables, which are optimized for hardware storage and lookup functionality.

### 42.1.1 Store and forward

A key function of a store and forward switch is to forward incoming packets to the appropriate destination interface. The mechanism by which packets are forwarded to the appropriate destination interface is called store and forward, whereby the packets received by the switch are stored in an input queue until they reach the head of the queue. Once at the head of the queue, the switch core examines the packets' destination and through a lookup mechanism determines how to forward the packet to its intended destination, forwarding the data through the switch fabric.

Before being forwarded through the switch fabric, the switch core may perform various Layer 2 (MAC layer) and Layer 3 (IP layer) validation checks. See “42.1.1.1 MAC Layer 2 validation” on page 336 and “42.1.1.2 IP Layer 3 validation” on page 336 respectively for more details.

#### 42.1.1.1 MAC Layer 2 validation

- **Ethernet frame validation**: Every Ethernet frame that is forwarded is first validated to ensure it is well-formed, that is, it is within the allowed frame size limits, and that known fields in the Ethernet frame are correct. Layer 3 (IP layer) validation may also occur to ensure the correct IP version field, protocol identifiers etc. are correct, see “42.1.1.2 IP Layer 3 validation” on page 336.
- **Ethernet Frame Check Sequence (FCS) error checking**: The Ethernet MAC FCS is compared against the Cyclic Redundancy Check (CRC) calculated by the store and forward switch. If the Ethernet frames’ FCS differs from the calculated CRC, the frame is considered to contain physical or data link errors and is dropped. In this way, corrupt Ethernet frames are prevented from propagating through the rest of the network.

#### 42.1.1.2 IP Layer 3 validation

- **Packet lifetime control**: Layer 3 switches must also decrement the Time-To-Live (TTL) field in the IP packet header to prevent packets infinitely circulating the network in routing loops. When the TTL value reaches zero, the packet is discarded.
- **Checksum recalculation**: If the Layer 3 switch modifies the TTL, the corresponding IP header checksum and Ethernet FCS need to be recalculated and updated.
- **Fragmentation**: Should the Maximum Transmission Unit (MTU) of the outgoing Ethernet link be smaller than the size of the packet; the packet needs to be fragmented before being forwarded.

If the Ethernet frame is determined to be valid, the switch begins the forwarding process whereby the switch core examines the packets' destination and looks up the forwarding table to determine which egress port (unicast) or ports (multicast/broadcast) are to be used. Since the destination MAC address is the first six bytes of the Ethernet frame, the forwarding process is generally faster than Layer 3 routing table lookup, which requires dissection of the various MAC and IP layer protocol fields.

If there is no entry for a given destination MAC address, the switch does not know where to forward the packet. In this case, the Ethernet frame is forwarded out to all ports on the switch, or flooded. As Ethernet frames are passed through the switch, the switch core updates the MAC forwarding table, noting the source MAC address and the interface on which it arrived. By doing this, the switch core is able to maintain the forwarding table. However, since MAC tables have a finite memory size, entries age out to ensure that the table is up-to-date.

## 42.2 Xbar switch fabric overview

To realize a flexible store and forward switching solution, a fully interconnected Xbar switching architecture with N input busses and N output busses is implemented where each crosspoint may be either on or off. Curtiss-Wright FTI switches that support this fully interconnected switching architecture are known as Xbar switches. The advantage of the Xbar architecture is its flexibility, enabling complete control over forwarding paths for Ethernet frames using a fully interconnected two-state crosspoint (on or off) switching fabric. Moreover, having high-speed data links in the fabric lowers the switching latency, compared to other switching architectures by minimizing the number of connecting points.

By default, all Ethernet frames received on the input ports are forwarded to all sink devices connected to the output ports. However, using Xbar switching technology it is possible to selectively forward the Ethernet frames from the input ports to specified output ports.

Consider an eight-port switch with four DAUs directly connected on ports 1, 3, 5, and 7, and an unmanaged Ethernet switch on port 6 as shown in the following figure. Ethernet frames transmitted by the DAUs and the switch are forwarded to a number of sink devices, such as a network recorder connected on port 2, an Ethernet-to-PCM gateway connected on port 4 and an analysis laptop connected on port 8.

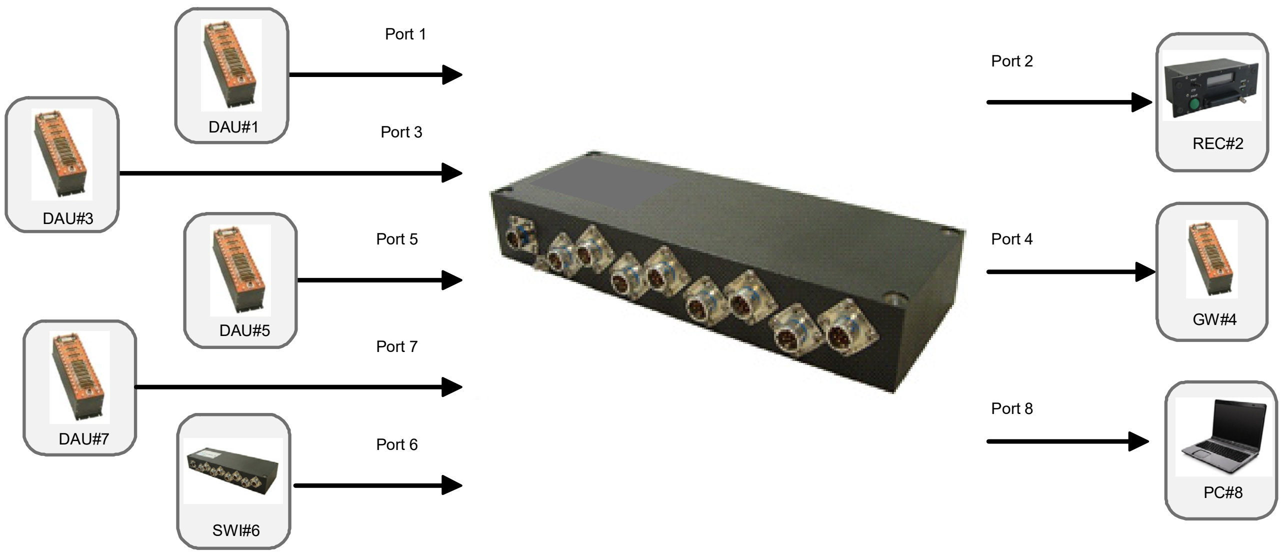



*Figure 42-1: Typical FTI switch configuration*

The following table summarizes the forwarding paths for each of the network devices connected to the Xbar switch. In this scenario, a DAU (named DAU#1) is connected to port 1 of the Xbar switch. The Ethernet frames transmitted by DAU#1 are received on port 1 and should be forwarded to a number of destination devices: a network recorder (REC#2) connected on port 2; an Ethernet-to-PCM gateway device (GW#4) connected on port 4; and an analysis laptop (named PC#8) connected on port 8.

Table 42-1: Example forwarding configuration

| Port number | Input source network node | Destination network node and description |
|---|---|---|
| 1 | DAU#1<br>Data acquisition unit | • REC#2: All data from this DAU are recorded.<br>• GW#4: A subset of the data streams from this DAU is relayed to the ground for real-time analysis.<br>• PC#8: The DAU is programmed by the PC. |
| 2 | REC#2<br>Network recorder | • GW#4: Transmits its memory utilization to the GW#4 network node where the parameter value is transmitted over the PCM link to be monitored in real-time on the ground.<br>• PC#8: It is programmed from the PC and also can be queried by the PC using SNMP. |
| 3 | DAU#3<br>Data acquisition unit | • REC#2: All data from this DAU are recorded.<br>• PC#8: The DAU is programmed by the PC. |
| 4 | GW#4<br>Ethernet -to-PCM gateway | • None: This device does not transmit any Ethernet packets to any other devices. For example, consider this as an Ethernet bus monitor module that only receives Ethernet frames and is programmed through a KAD/BCU/140 controller that is housed in the same chassis. |
| 5 | DAU#5<br>Data acquisition unit | • GW#4: A subset of the data streams from this DAU is relayed to the ground for real-time analysis.<br>• PC#8: The DAU is programmed by the PC. |
| 6 | SWI#6<br>Network switch | • REC#2: All data streams aggregated through the switch are recorded.<br>• PC#8: The DAU is programmed by the PC. |
| 7 | DAU#7<br>Data acquisition unit | • PC#8: The DAU is programmed by the PC. |

Table 42-1: Example forwarding configuration (continued)

| Port number | Input source network node | Destination network node and description |
|---|---|---|
| 8 | PC#8<br>Analysis and programming PC | • All Ports: Programs all devices in the system and analyzes all data from an onboard flying ground station. |

The following figure illustrates the Xbar configuration required to realize this forwarding configuration between the DAUs and the various sink devices. The Xbar switching fabric comprises a fully interconnected matrix of crosspoints between the input and output data lines.

Ethernet frames received on the ingress interface of a given port are never forwarded back out on the egress interface of the same port as indicated in the illustration. This blocked data path is indicated by the grey crosspoint, which denotes the interconnection between the ingress and egress interfaces as being blocked. However, Ethernet frames received on a given port can be potentially forwarded to one or more ports. You must explicitly define which interconnections are allowed by enabling the appropriate crosspoint.

The enabled crosspoints are denoted by the hashed crosspoint. All other interconnection paths that have not been enabled are denoted by the clear crosspoint. For example, Ethernet frames received on port 1 from DAU#1 are not forwarded through port 1 back to DAU#1. However, Ethernet frames received on port 1 are to be forwarded to the target devices connected on ports 2, 4 and 8. Similarly, the network recorder, REC#2, connected on port 2 periodically transmits its status information that is to be relayed to the ground via the Ethernet-to-PCM gateway, GW#4, connected on port 4 and to the analysis laptop, PC#8, connected on port 8.

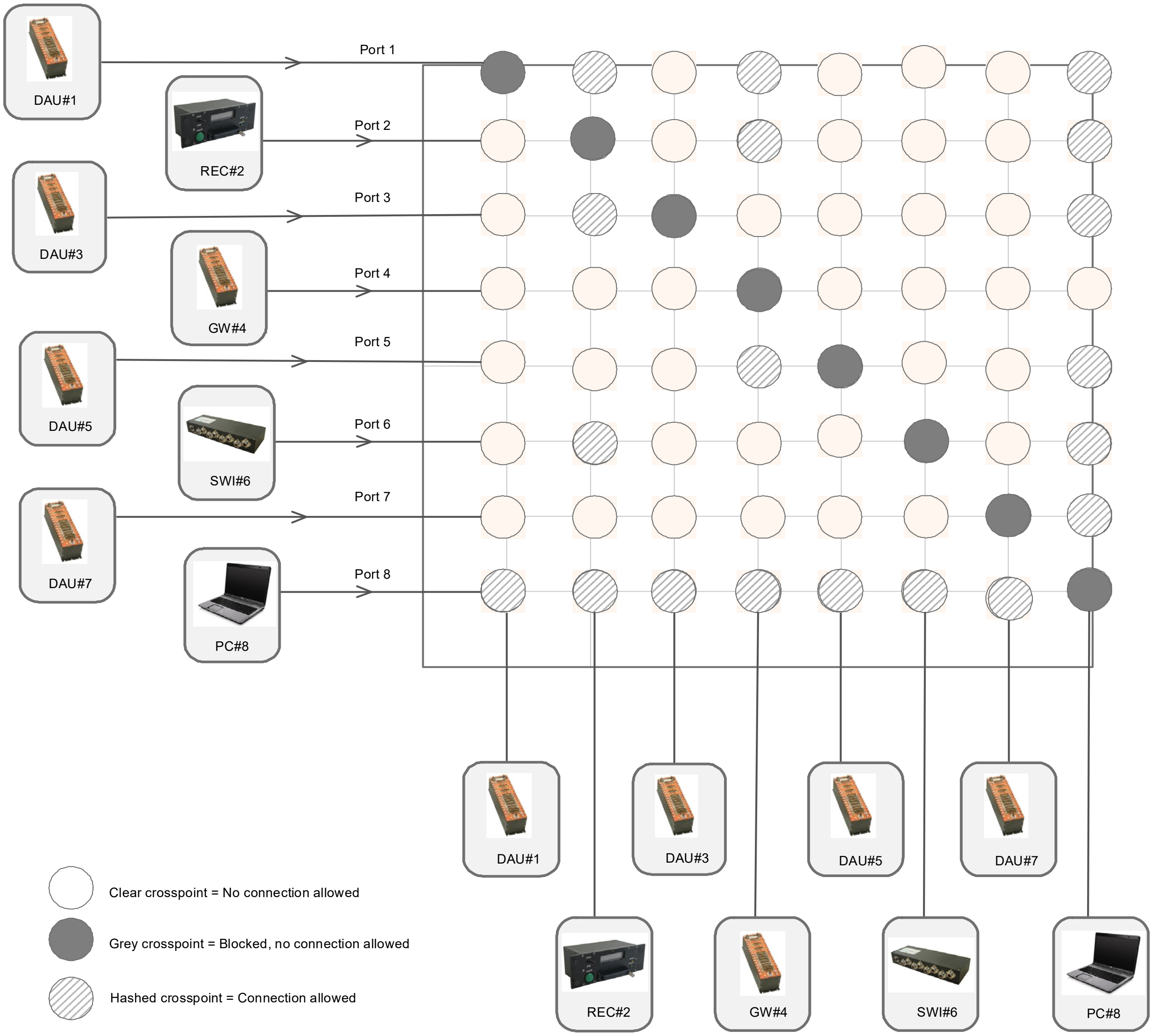



*Figure 42-2: Xbar crosspoint switch fabric*

**NOTE:** A DAU can only be programmed and/or pinged if the link is bi-directional. Therefore the crosspoint between the DAU and programming ports must be enabled. For devices that do not transmit any Ethernet data and only receive Ethernet frames, only those crosspoints which connect the input to output need to be enabled.

The configuration of the crosspoints is used to populate the static forwarding table. The table is considered to be static since it does not rely on adaptive or learning based routing protocols to populate the forwarding table, the table is static and fully-defined by you. The static forwarding table is set up in the Xbar switch using the SNMP. SNMP can be used to modify the static forwarding table at any time without having to interrupt or power cycle the Xbar switch.

## 42.3 Xbar forwarding and filtering

The previous section described the Xbar forwarding operations. As a consequence of a fully interconnected crosspoint switching fabric, all Ethernet frames received on a given port are forwarded to the appropriate destination if the interconnection is allowed in the forwarding table. However, often finer granularity is required in terms of the forwarding paths whereby only a selected subset of Ethernet frames received from a given input port should be forwarded to a specified output port. To achieve this, a filter is applied to the egress port buffer. The filter is applied only to the egress buffer in order to minimize the processing and lookup required for the forwarding process, thereby minimizing the forwarding latency.

In this section, consider a four-port Xbar switch with a DAU connected on port 1 and port 3 (DAU#1 and DAU#3 respectively) transmitting data to be forwarded to a network recorder (REC#2) and an Ethernet-to-PCM gateway (GW#4) as illustrated in Figure 42-3 on page 341. Defining the Xbar forwarding table alone enables all Ethernet frames transmitted by the DAU to be forwarded to the user-defined allowed destination devices. However, Xbar switching fabric allows for finer granularity with regards to the specification of the forwarding paths, where only Ethernet frames with destination MAC addresses that match the filter criteria may be forwarded through the egress interface of the output port. This mechanism is known as filtering.

For example, DAU#1 is transmitting three packet streams to unique destination multicast addresses:

- **Video data stream** (red): The video stream should only be forwarded to the network recorder, REC#2, but not the Ethernet-to-PCM gateway, GW#4. Essentially, the video stream is filtered from the outgoing egress interface with GW#4.
- **Analog data stream** (green): The analog stream should be forwarded to the Ethernet-to-PCM gateway, GW#4, but not the network recorder, REC#2. Similarly the analog stream is filtered on the output to the network recorder, REC#2.
- **ARINC-429 data stream** (blue): The ARINC-429 is forwarded to both the network recorder, REC#2, and the Ethernet-to-PCM gateway, GW#4.

The complete Xbar forwarding and filtering specification is summarized in the following figure.

Table 42-2: Example forwarding and filtering requirements

| Port Number | Input source network node | Destination network node and description |
|---|---|---|
| 1 | DAU#1<br>Data acquisition unit<br>• Video<br>• Analog<br>• ARINC-429 | • Video data stream is forwarded to the network recorder, REC#2, but not the Ethernet-to-PCM gateway., GW#4<br>• Analog is forwarded to the Ethernet-to-PCM gateway, GW#4, but not the network recorder, REC#2.<br>• ARINC-429 is forwarded to both the network recorder, REC#2, and the Ethernet-to-PCM gateway, GW#4. |
| 2 | REC#2<br>Network recorder<br>• Memory utilization and recorder status | • Transmits its memory utilization to the Ethernet-to-PCM gateway, GW#4, where the parameter value is transmitted over the PCM link to be monitored in real-time on the ground. |
| 3 | DAU#3<br>Data acquisition unit<br>• MIL-STD-1553<br>• Audio<br>• Temperature | • MIL-STD-1553 is forwarded to the Ethernet-to-PCM gateway, GW#4, but not the network recorder, REC#2.<br>• Audio data stream is forwarded to the network recorder, REC#2, but not the Ethernet-to-PCM gateway, GW#4.<br>• Temperature is forwarded to both the network recorder, REC#2, and the Ethernet-to-PCM gateway, GW#4. |
| 4 | GW#4<br>Ethernet-to-PCM gateway | • None: This device does not transmit any Ethernet packets to any other devices. For example, consider this as an Ethernet bus monitor module that only receives Ethernet frames and is programmed through a KAD/BCU/140 controller that is housed in the same chassis. |

There are two steps to set up the Xbar configuration:

1. Define the forwarding table to enable the required interconnection crosspoints.
   In Figure 42-3 on page 341, DAU#1 and DAU#3 must be able to communicate with both REC#2 and GW#4. In addition, REC#2 must be able to communicate with GW#4 in order to forward its memory utilization, health and status. This forwarding configuration is achieved by enabling/disabling the appropriate interconnection crosspoints in the Xbar fabric.
2. Define the filters to be applied to the outgoing ports.
   If the crosspoint is enabled, the forwarding table allows for all Ethernet frames to be forwarded to the specified destination network end nodes. If only a subset of the Ethernet frames are to be forwarded through the egress port, then a filter must be defined and associated with the egress port.

As with the forwarding configuration, SNMP can be used to modify the filter specification at any time without having to interrupt or power cycle the Xbar switch. “42.4.2  Setting the filter type” on page 345 details using SNMP to specify the filtering configuration.

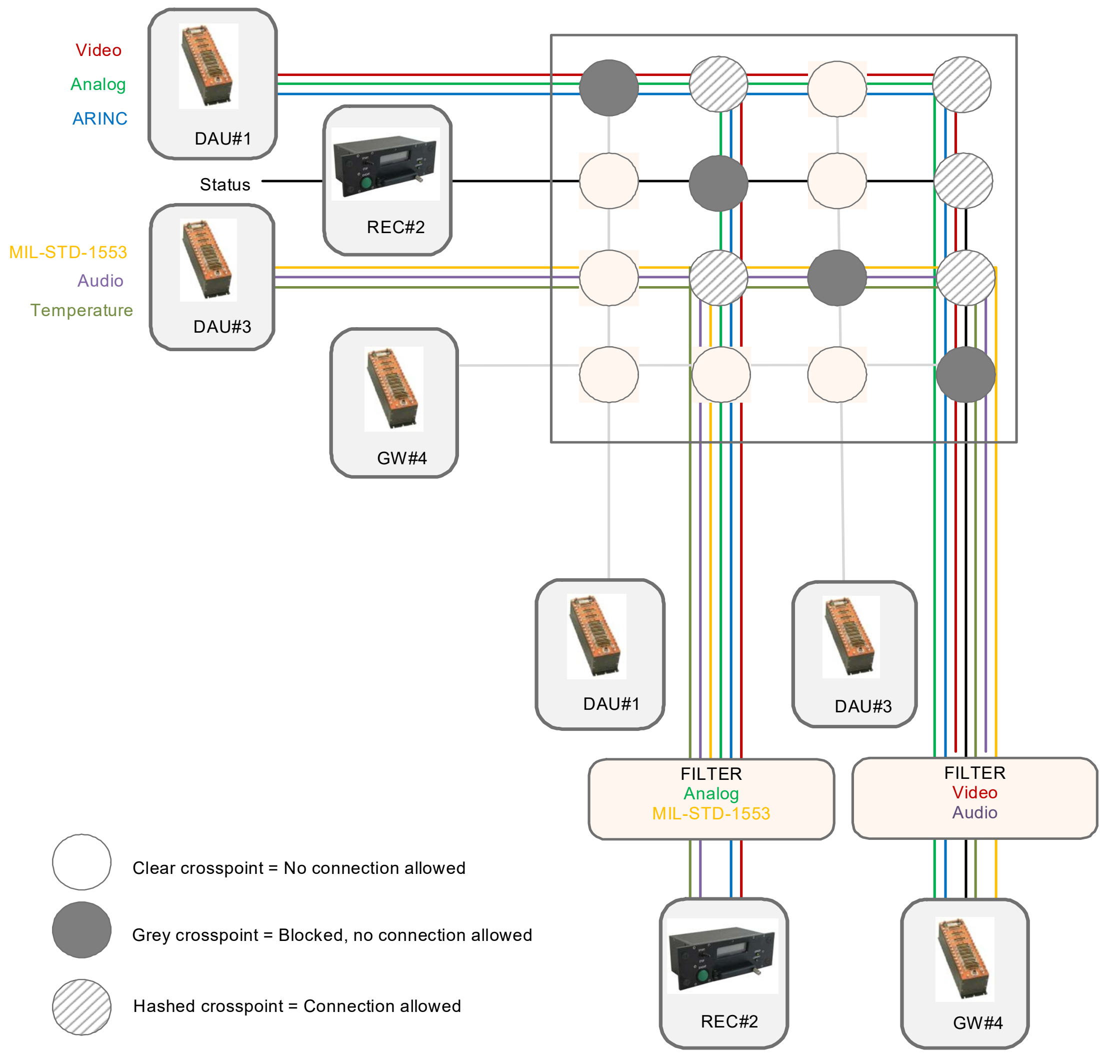



*Figure 42-3: Typical forwarding and filtering configuration*

## 42.4 Configuring forwarding and filtering using SNMP

The forwarding and filtering tables are configured in the Xbar switch using the dot1dStatic subtree originally defined in the SNMP Bridge Management Information Base (Bridge-MIB), (IETF RFC 4188).

**NOTE:** For more information on SNMP, refer to *TEC/NOT/058 - Overview of SNMP and using third party SNMP tools*. The Curtiss-Wright Studio software suite uses SNMP under the hood to interact with the SNMP-enabled devices. However, since SNMP is a standardized technology, for the purposes of illustration the following describes using the Net-SNMP open source utility to configure Xbar switches.

For simplicity, the dot1dStatic subtree in the Bridge-MIB shall be discussed, which is used to configure Xbar forwarding and filtering. The dot1dStatic subtree is a table that comprises a number of entries that define the forwarding and filtering information to be applied to the ports on the Xbar switch. Each entry in the table consists of four variables:

1. **Destination MAC address**: The destination MAC address in an Ethernet frame to which this entry's filtering information applies.
2. **Receive Port Interface**: The port number on which the frame must be received in order for this entry's filtering information to apply.
3. **Bitvector of the Allowed Outgoing Ports**: The set of ports to which this Ethernet frame is allowed to be forwarded. The bit vector is used to represent the on/off state or forwarding for each port in the switch.
4. **Entry Persistence**: States the persistence of this forwarding/filtering entry indicating if it is permanent until removed, deleted on reset or deleted on timeout.

### 42.4.1 Setting the forwarding table

The first N entries in the table are used to define the allowed forwarding paths in the Xbar switch, where N is the number of ports on the switch, that is, if the switch has eight-ports then the first eight entries of the table are used to define the forwarding configuration.

To define a forwarding entry the Receive Port Interface, Bitvector of the Allowed Outgoing Ports and Entry Persistence are used, see the following table.

**NOTE:** Port 1 is represented by the Least Significant Bit (LSB) of the bit vector. Any attempt to set other values in these fields using SNMP results in a "Bad Value" error message using an SNMP tool.

Table 42-3: Tabular representation of the dot1dStatic MIB

| Receive Port Interface | Destination MAC address | Bitvector of the Allowed Outgoing Ports | Entry Persistance |
|---|---|---|---|
| 1 | Used to define filter types, described in “42.4.2 Setting the filter type” on page 345. | | Permanent |
| 2 | | | Permanent |
| 3 | | | Permanent |
| 4 | | | Permanent |
| 5 | | | Permanent |
| 6 | | | Permanent |
| 7 | | | Permanent |
| 8 | | | Permanent |

The generic form for the SNMP command used to specify the forwarding configuration is as follows:

```
snmpset [Version] [Community][Agent] [OID] [Type] [Value]
```

Thus to specify the forwarding for a given port N, the SNMP command arguments are:

- `[Version]:` `-v2c`
- `[Community]:` `-c public`
- `[Agent]:` `192.168.1.1` which is the IP address of the Xbar switch being configured.
- `[OID]:` `.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.N,` where N is the port number.
- `[Type]:` `x` where x indicates that the following value is a hex value.
- `[Value]:` `0a` where 0x0a is the bit vector of Allowed outgoing ports with port 1 being the LSB of the vector.

The complete snmpset command for the forwarding configuration of port 1 is:

```
snmpset.exe-v2c-cpublic192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.do
t1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.1 x 0a
```

For more information on using SNMP see *TEC/NOT/058 - Overview of SNMP and using third party SNMP tools.*

#### 42.4.1.1 Example forwarding configuration

Consider the following example of an eight-port Xbar switch with only four devices connected to it, see the following figure.

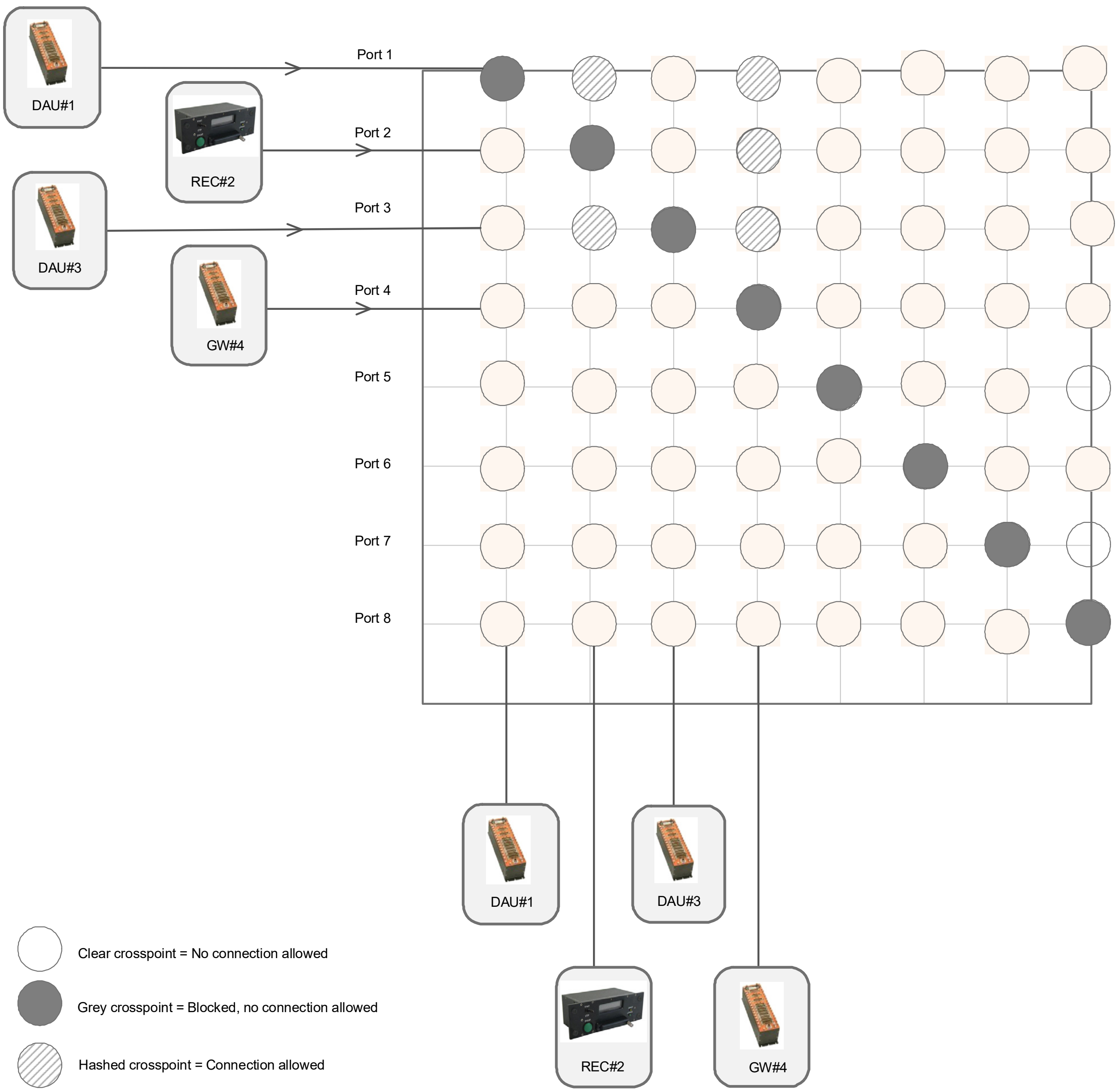



*Figure 42-4: Eight-port Xbar forwarding configuration*

See the following table for the SNMP commands for the forwarding configuration of each port in Figure 42-3 on page 341.

Table 42-4: Description of the Xbar forwarding SNMP command syntax

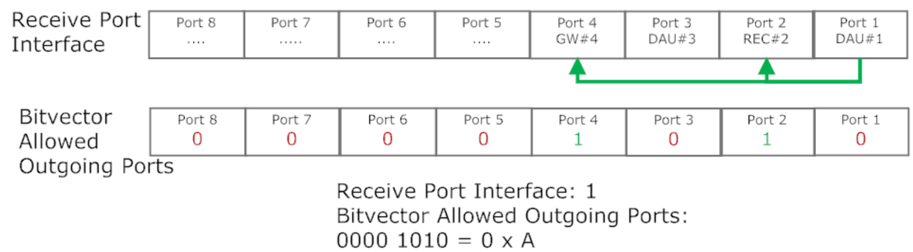
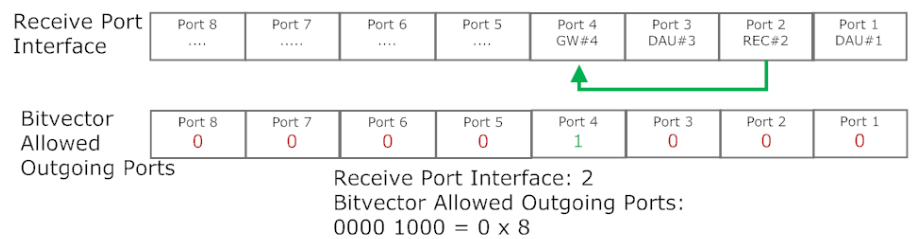
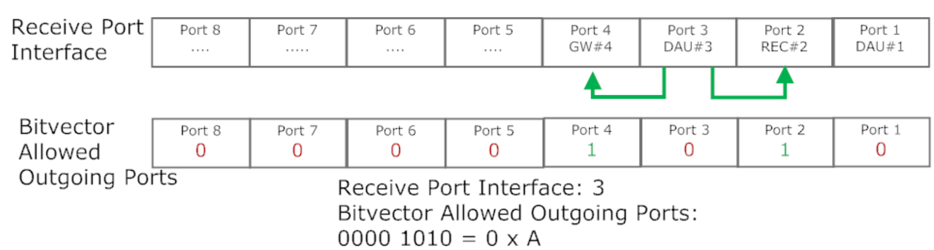
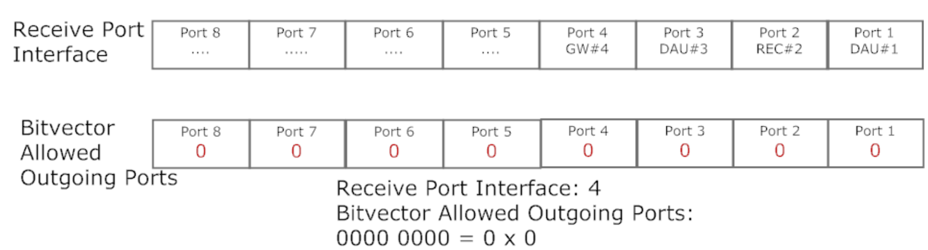
<table>
<tr><th>Receive Port Interface</th><th>Bitvector of the Allowed Outgoing Ports</th></tr>
<tr><td rowspan="2">Port 1<br>DAU#1</td><td>
</td></tr>
<tr><td><code>snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.1 x 0a</code></td></tr>
<tr><td rowspan="2">Port 2<br>REC#2</td><td>
</td></tr>
<tr><td><code>snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.2 x 08</code></td></tr>
<tr><td rowspan="2">Port 3<br>DAU#3</td><td>
</td></tr>
<tr><td><code>snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.3 x 0a</code></td></tr>
<tr><td rowspan="2">Port 4<br>GW#4</td><td>
</td></tr>
<tr><td><code>snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.4 x 00</code></td></tr>
</table>

Table 42-4: Description of the Xbar forwarding SNMP command syntax (continued)

| | |
|---|---|
| Ports 5 - 8<br>No devices connected | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.5 x 00`<br><br>`snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.6 x 00`<br><br>`snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.7 x 00`<br><br>`snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.8 x 00` |

The resulting forwarding table appears as follows:

Table 42-5: Resulting forwarding dot1dStatic MIB table entries

| Receive Port Interface | Destination MAC address | Bitvector of the Allowed Outgoing Ports | Entry Persistance |
|---|---|---|---|
| 1 | Used to define filter types, described in “42.4.2 Setting the filter type” on page 345. | 0x000A | Permanent |
| 2 | | 0x0008 | Permanent |
| 3 | | 0x000A | Permanent |
| 4 | | 0x0000 | Permanent |
| 5 | | 0x0000 | Permanent |
| 6 | | 0x0000 | Permanent |
| 7 | | 0x0000 | Permanent |
| 8 | | 0x0000 | Permanent |

## 42.4.2 Setting the filter type

Xbar switches have filtering capabilities, which may be configured to pass or reject unicast, multicast, or broadcast packets being forwarded out of each port.

The following three types of filter can be specified:

- Filter unicast
- Filter broadcast
- Filter multicast

### Filter unicast

The unicast filter is described by the SNMP OID variable contained in the Acra MIB. More details on the variable structure can be found in “42.5 Appendix: Xbar connection SNMP variables” on page 354.

This variable specifies whether unicast traffic is allowed at this output. The `FilterUnicast` variable may be set to the following values:

- `Allowed (0)`: All unicast packets are allowed out of this connection.
- `Blocked (1)`: No unicast packets are allowed out of this connection.

This does not affect unicast packets arriving at this connection. Such packets can be forwarded to other outputs, subject to routing defined in the dot1dStaticAddress array, regardless of this setting.

**NOTE:** The unicast filter and broadcast filter can only be Blocked or Allowed. The PassFilter and RejectFilter options can only be used with a multicast filter. If an attempt is made to apply a PassFilter or RejectFilter setting value to either a unicast filter or a broadcast filter, an "Unsupported" error message is returned.

When filtering, it is important to understand that if a unicast filter is applied to a given port, it is not possible to use SNMP, ping, or program the device connected on this port. As a precautionary measure, by default, the last port or port N on a N-port Xbar switch can never be set to block unicast in order to prevent permanently blocking access to the switch.

To specify the unicast filter for a given port N, the snmpset command arguments are:

- `[Version]:` `-v2c`
- `[Community]:` `-c public`
- `[Agent]:` `192.168.1.1` which is the IP address of the Xbar switch being configured.
- `[OID]:` `.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.N`, where N is the port number.
- `[Type]:` `i` where i indicates that the following value is a integer value.
- `[Value]:` where the possible values for this variable are: {Allowed(0), Blocked(1)}

Therefore, the complete snmpset command to set the unicast filter configuration of port 1 to '`Allowed`' is:

```
snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.
connection.connectionTable.connectionEntry.connectionFilterUnicast.1 i 0
```

For more information on using SNMP see *TEC/NOT/058 - Overview of SNMP and using third party SNMP tools.*

### Filter unicast examples

The following two tables provide examples of setting the unicast filter for an eight-port Xbar switch.

Table 42-6: Filter unicast configuration example 1

| **Port number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Unicast traffic** | Allow | Block | Allow | Block | Allow | Block | Allow | Allow |

| | |
|---|---|
| Port 1 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.1 i 0` |
| Port 2 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.2 i 1` |
| Port 3 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.3 i 0` |
| Port 4 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.4 i 1` |
| Port 5 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.5 i 0` |
| Port 6 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.6 i 1` |
| Port 7 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.7 i 0` |

Table 42-6: Filter unicast configuration example 1 (continued)

| | |
|---|---|
| Port 8 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.8 i 0` |

Table 42-7: Filter unicast configuration example 2

| **Port number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Unicast traffic** | Allow | Allow | Allow | Allow | Block | Block | Block | Allow |

| | |
|---|---|
| Port 1 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.1 i 0` |
| Port 2 | `ssnmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.2 i 0` |
| Port 3 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.3 i 0` |
| Port 4 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.4 i 0` |
| Port 5 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.5 i 1` |
| Port 6 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.6 i 1` |
| Port 7 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.7 i 1` |
| Port 8 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast.8 i 0` |

### Filter broadcast

The broadcast filter is similar to the unicast filter type. More details on the variable structure can be found in “42.5 Appendix: Xbar connection SNMP variables” on page 354. This variable specifies whether broadcast traffic is allowed at this output. The `FilterBroadcast` variable may be set to the following values:

- `Allowed (0)`: All broadcast packets are allowed out of this connection.
- `Blocked (1)`: No broadcast packets are allowed out of this connection.

This does not affect broadcast packets arriving at this connection. Such packets can be forwarded to other outputs, subject to routing defined in the dot1dStaticAddress array, regardless of this setting.

**NOTE:** The unicast filter and broadcast filter can only be Blocked or Allowed. The PassFilter and RejectFilter options can only be used with a multicast filter. If an attempt is made to apply a PassFilter or RejectFilter setting value to either a unicast filter or broadcast filter an "Unsupported" error message is returned.

When filtering, it is important to understand that if a broadcast filter is applied to a given port, it is not possible to use SNMP, ping, or program the device connected on this port. As a precautionary measure, by default, the last port or port

N on a N-port Xbar switch can never be set to block broadcast in order to prevent permanently blocking access to the switch.

### Filter broadcast examples

The following two tables provide examples of setting the broadcast filter for an eight-port Xbar switch.

Table 42-8: Filter broadcast configuration example 1

| **Port number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Broadcast traffic** | Allow | Block | Allow | Block | Allow | Block | Allow | Allow |

| | |
|---|---|
| Port 1 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.1 i 0` |
| Port 2 | `ssnmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.2 i 1` |
| Port 3 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.3 i 0` |
| Port 4 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.4 i 1` |
| Port 5 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.5 i 0` |
| Port 6 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.6 i 1` |
| Port 7 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.7 i 0` |
| Port 8 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.8 i 0` |

Table 42-9: Filter broadcast configuration example 2

| **Port number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Broadcast traffic** | Allow | Allow | Allow | Allow | Block | Block | Block | Allow |

| | |
|---|---|
| Port 1 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.1 i 0` |
| Port 2 | `ssnmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.2 i 0` |
| Port 3 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.3 i 0` |

Table 42-9: Filter broadcast configuration example 2 (continued)

| | |
|---|---|
| Port 4 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.4 i 0` |
| Port 5 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.5 i 1` |
| Port 6 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.6 i 1` |
| Port 7 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.7 i 1` |
| Port 8 | `snmpset.exe -v2c -c public 192.168.1.1.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast.8 i 0` |

### Filter multicast

Xbar switches support multicast filtering on the output. This variable specifies whether multicast traffic is allowed at this output. The `FilterMulticast` variable may be set to the following values:

- `Allowed (0)`: All multicast packets are allowed out of this connection.
- `Blocked (1)`: No multicast packets are allowed out of this connection.
- `PassFilter (2)`: The onlymulticast packets allowed out of this connection are those whose destination MAC is in the dot1dStatic table, with a 1 for this connection in the `AllowedToGoTo` value.
- `RejectFilter (3)`: All multicast packets are allowed out of this connection EXCEPT those whose destination MAC is in the dot1dStatic table, with a 1 for this connection in the `AllowedToGoTo` value.

This variable indicates the multicast filter type associated with a given output port. However, the dot1dStatic subtree in the Bridge-MIB is also used to enter the specific multicast addresses to which this filter is applied. Xbar switches can store up to 32 entries in the dot1dStatic table of which the first N entries of the table are used to configure the forwarding configuration of an N-port switch as described earlier. The remaining entries are available to set the specific multicast addresses used for filtering.

As before, the filter type associated with each port is configured.

**NOTE:** While Xbar switches can store up to 32 entries, the 32nd entry in the dot1dStatic table is reserved for PTP traffic and cannot be edited.

### Filter multicast examples

The following two tables provide examples of setting the multicast filter for an eight-port Xbar switch.

Table 42-10: Filter multicast configuration example 1

| **Port number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Multicast traffic** | Reject | Pass | Allow | Reject | Pass | Allow | Reject | Pass |

| | |
|---|---|
| Port 1 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.1 i 3` |
| Port 2 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.2 i 2` |

Table 42-10: Filter multicast configuration example 1 (continued)

| | |
|---|---|
| Port 3 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.3 i 0` |
| Port 4 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.4 i 3` |
| Port 5 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.5 i 2` |
| Port 6 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.6 i 0` |
| Port 7 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.7 i 3` |
| Port 8 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.8 i 2` |

Table 42-11: Filter multicast configuration example 2

| **Port number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Multicast traffic** | Allow | Pass | Reject | Allow | Pass | Reject | Allow | Pass |

| | |
|---|---|
| Port 1 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.1 i 0` |
| Port 2 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.2 i 2` |
| Port 3 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.3 i 3` |
| Port 4 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.4 i 0` |
| Port 5 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.5 i 2` |
| Port 6 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.6 i 3` |
| Port 7 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.7 i 0` |
| Port 8 | `snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterMulticast.8 i 2` |

### Specifying the multicast addresses to filter

To define a multicast filter entry the Destination MAC Address and Bitvector of Allowed Outgoing Ports are used. The general form for the table to store the multicast address filter information used in the dot1dStatic subtree is shown in the following table.

Table 42-12: Tabular representation of the dot1dStatic MIB

| Receive Port Interface | Destination MAC address | Bitvector of the Allowed Outgoing Ports | Entry Persistance |
|---|---|---|---|
| Used to define the forwarding configuration only, described in “42.4.1 Setting the forwarding table” on page 342. In the context of filtering it is used as an index of the filter entries. | | | Permanent |
| | | | Permanent |
| | | | Permanent |
| | | | Permanent |
| | | | Permanent |
| | | | Permanent |
| | | | Permanent |
| | | | Permanent |

**NOTE:** For more information on the notation used to specify the Bitvector of the Allowed Outgoing Ports refer to “42.4.1 Setting the forwarding table” on page 342 that describes the forwarding configuration.

The following table assumes an eight-port Ethernet switch. These filtering entries are for illustrative purposes only. It is assumed that the forwarding configuration has already been defined and the appropriate crosspoints have been enabled between the inputs and outputs. Since the first eight entries are used to specify the forwarding configuration, subsequent entries at index 9 are used to specify the multicast address used for filtering.

Table 42-13: Setting the multicast address filter

<table>
<tr><th>Table entry index</th><th>Description</th></tr>
<tr><td>Index entry 9</td><td>
<table>
<tr><th></th><th>Destination IP</th><th>Destination MAC</th><th>Port 1</th><th>Port 2</th><th>Port 3</th><th>Port 4</th><th>Port5</th><th>Port 6</th><th>Port 7</th><th>Port 8</th></tr>
<tr><td>Index 9</td><td>224.0.1.1</td><td>01005E000001</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Set the multicast address upon which to filter for the 9th entry in the table.<br>
<code>snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAddress.9 x 01005E000001</code><br><br>
This multicast address is <code>AllowedToGoTo</code> the specified ports.<br>
<code>snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.9 x 01</code><br><br>
If port 1 has a multicast filter setting:
<ul>
<li>Allowed: All Ethernet frames including those with this multicast address are forwarded to port 1 and allowed to pass through.</li>
<li>Blocked: All Ethernet frames including those with this multicast address are forwarded to port 1 but are blocked and do not pass through.</li>
<li>PassFilter: Ethernet frames with this multicast address are forwarded to port 1 and allowed to pass through.</li>
<li>RejectFilter: Ethernet frames with this multicast address are forwarded to port 1 but are rejected and do not pass through the filter.</li>
</ul>
If port 2 has a multicast filter setting
<ul>
<li>Allowed: All Ethernet frames including those with this multicast address are forwarded to port 2 and allowed to pass through.</li>
<li>Blocked: All Ethernet frames including those with this multicast address are forwarded to port 2 but are blocked and do not pass through.</li>
<li>PassFilter: Ethernet frames with this multicast address are forwarded to port 2.</li>
<li>RejectFilter: Ethernet frames with this multicast address are forwarded to port 2.</li>
</ul>
This same interpretation can be applied to each of the ports on the switch.
</td></tr>
<tr><td>Index entry 10</td><td>
<table>
<tr><th></th><th>Destination IP</th><th>Destination MAC</th><th>Port 1</th><th>Port 2</th><th>Port 3</th><th>Port 4</th><th>Port5</th><th>Port 6</th><th>Port 7</th><th>Port 8</th></tr>
<tr><td>Index 10</td><td>224.0.1.2</td><td>01005E000002</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
<code>snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAddress.10 x 01005E000001</code><br><br>
<code>snmpset.exe -v2c -c public 192.168.1.1 .iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.10 x 02</code>
</td></tr>
</table>

Table 42-13: Setting the multicast address filter (continued)

**Index entry 11**

| | Destination IP | Destination MAC | Port 1 | Port 2 | Port 3 | Port 4 | Port5 | Port 6 | Port 7 | Port 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Index 11** | 224.0.1.3 | 01005E000003 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

```
snmpset.exe -v2c -c public 192.168.1.1
.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTabl
e.dot1dStaticEntry.dot1dStaticAddress.11 x 01005E000003

snmpset.exe -v2c -c public 192.168.1.1
.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTabl
e.dot1dStaticEntry.dot1dStaticAllowedToGoTo.11 x 04
```

**Index entry 12**

| | Destination IP | Destination MAC | Port 1 | Port 2 | Port 3 | Port 4 | Port5 | Port 6 | Port 7 | Port 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Index 12** | 224.0.1.4 | 01005E000004 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

```
snmpset.exe -v2c -c public 192.168.1.1
.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTabl
e.dot1dStaticEntry.dot1dStaticAddress.12 x 01005E000004

snmpset.exe -v2c -c public 192.168.1.1
.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTabl
e.dot1dStaticEntry.dot1dStaticAllowedToGoTo.12 x 08
```

**Index entry 13**

| | Destination IP | Destination MAC | Port 1 | Port 2 | Port 3 | Port 4 | Port5 | Port 6 | Port 7 | Port 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Index 13** | 224.0.1.5 | 01005E000005 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

```
snmpset.exe -v2c -c public 192.168.1.1
.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTabl
e.dot1dStaticEntry.dot1dStaticAddress.13 x 01005E000005

snmpset.exe -v2c -c public 192.168.1.1
.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTabl
e.dot1dStaticEntry.dot1dStaticAllowedToGoTo.13 x 10
```

### Resetting filter multicast entries

To clear the multicast filter associated with a given port, the `dot1dStaticStatus` variable in the dot1dStatic is used.

OID: `1.3.6.1.2.1.17.5.1.1.4`

Path: `iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.dot1dStaticTable.dot1dStaticEntry.dot1dStaticStatus`

The `dot1dStaticStatus` variable may be set to the following values:

- `Other (1)`: This entry is currently in use but the conditions under which it remains so are different from each of the following values.
- `Invalid (2)`: Writing this value to the object removes the corresponding entry.
- `Permanent (3)`: This entry is currently in use and remains so after the next reset of the bridge.
- `deleteOnReset (4)`: This entry is currently in use and remains so until the next reset of the bridge.
- `deleteOnTimeout (5)`: This entry is currently in use and remains so until it is aged out.

This object indicates the status of this entry. The default value is `permanent (3)`.

To remove the Nth entry in the table:

1. Set the `AllowedToGoTo` variable to `0xFF`.

```
snmpset.exe-v2c-cpublic192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.do
t1dStaticTable.dot1dStaticEntry.dot1dStaticAllowedToGoTo.N x FF
```

2. Change the status of the entry to `invalid.`
   This effectively removes the entry.

```
snmpset.exe-v2c-cpublic192.168.1.1.iso.org.dod.internet.mgmt.mib-2.dot1dBridge.dot1dStatic.do
t1dStaticTable.dot1dStaticEntry.dot1dStaticStatus.N i 2
```

## 42.5 Appendix: Xbar connection SNMP variables

The connection settings of the Ethernet ports on the Xbar switch are accessed and modified using the connectionTable subtree in the Acra MIB, see the following table.

The full OID path to the connectionTable is given as:

| iso | org | dod | internet | private | enterprises | acra | connection | connection Table |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 1 | 14 |

The format of this table structure comprises a sequence of connectionEntries where each entry is identified by an index and has a number of settings such as connectionSpeed and connectionFilter settings associated with it as shown in the following table.

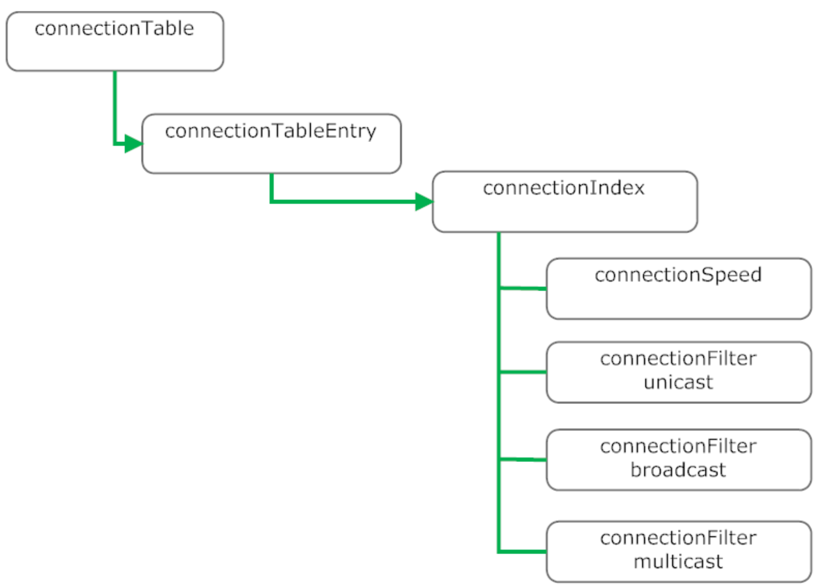



*Figure 42-5: connectionTable subtree*

#### 42.5.0.1 Connection speed

The speed at which each port operates can be specified using the `connectionSpeed` variable. The allowed values for the connection speed are {10, 100, 1000, Auto} in megabits per second (Mbps). The speed is described by the SNMP OID variable contained in the Acra MIB:

OID:`.1.3.6.1.4.1.33698.14.1.1.2`

Path:`.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry .connectionSpeed`

| iso | org | dod | internet | private | enterprises | acra | connection | connection Table | connection Entry | connection Speed |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 14 | 1 | 1 | 2 |

#### 42.5.0.2 Unicast filter

The unicast filter is described by the SNMP OID variable contained in the Acra MIB:

OID:.1.3.6.1.4.1.33698.14.1.1.3

Path:.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterUnicast

| iso | org | dod | internet | private | enterprises | acra | connection | connectionTable | connectionEntry | connectionFilterUnicast |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 14 | 1 | 1 | 3 |

#### 42.5.0.3 Broadcast filter

The broadcast filter is described by the SNMP OID variable contained in the Acra MIB:

OID:.1.3.6.1.4.1.33698.14.1.1.4

Path:.iso.org.dod.internet.private.enterprises.acra.connection.connectionTable.connectionEntry.connectionFilterBroadcast

| iso | org | dod | internet | private | enterprises | acra | connection | connectionTable | connectionEntry | connectionFilterBroadcast |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 6 | 1 | 4 | 1 | 33698 | 14 | 1 | 1 | 4 |

### 42.5.1 Connection table MIB listing

The Acra MIB detail for the connectionTable is listed below.
For more details on how to read the SNMP MIB see *TEC/NOT/058 - Overview of SNMP and using third party SNMP tools.*

```
connectionTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF ConnectionEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "Control each ethernet connection to the module"
        ::= { connection 1 }

connectionEntry OBJECT-TYPE
    SYNTAX      ConnectionEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "Settings for one ethernet connection on the module"
    INDEX { connectionIndex }
        ::= { connectionTable 1 }

ConnectionEntry ::= SEQUENCE {
        connectionIndex
            INTEGER,
        connectionSpeed
            Integer32,
        connectionFilterUnicast
            INTEGER,
        connectionFilterBroadcast
            INTEGER,
        connectionFilterMulticast
            INTEGER
        }

connectionIndex OBJECT-TYPE
    SYNTAX      INTEGER (1..255)
    MAX-ACCESS  read-only
```

```
    STATUS      current
    DESCRIPTION
        "Index of the connection"
        ::= { connectionEntry 1 }

connectionSpeed OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Set the interface speed. 0=Autonegotiate, 10=10BaseT,
         100=100BaseTX, 1000=Gigabit"
        ::= { connectionEntry 2 }

connectionFilterUnicast OBJECT-TYPE
    SYNTAX      INTEGER {
                          Allowed (0),
                          Blocked (1),
                          PassFilter (2),
                          RejectFilter (3)
                        }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
      "Specifies whether unicast traffic is allowed at this output.
       Allowed (0) means all unicast packets are allowed out of this
           connection.
       Blocked (1) means that no unicast packets are allowed out of this
           connection.
       PassFilter (2) means that the only unicast packets allowed out of
           this connection are those whose destination MAC is in the
           dot1dStatic table, with a '1' for this connection in the
           AllowedToGoTo value.
       RejectFilter (3) means that all unicast packets are allowed out of
           this connection EXCEPT those whose destination MAC is in the
           dot1dStatic table, with a '1' for this connection in the
           AllowedToGoTo value.
       This does not affect unicast packets arriving at this connection. Such
       packets can be forwarded to other outputs, subject to routing defined
       in the dot1dStaticAddress array, regardless of this setting."
    ::= { connectionEntry 3 }

connectionFilterBroadcast OBJECT-TYPE
    SYNTAX      INTEGER {
                          Allowed (0),
                          Blocked (1),
                          PassFilter (2),
                          RejectFilter (3)
                        }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
      "Specifies whether broadcast traffic is allowed at this output.
       Allowed (0) means all broadcast packets are allowed out of this
           connection.
```

```
        Blocked (1) means that no broadcast packets are allowed out of this
            connection.
        PassFilter (2) means that the only broadcast packets allowed out of
            this connection are those whose destination MAC is in the
            dot1dStatic table, with a '1' for this connection in the
            AllowedToGoTo value.
        RejectFilter (3) means that all broadcast packets are allowed out of
            this connection EXCEPT those whose destination MAC is in the
            dot1dStatic table, with a '1' for this connection in the
            AllowedToGoTo value.
        This does not affect broadcast packets arriving at this connection.
        Such packets can be forwarded to other outputs, subject to routing
        defined in the dot1dStaticAddress array, regardless of this setting."
    ::= { connectionEntry 4 }

connectionFilterMulticast OBJECT-TYPE
    SYNTAX      INTEGER {
                          Allowed (0),
                          Blocked (1),
                          PassFilter (2),
                          RejectFilter (3)
                        }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
      "Specifies whether multicast traffic is allowed at this output.
        Allowed (0) means all multicast packets are allowed out of this
            connection.
        Blocked (1) means that no multicast packets are allowed out of this
            connection.
        PassFilter (2) means that the only multicast packets allowed out of
            this connection are those whose destination MAC is in the
            dot1dStatic table, with a '1' for this connection in the
            AllowedToGoTo value.
        RejectFilter (3) means that all multicast packets are allowed out of
            this connection EXCEPT those whose destination MAC is in the
            dot1dStatic table, with a '1' for this connection in the
            AllowedToGoTo value.
        This does not affect multicast packets arriving at this connection.
        Such packets can be forwarded to other outputs, subject to routing
        defined in the dot1dStaticAddress array, regardless of this setting."
         ::= { connectionEntry 5 }
```

## 42.6 Recommended reading

To better understand this paper, read the following documents.

Table 42-14: Data sheets

| Document | Description |
|---|---|
| NET/SWI/003 | 8-port Gigabit Ethernet switch with configurable static forwarding and filtering. |
| NET/SWI/005 | 16-port Gigabit Ethernet switch with configurable static forwarding and filtering. |

Table 42-15: Technical notes

| Document | Description |
|---|---|
| *TEC/NOT/058* | *Overview of SNMP and using third party SNMP tools.* |

Chapter 43

# Using the KAD/DSI/003/B

TEC/NOT/071

The KAD/DSI/003/B can monitor up to 24 differential or single ended discrete channels. The first eight of these channels can be programmed as special function counters while the remaining 16 channels can be used to trigger time-tagged events.

This technical note describes how to set up the KAD/DSI/003/B, including details of counter settings and event tagging options and is divided into the following sections:

## 43.1 Physical interface details



The KAD/DSI/003/B has 24 channels, which can be divided into 8 counter channels and 16 trigger time-tagged events. As shown in the following figure, the first eight input channels (channel 0 to channel 7) can be used as programmable counters. See "43.3 Channels 0 to 7 - counter channels" on page 361 for further details.

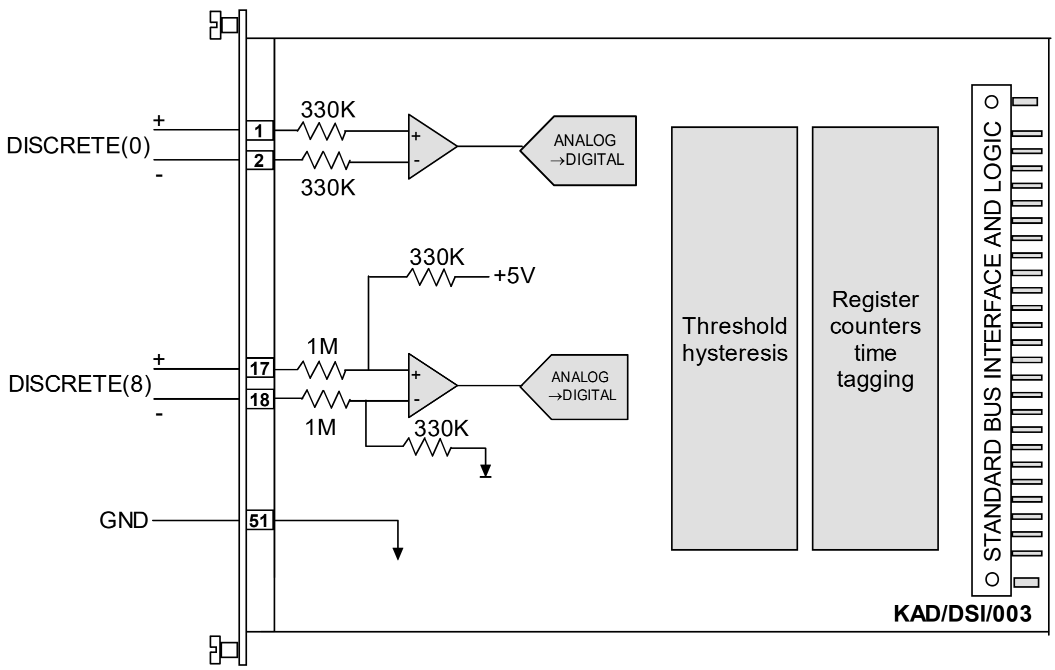



*Figure 43-1: First of eight counter inputs and first of sixteen discrete inputs*

The remaining 16 channels (channel 8 to channel 23) can be used to trigger time-tagged events and control time tagging to the 8K FIFO (First Input First Output).

## 43.2 Thresholds and hysteresis

The KAD/DSI/003/B uses upper and lower threshold voltages to achieve hysteresis. Without hysteresis, noisy signals are more prone to create spurious events as shown in the following figure.

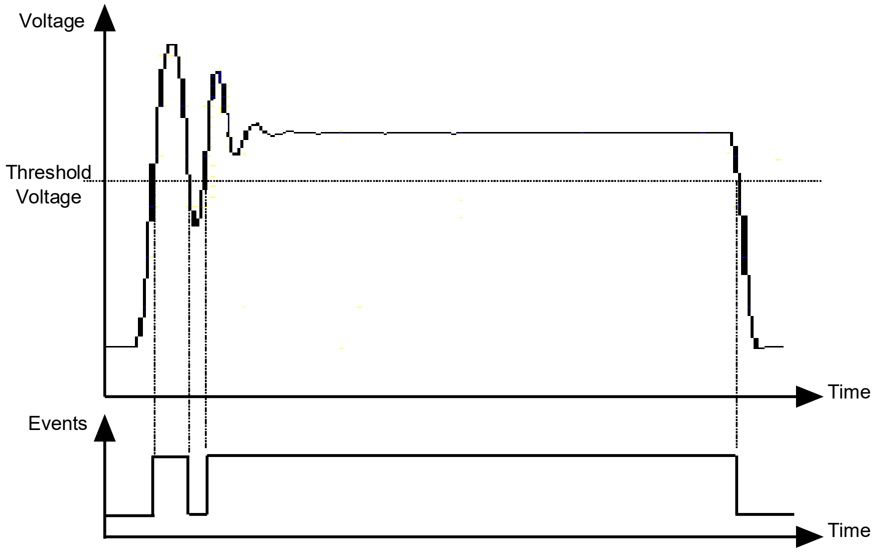



*Figure 43-2: Noisy signal creating spurious events*

However, by using an upper and lower threshold, these spurious events can be removed as shown in the following figure.

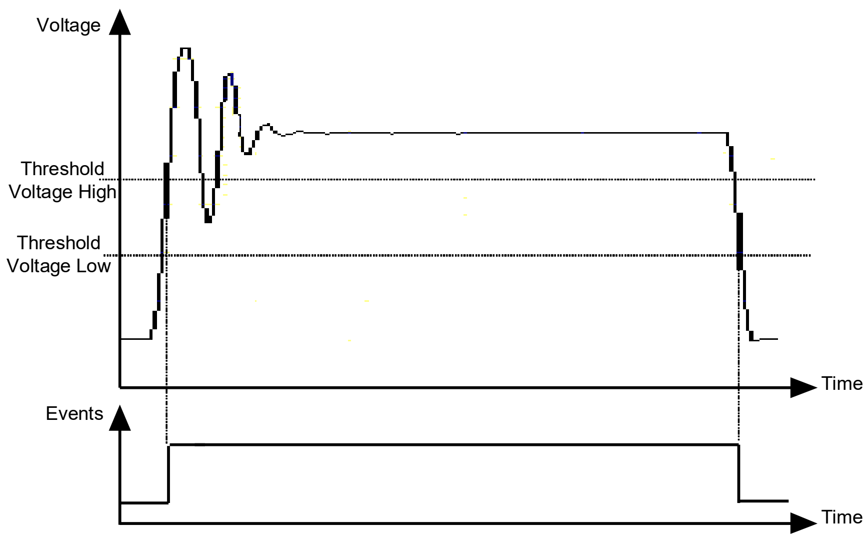



*Figure 43-3: Hysteresis prevents spurious events*

## 43.2.1 Event edge detection

When a channel is enabled and thresholds are set by the user, three types of edge detection for events are available: falling, rising, or both. The following figure shows how signal edge detection works.

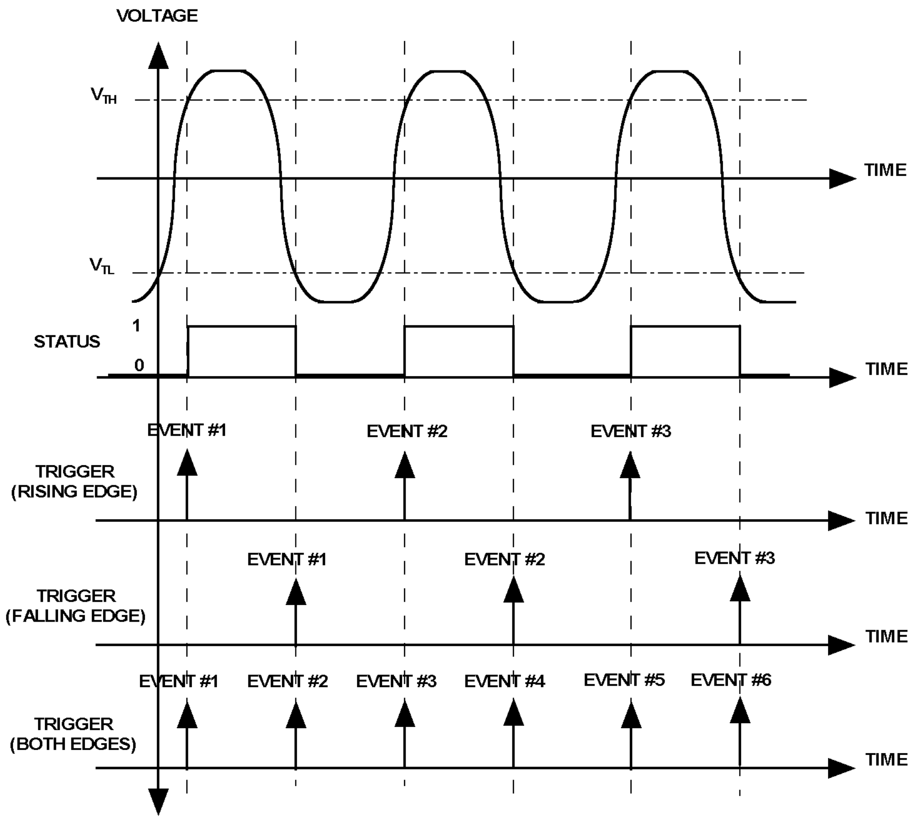



*Figure 43-4: Signal edge detection*

# 43.3 Channels 0 to 7 - counter channels

The first eight channels of the KAD/DSI/003/B are connected to special function registers, which can be configured on a channel-by-channel basis.

The frequency range of the counter channels is 0 kHz to 50 kHz. Refer to the *KAD/DSI/003/B* data sheet for further details.

## 43.3.1 Counter channel interface details

The first 8 channels (channel 0 to 7) have a physical interface as shown in the following figure.

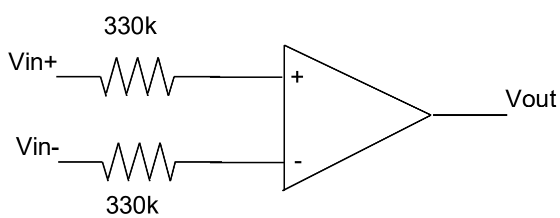



*Figure 43-5: Physical interface of channels 0 to 7*

The threshold voltages for the counter channels require no special formulas; ($V_{out}$ = $V_{in}$ + - Vin-); desired thresholds are entered into the setup software.

## 43.3.2 Channels 0 to 7 - Counter channel settings in KSM-500

The following figure shows how the registers for counter channels can be set up in KSM-500.

| Parameter Name | Mode | Type | Edge | Setting | Size | Rollover | Threshold Min(V) | Threshold Max(V) |
|---|---|---|---|---|---|---|---|---|
| * | * | * | * | * | * | * | * | * |
| DSI3_0_J5_CNT0_HI | COUNTER_0_HI | PERIOD | Rising | 10us | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT0_LO | COUNTER_0_LO | PERIOD | Rising | 10us | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT1_HI | COUNTER_1_HI | FREQUENCY | Rising | 1s | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT1_LO | COUNTER_1_LO | FREQUENCY | Rising | 1s | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT2_HI | COUNTER_2_HI | EVENTS_SINCE | Rising | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT2_LO | COUNTER_2_LO | EVENTS_SINCE | Rising | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT3_HI | COUNTER_3_HI | ELAPSED | Rising | 80us | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT3_LO | COUNTER_3_LO | ELAPSED | Rising | 80us | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT4_HI | COUNTER_4_HI | READ | N/A | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT4_LO | COUNTER_4_LO | READ | N/A | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT5_HI | COUNTER_5_HI | EVENTS | Rising | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT5_LO | COUNTER_5_LO | EVENTS | Rising | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT6_HI | COUNTER_6_HI | RESET | Rising | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT6_LO | COUNTER_6_LO | RESET | Rising | N/A | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT7_HI | COUNTER_7_HI | PERIOD | Rising | 20us | 32bit | YES | -10 | 10 |
| DSI3_0_J5_CNT7_LO | COUNTER_7_LO | PERIOD | Rising | 20us | 32bit | YES | -10 | 10 |

*Figure 43-6: DSI/003/B Parameter tab - counter settings in KSM-500*

Each counter type has some common settings, which are explained below.

### 43.3.2.1 Type

Seven counter types are available in KSM-500: PERIOD, FREQUENCY, EVENTS_SINCE, ELAPSED, READ, EVENTS, and RESET.

### 43.3.2.2 Edge

The counters can be configured to trigger on either Rising or Falling edges of input signals, or Both (rising and falling).

**NOTE:** In modes such as Frequency mode, the counter Trigger Edge set to Both, results in the values counted being doubled. The Both setting may be desirable when increasing the resolution of the frequency measurement by a factor of two.

### 43.3.2.3 Setting

Defines the clock period for a counter, if appropriate for the counter type.

### 43.3.2.4 Size

The counter channels can be 10, 12, 16, 20, 24, or 32 bits wide.

Each counter is divided in two registers with a maximum of 16 bits each: COUNTER_HI and COUNTER_LO.

**NOTE:** If the size is greater than 16 bits, then the COUNTER_HI register is used in addition to the COUNTER_LO register.

### 43.3.2.5 Rollover

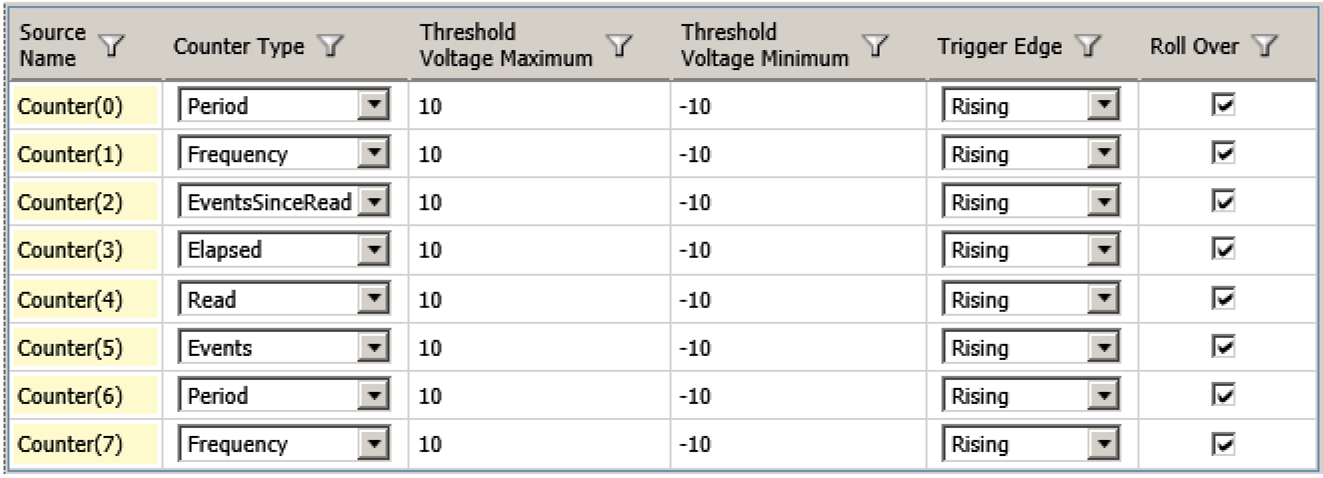
Determines whether the counter rolls over to zero when the maximum value is reached.

### 43.3.2.6 Threshold Max and Min

Determines the maximum and minimum threshold which are programmable. Threshold allowable levels are -10V to +10V. Refer to the *KAD/DSI/003/B* data sheet for further details.

## 43.3.3 Channels 0 to 7 - counter channel settings in DAS Studio 3

With a KAD/DSI/002 module in context, the Settings tab in DAS Studio 3 shows four panes. The following figure shows the pane for programming counter types and thresholds.



| Source Name | Counter Type | Threshold Voltage Maximum | Threshold Voltage Minimum | Trigger Edge | Roll Over |
|---|---|---|---|---|---|
| Counter(0) | Period | 10 | -10 | Rising | ☑ |
| Counter(1) | Frequency | 10 | -10 | Rising | ☑ |
| Counter(2) | EventsSinceRead | 10 | -10 | Rising | ☑ |
| Counter(3) | Elapsed | 10 | -10 | Rising | ☑ |
| Counter(4) | Read | 10 | -10 | Rising | ☑ |
| Counter(5) | Events | 10 | -10 | Rising | ☑ |
| Counter(6) | Period | 10 | -10 | Rising | ☑ |
| Counter(7) | Frequency | 10 | -10 | Rising | ☑ |

*Figure 43-7: Counter type settings in DAS Studio 3*

Channel 0 to 7 can be programmed with the same settings as KSM-500.

Each counter type has some common settings, which are explained below.

### 43.3.3.1 Counter Type

Six counter types are available in DAS Studio 3: Period, Frequency, Elapsed, EventsSinceRead, Events, and Read.

---

**NOTE:** The *Reset* Counter Type counter is not supported in DAS Studio 3.

### 43.3.3.2 Threshold Voltage Maximum/Minimum

Determines the maximum and minimum threshold, which are programmable. Threshold allowable levels are -10V to +10V. Refer to the *KAD/DSI/003/B* data sheet for further details.

### 43.3.3.3 Trigger Edge

The counters can be configured to trigger on either Rising or Falling edges of input signals, or Both (rising and falling).

---

**NOTE:** In modes such as Frequency mode, the counter Trigger Edge set to Both, results in the values counted being doubled. The Both setting may be desirable when increasing the resolution of the frequency measurement by a factor of two.

### 43.3.3.4 Rollover

Determines whether the counter rolls over to zero when the maximum value is reached.

The following figure shows the pane on the Settings tab that is used to program the counter range.

| Source Name | Parameter Type | Parameter Name | Range Maximum | Range Minimum |
|---|---|---|---|---|
| Counter(0) | Counter(0) | P_MyKAD_DSI_003_B_Counter(0) | 42949.67296 | 0 |
| Counter(0) | Counter(0) : CounterLo(0) | | | |
| Counter(0) | Counter(0) : CounterHi(0) | | | |
| Counter(1) | Counter(1) | P_MyKAD_DSI_003_B_Counter(1) | 42949672960 | 0 |
| Counter(1) | Counter(1) : CounterLo(1) | | | |
| Counter(1) | Counter(1) : CounterHi(1) | | | |
| Counter(2) | Counter(2) | P_MyKAD_DSI_003_B_Counter(2) | 4294967296 | 0 |
| Counter(2) | Counter(2) : CounterLo(2) | | | |
| Counter(2) | Counter(2) : CounterHi(2) | | | |
| Counter(3) | Counter(3) | P_MyKAD_DSI_003_B_Counter(3) | 42949.67296 | 0 |
| Counter(3) | Counter(3) : CounterLo(3) | | | |
| Counter(3) | Counter(3) : CounterHi(3) | | | |
| Counter(4) | Counter(4) | P_MyKAD_DSI_003_B_Counter(4) | 4294967296 | 0 |
| Counter(4) | Counter(4) : CounterLo(4) | | | |
| Counter(4) | Counter(4) : CounterHi(4) | | | |
| Counter(5) | Counter(5) | P_MyKAD_DSI_003_B_Counter(5) | 4294967296 | 0 |
| Counter(5) | Counter(5) : CounterLo(5) | | | |
| Counter(5) | Counter(5) : CounterHi(5) | | | |
| Counter(6) | Counter(6) | P_MyKAD_DSI_003_B_Counter(6) | 42949.67296 | 0 |
| Counter(6) | Counter(6) : CounterLo(6) | | | |
| Counter(6) | Counter(6) : CounterHi(6) | | | |
| Counter(7) | Counter(7) | P_MyKAD_DSI_003_B_Counter(7) | 42949672960 | 0 |
| Counter(7) | Counter(7) : CounterLo(7) | | | |
| Counter(7) | Counter(7) : CounterHi(7) | | | |

*Figure 43-8: Counter range settings in DAS Studio 3*

In DAS Studio 3, the registers for the counter channels are by default 32 bits and—as many other registers bigger than 16 bits—can be optionally split into 2 x 16-bit registers called Counter_HI and Counter_LO. If only Counter_LO is transmitted, the counter size is automatically set to 16 bits, whereas if the full 32-bit counter is transmitted, DAS Studio 3 sets the counter size to 32 bits.

In DAS Studio 3, setting up a clock frequency is not required; allowed frequency ranges are automatically displayed.

The Maximum and Minimum range settings in this block are chosen from a drop-down menu, while values are predetermined by the counter type (such as frequency and period) used in the previous section of this document. The frequency counter range is expressed in Hertz, while period counter is expressed in seconds.

Some Counter types such as Read have no Max/Min range settings. The following section explains how the values available in the range's drop-down menus are calculated.

# 43.4 Counter types

## 43.4.1 Counting events – Frequency counter

In Frequency mode operation, the number of events in a specified time interval are counted.

The formula to calculate the input frequency is:

$$Fin = counts \times \; F\_clk$$

Proper use of the Frequency and Period counters can maximize the resolution of the measurement being undertaken. As a general rule, Period is used for slower signals and Frequency for faster signals.

The sampling rate for Period and Frequency counters is only relevant for monitoring purposes. The sampling rate should be high enough to ensure that any event can be observed, while the maximum update rate is 1 Hz.

#### 43.4.1.1 Example of Frequency counter in KSM-500

Refer to the following table for Frequency counter settings.

| Type | Edge | Setting | Size | Fs (sampling frequency) |
|---|---|---|---|---|
| FREQUENCY | RISING | 1 second | 16 bits | 1000 sps |

Measuring input frequency of ($F_{in}$) = 100 Hz

In this case, events that occur at 100 Hz (10 ms) are counted for a duration of 1s.

Hence 100 counts result in: ($F_{in}$ = 100 / Flck = 1 sec)

#### 43.4.1.2 Frequency counter settings in DAS Studio 3

In DAS Studio 3, the Frequency counter is fixed at 32 bits and offers five ranges which correspond to the following clock setting intervals.

| Module level setting | | DAS Studio 3 setting | | | |
|---|---|---|---|---|---|
| Type | Interval setting | Required unit | Bits | Max range | Min range |
| FREQUENCY | 100 ms | HERTZ | 32 | 42949672960 | 0 |
| | 250 ms | HERTZ | 32 | 17179869184 | 0 |
| | 500 ms | HERTZ | 32 | 8589934592 | 0 |
| | 1s | HERTZ | 32 | 4294967296 | 0 |
| | 2s | HERTZ | 32 | 2147483648 | 0 |

A range of 2147483648 (2 seconds internal clock setting) offers the best resolution with 2 counts/Hertz making it a suitable counter for high frequency signals.

### 43.4.2 Counting events – Events counter

In the EVENTS mode of operation, the EVENTS register increments every time an event occurs and rolls over.

There is no clock setting required for the EVENTS mode of operation.

#### 43.4.2.1 Example of Events counter in KSM-500

Refer to the following table for Events counter settings.

| Type | Edge | Setting | Size | Fs (sampling frequency) |
|---|---|---|---|---|
| EVENTS | RISING | N/A | 16 bits | 1000 sps |

Measuring input frequency of ($F_{in}$) = 100 Hz

The EVENTS register increments every time an event occurs, in this case at 100 Hz.

Expected output = output incrementing at 100 counts/second

#### 43.4.2.2 Events counter settings in DAS Studio 3

There are no range settings in DAS Studio 3.

## 43.4.3 Counting events – Events_Since counter

In the EVENTS_SINCE mode of operation, all events are counted since the EVENTS_SINCE register was last read. In other words, when EVENTS_SINCE is read, the register resets it to 0, and then it increments every time an edge is detected until it is read again.

The formula to calculate the input frequency is:

F_in = counts x Fs

### 43.4.3.1 Example of EVENTS SINCE counter in KSM-500

Refer to the following table for EVENTS SINCE counter settings.

| Type | Edge | Setting | Size | Fs (sampling frequency) |
|---|---|---|---|---|
| EVENTS_SINCE | RISING | N/A | 16 bits | 1000 sps |

Measuring input frequency of (Fin) = 10 kHz

In this case, the EVENTS SINCE register is read at $F_s$ = 1000 sps (1 ms = 1000 µs). With events occurring at 10 kHz (100 µs), the EVENTS SINCE register reads 10 counts.

### 43.4.3.2 Events since counter/EventsSinceRead settings in DAS Studio 3

In DAS Studio 3, this register is called EventsSinceRead and has the following fixed range settings.

| Module level setting | | DAS Studio 3 setting | | | |
|---|---|---|---|---|---|
| **Type** | **Interval setting** | **Required unit** | **Bits** | **Max range** | **Min range** |
| EVENTS_SINCE | N/A | COUNTS | 32 | 4294967296 | 0 |

## 43.4.4 Counting time – Period counter

In the PERIOD counter mode of operation, an internal clock measures the time (clock ticks) between events and returns the number of clock ticks between edges.

The Period counter is typically used for measuring relatively low frequency pulse trains (for example, the 1pps output of a GPS).

The formula to calculate the input period is:

Pin = counts x P_clk

### 43.4.4.1 Example of PERIOD counter in KSM-500

Refer to the following table for PERIOD counter settings.

| Type | Edge | Setting | Size | Fs (sampling frequency) |
|---|---|---|---|---|
| PERIOD | RISING | 10 µs | 16 bits | 1000 sps |

Measuring input frequency of 100 Hz (PERIOD = 10 ms)

In this case, events occur at 100 Hz (10 ms) while the time between events is measured in units of 10 µs.

Hence 1000 counts are expected ($P_{in}$ = 10 ms / Plck = 0.01 ms)

#### 43.4.4.2 Period counter settings in DAS Studio 3

In DAS Studio 3, the Period counter is fixed at 32 bits and offers four ranges, which correspond to the following clock setting intervals.

| Module level setting | | DAS Studio 3 setting | | | |
|---|---|---|---|---|---|
| **Type** | **Interval setting** | **Required unit** | **Bits** | **Max range** | **Min range** |
| PERIOD | 10 µs | SECONDS | 32 | 42949.67296 | 0 |
| | 20 µs | SECONDS | 32 | 85899.34592 | 0 |
| | 40 µs | SECONDS | 32 | 171798.6918 | 0 |
| | 80 µs | SECONDS | 32 | 343597.3837 | 0 |

### 43.4.5 Counting time – ELAPSED

In the ELAPSED mode of operation, an internal clock measures the time between the last event and the current read of the ELAPSED register. In other words, the value of this register represents the number of ticks between samples.

---

**NOTE:** The EVENTS_SINCE and ELAPSED counters can be used to measure acceleration.

#### 43.4.5.1 Example of ELAPSED counter in KSM-500

Refer to the following table for ELAPSED counter settings.

| Type | Edge | Setting | Size | Fs (sampling frequency) |
|---|---|---|---|---|
| ELAPSED | RISING | 10 µs | 16 bits | 1000 sps |

Measuring input frequency of (Fin) = 10 kHz

In this case, events occur at 10 kHz (100 µs). Hence the time between the last event and the current read of the ELAPSED register is 0 to 100 µs. As the duration is measured in increments of 10 µs, then the ELAPSED register reads anything between 0 and 10.

Expected Output = a value between 0 and 10 counts

#### 43.4.5.2 Elapsed settings in DAS Studio 3

In DAS Studio 3 the ELAPSED counter is fixed at 32 bits and offers four ranges, which correspond to the following clock setting intervals.

| Module level setting | | DAS Studio 3 setting | | | |
|---|---|---|---|---|---|
| **Type** | **Interval setting** | **Required unit** | **Bits** | **Max range** | **Min range** |
| ELAPSED | 10 µs | SECONDS | 16 | 0.65536 | 0 |
| | 20 µs | SECONDS | 16 | 1.31072 | 0 |
| | 40 µs | SECONDS | 16 | 2.62144 | 0 |
| | 80 µs | SECONDS | 16 | 5.24288 | 0 |

### 43.4.6 Counting samples – Read

This counter increments every time it is sampled. There are no software settings for this register.

**NOTE:** The Read counter is useful in a telemetry application in a PCM frame as a minor frame counter. For example, if a 32-bit READ counter is read once per 1 ms major frame, then it can act as a major frame counter that cycles every 49.7 days (= 232 × 1 ms).

### 43.4.7 Counting samples - Event with Reset counter (KSM-500 only)

This counter acts as a reset input to the next counter. On detection of an event, the RESET counter increments and resets the next counter to 0. Channels 0, 2, 4, and 6 can be configured as Reset counters meaning that an event on a Reset channel resets the counter on the next channel. To do this, the next counter must be set to EVENT type.

For example:

- Reset Event on Channel 0 increments Counter 0 and resets Counter 1
- Reset Event on Channel 2 increments Counter 2 and resets Counter 3
- Reset Event on Channel 4 increments Counter 4 and resets Counter 5
- Reset Event on Channel 6 increments Counter 6 and resets Counter 7

There is no setting required for the RESET mode of operation.

The following figure shows the effect of a Reset counter on channel 0 configured for a rising edge trigger on a Read counter on channel 1.

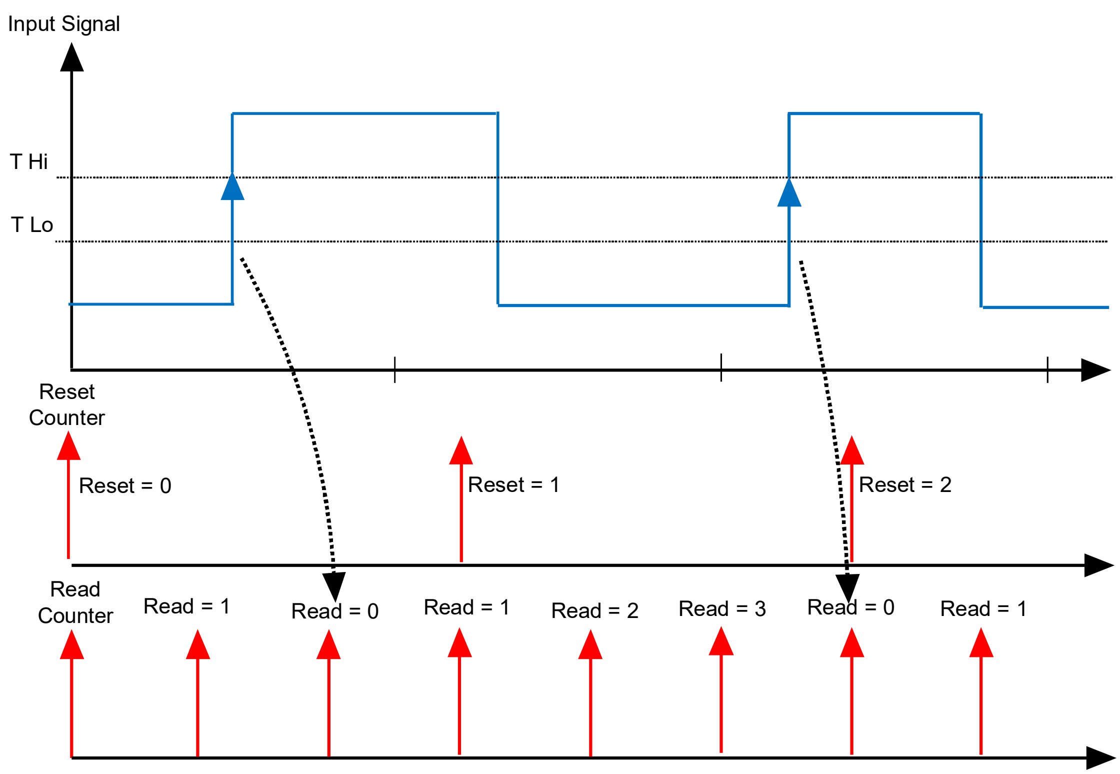



*Figure 43-9: Sample operation of the Reset counter*

**NOTE:** The RESET counter is implemented in KSM-500 only.

## 43.5 Discrete channels

Channels 8 through 23 of the KAD/DSI/003/B are discrete channels, which are used to measure simple on/off events. These events can be time tagged with microsecond time and sent to an 8K word FIFO for subsequent reading.

The TAG_EVENT_STATUS register gives the status of the 16 discrete channels at a particular instant in time.

## 43.5.1 Discrete channel interface details

The last 16 channels (channel 8 to 23) have a physical interface as shown in the following figure.

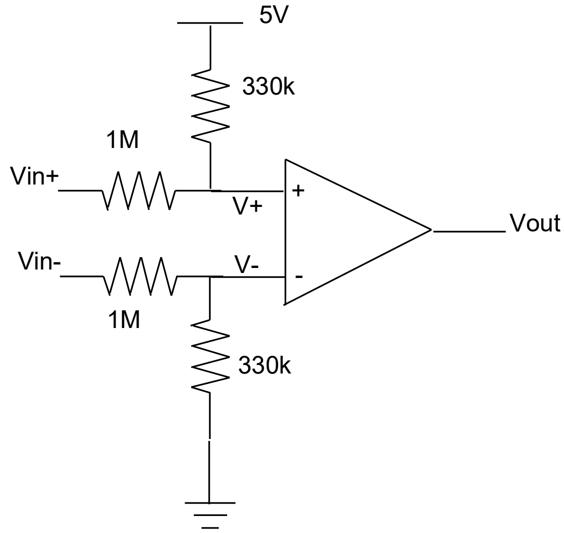



*Figure 43-10: Physical interface of channels 8 to 23*

### 43.5.1.1 Setting discrete channel threshold voltages

The required threshold voltages (Vout) can be calculated as follows:

The output value is: Vout = V(+) - V(-)

$$V_{+} = \frac{(V_{in+} * 330k\Omega + 5 * 1M\Omega M}{1M\Omega + 330k\Omega}$$

$$V- = \frac{(V_{in-} * 330k\Omega 3}{1M\Omega + 330k\Omega}$$

$$V_{out} = Vth = V_{+} - V_{-} = \frac{(V_{in+} - V_{in-}) * 330k\Omega}{1330k\Omega} + 5 * \frac{1000k\Omega}{1330k\Omega}$$

### 43.5.1.2 Floating Inputs Counter channels - Ch 0 to Ch 7

As per Figure 43-5 on page 361, floating Inputs on these channels could be pulled to either rail.

### 43.5.1.3 Inputs Discrete channels - Ch 8 to Ch 23

With DISCRETE(+) disconnected, then V+ is pulled to +5V.

With DISCRETE(-) disconnected, then V- is pulled to GND.

In order to achieve floating inputs to give logic 0, the threshold values must be set as follows:

5.5V < VTHL < 10V

VTHL < VTHH

See “43.6 Discrete channel wiring options” on page 374 for further details on wiring options.

## 43.5.2 Channels 8 to 23 - discrete channel settings in KSM-500

The following figure illustrates the setup of the KAD/DSI/003/B discrete channels (Ch8 to Ch23) in KSM-500.

Event Tagging

| Channel | Event | Threshold Min(V) | Threshold Max(V) |
|---|---|---|---|
| * | * | * | * |
| CHANNEL_8 | Off | 2 | 10 |
| CHANNEL_9 | Off | 2 | 10 |
| CHANNEL_10 | Armed | 2 | 10 |
| CHANNEL_11 | Off | 2 | 10 |
| CHANNEL_12 | Off | 2 | 10 |
| CHANNEL_13 | Off | 2 | 10 |
| CHANNEL_14 | Armed | 5 | 10 |
| CHANNEL_15 | Off | 5 | 10 |
| CHANNEL_16 | Off | 2 | 10 |
| CHANNEL_17 | Off | 2 | 10 |
| CHANNEL_18 | Off | 2 | 10 |
| CHANNEL_19 | Off | 2 | 10 |
| CHANNEL_20 | Off | 2 | 10 |
| CHANNEL_21 | Off | 2 | 10 |
| CHANNEL_22 | Off | 2 | 10 |
| CHANNEL_23 | Off | 2 | 10 |

*Figure 43-11: Discrete Channel set up in KSM-500*

The discrete channels have the following settings:

### 43.5.2.1 Event

This setting enables/disables a discrete channel. Each channel can be Armed or Off.

---

**NOTE:** Ensure that unused inputs are disabled in order to avoid FIFO overflows due to undesired events when using time tagging events. See “43.7 Using the event FIFO” on page 376 for further details.

### 43.5.2.2 Maximum/Minimum Threshold Voltage

The maximum/minimum threshold voltage allowed for channels 8 to 23 is -55V to 25V respectively.

Refer to the *KAD/DSI/003/B* data sheet for further details.

## 43.5.3 Channels 8 to 23 - Discrete channel settings in DAS Studio 3

The following figure illustrates the setup of the KAD/DSI/003/B discrete channels (Ch8 to Ch23) in DAS Studio 3.

| Source Name | Event Armed | Threshold Voltage Maximum | Threshold Voltage Minimum |
|---|---|---|---|
| Discrete(8) | ☐ | 10 | 2 |
| Discrete(9) | ☐ | 10 | 2 |
| Discrete(10) | ☐ | 10 | 2 |
| Discrete(11) | ☐ | 10 | 2 |
| Discrete(12) | ☐ | 10 | 2 |
| Discrete(13) | ☐ | 10 | 2 |
| Discrete(14) | ☐ | 10 | 2 |
| Discrete(15) | ☐ | 10 | 2 |
| Discrete(16) | ☐ | 10 | 2 |
| Discrete(17) | ☐ | 10 | 2 |
| Discrete(18) | ☐ | 10 | 2 |
| Discrete(19) | ☐ | 10 | 2 |
| Discrete(20) | ☐ | 10 | 2 |
| Discrete(21) | ☐ | 10 | 2 |
| Discrete(22) | ☐ | 10 | 2 |
| Discrete(23) | ☐ | 10 | 2 |

*Figure 43-12: Discrete Channel setup in DAS Studio 3*

The discrete channels have the following settings:

#### 43.5.3.1 Event/Event Armed

This setting enables/disables a discrete channel.

#### 43.5.3.2 Maximum/Minimum Threshold Voltage

The maximum/minimum threshold voltage allowed for channels 8 to 23 is -55V to 25V respectively.

#### 43.5.3.3 Event status and event time tagging

The 16 discrete channels (channel 8 to channel 23) control the time tagging to the 8K FIFO. For each armed (enabled) channel, time tagging can be triggered by an event.

Every time a trigger occurs, a 64-bit event status word that contains the microsecond timestamp of the event, is written to the FIFO.

This timestamping consists of a 48-bit register for time tagging and a 16-bit register to track the state of the 16 discrete inputs (after the change of state). The time tag is the Binary Coded Decimal (BCD) time of when the event happened (up to 23 hours 59 minutes 59.99 9999 seconds).

## 43.5.4 Channels 0 to 23 discrete status with time tagging in KSM-500

All 24 discrete signals corresponding to channel 0 to 23 can be read as a 24-bit words (16-bit + 8-bit or 12-bit + 12-bit).

The discrete channels have common settings, which are explained in the following figure and the table thereafter.

| Parameter Name | Mode | Type | Edge | Setting | Size | Rollover | Threshold Min(V) | Threshold Max(V) |
|---|---|---|---|---|---|---|---|---|
| * | * | * | * | * | * | * | * | * |
| DSI3_ST_LO_12B0_J6 | Status_11_0 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_ST_LO_16B0_J6 | Status_15_0 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_ST_HI_12B0_J6 | Status_23_12 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_ST_HI_8B0_J6 | Status_23_16 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_EV_0_J6_STATUS | TAG_EVENT_STATUS | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_EV_0_J6_HI | TAG_EVENT_TIME_HI | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_EV_0_J6_LO | TAG_EVENT_TIME_LO | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| DSI3_EV_0_J6_MICRO | TAG_EVENT_TIME_MICRO | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

*Figure 43-13: Discrete status parameters with time tagging in KSM-500*

The following STATUS registers are available.

| Register name | Bits | Description |
|---|---|---|
| DSI3_ST_HI_12B0_Jx | 16 | Bit 4 to bit 15 monitors the status (high/low) of channel 12 to channel 23. |
| DSI3_ST_LO_12B0_Jx | 16 | Bit 4 to bit 15 monitors the status (high/low) of channel 0 to channel 11. |
| DSI3_ST_HI_8B0_Jx | 16 | Bit 8 to bit 15 monitors the status (high/low) of channel 16 to channel 23.<br>Note: This register is padded with eight 0s on the LSB side. |
| DSI3_ST_LO_16B0_Jx | 16 | Bit 0 to bit 15 monitors the status (high/low) of channel 0 to channel 15. |

**NOTE:** The 12 + 12 or 16 + 8-bit distribution represents the same information and is supported under KSM-500 due to legacy reasons. All registers can be used at the same time.

Event related registers with timestamp are explained in the following table.

| Register name | Bits | Description |
|---|---|---|
| DSI3_EV_0_Jx_STATUS | 16 | Bit 0 to bit 15 monitors the status (high/low) of channel 8 to channel 23.<br>When the FIFO is empty the last values are repeated. |
| DSI3_EV_0_Jx_HI | 16 | Hours and minutes of the timestamp associated with the DSI3_EV_0_Jx_STATUS event. Refer to the *KAD/DSI/003/B* data sheet for further details. |
| DSI3_EV_0_Jx_LO | 16 | Centiseconds and seconds of the timestamp associated with the DSI3_EV_0_Jx_STATUS event.<br>Refer to the *KAD/DSI/003/B* data sheet for further details. |
| DSI3_EV_0_Jx_MICRO | 16 | Microseconds of the timestamp associated with the DSI3_EV_0_Jx_STATUS event.<br>Refer to the *KAD/DSI/003/B* data sheet for further details. |

**NOTE:** The EVENT TAG register is a 64-bit register split into 4 x16-bit registers above which coherency is guaranteed.

## 43.5.5 Channels 0 to 23 discrete status with time tagging in DAS Studio 3

The discrete channels have common settings, which are explained in the following figure and the table thereafter.

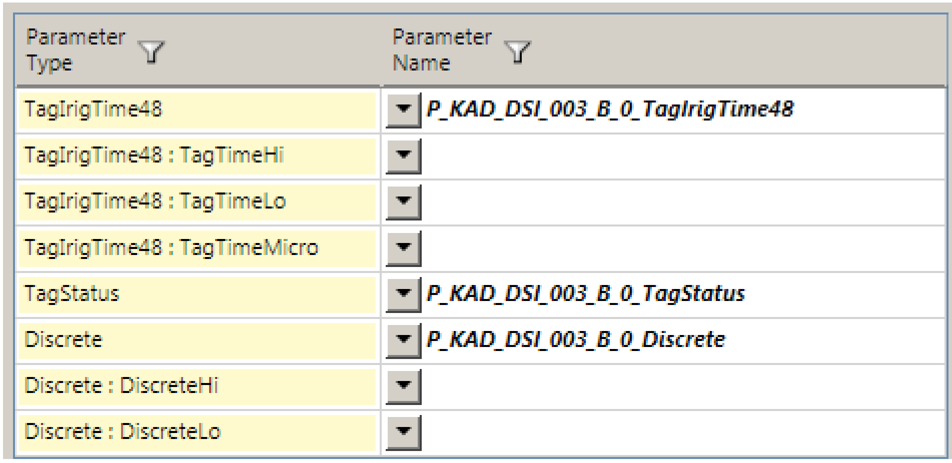



*Figure 43-14: Discrete status parameters with time tagging in DAS Studio 3*

Event related registers with timestamp are explained in the following table.

| Register name | Bits | Description |
|---|---|---|
| TagIrigTime48 | 48 | Time stamp with microsecond resolution of the timestamp associated with the register TagStatus. Contains TagTimeHi + TagTimeLo + TagTimeMicro.<br>This is equivalent to DSI3_EV_HI, DSI3_EV_LO and DSI3_EV_MICRO referred to DSI3_EV_STATUS in KSM-500. |
| TagIrigTime48:TagTimeHi | 16 | Hours and minutes of the timestamp associated with the register TagStatus.<br>This is equivalent to DSI3_EV_HI in KSM-500. |
| TagIrigTime48:TagTimeLo | 16 | Seconds and centiseconds of the timestamp associated with the register TagStatus.<br>This is equivalent to DSI3_EV_LO in KSM-500. |
| TagIrigTime48:TagTimeMicro | 16 | Microseconds of the timestamp associated with the register TagStatus.<br>This is equivalent to DSI3_EV_MICRO in KSM-500. |
| TagStatus | 16 | Bit 0 to bit 15 monitors the status (high/low) of channel 8 to channel 23.<br>When the FIFO is empty the last values are repeated.<br>This is equivalent to DSI3_EV_STATUS in KSM-500. |
| Discrete | 32 | The values of the 24 discrete inputs labeled 23 down to 0.<br>Bit 0 to bit 15 monitors the status (high/low) of channel 0 to channel 15.<br>Bit 24 to bit 31 monitors the status (high/low) of channel 16 to channel 23.<br>Contains the same information as DiscreteHi + DiscreteLo. |
| DiscreteHi | 16 | Bit 8 to bit 15 monitors the status (high/low) of channel 16 to channel 23. |
| DiscreteLo | 16 | Bit 0 to bit 15 monitors the status (high/low) of channel 0 to channel 15. |
| Discrete24Hi | 16 | Discrete24Hi is [15:4] discrete inputs 23 to 12 then [3:0] padded with 0s. |
| Discrete24Lo | 16 | Discrete24Lo is [15:4] discrete inputs 11 to 0 then [3:0] padded with 0s. |

## 43.6 Discrete channel wiring options

For single ended signals, connect to the positive input for each channel. The negative input can be left floating, however it is recommended to tie it to ground (GND).

The following examples illustrate some uses of the KAD/DSI/003/B discrete channels.

### 43.6.1 Detecting a 28V/open signal

The KAD/DSI/003/B discrete channels can be configured to read a 28V/open discrete signal as shown in the following figure.

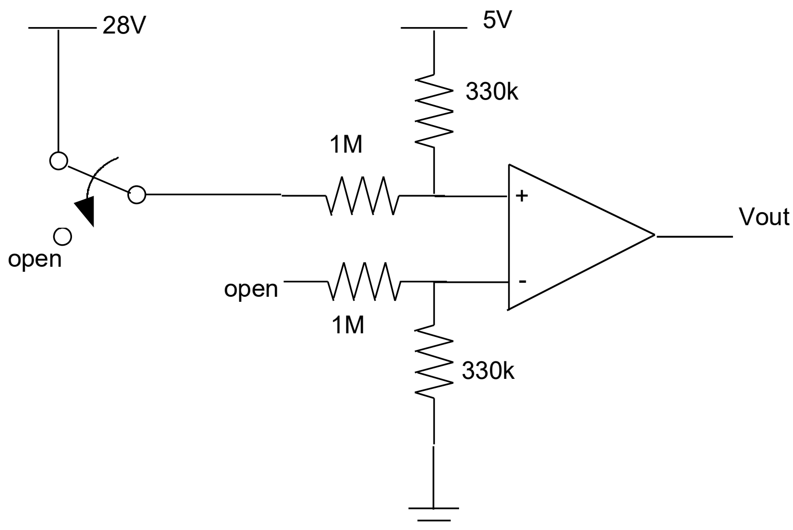



*Figure 43-15: Configuration for detecting a 28V/open signal*

With the Vin- input left floating, the input to the comparator is pulled to GND.

When the Vin+ input is switched to 28V, the input to the comparator is 10.71V. When the Vin+ input is left in the open position, then the input to the comparator is 5V.

The midpoint between these two values is 4.38V, therefore the minimum lower transition should be 4.07V and the maximum upper transition should be 4.69V. That is, in the setup GUI, a minimum threshold of 4.2V and a maximum threshold of 4.6V is reasonable.

### 43.6.2 Detecting 28V/GND signal

The KAD/DSI/003/B discrete channels can be configured to read a 28V/GND discrete signal as shown in the following figure.

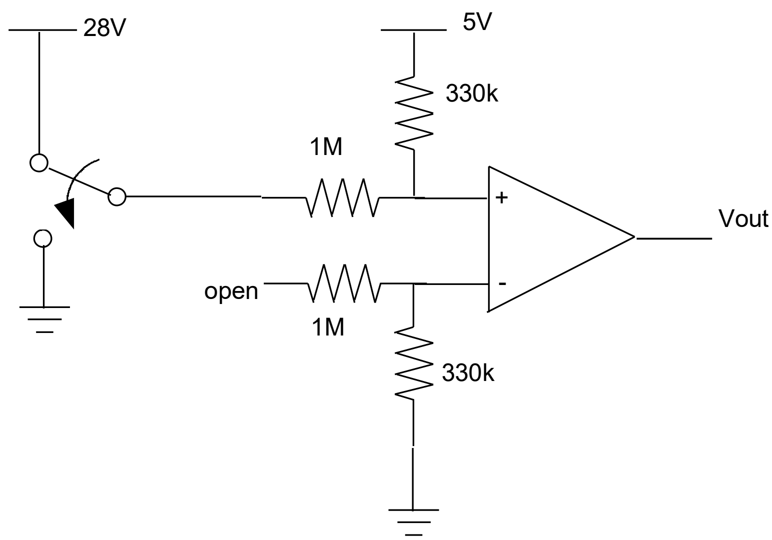



*Figure 43-16: Configuration for detecting a 28V/GND signal*

With the Vin- input left floating, the input to the comparator is pulled to GND.

When the Vin+ input is switched to 28V, the input to the comparator is 10.71V. When the Vin+ input is switched to the GND position, then the input to the comparator is 3.76V.

The midpoint between these two values is 7.235V, therefore the lower threshold should be 7V and the upper transition should be 7.5V.

### 43.6.3 Detecting GND/Open signal

The KAD/DSI/003/B discrete channels can be configured to read a GND/Open discrete signal as shown in the following figure.

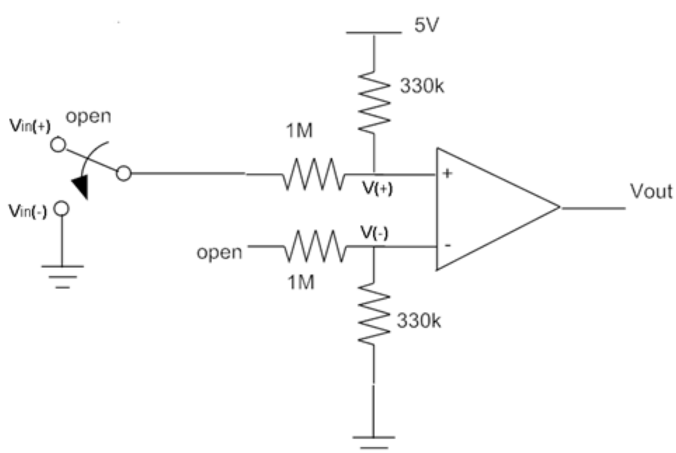



*Figure 43-17: Figure 65-16: Configuration for detecting an Open/GND signal*

Assuming that Vin- is left opened and Vin+ toggles between GND and open, then V- is pulled to GND.

When the switch is pulled to GND, V+ follows the equation shown in “43.5.1  Discrete channel interface details” on page 369, giving V+ = 3.76.

When the switch is opened then V+ is pulled to 5V.

The midpoint between these two values is 4.38 V, therefore the lower threshold should be 4.07V and the upper transition should be 4.69V.

## 43.7 Using the event FIFO

If a discrete channel is Armed, then when an event occurs on that channel it is sent to the FIFO. The following figure illustrates the relationship between events, the FIFO, and sampling.

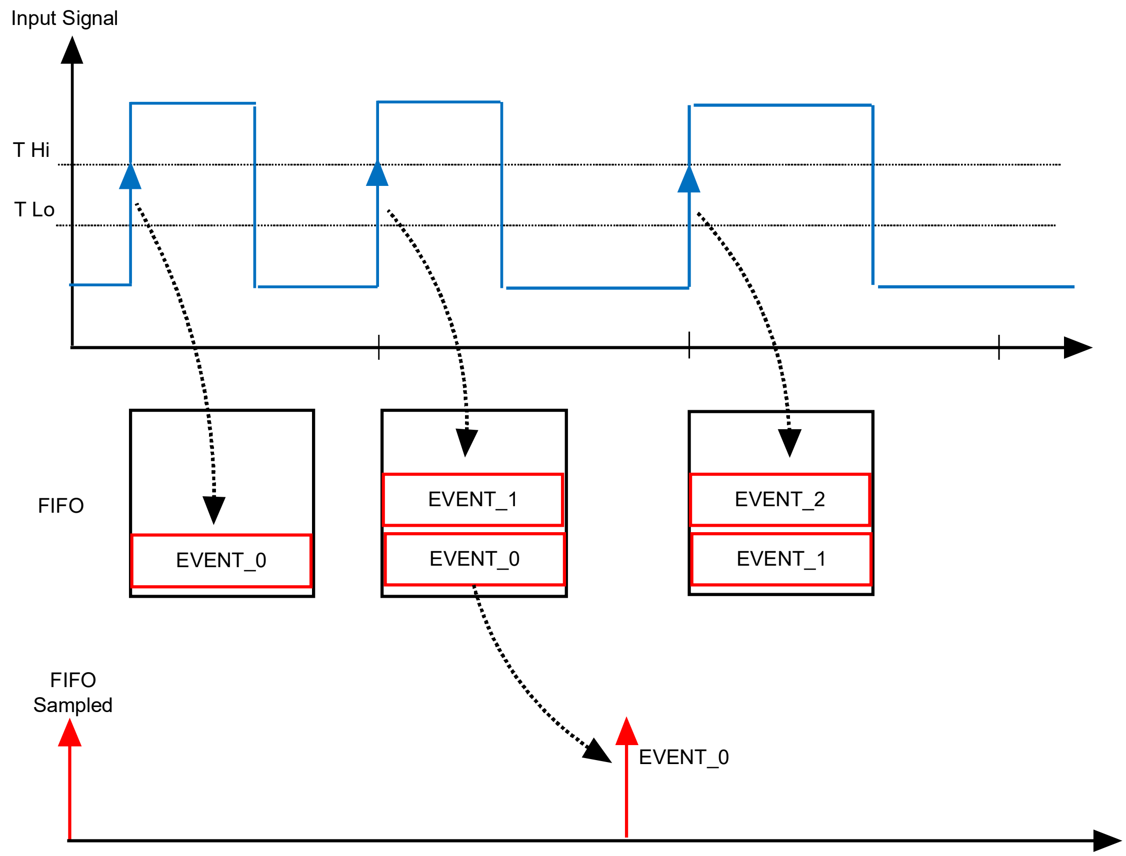



*Figure 43-18: Events and the FIFO*

**NOTE:** Each of the 64-bit registers associated with tagging (Event_Status, Event_Time_Hi, Event_Time_Lo, and Event_-Time_Micro) has its own dedicated 8K word buffer. This means that the FIFO buffer can fill if 8192 events occur between reads. To avoid this situation, the FIFO should be read so that the sampling speed at least equals the frequency of the incoming signals.

## 43.8 Choosing the correct counter mode

The frequency of an input signal can be measured in two ways:

Measure PERIOD and invert in Groundstation (Real Time or Post Processing)

Measure FREQUENCY over a defined period of time

FREQUENCY counter is directly calculated on the module over a defined time period and it is used to measure high frequency signals. The PERIOD counter provides poor resolution at high frequencies as the fastest clock for the PERIOD counter is 10 µs.

For example, at 50 kHz the PERIOD counter shows 1 count, while at 33 kHz the PERIOD counter shows 3 counts. However the PERIOD counter provides excellent resolution at low frequencies. For example, at 2 Hz, the PERIOD counter shows 50000 counts and at 2.01 Hz the PERIOD counter shows 49751 counts.

As a rule of thumb and depending on the resolution required, FREQUENCY counter mode provides better results for frequencies greater than 1 kHz, while PERIOD counter mode is recommended for frequencies lower than 1 kHz.

**NOTE:** The maximum update rate for the frequency counter is 1 Hz. Newer modules such as the KAD/DSI/102 support a maximum update rate of 10 Hz for the frequency counter.

## 43.9 Related documentation

| DOCUMENT | DETAILS |
| --- | --- |
| DOC/DBK/001 | Acra KAM-500 Databook |
| DOC/MAN/018 | KSM-500 Databook |
| DOC/MAN/030 | DAS Studio 3 User Manual |
| DST/N/091 | KAD/DSI/003/B data sheet |

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Chapter 44

# Time and leap seconds

TEC/NOT/072

This technical note describes how leap seconds and year information are set by Curtiss-Wright products and is divided into the following sections:



## 44.1 Time standards available for use with Curtiss-Wright products

Now that three standards of time can be used in the Acra KAM-500, switches, and recorders, better care can be taken to account for leap seconds. Leap seconds are adjusted automatically by AXN. AXN programs a serial EEPROM transparently when a leap second occurs.

The three standards times are:

- **TAI:** Temps Atomique International is the international atomic time scale based on a continuous counting of the International System of Units (SI) second. TAI is currently ahead of UTC by 37 seconds. TAI is always ahead of GPS by 19 seconds. Precision Time Protocol packet timestamp is based on TAI.
- **UTC:** Coordinated Universal Time, formerly known as Greenwich Mean Time (GMT), or Zulu time. Local time differs from UTC by the number of hours of your time zone. UTC is occasionally adjusted by lengthening or shortening the last minute of a month by one second because it is based on earth time. The world does not rotate uniformly, which causes a drift in UTC time. Of the 24 leap seconds that were added from 1972 to 2008, most were conveniently applied at the end of the last minute of the year. However, nine occurred on the 30th of June in various years. IENA packet timestamp time is based on UTC.
- **GPS:** Global Positioning System time is the atomic time scale implemented by the atomic clocks in the GPS ground control stations and the GPS satellites themselves. GPS time was zero at 0:00, 6-Jan-1980 and since it is not perturbed by leap seconds GPS is now ahead of UTC by 18 seconds.

In summary, the leap seconds for November 2023 are:

TAI = UTC + 37 seconds

GPS = UTC + 18 seconds

TAI = GPS + 19 seconds

## 44.2 Packet timestamps

AXN and Acra KAM-500 offer two types of Ethernet packets, that is, IENA and iNET-X. (AXN also supports Chapter 10 but this is not discussed in this document.) For more information on Ethernet packets, see *TEC/NOT/067 - IENA and iNET-X packet payload formats*.

This document refers to the timestamps of these packets.

### 44.2.1 IENA timestamps

These 48-bit timestamps are associated with the oldest unit of data in the payload. It represents the time of the current year, in microseconds, since the 1st January. In the case of analog data, the timestamp relates to the earliest sample contained in the payload.

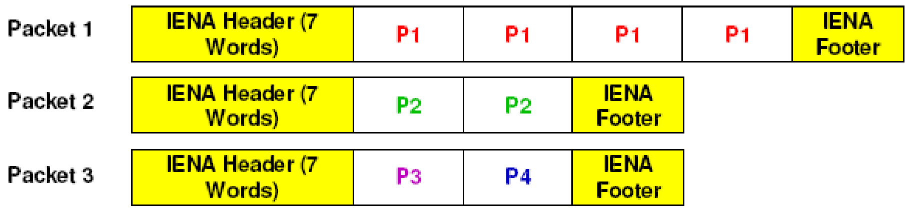



*Figure 44-1: IENA packet content*

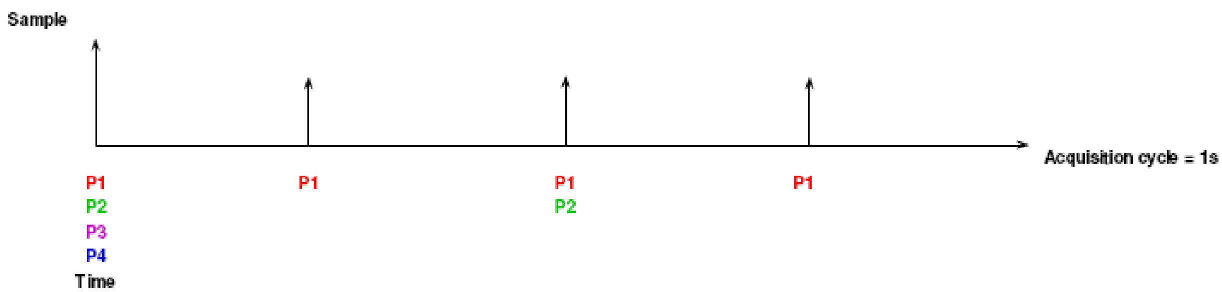



*Figure 44-2: Example of IENA timestamp*

### 44.2.2 iNET-X PTP timestamps

These 64-bit timestamps are associated with the oldest unit of data in the payload. In the case of analog data, the timestamp relates to the earliest sample contained in the payload. For bus monitor data, the timestamp relates to the first and earliest bit or message captured on the bus. The time format used is unsigned IEEE 1588 Precision Time Protocol (PTP) format using PTP epoch where:

- Bits [0:31] time = second count since January 1st 1970

- Bits [32:63] time = nanosecond count since start of second

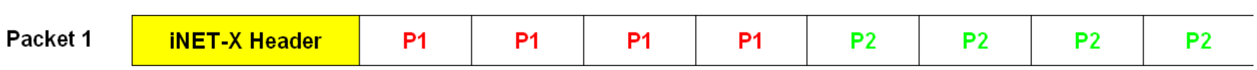



*Figure 44-3: iNET-X packet content*

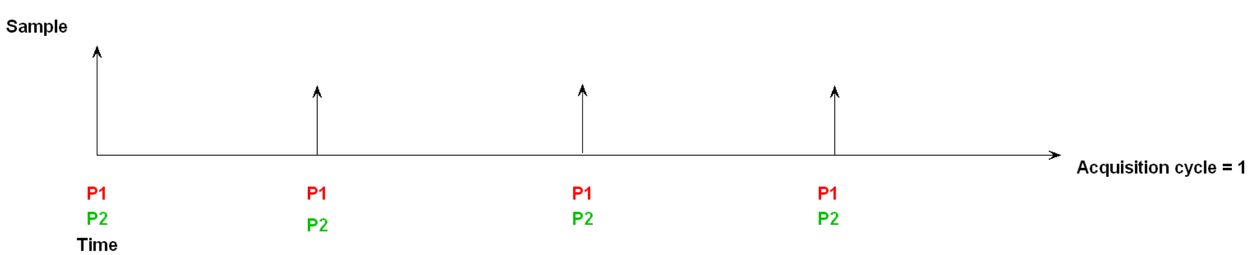



*Figure 44-4: Example of iNET-X placed packets timestamp*

## 44.3 Leap seconds

Leap seconds are used to align UTC with various reference times (for example, GPS, PTP). For correct translation from any reference time to UTC the correct number of leap seconds must be applied during the conversion. The International Earth Rotation and Reference Systems Service adds leap seconds to UTC at regular intervals. Typically leap seconds can be added on June 30 or December 31, but the UTC standard provides for leap seconds to be applied at the end of any month.

### 44.3.1 IENA and PTP: mid-year leap seconds and IENA time

The network switch PTP Grandmaster reports the number of seconds by which UTC currently differs from PTP time, but does not report whether any of these differences occurred since this year began.

A problem arises when an IENA transmitter, such as a KAD/BCU/105 or KAD/BCU/140, starts transmitting after a leap second has occurred during the current year. IENA time is based on the start of the current year in UTC. This means an IENA transmitter must calculate when the current year began.

If an IENA transmitter starts to synchronize with a network switch PTP Grandmaster during the second half of a year, it does not know whether a leap second was applied in June of the current year.

For this reason, the IENA transmitter always calculates the start of the current year by assuming every hour since the start of the year has had 3,600 seconds.

### 44.3.2 iNET-X: network switch PTP Grandmaster and IRIG

Year data is not transmitted in IRIG. As iNET-X requires year data, it is set by the network switch PTP Grandmaster.

### 44.3.3 iNET-X: network switch PTP Grandmaster and GPS

GPS requires the number of leap seconds between UTC and GPS. When first powered up, if the GPS onboard receiver does not know how many leap seconds to apply, within 12.5 minutes it receives a correction from GPS satellites. When this is applied, the time steps back the appropriate number of leap seconds.

For example, if the leap seconds are not set, or are not set with the exact same leap seconds as on the PTP Grandmaster, the KAD/BCU/XXX Ethernet controller module synchronized with PTP resets because it must adjust its clock by more than 500µs. This causes data acquisition to cease until the next two-second boundary, that is, packets are lost.

This happens once after power-up and once when the module synchronizes with a time master.

### 44.3.4 Time code modules with GPS input and leap seconds

A time code module with GPS input, such as the KAM/TCG/105, requires the number of leap seconds between UTC and GPS. When first powered up, if the GPS onboard receiver does not know how many leap seconds to apply, within 12.5 minutes it receives a correction from GPS satellites. When this is applied, the time steps forward the appropriate number of leap seconds.

Each KAM/TCG/102/D or KAM/TCG/105 has a programmable number of leap seconds. The legacy KAM/TCG/102/C has 13 hard-coded leap seconds. That is, if this module is used in November 2012 (leap seconds at that time equaled 15), it steps forward two seconds within 12.5 minutes (as it receives a correction from the GPS satellites).

## 44.4 Examples of leap seconds and year settings

**Example 1:** A single Acra KAM-500 chassis with IRIG time source from a KAM/TCG/10x with the time server set to Master.

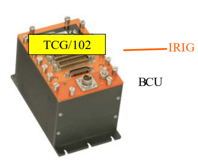



*Figure 44-5: Year is set by the KAM/TCG/10x if iNET-X is used to transmit packets*

---

**NOTE:** The KAM/TCG/105 supports IRIG-B-200-04 as a setting in IRIG-B, which decodes the year. That is, it ignores the Current Year field in DAS Studio 3.

**Example 2:** A single Acra KAM-500 chassis with GPS time source from a KAM/TCG/10x with the time server set to Master.

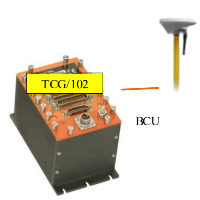



*Figure 44-6: Leap seconds are set by the KAM/TCG/10x*

**Example 3:** KAD/BCU/xxx Ethernet controller modules configured as PTP clients, synchronized with a network switch PTP Grandmaster connected to GPS.

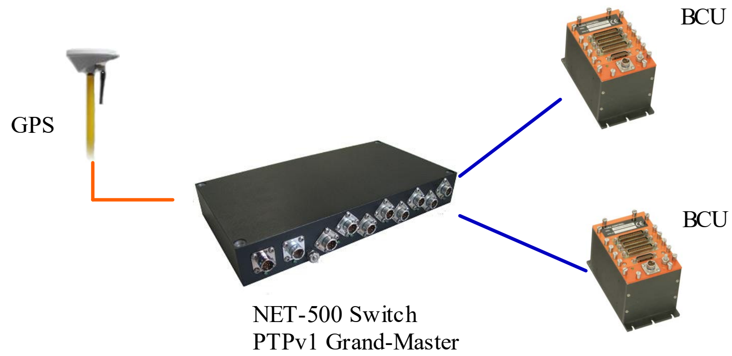



*Figure 44-7: Leap Second is set by the network switch PTP Grandmaster*

---

**NOTE:** When the KAD/BCU/140/D is configured as a PTP client, the PTP Leap Seconds field in DAS Studio is ignored as this value is transmitted by the PTP Grandmaster.

**Example 4:** KAD/BCU/xxx Ethernet controller modules configured as PTP client, synchronized with a network switch PTP Grandmaster connected to IRIG.

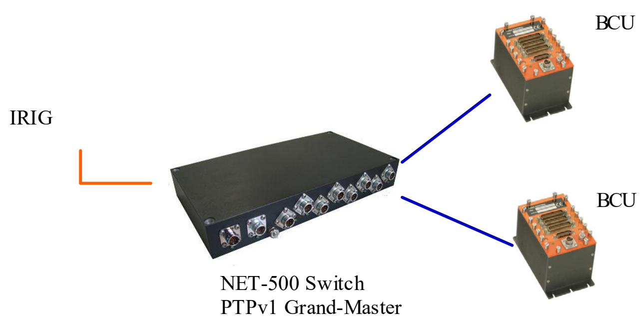



*Figure 44-8:* Year is set by the network switch PTP Grandmaster

**Example 5:** KAD/BCU/xxx Ethernet controller modules synchronized with a network switch PTP Grandmaster connected to an IRIG signal received from a KAM/TCG/10x with the time server set to Master.

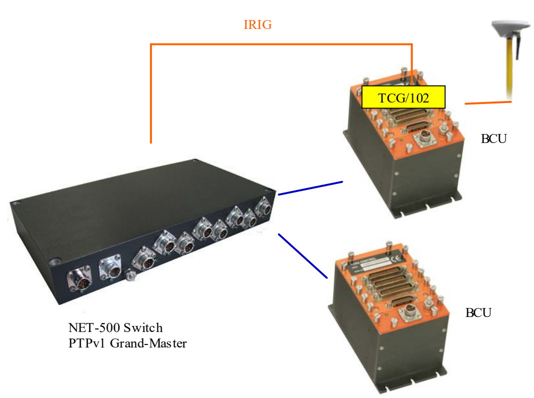



*Figure 44-9: Leap Seconds are set by the KAM/TCG/10x; year is set on the KAM/TCG/10x*

---

**NOTE:** This is an atypical configuration when using a NET/SWI/101/C as a network switch and PTP Grandmaster.

**Example 6:** KAD/BCU/xxx Ethernet controller modules synchronized with a network switch PTP Grandmaster connected to an IRIG signal received from a KAM/TCG/10x with the time server set to Master. The year must be set by both the network switch PTP Grandmaster and the KAM/TCG/10x.

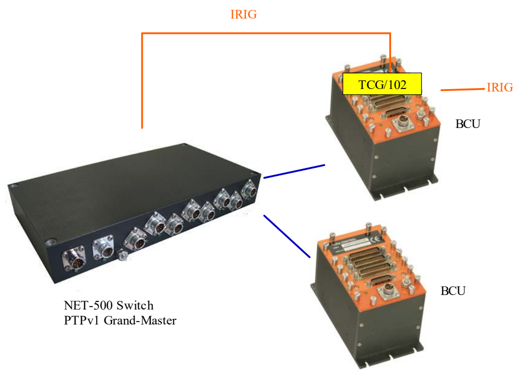



*Figure 44-10: Year must be set by the KAM/TCG/10x and on the network switch PTP Grandmaster*

**NOTE:** In a synchronized PCM distributed system where the year is not carried over X_SYNC, the KAD/ETH/102 has an option to capture the Year from PTP.

### 44.4.1 Leap year on the KAM/TCG/10x

If IRIG is the time source, then Leap year is automatically programmed by DAS Studio 3 depending on the Current Year field set in DAS Studio.

When RTC/GPS is the time source, the module will calculate the time accordingly from this source.

## 44.5 Axon and time

The AXN/BCU/402 only proposes PTP time as a parameter, which is based on TAI. Unlike KAM-500 TCG cards, the AXN/TCG/401/B does not expose time as parameters.

IRIG time (UTC + Local Time) is only available as a parameter from the AXN/ENC/40x. The AXN/ENC/402 also supports the Year and Day of Year parameters. For more information, refer to *TEC/NOT/089 - Using DAS Studio 3 to configure the AXN/ENC/402*.

The AXN/BCU/402/C supports Local Time, however this local time is not carried over PTP so any AXN/BCU/402 modules in the system must contain the same Local Time.

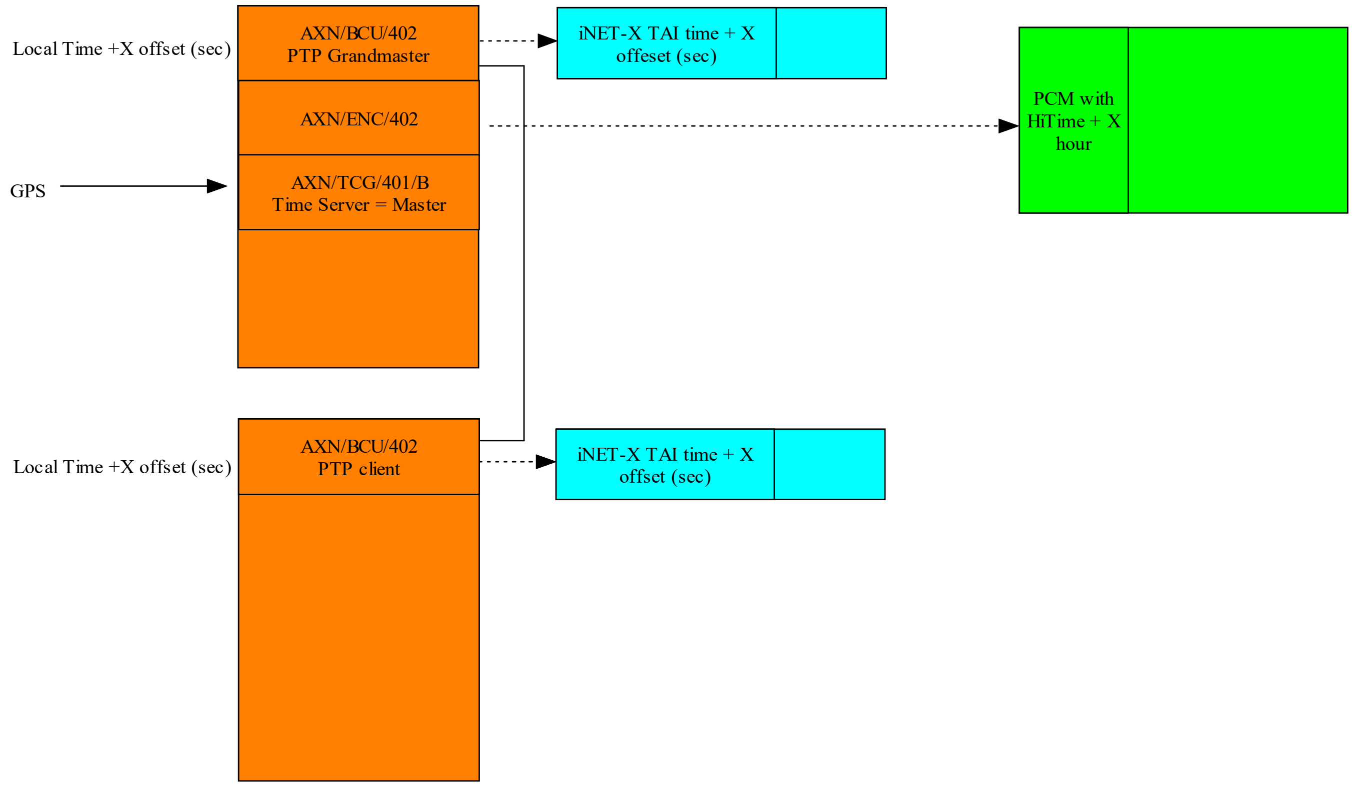



*Figure 44-11: Example of Local Time settings and how it is applied to different outputs*

For example, if a NET/REC/00x is connected to the AXN/BCU/402 Grandmaster, the time in the display will not have the local time because the display is calculating the time (UTC) on the PTP communication.

A KAM-500 does not support Local Time, therefore Local Time cannot be used in an Axon/KAM-500 hybrid system.

Chapter 45

# Using the KAD/VID/106

TEC/NOT/073

This paper discusses the following topics:



## 45.1 Overview

The KAD/VID/106 module is a video encoder module that converts one of three composite video (CVBS) inputs or one S-Video input into digital video and compresses it. Compressed video bit-rate is kept constant using multi-pass encoding and padding of the transport stream. Optional audio encoding produces a digital audio data stream. The left and right audio channels can be individually turned on or off. Selection of PAL or NTSC input format is a configurable setting.

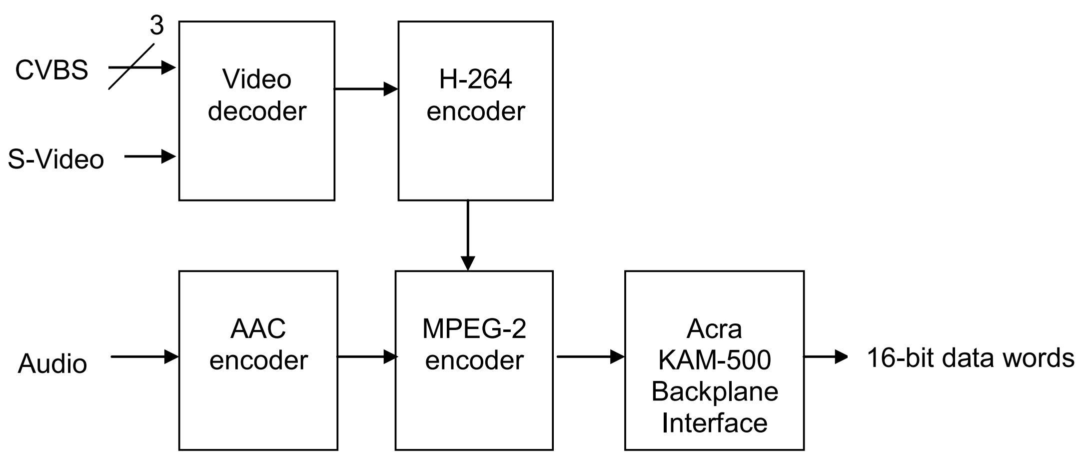



*Figure 45-1: KAD/VID/106 block diagram*

The KAD/VID/106 compresses video using the baseline profile H264.1 technique. This method encodes each received frame as either an I(ntra coded) frame or a P(redicted) frame depending on the module settings.

I frames take all the information in the received picture and encodes this information using a lossy compression scheme to create a reference frame. This reference frame can be thought of as a *stand alone* frame—it does not need any information from other frames in the video stream to be viewed. This means that each I frame is an accurate representation of the received analog picture.

P frames encode only the changes from the previous frame. This means that P frames need information from previous frames to be viewed. This results in a reduction of bandwidth needed to encode a moving picture—however, if the picture were to change quickly, an accurate representation would not be displayed until the next I frame was processed.

I frames and P frames are grouped together in a Group Of Pictures (GOP). The setting used for GOP determines the image quality and bandwidth.

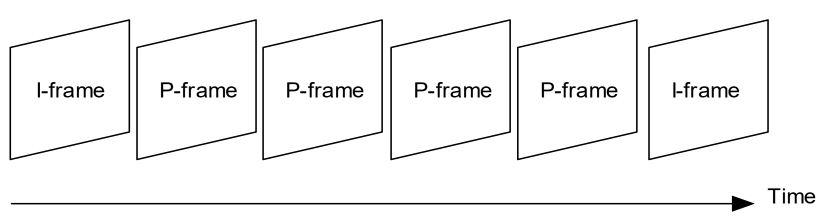



*Figure 45-2: GOP with P frame to I frame ratio of 5:1*

For more information, refer to http://en.wikipedia.org/wiki/H.264/MPEG-4_AVC#Profiles.

The KAD/VID/106 compresses (optional) audio using Advanced Audio Codec (AAC). The bit-rate for audio is fixed at 64 kbps per channel.

The video and audio are then encoded in an MPEG-2 transport stream. An MPEG-2 transport stream is a fixed length (188 bytes) packet.

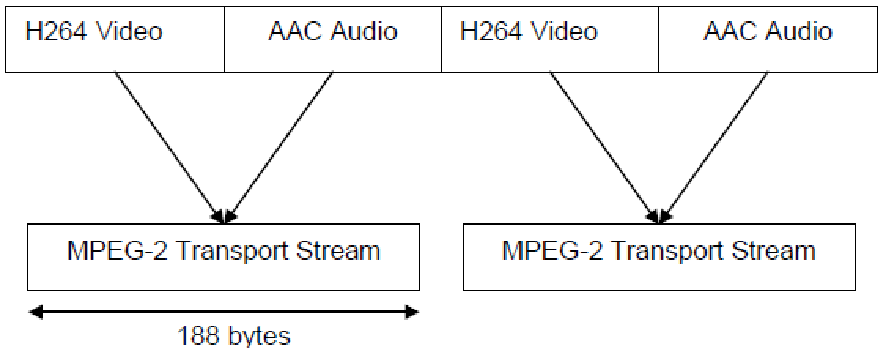



*Figure 45-3: Conversion of video and audio to MPEG-2*

These packets are then fragmented into 16-bit words, which are put out onto the Acra KAM-500 backplane on a FIFO basis. From there they can be inserted in a PCM frame, a UDP packet, logged to a memory module (such as a KAM/MEM/113), or a combination of all three.

# 45.2 Setting up the KAD/VID/106

## 45.2.1 Pinout connections

Pinout connections are described in the following table.

Table 45-1: Pinout connections

| Connection | Description |
|---|---|
| CVBS_0_IN<br>CVBS_1_IN<br>CVBS_2_IN | These input connections allow up to three independent composite video sources to be connected.<br><br>**NOTE:** The KAD/VID/106 can only process one video input at a time. |
| Y_IN<br>C_IN | These two input connections are used for component (S-Video) inputs. Y_IN corresponds to luminance; C_IN corresponds to chrominance. |
| CAM_2_GENLOCK_OUT<br>CAM_3_GENLOCK_OUT | Composite video waveforms output a regular sync pulse (every 64 µs for PAL, every 63.5 µs for NTSC) that can be used to synchronize multiple video inputs. When a video source is connected to CVBS_0_IN, its output waveform is available on both GENLOCK outputs. This allows up to two other composite video sources connected to CVBS_1_IN and CVBS_2_IN to be synchronized with the CVBS_0_IN input. |
| AUDIO_RIGHT_IN<br>AUDIO_LEFT_IN | These are the inputs for audio. |
| CAM_SEL_BIT_0<br>CAM_SEL_BIT_1<br>CAM_SEL_BIT_2 | If the Input Source option is set to Camera, then these three inputs can be used to select the input video source.<br><br>**NOTE:** These connections are internally pulled high; they must be tied to ground as shown in the following table to select the various inputs. |

Table 45-2: Camera Select pins (NC – Not Connected)

| CAM_SEL_BIT [2:0] | | | Selected Input |
|---|---|---|---|
| NC | NC | NC | Outputs a simple test pattern |
| NC | NC | GND | CVBS_0_IN |
| NC | GND | NC | CVBS_1_IN |
| NC | GND | GND | CVBS_2_IN |
| GND | NC | NC | Y_IN, C_IN |

## 45.2.2 Software setup

The KAD/VID/106 can be configured using kSetup or DAS Studio 3.

### 45.2.2.1 KSM-500 Parameters tab settings

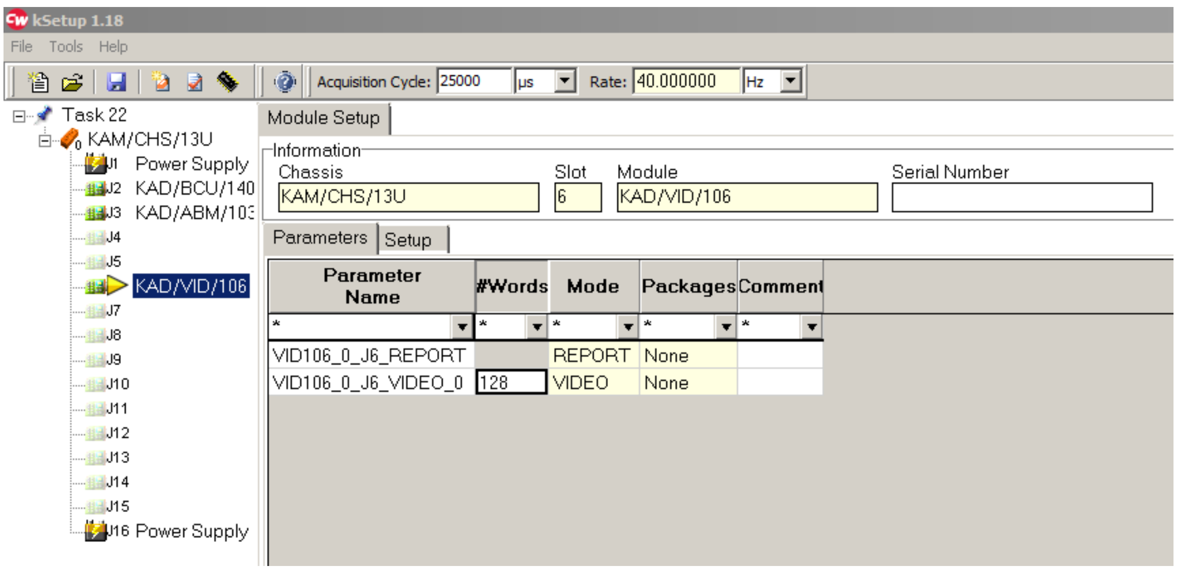



*Figure 45-4: Parameters tab in kSetup*

The Parameters tab has only two options: Report word and Video words.

#### Report word

The Report word relates the status of the module. Refer to the *KAD/VID/106* data sheet for bit definitions.

#### Video words

It is possible to specify more than one data word from the KAD/VID/106. The amount of video words specified should be chosen so as to optimize the available bandwidth. For example, 10 video words placed at 10:1 commutation in the frame is equivalent to 1 video word placed at 100:1 commutation. The advantage lies in the fact that 10:1 commutation is usually easier to achieve than 100:1 commutation.

## 45.2.2.2 KSM-500 Setup tab settings

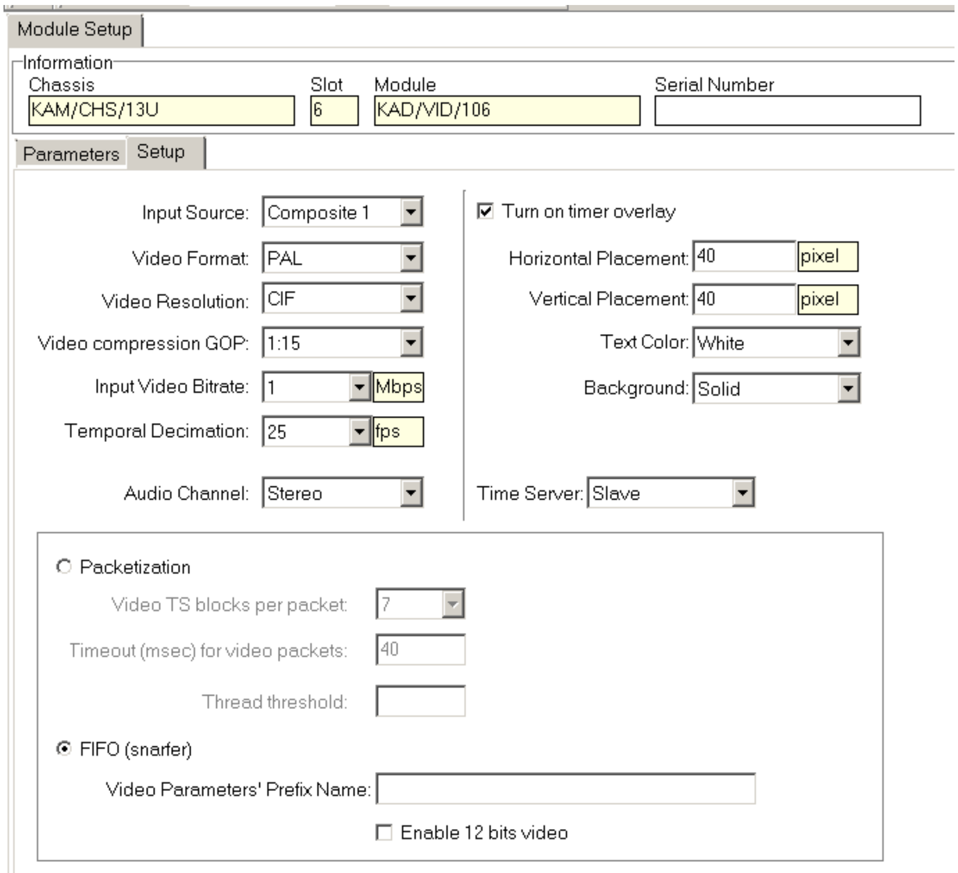



*Figure 45-5: Setup tab in kSetup*

The Setup tab covers video, audio, video source, and timer settings.

| Setting | Description |
|---|---|
| Input Source | If Input Source is set to EEPROM, then this option specifies the video source. The following Input Source options are available. |
| Camera | There are up to three camera inputs. The module acts as a multiplexer allowing you to switch between cameras. The active channel can be pre-set in the EEPROM during configuration, or it can be read from the configuration of several pins on the connector (see Table 45-1 on page 386). Use this option to select which method the module uses to select the camera input. |
| TEST | Outputs a simple test pattern |
| Composite 1 | Channel 1 composite |
| Composite 2 | Channel 2 composite |
| Composite 3 | Channel 3 composite |
| S-Video | YC input (S-video) |
| Video Format | Determines the output format: PAL (Europe and Asia) or NTSC (The Americas). This setting must match the video source. |

<table>
<tr><th>Setting</th><th>Description</th></tr>
<tr><td>Video Resolution<br><br>CIF<br><br><br>2CIF<br><br><br>D1</td><td>Determines the resolution of the displayed image. The following resolutions are available (pixel x pixel).<br><br>352 x 288 (PAL)<br>352 x 240 (NTSC)<br><br>704 x 288 (PAL)<br>704 x 240 (NTSC)<br><br>704 x 576 (PAL)<br>704 x 480 (NTSC)</td></tr>
<tr><td>Video compression GOP</td><td>Determines the amount of P frames to I frames in the output video. Allowed values range from All (all I frames) to 60 (1 I frame every 60 P frames).<br>A higher P:I frame ratio reduces the amount of bandwidth needed for a given video application. However, the video stream takes longer to recover should any bit errors occur.</td></tr>
<tr><td>Input Video Bitrate</td><td>H.264 encoding produces a bit stream with an average bit-rate close to the value specified in this setting. The video words that you want to transmit (later referred to as Sampling Video Rate), must have a value higher than the value set in this field.
<table>
<tr><th>Video input rate (kbps)</th><th>Sampling Video Rate with audio (kbps)</th><th>Sampling Video Rate without audio (kbps)</th></tr>
<tr><td>250 (KAD/VID/106/B only)</td><td>Not supported</td><td>380 (KAD/VID/106/B only)</td></tr>
<tr><td>512</td><td>700</td><td>560</td></tr>
<tr><td>750</td><td>960</td><td>820</td></tr>
<tr><td>900</td><td>1150</td><td>990</td></tr>
<tr><td>1000</td><td>1230</td><td>1090</td></tr>
</table></td></tr>
<tr><td>Temporal Decimation</td><td>Determines the number of frames per second (fps) displayed in the video output. This setting can be used as a crude method to reduce bandwidth. For example, displaying 12.5fps uses just over half the bandwidth needed to display 25fps.</td></tr>
<tr><td>Audio Channel</td><td>Determines which audio channels (if any) are to be used.</td></tr>
<tr><td>Turn on timer overlay</td><td>The KAD/VID/106 can display BCD time in the video output. Select this check box to enable this option.</td></tr>
<tr><td>Horizontal Placement/ Vertical Placement</td><td>Determines the location of the timer in x y co-ordinates in pixels from the top-left corner of the screen.</td></tr>
<tr><td>Text Color</td><td>Determines the timer text color.</td></tr>
<tr><td>Background</td><td>Determines the background shading of the timer.</td></tr>
<tr><td>Time Server</td><td>This determines the time source of the KAD/VID/106. If Time-Slave is selected, the KAD/VID/106 gets its time from an IRIG source (such as a KAD/BCU/XXX or KAM/TCG/XXX module). If Free-Running is selected, then the KAD/VID/106 counts its own time from power on without reference to an outside time source.</td></tr>
<tr><td>Packetization</td><td>Packetization can only be used with aperiodic Ethernet transmission modules such as the KAD/BCU/140. DAS Studio 3 is recommended to be used for such a setting. Refer to the DAS Studio 3 User Manual for more information.</td></tr>
<tr><td>FIFO (snarfer) Video Parameters’ Prefix Name</td><td>See “45.2.3.2 DAS Studio 3 - Using video over PCM” on page 395.</td></tr>
<tr><td>Enable 12 bits video</td><td>This setting is reserved for future use.</td></tr>
</table>

### 45.2.2.3 DAS Studio 3 Settings tab

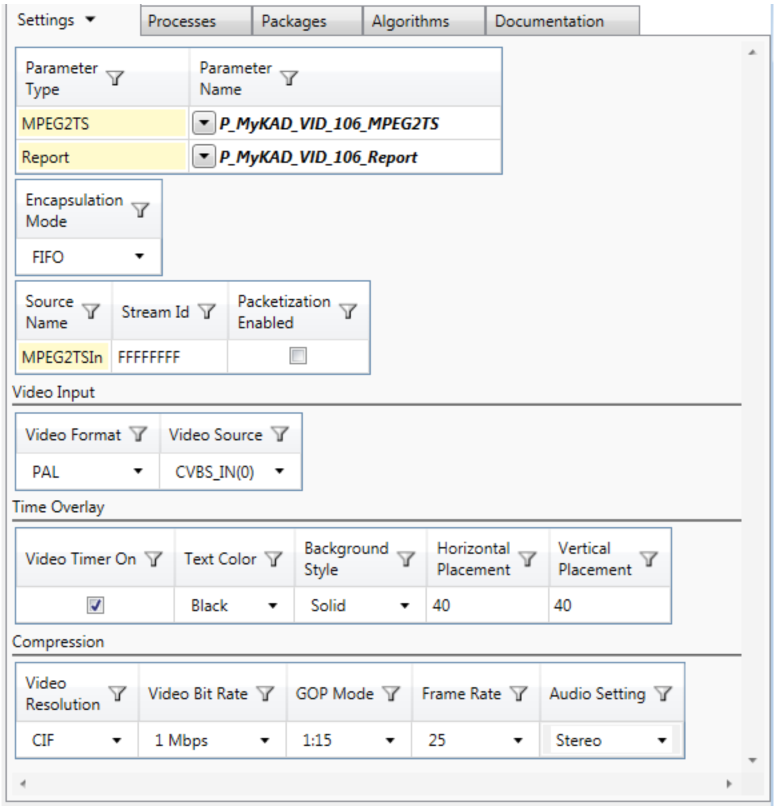



*Figure 45-6: Settings tab in DAS Studio 3*

| Setting | Description |
|---|---|
| Parameter Type/Name | The parameter type MPEG2TS is the MPEG2 transport stream of H.264 encoded video data and AAC encoded audio data used for FIFO. The Report provides a status of the KAD/VID/106. Refer to the *KAD/VID/106* data sheet for details. |
| Encapsulation Mode | There are two encapsulation modes: FIFO or Packetizer. Packetization can only be used with aperiodic Ethernet transmission modules such as the KAD/BCU/140. When using Packetizer mode, the Packetization Enabled check box must be selected and the Stream ID field must be filled in. |
| Source Name | Name of the iNET-X packetizer channel for the audio and video MPEG-2 transport stream. |
| Stream ID | Type in a stream ID when Encapsulation Mode is enabled. |
| Packetization Enabled | Packetization can only be used with aperiodic Ethernet transmission modules such as the KAD/BCU/140. |
| Video Format | Determines the output format: PAL (Europe and Asia) or NTSC (The Americas). This setting must match the video source. |
| Video Source | If Input Source is set to EEPROM, then this option specifies the video source. The following Input Source options are available. |
| CVBS_IN(0)<br>CVBS_IN(1)<br>CVBS_IN(2) | Single ended composite video inputs. |
| Y/C_IN | YC input (S-video) |

| Setting | Description |
|---|---|
| Test | Outputs a simple test pattern |
| CameraSelect(2:0) | There are up to three camera inputs. The module acts as a multiplexer allowing you to switch between cameras. The active channel can be pre-set in the EEPROM during configuration, or it can be read from the configuration of several pins on the connector (see Table 45-1 on page 386). Use this option to select which method the module uses to select the camera input. |
| None | No video source is selected. Use when only audio is required to be captured on the KAD/VID/106. |
| Video Timer On | The KAD/VID/106 can display BCD time in the video output. Select this check box to enable this option. |
| Text Color | Determines the timer text color. |
| Background Style | Determines the background shading of the timer. |
| Horizontal Placement/ Vertical Placement | Determines the location of the timer in x y co-ordinates in pixels from the top-left corner of the screen. |
| Video Resolution | Determines the resolution of the displayed image. The following resolutions are available (pixel x pixel). |
| CIF | 352 x 288 (PAL)<br>352 x 240 (NTSC) |
| 2CIF | 704 x 288 (PAL)<br>704 x 240 (NTSC) |
| D1 | 704 x 576 (PAL)<br>704 x 480 (NTSC) |
| Input Video Bitrate | H.264 encoding produces a bit stream with an average bit-rate close to the value specified in this setting. The video words that you want to transmit (later referred to as Sampling Video Rate), must have a value higher than the value set in this field. |
| GOP Mode | Determines the amount of P frames to I frames in the output video. Allowed values range from All (all I frames) to 60 (1 I frame every 60 P frames).<br>A higher P:I frame ratio reduces the amount of bandwidth needed for a given video application. However, the video stream takes longer to recover should any bit errors occur. |
| Frame Rate | Determines the number of frames per second (fps) displayed in the video output. This setting can be used as a crude method to reduce bandwidth. For example, displaying 12.5fps uses just over half the bandwidth needed to display 25fps. |
| Audio Setting | Determines which audio channels (if any) are to be used. |

| Video input rate (kbps) | Sampling Video Rate with audio (kbps) | Sampling Video Rate without audio (kbps) |
|---|---|---|
| 250 (KAD/VID/106/B only) | Not supported | 380 (KAD/VID/106/B only) |
| 512 | 700 | 560 |
| 750 | 960 | 820 |
| 900 | 1150 | 990 |
| 1000 | 1230 | 1090 |
| 2000 | 2320 | 2180 |

### 45.2.3 Using Video

There are no inherent differences between video data and other types of Acra KAM-500 data, except that video data generally uses a far greater bandwidth.

Sampling video bandwidth for a PCM stream can be calculated as follows:

Sampling video bit rate = number of video words × number of bits per video word × video sampling rate

A similar approach can be used to calculate the bandwidth for placement in a UDP packet or logging to a memory module.

The video bit rate needed depends on the application. The following table provides optimal settings for outputs of various quality.

Table 45-3: KAD/VID/106 optimal video settings

| Bit-rate (Mbps) | Resolution | Frame rate (fps) | GOP |
|---|---|---|---|
| **Optimal PAL video settings** | | | |
| 0.512 | CIF | 12.5 | 5 |
| 0.512 | 2CIF | 25 | 15 |
| 0.512 | D1 | 12.5 | 5 |
| 0.75 | CIF | 25 | 15 |
| 0.75 | D1 | 25 | 5 |
| 0.9 | CIF | 25 | 5 |
| 0.9 | D1 | 25 | 15 |
| 1 | 2CIF | 25 | 15 |
| 1 | D1 | 25 | 15 |
| 2 | 2CIF | 25 | 5 |
| 2 | D1 | 25 | 15 |
| 5 | 2CIF | 25 | 5 |
| 5 | D1 | 25 | 5 |
| 10 | 2CIF | 25 | 5 |
| 10 | D1 | 25 | 5 |
| **Optimal NTSC video settings** | | | |
| 0.75 | CIF | 30 | 5 |
| 0.75 | 2CIF | 30 | 15 |
| 0.75 | D1 | 1 | 5 |
| 0.9 | CIF | 30 | 5 |
| 0.9 | 2CIF | 30 | 15 |
| 0.9 | D1 | 1 | 5 |
| 0.9 | D1 | 15 | 15 |
| 1 | 2CIF | 30 | 5 |
| 1 | D1 | 30 | 15 |
| 2 | 2CIF | 30 | 5 |

Table 45-3: KAD/VID/106 optimal video settings (continued)

| Bit-rate (Mbps) | Resolution | Frame rate (fps) | GOP |
|---|---|---|---|
| 2 | D1 | 30 | 5 |
| 5 | 2CIF | 30 | 5 |
| 5 | D1 | 30 | 5 |
| 10 | 2CIF | 30 | 5 |
| 10 | D1 | 30 | 5 |

The KAD/VID/106 is unique amongst Acra KAM-500 modules in that it does not support different sample rates. If video data is being sent to more than one destination in the system (such as a PCM frame, UDP packet, or memory module) it must be sampled at exactly the same rate by the destination modules. kProgram will not flag this as an error.

### 45.2.3.1 KSM-500 - Using video over PCM

In order to ease placement and save bandwidth for PCM transmission, we recommended using multiples video words. To demonstrate this, refer to the settings in the following figure.

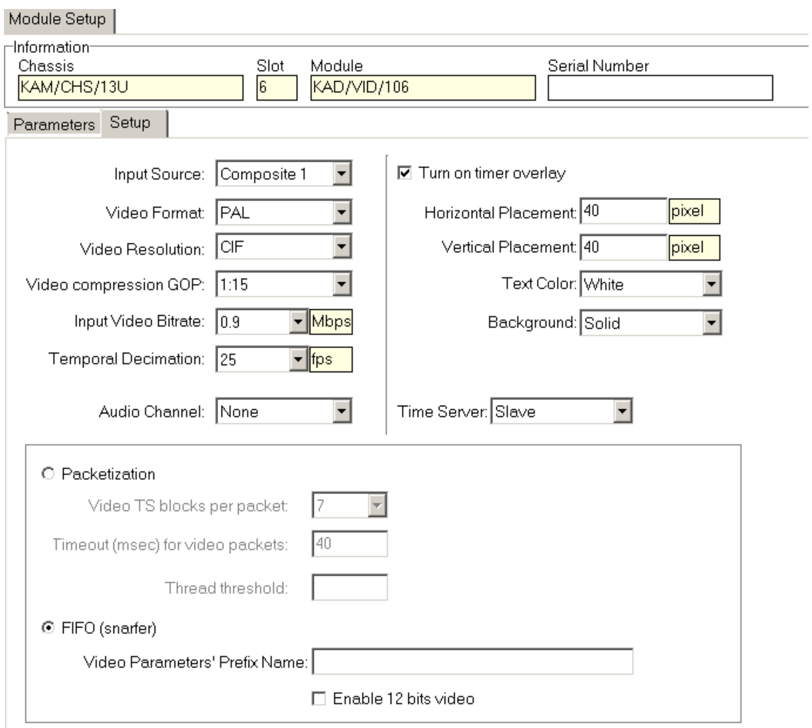



*Figure 45-7: Using multiple video words (KSM-500)*

The Input Video Bitrate is set to 0.9 Mbps. This provides the optimal video as shown in the *KAD/VID/106* data sheet and Table 45-3 on page 392.

With audio off, we require a sampling video bit rate at least 10% higher than 0.9 Mbps, that is at least 0.99 Mbps.

The following figure shows a PCM shape, which illustrates a sampling video rate.

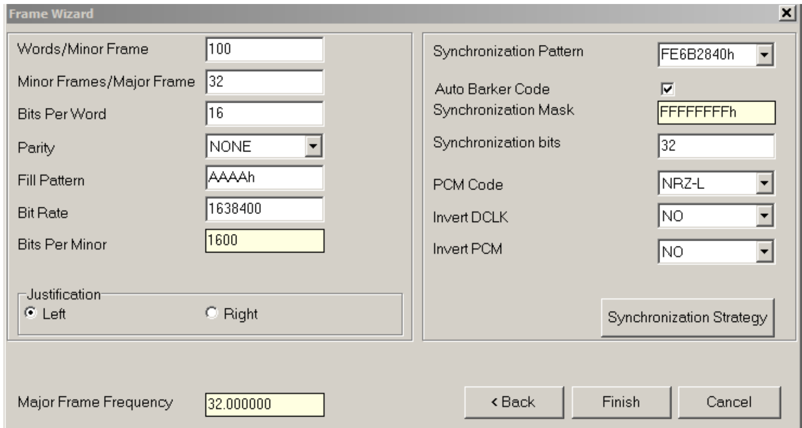
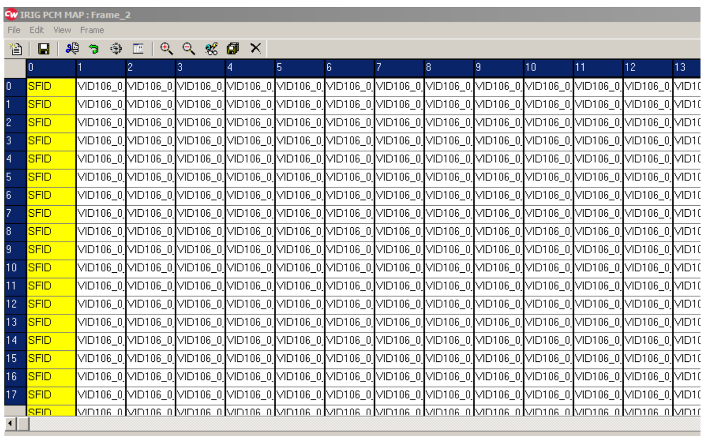



*Figure 45-8: Sampling video rate PCM shape*

Because we need to achieve 0.99 Mbps where the PCM bit-rate is 1.6384 Mbps, we need to cover at least 61% (0.99/1.6384) of the PCM with video words. Therefore, we set 64 video words commutated at 1:1.

To know the exact sampling video bit rate used, the video words being commutated 1:1 within this PCM gives 1024 Hz. Therefore, 1024 Hz × 64 Video Words × 16 bits = 1048576 bps, which is 10% higher than the Input Video Bitrate (0.9 Mbps).



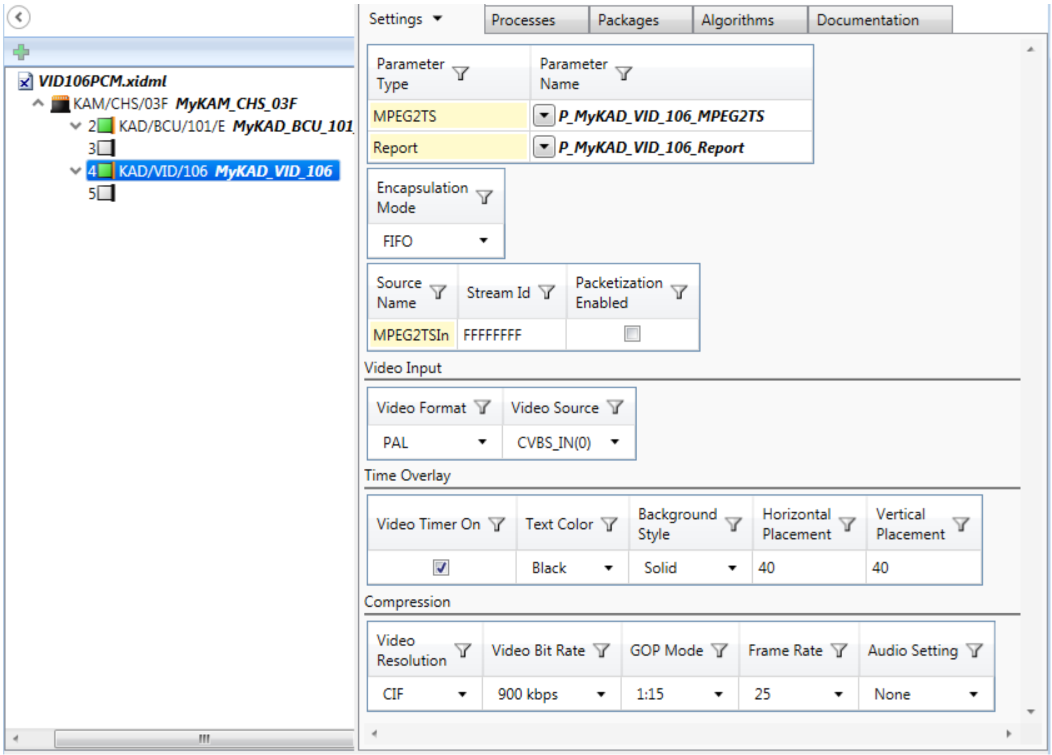

| Chassis | Module | Parameter Name | Enabled | Placed | Word Index | Minor Frame | Desired Rate | Real Rate | Commutation |
|---|---|---|---|---|---|---|---|---|---|
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_44 | Yes | Yes | 45 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_45 | Yes | Yes | 46 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_46 | Yes | Yes | 47 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_47 | Yes | Yes | 48 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_48 | Yes | Yes | 49 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_49 | Yes | Yes | 50 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_50 | Yes | Yes | 51 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_51 | Yes | Yes | 52 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_52 | Yes | Yes | 53 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_53 | Yes | Yes | 54 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_54 | Yes | Yes | 55 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_55 | Yes | Yes | 56 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_56 | Yes | Yes | 57 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_57 | Yes | Yes | 58 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_58 | Yes | Yes | 59 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_59 | Yes | Yes | 60 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_60 | Yes | Yes | 61 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_61 | Yes | Yes | 62 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_62 | Yes | Yes | 63 | 0 | 100 | 1024.000 | 1:1 |
| KAM/CHS/13U | KAD/VID/106 | VID106_0_J3_VIDEO_0_63 | Yes | Yes | 64 | 0 | 100 | 1024.000 | 1:1 |

*Figure 45-9: Frame Builder showing video words at 1024Hz*

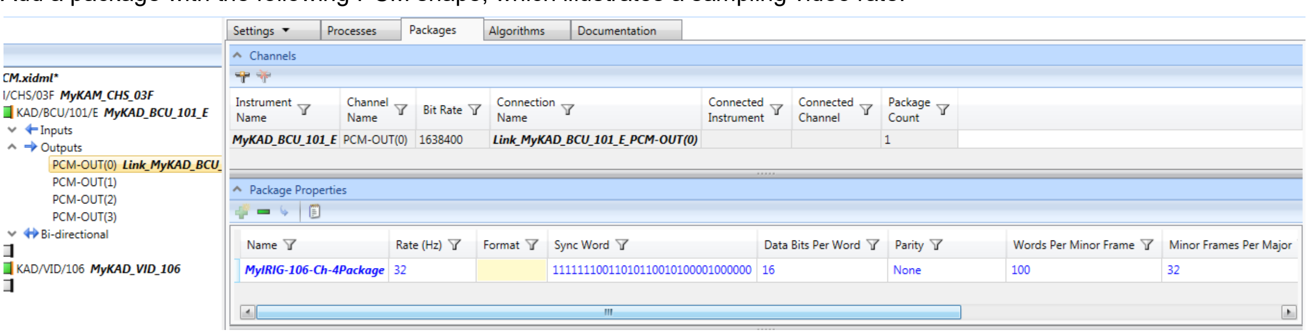
## 45.2.3.2 DAS Studio 3 - Using video over PCM

In order to ease placement and save bandwidth for PCM transmission, we recommended using multiples video words. To demonstrate this, refer to the following.

1. With a KAD/VID/106 module in context, click the **Settings** tab to show the following screen.

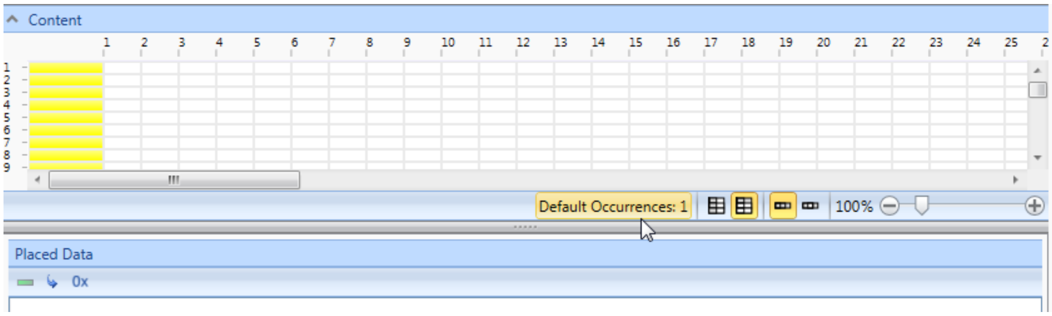



2. Set **Video Bit Rate** to **900 kbps**.
   This provides the optimal video as shown in the *KAD/VID/106* data sheet and Table 45-3 on page 392.
3. Set **Audio Setting** to **None**.
   This requires a sampling video bit rate at least 10% higher than 900 kbps, that is at least 990 kbps.
4. Now select a controller module (such as KAD/BCU/101) in the Navigator and then click the **Packages** tab.
5. Add a package with the following PCM shape, which illustrates a sampling video rate.

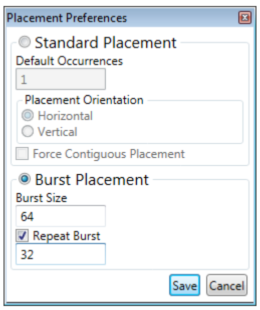



Because we need to achieve 990 kbps where the PCM bit-rate is 1638.4 kbps, we need to cover at least 61% (990 / 1638.4) of the PCM with video words. Therefore, we need 64 video words commutated at 1:1, which is 64 × 32 video burst words.

6. In the **Content** pane, click **Default Occurrences**.

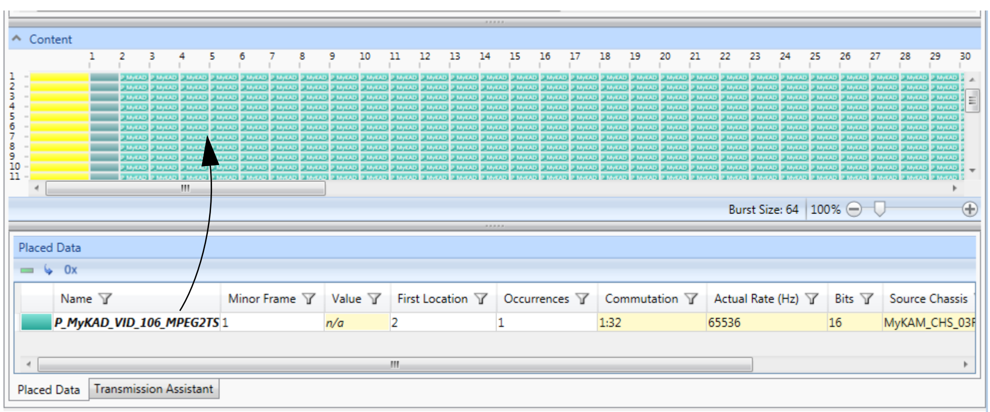



7. The **Placement Preferences** dialog box opens.




Select the **Burst Placement** radio button, set **Burst Size** to **64**, select the **Repeat Burst** check box, set **Repeat Burst** to **32**, and then click **Save**. (This results in 64 × 32 video words.)

8. Now drag the video parameter **P_MyKAD_VID_106_MPEG2TS** from the **Placed Data** pane to the **Content** pane.




To know the exact sampling video bit rate used, video words is showing 65536 Hz for the **Actual Rate**. Therefore, 65536 × 16 bits = 1048576 bps, which is 10% higher than the Video Bit Rate (900 kbps).

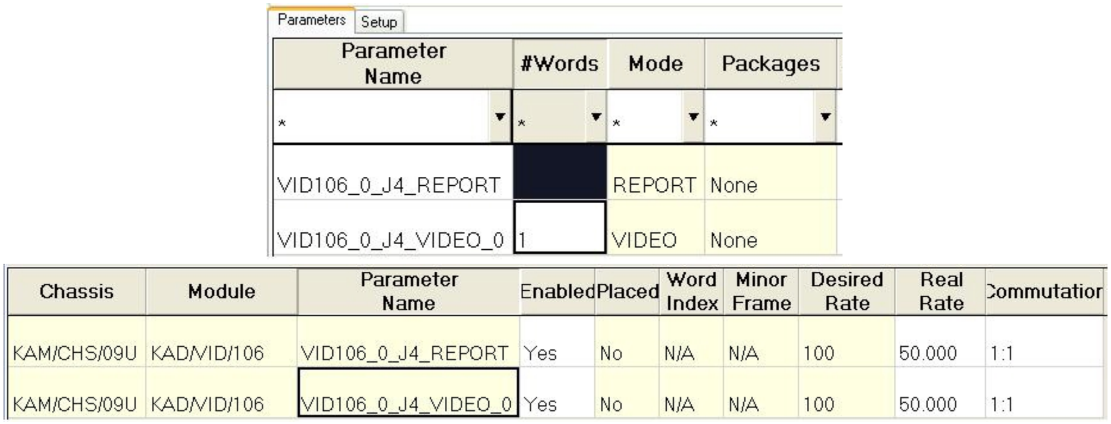
#### 45.2.3.3 KSM-500 - Using video over Ethernet

Video data can be placed in a UDP packet. However, due to the different transmission mechanisms between Ethernet packets and PCM frames, care has to be taken when using video over Ethernet.

The KAD/VID/106 places the Video words out onto the backplane in an order which is transparent to the user. This poses no problem when using PCM—each parameter is always read at a specific time by the controller module and then placed in a specific location in the PCM frame. However, when sampling using Ethernet, the UDP packet is not transmitted until it is full. This means that video parameters can appear out of order. Consequently, the MPEG-2 transport stream makes no sense to a decoding device.

There are three methods to get around this constraint:

- Use only one video word and transmit it as many times as necessary in the UDP packet. The disadvantage with this method is that the task may not compile due to timing considerations.



| Parameter Name | #Words | Mode | Packages |
|---|---|---|---|
| * | * | * | * |
| VID106_0_J4_REPORT | | REPORT | None |
| VID106_0_J4_VIDEO_0 | 1 | VIDEO | None |

| Chassis | Module | Parameter Name | Enabled | Placed | Word Index | Minor Frame | Desired Rate | Real Rate | Commutation |
|---|---|---|---|---|---|---|---|---|---|
| KAM/CHS/09U | KAD/VID/106 | VID106_0_J4_REPORT | Yes | No | N/A | N/A | 100 | 50.000 | 1:1 |
| KAM/CHS/09U | KAD/VID/106 | VID106_0_J4_VIDEO_0 | Yes | No | N/A | N/A | 100 | 50.000 | 1:1 |

*Figure 45-10: Transmitting one video word many times in a UDP packet*

- Place the video parameters in a PCM frame to force the ordering in the UDP packet (even if the PCM frame is not going to be used). If this method is to be used, ensure the video parameters do not occur more than 188 times in a single packet. The disadvantage with this method is that it uses up PCM bandwidth.
- Use Video Parameters' Prefix Name field on the KAD/VID/106 module Setup tab and set the video parameter name as shown in the following figure.


*Figure 45-11: Setting the video parameter name*

This setting allows the software to *thread* all the video words, that is, force the order on the backplane.

Sampling video bit rate is the acquisition cycle × packets per acquisition cycle × occurrences × number of video words × 16.

#### 45.2.3.4 DAS Studio 3 - Using video over Ethernet

Video data can be placed in a UDP packet. Video parameters can be transmitted as a FIFO parameter or as a packetizer.

The following figure shows a KAD/VID/106 module in context with the **Settings** tab selected. **Encapsulation Mode** is set to FIFO.

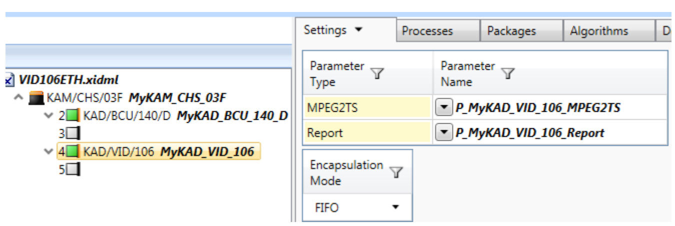



*Figure 45-12: Encapsulation Mode set to FIFO*

In the following figure, the KAD/BCU/140 is in context. The **Packages** tab is selected and we can see a KAD/BCU/140 package transmitting video.

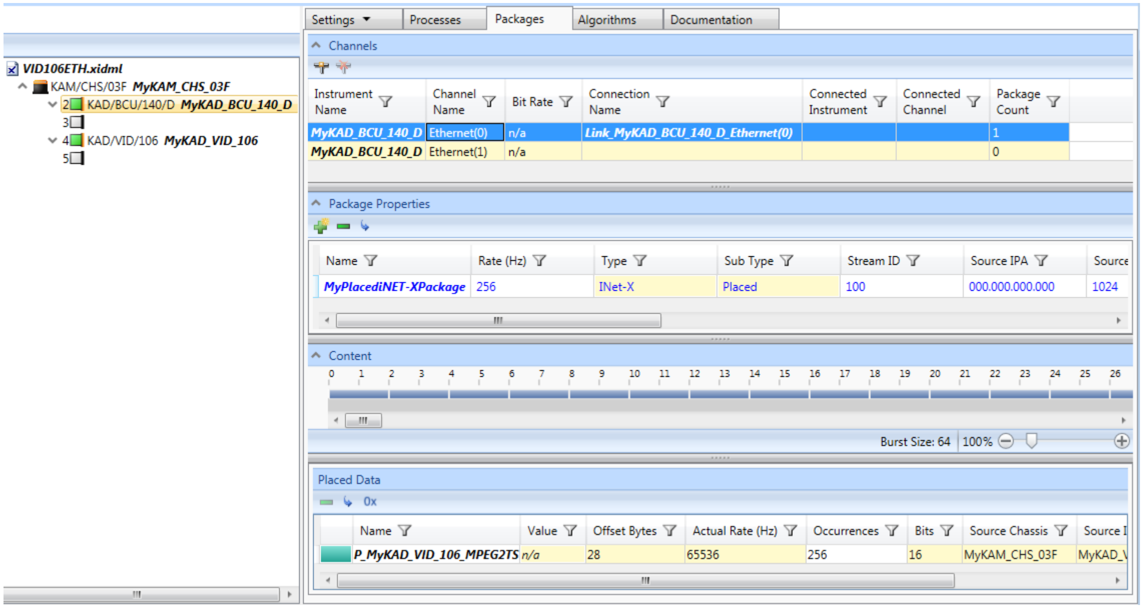



*Figure 45-13: KAD/BCU/140 package transmitting video*

The sampling video bit rate is the rate of the packet × occurrences × 16. Therefore, in the previous example: 256 × 256 × 16 = 1048576 bps.

Now we change **Encapsulation Mode** to **Packetizer** as shown in the following screen. A **Stream ID** must be defined and the **Packetization Enabled** check box must be selected.

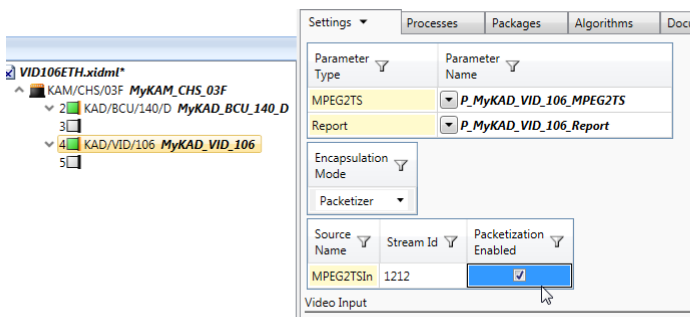



*Figure 45-14: Encapsulation Mode set to Packetizer*

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**NOTE:** This mode requires an aperiodic Ethernet transmitter module such as a KAD/BCU/140.

During Verify/Program, the iNET-X block packet is automatically created by DAS Studio 3.

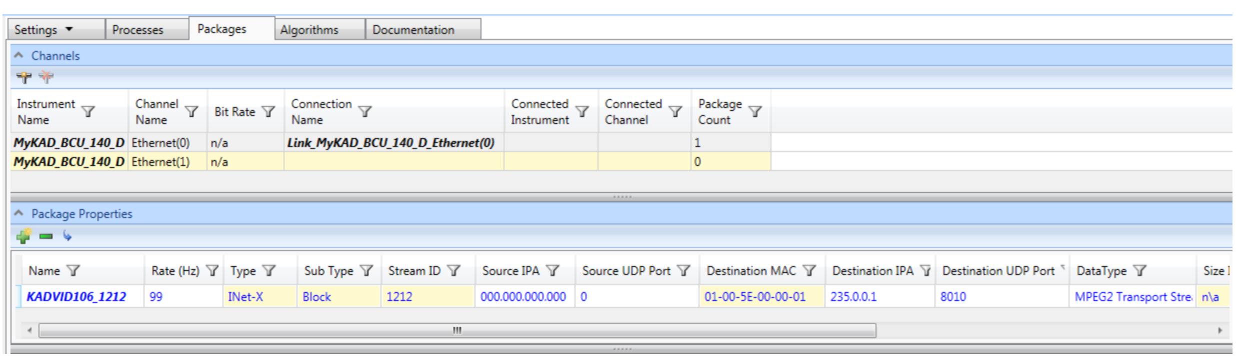



*Figure 45-15: iNET-X block packet on KAD/BCU/140*

#### 45.2.3.5 Using video with a memory module

Video data can be logged to a memory module the same way as any other type of data is logged. However, two constraints apply:

- Video parameter names must follow the syntax <optional_ label>VIDEO< optional_label>
- Video words must be sampled at the same rate in the memory module as in the PCM frame

Sampling video bit rate is: video sample rate × number of video words × 16.

## 45.3 Viewing KAD/VID/106 data

The data from the KAD/VID/106 can be viewed either in real-time (using GS Works 8) or at a later date using a memory module.

### 45.3.1 Using GS Works 8

Video data is treated the same as other types of Acra KAM-500 data by GS Works 8. That is, any data source such as PCM, UDP, or CompactFlash™ is supported by the KAD/VID/106. However, the ffdshow codec must be installed to view video using GS Works 8.

The KAD/VID/106 video is supported from GS Works 8.1.1. Refer to the GS Works 8 release notes. For example, in GS Works 8.1.1, audio is not available.

Video from the KAD/VID/106 module as displayed in the GS Works 8 video player is supported via the ffdshow_rev4513_20130525.exe video codec package. You can download ffdshow codec from source forge:

http://sourceforge.net/projects/ffdshow

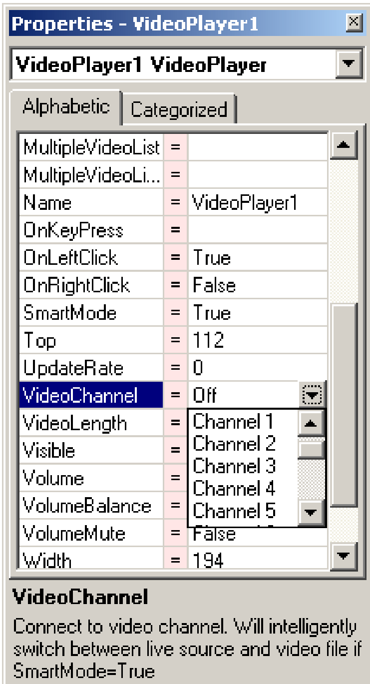
---

**NOTE:** You can only have one codec installed at a time. This means mixing KAD/VID/103 and KAD/VID/106 video in GS Works 8 is not supported.

After installing the codec, do the following to view video in GS Works 8.

1. Open GS Works 8 and follow the Start Wizard to load the data you want to view.
2. Click the **Display Builder** button on the dashboard to open the **Display Builder** window.
3. On the **Data Displays** tab, drag the **Analysis Window** icon to the desktop.
4. On the **ActiveX Controls** tab, drag the **VideoPlayer** icon to the **Analysis** window.


5. Right-click the **VideoPlayer** window and select **Properties**.
6. In the **Properties** window, scroll to the **VideoChannel** field and select the channel corresponding to the KAD/VID/106 output from the drop-down menu.




The video stream displays in the VideoPlayer.

### 45.3.2 Using kFlashCardXID and memory modules

As with other types of data, video data can be logged to a memory module for later viewing. Ensure that the KAD/VID/106 parameters are named <label>VIDEO<label> for correct operation.

Once the video data has been logged to the CompactFlash card, it can be extracted using kFlashCardXID. The output format must be Video (MPEG-2 Transport Stream) as shown in the following figure.

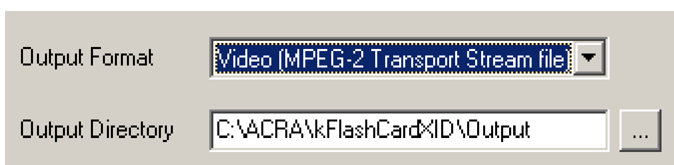



*Figure 45-16: Selecting Video output format in kFlashCardXID*

The video is extracted as a transport stream (<filename>.ts) file to the specified output directory. This transport stream file can then be viewed by MPEG viewing software such as VLC2.0 (http://www.videolan.org/vlc/).

**NOTE:** Contrary to the KAD/VID/103, audio is replayed by VLC because the KAD/VID/106 uses the MPEG Audio standard (AAC) in the audio stream.

### 45.3.3 Using UDP

An internal tool based on VLC can also be provided by Curtiss-Wright support (acra-support@curtisswright.com) to replay in real time KAD/VID/106 IENA/iNET-x placed or iNET-x packetizer video packets. Sound can also be replayed.

**NOTE:** This utility is an internal tool, therefore, no support is provided. When requesting this tool from Curtiss-Wright support, ask for TSD-AA-014 vlc to replay KAD/VID/106.

## 45.4 Troubleshooting

### 45.4.1 Only a black screen is displayed

If the Turn on timer overlay check box is selected on the Module Setup tab, and you see the time overlaid on a black screen, this means that the KAD/VID/106 is operating correctly, however, it is just not receiving a video stream. If the Turn on timer overlay check box is not selected, then select it now. This allows you to verify that the KAD/VID/106 is operating correctly before trying to troubleshoot video input problems.

- If camera selection is through the connector, ensure the correct pins are grounded. (See Table 45-1 on page 386.)
- If camera selection is through EEPROM, ensure that the camera is connected to the correct input. (See “Input Source” under “45.2.2.2  KSM-500 Setup tab settings” on page 388.)
- Verify the camera is working correctly.

### 45.4.2 GS Works 8 is in PCM lock but no video is displayed

This usually means that there is either a problem with the KAD/VID/106 video data, or destination modules.

- Ensure the correct output format is selected (PAL or NTSC). (See “Video Format” under “45.2.2.2  KSM-500 Setup tab settings” on page 388.)
- Ensure the MPEG bit-rate is adequate for the application. (See section “45.2.3  Using Video” on page 392.)
- If more than one destination module is being used in the system, ensure the KAD/VID/106 data is sampled at the same rate in each destination module. (See section “45.2.3  Using Video” on page 392.)

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Chapter 46

# Using DAS Studio 3 to configure the KAD/CBM/103

TEC/NOT/074

This technical note describes how to use DAS Studio 3 to configure the KAD/CBM/103 to parse messages.This paper discusses the following topics:



## 46.1 Overview

The KAD/CBM/103 is a 4-channel Cross Channel Data Link/Motor Controller Data Link (CCDL/MCDL) bus monitor. It can parse up to 127 unique messages per channel, with up to 65 bytes of data per message.

The CCDL/MCDL message structure is shown in the following figure. Messages are separated by gaps that are a minimum of 11 null bits wide. Bytes inside messages are transmitted without gaps.

| Header | Data | Cyclic Redundancy Check |
|---|---|---|
| 2 bytes | Up to 59 bytes | 4 bytes |

*Figure 46-1: Typical CCDL/MCDL message structure*

The header is composed as shown in the following figure.

| Bits 15 -11 | Bit 10 | Bits 9 - 6 | Bits 5 - 0 |
|---|---|---|---|
| Message ID | Master/slave bit | Freshness counter | Message length |

*Figure 46-2: Composition of header bytes*

Elements of the header are described as follows:

**Message ID:** a unique 5-bit identifier per message.

**Master/slave bit:** identifies whether the message came from a master unit (1) or a slave unit (0).

**Freshness counter:** 4-bit counter which increments every time a particular message ID is sent.

**Message length:** the number of data bytes contained in the current message.

## 46.2 About the CCDL/MCDL protocol

The CCDL/MCDL protocol uses a command-reply format. CCDL master devices request data from slave devices, which send replies using the same message ID. Considering the following example where a master device requests data with a message ID of 0, the header breakdown is as follows:

Message ID = 00000

Master bit = 1

Freshness counter = 0000

Message length = ******

When a slave device receives this request, it replies using the same message ID, incrementing the freshness counter by 1. The header breakdown is then:

Message ID = 00000

Master bit = 0

Freshness counter = 0001

Message length = ******

This continues until all required data from the slave has been received by the master.

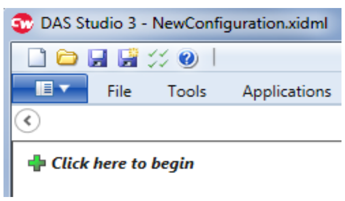
# 46.3 Using DAS Studio 3 to configure the KAD/CBM/103

DAS Studio 3 is used to create a configuration which contains the various elements which make up your data acquisition system. You may use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual.*

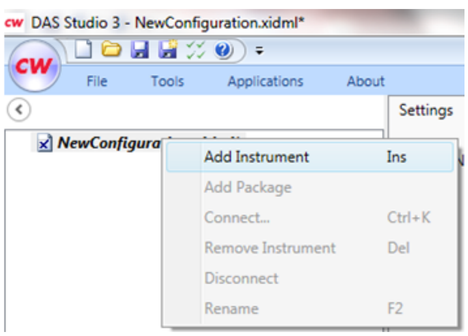
## 46.3.1 Creating a basic configuration

This section describes how to use DAS Studio 3 to create a basic configuration which includes the KAD/CBM/103.

1. On the **Quick Access Toolbar** or the **File** menu, click **New**.

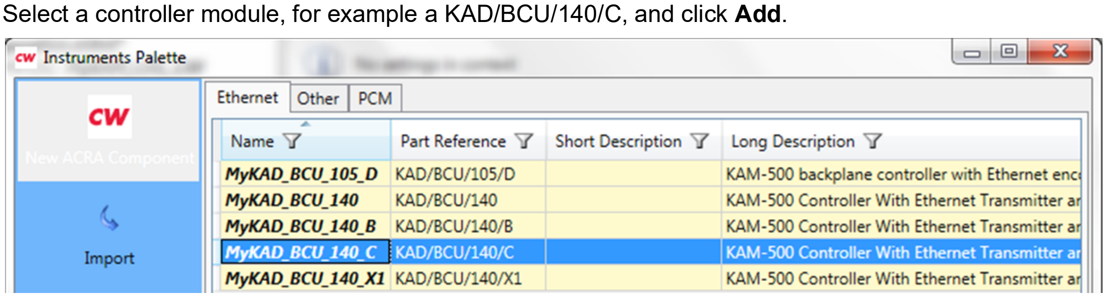



2. To add a chassis which represents the hardware you have connected, right-click on the overview node and click **Add Instrument**.

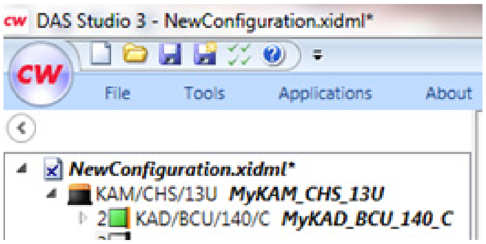



**Instruments Palette** opens. For information on **Instruments Palette** settings, see the *DAS Studio 3 User Manual*.

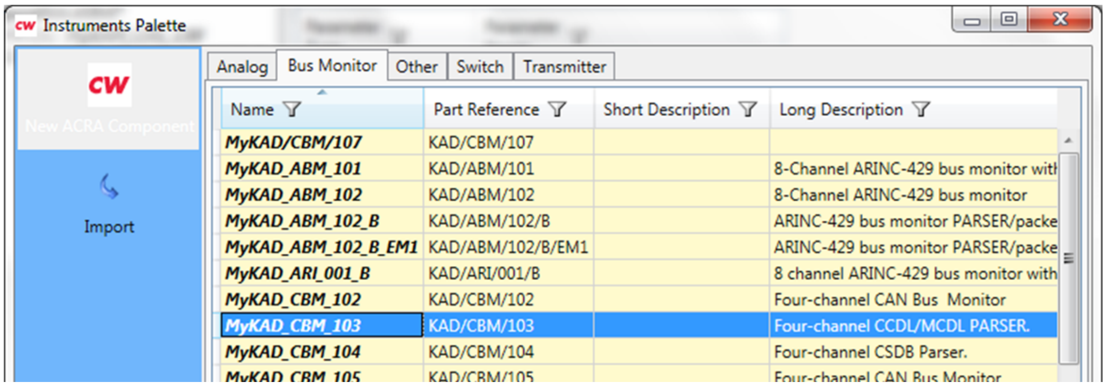
3. On the **DAU** tab, select the chassis connected and then click **Add**.
4. Click + to expand the chassis node.
Empty slots appear under the chassis indicating where modules can be added.
5. To add a controller module which represents the hardware you have connected, right-click on empty slot 2 and click **Add Instrument**.
**Instruments Palette** opens.
6. Select a controller module, for example a KAD/BCU/140/C, and click **Add**.



The module is added to slot 2.




7. To add the KAD/CBM/103 you have connected, right-click on an empty slot and click **Add Instrument**. **Instruments Palette** opens.
8. On the **Bus Monitor** tab, select the KAD/CBM/103 and click **Add**.

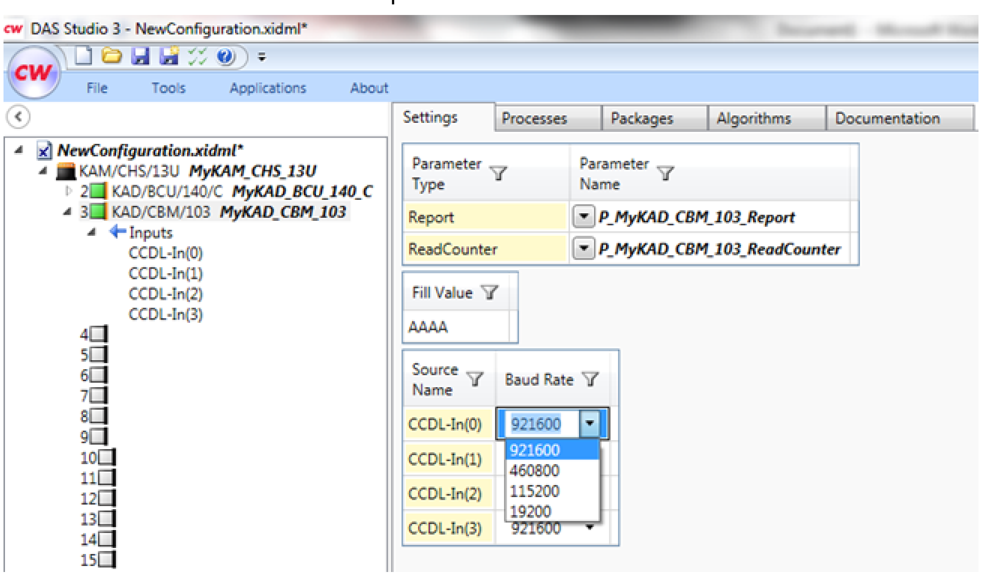



The module is added to the previously empty slot.

## 46.3.2 Setting bit-rates for the KAD/CBM/103

After adding the KAD/CBM/103 to your configuration, you can set bit-rates for channels.

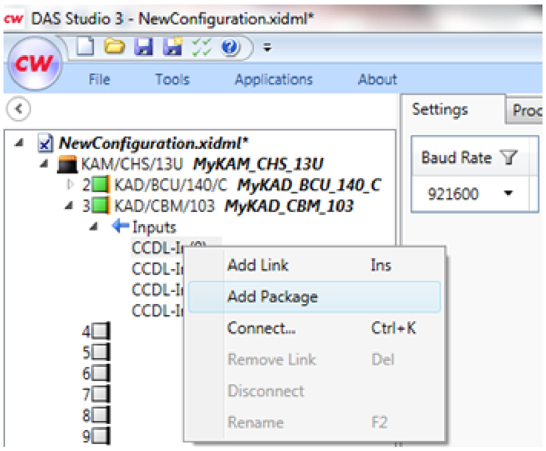
1. If required, click + to expand the KAD/CBM/103 node and the **Inputs** node.
2. On the **Settings** tab, set the bit-rate for each CCDL channel by changing the values in the **Baud Rate** field. Also, change the value in the **Fill Value** field as required.



## 46.3.3 Adding CCDL packages

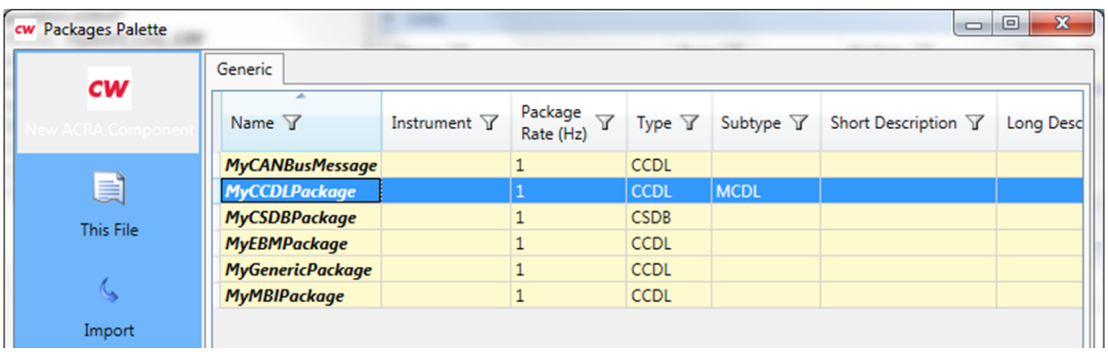
After setting bit-rates for each channel, add CCDL packages to each channel.

1. To add a package, right-click the channel where you want to add the package and click **Add Package**.

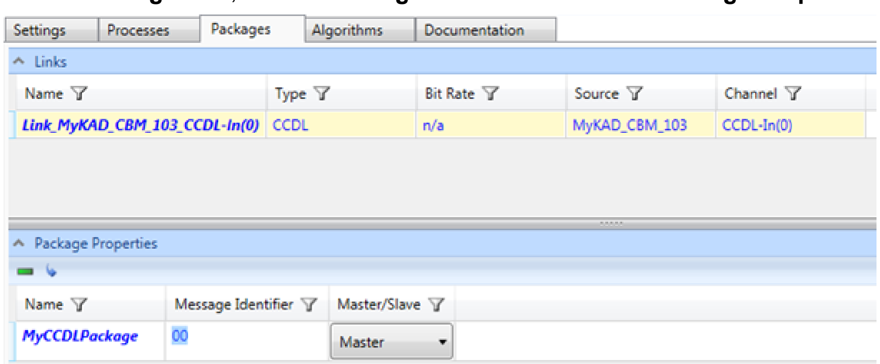



**Packages Palette** opens.

2. On the **Packages Palette**, select ***MyCCDLPackage*** and click **Add**.




3. On the **Packages** tab, set the **Message Identifier** field in the **Package Properties** pane.



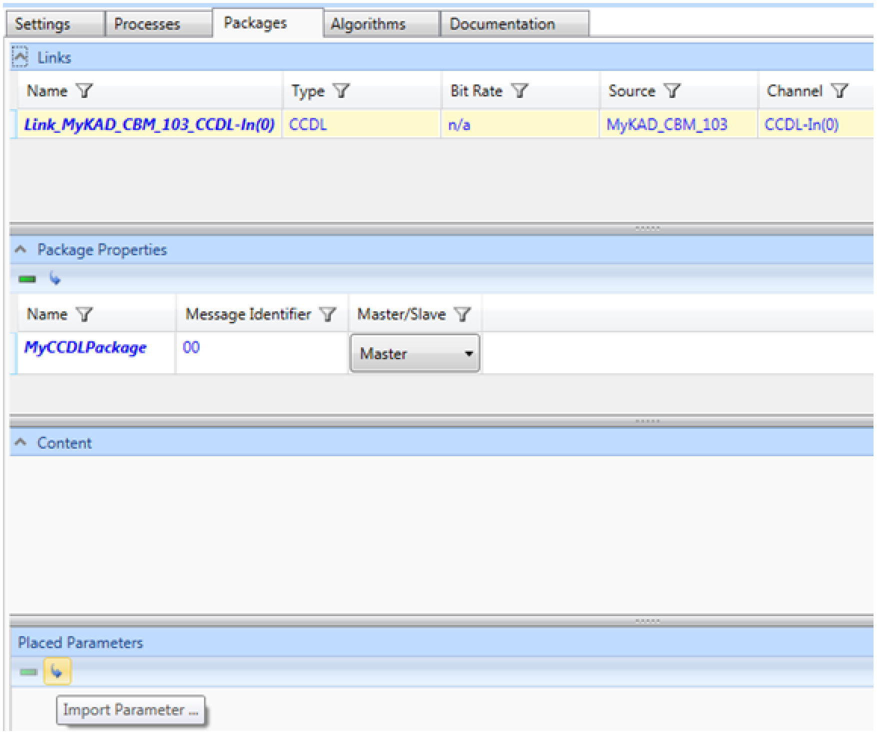

**NOTE:** Values must be in hex and in the range 00 to 1F.

4. In the **Master/Slave** field, select the message type.
Options available are: **Master**, **Slave** or **Both**.

## 46.3.4 Adding parameters to a CCDL package

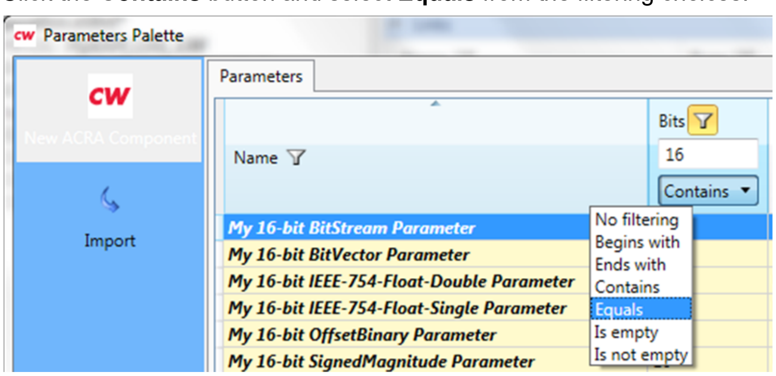
This section describes how to add parameters to the CCDL packages already defined.

1. In the **Placed Parameters** pane, click the **Import Parameter** button.



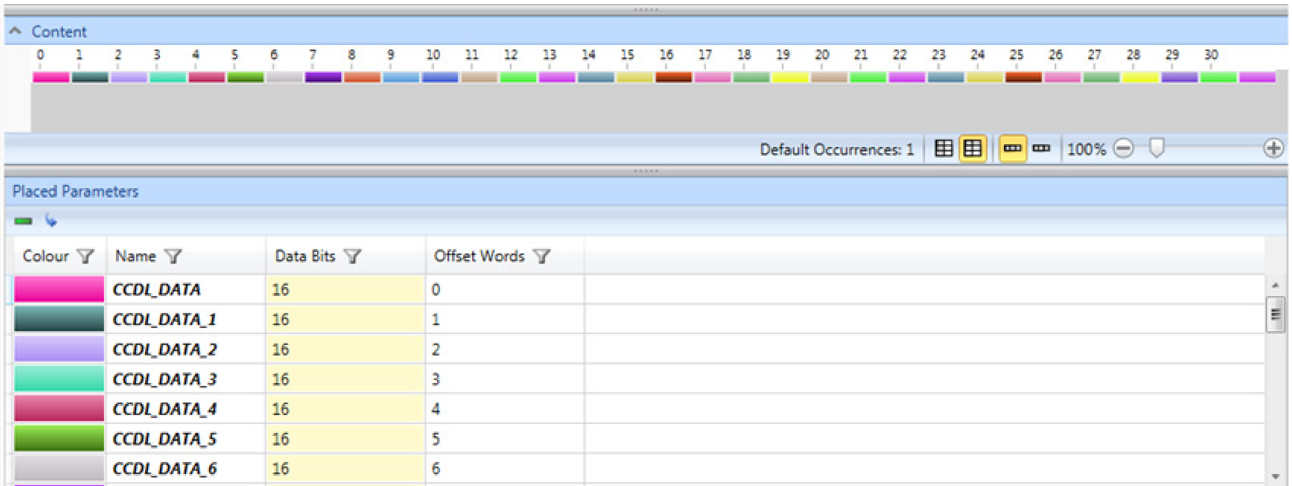

   **Parameters Palette** opens.
   **NOTE:** 32 x 16-bit parameters are required.

2. To filter the list of parameters so that only 16-bit parameters are displayed, click the icon in the **Bits** column heading and type **16** in the text box that appears.
3. Click the **Contains** button and select **Equals** from the filtering choices.




4. Select the first 32 x 16-bit parameters available.
   For information on using the **Shift** and **Ctrl** keys for selecting multiple fields, see the *DAS Studio 3 User Manual.*
5. Select the **Use My Renaming Rules** radio option.
6. Select the **Rename To** check box and type a unique parameter name in the box provided.
   For information on the **Use My Renaming Rules** and **Rename To** fields, see the *DAS Studio 3 User Manual.*

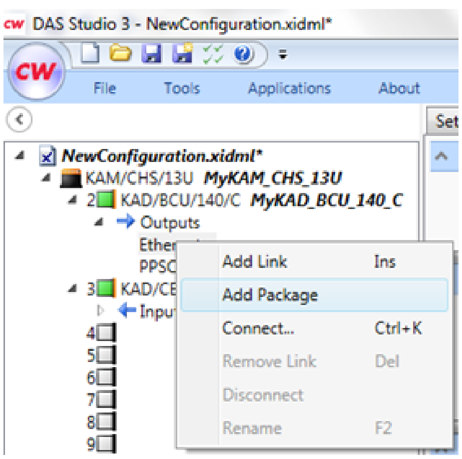
7. Click **Add**.
   On the **Packages** tab, 32 data words are added to the CCDL message.



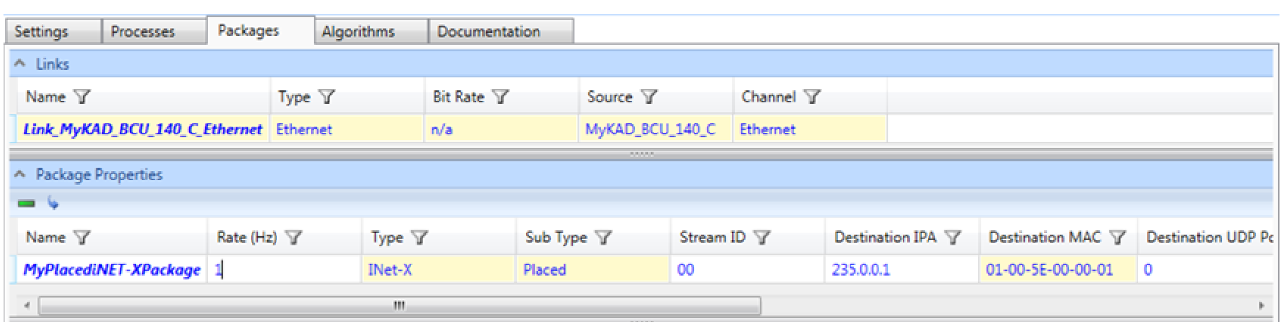

## 46.3.5 Placing incoming CCDL parameters

After adding parameters, it is necessary to place them into an outgoing package at a rate defined by you.

1. If required, click + to expand the controller node and the **Outputs** node.
2. Right-click the **Ethernet** link and select **Add Package**.




   **Packages Palette** opens.
3. On the **iNET-X** tab, select the ***MyPlacediNET-XPackage*** package type and click **Add**.
   On the **Packages** tab (ensuring the controller module is in context), an empty iNET-X packet with a **Stream ID** of **00** is created.




4. Set values for the **Rate (Hz)**, **Stream ID**, **Destination IPA**, and **Destination UDP Port** as required.

5. To place the CCDL parameters into this packet, click the **Import Parameter** button.
   **Parameters Palette** opens.
6. On the **Parameters Palette**, select all 32 of the CCDL data words previously created and click **Add Reference**.
   On the **Packages** tab, the CCDL parameters are added to the outgoing packet.

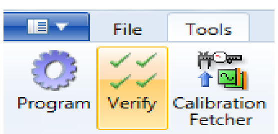
Placed Parameters

| Colour | Name | Data Bits | Occurrences | Offset Bytes | Actual Rate | Source Chass |
|---|---|---|---|---|---|---|
| | CCDL_DATA_10 | 16 | 1 | 28 | 16 | MyKAM_CHS |
| | CCDL_DATA_11 | 16 | 1 | 30 | 16 | MyKAM_CHS |
| | CCDL_DATA_12 | 16 | 1 | 32 | 16 | MyKAM_CHS |
| | CCDL_DATA_13 | 16 | 1 | 34 | 16 | MyKAM_CHS |
| | CCDL_DATA_14 | 16 | 1 | 36 | 16 | MyKAM_CHS |
| | CCDL_DATA_15 | 16 | 1 | 38 | 16 | MyKAM_CHS |
| | CCDL_DATA_16 | 16 | 1 | 40 | 16 | MyKAM_CHS |
| | CCDL_DATA_17 | 16 | 1 | 42 | 16 | MyKAM_CHS |
| | CCDL_DATA_18 | 16 | 1 | 44 | 16 | MyKAM_CHS |
| | CCDL_DATA_19 | 16 | 1 | 46 | 16 | MyKAM_CHS |

## 46.3.6 Verifying configuration

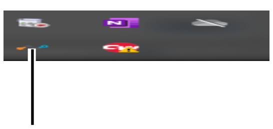
Use the Verify tool to check that the current configuration contains no errors.

1. On the **Quick Access Toolbar** or the **Tools** menu, click **Verify**.

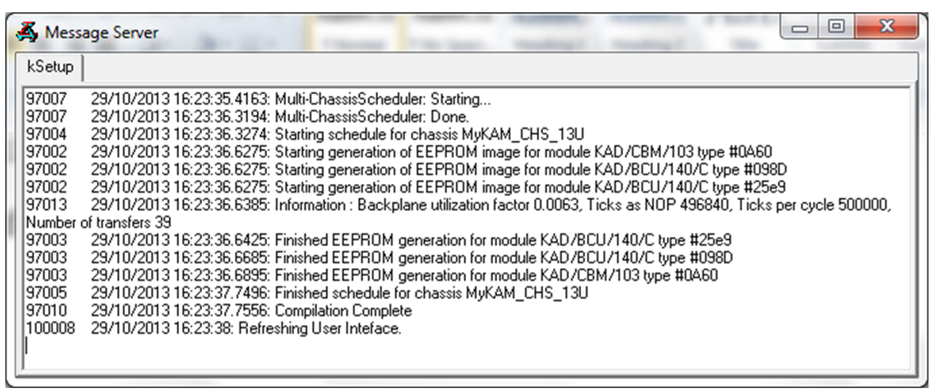



When verification is complete, a message displays to confirm whether the configuration was verified successfully.

**TIP!** Details of the verification are available in the Message Server window. To display the Message Server window, double-click its icon in the notification area.



Double-click to open Message Server



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Chapter 47

# Using DAS Studio 3 to configure the KAD/EBM/102

TEC/NOT/075

This paper discusses the following topics:



## 47.1 Module overview

The KAD/EBM/102 is a single-channel Ethernet bus monitor, which can parse and classify traffic using up to eight frame fields such as MAC addresses, IP addresses, and IP length with optional masking.

Like other Acra KAM-500 bus monitors, the data within the parsed Ethernet frames is available to be distributed to other modules via the KAM-500 backplane. It can identify and parse 254 unique Ethernet flows, where a flow represents a stream of Ethernet frames from a specific source to a specific destination. Flows are tagged with timestamps and packet counts.

The KAD/EBM/102 can be used to monitor, record, diagnose, and troubleshoot Ethernet network traffic. It can also be configured as an Ethernet-to-PCM bridge by means of the Multi Chassis Scheduler (MCS) software, which is integrated within the compiler of DAS Studio 3. The module can be programmed to operate in a promiscuous mode, which allows it to observe all traffic on the link, not only packets that are addressed to it.

Network management traffic, such as Address Resolution Protocol (ARP) packets and Internet Control Message Protocol (ICMP) packets, is optionally discarded or monitored via the catchall parser slot ID 254.

The KAD/EBM/102 supports Ethernet packet sizes up to 1,500 bytes and also features valid and error frame counters and error detection on Ethernet and IP layers. Connection speed is programmable to operate at 10BaseT, 100BaseTX, 1000BaseT or auto-negotiation.

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**NOTE:** The KAD/EBM/101 is a similar module to the KAD/EBM/102 in terms of set up (see *TEC/NOT/046 - Using the KAD/EBM/101)*, however it is limited to 100BaseTX.

## 47.2 Ethernet-to-PCM bridge overview

The MCS is system scheduling software that enables you to transparently transmit parameters from any available Data Acquisition Unit (DAU) in a networked system by means of an Ethernet bus monitoring module such as the KAD/EBM/102 located in an Ethernet-to-bridge chassis. This system is referred to as Scenario 1 throughout this document.

The MCS is in charge of automatically creating intra-chassis Ethernet packets that are captured by the KAD/EBM/102.

The following diagram shows a typical MCS over Ethernet scenario where PCM is used for real-time telemetry in an Ethernet system.

In this example, parameter **P1** comes from a module placed on a remote **DAU 1** and it is being transmitted over the network , then **P1** gets parsed by the KAD/EBM/102 and, once available in the KAM-500 backplane of the Ethernet-to-PCM bridge chassis, transmitted over PCM using a KAD/ENC/106.

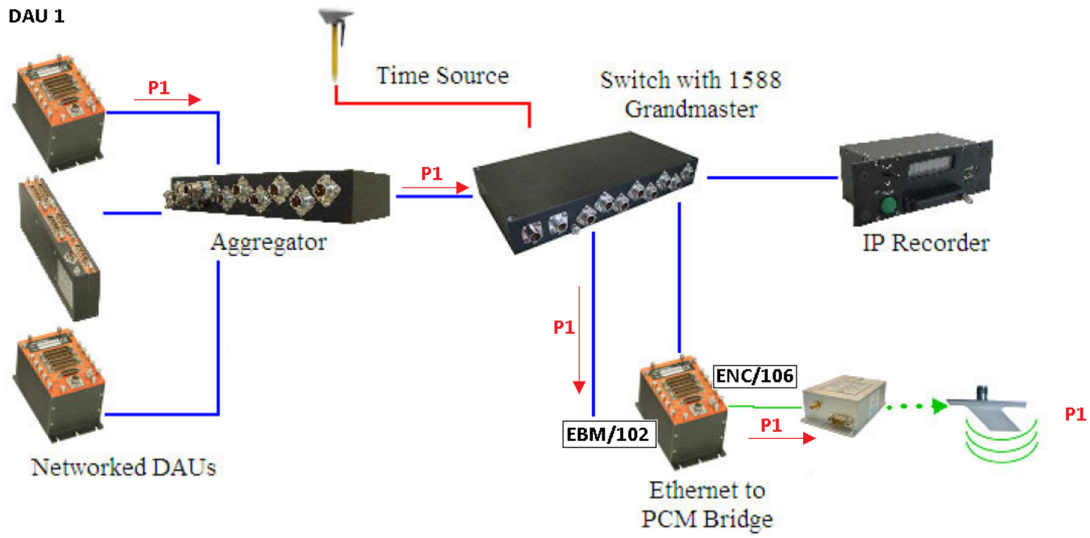


*Figure 47-1: Example of MCS traffic showing parameter P1 from remote DAU 1*

## 47.3 KAD/EBM/102 DAS Studio 3 settings

This technical note describes three scenarios (referenced as: *Scenario 1*; *Scenario 2*; *Scenario 3*) where DAS Studio 3 can be used to configure the KAD/EBM/102. Depending on the scenario, some of the default settings shown in the following table need to be modified.

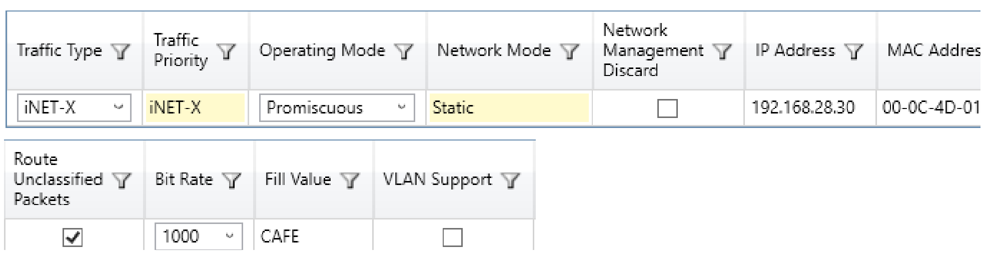


*Figure 47-2: DAS Studio 3 Settings tab for KAD/EBM/102*

Table 47-1: KAD/EBM/102 settings in DAS Studio 3

| Setting | Notes |
|---|---|
| Traffic Type | This setting defines the type of packet expected when configuring the KAD/EBM/102 as a bus monitor in different scenarios. In an Ethernet-to-PCM stream scenario (MCS), select **iNET-X** or **IENA**. (Scenario 1)<br>In a generic Ethernet bus monitor scenario, select **Generic**. (Scenario 2)<br>Select **All** when parsing both MCS packets and generic Ethernet packets. (Scenario 3)<br><br>**NOTE:** Select either iNET-X or IENA. Do not mix traffic types; if you decide to use iNET-X packets for all other traffic, then the transport packets must also be iNET-X.<br><br>**NOTE:** The MCS builds packets to transport parameters from DAUs to the PCM DAU at user-defined rates. It is necessary to separate MCS Ethernet packets from non-PCM bridge traffic (for more information, see “47.5.2 Filtering Ethernet packets” on page 415). |

Table 47-1: KAD/EBM/102 settings in DAS Studio 3 (continued)

| Setting | Notes |
|---|---|
| Traffic Priority | This advanced option is only available when parsing both MCS packets and generic Ethernet packets (Scenario 3). It defines the processing priority for package types when filtering rules overlap. |
| Operating Mode | By setting **Promiscuous**, the KAD/EBM/102 parses all traffic, even if not directed specifically at the KAD/EBM/102. That is, it parses all traffic regardless of the MAC address destinations.<br>If you select **Non-promiscuous**, the KAD/EBM/102 parses only those Ethernet packets with a Destination IP address and a Destination MAC address matching those defined for the KAD/EBM/102. All other traffic is discarded, including broadcast traffic.<br>**NOTE:** Promiscuous mode is the recommended setting as it covers the most common scenarios since users generally monitor traffic going to other devices. |
| Network Mode | Only Static IP addresses are supported by KAD/EBM/10x modules. This setting can not be modified.<br>**NOTE:** Protocols for automating the task of assigning IP addresses such as Dynamic Host Configuration Protocol (DHCP) are not supported . |
| Network Management Discard | This setting enables or disables network management commands ARP and PING. When this check box is selected, all broadcast ARP/PING requests are discarded. When this check box is cleared, ARP/PING requests are processed and a response is sent back by the module. The default and recommended setting is to have the check box cleared allowing you to ping the KAD/EBM/102. |
| IP Address | Allows you to specify a unique IP Address for the KAD/EBM/102.<br>**NOTE:** The KAD/EBM/102 requires an IP address primarily to work in non-promiscuous mode, that is, when data is being sent directly to it. |
| MAC Address | Allows you to specify a unique MAC Address for the KAD/EBM/102.The first three bytes for Curtiss-Wright MAC addresses are 00-0C-4D. |
| Route Unclassified Packets | When enabled, all unclassified traffic is routed to the Catchall-Parser (slot ID 254)<br>By default, this check box is selected. |
| Bit Rate | The following speed options are available: 10, 100, 1000, or Auto-negotiate. The main factor in selecting one of these options is the speed of the output port of the connecting switch. We recommend using 1000 (1000BaseT) whenever possible, as this offers the greatest Ethernet bandwidth. |
| Fill Value | The default value is 0xAAAA. To assist with identifying Ethernet connection issues, we recommend using a readily identifiable hex word such as 0xCAFE. |
| VLAN Support | This is an advanced option. Enabling VLAN Support allows parser slots—when present—to skip over VLAN packet headers, allowing you to classify traffic on the basis of IP and UDP/TCP packet header fields. Refer to “47.8.10 VLAN” on page 427 for further information. By default, this check box is cleared. |

For further information, refer to the latest *KAD/EBM/102* data sheet.

## 47.4 Using DAS Studio 3 to set up configuration scenarios

DAS Studio 3 is used to create a configuration, which contains the various elements, which make up your data acquisition system. You then use this configuration file to manage and program these elements.

To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

## 47.5 Scenario 1: using the KAD/EBM/102 to transmit Ethernet data to PCM

As described in “47.2 Ethernet-to-PCM bridge overview” on page 411, in Ethernet systems where every DAU has an Ethernet controller and transmits data to a central switch, the KAD/EBM/102 can act as a bridge module for transmitting Ethernet-captured data into a Pulse Code Modulation (PCM) stream.

In this scenario, the KAD/EBM/102 is connected to the output of an aggregating switch, through which data from all other DAUs is available to the PCM DAU.

This scenario is illustrated in the following figure where two DAUs (DAU_0 and DAU_1) are connected to a network switch; and a PCM DAU (containing a KAD/EBM/102) is connected between the output of the network switch and a PCM transmitter. Connecting the system in this way makes all DAU parameters available to the PCM stream transmitted by the KAD/ENC/106.

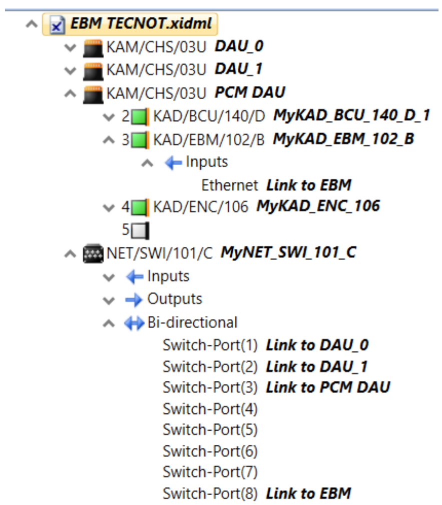


*Figure 47-3: Scenario 1 – Ethernet to PCM bridge (MCS)*

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**NOTE:** This example assumes the network switch is correctly configured to route packets from a remote DAU to the KAD/EBM/102.

### 47.5.1 Configuring the KAD/EBM/102 to transmit Ethernet data into a PCM stream

The following figure shows the settings when the KAD/EBM/102 has been configured to act as a bridge module for transmitting Ethernet data and Traffic Type is set to iNET-X or IENA.

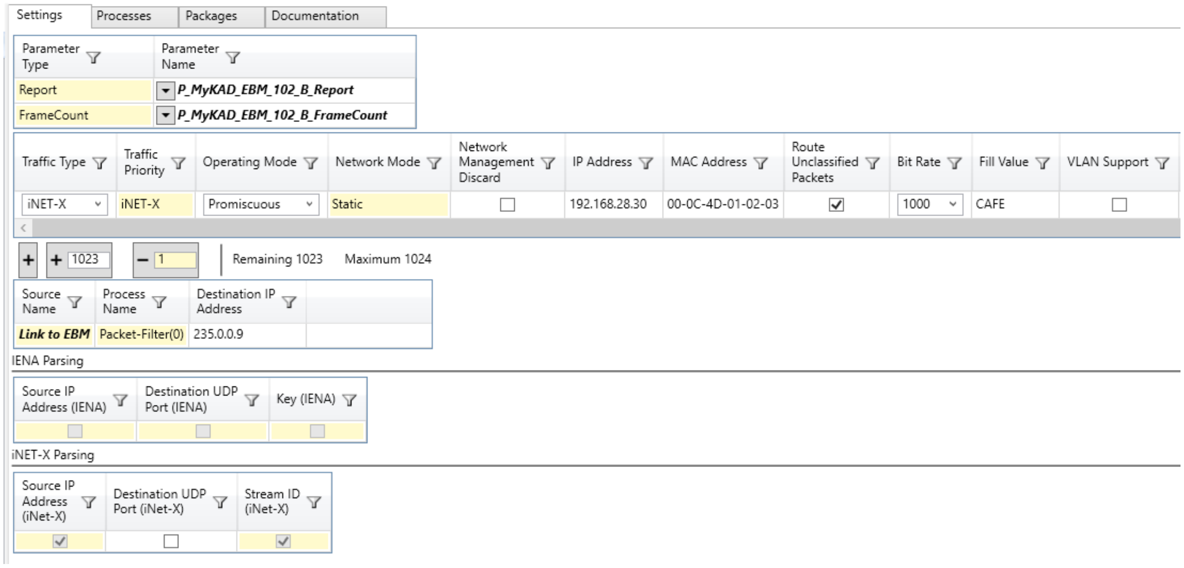



*Figure 47-4: DAS Studio 3 settings when configuring the KAD/EBM/102 for MCS*

The following settings need to be modified from the defaults.

Table 47-2: Settings for Scenario 1

| Setting | Notes |
|---|---|
| Traffic Type | Select **iNET-X** or **IENA**. |
| Operating Mode | Select **Promiscuous**. |
| IP Address | Change to a unique IP address in the system. |
| MAC Address | Change to a unique MAC address in the system starting as 00-0C-4D. |
| Bit Rate | Optional. Can be changed to Auto-negotiate if required. |
| Fill Value | Optional. Recommended to use a readily identifiable hex word such as 0xCAFE. |

### 47.5.2 Filtering Ethernet packets

Traffic from all connected DAUs is available to the KAD/EBM/102, so it is likely that non-PCM bridge traffic is also flowing across the same link. Therefore, the KAD/EBM/102 must be able to identify MCS packets. This is achieved by creating a filter for each KAD/EBM/102 input. To create such a filter, do the following.

1. Select the **KAD/EBM/102** in the Navigator pane and then click the **Settings** tab.
2. In the **Process Name** column, click the + button beside **<Create a new 'Packet-Filter' process on Ethernet>**.
   A **Packet-Filter** setting appears.
3. In the **Destination IP Address** field, insert a value for a multicast IP address.
   In the above example the Multicast IP address used is 235.0.0.9.
   **NOTE:** MCS also supports unicast packets for which the destination is the KAD/EBM/102 itself. In this case, in the **Destination IP Address** field, enter the KAD/EBM/102 IP address. So for the example above, type **192.168.28.30**.

### 47.5.3 Defining Ethernet packets to parse

In DAS Studio 3.4.16 onwards, when selecting the traffic type of the MCS packets, the settings which enable the KAD/EBM/102 to identify Ethernet packets for parsing are set automatically.

When Traffic Type IENA is selected, the IENA Parsing pane automatically selects Source IP Address (IENA) and Key (IENA).

When Traffic Type iNET-X is selected, the iNET-X Parsing pane automatically selects Source IP Address (iNET-X) and Stream ID (iNET-X).

---

**NOTE:** Select the **Destination UDP Port** check box if an Ethernet controller module is also used in the Ethernet system as the PTP Grandmaster. The reason is the Grandmaster generates PTP packets (UDP/IP packets), which could be parsed inadvertently by the KAD/EBM/102. Selecting the Destination UDP Port check box prevents from this happening.

### 47.5.4 Generating MCS packets

You can proceed to build a PCM frame once the routing of the switch (for example NET/SWI/101/C) and the module settings are configured correctly in DAS Studio 3. Once the PCM is created, click **Verify**; MCS packets are automatically built by DAS Studio 3 at the data source DAUs. This ensures that the data words to be sent over real-time PCM arrive at the data selector chassis in time for transmission. Refer to “47.8.12 Step-by-step instructions for generation of MCS packets (Scenario 1)” on page 427 for details on how MCS packets are automatically built.

## 47.6 Scenario 2: using the KAD/EBM/102 as a generic Ethernet parser

The KAD/EBM/102 can also be used as an Ethernet bus monitor to parse traffic from external sources, thereby making it available to the Acra KAM-500 backplane for use in other modules. In this scenario, all traffic to be parsed by the KAD/EBM/102 is considered generic, therefore you must use the Ethernet Builder application to parse Ethernet traffic.

For the KAD/EBM/102 to parse generic Ethernet traffic, you must set the **Traffic Type** field to **Generic** as shown in the following figure.

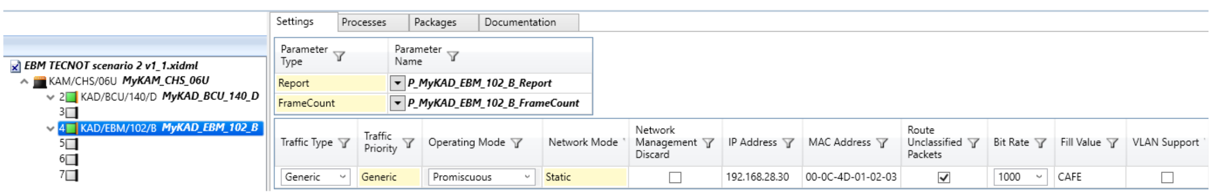



*Figure 47-5: Scenario 2 - KAD/EBM/102 acting as a generic Ethernet parser in DAS Studio 3*

The following settings need to be modified from the defaults.

Table 47-3: Settings for Scenario 2

| Setting | Notes |
|---|---|
| Traffic Type | Select **Generic.** |
| IP Address | Change to a unique IP address in the system. |
| MAC Address | Change to a unique MAC address in the system starting as 00-0C-4D. |
| Bit Rate | Optional. Can be changed to Auto-negotiate if required. |
| Fill Value | Optional. Recommended to use a readily identifiable hex word such as 0xCAFE. |
| VLAN Support | Optional. Depending on application. |

### 47.6.1 Using Ethernet Builder to configure the KAD/EBM/102

The Ethernet Builder application adds and configures Ethernet messages and parameters on Ethernet bus monitor modules, such as the KAD/EBM/102.

This section features a worked example of how to use Ethernet Builder to configure the KAD/EBM/102 to parse an Ethernet packet with a source IP of 10.11.12.13, a destination IP of 233.10.11.45, and a destination port of 1024.

In this worked example, words 100, 102, 104, and 106 are extracted from the parsed packet.

Knowing that the Word Offset is defined as per the example in the following table, Word Offset 0 is the start of the Ethernet Frame and is therefore the first 16 bits of the Destination MAC address.

Table 47-4: iNET-X, IENA, and VLAN word offset

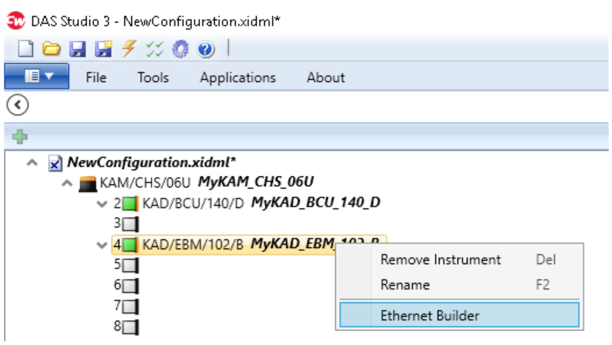
| Field name | Values of offset index words | |
|---|---|---|
| | **Offset If VLAN disabled** | **Offset If VLAN enabled** |
| MAC header | | |
| Destination MAC address, word 0 (MSW) | 0 | 0 |
| Destination MAC address, word 1 | 1 | 1 |
| Destination MAC address, word 2 (LSW) | 2 | 2 |
| Source MAC address, word 0 (MSW) | 3 | 3 |
| Source MAC address, word 1 | 4 | 4 |
| Source MAC address, word 2 (LSW) | 5 | 5 |
| Frame/Protocol type; 0x0*0 e.g. IP = 0800h | 6 | 8 |
| IP header | | |
| VLAN priority/ID | N/A | 7 |
| IP version/IHL/ToS | 7 | 9 |
| IP packet size | 8 | 10 |
| IP ID | 9 | 11 |
| IP flags and fragment offset | 10 | 12 |
| IP TTL and Protocol; xx11h for UDP and xx06h for TCP | 11 | 13 |
| IP header checksum | 12 | 14 |
| Source IP address, word 0 (MSW) | 13 | 15 |
| Source IP address, word 1 (LSW) | 14 | 16 |
| Destination IP address, word 0 (MSW) | 15 | 17 |
| Destination IP address, word 1 (LSW) | 16 | 18 |
| Source port no. | 17 | 19 |
| Destination port no. | 18 | 20 |
| UDP Length; TCP seq word 0 | 19 | 21 |
| UDP CSum; TCP seq word 1 | 20 | 22 |

Table 47-4: iNET-X, IENA, and VLAN word offset (continued)

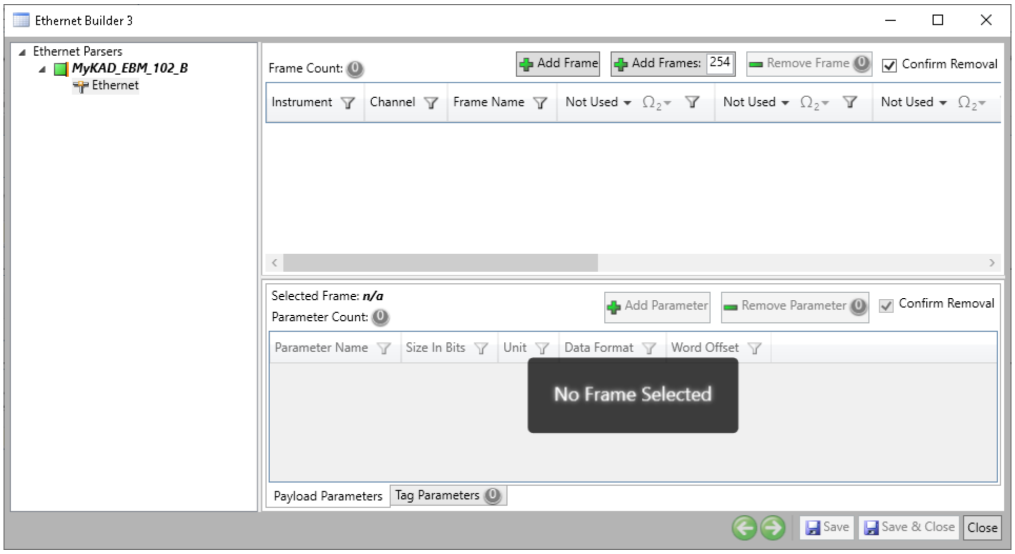
| Field name | Values of offset index words | |
|---|---|---|
| | Offset If VLAN disabled | Offset If VLAN enabled |
| Data payload | | |
| IENA key or iNET Control Field 0 // TCP Ack word 0 | 21 | 23 |
| IENA size or iNET Control Field 1 // TCP Ack word 1 | 22 | 24 |
| iNET-X Stream ID word 0 or IENA date 0 // TCP offset/flags | 23 | 25 |
| iNET-X Stream ID word 1 or IENA date 1// TCP window | 24 | 26 |
| iNET-X Seq Number 0 or IENA date 2 // TCP Csum | 25 | 27 |
| iNET-X Seq Number 1 or IENA status // TCP urgent Ptr | 26 | 28 |
| iNET-X Pckt Length 0 or IENA Seq // TCP Options (or TCP Data 0) | 27 | 29 |

To parse the Ethernet frame, do the following:

1. Before running this application, ensure that the KAD/EBM/102 has been added to the configuration, and that **Traffic Type** is set to **Generic** (see “47.6 Scenario 2: using the KAD/EBM/102 as a generic Ethernet parser” on page 416). Otherwise, a “No Supported Ethernet Parsers Found” message is displayed when you try to launch the Ethernet Builder application.
2. Right-click the KAD/EBM/102 module in the Navigator and then click **Ethernet Builder**. (You can also click the **Applications** menu and then click **Ethernet Builder**.)

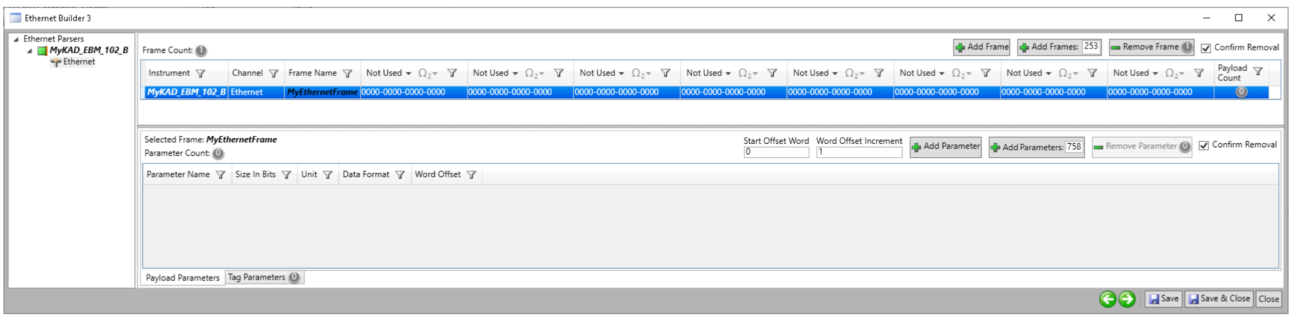



The **Ethernet Builder 3** dialog box opens.



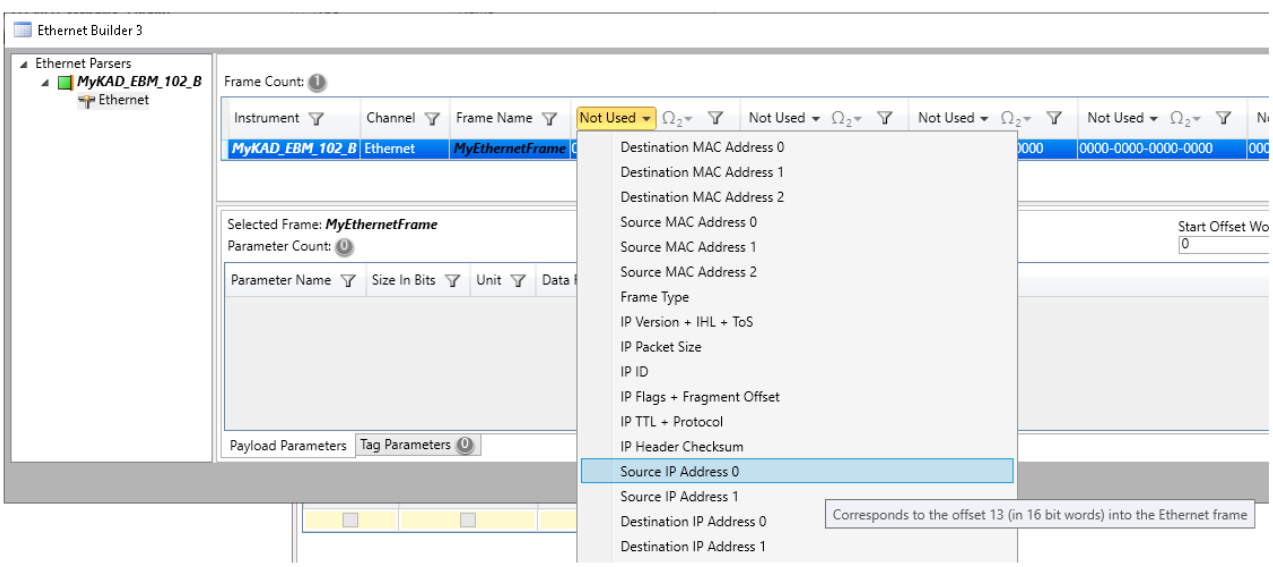

For dialog box navigation, see “Builder application GUI overview” in the *DAS Studio 3 User Manual*.

3. Add a single frame to the Ethernet link by selecting **Ethernet** in the Navigator pane and clicking **Add Frame**.

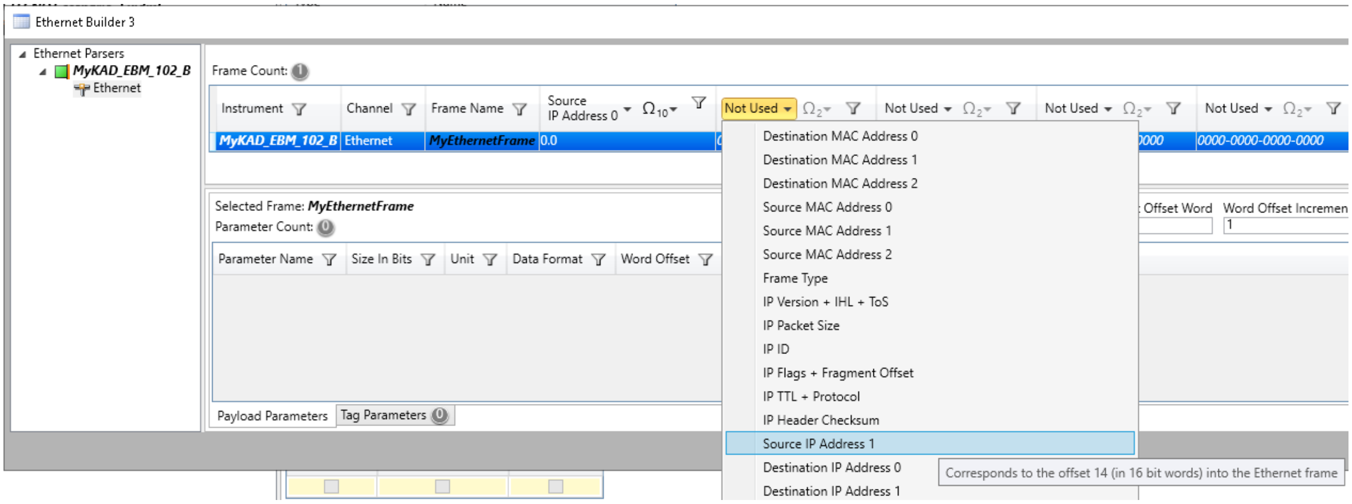



**NOTE:** In the **Frame Count** pane, there are eight 16-bit user-definable classifier fields (by default, these fields are labeled **Not Used**), which can be used to create the rules which help the KAD/EBM/102 identify Ethernet packets.
As the fields to be used for source IP and destination IP are both two 16-bit fields, two classifier rules for both the source IP and the destination IP are required.

4. In the first classifier field, click the drop-down arrow beside **Not Used** and select **Source IP Address 0**.

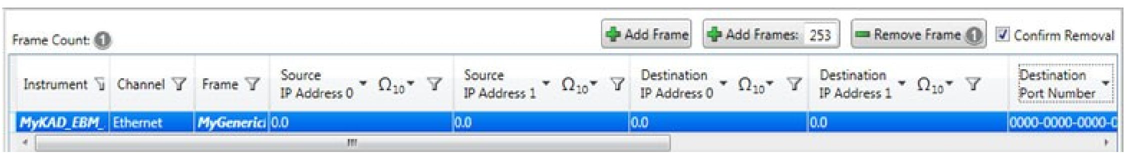


5. In the second classifier field, click the drop-down arrow beside **Not Used** and select **Source IP Address 1**.



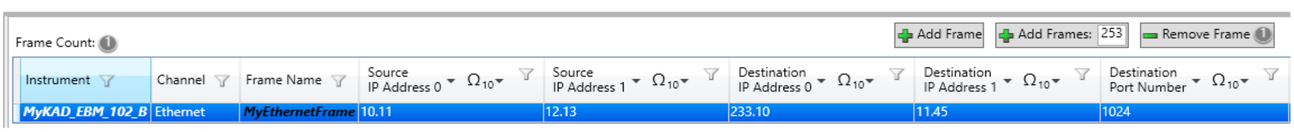

**NOTE:** When Source IP Address 0 is in use, it is not available in the drop-down list.

6. Set the remaining classifier fields by selecting **Destination IP** for the third and fourth classifier fields, and selecting **Destination Port Number** for the fifth classifier field.
Definitions for the required classifier fields are now set.



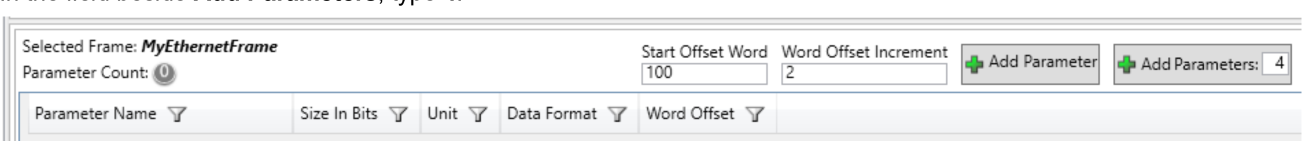

**NOTE:** Values for these classifier fields can be formatted using Decimal, Hex, Octal, or Binary format. To change a format, click the drop-down arrow by the Ω symbol for each classifier field and choose the desired format. In our working example, Decimal format suffices.

7. In the **Source IP Address 0** field, type **10.11**.
8. In the **Source IP Address 1** field, type **12.13**.
9. In the **Destination IP Address 0** field, type **233.10**.
10. In the **Destination IP Address 1** field, type **11.45**.
11. In the **Destination Port** field, type **1024**.
Values for the classifiers fields are now set.

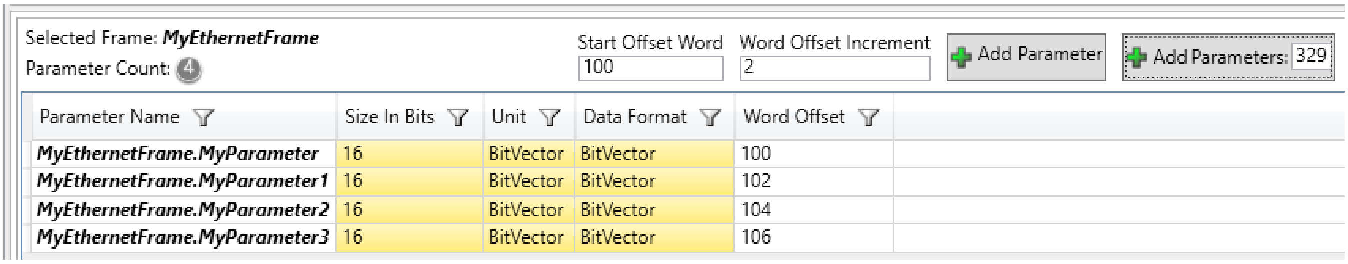



**NOTE:** Now that parsing classifiers have been defined, add the parameters to be extracted from the packet; specifically, words 100, 102, 104, and 106.

12. In the **Start Offset Word** field, type **100**.
13. In the **Word Offset Increment** field, type **2**.
14. In the field beside **Add Parameters**, type **4**.



15. Click **Add Parameters**.
    Four parameters are now created at offsets **100**, **102**, **104**, and **106**.




16. To save changes, click **Save & Close**.

## 47.7 Scenario 3: KAD/EBM/102 setup to parse Generic and MCS packets simultaneously

In this scenario the KAD/EBM/102 works as both MCS parser (Scenario 1) and generic Ethernet parser (Scenario 2).

**Traffic Type** must be set to **All** as shown in the following figure.

**NOTE:** The **Traffic Priority** field has to be set accordingly if the filtering rules overlap, which could happen in the unlikely case of having non-unique parsing rules on generic packets and IENA/iNET-X MCS packets.

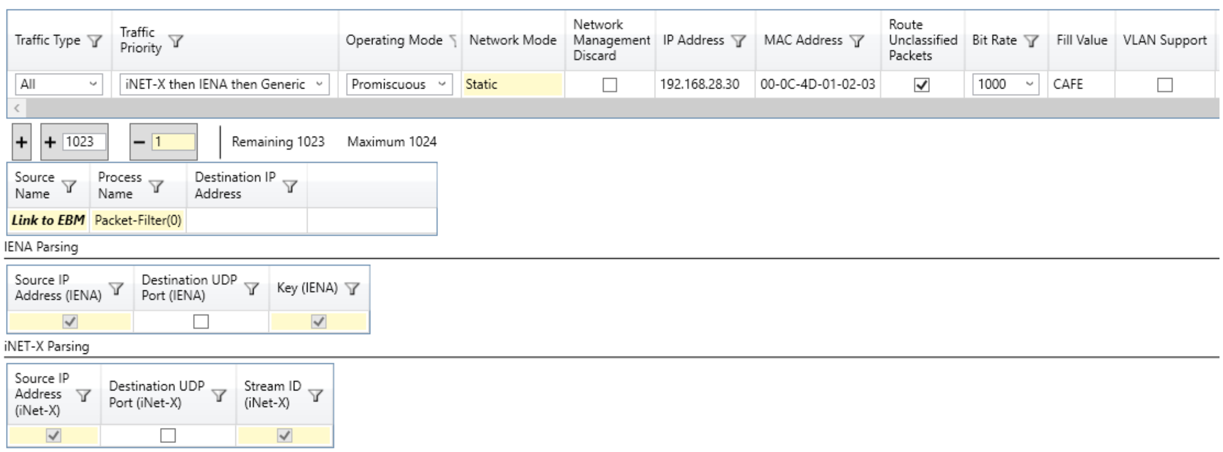



*Figure 47-6: Setup Scenario 3 - KAD/EBM/102 acting as both MCS and generic Ethernet parser in DAS Studio 3*

The following settings need to be modified from the defaults.

Table 47-5: Settings for Scenario 3

| Setting | Notes |
|---|---|
| Traffic Type | Select **All**. |
| Traffic Priority | Filtering rules overlap. Set depending on application. Leave as default if unsure. |
| IP Address | Change to a unique IP address in the system. |
| MAC Address | Change to a unique MAC address in the system starting as 00-0C-4D. |
| Bit Rate | Optional. Can be changed to Auto-negotiate if required. |
| Fill Value | Optional. Recommended to use a readily identifiable hex word such as 0xCAFE. |

Table 47-5: Settings for Scenario 3

| | |
|---|---|
| VLAN Support | Optional. Depending on application. |

To add MCS packets, see “47.5 Scenario 1: using the KAD/EBM/102 to transmit Ethernet data to PCM” on page 414.

To add generic packets, see “47.6 Scenario 2: using the KAD/EBM/102 as a generic Ethernet parser” on page 416.

# 47.8 Appendix

## 47.8.1 ARINC 664 Part 7 (A664P7) monitoring

The KAD/EBM/102 is an Ethernet packet parser and can therefore monitor ARINC 664 Part 7 (ARINC-664P7) messages, however the packets to be parsed must not be transmitted in burst and the parameters must be in a fixed location in the Ethernet packet. The KAD/EBM/103 can parse specific Rockwell Collins ARINC-664P7 messages and the KAD/EBM/104 can parse specific ARINC-664P7 messages from GE aviation.

A KAD/ARR/101 may be used to check the sequencing and remove the redundancy between the two source networks.

## 47.8.2 Triple buffer

For generic packets, the module uses the usual concept of triple buffer as per all Acra KAM-500 parser bus monitors. The following figure illustrates the triple buffering of data words (green) and time message tags (white) in the KAD/EBM/102 parser.

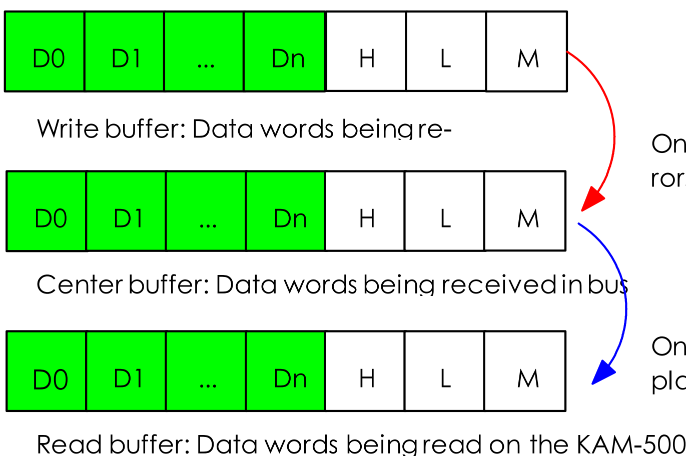



*Figure 47-7: Triple buffering of traffic and associated message tags*

D0, D1, D2, Dn in the previous figure corresponds to the Ethernet traffic data words with n < 758.

The time tags H, L, M correspond to High time, Low time, and Micro time—which is the time of the start of the first received bit of the message with a 1-µsec resolution.

The way triple buffering works is as follows:

Time message tags are added to each message received and stored in separate buffers. As soon as a message is received with no errors, the contents of the write buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped flag is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the contents of the center buffer (if new) are transferred to the read buffer. If no new data word has been received, the stale flag is set. A center and read buffer exist for every message ID (parser slot). Skipped and stale bits can be found in the Message Info register to indicate whether messages are lost or repeated (undersampling or oversampling situations).

Additional tags such as a Message Count, Message Size, Message Status and Message Info registers are also available as additional information and can be added from the Ethernet Builder application as explained in “47.8.11 Using wildcards and tags in Ethernet Builder” on page 427. For further information regarding these registers, refer to the *KAD/EBM/102* data sheet.

**NOTE:** For MCS operation, the KAD/EBM/102 uses a single buffer operation.

### 47.8.3 Burst packets

The KAD/EBM/102 parser is triple buffered, therefore if a burst of more than two packets to be parsed is received, the triple buffer gets saturated and packets are skipped.

In a situation where burst traffic is expected and all messages are required to be parsed, then the parser data must be sampled at a greater rate than the burst rate. This is effectively an oversampling situation and the sampling rate must be set at the maximum expected frequency of the burst packet. In this scenario, the KAD/EBM/102 MessageInfo register generates lots of stale (repeated) packets when the incoming traffic is steady.

### 47.8.4 Fragmented packets

The KAD/EBM/102 supports fragmented packets, however it does not re-assemble the packet.

For classification, the Fragmentation Flags/Offset described in the Internet Protocol RFC, needs to be included.

As shown in the following figure, the Fragment Offset is a 13-bit number (13 LSBs of the 16-bit field) present in the IP header of the packet. Where the first received fragment has an offset of 0, the second fragment specifies an offset equal to the number of bytes in the first fragment divided by 8; the nth fragment specifies an offset equal to the sum of the number of bytes in the preceding n-1 packets divided by 8.

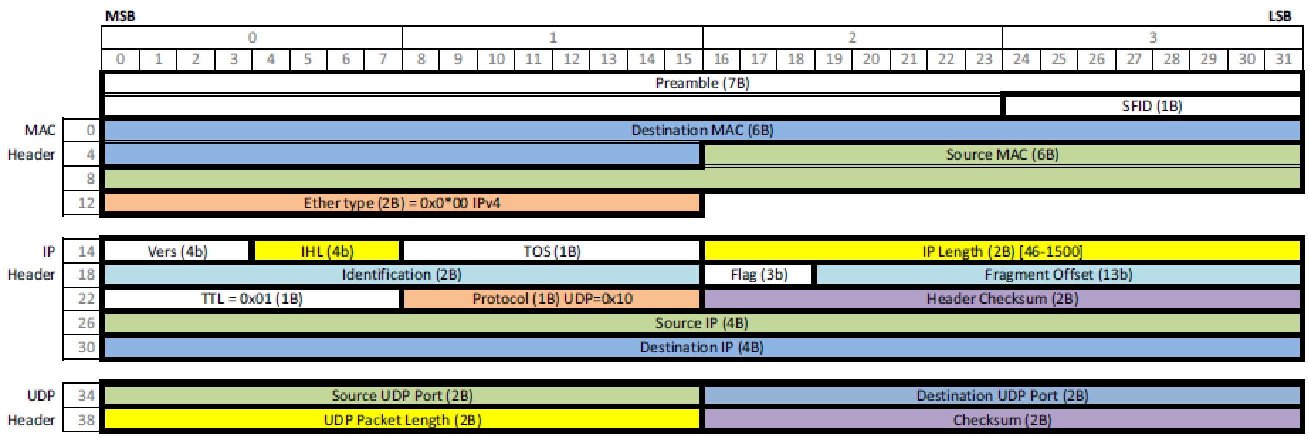



*Figure 47-8: MAC/IP/UDP header showing Fragmentation Flags/Offset*

Each fragment of an incoming packet must be treated as a separate flow of Ethernet frames, where the unique identifier for each flow is the IP fragmentation offset. For example, if you have a 64-k IP packet, fragmented into 1-k fragments, then 64 classifier slots for that IP packet must be set. The offset field is required to be set in the classifier fields in Ethernet Builder as **IP Flags + Fragment Offset** as shown in the following figure.

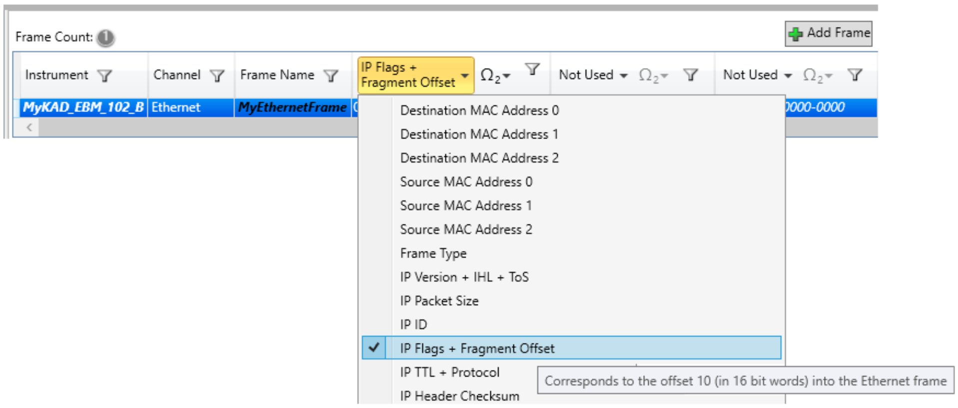



*Figure 47-9: Ethernet builder showing classification to select to parse fragmented packets*

## 47.8.5 Parsing non-fixed length Ethernet packets

Because the packet length is not fixed, you must specify the maximum data words (which is 758, the maximum for an Ethernet packet). You can decrease the number of data words if you know the maximum output from the device you are monitoring.

Discard the last data words if the packet length is not at its maximum. The data word 8 reports the IP size packet and can be used to discard the last data words after post-processing on the ground.

Table 47-6: Values of Offset Index Words

| | Values of Offset Index Words | |
|---|---|---|
| **FIELD NAME** | **OFFSET IF VLAN DISABLED** | **OFFSET IF VLAN ENABLED** |
| Destination MAC address, word 0 (MSW) | 0 | 0 |
| Destination MAC address, word 1 | 1 | 1 |
| Destination MAC address, word 2 (LSW) | 2 | 2 |
| Source MAC address, word 0 (MSW) | 3 | 3 |
| Source MAC address, word 1 | 4 | 4 |
| Source MAC address, word 2 (LSW) | 5 | 5 |
| Frame / Protocol type ; 0x0*0 e.g. IP = 0800h | 6 | 8 |
| VLAN priority/ID | N/A | 7 |
| IP version/IHL/ToS | 7 | 9 |
| IP packet size | 8 | 10 |

For example, if the packet is 700 data words, discard the last 58 data words because they will be random or previous data stored in RAM.

## 47.8.6 Parsing parameters with multiple occurrences in an Ethernet packet

The KAD/EBM/102 parses an Ethernet packet into 16-bit words. The KAD/EBM/102 parses an incoming Ethernet packet into 16-bit words, that is, the module splits the incoming Ethernet frames into N standalone 2-byte registers. The module's logic processes these registers as independent blocks of data without taking into account that they may be part of multiple words/occurrences. It is up to the real time or post-processing software to establish the relationship within the gathered data.

The following figure illustrates an example of a parameter P1 composed of two words in the same packet, which is a unique type of packet coming from an Ethernet device source IP 10.0.0.1. The first instance 1-P1 is at word offset 30; the second instance is at word offset 33.

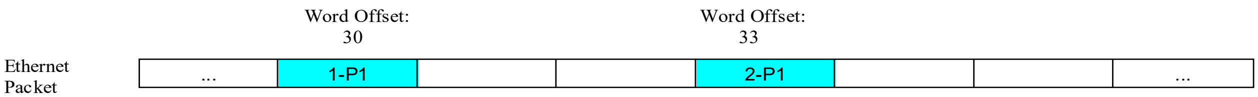



*Figure 47-10: Ethernet packet showing a parameter with 2 words*

Two distinct data words need to be set up in the Ethernet builder as shown in the following figure.

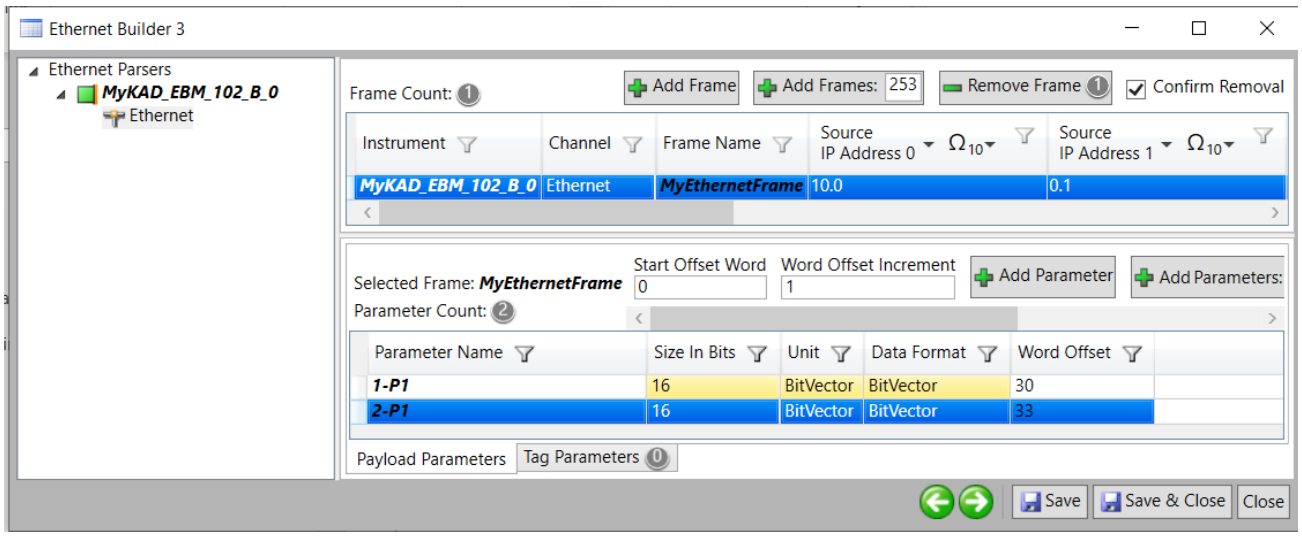



*Figure 47-11: Ethernet builder showing that the 2 words must be distinctly defined*

If the parameter needs to be placed, for example in PCM, the two samples composing the parameter P1 need to be commutated accordingly to match the PCM frame. In the following example it is set at 1:2.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SFID | | | | | | | Syncword |
| SFID | | | | | 1-P1 | | Syncword |
| SFID | | | | | | | Syncword |
| SFID | | | | | 2 -P1 | | Syncword |

*Figure 47-12: PCM showing the two samples composing the parameter P1*

For the software decommutating the PCM, such as GS Works, a mimic PCM is required with one single parameter at 1:2; this indicates to the decom software that the two samples are coming from a single parameter as shown in the following figure.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SFID | | | | | | | Syncword |
| SFID | | | | | P1 | | Syncword |
| SFID | | | | | | | Syncword |
| SFID | | | | | P1 | | Syncword |

*Figure 47-13: Mimic PCM indicating to decom software that two samples belong to the same parameter P1*

### 47.8.7 Latency

For a generic packet, the KAD/EBM/102 uses the triple buffer, therefore parameters extracted from it are 2 to 3 samples late. So for a packet at 100 Hz, the latency for a parameter extracted from it is between 20 ms to 30 ms.

For the MCS with a PCM, DAS Studio 3 delays the PCM in order to take into account all the delays associated with the different Ethernet devices. This latency is specified in the following PCM package definition in the XidML file. This latency does not take into account the delays associated with specific sources such as the filter delay on an analog module or the delay of the PCM decom.

```
<IRIG-106-Ch-4 Name="MyIRIG-106-Ch-4Package_4_256x16">
    <PackageRate>64</PackageRate>
    <Sequencing>
      <Offset_uS>7884.97924804688</Offset_uS>
    </Sequencing>
```

### 47.8.8 Auto-negotiation

Auto-negotiation can cause an interoperability problem. Two Ethernet devices linked to each other shall either be:

Both Auto

Both Force 100 Mbps

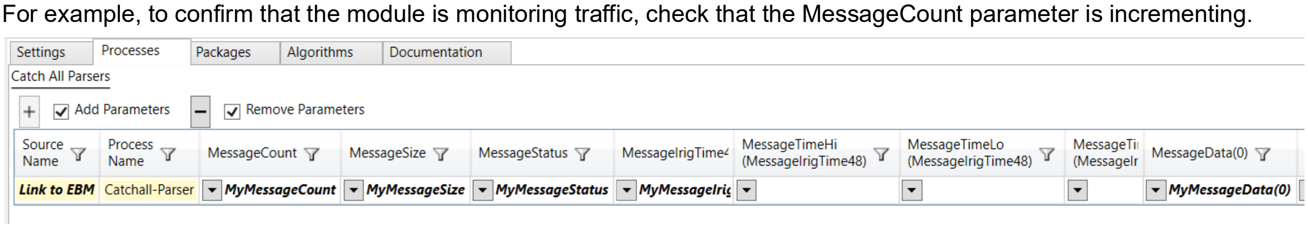
This interoperability is not a problem for a 1-Gbps link, that is, 1 Gbps and Auto can be mixed in the same link.

For details, request *TSD-AB-009 Auto-Negotiation issue.pdf* from Curtiss-Wright support (acra-support@curtisswright.com).

### 47.8.9 Not getting data – how to debug

Refer to the following if the KAD/EBM/102 is not getting data.

- Monitor the Report word of the KAD/EBM/102 if the link is connected to the Ethernet device for which the module is parsing data. Refer to the *KAD/EBM/102* data sheet for details of the Report word. If the Report word indicates that it's not connected, check the wiring.
- Use Wireshark on a PC directly connected to the Ethernet device to check if there's traffic and if it's as expected. If it's not, check the Ethernet device to be monitored by the KAD/EBM/102.
- Use catchall (remove all previously defined flows). With the KAD/EBM/102 selected, click the **Processes** tab. Select the **Add Parameters** check box and then click the **+** button. Data words and catchall tags are displayed as shown in the following figure.
  For example, to confirm that the module is monitoring traffic, check that the MessageCount parameter is incrementing.




  If there's traffic with the catch all, verify that the KAD/EBM/102 classifications with the Ethernet Builder are set up correctly.

If there's still no traffic after trying the above, the KAD/EBM/102 may be damaged, in which case contact Curtiss-Wright support (acra-support@curtisswright.com).

## 47.8.10 VLAN

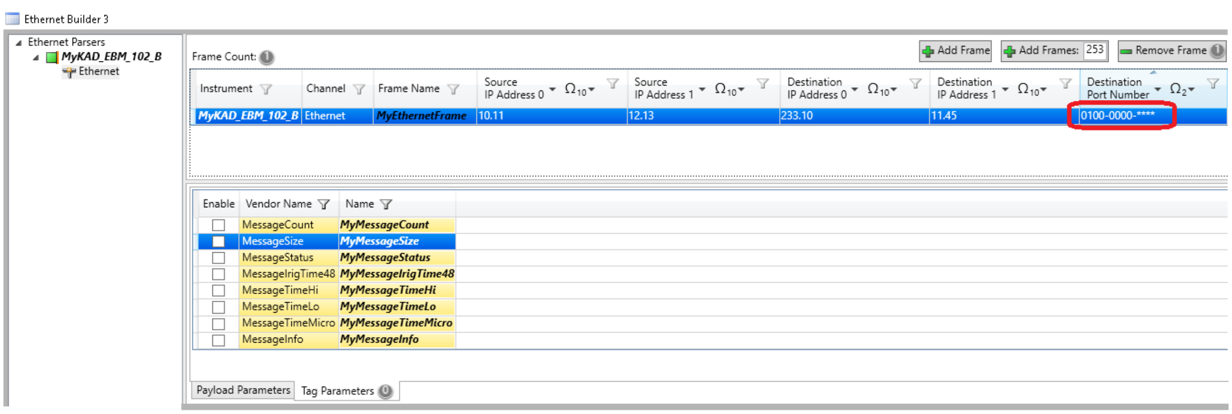
VLAN Tagging, also known as Frame Tagging, is a method developed by Cisco to help identify packets traveling through trunk links. When an Ethernet frame traverses a trunk link, a special VLAN tag is added to the frame and sent across the trunk link. A commercial switch maybe able to identify packets from different VLANs according to the information contained in its VLAN tags. IEEE 802.1Q adds a 4-byte VLAN tag between the Source/Destination MAC address and Length/Type fields of an Ethernet frame to identify the VLAN to which the frame belongs.

## 47.8.11 Using wildcards and tags in Ethernet Builder

On occasion, data may be required from a packet on the same link with the same source and destination IP addresses (but whose destination port may change). This data can be captured by using wildcards in the classifier settings. Wildcards are expressed as asterisks in Ethernet Builder, and can only be used when Binary format has been set for values in the classifier fields.

The following example illustrates how to set a wildcard in one of the filtering options.

1. Open **Ethernet Builder** and add a frame with the same settings as explained in "47.6.1 Using Ethernet Builder to configure the KAD/EBM/102" on page 417.
2. Select the **Destination Port Number** field in the new packet, and click the drop-down arrow next to the Ω symbol to change its format from **Decimal** to **Binary**.
   The 1024 value in the **Destination Port Number** field now reads **0100-0000-0000**.
3. To represent varying port numbers, insert wildcards (asterisks) where required. This forces the KAD/EBM/102 to capture this packet regardless of the destination port number.
   For example, 0100-0000-**** parses incoming packets with the same source and destination IP from port 1024 to 1039.
   **NOTE:** Wildcarding is only supported in binary mode. At this point, if the Binary format is changed back to Decimal (using the drop-down arrow beside the Ω symbol), the value for the **Destination Port Number** field (edited using wild-cards) does not change format.




4. Add parameters to the new packet as required.
5. Click the **Tag Parameters** tab to add additional message tag parameters such as **MessageTimeStamp** (timestamp of arrival of the message), **MessageCount**, **MessageSize** (bytes), **MessageStatus**, **MessageInfo** (stale / skipped message).
6. To save changes, click **Save & Close**.

## 47.8.12 Step-by-step instructions for generation of MCS packets (Scenario 1)

As explained in "47.5.4 Generating MCS packets" on page 416, MCS packets are created by the compiler. After settings are configured, you can proceed to build the PCM.

To generate MCS packets, on the **Tools** menu, click **Verify**. MCS packets are automatically built by DAS Studio 3 at the data source DAUs, this ensures that the data words to be sent over real-time PCM arrive at the data selector chassis in time for transmission.

In the following example, **P1** is a parameter sourced from an analog module (KAD/ADC/105/B) in slot 3 of **DAU_1**.

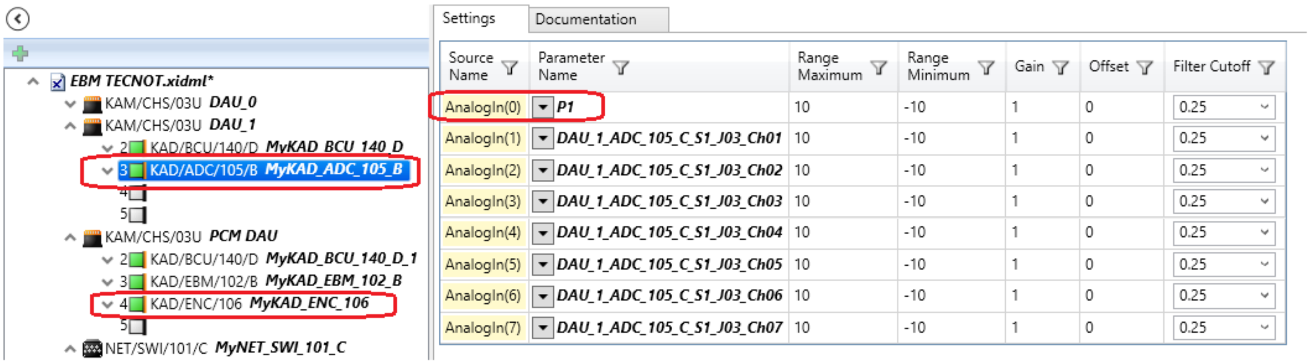


*Figure 47-14: Parameter P1 from remote DAU_1*

As shown in the following figure, **P1** is being transmitted over PCM at a rate of 512 sps.

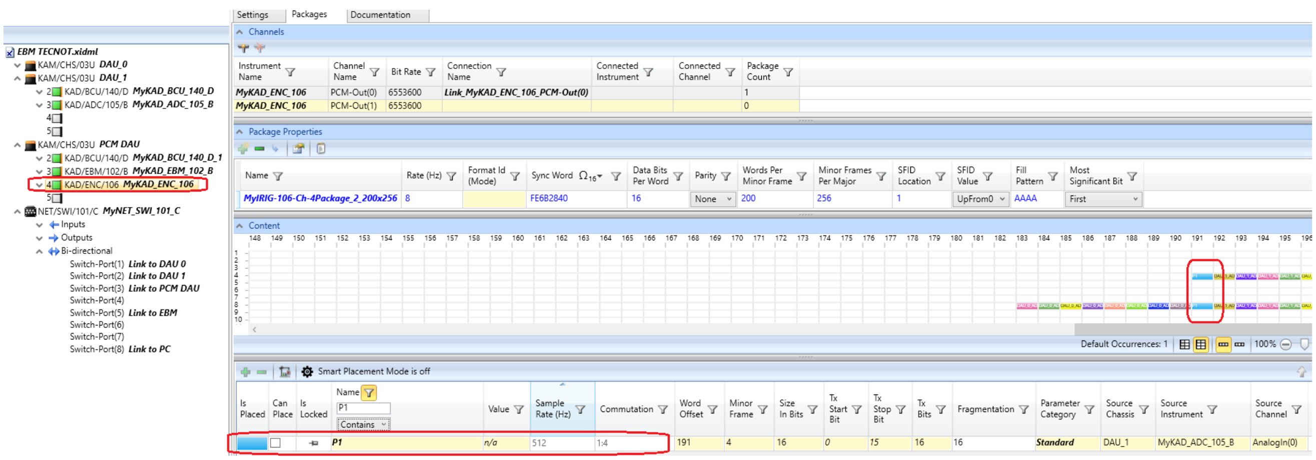


*Figure 47-15: Parameter P1 transmitted over PCM at 512 Hz*

After verification of the project, the compiler generates MCS packets (as shown in the following figure) with Multicast IP address 235.0.0.9 as per the KAD/EBM/102 setting in “47.5.4 Generating MCS packets” on page 416.

**NOTE:** The Stream ID is automatically generated and starts from 0xFFFF in the system. This value decrements by one for each new MCS packet required by DAS Studio 3.

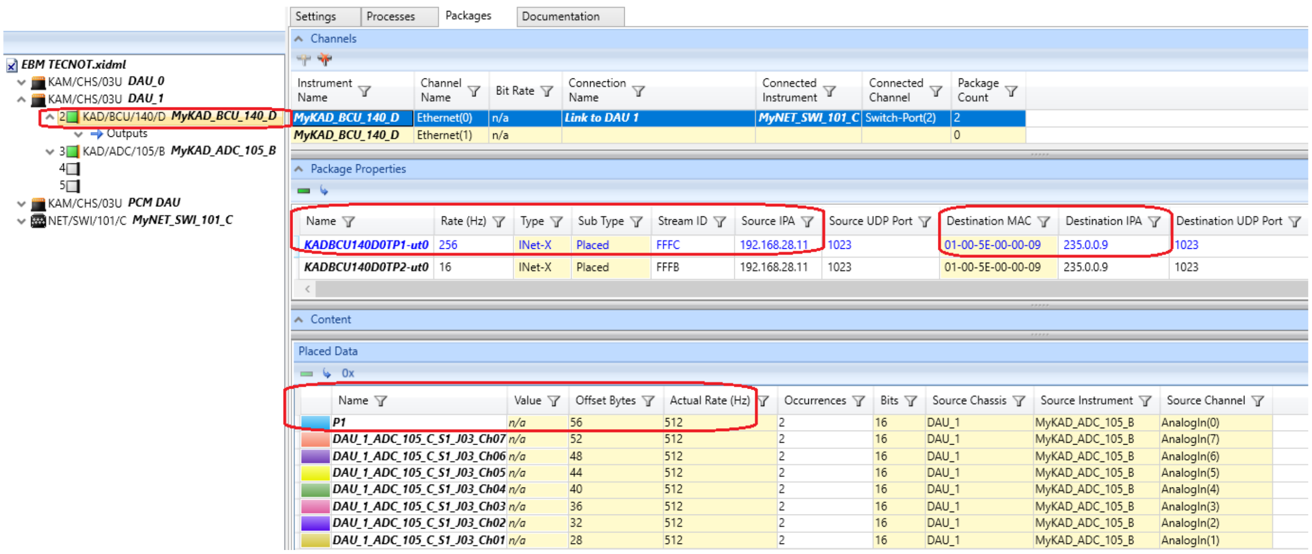


Figure 47-16: MCS packets generated at remote DAU_1

After verification of the project, the KAD/EBM/102 is also configured to automatically receive MCS packets.

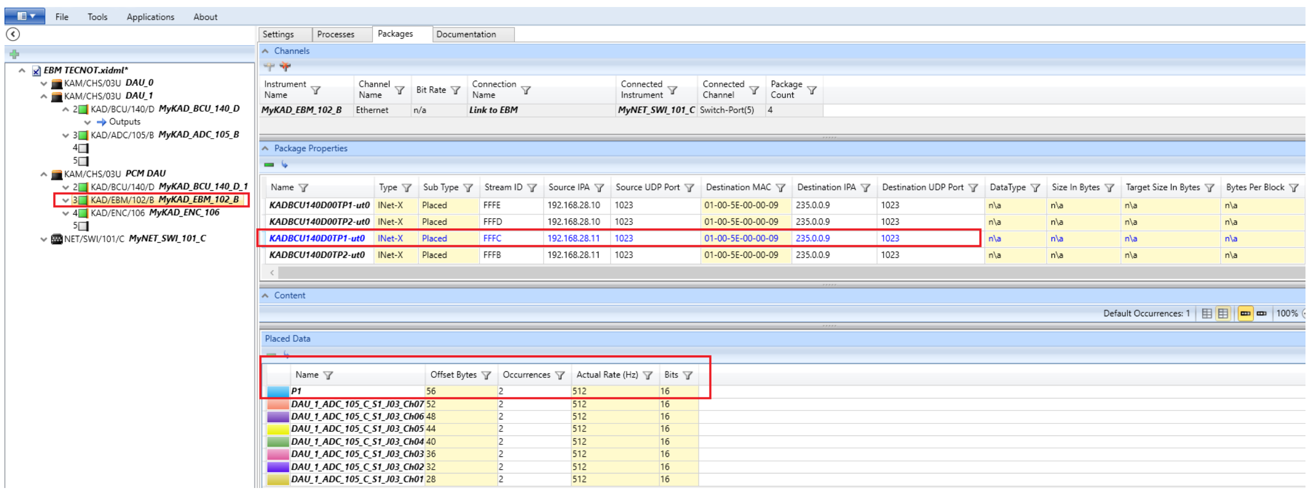


Figure 47-17: MCS packets created to parse MCS packets

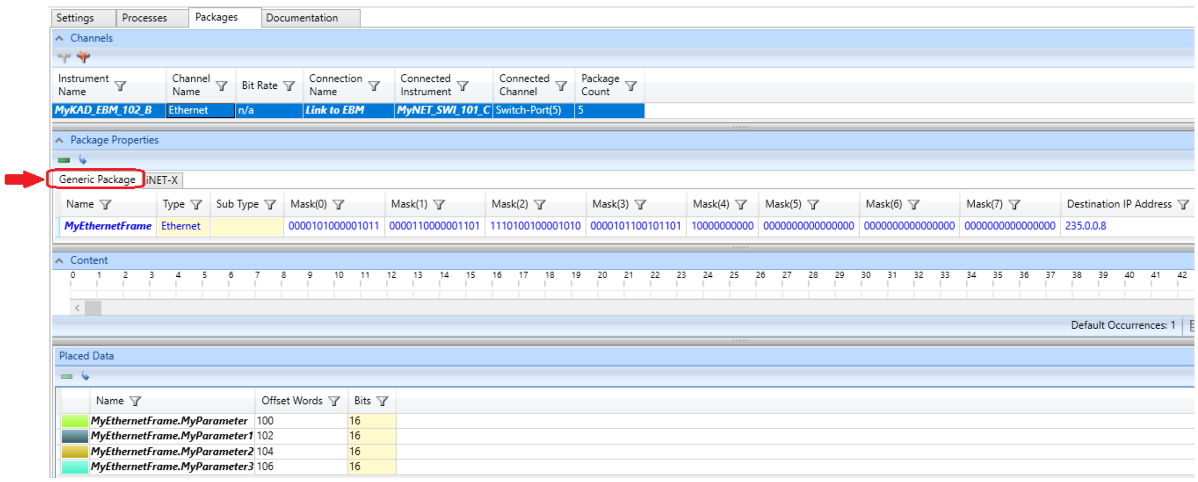
**NOTE:** Verification of a file containing MCS scheduling requires writing new sections into the XidML file. That is, the original XidML file is modified by the compiler.

## 47.8.13 Step-by-step instructions for adding generic parser rules (Scenario 3)

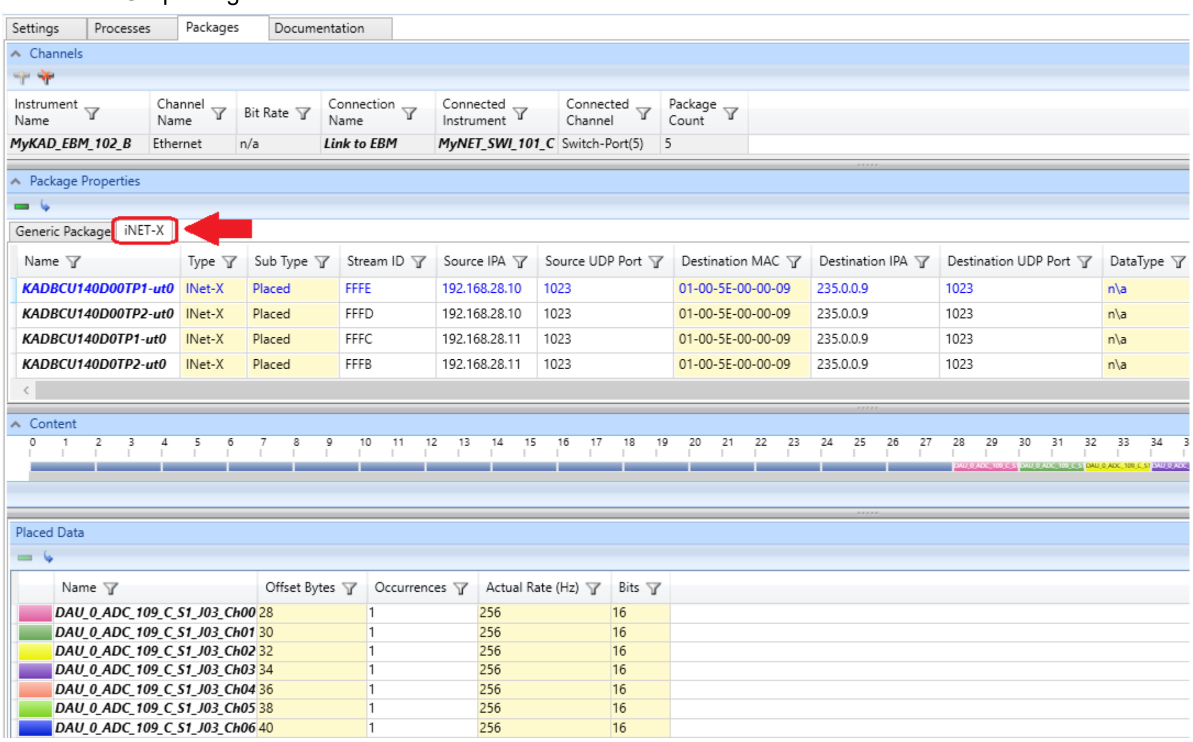
As explained in "47.7 Scenario 3: KAD/EBM/102 setup to parse Generic and MCS packets simultaneously" on page 421, the steps to add generic packets using the Ethernet Builder described in Scenario 2 can also be followed in Scenario 3.

The following example describes the procedure.

1. Ensure the KAD/EBM/102 is set up as per Scenario 3, that is, both Generic and MCS parser are set up.
   Note, at this stage of the configuration process:
   - The packages section of the KAD/EBM/102 is empty
   - Only one packet filter is set in the Settings tab
2. On the **Tools** menu, click **Verify**.
   Two tabs with packages appear.
   - A generic parser **Generic Package** tab.




   - And an MCS packages **iNET-X** tab.



### 47.8.14 Related documentation

To better understand this paper, read the following documents.

Table 47-7: Data sheets

| Document | Description |
| --- | --- |
| KAD/EBM/101/B | Ethernet bus monitor parser - 1ch |
| KAD/EBM/102/B | Gigabit Ethernet bus monitor parser - 1ch |
| KAD/ENC/106 | IRIG-106 PCM encoder (PMF output) |

Table 47-8: Data sheets

| Document | Description |
| --- | --- |
| TEC/NOT/046 | Using the KAD/EBM/101 |
| TEC/NOT/067 | IENA and iNET-X packet payload formats |
| TEC/NOT/068 | Network MCS in KSM-500 |

Table 47-9: User manual

| Document | Description |
| --- | --- |
| DOC/MAN/030 | DAS Studio 3 User Manual |

**NOTE:** Sample XidML files used to represent the scenarios in this technical note are available upon request from Curtiss-Wright support (acra-support@curtisswright.com).

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Chapter 48

# Using the KAD/HBM/102

TEC/NOT/076

This paper discusses the following topics:



## 48.1 Overview

The KAD/HBM/102 is a single-channel bus monitor module designed to monitor a High Speed Data Bus (HSDB) network link. It features a full-duplex 10BaseT, IEEE 802.3 compatible interface to connect to the HSDB network. It can be configured to act as a PC node on the network, sending and responding to PING and ACKnowledgment code (ACK) requests, and parsing up to 1,023 complete messages. It also features a 100BaseT output on which all HSDB traffic received on the 10BaseT input can be retransmitted across the FTI network for recording.

## 48.2 HSDB protocols overview

The HSDB protocols are essentially Hardware Manager (HWM) HSDB data wrapped in standard Ethernet packets. As shown in Figure 48-1 on page 434, there are two types of packet format: embedded and PC interface. The KAD/HBM/102 can be configured to capture either format. (For descriptions of abbreviations used in Figure 48-1 on page 434 and Figure 48-2 on page 435, see “48.4 Abbreviations” on page 438.)

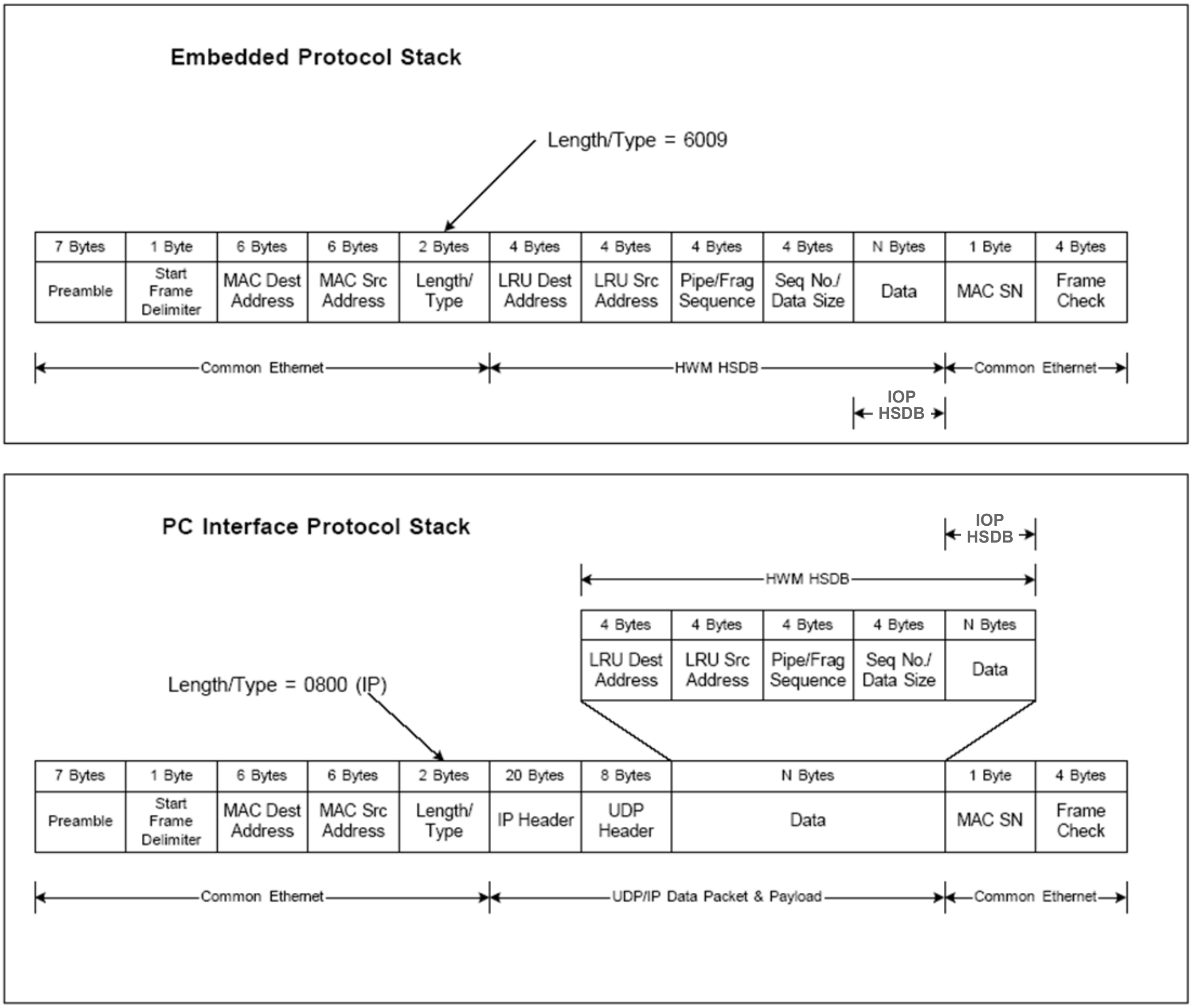



*Figure 48-1: Embedded and PC interface packet formats*

The HWM HSDB protocols shown in both the embedded and PC interface packet formats in Figure 48-1 on page 434, contain the data that must be extracted by the KAD/HBM/102. These protocols and how they are processed by the KAD/HBM/102 are explained in the following figure.

| Size | Field | | | | |
|---|---|---|---|---|---|
| 4 Bytes | Destination address | | | | |
| 4 Bytes | Source address | | | | |
| 1 Byte (1 bit each for ACK, Fin, Prd, and PING; 4 bits for the pipe) | ACK | Fin | Prd | PING | Pipe |
| 1 Byte | Reserved | | | | |
| 1 Byte | Fragment sequence | | | | |
| 1 Byte | Reserved | | | | |
| 2 Byte | Sequence number | | | | |
| 2 Bytes | Size of data | | | | |
| 0-1456 Bytes | Data | | | | |
| Most Significant Bit | b7 | | | | b0 |

Bytes within the frame are transmitted from top to bottom

V

Least Significant Bit (LSB)

Bits within the frame are transmitted LSB first

*Figure 48-2: HWM HSDB protocol*

HSDB frames are identified by their destination address. Each device on the network uses a pre-assigned address and the KAD/HBM/102 is connected to the network at a specific device location, for example PC1. In this case, the KAD/HBM/102 acts as PC1 in the HWM HSDB protocol, and is configured to use the address corresponding to device PC1.

The pipe field is the next field used to identify messages and process them to the correct parser slot. Up to 16 different pipes (0-15) can be specified. This allows for specific packets to be processed, utilizing unique resources (memory space and processing time) at various levels of criticality. The KAD/HBM/102 can be configured to parse data from A Pipe, B Pipe, C Pipe, D Pipe, D-Debug Pipe, and HSDB Manager Pipe.

Once a message has been identified by the destination address and the pipe ID, the data contained in the message is extracted and placed in the required parser slot for reading by the Data Acquisition Unit.

## 48.3 Configuring a KAD/HBM/102 to monitor HSDB traffic

This section describes how to configure a KAD/HBM/102 to monitor HSDB traffic. To do that, you first configure the path to the location of the HSDB Interface Control Document (ICD) XML file using DAS Studio 3. (The ICD file contains the definitions of all the parameters that can be extracted from HSDB traffic.) Then you use the HSDB Importer application to import the parameter definitions from the ICD file.

### 48.3.1 Setting up the KAD/HBM/102 with DAS Studio 3

DAS Studio 3 is used to create a configuration, which contains the various elements that make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

Figure 48-3 on page 436 shows a KAD/HBM/102 added to the configuration with the Settings tab selected.

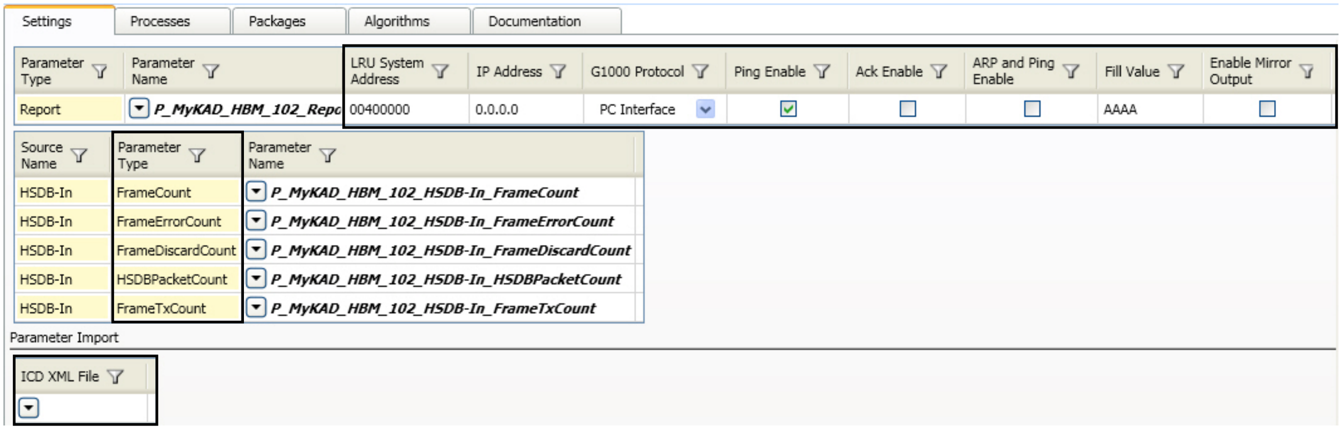



*Figure 48-3: Settings tab with KAD/HBM/102 in context (default settings shown)*

To configure the KAD/HBM/102 to import the ICD file, you only need to set the LRU System Address, IP Address, and the ICD XML File settings. The other settings can be left at the defaults. Refer to the following table to configure the KAD/HBM/102.

| Setting | Description |
|---|---|
| LRU System Address | This is the destination address of PC1 in the HSDB network. |
| IP Address | This is the IP address of PC1 in the HSDB network. Ensure this is the correct IP address as data for PC1 is not sent across the HSDB network until a valid connection to PC1 is established. |
| G1000 Protocol | This can be set to Embedded or PC Interface. This embeds the KAD/HBM/102 location in bytes into the HSDB packets of the destination address used to identify the packets. |
| Ping Enable | This configures the KAD/HBM/102 to transmit ping requests across the 10BaseT HSDB network. This must be enabled for data to flow. |
| Ack Enable | This configures the KAD/HBM/102 to respond to ping requests received across the 10BaseT HSDB network. Enabling this setting is not required for data to be parsed, but is recommended for correct operation of the HSDB network (contact Acra Business Unit support for further information). |
| ARP and Ping Enable | This setting lets the KAD/HBM/102 respond to ARP and ping requests received on the 100BaseT output from the FTI network. Enabling this setting may be useful for checking the wiring to the KAD/HBM/102. However, it is not recommended for normal operation as it requires the FTI network to be on the same Ethernet subnet as the 10BaseT HSDB network. In normal operation, these are on separate networks. |
| Fill Value | This is the default value written to empty parser slots to identify empty messages. For debug purposes it is recommended to use an easily identifiable hex word, different from all other fill words in your system. |
| Enable Mirror Output | When enabled, all received HSDB data on the 10BaseT input is transmitted on the 100BaseT output. Data can then be recorded with other FTI network traffic. |
| Parameter Type | There are five different global counter parameters available from the KAD/HBM/102. The definitions of these parameters can be found in the *KAD/HBM/102* data sheet. |
| ICD XML File | This setting configures the path to the location of the HSDB ICD XML file. The ICD file contains the definitions of all the parameters that can be extracted from HSDB traffic. |

## 48.3.2 Importing parameter definitions from the ICD file

After you have configured the KAD/HBM/102, use the HSDB Importer application to import the parameter definitions from the ICD file. To open the HSDB Importer application, go to the Applications menu and then click HSDB Importer (see the following figure).

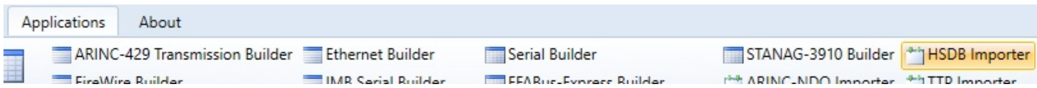



*Figure 48-4: Applications menu*

The HSDB Importer 3 dialog box appears (see the following figure). Select the settings you want and then click Import.

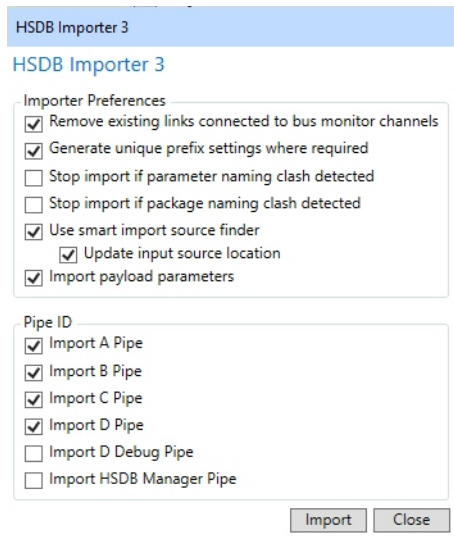



*Figure 48-5: HSDB Importer dialog box (default settings shown).*

| Setting | Description |
|---|---|
| Remove existing links connected to bus monitor channels | Specifies whether existing links on the module's input channels are removed on import. |
| Generate unique prefix settings where required | If required, specifies whether unique prefixes for imported bus definitions are generated and updates the corresponding prefix setting on the KAD/HBM/102. |
| Stop import if parameter naming clash detected | Specifies whether import stops when a parameter naming clash is detected. By default, newly imported parameters replace existing ones. |
| Stop import if package naming clash detected | Specifies whether import stops when a package naming clash is detected. By default, newly imported packages replace existing ones. |
| Use smart import source finder | Specifies whether, when the specified XML file location (specified via a setting on the KAD/HBM/102) is not present, the importer looks for this XML file in the same location as the XidML configuration file. |
| Update input source location | Specifies whether the importer, after finding the CSV file in the same location as the XidML configuration, updates the location setting/URL algorithm on the importer module. |
| Import payload parameters | Specifies whether the importer imports the subtypes under each packet in the HSDB XML file as parameters under each package in DAS Studio 3. |

| Setting | Description |
|---|---|
| Pipe ID | This defines the various Pipe IDs that the importer reads and imports from the ICD file. Selecting the pipes of interest allows you to limit the number of packages and parameters that are imported into your configuration. |

## 48.4 Abbreviations

| Abbreviation | Description |
|---|---|
| IOP | Input/Output Processing |
| Fin | Bit indicating whether it is the fragment of a fragmented packet |
| Prd | Bit indicating whether a packet is periodic or not |
| SN | Sequence Number |
| Dest | Destination |
| Src | Source |
| Frag | Fragment |
| Seq | Sequence |
| No. | Number |

Chapter 49

# Using shunting processes in Ethernet systems

TEC/NOT/077

This paper discusses the following topics:



## 49.1 Overview

Shunting is a calibration process for strain gauges. During this process, a simulated load is introduced to one arm of a balanced bridge by driving current into, or drawing current from, one bridge of the arm. This simulated load can then be used to calibrate the accuracy of the bridge.

## 49.2 Shunting in Ethernet systems

The following three types of shunting can be run on Ethernet systems:

- System-driven shunting
- Time-driven shunting
- External shunting

## 49.3 System-driven shunting

When a controller module in an Acra KAM-500 system is designated shunt master, this master controller module initiates shunting in other chassis by transmitting an Ethernet shunt packet that instructs other chassis to switch to a particular shunt format. The master controller module identifies the shunt format to switch to by reading the value of a user-defined shunt source parameter that you have associated with a shunt process.

### 49.3.1 Using DAS Studio 3 to configure system-driven shunting

As stated, master controller modules read the value of the shunt source parameter associated with a shunt process. You can use DAS Studio 3 to associate a user-defined shunt source parameter with a shunt process. DAS Studio 3 is used to create a configuration file which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

To configure system-driven shunting using DAS Studio 3, do the following:

- Associate a shunt source parameter with a shunt process
- Enable Shunt Mode
- Set the shunting current

#### 49.3.1.1 Associating a shunt source parameter with a shunt process

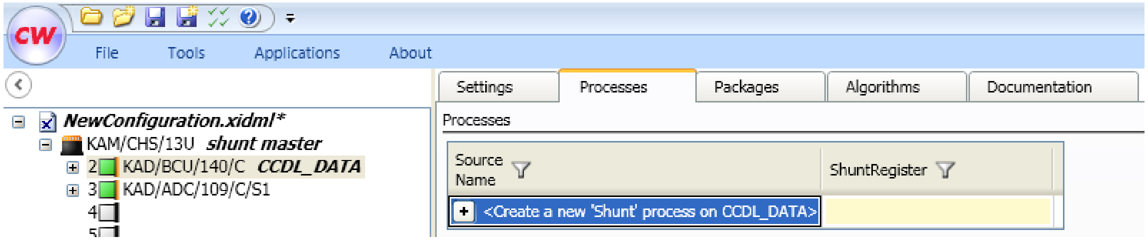
In the DAS Studio 3 GUI, the information displayed on the Processes tab relates to the node selected in the Navigator. When the overview node in the Navigator is selected, process registers for all the nodes in the Navigator are displayed. If another node is selected in the Navigator, only the process registers for that node are displayed.

In this section, a discrete low parameter from a KAD/DSI/102/B is the parameter used as an example of associating a shunt source parameter with a shunt process.

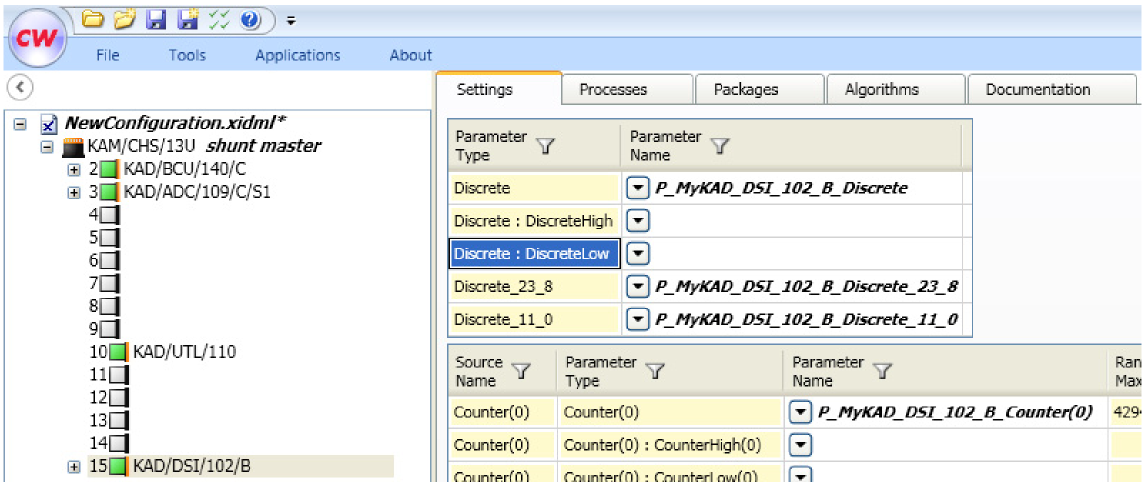
**TIP!** The KAD/DSI/102/B’s discrete low parameter is ideal as you can easily reflect any 16-bit value by tying input pins to reference voltages.

To create a new shunt process and associate it with a shunt source parameter, do the following:

1. In the shunt master chassis, select the designated master controller module and go to the **Processes** tab.
2. Create a new process by clicking the icon in the **Source Name** column.

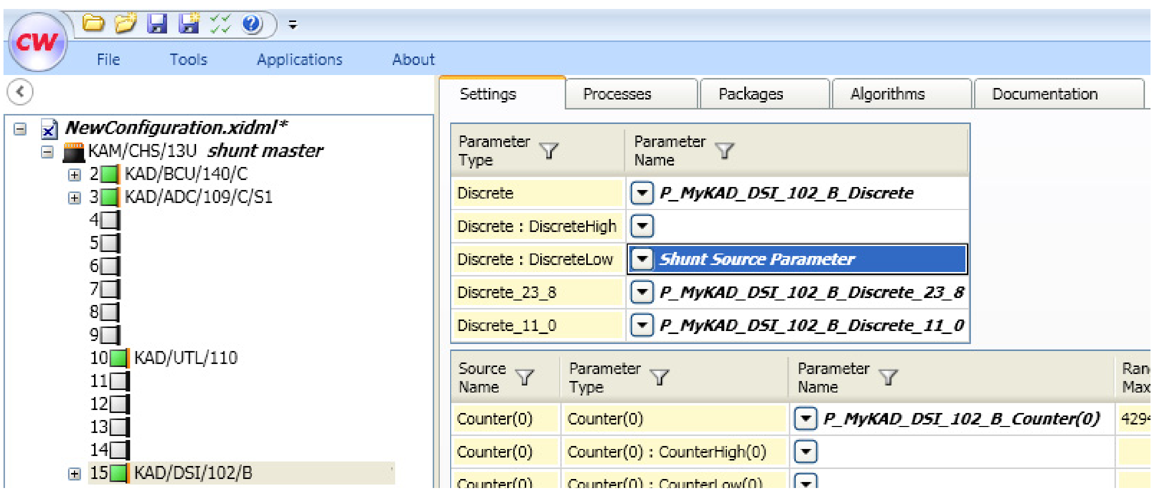



3. In the Navigator, select the **KAD/DSI/102/B** module and go to the **Settings** tab.



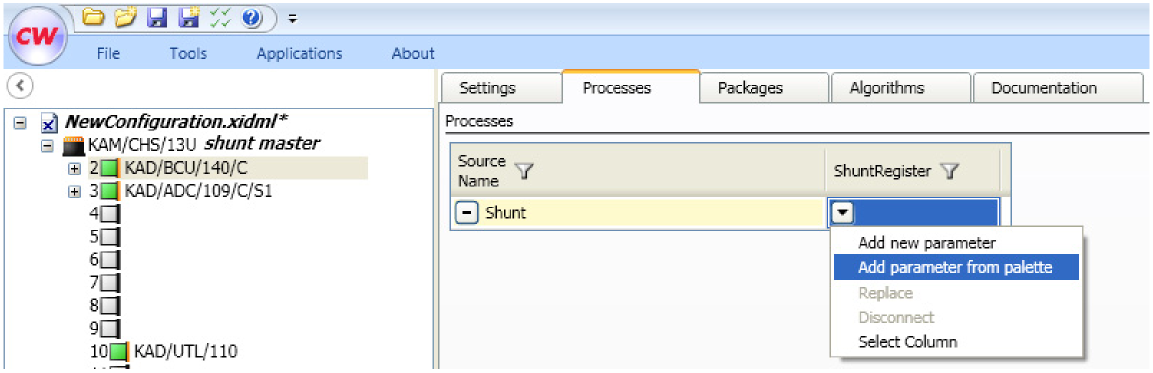

A discrete low parameter is displayed on the **Settings** tab.

4. In the **Parameter Name** column, type a name for the discrete low parameter.

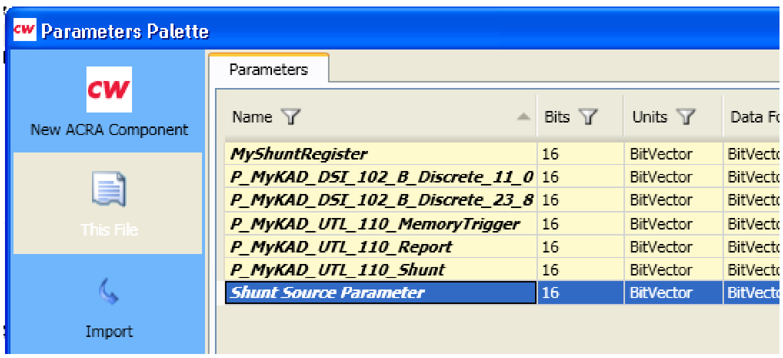



After naming this parameter, it is available in the **This File** library of the **Parameters Palette**.

5. In the Navigator pane, select the master controller module and go to the **Processes** tab. In the **ShuntRegister** column, click the drop-down arrow and select **Add parameter from palette**.

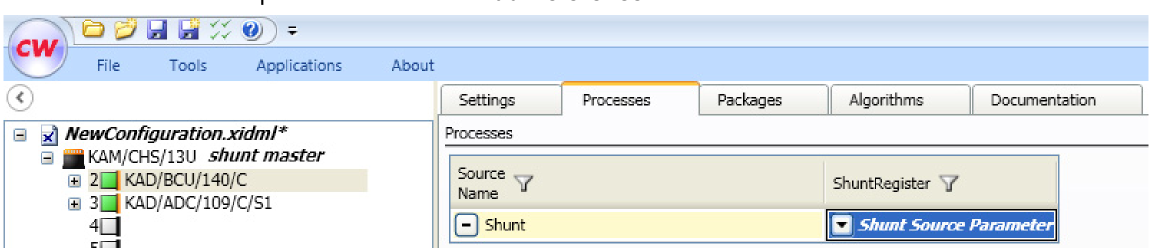



6. On the **Parameters Palette**, select the **This File** library to view the shunt source parameter.




**TIP!** On the left of the **Parameters Palette** are libraries which group parameters. The default library is **New ACRA Component**. By clicking on each library, you can display all parameters available.

7. Select the shunt source parameter and click **Add Reference**.




The shunt source parameter is now associated with the shunt process.

**NOTE:** Valid shunt format values are 0, 4, and 8. At this point, you are able to force shunting by setting discrete inputs 0 to 15 of the KAD/DSI/102/B to read 0, 4, or 8. For example, to set the KAD/DSI/102/B to read shunt format value 4, tie inputs 15 to 3 to GND, tie input 2 to +5V, and tie inputs 1 and 0 to GND (0x0004).

#### 49.3.1.2 Enabling Shunt Mode

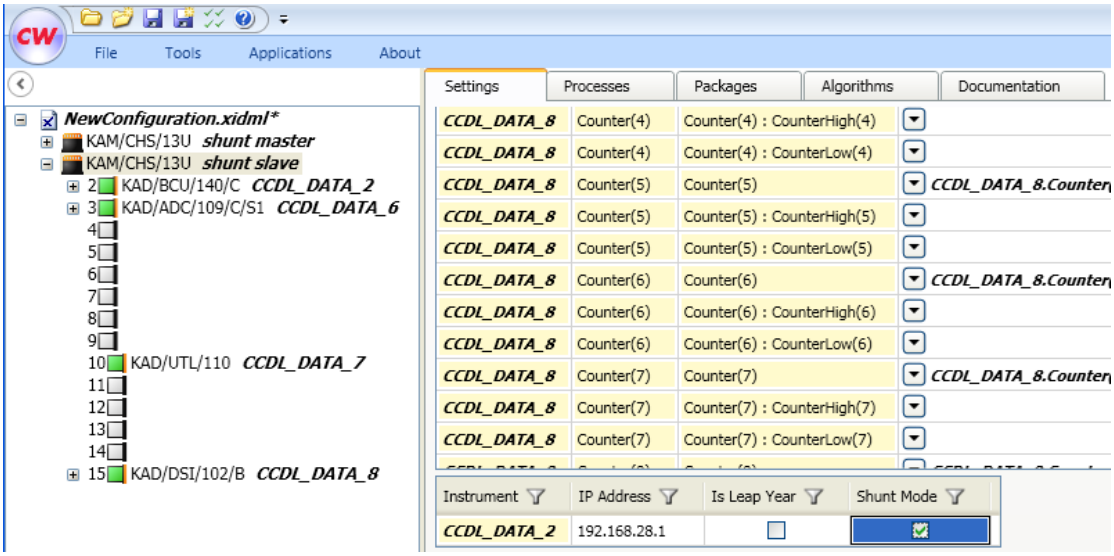
On any shunt slave chassis, the Shunt Mode setting must be enabled so that controller modules in a shunt slave chassis react to the Ethernet shunt packet transmitted from the shunt master controller.

**NOTE:** For successful shunting, enable Shunt Mode only in a chassis that contains shuntable user-modules such as the KAD/ADC/109/C/S1, modules from the KAD/ADC/118 family, and all other full-bridge modules.

To enable Shunt Mode, do the following:

1. Select a shunt slave chassis in the Navigator pane, then click the **Settings** tab.

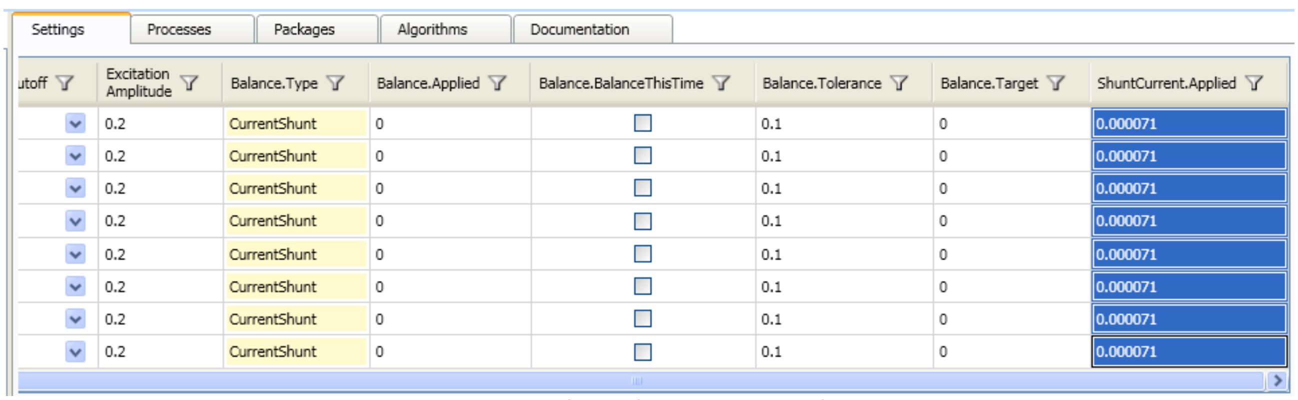
2. On the **Settings** tab, select the **Shunt Mode** checkbox.




To locate the **Shunt Mode** checkbox, scroll down

### 49.3.1.3 Setting shunt current

To set a shunt current on a shuntable user-module, go to the **Settings** tab and insert a value in the **ShuntCurrent.Applied** field.




To locate the **ShuntCurrent.Applied** field, scroll to end of screen

**NOTE:** Insert the required current in amps, in the range -0.000071 to 0.000071 amps.

## 49.3.2 Summary

On the next acquisition cycle, when the master controller module identifies a defined value (for example, 4) in the parameter associated with shunting, it switches to using a shunt value of 4. At this time, the master controller module transmits an Ethernet shunt packet which instructs all shunt slave controller modules to also switch to using 4. When a shunt slave controller receives this packet, the balance adjust output of the KAD/ADC/109/C/S1 outputs 71µA while 4 is enabled. (Up to 71µA is available for use in both the ShuntCurrent.Applied field or the Balance.Applied field. Therefore, if Balance.Applied is set to output, for example, 20µA constantly, an additional 71µA cannot be shunted.)

When 8 is transmitted by the shunt master chassis, the inverse shunt current is output from the KAD/ADC/109/C/S1.

When 0 is transmitted by the shunt master chassis, the shunt current is removed from the balance adjust output, returning the channel to normal operation.

Shunt or Classic Shunt can be enabled for newer modules such as the KAD/ADC/134, KAD/ADC/135, and KAD/AC/136. When Classic Shunt is enabled (see far-right column), it is not required to set a ShuntCurrent.Applied value.

In shunt format 4 and shunt format 8, the resistor for Classic Shunt is added; in shunt format 0 it is removed.

### 49.3.3 Considerations when working with system-driven shunting

- Enable Shunt Mode only on a chassis that contains shuntable modules, for example full-bridge modules.
- Ethernet shunt packets are only transmitted when a change is identified in the value of the parameter associated with a shunt process.
- Ethernet shunt packets are iNET-X packets with a stream ID of 0; using this stream ID for any other packets is not recommended.
- In system-driven shunting, Shunt Mode remains active until another Ethernet shunt packet is received from the shunt master controller module.
- Ensure there is a path across the network from the shunt master controller module to all shunt slave controller modules. Ensure also that this path is not swamped by other traffic as this may cause shunt packets to be missed by shunt slave controller modules.

## 49.4 Time-driven shunting

Time-driven shunting works in the same way as system-driven shunting, with the exception that the shunt source parameter is derived from a KAD/UTL/110 and it is this parameter which must be associated with a shunt process on the master controller module.

The KAD/UTL/110 goes through a sequence of user-defined shunt formats and durations at power-up, giving you the option to automatically check bridges at power-up. The following figure displays the Settings tab for a KAD/UTL/110 module. This is where you locate the settings used to configure time-driven shunting.

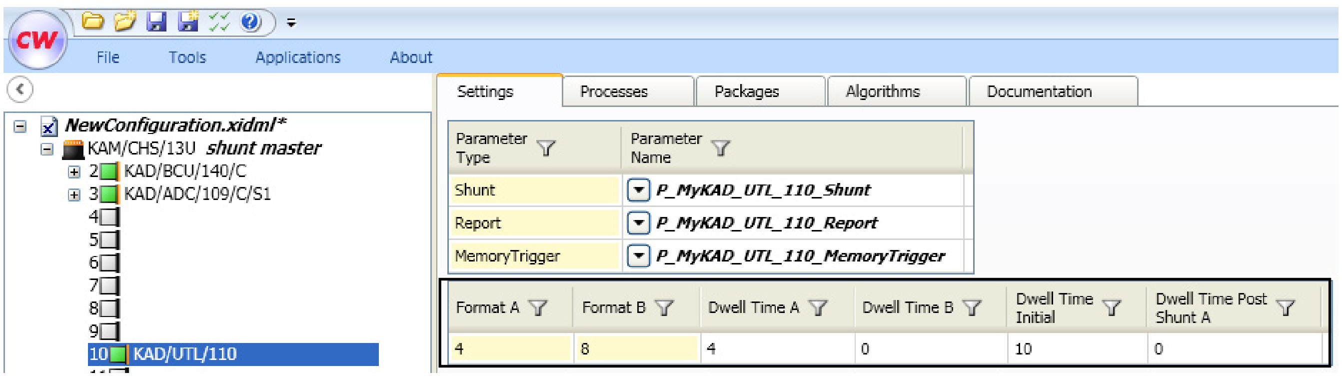



*Figure 49-1: Time-driven shunting settings*

The following table describes the fields required to configure time-driven shunting.

| Setting | Description |
|---|---|
| Format A | After power-up, this is the first format the KAD/UTL/110 initiates. The default value is 4. |
| Format B | This is the format the KAD/UTL/110 initiates after the time set in Dwell Time B has elapsed. The default value is 8. |
| Dwell Time A | This is the number of seconds the system remains in Format A once it has been initiated. To skip Format A, set this field to 0 seconds. |
| Dwell Time B | This is the number of seconds the system remains in Format B once it has been initiated. To skip format B, set this field to 0 seconds. |
| Dwell Time Initial | This is the number of seconds the KAD/UTL/110 waits after power-up before initiating the first format switch. |
| Dwell Time Post Shunt A | This is the gap between Format A and Format B. To switch from Format A to Format B instantly, set this field to 0. Any other setting switches to 0 for the defined time before switching to Format B. |

**NOTE:** The maximum value for dwell time allowable, for either format, is 3,600 seconds (one hour).

## 49.5 External shunting

External shunting refers to the process of using a PC or a laptop to initiate the shunting. In the example given below, there is no shunt master controller module. All controller modules that have shunting enabled respond to the shunt command from a PC.

The shunt command is an iNET-X packet with the following requirements for the destination MAC address, destination IP address, source and destination ports:

Destination MAC address = 01-00-5E-00-00-FA

Destination IP address = 224.0.0.250

Source port = 10220

Destination port = 10250

**Example iNET-X packet header and payload**

iNET-X versions = 0x11000000

iNET-X stream ID = 0x00000000

iNET-X sequence = 0x00000000

iNET-X length = 0x00000028

iNET-X seconds = 0x4EFFA3E6

iNET-X nano-seconds = 0x2470620A

iNET-X flags = 0x00000000

Event code (0x0310) and parameter (16 bits), that is, 0x0310nnnn where nnnn is the format number.

Optional description up to 16 bytes, null terminated. The default value is FORMAT, for example, FORMAT4 0x464F524D41543400.

The destination address of the iNET-X packet must be the multicast address 224.0.0.250, UDP source port 10220 and destination port 10250.

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**NOTE:** Shunt initiated by this method times out and the system reverts to 0 after 12 seconds. You must ensure that there is a communication path between all controller modules with shunting enabled and the PC or laptop.

Chapter 50

# Using the KAD/UBM/104

TEC/NOT/078

This paper discusses the following topics:



## 50.1 Overview

The KAD/UBM/104 is an 8-channel Actuator Bus Interface (ABI), Actuator Control Equipment-Cross Channel Data Link (ACE-CCDL), or Actuator Control Bus (ACB) serial bus monitor and packetizer. You can select which mode to use on a module-wide level and then coherently parse up to 255 messages, while packetizing all traffic on a channel-by-channel basis.

## 50.2 ABI protocol overview

The ABI protocol uses a 1Mbps RS-485 Bi-Phase-S encoded physical layer.

There are two types of messages used in the ABI protocol: ABI write messages and ABI read messages.

### 50.2.1 ABI write messages

ABI write messages are made up of 12 bytes of header, followed by up to 255 bytes of data, followed by 2 bytes of Cyclic Redundancy Check (CRC). ABI write messages are preceded and followed by an idle pattern of up to 7 µs of Bi-Phase-S 1s.

The following figure shows the format of an ABI write message.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | Break | Sync | FC1 | Addr1 | Addr2 | Length | Spare | CRC1 | CRC2 | Break | Sync | FC2 | Data 0 | Data N | CRC3 | CRC4 | Idle |

*Figure 50-1: ABI write message format*

The Break field is a 12-bit 0 pattern preceded by a 0 start bit and completed by a 1 stop bit.

The Sync field is an 8-bit value of 0x55 preceded by a 0 start bit and completed by a 1 stop bit.

The function code (FC1) for ABI write messages is 0x11 preceded by a 0 start bit and completed by a 1 stop bit.

The address field is made up of 2 bytes (1 byte each for Addr1 and Addr2), each preceded by a 0 start bit and completed by a 1 stop bit.

The Length field is an 8-bit value preceded by a 0 start bit and completed by a 1 stop bit that describes the length of the data that follows.

The Spare field reads 0x00 preceded by a 0 start bit and completed by a 1 stop bit.

The first CRC field (CRC1) is the high byte of CRC calculated on the function code field (preamble) and the Data field (preamble), using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

The second CRC field (CRC2) is the low byte of CRC calculated on the function code field (preamble) and the Data field (preamble), using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

The second function code (FC2) for ABI write messages is 0xFE preceded by a 0 start bit and completed by a 1 stop bit.

All Data fields are preceded by a 0 start bit and completed by a 1 stop bit.

The third CRC field (CRC3) is the high byte of CRC calculated on the function code field and the Data field, using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

The fourth CRC field (CRC4) is the low byte of CRC calculated on the function code field and the Data field, using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

### 50.2.2 ABI read messages

ABI read messages look just like write messages on the physical layer except for the following:

- They have a different function code, which is 0x01 preceded by a 0 start bit and completed by a 1 stop bit.
- They have a gap of between 6.4 µs to 8.8 µs after the second function code and again after the fourth CRC.

---

**NOTE:** The KAD/UBM/104 does not flag CRC errors within ABI messages. CRC data is treated as packet payload data.

The KAD/UBM/104 uses a combination of function code and address values to uniquely identify each ABI message.

## 50.3 ACE-CCDL protocol overview

Write messages in the ACE-CCDL protocol are identical to the write messages in the ABI protocol. There is no read message type in the ACE-CCDL protocol.

When the KAD/UBM/104 is programmed to operate in ACE-CCDL mode, all messages that do not have the ABI write function code (0x11) are packetized and flagged as error messages.

The KAD/UBM/104 uses a combination of function code and address values to uniquely identify each ACE-CCDL message.

## 50.4 ACB protocol overview

The ACB protocol uses a 1Mbps RS-485 Bi-Phase-M encoded physical layer. This is basically the inverse of the ABI line code.

There are three message types in the ACB protocol, each of which works in a master-request followed by a slave-response format.

There are always two types of slave response to each message type: good response or error response.

The three message types are:

"50.4.1 ACB Read Holding Registers messages" on page 446

"50.4.2 ACB Write Multiple Registers messages" on page 448

"50.4.3 ACB Read/Write Multiple Registers messages" on page 450

### 50.4.1 ACB Read Holding Registers messages

#### 50.4.1.1 Master request

The request from master part of these ACB Read Holding Registers messages is an 8-byte message preceded by a minimum gap of 40 µs where the bus is reading Bi-Phase-M 1s and is followed by a gap of 40 – 50 µs of Bi-Phase-M 1s.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC1 | RDAD1 | RDAD2 | Q RD 1 | Q RD 2 | CRC1 | CRC2 | EDELIM |

*Figure 50-2: Request from master message*

SDELIM = 40 – 50 µs of Bi-Phase-M 1s.

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC1 = Function code of ACB Read Holding Registers messages, reads 0x03, preceded by a 0 start bit and completed by a 1 stop bit.

RDAD1 = High byte of the read address of the start memory location on the slave node the ACB master is requesting data from, preceded by a 0 start bit and completed by a 1 stop bit.

RDAD2 = Low byte of the read address of the start memory location on the slave node the ACB master is requesting data from, preceded by a 0 start bit and completed by a 1 stop bit.

QRD1 = High byte of quantity of reads of the number of addresses to be read from the slave, starting at the above read address, preceded by a 0 start bit and completed by a 1 stop bit.

QRD2 = Low byte of quantity of reads of the number of addresses to be read from the slave, starting at the above read address, preceded by a 0 start bit and completed by a 1 stop bit.

CRC1 = High byte of the CRC for the ACB read holding request, calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^{5} + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB read holding request, calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^{5} + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

#### 50.4.1.2 Good data response

A good data response from a slave may contain up to 250 bytes of data, preceded by 3 bytes of header, and followed by 2 bytes of CRC; the full message is appended by message delimiter patterns of minimum 40 µs of Bi-Phase-M 1s.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC2 | Length | Data0 | Data1 | DataN | CRC1 | CRC2 | EDELIM |

*Figure 50-3: Good data response message*

SDELIM = Minimum 40 µs of Bi-Phase-M 1s (same delimiter as EDELIM described in the request; the end delimiter for the request is the start delimiter for the response).

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC2 = Function code of ACB Read Holding Registers messages, reads 0x03, preceded by a 0 start bit and completed by a 1 stop bit.

Length = Count of the number of bytes of data that follows, preceded by a 0 start bit and completed by a 1 stop bit.

Data 0 – N = Data bytes, preceded by a 0 start bit and completed by a 1 stop bit.

CRC1 = High byte of the CRC for the ACB read holding request, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^{5} + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB Read Holding Registers message, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^{5} + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

#### 50.4.1.3 Error Response

An error response from a slave is a 5-byte message appended by message delimiter patterns of minimum 40 µs Bi-Phase-M 1s.

| | | | | | | |
|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC2 | ERRC | CRC1 | CRC2 | EDELIM |

*Figure 50-4: Error response message*

SDELIM = Minimum 40 µs of Bi-Phase-M 1s (same delimiter as EDELIM described in the request; the end delimiter for the request is the start delimiter for the response).

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC2 = Function code of ACB Read Holding Registers messages, reads 0x83, preceded by a 0 start bit and completed by a 1 stop bit.

ERRC = Error code, ACB protocol error code, preceded by a 0 start bit and completed by a 1 stop bit. 0x01 = illegal function, 0x02 = illegal data address, 0x03 = illegal data value, 0x04 = slave device failure.

CRC1 = High byte of the CRC for the ACB read holding request, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB Read Holding Registers message, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

### 50.4.2 ACB Write Multiple Registers messages

#### 50.4.2.1 Master request

The request from the master part of these ACB Write Multiple Registers messages can contain up to 246 bytes of data preceded by a 7-byte header and followed by 2 bytes of CRC.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC1 | WRAD1 | WRAD2 | QWR1 | QWR2 | DATA0 | DATAN | CRC1 | CRC2 | EDELIM |

*Figure 50-5: Request from master message*

SDELIM = 40 – 50 µs of Bi-Phase-M 1s.

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC1 = Function code of ACB Write Multiple Registers messages, reads 0x10, preceded by a 0 start bit and completed by a 1 stop bit.

WRAD1 = High byte of the write address of the start memory location on the slave node the ACB master is writing data to, preceded by a 0 start bit and completed by a 1 stop bit.

WRAD2 = Low byte of the write address of the start memory location on the slave node the ACB master is writing data to, preceded by a 0 start bit and completed by a 1 stop bit.

QWR1 = High byte of quantity of writes of the number of addresses to be written to on the slave, starting at the above write address, preceded by a 0 start bit and completed by a 1 stop bit.

QWR2 = Low byte of quantity of writes of the number of addresses to be written to on the slave, starting at the above write address, preceded by a 0 start bit and completed by a 1 stop bit.

Data 0 – N = Data bytes preceded by a 0 start bit and completed by a 1 stop bit.

CRC1 = High byte of the CRC for the ACB write request calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB write request calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

#### 50.4.2.2 Good data response

A good data response is made up of 8 bytes prepended and appended by message delimiter patterns of up to 50 µs of Bi-Phase-M 1s.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC2 | WRAD 1 | WRAD 2 | QWR 1 | QWR 2 | CRC1 | CRC2 | EDELIM |

*Figure 50-6: Good data response message*

SDELIM = Minimum 40 µs of Bi-Phase-M 1s (same delimiter as EDELIM described in the request; the end delimiter for the request is the start delimiter for the response).

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC2 = Function code of ACB Write Multiple Registers messages, reads 0x10, preceded by a 0 start bit and completed by a 1 stop bit.

WRAD1 = High byte of the write address of the start memory location on the slave node the ACB master is writing data to, preceded by a 0 start bit and completed by a 1 stop bit.

WRAD2 = Low byte of the write address of the start memory location on the slave node the ACB master is writing data to, preceded by a 0 start bit and completed by a 1 stop bit.

QWR1 = High byte of quantity of writes of the number of addresses to be written to on the slave, starting at the above write address, preceded by a 0 start bit and completed by a 1 stop bit.

QWR2 = Low byte of quantity of writes of the number of addresses to be written to on the slave, starting at the above write address, preceded by a 0 start bit and completed by a 1 stop bit.

CRC1 = High byte of the CRC for the ACB write request calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB write request calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

#### 50.4.2.3 Error response

An error response from a slave is a 5-byte message prepended and appended by message delimiter patterns of up to 50 µs of Bi-Phase-M 1s.

| | | | | | | |
|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC2 | ERRC | CRC1 | CRC2 | EDELIM |

*Figure 50-7: Error response message*

SDELIM = Minimum 40 µs of Bi-Phase-M 1s (same delimiter as EDELIM described in the request; the end delimiter for the request is the start delimiter for the response).

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC2= Function code of ACB write error response, reads 0x90, preceded by a 0 start bit and completed by a 1 stop bit.

ERRC = Error code, ACB protocol error code, preceded by a 0 start bit and completed by a 1 stop bit. 0x01 = illegal function, 0x02 = illegal data address, 0x03 = illegal data value, 0x04 = slave device failure.

CRC1 = High byte of the CRC for the ACB write error response calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB write error response calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

## 50.4.3 ACB Read/Write Multiple Registers messages

ACB Read/Write Multiple Registers messages consist of a request that contains up to 246 bytes of write data and a response that contains up to 250 bytes of read data.

### 50.4.3.1 Master request

The request from master part of these ACB read/write messages can contain up to 246 bytes of data, preceded by an 11-byte header, followed by 2 bytes of CRC, and book-ended by message delimiter patterns of up to 50 µs of Bi-Phase-M 1s.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC1 | RDAD1 | RDAD2 | QRD1 | QRD2 | WRAD1 | WRAD2 | QWR1 | QWR2 | DATA0 | DATAN | CRC1 | CRC2 | EDELIM |

*Figure 50-8: Request from master message*

SDELIM = 40 – 50 µs of Bi-Phase-M 1s.

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC1 = Function code of ACB read/write messages, reads 0x17, preceded by a 0 start bit and completed by a 1 stop bit.

RDAD1 = High byte of the read address the start memory location on the slave node the ACB master is requesting data from, preceded by a 0 start bit and completed by a 1 stop bit.

RDAD2 = Low byte of the read address the start memory location on the slave node the ACB master is requesting data from, preceded by a 0 start bit and completed by a 1 stop bit.

QRD1 = High byte of quantity of reads of the number of addresses to be read from the slave, starting at the above read address, preceded by a 0 start bit and completed by a 1 stop bit.

QRD2 = Low byte of quantity of reads of the number of addresses to be read from the slave, starting at the above read address, preceded by a 0 start bit and completed by a 1 stop bit.

WRAD1 = High byte of the write address of the start memory location on the slave node the ACB master is writing data to, preceded by a 0 start bit and completed by a 1 stop bit.

WRAD2 = Low byte of the write address of the start memory location on the slave node the ACB master is writing data to, preceded by a 0 start bit and completed by a 1 stop bit.

QWR1 = High byte of quantity of writes of the number of addresses to be written to on the slave, starting at the above write address, preceded by a 0 start bit and completed by a 1 stop bit.

QWR2 = Low byte of quantity of writes of the number of addresses to be written to on the slave, starting at the above write address, preceded by a 0 start bit and completed by a 1 stop bit.

Data 0 – N = Data bytes preceded by a 0 start bit and completed by a 1 stop bit.

CRC1 = High byte of the CRC for the ACB read/write request, calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB read/write request, calculated across all fields of the request, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

### 50.4.3.2 Good data response

A good data response may contain up to 250 bytes of read data preceded by 3 bytes of header, prepended and appended by message delimiter patterns of up to 50 µs of Bi-Phase-M 1s.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC2 | RD CNT | DATA 0 | DATA N | CRC1 | CRC2 | EDELIM |

*Figure 50-9: Good data response message*

SDELIM = Minimum 40 µs of Bi-Phase-M 1s (same delimiter as EDELIM described in the request; the end delimiter for the request is the start delimiter for the response).

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC2 = Function code of ACB read/write messages reads 0x03, preceded by a 0 start bit and completed by a 1 stop bit.

Data 0 – N = Data bytes preceded by a 0 start bit and completed by a 1 stop bit.

CRC1 = High byte of the CRC for the ACB read/write good response, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB read/write good response, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

### 50.4.3.3 Error Response

An error response from a slave is a 5-byte message, prepended and appended by message delimiter patterns of up to 50 µs of Bi-Phase-M 1s.

| | | | | | | |
|---|---|---|---|---|---|---|
| SDELIM | SLAVE | FC2 | ERRC | CRC1 | CRC2 | EDELIM |

*Figure 50-10: Error response message*

SDELIM = Minimum 40 µs of Bi-Phase-M 1s (same delimiter as EDELIM described in the request; the end delimiter for the request is the start delimiter for the response).

SLAVE = Slave address identifier of slave node on the ACB bus, preceded by a 0 start bit and completed by a 1 stop bit.

FC2= Function code of ACB read/write error response, reads 0x90, preceded by a 0 start bit and completed by a 1 stop bit.

ERRC = Error code, ACB protocol error code, preceded by a 0 start bit and completed by a 1 stop bit. 0x01 = illegal function, 0x02 = illegal data address, 0x03 = illegal data value, 0x04 = slave device failure.

CRC1 = High byte of the CRC for the ACB read/write error response, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

CRC2 = Low byte of the CRC for the ACB read/write error response, calculated across all fields of the response, excluding the delimiters using $X^{16} + X^{12} + X^5 + 1$ preceded by a 0 start bit and completed by a 1 stop bit.

The KAD/UBM/104 uses a combination of slave address, function code, and address values to uniquely identify each ACB message.

EDELIM = Minimum 40 µs of Bi-Phase-M 1s.

## 50.5 Configuring the KAD/UBM/104 to parse and packetize traffic

DAS Studio 3 is used to create a configuration which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the DAS Studio 3 User Manual.

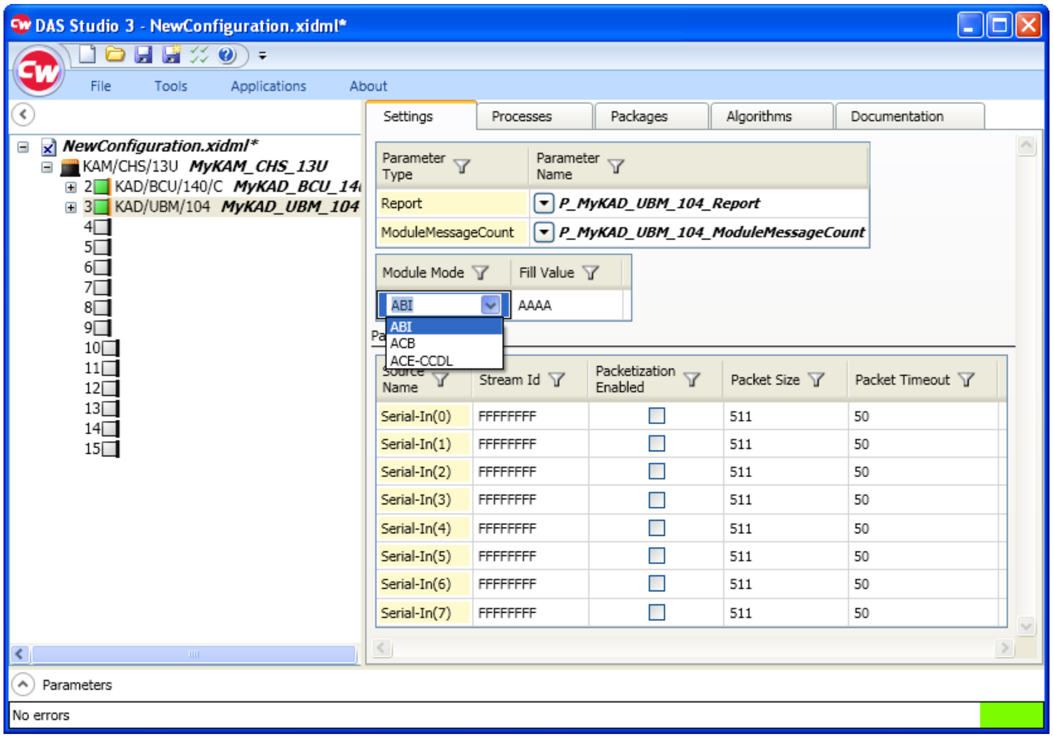
---

**NOTE:** In this technical note, the terms *message* and *package* have the same meaning. The term package is used consistently in the software GUI interface, while the term message is used in the hardware specifications.

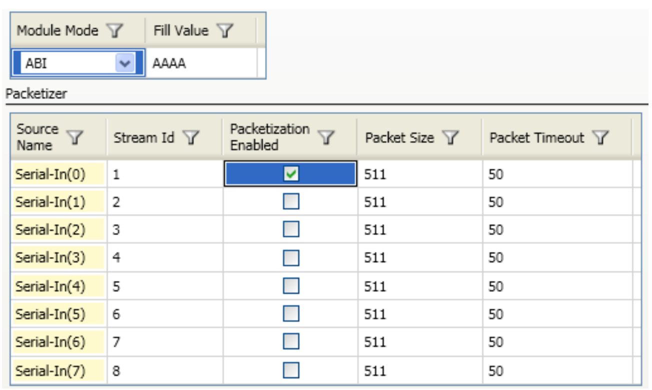
### 50.5.1 Setting up the packetizer

For this example, the configuration file contains a KAM/CHS/13U (chassis), a KAD/BCU/140/C (controller module), and the KAD/UBM/104.

1. Ensure the KAD/UBM/104 is selected in the Navigator on the left of the screen so that it is in context in the **Settings** tab.



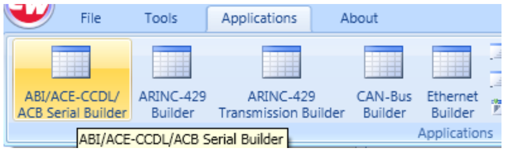

2. Click the drop-down arrow in the **Module Mode** field and select a mode.
3. Assign a unique stream ID to each channel and enable **Packetization Enabled** for channels of interest.



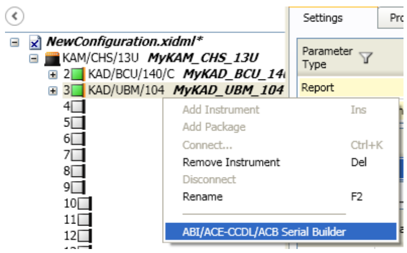
## 50.5.2 Setting up the parser

Refer to the following to define rules for the module to identify and parse data.

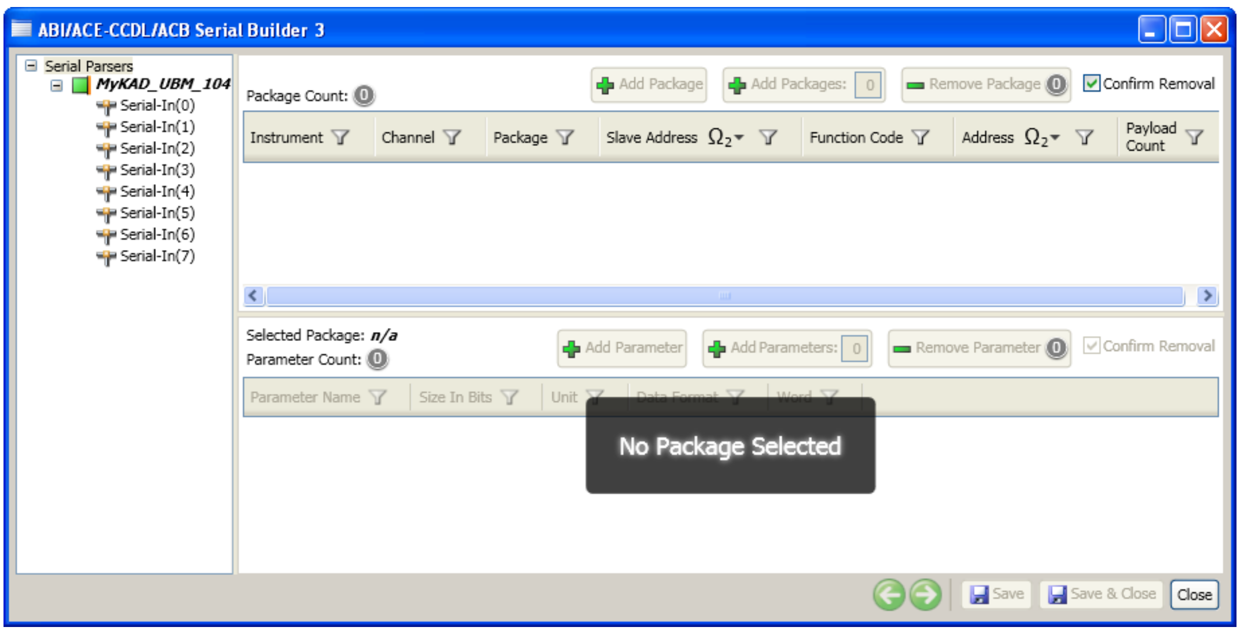
1. On the **Applications** menu, click **ABI/ACE-CCDL/ACB Serial Builder**.




**ABI/ACE-CCDL/ACB Serial Builder** may also be opened by right-clicking on the KAD/UBM/104 in the Navigator.



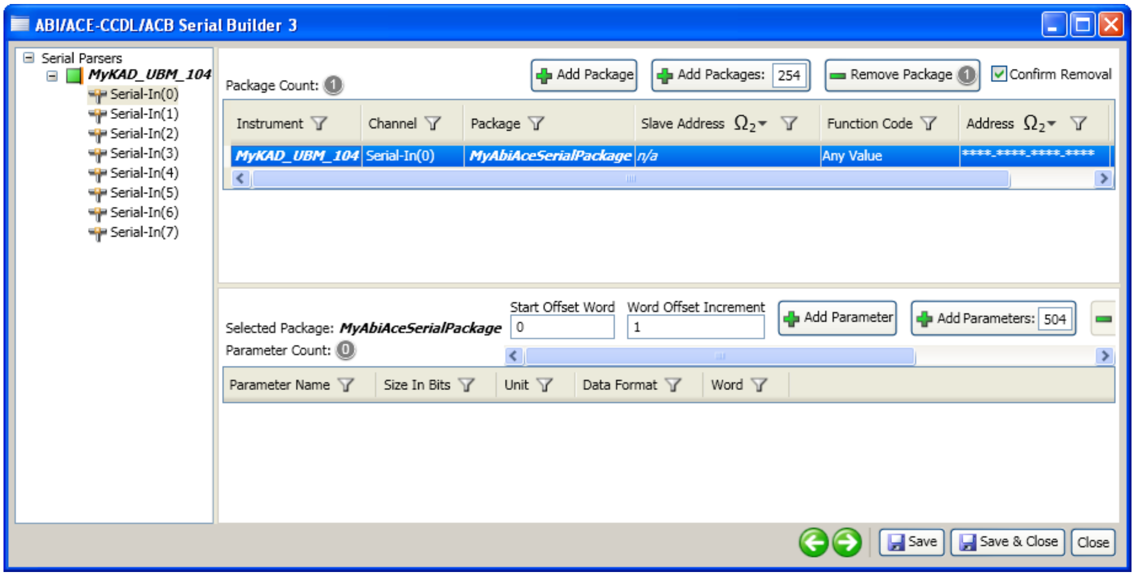

The **ABI/ACE-CCDL/ACB Serial Builder 3** dialog box opens.



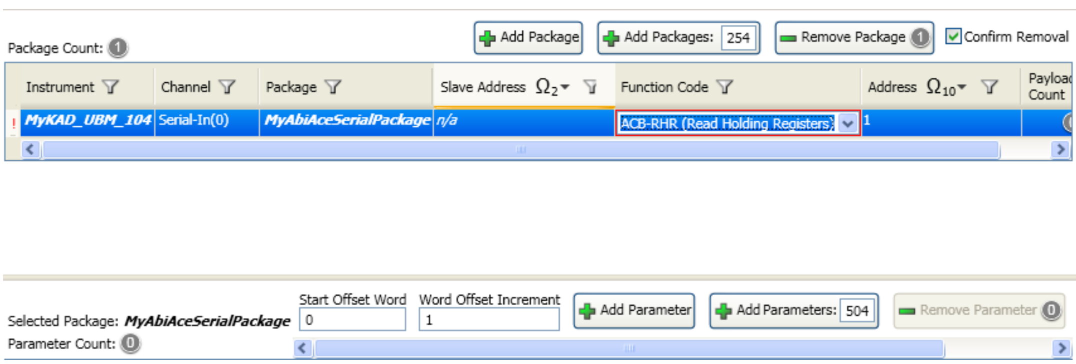

For dialog box navigation, see “Builder application GUI overview” in the *DAS Studio 3 User Manual*.

2. To define a parsing rule for ABI messages, select a channel in the Navigator and then click **Add Package**.
   To add multiple packages, type the number of packages in the **Add Package** field and then click **Add Packages**. (The maximum number of packages you can add is shown in the field.)

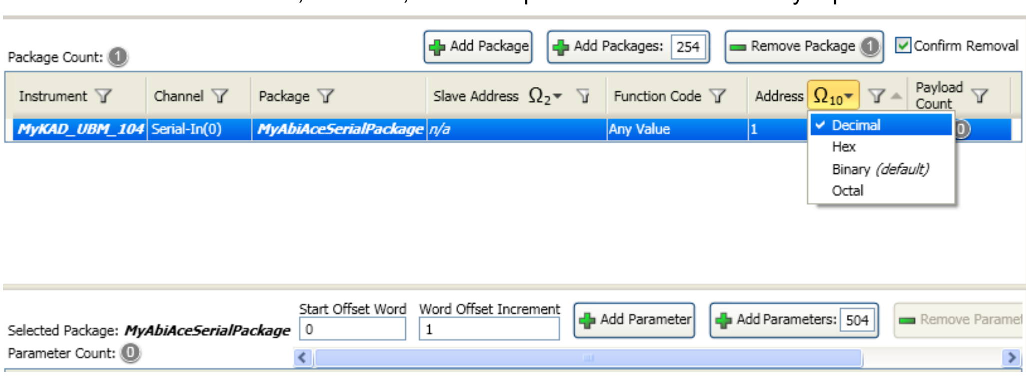
The package is added.




3. Click the **Function Code** drop-down arrow (the drop-down arrow is only visible after you click twice in the field) and select the type of package you want.
If an invalid package type is selected for the current module mode setting (such as **ACB Read Holding Registers** when the module is in ABI mode) the **Function Code** field is highlighted in red to indicate the error and the **Save** function is disabled until the error is resolved.

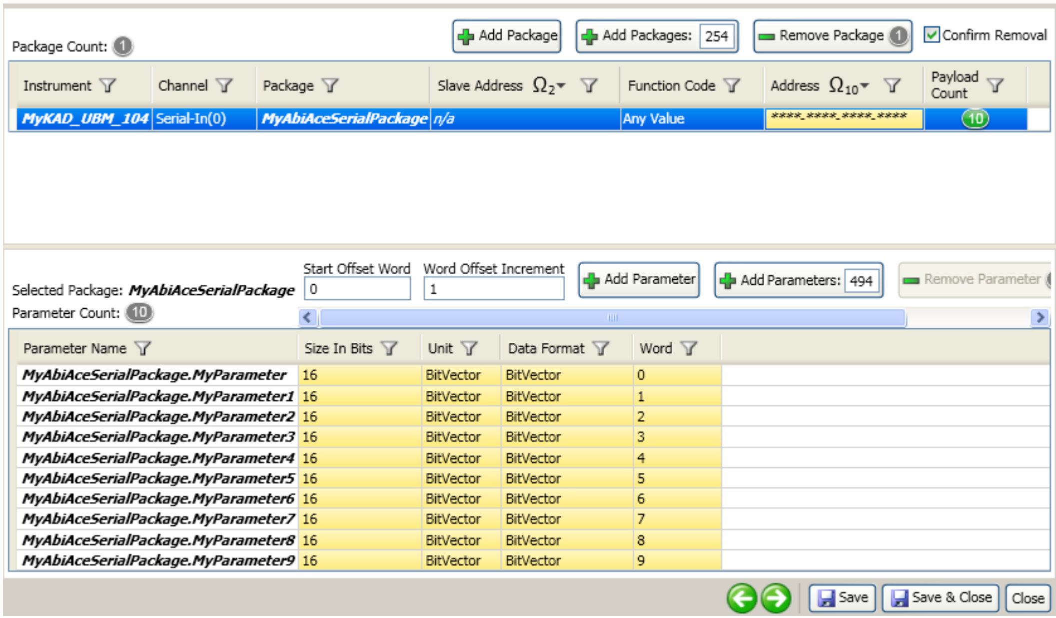



4. Type a unique identifier for the package in the **Address** field.
By default the **Address** field is ****_****_****_****, where * represents a binary wild card bit. This 16-bit value can be changed to hexadecimal, decimal, or octal by replacing the default string with 0000000000000001. This removes the wild cards and activates the **Hex**, **Decimal**, or **Octal** options. Wild cards are only represented in **Binary** mode.




5. To add a parameter to the parsed package, click **Add Parameter**.
To add multiple parameters, type the number of parameters in the **Add Parameter** field and then click **Add Parameters**.

(The maximum number of parameters you can add is shown in the field.)




6. Click **Save & Close** to complete the parser rules setup.

### 50.5.3 Parsing ACB messages

As stated previously, the KAD/UBM/104 uses a combination of slave address, function code, and address values to uniquely identify each ACB package.

When the Module Mode setting is set to ACB mode (see the following figure), the ABI/ACE-CCDL/ACB Serial Builder reads this setting and makes the Slave Address setting available using a wild card as default (see Figure 50-12 on page 457).

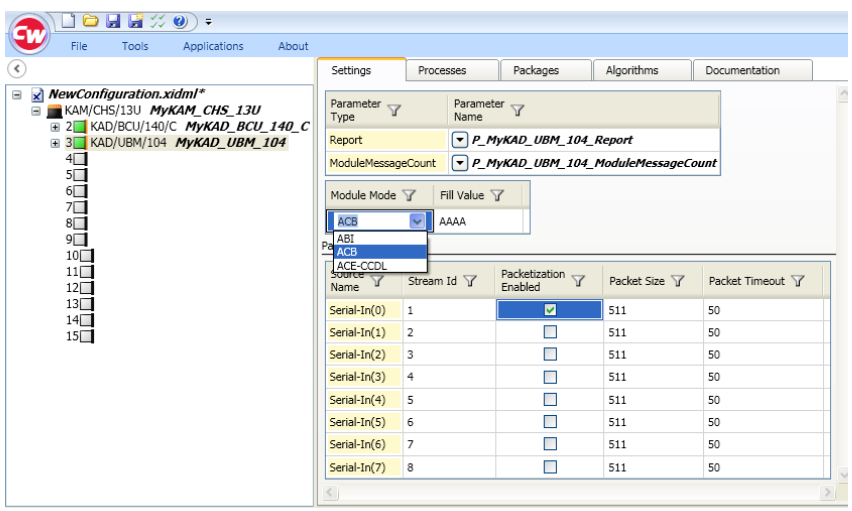



*Figure 50-11: Module Mode set to ACB*

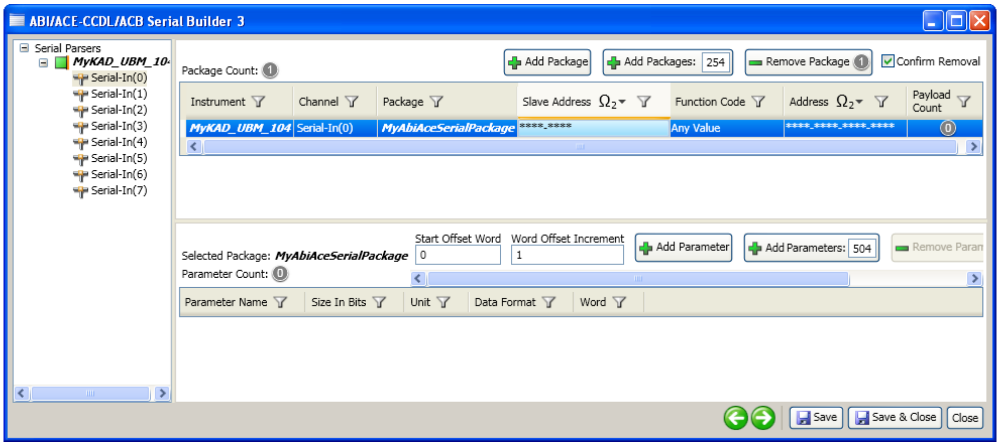



*Figure 50-12: Slave Address setting in ACB mode*

This Slave Address setting is only available in ACB mode.

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# Chapter 51

# Using the KAD/UBM/103

TEC/NOT/079

This paper discusses the following topics:



## 51.1 RS-232/RS-422/RS-485 overview

This section introduces RS-232/422/485, focusing on the physical layer and the bit definition.

### 51.1.1 Physical layer

RS-232 is single ended, so the difference voltage is relative to ground. RS-422 and RS-485 are differential ended, so the difference voltage is between the positive and negative terminals. RS-422 and RS-485 are nominally independent of ground, but if the ground potential differs by too much between end nodes, then no data is received.

The RS-232, RS-422 and RS-485 logic 0 is less than -200 mV. Logic 1 is more than 200 mV (see the following figure).

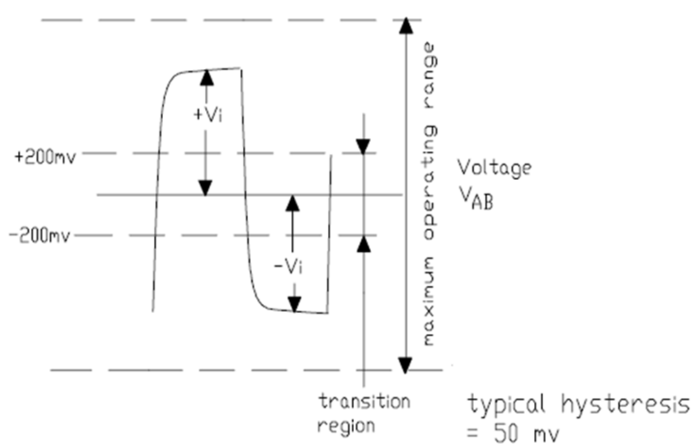



*Figure 51-1: Differential input*

RS-422 and RS-485 require a termination at the end of the transmission line (see the following figure).


*Figure 51-2: Termination differential input*

## 51.1.2 Bit definition

A data word can be either seven or eight bits in length. There is 1 start and 1 stop bit and 1 optional parity bit. A parity bit can be placed at the end of each data word (see the following figure).

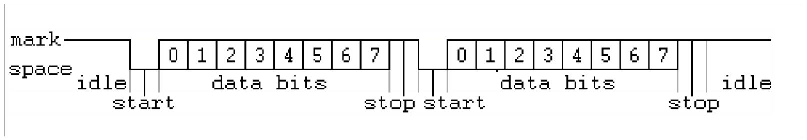



*Figure 51-3: Serial bit definition*

As shown in the previous figure and the following figure, before the serial communication starts, there is an idle voltage in the bus which is represented as a constant value. At the beginning of each transmission, the start bit is transmitted indicating to the receiver that a flow of 7 or 8 bits of data is about to follow. The start bit is represented as a signal edge opposite the idle time. After the data bits are transmitted, there is an optional bit called parity bit which is an error basic detection mechanism that indicates whether the transmission contains an even or odd number of bits transmitted. The stop bit is the last one in the transmission and is represented as a signal edge opposite the start bit (it is the same as the idle time). The KAD/UBM/103 uses 1 stop bit; this setting is not programmable.

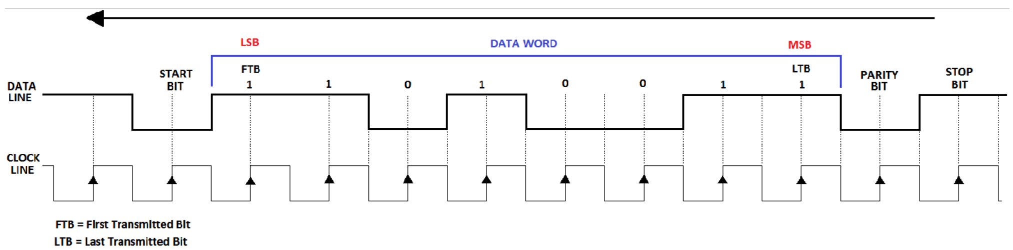



*Figure 51-4: Example of sending 0xCB as 8 bits payload and parity*

# 51.2 Module overview

The KAD/UBM/103 is a 16-channel RS-232, RS-422, RS-485 which can parse and/or packetize each channel at the same time.

You can select the Signal Type (RS-232, RS-422, RS485), Baud Rate (0.2-1 Mbps), Data Bits Per Word (7/8 bits per word), and Parity (None, Even, Odd) on a channel-by-channel basis.

Screen shots and descriptions of settings shown in this technical note are from DAS Studio 3 software. DAS Studio 3 is used to create a configuration, which contains the various elements that make up your data acquisition system. You then use this configuration file to manage and program these elements.

To see how hardware is represented in the DAS Studio 3 graphical user interface, refer to the *DAS Studio 3 User Manual*.

## 51.2.1 Key features

- Monitors up to sixteen independent input RS-422/485/232 busses
- Bit-rates from 300 bps to 1,000,000 bps
- 7/8 bits per word with odd, even or no parity
- Programmable start sequence (1 to 8 bytes), stop sequence (1 byte or by fixed length) and message gap (idle time)
- Coherently parses traffic and tags for up to 511 messages per module. Each message can be 4 to 1024 bytes long
- Aperiodic transmission of packetized serial messages including tags as iNET-X parser-aligned payload structure
- Message wide stale and skipped indication

# 51.3 Serial module history

The following table below describes the different serial modules.

| Module | Description |
|---|---|
| KAD/UAR/002 | RS-232/422/485 bus monitor parser – parse up to 126 messages from 9 to 511 bytes - 300 bps to 115 kbps - 4ch |

| Module | Description |
|---|---|
| KAD/UAR/102 | RS-232/422/485 bus monitor parser and snarfer – parse up to 125 messages from 4 to 512 bytes - 300 bps to 1Mbps - 4ch |
| KAD/UBM/103 | RS-232/422/485 bus monitor parser and packetizer – parse up to 511 messages from 4 to 1024 bytes - 300 bps to 1 Mbps - 16ch |
| KAD/UBM/105 | RS-232/422/485 bus monitor parser and packetizer – parse up to 511 messages from 4 to 1024 bytes - 300 bps to 5 Mbps - 12ch |
| KAD/UBM/106 | RS-232/422/485 bus monitor snarfer - 300 bps to 1 Mbps - 16ch |

## 51.4 Parser operation

### 51.4.1 How parsing works

Like other Curtiss-Wright bus monitors, the KAD/UBM/103 uses a triple buffer for parsing. The following figure illustrates the triple buffering of data words (green) and time message tags (white) used for each bus in the KAD/UBM/103's parser.

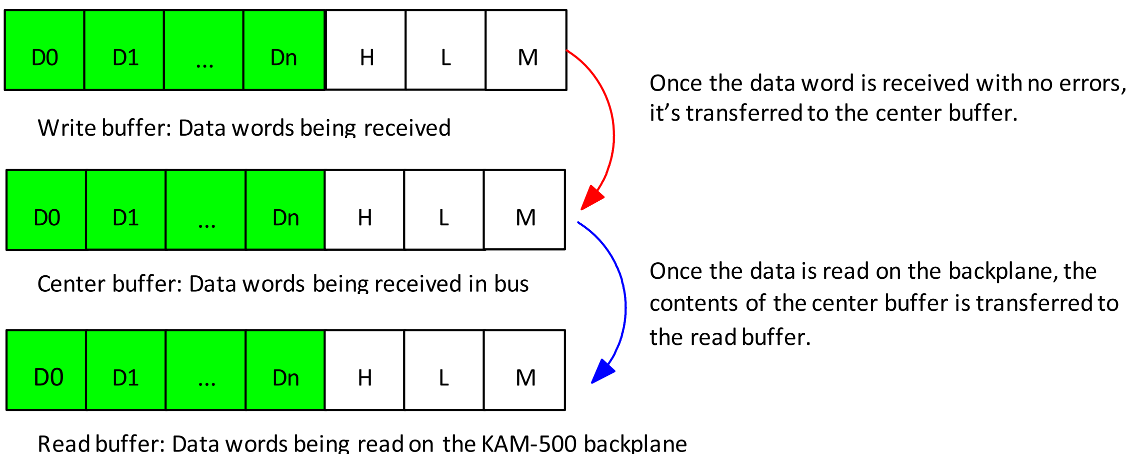



*Figure 51-5: Triple buffering of traffic and associated message tags*

In the previous figure, D0, D1, D2, Dn corresponds to the traffic data words with n < 511.

The time tags H, L, M correspond to High time, Low time and Micro time, which is the time of the first transmitted bit of the message with a 1-µsec resolution.

The way triple buffering works is as follows:

Time message tags are added to each message received and stored in separate buffers for each of the four busses. As soon as a message is received with no errors, the contents of the write buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped flag is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the contents of the center buffer (if new) are transferred to the read buffer. If no new data word has been received, the stale flag is set. A center and read buffer exist for every message ID (parser slot). Skipped and stale bits can be found in the Message Info register to indicate whether messages are lost or repeated (undersampling or oversampling situations).

Additional tags such as Message Count, Message Size, and Message Info registers are also available as additional information and can be added from DAS Studio's Serial Builder application as explained in "51.6.4 Adding parameters to the package" on page 467. For further information regarding these registers, refer to the *KAD/UBM/103* data sheet.

## 51.5 Module Settings tab

### 51.5.1 Parser Data Endianness

In the parser, a total of up to 511 complete messages are triple buffered so that the stale indication is message-wide. Each message can be up to 1024 characters (bytes) long (including start and stop characters). Each message is tagged to 0.1 ms resolution; a message is considered found when a start sequence up to 8 user-defined characters are received. The end-of-message delimiter is determined by either a user-defined stop character or a specific number of bytes. A parsed message is not updated/parsed if the start sequence does not match.

---

**NOTE:** To view the screen shots shown in this section in DAS Studio 3, ensure the KAD/UBM/103 module is in context and the Settings tab is selected.

To configure the parser, first you must decide on the endianness of the data you wish to receive.

As shown in the following figure, there are three choices available for Parser Data Endianness.

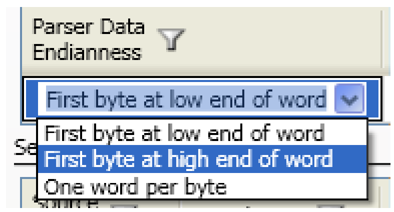



*Figure 51-6: Parser Data Endianness settings*

Considering the input data ABCD:

First byte at low end of word returns the hex values 0x4142, 0x4344, which corresponds to the decimal values 65, 66, 67, and 68, the ASCII codes for ABCD.

First byte at high end of word returns the hex values 0x4344 0x4142, which corresponds to the decimal values 67, 68, 65, and 66, the ASCII codes for CDAB.

One word per byte returns one byte of data per 16-bit word, with the lower byte padded with 0s. That is, 0x4100, 0x4200, 0x4300, and 0x4400, which corresponds to the decimal values 65, 66, 67, and 68, which are the ASCII codes for ABCD once the padded bits are removed.

---

**NOTE:** This byte arrangement is equivalent to KAD/UAR/102 even or data words.

### 51.5.2 Setting up the incoming signal

In this section you define the signal type of the incoming data for that channel.

As shown in the following figure, there are three choices available for Signal Type.

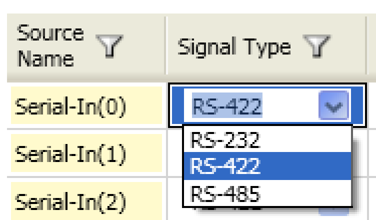



*Figure 51-7: Signal Type settings on channel 0*

RS-232 is a single ended input signal. For this mode, the data source must be connected to the positive input pin of the channel pair and the negative input must be left unconnected.

RS-422 and RS-485 are both differential inputs, so the source positive signal must be connected to the positive input, while the source negative input must be connected to the negative input.

For each input pair, there are individual termination pins. To use these, the negative input must be connected to the correct termination pin for that input.

The remaining channel settings to be configured for the parser are Baud Rate, Data Bits Per Word, and Parity as shown in the following figure and the table that follows.

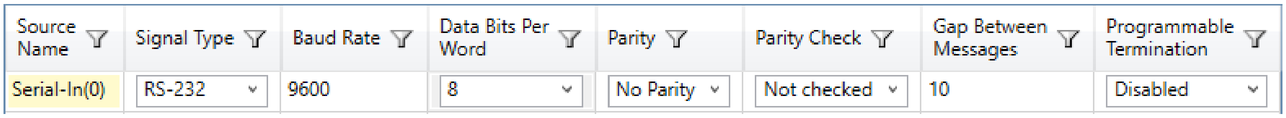
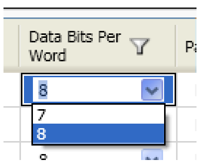
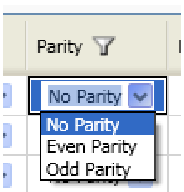
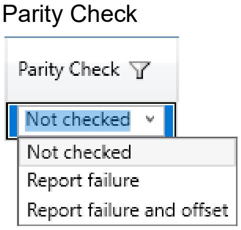
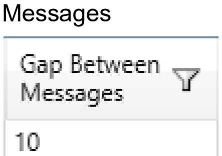
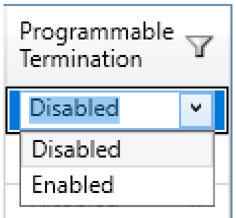


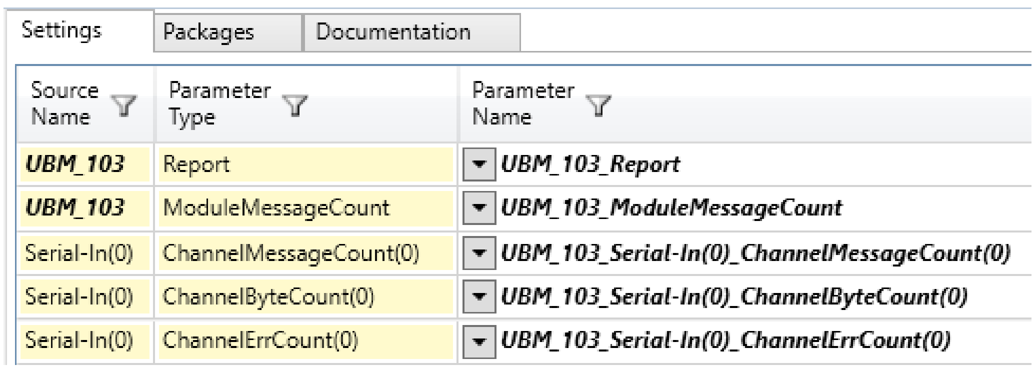

*Figure 51-8: Baud Rate, Data Bits Per Word, and Parity settings*

| Setting | Description |
|---|---|
| Baud Rate (or bit rate) | Specifies the number of symbols (0s or 1s) transmitted per second. The KAD/UBM/103 can coherently parse messages at any bit rate in the range 300 bps to 1 Mbps. |
| Data Bits Per Word<br><br> | Can be either 7 or 8 bits. This does not include Start, Stop, or Parity bits. |
| Parity<br><br> | Parity configures whether a parity bit is present in incoming data. It can be set to No Parity, Even Parity, or Odd Parity.<br>**No Parity** means no parity bit is expected to be present in the incoming data words.<br>**Even Parity** means a parity bit is expected to be present at the end of the incoming data word. This bit is set to either 1 or 0 so that the total number of 1s in the word adds up to an even number.<br>Similarly, **Odd Parity** means this bit is set to either 1 or 0 so that the total number of 1s in the word adds up to an odd number. |
| Parity Check<br><br> | Parity error detection can be enabled by choosing an option from the Parity Check drop-down list as shown in the following figure.<br>The following three Parity Check options are available:<br>• **Not checked** results in all parity errors being ignored.<br>• **Report failure** results in a parity error being indicated in the parser block header and Report Word parameter.<br>• **Report failure and offset** is a packetizer only option which reports the error in the packet and parser block headers and in the Report Word parameter, while also appending a 32-bit word to the packetizer parser block in question, which indicates the byte offset of the first error. An example of this setting is shown in Figure 51-18 on page 472. |
| Gap Between Messages<br><br> | This represents the time gap (represented in characters) between consecutive characters required before starting a new message. The value is expressed in units of character periods at the configured bit rate.<br>This setting can be used as both a packetizer and parser. When using as a packetizer, set to 0 to ignore all gaps and create a message filled with all incoming messages. Refer to "51.7  Packetizer operation" on page 469 for more information.<br>When using as a parser, the message gap (also known as idle time or sync time) can be used to parse messages which do not have a start sequence and/or the start sequence appears within the message. Refer to "51.11.3  Message gap" on page 474 for more information. |

| Setting | Description |
|---|---|
| Programmable Termination   | This is an optional setting to enable an internal 120-ohm termination resistance. This termination is only active when the module power is powered on. Use wiring selectable termination instead if termination is required at all times.<br>Note: Implementing wiring termination and enabling programmable termination by mistake reduces the value of the termination resistor by half, making termination less efficient. Refer to “51.11.1  Termination” on page 473 for more information. |

## 51.5.3 Global parameters settings

Like most bus monitors, the KAD/UBM/103 has global parameters, which can be used for debugging. The main global parameters are Report word and several counters such as module, message, error and byte counters as described in the following table.



Settings | Packages | Documentation

| Source Name | Parameter Type | Parameter Name |
|---|---|---|
| UBM_103 | Report | UBM_103_Report |
| UBM_103 | ModuleMessageCount | UBM_103_ModuleMessageCount |
| Serial-In(0) | ChannelMessageCount(0) | UBM_103_Serial-In(0)_ChannelMessageCount(0) |
| Serial-In(0) | ChannelByteCount(0) | UBM_103_Serial-In(0)_ChannelByteCount(0) |
| Serial-In(0) | ChannelErrCount(0) | UBM_103_Serial-In(0)_ChannelErrCount(0) |

*Figure 51-9: Global parameters in DAS Studio 3 Settings tab*

| Setting | Description |
|---|---|
| Report | The Report word is a 16-bit register, which provides information regarding errors detected in the card and the bus. The Report word is recommended to be monitored as a debug register when abnormal conditions are detected. Refer to the *KAD/UBM/103* data sheet and “51.5.3  Global parameters settings” on page 464 for further information. |
| ModuleMessageCount | ModuleMessageCount increments by one each time the parser logic detects a complete message. Note that the module does not know which bytes form a message until it is parsed. This register counts how many messages the module has parsed by any of the channels. |
| ChannelMessageCount (0 to 15) | Increments by one each time the parser logic detects a complete message. Note that messages which are not defined in the parser are just considered bytes, which can be tracked with ChannelByteCount.<br>Note: Do not confuse this register with MessageCount, which corresponds to a counter added to each message (see “51.6.4  Adding parameters to the package” on page 467). |
| ChannelByteCount (0 to 15) | Count the overall bytes received on this bus, regardless whether they are defined in the parser or not. |
| ChannelErrCount (0 to 15) | Count of errors detected on this bus. See “51.5.4  Errors” on page 465 for error definitions. |

## 51.5.4 Errors

There are several errors reported by the KAD/UBM/103. As explained in the previous section, the Report word provides an indicator of the different errors detected in any of the busses, and ChannelErrCount provides an indicator of the number of errors detected on each bus. Additional packetizer headers contains an error flag Er (1 bit) and a 6 bits Error Code indicator.

The supported errors are:

- **Parity Error**: value 0x1 - This error can be ignored if Parity Check is set to *Not checked*.
- **Bad Stop Bit**: value 0x2 - Refer to “51.11.5  Bad Stop Bit” on page 474.
- **Too many data words**: value 0x4 - Stop character has not been found in 1024 characters. This error is not reported in the packetizer error code.

# 51.6 Serial Builder

For the following sections, use the Serial Builder application in DAS Studio 3. Refer to the “Builder application GUI overview” section of the *DAS Studio 3 User Manual* for a brief overview of navigating the application.

“51.6.1  Defining parsing rules” on page 465

“51.6.2  Parsing Mode” on page 466

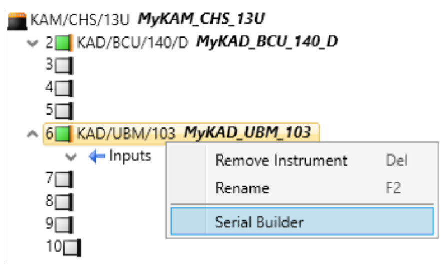
“51.6.3  Start/Stop Sequence format” on page 467

“51.6.4  Adding parameters to the package” on page 467

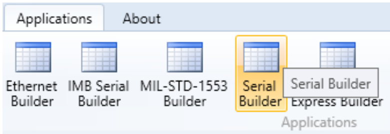
## 51.6.1 Defining parsing rules

After you have all channel settings configured, refer to the following to define rules to identify messages.

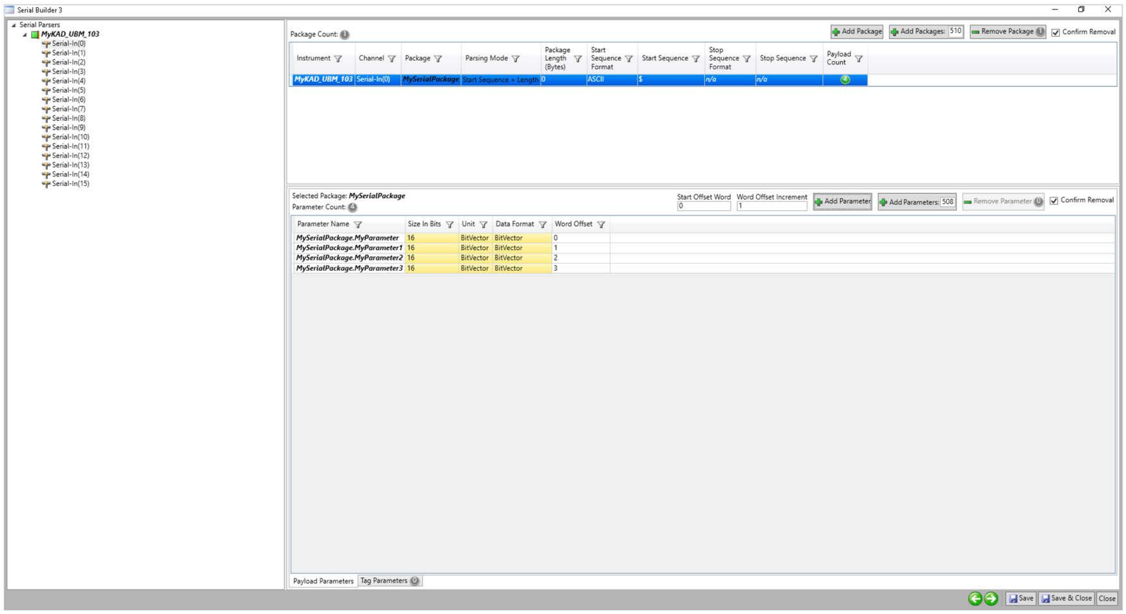
1. Do one of the following.
   - In the Navigator, right-click the KAD/UBM/103 module and then click **Serial Builder**.



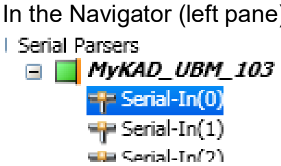
- On the **Applications** tab click **Serial Builder**.




The **Serial Builder** application opens.



2. In the Navigator (left pane), select the channel on the KAD/UBM/103 that you want to parse data off.

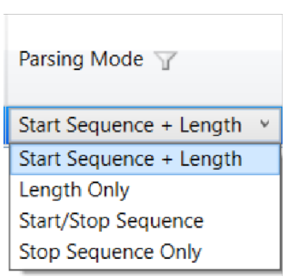



3. Click the **Add Package** button to add a single package. To add multiple packages (up to 511), click the **Add Packages** button (typing the number of packages in the field).


## 51.6.2 Parsing Mode

Now you must define the rules to identify or parse the desired message.

4. The first rule to define is **Parsing Mode**. In the **Parsing Mode** field, open the drop-down list.




Choose **Start Sequence+Length** if you know the start pattern of the message and the number of bytes of data that make up the entire message.

Choose **Length Only** if there is no unique start sequence and you know the number of bytes of the entire message. A message gap needs to be known for it. Refer to “51.11.3 Message gap” on page 474 for further information.

Choose **Start/Stop Sequence** if you know a fixed sequence of 1 to 8 characters that uniquely identify this message, and the stop character that indicates the end of the message.

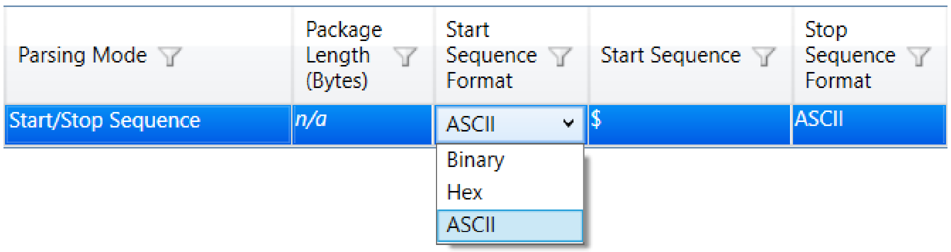
Choose **Stop Sequence Only** if there is no unique start sequence and you only know the stop character that indicates the end of the message. A message gap will need to be known for it. Refer to “51.11.3  Message gap” on page 474 for further information.

When **Start/Stop Sequence** is chosen, the **Package Length** field is not available and the relevant **Start/Stop Sequence** fields are made available.

## 51.6.3 Start/Stop Sequence format

Now you define the **Start Sequence Format** as **ASCII**, **Hex** or **Binary**.

The **Start Sequence** can be up to eight characters long. Binary and Hex can be used when wildcards are required to identify the message. See “51.11.4  Wildcard in Start Sequence” on page 474 for more information.



| Parsing Mode | Package Length (Bytes) | Start Sequence Format | Start Sequence | Stop Sequence Format |
|---|---|---|---|---|
| Start/Stop Sequence | n/a | ASCII | $ | ASCII |



*Figure 51-10: Start Sequence Format options*

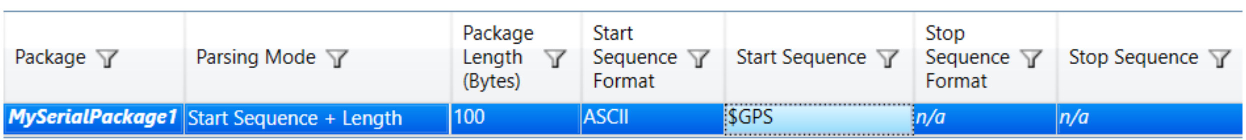
A common start sequence example is the one used with NMEA messages such as ASCII characters $GPSZDA.

**Stop Sequence** is a single byte used to identify the end of the message. By default, this is the ASCII character for line feed (\l).

A typical NMEA message ends with ASCII line feed (0xD) and stop sequence of ASCII Carriage Return (0x0A).

Similarly when **Stop Sequence Only** is selected, only the **Stop Sequence** field is available.

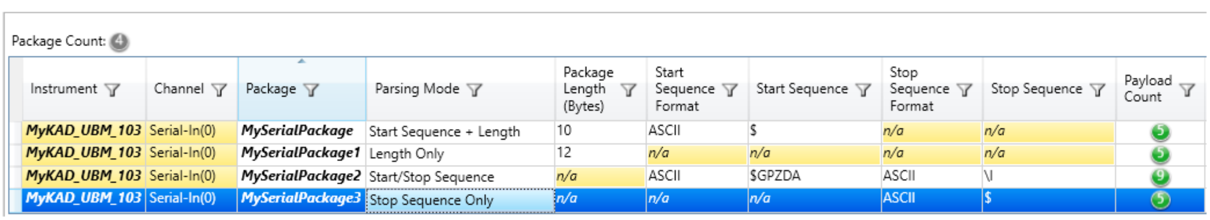
When **Start Sequence+Length** is chosen, the **Package Length** and **Start Sequence** fields are made available and the **Stop Sequence** field is not available.



| Package | Parsing Mode | Package Length (Bytes) | Start Sequence Format | Start Sequence | Stop Sequence Format | Stop Sequence |
|---|---|---|---|---|---|---|
| MySerialPackage1 | Start Sequence + Length | 100 | ASCII | $GPS | n/a | n/a |

*Figure 51-11: Start Sequence + length option*

Similarly when **Length Only** is selected, only the **Package Length** field is available.



Package Count: 4

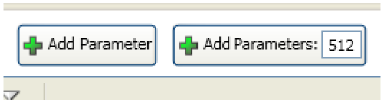
| Instrument | Channel | Package | Parsing Mode | Package Length (Bytes) | Start Sequence Format | Start Sequence | Stop Sequence Format | Stop Sequence | Payload Count |
|---|---|---|---|---|---|---|---|---|---|
| MyKAD_UBM_103 | Serial-In(0) | MySerialPackage | Start Sequence + Length | 10 | ASCII | $ | n/a | n/a | 5 |
| MyKAD_UBM_103 | Serial-In(0) | MySerialPackage1 | Length Only | 12 | n/a | n/a | n/a | n/a | 5 |
| MyKAD_UBM_103 | Serial-In(0) | MySerialPackage2 | Start/Stop Sequence | n/a | ASCII | $GPZDA | ASCII | \l | 9 |
| MyKAD_UBM_103 | Serial-In(0) | MySerialPackage3 | Stop Sequence Only | n/a | n/a | n/a | ASCII | $ | 5 |

*Figure 51-12: Example of the setup of each message type available in the KAD/UBM/103*

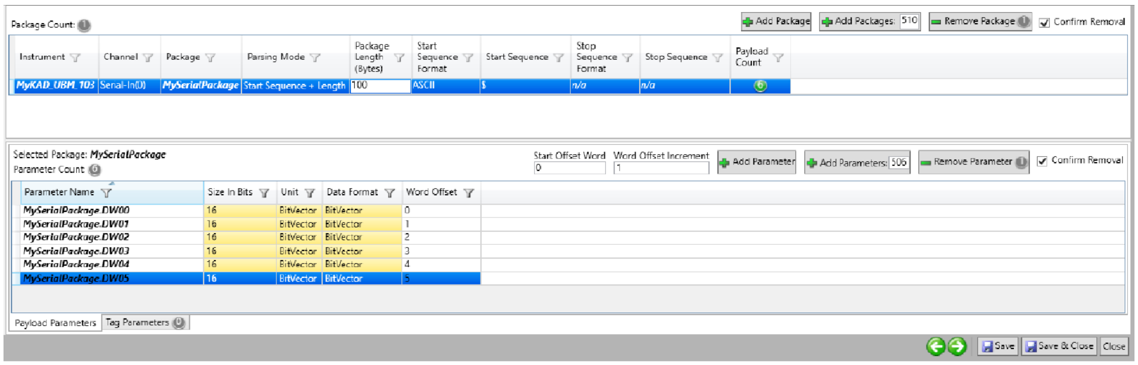
## 51.6.4 Adding parameters to the package

After you have defined rules to identify a message, refer to the following to select the number of bytes required to be parsed.

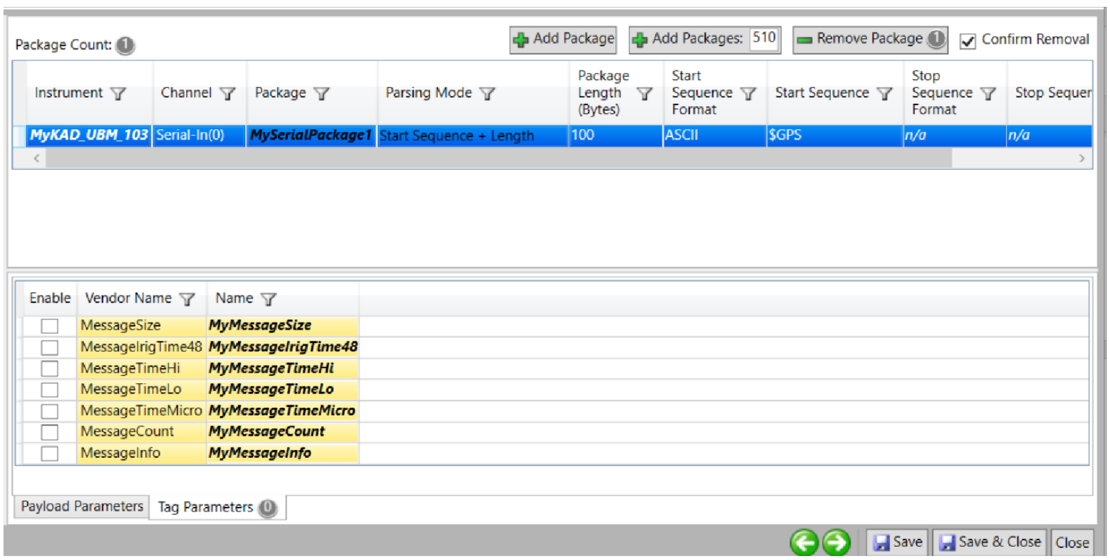
1. Click **Add Parameter** to add a single parameter. To add multiple parameters, click **Add Parameters** (typing the number of parameters in the field). Up to 512, 16-bit parameters can be defined for every message. This corresponds to a maximum of 1024 characters per message.




In the following example, 6 parameters are added.
*Serial message with 6 data words starting from offset 0 and increasing by 1 position.*



2. To tag a message, select the message and then click the **Tag Parameters** tab.




The tags associated with the message are described as follows:

| Setting | Description |
|---|---|
| MessageIrigTime48 | MessageIrigTime48 is a 48 bit register consisting of three 16 bits time register: TimeHi , TimeLo and TimeMicro. Represents the time stamp of a valid parsed message |
| TimeHi, TimeLo and TimeMicro | Same information as MessageIrigTime48 but split in three 16 bit register.<br>Note: these registers are implemented to provide compatibility with legacy systems |
| MessageSize | Number of received bytes including start bytes. |
| MessageCount | Counter of the received messages , however this counter might not increase smoothly. As explained in section “51.5.3 Global parameters settings” in this document, the ModuleMessageCount is the only counter in the module counting messages received in all channels of the module. ModuleMessageCount stores the current value of that counter in the slot with each message , therefore ModuleMessageCount increases smoothly. MessageCount indicates where, in the arrival order, the particular message was received. For this reason consecutive messages on a single bus may not have consecutive values as messages on other channels may have been received, however it increase. Individual MessageCount from different channels can be correlated with ModuleMessageCount |

| | |
|---|---|
| MessageInfo | Stale/skipped indication for each parsed message. These flags indicate whether messages are repeated or lost, that is, oversampling or undersampling situations respectively |

Refer to the *KAD/UBM/103* data sheet for further information regarding these additional tags.

3. To save your changes and close **Serial Builder**, click **Save & Close**.


When package building in Serial Builder is complete, these parameters become available to be placed in a PCM stream or placed packet.

## 51.7 Packetizer operation

Independently of the parser, when packetizer is enabled, an iNET-X packet stream is generated for each channel. All received bytes are encapsulated in an iNET-X parser-aligned payload structure. The programmable message gap allows the module to split the incoming bytes into shorter timestamped sequences. A block header attached to each sequence stores the channel index, length, and the time each message is received. These parser-aligned packets may be transmitted aperiodically to optimize network bandwidth utilization and memory usage when recording serial traffic.

There are many settings available to configure or tune packetizer behavior.

While the structure of the packetizer packets are what we refer to as parser-aligned packets, the KAD/UBM/103 relies on gaps between the data to identify the start/end of the parser-aligned blocks. The size of the gap between messages can be set on a channel-by-channel basis. The Gap Between Messages setting (see the following figure) is expressed in characters, and ranges from 0 to 10,000 characters.

---

**NOTE:** To view the screen shots shown in this section in DAS Studio 3, ensure the KAD/UBM/103 module is in context and the Settings tab is selected.

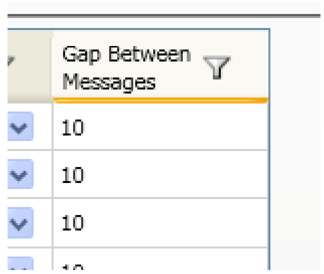



*Figure 51-13: Gap Between Messages setting from Settings tab*

Setting 0 characters results in all gaps being ignored and the packetizer packets being filled with bytes of data until the packet is either full or times out; thereafter the packet is transmitted.

The other available packetizer settings are shown in the following figure and described in the table that follows.

Packetizer

| Source Name | Packetizer Format | Stream Id | Packetization Enabled | Packet Size | Packet Timeout | Utilization | IENA Key | One Message Per Packet | Packetization Sink |
|---|---|---|---|---|---|---|---|---|---|
| Serial-In(0) | iNET-X | FFFFFFFF | ☐ | 511 | 50 | 1.00 | 0 | ☐ | All |
| Serial-In(1) | iNET-X | FFFFFFFF | ☐ | 511 | 50 | 1.00 | 0 | ☐ | All |
| Serial-In(2) | iNET-X | FFFFFFFF | ☐ | 511 | 50 | 1.00 | 0 | ☐ | All |
| Serial-In(3) | iNET-X | FFFFFFFF | ☐ | 511 | 50 | 1.00 | 0 | ☐ | All |

*Figure 51-14: Packetizer settings*

| Setting | Description |
|---|---|
| Source Name | Channel to packetize. |
| Packetizer Format | iNET-X or IENA-iNET-X hybrid. This setting defines the packetizer format of all channels.<br>Note, IENA-iNET-X hybrid is a non-standard format. |
| Stream ID | iNET-X stream identifier for selected channel if a packet is generated via the assertion of Packetization Enabled. This is a conditional setting and is only active when the Packetizer Format is set to iNET-X. |
| Packetization Enabled | Enables the transmission of a packetizer packet containing the contents of this channel if an packetizer transmitter or memory module is present in the chassis.<br>DAS Studio 3 automatically creates a packetizer packet after verification/programming. |
| Packet Size | The number of words in the packet buffer, ranges from 200 words to 511 words. The default value is 511 words; reducing this value results in smaller and therefore generally more frequent packets. |
| Packet Timeout | The timeout in milliseconds before a packet is generated if insufficient messages have been received to reach the Packet Size. Packets generated due to Packet Timeout are tagged in the iNET-X header. The Packet Timeout ranges from 10 ms to 999 ms (default value is 50 ms).<br>Reducing this value results in more frequent and generally smaller packets. Increasing the value results in less frequent, but generally bigger packets. |
| Utilization | The setting is a way for the user to schedule fewer packets per second for situations where they know that traffic on the bus is less frequent. It is expressed as a decimal number in the range 0.0 to 1.0 where 1.0 = 100% bus utilization. As an example for an input bit-rate configured to 1 Mbps, the KAD/UBM/103 schedules 256 packets per second with 100% bus utilization. If set to 50% bus utilization, the scheduler can drop this as low as 128 packets per second.<br>This setting can be considered as an advanced setting and can be useful on a chassis populated with multiple packetizer channels enabled for which the compiler has difficulties to schedule all the traffic in the KAM-500 backplane. Reducing the utilization on a channel alleviates the backplane traffic. |
| One Message Per Packet | This setting determines whether multiple or a single message should be included in a packet. When enabled, a packet is generated after a valid message has been detected. Subsequent messages are placed in separate packets. This simplifies message extraction as there is only one message per packet. |
| Packetization Sink | Selects which modules the packetizer package is sent to for transmission or storage. The choices are *Controller only*, *All slots* or *Slot* in which a sink module that supports packetizer logging such as KAM/MEM/113 is placed. For example, on a system consisting of KAD/BCU/140/D controller on J2, KAD/UBM/103 on J3, and KAM/MEM/113 on J4, setting *Slot 4* creates packetizer packets on the KAM/MEM/113 only and setting *All* creates packets on both KAD/BCU/140/D and KAM/MEM/113. |

Conversely, if a single message continues past the end of one packet with no gap, the succeeding bytes are packetized in a new parser block in the next packet. A bit in the header of the first parser block in the following packet, is set to indicate that this block is a continuation of the message in the final block of the previous packet. The location of this continuation bit is marked **Cn** (Continuation Indicator) in the example parser blocks shown in Figure 51-17 on page 472.

For further information regarding iNET-X Placed packets used by the packetizer refer to *TEC/NOT/067 - IENA and iNET-X packet payload formats*. Additionally the *KAD/UBM/103* data sheet provides several examples of packetizer parser blocks.

## 51.8 Parity Check– Report failure and offset

This is a packetizer only option. See *Parity Check* in Figure 51-8 on page 463 and the description that follows.

## 51.9 Enabling packetizer

To turn on packetizer operation on any channel, define a unique stream ID for that channel and then select the Packetization Enabled check box for that channel as shown in the following figure. The packetizer is enabled the next time the module is programmed.

| Source Name | Stream Id | Packetization Enabled |
|---|---|---|
| Serial-In(0) | 1 | ☑ |
| Serial-In(1) | 2 | ☑ |
| Serial-In(2) | 3 | ☑ |

*Figure 51-15: Packetization Enabled setting*

## 51.10 Packetizer packet format (parser aligned)

The generalized iNET-X payload structure for parser-aligned packets is shown in the following figure and examples of parser block formats are shown in Figure 51-17 on page 472. A parser block is created for each logical message, based on the gaps between sequences of bytes. A new parser block is created at the start of each iNET-X packet and also when the time gap between successive bytes exceeds a programmable threshold.

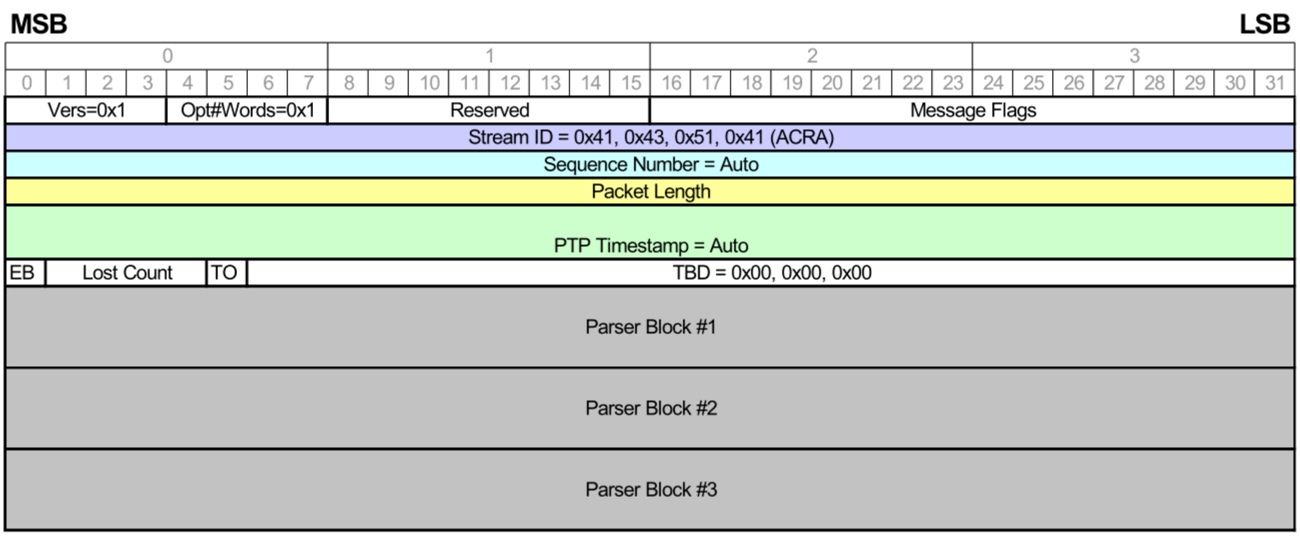



*Figure 51-16: Generalized parser-aligned iNET-X packet*

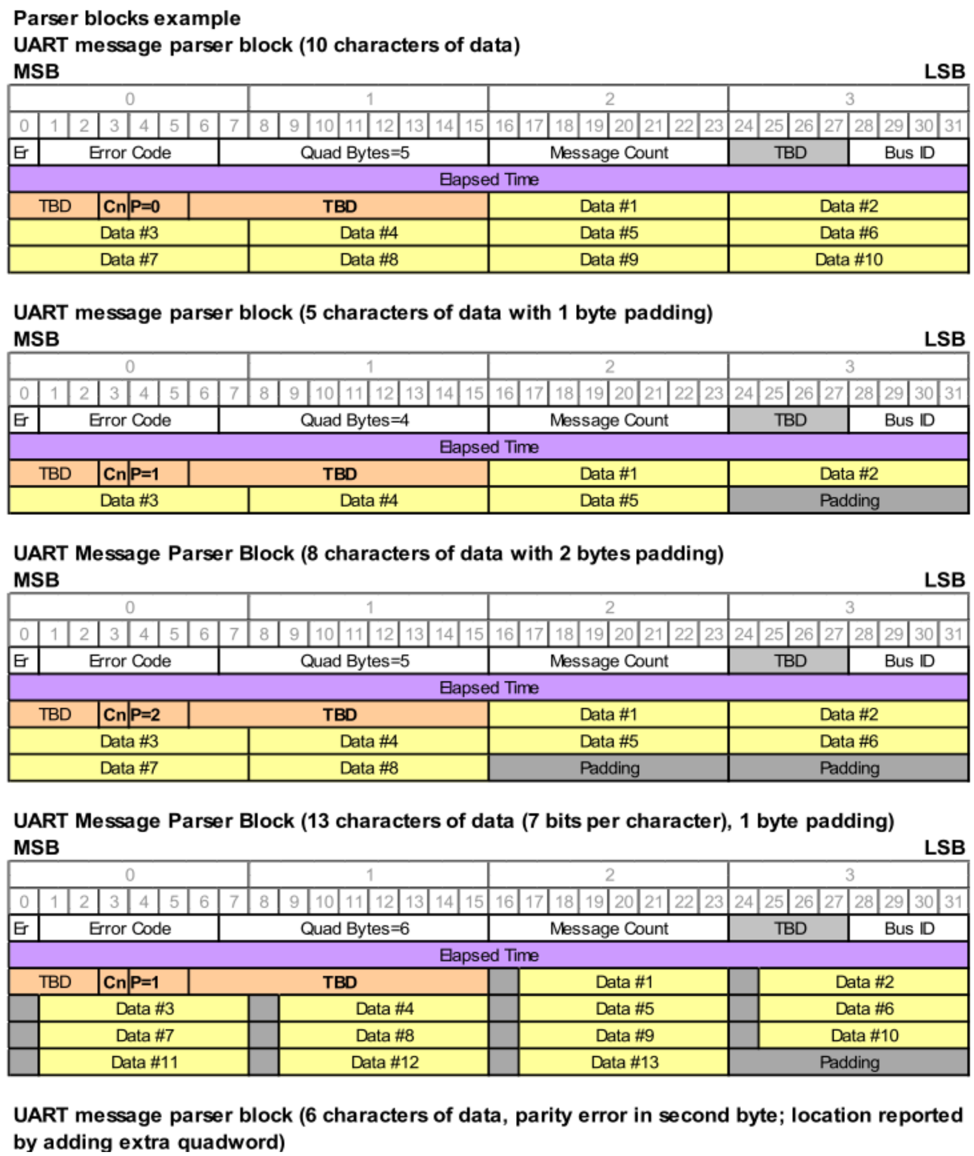
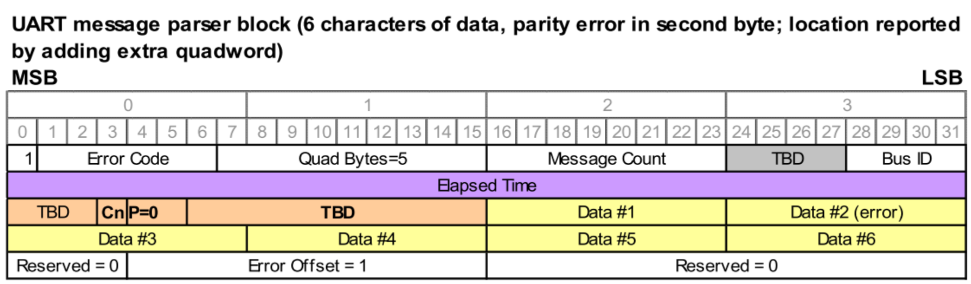



*Figure 51-17: Parser block formats used in packetizer*




P = Number of padding bytes added to complete final quadbyte to 32 bits
Cn = Continuation Indicator (1 = this block continues the block that ended the previous packet.)

*Figure 51-18: Parser block formats used in packetizer with option "Report failure and offset" enabled*

## 51.11 Appendix

### 51.11.1 Termination

For an RS422/485 bus, the transmission line should be terminated at the last transceiver on the line (bus). Transmission line termination schemes is a topic of discussion beyond the scope of this technical note. The section gives a basic overview of the termination schemes.

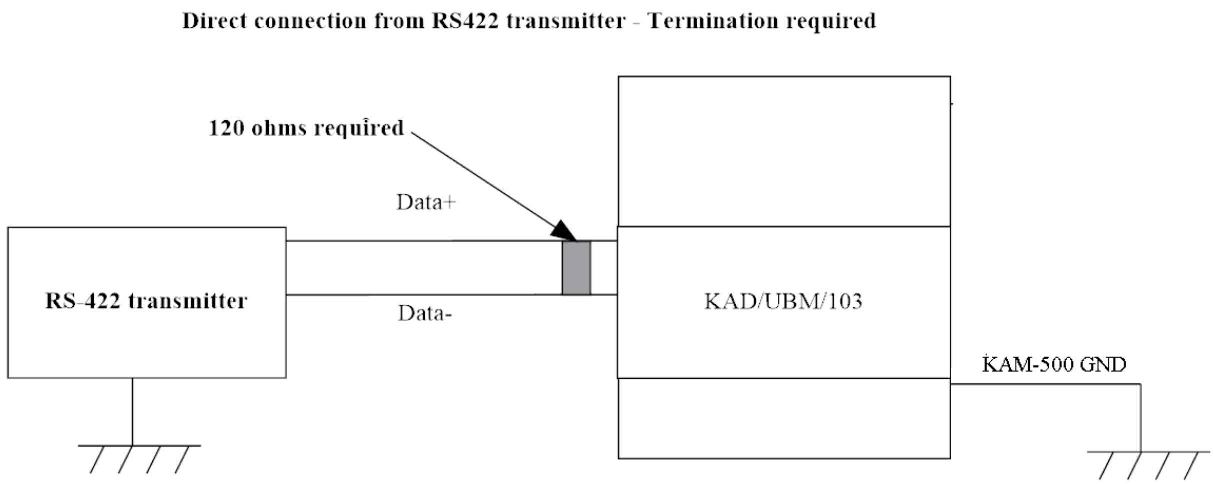



*Figure 51-19: Example of termination required on the KAD/UBM/103*

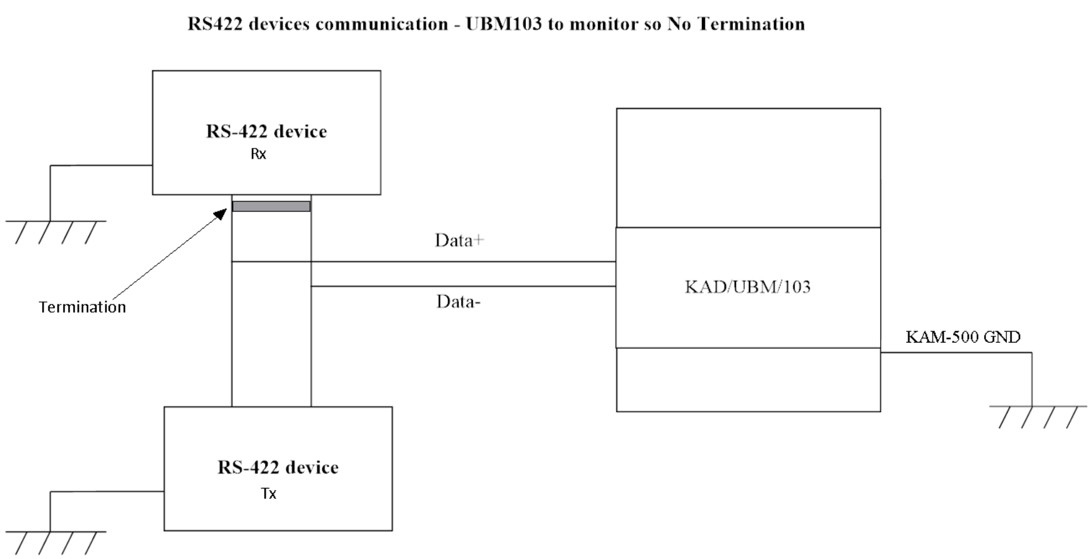



*Figure 51-20: Example of no termination required on the KAD/UBM/103*

The KAD/UBM/103 can be programmed to have termination. This programmable termination is not active when the power is off, that is, the bus is not terminated if the KAM-500 is powered off. If permanent termination is required, then external termination should be used. Refer to the Getting the most from section of the *KAD/UBM/103* data sheet.

### 51.11.2 Grounding

Grounding schemes is a topic of discussion beyond the scope of this technical note. Unlike RS-232, RS-422, and RS-485 transmission is differential. The previous two figures show a system configuration presented without a separate ground wire. The basic rules for electronic circuits still require a clean ground connection to ensure error-free communication between drivers (Tx) and receivers (Rx). For further information refer to *TEC/NOT/063 — Grounding and shielding of the Acra KAM-500*.

### 51.11.3 Message gap

The gap between messages can also be used for parsing. The idea is the same as the Idle Time/Sync Interval functionality on the KAD/UAR/102.The gap from the KAD/UBM/103 is expressed in units of character period at the configured bit-rate.

This gap needs to be defined if the start sequence appears inside the message or there is no unique start sequence.

The example below shows a chain of characters. The KAD/UBM/103 is programmed with AB as a Start Sequence and with a length of 10 bytes for the Stop Sequence, which means DW0 to DW4 are required. The Parser Data Endianness is set to First byte at low end of word.

If you set the gap at 0—because only the start sequence is used as a parser slot—the module may start parsing when it encounters the start sequence AB inside the message.

So the KAD/UBM/103 could output DW0 = AB, DW1 = CD, DW2 = EF then all the other DW will be random data or data previously stored in RAM, the next instance of the data word, will be DW0 = AB, DW1 = G\n then DW2 will be from the next instance, that is, AB, DW3= DD…

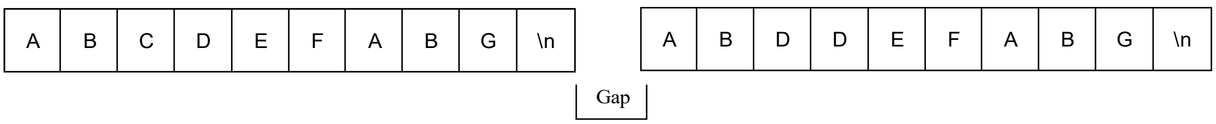
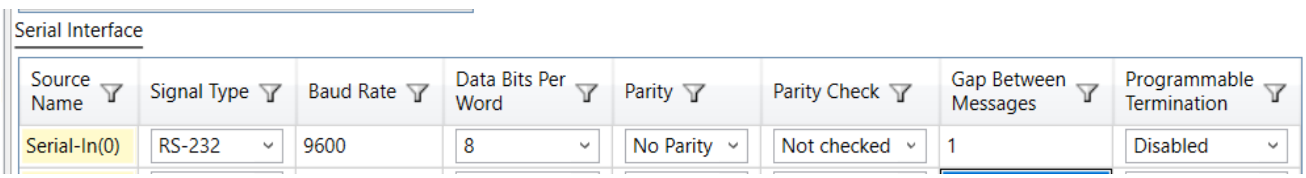



*Figure 51-21: Example of gap between messages*

To parse the whole message correctly, the KAD/UBM/103 gap between messages needs to be programmed with at least 1 byte. The module then outputs DW0 = AB, DW1 = CD, DW2 = EF, DW3= AB, DW4= G\n.



Serial Interface

| Source Name | Signal Type | Baud Rate | Data Bits Per Word | Parity | Parity Check | Gap Between Messages | Programmable Termination |
|---|---|---|---|---|---|---|---|
| Serial-In(0) | RS-232 | 9600 | 8 | No Parity | Not checked | 1 | Disabled |

*Figure 51-22: Example of gap between messages being set to 1 character in DAS Studio 3*

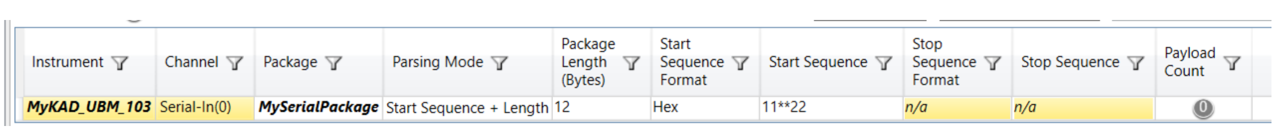
As explained in "51.6.2 Parsing Mode" on page 466, parsing modes *Length Only* and *Stop Sequence Only* can use *Message gap* when the incoming message has no unique start sequence or the start sequence is present within the message. It is recommended to use these advanced parsing options with prior knowledge of the incoming message. Care must be taken in order to ensure the programmed message gap is not greater than the time of the next incoming message. Also power up conditions should be considered as incorrect parsing could occur when the module is powered up in the middle of the reception of a message.

---

**NOTE:** The KAD/UBM/105 does not support message gap for parsers.

### 51.11.4 Wildcard in Start Sequence

Serial Builder supports wildcard symbols '*' in the Start Sequence. When using Hex format for Start Sequence, each wildcard represents 4 bits (nibble), therefore two wild cards symbols "**" are required to represent one character boundary (1 byte). When using Binary format for Start Sequence, each bit can be wildcarded on a bit-to-bit basis.



| Instrument | Channel | Package | Parsing Mode | Package Length (Bytes) | Start Sequence Format | Start Sequence | Stop Sequence Format | Stop Sequence | Payload Count |
|---|---|---|---|---|---|---|---|---|---|
| MyKAD_UBM_103 | Serial-In(0) | MySerialPackage | Start Sequence + Length | 12 | Hex | 11**22 | n/a | n/a | |

*Figure 51-23: Serial Builder - Example of wildcard used on a 3-character start sequence using Hex format*

### 51.11.5 Bad Stop Bit

The module detects a Bad Stop Bit if it's not as expected, see Figure 51-4 on page 460.

For example:

• No parity is configured and a message is received that was transmitted with a Parity bit. In this case the parity bit is decoded as a bad stop bit.

• Parity is configured and a message is received that was transmitted with no Parity bit. In this case since no Parity bit was sent, the module decodes the received Stop bit as an invalid Parity bit and then expects a Stop bit but never receives it and thus reports it as a Bad Stop Bit.

### 51.11.6 Recommended reading

To better understand this paper, read the following documents.

Table 51-1: Data sheets

| Document | Description |
|---|---|
| KAD/UAR/102/C | RS-232/RS-422/RS-485 universal asynchronous parser and snarfer - 4ch |
| KAD/UBM/103 | RS-232, RS-422 or RS-485 serial bus parser/packetizer - 16ch |

Table 51-2: Data sheets

| Document | Description |
|---|---|
| TEC/NOT/062 | Using the KAD/UAR/102 |
| TEC/NOT/063 | Grounding and shielding of the Acra KAM-500 |
| TEC/NOT/067 | IENA and iNET-X packet payload formats |

Table 51-3: User manual

| Document | Description |
|---|---|
| DOC/MAN/030 | DAS Studio 3 User Manual |

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Chapter 52

# Visualization effects while reconstructing time waveforms from sampled data

TEC/NOT/081

This technical note describes the most common visual effects due to sampling in the time domain. This technical note should be read in conjunction with *TEC/NOT/019 - An Introduction to digital filtering*.

This paper discusses the following topics:



## 52.1 Overview

In signal processing, sampling is the reduction of a continuous signal to a discrete signal. A common example is the conversion of a sound wave (a continuous signal) to a sequence of samples (a discrete time signal).

A sample is a value or set of values at a point in time and/or space. A sampler is a subsystem or operation that extracts samples from a continuous signal.

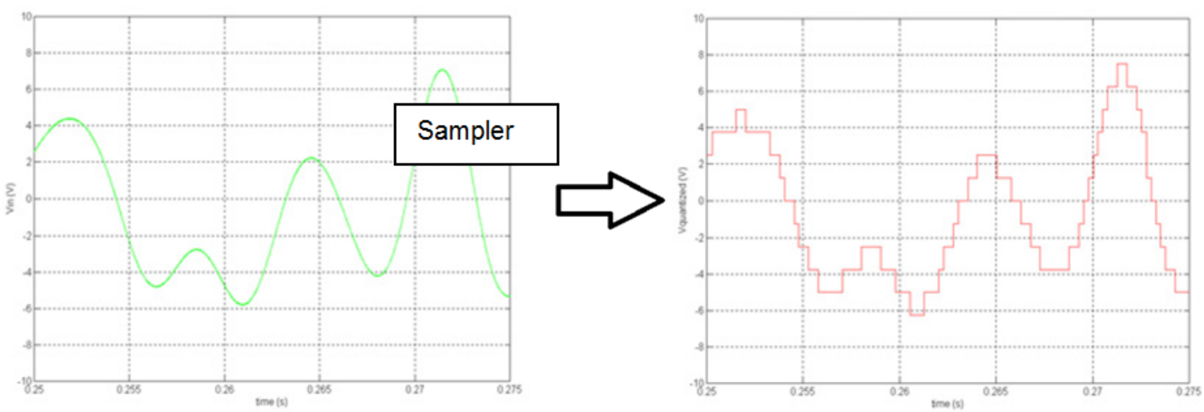



*Figure 52-1: Sampler example using rectangular interpolation (see "52.5 Sampling: signal reconstruction" on page 482)*

A theoretical ideal sampler produces samples equivalent to the instantaneous value of the continuous signal at the desired points.

**NOTE:** Aliasing and quantization noise effects are not mentioned in this technical note. They are already discussed in *TEC/NOT/019 - An Introduction to digital filtering*.

## 52.2 Sampling: amplitude visual effect

When sampled at 100 samples per second, a 0.2Hz sine wave (500 points per period) creates a visually identical shape to the input signal (as shown in the following figure).

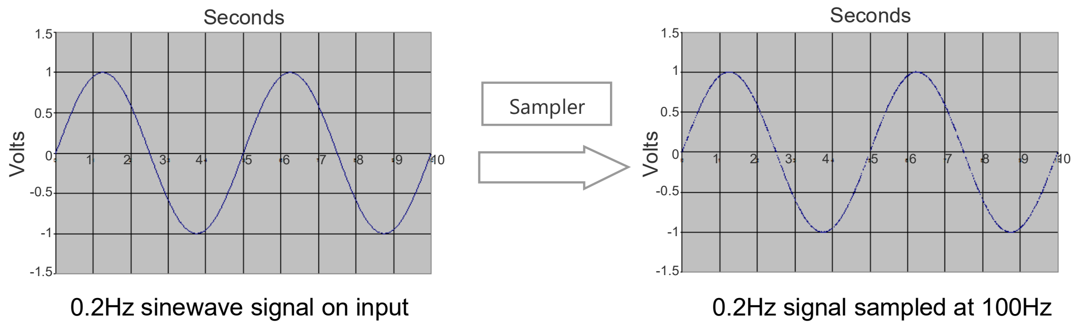



*Figure 52-2: Sampler at 100Hz*

However, when the same sine wave is sampled at 1 sample per second (5 points per period), the visual aspect of the samples are different. The maximum-minimum is no longer equal to the amplitude (as shown in the following figure).

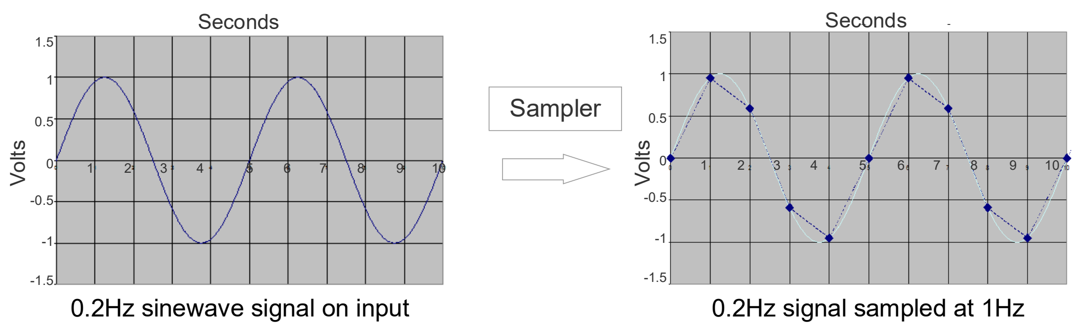



*Figure 52-3: Sampler at 1Hz*

In the following figure, we want to check the cut-off frequency ($F_c$) of an analog module. In the example, we input a sine wave at the same frequency ($F_{in}$) than $F_c$ and expect to see a stable attenuation due to the filter used on the ADC module.

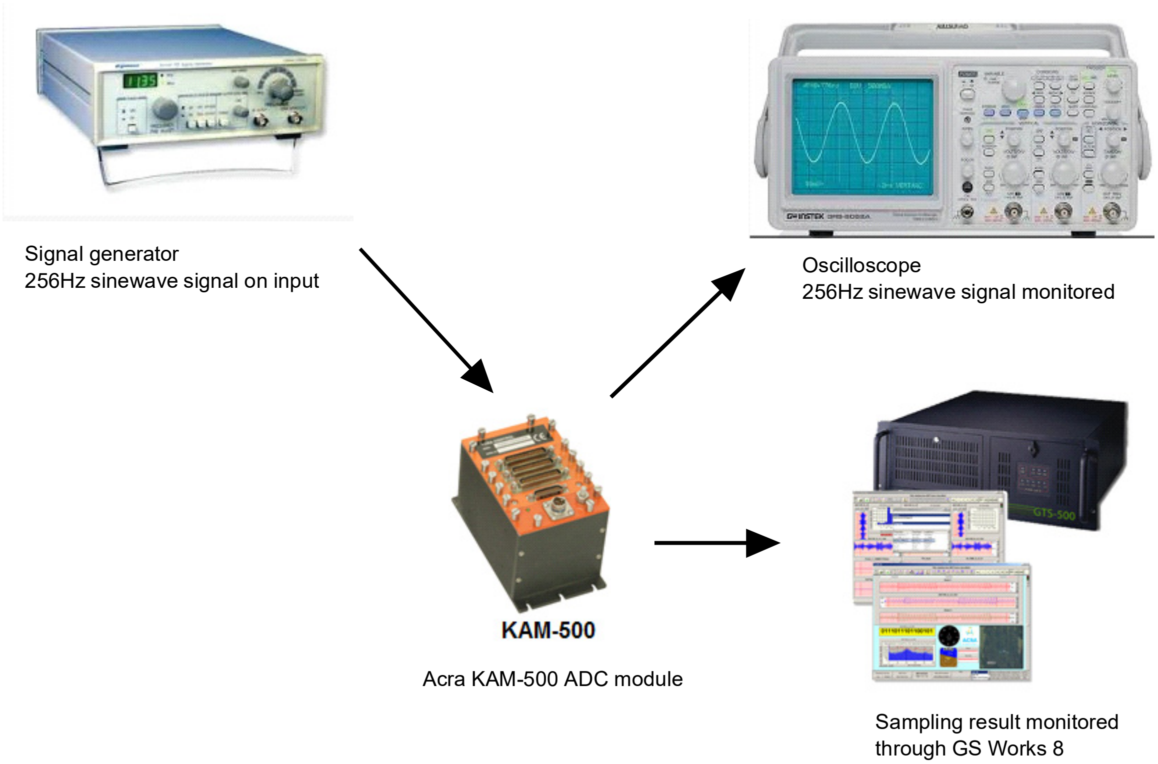



*Figure 52-4: Setup for $F_{in}$ = $F_c$*

The results that can be seen in GS Works 8 are shown in the following figure.

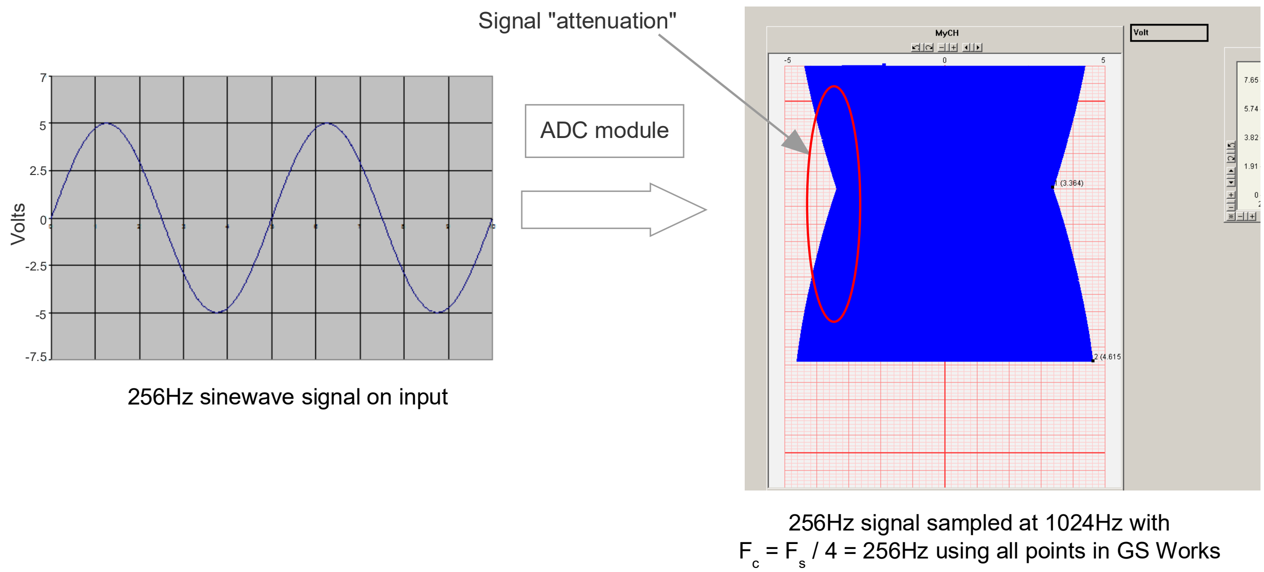



*Figure 52-5: Sample result for $F_{in}$ = $F_c$ using GS Works showing attenuation*

As seen in the GS Works 8 screen, the attenuation is not stable. However, this is a visual effect caused by $F_{in}$ not being in perfect synchronization with $F_s$. The signal generator/Acra KAM-500 clock varies slightly causing the maximum-minimum to vary, which explains this visual aspect.

---

**NOTE:** If $F_{in}$ × 4 is slightly off $F_s$, the sample points shift, and peak-peak voltage goes slowly down, and then up again. At $F_{in}$ ~ $0.5F_s$, you may see a DC signal response (when the samples are exactly at mid-point of your input sine wave amplitude).

Running an FFT on the resulting signal that's been sampled provides the correct amplitude with no attenuations seen.

## 52.3 Sampling: square wave visual effect

In theory, a square wave contains an infinite component of odd-integer harmonic frequencies.

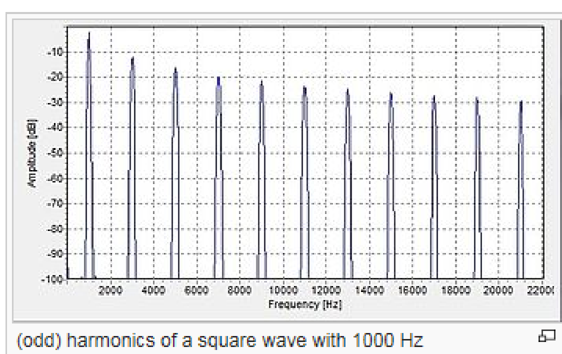
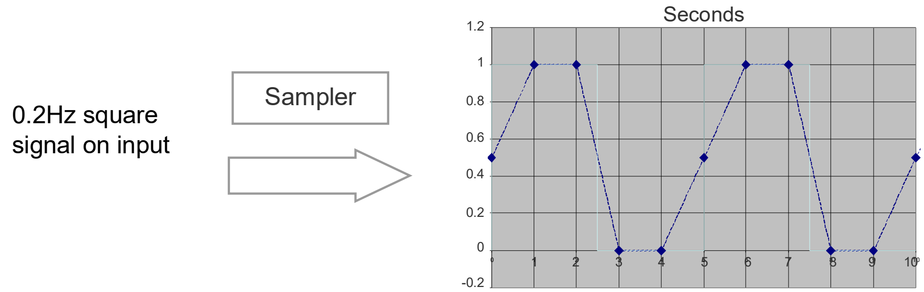



*Figure 52-6: Harmonics of a square wave*

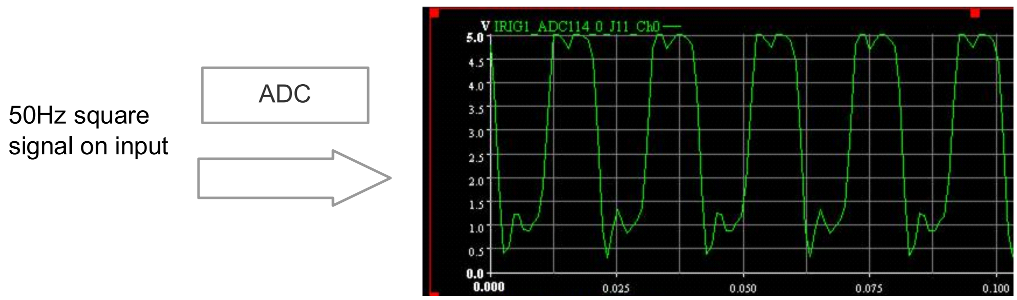
As shown in the following figure, sampling a square wave does not display a square wave visually; filtering is not performed before the sampling.




0.2Hz square wave signal sampled at 1Hz

*Figure 52-7: Sampling a square wave and displaying results with linear interpolation between points*

Because a square wave has infinite harmonics, and the Acra KAM-500 ADC module filters out the harmonic frequencies above $F_c$, the sampled result exhibits some overshoot/undershoot ringing effect (due to absence of the filtered harmonics) as shown in the following figure.




50Hz square wave signal sampled at 1024Hz

*Figure 52-8: Sampling a square wave using a KAM-500 ADC module*

If a period/frequency/pulse width measurement was the goal of sampling a square wave, an Acra discrete input (DSI) type module is more appropriate. Otherwise, it is recommended to sample the ADC module as fast as possible using the highest $F_c$ setting such as $F_c = 16F_s$. This type of setting attenuates the ringing affect further but may introduce unwanted affects such as aliasing.

## 52.4 Sampling: screen effect

When viewing plots containing a large number of sample points, the true nature of the waveform could be hidden, due to visual effects (Moiré effect) caused by the closely spaced lines. Re-scaling the plot to reduce the number of viewed sample points, reduces this visual effect and the true waveform becomes more apparent.

The following figures show how the Moiré effect can hide the true waveform being viewed.

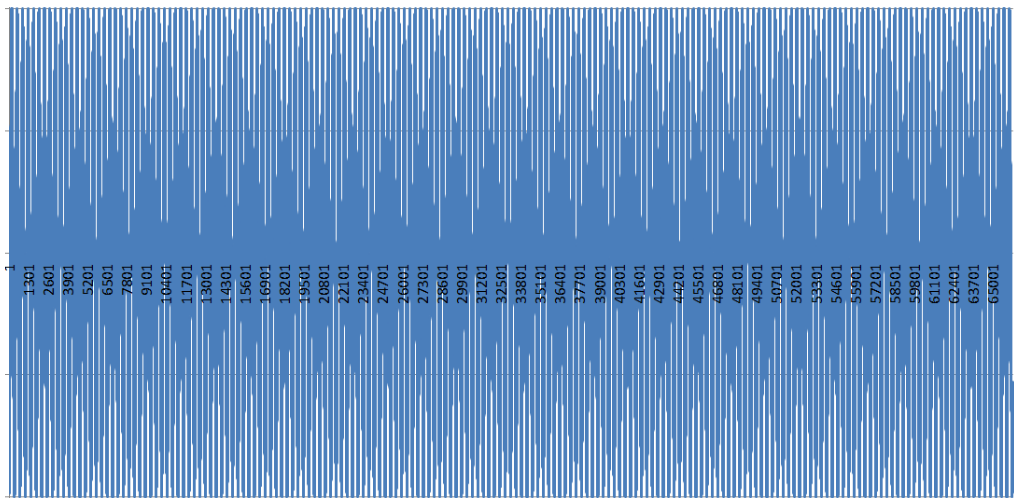



*Figure 52-9: Sine waves plotted in Excel – 65536 points and 360 periods*

The same sine wave rescaled to have less points shows the expected signal.

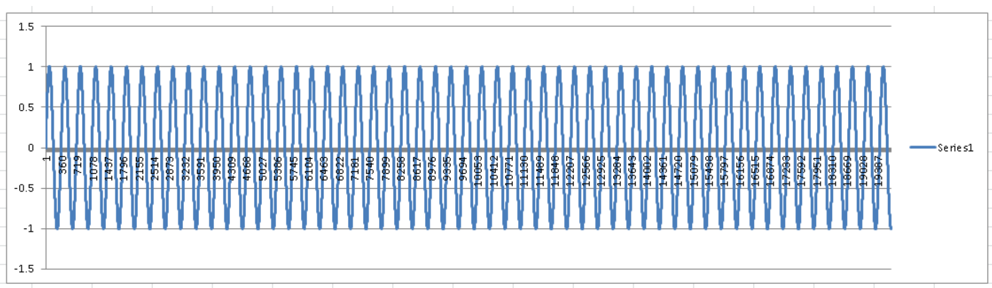



*Figure 52-10: Sine waves plotted in Excel – 20000 points*

In GS Works 8, this would be equivalent to clicking the resolution buttons mm/sec.


*Figure 52-11: GS Works 8 resolution buttons*

## 52.5 Sampling: signal reconstruction

The following figure shows two methods for reconstruction of an original signal (green line):

Rectangular - which extends the sample value across ± 0.5 of the time sample (pink line)

Linear - which joins each sample with a straight line (blue line)

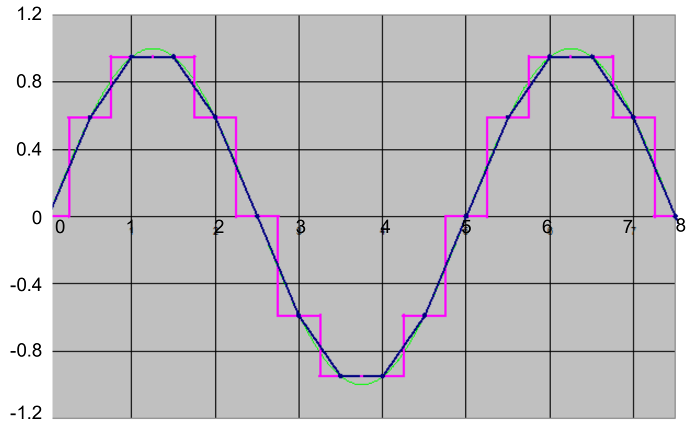
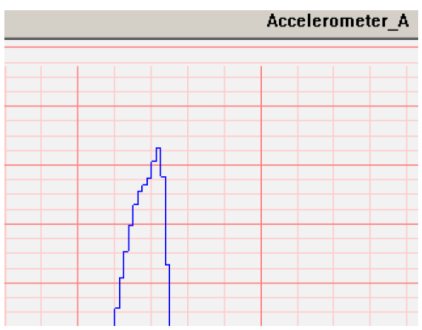


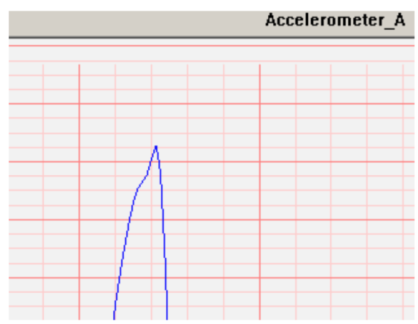

*Figure 52-12: Simple signal reconstruction*

These are simple methods that require almost no post-processing and they work well with any periodical and non-periodical signals.

The disadvantage is that they require a much higher sample rate than the maximum frequency of interest to visualize the original signal. For a linear reconstruction, they require at least 10 times higher $F_s$, while for a rectangular reconstruction at least 30 times higher $F_s$ is required.

**NOTE:** GS Works 8 has an option on the strip charts called Digital Draw Style**.** When enabled, it implements a digitized drawing style (rectangular reconstruction) instead of drawing a smooth curve between data points.




The effect of drawing digital (left) compared to smoothed drawing (right)

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Chapter 53

# Analog modules specifications explained

TEC/NOT/082

Curtiss-Wright provides a wide range of analog modules, which offer a number of features and functionality. A lot of feature-specific terminology is used in the data sheets of these modules. This technical note explains some of the less common terminology used.

The following terms are discussed:



## 53.1 DC error: primary gain vs. secondary gain

Primary or analog gain can be defined as the analog amplification factor or *true hardware gain*. It is integrated in some, but not all, instrumentation amplifiers used on Curtiss-Wright analog modules. Because the analog gain amplifies the input signal in order to use the full scale range of the Analog-to-Digital Converter (ADC), it does not decrease the performance of the analog module (except for gain of 1000).

Secondary or digital gain is purely a software artifact that increases the overall performance of the module.

All Curtiss-Wright analog modules incorporate programmable digital gain, however only some modules incorporate programmable analog gain. For example, a KAD/ADC/105 provides both programmable analog and programmable digital gain; whereas a KAD/ADC/112/10V provides fixed analog gain and programmable digital gain.

Both analog and digital gain are programmed by software.

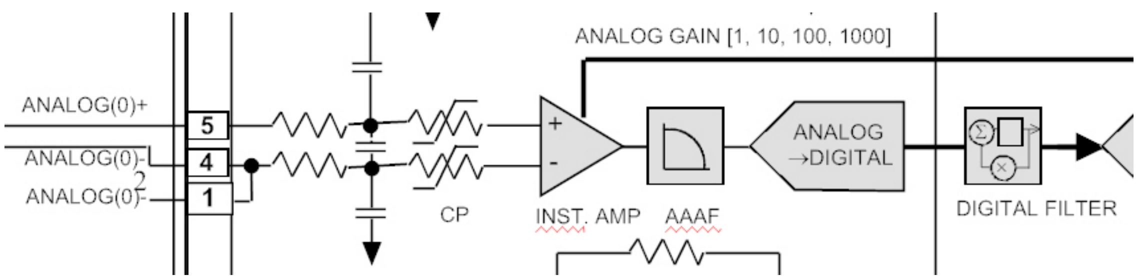



*Figure 53-1: KAD/ADC/109 analog signal gain*

The data sheet specifies the primary gains (analog gain) used on the module as shown in the following figure.

| Input voltage | | | | | |
|---|---|---|---|---|---|
| operating range ($G_p$ = 1) | -10 | – | 10 | V | Primary gain = 1 |
| operating range ($G_p$ = 10) | -1 | – | 1 | V | Primary gain = 10 |
| operating range ($G_p$ = 100) | -100 | – | 100 | mV | Primary gain = 100 |
| operating range ($G_p$ = 1000) | -10 | – | 10 | mV | Primary gain = 1000 |

*Figure 53-2: KAD/ADC/109 input voltage as defined in the data sheet*

The data sheet also specifies the DC error at different gains. These gains include the primary gain (analog gain) and the secondary gain (digital gain).

| DC error | | | | |
|---|---|---|---|---|
| gain = 1, 10, 100 | – | – | 0.08 | %FSR |
| gain = 2, 20, 200 | – | – | 0.14 | %FSR |
| gain = 4, 40, 400 | – | – | 0.25 | %FSR |
| gain = 8, 80, 800 | – | – | 0.44 | %FSR |
| gain = 1000 | – | – | 0.3 | %FSR |
| gain = 2000 | – | – | 0.6 | %FSR |
| gain = 4000 | – | – | 1.2 | %FSR |

*Figure 53-3: KAD/ADC/109 DC error specification as defined in the data sheet*

The gain stated in the data sheet is a combination of digital gain and analog gain; analog gains are: 1, 10, 100, and 1000. For example, a gain of 400 is composed of an analog gain of 100 and a digital gain of 4.

Curtiss-Wright recommends using a digital gain up to the maximum gain stated in the DC error specifications.

That is, for the above example, up to a digital gain of 8 for primary gain of 1, 10 and 100 and up to 4 for primary gain of 1000.

The KAD/ADC/109 can operate up to a digital gain of 16, for example, when only transmitting or analyzing the 12 most significant bits. However, at such a gain, the performance of the card is greatly decreased.

The digital gain is implemented by the FPGA on the module. Using a digital camera as an example: think of the camera's optical zoom as the primary gain (analog gain) on the module; while the camera's digital zoom is the secondary gain (digital gain) on the module.

As shown in the previous figure, the DC error stated on the KAD/ADC/109 does not linearly increase with digital gain.

If this was purely a software zoom, you would expect the DC error to be 8 times more when using a digital gain of 8, that is, 0.64%, whereas in fact it's 0.44%.

The digital gain is therefore not purely a software zoom because the module incorporates performance boosting techniques such as oversampling and decimation together with digital filtering that allows for more accurate signal digital processing.

Digital gain helps to increase the accuracy of DC signals but not AC signals. In other words, digital gain does not degrade or have any effect on AC signals, however too much digital gain can degrade DC signals due to offset errors.

A gain of 1,000 decreases the performance because it acts like a *natural* first order, low pass gain. An instrumentation amplifier with a bandwidth of 1 Mhz and a gain of 1000, effectively has a bandwidth with a cutoff frequency of 1,000 MHz. This is common to all operational amplifiers.

Newer modules such as the KAD/ADC/136 have more primary gains, which occur from 1 to 256 in steps to the power of 2. This increased decimation between primary gains means the KAD/ADC/136 is more accurate.

For Gp = 32, the range is ±10 / 32 so ±0.3125 so 0.08 / 100 × (2 × 0.3125) = 0.5 mV max error.

For a KAD/ADC/109, using a range of ±0.3125, the primary gain is 10 and the digital gain is 3.2 so considering the maximum DC error is 0.14% for a gain of 2, and 0.25% for a gain of 4, maximum DC error for a digital gain of 3.2 can be approximately averaged using a first order linear interpolation as follows:

((3.2 × 0.14 / 2) + (3.2 × 0.25 / 4)) / 2 = 0.21% so 0.21 / 100 × (2 × 0.3125) = 1.31 mV max error

**Example of digital gain calculation for KAD/ADC/109**

The primary gain is the sum of the operating range and the digital gain; it is calculated as follows:

(MaxOperatingRangeInput- MinOperatingRangeInput) / (MaxV-MinV)

The overall gain of a KAD/ADC/109 channel with min = -1.1V and max = 1.1V can be calculated as shown below:

Overall gain = analog gain × digital gain

Analog gain = 1 because the range of ±1.1V belongs to ±10V analog input range

Digital gain = (10- (-10)) / (1.1- (-1.1)) = 20 / 2.2 = 9.091

**Example of digital gain calculation for KAD/ADC/135**

For the gains, the same equation as the KAD/ADC/109 applies:

Overall gain = analog gain × digital gain

The overall gain of a KAD/ADC/135 channel with min = -195mV and max = 195mV can be calculated as shown below:

Analog gain = 8 because the range of ±195 mV belongs to ±312.5 mV analog input range

Digital gain = (312.5- (-312.5)) / (195- (-195)) = 1.6

For high primary gain that is, less than 8, the rule is approximately:

If the digital gain is 2, multiply the analog gain DC error by 1.75

If the digital gain is 4, multiply the analog gain DC error by 3.125

If the digital gain is 8, multiply the analog gain DC error by 5.5

So the overall max error for ±195 mV is approx. 1.75 × 0.06 = 0.1% (assuming that a 0.06% error is the maximum DC error for an analog gain [Gp] of 8)

## 53.2 Common-Mode Rejection Ratio (CMRR)

The CMRR of a differential amplifier is a metric used to quantify the ability of the device to reject common-mode signals, that is, signals that appear simultaneously and in-phase on both inputs.

A high CMRR is required when a differential signal must be amplified in the presence of a possibly large common-mode input, such as strong electromagnetic interference (EMI).

The CMRR is calculated as CMRR = 20Log(Acm / Ameas) where Acm is the specified CMRR voltage range and Ameas is the measured amplitude in volts.

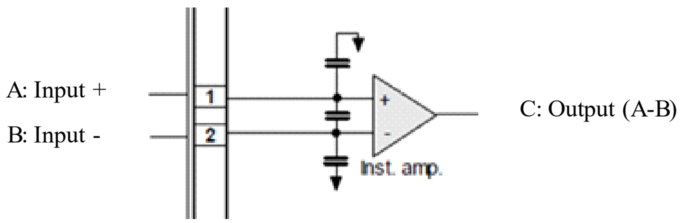



*Figure 53-4: Instrumentation Amplifier with Input± and output*

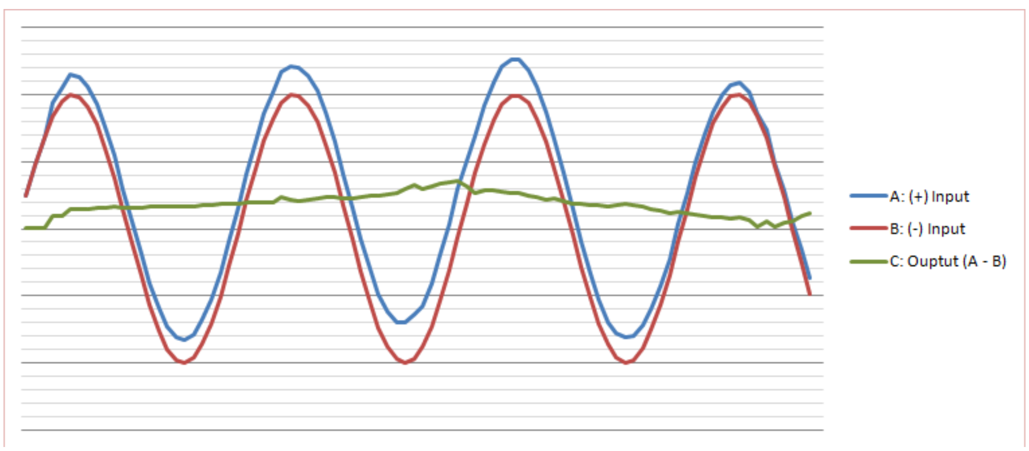



*Figure 53-5: Input+ and Input- not in-phase signal and output result showing a poor CMRR*

## 53.3 Effective Number of Bits (ENOB)

Effective Number Of Bits (ENOB) is a specification that helps to quantify dynamic performance.

ENOB states that a converter performs as though it were a theoretically perfect converter with a resolution of ENOB. The ideal (perfect) ADC has absolutely no distortion and the only noise it exhibits is quantization noise.

No instrument is ideal, so performance specifications show how close a device is to ideal. ENOB is calculated directly from SINAD using values for ideal ADC noise and spurs as shown in the following formula. This calculation shows how close to an ideal instrument the device is performing.

**NOTE:** In the following formula, SINAD is in dB and ENOB is in bits; otherwise the formula would not be valid.

ENOB [bits] = (SINAD [dB]-1.76) / 6.02

SINAD, also known as THD plus noise (THD + N), is the ratio of the RMS signal amplitude to the RMS sum of all other spectral components. All other spectral components include the harmonics but exclude DC. The most useful approximation of SINAD is the power of the fundamental signal frequency, plus the power of device spurs, plus the power of noise, divided by the power of noise, plus the power of distortion.

$$SINAD[dB] = 10Log_{10}\frac{Power_{Signal} + Power_{Noise} + Power_{Distortion}}{Power_{Noise} + Power_{Distortion}}$$

For the DC error, the results of the two sine waves in the following figure are very similar, however, the AC result is not the same; ENOB measures this distortion.

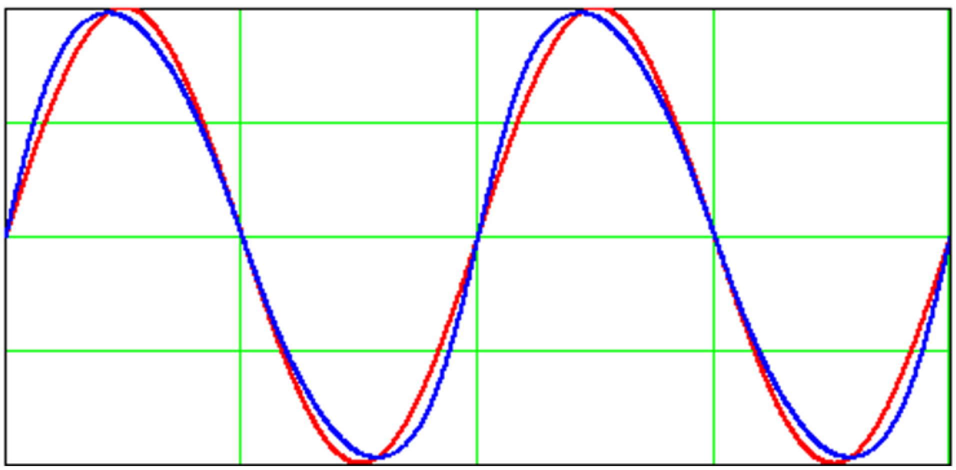


*Figure 53-6: Comparison distorted sine (red) and undistorted sine (blue)*

## 53.4 Crosstalk

Crosstalk has the potential to increase uncorrelated noise in ADCs, reducing signal-to-noise-ratio (SNR). Cross-coupled signals can create spurs (fraction of the coupled signal added on top of the considered channel), reducing spurious free dynamic range (SFDR).

Crosstalk can be expressed in dB as follows: 20 Log ($V_{ppin}$ / $V_{ppmeas}$), where $V_{ppmeas}$ is the amplitude of the signal measured by the channel under normal conditions (desired signal + crosstalk) and where $V_{ppin}$ is the amplitude when the input of the channel is grounded (crosstalk alone).

## 53.5 Common mode range

The common mode range is the operational voltage range. For example, if the common mode voltage is ±10V, you cannot measure a signal from 27.5V to 28.5V even though the signal range of interest is only 1V. The common mode voltage of Curtiss-Wright modules is driven by the instrumentation amplifier voltage, which usually comes from the ±12V of the backplane.

## 53.6 Conclusion

DC error specification is important but it is not enough to select a device which is required to measure an AC signal. CMRR value for a differential device determines the level of noise which can be eliminated. ENOB value determines the level of distortion of the result.

**NOTE:** All specifications in Curtiss-Wright data sheets are valid within the operating temperature range (usually -40°C to 85°C) specified under “Environmental ratings” in the “General specifications” table of the respective data sheet.

Chapter 54

# Using the KAM/MEM/113

TEC/NOT/083

The KAM/MEM/113 is a CompactFlash® memory module that records parameters from the Acra KAM-500 backplane in a PCAP format using either IENA and/or iNET-X packets.

This paper discusses the following topics:

## 54.1 Setting up the KAM/MEM/113 using DAS Studio 3



This section explains how to set up the KAM/MEM/113 using DAS Studio 3. For the example screens shown, you need to add a chassis, controller module, a KAM/TCG/105, and a KAM/MEM/113 module to the configuration. For information on adding modules, see the *DAS Studio 3 User Manual*.

### 54.1.1 Parameters

To see available parameters in the KAM/MEM/113 module, select the module in the Navigator and then click the Settings tab.

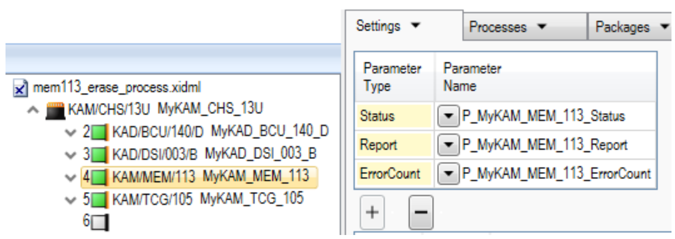



*Figure 54-1: Parameters available in the KAM/MEM/113*

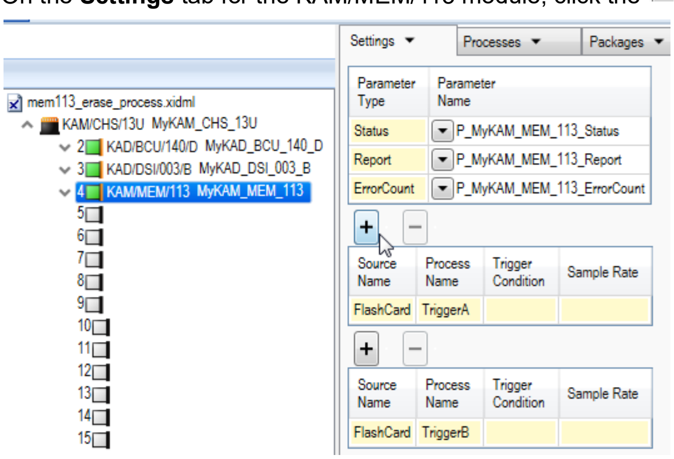
Only the Report parameter can be recorded in KAM/MEM/113 packets. For information on the Status and Report parameters, see “54.5.8 Status and Report parameters” on page 502.

For details on the ErrorCount parameter, refer to the *KAM/MEM/113* data sheet.

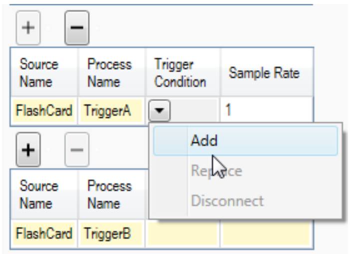
### 54.1.2 Triggers

Triggers from any available 16-bit parameters on the backplane can be used to trigger recording on the KAM/MEM/113. The following example shows how to trigger the KAM/MEM113 when a KAM/TCG/105 module has GPS lock.

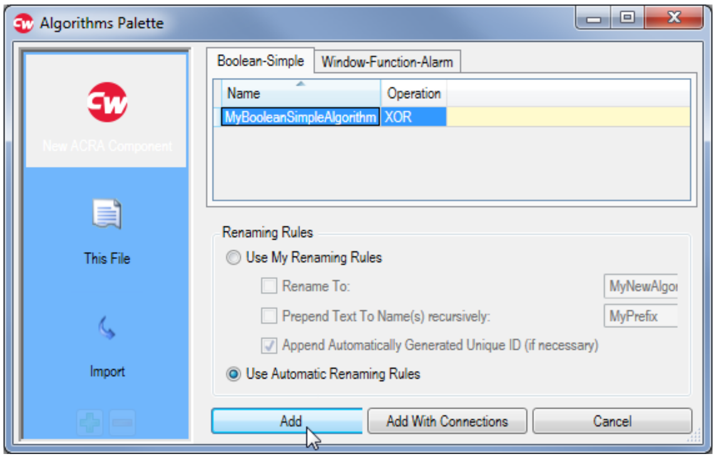
1. On the **Settings** tab for the KAM/MEM/113 module, click the + icon to add a process.



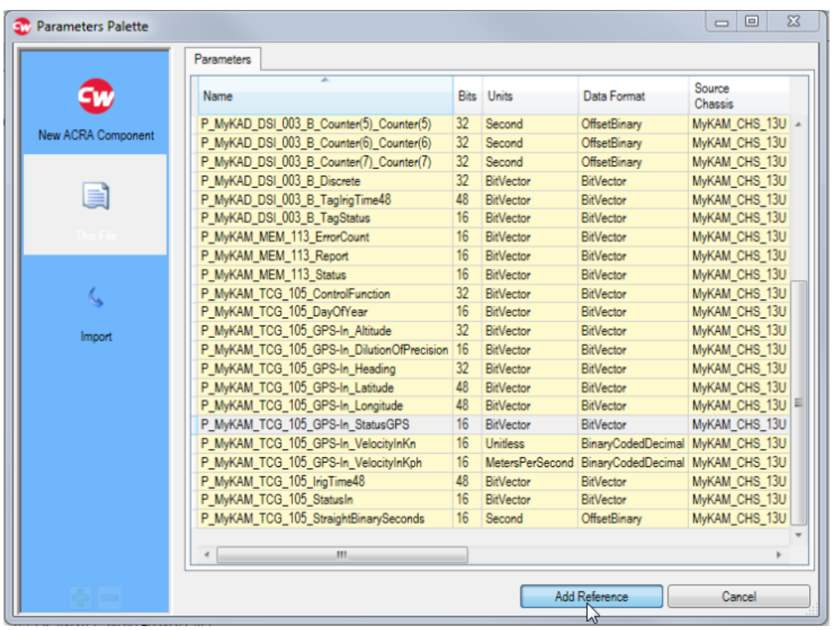
2. In the **Trigger Condition** field, click the drop-down arrow and then click **Add**.



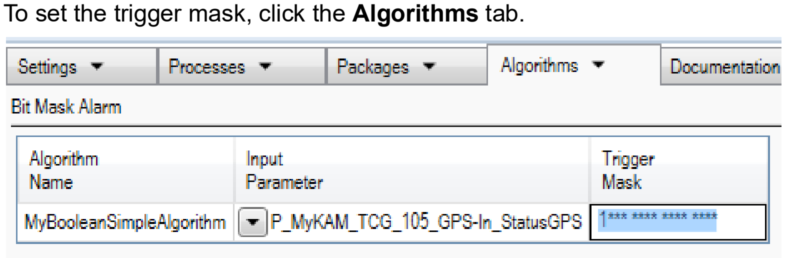

3. In The **Algorithms Palette**, select **MyBooleanSimpleAlgorithm** and then click **Add**.



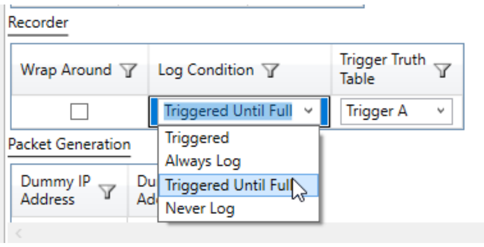

The **Parameters Palette** opens.



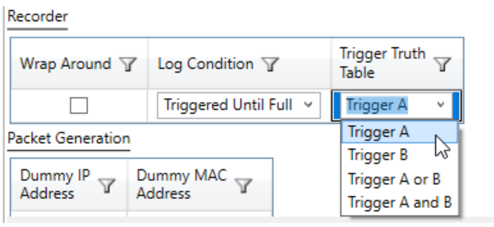

4. Click **This File**, then select **TCG_105_GPS-In_StatusGPS** and then click **Add Reference**.
5. To set the trigger mask, click the **Algorithms** tab.



6. In the **Trigger Mask** field, type 1*** **** **** ****.
   This mask ignores all other bits except bit 15 and triggers (via GPS status lock) when bit 15 is 1.
7. Under **Log Condition**, click the drop-down arrow and then select **Triggered Until Full**.




8. Under **Trigger Truth Table**, click the drop-down arrow and then select **Trigger A**.




**NOTE:** If **Log Condition** is **Triggered**, recording stops as soon as the trigger condition is removed.
For example, the trigger is bit 15 when 1 on parameter P1, recording starts when bit 15 is 1 on P1; recording stops when bit 15 is 0.

For more information, refer to the “Algorithms tab” chapter in the *DAS Studio 3 User Manual*.

### 54.1.3 Other settings

Refer to the *KAM/MEM/113* data sheet for a description of the fields in the following figure.

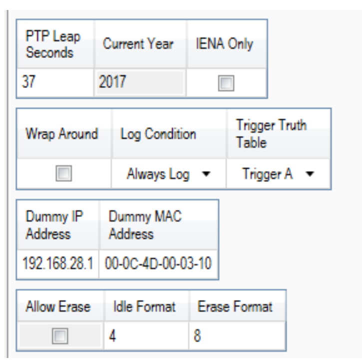


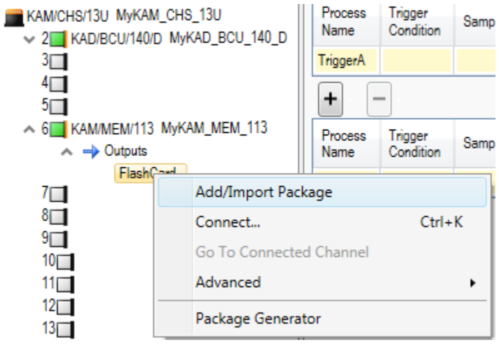

*Figure 54-2: Other settings*

For the Erase/Format fields at the bottom of the screen, refer to “54.4.1 Format a CF card using the erase format from the KAM/KAM/MEM/113” on page 494.

## 54.1.4 Adding packets to the KAM/MEM/113

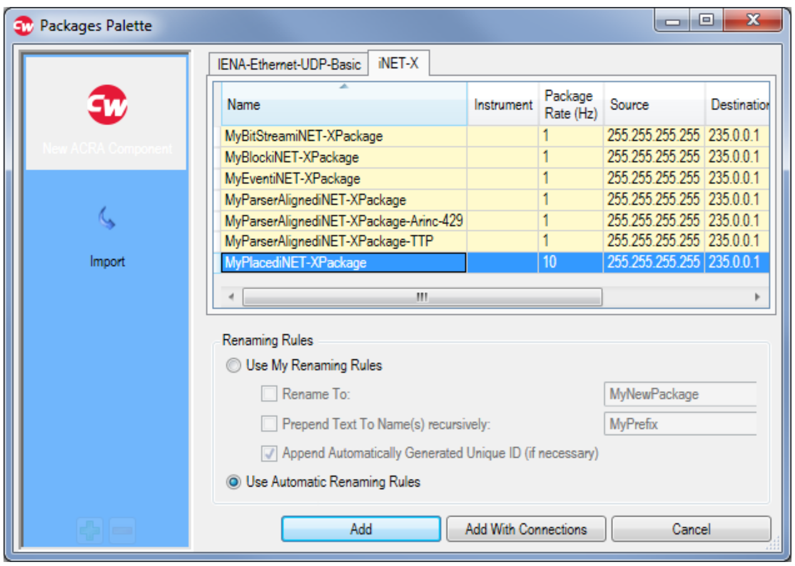
Just as with an Ethernet transmitter, you can define which packets are logged to the KAM/MEM/113. Refer to the following.

1. In the **Navigator**, click the **KAM/MEM/13** and then click the **Outputs** node to expand it.
2. Right-click the **Flashcard** output and then select **Add/Import Package**.

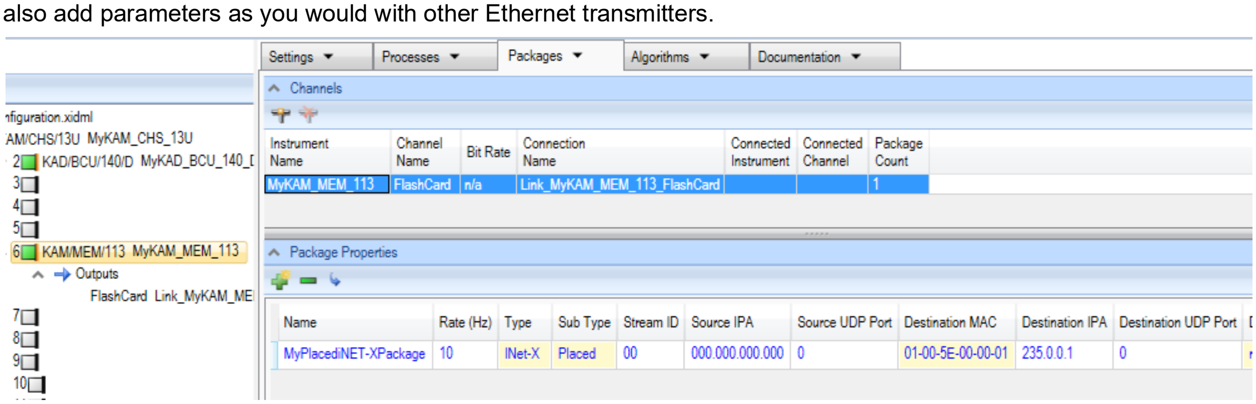



**Packages Palette** opens.

3. On the **iNET-X** tab, select a package such as **MyPlacediNET-XPackage** (this is a transmission package, and is empty by default), and then click **Add**.




On the **Packages** tab you can define the Package Name, Stream ID, Destination IPA and Destination UDP Port. You can also add parameters as you would with other Ethernet transmitters.




For further information, refer to the “Packages tab” chapter in the *DAS Studio 3 User Manual*.

## 54.2 Setting up the KAM/KAM/MEM/113 using KSM-500

This section explains how to set up the KAM/MEM/113 using KSM-500.

### 54.2.1 Parameters tab

Refer to the *KAM/MEM/113* data sheet for descriptions of the bit settings of the parameters shown in the following figure. In KSM-500, all these parameters can be recorded into KAM/MEM/113 packets.

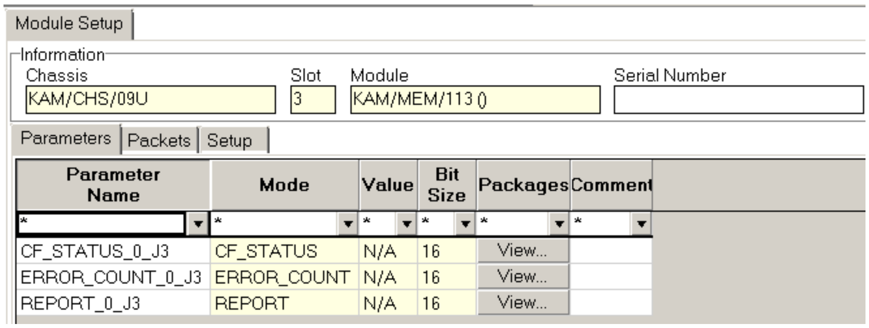



*Figure 54-3: Parameters tab*

**NOTE:** CF_STATUS is referred to as STATUS in the *KAM/MEM/113* data sheet.

### 54.2.2 Setup tab

The following screen shows setup options for the module.

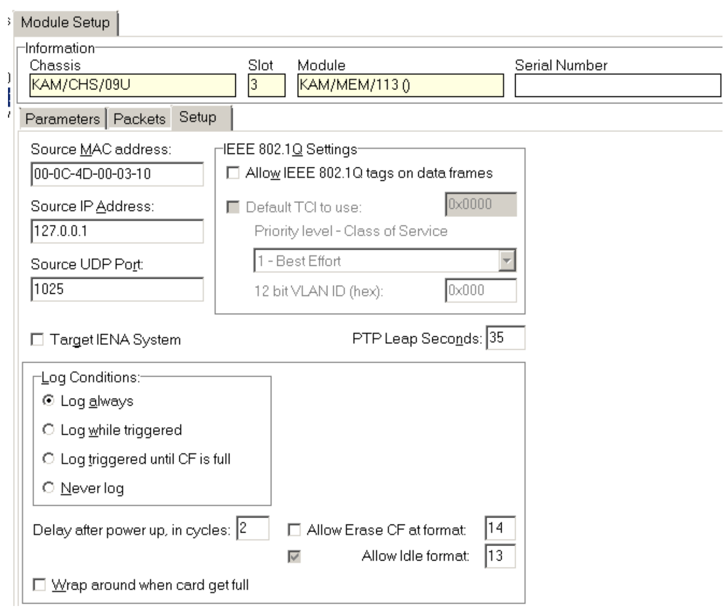



*Figure 54-4: Setup tab*

*IEEE 802 Q* tags are specific Ethernet fields, which can be added to Ethernet packets. For more information, contact Curtiss-Wright support (acra-support@curtisswright.com).

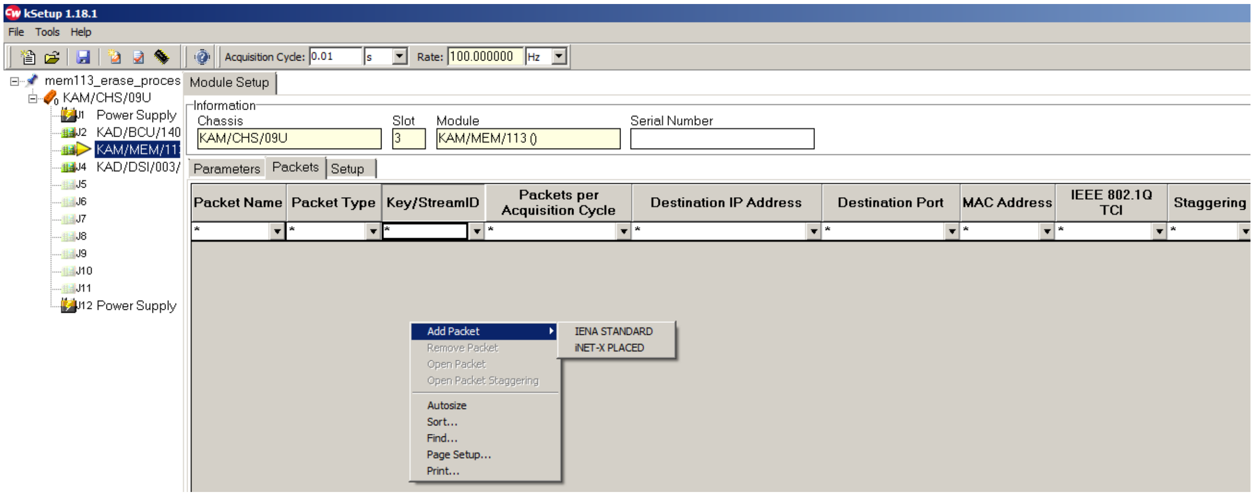
*Delay after power up in cycles* means that the KAM/MEM/113 does not record, even if triggered, for the amount of acquisition cycles specified.

The other fields are explained in the *KAM/MEM/113* data sheet.

## 54.3 Building packets

This user interface is the same as for other Ethernet transmitters in KSM-500. To add a packet.

1. Click the **Packets** tab.
2. Right-click the **Packets** pane, click **Add Packet**, and then click **IENA STANDARD** or **iNET-X PLACED**.




As the procedure for adding parameters is the same for both IENA and iNET-X placed packages, you can refer to the "Adding IENA packets" section in *TEC/NOT/053 - Using the KAD/BCU/105* for more information.

**NOTE:** If there is a packetizer module in the chassis, such as a KAD/ABM/103, packetizer packet types can be added.

## 54.4 Formatting the CompactFlash card to be used on the KAM/KAM/MEM/113

Each CompactFlash (CF) card must first be formatted before it can be used in the KAM/KAM/MEM/113. One of the following methods can be used for formatting:

- Format a card using an SSR/CHS/001/B (see the *Multi-role Recorder's User Guide*).
- Format a card using the erase format on the KAM/MEM/113.
- Format a card using a software utility (ssrformat) to format the CF card on a PC. Note, this software utility can only be used if the card has already been formatted using one of the above two methods.

### 54.4.1 Format a CF card using the erase format from the KAM/KAM/MEM/113

Formatting the CF card creates pre-allocated empty files for storing recordings in a flat directory structure. The purpose of formatting the CF card is to allow the KAM/MEM/113 to record in contiguous locations on the CF card and to ensure that no other files are stored or created on the CF card.

The KAM/MEM/113 can be configured to enable erase and the user can select the format number.

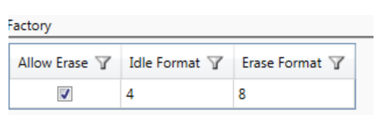



*Figure 54-5: DAS Studio 3 example of Allow Erase and Erase Format*

The erase/idle format number has to be used in conjunction with the Backplane Controller Unit (BCU). The BCU must support format select (such as on a KAD/BCU/101) or Shunt Mode (such as a KAD/BCU/140/C and subsequent revisions).

The KAD/BCU/101 format support has to be selected through the physical pins on the module (refer to the *KAD/BCU/101* data sheet for further information). If Allow Erase is enabled and Erase Format is set to 8, providing 5V (BVDD) to the Format(3) pin starts the erase format process of the KAM/MEM/113.

The KAD/BCU/140/C (and subsequent revisions) can initiate the erase format on the KAM/MEM/113 by sending an event packet from a PC to the BCU. Contact Curtiss-Wright support (acra-support@curtisswright.com) to request the *TSD-AC-021* support document. This support document contains a python script that sends this event packet from PC to BCU.

The KAD/BCU/140/C (and subsequent revisions) can also initiate the erase format on the KAM/MEM/113 by sinking a parameter (such as the Discrete parameter of a DSI module) with the value of the erase format into the shunt process of the BCU.

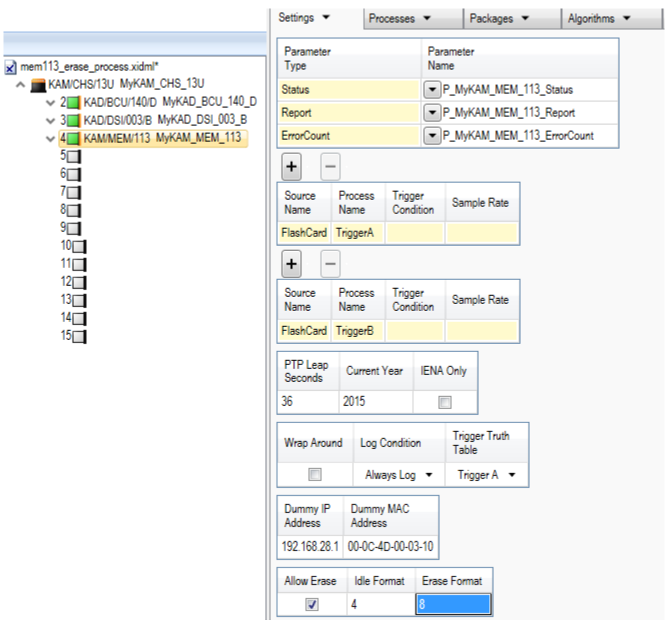
---

**NOTE:** We don't recommend using KSM-500 to format a CF card. A CF card cannot be formatted on a KAM/MEM/113 when using a KAD/BCU/105 module. This is because the KAD/BCU/105 module does not support format switching or Shunt Mode.

### 54.4.2 Formatting a CF card on a KAM/MEM/113 in DAS Studio 3

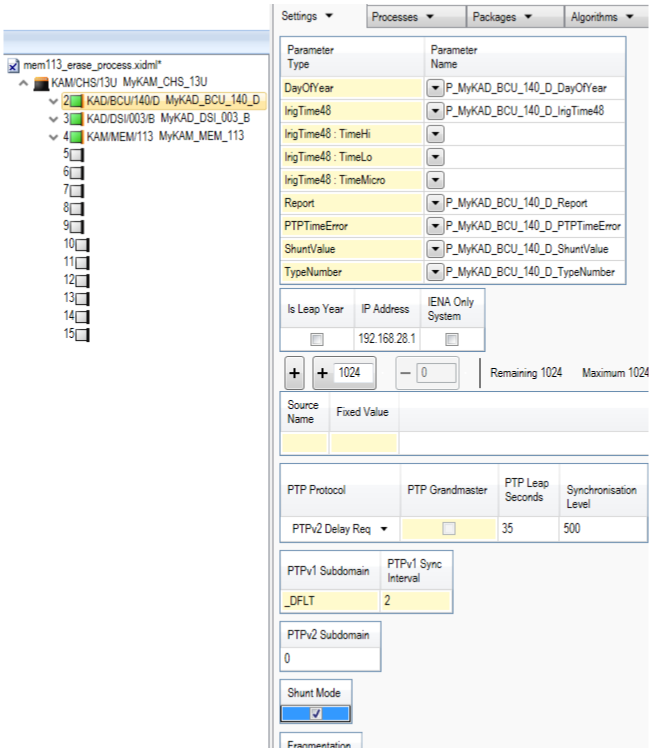
For this format procedure, do not use a XidML® file from a current program (example, **flight-test.configuration**), as doing so may introduce unwanted settings from the format procedure below to your **flight-test.configuration**. Instead you must create a new XidML configuration file.

1. Create a new XidML configuration file and then add a chassis, a KAD/BCU/140/C (/C or subsequent revision), a KAD/DSI/003/B, and a KAM/MEM/113 module.
2. Go to the **Settings** tab of the KAM/MEM/113.
3. Select the **Allow Erase** check box and set **Erase Format** to **8**.

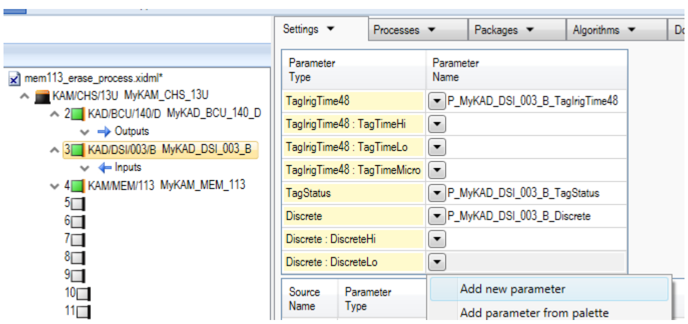



4. Go to the **Settings** tab of the KAD/BCU/140/D.

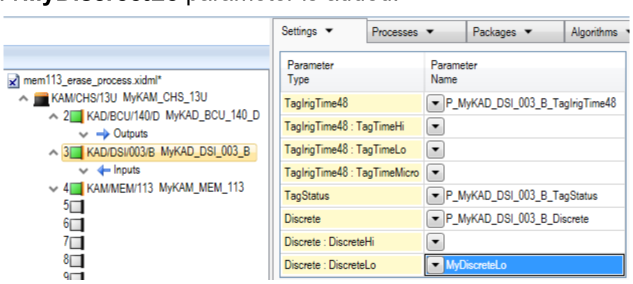
5. Select the **Shunt Mode** check box.



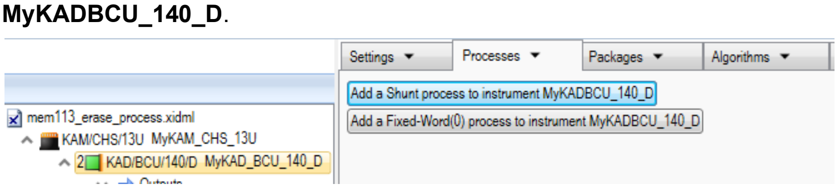

6. Go to the **Settings** tab of the KAD/DSI/003/B.



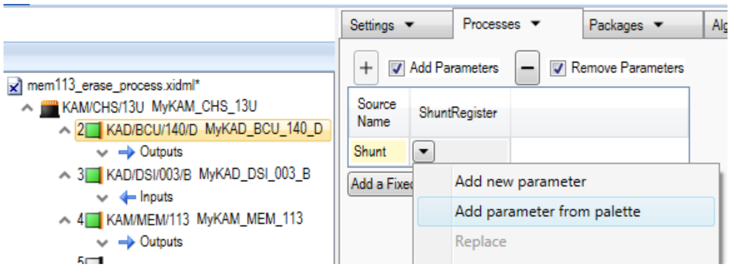

7. In the **Discrete : DiscreteLo** row, click the drop-down menu and then click **Add new parameter**.
A **MyDiscreetLo** parameter is added.



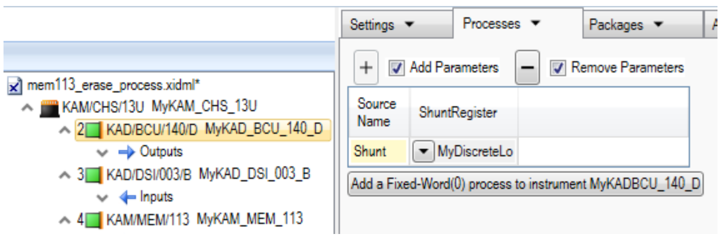

8. Go to the **Processes** tab of the KAD/BCU/140/D and then click **Add a Shunt process to instrument MyKADBCU_140_D**.



9. Click the **ShuntRegister** drop-down menu and then click **Add parameter from palette**.




10. In the **Parameters Palette**, click the **This File** library.
11. Click the **MyDiscreteLo** parameter and then click **Add Reference**.
    The MyDiscreteLo parameter from the KAD/DSI/003/B is sunk into the shunt register on the **Process** tab.



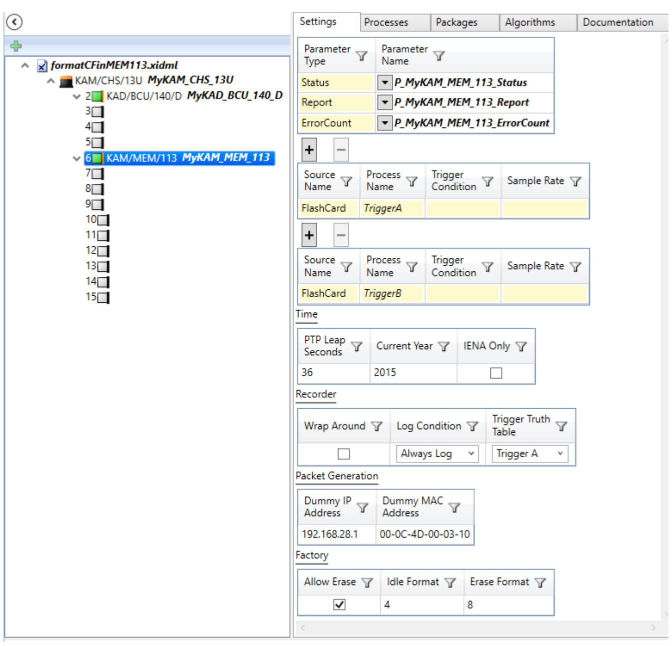

12. Apply a voltage above the threshold defined in the KAD/DSI/003/B Discrete(3) and a voltage below the threshold defined in the KAD/DSI/003/B Discrete(0), Discrete(1) and Discrete(2), to get 1000 in binary, which is 8 in decimal into the Status_15_0 parameter.
    The erase format on the KAM/MEM/113 starts.

When formatting is done, you can close this configuration file and continue programming using your own system configuration files.

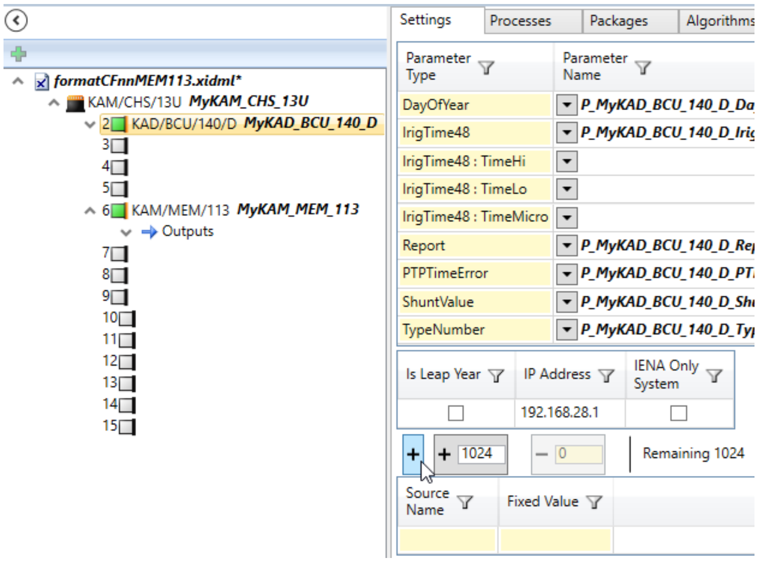
## 54.4.3 Formatting a CF card on a KAM/MEM/113 using fixed data in DAS Studio 3

For this format procedure, do not use a XidML file from a current program (example, **flight-test.configuration**), as doing so may introduce unwanted settings from the format procedure below to your **flight-test.configuration**. Instead you must create a new XidML configuration file.

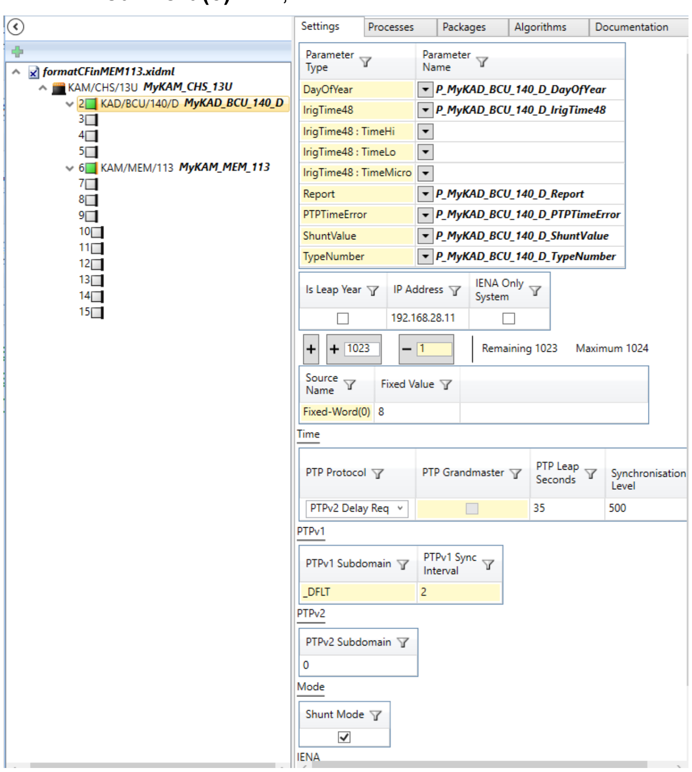
1. Create a new XidML configuration file and then add a chassis, a KAD/BCU/140/C (/C or subsequent revision), and a KAM/MEM/113 module.
2. Go to the **Settings** tab of the KAM/MEM/113.
3. Select the **Allow Erase** check box and set **Erase Format** to **8**.



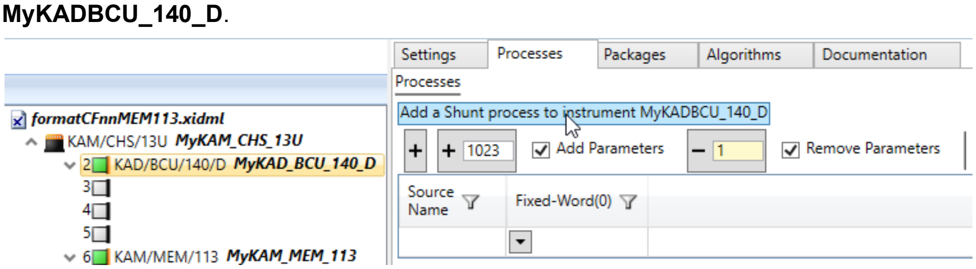
4. Go to the **Settings** tab of the KAD/BCU/140/D.



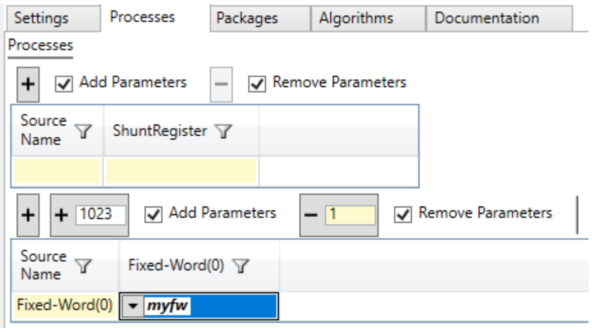

5. Click **+** (Adds a single process).
   A **Fixed-Word(0)** is added to the **Source Name** field.
6. At the **Fixed-Word(0)** field, add a fixed data with a fixed value of **8** and then select the **Shunt Mode** check box.



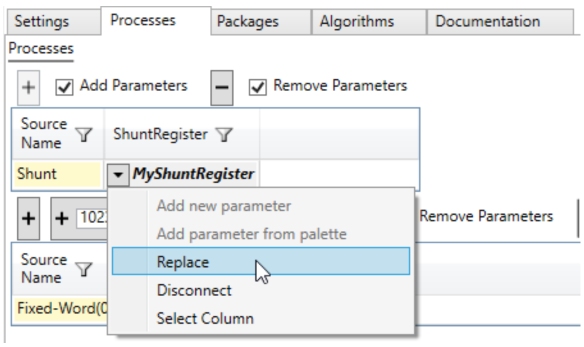

7. Go to the **Processes** tab of the KAD/BCU/140/D and then click **Add a Shunt process to instrument MyKADBCU_140_D**.



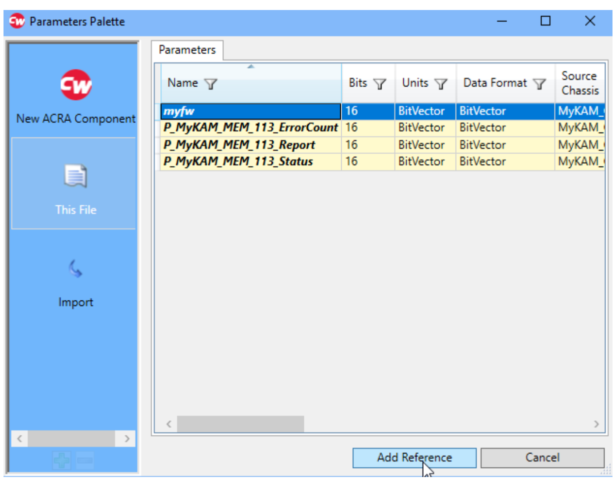
8. Click **+ Fixed-Word(0)** and rename to **myfw**.



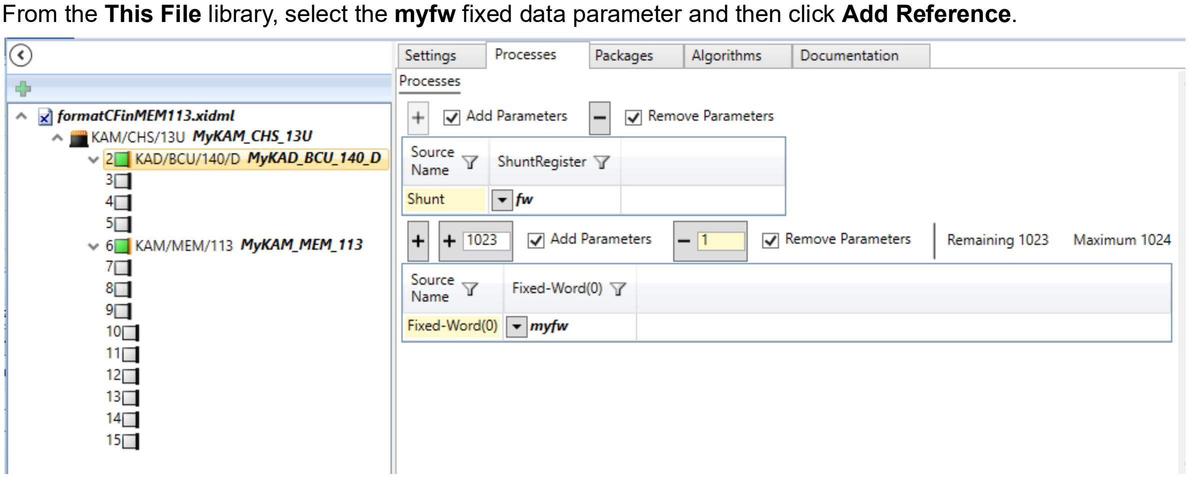

9. Click **+ Processes**.
   A shuntregister is added.




10. Click the drop-down arrow and then click **Replace**.




11. From the **This File** library, select the **myfw** fixed data parameter and then click **Add Reference**.



12. Program the system and monitor the KAM/MEM/113 status word. You should see bit 2 (formatting) at 1 and the bit[15:8] incrementing.

    **NOTE:** It should take only few minutes to format a 32-GB CF card. When formatting is done, bit 2 should go to 0 indicating the system is ready for programming.

When formatting is done, you can close this configuration file and continue programming using your own system configuration files.

### 54.4.4 Formatting a CF card using a software utility (ssrformat) on a PC

SSRformat.exe (AcraCD_SWS-FMT-001-01, version 1.1.0.2) supports the file system used on the KAM/MEM/113.

Use the below command line:

ssrformat.exe -2 -n <Drive Letter>

where:

-2 = the file system to use.

-n = no trim (trim only applies to SSD disks)

<Drive Letter> (optional) drive letter for the CF card which is plugged into the CF card reader connected to the PC. In this example, the drive letter is H.

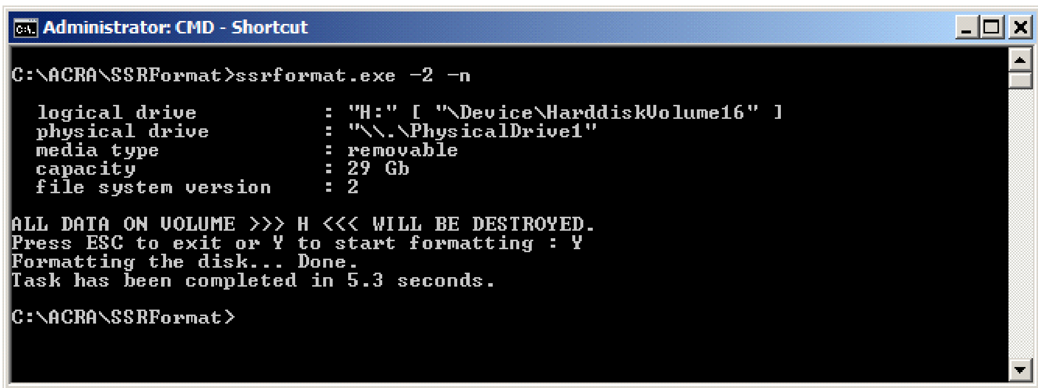



*Figure 54-6: Example of ssrformat result run successfully with CF card on drive H*

**NOTE:** When the drive letter is added to the command line of ssrformat, the formatting process for a 32-GB CF card should take a few seconds; ssrformat does not provide information to indicate successful formatting of the card.

The following screen shows the ssrformat result if the CF card was not previously formatted on either an SSR/CHS/001/B or a KAM/MEM/113. If the drive letter is displayed in the command line, nothing is reported. However, if the drive letter is not displayed in the command line, ssrformat scans all devices connected to the computer. If the CF card is not attached to the computer—or the CF card was not pre-formatted for use in the KAM/MEM/113—ssrformat returns a *cannot find any disk suitable for formatting* message.

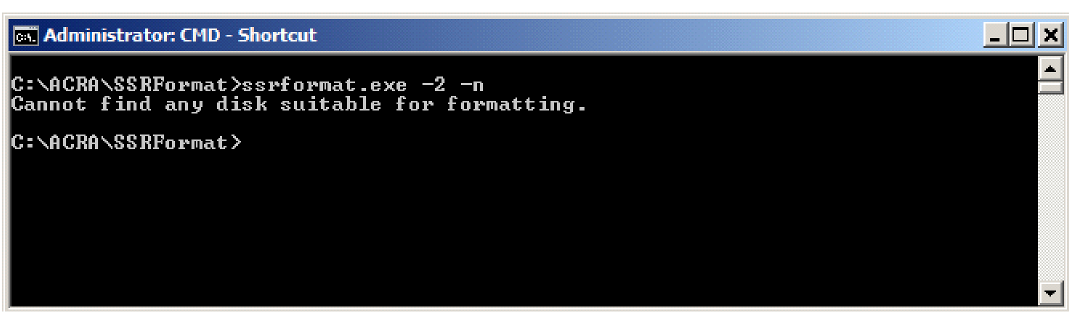



*Figure 54-7: Example of ssrformat result if CF card not previously formatted on SSR/CHS/001/B or KAM/MEM/113*

## 54.5 Troubleshooting and tips

### 54.5.1 Hot plug

Hot plug is supported. However, unplugging while recording on the KAM/MEM/113 can cause the last PCAP file to be corrupted.

### 54.5.2 Power loss or power off during recording

The KAM/KAM/MEM/113 has a capacitor bank that finishes writing PCAP files during a power out. However, the last PCAP file may be corrupted, which may cause new and old data to be mixed (this is due to the module not having enough time to update the FAT).

By comparing file dates you can determine old data, which can then be discarded. You can also use the SSRFormatEmpty utility to erase all data from the CF card. Contact Curtiss-Wright support (acra-support@curtisswright.com) to obtain this utility.

### 54.5.3 Always log

Always log is supported, however the first few PCAP files may be corrupted.

---

**NOTE:** In DAS Studio 3, the KAM/MEM/113 is configured to start recording after 10 acquisition cycles.

### 54.5.4 How to fix a corrupted PCAP file

GS Works 9/IADS RT Station has the capability to read corrupted PCAP files.

If you open a corrupt PCAP file in Wireshark, the following screen is shown.

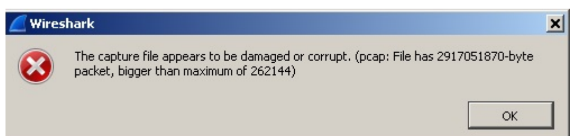



*Figure 54-8: Example of a corrupted PCAP file loaded in Wireshark*

Click **OK** and then use **Save As** to repair the file.

---

**NOTE:** Some versions of Wireshark (including v 1.12) cannot repair the file using **Save As**. Instead you must use **Export specified packets** on the **File** menu.

### 54.5.5 PCAP file size

Regardless of the size of the CF card, the maximum PCAP file size is 32 MB when formatted with a KAM/MEM/113 and 156 MB when formatted using ssrformat.. This is hard-coded into the FPGA and is not configurable.

### 54.5.6 PCAP file name

As shown in the following figure, recorded data can be read directly from the CF card on a PC with any off-the-shelf card reader.

---

**NOTE:** If the CF card folder is empty but you know the card has been formatted on the KAM/MEM/113, then most likely the PCAP files are hidden. See Windows Help for how to show hidden files.

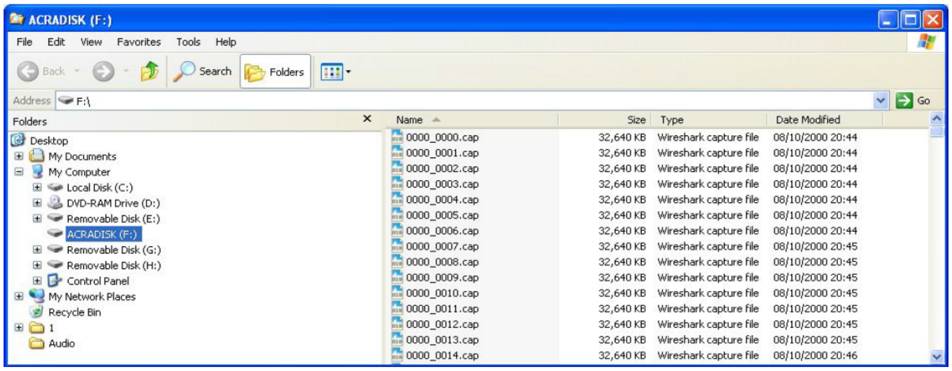



*Figure 54-9: CF card viewed in Windows explorer*

Each filename is automatically generated by the KAM/MEM/113 during the formatting process.

Filenames have the generalized format <DATA_sss_fff.cap> where:

- ssss: is a session number (0-9999). This number increments when the KAM/MEM/113 starts using the CF card, that is, when the CF card is mounted in the KAM/MEM/113. The CF card is mounted when it is inserted in the KAM/MEM/113 or after a power-cycle.
- ffff: is a file number (0-9999). This number resets to zero on the start of a new session, that is, if 0011_0006.cap is the last file in a session, the next file is 0012_0000.cap

## 54.5.7 PCAP structure

For information on how data is stored in PCAP files, see *TEC/NOT/051 - Ethernet frames, Wireshark® and FAT32*.

## 54.5.8 Status and Report parameters

These parameters are important to monitor. Status indicates if the CF card is logging, how full the CF card is, if the CF card is valid, and if the CF card is present. The Report parameter indicates when events or errors occur.

## 54.5.9 CF card type supported

DRE/CFM/007/32GB is the only CF card which has been design verified at the time of writing. This CF card has been tested successfully at 2 megasamples per second, that is, 32 megabits per second at 85 degrees.

## 54.5.10 PCAP replay

GS Works/IADS RT Station can replay PCAP files recorded in the KAM/MEM/113, however, you must only select packets in the XidML file that were recorded in the KAM/MEM/113. Packets from other modules (such as Ethernet) that may be in the XidML file must not be selected.

PCAP files must be copied from the CF card to the PC for viewing. If you open a PCAP file directly from the CF card, Wireshark may write to the CF card and render it invalid for use with the KAM/MEM/113. If this occurs, you need to reformat the CF card before use in the KAD/MEM/113.

Alternatively, the Data Exporter tool can be used to extract the parameters defined in XidML 3.0 file from the PCAP file and output the data as CSV or MATLAB files.

Starting with version 3.4.23 of DAS Studio 3, Data Exporter is now installed at this default path: C:\acra\DASStudio\3.4.23\Tools\DataExporter

If using an earlier version of DAS Studio 3, contact Curtiss-Wright support (acra-support@curtisswright.com) to request a copy of Data Exporter (document reference TSD/AE/031 Data Exporter).

## 54.5.11 No date on first PCAP recorded

When recording with a KAM/MEM/113 that has the Log Condition set to Always Log, and using a KAM/TCG/105 module as the Time master, the first recorded PCAP file may not show a date in Windows Explorer.

This occurs when the KAM/TCG/105 is powered on, its time defaults to 1 January, 1970 until it seeds time from its internal RTC timer, which takes about 2 seconds. (This behavior is true for any mode GPS, IRIG, or RTC.)

As recording on the KAM/MEM/113 begins in this 2-second window prior to RTC time being seeded, the file would be dated 1 January, 1970. However, Windows Explorer considers the date invalid as it pre-dates the FAT (File Allocation Table) file system.

A way around is to trigger the KAM/MEM/113 with the DAY OF YEAR parameter when it is greater than 1, however that means the module will not record on the 1st of January.

### 54.5.12 Reading a CF with Windows 10

Windows 10 has a feature that creates a System Volume Information folder on external drives such as USB and SSD. This feature must be disabled when a CF card is accessed from Windows 10. Otherwise the CF card will be unreadable when used again with a KAM/MEM/113.

Contact Curtiss-Wright support (acra-support@curtisswright.com) to request the document *TSD-AE-002 Prevent System Volume Information folder creation on USB in Windows 10.pdf* to resolve this issue.

### 54.5.13 IENA timestamp and PCAP timestamp

PCAP time is the same as PTP time except that the lower 32 bits are a count of microseconds instead of nanoseconds.

IENA time is the number of microseconds since the start of the year and is based on UTC.

PTP time is ahead of UTC by PTP leap seconds which is currently 37 seconds.

### 54.5.14 Recording packetizers

Packetizers can only be recorded on the chassis where the KAM/MEM/113 is located.

### 54.5.15 KAM/MEM/113 and mode select

When a mode is changed, for example during shunt from mode 0 to mode 8, the KAM/MEM/113 resets and a new PCAP file is created. Then if you revert to mode 0 a new PCAP file is again created. This is an explicit function of the FPGA for mode/reset.

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Chapter 55

# Using the KAM/WSI/104

TEC/NOT/084

The KAM/WSI/104 module contains a base station, or gateway, licensed from LORD Corporation (microstrain.com) for communicating with a wireless sensor network using the LXRS protocol. The module collects node data for transmission over the Acra KAM-500 backplane in packetized format and/or mapped analog channel format.

This paper discusses the following topics:



## 55.1 Introduction

LXRS uses a star network topology for bi-directional communication between one gateway and multiple wireless sensor nodes. All nodes communicate directly to the gateway using assigned time-division-multiplexing (TDM) slots, and each network operates on a designated frequency channel within the 2.4 GHz license-free ISM band. (See “55.8 References” on page 516 - LORD technical note link.)

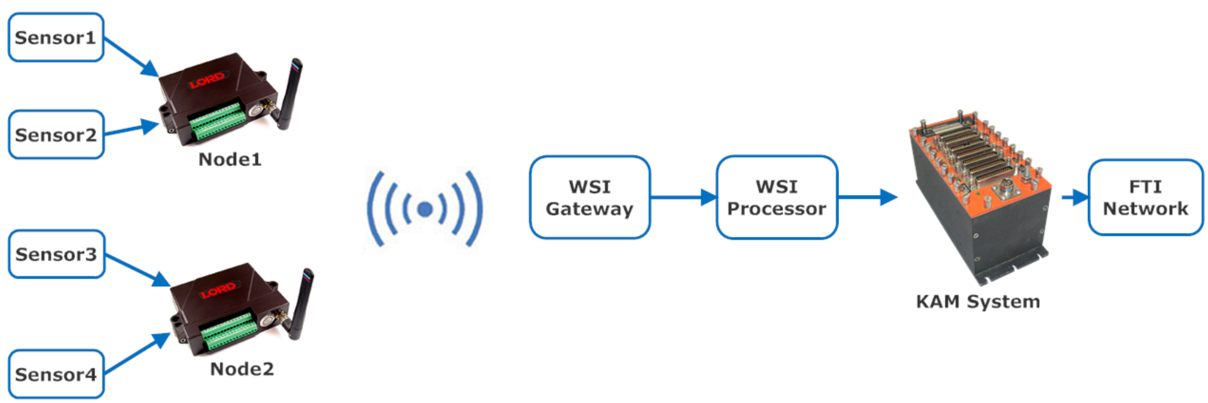



*Figure 55-1: LXRS network topology*

Setting up the wireless sensor network requires two steps.

1. Set up the KAM/WSI/104 in DAS Studio 3.
2. Set up the wireless nodes using SensorConnect.

This document contains instructions on how to set up the KAM/WSI/104.

### 55.1.1 Required software

DAS Studio 3 - contact Curtiss-Wright support (acra-support@curtisswright.com)

SensorConnect (http://www.microstrain.com/software)

### 55.1.2 Required hardware and cables

KAM/WSI/104: Wireless sensor module

KAD/BCU/140: Ethernet controller

ACC/CON/051: USB to 19 way cable

Wireless sensors (nodes) compatible with LXRS protocol

## 55.2 Network planning

Before programming the KAM/WSI/104, plan your wireless sampling network.

SensorCloud Sensing Wireless Network Calculator (https://sensorcloud.com/pricing?onlyCalc=true; requires Google Chrome browser) is recommended for planning. It estimates the bandwidth required for various combinations of nodes and channels and sampling rates.

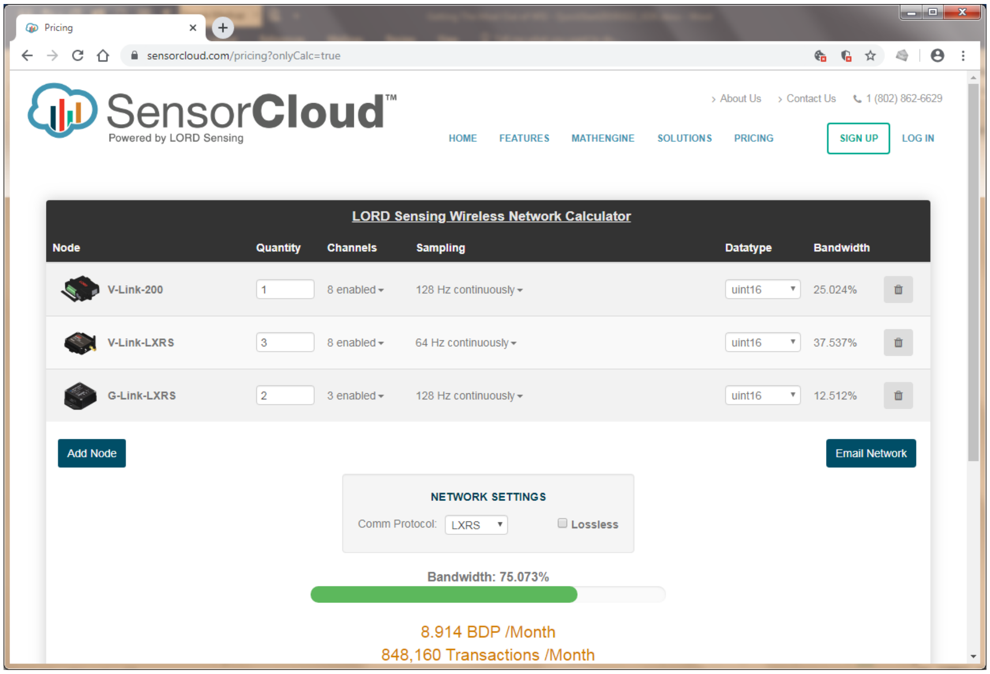



*Figure 55-2: SensorCloud Sensing Wireless Network Calculator*

The KAM/WSI/104 uses Synchronized Sampling Mode, LXRS Protocol, and 16-bit data words. Lossless mode is recommended. Use these settings when planning the network.

It is also possible to set up a live network using SensorConnect, before programming the KAM/WSI/104, to see what configurations are allowed by the software through experimentation (see “55.4 Talking to the gateway” on page 509). Once you have set up one working network, it is easy to tweak and experiment with settings.

The node IDs and sampling rates is required for both KAM/WSI/104 programming (“55.3.1 Analog channel mapping” on page 507) and network setup (“55.4.3 Setting up the network” on page 509).

## 55.3 Programming the KAM/WSI/104

The KAM/WSI/104 must be programmed with DAS Studio 3. (The PC requires an Ethernet connection to the KAD/BCU/140 for programming.)

DAS Studio 3 is used to create a configuration, which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

To begin, open DAS Studio 3 and create a task with the KAD/BCU/140 and a KAM/WSI/104.

The KAM/WSI/104 can handle incoming node data in two ways:

1. It can map specific node channels to placeable analog parameters.
2. It can packetize node data into streams.

Analog parameters are easier to display and view but have specific requirements to match the sampling rate with the incoming data rate. Packetizers have no sampling rate restrictions but can produce varying length packets.

Both approaches can be used in combination, for any node, up to the channel count limits.

Save, verify, and program the Acra KAM-500 system when the task file is configured to your requirements.

### 55.3.1 Analog channel mapping

The KAM/WSI/104 can support up to 31 placeable parameters, each a 16-bit word with mapping to a remote node and channel. These appear to the Acra KAM-500 backplane as Analog channels 0 to 30.

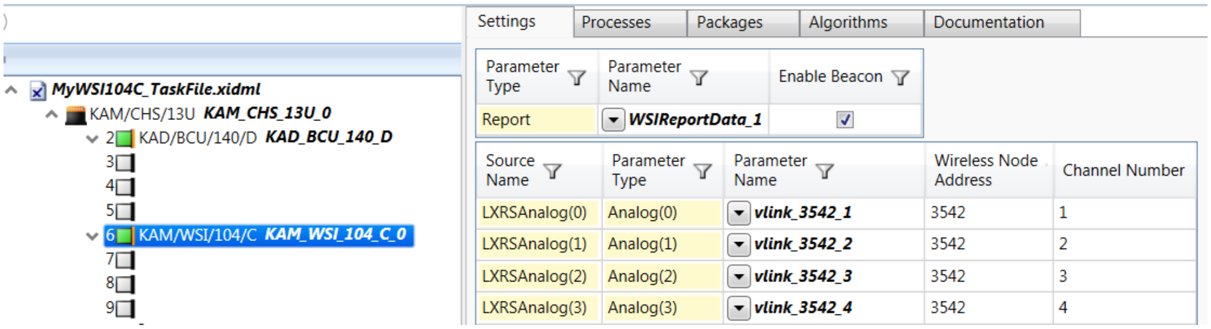



*Figure 55-3: KAM/WSI/104C Settings tab*

Enter both the wireless node address and the channel number to create a mapping to a parameter. Rename the parameter to suit. (Including the node ID and channel number in the name, as in example above for node *vlink #3542*, may be a useful viewing aid.) Leave unused parameters as address 65535.

As shown in the following figure, the wireless node address (also known as node ID) is visible in SensorConnect and printed on the node label as part of the serial number. (In the serial number format XXXX-YYYYY, the YYYYY is the node ID.) The channel number corresponds to the input ports on the node.

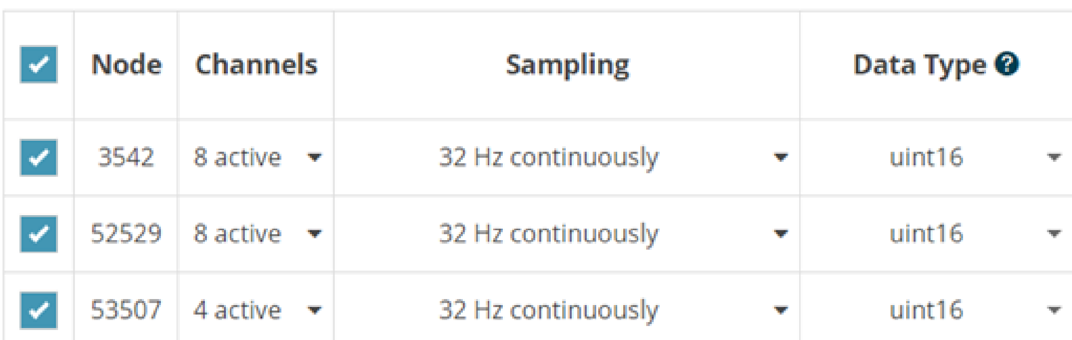



*Figure 55-4: SensorConnect network setup showing Node ID and 32Hz sampling rate*

You can now place these parameters in PCM or Ethernet or any standard Curtiss-Wright output format. Refer to the "Package Generator" chapter of the *DAS Studio 3 User Manual*.

When placing the parameters in a package, ensure that the sampling rate for the parameter on the KAM-500 backplane matches the sampling rate for the data source. It must be the same rate as is assigned to the node in SensorConnect (see the previous screen). This example uses 32 Hz for both the parameter sampling rate and the node sampling rate. The sampling rate for the parameter can be doubled by doubling the number of occurrences in the package.

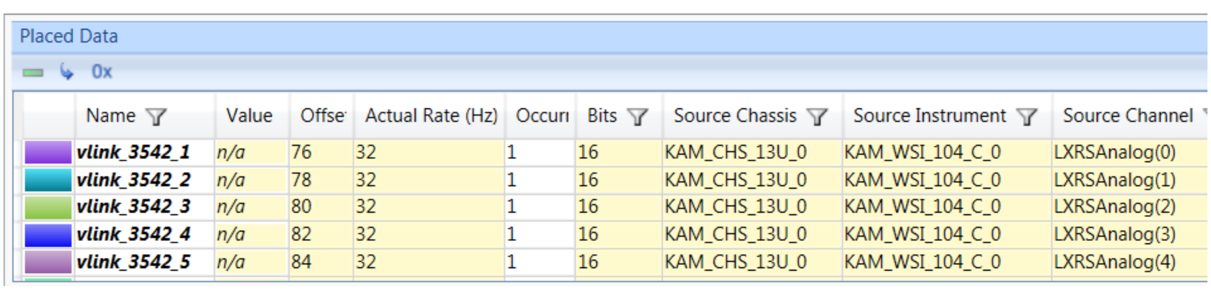



*Figure 55-5: Placed Data pane in a KAD/BCU/140 Package tab in DAS Studio 3*

Inactive (*dead*) nodes or invalid mappings have their placed data replaced with a constant value, 0xDEAD.

## 55.3.2 Packetizer

The packetizer supports both IENA and INET-X formats, but it cannot mix formats.

There is a unique packetizer stream for *LXRS RAW* packets. If enabled, this stream fires on every data packet received from the gateway, from any connected node, whether or not it is mapped to any stream or parameter. The contents are the data packet with a wrapper, following the *LXRS RAW* format in the *KAM/WSI/104* data sheet. These can be decoded in Wireshark using an *LXRS* dissector; contact Curtiss-Wright support (acra-support@curtisswright.com) for details.

Packetizer

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Packetization Enabled | IENA-M Param ID | Packetization Sink |
|---|---|---|---|---|---|---|---|
| LXRSRaw | iNET-X | ABCD0A9A | N/A | 0 | ☑ | 0 | All |

*Figure 55-6: LXRS Raw packetizer settings in DAS Studio 3*

The *LXRS Node* packetizer streams reformat the received data from a matching node into *Analog Packetizer* format, described in the *KAM/WSI/104* data sheet.

LXRS Node packetizers require a unique iNET-X stream ID (or IENA key) and a node ID (Wireless Node Address). The same node ID cannot be used for two different streams; it must be a 1:1 mapping between streams and nodes. The **Packetization Enabled** check box must be selected for streams to be active.

| Source Name | Packetizer Format | Stream Id | IENA Type | Packetization Enabled | IENA Key | Wireless Node Address | Packetization Sink |
|---|---|---|---|---|---|---|---|
| LXRSNode(0) | iNET-X | dc52940 | N/A | ☑ | 0 | 52940 | All |
| LXRSNode(1) | iNET-X | dc03542 | N/A | ☑ | 0 | 3542 | All |
| LXRSNode(2) | iNET-X | dc52529 | N/A | ☑ | 0 | 52529 | All |

*Figure 55-7: LXRS Node packetizer settings in DAS Studio 3*

DAS Studio 3 assigns a destination IP unique to the stream after verification. These can be edited in the Packages tab of the KAD/BCU/140. Note the *Sub Type* and *DataType* identifying the streams.

Package Properties

| Name | Rate (Hz) | Type | Sub Type | Stream ID | Source IPA | Source UDP Port | Destination MAC | Destination IPA | Destination UDP Port | DataType |
|---|---|---|---|---|---|---|---|---|---|---|
| ***KADBCU140D01ut100*** | 64 | INet-X | Placed | D000 | 000.000.000.000 | 1023 | 01-00-5E-00-00-01 | 235.0.0.1 | 1023 | n\a |
| ***KAMWSI104C_ABCD0A9A*** | 576 | INet-X | Parser aligned | ABCD0A9A | 192.168.28.1 | 1023 | 01-00-5E-00-00-02 | 235.0.0.2 | 8010 | LXRSRaw |
| ***KAMWSI104C_DC03542*** | 640 | INet-X | Parser aligned | 0dc03542 | 192.168.28.1 | 1023 | 01-00-5E-00-00-0B | 235.0.0.11 | 8010 | LXRSNode |
| ***KAMWSI104C_DC52529*** | 640 | INet-X | Parser aligned | 0dc52529 | 192.168.28.1 | 1023 | 01-00-5E-00-00-0C | 235.0.0.12 | 8010 | LXRSNode |

*Figure 55-8: DAS Studio 3 Package tab showing the packetizer packet automatically added after verification*

## 55.3.3 Report and Beacon

The Enable Beacon check box next to the Report parameter is enabled by default. It is recommended to keep the beacon enabled, as the beacon allows the nodes to detect the base station. The beacon is sent at 1-second intervals and contains a timestamp from the KAM-500 which the nodes use to synchronize their clocks with the KAM-500.

The Beacon status does not affect the contents of the Report parameter word. The Report flags are defined in the KAM/WSI/104 data sheet. The Report also contains a count of currently active nodes.

| Parameter Type | Parameter Name | Enable Beacon |
|---|---|---|
| Report | ***WSIReportData_1*** | ☑ |

*Figure 55-9: Report parameter and Beacon setting in DAS Studio 3*

## 55.4 Talking to the gateway

For this procedure, you need a PC with SensorConnect installed and the USB cable (ACC/CON/051) supplied with the KAM/WSI/104 module.

### 55.4.1 SensorConnect

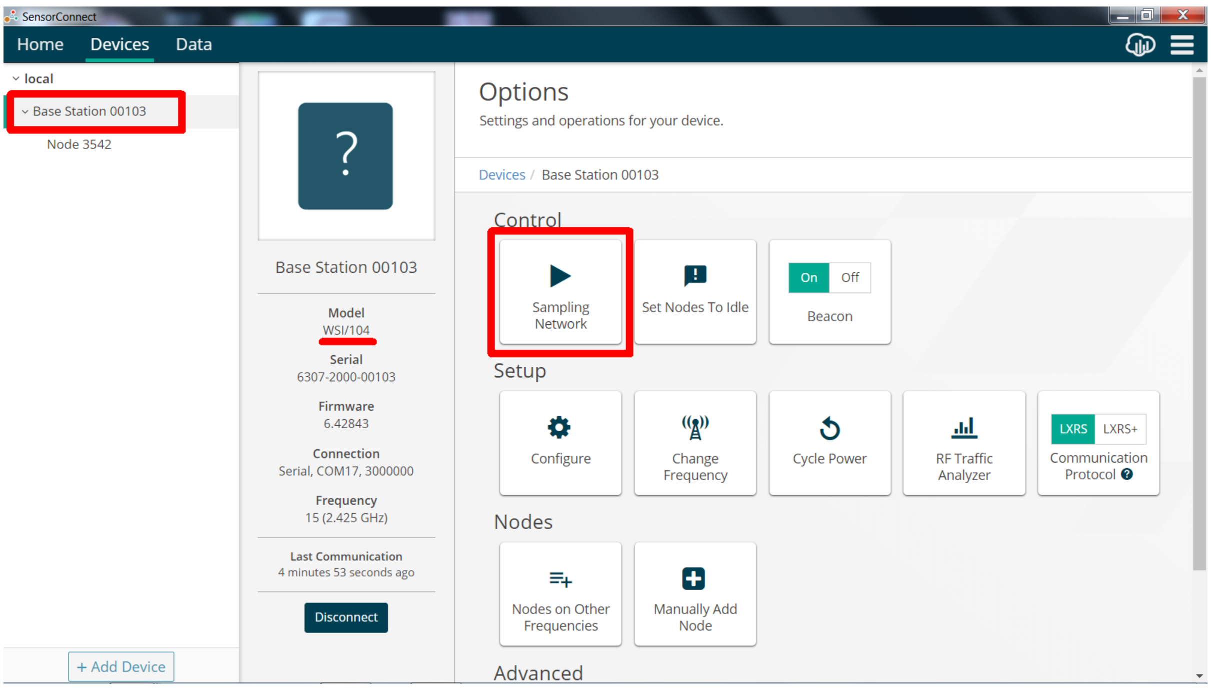
SensorConnect is Windows-compatible software from LORD (MicroStrain) for communicating to a base station over USB.

It is available from https://www.microstrain.com/software/sensorconnect.

Download and install SensorConnect to a PC.

### 55.4.2 Communication

1. Connect the USB cable to the KAM/WSI/104 top block and to the PC.
2. Power up the KAM-500 chassis and start SensorConnect.
3. The first run of SensorConnect creates a default data depository, visible under the **Home** tab. This stores base station and network configurations. (Refer to SensorConnect documentation if you want to change the data depository or save location.)
4. Click the **Devices** tab.
5. In SensorConnect, the KAM/WSI/104 appears as a Base Station, model **WSI/104**.



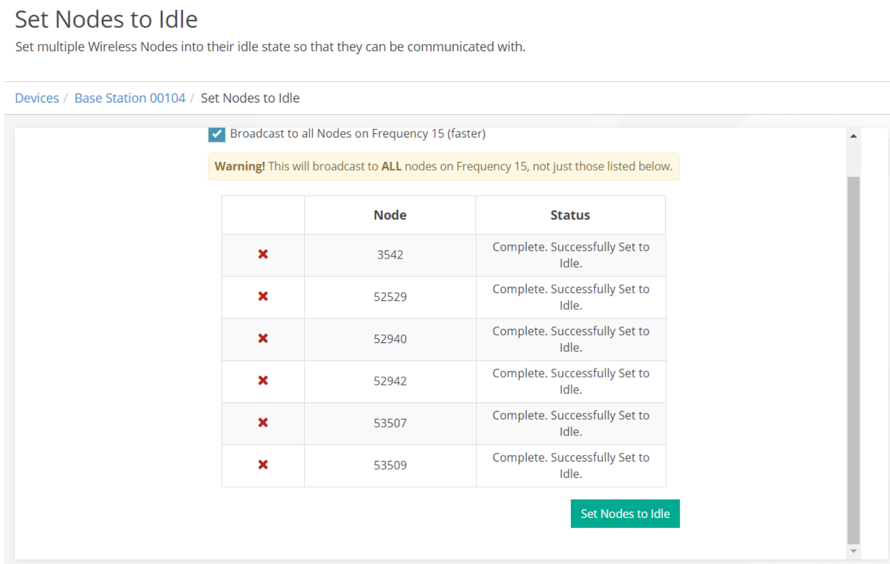

6. Power up the remote node(s). After a few seconds (assuming factory default settings) Series 200 nodes appear in the SensorConnect device list. Older nodes such as VLink-LXRS need to be put into idle mode to be recognized; this is easily done by toggling the node's power switch rapidly off and on twice.

   Nodes that don't show up automatically can be checked using the **Manually Add Node** command and entering the ID; they are added if they respond to a ping request sent as part of this procedure. Refer to the SensorConnect user guide for more details.

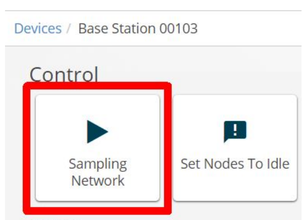
### 55.4.3 Setting up the network

This section covers setting up the nodes to form a sampling network. Settings can be sent to each node individually, however it is faster to use the base station menu and the **Sampling Network** button to set up multiple nodes on the same screen.

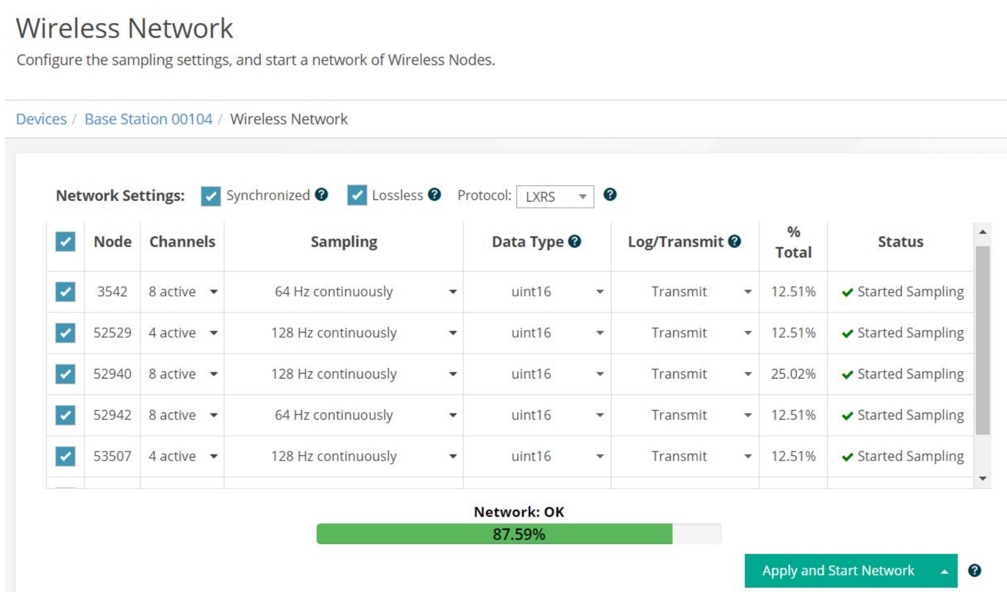
1. Click **Set Nodes To Idle** to set all nodes into their idle state.
   Nodes in idle mode respond to setup commands.




2. Click the base station **Sampling Network** control.




   The **Wireless Network** screen appears.




3. Set the sampling frequency for each node to match the sampling rate in the KAM/WSI/104 task file.
   a. The supported **Network Settings** are [Synchronized=TRUE, Lossless=TRUE, Protocol=**LXRS**].
   b. The supported settings for nodes are [Data Type=**uint16**, Log/Transmit=**Transmit**].
   c. **Channels** and **Sampling** are drop-down menus that can be customized per node.
   d. Total bandwidth requirement must be < 100%. The **Apply** button is disabled if the total bandwidth requirement exceeds 100%.

Channels that are mapped to KAM/WSI/104 placed parameters must be active to transmit the data. Inactive channels are replaced by placeholder value 0xDEAD.

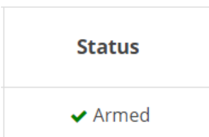
### 55.4.4 Starting the network with backplane controller as time source

The base station sends out *beacon* packets to synchronize the nodes to its time source. It is possible to start an ad-hoc network immediately by clicking **Apply and Start Network** while SensorConnect is running on the PC, however it will start with timestamps based on the PC clock. (After the USB cable is unplugged, it can take a minute or two for the network to resynchronize to the KAM-500 backplane controller timebase.) The following procedure starts the network with the KAM-500 backplane controller as time source instead of the PC.

1. After setting up the synchronized sampling network, click the **Apply and Start Network** drop-down menu and then select **Apply and Arm Nodes**.

   The node status indicates **Armed** when the command is received.

2. Power down the KAM-500 and unplug the USB cables.
   (SensorConnect can be powered down at this stage.)
3. Power up the KAM-500.
   About a minute after startup, the nodes synchronize to the KAM-500 beacon and start transmitting data.

---

**NOTE:** SensorConnect turns on and off the beacon as required when arming the network, as does the KAM/WSI/104 when rebooted. There is a Beacon button in SensorConnect base station menu but there shouldn't be any need to use it.

### 55.4.5 Viewing data in SensorConnect

SensorConnect has a Data tab that can display live node data in widgets and dashboards. This can be useful for verifying incoming data at the gateway, independently of its path through the KAM-500 system. This live display is only possible while the USB cable is connected. Once this connection is removed, you cannot view the signal in SensorConnect.

For more on this and the Data Depository tab, refer to the SensorConnect built-in help and documentation.

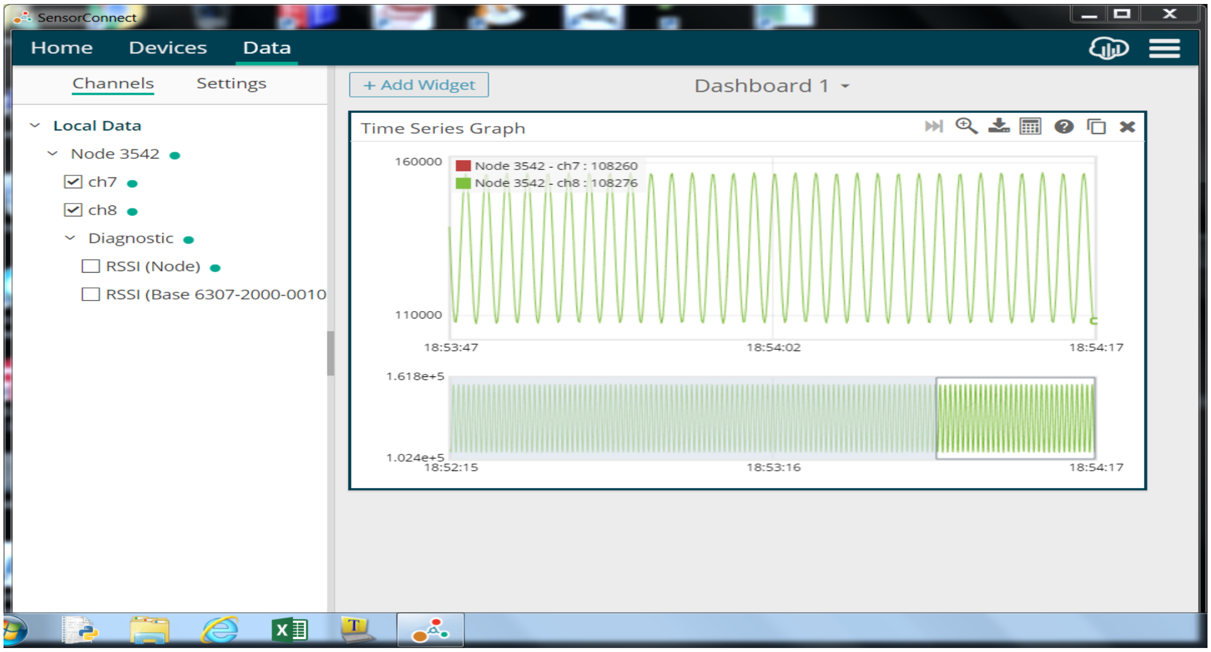



*Figure 55-10: SensorConnect Data tab*

## 55.5 Timestamping and latency

Incoming data for mapped analog channels is buffered by the KAM/WSI/104. The buffers are slightly larger than one second in depth and the data has a fixed one-second latency (based on sampling rate) between receipt from the gateway and output as a placed parameter.

If the received data rate is less than the outgoing data rate—due to radio network packet losses or under sampling—the under filled buffer does not have valid data for its entire length.

If incoming data is more than one second old, it is not recognized as old data and is still placed in the buffers. This is a known issue.

The latency is only relevant to placed analog parameters. The packetizers transmit a packet immediately when a message is received and processed.

The nodes operate on a UTC internal clock with node-to-node synchronization of 50 µs and synchronized to the base station beacon packets. When a node sends a data packet, the timestamp corresponds to the time of the first sample in the packet. IENA packetizers use the UTC timestamp provided by the node. iNET-X packetizers use a PTP timestamp so leap seconds (defined in the backplane controller setup) are added to the node timestamp. This *first sample* timestamp is regardless of network transport time, packet length, or retries required.

## 55.6 LED behavior

As an aid to debugging and bench testing, the KAM/WSI/104 has a mode LED (D1) and an activity LED (D5) on the motherboard. They are not visible when all chassis slots are covered by lids or modules.

When the USB connection to the PC is active, D1 is red.

When there is a node detected on the network, D1 is green.

When neither of these is true, and the module is polling for nodes, D1 is blue.

When the gateway is actively receiving node data samples, D5 is green and flickering.

There are also LEDs on the gateway board that follow D1 behavior.

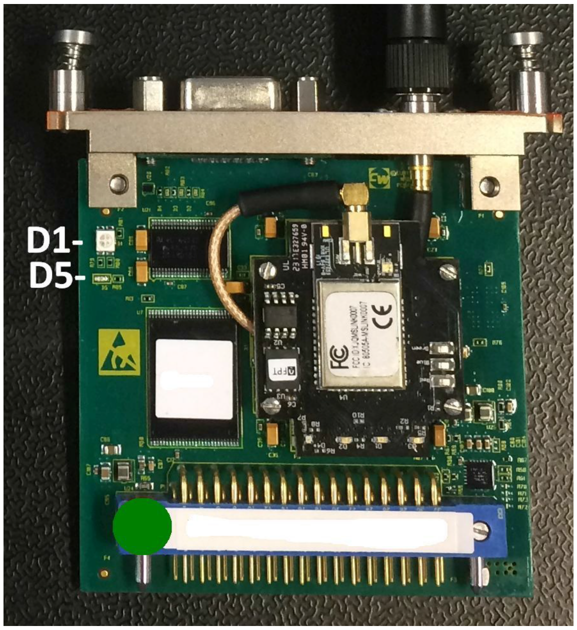



*Figure 55-11: KAM/WSI/104 LED location*

## 55.7 Wireless network tips

LXRS network behavior is covered in more detail in LORD documentation.

### 55.7.1 Radio interference and lossless mode

Under noisy RF environments, packets can be lost. When the network is in lossless mode, unacknowledged packets are buffered by the node and retransmitted until acknowledged. This can compensate for the odd missed packet with no visible effects in the packetized or placed data sequence.

Even with lossless mode, under poor conditions some packets may be delayed and arrive too late to be placed in the correct latency buffer, and corrupt the placed data feed. Packetized streams are not affected by delays.

Under extremely poor conditions the node buffering itself may fill up causing the oldest data in the node to be lost permanently. (See “55.8 References” on page 516 - LORD technical note link.)

Under good conditions with no need for retransmission, there is very little network delay and the delay has near-deterministic timing.

### 55.7.2 LXRS vs LXRS+ protocol

Some newer nodes support both the LXRS and LXRS+ protocol. The LXRS protocol has greater range whereas the LXRS+ protocol supports higher speeds. (See “55.8 References” on page 516 - LORD technical note 8401-0084 link.) The KAM/WSI/104 only supports the LXRS protocol at this time.


*Figure 55-12: Communication protocol button*

## 55.7.3 Frequencies

There are 14 available frequency channels between 2.405 and 2.470 GHz. Wireless nodes and the gateway must be on the same frequency channel to communicate. (See “55.8 References” on page 516 - LORD user manual link.)

This guide assumes the factory default (channel 15) is used for all nodes and the base station. It is possible to set up or migrate the entire network to another available frequency using the SensorConnect *Change Frequency* utility.

One strategy to mitigate noise is to move to a less noisy channel. SensorConnect has an *RF Traffic Analyzer* utility for monitoring the available frequencies to help determine which ones are noisy and should be avoided.

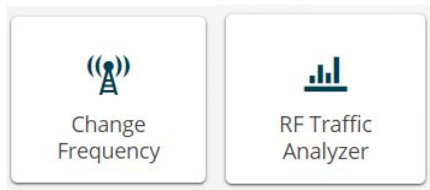



*Figure 55-13: Change Frequency and RF Traffic Analyzer utilities*

Two KAM/WSI/104 base stations can operate with overlapping range (even in the same chassis) if they are on different frequencies.

---

**NOTE:** In this case, the limit of 24 WSI packetizers per chassis applies and must be split between the base stations.

## 55.7.4 Transmit Power

Both the nodes and the base station have adjustable transmit power settings.

Transmit Power can range from 0 to 20 dBm. Higher transmit power normally helps with communication but can reduce battery life of the nodes, and may affect other electronic devices by adding to EMI. The default power setting is 10 dBm.

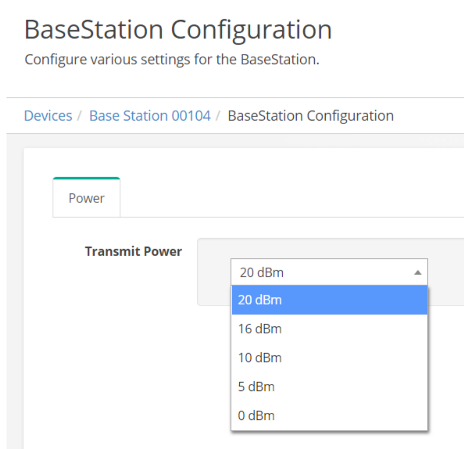



*Figure 55-14: Transmit Power range*

Range testing and received signal strength indicators (RSSI) are available through the Node menu in SensorConnect, as shown in the following figure.

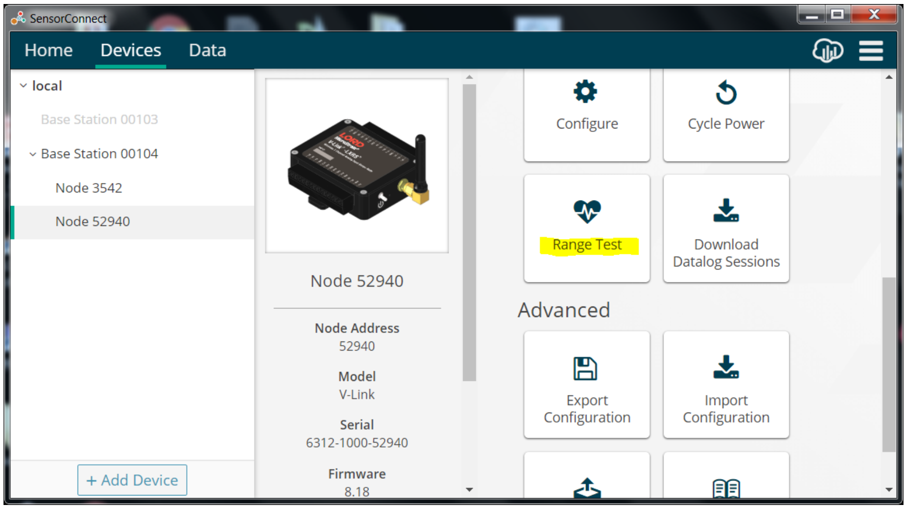



*Figure 55-15: Range Test control*

RSSI data from nodes is also available on the SensorConnect Data tab and in LXRS RAW data.

## 55.7.5 Node configuration

Node configuration is done through the Configure command on the Node menu. The Power tab allows setting the transmit power level and the default power-up and power-off behaviors. For Analog nodes the Hardware tab allows changes to the range and gain of the input amplifiers. Refer to node data sheets for limits and other details.

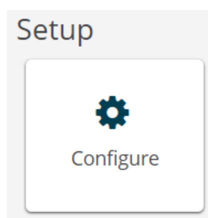



*Figure 55-16: Node configuration control*

The following figure shows the Power tab of the Wireless Node Configuration control panel.

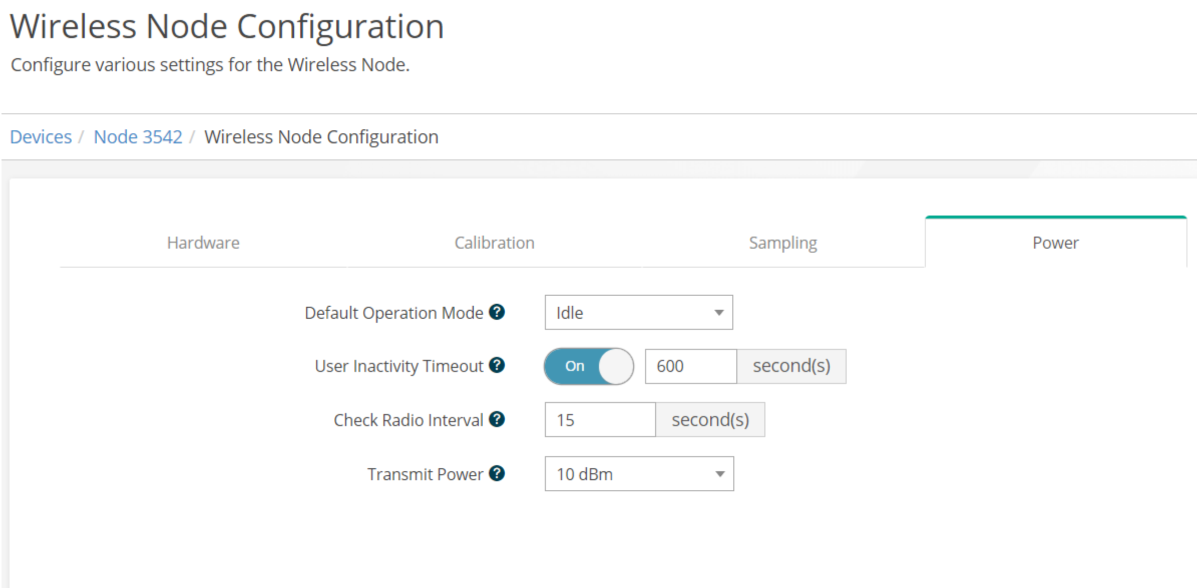



*Figure 55-17: Wireless Node Configuration Power tab*

### 55.7.6 Antenna location and orientation

Range is maximized by having line-of-sight between antennas, and decreases when line-of-sight is blocked by metalwork, cables and backshells—especially shielded cables going to the KAM-500 chassis.

## 55.8 References

LORD technical note 8401-0084 *LXRS® and LXRS+ Wireless Sensor Protocol*

https://www.microstrain.com/sites/default/files/tech_note_-_lxrs_and_lxrs_8401-0084_0.pdf

LORD user manual *WSDA®-200-USB Wireless USB Base Station*

https://www.microstrain.com/wireless/WSDA-200-USB

SensorConnect screenshots taken from version 10.4.9.

https://www.microstrain.com/software/sensorconnect

DAS Studio screenshots taken from version 3.4.11.

acra-support@curtisswright.com

# Using the KAM/TCG/105 and KAM/TCG/106

TEC/NOT/085

The KAM/TCG/105 is a time-code generator with GPS/IRIG input and internal battery backup. The KAM/TCG/106 is based on the KAM/TCG/105; the main difference being the external battery backup for applications in which using an internal battery is not optimal.

This technical note introduces the KAM/TCG/105 module, and describes how to set it up, as well as troubleshoot GPS. This paper is divided into the following sections:



Throughout this document, where the KAM/TCG/105 is mentioned, the same information and settings are valid for the KAM/TCG/106. Any exceptions are indicated in specific notes.

## 56.1 Time code modules

The following table describes Acra KAM-500 time code modules.

Table 56-1: Different time code modules

| Module | Description |
|---|---|
| KAM/TCG/001 | IRIG-B time code reader and generator with external battery. The KAM/TCG/001/C version provides an option to use an external battery. This product is discontinued. |
| KAM/RTC/003 | RTC generator with memory status outputs. This module does not have any time input capabilities other that its own real time clock; it works with an internal battery only. |
| KAM/TCG/102 | Combined GPS and IRIG input. This module is the predecessor of the KAM/TCG/105. The KAM/TCG/102 supports an external battery only and does not feature memory status outputs. This product is obsolete. |
| KAM/TCG/105 | Time-code generator with GPS/IRIG input and battery backup. This product is recommended for new programs. |
| KAM/TCG/106 | Time-code generator with GPS/IRIG input and external battery backup. This product is recommended for new programs. |

## 56.2 Module overview

The KAM/TCG/105 is a time-code generator with GPS/IRIG inputs, which incorporates a number of improvements over the KAM/TCG/102, principally the inclusion of an RTC with built-in battery backup.

The KAM/TCG/105 can accept time from an IRIG-B time source, from its onboard GPS receiver (external antenna required), or from an external GPS receiver outputting NMEA messages and a one PPS signal. The received time is written to an internal timer.

On power-up of the Acra KAM-500, the KAM/TCG/105's timer is seeded with time from the RTC. When powered down, the battery maintains time on the RTC.

On subsequent power-ups, time is loaded from the RTC and the RTC time is updated when a time source (GPS or IRIG) is locked. If the module is in slave mode, the RTC time is updated with time from the master module.

Alternatively, the initial time can be set from the PC using either Time Seeder or kTimeseed. Refer to the *KAM/TCG/105* data sheet for more information.

## 56.3 Setting up the KAM/TCG/105 using KSM-500

kSetup software can be used to configure the KAM/TCG/105. kSetup is included in the KSM-500 suite of tools.

### 56.3.1 Setting parameters

The Parameters tab (see the following figure) displays all parameters available from the module. To select parameters from the KAM/TCG/105, select the module in the Task Explorer pane of kSetup. From the Parameters tab, complete the fields described in Table 56-2 on page 518. For more information on using kSetup, contact Curtiss-Wright support (acra-support@curtisswright.com).

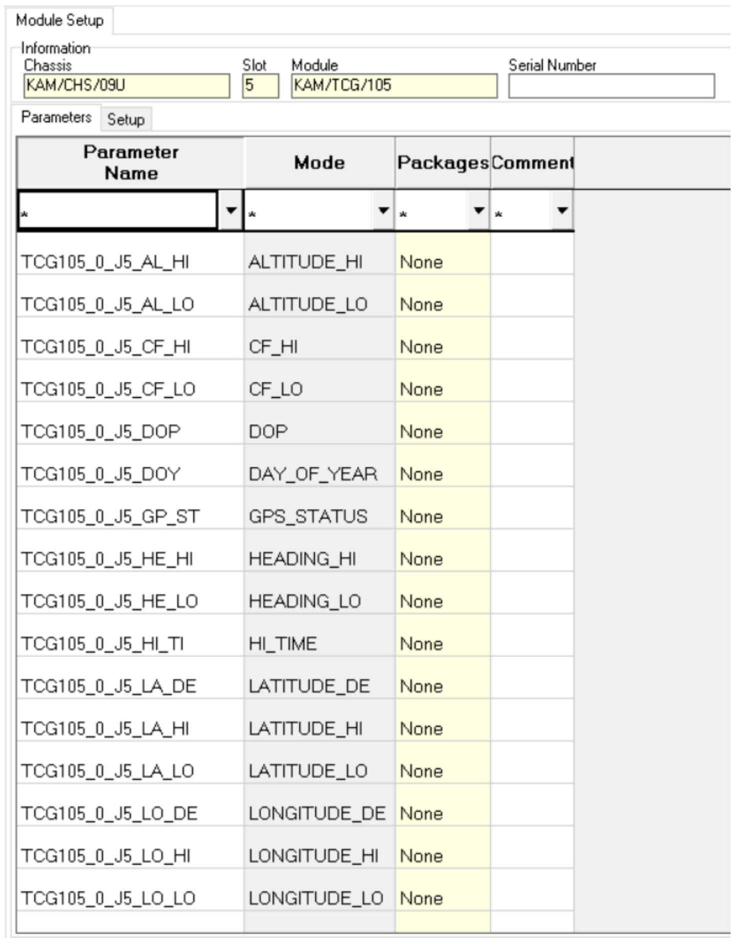



*Figure 56-1: Parameters tab in kSetup*

Table 56-2: Parameters tab settings

| Field name | Description |
|---|---|
| Parameter Name | Name of the parameter. |
| Mode | Time or navigation data such as position, altitude, velocity and heading. For more information on the Mode column values, see the Parameter definition table in the *KAM/TCG/105* data sheet. |
| Packages | When you place the parameter in a PCM frame, you can double-click a Packages cell. A window displays the transmission details in the PCM frame, such as the transmission rate. |
| Comment | User-defined text relating to the parameter. |

## 56.3.2 Setup tab settings

Fields on the Setup tab (see the following figure) allow you to configure available settings for the KAM/TCG/105. For more information on Setup definition, see the *KAM/TCG/105* data sheet.

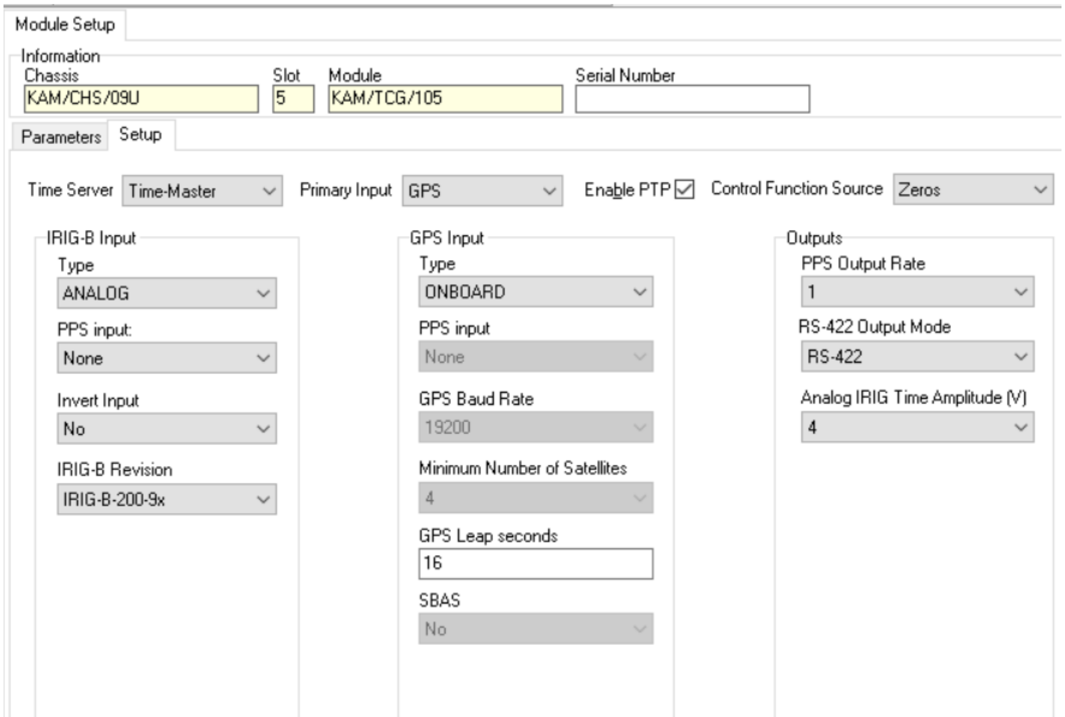



*Figure 56-2: Setup tab in kSetup*

The data sheet mentions two fields which are not configurable in KSM-500.

**Current Year:** The current year is automatically set by the software during programming. This is used when there is no other source of year. For example, when IRIG-B-200-9x is the input; this IRIG format does not carry year information.

**MEM_Status:** KSM-500 automatically sets the KAM/MEM/003, KAM/MEM/103, or KAD/MEM/004 report register into this KAM/TCG/105 register in order to drive the MEM_STATUS(1:0) outputs.

---

**NOTE:** The KAM/TCG/106 only supports one MEM_STATUS output showing whether the MEM is logging or not.
Parsing of NMEA messages is not supported by KSM-500.
Enable PTP is reserved. Enabling or disabling it does not have any effect.

# 56.4 Setting up the KAM/TCG/105 using DAS Studio 3

You can use DAS Studio 3 software to configure the KAM/TCG/105. Features that can be set up include configuring channels, setting messages, and adding data words to messages. More information on these settings can be found in the “Setting up packages” and “Setting up datalinks” sections of the *KAM/TCG/105* data sheet.

DAS Studio 3 is used to create a configuration file which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

## 56.4.1 Settings tab

The Settings tab as shown in the following figure, shows available parameters for the module. The parameters shown in the Settings tab are defined in the *KAM/TCG/105* data sheet.

Settings | Processes | Packages | Algorithms | Documentation

| Source Name | Parameter Type | Parameter Name |
|---|---|---|
| ***MyKAM_TCG_105*** | StatusIn | ***P_MyKAM_TCG_105_StatusIn*** |
| ***MyKAM_TCG_105*** | ControlFunction | ***P_MyKAM_TCG_105_ControlFunction*** |
| ***MyKAM_TCG_105*** | StraightBinarySeconds | ***P_MyKAM_TCG_105_StraightBinarySeconds*** |
| ***MyKAM_TCG_105*** | IrigTime48 | ***P_MyKAM_TCG_105_IrigTime48*** |
| ***MyKAM_TCG_105*** | IrigTime48 : TimeHi | |
| ***MyKAM_TCG_105*** | IrigTime48 : TimeLo | |
| ***MyKAM_TCG_105*** | IrigTime48 : TimeMicro | |
| ***MyKAM_TCG_105*** | DayOfYear | ***P_MyKAM_TCG_105_DayOfYear*** |
| GPS-In | Latitude | ***P_MyKAM_TCG_105_GPS-In_Latitude*** |
| GPS-In | Latitude : LatitudeHi | |
| GPS-In | Latitude : LatitudeLo | |
| GPS-In | Latitude : LatitudeMicroMinutes | |
| GPS-In | Longitude | ***P_MyKAM_TCG_105_GPS-In_Longitude*** |
| GPS-In | Longitude : LongitudeHi | |
| GPS-In | Longitude : LongitudeLo | |
| GPS-In | Longitude : LongitudeMicroMinutes | |
| GPS-In | Altitude | ***P_MyKAM_TCG_105_GPS-In_Altitude*** |
| GPS-In | Altitude : AltitudeHi | |
| GPS-In | Altitude : AltitudeLo | |
| GPS-In | VelocityInKph | ***P_MyKAM_TCG_105_GPS-In_VelocityInKph*** |
| GPS-In | VelocityInKn | ***P_MyKAM_TCG_105_GPS-In_VelocityInKn*** |
| GPS-In | Heading | ***P_MyKAM_TCG_105_GPS-In_Heading*** |
| GPS-In | Heading : HeadingHi | |
| GPS-In | Heading : HeadingLo | |
| GPS-In | DilutionOfPrecision | ***P_MyKAM_TCG_105_GPS-In_DilutionOfPrecision*** |
| GPS-In | StatusGPS | ***P_MyKAM_TCG_105_GPS-In_StatusGPS*** |

*Figure 56-3: Settings tab showing available parameters*

**NOTE:** To see module settings, the module must be in context in the Navigator. Refer to the *DAS Studio 3 User Manual* for more information.

The Settings tab as shown in the following figure, shows available settings for the module. These settings are defined in the *KAM/TCG/105* data sheet.

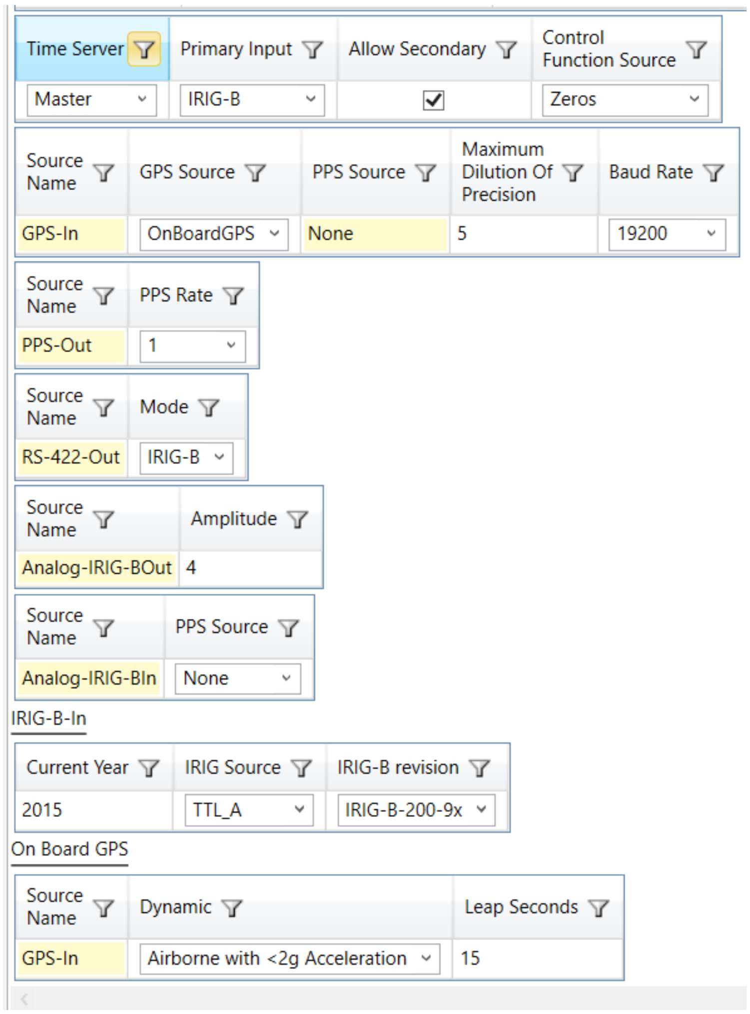


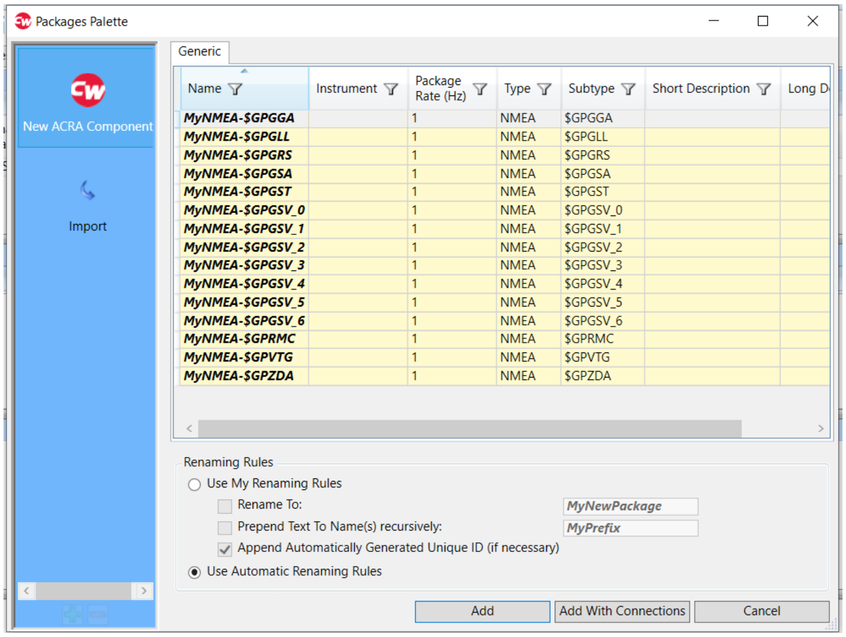

*Figure 56-4: Settings tab showing available settings*

## 56.4.2 Packages tab - setting parser of NMEA packages

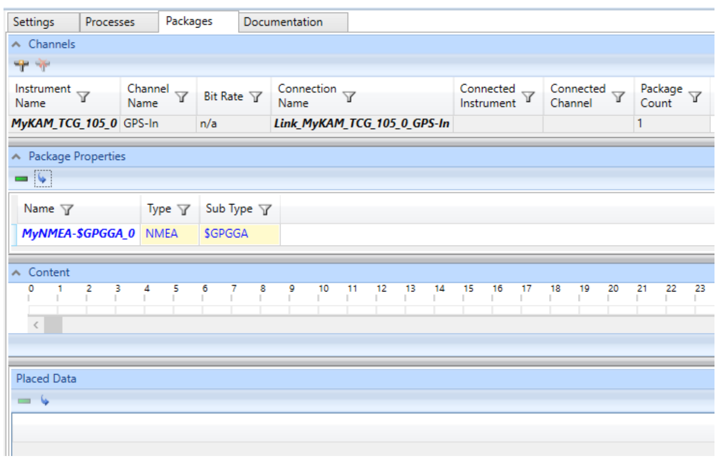
The KAM/TCG/105 allows parsing of any of the 15 predefined National Marine Electronics Association (NMEA) messages supported by the module: GGA, GLL, GRS, GSA, GST, GSV0 to GSV6, RMC, VTG and ZDA. For further information regarding NMEA 0183 refer to the latest standard available.

To create an NMEA message, the corresponding predefined package needs to be created. Refer to the following to create the predefined package.

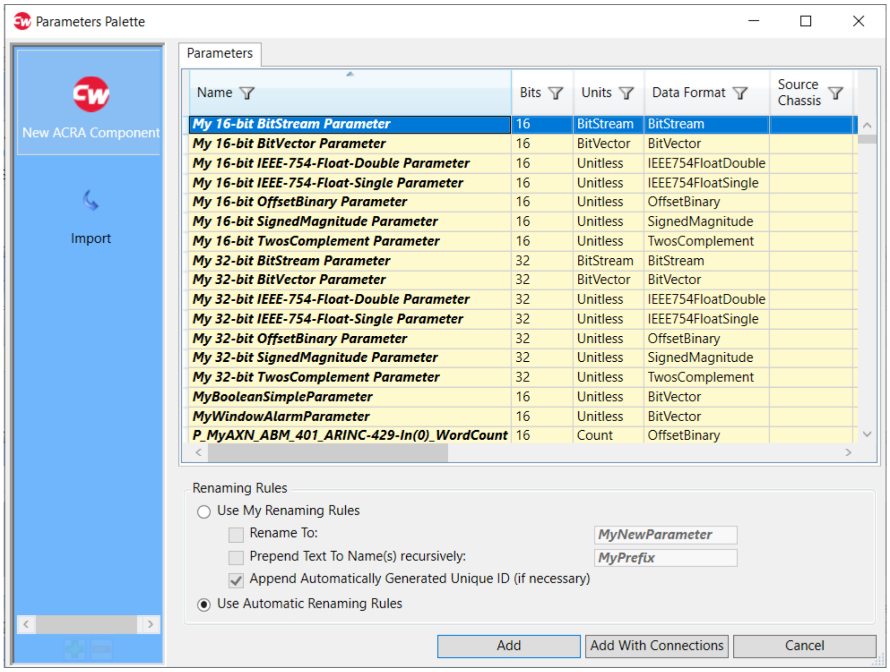
1. On the **Packages** tab of the KAM/TCG/105, click the arrow under **Package Properties**.
   The following screen with the 15 predefined NMEA messages supported by the KAM/TCG/105 appears.



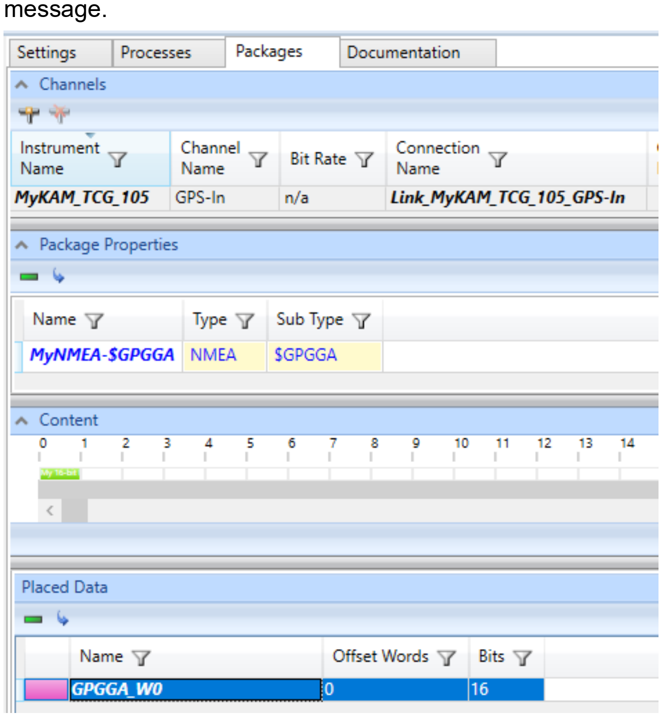
2. Select a message to parse (for example **$GPGGA**) and then click **Add**.
   The new NMEA is created.



3. Click the arrow under **Placed Data**.
**Parameters Palette** appears.




4. Select a 16-bit parameter such as **My 16-bit BitStream Parameter** and then click **Add**.
A generic 16-bit parameter with the default message name and offset 0 is created. This can be renamed to a more meaningful name such as **GPGGA_W0** (see following screen), which corresponds to the first two bytes of the $GPGGA message.




In the previous example, the first data word with offset 0 for $GPGGA has the following result: $G, a second word with offset 1 results in PG and so on. Additional data words can be added up to a maximum offset of 41 (the maximum supported length of full NMEA 0183 messages is 82 characters). Full NMEA 0183 messages consist of a maximum of 79 characters between start of message "$" or "!" and terminating delimiter <CR><LF> (HEX 0D and 0A).

An additional Info register associated with each NMEA message to indicate the status of the message can be added. See “56.4.3.2 Parsers – Setting up MessageInfo” on page 524.

## 56.4.3 Processes tab

The following Processes tab shows available processes for the module. The processes shown in the Processes tab are defined in the *KAM/TCG/105* data sheet.

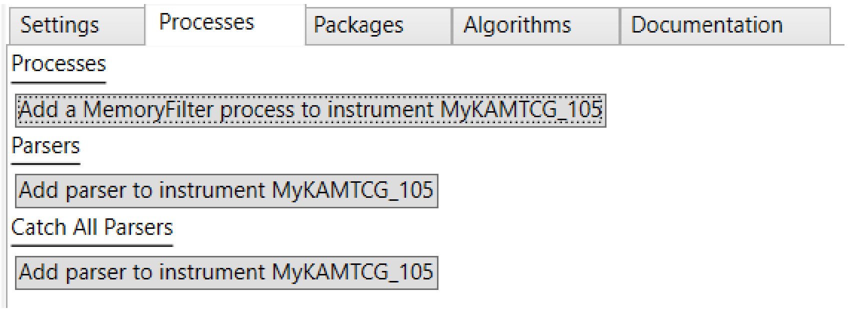



*Figure 56-5: Processes tab showing available processes*

### 56.4.3.1 MemoryFilter

The MemoryFilter process drives the MEM_STATUS(1:0) outputs of the KAM/TCG/105 by assigning the MEM Status register to it. To carry out this process, a KAM/MEM/003, KAM/MEM/103, or KAM/MEM/004 is required in the chassis where the KAM/TCG/105 is located. For further details on how to use a process, refer to the "Processes tab" section in the *DAS Studio User Manual*. As shown in the following figure, the default name of MEM Status parameter is FlashCard_Status and can be selected from the palette.

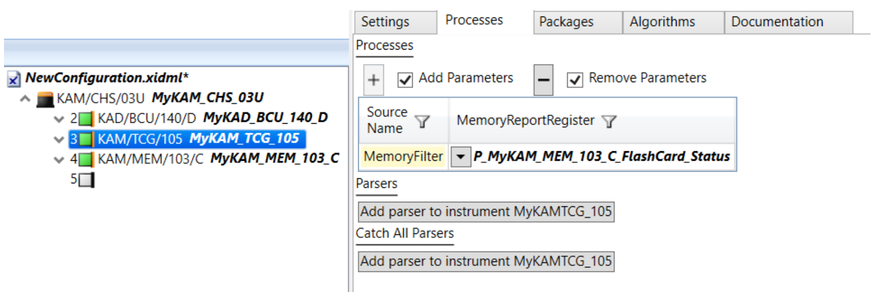



*Figure 56-6: Processes tab example showing the KAM/MEM/103/C Status to drive the TCG/105 MEM_STATUS(1:0)*

---

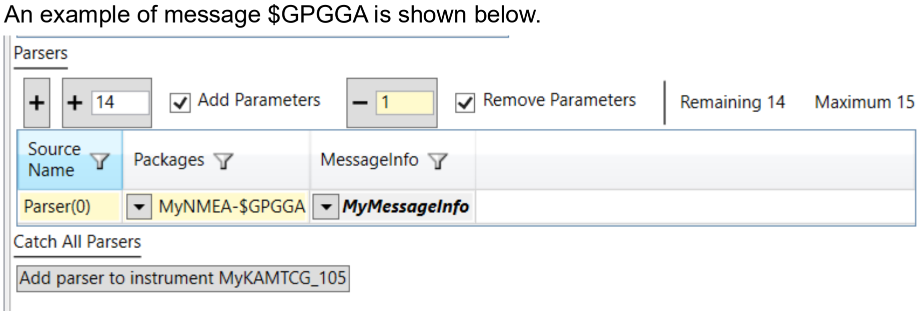
**NOTE:** The KAM/TCG/106 only supports one MEM_STATUS output showing whether the MEM is logging or not.

### 56.4.3.2 Parsers – Setting up MessageInfo

The MessageInfo register indicates the status of the message as empty (no message), stale (repeated) and skipped. The Parsers process allows you to associate the MessageInfo parameter with one of the 15 predefined NMEA packages previously set in "56.4.2 Packages tab - setting parser of NMEA packages" on page 521.

Refer to the following to create the MessageInfo.

1. On the **Processes** tab, click **Add parser to instrument KAM/TCG/105**".
2. Click **Packages** and then click **Add package reference**.
3. Select one of the NMEA packages already added in the packages tab and then click **Add reference**.
   An example of message $GPGGA is shown below.



**NOTE:** For further details on how to use a process, refer to the "Processes tab" section in the *DAS Studio User Manual*.

#### 56.4.3.3 Catch All Parsers

Any package that is not assigned to a parser is sent to this catchall parser where it can be sampled if required. Unlike Parsers, Catch All Parsers automatically sets 41 words and MessageInfo.

This feature is not recommended and should be used as a debug tool only.

## 56.5 Example configurations

### 56.5.1 External GPS receiving NMEA messages over RS-422

The setup for an external GPS receiving NMEA RS-422 at 19,200 bps is shown in the following three figures.

**NOTE:** For the following three sample configurations, it is assumed that the secondary input IRIG is not used.

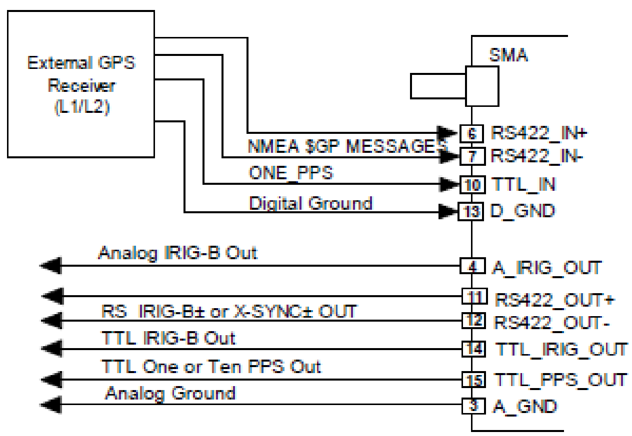



*Figure 56-7: Setup for external GPS receiving RS-422*

| Time Server | Primary Input | Allow Secondary | Control Function Source |
|---|---|---|---|
| Master | GPS | ☑ | Zeros |

| Source Name | GPS Source | PPS Source | Maximum Dilution Of Precision | Baud Rate |
|---|---|---|---|---|
| *Link_MyKAM_TCG_105_GPS-In* | RS-422 | TTL_A | 5 | 19200 |

*Figure 56-8: Example of setup for external GPS receiving RS-422 in DAS Studio 3*

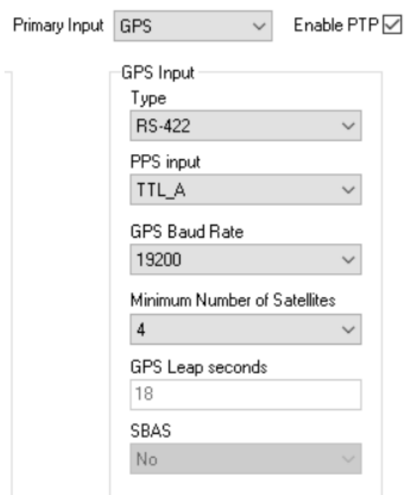



*Figure 56-9: Example of setup for external GPS receiving RS-422 in kSetup*

---

**NOTE:** ONE_PPS is required for the KAM/TCG/105 to synchronize its time with the minimum set of external NMEA messages.

## 56.5.2 Active GPS antenna

The setup for an active GPS antenna is shown in the following three figures.

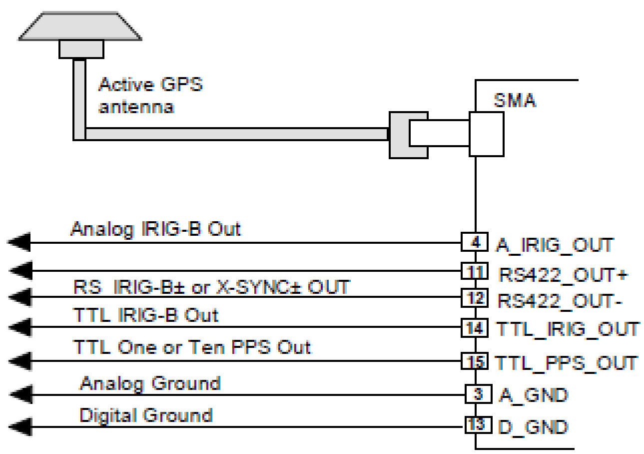
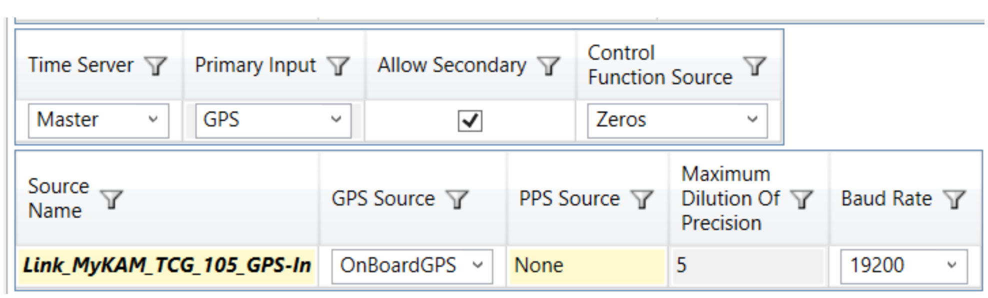



*Figure 56-10: Setup for active GPS antenna*



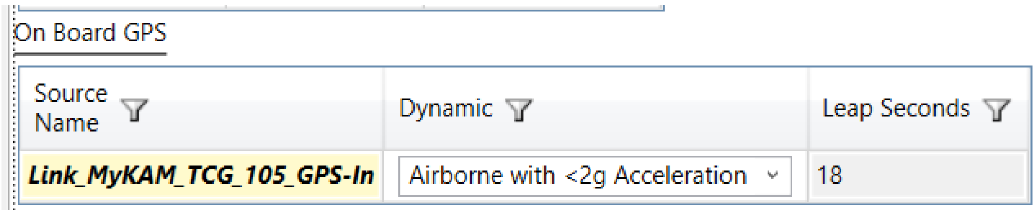



*Figure 56-11: Example of setup for active GPS antenna in DAS Studio 3*

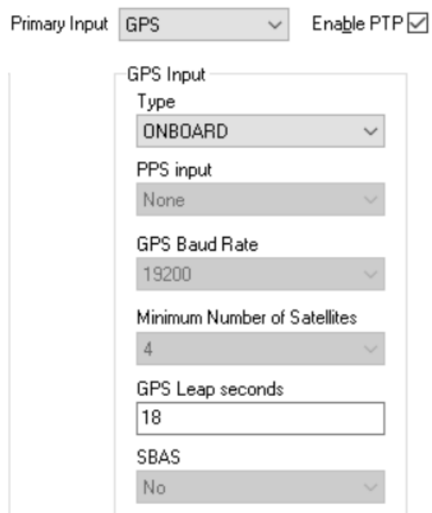



*Figure 56-12: Example of setup for active GPS antenna in kSetup*

**NOTE:** Leap Seconds is an important setting when GPS onboard is used. Refer to *TEC/NOT/072 — Time and leap seconds*. Baud Rate is not used when the GPS Source is set to OnBoard GPS.

## 56.5.3 External GPS receiver using NMEA messages over RS-232 and one PPS TTL

The setup for an external GPS receiver using NMEA RS-232 at 19,200bps and TTL_IN_A one PPS is shown in the following three figures.

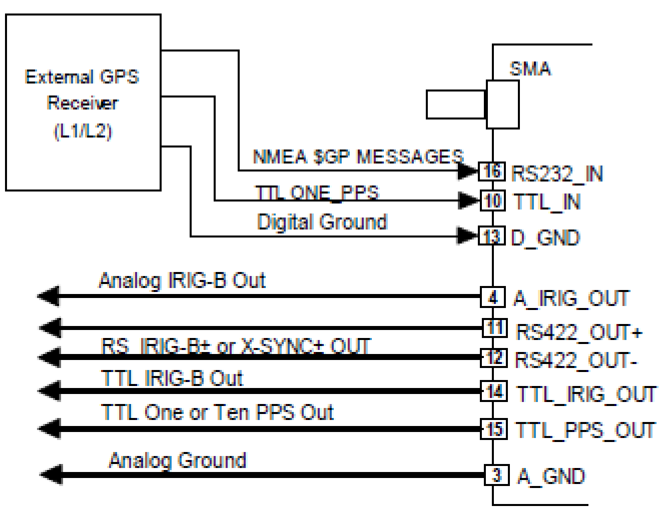



*Figure 56-13: Setup for external GPS receiver using RS-232 and TTL PPS*

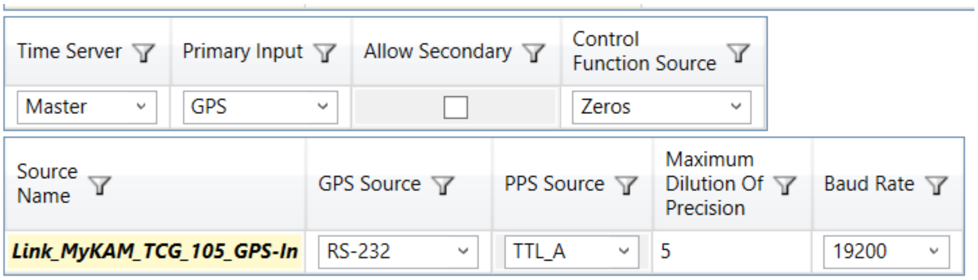



*Figure 56-14: Example of setup for external GPS receiver using RS-232 and TTL in DAS Studio 3*

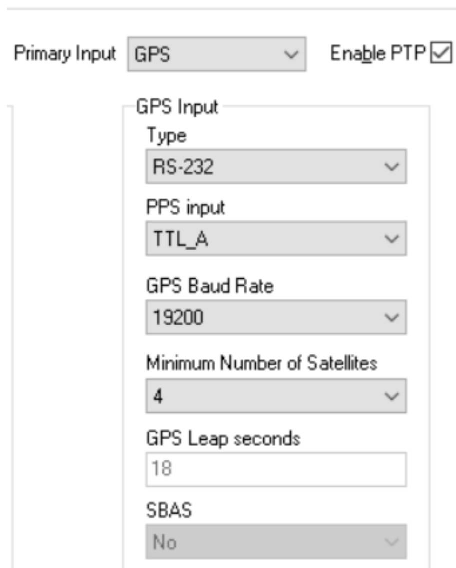



*Figure 56-15: Example of setup for external GPS receiver using RS-232 and TTL in kSetup*

## 56.5.4 Analog IRIG-B input

The setup for an analog IRIG-B input is shown in the following three figures.

---

**NOTE:** Analog IRIG-B only support 1 PPS signal over pin 9 TTL_IN_B.

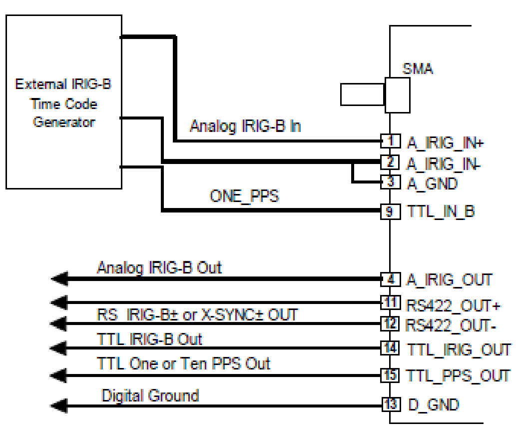



*Figure 56-16: Setup for analog IRIG-B input with 1 TTL PPS*

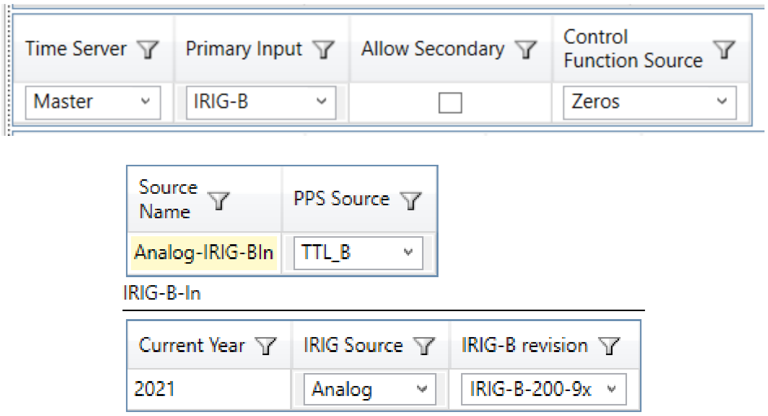



*Figure 56-17: Example of setup for analog IRIG-B input with 1 PPS in DAS Studio 3*

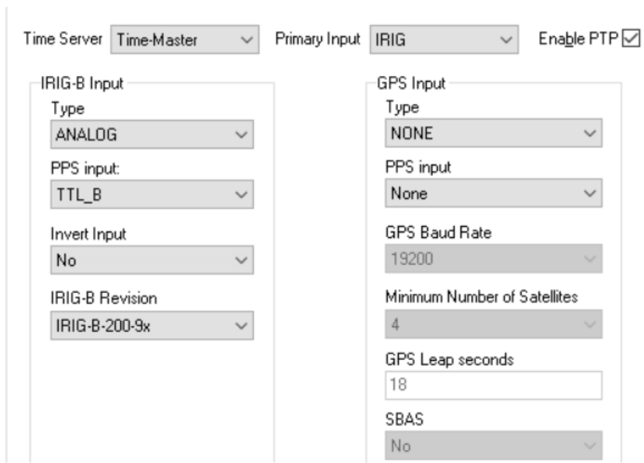



*Figure 56-18: Example of setup for analog IRIG-B with 1 PPS input in kSetup*

---

**NOTE:** ONE_PPS connection is optional on the previous figure, however it is recommended in order to increase accuracy. When IRIG-B-200-04 is selected, the module decodes the year from the control function (CF) bits, however IRIG-B-200-9x does not contain year information.

## 56.5.5 Digital IRIG-B input - TTL

The setup for a digital IRIG-B input is shown in the following three figures.

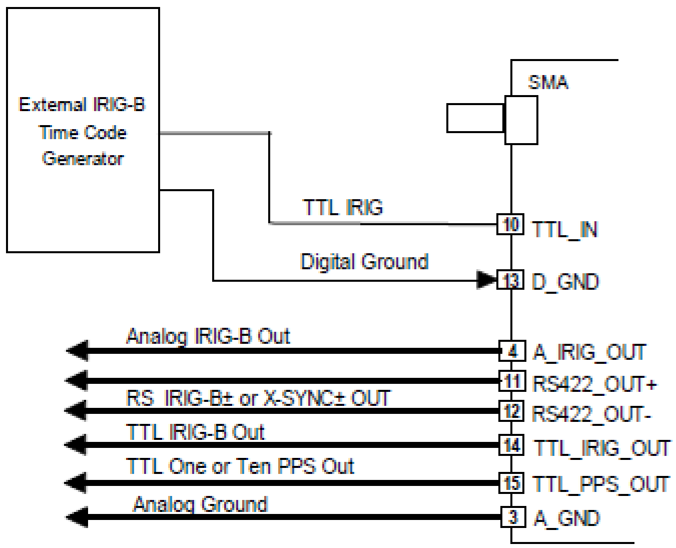



*Figure 56-19: Setup for digital IRIG-B input*

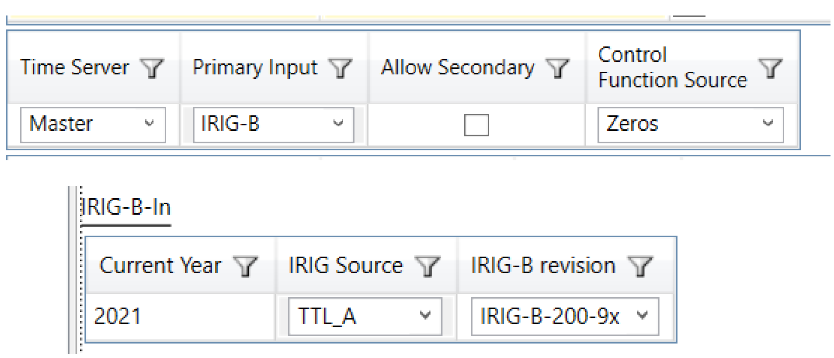



*Figure 56-20: Example of setup for digital IRIG-B input in DAS Studio 3*

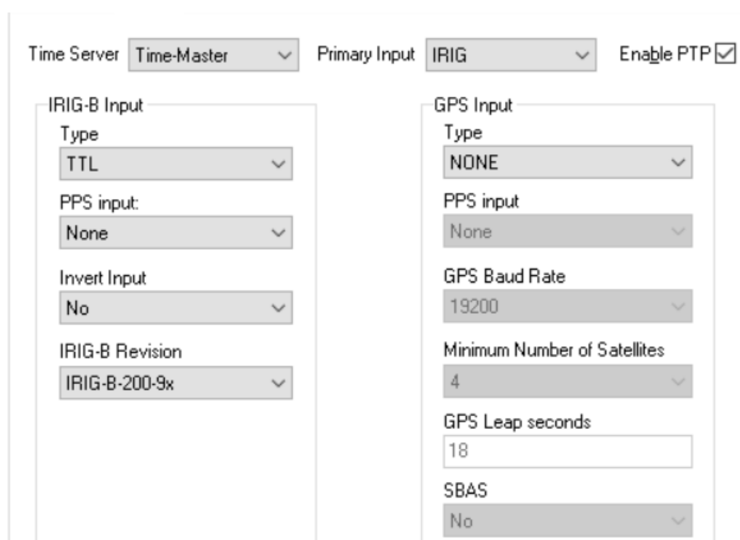



*Figure 56-21: Example of setup for digital IRIG-B input in kSetup*

## 56.5.6 Digital IRIG-B input - RS-422

The setup for a RS-422 IRIG-B input is shown in the following three figures.

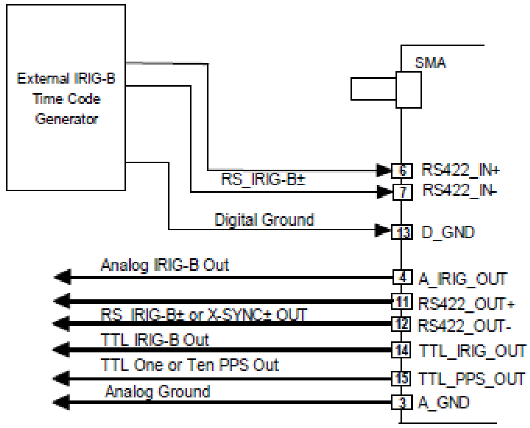



*Figure 56-22: Setup for RS-422 IRIG-B input*

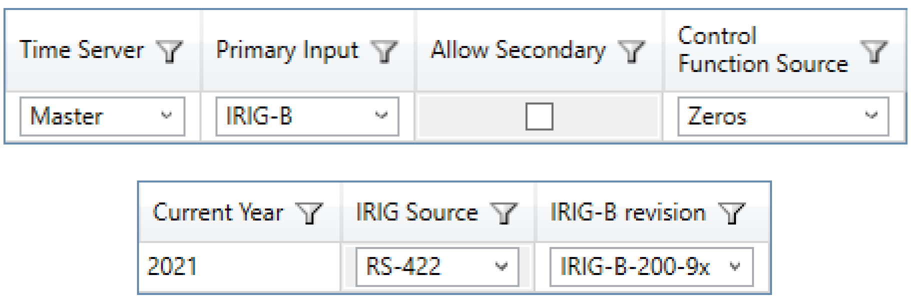



*Figure 56-23: Example of setup for RS-422 IRIG-B input in DAS Studio 3*

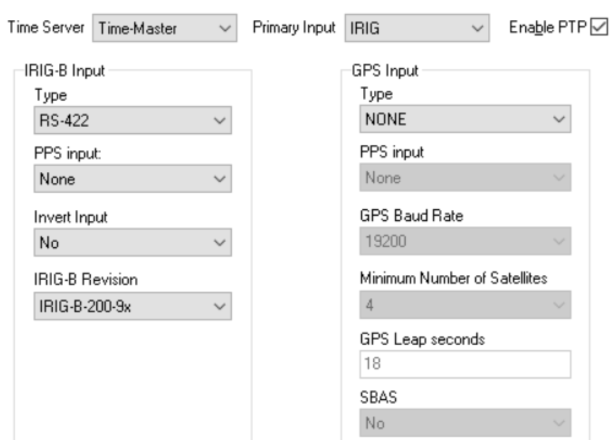



*Figure 56-24: Example of setup for RS-422 IRIG-B input in kSetup*

## 56.5.7 RTC input

When the module is set to RTC, the seeded time is loaded from the RTC. The initial time can be set from the PC using either Time Seeder (refer to the *DAS Studio User Manual*) or kTimeseed (KSM-500 tool)

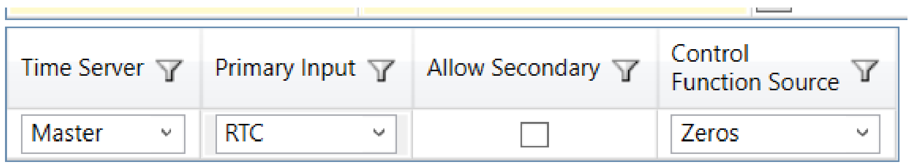



*Figure 56-25: Example of setup for RTC DAS Studio 3*

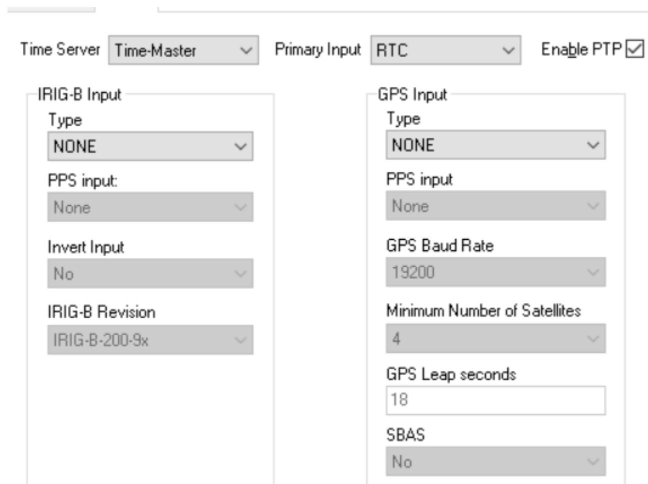



*Figure 56-26: Example of setup for RTC in kSetup*

**NOTE:** Time Seeder and kTimeSeed also support the KAM/TCG/106.
In RTC mode, the KAM/TCG/105 does not get GPS nor IRIG information even if they are physically connected.

# 56.6 Troubleshooting GPS

This section explains the most common issues with GPS. For GPS antenna recommendations, see the *KAM/TCG/105* data sheet.

## 56.6.1 GPS not in lock

Check the StatusGPS parameter. This parameter provides information on the current GPS status, such as GPS lock, Dilution of Precision (DOP) in and out of range, and number of satellites in use.

**NOTE:** Bit 15 of the StatusGPS parameter defaults to 0, which indicates the module does not have GPS lock. Bit 15 is only set to 1 when the GPS receiver has achieved GPS lock.

If bit 15 remains at 0, the module is unable to achieve GPS lock and there are problems with satellite coverage. This may be due to poor satellite coverage or issues with the GPS antenna or cabling.

If bit 15 is set to 1 (GPS lock) but the position is incorrect, check bit 11. If bit 11 of the StatusGPS parameter is set to 1, this indicates that the DOP figures are out of range. The actual DOP figures can be read from the DilutionOfPrecision parameter.

Also, check the number of satellites in view (StatusGPS[7:4]) and the number of satellites in use (StatusGPS[3:0]). If the number of satellites in view is less than four, try the other troubleshooting hints in this section.

**NOTE:** The antenna must be connected before powering up the Acra KAM-500 chassis with the KAM/TCG/105.

## 56.6.2 Multipath errors

A multipath environment exists if GPS signals arrive at the antenna directly from the satellite and also from reflective surfaces, for example water or building walls (see Multipath environment).

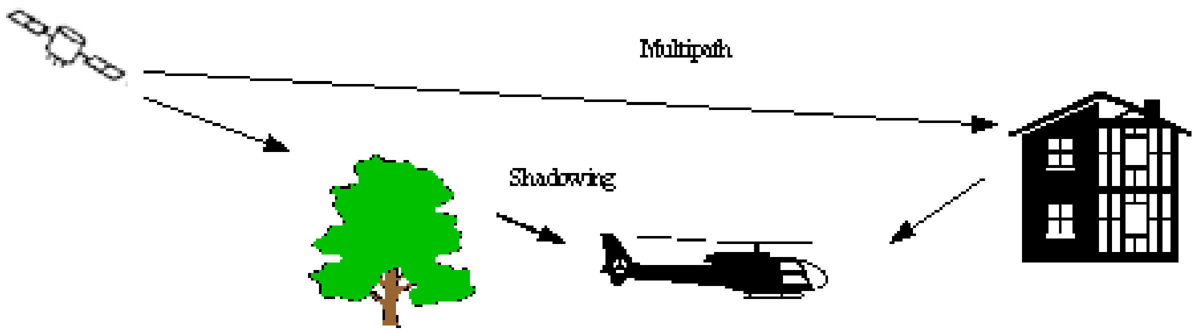



*Figure 56-27: Multipath environment*

If there is a direct path in addition to the reflected path available, the receiver can usually detect the situation and compensate to some extent. If there is no direct line of sight, but only reflections, the receiver is not able to detect the situation.

Under multipath conditions, range measurement to the satellite provides incorrect information to the navigation solution, resulting in less accurate positioning. If there are few satellites in view, the navigation solution might be wrong by several hundred meters.

Location of the antenna close to a vertical metal surface can be harmful owing to the fact that metal is an almost perfect reflector. When mounting an antenna on top of a reflective surface, the antenna should be mounted as close to the surface as possible. Then, the reflective surface acts as an extension of the antennas ground place and not as a source multipath.

### 56.6.3 Antenna shortcomings

Although GPS can work with a weak signal, to have a reliable GPS system the antenna selection and location should be considered carefully as inappropriate selection and poor location degrades GPS performance. Factors which degrade the GPS performance include the following:

- Inadequate gain of the GPS antenna
- Poor directivity of the GPS antenna
- Improper orientation of the antenna to the sky
- Poor matching of antenna, cable, and receiver impedance
- Poor noise performance of the input stage of the antenna amplifier
- GPS antenna is connected to the module after the KAM-500 is powered up.

For more information on getting the most from the antenna, see the *KAM/TCG/105* data sheet.

## 56.7 Tips

### 56.7.1 Battery backup

The battery duration is specified to a maximum of four years on the KAM/TCG/105. To replace the battery, the unit must be returned to Curtiss-Wright.

The KAM/TCG/106 is designed for use with an external battery; therefore the unit does not need to be returned to Curtiss-Wright for replacement.

### 56.7.2 Battery model

Contact Curtiss-Wright support (acra-support@curtisswright.com) for details.

### 56.7.3 Representing GPS position in GS Works

Contact Curtiss-Wright support (acra-support@curtisswright.com) to obtain a copy of technical document *TSD/AC/005 GS Works derive equation for TCG Altitude Latitude Longitude Heading.*

Latitude/Longitude are specified in degrees/minutes/seconds (DMS) in the *KAM/TCG/105* data sheet while some GPS localization system may express it in Decimal Degrees (DD).

## 56.7.4 Pulses Per Second (PPS)

No more than one PPS should be used with the KAM/TCG/105 as the Phase Locked Loop has been designed to work with one PPS only.

The PPS output is driven by the internal time on the KAM/TCG/105 so you always have 1 PPS regardless of the time source and even if there’s no time connected such as GPS or IRIG that is using the battery backup.

## 56.7.5 RFE/AEG/001

There are no special accessories required to mount this antenna; it is shipped complete for mounting. The antenna in this series is hard-mounted through a unique single hole feed structure and includes gaskets to prevent air and water leaks. The mounting is a through hole 5/8-18UNC-2A thread.

## 56.7.6 SMA torque setting

The recommended torque setting for the SMA connector on the KAM/TCG/105 is 0.45 Nm (0.33 foot pound-force).

# Using the KAD/ABM/103

TEC/NOT/086

This paper discusses the following topics:



## 57.1 ARINC-429 overview

ARINC-429 is the standard for the predominant avionics data bus used on most high-end commercial and transport aircraft.

Connected to the busses is a transmitter (source), a receiver (sink), or a transmitter and receiver (see the following figure). All data is transmitted over a single, twisted pair in one direction only.

**NOTE:** The first revision of the ARINC-429 mark 33 Digital Information Transfer System (DITS) was generated on 11 April 1978. The current specification is ARINC-429-10.

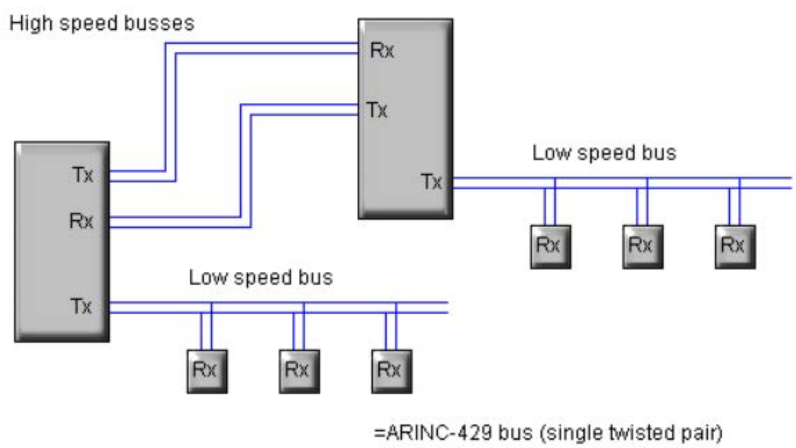



*Figure 57-1: An example of ARINC-429 architecture*

A transmitter (Tx) may transmit to up to 20 Receivers (Rx). If an Rx is required to acknowledge reception of data, another ARINC-429 Tx is required in the opposite direction.

Data is sent in single words identified by one of 255 Labels and a two-bit source/destination identifier.

## 57.1.1 Physical layer

Data is transmitted in a bipolar Return-to-Zero (RZ) format. This is a trilevel code (see the following figure).

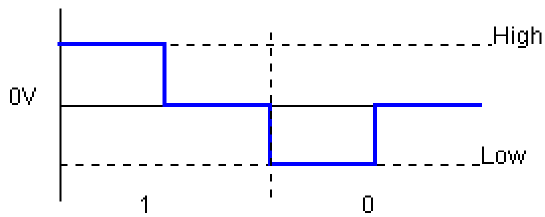



*Figure 57-2: ARINC-429's bipolar, RZ code*

For a Tx, the high (low) voltage must be +10V ±10% (-10V ±10%). A receiver must be specified to a minimum level of ±5V. The Tx output impedance is 75Ω (±5Ω) and a suitable 75Ω cable should be used.

Typically, there are two bit-rates: the high speed bus is 100 kbps and the low speed bus is between 12 and 14.5 kbps. Only one data rate is allowed per bus.

ARINC-429 also specifies the data rate tolerances and rise and fall times.

## 57.1.2 Word definition

The following figure illustrates the generic format of an ARINC-429 word.

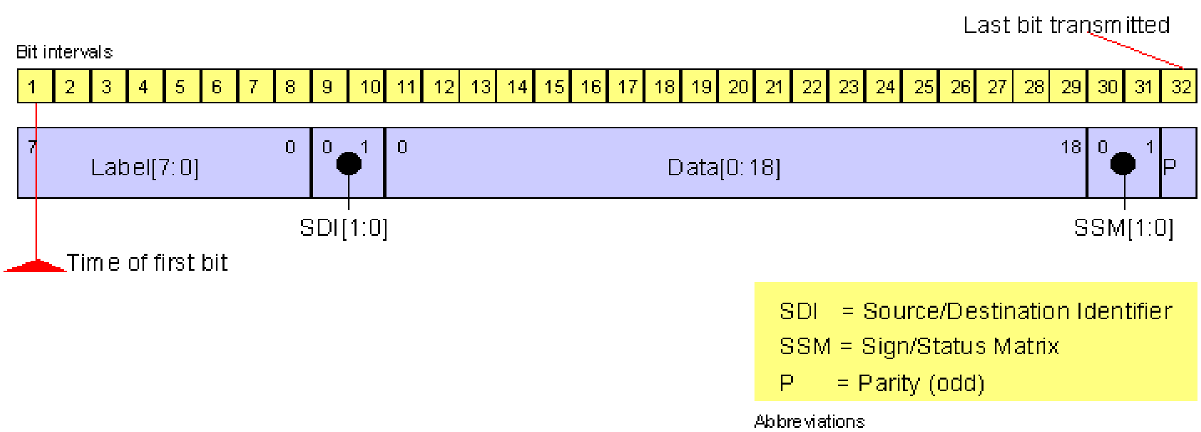



*Figure 57-3: Generic word definition for ARINC-429*

As shown in the previous figure, the eight-bit Label identifies the parameter being transmitted.

The main purpose of the Source/Destination Identifier (SDI) bits are to direct data words to a particular Rx. The SDI bits are not used with certain types of data.

The Sign/Status Matrix (SSM) bits are used to indicate plus or minus, north, south, east or west and so on for certain types of data, the word type for AIM (Acknowledge, ISO alphabet No. 5 and Maintenance) data and the status of the Tx. For binary data, bit 29 (Data18) is used to indicate sign.

There are five types of data words:

- Binary
- BCD subset of ISO Alphabet No. 5
- Discrete
- Maintenance
- AIM

Also, file transfer is supported.

## 57.2 Module overview

The KAD/ABM/103 is a 24-channel ARINC-429 bus monitor which can parse and/or packetize each channel at the same time. It can coherently parse traffic and tags for up to 8191 messages and it can transmit aperiodically packetized ARINC-429 messages including tags as iNET-X parser-aligned, IENA D Type, or IENA N Type payload structures per channel or per instrument.

The sections below show screen shots and descriptions of settings in DAS Studio 3 software. DAS Studio 3 is used to create a configuration, which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

## 57.3 ARINC-429 bus monitor modules history

The following table below describes the different ARINC-429 bus monitor modules.

Table 57-1: ARINC-429 module history

| Module | Description |
|---|---|
| KAD/ARI/001/B | Legacy - ARINC-429 bus monitor parser/snarfer - 8ch |
| KAD/ABM/101 | Replacement of the KAD/ARI/001 |
| KAD/ABM/102/B | ARINC-429 bus monitor parser/packetizer - 8ch (The KAD/ABM/102 only supports packetizer) |
| KAD/ABM/103 | ARINC-429 bus monitor parser/packetizer - 24ch |

**NOTE:** Packetizer cannot be used over PCM. An aperiodic sink is required for the packetizer operation such as the KAD/BCU/140 or KAM/MEM/113.

## 57.4 Parser operation

### 57.4.1 How parsing works

Like other Curtiss-Wright bus monitors, the KAD/ABM/103 uses a triple buffer for parsing. The following figure illustrates the triple buffering of data words (green) and message tags (white) used for each bus in the KAD/ABM/103's parser.

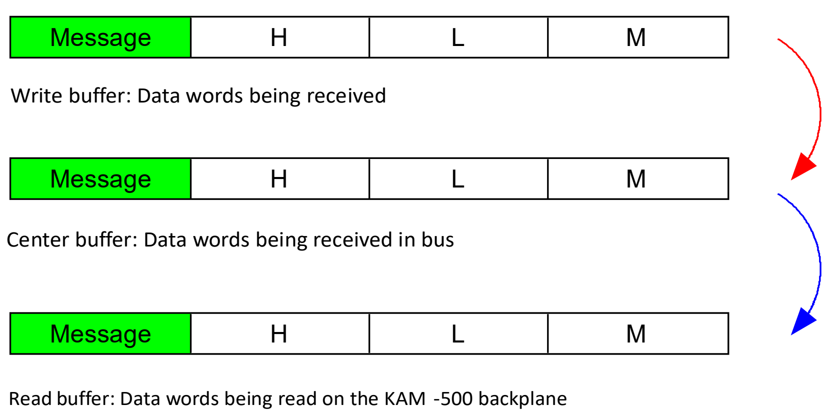



*Figure 57-4: Triple buffering of traffic and associated message tags*

Message corresponds to MessageDataStyle as described in the module data sheet.

The time tags H, L, M correspond to High time, Low time and Micro time, which is the time midway through the first transmitted bit. It has a 1-µsec resolution.

The way triple buffering works is as follows:

Time message tags are added to each message received and stored in separate buffers for each of the four busses. As soon as a message is received with no errors, the contents of the write buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped flag is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane, the contents of the center buffer (if new) are transferred to the read buffer. If no new data word has been received, the stale flag is set. A center and read buffer exist for every message ID (parser slot). Skipped and stale bits can be found in the Message Info register to indicate whether messages have been lost or repeated (undersampling or oversampling situations).

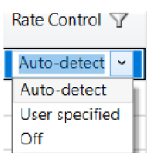
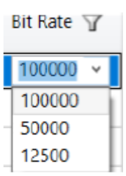
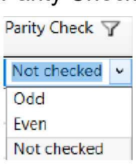
A Message Count register is also available as additional information and can be added from DAS Studio's ARINC-429 Builder application as explained in section "57.4.3 Defining parsing rules" on page 538. For further information regarding this register refer to the *KAD/ABM/103* data sheet.

## 57.4.2 Module Settings tab

---

**NOTE:** To view the screen shots shown in this section in DAS Studio 3, ensure the KAD/ABM/103 module is in context and the Settings tab is selected.

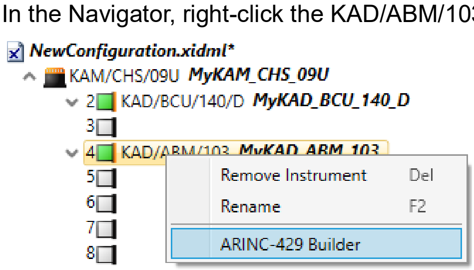
Before using the module, you need to define Rate Control and Parity Check.

| Setting | Description |
|---|---|
| Rate Control   | Auto-detect: module detects bus speed automatically.<br>User specified: restricts reception to specific bus rate. Because DAS Studio automatically calculates the packetizer rate according to the ARINC-429 bit rate when verifying the XidML file, this should be set if using a lower ARINC-429 bit rate than 100 kbps and packetizer in order to make the backplane scheduling easier.<br>Off: no messages are parsed or packetized from channel. |
| Bit Rate   | Input bus bit rate. (Auto-detected bit rate sets to maximum to reserve backplane capacity for maximum rate. Note: 50 kbps is a non-standard ARINC-429 rate. |
| Parity Check   | Parity settings configures whether parity bit is present in incoming data. It can be set to Not checked, Even Parity, or Odd Parity.<br>Not checked means the parity bit in the ARINC-429 message parser/packetizer is not checked. Odd Parity/Even Parity means the parity bit in the ARINC-429 message is checked against the bits received. If there's a parity error, the REPORT word reports it and the error code is set accordingly in the packetizer packet. |

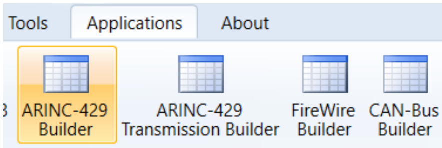
## 57.4.3 Defining parsing rules

After you have all channel settings configured, refer to the following to define rules to identify messages.

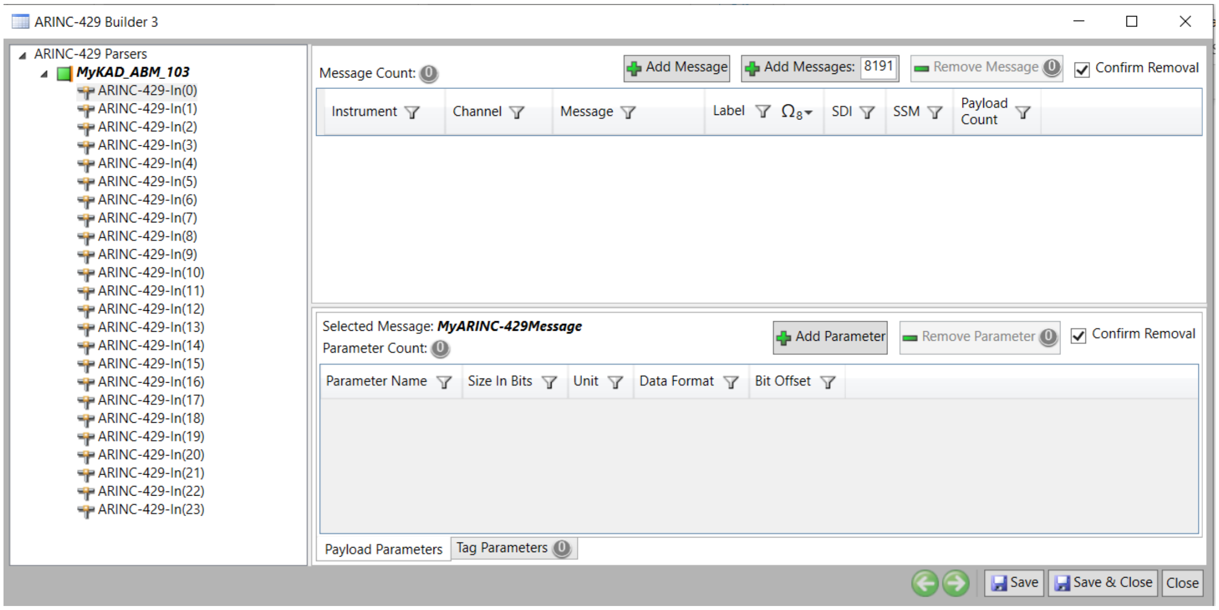
1. Do one of the following.
   - In the Navigator, right-click the KAD/ABM/103 module and then click **ARINC-429 Builder**.



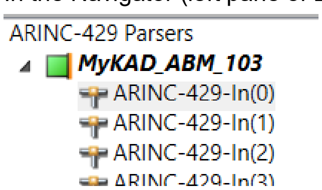
- On the **Applications** menu click **ARINC-429 Builder**.



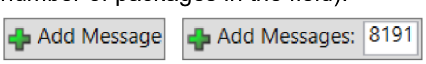

The **ARINC-429 Builder** application opens.




2. In the Navigator (left pane of Builder application), select the channel on the KAD/ABM/103 that you want to parse data off.



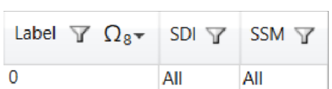

3. Click **Add Message** to add a single message. To add multiple messages (up to 8191), click **Add Messages** (typing the number of packages in the field).



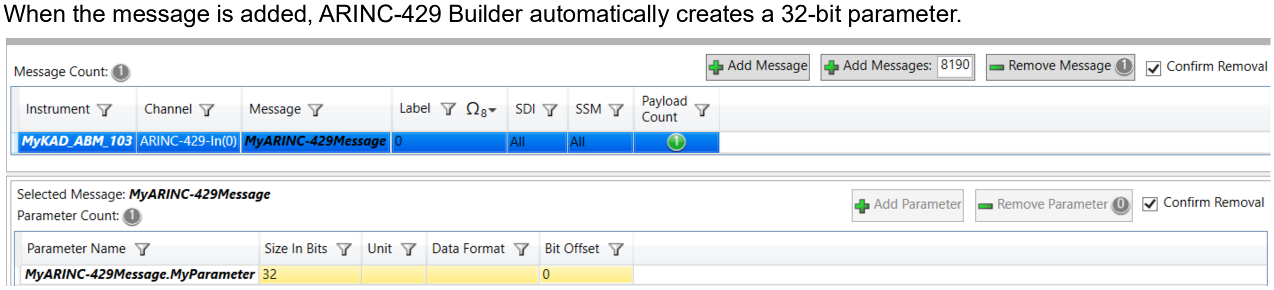

Now you must define the rules to identify or parse the desired message.

4. Define **Label**.

   The default is **Octal** as indicated by $\Omega_8$. Values can be from **0** to **255** in decimal.



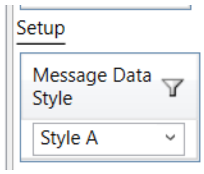

5. Define **SDI** and **SSM**.
   These can be either **All**, **00**, **01**, **10** or **01**. **All** being the wildcard.
6. Click **Add Message** to add the message.
   When the message is added, ARINC-429 Builder automatically creates a 32-bit parameter.



Although the parameter has 32 bits, it has a different layout than the 32-bit ARINC-429 message defined in “57.1 ARINC-429 overview” on page 535. This is because the message is parsed using the label; the parameter itself doesn’t contain the label.

7. Click **Save & Close** to save your changes and close **ARINC-429 Builder**.


8. With the KAD/ABM/103 selected, click the **Settings** tab.
9. To program the Message Data Style, click the **Message Data Style** drop-down menu and choose **Style A** or **Style B**.




Style A = MessageDataStyleA and is defined as:

R[31:0]

R[31:30] SSM - Sign/Status Matrix.

R[29:11] Data - Data Word.

R[10:9] SDI - Source Destination Identifier.

R(8) Empty - This parser slot has not been written to yet.

R(7) Stale - This parser slot has been read before.

R(6) Skipped - This parser slot has been overwritten without being read.

R[5:1] Bus - The bus the message was received on.

R(0) Parity - The parity bit received.

Style B = MessageDataStyleB (see “57.8 MessageStyleB” on page 542) and is defined as:

R[31:0]

R(31) Parity - The parity bit received.

R[30:29] SSM - Sign/Status Matrix.

R[28:20] Data[18:10] - Bits 18 to 10 of the Data Word.

R[19:17] Bus - The bus the message was received on (3 least significant bits only).

R(16) Reserved

R[15:6] Data[9:0] - Bits 9 to 0 of the Data Word.

R[5:4] SDI - Source Destination Identifier.

R(3) Empty - This parser slot has not been written to yet.

R(2) Stale - This parser slot has been read before.

R(1) Skipped - This parser slot has been overwritten without being read.

R(0) Reserved

Messages are saved to the configuration file and parameters become available to be placed to any sinks in the chassis such as a PCM stream or placed packet.

---

**NOTE:** Tags such at the Message Time, Message count can be enabled on the Tag Parameters tab of the ARINC-429 Builder as shown below. The tags are described in the KAD/ABM/103 data sheet.

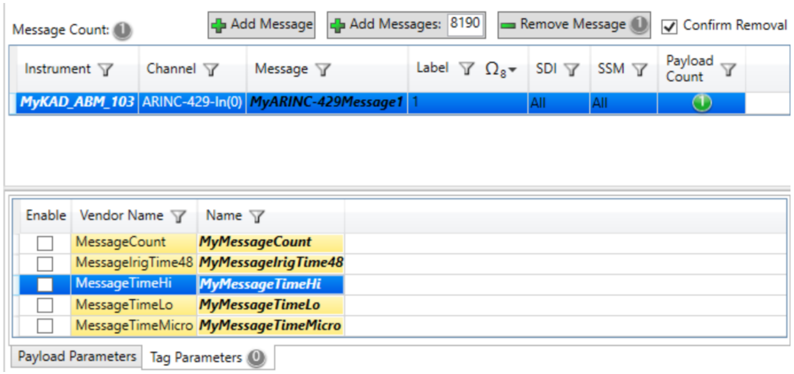



*Figure 57-5: Tag Parameters tab*

## 57.5 Packetizer operation

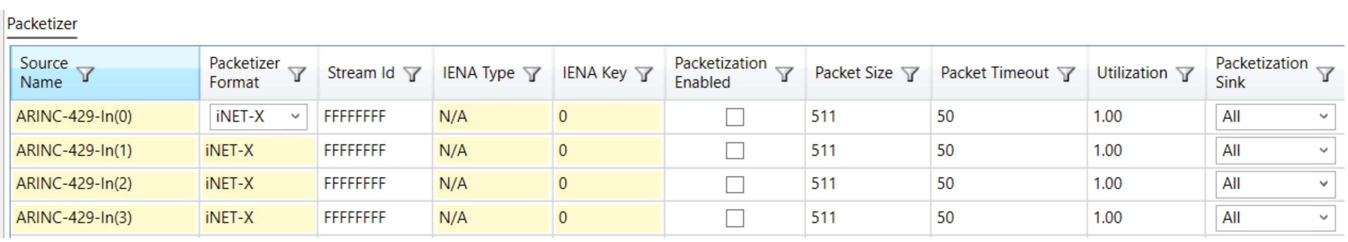
Independently of the parser, a packetizer stream is generated for each channel or per instrument. All received ARINC-429 messages are encapsulated in an iNET-X parser-aligned or IENA Type N/D payload structure. A block header attached to each sequence stores the channel index, length, and the time each message is received. These parser-aligned packets may be transmitted aperiodically to optimize network bandwidth utilization and memory usage when recording ARINC-429 traffic.

There are many settings available to configure or tune packetizer behavior.

---

**NOTE:** To view the screen shots shown in this section in DAS Studio 3, ensure the KAD/ABM/103 module is in context and the Settings tab is selected.

The available packetizer settings are shown in the following figure and described in the table that follows.


Packetizer

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Packetization Enabled | Packet Size | Packet Timeout | Utilization | Packetization Sink |
|---|---|---|---|---|---|---|---|---|---|
| ARINC-429-In(0) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |
| ARINC-429-In(1) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |
| ARINC-429-In(2) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |
| ARINC-429-In(3) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |

*Figure 57-6: Packetizer settings*

| Setting | Description |
|---|---|
| Source Name | Channel to packetize |
| Packetizer Format | iNET-X, IENA or IENA-iNET-X hybrid.<br>Note: IENA-iNET-X hybrid is a non-standard format. |
| Stream ID | iNET-X stream identifier for selected channel if a packet is generated via the assertion of Packetization Enabled. This is a conditional setting and is only active when the Packetizer Format is set to iNET-X. |
| IENA Type | IENA Type D or Type N packet payload. |
| IENA Key | IENA Key for selected channel if a packet is generated via the assertion of Packetization Enabled. |
| Packetization Enabled | Enables the transmission of a packetizer packet containing the contents of this channel if a packetizer transmitter or memory module is present in the chassis.<br>DAS Studio automatically creates a packetizer packet after verification/programming. |
| Packet Size | The number of words in the packet buffer, ranges from 200 words to 511 words. The default value is 511 words; reducing this value results in smaller and therefore generally more frequent packets. |

| Setting | Description |
|---|---|
| Packet Timeout | The timeout in milliseconds before a packet is generated if insufficient messages have been received to reach the Packet Size. Packets generated due to Packet Timeout are tagged in the iNET-X header. The Packet Timeout ranges from 10 ms to 999 ms (default value is 50 ms). Reducing this value results in more frequent and generally smaller packets. Increasing the value results in less frequent, but generally bigger packets. |
| Utilization | The default of 1.0 should be used as it provides sufficient packets to carry all messages even when the bus is 100% active. Reducing Utilization schedules less packets for this bus, releasing backplane capacity for reading other modules. It should only be used when incoming message rates on the bus are known to be less than the maximum possible rate. |
| Packetization Sink | Selects which modules the packetizer package is sent to for transmission or storage. The choices are **Controller only**, **All slots** or **Slot** in which a sink module that supports packetizer logging such as KAM/MEM/113 is placed. For example, on a system consisting of KAD/BCU/140 controller on J2, KAD/ABM/103 on J3, and KAM/MEM/113 on J4, setting up **Slot 4** creates packetizer packets on the KAM/MEM/113 only and setting up **All** creates packets on both KAD/BCU/140 and KAM/MEM/113. |

For further information regarding iNET-X parser aligned packets used by the packetizer, refer to *TEC/NOT/067 - IENA and iNET-X packet payload formats*.

## 57.6 Enabling packetizer

To turn on packetizer operation on any channel, define a unique stream ID for that channel and then select the **Packetization Enabled** check box for that channel as shown in the following figure. The packetizer is enabled the next time the module is programmed.

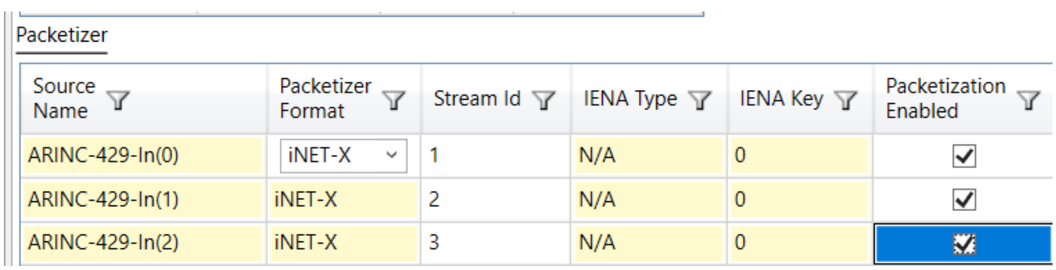
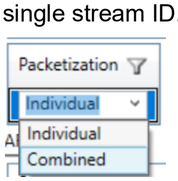



*Figure 57-7: Packetization Enabled setting*

**NOTE:** When Combined Packetization is selected, messages from all busses are placed in a single stream of packets, with a single stream ID. The bus ID field identifies on which bus a message was received.




## 57.7 Packet format

Refer to the “Getting the most from the KAD/ABM/103” section of the KAD/ABM/103 data sheet.

## 57.8 MessageStyleB

MessageStyleB was specifically designed for 12 bits of PCM. From this 32-bit parameter in PCM, you can reduce bandwidth by reducing it to the most necessary information such as Parity, SSM, Data and SDI.

When MessageStyleB is selected in the KAD/ABM/103 module Settings tab and you add parameter(s) using ARINC-429 Builder, DAS Studio 3 automatically and transparently creates 24-bit discrete parameters. These parameters are then available to be placed in the PCM as shown in the following figure.

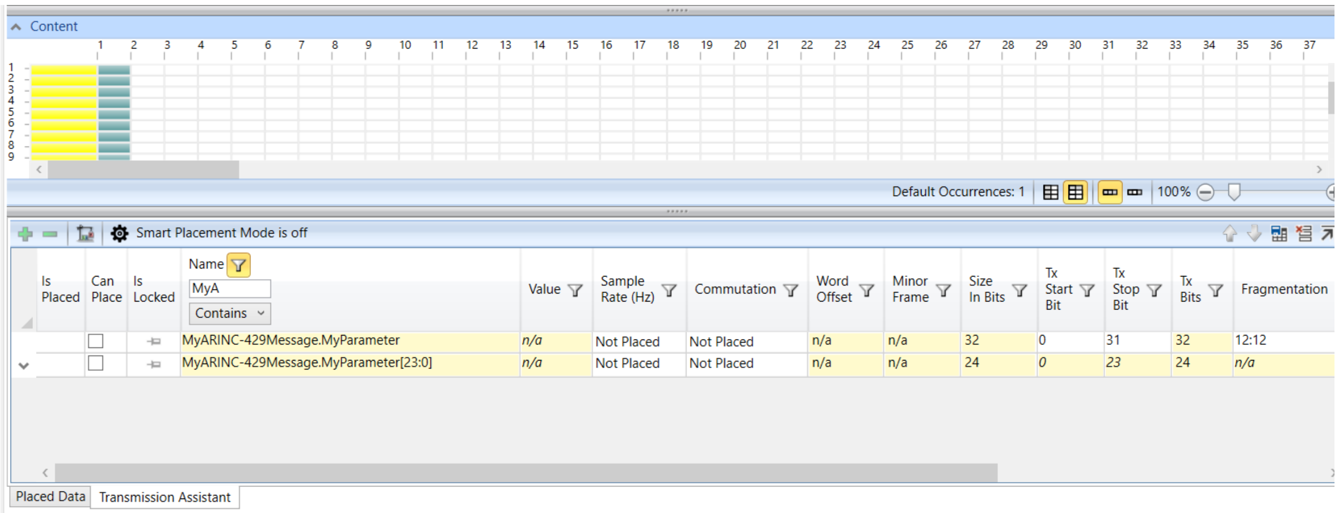



*Figure 57-8: MyARINC-429Message.MyParameter[23:0] 24-bit discrete parameter*

The previous figure shows the **MyARINC-429Message.MyParameter[23:0]** 24-bit discrete parameter. The following figure shows the bits that are used (gray bits are masked out).

| | Parity | SSM | | Data | | | | | | | | Bus | | | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |

| | Data | | | | | | | | | | SDI | | Empty | Stale | SKipped | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

R = Reserved

*Figure 57-9: MyARINC-429Message.MyParameter[23:0] used bits*

## 57.9 Related documentation

To better understand this paper, read the following documents.

Table 57-2: Data sheets

| Document | Description |
|---|---|
| KAD/ABM/103 | ARINC-429 bus monitor parser/packetizer - 24ch |

Table 57-3: Technical notes

| Document | Description |
|---|---|
| TEC/NOT/006 | ARINC-429 |
| TEC/NOT/052 | Using the KAD/ARI/001 |
| TEC/NOT/063 | Grounding and shielding of the Acra KAM-500 |
| TEC/NOT/067 | IENA and iNET-X packet payload formats |

Table 57-4: User manuals

| Document | Description |
|---|---|
| DOC/MAN/030 | DAS Studio 3 User Manual |

# Using the AXN/ABM/401

TEC/NOT/087

This paper discusses the following topics:



## 58.1 ARINC-429 overview

ARINC-429 is the standard for the predominant avionics data bus used on most high-end commercial and transport aircraft.

Connected to the busses is a transmitter (source), a receiver (sink), or a transmitter and receiver (see the following figure). All data is transmitted over a single, twisted pair in one direction only.

**NOTE:** The first revision of the ARINC-429 mark 33 Digital Information Transfer System (DITS) was generated on 11 April 1978. The current specification is ARINC-429-10.

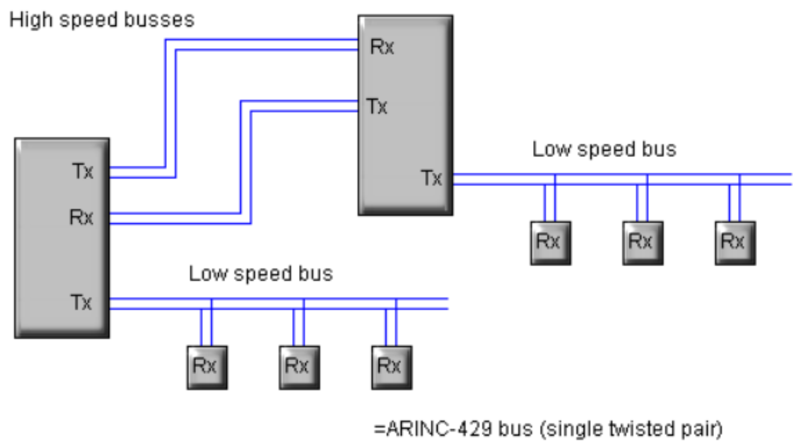



*Figure 58-1: An example of ARINC-429 architecture*

A transmitter (Tx) may transmit to up to 20 Receivers (Rx). If an Rx is required to acknowledge reception of data, another ARINC-429 Tx is required in the opposite direction.

Data is sent in single words identified by one of 255 Labels and a two-bit source/destination identifier.

### 58.1.1 Physical layer

Data is transmitted in a bipolar Return-to-Zero (RZ) format. This is a trilevel code (see the following figure).

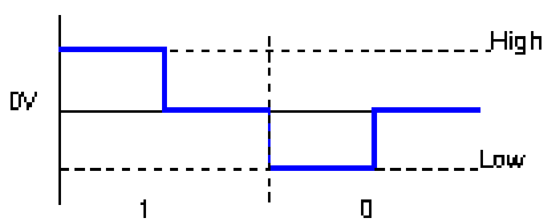



*Figure 58-2: ARINC-429's bipolar, RZ code*

For a Tx, the high (low) voltage must be +10V ±10% (-10V ±10%). A receiver must be specified to a minimum level of ±5V. The Tx output impedance is 75Ω (±5Ω) and a suitable 75Ω cable should be used.

Typically, there are two bit-rates: the high speed bus is 100 kbps and the low speed bus is between 12 and 14.5 kbps. Only one data rate is allowed per bus.

ARINC-429 also specifies the data rate tolerances and rise and fall times.

### 58.1.2 Word definition

The following figure illustrates the generic format of an ARINC-429 word.

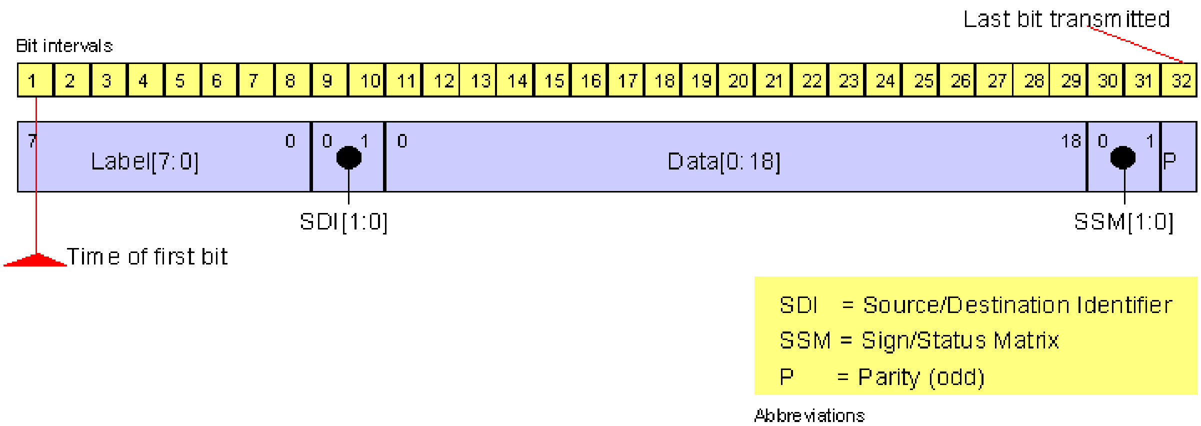



*Figure 58-3: Generic word definition for ARINC-429*

As shown in the previous figure, the eight-bit Label identifies the parameter being transmitted.

The main purpose of the Source/Destination Identifier (SDI) bits are to direct data words to a particular Rx. The SDI bits are not used with certain types of data.

The Sign/Status Matrix (SSM) bits are used to indicate plus or minus, north, south, east or west and so on for certain types of data, the word type for AIM (Acknowledge, ISO alphabet No. 5 and Maintenance) data and the status of the Tx. For binary data, bit 29 (Data18) is used to indicate sign.

There are five types of data words:

- Binary
- BCD subset of ISO Alphabet No. 5
- Discrete
- Maintenance
- AIM

Also, file transfer is supported.

## 58.2 Module overview

The AXN/ABM/401 is a 24-channel ARINC-429 bus monitor, which can parse and/or packetize each channel at the same time. It can coherently parse traffic and tags for up to 24575 messages and it can transmit aperiodically packetized ARINC-429 messages including tags as iNET-X parser-aligned, Chapter 10, IENA D Type, or IENA N Type payload structures per channel or per instrument.

The sections below show screen shots and descriptions of settings in DAS Studio 3 software. DAS Studio 3 is used to create a configuration, which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the DAS Studio 3 User Manual.

## 58.3 Parser operation

### 58.3.1 How parsing works

Like other Curtiss-Wright bus monitors, the AXN/ABM/401 uses a triple buffer for parsing. The following figure illustrates the triple buffering of data words (green) and message tags (white) used for each bus in the AXN/ABM/401's parser.

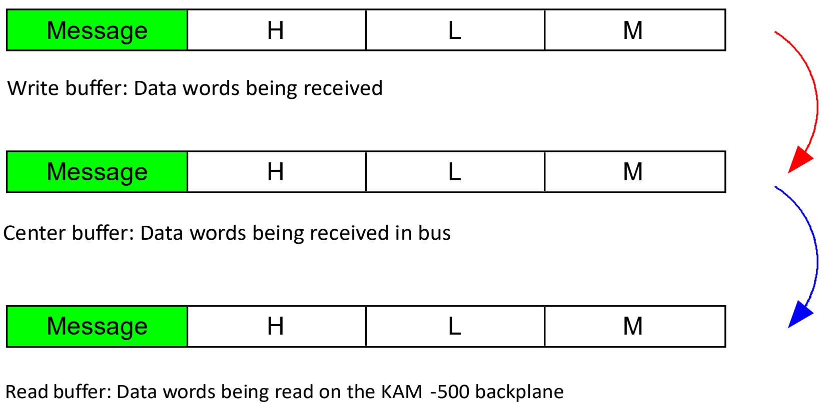



*Figure 58-4: Triple buffering of traffic and associated message tags*

Message corresponds to MessageDataStyle as described in the module data sheet.

The time tags H, L, M correspond to High time, Low time and Micro time, which is the time at the end of the first transmitted bit. It has a 1-µsec resolution.

The way triple buffering works is as follows:

Time message tags are added to each message received and stored in separate buffers for each of the busses. As soon as a message is received with no errors, the contents of the write buffer is transferred to the center buffer. If the data in the center buffer has not been transferred to a read buffer, a skipped flag is set.

As soon as the last parameter of interest has been read from the buffer being read by the backplane (read buffer), the contents of the center buffer (if new) are transferred to the read buffer. If no new data word has been received, the stale flag is set. A center and read buffer exist for every message ID (parser slot). Skipped and stale bits can be found in the Message Info register to indicate whether messages have been lost or repeated (undersampling or oversampling situations).

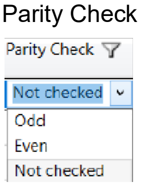
A Message Count register is also available as additional information and can be added from DAS Studio's ARINC-429 Builder application as explained in section Defining parsing rules. For further information regarding this register, refer to the AXN/ABM/401 data sheet.

### 58.3.2 Module Settings tab

---

**NOTE:** To view the screen shots shown in this section in DAS Studio 3, ensure the AXN/ABM/401 module is in context and the Settings tab is selected.

Before using the module, you need to define the Parity Check.

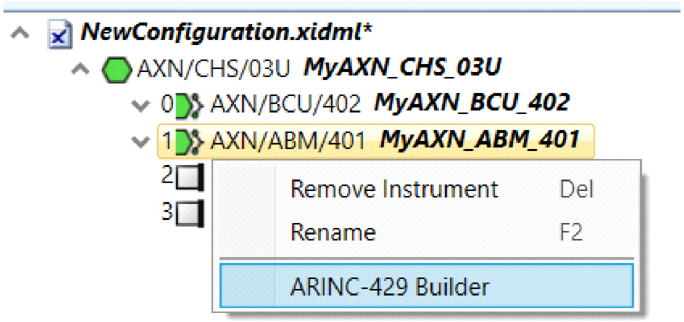
| Setting | Description |
|---|---|
| Parity Check   | Parity settings configures whether parity bit is present in incoming data. It can be set to Not checked, Even Parity, or Odd Parity.<br>Not checked means the parity bit in the ARINC-429 message parser/packetizer is not checked.<br>Odd Parity/Even Parity means the parity bit in the ARINC-429 message is checked against the bits received. If there's a parity error, the REPORT word reports it and the error code is set accordingly in the packetizer packet. |

The module will automatically detect the ARINC-429 signaling rate which can be either 12.5, 50, or 100 kbps.

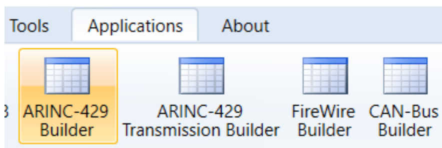
## 58.3.3 Defining parsing rules

After you have all channel settings configured, refer to the following to define rules to identify messages.

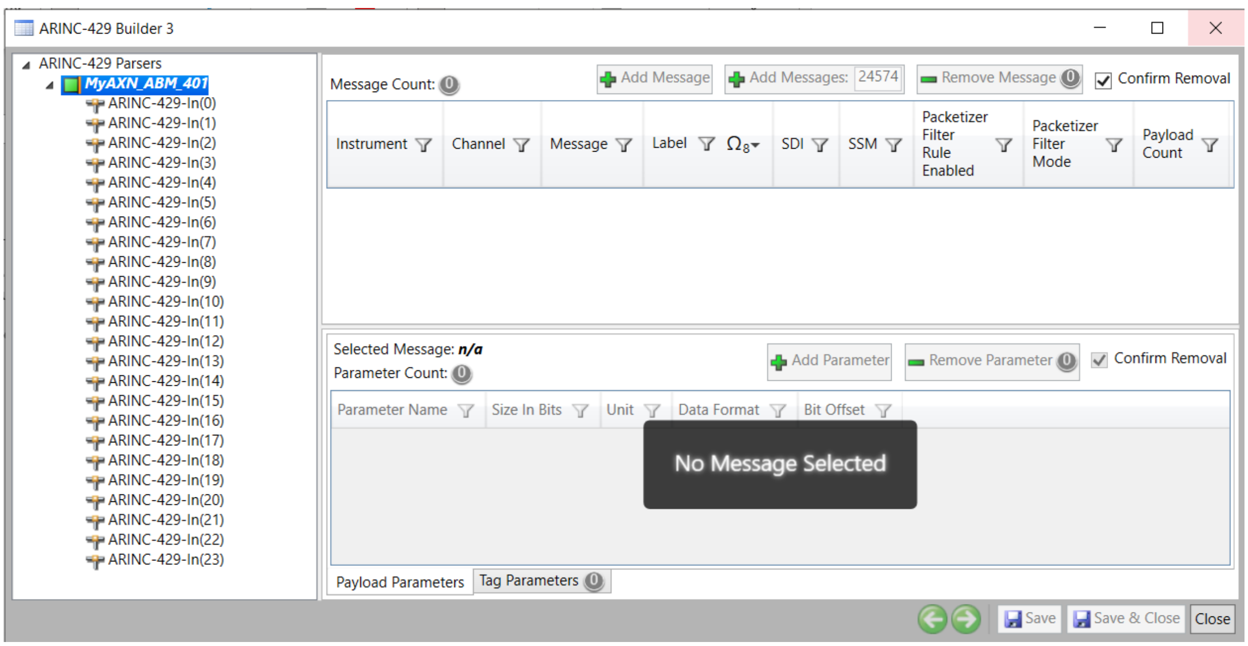
1. Do one of the following.
   - In the Navigator, right-click the AXN/ABM/401 module and then click **ARINC-429 Builder**.



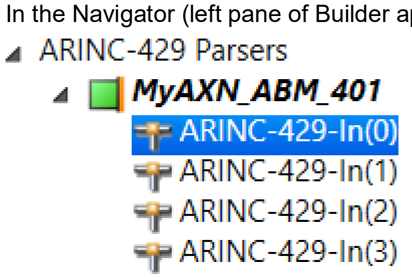

   - On the **Applications** menu click **ARINC-429 Builder**.




   The **ARINC-429 Builder** application opens.




2. In the Navigator (left pane of Builder application), select the channel on the AXN/ABM/401 that you want to parse data off.

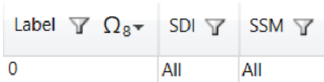



3. Click **Add Message** to add a single message. To add multiple messages (up to 8191), click **Add Messages** (typing the number of packages in the field).

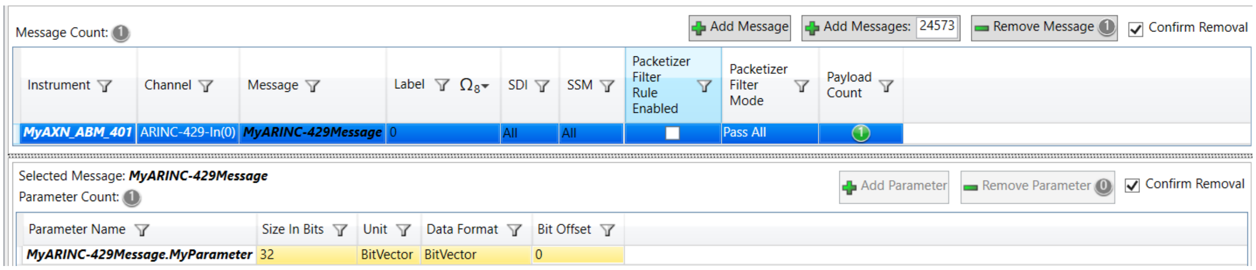
Now you must define the rules to identify or parse the desired message.

4. Define **Label**.

   The default is **Octal** as indicated by $\Omega_8$. Values can be from **0** to **255** in decimal.




5. Define **SDI** and **SSM**.
   These can be either **All**, **00**, **01**, **10** or **01**. **All** being the wildcard.
6. Click **Add Message** to add the message.
   When the message is added, ARINC-429 Builder automatically creates a 32-bit parameter.




   Although the parameter has 32 bits, it has a different layout than the 32-bit ARINC-429 message defined in “58.1 ARINC-429 overview” on page 545. This is because the message is parsed using the label; the parameter itself doesn’t contain the label.
7. Select the **Packetizer Filter Rule Enabled** check box to allow the messages to be either Blocked or Passed in the packetizer (depending on the channel Packetizer Filter Mode set in the setting tab) when they meet the packetizer filtering condition referenced by this process.

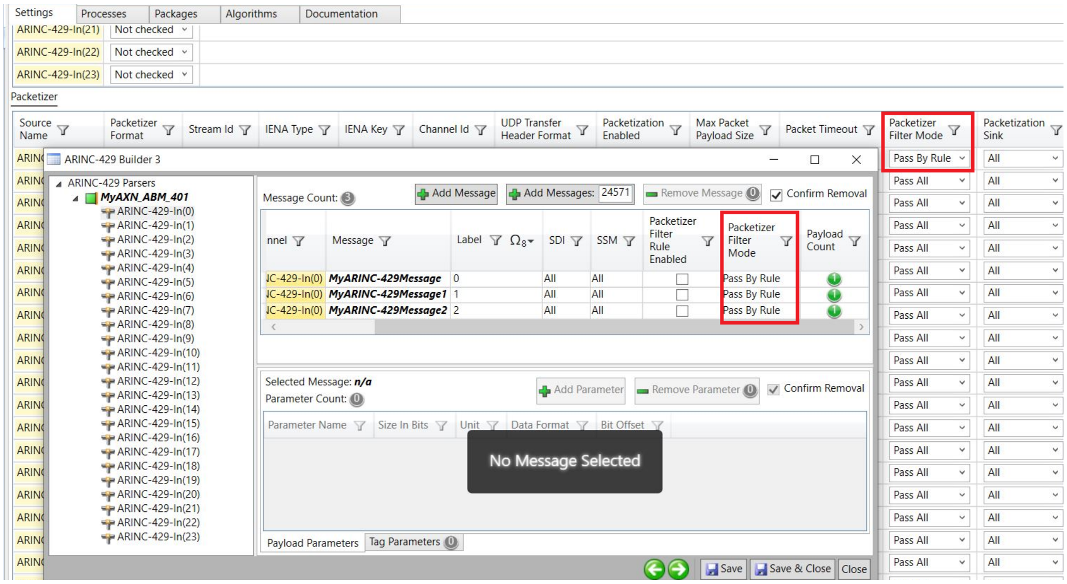
---

**NOTE:** **Packetizer Filter Rule Enabled** and **Packetizer Filter Mode** are only applicable when Packetization is enabled.

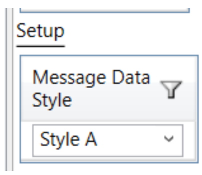
8. Specify the **Packetizer Filter Mode**:
   - **Block By Rule** means that messages that match defined filter rules are blocked and all other messages are passed through in the packetizer.
   - **Pass By Rule** means that messages that match defined filter rules are passed through and all other messages are blocked in the packetizer.
   - **Pass All** means that all messages are passed through the packetizer.

   In Packetization/Combined mode, the filtering rules from individual channels are applied to the combined packetizer output.

   Packetizer Filter Mode is a channel setting; this field must be set to the same rules in both the Settings tab and ARINC-429 Builder. To avoid a discrepancy between ARINC-429 Builder and the channel settings, DAS Studio automatically changes Packetizer Filter Mode for all messages in the same channel and in the Settings tab as shown in the following example.



9. Click **Save & Close** to save your changes and close **ARINC-429 Builder**.
10. With AXN/ABM/401 selected, click the **Settings** tab.
11. To program Message Data Style, click the **Message Data Style** drop-down arrow and choose **Style A** or **Style B**.




Style A = MessageDataStyleA and is defined as:

R[31:0]

R[31:30] SSM - Sign/Status Matrix.

R[29:11] Data - Data Word.

R[10:9] SDI - Source Destination Identifier.

R(8) Empty - This parser slot has not been written to yet.

R(7) Stale - This parser slot has been read before.

R(6) Skipped - This parser slot has been overwritten without being read.

R[5:1] Bus - The bus the message was received on.

R(0) Parity - The parity bit received.

---

**NOTE:** MessageDataStyleA is the default style

Style B = MessageDataStyleB (see MessageStyleB) and is defined as:

R[31:0]

R(31) Parity - The parity bit received.

R[30:29] SSM - Sign/Status Matrix.

R[28:20] Data[18:10] - Bits 18 to 10 of the Data Word.

R[19:17] Bus - The bus the message was received on (3 least significant bits only).

R(16) Reserved

R[15:6] Data[9:0] - Bits 9 to 0 of the Data Word.

R[5:4] SDI - Source Destination Identifier.

R(3) Empty - This parser slot has not been written to yet.

R(2) Stale - This parser slot has been read before.

R(1) Skipped - This parser slot has been overwritten without being read.

R(0) Reserved

Messages are saved to the configuration file and parameters become available to be placed to any sinks in the chassis such as a PCM stream or placed packet.

**NOTE:** Tags such as Message Time and Message Count can be enabled on the Tag Parameters tab of the ARINC-429 Builder as shown in the following figure. The tags are described in the AXN/ABM/401 data sheet.

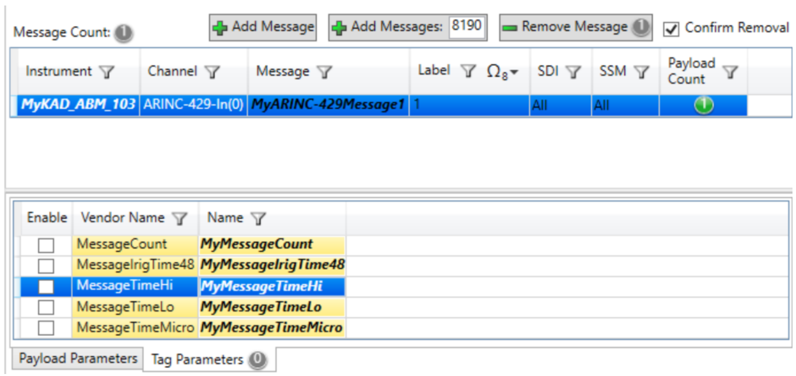



*Figure 58-5: Tag Parameters tab*

# 58.4 Packetizer operation

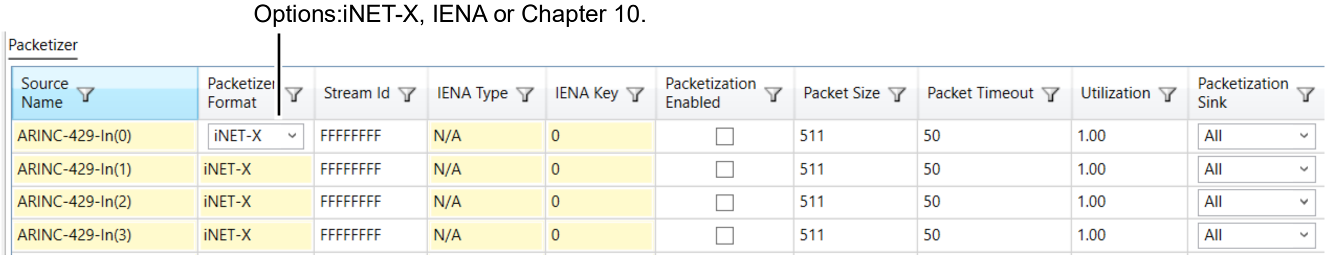
Independently of the parser, a packetizer stream can be generated for each channel or per instrument. All received ARINC-429 messages are encapsulated in an iNET-X parser-aligned, Chapter 10, or IENA Type N/D payload structure. A block header attached to each sequence stores the channel index, length, and the time each message is received. These parser-aligned packets may be transmitted aperiodically to optimize network bandwidth utilization and memory usage when recording ARINC-429 traffic.

There are many settings available to configure or tune packetizer behavior.

**NOTE:** To view the screen shots shown in this section in DAS Studio 3, ensure the AXN/ABM/401 module is in context and the Settings tab is selected.

The Packetizer Format settings are shown in the following figure.

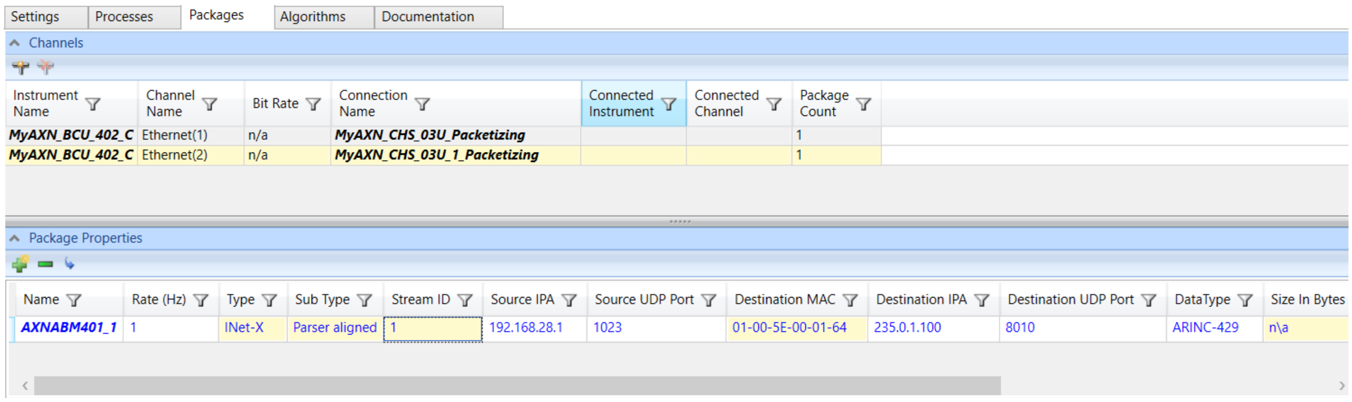
Options:iNET-X, IENA or Chapter 10.


Packetizer

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Packetization Enabled | Packet Size | Packet Timeout | Utilization | Packetization Sink |
|---|---|---|---|---|---|---|---|---|---|
| ARINC-429-In(0) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |
| ARINC-429-In(1) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |
| ARINC-429-In(2) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |
| ARINC-429-In(3) | iNET-X | FFFFFFFF | N/A | 0 | ☐ | 511 | 50 | 1.00 | All |

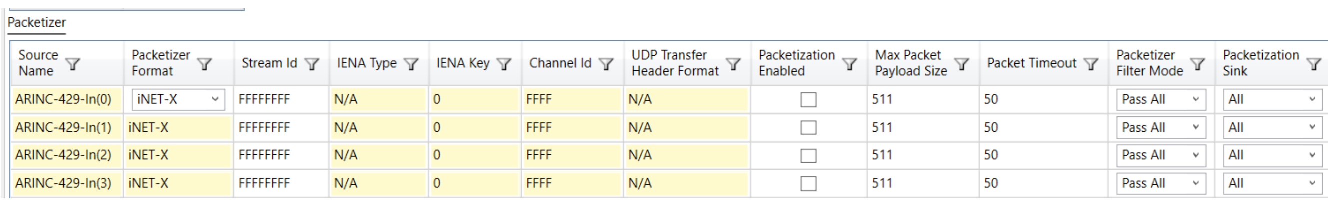
*Figure 58-6: Packetizer Format settings*

**NOTE:** DAS Studio automatically creates packetizer packets on the aperiodic transmitter (such as the AXN/BCU/402). The packet rate is always 1 Hz but this value is only required for XidML. This value is not used by AXN hardware.




## 58.4.1 Packetizer format: iNET-X

When iNET-X packetizer format is selected, the following fields are enabled.




| Setting | Description |
|---|---|
| Stream ID | iNET-X stream ID for selected channel if a packet is generated via the assertion of Packetization Enabled. This is a conditional setting and is only active when the Packetizer Format is set to iNET-X. |
| Packetization Enabled | Enables the transmission of an iNET-X packet containing the contents of this channel if an iNET-X transmitter is present in the chassis. DAS Studio automatically creates a packetizer packet after verification/programming. |
| Max Packet Payload Size | The number of words in the packet buffer; ranges from 200 words to 511 words. The default value is 511 words; reducing this value results in smaller and therefore generally more frequent packets. |
| Packet Timeout | Generates a packet when the oldest data recorded is this old (ms). Reducing this value results in more frequent and generally smaller packets. Increasing the value results in less frequent, but generally bigger packets. |
| Packetizer Filter Mode | Specifies the filtering mode for the channel:<br>Block By Rule means that messages that match defined filter rules are blocked and all other messages are passed through.<br>Pass By Rule means that messages that match defined filter rules are passed through and allother messages are blocked.<br>Pass All means that all messages are passed through. This is only applicable when Packetization is enabled.<br>In Packetization/Combined mode, the filtering rules from individual channels are applied to the combined packetizer output. |
| Packetization Sink | Selects which modules the packetizer package is sent to for transmission or storage. The choices are **Controller Only**, **All** (slots), or a slot in which a sink module supports packetizer logging. |

For further information regarding iNET-X parser aligned packets used by the packetizer, refer to *TEC/NOT/067 - IENA and iNET-X packet payload formats*.

To turn on packetizer operation on any channel, define a unique stream ID for that channel and then select the **Packetization Enabled** check box for that channel as shown in the following figure. The packetizer is enabled the next time the module is programmed.

Packetizer

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Channel Id | UDP Transfer Header Format | Packetization Enabled |
|---|---|---|---|---|---|---|---|
| ***MyAXN_ABM_401.MyARINC-429-In(0)Link*** | iNET-X | 1 | N/A | 0 | FFFF | N/A | ☑ |
| ARINC-429-In(1) | iNET-X | 2 | N/A | 0 | FFFF | N/A | ☑ |
| ARINC-429-In(2) | iNET-X | 3 | N/A | 0 | FFFF | N/A | ☑ |

*Figure 58-7: Packetization Enabled setting*

## 58.4.2 Packetizer format: Chapter 10

When Chapter 10 packetizer format is selected, the following fields are enabled.

Packetizer

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Channel Id | UDP Transfer Header Format | Packetization Enabled | Max Packet Payload Size | Packet Timeout | Packetizer Filter Mode | Packetization Sink |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ARINC-429-In(0) | Chapter 10 | FFFFFFFF | N/A | 0 | 1 | Format 1 | ☑ | 511 | 50 | Pass All | All |
| ARINC-429-In(1) | Chapter 10 | FFFFFFFF | N/A | 0 | 2 | Format 1 | ☑ | 511 | 50 | Pass All | All |
| ARINC-429-In(2) | Chapter 10 | FFFFFFFF | N/A | 0 | 3 | Format 1 | ☑ | 511 | 50 | Pass All | All |

| Setting | Description |
|---|---|
| Channel ID | Chapter 10 channel ID for selected channel if a packet is generated via the assertion of Packetization Enabled. This is a conditional setting and is only active when the Packetizer Format is set to Chapter 10. |
| UDP Transfer Header Format | UDP Transfer Header Format used to wrap Chapter 10 packets for streaming. The module only supports Format 1. |
| Packetization Enabled | Enables the transmission of a packetizer packet containing the contents of this channel if an aperiodic transmitter is present in the chassis. DAS Studio automatically creates a Chapter 10 packetizer packet after verification/programming. |
| Max Packet Payload Size | The number of words in the packet buffer; ranges from 200 words to 511 words. The default value is 511 words; reducing this value results in smaller and therefore generally more frequent packets. |
| Packet Timeout | Generates a packet when the oldest data recorded is this old (ms). Reducing this value results in more frequent and generally smaller packets. Increasing the value results in less frequent, but generally bigger packets. |
| Packetizer Filter Mode | Specifies the filtering mode for the channel:<br>Block By Rule means that messages that match defined filter rules are blocked and all other messages are passed through.<br>Pass By Rule means that messages that match defined filter rules are passed through and all other messages are blocked.<br>Pass All means that all messages are passed through. This is only applicable when Packetization is enabled.<br>In Packetization/Combined mode, the filtering rules from individual channels are applied to the combined packetizer output. |
| Packetization Sink | Selects which modules the packetizer package is sent to for transmission or storage. The choices are **Controller Only**, **All** (slots), or a slot in which a sink module supports packetizer logging. |

The AXN/ABM/401 data sheet explains the Chapter 10 packetizer format generated by the module.

**NOTE:** IADS does not currently support the Chapter 10 format.

## 58.4.3 57.5.2 Packetizer format: IENA

When IENA packetizer format is selected, the following fields are enabled:

Packetizer

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Channel Id | UDP Transfer Header Format | Packetization Enabled | Max Packet Payload Size | Packet Timeout | Packetizer Filter Mode | Packetization Sink |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ARINC-429-In(0) | IENA | FFFFFFFF | N | 0 | FFFF | N/A | ☐ | 511 | 50 | Pass All | All |
| ARINC-429-In(1) | IENA | FFFFFFFF | N | 0 | FFFF | N/A | ☐ | 511 | 50 | Pass All | All |
| ARINC-429-In(2) | IENA | FFFFFFFF | N | 0 | FFFF | N/A | ☐ | 511 | 50 | Pass All | All |

| Setting | Description |
|---|---|
| IENA Type | Describes the IENA parameter type of the packet payload: D or N. This is a conditional setting and is active when the Packetizer Format is set to IENA. Refer to the AXN/ABM/401 data sheet for a description of IENA packetizer packets. |
| IENA Key | IENA Key for selected channel if a packet is generated via the assertion of Packetization Enabled. This is a conditional setting and is active when the Packetizer Format is set to IENA. |
| Packetization Enabled | Enables the transmission of a packetizer packet containing the contents of this channel if an aperiodic transmitter is present in the chassis. DAS Studio automatically creates an IENA packetizer packet after verification/programming. |
| Max Packet Payload Size | The number of words in the packet buffer; ranges from 200 words to 511 words. The default value is 511 words; reducing this value results in smaller and therefore generally more frequent packets. |
| Packet Timeout | Generates a packet when the oldest data recorded is this old (ms). Reducing this value results in more frequent and generally smaller packets. Increasing the value results in less frequent, but generally bigger packets. |
| Packetizer Filter Mode | Specifies the filtering mode for the channel:<br>Block By Rule means that messages that match defined filter rules are blocked and all other messages are passed through.<br>Pass By Rule means that messages that match defined filter rules are passed through and all other messages are blocked.<br>Pass All means that all messages are passed through. This is only applicable when Packetization is enabled.<br>In Packetization/Combined mode, the filtering rules from individual channels are applied to the combined packetizer output. |
| Packetization Sink | Selects which modules the packetizer package is sent to for transmission or storage. The choices are **Controller Only**, **All** (slots), or a slot in which a sink module supports packetizer logging. |

The AXN/ABM/401 data sheet explains the IENA D and N packetizer format generated by the module.

**NOTE:** IADS doesn't support these IENA formats.

## 58.4.4 Packetization Individual/Combined

| Packetization |
|---|
| Combined |

When Packetization/Combined mode is selected, messages from all busses are placed in a single stream of packets, with a single stream ID for iNET-X (respectively Key for IENA and Channel ID for Chapter 10). The bus ID field identifies on which bus a message was received.

| Source Name | Packetizer Format | Stream Id | IENA Type | IENA Key | Channel Id | UDP Transfer Header Format | Packetization Enabled | Max Packet Payload Size | Packet Timeout | Packetization Sink |
|---|---|---|---|---|---|---|---|---|---|---|
| ARINC-429-In-Combined | iNET-X | FFFFFFFF | N/A | 0 | FFFF | N/A | ☑ | 511 | 50 | All |

Using Combined is recommended if IADS is used to decom in real time and if many buses are connected to the module.

**WARNING:** Using Combined is recommended if IADS is used to decom in real time and if many buses are connected to the module.

## 58.5 MessageStyleB

MessageStyleB was specifically designed for 12 bits of PCM. From this 32-bit parameter in IRIG-106 Ch4 PCM, you can reduce bandwidth by reducing it to the most necessary information such as Parity, SSM, Data, and SDI.

When MessageStyleB is selected in the AXN/ABM/401 module Settings tab and you add parameter(s) using ARINC-429 Builder, DAS Studio 3 automatically and transparently creates 24-bit discrete parameters. These parameters are then available to be placed in the PCM as shown in the following figure.

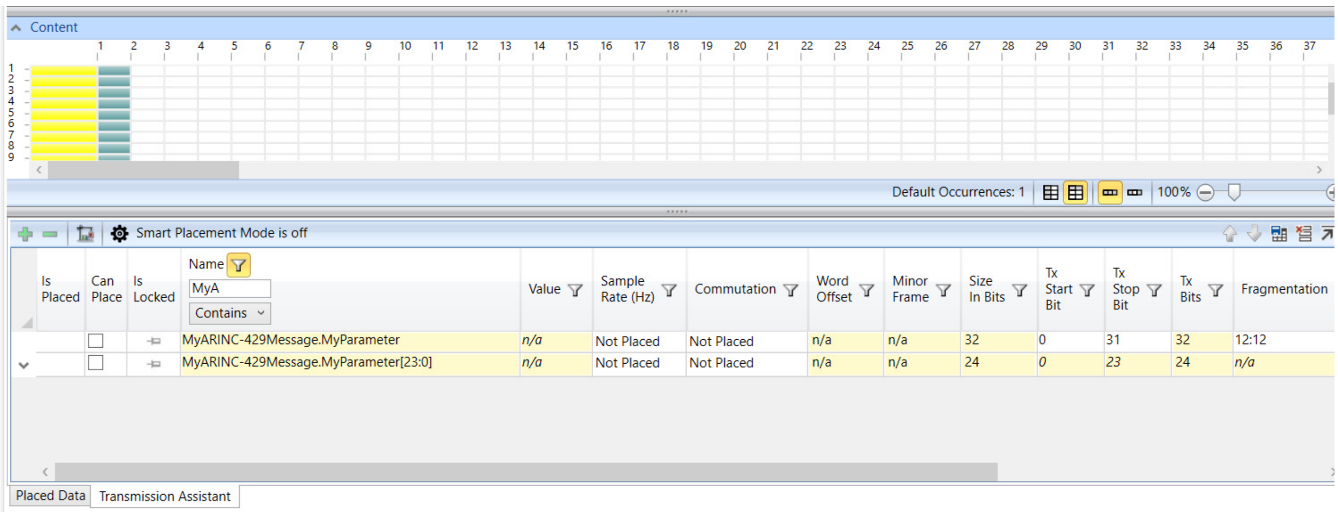



*Figure 58-8: MyARINC-429Message.MyParameter[23:0] 24-bit discrete parameter*

The previous figure shows the MyARINC-429Message.MyParameter[23:0] 24-bit discrete parameter. The following figure shows the bits that are used (gray bits are masked out).

| | Parity | SSM | | Data | | | | | | | | | Bus | | | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |

| | Data | | | | | | | | | | SDI | | Empty | Stale | Skipped | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

R = Reserved

*Figure 58-9: MyARINC-429Message.MyParameter[23:0] used bits*

## 58.6 Troubleshooting

The common issues while parsing are:

The bus +/- is physically inverted.

The wrong bus is being parsed.

The label is defined in the ARINC-429 builder in decimal while in the ICD avionics it is defined in octal.

The BusActiveAll parameter can be monitored to help on the port where the bus is connected. The REPORT parameter can help demonstrate if there are errors on the bus. A packetizer packet can also be configured on the suspected bus to check if the module *sees* the ARINC-429 bus.

## 58.7 Related documentation

To better understand this paper, read the following documents.

Table 58-1: Data sheets

| Document | Description |
|---|---|
| AXN/ABM/401 | ARINC-429 bus monitor parser/packetizer - 24ch |

Table 58-2: Technical notes

| Document | Description |
|---|---|
| TEC/NOT/002 | ARINC-429 |
| TEC/NOT/063 | Grounding and shielding of the Axon and Acra KAM-500 |
| TEC/NOT/067 | IENA and iNET-X packet payload formats |

Table 58-3: User manual

| Document | Description |
|---|---|
| DOC/MAN/030 | DAS Studio 3 User Manual |

Chapter 59

# Using DAS Studio 3 to configure the AXN/ENC/402

TEC/NOT/089

This paper discusses the following topics:



## 59.1 Module overview

The AXN/ENC/402 is used to encode data in an IRIG-106 Chapter 7 (2017) PCM stream. IRIG-106 Chapter 7 defines the method for transporting variable-length, well-defined data formats in a Chapter 4 pulse code modulation (PCM) stream.

The following can be encoded:

- Parameters from any Axon module in a chassis can be placed in the Ch.7 PCM stream.
- Parameters from other Axon chassis or Ethernet sources can also be placed in the Ch.7 PCM stream.
- Ethernet frames generated in the Axon chassis can be wrapped and placed in the Ch.7 PCM stream.
- Ethernet frames from other Axon chassis or Ethernet sources can also be wrapped and placed in the Ch.7 PCM stream.

The following figure shows an example of two Axon chassis connected in a daisy-chain configuration. The AXN/BCU/402/B (or later) can transmit parameters from the remote Axon chassis to the AXN/ENC/402. It can parse a specific 3rd party Ethernet packet to transmit a specific parameter from it. It can transmit selected 3rd party Ethernet packets and transmit packetizer packets from local and remote chassis over Ch.7.

**NOTE:** Daisy-chaining is only supported from the AXN/BCU/402/B (or later). Instances of AXN/BCU/402 in the following figure are considered as AXN/BCU/402/B (or later).

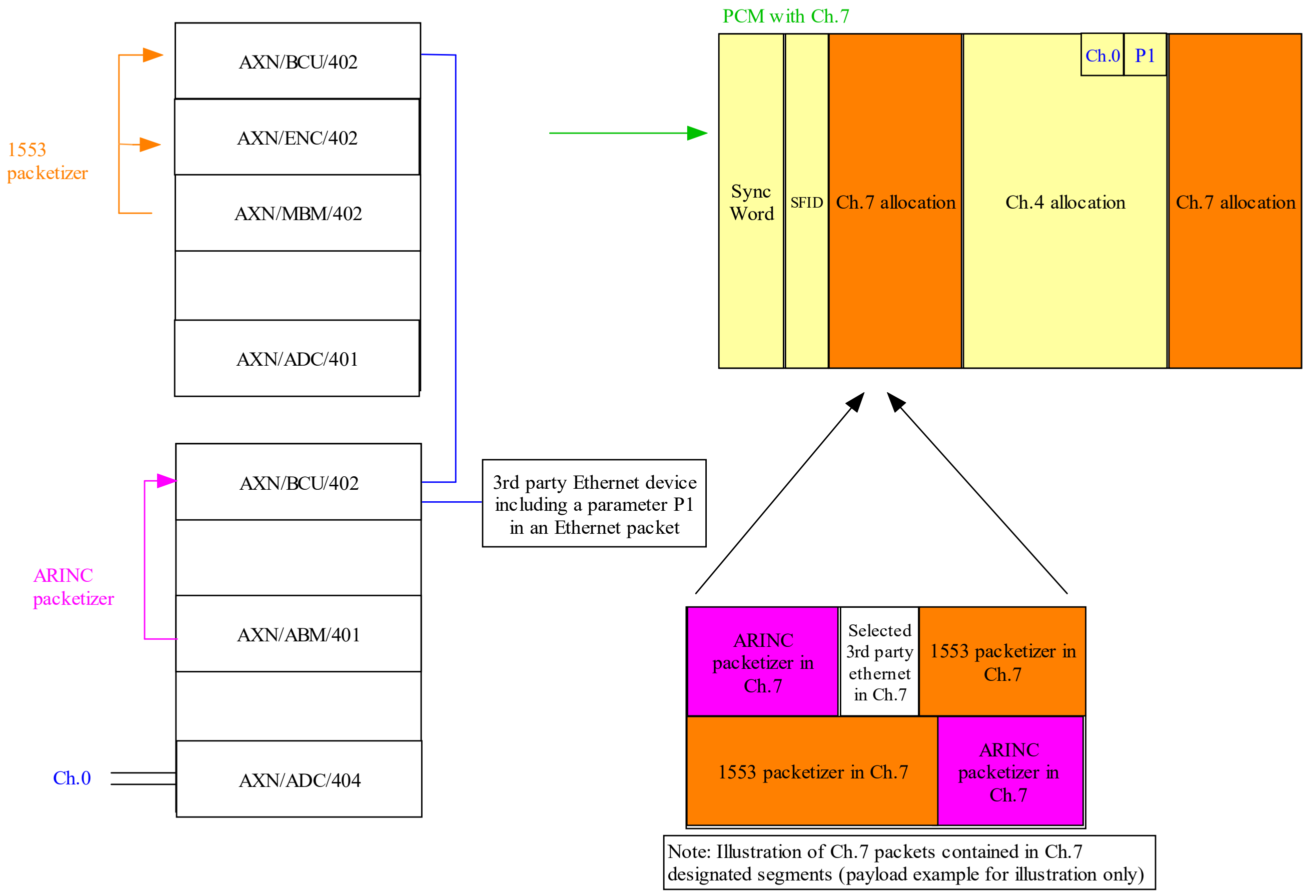



*Figure 59-1: Example Ch.7 transmission*

---

**NOTE:** The remote Axon chassis could also be an Acra KAM-500 chassis with an Ethernet controller.

The AXN/ENC/402 has multiple outputs such as TTL, RS422, and PMF with different PCM codes, however, only one PCM can be defined.

---

**NOTE:** The AXN/ENC/401 is similar to the AXN/ENC/402 in terms of set up. However, it can only perform IRIG-106 Chapter 4 PCM.

## 59.2 Ethernet-to-PCM bridge overview

A Multi Chassis Scheduler (MCS) is system scheduling software that enables you to transparently transmit parameters from any available Data Acquisition Unit (DAU) in a networked system by means of an Ethernet bus monitoring module located in an AXN/ENC/402 in the chassis. This system is referred to as Scenario 1 throughout this document.

The MCS software—which is integrated within the compiler of DAS Studio 3—is in charge of automatically creating intra-chassis Ethernet packets that are captured by the AXN/ENC/402.

The following diagram shows a typical MCS-over-Ethernet scenario where PCM is used for real-time telemetry in an Ethernet system.

In this example, parameter P1 comes from a module placed on a remote DAU 1 and is being transmitted over the network, then P1 gets parsed and transmitted over PCM by the AXN/ENC/402.

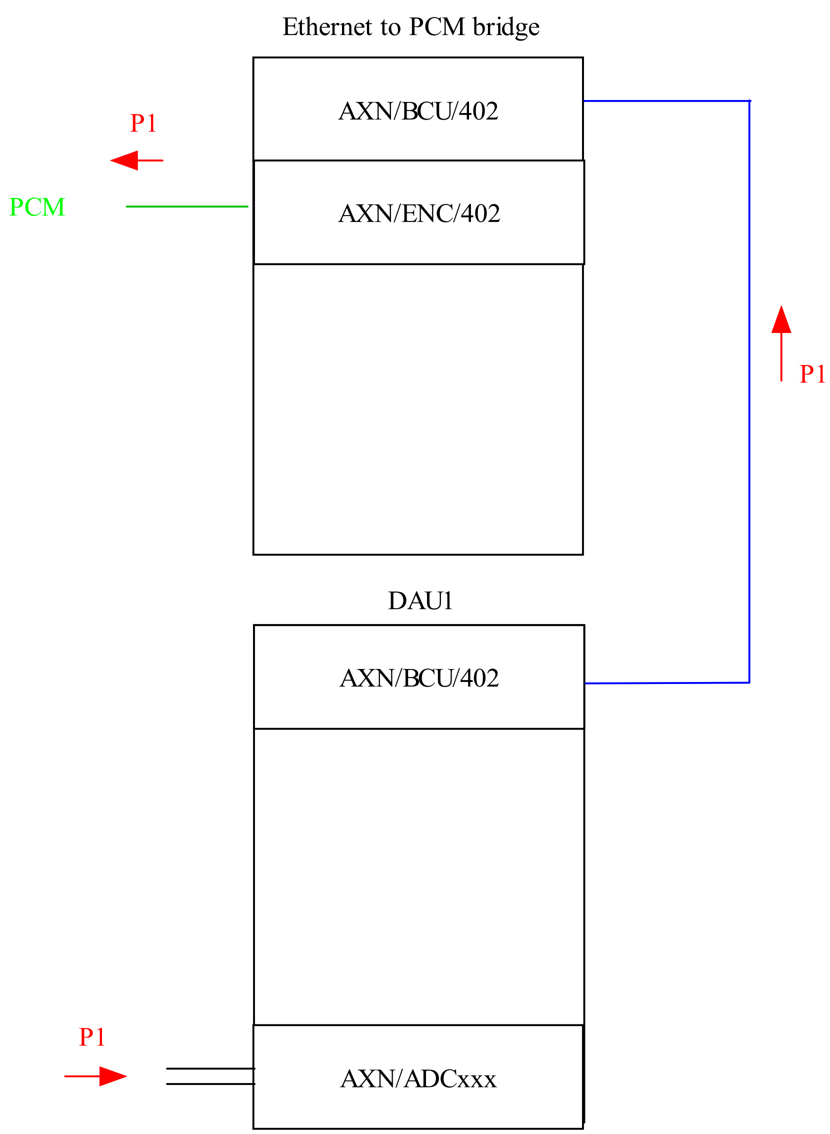



*Figure 59-2: Example of MCS traffic showing parameter P1 from remote DAU 1*

## 59.3 AXN/ENC/402 DAS Studio 3 settings

This technical note describes some scenarios where DAS Studio 3 can be used to configure the AXN/ENC/402. Depending on the scenario, some of the default settings shown in the following table need to be modified.

Backplane Ethernet

| Source Name | Traffic Priority | VLAN Support | Traffic Type |
|---|---|---|---|
| BackplaneEthernet | iNET-X | ☐ | iNET-X |

*Figure 59-3: DAS Studio 3 Settings tab for AXN/ENC/402*

Table 59-1: AXN/ENC/402 settings in DAS Studio 3

| Setting | Notes |
|---|---|
| Traffic Type | This setting defines the type of packet expected when configuring the AXN/ENC/402 as a bus monitor in different scenarios. In an Ethernet-to-PCM stream scenario (MCS), select **iNET-X** or **IENA**. (Scenario 1)<br>In a generic Ethernet bus monitor scenario, select **Generic**. (Scenario 2 and 3)<br>Select **All** when parsing both MCS packets and generic Ethernet packets.<br><br>**NOTE:** Select either iNET-X or IENA. Do not mix traffic types; if you decide to use iNET-X packets for all other traffic, then the transport packets must also be iNET-X. |
| Traffic Priority | This advanced option is only available when parsing both MCS packets and generic Ethernet packets (Scenario 3). It defines the processing priority for package types when filtering rules overlap. |
| VLAN Support | This is an advanced option. Enabling VLAN Support allows parser slots—when present—to skip over VLAN packet headers, allowing you to classify traffic on the basis of IP and UDP/TCP packet header fields. By default, this check box is cleared. |

For further information, refer to the latest *AXN/ENC/402* data sheet.

## 59.4 Using DAS Studio 3 to set up configuration scenarios

DAS Studio 3 is used to create a configuration, which contains the various elements, which make up your data acquisition system. You then use this configuration file to manage and program these elements.

To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

## 59.5 Scenario 1: using the AXN/ENC/402 to act as an Ethernet to PCM bridge

As described in “59.2 Ethernet-to-PCM bridge overview” on page 558, in Ethernet systems where every DAU has an Ethernet controller and transmits data to a central switch, the AXN/ENC/402 can act as a bridge module for transmitting Ethernet-captured data into a Pulse Code Modulation (PCM) stream.

In this scenario, the AXN/ENC/402 is connected to the output of an aggregating switch, through which data from all other DAUs is available to the PCM DAU.

This scenario is illustrated in the following figure where 3 DAUs (DAU_0, DAU_1, and PCM_DAU) are connected to a network switch; connecting the system in this way makes all DAU parameters available to the PCM stream transmitted by the AXN/ENC/402.

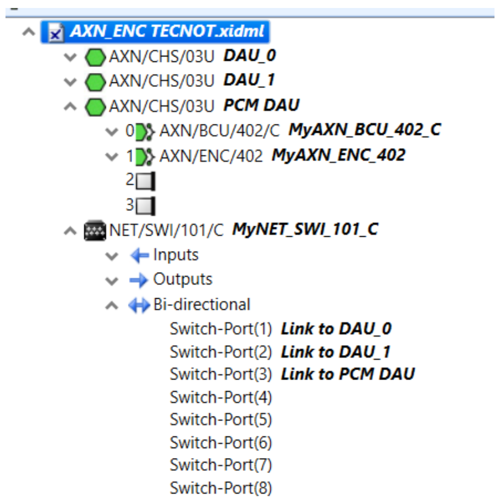
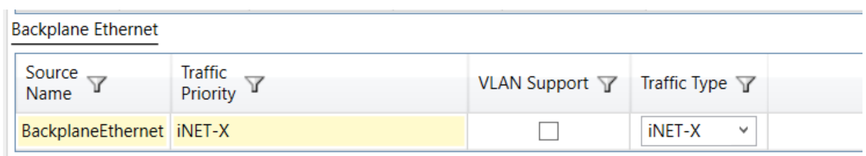



*Figure 59-4: Scenario 1 – Ethernet to PCM bridge (MCS)*

---

**NOTE:** This example assumes the network switch is correctly configured to route packets from a remote DAU to the AXN/ENC/402.

In the following figure, Traffic Type has to be configured to IENA or iNET-X to act as a bridge module for transmitting Ethernet data and Traffic Type is set to iNET-X or IENA.

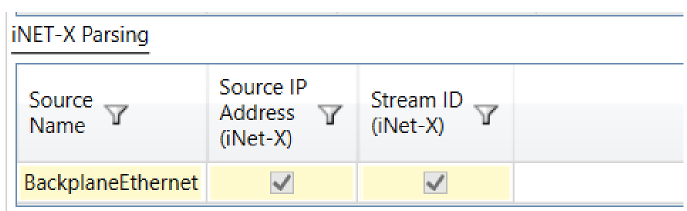


Backplane Ethernet

| Source Name | Traffic Priority | VLAN Support | Traffic Type |
|---|---|---|---|
| BackplaneEthernet | iNET-X | ☐ | iNET-X |

*Figure 59-5: DAS Studio 3 settings when configuring the AXN/ENC/402 for MCS*

The following figure shows the read only fields, which are automatically set showing what Ethernet field the module uses to parse the MCS packet.



iNET-X Parsing

| Source Name | Source IP Address (iNet-X) | Stream ID (iNet-X) |
|---|---|---|
| BackplaneEthernet | ☑ | ☑ |

*Figure 59-6: DAS Studio 3 read only settings when configuring the AXN/ENC/402 for MCS*

You can proceed to build a PCM frame once the routing of the switch (for example NET/SWI/101/C) and the module settings are configured correctly in DAS Studio 3. Once the PCM is created, click Verify; MCS packets are automatically built by DAS Studio 3 at the data source DAUs. This ensures that the data words to be sent over real-time PCM arrive at the data selector chassis in time for transmission.

Refer to the *DAS Studio 3 User Manual* to build an IRIG-106 PCM using Transmission Assistant.

## 59.6 Scenario 2: using the AXN/ENC/402 as a generic Ethernet parser to be transmitted over PCM

The AXN/ENC/402 can also be used as an Ethernet bus monitor to parse traffic from external sources, thereby making it available to the AXN/ENC/402 PCM. In this scenario, all traffic to be parsed by the AXN/ENC/402 is considered generic, therefore you must use the Ethernet Builder application to parse Ethernet traffic.

Set the **Route Internal Ethernet Placed Packets to Backplane** field on the AXN/BCU/402/B (or later) to indicate where the generic packets are destined.

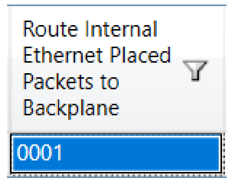



*Figure 59-7: Example of the AXN/BCU/40x routing to the AXN/ENC/402 in slot 1*

For the AXN/ENC/402 to parse generic Ethernet traffic, you must set the Traffic Type field to Generic as shown in the following figure.

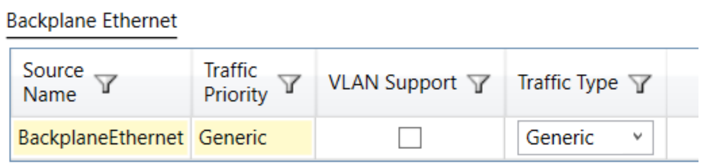



*Figure 59-8: Scenario 2 - AXN/ENC/402 acting as a generic Ethernet parser in DAS Studio 3*

The **Ethernet Builder** application adds and configures Ethernet messages and parameters on Ethernet bus monitor modules.

This section features a worked example of how to use Ethernet Builder to configure the AXN/ENC/40x to parse an Ethernet packet with a source IP of 10.11.12.13, a destination IP of 233.10.11.45, and a destination port of 1024.

In this worked example, words 100, 102, 104, and 106 are extracted from the parsed packet.

Knowing that the Word Offset is defined as per the example in the following table, Word Offset 0 is the start of the Ethernet Frame and is therefore the first 16 bits of the Destination MAC Address.

Table 59-2: iNET-X, IENA, and VLAN word offset

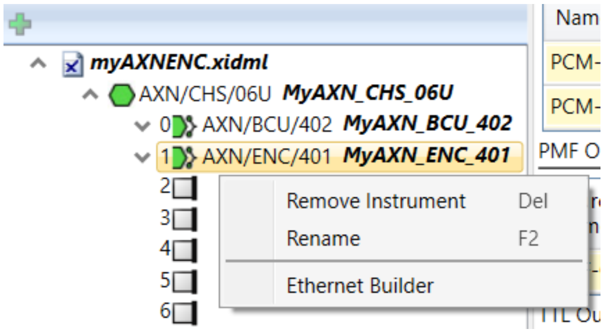
| Field name | Values of offset index words | |
|---|---|---|
| | **Offset If VLAN disabled** | **Offset If VLAN enabled** |
| **MAC header** | | |
| Destination MAC address, word 0 (MSW) | 0 | 0 |
| Destination MAC address, word 1 | 1 | 1 |
| Destination MAC address, word 2 (LSW) | 2 | 2 |
| Source MAC address, word 0 (MSW) | 3 | 3 |
| Source MAC address, word 1 | 4 | 4 |
| Source MAC address, word 2 (LSW) | 5 | 5 |
| Frame/Protocol type; 0x0*0 e.g. IP = 0800h | 6 | 8 |

Table 59-2: iNET-X, IENA, and VLAN word offset (continued)

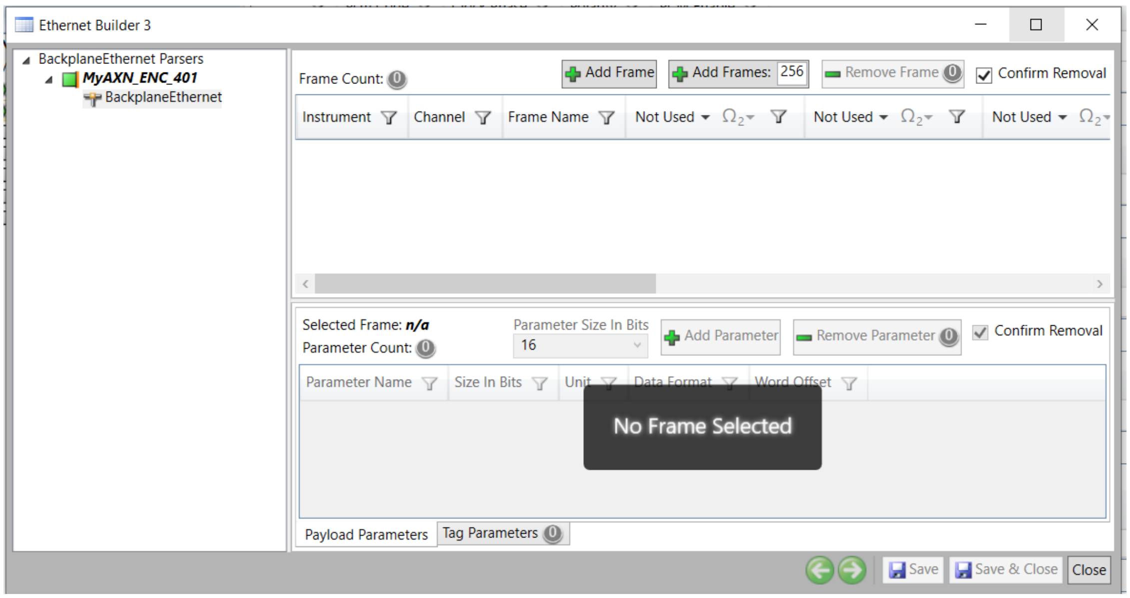
| Field name | Values of offset index words | |
|---|---|---|
| | Offset If VLAN disabled | Offset If VLAN enabled |
| **IP header** | | |
| VLAN priority/ID | N/A | 7 |
| IP version/IHL/ToS | 7 | 9 |
| IP packet size | 8 | 10 |
| IP ID | 9 | 11 |
| IP flags and fragment offset | 10 | 12 |
| IP TTL and Protocol; xx11h for UDP and xx06h for TCP | 11 | 13 |
| IP header checksum | 12 | 14 |
| Source IP address, word 0 (MSW) | 13 | 15 |
| Source IP address, word 1 (LSW) | 14 | 16 |
| Destination IP address, word 0 (MSW) | 15 | 17 |
| Destination IP address, word 1 (LSW) | 16 | 18 |
| Source port no. | 17 | 19 |
| Destination port no. | 18 | 20 |
| UDP Length; TCP seq word 0 | 19 | 21 |
| UDP CSum; TCP seq word 1 | 20 | 22 |
| **Data payload** | | |
| IENA key or iNET Control Field 0 // TCP Ack word 0 | 21 | 23 |
| IENA size or iNET Control Field 1 // TCP Ack word 1 | 22 | 24 |
| iNET-X Stream ID word 0 or IENA date 0 // TCP offset/flags | 23 | 25 |
| iNET-X Stream ID word 1 or IENA date 1// TCP window | 24 | 26 |
| iNET-X Seq Number 0 or IENA date 2 // TCP Csum | 25 | 27 |
| iNET-X Seq Number 1 or IENA status // TCP urgent Ptr | 26 | 28 |
| iNET-X Pckt Length 0 or IENA Seq // TCP Options (or TCP Data 0) | 27 | 29 |

In the following example, an AXN/ENC/401 is used. The AXN/ENC/402 follows the same concept.

1. Right-click the AXN/ENC/401 module in the Navigator and then click **Ethernet Builder**. (You can also click the **Applications** menu and then click **Ethernet Builder**.)

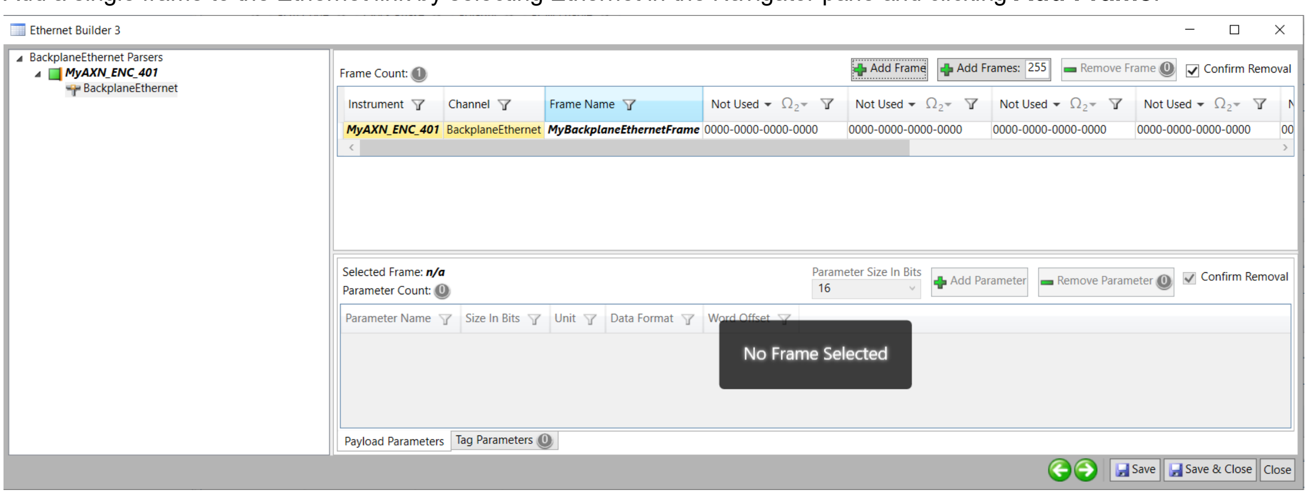



The **Ethernet Builder 3** dialog box opens.



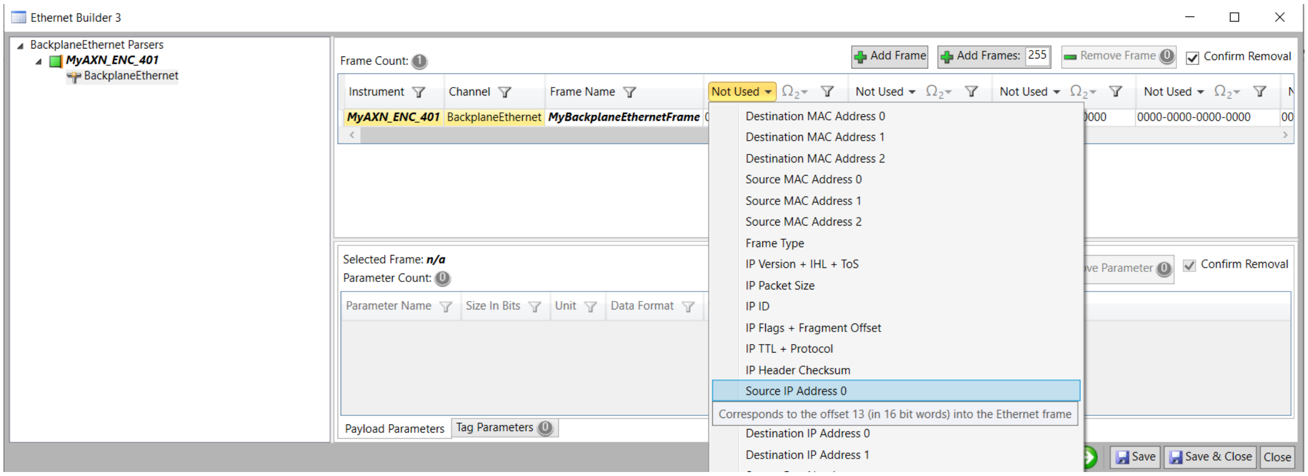

For dialog box navigation, see “Builder application GUI overview” in the *DAS Studio 3 User Manual*.

2. Add a single frame to the Ethernet link by selecting Ethernet in the Navigator pane and clicking **Add Frame**.

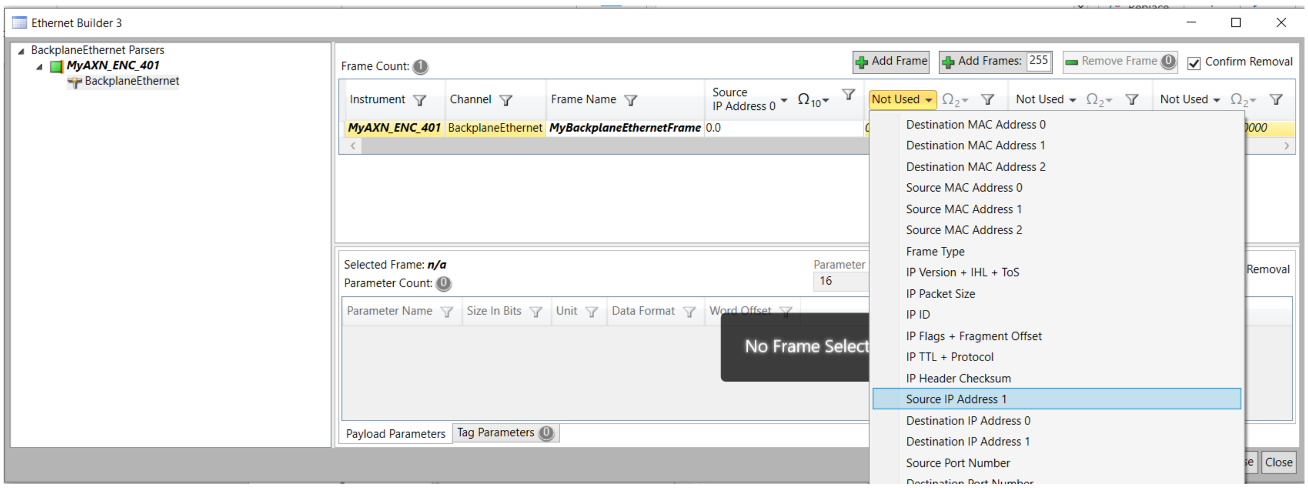



**NOTE:** In the **Frame Count** pane, there are eight 16-bit user-definable classifier fields (by default, these fields are labeled **Not Used**), which can be used to create the rules which help the AXN/ENC/40x identify Ethernet packets.
As the fields to be used for source IP and destination IP are both two 16-bit fields, two classifier rules for both the source IP and the destination IP are required.

3. In the first classifier field, click the drop-down arrow beside **Not Used** and select **Source IP Address 0**.

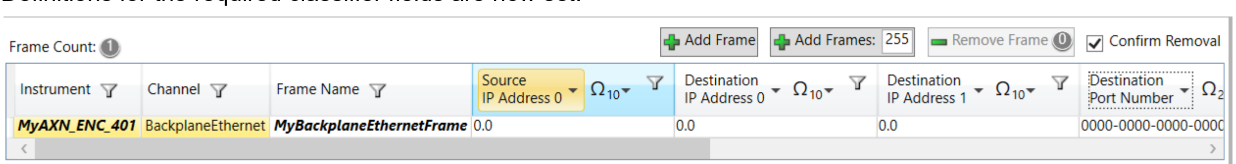



4. In the second classifier field, click the drop-down arrow beside **Not Used** and select **Source IP Address 1**.




**NOTE:** When Source IP Address 0 is in use, it is not available in the drop-down list.

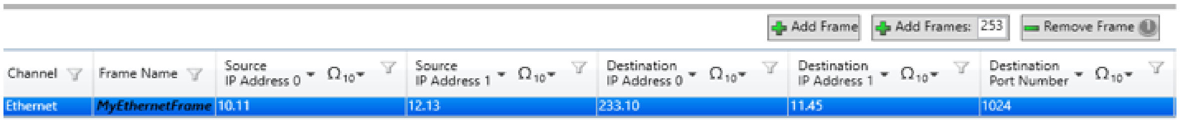
5. Set the remaining classifier fields by selecting **Destination IP** for the third and fourth classifier fields, and selecting **Destination Port Number** for the fifth classifier field.
   Definitions for the required classifier fields are now set.




**NOTE:** Values for these classifier fields can be formatted using Decimal, Hex, Octal, or Binary format. To change a format, click the drop-down arrow by the Ω symbol for each classifier field and choose the desired format. In our working example, Decimal format suffices.

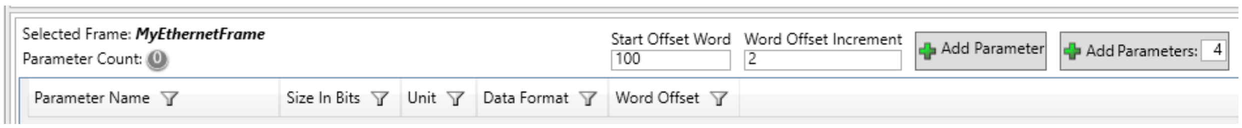
6. In the **Source IP Address 0** field, type **10.11**.
7. In the **Source IP Address 1** field, type **12.13**.
8. In the **Destination IP Address 0** field, type **233.10**.
9. In the **Destination IP Address 1** field, type **11.45**.

10. In the **Destination Port** field, type **1024**.
    Values for the classifiers fields are now set.

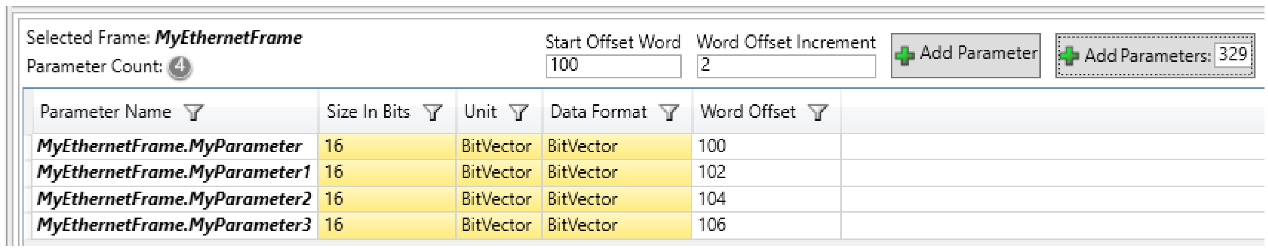



**NOTE:** Now that parsing classifiers have been defined, add the parameters to be extracted from the packet; specifically, words 100, 102, 104, and 106.

11. In the **Start Offset Word** field, type **100**.
12. In the **Word Offset Increment** field, type **2**.
13. In the field beside **Add Parameters**, type **4**.




14. Click **Add Parameters**.
    Four parameters are now created at offsets **100**, **102**, **104**, and **106**.




15. To save changes, click **Save & Close**.

For further information on Ethernet Builder, refer to the *DAS Studio 3 User Manual*.

MyEthernetFrame.MyParameter created are now available to be placed in the PCM. Refer to the DAS Studio manual to build an IRIG-106 PCM using Transmission Assistant.

---

**NOTE:** The parameters parsed by the AXN/ENC/402 are not available to any other modules in the system.

The AXN/ENC/402 can simultaneously operate as Generic and Ethernet-to-PCM bridge by setting **Traffic Type** to **All** as shown in the following figure.

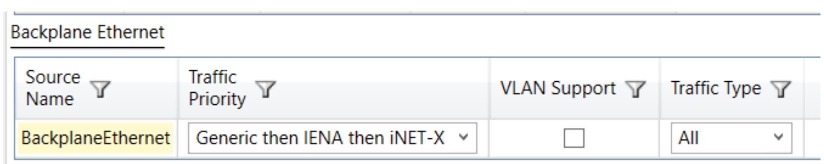



*Figure 59-9: Backplane Ethernet with Traffic Type set to All*

## 59.7 Scenario 3: using the AXN/ENC/402 to transmit Chapter 7

IRIG-106 Chapter 7 defines the method for transporting variable-length, well-defined data formats in a Chapter 4 pulse code modulation (PCM) stream.

Any Ethernet frames (even generated in the Axon chassis such as packetizer) can be wrapped and placed in the Ch.7 PCM stream. AXN/ENC/402 only supports PT Raw Ethernet Media Access Control (MAC) Frame Packet (type 0x4) type packets.

Both high latency and low latency packet definitions are supported.

If the packet is coming externally, set the field **Route Internal Ethernet Placed Packets to Backplane** on the AXN/BCU/40x to indicate where the generic packets are destined.

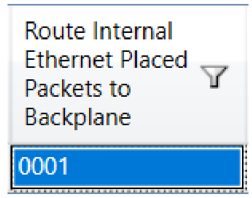
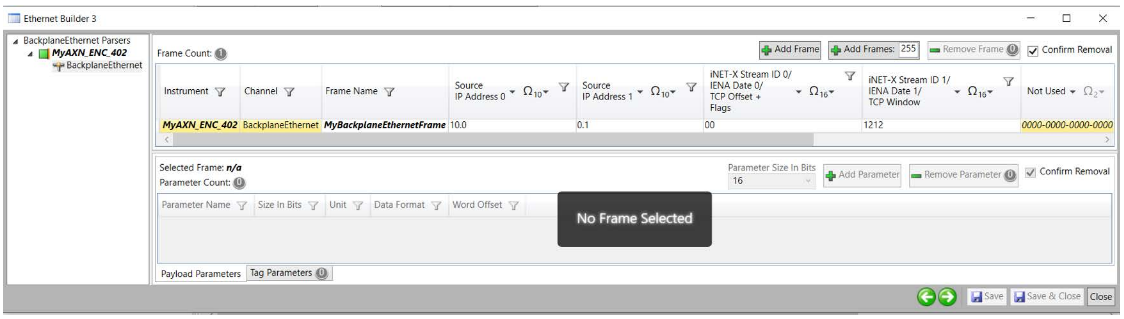


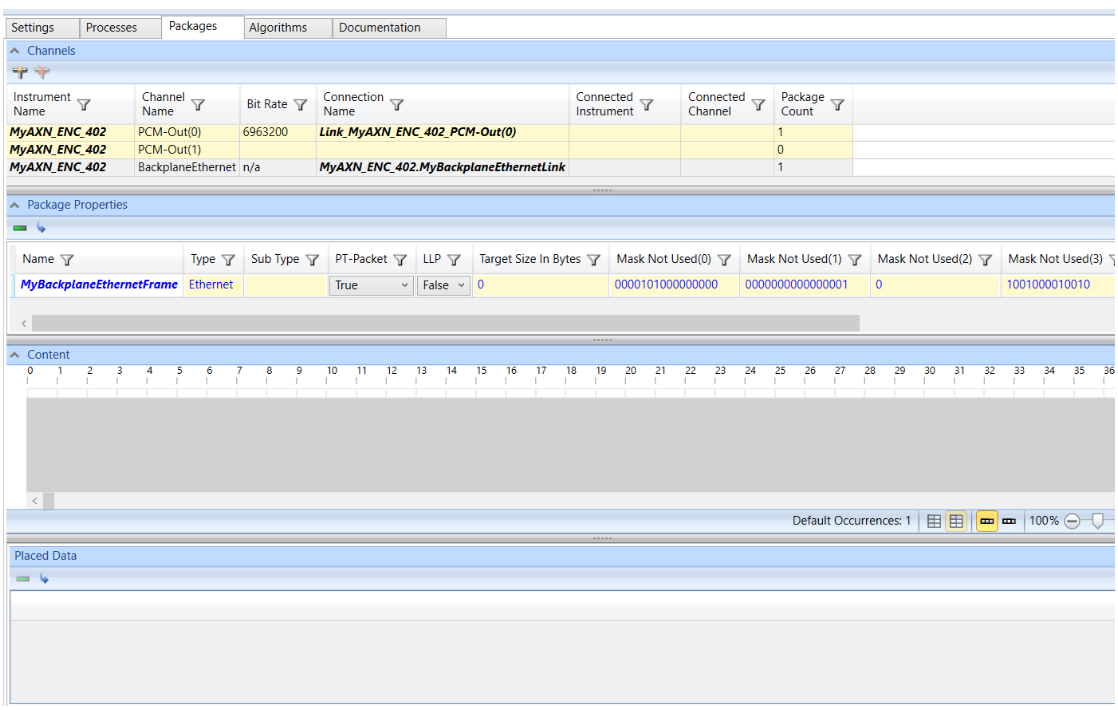

*Figure 59-10: Example of AXN/BCU/40x routing to the AXN/ENC/402 in slot 1*

Use **Ethernet Builder** to define the frame you want to select.

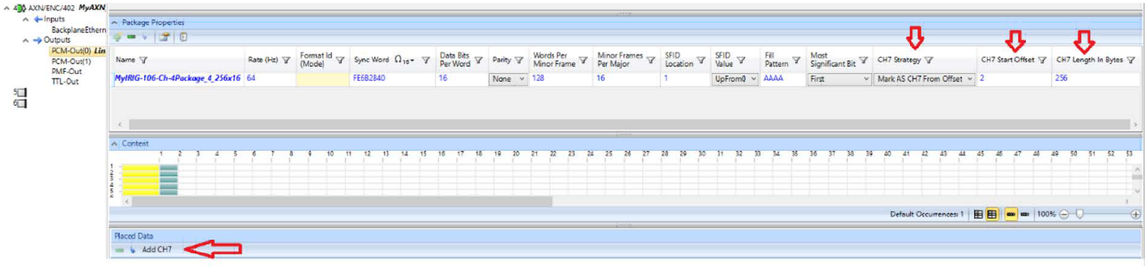
1. Right-click the AXN/ENC/401 module in the Navigator and then click **Ethernet Builder**. (You can also click the **Applications** menu and then click **Ethernet Builder**.)
   The settings here are configured to select a packet with source IP 10.0.0.1 and Stream ID 1212h. (This packet could be a packetizer from an AXN/ABM/401 for example.)



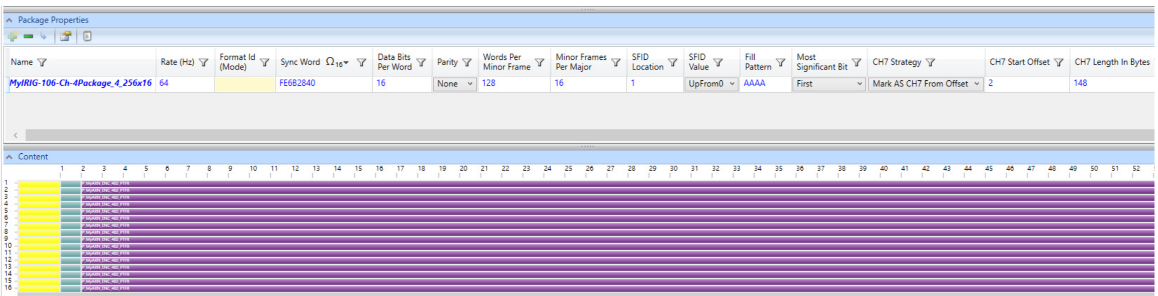

2. Click **Save & Close** and then go to the **Packages** tab of the AXN/ENC/402.
3. Select **BackplaneEthernet** and set **PT-Packet** to **True**.
   LLP (Low Latency Packet) is set to False by default. If set to True, a target payload size in bytes must be provided.




When you mark packets as PT-Packets, an area of the PCM frame must be reserved for transmission of these packets. You can reserve unused space in the minor frame starting from a particular offset. The reserved space must be the same length and start at the same offset in each minor frame.



4. Click the **Add CH7** button.
   The **Content** pane is updated.



   Each minor frame carries a payload of a single transport packet, which may be segmented. This means that Ch.7 data may be interleaved with non-Ch.7 data.

For details on building Ch.7 streams, refer to the *DAS Studio 3 User Manual*. For additional information, refer to the IRIG-106 Chapter 7 specification and the *AXN/ENC/402* data sheet.

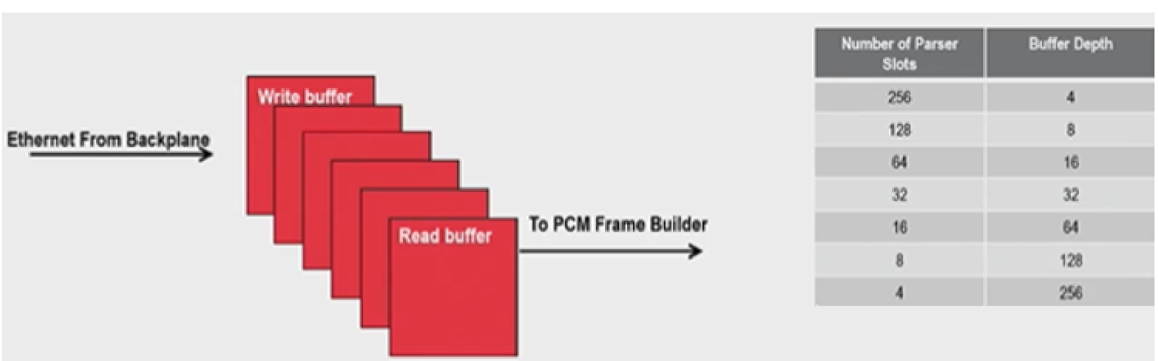
---

**NOTE:** You cannot transmit an Ethernet packet over Ch.7 and parse it in Generic mode simultaneously.
IADS doesn't support Chapter 7.

# 59.8 Appendix

## 59.8.1 Buffer depth to handle burst packet

The AXN/ENC/402 has the capability to set the buffer depth to allow parsing of 3rd party bursty Ethernet packets. Increasing the buffer depth, decreases the number of available parser slots.




| Number of Parser Slots | Buffer Depth |
|---|---|
| 256 | 4 |
| 128 | 8 |
| 64 | 16 |
| 32 | 32 |
| 16 | 64 |
| 8 | 128 |
| 4 | 256 |

*Figure 59-11: Deep buffer versus parser slot*

---

**NOTE:** Buffer depth is not used for parsing MCS packets.

### 59.8.2 Bit-rate

The bit-rate is automatically calculated by DAS Studio according to the major frame rate and total bits. The AXN/ENC/402 is capable of generating whatever bit-rate value that results from the defined frame size and rate, as long as the rate is a reasonable float number and in the min/max limits specified in the data sheet.

### 59.8.3 Parsing non fixed length Ethernet generic packet

Because the packet length is not fixed, you will need to get the maximum data words (that is 758, which is the maximum for an Ethernet packet). You can decrease it if you know the maximum output from the device you are trying to monitor.

You must discard the last data words if the packet length is not at its maximum. The data word 8 reports the IP size packet. Therefore, you can use it to discard them after post-processing on the ground.

| | Values of offset index words | |
|---|---|---|
| **Field name** | **Offset If VLAN disabled** | **Offset If VLAN enabled** |
| Destination MAC address, word 0 (MSW) | 0 | 0 |
| Destination MAC address, word 1 | 1 | 1 |
| Destination MAC address, word 2 (LSW) | 2 | 2 |
| Source MAC address, word 0 (MSW) | 3 | 3 |
| Source MAC address, word 1 | 4 | 4 |
| Source MAC address, word 2 (LSW) | 5 | 5 |
| Frame/Protocol type; 0x0*0 e.g. IP = 0800h | 6 | 8 |
| VLAN priority/ID | N/A | 7 |
| IP version/IHL/ToS | 7 | 9 |
| IP packet size | 8 | 10 |

For example, if the packet is 700 data words, discard the last 58 data words because they will be rubbish values (RAM).

### 59.8.4 Parsing parameters with multiple occurrences in an Ethernet generic packet

The AXN/ENC/402 parses Ethernet packets into 16-bits words; regardless of whether parameters are composed of multiple words/occurrences.

The following figure shows an example of a parameter P1 composed of two words in the same packet, which is a unique type of packet coming from an Ethernet device source IP 10.0.0.1. The first instance 1-P1 is at word offset 30; the second instance is at word offset 33.

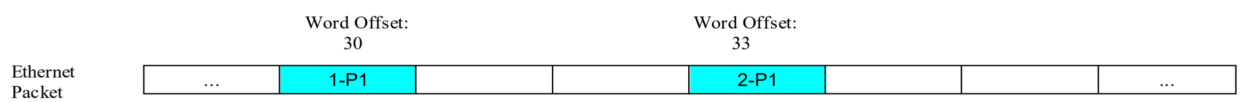



*Figure 59-12: Example of a parameter P1 composed of two words in the same packet*

Two distinct data words need to be set up in Ethernet Builder as shown in the following figure.

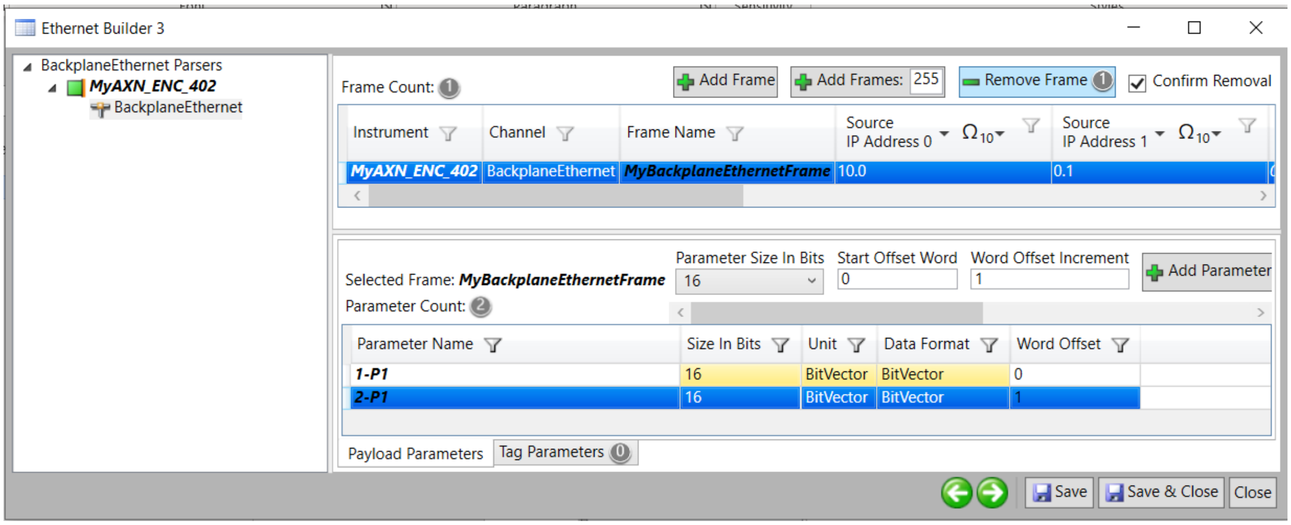



*Figure 59-13: Defining distinct data words in Ethernet Builder*

If the parameter needs to be placed in PCM for example, the two samples composing the parameter P1 need to be commutated accordingly to match the PCM frame. In our example below it is set at 1:2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SFID | | | | | | | Syncword |
| SFID | | | | | 1-P1 | | Syncword |
| SFID | | | | | | | Syncword |
| SFID | | | | | 2 -P1 | | Syncword |

*Figure 59-14: PCM showing the two samples composing the parameter P1*

When decommutating the PCM using software such as IADS, a mimic PCM is required with one single parameter at 1:2. This signals the decom software that the two samples are coming from a single parameter.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SFID | | | | | | | Syncword |
| SFID | | | | | P1 | | Syncword |
| SFID | | | | | | | Syncword |
| SFID | | | | | P1 | | Syncword |

*Figure 59-15: Mimic PCM indicating to decom software that two samples belong to the same parameter P1*

## 59.8.5 VLAN

### 59.8.5.1

VLAN Tagging, also known as Frame Tagging, is a method developed by Cisco to help identify packets traveling through trunk links. When an Ethernet frame traverses a trunk link, a special VLAN tag is added to the frame and sent across the trunk link. A commercial switch maybe able to identify packets from different VLANs according to the information contained in its VLAN tags. IEEE 802.1Q adds a 4-byte VLAN tag between the Source/Destination MAC address and Length/Type fields of an Ethernet frame to identify the VLAN to which the frame belongs

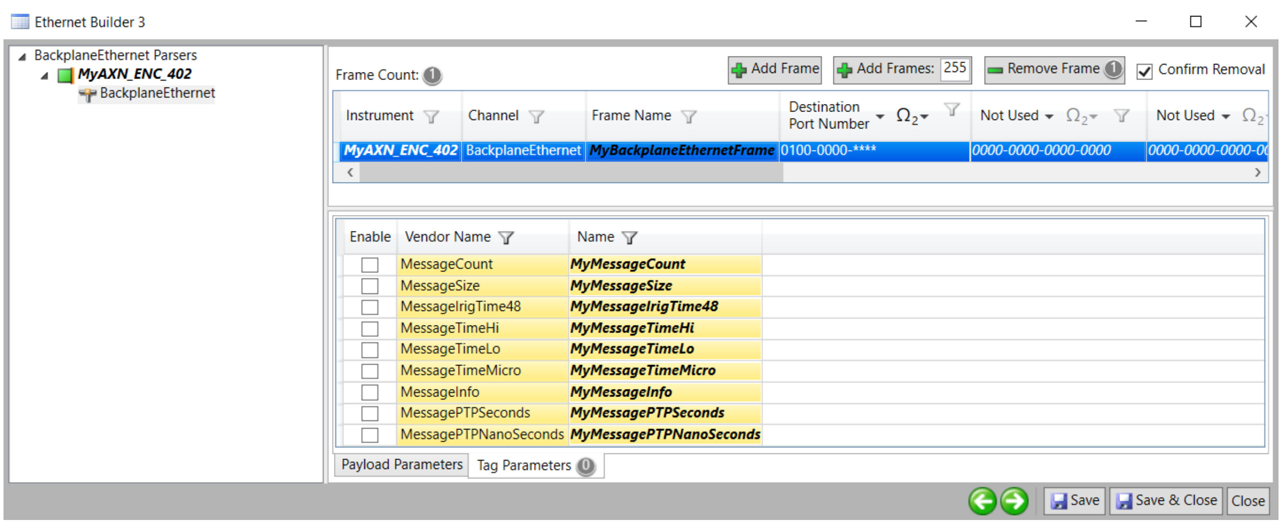
## 59.8.6 Using wildcards and tags in Ethernet Builder

### 59.8.6.1

On occasion, data may be required from a packet on the same link with the same source and destination IP addresses (but whose destination port may change). This data can be captured by using wildcards in the classifier settings. Wildcards are expressed as asterisks in the Ethernet builder, and can only be used when Binary format has been set for values in the classifier fields.

To add another packet with the exact same settings as the packet above, do the following:

1. Open **Ethernet Builder**.
1. Click **Add Frame**.
2. Select the **Destination Port Number** field in the new packet, and click the drop-down arrow by the Ω symbol to change its format from **Decimal** to **Binary**.
   The 1024 value in the **Destination Port Number** field now reads **0100-0000-0000**.
3. To represent varying port numbers, insert wildcards (asterisks) where required. This forces the AXN/ENC/402 to capture this packet regardless of the destination port number.
4. For example, 0100-0000-**** parses incoming packets with the same source and destination IP from port 1024 to 1039.
   **NOTE:** Wildcarding is only supported in binary mode.At this point, if the Binary format is changed back to Decimal (using the drop-down arrow beside an Ω symbol), the value for the Destination Port Number field (edited using wildcards) does not change format.




5. Add parameters to the new packet as required.
6. Click the **Tag Parameters** tab to add additional message tag parameters such as **MessageTimeStamp** (timestamp of arrival of the message), **MessageCount**, **MessageSize** (bytes), **MessageStatus**, **MessageInfo** (stale / skipped message).
7. To save changes, click **Save & Close**.

## 59.8.7 Related documentation

To better understand this paper, read the following documents.

Table 59-3: Data sheets

| Document | Description |
|---|---|
| AXN/ENC/401 | IRIG-106 PCM encoder (PMF output) |
| AXN/ENC/402 | IRIG-106 PCM encoder (PMF output) with Chapter 7 |

Table 59-4: Data sheets

| Document | Description |
|---|---|
| TEC/NOT/024 | Evolution of Pulse Code Modulation (PCM) |
| TEC/NOT/027 | IRIG 106-96 Chapter 4 |
| TEC/NOT/067 | IENA and iNET-X packet payload formats |

Table 59-5: User manual

| Document | Description |
|---|---|
| DOC/MAN/030 | DAS Studio 3 User Manual |

Chapter 60

# Using the AXN/TCG/401

TEC/NOT/091

The AXN/TCG/401/B is a time-code generator with GNSS/IRIG input with voice-to-digital converter (CVSD).

This technical note introduces the AXN/TCG/401/B module, and describes how to set it up, as well as troubleshooting GNSS. This paper is divided into the following sections:



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**NOTE:** The AXN/TCG/401 only functioned as a voice-to-digital converter (CVSD); that is, it did not feature time code generation functionality. This technical note only applies to the AXN/TCG/401/B and later. Any mention of AXN/TCG/401 in this technical note is referring to AXN/TCG/401/B or later.

## 60.1 Module overview

The AXN/TCG/401 can accept time from an IRIG-B time source, from its onboard GNSS receiver (external antenna required), or from an external GNSS receiver outputting NMEA messages and a one PPS signal.

The AXN/TCG/401 also has two channels of audio-to-digital conversion. The encoding scheme used is Continuously Variable Slope Delta (CVSD) modulation.

## 60.2 Setting up the AXN/TCG/401 using DAS Studio 3

You can use DAS Studio 3 software to configure the AXN/TCG/401. DAS Studio 3 is used to create a configuration file which contains the various elements which make up your data acquisition system. You then use this configuration file to manage and program these elements. To see how hardware is represented in the DAS Studio 3 graphical user interface, see Figure 1 in the *DAS Studio 3 User Manual*.

The module can concurrently receive up to two GNSS systems GPS together with GLONASS.

## 60.2.1 Settings tab

The Settings tab as shown in the following figure, shows available parameters for the module. The parameters shown in the Settings tab are defined in the *AXN/TCG/401* data sheet.

Settings | Processes | Packages | Algorithms | Documentation

| Name | Type | Name | |
|---|---|---|---|
| Audio-In(0) | VoiceChannelData(0) | P_MyAXN_TCG_401_B_Audio-In(0)_VoiceChannelData(0) | 16 |
| Audio-In(1) | VoiceChannelData(1) | P_MyAXN_TCG_401_B_Audio-In(1)_VoiceChannelData(1) | 16 |

| Source Name | Parameter Type | Parameter Name |
|---|---|---|
| MyAXN_TCG_401_B | Status | P_MyAXN_TCG_401_B_Status |
| MyAXN_TCG_401_B | LeapSeconds | P_MyAXN_TCG_401_B_LeapSeconds |
| MyAXN_TCG_401_B | ControlFunction | P_MyAXN_TCG_401_B_ControlFunction |
| GNSS-In | Latitude | P_MyAXN_TCG_401_B_GNSS-In_Latitude |
| GNSS-In | Latitude : LatitudeHi | |
| GNSS-In | Latitude : LatitudeLo | |
| GNSS-In | Latitude : LatitudeMicroMinutes | |
| GNSS-In | Longitude | P_MyAXN_TCG_401_B_GNSS-In_Longitude |
| GNSS-In | Longitude : LongitudeHi | |
| GNSS-In | Longitude : LongitudeLo | |
| GNSS-In | Longitude : LongitudeMicroMinutes | |
| GNSS-In | Altitude | P_MyAXN_TCG_401_B_GNSS-In_Altitude |
| GNSS-In | Altitude : AltitudeHi | |
| GNSS-In | Altitude : AltitudeLo | |
| GNSS-In | VelocityInKph | P_MyAXN_TCG_401_B_GNSS-In_VelocityInKph |
| GNSS-In | VelocityInKn | P_MyAXN_TCG_401_B_GNSS-In_VelocityInKn |
| GNSS-In | Heading | P_MyAXN_TCG_401_B_GNSS-In_Heading |
| GNSS-In | Heading : HeadingHi | |
| GNSS-In | Heading : HeadingLo | |
| GNSS-In | DilutionOfPrecision | P_MyAXN_TCG_401_B_GNSS-In_DilutionOfPrecision |
| GNSS-In | StatusGNSS | P_MyAXN_TCG_401_B_GNSS-In_StatusGNSS |
| GNSS-In | SatellitesInView | P_MyAXN_TCG_401_B_GNSS-In_SatellitesInView |

*Figure 60-1: Settings tab showing available parameters*

**NOTE:** To see module settings, the module must be in context in the Navigator. Refer to the *DAS Studio 3 User Manual* for more information.

The Settings tab as shown in the following figure, shows available settings for the module. These settings are defined in the *AXN/TCG/401* data sheet.

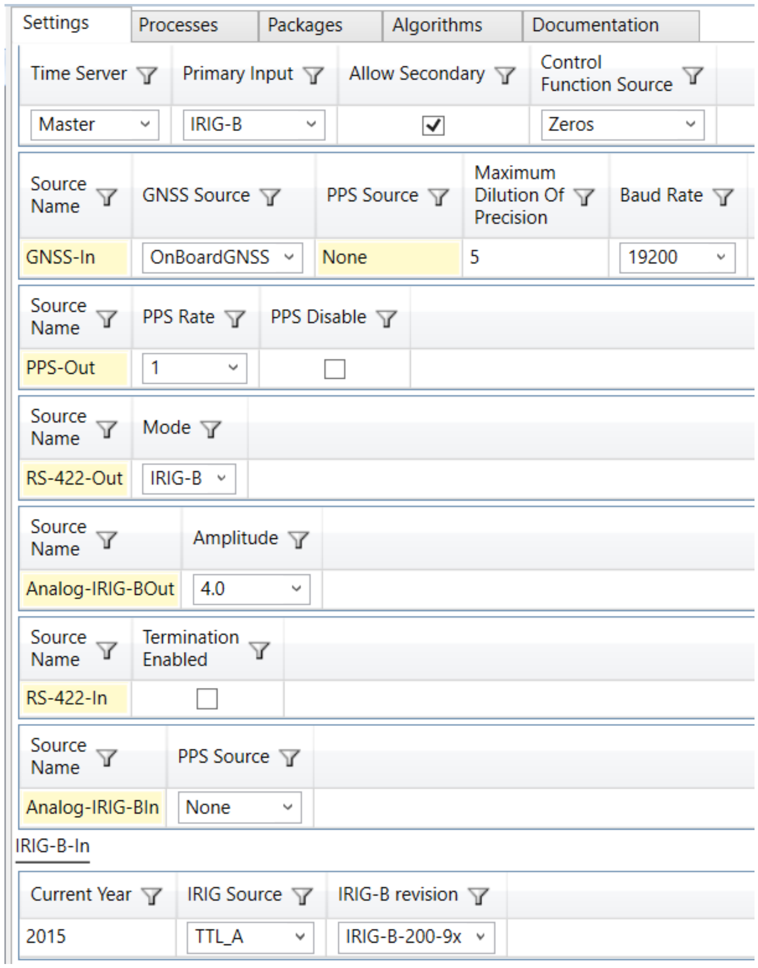


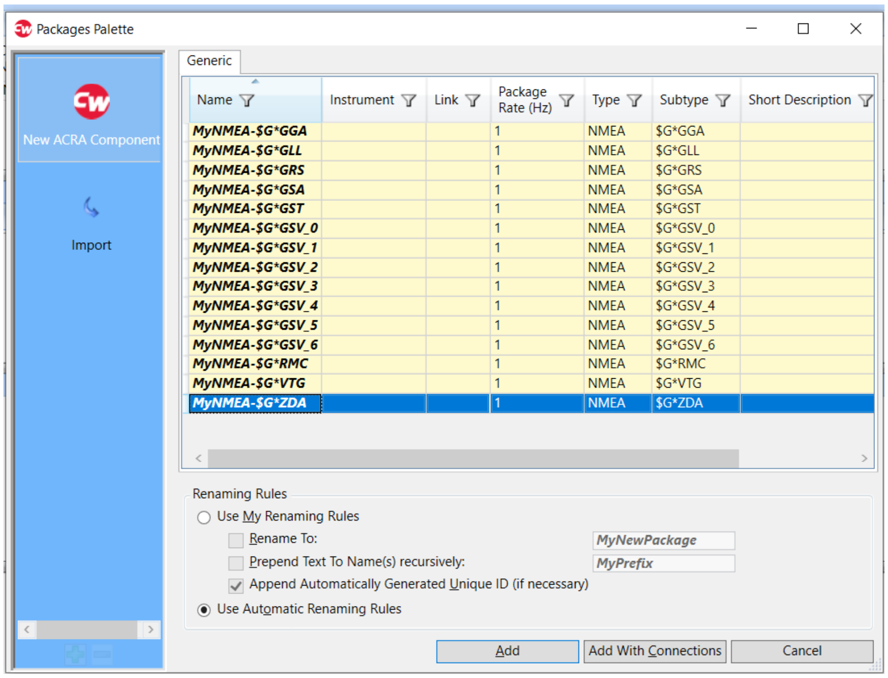

*Figure 60-2: Settings tab showing available settings*

## 60.2.2 Packages tab - setting parser of NMEA packages

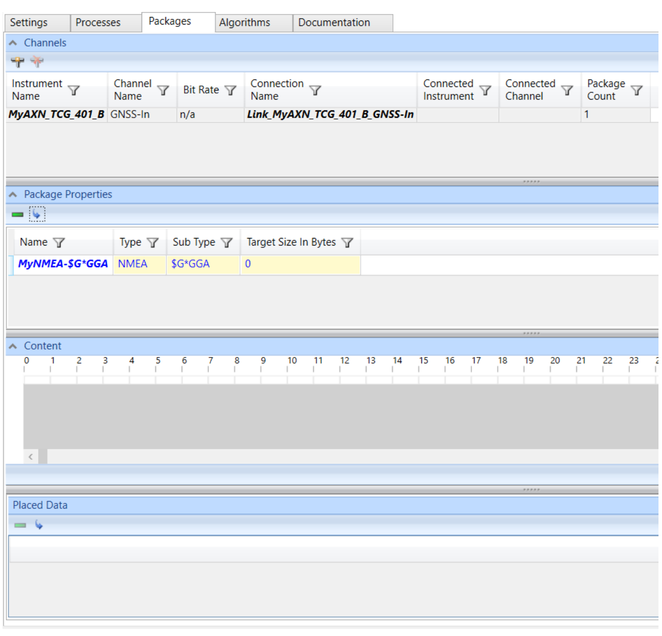
The AXN/TCG/401 allows parsing of any of the 15 predefined National Marine Electronics Association (NMEA) messages supported by the module: GGA, GLL, GRS, GSA, GST, GSV0 to GSV6, RMC, VTG and ZDA. For further information regarding NMEA 0183, refer to the latest standard available.

To create an NMEA message, the corresponding predefined package needs to be created. Refer to the following to create the predefined package.

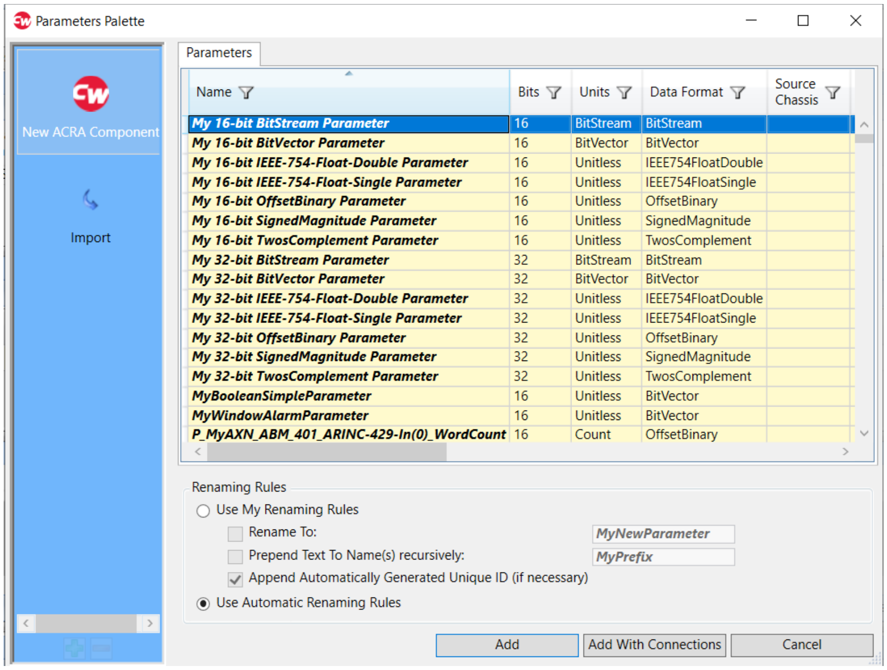
1. On the **Packages** tab of the AXN/TCG/401, click the arrow under **Package Properties**.
   The following screen with the 15 predefined NMEA messages supported by the AXN/TCG/401 appears.



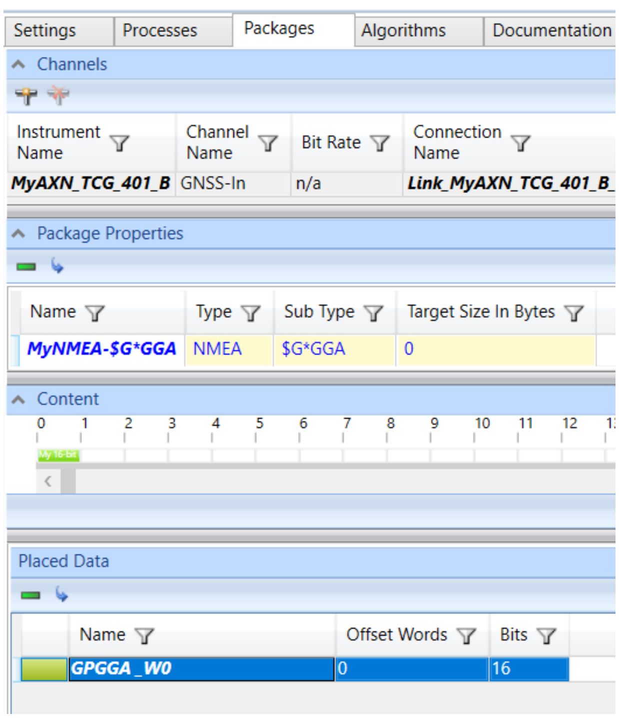

2. Select a message to parse (for example $G*GGA) and then click **Add**.
   The new NMEA is created.



3. Click the arrow under **Placed Data**.
**Parameters Palette** appears.




4. Select a 16-bit parameter such as **My 16-bit BitStream Parameter** and then click **Add**.
A generic 16-bit parameter with the default message name and offset 0 is created. This can be renamed to a more meaningful name such as **GPGGA_W0** (see following screen), which corresponds to the first two bytes of the $G*GGA message.




In the previous example, the first data word with offset 0 for $GPGGA has the following result: $G, a second word with offset 1 results in PG and so on. Additional data words can be added up to a maximum offset of 41 (the maximum supported length of full NMEA 0183 messages is 82 characters). Full NMEA 0183 messages consist of a maximum of 79 characters between start of message "$" or "!" and terminating delimiter <CR><LF> (HEX 0D and 0A).

An additional Info register associated with each NMEA message to indicate the status of the message can be added. See "60.2.3.1 Parsers – Setting up MessageInfo" on page 578.

## 60.2.3 Processes tab

The following Processes tab shows available processes for the module. The processes shown in the Processes tab are defined in the *AXN/TCG/401* data sheet.

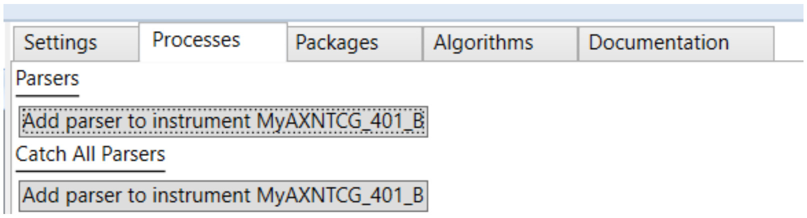


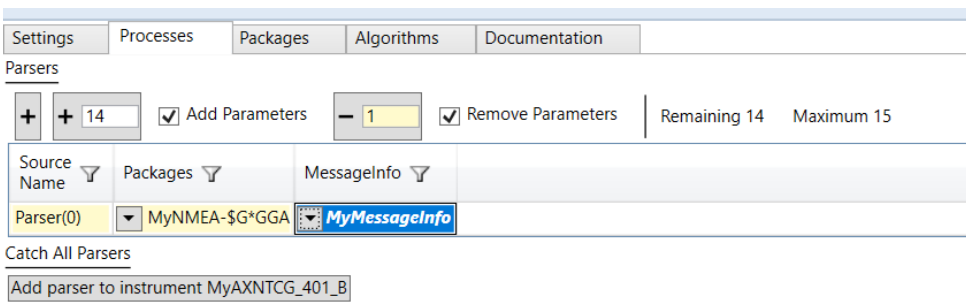

*Figure 60-3: Processes tab showing available processes*

### 60.2.3.1 Parsers – Setting up MessageInfo

The MessageInfo register indicates the status of the message as empty (no message), stale (repeated) and skipped. The Parsers process allows you to associate the MessageInfo parameter with one of the 15 predefined NMEA packages previously set in "60.2.2 Packages tab - setting parser of NMEA packages" on page 576.

Refer to the following to create the MessageInfo.

1. On the **Processes** tab, click **Add parser to instrument AXN/TCG/401**.
2. Click **Packages** and then click **Add package reference**.
3. Select one of the NMEA packages already added in the packages tab and then click **Add reference**. An example of message $G*GGA is shown below.




**NOTE:** For further details on how to use a process, refer to the "Processes tab" section in the *DAS Studio User Manual*.

### 60.2.3.2 Catch All Parsers

Any package that is not assigned to a parser is sent to this catchall parser where it can be sampled if required. Unlike Parsers, Catch All Parsers automatically sets 41 words and MessageInfo.

This feature is not recommended and should be used as a debug tool only.

# 60.3 Example configurations

## 60.3.1 External GNSS receiving NMEA messages over RS-422

The setup for an external GNSS receiving NMEA RS-422 at 19,200 bps is shown in the following two figures.

**NOTE:** For the following two sample configurations, it is assumed that the secondary input IRIG is not used.

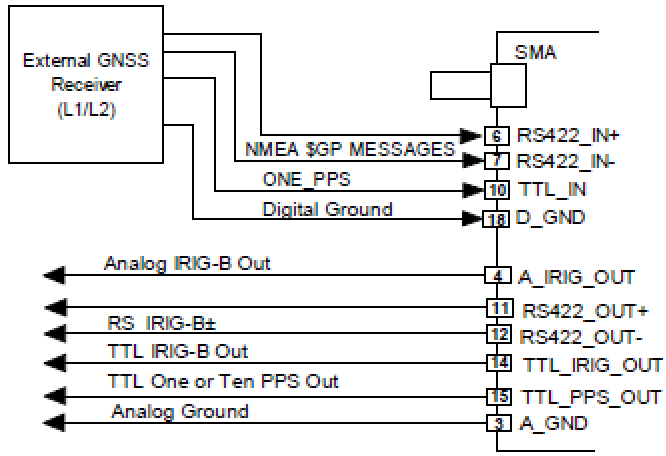



*Figure 60-4: Setup for external GNSS receiving RS-422*

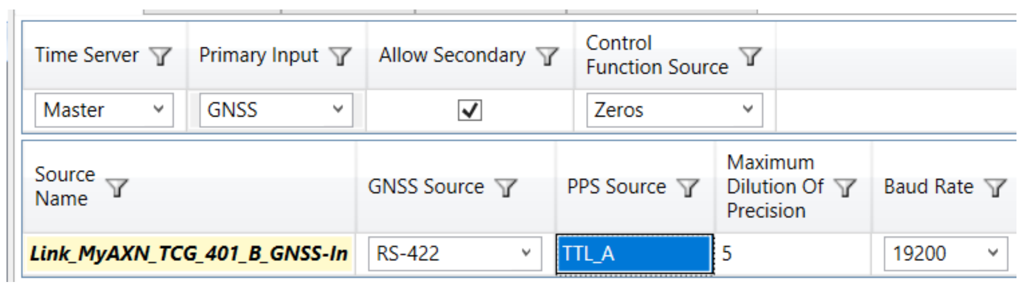



*Figure 60-5: Example of setup for external GNSS receiving RS-422 in DAS Studio 3*

**NOTE:** ONE_PPS is required for the AXN/TCG/401 to synchronize its time with the minimum set of external NMEA messages.

## 60.3.2 Active GNSS antenna

The setup for an active GNSS antenna is shown in the following two figures.

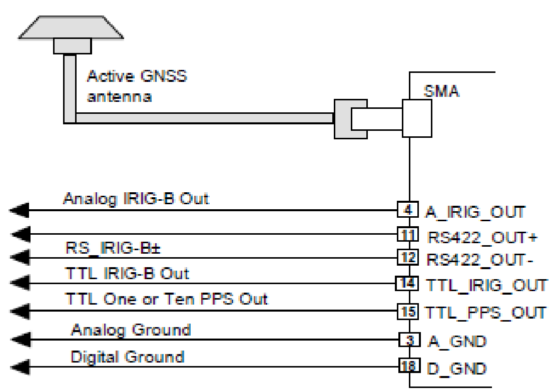
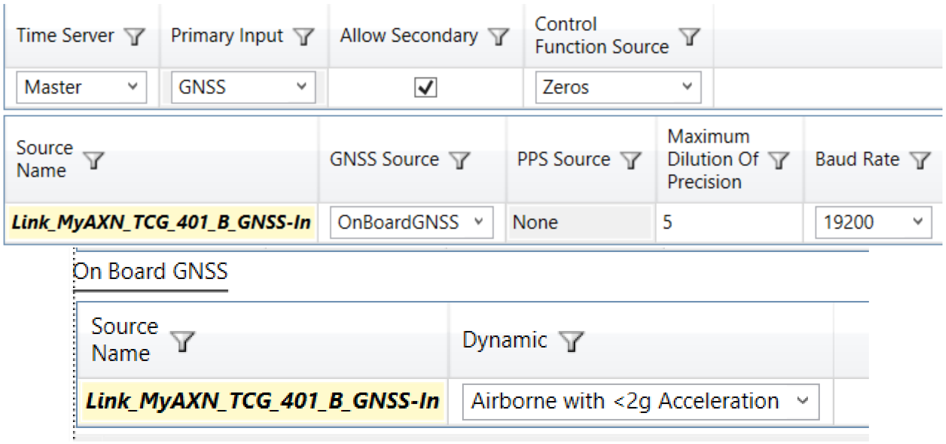



*Figure 60-6: Setup for active GNSS antenna*



| Time Server | Primary Input | Allow Secondary | Control Function Source |
|---|---|---|---|
| Master | GNSS | ☑ | Zeros |

| Source Name | GNSS Source | PPS Source | Maximum Dilution Of Precision | Baud Rate |
|---|---|---|---|---|
| Link_MyAXN_TCG_401_B_GNSS-In | OnBoardGNSS | None | 5 | 19200 |

On Board GNSS

| Source Name | Dynamic |
|---|---|
| Link_MyAXN_TCG_401_B_GNSS-In | Airborne with <2g Acceleration |

*Figure 60-7: Example of setup for active GNSS antenna in DAS Studio 3*

---

**NOTE:** Leap Seconds are automatically updated on Axon.

### 60.3.3 External GNSS receiver using NMEA messages over RS-232 and one PPS TTL

The setup for an external GNSS receiver using NMEA RS-232 at 19,200bps and TTL_IN_A one PPS is shown in the following two figures.

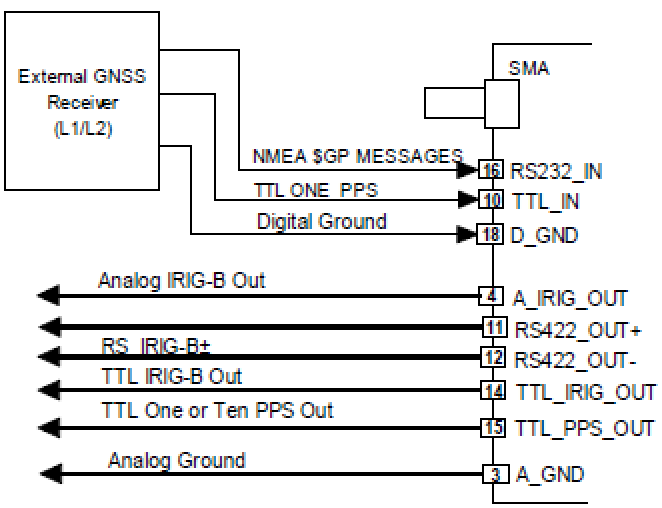
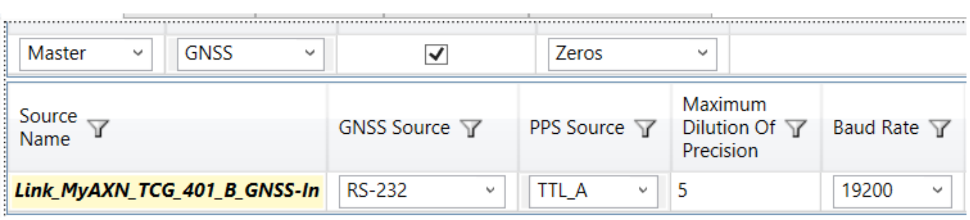



*Figure 60-8: Setup for external GNSS receiver using RS-232 and TTL PPS*



| | | | |
|---|---|---|---|
| Master | GNSS | ☑ | Zeros |

| Source Name | GNSS Source | PPS Source | Maximum Dilution Of Precision | Baud Rate |
|---|---|---|---|---|
| Link_MyAXN_TCG_401_B_GNSS-In | RS-232 | TTL_A | 5 | 19200 |

*Figure 60-9: Example of setup for external GNSS receiver using RS-232 and TTL in DAS Studio 3*

## 60.3.4 Analog IRIG-B input

The setup for an analog IRIG-B input is shown in the following two figures.

---

**NOTE:** Analog IRIG-B only support 1 PPS signal over pin 9 TTL_IN_B.

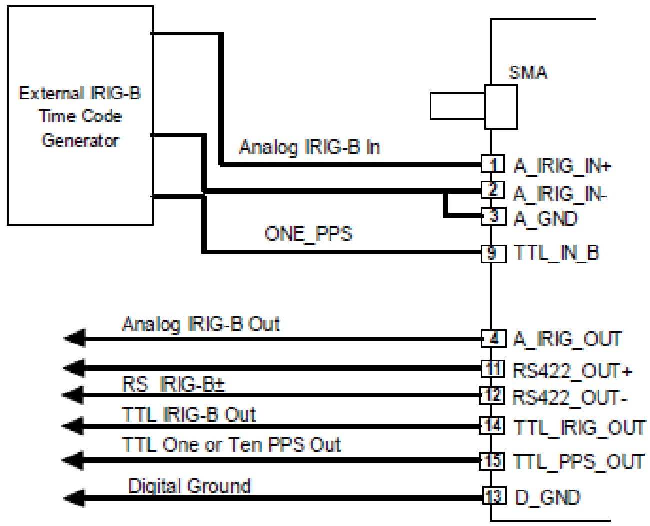



*Figure 60-10: Setup for analog IRIG-B input with 1 TTL PPS*

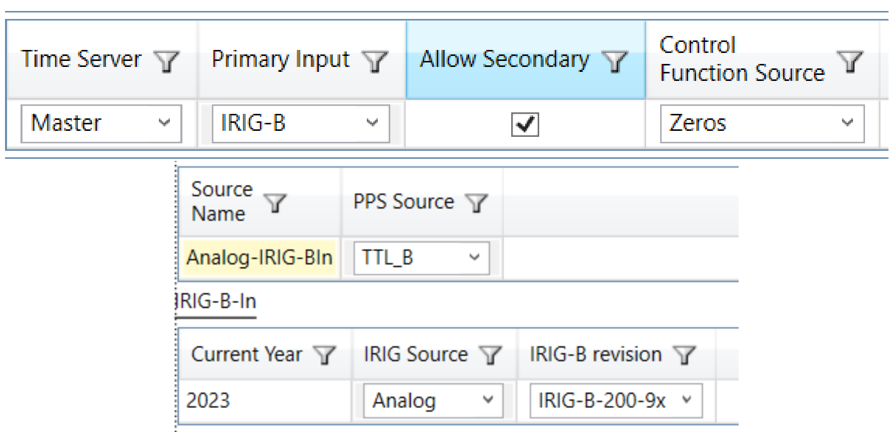



*Figure 60-11: Example of setup for analog IRIG-B input with 1 PPS in DAS Studio 3*

---

**NOTE:** ONE_PPS connection is optional on the previous figure, however it is recommended in order to increase accuracy. When IRIG-B-200-04 is selected, the module decodes the year from the control function (CF) bits, however IRIG-B-200-9x does not contain year information.

## 60.3.5 Digital IRIG-B input - TTL

The setup for a digital IRIG-B input is shown in the following two figures.

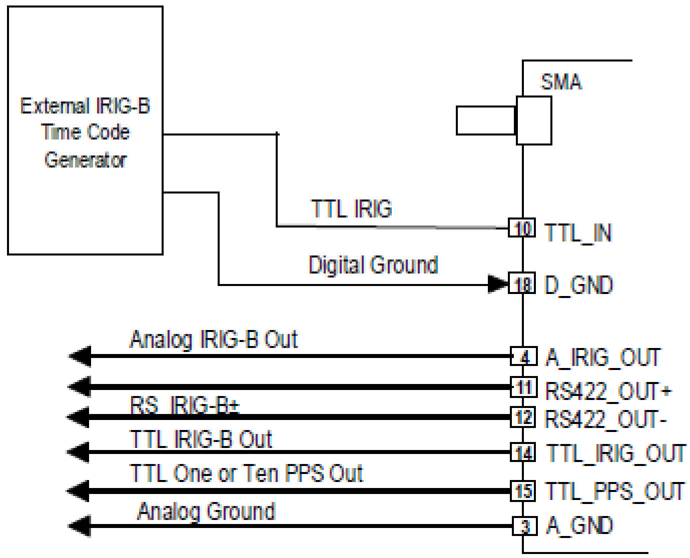



*Figure 60-12: Setup for digital IRIG-B input*

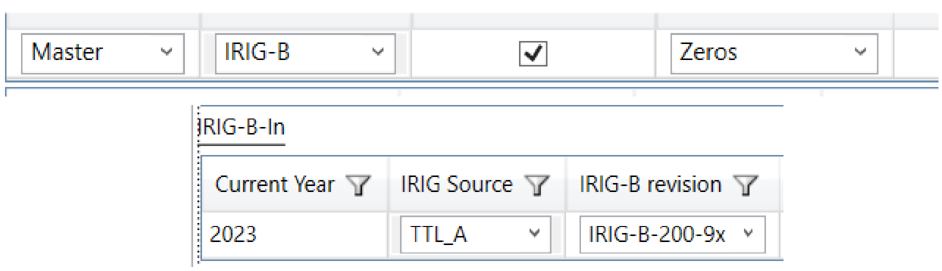



*Figure 60-13: Example of setup for digital IRIG-B input in DAS Studio 3*

## 60.3.6 Digital IRIG-B input - RS-422

The setup for a RS-422 IRIG-B input is shown in the following two figures.

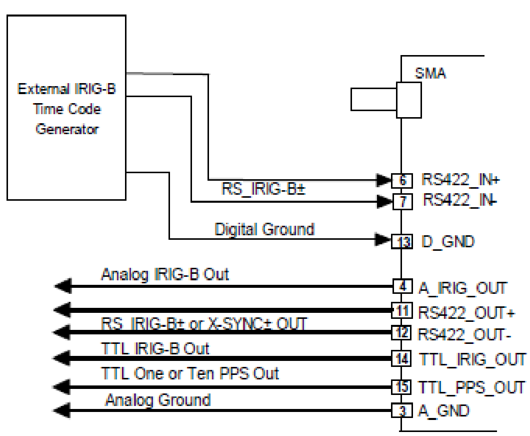



*Figure 60-14: Setup for RS-422 IRIG-B input*

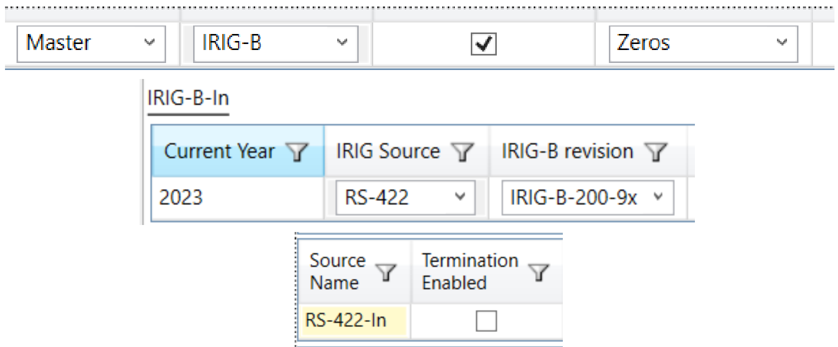


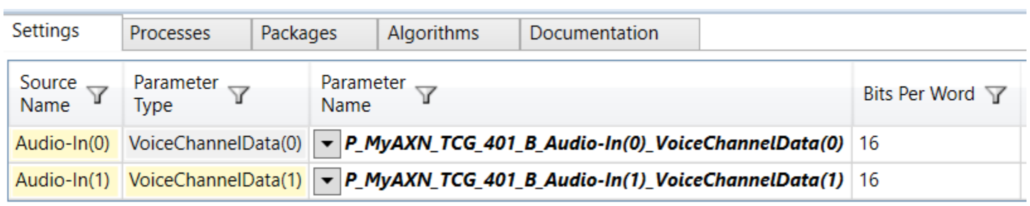

*Figure 60-15: Example of setup for RS-422 IRIG-B input in DAS Studio 3*

---

**NOTE:** When termination is enabled, a 120-ohm termination resistor is active between input pins RS422_IN(+) and RS422_IN(-). This resistor is not active when the module is powered off.

### 60.3.7 Voice channels

The module supports Audio. The encoding scheme used is Continuously Variable Slope Delta (CVSD) modulation. IADS supports this encoding. Due to the compression scheme, an Audio-In parameter can be transmitted into different sinks (Ethernet or PCM for example) but it must be transmitted at the same rate. For audio quality versus sampling rate recommendations, see the *AXN/TCG/401* data sheet, "Voice-to-digital converter" section.




| Source Name | Parameter Type | Parameter Name | Bits Per Word |
|---|---|---|---|
| Audio-In(0) | VoiceChannelData(0) | ***P_MyAXN_TCG_401_B_Audio-In(0)_VoiceChannelData(0)*** | 16 |
| Audio-In(1) | VoiceChannelData(1) | ***P_MyAXN_TCG_401_B_Audio-In(1)_VoiceChannelData(1)*** | 16 |

*Figure 60-16: Voice channels*

## 60.4 Troubleshooting GNSS

This section explains the most common issues with GNSS. For GNSS antenna recommendations, see the *AXN/TCG/401* data sheet.

### 60.4.1 GNSS not in lock

Check the StatusGNSS parameter. This parameter provides information on the current GNSS status, such as GNSS lock, Dilution of Precision (DOP) in and out of range, and number of satellites in use.

---

**NOTE:** Bit 15 of the StatusGNSS parameter defaults to 0, which indicates the module does not have GNSS lock. Bit 15 is only set to 1 when the GNSS receiver has achieved GNSS lock.

If bit 15 remains at 0, the module is unable to achieve GNSS lock and there are problems with satellite coverage. This may be due to poor satellite coverage or issues with the GNSS antenna or cabling.

If bit 15 is set to 1 (GNSS lock) but the position is incorrect, check bit 11. If bit 11 of the StatusGNSS parameter is set to 1, this indicates that the DOP figures are out of range. The actual DOP figures can be read from the DilutionOfPrecision parameter.

Also, check the number of satellites in view (SatellitesInView parameter) and the number of satellites in use (StatusGNSS[3:0]). If the number of satellites in view is less than four, try the other troubleshooting hints in this section.

---

**NOTE:** The antenna must be connected before powering up the Axon chassis with the AXN/TCG/401.

### 60.4.2 Multipath errors

A multipath environment exists if GNSS signals arrive at the antenna directly from the satellite and also from reflective surfaces, for example water or building walls (see the following figure).

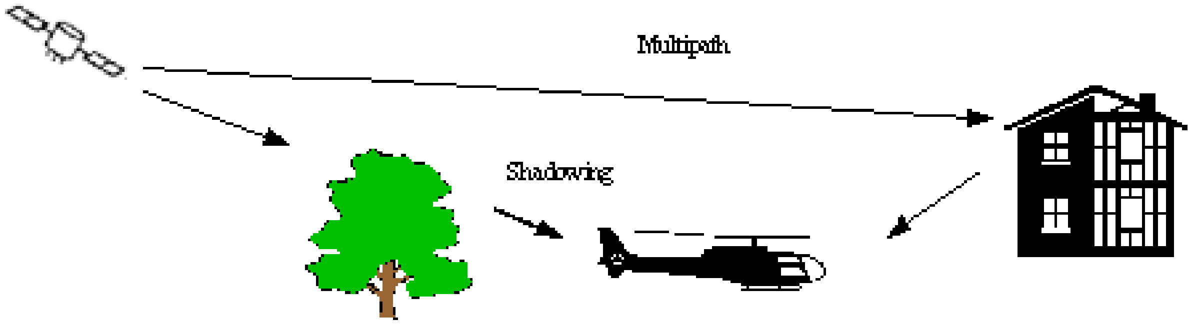



*Figure 60-17: Multipath environment*

If there is a direct path in addition to the reflected path available, the receiver can usually detect the situation and compensate to some extent. If there is no direct line of sight, but only reflections, the receiver is not able to detect the situation.

Under multipath conditions, range measurement to the satellite provides incorrect information to the navigation solution, resulting in less accurate positioning. If there are few satellites in view, the navigation solution might be wrong by several hundred meters.

Location of the antenna close to a vertical metal surface can be harmful owing to the fact that metal is an almost perfect reflector. When mounting an antenna on top of a reflective surface, the antenna should be mounted as close to the surface as possible. Then, the reflective surface acts as an extension of the antennas ground place and not as a source multipath.

### 60.4.3 Antenna shortcomings

Although GNSS can work with a weak signal, to have a reliable GNSS system the antenna selection and location should be considered carefully as inappropriate selection and poor location degrades GNSS performance. Factors which degrade the GNSS performance include the following:

- Inadequate gain of the GNSS antenna
- Poor directivity of the GNSS antenna
- Improper orientation of the antenna to the sky
- Poor matching of antenna, cable, and receiver impedance
- Poor noise performance of the input stage of the antenna amplifier
- GNSS antenna is connected to the module after the Axon is powered up.

For more information on getting the most from the antenna, see the *AXN/TCG/401* data sheet.

## 60.5 Tips

### 60.5.1 Power up

The module has no battery backup and cannot be connected to a battery backup. The module will cold power-up each time.

### 60.5.2 Representing GNSS position in IADS

Contact Curtiss-Wright support (acra-support@curtisswright.com) to obtain a copy of technical document TSD/AC/005 IADS derive equation for TCG Altitude Latitude Longitude Heading.

Latitude/Longitude are specified in degrees/minutes/seconds (DMS) in the *AXN/TCG/401* data sheet while some GNSS localization system may express it in Decimal Degrees (DD).

## 60.5.3 RFE/AEG/001

There are no special accessories required to mount this antenna; it is shipped complete for mounting. The antenna in this series is hard-mounted through a unique single hole feed structure and includes gaskets to prevent air and water leaks. The mounting is a through hole 5/8-18UNC-2A thread.

## 60.5.4 SMA torque setting

The recommended torque setting for the SMA connector on the AXN/TCG/401 is 0.45 Nm (0.33 foot pound-force).

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# AXN capabilities and FAQ

TEC/NOT/092

This document is for readers already familiar with KAM-500 architecture who would like to know the differences from a feature and system architecture point of view between KAM-500 and AXN.

This document discusses aspects of AXN other than its smaller size, lower weight, and higher bandwidth as compared with KAM-500.

This paper is divided into the following sections:



## 61.1 AXN system architecture

The AXN/BCU/402 has an internal switch with two 1-Gbps ports; the internal switch also supports a 100-Mbps link. This allows various configurations such as the following:

- Daisy chain configuration with AXN
- Connecting 3rd party devices directly to an AXN/BCU/402 switch
- Daisy chain configuration with KAM-500

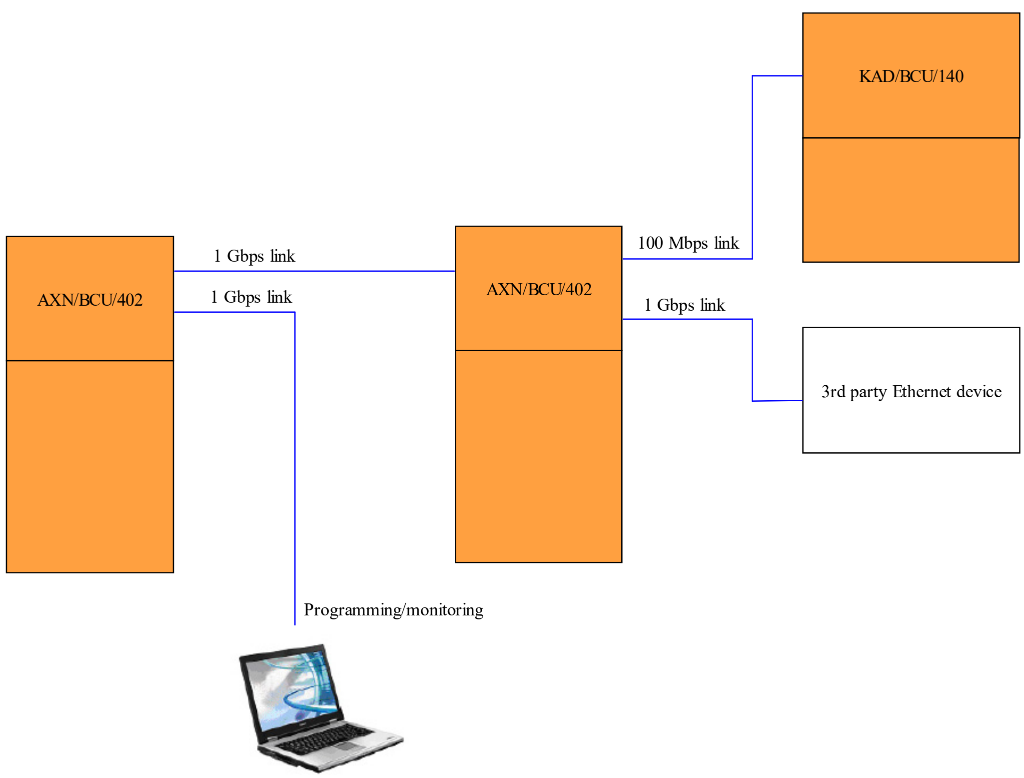



*Figure 61-1: AXN network system using the internal switch from the AXN/BCU/402*

**NOTE:** Daisy chain configuration is supported from the AXN/BCU/402/B onwards.

The AXN/BCU/402 supports PTPv2 and PTPv1 Grandmaster allowing the system (see the following figure) to be synchronized. The AXN/TCG/401 connected to GNSS (GPS and GLONASS simultaneously) provides time to the system.

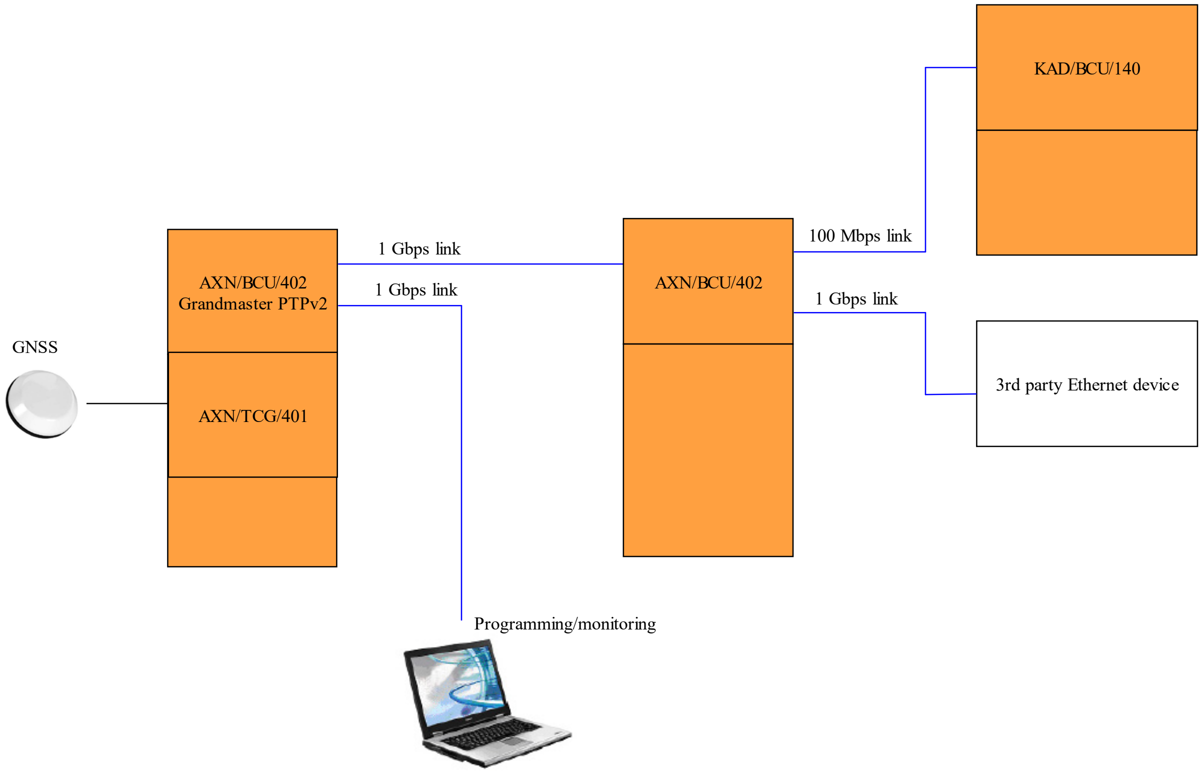



*Figure 61-2: AXN network system with the AXN/BCU/402 as a PTPv2 Grandmaster*

---

**NOTE:** Time code generation functionality is supported from the AXN/TCG/401/B onwards.

The AXN/ENC/402 can be used for telemetry. It can achieve 40 Mbps while the KAD/ENC/106 is limited to 20 Mbps.

Unlike KAM-500, the AXN/ENC/402 has a mini Ethernet bus monitor to allow parsing of remote chassis and 3rd party devices; an additional module such as the KAD/EBM/102 for the KAM-500 is not required to run the Multi Chassis Scheduler (MCS). It can also handle burst packets due to the deep buffer.

The AXN/ENC/402 is also capable of transmitting IRIG-106 Chapter 7 PCM streams containing wrapped Ethernet frames as well as IRIG-106 Chapter 4 PCM streams. These wrapped Ethernet frames include packetizers packets from remote chassis as shown in the following figure.

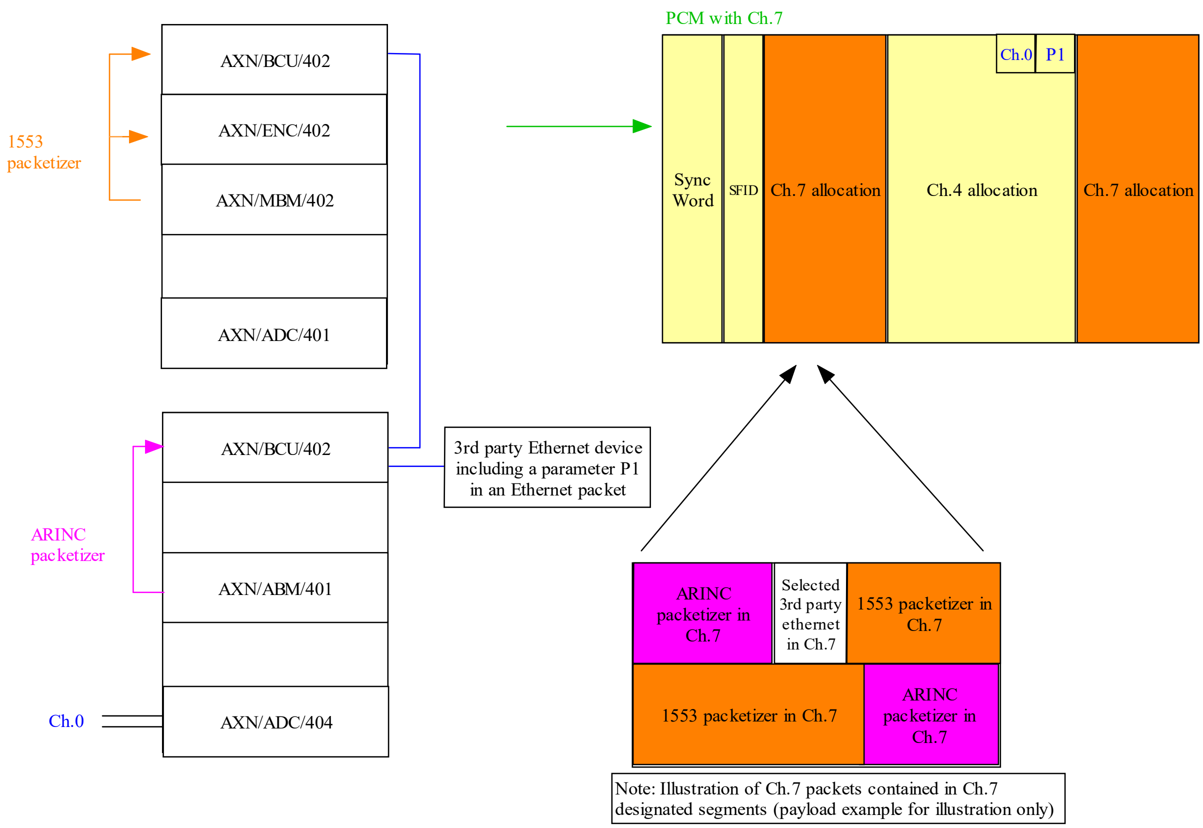



*Figure 61-3: AXN network system with the AXN/ENC/402 Chapter 7*

## 61.2 Axonite

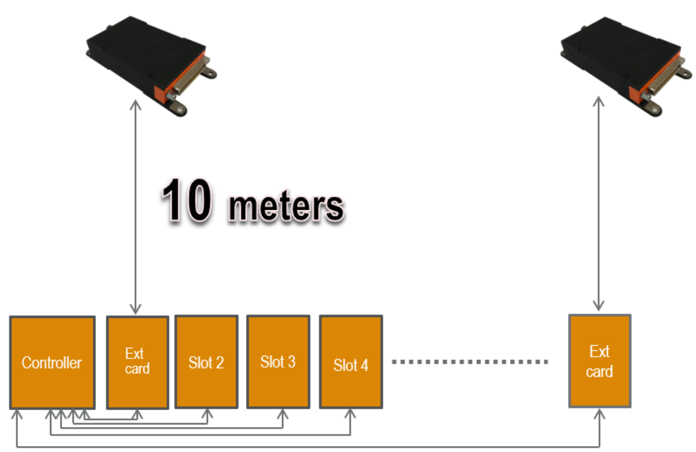



*Figure 61-4: Axonite ten meters away from an AXN chassis*

The Axonite (AXN/ITE/01U) allows AXN user modules to be housed remotely from the AXN chassis (up to ten meters) and include the following features:

- Designed to fit into compact spaces.
- Reduces heat generated in the chassis.
- Greater heat dissipation due to the greater relative surface area for the module to dissipate heat.
- Modules can be located closer to sensors resulting in a shorter connection between module and sensor.
- Reduced signal-to-noise ratio.
- Reduce system wiring.

There is no enforced software or hardware limit to the number of Axonites you can use in a chassis; the limiting factor is the available power.

## 61.3 ADC

AXN analog modules follow the same concept as analog modules in KAM-500, however AXN ADC modules have more capabilities as described in the following sections.

### 61.3.1 Multiple output data streams

Three output data streams per channel, which allow different settings per channel such as filter cutoff frequency (Fc) and filter type (IIR/FIR per streams and sampling frequencies [Fs]). These output data streams allow you to have different filtering schemes depending on the transmission such as the following examples:

Stream 1 to PCM for real time transmission to ground station at 32 Hz with Fc = Fs/4 so Fc = 8 Hz and Filter type = IIR8 (IIR8 has the lowest latency)

Stream 2 to onboard monitoring at 256 Hz with Fc = Fs/4 so Fc = 64 Hz and Filter type = IIR16

Stream 3 to recorder at 1024 Hz with Fc = Fs/4 so Fc = 256 Hz and Filter type = FIR (FIR has a constant delay, that is, 4/Fc on the AXN/ADC/401, which simplifies post processing parameter correlation compared to IIR8 or IIR16 for which the filter delay is dependent on the signal input frequency)

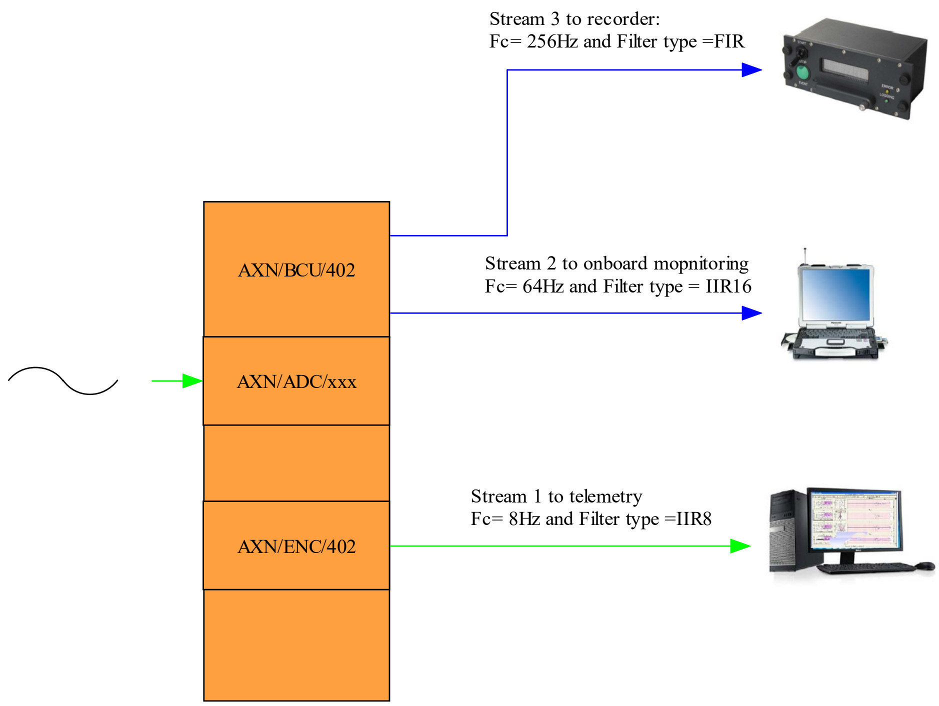



*Figure 61-5: Example of 3 streams per channel*

### 61.3.2 Auto-balance

Auto-balance is done digitally to speed up the balancing process; compare this to the balance current used on KAM-500, which requires reprogramming for each iteration. That is, AXN is faster than KAM-500 at balancing channels taking just a few seconds per module or several modules in parallel.

### 61.3.3 User compensation

User compensation per channel can be used to include user calibration/correction of module channels and external sensor/cabling errors compensation.

### 61.3.4 Linearization

Linearization URL per channel can be used to linearize a non-linear sensor.

### 61.3.5 Different IIR and Fc filtering

AXN ADC modules supports per stream FIR, IIR8 (8th order filter) and IIR16 (16th order filter). IIR8 is similar to the IIR used on the KAM-500 (passband is flatter and phase is different).

AXN ADC modules support the same KAM-500 Fc but also support additional Fc, such as Fc = Fs/2.5 or Fs/3. These cut-off frequencies are commonly used by products designed by Curtiss-Wright or for compatibility with non Curtiss-Wright DAUs.

### 61.3.6 BIT

AXN ADC modules have a built-in temperature sensor on the module motherboard that can be monitored via a parameter called ModuleTemperature indicating its temperature. This parameter can be used as a reference temperature for customer-defined linearization tables.

Most AXN ADC modules have a Temperature sensor on the top block of the module. This can be used as a cold junction for Thermocouple sensor operation.

Some AXN ADC modules have a REPORT word, which mentions if a channel is not responding.

## 61.4 Bus monitor

AXN bus monitor modules follow the same concept as bus modules in KAM-500 (parser and packetizer), however the AXN bus monitors modules have more capabilities as described in the following sections.

### 61.4.1 Packetizer filtering

You can specifically select messages you want to place/remove from the packetizer.

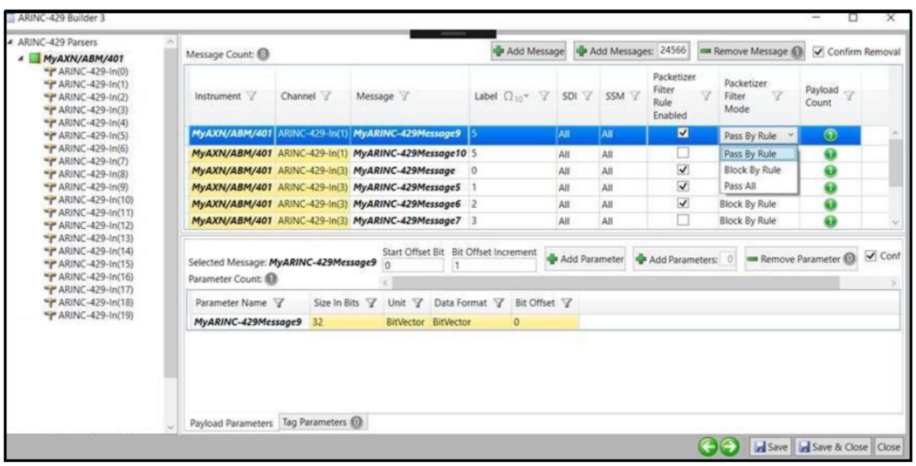



*Figure 61-6: DAS Studio ARINC-429 builder showing the messages to be filtered on the packetizer*

### 61.4.2 IENA/Chapter 10 packetizer

Unlike KAM-500, which only supported IENA P and iNET-X, most AXN bus monitors modules support Chapter 10 and IENA formats (such as D or N).

## 61.5 FAQ

| Question | Answer |
|---|---|
| Does AXN use the same connector as KAM-500? | AXN uses the same double-density connector as KAM-500. However the AXN/BCU/402 pin-out is different to the KAD/BCU/140; this is to allow a higher isolation voltage. Also the power connector is different; the AXN power connector allows for a higher current up to 100W. |
| Does AXN support In Service Programming (ISP)? | AXN supports ISP. ISP allows customers to program firmware and the FPGA of AXN modules without the need to return modules to Curtiss-Wright for updates. |
| Why are AXN/BCU/xxx controllers not located closer to the AXN PSU as is the case with KAM-500? | The location of AXN/BCU/xxx controllers allows for better heat distribution. |
| What is the maximum power consumption on AXN? | The AXN backplane provides a single, shared, 15V power line to all user modules, with up to 100W of power available from the PSU (KAM-500 PSU is maximum 81W). This single power line (15V) offers greater flexibility for higher density of excitation channels in a single chassis compared to the split power rails of the KAM-500 design. This means on AXN, all unused power is available for excitation. |
| KAM-500 has a setting to adjust for leap seconds. Why does AXN not have this setting? | Leap seconds are adjusted automatically by AXN. AXN programs a serial EEPROM transparently when a leap second occurs. |
| KAM-500 supports snarfer. How is the same concept achieved with AXN? | AXN supports packetizer, which can be transmitted over telemetry using Chapter 7. |
| What is the bandwidth of AXN compared to KAM-500? | KAM-500 is limited to an access rate of 2 Msps (so 32 Mbit/s) using a KAD/BCU/140/D 100 Mbps link. The AXN/BCU/402/C supports Gigabit link with AXN user modules and 380 Mbps data throughput to external Ethernet connections. |
| Can KAM-500 and AXN work together? | Yes. Users already familiar with KAM-500 can seamlessly upgrade their systems by adding AXN. KAM-500 and AXN can be time synchronized on a network and produce coherent data. DAS Studio 3 allows setting up and programming of this type of hybrid system. IADS software also supports these configurations. |

## 61.6 Related documentation

To better understand this paper, read the following documents.

| Document | Description |
|---|---|
| DOC/DBK/011 | AXN Databook |
| TEC-NOT-089 | Using DAS Studio 3 to configure the AXN/ENC/402 |

Chapter 62

# Reference

This section contains tables, equations and general reference information frequently required by data acquisition engineers and in particular those in the aerospace industry.

This appendix discusses the following topics:

### General



### Shunt resistor values



### Thermocouple response tables

## 62.1 Physical units and conversions

### 62.1.1 Decimal prefixes

| | | | | | | |
|---|---|---|---|---|---|---|
| **$10^1$** | deca | da | | **$10^{-1}$** | deci | d |
| **$10^2$** | hecto | h | | **$10^{-2}$** | centi | c |
| **$10^3$** | kilo | k | | **$10^{-3}$** | milli | m |
| **$10^6$** | mega | M | | **$10^{-6}$** | micro | m |
| **$10^9$** | giga | G | | **$10^{-9}$** | nano | n |
| **$10^{12}$** | tera | T | | **$10^{-12}$** | pico | p |
| **$10^{15}$** | peta | P | | **$10^{-15}$** | femto | f |
| **$10^{18}$** | exa | E | | **$10^{-18}$** | atto | a |

**NOTE:** Curtiss-Wright use an upper case K for 1,024 (for example KBytes). Unless otherwise stated, MByte means 1,048,576 bytes.

### 62.1.2 Units of length

The metric or International System (SI) unit of length is a meter (m).

| | | |
|---|---|---|
| **1 kilometer** | 1 km | = 1000m |

Some conversions from Anglo-American units are:

| | | | |
|---|---|---|---|
| **1 foot** | 1 ft | = 30.48 cm | |
| **1 inch** | 1 in. or 1" | = 2.54 cm | = 25.4 mm |
| **1 English mile** | 1M | = 1609m | = 1.6 km |
| **1 Nautical mile** | 1 knot | = 1852m | = 1.9 km |
| **1 mil** | $10^{-3}$ in | = 25.4 mm | |

### 62.1.3 Units of temperature

There are four popular units of temperature: Celsius, Fahrenheit, Kelvin and Rankine. The conversion formulas to and from Celsius (sometimes called centigrade) are:

| | | |
|---|---|---|
| **Kelvin** | Celsius + 273.15 | Celsius = Kelvin - 273.15 |
| **Rankine** | (Celsius + 273.15) x 9/5 | Celsius = (Rankine x 5/9) - 273.15 |
| **Fahrenheit** | (Celsius x 9/5) + 32 | Celsius = (Fahrenheit-32) x 5/9 |

Some examples are:

| | Celsius | Fahrenheit | Kelvin | Rankine |
|---|---|---|---|---|
| **Absolute zero** | -273.15° C | -459.67°F | 0K | 0 Rank |
| **Melting point of water** | 0°C | 32°F | 273.15K | 491.67 Rank |
| **Boiling point of water** | 100°C | 212°F | 373.15K | 671.67 Rank |

## 62.2 Bits, counts, and noise

An analog to digital converter (A/D) with one bit, can count 0 to 1. In general the number of counts of an *n*-bit A/D is given by:

$$Counts = 2^n$$

For the 1-bit A/D, each count value represents 50% of the span of the A/D. In general for an n-bit A/D, each count represents the following percentage of the span:

$$\% = \frac{100}{Counts} = 100 \cdot 2^{-n}$$

Similarly the resolution of an A/D, in parts per million (ppm), can be calculated using:

$$ppm = 10^6 \cdot 2^{-n}$$

The dynamic range of an A/D can be calculated using the following formula:

$$Range_{dB} = 20 \cdot log_{10}\left(\frac{resolution}{span}\right) = 20 \cdot log_{10}(2^{-n}) \approx -6.02 \cdot n$$

Assuming every value is equally likely to appear at the input to the A/D, the quantization error is between ±*r*/2. The square of the error is between 0 and *r*/4, the average value of which is $r^2/12$. The root of the average value of the error squared is *r*/square root 12.

For example, a 12-bit A/D with an input range of ±10V has a resolution of 4.882 mv and a quantization noise of 1.407 Vrms. The maximum signal to the A/D is ±10V, so the signal-to-noise ratio for the 12-bit A/D is:

$$-20 \cdot \log\left(\frac{10}{1.407}\right) = -77.03dB$$

| Bits | Counts | % | Ppm | Dynamic range (dB) | Signal/Noise (dB) |
|---|---|---|---|---|---|
| **1** | 2 | 50.00 | 500,000.0 | -6.02 | 10.79 |
| **2** | 4 | 25.00 | 250,000.0 | -12.04 | 16.81 |
| **3** | 8 | 12.50 | 125,000.0 | -18.06 | 22.83 |
| **4** | 16 | 6.25 | 62,500.0 | -24.08 | 28.85 |
| **5** | 32 | 3.13 | 31,250.0 | -30.10 | 34.87 |
| **6** | 64 | 1.56 | 15,625.0 | -36.12 | 40.89 |
| **7** | 128 | 0.78 | 7,812.5 | -42.14 | 46.91 |
| **8** | 256 | 0.39 | 3,906.2 | -48.16 | 52.93 |

| Bits | Counts | % | Ppm | Dynamic range (dB) | Signal/Noise (dB) |
|---|---|---|---|---|---|
| **9** | 512 | 0.20 | 1,953.1 | -54.19 | 58.95 |
| **10** | 1024 | 0.10 | 976.6 | -60.21 | 64.97 |
| **11** | 2048 | 0.05 | 488.3 | -66.23 | 70.99 |
| **12** | 4096 | 0.02 | 244.1 | -72.25 | 77.01 |
| **13** | 8192 | 0.01 | 122.1 | -78.27 | 83.03 |
| **14** | 16384 | 0.01 | 61.0 | -84.29 | 89.05 |
| **15** | 32768 | | 30.5 | -90.31 | 95.07 |
| **16** | 65536 | | 15.3 | -96.33 | 101.09 |
| **17** | 131072 | | 7.6 | -102.35 | 107.11 |
| **18** | 262144 | | 3.8 | -108.37 | 113.13 |
| **19** | 524288 | | 1.9 | -114.39 | 119.15 |
| **20** | 1048576 | | 1.0 | -120.41 | 125.17 |
| **21** | 2097152 | | 0.5 | -126.43 | 131.19 |
| **22** | 4194304 | | 0.2 | -132.45 | 137.21 |
| **23** | 8388608 | | 0.1 | -138.47 | 143.23 |
| **24** | 16777216 | | 0.1 | -144.49 | 149.25 |

Reference: *Information Transmission Modulation And Noise*

Mischa Schwartz; McGraw-Hill International Editions

## 62.3 Numbers and formats

The following table illustrates how hexadecimal, octal, and binary coded decimal digits are represented in binary. It also lists (for completeness only) the first 16 Gray codes.

| Binary (Bin) | Hexadecimal (Hex) | Binary Coded Decimal (BCD) | Octal (Oct) | Gray code |
|---|---|---|---|---|
| **0** | 0 | 0 | 0 | 0000 |
| **1** | 1 | 1 | 1 | 0001 |
| **10** | 2 | 2 | 2 | 0011 |
| **11** | 3 | 3 | 3 | 0010 |
| **100** | 4 | 4 | 4 | 0110 |
| **101** | 5 | 5 | 5 | 0111 |
| **110** | 6 | 6 | 6 | 0101 |
| **111** | 7 | 7 | 7 | 0100 |
| **1000** | 8 | 8 | | 1100 |
| **1001** | 9 | 9 | | 1101 |
| **1010** | A | | | 1111 |

| Binary (Bin) | Hexadecimal (Hex) | Binary Coded Decimal (BCD) | Octal (Oct) | Gray code |
|---|---|---|---|---|
| **1011** | B | | | 1110 |
| **1100** | C | | | 1010 |
| **1101** | D | | | 1011 |
| **1110** | E | | | 1001 |
| **1111** | F | | | 1000 |

For example, the number 365 (decimal) can be written in the following ways:

| | | | | | |
|---|---|---|---|---|---|
| **BCD** | 365 | Þ | 11 | 0110 | 0101 |
| **HEX** | 16D | Þ | 1 | 0110 | 1101 |
| **OCT** | 555 | Þ | 101 | 101 | 101 |

**NOTE:** For large numbers, BCD requires more bits.
To convert Hex or Oct to binary, convert each digit using the table above.
To convert from binary to Hex (Oct), start at the least significant bits (LSBs) to the left and arrange them in groups of four (three) and use the table above.

There are three popular ways of representing negative numbers as illustrated below for a four-bit analog-to-digital converter with a ±8V input range:

| Voltage In | Sign plus magnitude | Offset Binary | 2's complement |
|---|---|---|---|
| **+7** | + 111 | 1111 | 0111 |
| **+6** | + 110 | 1110 | 0110 |
| **+5** | + 101 | 1101 | 0101 |
| **+4** | + 100 | 1100 | 0100 |
| **+3** | + 011 | 1011 | 0011 |
| **+2** | + 010 | 1010 | 0010 |
| **+1** | + 001 | 1001 | 0001 |
| **+0** | ± 000 | 1000 | 0000 |
| **-1** | - 001 | 0111 | 1111 |
| **-2** | - 010 | 0110 | 1110 |
| **-3** | - 011 | 0101 | 1101 |
| **-4** | - 100 | 0100 | 1100 |
| **-5** | - 101 | 0011 | 1011 |
| **-6** | - 110 | 0010 | 1010 |
| **-7** | - 111 | 0001 | 1001 |
| **-8** | N/A | 0000 | 1000 |

**NOTE:** Offset Binary starts at the lower end of the range and counts from there. As such it can readily be used for non-symmetrical ranges.
To convert from offset binary to 2's complement (or vice versa), invert the most significant bit (MSB).
To convert from binary to 1's complement invert each bit.

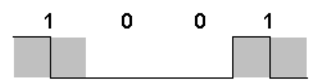
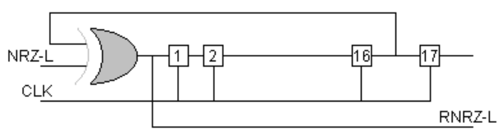
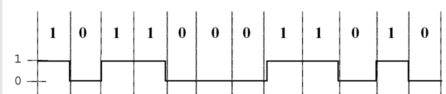
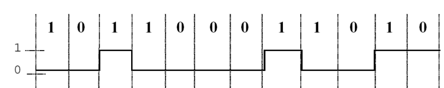
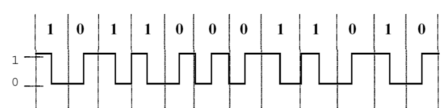
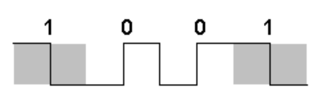
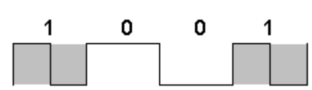
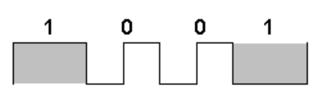
## 62.4 PCM codes

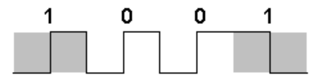
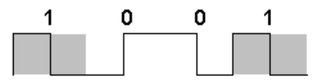
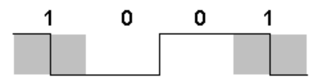
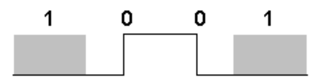
At first glance it may appear that representing a logic 1 with one level and a logic 0 with another would be as good a way as any to transmit data (this is called NRZ-L and is illustrated below). However, unless a clock is also transmitted there may be problems with transmitting long patterns of 1s (or 0s).

For example, if due to Doppler effects or oscillator drift there is a 10% uncertainty, the receiver cannot be sure if it has received 9, 10, or 11 consecutive bits. Also, long patterns of 1s (or 0s) may appear as a dc signal, which may be difficult to retrieve from a tape recorder.

One popular solution is to ensure a transition in the center of each bit (such as with BIϕ-L below). However, this requires extra bandwidth in the data channel.

Another popular method is to try to ensure a continuous pattern is unlikely to occur using a *randomizer* circuit as illustrated for RNRZ-L below. However, this means that one bit received incorrectly may cause three bits to be decoded incorrectly.

| | | |
|---|---|---|
| **RZ** | Return to Zero<br>1 ⇒ level 1 for the first half of the bit only<br>0 ⇒ level 0 throughout the bit |  |
| **RNRZ-L x 4** | Random Non-Return to Zero-Level<br> | |
| **NRZ-L** | Non Return to Zero - Level<br>ONE is represented by one level<br>ZERO is represented by the other level |  |
| **NRZ-M** | Non Return to Zero - Mark<br>ONE is represented by a change in level<br>ZERO is represented by NO change in level |  |
| **NRZ-S** | Non Return to Zero - Space<br>ONE is represented by NO change in level<br>ZERO is represented by a change in level |  |
| **BIϕ-L** | Bi-Phase-Level<br>1 ⇒ change from level 1 to level 0 at the center of a bit<br>0 ⇒ change from level 0 to level 1 at the center of a bit |  |
| **BIϕ-M (before 1996)** | Bi-phase - Mark<br>1 ⇒ change of level at the start and in the center of the bit<br>0 ⇒ change of level at the start of the bit only |  |
| **BIϕ-S (before 1996)*** | Bi-phase - Space<br>1 ⇒ change of level at the start of the bit only<br>0 ⇒ change of level at the start and in the center of the bit |  |

| | | |
|---|---|---|
| **DBIϕ-M (before 1996)**<br>**BIϕ-S (after 1996)*** | Differential Bi-phase - Mark (before 1996)<br>Bi-phase - Space (after 1996)<br>1 ⇒ change of level at the center of the bit only<br>0 ⇒ change of level at the center and at the start of the bit |  |
| **DBIϕ-S (before 1996)**<br>**BIϕ-M (after 1996)*** | Differential Bi-phase - Space (before 1996)<br>Bi-phase - Mark (after 1996)<br>1 ⇒ change of level at the center and at the start of the bit<br>0 ⇒ change of level at the center of the bit only |  |
| **DM-M** | Delay modulation - Mark**<br>1 ⇒ change of level at the center of the bit<br>0 ⇒ change of level at the start of the bit if the previous bit was 0 |  |
| **DM-S** | Delay Modulation - Space**<br>1 ⇒ change of level at the start of the bit if the previous bit was 1<br>0 ⇒ change of level at the center of the bit |  |

*Care must be taken with BIϕ-M(S) and DBIϕ-S(M). In the 1996 and 1993 versions of IRIG-106, both pairs of codes were included. However, after 1996 DBIϕ-M is to be referred to as BIϕ-S and DBIϕ-S is to be referred to as BIϕ-M.

**Delay modulation is sometimes referred to as Miller Code.

## 62.5 Frame synchronization patterns

In Pulse Code Modulation (PCM) systems, a pattern is often used to identify the occurrence of a frame.

In particular with IRIG-106-Ch. 4, a syncword appears at the start of every minor frame.

At first glance, it may appear that for a given number of bits, one pattern is as likely to occur as any other. However, if the link is open all 1s (or 0s) might be received or in the presence of oscillations or non-zero memory patterns may repeat for example 00110011 or 00010001.

The problem of finding optimum patterns in noisy non-zero memory systems was addressed by Barker and the following patterns are sometimes referred to as *Barker Codes*.

| Bits | CODE (Bin) | CODE (Hex) |
|---|---|---|
| **7** | 101 1000 | 58 |
| **8** | 1011 1000 | B8 |
| **9** | 1 0111 0000 | 170 |
| **10** | 11 0111 0000 | 370 |
| **11** | 101 1011 1000 | 5B8 |
| **12** | 1101 0110 0000 | D60 |
| **13** | 1 1101 0110 0000 | 1D60 |
| **14** | 11 1001 1010 0000 | 39A0 |
| **15** | 111 0110 0101 0000 | 7650 |
| **16** | 1110 1011 1001 0000 | EB90 |
| **17** | 1 1110 0110 1010 0000 | 1 E6A0 |
| **18** | 11 1100 1101 0100 0000 | 3 CD40 |

| Bits | CODE (Bin) | CODE (Hex) |
|---|---|---|
| **19** | 111 1100 1100 1010 0000 | 7 CCA0 |
| **20** | 1110 1101 1110 0010 0000 | E DE20 |
| **21** | 1 1101 1101 0010 1100 0000 | 1D D2C0 |
| **22** | 11 1100 1101 1010 1000 0000 | 3C DA80 |
| **23** | 111 1010 1110 0110 1000 0000 | 7A E680 |
| **24** | 1111 1010 1111 0011 0010 0000 | FA F320 |
| **25** | 1 1111 0010 1101 1100 0100 0000 | 1F2 DC40 |
| **26** | 11 1110 1001 1010 1100 1100 0000 | 3E9 ACC0 |
| **27** | 111 1101 0110 1001 1001 1000 0000 | 7D6 9980 |
| **28** | 1111 0101 1110 0101 1001 1000 0000 | F5E 5980 |
| **29** | 1 1110 1011 1100 1100 1101 0000 0000 | 1EBC CD00 |
| **30** | 11 1101 1011 1100 1100 1101 0000 0000 | 3DBC CD00 |
| **31** | 111 1111 0011 0111 1101 0100 0010 0000 | 7F37 D420 |
| **32** | 1111 1110 0110 1011 0010 1000 0100 0000 | F E6B2 840 |
| **33** | 1 1111 0111 0100 1110 1001 0100 1001 1000 | 1 F74E 9498 |

**NOTE:** The convention followed by default at Curtiss-Wright is that the left-most bit is the first transmitted bit.

## 62.6 100Ω shunt resistor table (traditional values)

The shunt values in this table are those most commonly used for strain gage calibration. However, the output voltage versus µΩ/Ω response is non-linear. With today's acquisition systems (better than 10-bit resolution) pseudo errors appear. The values are given here for completeness only. The linear-response values on the next page are those recommended by Curtiss-Wright.

**How to use the table**: 90809.10Ω is the shunt resistance required to produce a 1100 µΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 999900.00 | 499900.00 | 333233.0<br>0 | 249900.00 | 199900.00 | 166567.00 | 142757.00 | 124900.00 | 111011.00 |
| 1000 | 99900.00 | 90809.10 | 83233.30 | 76823.10 | 71328.60 | 66566.70 | 62400.00 | 58723.50 | 55455.60 | 52531.60 |
| 2000 | 49900.00 | 47519.00 | 45354.50 | 43378.30 | 41566.70 | 39900.00 | 38361.50 | 36937.00 | 35614.30 | 34382.80 |
| 3000 | 33233.30 | 32158.10 | 31150.00 | 30203.00 | 29311.80 | 28471.40 | 27677.80 | 26927.00 | 26215.80 | 25541.00 |
| 4000 | 24900.00 | 24290.20 | 23709.50 | 23155.80 | 22627.30 | 22122.20 | 21639.10 | 21176.60 | 20733.30 | 20308.20 |
| 5000 | 19900.00 | 19507.80 | 19130.80 | 18767.90 | 18418.50 | 18081.80 | 17757.10 | 17443.90 | 17141.40 | 16849.20 |
| 6000 | 16566.70 | 16293.40 | 16029.00 | 15773.00 | 15525.00 | 15284.60 | 15051.50 | 14825.40 | 14605.90 | 14392.80 |
| 7000 | 14185.70 | 13984.50 | 13788.90 | 13598.60 | 13413.50 | 13233.30 | 13057.90 | 12887.00 | 12720.50 | 12558.20 |
| 8000 | 12400.00 | 12245.70 | 12095.10 | 11948.20 | 11804.80 | 11664.70 | 11527.90 | 11394.30 | 11263.60 | 11136.00 |
| 9000 | 11011.10 | 10889.00 | 10769.60 | 10652.70 | 10538.30 | 10426.30 | 10316.70 | 10209.30 | 10104.10 | 10001.00 |
| 10000 | 9900.00 | 9800.99 | 9703.92 | 9608.74 | 9515.38 | 9423.81 | 9333.96 | 9245.79 | 9159.26 | 9074.31 |
| 11000 | 8990.91 | 8909.01 | 8828.57 | 8749.56 | 8671.93 | 8595.65 | 8520.69 | 8447.01 | 8374.58 | 8303.36 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 12000 | 8233.33 | 8164.46 | 8096.72 | 8030.08 | 7964.52 | 7900.00 | 7836.51 | 7774.02 | 7712.50 | 7651.94 |
| 13000 | 7592.31 | 7533.59 | 7475.76 | 7418.80 | 7362.69 | 7307.41 | 7252.94 | 7199.27 | 7146.38 | 7094.24 |
| 14000 | 7042.86 | 6992.20 | 6942.25 | 6893.01 | 6844.44 | 6796.55 | 6749.32 | 6702.72 | 6656.76 | 6611.41 |
| 15000 | 6566.67 | 6522.52 | 6478.95 | 6435.95 | 6393.51 | 6351.61 | 6310.26 | 6269.43 | 6229.11 | 6189.31 |
| 16000 | 6150.00 | 6111.18 | 6072.84 | 6034.97 | 5997.56 | 5960.61 | 5924.10 | 5888.02 | 5852.38 | 5817.16 |
| 17000 | 5782.35 | 5747.95 | 5713.95 | 5680.35 | 5647.13 | 5614.29 | 5581.82 | 5549.72 | 5517.98 | 5486.59 |
| 18000 | 5455.56 | 5424.86 | 5394.51 | 5364.48 | 5334.78 | 5305.41 | 5276.34 | 5247.59 | 5219.15 | 5191.01 |
| 19000 | 5163.16 | 5135.60 | 5108.33 | 5081.35 | 5054.64 | 5028.21 | 5002.04 | 4976.14 | 4950.51 | 4925.13 |
| 20000 | 4900.00 | 4875.12 | 4850.50 | 4826.11 | 4801.96 | 4778.05 | 4754.37 | 4730.92 | 4707.69 | 4684.69 |
| 21000 | 4661.90 | 4639.34 | 4616.98 | 4594.84 | 4572.90 | 4551.16 | 4529.63 | 4508.29 | 4487.16 | 4466.21 |
| 22000 | 4445.45 | 4424.89 | 4404.50 | 4384.30 | 4364.29 | 4344.44 | 4324.78 | 4305.29 | 4285.96 | 4266.81 |
| 23000 | 4247.83 | 4229.00 | 4210.34 | 4191.85 | 4173.50 | 4155.32 | 4137.29 | 4119.41 | 4101.68 | 4084.10 |
| 24000 | 4066.67 | 4049.38 | 4032.23 | 4015.23 | 3998.36 | 3981.63 | 3965.04 | 3948.58 | 3932.26 | 3916.06 |
| 25000 | 3900.00 | 3884.06 | 3868.25 | 3852.57 | 3837.01 | 3821.57 | 3806.25 | 3791.05 | 3775.97 | 3761.00 |
| 26000 | 3746.15 | 3731.42 | 3716.79 | 3702.28 | 3687.88 | 3673.58 | 3659.40 | 3645.32 | 3631.34 | 3617.47 |
| 27000 | 3603.70 | 3590.04 | 3576.47 | 3563.00 | 3549.64 | 3536.36 | 3523.19 | 3510.11 | 3497.12 | 3484.23 |
| 28000 | 3471.43 | 3458.72 | 3446.10 | 3433.57 | 3421.13 | 3408.77 | 3396.50 | 3384.32 | 3372.22 | 3360.21 |
| 29000 | 3348.28 | 3336.43 | 3324.66 | 3312.97 | 3301.36 | 3289.83 | 3278.38 | 3267.00 | 3255.70 | 3244.48 |
| 30000 | 3233.33 | 3222.26 | 3211.26 | 3200.33 | 3189.47 | 3178.69 | 3167.97 | 3157.33 | 3146.75 | 3136.25 |
| 31000 | 3125.81 | 3115.43 | 3105.13 | 3094.89 | 3084.71 | 3074.60 | 3064.56 | 3054.57 | 3044.65 | 3034.80 |
| 32000 | 3025.00 | 3015.26 | 3005.59 | 2995.98 | 2986.42 | 2976.92 | 2967.48 | 2958.10 | 2948.78 | 2939.51 |
| 33000 | 2930.30 | 2921.15 | 2912.05 | 2903.00 | 2894.01 | 2885.07 | 2876.19 | 2867.36 | 2858.58 | 2849.85 |
| 34000 | 2841.18 | 2832.55 | 2823.98 | 2815.45 | 2806.98 | 2798.55 | 2790.17 | 2781.84 | 2773.56 | 2765.33 |
| 35000 | 2757.14 | 2749.00 | 2740.91 | 2732.86 | 2724.86 | 2716.90 | 2708.99 | 2701.12 | 2693.30 | 2685.52 |
| 36000 | 2677.78 | 2670.08 | 2662.43 | 2654.82 | 2647.25 | 2639.73 | 2632.24 | 2624.80 | 2617.39 | 2610.03 |
| 37000 | 2602.70 | 2595.42 | 2588.17 | 2580.97 | 2573.80 | 2566.67 | 2559.57 | 2552.52 | 2545.50 | 2538.52 |
| 38000 | 2531.58 | 2524.67 | 2517.80 | 2510.97 | 2504.17 | 2497.40 | 2490.67 | 2483.98 | 2477.32 | 2470.69 |
| 39000 | 2464.10 | 2457.54 | 2451.02 | 2444.53 | 2438.07 | 2431.65 | 2425.25 | 2418.89 | 2412.56 | 2406.27 |
| 40000 | 2400.00 | 2393.77 | 2387.56 | 2381.39 | 2375.25 | 2369.14 | 2363.05 | 2357.00 | 2350.98 | 2344.99 |
| 41000 | 2339.02 | 2333.09 | 2327.18 | 2321.31 | 2315.46 | 2309.64 | 2303.85 | 2298.08 | 2292.34 | 2286.63 |
| 42000 | 2280.95 | 2275.30 | 2269.67 | 2264.07 | 2258.49 | 2252.94 | 2247.42 | 2241.92 | 2236.45 | 2231.00 |
| 43000 | 2225.58 | 2220.19 | 2214.81 | 2209.47 | 2204.15 | 2198.85 | 2193.58 | 2188.33 | 2183.11 | 2177.90 |
| 44000 | 2172.73 | 2167.57 | 2162.44 | 2157.34 | 2152.25 | 2147.19 | 2142.15 | 2137.14 | 2132.14 | 2127.17 |
| 45000 | 2122.22 | 2117.29 | 2112.39 | 2107.51 | 2102.64 | 2097.80 | 2092.98 | 2088.18 | 2083.41 | 2078.65 |
| 46000 | 2073.91 | 2069.20 | 2064.50 | 2059.83 | 2055.17 | 2050.54 | 2045.92 | 2041.33 | 2036.75 | 2032.20 |
| 47000 | 2027.66 | 2023.14 | 2018.64 | 2014.16 | 2009.70 | 2005.26 | 2000.84 | 1996.44 | 1992.05 | 1987.68 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 48000 | 1983.33 | 1979.00 | 1974.69 | 1970.39 | 1966.12 | 1961.86 | 1957.61 | 1953.39 | 1949.18 | 1944.99 |
| 49000 | 1940.82 | 1936.66 | 1932.52 | 1928.40 | 1924.29 | 1920.20 | 1916.13 | 1912.07 | 1908.03 | 1904.01 |
| 50000 | 1900.00 | 1896.01 | 1892.03 | 1888.07 | 1884.13 | 1880.20 | 1876.28 | 1872.39 | 1868.50 | 1864.64 |
| 51000 | 1860.78 | 1856.95 | 1853.13 | 1849.32 | 1845.53 | 1841.75 | 1837.98 | 1834.24 | 1830.50 | 1826.78 |
| 52000 | 1823.08 | 1819.39 | 1815.71 | 1812.05 | 1808.40 | 1804.76 | 1801.14 | 1797.53 | 1793.94 | 1790.36 |
| 53000 | 1786.79 | 1783.24 | 1779.70 | 1776.17 | 1772.66 | 1769.16 | 1765.67 | 1762.20 | 1758.74 | 1755.29 |
| 54000 | 1751.85 | 1748.43 | 1745.02 | 1741.62 | 1738.24 | 1734.86 | 1731.50 | 1728.15 | 1724.82 | 1721.49 |
| 55000 | 1718.18 | 1714.88 | 1711.59 | 1708.32 | 1705.05 | 1701.80 | 1698.56 | 1695.33 | 1692.11 | 1688.91 |
| 56000 | 1685.71 | 1682.53 | 1679.36 | 1676.20 | 1673.05 | 1669.91 | 1666.78 | 1663.67 | 1660.56 | 1657.47 |
| 57000 | 1654.39 | 1651.31 | 1648.25 | 1645.20 | 1642.16 | 1639.13 | 1636.11 | 1633.10 | 1630.10 | 1627.12 |
| 58000 | 1624.14 | 1621.17 | 1618.21 | 1615.27 | 1612.33 | 1609.40 | 1606.48 | 1603.58 | 1600.68 | 1597.79 |
| 59000 | 1594.92 | 1592.05 | 1589.19 | 1586.34 | 1583.50 | 1580.67 | 1577.85 | 1575.04 | 1572.24 | 1569.45 |

## 62.7 100Ω shunt resistor table (linear response)

The shunt values in this table produce a linear response (output voltage versus µΩ/Ω) and as such are the values recommended by Curtiss-Wright.

**How to use the table**: 90859.10Ω is the shunt resistance required to produce a 1100 µΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 999950.00 | 499950.00 | 333283.00 | 249950.0<br>0 | 199950.00 | 166617.0<br>0 | 142807.00 | 124950.00 | 111061.00 |
| 1000 | 99950.00 | 90859.10 | 83283.30 | 76873.10 | 71378.60 | 66616.70 | 62450.00 | 58773.50 | 55505.60 | 52581.60 |
| 2000 | 49950.00 | 47569.00 | 45404.50 | 43428.30 | 41616.70 | 39950.00 | 38411.50 | 36987.00 | 35664.30 | 34432.80 |
| 3000 | 33283.30 | 32208.10 | 31200.00 | 30253.00 | 29361.80 | 28521.40 | 27727.80 | 26977.00 | 26265.80 | 25591.00 |
| 4000 | 24950.00 | 24340.20 | 23759.50 | 23205.80 | 22677.30 | 22172.20 | 21689.10 | 21226.60 | 20783.30 | 20358.20 |
| 5000 | 19950.00 | 19557.80 | 19180.80 | 18817.90 | 18468.50 | 18131.80 | 17807.10 | 17493.90 | 17191.40 | 16899.20 |
| 6000 | 16616.70 | 16343.40 | 16079.00 | 15823.00 | 15575.00 | 15334.60 | 15101.50 | 14875.40 | 14655.90 | 14442.80 |
| 7000 | 14235.70 | 14034.50 | 13838.90 | 13648.60 | 13463.50 | 13283.30 | 13107.90 | 12937.00 | 12770.50 | 12608.20 |
| 8000 | 12450.00 | 12295.70 | 12145.10 | 11998.20 | 11854.80 | 11714.70 | 11577.90 | 11444.30 | 11313.60 | 11186.00 |
| 9000 | 11061.10 | 10939.00 | 10819.60 | 10702.70 | 10588.30 | 10476.30 | 10366.70 | 10259.30 | 10154.10 | 10051.00 |
| 10000 | 9950.00 | 9850.99 | 9753.92 | 9658.74 | 9565.38 | 9473.81 | 9383.96 | 9295.79 | 9209.26 | 9124.31 |
| 11000 | 9040.91 | 8959.01 | 8878.57 | 8799.56 | 8721.93 | 8645.65 | 8570.69 | 8497.01 | 8424.58 | 8353.36 |
| 12000 | 8283.33 | 8214.46 | 8146.72 | 8080.08 | 8014.52 | 7950.00 | 7886.51 | 7824.02 | 7762.50 | 7701.94 |
| 13000 | 7642.31 | 7583.59 | 7525.76 | 7468.80 | 7412.69 | 7357.41 | 7302.94 | 7249.27 | 7196.38 | 7144.24 |
| 14000 | 7092.86 | 7042.20 | 6992.25 | 6943.01 | 6894.44 | 6846.55 | 6799.32 | 6752.72 | 6706.76 | 6661.41 |
| 15000 | 6616.67 | 6572.52 | 6528.95 | 6485.95 | 6443.51 | 6401.61 | 6360.26 | 6319.43 | 6279.11 | 6239.31 |
| 16000 | 6200.00 | 6161.18 | 6122.84 | 6084.97 | 6047.56 | 6010.61 | 5974.10 | 5938.02 | 5902.38 | 5867.16 |
| 17000 | 5832.35 | 5797.95 | 5763.95 | 5730.35 | 5697.13 | 5664.29 | 5631.82 | 5599.72 | 5567.98 | 5536.59 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 18000 | 5505.56 | 5474.86 | 5444.51 | 5414.48 | 5384.78 | 5355.41 | 5326.34 | 5297.59 | 5269.15 | 5241.01 |
| 19000 | 5213.16 | 5185.60 | 5158.33 | 5131.35 | 5104.64 | 5078.21 | 5052.04 | 5026.14 | 5000.51 | 4975.13 |
| 20000 | 4950.00 | 4925.12 | 4900.50 | 4876.11 | 4851.96 | 4828.05 | 4804.37 | 4780.92 | 4757.69 | 4734.69 |
| 21000 | 4711.90 | 4689.34 | 4666.98 | 4644.84 | 4622.90 | 4601.16 | 4579.63 | 4558.29 | 4537.16 | 4516.21 |
| 22000 | 4495.45 | 4474.89 | 4454.50 | 4434.30 | 4414.29 | 4394.44 | 4374.78 | 4355.29 | 4335.96 | 4316.81 |
| 23000 | 4297.83 | 4279.00 | 4260.34 | 4241.85 | 4223.50 | 4205.32 | 4187.29 | 4169.41 | 4151.68 | 4134.10 |
| 24000 | 4116.67 | 4099.38 | 4082.23 | 4065.23 | 4048.36 | 4031.63 | 4015.04 | 3998.58 | 3982.26 | 3966.06 |
| 25000 | 3950.00 | 3934.06 | 3918.25 | 3902.57 | 3887.01 | 3871.57 | 3856.25 | 3841.05 | 3825.97 | 3811.00 |
| 26000 | 3796.15 | 3781.42 | 3766.79 | 3752.28 | 3737.88 | 3723.58 | 3709.40 | 3695.32 | 3681.34 | 3667.47 |
| 27000 | 3653.70 | 3640.04 | 3626.47 | 3613.00 | 3599.64 | 3586.36 | 3573.19 | 3560.11 | 3547.12 | 3534.23 |
| 28000 | 3521.43 | 3508.72 | 3496.10 | 3483.57 | 3471.13 | 3458.77 | 3446.50 | 3434.32 | 3422.22 | 3410.21 |
| 29000 | 3398.28 | 3386.43 | 3374.66 | 3362.97 | 3351.36 | 3339.83 | 3328.38 | 3317.00 | 3305.70 | 3294.48 |
| 30000 | 3283.33 | 3272.26 | 3261.26 | 3250.33 | 3239.47 | 3228.69 | 3217.97 | 3207.33 | 3196.75 | 3186.25 |
| 31000 | 3175.81 | 3165.43 | 3155.13 | 3144.89 | 3134.71 | 3124.60 | 3114.56 | 3104.57 | 3094.65 | 3084.80 |
| 32000 | 3075.00 | 3065.26 | 3055.59 | 3045.98 | 3036.42 | 3026.92 | 3017.48 | 3008.10 | 2998.78 | 2989.51 |
| 33000 | 2980.30 | 2971.15 | 2962.05 | 2953.00 | 2944.01 | 2935.07 | 2926.19 | 2917.36 | 2908.58 | 2899.85 |
| 34000 | 2891.18 | 2882.55 | 2873.98 | 2865.45 | 2856.98 | 2848.55 | 2840.17 | 2831.84 | 2823.56 | 2815.33 |
| 35000 | 2807.14 | 2799.00 | 2790.91 | 2782.86 | 2774.86 | 2766.90 | 2758.99 | 2751.12 | 2743.30 | 2735.52 |
| 36000 | 2727.78 | 2720.08 | 2712.43 | 2704.82 | 2697.25 | 2689.73 | 2682.24 | 2674.80 | 2667.39 | 2660.03 |
| 37000 | 2652.70 | 2645.42 | 2638.17 | 2630.97 | 2623.80 | 2616.67 | 2609.57 | 2602.52 | 2595.50 | 2588.52 |
| 38000 | 2581.58 | 2574.67 | 2567.80 | 2560.97 | 2554.17 | 2547.40 | 2540.67 | 2533.98 | 2527.32 | 2520.69 |
| 39000 | 2514.10 | 2507.54 | 2501.02 | 2494.53 | 2488.07 | 2481.65 | 2475.25 | 2468.89 | 2462.56 | 2456.27 |
| 40000 | 2450.00 | 2443.77 | 2437.56 | 2431.39 | 2425.25 | 2419.14 | 2413.05 | 2407.00 | 2400.98 | 2394.99 |
| 41000 | 2389.02 | 2383.09 | 2377.18 | 2371.31 | 2365.46 | 2359.64 | 2353.85 | 2348.08 | 2342.34 | 2336.63 |
| 42000 | 2330.95 | 2325.30 | 2319.67 | 2314.07 | 2308.49 | 2302.94 | 2297.42 | 2291.92 | 2286.45 | 2281.00 |
| 43000 | 2275.58 | 2270.19 | 2264.81 | 2259.47 | 2254.15 | 2248.85 | 2243.58 | 2238.33 | 2233.11 | 2227.90 |
| 44000 | 2222.73 | 2217.57 | 2212.44 | 2207.34 | 2202.25 | 2197.19 | 2192.15 | 2187.14 | 2182.14 | 2177.17 |
| 45000 | 2172.22 | 2167.29 | 2162.39 | 2157.51 | 2152.64 | 2147.80 | 2142.98 | 2138.18 | 2133.41 | 2128.65 |
| 46000 | 2123.91 | 2119.20 | 2114.50 | 2109.83 | 2105.17 | 2100.54 | 2095.92 | 2091.33 | 2086.75 | 2082.20 |
| 47000 | 2077.66 | 2073.14 | 2068.64 | 2064.16 | 2059.70 | 2055.26 | 2050.84 | 2046.44 | 2042.05 | 2037.68 |
| 48000 | 2033.33 | 2029.00 | 2024.69 | 2020.39 | 2016.12 | 2011.86 | 2007.61 | 2003.39 | 1999.18 | 1994.99 |
| 49000 | 1990.82 | 1986.66 | 1982.52 | 1978.40 | 1974.29 | 1970.20 | 1966.13 | 1962.07 | 1958.03 | 1954.01 |
| 50000 | 1950.00 | 1946.01 | 1942.03 | 1938.07 | 1934.13 | 1930.20 | 1926.28 | 1922.39 | 1918.50 | 1914.64 |
| 51000 | 1910.78 | 1906.95 | 1903.13 | 1899.32 | 1895.53 | 1891.75 | 1887.98 | 1884.24 | 1880.50 | 1876.78 |
| 52000 | 1873.08 | 1869.39 | 1865.71 | 1862.05 | 1858.40 | 1854.76 | 1851.14 | 1847.53 | 1843.94 | 1840.36 |
| 53000 | 1836.79 | 1833.24 | 1829.70 | 1826.17 | 1822.66 | 1819.16 | 1815.67 | 1812.20 | 1808.74 | 1805.29 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 54000 | 1801.85 | 1798.43 | 1795.02 | 1791.62 | 1788.24 | 1784.86 | 1781.50 | 1778.15 | 1774.82 | 1771.49 |
| 55000 | 1768.18 | 1764.88 | 1761.59 | 1758.32 | 1755.05 | 1751.80 | 1748.56 | 1745.33 | 1742.11 | 1738.91 |
| 56000 | 1735.71 | 1732.53 | 1729.36 | 1726.20 | 1723.05 | 1719.91 | 1716.78 | 1713.67 | 1710.56 | 1707.47 |
| 57000 | 1704.39 | 1701.31 | 1698.25 | 1695.20 | 1692.16 | 1689.13 | 1686.11 | 1683.10 | 1680.10 | 1677.12 |
| 58000 | 1674.14 | 1671.17 | 1668.21 | 1665.27 | 1662.33 | 1659.40 | 1656.48 | 1653.58 | 1650.68 | 1647.79 |
| 59000 | 1644.92 | 1642.05 | 1639.19 | 1636.34 | 1633.50 | 1630.67 | 1627.85 | 1625.04 | 1622.24 | 1619.45 |

## 62.8 120Ω shunt resistor table (traditional values)

The shunt values in this table are those most commonly used for strain gage calibration. However the output voltage versus µΩ/Ω response is non-linear. With today's acquisition systems (better than 10-bit resolution) pseudo errors appear. The values are given here for completeness only. The linear-response values on the next page are those recommended by Curtiss-Wright. **How to use the table**: 108971.00Ω is the shunt resistance required to produce a 1100 µΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 1199880.00 | 599880.0 0 | 399880.0 0 | 299880.0 0 | 239880.0 0 | 199880.0 0 | 171309.00 | 149880.0 0 | 133213.0 0 |
| 1000 | 119880.00 | 108971.00 | 99880.00 | 92187.70 | 85594.30 | 79880.00 | 74880.00 | 70468.20 | 66546.70 | 63037.90 |
| 2000 | 59880.00 | 57022.90 | 54425.50 | 52053.90 | 49880.00 | 47880.00 | 46033.80 | 44324.40 | 42737.10 | 41259.30 |
| 3000 | 39880.00 | 38589.70 | 37380.00 | 36243.60 | 35174.10 | 34165.70 | 33213.30 | 32312.40 | 31458.90 | 30649.20 |
| 4000 | 29880.00 | 29148.30 | 28451.40 | 27787.00 | 27152.70 | 26546.70 | 25967.00 | 25411.90 | 24880.00 | 24369.80 |
| 5000 | 23880.00 | 23409.40 | 22956.90 | 22521.50 | 22102.20 | 21698.20 | 21308.60 | 20932.60 | 20569.70 | 20219.00 |
| 6000 | 19880.00 | 19552.10 | 19234.80 | 18927.60 | 18630.00 | 18341.50 | 18061.80 | 17790.40 | 17527.10 | 17271.30 |
| 7000 | 17022.90 | 16781.40 | 16546.70 | 16318.40 | 16096.20 | 15880.00 | 15669.50 | 15464.40 | 15264.60 | 15069.90 |
| 8000 | 14880.00 | 14694.80 | 14514.10 | 14337.80 | 14165.70 | 13997.60 | 13833.50 | 13673.10 | 13516.40 | 13363.10 |
| 9000 | 13213.30 | 13066.80 | 12923.50 | 12783.20 | 12646.00 | 12511.60 | 12380.00 | 12251.10 | 12124.90 | 12001.20 |
| 10000 | 11880.00 | 11761.20 | 11644.70 | 11530.50 | 11418.50 | 11308.60 | 11200.80 | 11095.00 | 10991.10 | 10889.20 |
| 11000 | 10789.10 | 10690.80 | 10594.30 | 10499.50 | 10406.30 | 10314.80 | 10224.80 | 10136.40 | 10049.50 | 9964.03 |
| 12000 | 9880.00 | 9797.36 | 9716.07 | 9636.10 | 9557.42 | 9480.00 | 9403.81 | 9328.82 | 9255.00 | 9182.33 |
| 13000 | 9110.77 | 9040.31 | 8970.91 | 8902.56 | 8835.22 | 8768.89 | 8703.53 | 8639.12 | 8575.65 | 8513.09 |
| 14000 | 8451.43 | 8390.64 | 8330.70 | 8271.61 | 8213.33 | 8155.86 | 8099.18 | 8043.27 | 7988.11 | 7933.69 |
| 15000 | 7880.00 | 7827.02 | 7774.74 | 7723.14 | 7672.21 | 7621.94 | 7572.31 | 7523.31 | 7474.94 | 7427.17 |
| 16000 | 7380.00 | 7333.42 | 7287.41 | 7241.96 | 7197.07 | 7152.73 | 7108.92 | 7065.63 | 7022.86 | 6980.59 |
| 17000 | 6938.82 | 6897.54 | 6856.74 | 6816.42 | 6776.55 | 6737.14 | 6698.18 | 6659.66 | 6621.57 | 6583.91 |
| 18000 | 6546.67 | 6509.83 | 6473.41 | 6437.38 | 6401.74 | 6366.49 | 6331.61 | 6297.11 | 6262.98 | 6229.21 |
| 19000 | 6195.79 | 6162.72 | 6130.00 | 6097.62 | 6065.57 | 6033.85 | 6002.45 | 5971.37 | 5940.61 | 5910.15 |
| 20000 | 5880.00 | 5850.15 | 5820.59 | 5791.33 | 5762.35 | 5733.66 | 5705.24 | 5677.10 | 5649.23 | 5621.63 |
| 21000 | 5594.29 | 5567.20 | 5540.38 | 5513.80 | 5487.48 | 5461.40 | 5435.56 | 5409.95 | 5384.59 | 5359.45 |
| 22000 | 5334.55 | 5309.86 | 5285.41 | 5261.17 | 5237.14 | 5213.33 | 5189.73 | 5166.34 | 5143.16 | 5120.17 |
| 23000 | 5097.39 | 5074.81 | 5052.41 | 5030.21 | 5008.21 | 4986.38 | 4964.75 | 4943.29 | 4922.02 | 4900.92 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 24000 | 4880.00 | 4859.25 | 4838.68 | 4818.27 | 4798.03 | 4777.96 | 4758.05 | 4738.30 | 4718.71 | 4699.28 |
| 25000 | 4680.00 | 4660.88 | 4641.90 | 4623.08 | 4604.41 | 4585.88 | 4567.50 | 4549.26 | 4531.16 | 4513.20 |
| 26000 | 4495.38 | 4477.70 | 4460.15 | 4442.74 | 4425.45 | 4408.30 | 4391.28 | 4374.38 | 4357.61 | 4340.97 |
| 27000 | 4324.44 | 4308.04 | 4291.76 | 4275.60 | 4259.56 | 4243.64 | 4227.83 | 4212.13 | 4196.55 | 4181.08 |
| 28000 | 4165.71 | 4150.46 | 4135.32 | 4120.28 | 4105.35 | 4090.53 | 4075.80 | 4061.18 | 4046.67 | 4032.25 |
| 29000 | 4017.93 | 4003.71 | 3989.59 | 3975.56 | 3961.63 | 3947.80 | 3934.05 | 3920.40 | 3906.85 | 3893.38 |
| 30000 | 3880.00 | 3866.71 | 3853.51 | 3840.40 | 3827.37 | 3814.43 | 3801.57 | 3788.79 | 3776.10 | 3763.50 |
| 31000 | 3750.97 | 3738.52 | 3726.15 | 3713.87 | 3701.66 | 3689.52 | 3677.47 | 3665.49 | 3653.58 | 3641.76 |
| 32000 | 3630.00 | 3618.32 | 3606.71 | 3595.17 | 3583.70 | 3572.31 | 3560.98 | 3549.72 | 3538.54 | 3527.42 |
| 33000 | 3516.36 | 3505.38 | 3494.46 | 3483.60 | 3472.81 | 3462.09 | 3451.43 | 3440.83 | 3430.30 | 3419.82 |
| 34000 | 3409.41 | 3399.06 | 3388.77 | 3378.54 | 3368.37 | 3358.26 | 3348.21 | 3338.21 | 3328.28 | 3318.40 |
| 35000 | 3308.57 | 3298.80 | 3289.09 | 3279.43 | 3269.83 | 3260.28 | 3250.79 | 3241.34 | 3231.96 | 3222.62 |
| 36000 | 3213.33 | 3204.10 | 3194.92 | 3185.79 | 3176.70 | 3167.67 | 3158.69 | 3149.75 | 3140.87 | 3132.03 |
| 37000 | 3123.24 | 3114.50 | 3105.81 | 3097.16 | 3088.56 | 3080.00 | 3071.49 | 3063.02 | 3054.60 | 3046.23 |
| 38000 | 3037.89 | 3029.61 | 3021.36 | 3013.16 | 3005.00 | 2996.88 | 2988.81 | 2980.78 | 2972.78 | 2964.83 |
| 39000 | 2956.92 | 2949.05 | 2941.22 | 2933.44 | 2925.69 | 2917.97 | 2910.30 | 2902.67 | 2895.08 | 2887.52 |
| 40000 | 2880..00 | 2872.52 | 2865.07 | 2857.67 | 2850.30 | 2842.96 | 2835.67 | 2828.40 | 2821.18 | 2813.99 |
| 41000 | 2806.83 | 2799.71 | 2792.62 | 2785.57 | 2778.55 | 2771.57 | 2764.62 | 2757.70 | 2750.81 | 2743.96 |
| 42000 | 2737.14 | 2730.36 | 2723.60 | 2716.88 | 2710.19 | 2703.53 | 2696.90 | 2690.30 | 2683.74 | 2677.20 |
| 43000 | 2670.70 | 2664.22 | 2657.78 | 2651.36 | 2644.98 | 2638.62 | 2632.29 | 2626.00 | 2619.73 | 2613.49 |
| 44000 | 2607.27 | 2601.09 | 2594.93 | 2588.80 | 2582.70 | 2576.63 | 2570.58 | 2564.56 | 2558.57 | 2552.61 |
| 45000 | 2546.67 | 2540.75 | 2534.87 | 2529.01 | 2523.17 | 2517.36 | 2511.58 | 2505.82 | 2500.09 | 2494.38 |
| 46000 | 2488.70 | 2483.04 | 2477.40 | 2471.79 | 2466.21 | 2460.65 | 2455.11 | 2449.59 | 2444.10 | 2438.64 |
| 47000 | 2433.19 | 2427.77 | 2422.37 | 2417.00 | 2411.65 | 2406.32 | 2401.01 | 2395.72 | 2390.46 | 2385.22 |
| 48000 | 2380.00 | 2374.80 | 2369.63 | 2364.47 | 2359.34 | 2354.23 | 2349.14 | 2344.07 | 2339.02 | 2333.99 |
| 49000 | 2328.98 | 2323.99 | 2319.02 | 2314.08 | 2309.15 | 2304.24 | 2299.35 | 2294.49 | 2289.64 | 2284.81 |
| 50000 | 2280.00 | 2275.21 | 2270.44 | 2265.69 | 2260.95 | 2256.24 | 2251.54 | 2246.86 | 2242.20 | 2237.56 |
| 51000 | 2232.94 | 2228.34 | 2223.75 | 2219.18 | 2214.63 | 2210.10 | 2205.58 | 2201.08 | 2196.60 | 2192.14 |
| 52000 | 2187.69 | 2183.26 | 2178.85 | 2174.46 | 2170.08 | 2165.71 | 2161.37 | 2157.04 | 2152.73 | 2148.43 |
| 53000 | 2144.15 | 2139.89 | 2135.64 | 2131.41 | 2127.19 | 2122.99 | 2118.81 | 2114.64 | 2110.48 | 2106.35 |
| 54000 | 2102.22 | 2098.11 | 2094.02 | 2089.94 | 2085.88 | 2081.83 | 2077.80 | 2073.78 | 2069.78 | 2065.79 |
| 55000 | 2061.82 | 2057.86 | 2053.91 | 2049.98 | 2046.06 | 2042.16 | 2038.27 | 2034.40 | 2030.54 | 2026.69 |
| 56000 | 2022.86 | 2019.04 | 2015.23 | 2011.44 | 2007.66 | 2003.89 | 2000.14 | 1996.40 | 1992.68 | 1988.96 |
| 57000 | 1985.26 | 1981.58 | 1977.90 | 1974.24 | 1970.59 | 1966.96 | 1963.33 | 1959.72 | 1956.12 | 1952.54 |
| 58000 | 1948.97 | 1945.40 | 1941.86 | 1938.32 | 1934.79 | 1931.28 | 1927.78 | 1924.29 | 1920.82 | 1917.35 |
| 59000 | 1913.90 | 1910.46 | 1907.03 | 1903.61 | 1900.20 | 1896.81 | 1893.42 | 1890.05 | 1886.69 | 1883.34 |

## 62.9 120Ω shunt resistor table (linear response)

The shunt values in this table produce a linear response (output voltage versus μΩ/Ω) and as such are the values recommended by Curtiss-Wright.

**How to use the table**: 109031.00Ω is the shunt resistance required to produce a 1100 μΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 1199940.00 | 599940.00 | 399940.00 | 299940.00 | 239940.00 | 199940.00 | 171369.00 | 149940.00 | 133273.00 |
| 1000 | 119940.00 | 109031.00 | 99940.00 | 92247.70 | 85654.30 | 79940.00 | 74940.00 | 70528.20 | 66606.70 | 63097.90 |
| 2000 | 59940.00 | 57082.90 | 54485.50 | 52113.90 | 49940.00 | 47940.00 | 46093.80 | 44384.40 | 42797.10 | 41319.30 |
| 3000 | 39940.00 | 38649.70 | 37440.00 | 36303.60 | 35234.10 | 34225.70 | 33273.30 | 32372.40 | 31518.90 | 30709.20 |
| 4000 | 29940.00 | 29208.30 | 28511.40 | 27847.00 | 27212.70 | 26606.70 | 26027.00 | 25471.90 | 24940.00 | 24429.80 |
| 5000 | 23940.00 | 23469.40 | 23016.90 | 22581.50 | 22162.20 | 21758.20 | 21368.60 | 20992.60 | 20629.70 | 20279.00 |
| 6000 | 19940.00 | 19612.10 | 19294.80 | 18987.60 | 18690.00 | 18401.50 | 18121.80 | 17850.40 | 17587.10 | 17331.30 |
| 7000 | 17082.90 | 16841.40 | 16606.70 | 16378.40 | 16156.20 | 15940.00 | 15729.50 | 15524.40 | 15324.60 | 15129.90 |
| 8000 | 14940.00 | 14754.80 | 14574.10 | 14397.80 | 14225.70 | 14057.60 | 13893.50 | 13733.10 | 13576.40 | 13423.10 |
| 9000 | 13273.30 | 13126.80 | 12983.50 | 12843.20 | 12706.00 | 12571.60 | 12440.00 | 12311.10 | 12184.90 | 12061.20 |
| 10000 | 11940.00 | 11821.20 | 11704.70 | 11590.50 | 11478.50 | 11368.60 | 11260.80 | 11155.00 | 11051.10 | 10949.20 |
| 11000 | 10849.10 | 10750.80 | 10654.30 | 10559.50 | 10466.30 | 10374.80 | 10284.80 | 10196.40 | 10109.50 | 10024.00 |
| 12000 | 9940.00 | 9857.36 | 9776.07 | 9696.10 | 9617.42 | 9540.00 | 9463.81 | 9388.82 | 9315.00 | 9242.33 |
| 13000 | 9170.77 | 9100.31 | 9030.91 | 8962.56 | 8895.22 | 8828.89 | 8763.53 | 8699.12 | 8635.65 | 8573.09 |
| 14000 | 8511.43 | 8450.64 | 8390.70 | 8331.61 | 8273.33 | 8215.86 | 8159.18 | 8103.27 | 8048.11 | 7993.69 |
| 15000 | 7940.00 | 7887.02 | 7834.74 | 7783.14 | 7732.21 | 7681.94 | 7632.31 | 7583.31 | 7534.94 | 7487.17 |
| 16000 | 7440.00 | 7393.42 | 7347.41 | 7301.96 | 7257.07 | 7212.73 | 7168.92 | 7125.63 | 7082.86 | 7040.59 |
| 17000 | 6998.82 | 6957.54 | 6916.74 | 6876.42 | 6836.55 | 6797.14 | 6758.18 | 6719.66 | 6681.57 | 6643.91 |
| 18000 | 6606.67 | 6569.83 | 6533.41 | 6497.38 | 6461.74 | 6426.49 | 6391.61 | 6357.11 | 6322.98 | 6289.21 |
| 19000 | 6255.79 | 6222.72 | 6190.00 | 6157.62 | 6125.57 | 6093.85 | 6062.45 | 6031.37 | 6000.61 | 5970.15 |
| 20000 | 5940.00 | 5910.15 | 5880.59 | 5851.33 | 5822.35 | 5793.66 | 5765.24 | 5737.10 | 5709.23 | 5681.63 |
| 21000 | 5654.29 | 5627.20 | 5600.38 | 5573.80 | 5547.48 | 5521.40 | 5495.56 | 5469.95 | 5444.59 | 5419.45 |
| 22000 | 5394.55 | 5369.86 | 5345.41 | 5321.17 | 5297.14 | 5273.33 | 5249.73 | 5226.34 | 5203.16 | 5180.17 |
| 23000 | 5157.39 | 5134.81 | 5112.41 | 5090.21 | 5068.21 | 5046.38 | 5024.75 | 5003.29 | 4982.02 | 4960.92 |
| 24000 | 4940.00 | 4919.25 | 4898.68 | 4878.27 | 4858.03 | 4837.96 | 4818.05 | 4798.30 | 4778.71 | 4759.28 |
| 25000 | 4740.00 | 4720.88 | 4701.90 | 4683.08 | 4664.41 | 4645.88 | 4627.50 | 4609.26 | 4591.16 | 4573.20 |
| 26000 | 4555.38 | 4537.70 | 4520.15 | 4502.74 | 4485.45 | 4468.30 | 4451.28 | 4434.38 | 4417.61 | 4400.97 |
| 27000 | 4384.44 | 4368.04 | 4351.76 | 4335.60 | 4319.56 | 4303.64 | 4287.83 | 4272.13 | 4256.55 | 4241.08 |
| 28000 | 4225.71 | 4210.46 | 4195.32 | 4180.28 | 4165.35 | 4150.53 | 4135.80 | 4121.18 | 4106.67 | 4092.25 |
| 29000 | 4077.93 | 4063.71 | 4049.59 | 4035.56 | 4021.63 | 4007.80 | 3994.05 | 3980.40 | 3966.85 | 3953.38 |
| 30000 | 3940.00 | 3926.71 | 3913.51 | 3900.40 | 3887.37 | 3874.43 | 3861.57 | 3848.79 | 3836.10 | 3823.50 |
| 31000 | 3810.97 | 3798.52 | 3786.15 | 3773.87 | 3761.66 | 3749.52 | 3737.47 | 3725.49 | 3713.58 | 3701.76 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 32000 | 3690.00 | 3678.32 | 3666.71 | 3655.17 | 3643.70 | 3632.31 | 3620.98 | 3609.72 | 3598.54 | 3587.42 |
| 33000 | 3576.36 | 3565.38 | 3554.46 | 3543.60 | 3532.81 | 3522.09 | 3511.43 | 3500.83 | 3490.30 | 3479.82 |
| 34000 | 3469.41 | 3459.06 | 3448.77 | 3438.54 | 3428.37 | 3418.26 | 3408.21 | 3398.21 | 3388.28 | 3378.40 |
| 35000 | 3368.57 | 3358.80 | 3349.09 | 3339.43 | 3329.83 | 3320.28 | 3310.79 | 3301.34 | 3291.96 | 3282.62 |
| 36000 | 3273.33 | 3264.10 | 3254.92 | 3245.79 | 3236.70 | 3227.67 | 3218.69 | 3209.75 | 3200.87 | 3192.03 |
| 37000 | 3183.24 | 3174.50 | 3165.81 | 3157.16 | 3148.56 | 3140.00 | 3131.49 | 3123.02 | 3114.60 | 3106.23 |
| 38000 | 3097.89 | 3089.61 | 3081.36 | 3073.16 | 3065.00 | 3056.88 | 3048.81 | 3040.78 | 3032.78 | 3024.83 |
| 39000 | 3016.92 | 3009.05 | 3001.22 | 2993.44 | 2985.69 | 2977.97 | 2970.30 | 2962.67 | 2955.08 | 2947.52 |
| 40000 | 2940.00 | 2932.52 | 2925.07 | 2917.67 | 2910.30 | 2902.96 | 2895.67 | 2888.40 | 2881.18 | 2873.99 |
| 41000 | 2866.83 | 2859.71 | 2852.62 | 2845.57 | 2838.55 | 2831.57 | 2824.62 | 2817.70 | 2810.81 | 2803.96 |
| 42000 | 2797.14 | 2790.36 | 2783.60 | 2776.88 | 2770.19 | 2763.53 | 2756.90 | 2750.30 | 2743.74 | 2737.20 |
| 43000 | 2730.70 | 2724.22 | 2717.78 | 2711.36 | 2704.98 | 2698.62 | 2692.29 | 2686.00 | 2679.73 | 2673.49 |
| 44000 | 2667.27 | 2661.09 | 2654.93 | 2648.80 | 2642.70 | 2636.63 | 2630.58 | 2624.56 | 2618.57 | 2612.61 |
| 45000 | 2606.67 | 2600.75 | 2594.87 | 2589.01 | 2583.17 | 2577.36 | 2571.58 | 2565.82 | 2560.09 | 2554.38 |
| 46000 | 2548.70 | 2543.04 | 2537.40 | 2531.79 | 2526.21 | 2520.65 | 2515.11 | 2509.59 | 2504.10 | 2498.64 |
| 47000 | 2493.19 | 2487.77 | 2482.37 | 2477.00 | 2471.65 | 2466.32 | 2461.01 | 2455.72 | 2450.46 | 2445.22 |
| 48000 | 2440.00 | 2434.80 | 2429.63 | 2424.47 | 2419.34 | 2414.23 | 2409.14 | 2404.07 | 2399.02 | 2393.99 |
| 49000 | 2388.98 | 2383.99 | 2379.02 | 2374.08 | 2369.15 | 2364.24 | 2359.35 | 2354.49 | 2349.64 | 2344.81 |
| 50000 | 2340.00 | 2335.21 | 2330.44 | 2325.69 | 2320.95 | 2316.24 | 2311.54 | 2306.86 | 2302.20 | 2297.56 |
| 51000 | 2292.94 | 2288.34 | 2283.75 | 2279.18 | 2274.63 | 2270.10 | 2265.58 | 2261.08 | 2256.60 | 2252.14 |
| 52000 | 2247.69 | 2243.26 | 2238.85 | 2234.46 | 2230.08 | 2225.71 | 2221.37 | 2217.04 | 2212.73 | 2208.43 |
| 53000 | 2204.15 | 2199.89 | 2195.64 | 2191.41 | 2187.19 | 2182.99 | 2178.81 | 2174.64 | 2170.48 | 2166.35 |
| 54000 | 2162.22 | 2158.11 | 2154.02 | 2149.94 | 2145.88 | 2141.83 | 2137.80 | 2133.78 | 2129.78 | 2125.79 |
| 55000 | 2121.82 | 2117.86 | 2113.91 | 2109.98 | 2106.06 | 2102.16 | 2098.27 | 2094.40 | 2090.54 | 2086.69 |
| 56000 | 2082.86 | 2079.04 | 2075.23 | 2071.44 | 2067.66 | 2063.89 | 2060.14 | 2056.40 | 2052.68 | 2048.96 |
| 57000 | 2045.26 | 2041.58 | 2037.90 | 2034.24 | 2030.59 | 2026.96 | 2023.33 | 2019.72 | 2016.12 | 2012.54 |
| 58000 | 2008.97 | 2005.40 | 2001.86 | 1998.32 | 1994.79 | 1991.28 | 1987.78 | 1984.29 | 1980.82 | 1977.35 |
| 59000 | 1973.90 | 1970.46 | 1967.03 | 1963.61 | 1960.20 | 1956.81 | 1953.42 | 1950.05 | 1946.69 | 1943.34 |

## 62.10 350Ω shunt resistor table (traditional values)

The shunt values in this table are those most commonly used for strain gage calibration. However the output voltage versus µΩ/Ω response is non-linear. With today's acquisition systems (better than 10-bit resolution) pseudo errors appear. The values are given here for completeness only. The linear-response values on the next page are those recommended by Curtiss-Wright.
**How to use the table**: 317832.00Ω is the shunt resistance required to produce a 1100 µΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 3499650.00 | 1749650.00 | 1166317.00 | 874650.00 | 699650.00 | 582983.00 | 499650.00 | 437150.00 | 388539.00 |
| 1000 | 349650.00 | 317832.00 | 291317.00 | 268881.00 | 249650.00 | 232983.00 | 218400.00 | 205532.00 | 194094.00 | 183861.00 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 174650.00 | 166317.00 | 158741.00 | 151824.00 | 145483.00 | 139650.00 | 134265.00 | 129280.00 | 124650.00 | 120340.00 |
| 3000 | 116317.00 | 112553.00 | 109025.00 | 105711.00 | 102591.00 | 99650.00 | 96872.20 | 94244.60 | 91755.30 | 89393.60 |
| 4000 | 87150.00 | 85015.90 | 82983.30 | 81045.30 | 79195.50 | 77427.80 | 75737.00 | 74118.10 | 72566.70 | 71078.60 |
| 5000 | 69650.00 | 68277.50 | 66957.70 | 65687.70 | 64464.80 | 63286.40 | 62150.00 | 61053.50 | 59994.80 | 58972.00 |
| 6000 | 57983.30 | 57027.00 | 56101.60 | 55205.60 | 54337.50 | 53496.20 | 52680.30 | 51888.80 | 51120.60 | 50374.60 |
| 7000 | 49650.00 | 48945.80 | 48261.10 | 47595.20 | 46947.30 | 46316.70 | 45702.60 | 45104.50 | 44521.80 | 43953.80 |
| 8000 | 43400.00 | 42859.90 | 42332.90 | 41818.70 | 41316.70 | 40826.50 | 40347.70 | 39879.90 | 39422.70 | 38975.80 |
| 9000 | 38538.90 | 38111.50 | 37693.50 | 37284.40 | 36884.00 | 36492.10 | 36108.30 | 35732.50 | 35364.30 | 35003.50 |
| 10000 | 34650.00 | 34303.50 | 33963.70 | 33630.60 | 33303.80 | 32983.30 | 32668.90 | 32360.30 | 32057.40 | 31760.10 |
| 11000 | 31468.20 | 31181.50 | 30900.00 | 30623.50 | 30351.80 | 30084.80 | 29822.40 | 29564.50 | 29311.00 | 29061.80 |
| 12000 | 28816.70 | 28575.60 | 28338.50 | 28105.30 | 27875.80 | 27650.00 | 27427.80 | 27209.10 | 26993.80 | 26781.80 |
| 13000 | 26573.10 | 26367.60 | 26165.20 | 25965.80 | 25769.40 | 25575.90 | 25385.30 | 25197.40 | 25012.30 | 24829.90 |
| 14000 | 24650.00 | 24472.70 | 24297.90 | 24125.50 | 23955.60 | 23787.90 | 23622.60 | 23459.50 | 23298.60 | 23139.90 |
| 15000 | 22983.30 | 22828.80 | 22676.30 | 22525.80 | 22377.30 | 22230.60 | 22085.90 | 21943.00 | 21801.90 | 21662.60 |
| 16000 | 21525.00 | 21389.10 | 21254.90 | 21122.40 | 20991.50 | 20862.10 | 20734.30 | 20608.10 | 20483.30 | 20360.10 |
| 17000 | 20238.20 | 20117.80 | 19998.80 | 19881.20 | 19764.90 | 19650.00 | 19536.40 | 19424.00 | 19312.90 | 19203.10 |
| 18000 | 19094.40 | 18987.00 | 18880.80 | 18775.70 | 18671.70 | 18568.90 | 18467.20 | 18366.60 | 18267.00 | 18168.50 |
| 19000 | 18071.10 | 17974.60 | 17879.20 | 17784.70 | 17691.20 | 17598.70 | 17507.10 | 17416.50 | 17326.80 | 17237.90 |
| 20000 | 17150.00 | 17062.90 | 16976.70 | 16891.40 | 16806.90 | 16723.20 | 16640.30 | 16558.20 | 16476.90 | 16396.40 |
| 21000 | 16316.70 | 16237.70 | 16159.40 | 16081.90 | 16005.10 | 15929.10 | 15853.70 | 15779.00 | 15705.00 | 15631.70 |
| 22000 | 15559.10 | 15487.10 | 15415.80 | 15345.10 | 15275.00 | 15205.60 | 15136.70 | 15068.50 | 15000.90 | 14933.80 |
| 23000 | 14867.40 | 14801.50 | 14736.20 | 14671.50 | 14607.30 | 14543.60 | 14480.50 | 14417.90 | 14355.90 | 14294.40 |
| 24000 | 14233.30 | 14172.80 | 14112.80 | 14053.30 | 13994.30 | 13935.70 | 13877.60 | 13820.00 | 13762.90 | 13706.20 |
| 25000 | 13650.00 | 13594.20 | 13538.90 | 13484.00 | 13429.50 | 13375.50 | 13321.90 | 13268.70 | 13215.90 | 13163.50 |
| 26000 | 13111.50 | 13060.00 | 13008.80 | 12958.00 | 12907.60 | 12857.50 | 12807.90 | 12758.60 | 12709.70 | 12661.20 |
| 27000 | 12613.00 | 12565.10 | 12517.60 | 12470.50 | 12423.70 | 12377.30 | 12331.20 | 12285.40 | 12239.90 | 12194.80 |
| 28000 | 12150.00 | 12105.50 | 12061.30 | 12017.50 | 11973.90 | 11930.70 | 11887.80 | 11845.10 | 11802.80 | 11760.70 |
| 29000 | 11719.00 | 11677.50 | 11636.30 | 11595.40 | 11554.80 | 11514.40 | 11474.30 | 11434.50 | 11395.00 | 11355.70 |
| 30000 | 11316.70 | 11277.90 | 11239.40 | 11201.20 | 11163.20 | 11125.40 | 11087.90 | 11050.70 | 11013.60 | 10976.90 |
| 31000 | 10940.30 | 10904.00 | 10867.90 | 10832.10 | 10796.50 | 10761.10 | 10725.90 | 10691.00 | 10656.30 | 10621.80 |
| 32000 | 10587.50 | 10553.40 | 10519.60 | 10485.90 | 10452.50 | 10419.20 | 10386.20 | 10353.40 | 10320.70 | 10288.30 |
| 33000 | 10256.10 | 10224.00 | 10192.20 | 10160.50 | 10129.00 | 10097.80 | 10066.70 | 10035.80 | 10005.00 | 9974.48 |
| 34000 | 9944.12 | 9913.93 | 9883.92 | 9854.08 | 9824.42 | 9794.93 | 9765.61 | 9736.46 | 9707.47 | 9678.65 |
| 35000 | 9650.00 | 9621.51 | 9593.18 | 9565.01 | 9537.01 | 9509.15 | 9481.46 | 9453.92 | 9426.54 | 9399.30 |
| 36000 | 9372.22 | 9345.29 | 9318.51 | 9291.87 | 9265.38 | 9239.04 | 9212.84 | 9186.78 | 9160.87 | 9135.09 |
| 37000 | 9109.46 | 9083.96 | 9058.60 | 9033.38 | 9008.29 | 8983.33 | 8958.51 | 8933.82 | 8909.26 | 8884.83 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 38000 | 8860.53 | 8836.35 | 8812.30 | 8788.38 | 8764.58 | 8740.91 | 8717.36 | 8693.93 | 8670.62 | 8647.43 |
| 39000 | 8624.36 | 8601.41 | 8578.57 | 8555.85 | 8533.25 | 8510.76 | 8488.38 | 8466.12 | 8443.97 | 8421.93 |
| 40000 | 8400.00 | 8378.18 | 8356.47 | 8334.86 | 8313.37 | 8291.98 | 8270.69 | 8249.51 | 8228.43 | 8207.46 |
| 41000 | 8186.59 | 8165.82 | 8145.15 | 8124.58 | 8104.11 | 8083.73 | 8063.46 | 8043.29 | 8023.21 | 8003.22 |
| 42000 | 7983.33 | 7963.54 | 7943.84 | 7924.23 | 7904.72 | 7885.29 | 7865.96 | 7846.72 | 7827.57 | 7808.51 |
| 43000 | 7789.53 | 7770.65 | 7751.85 | 7733.14 | 7714.52 | 7695.98 | 7677.52 | 7659.15 | 7640.87 | 7622.67 |
| 44000 | 7604.55 | 7586.51 | 7568.55 | 7550.68 | 7532.88 | 7515.17 | 7497.53 | 7479.98 | 7462.50 | 7445.10 |
| 45000 | 7427.78 | 7410.53 | 7393.36 | 7376.27 | 7359.25 | 7342.31 | 7325.44 | 7308.64 | 7291.92 | 7275.27 |
| 46000 | 7258.70 | 7242.19 | 7225.76 | 7209.40 | 7193.10 | 7176.88 | 7160.73 | 7144.65 | 7128.63 | 7112.69 |
| 47000 | 7096.81 | 7081.00 | 7065.25 | 7049.58 | 7033.97 | 7018.42 | 7002.94 | 6987.53 | 6972.18 | 6956.89 |
| 48000 | 6941.67 | 6926.51 | 6911.41 | 6896.38 | 6881.40 | 6866.49 | 6851.65 | 6836.86 | 6822.13 | 6807.46 |
| 49000 | 6792.86 | 6778.31 | 6763.82 | 6749.39 | 6735.02 | 6720.71 | 6706.45 | 6692.25 | 6678.11 | 6664.03 |
| 50000 | 6650.00 | 6636.03 | 6622.11 | 6608.25 | 6594.44 | 6580.69 | 6567.00 | 6553.35 | 6539.76 | 6526.23 |
| 51000 | 6512.75 | 6499.32 | 6485.94 | 6472.61 | 6459.34 | 6446.12 | 6432.95 | 6419.83 | 6406.76 | 6393.74 |
| 52000 | 6380.77 | 6367.85 | 6354.98 | 6342.16 | 6329.39 | 6316.67 | 6303.99 | 6291.37 | 6278.79 | 6266.26 |
| 53000 | 6253.77 | 6241.34 | 6228.95 | 6216.60 | 6204.31 | 6192.06 | 6179.85 | 6167.69 | 6155.58 | 6143.51 |
| 54000 | 6131.48 | 6119.50 | 6107.56 | 6095.67 | 6083.82 | 6072.02 | 6060.26 | 6048.54 | 6036.86 | 6025.23 |
| 55000 | 6013.64 | 6002.09 | 5990.58 | 5979.11 | 5967.69 | 5956.31 | 5944.96 | 5933.66 | 5922.40 | 5911.18 |
| 56000 | 5900.00 | 5888.86 | 5877.76 | 5866.70 | 5855.67 | 5844.69 | 5833.75 | 5822.84 | 5811.97 | 5801.14 |
| 57000 | 5790.35 | 5779.60 | 5768.88 | 5758.20 | 5747.56 | 5736.96 | 5726.39 | 5715.86 | 5705.36 | 5694.91 |
| 58000 | 5684.48 | 5674.10 | 5663.75 | 5653.43 | 5643.15 | 5632.91 | 5622.70 | 5612.52 | 5602.38 | 5592.28 |
| 59000 | 5582.20 | 5572.17 | 5562.16 | 5552.19 | 5542.26 | 5532.35 | 5522.48 | 5512.65 | 5502.84 | 5493.07 |

## 62.11 350Ω shunt resistor table (linear response)

The shunt values in this table produce a linear response (output voltage versus µΩ/Ω) and as such are the values recommended by Curtiss-Wright.
**How to use the table**: 318007.00Ω is the shunt resistance required to produce a 1100 µΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 3499825.00 | 174985.00 | 1166492.00 | 874825.00 | 699825.00 | 583158.00 | 499825.00 | 437325.00 | 388714.00 |
| 1000 | 349825.00 | 318007.00 | 291492.00 | 269056.00 | 249825.00 | 233158.00 | 218575.00 | 205707.00 | 194269.00 | 184036.00 |
| 2000 | 174825.00 | 166492.00 | 158916.00 | 151999.00 | 145658.00 | 139825.00 | 134440.00 | 129455.00 | 124825.00 | 120515.00 |
| 3000 | 116492.00 | 112728.00 | 109200.00 | 105886.00 | 102766.00 | 99825.00 | 97047.20 | 94419.60 | 91930.30 | 89568.60 |
| 4000 | 87325.00 | 85190.90 | 83158.30 | 81220.30 | 79370.50 | 77602.80 | 75912.00 | 74293.10 | 72741.70 | 71253.60 |
| 5000 | 69825.00 | 68452.50 | 67132.70 | 65862.70 | 64639.80 | 63461.40 | 62325.00 | 61228.50 | 60169.80 | 59147.00 |
| 6000 | 58158.30 | 57202.00 | 56276.60 | 55380.60 | 54512.50 | 53671.20 | 52855.30 | 52063.80 | 51295.60 | 50549.60 |
| 7000 | 49825.00 | 49120.80 | 48436.10 | 47770.20 | 47122.30 | 46491.70 | 45877.60 | 45279.50 | 44696.80 | 44128.80 |
| 8000 | 43575.00 | 43034.90 | 42507.90 | 41993.70 | 41491.70 | 41001.50 | 40522.70 | 40054.90 | 39597.70 | 39150.80 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 9000 | 38713.90 | 38286.50 | 37868.50 | 37459.40 | 37059.00 | 36667.10 | 36283.30 | 35907.50 | 35539.30 | 35178.50 |
| 10000 | 34825.00 | 34478.50 | 34138.70 | 33805.60 | 33478.80 | 33158.30 | 32843.90 | 32535.30 | 32232.40 | 31935.10 |
| 11000 | 31643.20 | 31356.50 | 31075.00 | 30798.50 | 30526.80 | 30259.80 | 29997.40 | 29739.50 | 29486.00 | 29236.80 |
| 12000 | 28991.70 | 28750.60 | 28513.50 | 28280.30 | 28050.80 | 27825.00 | 27602.80 | 27384.10 | 27168.80 | 26956.80 |
| 13000 | 26748.10 | 26542.60 | 26340.20 | 26140.80 | 25944.40 | 25750.90 | 25560.30 | 25372.40 | 25187.30 | 25004.90 |
| 14000 | 24825.00 | 24647.70 | 24472.90 | 24300.50 | 24130.60 | 23962.90 | 23797.60 | 23634.50 | 23473.60 | 23314.90 |
| 15000 | 23158.30 | 23003.80 | 22851.30 | 22700.80 | 22552.30 | 22405.60 | 22260.90 | 22118.00 | 21976.90 | 21837.60 |
| 16000 | 21700.00 | 21564.10 | 21429.90 | 21297.40 | 21166.50 | 21037.10 | 20909.30 | 20783.10 | 20658.30 | 20535.10 |
| 17000 | 20413.20 | 20292.80 | 20173.80 | 20056.20 | 19939.90 | 19825.00 | 19711.40 | 19599.00 | 19487.90 | 19378.10 |
| 18000 | 19269.40 | 19162.00 | 19055.80 | 18950.70 | 18846.70 | 18743.90 | 18642.20 | 18541.60 | 18442.00 | 18343.50 |
| 19000 | 18246.10 | 18149.60 | 18054.20 | 17959.70 | 17866.20 | 17773.70 | 17682.10 | 17591.50 | 17501.80 | 17412.90 |
| 20000 | 17325.00 | 17237.90 | 17151.70 | 17066.40 | 16981.90 | 16898.20 | 16815.30 | 16733.20 | 16651.90 | 16571.40 |
| 21000 | 16491.70 | 16412.70 | 16334.40 | 16256.90 | 16180.10 | 16104.10 | 16028.70 | 15954.00 | 15880.00 | 15806.70 |
| 22000 | 15734.10 | 15662.10 | 15590.80 | 15520.10 | 15450.00 | 15380.60 | 15311.70 | 15243.50 | 15175.90 | 15108.80 |
| 23000 | 15042.40 | 14976.50 | 14911.20 | 14846.50 | 14782.30 | 14718.60 | 14655.50 | 14592.90 | 14530.90 | 14469.40 |
| 24000 | 14408.30 | 14347.80 | 14287.80 | 14228.30 | 14169.30 | 14110.70 | 14052.60 | 13995.00 | 13937.90 | 13881.20 |
| 25000 | 13825.00 | 13769.20 | 13713.90 | 13659.00 | 13604.50 | 13550.50 | 13496.90 | 13443.70 | 13390.90 | 13338.50 |
| 26000 | 13286.50 | 13235.00 | 13183.80 | 13133.00 | 13082.60 | 13032.50 | 12982.90 | 12933.60 | 12884.70 | 12836.20 |
| 27000 | 12788.00 | 12740.10 | 12692.60 | 12645.50 | 12598.70 | 12552.30 | 12506.20 | 12460.40 | 12414.90 | 12369.80 |
| 28000 | 12325.00 | 12280.50 | 12236.30 | 12192.50 | 12148.90 | 12105.70 | 12062.80 | 12020.10 | 11977.80 | 11935.70 |
| 29000 | 11894.00 | 11852.50 | 11811.30 | 11770.40 | 11729.80 | 11689.40 | 11649.30 | 11609.50 | 11570.00 | 11530.70 |
| 30000 | 11491.70 | 11452.90 | 11414.40 | 11376.20 | 11338.20 | 11300.40 | 11262.90 | 11225.70 | 11188.60 | 11151.90 |
| 31000 | 11115.30 | 11079.00 | 11042.90 | 11007.10 | 10971.50 | 10936.10 | 10900.90 | 10866.00 | 10831.30 | 10796.80 |
| 32000 | 10762.50 | 10728.40 | 10694.60 | 10660.90 | 10627.50 | 10594.20 | 10561.20 | 10528.40 | 10495.70 | 10463.30 |
| 33000 | 10431.10 | 10399.00 | 10367.20 | 10335.50 | 10304.00 | 10272.80 | 10241.70 | 10210.80 | 10180.00 | 10149.50 |
| 34000 | 10119.10 | 10088.90 | 10058.90 | 10029.10 | 9999.42 | 9969.93 | 9940.61 | 9911.46 | 9882.47 | 9853.65 |
| 35000 | 9825.00 | 9796.51 | 9768.18 | 9740.01 | 9712.01 | 9684.15 | 9656.46 | 9628.92 | 9601.54 | 9574.30 |
| 36000 | 9547.22 | 9520.29 | 9493.51 | 9466.87 | 9440.38 | 9414.04 | 9387.84 | 9361.78 | 9335.87 | 9310.09 |
| 37000 | 9284.46 | 9258.96 | 9233.60 | 9208.38 | 9183.29 | 9158.33 | 9133.51 | 9108.82 | 9084.26 | 9059.83 |
| 38000 | 9035.53 | 9011.35 | 8987.30 | 8963.38 | 8939.58 | 8915.91 | 8892.36 | 8868.93 | 8845.62 | 8822.43 |
| 39000 | 8799.36 | 8776.41 | 8753.57 | 8730.85 | 8708.25 | 8685.76 | 8663.38 | 8641.12 | 8618.97 | 8596.93 |
| 40000 | 8575.00 | 8553.18 | 8531.47 | 8509.86 | 8488.37 | 8466.98 | 8445.69 | 8424.51 | 8403.43 | 8382.46 |
| 41000 | 8361.59 | 8340.82 | 8320.15 | 8299.58 | 8279.11 | 8258.73 | 8238.46 | 8218.29 | 8198.21 | 8178.22 |
| 42000 | 8158.33 | 8138.54 | 8118.84 | 8099.23 | 8079.72 | 8060.29 | 8040.96 | 8021.72 | 8002.57 | 7983.51 |
| 43000 | 7964.53 | 7945.65 | 7926.85 | 7908.14 | 7889.52 | 7870.98 | 7852.52 | 7834.15 | 7815.87 | 7797.67 |
| 44000 | 7779.55 | 7761.51 | 7743.55 | 7725.68 | 7707.88 | 7690.17 | 7672.53 | 7654.98 | 7637.50 | 7620.10 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 45000 | 7602.78 | 7585.53 | 7568.36 | 7551.27 | 7534.25 | 7517.31 | 7500.44 | 7483.64 | 7466.92 | 7450.27 |
| 46000 | 7433.70 | 7417.19 | 7400.76 | 7384.40 | 7368.10 | 7351.88 | 7335.73 | 7319.65 | 7303.63 | 7287.69 |
| 47000 | 7271.81 | 7256.00 | 7240.25 | 7224.58 | 7208.97 | 7193.42 | 7177.94 | 7162.53 | 7147.18 | 7131.89 |
| 48000 | 7116.67 | 7101.51 | 7086.41 | 7071.38 | 7056.40 | 7041.49 | 7026.65 | 7011.86 | 6997.13 | 6982.46 |
| 49000 | 6967.86 | 6953.31 | 6938.82 | 6924.39 | 6910.02 | 6895.71 | 6881.45 | 6867.25 | 6853.11 | 6839.03 |
| 50000 | 6825.00 | 6811.03 | 6797.11 | 6783.25 | 6769.44 | 6755.69 | 6742 | 6728.35 | 6714.76 | 6701.23 |
| 51000 | 6687.75 | 6674.32 | 6660.94 | 6647.61 | 6634.34 | 6621.12 | 6607.95 | 6594.83 | 6581.76 | 6568.74 |
| 52000 | 6555.77 | 6542.85 | 6529.98 | 6517.16 | 6504.39 | 6491.67 | 6478.99 | 6466.37 | 6453.79 | 6441.26 |
| 53000 | 6428.77 | 6416.34 | 6403.95 | 6391.60 | 6379.31 | 6367.06 | 6354.85 | 6342.69 | 6330.58 | 6318.51 |
| 54000 | 6306.48 | 6294.50 | 6282.56 | 6270.67 | 6258.82 | 6247.02 | 6235.26 | 6223.54 | 6211.86 | 6200.23 |
| 55000 | 6188.64 | 6177.09 | 6165.58 | 6154.11 | 6142.69 | 6131.31 | 6119.96 | 6108.66 | 6097.40 | 6086.18 |
| 56000 | 6075.00 | 6063.86 | 6052.76 | 6041.70 | 6030.67 | 6019.69 | 6008.75 | 5997.84 | 5986.97 | 5976.14 |
| 57000 | 5965.35 | 5954.60 | 5943.88 | 5933.20 | 5922.56 | 5911.96 | 5901.39 | 5890.86 | 5880.36 | 5869.91 |
| 58000 | 5859.48 | 5849.10 | 5838.75 | 5828.43 | 5818.15 | 5807.91 | 5797.70 | 5787.52 | 5777.38 | 5767.28 |
| 59000 | 5757.20 | 5747.17 | 5737.16 | 5727.19 | 5717.26 | 5707.35 | 5697.48 | 5687.65 | 5677.84 | 5668.07 |

## 62.12 1kΩ shunt resistor table (traditional values)

The shunt values in this table are those most commonly used for strain gage calibration. However the output voltage versus µΩ/Ω response is non-linear. With today's acquisition systems (better than 10-bit resolution) pseudo errors appear. The values are given here for completeness only. The linear-response values on the next page are those recommended by Curtiss-Wright. How to use the table: 908091.00Ω is the shunt resistance required to produce a 1100 µΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 9999000.00 | 4999000.00 | 3332333.00 | 2499000.00 | 1999000.00 | 1665667.00 | 1427571.00 | 1249000.00 | 1110111.00 |
| 1000 | 999000.00 | 908091.00 | 832333.00 | 768231.00 | 713286.00 | 665667.00 | 624000.00 | 587235.00 | 554556.00 | 525316.00 |
| 2000 | 499000.00 | 475190.00 | 453545.00 | 433783.00 | 415667.00 | 399000.00 | 383615.00 | 369370.00 | 356143.00 | 343828.00 |
| 3000 | 332333.00 | 321581.00 | 311500.00 | 302030.00 | 293118.00 | 284714.00 | 276778.00 | 269270.00 | 262158.00 | 255410.00 |
| 4000 | 249000.00 | 242902.00 | 237095.00 | 231558.00 | 226273.00 | 221222.00 | 216391.00 | 211766.00 | 207333.00 | 203082.00 |
| 5000 | 199000.00 | 195078.00 | 191308.00 | 187679.00 | 184185.00 | 180818.00 | 177571.00 | 174439.00 | 171414.00 | 168492.00 |
| 6000 | 165667.00 | 162934.00 | 160290.00 | 157730.00 | 155250.00 | 152846.00 | 150515.00 | 148254.00 | 146059.00 | 143928.00 |
| 7000 | 141857.00 | 139845.00 | 137889.00 | 135986.00 | 134135.00 | 132333.00 | 130579.00 | 128870.00 | 127205.00 | 125582.00 |
| 8000 | 124000.00 | 122457.00 | 120951.00 | 119482.00 | 118048.00 | 116647.00 | 115279.00 | 113943.00 | 112636.00 | 111360.00 |
| 9000 | 110111.00 | 108890.00 | 107696.00 | 106527.00 | 105383.00 | 104263.00 | 103167.00 | 102093.00 | 101041.00 | 100010.00 |
| 10000 | 99000.00 | 98009.90 | 97039.20 | 96087.40 | 95153.80 | 94238.10 | 93339.60 | 92457.90 | 91592.60 | 90743.10 |
| 11000 | 89909.10 | 89090.10 | 88285.70 | 87495.60 | 86719.30 | 85956.50 | 85206.90 | 84470.10 | 83745.80 | 83033.60 |
| 12000 | 82333.30 | 81644.60 | 80967.20 | 80300.80 | 79645.20 | 79000.00 | 78365.10 | 77740.20 | 77125.00 | 76519.40 |
| 13000 | 75923.10 | 75335.90 | 74757.60 | 74188.00 | 73626.90 | 73074.10 | 72529.40 | 71992.70 | 71463.80 | 70942.40 |
| 14000 | 70428.60 | 69922.00 | 69422.50 | 68930.10 | 68444.40 | 67965.50 | 67493.20 | 67027.20 | 66567.60 | 66114.10 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 15000 | 65666.70 | 65225.20 | 64789.50 | 64359.50 | 63935.10 | 63516.10 | 63102.60 | 62694.30 | 62291.10 | 61893.10 |
| 16000 | 61500.00 | 61111.80 | 60728.40 | 60349.70 | 59975.60 | 59606.10 | 59241.00 | 58880.20 | 58523.80 | 58171.60 |
| 17000 | 57823.50 | 57479.50 | 57139.50 | 56803.50 | 56471.30 | 56142.90 | 55818.20 | 55497.20 | 55179.80 | 54865.90 |
| 18000 | 54555.60 | 54248.60 | 53945.10 | 53644.80 | 53347.80 | 53054.10 | 52763.40 | 52475.90 | 52191.50 | 51910.10 |
| 19000 | 51631.60 | 51356.00 | 51083.30 | 50813.50 | 50546.40 | 50282.10 | 50020.40 | 49761.40 | 49505.10 | 49251.30 |
| 20000 | 49000.00 | 48751.20 | 48505.00 | 48261.10 | 48019.60 | 47780.50 | 47543.70 | 47309.20 | 47076.90 | 46846.90 |
| 21000 | 46619.00 | 46393.40 | 46169.80 | 45948.40 | 45729.00 | 45511.60 | 45296.30 | 45082.90 | 44871.60 | 44662.10 |
| 22000 | 44454.50 | 44248.90 | 44045.00 | 43843.00 | 43642.90 | 43444.40 | 43247.80 | 43052.90 | 42859.60 | 42668.10 |
| 23000 | 42478.30 | 42290.00 | 42103.40 | 41918.50 | 41735.00 | 41553.20 | 41372.90 | 41194.10 | 41016.80 | 40841.00 |
| 24000 | 40666.70 | 40493.80 | 40322.30 | 40152.30 | 39983.60 | 39816.30 | 39650.40 | 39485.80 | 39322.60 | 39160.60 |
| 25000 | 39000.00 | 38840.60 | 38682.50 | 38525.70 | 38370.10 | 38215.70 | 38062.50 | 37910.50 | 37759.70 | 37610.00 |
| 26000 | 37461.50 | 37314.20 | 37167.90 | 37022.80 | 36878.80 | 36735.80 | 36594.00 | 36453.20 | 36313.40 | 36174.70 |
| 27000 | 36037.00 | 35900.40 | 35764.70 | 35630.00 | 35496.40 | 35363.60 | 35231.90 | 35101.10 | 34971.20 | 34842.30 |
| 28000 | 34714.30 | 34587.20 | 34461.00 | 34335.70 | 34211.30 | 34087.70 | 33965.00 | 33843.20 | 33722.20 | 33602.10 |
| 29000 | 33482.80 | 33364.30 | 33246.60 | 33129.70 | 33013.60 | 32898.30 | 32783.80 | 32670.00 | 32557.00 | 32444.80 |
| 30000 | 32333.30 | 32222.60 | 32112.60 | 32003.30 | 31894.70 | 31786.90 | 31679.70 | 31573.30 | 31467.50 | 31362.50 |
| 31000 | 31258.10 | 31154.30 | 31051.30 | 30948.90 | 30847.10 | 30746.00 | 30645.60 | 30545.70 | 30446.50 | 30348.00 |
| 32000 | 30250.00 | 30152.60 | 30055.90 | 29959.80 | 29864.20 | 29769.20 | 29674.80 | 29581.00 | 29487.80 | 29395.10 |
| 33000 | 29303.00 | 29211.50 | 29120.50 | 29030.00 | 28940.10 | 28850.70 | 28761.90 | 28673.60 | 28585.80 | 28498.50 |
| 34000 | 28411.80 | 28325.50 | 28239.80 | 28154.50 | 28069.80 | 27985.50 | 27901.70 | 27818.40 | 27735.60 | 27653.30 |
| 35000 | 27571.40 | 27490.00 | 27409.10 | 27328.60 | 27248.60 | 27169.00 | 27089.90 | 27011.20 | 26933.00 | 26855.20 |
| 36000 | 26777.80 | 26700.80 | 26624.30 | 26548.20 | 26472.50 | 26397.30 | 26322.40 | 26248.00 | 26173.90 | 26100.30 |
| 37000 | 26027.00 | 25954.20 | 25881.70 | 25809.70 | 25738.00 | 25666.70 | 25595.70 | 25525.20 | 25455.00 | 25385.20 |
| 38000 | 25315.80 | 25246.70 | 25178.00 | 25109.70 | 25041.70 | 24974.00 | 24906.70 | 24839.80 | 24773.20 | 24706.90 |
| 39000 | 24641.00 | 24575.40 | 24510.20 | 24445.30 | 24380.70 | 24316.50 | 24252.50 | 24188.90 | 24125.60 | 24062.70 |
| 40000 | 24000.00 | 23937.70 | 23875.60 | 23813.90 | 23752.50 | 23691.40 | 23630.50 | 23570.00 | 23509.80 | 23449.90 |
| 41000 | 23390.20 | 23330.90 | 23271.80 | 23213.10 | 23154.60 | 23096.40 | 23038.50 | 22980.80 | 22923.40 | 22866.30 |
| 42000 | 22809.50 | 22753.00 | 22696.70 | 22640.70 | 22584.90 | 22529.40 | 22474.20 | 22419.20 | 22364.50 | 22310.00 |
| 43000 | 22255.80 | 22201.90 | 22148.10 | 22094.70 | 22041.50 | 21988.50 | 21935.80 | 21883.30 | 21831.10 | 21779.00 |
| 44000 | 21727.30 | 21675.70 | 21624.40 | 21573.40 | 21522.50 | 21471.90 | 21421.50 | 21371.40 | 21321.40 | 21271.70 |
| 45000 | 21222.20 | 21172.90 | 21123.90 | 21075.10 | 21026.40 | 20978.00 | 20929.80 | 20881.80 | 20834.10 | 20786.50 |
| 46000 | 20739.10 | 20692.00 | 20645.00 | 20598.30 | 20551.70 | 20505.40 | 20459.20 | 20413.30 | 20367.50 | 20322.00 |
| 47000 | 20276.60 | 20231.40 | 20186.40 | 20141.60 | 20097.00 | 20052.60 | 20008.40 | 19964.40 | 19920.50 | 19876.80 |
| 48000 | 19833.30 | 19790.00 | 19746.90 | 19703.90 | 19661.20 | 19618.60 | 19576.10 | 19533.90 | 19491.80 | 19449.90 |
| 49000 | 19408.20 | 19366.60 | 19325.20 | 19284.00 | 19242.90 | 19202.00 | 19161.30 | 19120.70 | 19080.30 | 19040.10 |
| 50000 | 19000.00 | 18960.10 | 18920.30 | 18880.70 | 18841.30 | 18802.00 | 18762.80 | 18723.90 | 18685.00 | 18646.40 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 51000 | 18607.80 | 18569.50 | 18531.30 | 18493.20 | 18455.30 | 18417.50 | 18379.80 | 18342.40 | 18305.00 | 18267.80 |
| 52000 | 18230.80 | 18193.90 | 18157.10 | 18120.50 | 18084.00 | 18047.60 | 18011.40 | 17975.30 | 17939.40 | 17903.60 |
| 53000 | 17867.90 | 17832.40 | 17797.00 | 17761.70 | 17726.60 | 17691.60 | 17656.70 | 17622.00 | 17587.40 | 17552.90 |
| 54000 | 17518.50 | 17484.30 | 17450.20 | 17416.20 | 17382.40 | 17348.60 | 17315.00 | 17281.50 | 17248.20 | 17214.90 |
| 55000 | 17181.80 | 17148.80 | 17115.90 | 17083.20 | 17050.50 | 17018.00 | 16985.60 | 16953.30 | 16921.10 | 16889.10 |
| 56000 | 16857.10 | 16825.30 | 16793.60 | 16762.00 | 16730.50 | 16699.10 | 16667.80 | 16636.70 | 16605.60 | 16574.70 |
| 57000 | 16543.90 | 16513.10 | 16482.50 | 16452.00 | 16421.60 | 16391.30 | 16361.10 | 16331.00 | 16301.00 | 16271.20 |
| 58000 | 16241.40 | 16211.70 | 16182.10 | 16152.70 | 16123.30 | 16094.00 | 16064.80 | 16035.80 | 16006.80 | 15977.90 |
| 59000 | 15949.20 | 15920.50 | 15891.90 | 15863.40 | 15835.00 | 15806.70 | 15778.50 | 15750.40 | 15722.40 | 15694.50 |

## 62.13 1 kΩ shunt resistor table (linear response)

The shunt values in this table produce a linear response (output voltage versus μΩ/Ω) and as such are the values recommended by Curtiss-Wright.
**How to use the table**: 908591.00Ω is the shunt resistance required to produce a 1100 μΩ/Ω deflection.

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | *open* | 999950.00 | 4999500.00 | 3332833.00 | 2499500.00 | 1999500.00 | 1666167.00 | 1428071.00 | 1249500.00 | 1110611.00 |
| 1000 | 999500.00 | 908591.00 | 832833.00 | 768731.00 | 713786.00 | 666167.00 | 624500.00 | 587735.00 | 555056.00 | 525816.00 |
| 2000 | 499500.00 | 475690.00 | 454045.00 | 434283.00 | 416167.00 | 399500.00 | 384115.00 | 369870.00 | 356643.00 | 344328.00 |
| 3000 | 332833.00 | 322081.00 | 312000.00 | 302530.00 | 293618.00 | 285214.00 | 277278.00 | 269770.00 | 262658.00 | 255910.00 |
| 4000 | 249500.00 | 243402.00 | 237595.00 | 232058.00 | 226773.00 | 221722.00 | 216891.00 | 212266.00 | 207833.00 | 203582.00 |
| 5000 | 199500.00 | 195578.00 | 191808.00 | 188179.00 | 184685.00 | 181318.00 | 178071.00 | 174939.00 | 171914.00 | 168992.00 |
| 6000 | 166167.00 | 163434.00 | 160790.00 | 158230.00 | 155750.00 | 153346.00 | 151015.00 | 148754.00 | 146559.00 | 144428.00 |
| 7000 | 142357.00 | 140345.00 | 138389.00 | 136486.00 | 134635.00 | 132833.00 | 131079.00 | 129370.00 | 127705.00 | 126082.00 |
| 8000 | 124500.00 | 122957.00 | 121451.00 | 119982.00 | 118548.00 | 117147.00 | 115779.00 | 114443.00 | 113136.00 | 111860.00 |
| 9000 | 110611.00 | 109390.00 | 108196.00 | 107027.00 | 105883.00 | 104763.00 | 103667.00 | 102593.00 | 101541.00 | 100510.00 |
| 10000 | 99500.00 | 98509.90 | 97539.20 | 96587.40 | 95653.80 | 94738.10 | 93839.60 | 92957.90 | 92092.60 | 91243.10 |
| 11000 | 90409.10 | 89590.10 | 88785.70 | 87995.60 | 87219.30 | 86456.50 | 85706.90 | 84970.10 | 84245.80 | 83533.60 |
| 12000 | 82833.30 | 82144.60 | 81467.20 | 80800.80 | 80145.20 | 79500.00 | 78865.10 | 78240.20 | 77625.00 | 77019.40 |
| 13000 | 76423.10 | 75835.90 | 75257.60 | 74688.00 | 74126.90 | 73574.10 | 73029.40 | 72492.70 | 71963.80 | 71442.40 |
| 14000 | 70928.60 | 70422.00 | 69922.50 | 69430.10 | 68944.40 | 68465.50 | 67993.20 | 67527.20 | 67067.60 | 66614.10 |
| 15000 | 66166.70 | 65725.20 | 65289.50 | 64859.50 | 64435.10 | 64016.10 | 63602.60 | 63194.30 | 62791.10 | 62393.10 |
| 16000 | 62000.00 | 61611.80 | 61228.40 | 60849.70 | 60475.60 | 60106.10 | 59741.00 | 59380.20 | 59023.80 | 58671.60 |
| 17000 | 58323.50 | 57979.50 | 57639.50 | 57303.50 | 56971.30 | 56642.90 | 56318.20 | 55997.20 | 55679.80 | 55365.90 |
| 18000 | 55055.60 | 54748.60 | 54445.10 | 54144.80 | 53847.80 | 53554.10 | 53263.40 | 52975.90 | 52691.50 | 52410.10 |
| 19000 | 52131.60 | 51856.00 | 51583.30 | 51313.50 | 51046.40 | 50782.10 | 50520.40 | 50261.40 | 50005.10 | 49751.30 |

| mΩ/ Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 20000 | 49500.00 | 49251.20 | 49005.00 | 48761.10 | 48519.60 | 48280.50 | 48043.70 | 47809.20 | 47576.90 | 47346.90 |
| 21000 | 47119.00 | 46893.40 | 46669.80 | 46448.40 | 46229.00 | 46011.60 | 45796.30 | 45582.90 | 45371.60 | 45162.10 |
| 22000 | 44954.50 | 44748.90 | 44545.00 | 44343.00 | 44142.90 | 43944.40 | 43747.80 | 43552.90 | 43359.60 | 43168.10 |
| 23000 | 42978.30 | 42790.00 | 42603.40 | 42418.50 | 42235.00 | 42053.20 | 41872.90 | 41694.10 | 41516.80 | 41341.00 |
| 24000 | 41166.70 | 40993.80 | 40822.30 | 40652.30 | 40483.60 | 40316.30 | 40150.40 | 39985.80 | 39822.60 | 39660.60 |
| 25000 | 39500.00 | 39340.60 | 39182.50 | 39025.70 | 38870.10 | 38715.70 | 38562.50 | 38410.50 | 38259.70 | 38110.00 |
| 26000 | 37961.50 | 37814.20 | 37667.90 | 37522.80 | 37378.80 | 37235.80 | 37094.00 | 36953.20 | 36813.40 | 36674.70 |
| 27000 | 36537.00 | 36400.40 | 36264.70 | 36130.00 | 35996.40 | 35863.60 | 35731.90 | 35601.10 | 35471.20 | 35342.30 |
| 28000 | 35214.30 | 35087.20 | 34961.00 | 34835.70 | 34711.30 | 34587.70 | 34465.00 | 34343.20 | 34222.20 | 34102.10 |
| 29000 | 33982.80 | 33864.30 | 33746.60 | 33629.70 | 33513.60 | 33398.30 | 33283.80 | 33170.00 | 33057.00 | 32944.80 |
| 30000 | 32833.30 | 32722.60 | 32612.60 | 32503.30 | 32394.70 | 32286.90 | 32179.70 | 32073.30 | 31967.50 | 31862.50 |
| 31000 | 31758.10 | 31654.30 | 31551.30 | 31448.90 | 31347.10 | 31246.00 | 31145.60 | 31045.70 | 30946.50 | 30848.00 |
| 32000 | 30750.00 | 30652.60 | 30555.90 | 30459.80 | 30364.20 | 30269.20 | 30174.80 | 30081.00 | 29987.80 | 29895.10 |
| 33000 | 29803.00 | 29711.50 | 29620.50 | 29530.00 | 29440.10 | 29350.70 | 29261.90 | 29173.60 | 29085.80 | 28998.50 |
| 34000 | 28911.80 | 28825.50 | 28739.80 | 28654.50 | 28569.80 | 28485.50 | 28401.70 | 28318.40 | 28235.60 | 28153.30 |
| 35000 | 28071.40 | 27990.00 | 27909.10 | 27828.60 | 27748.60 | 27669.00 | 27589.90 | 27511.20 | 27433.00 | 27355.20 |
| 36000 | 27277.80 | 27200.80 | 27124.30 | 27048.20 | 26972.50 | 26897.30 | 26822.40 | 26748.00 | 26673.90 | 26600.30 |
| 37000 | 26527.00 | 26454.20 | 26381.70 | 26309.70 | 26238.00 | 26166.70 | 26095.70 | 26025.20 | 25955.00 | 25885.20 |
| 38000 | 25815.80 | 25746.70 | 25678.00 | 25609.70 | 25541.70 | 25474.00 | 25406.70 | 25339.80 | 25273.20 | 25206.90 |
| 39000 | 25141.00 | 25075.40 | 25010.20 | 24945.30 | 24880.70 | 24816.50 | 24752.50 | 24688.90 | 24625.60 | 24562.70 |
| 40000 | 24500.00 | 24437.70 | 24375.60 | 24313.90 | 24252.50 | 24191.40 | 24130.50 | 24070.00 | 24009.80 | 23949.90 |
| 41000 | 23890.20 | 23830.90 | 23771.80 | 23713.10 | 23654.60 | 23596.40 | 23538.50 | 23480.80 | 23423.40 | 23366.30 |
| 42000 | 23309.50 | 23253.00 | 23196.70 | 23140.70 | 23084.90 | 23029.40 | 22974.20 | 22919.20 | 22864.50 | 22810.00 |
| 43000 | 22755.80 | 22701.90 | 22648.10 | 22594.70 | 22541.50 | 22488.50 | 22435.80 | 22383.30 | 22331.10 | 22279.00 |
| 44000 | 22227.30 | 22175.70 | 22124.40 | 22073.40 | 22022.50 | 21971.90 | 21921.50 | 21871.40 | 21821.40 | 21771.70 |
| 45000 | 21722.20 | 21672.90 | 21623.90 | 21575.10 | 21526.40 | 21478.00 | 21429.80 | 21381.80 | 21334.10 | 21286.50 |
| 46000 | 21239.10 | 21192.00 | 21145.00 | 21098.30 | 21051.70 | 21005.40 | 20959.20 | 20913.30 | 20867.50 | 20822.00 |
| 47000 | 20776.60 | 20731.40 | 20686.40 | 20641.60 | 20597.00 | 20552.60 | 20508.40 | 20464.40 | 20420.50 | 20376.80 |
| 48000 | 20333.30 | 20290.00 | 20246.90 | 20203.90 | 20161.20 | 20118.60 | 20076.10 | 20033.90 | 19991.80 | 19949.90 |
| 49000 | 19908.20 | 19866.60 | 19825.20 | 19784.00 | 19742.90 | 19702.00 | 19661.30 | 19620.70 | 19580.30 | 19540.10 |
| 50000 | 19500.00 | 19460.10 | 19420.30 | 19380.70 | 19341.30 | 19302.00 | 19262.80 | 19223.90 | 19185.00 | 19146.40 |
| 51000 | 19107.80 | 19069.50 | 19031.30 | 18993.20 | 18955.30 | 18917.50 | 18879.80 | 18842.40 | 18805.00 | 18767.80 |
| 52000 | 18730.80 | 18693.90 | 18657.10 | 18620.50 | 18584.00 | 18547.60 | 18511.40 | 18475.30 | 18439.40 | 18403.60 |
| 53000 | 18367.90 | 18332.40 | 18297.00 | 18261.70 | 18226.60 | 18191.60 | 18156.70 | 18122.00 | 18087.40 | 18052.90 |
| 54000 | 18018.50 | 17984.30 | 17950.20 | 17916.20 | 17882.40 | 17848.60 | 17815.00 | 17781.50 | 17748.20 | 17714.90 |

| mΩ/Ω | +0 | +100 | +200 | +300 | +400 | +500 | +600 | +700 | +800 | +900 |
|---|---|---|---|---|---|---|---|---|---|---|
| 55000 | 17681.80 | 17648.80 | 17615.90 | 17583.20 | 17550.50 | 17518.00 | 17485.60 | 17453.30 | 17421.10 | 17389.10 |
| 56000 | 17357.10 | 17325.30 | 17293.60 | 17262.00 | 17230.50 | 17199.10 | 17167.80 | 17136.70 | 17105.60 | 17074.70 |
| 57000 | 17043.90 | 17013.10 | 16982.50 | 16952.00 | 16921.60 | 16891.30 | 16861.10 | 16831.00 | 16801.00 | 16771.20 |
| 58000 | 16741.40 | 16711.70 | 16682.10 | 16652.70 | 16623.30 | 16594.00 | 16564.80 | 16535.80 | 16506.80 | 16477.90 |
| 59000 | 16449.20 | 16420.50 | 16391.90 | 16363.40 | 16335.00 | 16306.70 | 16278.50 | 16250.40 | 16222.40 | 16194.50 |

## 62.14 J-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology (NIST) in the US for a metal pair of Iron-Copper and Nickel referenced to a cold junction at 0°C. J is the letter designation approved by the American Institute for Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the μV produced in intervals of 1°C. For example -8076.34 in the emf produced at -209°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -210 | -8095.61 | -8076.34 | -8056.79 | -8036.96 | -8016.85 | -7996.47 | -7975.81 | -7954.88 | -7933.67 | -7912.20 |
| -200 | -7890.46 | -7868.45 | -7846.19 | -7823.65 | -7800.86 | -7777.81 | -7754.51 | -7730.94 | -7707.13 | -7683.06 |
| -190 | -7658.75 | -7634.18 | -7609.37 | -7584.31 | -7559.01 | -7533.47 | -7507.69 | -7481.67 | -7455.41 | -7428.92 |
| -180 | -7402.19 | -7375.24 | -7348.05 | -7320.63 | -7292.99 | -7265.12 | -7237.02 | -7208.71 | -7180.17 | -7151.41 |
| -170 | -7122.43 | -7093.24 | -7063.83 | -7034.21 | -7004.38 | -6974.33 | -6944.08 | -6913.62 | -6882.95 | -6852.07 |
| -160 | -6821.00 | -6789.72 | -6758.24 | -6726.56 | -6694.68 | -6662.60 | -6630.33 | -6597.87 | -6565.21 | -6532.36 |
| -150 | -6499.32 | -6466.10 | -6432.68 | -6399.08 | -6365.29 | -6331.32 | -6297.17 | -6262.84 | -6228.33 | -6193.64 |
| -140 | -6158.77 | -6123.72 | -6088.51 | -6053.11 | -6017.55 | -5981.81 | -5945.91 | -5909.83 | -5873.59 | -5837.18 |
| -130 | -5800.61 | -5763.87 | -5726.97 | -5689.91 | -5652.68 | -5615.30 | -5577.76 | -5540.06 | -5502.21 | -5464.20 |
| -120 | -5426.04 | -5387.72 | -5349.25 | -5310.63 | -5271.87 | -5232.95 | -5193.89 | -5154.68 | -5115.32 | -5075.82 |
| -110 | -5036.18 | -4996.39 | -4956.47 | -4916.40 | -4876.20 | -4835.85 | -4795.37 | -4754.75 | -4714.00 | -4673.12 |
| -100 | -4632.10 | -4590.94 | -4549.66 | -4508.25 | -4466.70 | -4425.03 | -4383.23 | -4341.31 | -4299.25 | -4257.08 |
| -90 | -4214.78 | -4172.35 | -4129.81 | -4087.14 | -4044.35 | -4001.45 | -3958.42 | -3915.28 | -3872.02 | -3828.65 |
| -80 | -3785.16 | -3741.55 | -3697.83 | -3654.00 | -3610.06 | -3566.01 | -3521.84 | -3477.57 | -3433.19 | -3388.70 |
| -70 | -3344.11 | -3299.41 | -3254.60 | -3209.69 | -3164.68 | -3119.56 | -3074.34 | -3029.02 | -2983.60 | -2938.08 |
| -60 | -2892.46 | -2846.74 | -2800.92 | -2755.01 | -2709.00 | -2662.90 | -2616.70 | -2570.41 | -2524.02 | -2477.54 |
| -50 | -2430.97 | -2384.31 | -2337.56 | -2290.72 | -2243.79 | -2196.78 | -2149.67 | -2102.48 | -2055.20 | -2007.84 |
| -40 | -1960.39 | -1912.85 | -1865.24 | -1817.54 | -1769.76 | -1721.89 | -1673.95 | -1625.92 | -1577.82 | -1529.64 |
| -30 | -1481.37 | -1433.03 | -1384.62 | -1336.12 | -1287.56 | -1238.91 | -1190.19 | -1141.4 | -1092.53 | -1043.59 |
| -20 | -994.58 | -945.49 | -896.34 | -847.11 | -797.82 | -748.45 | -699.01 | -649.51 | -599.94 | -550.30 |
| -10 | -500.60 | -450.83 | -400.99 | -351.09 | -301.12 | -251.09 | -201.00 | -150.84 | -100.62 | -50.34 |
| 0 | 0.00 | 50.40 | 100.87 | 151.39 | 201.97 | 252.61 | 303.31 | 354.07 | 404.89 | 455.76 |
| 10 | 506.69 | 557.67 | 608.71 | 659.80 | 710.95 | 762.15 | 813.41 | 864.72 | 916.08 | 967.50 |
| 20 | 1018.96 | 1070.48 | 1122.04 | 1173.66 | 1225.33 | 1277.05 | 1328.81 | 1380.63 | 1432.49 | 1484.40 |
| 30 | 1536.36 | 1588.36 | 1640.41 | 1692.51 | 1744.65 | 1796.84 | 1849.07 | 1901.34 | 1953.66 | 2006.03 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 2058.43 | 2110.88 | 2163.37 | 2215.91 | 2268.48 | 2321.10 | 2373.75 | 2426.45 | 2479.19 | 2531.96 |
| 50 | 2584.78 | 2637.63 | 2690.52 | 2743.45 | 2796.42 | 2849.43 | 2902.47 | 2955.55 | 3008.66 | 3061.81 |
| 60 | 3115.00 | 3168.22 | 3221.48 | 3274.77 | 3328.09 | 3381.45 | 3434.84 | 3488.27 | 3541.72 | 3595.21 |
| 70 | 3648.73 | 3702.29 | 3755.87 | 3809.49 | 3863.13 | 3916.81 | 3970.52 | 4024.25 | 4078.02 | 4131.82 |
| 80 | 4185.64 | 4239.49 | 4293.37 | 4347.28 | 4401.22 | 4455.18 | 4509.17 | 4563.19 | 4617.23 | 4671.30 |
| 90 | 4725.39 | 4779.51 | 4833.66 | 4887.83 | 4942.02 | 4996.24 | 5050.49 | 5104.75 | 5159.04 | 5213.36 |
| 100 | 5267.69 | 5322.05 | 5376.43 | 5430.83 | 5485.26 | 5539.71 | 5594.17 | 5648.66 | 5703.17 | 5757.70 |
| 110 | 5812.25 | 5866.82 | 5921.41 | 5976.02 | 6030.65 | 6085.30 | 6139.96 | 6194.65 | 6249.35 | 6304.07 |
| 120 | 6358.81 | 6413.57 | 6468.34 | 6523.13 | 6577.94 | 6632.76 | 6687.60 | 6742.45 | 6797.32 | 6852.21 |
| 130 | 6907.11 | 6962.03 | 7016.96 | 7071.91 | 7126.87 | 7181.85 | 7236.84 | 7291.84 | 7346.86 | 7401.89 |
| 140 | 7456.93 | 7511.99 | 7567.06 | 7622.14 | 7677.24 | 7732.34 | 7787.46 | 7842.59 | 7897.73 | 7952.89 |
| 150 | 8008.05 | 8063.23 | 8118.41 | 8173.61 | 8228.81 | 8284.03 | 8339.26 | 8394.49 | 8449.74 | 8505.00 |
| 160 | 8560.26 | 8615.54 | 8670.82 | 8726.11 | 8781.41 | 8836.72 | 8892.04 | 8947.36 | 9002.69 | 9058.03 |
| 170 | 9113.38 | 9168.74 | 9224.10 | 9279.47 | 9334.84 | 9390.23 | 9445.62 | 9501.01 | 9556.41 | 9611.82 |
| 180 | 9667.23 | 9722.65 | 9778.08 | 9833.51 | 9888.95 | 9944.39 | 9999.83 | 10055.30 | 10110.70 | 10166.20 |
| 190 | 10221.70 | 10277.10 | 10332.60 | 10388.10 | 10443.60 | 10499.00 | 10554.50 | 10610.00 | 10665.50 | 10721.00 |
| 200 | 10776.50 | 10832.00 | 10887.50 | 10943.00 | 10998.50 | 11054.10 | 11109.60 | 11165.10 | 11220.60 | 11276.10 |
| 210 | 11331.70 | 11387.20 | 11442.70 | 11498.20 | 11553.80 | 11609.30 | 11664.80 | 11720.40 | 11775.90 | 11831.40 |
| 220 | 11887.00 | 11942.50 | 11998.10 | 12053.60 | 12109.10 | 12164.70 | 12220.20 | 12275.70 | 12331.30 | 12386.80 |
| 230 | 12442.40 | 12497.90 | 12553.40 | 12609.00 | 12664.50 | 12720.00 | 12775.60 | 12831.10 | 12886.60 | 12942.20 |
| 240 | 12997.70 | 13053.20 | 13108.80 | 13164.30 | 13219.80 | 13275.30 | 13330.90 | 13386.40 | 13441.90 | 13497.40 |
| 250 | 13552.90 | 13608.40 | 13663.90 | 13719.50 | 13775.00 | 13830.50 | 13886.00 | 13941.50 | 13997.00 | 14052.50 |
| 260 | 14107.90 | 14163.40 | 14218.90 | 14274.40 | 14329.90 | 14385.40 | 14440.80 | 14496.30 | 14551.80 | 14607.30 |
| 270 | 14662.70 | 14718.20 | 14773.60 | 14829.10 | 14884.60 | 14940.00 | 14995.50 | 15050.90 | 15106.30 | 15161.80 |
| 280 | 15217.20 | 15272.60 | 15328.10 | 15383.50 | 15438.90 | 15494.30 | 15549.70 | 15605.10 | 15660.50 | 15715.90 |
| 290 | 15771.30 | 15826.70 | 15882.10 | 15937.50 | 15992.90 | 16048.30 | 16103.60 | 16159.00 | 16214.40 | 16269.80 |
| 300 | 16325.10 | 16380.50 | 16435.80 | 16491.20 | 16546.50 | 16601.90 | 16657.20 | 16712.50 | 16767.90 | 16823.20 |
| 310 | 16878.50 | 16933.80 | 16989.10 | 17044.50 | 17099.80 | 17155.10 | 17210.40 | 17265.70 | 17321.00 | 17376.30 |
| 320 | 17431.50 | 17486.80 | 17542.10 | 17597.40 | 17652.60 | 17707.90 | 17763.20 | 17818.40 | 17873.70 | 17928.90 |
| 330 | 17984.20 | 18039.40 | 18094.70 | 18149.90 | 18205.20 | 18260.40 | 18315.60 | 18370.80 | 18426.10 | 18481.30 |
| 340 | 18536.50 | 18591.70 | 18646.90 | 18702.10 | 18757.30 | 18812.50 | 18867.70 | 18922.90 | 18978.10 | 19033.30 |
| 350 | 19088.50 | 19143.70 | 19198.90 | 19254.10 | 19309.20 | 19364.40 | 19419.60 | 19474.80 | 19529.90 | 19585.10 |
| 360 | 19640.30 | 19695.40 | 19750.60 | 19805.70 | 19860.90 | 19916.00 | 19971.20 | 20026.30 | 20081.50 | 20136.60 |
| 370 | 20191.80 | 20246.90 | 20302.10 | 20357.20 | 20412.40 | 20467.50 | 20522.60 | 20577.80 | 20632.90 | 20688.00 |
| 380 | 20743.20 | 20798.30 | 20853.40 | 20908.60 | 20963.70 | 21018.80 | 21074.00 | 21129.10 | 21184.20 | 21239.40 |
| 390 | 21294.50 | 21349.60 | 21404.80 | 21459.90 | 21515.10 | 21570.20 | 21625.30 | 21680.50 | 21735.60 | 21790.70 |
| 400 | 21845.90 | 21901.00 | 21956.20 | 22011.30 | 22066.50 | 22121.60 | 22176.80 | 22231.90 | 22287.10 | 22342.20 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 410 | 22397.40 | 22452.50 | 22507.70 | 22562.90 | 22618.00 | 22673.20 | 22728.40 | 22783.60 | 22838.70 | 22893.90 |
| 420 | 22949.10 | 23004.30 | 23059.50 | 23114.70 | 23169.90 | 23225.10 | 23280.30 | 23335.60 | 23390.80 | 23446.00 |
| 430 | 23501.20 | 23556.50 | 23611.70 | 23667.00 | 23722.20 | 23777.50 | 23832.70 | 23888.00 | 23943.30 | 23998.50 |
| 440 | 24053.80 | 24109.10 | 24164.40 | 24219.70 | 24275.00 | 24330.40 | 24385.70 | 24441.00 | 24496.40 | 24551.70 |
| 450 | 24607.10 | 24662.40 | 24717.80 | 24773.20 | 24828.60 | 24884.00 | 24939.40 | 24994.80 | 25050.20 | 25105.70 |
| 460 | 25161.10 | 25216.50 | 25272.00 | 25327.50 | 25383.00 | 25438.40 | 25493.90 | 25549.50 | 25605.00 | 25660.50 |
| 470 | 25716.10 | 25771.60 | 25827.20 | 25882.80 | 25938.30 | 25993.90 | 26049.60 | 26105.20 | 26160.80 | 26216.50 |
| 480 | 26272.10 | 26327.80 | 26383.50 | 26439.20 | 26494.90 | 26550.60 | 26606.40 | 26662.10 | 26717.90 | 26773.70 |
| 490 | 26829.50 | 26885.30 | 26941.10 | 26996.90 | 27052.80 | 27108.70 | 27164.60 | 27220.50 | 27276.40 | 27332.30 |
| 500 | 27388.30 | 27444.20 | 27500.20 | 27556.20 | 27612.20 | 27668.20 | 27724.30 | 27780.40 | 27836.40 | 27892.60 |
| 510 | 27948.70 | 28004.80 | 28061.00 | 28117.10 | 28173.30 | 28229.50 | 28285.80 | 28342.00 | 28398.30 | 28454.60 |
| 520 | 28510.90 | 28567.20 | 28623.60 | 28680.00 | 28736.30 | 28792.80 | 28849.20 | 28905.60 | 28962.10 | 29018.60 |
| 530 | 29075.10 | 29131.70 | 29188.20 | 29244.80 | 29301.40 | 29358.00 | 29414.70 | 29471.40 | 29528.10 | 29584.80 |
| 540 | 29641.50 | 29698.30 | 29755.10 | 29811.90 | 29868.80 | 29925.60 | 29982.50 | 30039.40 | 30096.40 | 30153.30 |
| 550 | 30210.30 | 30267.30 | 30324.40 | 30381.40 | 30438.50 | 30495.70 | 30552.80 | 30610.00 | 30667.20 | 30724.40 |
| 560 | 30781.70 | 30838.90 | 30896.20 | 30953.60 | 31010.90 | 31068.30 | 31125.80 | 31183.20 | 31240.70 | 31298.20 |
| 570 | 31355.70 | 31413.30 | 31470.90 | 31528.50 | 31586.20 | 31643.80 | 31701.50 | 31759.30 | 31817.10 | 31874.90 |
| 580 | 31932.70 | 31990.60 | 32048.50 | 32106.40 | 32164.30 | 32222.30 | 32280.40 | 32338.40 | 32396.50 | 32454.60 |
| 590 | 32512.80 | 32570.90 | 32629.10 | 32687.40 | 32745.70 | 32804.00 | 32862.30 | 32920.70 | 32979.10 | 33037.60 |
| 600 | 33096.00 | 33154.60 | 33213.10 | 33271.70 | 33330.30 | 33388.90 | 33447.60 | 33506.30 | 33565.10 | 33623.90 |
| 610 | 33682.70 | 33741.60 | 33800.50 | 33859.40 | 33918.40 | 33977.40 | 34036.40 | 34095.50 | 34154.60 | 34213.70 |
| 620 | 34272.90 | 34332.10 | 34391.40 | 34450.70 | 34510.00 | 34569.30 | 34628.70 | 34688.20 | 34747.70 | 34807.20 |
| 630 | 34866.70 | 34926.30 | 34985.90 | 35045.60 | 35105.30 | 35165.00 | 35224.80 | 35284.60 | 35344.40 | 35404.30 |
| 640 | 35464.30 | 35524.20 | 35584.20 | 35644.30 | 35704.30 | 35764.50 | 35824.60 | 35884.80 | 35945.00 | 36005.30 |
| 650 | 36065.60 | 36126.00 | 36186.30 | 36246.80 | 36307.20 | 36367.70 | 36428.30 | 36488.90 | 36549.50 | 36610.10 |
| 660 | 36670.80 | 36731.60 | 36792.30 | 36853.10 | 36914.00 | 36974.90 | 37035.80 | 37096.80 | 37157.80 | 37218.80 |
| 670 | 37279.90 | 37341.00 | 37402.20 | 37463.40 | 37524.60 | 37585.90 | 37647.20 | 37708.60 | 37770.00 | 37831.40 |
| 680 | 37892.90 | 37954.40 | 38015.90 | 38077.50 | 38139.10 | 38200.80 | 38262.50 | 38324.20 | 38386.00 | 38447.80 |
| 690 | 38509.70 | 38571.60 | 38633.50 | 38695.50 | 38757.50 | 38819.50 | 38881.60 | 38943.70 | 39005.80 | 39068.00 |
| 700 | 39130.20 | 39192.50 | 39254.80 | 39317.10 | 39379.50 | 39441.90 | 39504.30 | 39566.80 | 39629.30 | 39691.80 |
| 710 | 39754.40 | 39817.00 | 39879.70 | 39942.30 | 40005.10 | 40067.80 | 40130.60 | 40193.40 | 40256.20 | 40319.10 |
| 720 | 40382.00 | 40445.00 | 40508.00 | 40571.00 | 40634.00 | 40697.10 | 40760.20 | 40823.30 | 40886.50 | 40949.70 |
| 730 | 41012.90 | 41076.20 | 41139.50 | 41202.80 | 41266.10 | 41329.50 | 41392.90 | 41456.30 | 41519.80 | 41583.30 |
| 740 | 41646.80 | 41710.30 | 41773.90 | 41837.50 | 41901.10 | 41964.70 | 42028.40 | 42092.00 | 42155.80 | 42219.50 |
| 750 | 42283.20 | 42347.00 | 42410.80 | 42474.60 | 42538.50 | 42602.40 | 42666.20 | 42730.10 | 42794.10 | 42858.00 |
| 760 | 42921.90 | 42985.90 | 43049.90 | 43114.00 | 43178.00 | 43242.20 | 43306.30 | 43370.50 | 43434.70 | 43498.90 |
| 770 | 43563.10 | 43627.40 | 43691.70 | 43756.00 | 43820.40 | 43884.80 | 43949.10 | 44013.60 | 44078.00 | 44142.40 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 780 | 44206.90 | 44271.40 | 44335.80 | 44400.30 | 44464.90 | 44529.40 | 44593.90 | 44658.50 | 44723.00 | 44787.60 |
| 790 | 44852.20 | 44916.80 | 44981.40 | 45045.90 | 45110.50 | 45175.20 | 45239.80 | 45304.40 | 45369.00 | 45433.60 |
| 800 | 45498.20 | 45562.80 | 45627.50 | 45692.10 | 45756.70 | 45821.30 | 45885.90 | 45950.50 | 46015.10 | 46079.70 |
| 810 | 46144.30 | 46208.80 | 46273.40 | 46338.00 | 46402.50 | 46467.10 | 46531.60 | 46596.10 | 46660.70 | 46725.20 |
| 820 | 46789.70 | 46854.10 | 46918.60 | 46983.10 | 47047.50 | 47111.90 | 47176.30 | 47240.70 | 47305.10 | 47369.50 |
| 830 | 47433.80 | 47498.10 | 47562.40 | 47626.70 | 47691.00 | 47755.30 | 47819.50 | 47883.70 | 47947.90 | 48012.10 |
| 840 | 48076.20 | 48140.40 | 48204.50 | 48268.50 | 48332.60 | 48396.60 | 48460.70 | 48524.60 | 48588.60 | 48652.60 |
| 850 | 48716.50 | 48780.40 | 48844.20 | 48908.10 | 48971.90 | 49035.70 | 49099.40 | 49163.20 | 49226.90 | 49290.50 |
| 860 | 49354.20 | 49417.80 | 49481.40 | 49545.00 | 49608.50 | 49672.00 | 49735.50 | 49798.90 | 49862.30 | 49925.70 |
| 870 | 49989.10 | 50052.40 | 50115.70 | 50178.90 | 50242.20 | 50305.40 | 50368.50 | 50431.70 | 50494.80 | 50557.80 |
| 880 | 50620.90 | 50683.90 | 50746.90 | 50809.80 | 50872.70 | 50935.60 | 50998.40 | 51061.20 | 51124.00 | 51186.70 |
| 890 | 51249.40 | 51312.10 | 51374.70 | 51437.30 | 51499.90 | 51562.50 | 51625.00 | 51687.40 | 51749.90 | 51812.20 |
| 900 | 51874.60 | 51936.90 | 51999.20 | 52061.50 | 52123.70 | 52185.90 | 52248.10 | 52310.20 | 52372.30 | 52434.30 |
| 910 | 52496.30 | 52558.30 | 52620.20 | 52682.20 | 52744.00 | 52805.90 | 52867.70 | 52929.40 | 52991.20 | 53052.90 |
| 920 | 53114.50 | 53176.20 | 53237.80 | 53299.30 | 53360.80 | 53422.30 | 53483.80 | 53545.20 | 53606.60 | 53667.90 |
| 930 | 53729.30 | 53790.50 | 53851.80 | 53913.00 | 53974.20 | 54035.30 | 54096.40 | 54157.50 | 54218.50 | 54279.60 |
| 940 | 54340.50 | 54401.50 | 54462.40 | 54523.20 | 54584.10 | 54644.90 | 54705.70 | 54766.40 | 54827.10 | 54887.80 |
| 950 | 54948.40 | 55009.00 | 55069.60 | 55130.20 | 55190.70 | 55251.10 | 55311.60 | 55372.00 | 55432.40 | 55492.80 |
| 960 | 55553.10 | 55613.40 | 55673.60 | 55733.80 | 55794.00 | 55854.20 | 55914.30 | 55974.50 | 56034.50 | 56094.60 |
| 970 | 56154.60 | 56214.60 | 56274.50 | 56334.50 | 56394.40 | 56454.20 | 56514.10 | 56573.90 | 56633.70 | 56693.40 |
| 980 | 56753.10 | 56812.80 | 56872.50 | 56932.20 | 56991.80 | 57051.40 | 57110.90 | 57170.50 | 57230.00 | 57289.50 |
| 990 | 57348.90 | 57408.40 | 57467.80 | 57527.10 | 57586.50 | 57645.80 | 57705.10 | 57764.40 | 57823.70 | 57882.90 |
| 1000 | 57942.10 | 58001.30 | 58060.40 | 58119.60 | 58178.70 | 58237.80 | 58296.80 | 58355.90 | 58414.90 | 58473.90 |
| 1010 | 58532.90 | 58591.80 | 58650.80 | 58709.70 | 58768.60 | 58827.40 | 58886.30 | 58945.10 | 59003.90 | 59062.70 |
| 1020 | 59121.50 | 59180.20 | 59239.00 | 59297.70 | 59356.40 | 59415.10 | 59473.70 | 59532.30 | 59591.00 | 59649.60 |
| 1030 | 59708.20 | 59766.70 | 59825.30 | 59883.80 | 59942.30 | 60000.80 | 60059.30 | 60117.80 | 60176.20 | 60234.60 |
| 1040 | 60293.10 | 60351.50 | 60409.90 | 60468.20 | 60526.60 | 60584.90 | 60643.30 | 60701.60 | 60759.90 | 60818.20 |
| 1050 | 60876.50 | 60934.70 | 60993.00 | 61051.20 | 61109.40 | 61167.60 | 61225.80 | 61284.00 | 61342.20 | 61400.40 |
| 1060 | 61458.50 | 61516.70 | 61574.80 | 61632.90 | 61691.00 | 61749.10 | 61807.20 | 61865.30 | 61923.40 | 61981.40 |
| 1070 | 62039.50 | 62097.50 | 62155.50 | 62213.60 | 62271.60 | 62329.60 | 62387.60 | 62445.60 | 62503.50 | 62561.50 |
| 1080 | 62619.50 | 62677.40 | 62735.40 | 62793.30 | 62851.20 | 62909.20 | 62967.10 | 63025.00 | 63082.90 | 63140.80 |
| 1090 | 63198.70 | 63256.60 | 63314.50 | 63372.30 | 63430.20 | 63488.10 | 63545.90 | 63603.80 | 63661.60 | 63719.50 |
| 1100 | 63777.30 | 63835.10 | 63892.90 | 63950.80 | 64008.60 | 64066.40 | 64124.20 | 64182.00 | 64239.80 | 64297.60 |
| 1110 | 64355.40 | 64413.10 | 64470.90 | 64528.70 | 64586.50 | 64644.20 | 64702.00 | 64759.70 | 64817.50 | 64875.20 |
| 1120 | 64933.00 | 64990.70 | 65048.50 | 65106.20 | 65163.90 | 65221.70 | 65279.40 | 65337.10 | 65394.80 | 65452.50 |
| 1130 | 65510.20 | 65567.90 | 65625.60 | 65683.30 | 65741.00 | 65798.70 | 65856.40 | 65914.10 | 65971.80 | 66029.50 |
| 1140 | 66087.10 | 66144.80 | 66202.50 | 66260.10 | 66317.80 | 66375.40 | 66433.10 | 66490.70 | 66548.40 | 66606.00 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1150 | 66663.60 | 66721.20 | 66778.90 | 66836.50 | 66894.10 | 66951.70 | 67009.30 | 67066.90 | 67124.50 | 67182.10 |
| 1160 | 67239.60 | 67297.20 | 67354.80 | 67412.40 | 67469.90 | 67527.50 | 67585.00 | 67642.50 | 67700.10 | 67757.60 |
| 1170 | 67815.10 | 67872.60 | 67930.10 | 67987.60 | 68045.10 | 68102.60 | 68160.00 | 68217.50 | 68274.90 | 68332.40 |
| 1180 | 68389.80 | 68447.20 | 68504.60 | 68562.00 | 68619.40 | 68676.80 | 68734.20 | 68791.50 | 68848.90 | 68906.20 |
| 1190 | 68963.50 | 69020.90 | 69078.10 | 69135.40 | 69192.70 | 69250.00 | 69307.20 | 69364.40 | 69421.60 | 69478.80 |

## 62.15 K-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology (NIST) in the US for a metal pair of Nickel-Chromium vs.Nickel-Aluminum referenced to a cold junction at 0°C. K is the letter designation approved by the American Institute for Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the µV produced in intervals of 1°C. For example -6456.99µ V is produced at -269°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -270 | -6457.82 | -6456.99 | -6455.99 | -6454.81 | -6453.45 | -6451.90 | -6450.15 | -6448.20 | -6446.06 | -6443.71 |
| -260 | -6441.15 | -6438.38 | -6435.40 | -6432.20 | -6428.79 | -6425.15 | -6421.30 | -6417.23 | -6412.94 | -6408.42 |
| -250 | -6403.68 | -6398.71 | -6393.53 | -6388.11 | -6382.47 | -6376.61 | -6370.52 | -6364.21 | -6357.67 | -6350.91 |
| -240 | -6343.92 | -6336.72 | -6329.29 | -6321.63 | -6313.76 | -6305.67 | -6297.36 | -6288.83 | -6280.08 | -6271.12 |
| -230 | -6261.93 | -6252.54 | -6242.93 | -6233.11 | -6223.08 | -6212.83 | -6202.38 | -6191.72 | -6180.85 | -6169.77 |
| -220 | -6158.49 | -6147.01 | -6135.32 | -6123.43 | -6111.34 | -6099.05 | -6086.56 | -6073.87 | -6060.98 | -6047.90 |
| -210 | -6034.63 | -6021.16 | -6007.49 | -5993.64 | -5979.59 | -5965.36 | -5950.93 | -5936.32 | -5921.52 | -5906.53 |
| -200 | -5891.36 | -5876.00 | -5860.46 | -5844.74 | -5828.84 | -5812.75 | -5796.48 | -5780.03 | -5763.41 | -5746.61 |
| -190 | -5729.62 | -5712.47 | -5695.13 | -5677.62 | -5659.94 | -5642.08 | -5624.05 | -5605.85 | -5587.47 | -5568.92 |
| -180 | -5550.21 | -5531.32 | -5512.27 | -5493.04 | -5473.65 | -5454.09 | -5434.36 | -5414.47 | -5394.41 | -5374.19 |
| -170 | -5353.80 | -5333.25 | -5312.54 | -5291.66 | -5270.63 | -5249.43 | -5228.07 | -5206.55 | -5184.87 | -5163.03 |
| -160 | -5141.03 | -5118.88 | -5096.57 | -5074.10 | -5051.47 | -5028.69 | -5005.76 | -4982.67 | -4959.42 | -4936.03 |
| -150 | -4912.48 | -4888.77 | -4864.92 | -4840.92 | -4816.76 | -4792.46 | -4768.00 | -4743.40 | -4718.65 | -4693.75 |
| -140 | -4668.71 | -4643.52 | -4618.18 | -4592.70 | -4567.07 | -4541.30 | -4515.38 | -4489.33 | -4463.13 | -4436.78 |
| -130 | -4410.30 | -4383.68 | -4356.92 | -4330.02 | -4302.97 | -4275.80 | -4248.48 | -4221.03 | -4193.44 | -4165.71 |
| -120 | -4137.85 | -4109.86 | -4081.73 | -4053.47 | -4025.08 | -3996.55 | -3967.89 | -3939.10 | -3910.19 | -3881.14 |
| -110 | -3851.96 | -3822.66 | -3793.22 | -3763.66 | -3733.98 | -3704.16 | -3674.23 | -3644.16 | -3613.98 | -3583.67 |
| -100 | -3553.23 | -3522.68 | -3492.00 | -3461.21 | -3430.29 | -3399.25 | -3368.10 | -3336.82 | -3305.43 | -3273.92 |
| -90 | -3242.30 | -3210.55 | -3178.70 | -3146.73 | -3114.64 | -3082.44 | -3050.13 | -3017.71 | -2985.17 | -2952.53 |
| -80 | -2919.77 | -2886.91 | -2853.93 | -2820.85 | -2787.66 | -2754.36 | -2720.96 | -2687.45 | -2653.84 | -2620.12 |
| -70 | -2586.30 | -2552.37 | -2518.34 | -2484.21 | -2449.98 | -2415.65 | -2381.22 | -2346.69 | -2312.06 | -2277.34 |
| -60 | -2242.51 | -2207.59 | -2172.58 | -2137.47 | -2102.26 | -2066.96 | -2031.57 | -1996.08 | -1960.50 | -1924.83 |
| -50 | -1889.07 | -1853.23 | -1817.29 | -1781.26 | -1745.14 | -1708.94 | -1672.65 | -1636.27 | -1599.81 | -1563.27 |
| -40 | -1526.64 | -1489.92 | -1453.13 | -1416.25 | -1379.29 | -1342.25 | -1305.13 | -1267.93 | -1230.65 | -1193.29 |
| -30 | -1155.85 | -1118.34 | -1080.75 | -1043.09 | -1005.35 | -967.54 | -929.65 | -891.69 | -853.66 | -815.55 |
| -20 | -777.38 | -739.13 | -700.81 | -662.43 | -623.97 | -585.45 | -546.87 | -508.21 | -469.49 | -430.70 |
| -10 | -391.86 | -352.94 | -313.97 | -274.93 | -235.83 | -196.67 | -157.45 | -118.17 | -78.84 | -39.45 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 39.50 | 79.04 | 118.63 | 158.26 | 197.94 | 237.66 | 277.43 | 317.23 | 357.08 |
| 10 | 396.98 | 436.91 | 476.89 | 516.90 | 556.96 | 597.06 | 637.20 | 677.38 | 717.59 | 757.85 |
| 20 | 798.14 | 838.48 | 878.85 | 919.25 | 959.70 | 1000.18 | 1040.69 | 1081.24 | 1121.83 | 1162.45 |
| 30 | 1203.10 | 1243.79 | 1284.51 | 1325.26 | 1366.04 | 1406.86 | 1447.70 | 1488.58 | 1529.49 | 1570.42 |
| 40 | 1611.38 | 1652.37 | 1693.39 | 1734.44 | 1775.51 | 1816.61 | 1857.73 | 1898.87 | 1940.04 | 1981.24 |
| 50 | 2022.45 | 2063.69 | 2104.94 | 2146.22 | 2187.52 | 2228.83 | 2270.17 | 2311.52 | 2352.89 | 2394.27 |
| 60 | 2435.67 | 2477.08 | 2518.51 | 2559.95 | 2601.40 | 2642.87 | 2684.34 | 2725.83 | 2767.32 | 2808.82 |
| 70 | 2850.33 | 2891.85 | 2933.37 | 2974.90 | 3016.43 | 3057.97 | 3099.51 | 3141.05 | 3182.59 | 3224.13 |
| 80 | 3265.67 | 3307.21 | 3348.75 | 3390.29 | 3431.82 | 3473.35 | 3514.87 | 3556.39 | 3597.90 | 3639.41 |
| 90 | 3680.90 | 3722.39 | 3763.87 | 3805.33 | 3846.79 | 3888.24 | 3929.67 | 3971.09 | 4012.50 | 4053.89 |
| 100 | 4095.27 | 4136.63 | 4177.98 | 4219.31 | 4260.63 | 4301.92 | 4343.20 | 4384.46 | 4425.70 | 4466.92 |
| 110 | 4508.13 | 4549.31 | 4590.47 | 4631.61 | 4672.72 | 4713.82 | 4754.89 | 4795.94 | 4836.97 | 4877.97 |
| 120 | 4918.96 | 4959.91 | 5000.85 | 5041.76 | 5082.64 | 5123.50 | 5164.34 | 5205.15 | 5245.94 | 5286.71 |
| 130 | 5327.44 | 5368.16 | 5408.85 | 5449.51 | 5490.15 | 5530.77 | 5571.36 | 5611.93 | 5652.48 | 5693.00 |
| 140 | 5733.49 | 5773.97 | 5814.42 | 5854.84 | 5895.25 | 5935.63 | 5975.99 | 6016.33 | 6056.65 | 6096.94 |
| 150 | 6137.22 | 6177.48 | 6217.71 | 6257.93 | 6298.13 | 6338.31 | 6378.47 | 6418.61 | 6458.74 | 6498.85 |
| 160 | 6538.95 | 6579.03 | 6619.09 | 6659.14 | 6699.18 | 6739.20 | 6779.22 | 6819.22 | 6859.20 | 6899.18 |
| 170 | 6939.15 | 6979.11 | 7019.06 | 7059.00 | 7098.93 | 7138.86 | 7178.78 | 7218.69 | 7258.60 | 7298.51 |
| 180 | 7338.41 | 7378.31 | 7418.20 | 7458.10 | 7497.99 | 7537.88 | 7577.77 | 7617.66 | 7657.55 | 7697.45 |
| 190 | 7737.34 | 7777.24 | 7817.15 | 7857.05 | 7896.96 | 7936.88 | 7976.80 | 8016.73 | 8056.66 | 8096.61 |
| 200 | 8136.55 | 8176.51 | 8216.48 | 8256.45 | 8296.44 | 8336.43 | 8376.44 | 8416.46 | 8456.48 | 8496.52 |
| 210 | 8536.57 | 8576.64 | 8616.72 | 8656.81 | 8696.91 | 8737.03 | 8777.16 | 8817.30 | 8857.46 | 8897.64 |
| 220 | 8937.83 | 8978.04 | 9018.26 | 9058.50 | 9098.75 | 9139.02 | 9179.31 | 9219.62 | 9259.94 | 9300.27 |
| 230 | 9340.63 | 9381.00 | 9421.39 | 9461.80 | 9502.23 | 9542.67 | 9583.13 | 9623.61 | 9664.11 | 9704.62 |
| 240 | 9745.15 | 9785.71 | 9826.27 | 9866.86 | 9907.47 | 9948.09 | 9988.73 | 10029.40 | 10070.10 | 10110.80 |
| 250 | 10151.50 | 10192.20 | 10233.00 | 10273.70 | 10314.50 | 10355.30 | 10396.10 | 10437.00 | 10477.80 | 10518.70 |
| 260 | 10559.60 | 10600.50 | 10641.40 | 10682.30 | 10723.30 | 10764.30 | 10805.20 | 10846.30 | 10887.30 | 10928.30 |
| 270 | 10969.40 | 11010.40 | 11051.50 | 11092.60 | 11133.70 | 11174.80 | 11216.00 | 11257.10 | 11298.30 | 11339.50 |
| 280 | 11380.70 | 11421.90 | 11463.10 | 11504.40 | 11545.60 | 11586.90 | 11628.20 | 11669.50 | 11710.80 | 11752.10 |
| 290 | 11793.40 | 11834.80 | 11876.10 | 11917.50 | 11958.90 | 12000.30 | 12041.70 | 12083.10 | 12124.50 | 12166.00 |
| 300 | 12207.40 | 12248.90 | 12290.40 | 12331.90 | 12373.40 | 12414.90 | 12456.40 | 12497.90 | 12539.50 | 12581.00 |
| 310 | 12622.60 | 12664.10 | 12705.70 | 12747.30 | 12788.90 | 12830.50 | 12872.10 | 12913.80 | 12955.40 | 12997.10 |
| 320 | 13038.70 | 13080.40 | 13122.00 | 13163.70 | 13205.40 | 13247.10 | 13288.80 | 13330.50 | 13372.30 | 13414.00 |
| 330 | 13455.70 | 13497.50 | 13539.30 | 13581.00 | 13622.80 | 13664.60 | 13706.40 | 13748.20 | 13790.00 | 13831.80 |
| 340 | 13873.60 | 13915.40 | 13957.30 | 13999.10 | 14041.00 | 14082.80 | 14124.70 | 14166.60 | 14208.50 | 14250.30 |
| 350 | 14292.20 | 14334.10 | 14376.10 | 14418.00 | 14459.90 | 14501.80 | 14543.80 | 14585.70 | 14627.70 | 14669.60 |
| 360 | 14711.60 | 14753.60 | 14795.50 | 14837.50 | 14879.50 | 14921.50 | 14963.50 | 15005.50 | 15047.50 | 15089.60 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 370 | 15131.60 | 15173.60 | 15215.70 | 15257.70 | 15299.80 | 15341.90 | 15383.90 | 15426.00 | 15468.10 | 15510.20 |
| 380 | 15552.30 | 15594.40 | 15636.50 | 15678.60 | 15720.70 | 15762.80 | 15805.00 | 15847.10 | 15889.30 | 15931.40 |
| 390 | 15973.60 | 16015.70 | 16057.90 | 16100.10 | 16142.30 | 16184.40 | 16226.60 | 16268.80 | 16311.00 | 16353.20 |
| 400 | 16395.50 | 16437.70 | 16479.90 | 16522.10 | 16564.40 | 16606.60 | 16648.90 | 16691.10 | 16733.40 | 16775.60 |
| 410 | 16817.90 | 16860.20 | 16902.50 | 16944.80 | 16987.00 | 17029.30 | 17071.60 | 17113.90 | 17156.30 | 17198.60 |
| 420 | 17240.90 | 17283.20 | 17325.60 | 17367.90 | 17410.20 | 17452.60 | 17494.90 | 17537.30 | 17579.70 | 17622.00 |
| 430 | 17664.40 | 17706.80 | 17749.20 | 17791.60 | 17833.90 | 17876.30 | 17918.70 | 17961.10 | 18003.60 | 18046.00 |
| 440 | 18088.40 | 18130.80 | 18173.20 | 18215.70 | 18258.10 | 18300.50 | 18343.00 | 18385.40 | 18427.90 | 18470.40 |
| 450 | 18512.80 | 18555.30 | 18597.80 | 18640.20 | 18682.70 | 18725.20 | 18767.70 | 18810.20 | 18852.70 | 18895.10 |
| 460 | 18937.60 | 18980.20 | 19022.70 | 19065.20 | 19107.70 | 19150.20 | 19192.70 | 19235.20 | 19277.80 | 19320.30 |
| 470 | 19362.80 | 19405.40 | 19447.90 | 19490.50 | 19533.00 | 19575.60 | 19618.10 | 19660.70 | 19703.20 | 19745.80 |
| 480 | 19788.40 | 19830.90 | 19873.50 | 19916.10 | 19958.60 | 20001.20 | 20043.80 | 20086.40 | 20129.00 | 20171.60 |
| 490 | 20214.20 | 20256.70 | 20299.30 | 20341.90 | 20384.50 | 20427.10 | 20469.70 | 20512.30 | 20555.00 | 20597.60 |
| 500 | 20640.20 | 20682.80 | 20725.40 | 20768.00 | 20810.60 | 20853.30 | 20895.90 | 20938.50 | 20981.10 | 21023.80 |
| 510 | 21066.40 | 21109.00 | 21151.60 | 21194.30 | 21236.90 | 21279.50 | 21322.20 | 21364.80 | 21407.40 | 21450.10 |
| 520 | 21492.70 | 21535.30 | 21578.00 | 21620.60 | 21663.30 | 21705.90 | 21748.60 | 21791.20 | 21833.80 | 21876.50 |
| 530 | 21919.10 | 21961.80 | 22004.40 | 22047.00 | 22089.70 | 22132.30 | 22175.00 | 22217.60 | 22260.30 | 22302.90 |
| 540 | 22345.60 | 22388.20 | 22430.80 | 22473.50 | 22516.10 | 22558.80 | 22601.40 | 22644.00 | 22686.70 | 22729.30 |
| 550 | 22772.00 | 22814.60 | 22857.20 | 22899.90 | 22942.50 | 22985.10 | 23027.80 | 23070.40 | 23113.00 | 23155.60 |
| 560 | 23198.30 | 23240.90 | 23283.50 | 23326.10 | 23368.80 | 23411.40 | 23454.00 | 23496.60 | 23539.20 | 23581.80 |
| 570 | 23624.50 | 23667.10 | 23709.70 | 23752.30 | 23794.90 | 23837.50 | 23880.10 | 23922.70 | 23965.30 | 24007.80 |
| 580 | 24050.40 | 24093.00 | 24135.60 | 24178.20 | 24220.80 | 24263.30 | 24305.90 | 24348.50 | 24391.00 | 24433.60 |
| 590 | 24476.20 | 24518.70 | 24561.30 | 24603.80 | 24646.40 | 24688.90 | 24731.50 | 24774.00 | 24816.50 | 24859.10 |
| 600 | 24901.60 | 24944.10 | 24986.70 | 25029.20 | 25071.70 | 25114.20 | 25156.70 | 25199.20 | 25241.70 | 25284.20 |
| 610 | 25326.70 | 25369.20 | 25411.70 | 25454.10 | 25496.60 | 25539.10 | 25581.50 | 25624.00 | 25666.50 | 25708.90 |
| 620 | 25751.40 | 25793.80 | 25836.20 | 25878.70 | 25921.10 | 25963.50 | 26006.00 | 26048.40 | 26090.80 | 26133.20 |
| 630 | 26175.60 | 26218.00 | 26260.40 | 26302.70 | 26345.10 | 26387.50 | 26429.90 | 26472.20 | 26514.60 | 26556.90 |
| 640 | 26599.30 | 26641.60 | 26684.00 | 26726.30 | 26768.60 | 26810.90 | 26853.20 | 26895.60 | 26937.90 | 26980.20 |
| 650 | 27022.40 | 27064.70 | 27107.00 | 27149.30 | 27191.50 | 27233.80 | 27276.00 | 27318.30 | 27360.50 | 27402.80 |
| 660 | 27445.00 | 27487.20 | 27529.40 | 27571.60 | 27613.80 | 27656.00 | 27698.20 | 27740.40 | 27782.60 | 27824.70 |
| 670 | 27866.90 | 27909.00 | 27951.20 | 27993.30 | 28035.50 | 28077.60 | 28119.70 | 28161.80 | 28203.90 | 28246.00 |
| 680 | 28288.10 | 28330.20 | 28372.30 | 28414.30 | 28456.40 | 28498.40 | 28540.50 | 28582.50 | 28624.60 | 28666.60 |
| 690 | 28708.60 | 28750.60 | 28792.60 | 28834.60 | 28876.60 | 28918.60 | 28960.50 | 29002.50 | 29044.40 | 29086.40 |
| 700 | 29128.30 | 29170.30 | 29212.20 | 29254.10 | 29296.00 | 29337.90 | 29379.80 | 29421.70 | 29463.50 | 29505.40 |
| 710 | 29547.20 | 29589.10 | 29630.90 | 29672.80 | 29714.60 | 29756.40 | 29798.20 | 29840.00 | 29881.80 | 29923.60 |
| 720 | 29965.30 | 30007.10 | 30048.80 | 30090.60 | 30132.30 | 30174.00 | 30215.80 | 30257.50 | 30299.20 | 30340.90 |
| 730 | 30382.50 | 30424.20 | 30465.90 | 30507.50 | 30549.20 | 30590.80 | 30632.40 | 30674.10 | 30715.70 | 30757.30 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 740 | 30798.90 | 30840.50 | 30882.00 | 30923.60 | 30965.10 | 31006.70 | 31048.20 | 31089.80 | 31131.30 | 31172.80 |
| 750 | 31214.30 | 31255.80 | 31297.20 | 31338.70 | 31380.20 | 31421.60 | 31463.10 | 31504.50 | 31545.90 | 31587.30 |
| 760 | 31628.70 | 31670.10 | 31711.50 | 31752.90 | 31794.30 | 31835.60 | 31877.00 | 31918.30 | 31959.60 | 32000.90 |
| 770 | 32042.20 | 32083.50 | 32124.80 | 32166.10 | 32207.40 | 32248.60 | 32289.90 | 32331.10 | 32372.30 | 32413.50 |
| 780 | 32454.80 | 32495.90 | 32537.10 | 32578.30 | 32619.50 | 32660.60 | 32701.80 | 32742.90 | 32784.00 | 32825.20 |
| 790 | 32866.30 | 32907.40 | 32948.50 | 32989.50 | 33030.60 | 33071.70 | 33112.70 | 33153.70 | 33194.80 | 33235.80 |
| 800 | 33276.80 | 33317.80 | 33358.80 | 33399.70 | 33440.70 | 33481.60 | 33522.60 | 33563.50 | 33604.40 | 33645.40 |
| 810 | 33686.30 | 33727.20 | 33768.00 | 33808.90 | 33849.80 | 33890.60 | 33931.50 | 33972.30 | 34013.10 | 34053.90 |
| 820 | 34094.70 | 34135.50 | 34176.30 | 34217.10 | 34257.80 | 34298.60 | 34339.30 | 34380.00 | 34420.70 | 34461.40 |
| 830 | 34502.10 | 34542.80 | 34583.50 | 34624.20 | 34664.80 | 34705.50 | 34746.10 | 34786.70 | 34827.30 | 34867.90 |
| 840 | 34908.50 | 34949.10 | 34989.70 | 35030.20 | 35070.80 | 35111.30 | 35151.80 | 35192.30 | 35232.90 | 35273.30 |
| 850 | 35313.80 | 35354.30 | 35394.80 | 35435.20 | 35475.70 | 35516.10 | 35556.50 | 35596.90 | 35637.30 | 35677.70 |
| 860 | 35718.10 | 35758.50 | 35798.80 | 35839.20 | 35879.50 | 35919.90 | 35960.20 | 36000.50 | 36040.80 | 36081.10 |
| 870 | 36121.30 | 36161.60 | 36201.90 | 36242.10 | 36282.30 | 36322.60 | 36362.80 | 36403.00 | 36443.20 | 36483.30 |
| 880 | 36523.50 | 36563.70 | 36603.80 | 36644.00 | 36684.10 | 36724.20 | 36764.30 | 36804.40 | 36844.50 | 36884.60 |
| 890 | 36924.60 | 36964.70 | 37004.70 | 37044.80 | 37084.80 | 37124.80 | 37164.80 | 37204.80 | 37244.80 | 37284.80 |
| 900 | 37324.70 | 37364.70 | 37404.60 | 37444.50 | 37484.50 | 37524.40 | 37564.30 | 37604.20 | 37644.00 | 37683.90 |
| 910 | 37723.80 | 37763.60 | 37803.40 | 37843.30 | 37883.10 | 37922.90 | 37962.70 | 38002.50 | 38042.20 | 38082.00 |
| 920 | 38121.80 | 38161.50 | 38201.20 | 38241.00 | 38280.70 | 38320.40 | 38360.10 | 38399.80 | 38439.40 | 38479.10 |
| 930 | 38518.70 | 38558.40 | 38598.00 | 38637.60 | 38677.20 | 38716.80 | 38756.40 | 38796.00 | 38835.60 | 38875.10 |
| 940 | 38914.70 | 38954.20 | 38993.70 | 39033.20 | 39072.80 | 39112.20 | 39151.70 | 39191.20 | 39230.70 | 39270.10 |
| 950 | 39309.60 | 39349.00 | 39388.40 | 39427.80 | 39467.20 | 39506.60 | 39546.00 | 39585.40 | 39624.80 | 39664.10 |
| 960 | 39703.50 | 39742.80 | 39782.10 | 39821.40 | 39860.70 | 39900.00 | 39939.30 | 39978.60 | 40017.80 | 40057.10 |
| 970 | 40096.30 | 40135.50 | 40174.80 | 40214.00 | 40253.20 | 40292.30 | 40331.50 | 40370.70 | 40409.90 | 40449.00 |
| 980 | 40488.10 | 40527.30 | 40566.40 | 40605.50 | 40644.60 | 40683.70 | 40722.70 | 40761.80 | 40800.90 | 40839.90 |
| 990 | 40878.90 | 40918.00 | 40957.00 | 40996.00 | 41035.00 | 41074.00 | 41112.90 | 41151.90 | 41190.80 | 41229.80 |
| 1000 | 41268.70 | 41307.60 | 41346.50 | 41385.40 | 41424.30 | 41463.20 | 41502.10 | 41540.90 | 41579.80 | 41618.60 |
| 1010 | 41657.50 | 41696.30 | 41735.10 | 41773.90 | 41812.70 | 41851.50 | 41890.20 | 41929.00 | 41967.70 | 42006.50 |
| 1020 | 42045.20 | 42083.90 | 42122.60 | 42161.30 | 42200.00 | 42238.60 | 42277.30 | 42316.00 | 42354.60 | 42393.20 |
| 1030 | 42431.80 | 42470.50 | 42509.10 | 42547.60 | 42586.20 | 42624.80 | 42663.30 | 42701.90 | 42740.40 | 42778.90 |
| 1040 | 42817.50 | 42856.00 | 42894.50 | 42932.90 | 42971.40 | 43009.90 | 43048.30 | 43086.80 | 43125.20 | 43163.60 |
| 1050 | 43202.00 | 43240.40 | 43278.80 | 43317.20 | 43355.50 | 43393.90 | 43432.20 | 43470.60 | 43508.90 | 43547.20 |
| 1060 | 43585.50 | 43623.80 | 43662.10 | 43700.30 | 43738.60 | 43776.80 | 43815.10 | 43853.30 | 43891.50 | 43929.70 |
| 1070 | 43967.90 | 44006.10 | 44044.20 | 44082.40 | 44120.50 | 44158.70 | 44196.80 | 44234.90 | 44273.00 | 44311.10 |
| 1080 | 44349.10 | 44387.20 | 44425.30 | 44463.30 | 44501.30 | 44539.40 | 44577.40 | 44615.40 | 44653.40 | 44691.30 |
| 1090 | 44729.30 | 44767.20 | 44805.20 | 44843.10 | 44881.00 | 44918.90 | 44956.80 | 44994.70 | 45032.60 | 45070.40 |
| 1100 | 45108.30 | 45146.10 | 45183.90 | 45221.70 | 45259.50 | 45297.30 | 45335.10 | 45372.90 | 45410.60 | 45448.30 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1110 | 45486.10 | 45523.80 | 45561.50 | 45599.20 | 45636.90 | 45674.50 | 45712.20 | 45749.80 | 45787.40 | 45825.10 |
| 1120 | 45862.70 | 45900.30 | 45937.80 | 45975.40 | 46013.00 | 46050.50 | 46088.00 | 46125.60 | 46163.10 | 46200.50 |
| 1130 | 46238.00 | 46275.50 | 46312.90 | 46350.40 | 46387.80 | 46425.20 | 46462.60 | 46500.00 | 46537.40 | 46574.80 |
| 1140 | 46612.10 | 46649.40 | 46686.80 | 46724.10 | 46761.40 | 46798.70 | 46835.90 | 46873.20 | 46910.40 | 46947.70 |
| 1150 | 46984.90 | 47022.10 | 47059.30 | 47096.50 | 47133.60 | 47170.80 | 47207.90 | 47245.00 | 47282.20 | 47319.30 |
| 1160 | 47356.30 | 47393.40 | 47430.50 | 47467.50 | 47504.50 | 47541.60 | 47578.60 | 47615.50 | 47652.50 | 47689.50 |
| 1170 | 47726.40 | 47763.30 | 47800.30 | 47837.20 | 47874.10 | 47910.90 | 47947.80 | 47984.60 | 48021.50 | 48058.30 |
| 1180 | 48095.10 | 48131.90 | 48168.60 | 48205.40 | 48242.10 | 48278.90 | 48315.60 | 48352.30 | 48389.00 | 48425.60 |
| 1190 | 48462.30 | 48498.90 | 48535.60 | 48572.20 | 48608.80 | 48645.40 | 48681.90 | 48718.50 | 48755.00 | 48791.50 |
| 1200 | 48828.00 | 48864.50 | 48901.00 | 48937.50 | 48973.90 | 49010.30 | 49046.80 | 49083.20 | 49119.50 | 49155.90 |
| 1210 | 49192.30 | 49228.60 | 49264.90 | 49301.20 | 49337.50 | 49373.80 | 49410.10 | 49446.30 | 49482.50 | 49518.80 |
| 1220 | 49555.00 | 49591.10 | 49627.30 | 49663.50 | 49699.60 | 49735.70 | 49771.80 | 49807.90 | 49844.00 | 49880.00 |
| 1230 | 49916.10 | 49952.10 | 49988.10 | 50024.10 | 50060.10 | 50096.00 | 50132.00 | 50167.90 | 50203.80 | 50239.70 |
| 1240 | 50275.60 | 50311.40 | 50347.30 | 50383.10 | 50418.90 | 50454.70 | 50490.50 | 50526.30 | 50562.00 | 50597.80 |
| 1250 | 50633.50 | 50669.20 | 50704.90 | 50740.50 | 50776.20 | 50811.80 | 50847.40 | 50883.00 | 50918.60 | 50954.20 |
| 1260 | 50989.80 | 51025.30 | 51060.80 | 51096.30 | 51131.80 | 51167.30 | 51202.70 | 51238.20 | 51273.60 | 51309.00 |
| 1270 | 51344.40 | 51379.80 | 51415.10 | 51450.40 | 51485.80 | 51521.10 | 51556.40 | 51591.60 | 51626.90 | 51662.10 |
| 1280 | 51697.40 | 51732.60 | 51767.80 | 51802.90 | 51838.10 | 51873.30 | 51908.40 | 51943.50 | 51978.60 | 52013.70 |
| 1290 | 52048.70 | 52083.80 | 52118.80 | 52153.80 | 52188.80 | 52223.80 | 52258.80 | 52293.70 | 52328.70 | 52363.60 |
| 1300 | 52398.50 | 52433.40 | 52468.30 | 52503.10 | 52537.90 | 52572.80 | 52607.60 | 52642.40 | 52677.20 | 52711.90 |
| 1310 | 52746.70 | 52781.40 | 52816.10 | 52850.80 | 52885.50 | 52920.20 | 52954.90 | 52989.50 | 53024.10 | 53058.70 |
| 1320 | 53093.30 | 53127.90 | 53162.50 | 53197.10 | 53231.60 | 53266.10 | 53300.60 | 53335.10 | 53369.60 | 53404.10 |
| 1330 | 53438.60 | 53473.00 | 53507.40 | 53541.80 | 53576.30 | 53610.60 | 53645.00 | 53679.40 | 53713.70 | 53748.10 |
| 1340 | 53782.40 | 53816.70 | 53851.00 | 53885.30 | 53919.60 | 53953.80 | 53988.10 | 54022.30 | 54056.60 | 54090.80 |
| 1350 | 54125.00 | 54159.20 | 54193.40 | 54227.50 | 54261.70 | 54295.80 | 54330.00 | 54364.10 | 54398.20 | 54432.30 |
| 1360 | 54466.40 | 54500.50 | 54534.60 | 54568.70 | 54602.70 | 54636.80 | 54670.80 | 54704.90 | 54738.90 | 54772.90 |

## 62.16 E-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology (NIST) in the US for a metal pair of Nickel-Chromium vs.Copper-Nickel referenced to a cold junction at 0°C. E is the letter designation approved by the American Institute of Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the μV produced in intervals of 1°C. For example -9833.22 μV is produced at -269°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -270 | -9835.03 | -9833.22 | -9830.93 | -9828.16 | -9824.93 | -9821.27 | -9817.17 | -9812.65 | -9807.72 | -9802.39 |
| -260 | -9796.66 | -9790.54 | -9784.04 | -9777.15 | -9769.89 | -9762.25 | -9754.25 | -9745.87 | -9737.13 | -9728.02 |
| -250 | -9718.55 | -9708.71 | -9698.52 | -9687.96 | -9677.05 | -9665.78 | -9654.16 | -9642.18 | -9629.85 | -9617.18 |
| -240 | -9604.15 | -9590.78 | -9577.06 | -9563.00 | -9548.61 | -9533.87 | -9518.80 | -9503.39 | -9487.65 | -9471.59 |
| -230 | -9455.19 | -9438.48 | -9421.44 | -9404.09 | -9386.41 | -9368.43 | -9350.13 | -9331.53 | -9312.62 | -9293.41 |
| -220 | -9273.90 | -9254.09 | -9233.99 | -9213.59 | -9192.91 | -9171.94 | -9150.68 | -9129.14 | -9107.32 | -9085.23 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -210 | -9062.86 | -9040.21 | -9017.30 | -8994.12 | -8970.67 | -8946.96 | -8922.98 | -8898.75 | -8874.25 | -8849.50 |
| -200 | -8824.50 | -8799.24 | -8773.73 | -8747.97 | -8721.96 | -8695.70 | -8669.20 | -8642.46 | -8615.47 | -8588.25 |
| -190 | -8560.78 | -8533.08 | -8505.14 | -8476.96 | -8448.55 | -8419.90 | -8391.03 | -8361.92 | -8332.59 | -8303.02 |
| -180 | -8273.23 | -8243.21 | -8212.97 | -8182.50 | -8151.81 | -8120.90 | -8089.77 | -8058.42 | -8026.84 | -7995.06 |
| -170 | -7963.05 | -7930.83 | -7898.39 | -7865.74 | -7832.88 | -7799.81 | -7766.52 | -7733.03 | -7699.32 | -7665.41 |
| -160 | -7631.29 | -7596.97 | -7562.44 | -7527.70 | -7492.77 | -7457.63 | -7422.29 | -7386.75 | -7351.00 | -7315.06 |
| -150 | -7278.93 | -7242.59 | -7206.06 | -7169.34 | -7132.42 | -7095.30 | -7058.00 | -7020.50 | -6982.81 | -6944.93 |
| -140 | -6906.86 | -6868.60 | -6830.15 | -6791.52 | -6752.70 | -6713.70 | -6674.50 | -6635.13 | -6595.57 | -6555.83 |
| -130 | -6515.91 | -6475.80 | -6435.52 | -6395.05 | -6354.40 | -6313.58 | -6272.58 | -6231.40 | -6190.04 | -6148.51 |
| -120 | -6106.80 | -6064.91 | -6022.85 | -5980.62 | -5938.21 | -5895.64 | -5852.88 | -5809.96 | -5766.87 | -5723.61 |
| -110 | -5680.17 | -5636.57 | -5592.80 | -5548.86 | -5504.76 | -5460.49 | -5416.05 | -5371.45 | -5326.68 | -5281.74 |
| -100 | -5236.65 | -5191.39 | -5145.97 | -5100.39 | -5054.64 | -5008.74 | -4962.67 | -4916.45 | -4870.07 | -4823.53 |
| -90 | -4776.83 | -4729.97 | -4682.96 | -4635.80 | -4588.48 | -4541.00 | -4493.37 | -4445.59 | -4397.65 | -4349.57 |
| -80 | -4301.33 | -4252.94 | -4204.40 | -4155.72 | -4106.88 | -4057.90 | -4008.77 | -3959.49 | -3910.06 | -3860.49 |
| -70 | -3810.78 | -3760.92 | -3710.91 | -3660.76 | -3610.47 | -3560.04 | -3509.46 | -3458.75 | -3407.89 | -3356.89 |
| -60 | -3305.75 | -3254.48 | -3203.06 | -3151.51 | -3099.82 | -3047.99 | -2996.02 | -2943.92 | -2891.69 | -2839.31 |
| -50 | -2786.81 | -2734.17 | -2681.39 | -2628.48 | -2575.44 | -2522.27 | -2468.97 | -2415.53 | -2361.96 | -2308.27 |
| -40 | -2254.44 | -2200.48 | -2146.40 | -2092.18 | -2037.84 | -1983.37 | -1928.78 | -1874.05 | -1819.20 | -1764.23 |
| -30 | -1709.13 | -1653.91 | -1598.56 | -1543.09 | -1487.49 | -1431.77 | -1375.93 | -1319.97 | -1263.88 | -1207.67 |
| -20 | -1151.34 | -1094.90 | -1038.33 | -981.64 | -924.83 | -867.90 | -810.85 | -753.68 | -696.40 | -639.00 |
| -10 | -581.48 | -523.84 | -466.09 | -408.22 | -350.24 | -292.14 | -233.93 | -175.61 | -117.18 | -58.64 |
| 0 | 0.00 | 58.74 | 117.56 | 176.48 | 235.48 | 294.56 | 353.74 | 413.00 | 472.35 | 531.79 |
| 10 | 591.32 | 650.94 | 710.65 | 770.44 | 830.33 | 890.30 | 950.37 | 1010.53 | 1070.77 | 1131.11 |
| 20 | 1191.54 | 1252.06 | 1312.66 | 1373.37 | 1434.16 | 1495.04 | 1556.01 | 1617.08 | 1678.23 | 1739.48 |
| 30 | 1800.82 | 1862.25 | 1923.77 | 1985.38 | 2047.09 | 2108.89 | 2170.77 | 2232.75 | 2294.82 | 2356.99 |
| 40 | 2419.24 | 2481.58 | 2544.02 | 2606.55 | 2669.17 | 2731.88 | 2794.68 | 2857.57 | 2920.55 | 2983.63 |
| 50 | 3046.79 | 3110.05 | 3173.39 | 3236.83 | 3300.35 | 3363.97 | 3427.68 | 3491.47 | 3555.36 | 3619.33 |
| 60 | 3683.40 | 3747.55 | 3811.80 | 3876.13 | 3940.55 | 4005.06 | 4069.66 | 4134.34 | 4199.12 | 4263.98 |
| 70 | 4328.93 | 4393.97 | 4459.09 | 4524.30 | 4589.60 | 4654.98 | 4720.46 | 4786.01 | 4851.66 | 4917.38 |
| 80 | 4983.20 | 5049.10 | 5115.08 | 5181.15 | 5247.31 | 5313.54 | 5379.87 | 5446.27 | 5512.76 | 5579.34 |
| 90 | 5645.99 | 5712.73 | 5779.55 | 5846.45 | 5913.44 | 5980.51 | 6047.66 | 6114.89 | 6182.2 | 6249.59 |
| 100 | 6317.06 | 6384.61 | 6452.24 | 6519.95 | 6587.74 | 6655.61 | 6723.56 | 6791.58 | 6859.69 | 6927.87 |
| 110 | 6996.13 | 7064.46 | 7132.88 | 7201.37 | 7269.93 | 7338.57 | 7407.29 | 7476.08 | 7544.95 | 7613.90 |
| 120 | 7682.91 | 7752.00 | 7821.17 | 7890.41 | 7959.72 | 8029.11 | 8098.56 | 8168.09 | 8237.7 | 8307.37 |
| 130 | 8377.11 | 8446.93 | 8516.82 | 8586.78 | 8656.80 | 8726.90 | 8797.07 | 8867.31 | 8937.61 | 9007.99 |
| 140 | 9078.43 | 9148.94 | 9219.52 | 9290.16 | 9360.88 | 9431.66 | 9502.50 | 9573.42 | 9644.40 | 9715.44 |
| 150 | 9786.55 | 9857.72 | 9928.96 | 10000.30 | 10071.60 | 10143.10 | 10214.60 | 10286.10 | 10357.70 | 10429.40 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 160 | 10501.20 | 10573.00 | 10644.80 | 10716.80 | 10788.8 | 10860.80 | 10932.90 | 11005.10 | 11077.30 | 11149.60 |
| 170 | 11222.00 | 11294.40 | 11366.90 | 11439.40 | 11512.00 | 11584.60 | 11657.30 | 11730.10 | 11802.90 | 11875.80 |
| 180 | 11948.70 | 12021.70 | 12094.70 | 12167.80 | 12241.00 | 12314.20 | 12387.40 | 12460.70 | 12534.10 | 12607.50 |
| 190 | 12681.00 | 12754.50 | 12828.10 | 12901.80 | 12975.40 | 13049.20 | 13123.00 | 13196.80 | 13270.70 | 13344.70 |
| 200 | 13418.60 | 13492.70 | 13566.80 | 13640.90 | 13715.10 | 13789.40 | 13863.70 | 13938.00 | 14012.40 | 14086.80 |
| 210 | 14161.30 | 14235.90 | 14310.50 | 14385.10 | 14459.80 | 14534.50 | 14609.30 | 14684.10 | 14759.00 | 14833.90 |
| 220 | 14908.80 | 14983.80 | 15058.90 | 15134.00 | 15209.10 | 15284.30 | 15359.50 | 15434.80 | 15510.10 | 15585.40 |
| 230 | 15660.80 | 15736.30 | 15811.80 | 15887.30 | 15962.90 | 16038.50 | 16114.10 | 16189.80 | 16265.60 | 16341.30 |
| 240 | 16417.20 | 16493.00 | 16568.90 | 16644.90 | 16720.80 | 16796.90 | 16872.90 | 16949.00 | 17025.10 | 17101.30 |
| 250 | 17177.50 | 17253.80 | 17330.10 | 17406.40 | 17482.80 | 17559.20 | 17635.60 | 17712.10 | 17788.60 | 17865.20 |
| 260 | 17941.80 | 18018.40 | 18095.10 | 18171.80 | 18248.50 | 18325.30 | 18402.10 | 18478.90 | 18555.80 | 18632.70 |
| 270 | 18709.60 | 18786.60 | 18863.60 | 18940.70 | 19017.80 | 19094.90 | 19172.00 | 19249.20 | 19326.40 | 19403.70 |
| 280 | 19481.00 | 19558.30 | 19635.60 | 19713.00 | 19790.40 | 19867.80 | 19945.30 | 20022.80 | 20100.30 | 20177.90 |
| 290 | 20255.50 | 20333.10 | 20410.80 | 20488.50 | 20566.20 | 20644.00 | 20721.70 | 20799.50 | 20877.40 | 20955.20 |
| 300 | 21033.10 | 21111.10 | 21189.00 | 21267.00 | 21345.00 | 21423.00 | 21501.10 | 21579.20 | 21657.30 | 21735.50 |
| 310 | 21813.70 | 21891.90 | 21970.10 | 22048.30 | 22126.60 | 22204.90 | 22283.30 | 22361.60 | 22440.00 | 22518.40 |
| 320 | 22596.90 | 22675.40 | 22753.80 | 22832.40 | 22910.90 | 22989.50 | 23068.10 | 23146.70 | 23225.30 | 23304.00 |
| 330 | 23382.70 | 23461.40 | 23540.10 | 23618.90 | 23697.70 | 23776.50 | 23855.30 | 23934.20 | 24013.10 | 24092.00 |
| 340 | 24170.90 | 24249.90 | 24328.80 | 24407.80 | 24486.80 | 24565.90 | 24644.90 | 24724.00 | 24803.10 | 24882.20 |
| 350 | 24961.40 | 25040.50 | 25119.70 | 25198.90 | 25278.20 | 25357.40 | 25436.70 | 25516.00 | 25595.30 | 25674.60 |
| 360 | 25754.00 | 25833.30 | 25912.70 | 25992.10 | 26071.60 | 26151.00 | 26230.50 | 26310.00 | 26389.50 | 26469.00 |
| 370 | 26548.50 | 26628.10 | 26707.70 | 26787.30 | 26866.90 | 26946.50 | 27026.20 | 27105.80 | 27185.50 | 27265.20 |
| 380 | 27344.90 | 27424.70 | 27504.40 | 27584.20 | 27664.00 | 27743.80 | 27823.60 | 27903.40 | 27983.30 | 28063.20 |
| 390 | 28143.00 | 28222.90 | 28302.90 | 28382.80 | 28462.70 | 28542.70 | 28622.70 | 28702.70 | 28782.70 | 28862.70 |
| 400 | 28942.70 | 29022.80 | 29102.80 | 29182.90 | 29263.00 | 29343.10 | 29423.20 | 29503.40 | 29583.50 | 29663.70 |
| 410 | 29743.90 | 29824.00 | 29904.20 | 29984.50 | 30064.70 | 30144.90 | 30225.20 | 30305.40 | 30385.70 | 30466.00 |
| 420 | 30546.30 | 30626.60 | 30706.90 | 30787.30 | 30867.60 | 30948.00 | 31028.40 | 31108.70 | 31189.10 | 31269.50 |
| 430 | 31350.00 | 31430.40 | 31510.80 | 31591.30 | 31671.70 | 31752.20 | 31832.70 | 31913.20 | 31993.60 | 32074.20 |
| 440 | 32154.70 | 32235.20 | 32315.70 | 32396.30 | 32476.80 | 32557.40 | 32638.00 | 32718.60 | 32799.10 | 32879.70 |
| 450 | 32960.40 | 33041.00 | 33121.60 | 33202.20 | 33282.90 | 33363.50 | 33444.20 | 33524.80 | 33605.50 | 33686.20 |
| 460 | 33766.90 | 33847.60 | 33928.30 | 34009.00 | 34089.70 | 34170.40 | 34251.10 | 34331.90 | 34412.60 | 34493.30 |
| 470 | 34574.10 | 34654.90 | 34735.60 | 34816.40 | 34897.20 | 34977.90 | 35058.70 | 35139.50 | 35220.30 | 35301.10 |
| 480 | 35381.90 | 35462.70 | 35543.60 | 35624.40 | 35705.20 | 35786.00 | 35866.90 | 35947.70 | 36028.60 | 36109.40 |
| 490 | 36190.30 | 36271.10 | 36352.00 | 36432.80 | 36513.70 | 36594.60 | 36675.50 | 36756.30 | 36837.20 | 36918.10 |
| 500 | 36999.00 | 37079.90 | 37160.80 | 37241.70 | 37322.50 | 37403.40 | 37484.30 | 37565.20 | 37646.20 | 37727.10 |
| 510 | 37808.00 | 37888.90 | 37969.80 | 38050.70 | 38131.60 | 38212.50 | 38293.40 | 38374.40 | 38455.30 | 38536.20 |
| 520 | 38617.10 | 38698.00 | 38779.00 | 38859.90 | 38940.80 | 39021.70 | 39102.60 | 39183.60 | 39264.50 | 39345.40 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 530 | 39426.30 | 39507.30 | 39588.20 | 39669.10 | 39750.00 | 39830.90 | 39911.90 | 39992.80 | 40073.70 | 40154.60 |
| 540 | 40235.50 | 40316.40 | 40397.30 | 40478.30 | 40559.20 | 40640.10 | 40721.00 | 40801.90 | 40882.80 | 40963.70 |
| 550 | 41044.60 | 41125.50 | 41206.40 | 41287.20 | 41368.10 | 41449.00 | 41529.90 | 41610.80 | 41691.70 | 41772.50 |
| 560 | 41853.40 | 41934.30 | 42015.10 | 42096.00 | 42176.80 | 42257.70 | 42338.50 | 42419.40 | 42500.20 | 42581.10 |
| 570 | 42661.90 | 42742.70 | 42823.60 | 42904.40 | 42985.20 | 43066.00 | 43146.80 | 43227.60 | 43308.40 | 43389.20 |
| 580 | 43470.00 | 43550.80 | 43631.60 | 43712.40 | 43793.10 | 43873.90 | 43954.60 | 44035.40 | 44116.20 | 44196.90 |
| 590 | 44277.60 | 44358.40 | 44439.10 | 44519.80 | 44600.50 | 44681.20 | 44761.90 | 44842.60 | 44923.30 | 45004.00 |
| 600 | 45084.70 | 45165.40 | 45246.00 | 45326.70 | 45407.30 | 45488.00 | 45568.60 | 45649.30 | 45729.90 | 45810.50 |
| 610 | 45891.10 | 45971.70 | 46052.30 | 46132.90 | 46213.50 | 46294.10 | 46374.60 | 46455.20 | 46535.80 | 46616.30 |
| 620 | 46696.80 | 46777.40 | 46857.90 | 46938.40 | 47018.90 | 47099.40 | 47179.90 | 47260.40 | 47340.90 | 47421.30 |
| 630 | 47501.80 | 47582.30 | 47662.70 | 47743.10 | 47823.60 | 47904.00 | 47984.40 | 48064.80 | 48145.20 | 48225.60 |
| 640 | 48305.90 | 48386.30 | 48466.60 | 48547.00 | 48627.30 | 48707.70 | 48788.00 | 48868.30 | 48948.60 | 49028.90 |
| 650 | 49109.20 | 49189.40 | 49269.70 | 49349.90 | 49430.20 | 49510.40 | 49590.70 | 49670.90 | 49751.10 | 49831.30 |
| 660 | 49911.50 | 49991.60 | 50071.80 | 50152.00 | 50232.10 | 50312.20 | 50392.40 | 50472.50 | 50552.60 | 50632.70 |
| 670 | 50712.80 | 50792.80 | 50872.90 | 50953.00 | 51033.00 | 51113.00 | 51193.10 | 51273.10 | 51353.10 | 51433.10 |
| 680 | 51513.00 | 51593.00 | 51673.00 | 51752.90 | 51832.80 | 51912.80 | 51992.70 | 52072.60 | 52152.50 | 52232.40 |
| 690 | 52312.20 | 52392.10 | 52471.90 | 52551.80 | 52631.60 | 52711.40 | 52791.20 | 52871.00 | 52950.80 | 53030.60 |
| 700 | 53110.30 | 53190.10 | 53269.80 | 53349.50 | 53429.20 | 53508.90 | 53588.60 | 53668.30 | 53748.00 | 53827.60 |
| 710 | 53907.20 | 53986.90 | 54066.50 | 54146.10 | 54225.70 | 54305.30 | 54384.80 | 54464.40 | 54543.90 | 54623.50 |
| 720 | 54703.00 | 54782.50 | 54862.00 | 54941.50 | 55020.90 | 55100.40 | 55179.80 | 55259.30 | 55338.70 | 55418.10 |
| 730 | 55497.50 | 55576.90 | 55656.30 | 55735.60 | 55815.00 | 55894.30 | 55973.60 | 56052.90 | 56132.20 | 56211.50 |
| 740 | 56290.80 | 56370.00 | 56449.30 | 56528.50 | 56607.70 | 56686.90 | 56766.10 | 56845.30 | 56924.50 | 57003.60 |
| 750 | 57082.80 | 57161.90 | 57241.00 | 57320.10 | 57399.20 | 57478.30 | 57557.30 | 57636.40 | 57715.40 | 57794.40 |
| 760 | 57873.40 | 57952.40 | 58031.40 | 58110.40 | 58189.30 | 58268.30 | 58347.20 | 58426.10 | 58505.00 | 58583.90 |
| 770 | 58662.80 | 58741.60 | 58820.50 | 58899.30 | 58978.10 | 59056.90 | 59135.70 | 59214.50 | 59293.20 | 59372.00 |
| 780 | 59450.70 | 59529.40 | 59608.10 | 59686.80 | 59765.50 | 59844.10 | 59922.80 | 60001.40 | 60080.00 | 60158.60 |
| 790 | 60237.20 | 60315.80 | 60394.30 | 60472.90 | 60551.40 | 60629.90 | 60708.40 | 60786.90 | 60865.40 | 60943.80 |
| 800 | 61022.30 | 61100.70 | 61179.10 | 61257.50 | 61335.90 | 61414.30 | 61492.60 | 61570.90 | 61649.30 | 61727.60 |
| 810 | 61805.80 | 61884.10 | 61962.40 | 62040.60 | 62118.80 | 62197.10 | 62275.30 | 62353.40 | 62431.60 | 62509.70 |
| 820 | 62587.90 | 62666.00 | 62744.10 | 62822.20 | 62900.30 | 62978.30 | 63056.30 | 63134.40 | 63212.40 | 63290.40 |
| 830 | 63368.30 | 63446.30 | 63524.20 | 63602.10 | 63680.10 | 63757.90 | 63835.80 | 63913.70 | 63991.50 | 64069.30 |
| 840 | 64147.20 | 64224.90 | 64302.70 | 64380.50 | 64458.20 | 64535.90 | 64613.60 | 64691.30 | 64769.00 | 64846.70 |
| 850 | 64924.30 | 65001.90 | 65079.50 | 65157.10 | 65234.70 | 65312.20 | 65389.80 | 65467.30 | 65544.80 | 65622.30 |
| 860 | 65699.70 | 65777.10 | 65854.60 | 65932.00 | 66009.40 | 66086.80 | 66164.10 | 66241.40 | 66318.80 | 66396.10 |
| 870 | 66473.40 | 66550.60 | 66627.90 | 66705.10 | 66782.30 | 66859.50 | 66936.60 | 67013.80 | 67090.90 | 67168.10 |
| 880 | 67245.10 | 67322.20 | 67399.30 | 67476.30 | 67553.40 | 67630.40 | 67707.30 | 67784.30 | 67861.30 | 67938.20 |
| 890 | 68015.10 | 68092.00 | 68168.80 | 68245.70 | 68322.50 | 68399.30 | 68476.10 | 68552.90 | 68629.60 | 68706.40 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 900 | 68783.10 | 68859.80 | 68936.50 | 69013.10 | 69089.80 | 69166.40 | 69243.00 | 69319.50 | 69396.10 | 69472.60 |
| 910 | 69549.10 | 69625.60 | 69702.10 | 69778.60 | 69855.00 | 69931.40 | 70007.80 | 70084.20 | 70160.60 | 70236.90 |
| 920 | 70313.20 | 70389.50 | 70465.80 | 70542.00 | 70618.30 | 70694.50 | 70770.70 | 70846.90 | 70923.00 | 70999.20 |
| 930 | 71075.30 | 71151.40 | 71227.40 | 71303.50 | 71379.50 | 71455.60 | 71531.60 | 71607.50 | 71683.50 | 71759.40 |
| 940 | 71835.30 | 71911.20 | 71987.10 | 72063.00 | 72138.80 | 72214.60 | 72290.40 | 72366.20 | 72442.00 | 72517.70 |
| 950 | 72593.40 | 72669.10 | 72744.80 | 72820.50 | 72896.10 | 72971.80 | 73047.40 | 73122.90 | 73198.50 | 73274.10 |
| 960 | 73349.60 | 73425.10 | 73500.60 | 73576.10 | 73651.60 | 73727.00 | 73802.40 | 73877.80 | 73953.20 | 74028.60 |
| 970 | 74103.90 | 74179.30 | 74254.60 | 74329.90 | 74405.20 | 74480.50 | 74555.70 | 74631.00 | 74706.20 | 74781.40 |
| 980 | 74856.60 | 74931.80 | 75006.90 | 75082.10 | 75157.20 | 75232.30 | 75307.40 | 75382.50 | 75457.60 | 75532.60 |
| 990 | 75607.7 | 75682.70 | 75757.80 | 75832.80 | 75907.80 | 75982.70 | 76057.70 | 76132.70 | 76207.60 | 76282.60 |

## 62.17 B-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology (NIST) in the US for a metal pair of Pt-30% Rh and Pt-6% Rh referenced to a cold junction at 0°C. B is the letter designation approved by the American Institute for Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the $\mu$V produced in intervals of 1°C. For example -0.24 is the emf produced at +1°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | -0.24 | -0.47 | -0.69 | -0.89 | -1.09 | -1.27 | -1.44 | -1.60 | -1.74 |
| 10 | -1.88 | -2.00 | -2.11 | -2.21 | -2.30 | -2.38 | -2.44 | -2.49 | -2.53 | -2.56 |
| 20 | -2.58 | -2.59 | -2.58 | -2.57 | -2.54 | -2.50 | -2.44 | -2.38 | -2.31 | -2.22 |
| 30 | -2.12 | -2.01 | -1.89 | -1.76 | -1.61 | -1.45 | -1.29 | -1.11 | -0.92 | -0.71 |
| 40 | -0.50 | -0.27 | -0.04 | 0.21 | 0.47 | 0.74 | 1.03 | 1.32 | 1.63 | 1.94 |
| 50 | 2.27 | 2.61 | 2.96 | 3.33 | 3.70 | 4.09 | 4.48 | 4.89 | 5.31 | 5.75 |
| 60 | 6.19 | 6.64 | 7.11 | 7.59 | 8.07 | 8.57 | 9.09 | 9.61 | 10.14 | 10.69 |
| 70 | 11.24 | 11.81 | 12.39 | 12.98 | 13.58 | 14.20 | 14.82 | 15.46 | 16.10 | 16.76 |
| 80 | 17.43 | 18.11 | 18.80 | 19.51 | 20.22 | 20.95 | 21.69 | 22.43 | 23.19 | 23.96 |
| 90 | 24.75 | 25.54 | 26.34 | 27.16 | 27.99 | 28.82 | 29.67 | 30.53 | 31.41 | 32.29 |
| 100 | 33.18 | 34.09 | 35.00 | 35.93 | 36.87 | 37.82 | 38.78 | 39.75 | 40.74 | 41.73 |
| 110 | 42.74 | 43.75 | 44.78 | 45.82 | 46.87 | 47.93 | 49.00 | 50.08 | 51.18 | 52.28 |
| 120 | 53.40 | 54.53 | 55.66 | 56.81 | 57.97 | 59.15 | 60.33 | 61.52 | 62.73 | 63.94 |
| 130 | 65.17 | 66.41 | 67.66 | 68.92 | 70.19 | 71.47 | 72.76 | 74.07 | 75.38 | 76.71 |
| 140 | 78.04 | 79.39 | 80.75 | 82.12 | 83.50 | 84.89 | 86.29 | 87.71 | 89.13 | 90.57 |
| 150 | 92.01 | 93.47 | 94.94 | 96.42 | 97.91 | 99.41 | 100.92 | 102.44 | 103.98 | 105.52 |
| 160 | 107.08 | 108.64 | 110.22 | 111.81 | 113.41 | 115.02 | 116.64 | 118.27 | 119.91 | 121.56 |
| 170 | 123.23 | 124.90 | 126.59 | 128.29 | 129.99 | 131.71 | 133.44 | 135.18 | 136.93 | 138.69 |
| 180 | 140.47 | 142.25 | 144.04 | 145.85 | 147.66 | 149.49 | 151.33 | 153.18 | 155.04 | 156.91 |
| 190 | 158.79 | 160.68 | 162.58 | 164.49 | 166.41 | 168.35 | 170.29 | 172.25 | 174.22 | 176.19 |
| 200 | 178.18 | 180.18 | 182.19 | 184.21 | 186.24 | 188.28 | 190.33 | 192.40 | 194.47 | 196.55 |
| 210 | 198.65 | 200.76 | 202.87 | 205.00 | 207.14 | 209.29 | 211.44 | 213.61 | 215.80 | 217.99 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 220 | 220.19 | 222.40 | 224.62 | 226.86 | 229.10 | 231.36 | 233.62 | 235.90 | 238.19 | 240.48 |
| 230 | 242.79 | 245.11 | 247.44 | 249.78 | 252.13 | 254.49 | 256.86 | 259.25 | 261.64 | 264.04 |
| 240 | 266.46 | 268.88 | 271.32 | 273.76 | 276.22 | 278.69 | 281.16 | 283.65 | 286.15 | 288.66 |
| 250 | 291.18 | 293.71 | 296.25 | 298.80 | 301.36 | 303.94 | 306.52 | 309.11 | 311.72 | 314.33 |
| 260 | 316.96 | 319.59 | 322.24 | 324.90 | 327.56 | 330.24 | 332.93 | 335.63 | 338.34 | 341.06 |
| 270 | 343.79 | 346.53 | 349.28 | 352.04 | 354.81 | 357.59 | 360.38 | 363.19 | 366.00 | 368.82 |
| 280 | 371.66 | 374.50 | 377.36 | 380.22 | 383.10 | 385.99 | 388.88 | 391.79 | 394.71 | 397.64 |
| 290 | 400.58 | 403.52 | 406.48 | 409.45 | 412.43 | 415.42 | 418.42 | 421.44 | 424.46 | 427.49 |
| 300 | 430.53 | 433.58 | 436.65 | 439.72 | 442.80 | 445.90 | 449.00 | 452.12 | 455.24 | 458.38 |
| 310 | 461.52 | 464.68 | 467.84 | 471.02 | 474.21 | 477.40 | 480.61 | 483.83 | 487.06 | 490.29 |
| 320 | 493.54 | 496.80 | 500.07 | 503.35 | 506.64 | 509.94 | 513.25 | 516.57 | 519.90 | 523.24 |
| 330 | 526.59 | 529.95 | 533.32 | 536.71 | 540.10 | 543.50 | 546.91 | 550.33 | 553.77 | 557.21 |
| 340 | 560.66 | 564.13 | 567.60 | 571.08 | 574.58 | 578.08 | 581.60 | 585.12 | 588.65 | 592.20 |
| 350 | 595.75 | 599.32 | 602.89 | 606.48 | 610.07 | 613.68 | 617.30 | 620.92 | 624.56 | 628.20 |
| 360 | 631.86 | 635.53 | 639.20 | 642.89 | 646.58 | 650.29 | 654.01 | 657.73 | 661.47 | 665.22 |
| 370 | 668.98 | 672.74 | 676.52 | 680.31 | 684.10 | 687.91 | 691.73 | 695.56 | 699.39 | 703.24 |
| 380 | 707.10 | 710.97 | 714.84 | 718.73 | 722.63 | 726.54 | 730.45 | 734.38 | 738.32 | 742.27 |
| 390 | 746.22 | 750.19 | 754.17 | 758.15 | 762.15 | 766.16 | 770.18 | 774.20 | 778.24 | 782.29 |
| 400 | 786.35 | 790.41 | 794.49 | 798.58 | 802.67 | 806.78 | 810.90 | 815.02 | 819.16 | 823.31 |
| 410 | 827.46 | 831.63 | 835.80 | 839.99 | 844.18 | 848.39 | 852.61 | 856.83 | 861.07 | 865.31 |
| 420 | 869.57 | 873.83 | 878.11 | 882.39 | 886.68 | 890.99 | 895.30 | 899.63 | 903.96 | 908.30 |
| 430 | 912.66 | 917.02 | 921.39 | 925.77 | 930.17 | 934.57 | 938.98 | 943.40 | 947.83 | 952.27 |
| 440 | 956.73 | 961.19 | 965.66 | 970.14 | 974.63 | 979.13 | 983.64 | 988.16 | 992.68 | 997.22 |
| 450 | 1001.77 | 1006.33 | 1010.90 | 1015.47 | 1020.06 | 1024.66 | 1029.26 | 1033.88 | 1038.51 | 1043.14 |
| 460 | 1047.79 | 1052.44 | 1057.11 | 1061.78 | 1066.46 | 1071.16 | 1075.86 | 1080.57 | 1085.29 | 1090.03 |
| 470 | 1094.77 | 1099.52 | 1104.28 | 1109.05 | 1113.83 | 1118.62 | 1123.42 | 1128.23 | 1133.05 | 1137.87 |
| 480 | 1142.71 | 1147.56 | 1152.41 | 1157.28 | 1162.16 | 1167.04 | 1171.94 | 1176.84 | 1181.75 | 1186.68 |
| 490 | 1191.61 | 1196.55 | 1201.50 | 1206.47 | 1211.44 | 1216.42 | 1221.41 | 1226.41 | 1231.42 | 1236.43 |
| 500 | 1241.46 | 1246.50 | 1251.55 | 1256.60 | 1261.67 | 1266.74 | 1271.83 | 1276.92 | 1282.02 | 1287.14 |
| 510 | 1292.26 | 1297.39 | 1302.53 | 1307.68 | 1312.84 | 1318.01 | 1323.19 | 1328.38 | 1333.58 | 1338.78 |
| 520 | 1344.00 | 1349.22 | 1354.46 | 1359.70 | 1364.96 | 1370.22 | 1375.49 | 1380.77 | 1386.06 | 1391.37 |
| 530 | 1396.67 | 1401.99 | 1407.32 | 1412.66 | 1418.01 | 1423.36 | 1428.73 | 1434.10 | 1439.49 | 1444.88 |
| 540 | 1450.28 | 1455.69 | 1461.12 | 1466.55 | 1471.99 | 1477.43 | 1482.89 | 1488.36 | 1493.84 | 1499.32 |
| 550 | 1504.82 | 1510.32 | 1515.83 | 1521.36 | 1526.89 | 1532.43 | 1537.98 | 1543.54 | 1549.11 | 1554.69 |
| 560 | 1560.27 | 1565.87 | 1571.47 | 1577.09 | 1582.71 | 1588.34 | 1593.99 | 1599.64 | 1605.30 | 1610.97 |
| 570 | 1616.64 | 1622.33 | 1628.03 | 1633.73 | 1639.45 | 1645.17 | 1650.91 | 1656.65 | 1662.40 | 1668.16 |
| 580 | 1673.93 | 1679.71 | 1685.49 | 1691.29 | 1697.09 | 1702.91 | 1708.73 | 1714.57 | 1720.41 | 1726.26 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 590 | 1732.12 | 1737.99 | 1743.86 | 1749.75 | 1755.65 | 1761.55 | 1767.46 | 1773.39 | 1779.32 | 1785.26 |
| 600 | 1791.21 | 1797.17 | 1803.13 | 1809.11 | 1815.09 | 1821.09 | 1827.09 | 1833.10 | 1839.12 | 1845.15 |
| 610 | 1851.19 | 1857.24 | 1863.30 | 1869.36 | 1875.44 | 1881.52 | 1887.61 | 1893.71 | 1899.82 | 1905.94 |
| 620 | 1912.07 | 1918.20 | 1924.35 | 1930.50 | 1936.67 | 1942.84 | 1949.02 | 1955.21 | 1961.41 | 1967.61 |
| 630 | 1973.83 | 1980.05 | 1986.29 | 1992.53 | 1998.78 | 2005.04 | 2011.31 | 2017.59 | 2023.87 | 2030.17 |
| 640 | 2036.47 | 2042.78 | 2049.10 | 2055.43 | 2061.77 | 2068.12 | 2074.47 | 2080.84 | 2087.21 | 2093.59 |
| 650 | 2099.99 | 2106.38 | 2112.79 | 2119.21 | 2125.63 | 2132.07 | 2138.51 | 2144.96 | 2151.42 | 2157.89 |
| 660 | 2164.37 | 2170.86 | 2177.35 | 2183.85 | 2190.37 | 2196.89 | 2203.41 | 2209.95 | 2216.50 | 2223.05 |
| 670 | 2229.62 | 2236.19 | 2242.77 | 2249.36 | 2255.96 | 2262.56 | 2269.18 | 2275.80 | 2282.43 | 2289.07 |
| 680 | 2295.72 | 2302.38 | 2309.05 | 2315.72 | 2322.41 | 2329.10 | 2335.80 | 2342.51 | 2349.22 | 2355.95 |
| 690 | 2362.68 | 2369.43 | 2376.18 | 2382.94 | 2389.71 | 2396.48 | 2403.27 | 2410.06 | 2416.86 | 2423.67 |
| 700 | 2430.49 | 2437.32 | 2444.15 | 2451.00 | 2457.85 | 2464.71 | 2471.58 | 2478.46 | 2485.34 | 2492.24 |
| 710 | 2499.14 | 2506.05 | 2512.97 | 2519.90 | 2526.84 | 2533.78 | 2540.73 | 2547.70 | 2554.66 | 2561.64 |
| 720 | 2568.63 | 2575.62 | 2582.63 | 2589.64 | 2596.66 | 2603.68 | 2610.72 | 2617.77 | 2624.82 | 2631.88 |
| 730 | 2638.95 | 2646.03 | 2653.11 | 2660.21 | 2667.31 | 2674.42 | 2681.54 | 2688.66 | 2695.80 | 2702.94 |
| 740 | 2710.09 | 2717.25 | 2724.42 | 2731.60 | 2738.78 | 2745.98 | 2753.18 | 2760.38 | 2767.60 | 2774.83 |
| 750 | 2782.06 | 2789.30 | 2796.55 | 2803.81 | 2811.08 | 2818.35 | 2825.63 | 2832.92 | 2840.22 | 2847.53 |
| 760 | 2854.84 | 2862.17 | 2869.50 | 2876.84 | 2884.18 | 2891.54 | 2898.90 | 2906.27 | 2913.65 | 2921.04 |
| 770 | 2928.44 | 2935.84 | 2943.25 | 2950.67 | 2958.10 | 2965.54 | 2972.98 | 2980.43 | 2987.89 | 2995.36 |
| 780 | 3002.84 | 3010.32 | 3017.81 | 3025.31 | 3032.82 | 3040.34 | 3047.86 | 3055.39 | 3062.93 | 3070.48 |
| 790 | 3078.04 | 3085.60 | 3093.17 | 3100.75 | 3108.34 | 3115.93 | 3123.54 | 3131.15 | 3138.77 | 3146.39 |
| 800 | 3154.03 | 3161.67 | 3169.32 | 3176.98 | 3184.65 | 3192.32 | 3200.00 | 3207.69 | 3215.39 | 3223.10 |
| 810 | 3230.81 | 3238.53 | 3246.26 | 3254.00 | 3261.74 | 3269.50 | 3277.26 | 3285.03 | 3292.8 | 3300.59 |
| 820 | 3308.38 | 3316.18 | 3323.99 | 3331.80 | 3339.62 | 3347.46 | 3355.29 | 3363.14 | 3370.99 | 3378.86 |
| 830 | 3386.73 | 3394.60 | 3402.49 | 3410.38 | 3418.28 | 3426.19 | 3434.10 | 3442.03 | 3449.96 | 3457.9 |
| 840 | 3465.84 | 3473.80 | 3481.76 | 3489.73 | 3497.71 | 3505.69 | 3513.69 | 3521.69 | 3529.69 | 3537.71 |
| 850 | 3545.73 | 3553.76 | 3561.80 | 3569.85 | 3577.90 | 3585.96 | 3594.03 | 3602.11 | 3610.19 | 3618.28 |
| 860 | 3626.38 | 3634.49 | 3642.60 | 3650.73 | 3658.86 | 3666.99 | 3675.14 | 3683.29 | 3691.45 | 3699.62 |
| 870 | 3707.79 | 3715.97 | 3724.16 | 3732.36 | 3740.57 | 3748.78 | 3757.00 | 3765.23 | 3773.46 | 3781.70 |
| 880 | 3789.95 | 3798.21 | 3806.48 | 3814.75 | 3823.03 | 3831.31 | 3839.61 | 3847.91 | 3856.22 | 3864.54 |
| 890 | 3872.86 | 3881.19 | 3889.53 | 3897.88 | 3906.23 | 3914.59 | 3922.96 | 3931.34 | 3939.72 | 3948.11 |
| 900 | 3956.51 | 3964.92 | 3973.33 | 3981.75 | 3990.18 | 3998.61 | 4007.06 | 4015.51 | 4023.96 | 4032.43 |
| 910 | 4040.90 | 4049.38 | 4057.86 | 4066.36 | 4074.86 | 4083.37 | 4091.88 | 4100.40 | 4108.93 | 4117.47 |
| 920 | 4126.02 | 4134.57 | 4143.13 | 4151.69 | 4160.27 | 4168.85 | 4177.44 | 4186.03 | 4194.63 | 4203.24 |
| 930 | 4211.86 | 4220.48 | 4229.12 | 4237.75 | 4246.40 | 4255.05 | 4263.71 | 4272.38 | 4281.05 | 4289.74 |
| 940 | 4298.43 | 4307.12 | 4315.82 | 4324.53 | 4333.25 | 4341.98 | 4350.71 | 4359.45 | 4368.19 | 4376.94 |
| 950 | 4385.70 | 4394.47 | 4403.25 | 4412.03 | 4420.82 | 4429.61 | 4438.41 | 4447.22 | 4456.04 | 4464.86 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 960 | 4473.69 | 4482.53 | 4491.38 | 4500.23 | 4509.09 | 4517.95 | 4526.83 | 4535.71 | 4544.59 | 4553.49 |
| 970 | 4562.39 | 4571.30 | 4580.21 | 4589.13 | 4598.06 | 4607.00 | 4615.94 | 4624.89 | 4633.85 | 4642.81 |
| 980 | 4651.78 | 4660.76 | 4669.74 | 4678.73 | 4687.73 | 4696.74 | 4705.75 | 4714.77 | 4723.79 | 4732.83 |
| 990 | 4741.86 | 4750.91 | 4759.96 | 4769.02 | 4778.09 | 4787.17 | 4796.25 | 4805.33 | 4814.43 | 4823.53 |
| 1000 | 4832.64 | 4841.75 | 4850.87 | 4860.00 | 4869.14 | 4878.28 | 4887.43 | 4896.59 | 4905.75 | 4914.92 |
| 1010 | 4924.09 | 4933.28 | 4942.47 | 4951.66 | 4960.86 | 4970.07 | 4979.29 | 4988.51 | 4997.74 | 5006.98 |
| 1020 | 5016.22 | 5025.47 | 5034.73 | 5044.00 | 5053.27 | 5062.54 | 5071.83 | 5081.12 | 5090.41 | 5099.72 |
| 1030 | 5109.03 | 5118.34 | 5127.67 | 5137 | 5146.33 | 5155.68 | 5165.03 | 5174.38 | 5183.75 | 5193.12 |
| 1040 | 5202.49 | 5211.88 | 5221.27 | 5230.66 | 5240.07 | 5249.47 | 5258.89 | 5268.31 | 5277.74 | 5287.18 |
| 1050 | 5296.62 | 5306.07 | 5315.52 | 5324.99 | 5334.45 | 5343.93 | 5353.41 | 5362.90 | 5372.39 | 5381.89 |
| 1060 | 5391.40 | 5400.91 | 5410.43 | 5419.96 | 5429.49 | 5439.03 | 5448.58 | 5458.13 | 5467.69 | 5477.25 |
| 1070 | 5486.82 | 5496.40 | 5505.99 | 5515.58 | 5525.18 | 5534.78 | 5544.39 | 5554.00 | 5563.63 | 5573.26 |
| 1080 | 5582.89 | 5592.53 | 5602.18 | 5611.84 | 5621.50 | 5631.16 | 5640.84 | 5650.52 | 5660.20 | 5669.89 |
| 1090 | 5679.59 | 5689.30 | 5699.01 | 5708.73 | 5718.45 | 5728.18 | 5737.92 | 5747.66 | 5757.41 | 5767.16 |
| 1100 | 5776.92 | 5786.69 | 5796.46 | 5806.24 | 5816.03 | 5825.82 | 5835.62 | 5845.42 | 5855.24 | 5865.05 |
| 1110 | 5874.87 | 5884.70 | 5894.54 | 5904.38 | 5914.23 | 5924.08 | 5933.94 | 5943.81 | 5953.68 | 5963.56 |
| 1120 | 5973.44 | 5983.33 | 5993.23 | 6003.13 | 6013.04 | 6022.95 | 6032.88 | 6042.80 | 6052.73 | 6062.67 |
| 1130 | 6072.62 | 6082.57 | 6092.53 | 6102.49 | 6112.46 | 6122.43 | 6132.41 | 6142.4 | 6152.39 | 6162.39 |
| 1140 | 6172.40 | 6182.41 | 6192.42 | 6202.45 | 6212.47 | 6222.51 | 6232.55 | 6242.60 | 6252.65 | 6262.71 |
| 1150 | 6272.77 | 6282.84 | 6292.91 | 6303.00 | 6313.08 | 6323.18 | 6333.28 | 6343.38 | 6353.49 | 6363.61 |
| 1160 | 6373.73 | 6383.86 | 6393.99 | 6404.13 | 6414.28 | 6424.43 | 6434.59 | 6444.75 | 6454.92 | 6465.09 |
| 1170 | 6475.27 | 6485.46 | 6495.65 | 6505.85 | 6516.05 | 6526.26 | 6536.47 | 6546.69 | 6556.92 | 6567.15 |
| 1180 | 6577.39 | 6587.63 | 6597.88 | 6608.13 | 6618.39 | 6628.66 | 6638.93 | 6649.21 | 6659.49 | 6669.78 |
| 1190 | 6680.07 | 6690.37 | 6700.67 | 6710.98 | 6721.30 | 6731.62 | 6741.95 | 6752.28 | 6762.62 | 6772.96 |
| 1200 | 6783.31 | 6793.66 | 6804.02 | 6814.39 | 6824.76 | 6835.14 | 6845.52 | 6855.91 | 6866.30 | 6876.70 |
| 1210 | 6887.10 | 6897.51 | 6907.92 | 6918.34 | 6928.77 | 6939.20 | 6949.64 | 6960.08 | 6970.52 | 6980.98 |
| 1220 | 6991.43 | 7001.90 | 7012.36 | 7022.84 | 7033.32 | 7043.80 | 7054.29 | 7064.79 | 7075.29 | 7085.79 |
| 1230 | 7096.30 | 7106.82 | 7117.34 | 7127.86 | 7138.40 | 7148.93 | 7159.48 | 7170.02 | 7180.57 | 7191.13 |
| 1240 | 7201.70 | 7212.26 | 7222.84 | 7233.41 | 7244.00 | 7254.59 | 7265.18 | 7275.78 | 7286.38 | 7296.99 |
| 1250 | 7307.61 | 7318.23 | 7328.85 | 7339.48 | 7350.11 | 7360.75 | 7371.40 | 7382.05 | 7392.70 | 7403.36 |
| 1260 | 7414.03 | 7424.70 | 7435.37 | 7446.05 | 7456.74 | 7467.42 | 7478.12 | 7488.82 | 7499.52 | 7510.23 |
| 1270 | 7520.95 | 7531.67 | 7542.39 | 7553.12 | 7563.85 | 7574.59 | 7585.33 | 7596.08 | 7606.84 | 7617.59 |
| 1280 | 7628.36 | 7639.12 | 7649.90 | 7660.67 | 7671.46 | 7682.24 | 7693.03 | 7703.83 | 7714.63 | 7725.44 |
| 1290 | 7736.25 | 7747.06 | 7757.88 | 7768.71 | 7779.54 | 7790.37 | 7801.21 | 7812.05 | 7822.90 | 7833.75 |
| 1300 | 7844.61 | 7855.47 | 7866.34 | 7877.21 | 7888.09 | 7898.97 | 7909.85 | 7920.74 | 7931.64 | 7942.53 |
| 1310 | 7953.44 | 7964.34 | 7975.26 | 7986.17 | 7997.09 | 8008.02 | 8018.95 | 8029.88 | 8040.82 | 8051.77 |
| 1320 | 8062.71 | 8073.67 | 8084.62 | 8095.58 | 8106.55 | 8117.52 | 8128.49 | 8139.47 | 8150.45 | 8161.44 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 1330 | 8172.43 | 8183.43 | 8194.43 | 8205.43 | 8216.44 | 8227.45 | 8238.47 | 8249.49 | 8260.52 | 8271.55 |
| 1340 | 8282.58 | 8293.62 | 8304.66 | 8315.71 | 8326.76 | 8337.81 | 8348.87 | 8359.94 | 8371.00 | 8382.08 |
| 1350 | 8393.15 | 8404.23 | 8415.31 | 8426.40 | 8437.49 | 8448.59 | 8459.69 | 8470.79 | 8481.90 | 8493.01 |
| 1360 | 8504.13 | 8515.25 | 8526.37 | 8537.50 | 8548.63 | 8559.77 | 8570.91 | 8582.05 | 8593.20 | 8604.35 |
| 1370 | 8615.51 | 8626.67 | 8637.83 | 8648.99 | 8660.17 | 8671.34 | 8682.52 | 8693.7 | 8704.89 | 8716.08 |
| 1380 | 8727.27 | 8738.47 | 8749.67 | 8760.87 | 8772.08 | 8783.29 | 8794.51 | 8805.73 | 8816.95 | 8828.18 |
| 1390 | 8839.41 | 8850.64 | 8861.88 | 8873.12 | 8884.36 | 8895.61 | 8906.86 | 8918.12 | 8929.38 | 8940.64 |
| 1400 | 8951.91 | 8963.18 | 8974.45 | 8985.73 | 8997.01 | 9008.29 | 9019.58 | 9030.87 | 9042.16 | 9053.46 |
| 1410 | 9064.76 | 9076.06 | 9087.37 | 9098.68 | 9109.99 | 9121.31 | 9132.63 | 9143.95 | 9155.28 | 9166.61 |
| 1420 | 9177.95 | 9189.28 | 9200.62 | 9211.97 | 9223.31 | 9234.66 | 9246.02 | 9257.37 | 9268.73 | 9280.09 |
| 1430 | 9291.46 | 9302.83 | 9314.20 | 9325.57 | 9336.95 | 9348.33 | 9359.72 | 9371.10 | 9382.49 | 9393.89 |
| 1440 | 9405.28 | 9416.68 | 9428.09 | 9439.49 | 9450.90 | 9462.31 | 9473.72 | 9485.14 | 9496.56 | 9507.98 |
| 1450 | 9519.41 | 9530.84 | 9542.27 | 9553.70 | 9565.14 | 9576.58 | 9588.02 | 9599.47 | 9610.91 | 9622.36 |
| 1460 | 9633.82 | 9645.27 | 9656.73 | 9668.19 | 9679.66 | 9691.13 | 9702.59 | 9714.07 | 9725.54 | 9737.02 |
| 1470 | 9748.50 | 9759.98 | 9771.47 | 9782.95 | 9794.44 | 9805.94 | 9817.43 | 9828.93 | 9840.43 | 9851.93 |
| 1480 | 9863.44 | 9874.94 | 9886.45 | 9897.97 | 9909.48 | 9921.00 | 9932.52 | 9944.04 | 9955.56 | 9967.09 |
| 1490 | 9978.62 | 9990.15 | 10001.70 | 10013.20 | 10024.80 | 10036.30 | 10047.80 | 10059.40 | 10070.90 | 10082.50 |
| 1500 | 10094.00 | 10105.60 | 10117.10 | 10128.70 | 10140.30 | 10151.80 | 10163.40 | 10174.90 | 10186.50 | 10198.10 |
| 1510 | 10209.70 | 10221.20 | 10232.80 | 10244.40 | 10256.00 | 10267.50 | 10279.10 | 10290.70 | 10302.30 | 10313.90 |
| 1520 | 10325.50 | 10337.10 | 10348.70 | 10360.30 | 10371.90 | 10383.50 | 10395.10 | 10406.70 | 10418.30 | 10429.90 |
| 1530 | 10441.50 | 10453.10 | 10464.70 | 10476.30 | 10487.90 | 10499.60 | 10511.20 | 10522.80 | 10534.40 | 10546.00 |
| 1540 | 10557.70 | 10569.30 | 10580.90 | 10592.60 | 10604.20 | 10615.80 | 10627.40 | 10639.10 | 10650.70 | 10662.40 |
| 1550 | 10674.00 | 10685.60 | 10697.30 | 10708.90 | 10720.60 | 10732.20 | 10743.90 | 10755.50 | 10767.20 | 10778.80 |
| 1560 | 10790.50 | 10802.10 | 10813.80 | 10825.40 | 10837.10 | 10848.70 | 10860.40 | 10872.10 | 10883.70 | 10895.40 |
| 1570 | 10907.10 | 10918.70 | 10930.40 | 10942.10 | 10953.70 | 10965.40 | 10977.10 | 10988.70 | 11000.40 | 11012.10 |
| 1580 | 11023.70 | 11035.40 | 11047.10 | 11058.80 | 11070.50 | 11082.10 | 11093.80 | 11105.50 | 11117.20 | 11128.90 |
| 1590 | 11140.50 | 11152.20 | 11163.90 | 11175.60 | 11187.30 | 11199.00 | 11210.60 | 11222.30 | 11234.00 | 11245.70 |
| 1600 | 11257.40 | 11269.10 | 11280.80 | 11292.50 | 11304.10 | 11315.80 | 11327.50 | 11339.20 | 11350.90 | 11362.60 |
| 1610 | 11374.30 | 11386.00 | 11397.70 | 11409.40 | 11421.10 | 11432.80 | 11444.50 | 11456.20 | 11467.90 | 11479.60 |
| 1620 | 11491.30 | 11503.00 | 11514.70 | 11526.40 | 11538.00 | 11549.70 | 11561.40 | 11573.10 | 11584.80 | 11596.50 |
| 1630 | 11608.20 | 11619.90 | 11631.60 | 11643.30 | 11655.00 | 11666.70 | 11678.40 | 11690.10 | 11701.80 | 11713.50 |
| 1640 | 11725.20 | 11736.90 | 11748.60 | 11760.30 | 11772.00 | 11783.70 | 11795.40 | 11807.10 | 11818.80 | 11830.50 |
| 1650 | 11842.20 | 11853.90 | 11865.60 | 11877.30 | 11889.00 | 11900.70 | 11912.40 | 11924.10 | 11935.80 | 11947.50 |
| 1660 | 11959.10 | 11970.80 | 11982.50 | 11994.20 | 12005.90 | 12017.60 | 12029.30 | 12041.00 | 12052.70 | 12064.40 |
| 1670 | 12076.10 | 12087.70 | 12099.40 | 12111.10 | 12122.80 | 12134.50 | 12146.20 | 12157.90 | 12169.50 | 12181.20 |
| 1680 | 12192.90 | 12204.60 | 12216.30 | 12227.90 | 12239.60 | 12251.30 | 12263.00 | 12274.60 | 12286.30 | 12298.00 |
| 1690 | 12309.70 | 12321.30 | 12333.00 | 12344.70 | 12356.40 | 12368.00 | 12379.70 | 12391.40 | 12403.00 | 12414.70 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 1700 | 12426.30 | 12438.00 | 12449.70 | 12461.30 | 12473.00 | 12484.60 | 12496.30 | 12508.00 | 12519.60 | 12531.30 |
| 1710 | 12542.90 | 12554.60 | 12566.20 | 12577.90 | 12589.50 | 12601.20 | 12612.80 | 12624.40 | 12636.10 | 12647.70 |
| 1720 | 12659.40 | 12671.00 | 12682.60 | 12694.30 | 12705.90 | 12717.50 | 12729.20 | 12740.80 | 12752.40 | 12764.00 |
| 1730 | 12775.70 | 12787.30 | 12798.90 | 12810.50 | 12822.10 | 12833.80 | 12845.40 | 12857.00 | 12868.60 | 12880.20 |
| 1740 | 12891.80 | 12903.40 | 12915.00 | 12926.60 | 12938.20 | 12949.80 | 12961.40 | 12973.00 | 12984.60 | 12996.20 |
| 1750 | 13007.80 | 13019.40 | 13030.90 | 13042.50 | 13054.10 | 13065.70 | 13077.30 | 13088.80 | 13100.40 | 13112.00 |
| 1760 | 13123.60 | 13135.10 | 13146.70 | 13158.30 | 13169.80 | 13181.40 | 13192.90 | 13204.50 | 13216.00 | 13227.60 |
| 1770 | 13239.10 | 13250.70 | 13262.20 | 13273.80 | 13285.30 | 13296.80 | 13308.40 | 13319.90 | 13331.40 | 13343.00 |
| 1780 | 13354.50 | 13366.00 | 13377.50 | 13389.10 | 13400.60 | 13412.10 | 13423.60 | 13435.10 | 13446.60 | 13458.10 |
| 1790 | 13469.60 | 13481.10 | 13492.60 | 13504.10 | 13515.60 | 13527.10 | 13538.60 | 13550.10 | 13561.60 | 13573.00 |
| 1800 | 13584.50 | 13596.00 | 13607.50 | 13618.90 | 13630.40 | 13641.90 | 13653.30 | 13664.80 | 13676.20 | 13687.70 |
| 1810 | 13699.10 | 13710.60 | 13722.00 | 13733.50 | 13744.90 | 13756.40 | 13767.80 | 13779.20 | 13790.70 | 13802.10 |

## 62.18 R-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology of (NIST) in the US for a metal pair of Pt-13% Rh vs. Pt referenced to a cold junction at 0°C. R is the letter designation approved by the American Institute for Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the µV produced in intervals of 1°C. For example -222.72 µV is produced at -49°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -50 | -226.44 | -222.72 | -218.97 | -215.18 | -211.36 | -207.50 | -203.60 | -199.67 | -195.71 | -191.71 |
| -40 | -187.67 | -183.61 | -179.50 | -175.37 | -171.20 | -166.99 | -162.76 | -158.48 | -154.18 | -149.84 |
| -30 | -145.48 | -141.07 | -136.64 | -132.17 | -127.67 | -123.14 | -118.58 | -113.99 | -109.36 | -104.71 |
| -20 | -100.02 | -95.30 | -90.55 | -85.77 | -80.96 | -76.12 | -71.25 | -66.35 | -61.42 | -56.46 |
| -10 | -51.48 | -46.46 | -41.41 | -36.33 | -31.23 | -26.09 | -20.93 | -15.74 | -10.52 | -5.28 |
| 0 | 0.00 | 5.30 | 10.63 | 15.99 | 21.38 | 26.79 | 32.23 | 37.70 | 43.19 | 48.71 |
| 10 | 54.26 | 59.83 | 65.43 | 71.06 | 76.71 | 82.39 | 88.09 | 93.82 | 99.58 | 105.36 |
| 20 | 111.16 | 116.99 | 122.85 | 128.73 | 134.63 | 140.56 | 146.52 | 152.49 | 158.50 | 164.52 |
| 30 | 170.57 | 176.65 | 182.75 | 188.87 | 195.01 | 201.18 | 207.38 | 213.59 | 219.83 | 226.09 |
| 40 | 232.38 | 238.68 | 245.01 | 251.36 | 257.74 | 264.13 | 270.55 | 276.99 | 283.46 | 289.94 |
| 50 | 296.45 | 302.97 | 309.52 | 316.09 | 322.69 | 329.30 | 335.93 | 342.59 | 349.27 | 355.96 |
| 60 | 362.68 | 369.42 | 376.18 | 382.95 | 389.75 | 396.57 | 403.41 | 410.27 | 417.15 | 424.05 |
| 70 | 430.97 | 437.91 | 444.87 | 451.84 | 458.84 | 465.85 | 472.89 | 479.94 | 487.02 | 494.11 |
| 80 | 501.22 | 508.35 | 515.49 | 522.66 | 529.85 | 537.05 | 544.27 | 551.51 | 558.77 | 566.04 |
| 90 | 573.33 | 580.64 | 587.97 | 595.32 | 602.68 | 610.06 | 617.46 | 624.88 | 632.31 | 639.76 |
| 100 | 647.23 | 654.71 | 662.22 | 669.73 | 677.27 | 684.82 | 692.39 | 699.97 | 707.57 | 715.19 |
| 110 | 722.83 | 730.48 | 738.14 | 745.82 | 753.52 | 761.24 | 768.96 | 776.71 | 784.47 | 792.25 |
| 120 | 800.04 | 807.85 | 815.67 | 823.51 | 831.36 | 839.23 | 847.12 | 855.02 | 862.93 | 870.86 |
| 130 | 878.80 | 886.76 | 894.74 | 902.72 | 910.73 | 918.74 | 926.78 | 934.82 | 942.88 | 950.96 |
| 140 | 959.05 | 967.15 | 975.27 | 983.40 | 991.54 | 999.70 | 1007.87 | 1016.06 | 1024.26 | 1032.47 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 150 | 1040.70 | 1048.94 | 1057.20 | 1065.47 | 1073.75 | 1082.04 | 1090.35 | 1098.67 | 1107.00 | 1115.35 |
| 160 | 1123.71 | 1132.08 | 1140.47 | 1148.87 | 1157.28 | 1165.70 | 1174.14 | 1182.59 | 1191.05 | 1199.52 |
| 170 | 1208.01 | 1216.51 | 1225.02 | 1233.54 | 1242.08 | 1250.63 | 1259.19 | 1267.76 | 1276.34 | 1284.94 |
| 180 | 1293.55 | 1302.17 | 1310.80 | 1319.44 | 1328.10 | 1336.77 | 1345.44 | 1354.13 | 1362.84 | 1371.55 |
| 190 | 1380.27 | 1389.01 | 1397.76 | 1406.51 | 1415.28 | 1424.06 | 1432.86 | 1441.66 | 1450.47 | 1459.30 |
| 200 | 1468.13 | 1476.98 | 1485.84 | 1494.71 | 1503.59 | 1512.47 | 1521.38 | 1530.29 | 1539.21 | 1548.14 |
| 210 | 1557.08 | 1566.04 | 1575 | 1583.97 | 1592.96 | 1601.95 | 1610.96 | 1619.97 | 1629.00 | 1638.03 |
| 220 | 1647.08 | 1656.13 | 1665.20 | 1674.27 | 1683.36 | 1692.45 | 1701.56 | 1710.67 | 1719.80 | 1728.93 |
| 230 | 1738.08 | 1747.23 | 1756.39 | 1765.56 | 1774.75 | 1783.94 | 1793.14 | 1802.35 | 1811.57 | 1820.80 |
| 240 | 1830.04 | 1839.28 | 1848.54 | 1857.81 | 1867.08 | 1876.36 | 1885.66 | 1894.96 | 1904.27 | 1913.59 |
| 250 | 1922.92 | 1932.26 | 1941.61 | 1950.96 | 1960.33 | 1969.70 | 1979.08 | 1988.47 | 1997.87 | 2007.28 |
| 260 | 2016.70 | 2026.12 | 2035.56 | 2045 | 2054.45 | 2063.91 | 2073.37 | 2082.85 | 2092.33 | 2101.83 |
| 270 | 2111.33 | 2120.84 | 2130.35 | 2139.88 | 2149.41 | 2158.95 | 2168.50 | 2178.06 | 2187.63 | 2197.20 |
| 280 | 2206.78 | 2216.37 | 2225.97 | 2235.58 | 2245.19 | 2254.81 | 2264.44 | 2274.08 | 2283.72 | 2293.37 |
| 290 | 2303.03 | 2312.70 | 2322.37 | 2332.06 | 2341.75 | 2351.45 | 2361.15 | 2370.86 | 2380.58 | 2390.31 |
| 300 | 2400.05 | 2409.79 | 2419.54 | 2429.30 | 2439.06 | 2448.83 | 2458.61 | 2468.40 | 2478.19 | 2487.99 |
| 310 | 2497.80 | 2507.62 | 2517.44 | 2527.27 | 2537.10 | 2546.95 | 2556.80 | 2566.65 | 2576.52 | 2586.39 |
| 320 | 2596.27 | 2606.15 | 2616.05 | 2625.94 | 2635.85 | 2645.76 | 2655.68 | 2665.61 | 2675.54 | 2685.48 |
| 330 | 2695.43 | 2705.38 | 2715.34 | 2725.31 | 2735.28 | 2745.26 | 2755.24 | 2765.24 | 2775.24 | 2785.24 |
| 340 | 2795.25 | 2805.27 | 2815.30 | 2825.33 | 2835.37 | 2845.41 | 2855.46 | 2865.52 | 2875.58 | 2885.65 |
| 350 | 2895.73 | 2905.81 | 2915.90 | 2925.99 | 2936.09 | 2946.20 | 2956.31 | 2966.43 | 2976.56 | 2986.69 |
| 360 | 2996.83 | 3006.97 | 3017.12 | 3027.28 | 3037.44 | 3047.61 | 3057.79 | 3067.97 | 3078.15 | 3088.34 |
| 370 | 3098.54 | 3108.75 | 3118.96 | 3129.17 | 3139.40 | 3149.62 | 3159.86 | 3170.10 | 3180.34 | 3190.59 |
| 380 | 3200.85 | 3211.11 | 3221.38 | 3231.66 | 3241.94 | 3252.22 | 3262.51 | 3272.81 | 3283.11 | 3293.42 |
| 390 | 3303.74 | 3314.06 | 3324.38 | 3334.71 | 3345.05 | 3355.39 | 3365.74 | 3376.10 | 3386.45 | 3396.82 |
| 400 | 3407.19 | 3417.57 | 3427.95 | 3438.33 | 3448.73 | 3459.12 | 3469.53 | 3479.94 | 3490.35 | 3500.77 |
| 410 | 3511.19 | 3521.62 | 3532.06 | 3542.50 | 3552.95 | 3563.40 | 3573.86 | 3584.32 | 3594.79 | 3605.26 |
| 420 | 3615.74 | 3626.22 | 3636.71 | 3647.21 | 3657.71 | 3668.21 | 3678.72 | 3689.24 | 3699.76 | 3710.29 |
| 430 | 3720.82 | 3731.35 | 3741.89 | 3752.44 | 3762.99 | 3773.55 | 3784.11 | 3794.68 | 3805.25 | 3815.83 |
| 440 | 3826.41 | 3837.00 | 3847.60 | 3858.19 | 3868.80 | 3879.41 | 3890.02 | 3900.64 | 3911.26 | 3921.89 |
| 450 | 3932.53 | 3943.17 | 3953.81 | 3964.46 | 3975.11 | 3985.77 | 3996.44 | 4007.11 | 4017.78 | 4028.46 |
| 460 | 4039.14 | 4049.83 | 4060.53 | 4071.23 | 4081.93 | 4092.64 | 4103.35 | 4114.07 | 4124.80 | 4135.53 |
| 470 | 4146.26 | 4157 | 4167.74 | 4178.49 | 4189.24 | 4200 | 4210.77 | 4221.54 | 4232.31 | 4243.09 |
| 480 | 4253.87 | 4264.66 | 4275.45 | 4286.25 | 4297.05 | 4307.86 | 4318.67 | 4329.49 | 4340.31 | 4351.14 |
| 490 | 4361.97 | 4372.80 | 4383.65 | 4394.49 | 4405.34 | 4416.20 | 4427.06 | 4437.93 | 4448.80 | 4459.67 |
| 500 | 4470.55 | 4481.44 | 4492.33 | 4503.22 | 4514.12 | 4525.02 | 4535.93 | 4546.85 | 4557.76 | 4568.69 |
| 510 | 4579.62 | 4590.55 | 4601.49 | 4612.43 | 4623.37 | 4634.33 | 4645.28 | 4656.24 | 4667.21 | 4678.18 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 520 | 4689.16 | 4700.14 | 4711.12 | 4722.11 | 4733.10 | 4744.10 | 4755.11 | 4766.12 | 4777.13 | 4788.15 |
| 530 | 4799.17 | 4810.20 | 4821.23 | 4832.27 | 4843.31 | 4854.35 | 4865.41 | 4876.46 | 4887.52 | 4898.59 |
| 540 | 4909.66 | 4920.73 | 4931.81 | 4942.89 | 4953.98 | 4965.07 | 4976.17 | 4987.27 | 4998.38 | 5009.49 |
| 550 | 5020.61 | 5031.73 | 5042.86 | 5053.99 | 5065.12 | 5076.26 | 5087.40 | 5098.55 | 5109.71 | 5120.87 |
| 560 | 5132.03 | 5143.20 | 5154.37 | 5165.54 | 5176.72 | 5187.91 | 5199.10 | 5210.30 | 5221.49 | 5232.70 |
| 570 | 5243.91 | 5255.12 | 5266.34 | 5277.56 | 5288.79 | 5300.02 | 5311.26 | 5322.50 | 5333.74 | 5344.99 |
| 580 | 5356.24 | 5367.50 | 5378.77 | 5390.03 | 5401.31 | 5412.58 | 5423.86 | 5435.15 | 5446.44 | 5457.74 |
| 590 | 5469.03 | 5480.34 | 5491.65 | 5502.96 | 5514.28 | 5525.60 | 5536.92 | 5548.25 | 5559.59 | 5570.93 |
| 600 | 5582.27 | 5593.62 | 5604.97 | 5616.33 | 5627.69 | 5639.05 | 5650.42 | 5661.80 | 5673.18 | 5684.56 |
| 610 | 5695.95 | 5707.34 | 5718.73 | 5730.13 | 5741.54 | 5752.95 | 5764.36 | 5775.78 | 5787.20 | 5798.62 |
| 620 | 5810.05 | 5821.49 | 5832.93 | 5844.37 | 5855.82 | 5867.27 | 5878.72 | 5890.18 | 5901.64 | 5913.11 |
| 630 | 5924.58 | 5936.06 | 5947.57 | 5959.07 | 5970.58 | 5982.10 | 5993.62 | 6005.14 | 6016.67 | 6028.21 |
| 640 | 6039.75 | 6051.30 | 6062.85 | 6074.40 | 6085.96 | 6097.53 | 6109.10 | 6120.67 | 6132.25 | 6143.84 |
| 650 | 6155.43 | 6167.02 | 6178.62 | 6190.22 | 6201.83 | 6213.45 | 6225.07 | 6236.69 | 6248.32 | 6259.95 |
| 660 | 6271.59 | 6283.24 | 6294.89 | 6306.54 | 6318.20 | 6329.86 | 6341.53 | 6353.20 | 6364.88 | 6376.57 |
| 670 | 6388.25 | 6399.95 | 6411.64 | 6423.35 | 6435.05 | 6446.77 | 6458.48 | 6470.21 | 6481.93 | 6493.67 |
| 680 | 6505.40 | 6517.14 | 6528.89 | 6540.64 | 6552.40 | 6564.16 | 6575.93 | 6587.70 | 6599.47 | 6611.26 |
| 690 | 6623.04 | 6634.83 | 6646.63 | 6658.43 | 6670.23 | 6682.04 | 6693.86 | 6705.68 | 6717.50 | 6729.33 |
| 700 | 6741.17 | 6753.00 | 6764.85 | 6776.70 | 6788.55 | 6800.41 | 6812.27 | 6824.14 | 6836.01 | 6847.89 |
| 710 | 6859.77 | 6871.66 | 6883.55 | 6895.45 | 6907.35 | 6919.26 | 6931.17 | 6943.09 | 6955.01 | 6966.94 |
| 720 | 6978.87 | 6990.80 | 7002.74 | 7014.69 | 7026.64 | 7038.59 | 7050.55 | 7062.52 | 7074.49 | 7086.46 |
| 730 | 7098.44 | 7110.43 | 7122.41 | 7134.41 | 7146.41 | 7158.41 | 7170.42 | 7182.43 | 7194.45 | 7206.47 |
| 740 | 7218.50 | 7230.53 | 7242.56 | 7254.61 | 7266.65 | 7278.70 | 7290.76 | 7302.82 | 7314.88 | 7326.95 |
| 750 | 7339.03 | 7351.11 | 7363.19 | 7375.28 | 7387.38 | 7399.47 | 7411.58 | 7423.69 | 7435.80 | 7447.92 |
| 760 | 7460.04 | 7472.17 | 7484.30 | 7496.43 | 7508.58 | 7520.72 | 7532.87 | 7545.03 | 7557.19 | 7569.35 |
| 770 | 7581.52 | 7593.70 | 7605.88 | 7618.06 | 7630.25 | 7642.44 | 7654.64 | 7666.85 | 7679.05 | 7691.27 |
| 780 | 7703.48 | 7715.71 | 7727.93 | 7740.16 | 7752.40 | 7764.64 | 7776.89 | 7789.14 | 7801.39 | 7813.65 |
| 790 | 7825.91 | 7838.18 | 7850.46 | 7862.74 | 7875.02 | 7887.31 | 7899.60 | 7911.90 | 7924.20 | 7936.50 |
| 800 | 7948.82 | 7961.13 | 7973.45 | 7985.78 | 7998.11 | 8010.44 | 8022.78 | 8035.13 | 8047.47 | 8059.83 |
| 810 | 8072.19 | 8084.55 | 8096.92 | 8109.29 | 8121.67 | 8134.05 | 8146.43 | 8158.82 | 8171.22 | 8183.62 |
| 820 | 8196.02 | 8208.43 | 8220.85 | 8233.27 | 8245.69 | 8258.12 | 8270.55 | 8282.99 | 8295.43 | 8307.88 |
| 830 | 8320.33 | 8332.78 | 8345.24 | 8357.71 | 8370.18 | 8382.65 | 8395.13 | 8407.62 | 8420.10 | 8432.60 |
| 840 | 8445.09 | 8457.60 | 8470.10 | 8482.61 | 8495.13 | 8507.65 | 8520.18 | 8532.71 | 8545.24 | 8557.78 |
| 850 | 8570.32 | 8582.87 | 8595.42 | 8607.98 | 8620.54 | 8633.11 | 8645.68 | 8658.26 | 8670.84 | 8683.42 |
| 860 | 8696.01 | 8708.61 | 8721.21 | 8733.81 | 8746.42 | 8759.03 | 8771.65 | 8784.27 | 8796.90 | 8809.53 |
| 870 | 8822.16 | 8834.80 | 8847.45 | 8860.10 | 8872.75 | 8885.41 | 8898.07 | 8910.74 | 8923.41 | 8936.09 |
| 880 | 8948.77 | 8961.46 | 8974.15 | 8986.84 | 8999.54 | 9012.24 | 9024.95 | 9037.67 | 9050.38 | 9063.11 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 890 | 9075.83 | 9088.56 | 9101.30 | 9114.04 | 9126.79 | 9139.54 | 9152.29 | 9165.05 | 9177.81 | 9190.58 |
| 900 | 9203.35 | 9216.13 | 9228.91 | 9241.69 | 9254.48 | 9267.28 | 9280.08 | 9292.88 | 9305.69 | 9318.50 |
| 910 | 9331.32 | 9344.14 | 9356.97 | 9369.80 | 9382.63 | 9395.47 | 9408.32 | 9421.17 | 9434.02 | 9446.88 |
| 920 | 9459.74 | 9472.61 | 9485.48 | 9498.36 | 9511.24 | 9524.12 | 9537.01 | 9549.90 | 9562.80 | 9575.71 |
| 930 | 9588.61 | 9601.52 | 9614.44 | 9627.36 | 9640.29 | 9653.22 | 9666.15 | 9679.09 | 9692.03 | 9704.98 |
| 940 | 9717.93 | 9730.89 | 9743.85 | 9756.81 | 9769.78 | 9782.76 | 9795.74 | 9808.72 | 9821.71 | 9834.70 |
| 950 | 9847.70 | 9860.70 | 9873.70 | 9886.71 | 9899.73 | 9912.74 | 9925.77 | 9938.80 | 9951.83 | 9964.86 |
| 960 | 9977.90 | 9990.95 | 10004.00 | 10017.10 | 10030.10 | 10043.20 | 10056.20 | 10069.30 | 10082.40 | 10095.50 |
| 970 | 10108.60 | 10121.70 | 10134.70 | 10147.80 | 10160.90 | 10174.10 | 10187.20 | 10200.30 | 10213.40 | 10226.50 |
| 980 | 10239.70 | 10252.80 | 10265.90 | 10279.10 | 10292.20 | 10305.40 | 10318.50 | 10331.70 | 10344.80 | 10358.00 |
| 990 | 10371.20 | 10384.40 | 10397.50 | 10410.70 | 10423.90 | 10437.10 | 10450.30 | 10463.50 | 10476.70 | 10489.90 |
| 1000 | 10503.20 | 10516.40 | 10529.60 | 10542.80 | 10556.10 | 10569.30 | 10582.60 | 10595.80 | 10609.10 | 10622.30 |
| 1010 | 10635.60 | 10648.80 | 10662.10 | 10675.40 | 10688.70 | 10701.90 | 10715.20 | 10728.50 | 10741.80 | 10755.10 |
| 1020 | 10768.40 | 10781.70 | 10795.00 | 10808.40 | 10821.70 | 10835.00 | 10848.30 | 10861.70 | 10875.00 | 10888.30 |
| 1030 | 10901.70 | 10915.00 | 10928.40 | 10941.80 | 10955.10 | 10968.50 | 10981.90 | 10995.20 | 11008.60 | 11022.00 |
| 1040 | 11035.40 | 11048.80 | 11062.20 | 11075.60 | 11089.00 | 11102.40 | 11115.80 | 11129.30 | 11142.70 | 11156.10 |
| 1050 | 11169.50 | 11183.00 | 11196.40 | 11209.90 | 11223.30 | 11236.80 | 11250.20 | 11263.70 | 11277.20 | 11290.60 |
| 1060 | 11304.10 | 11317.60 | 11331.10 | 11344.60 | 11358.10 | 11371.50 | 11385.00 | 11398.60 | 11412.10 | 11425.60 |
| 1070 | 11439.10 | 11452.60 | 11466.10 | 11479.70 | 11493.20 | 11506.70 | 11520.30 | 11533.80 | 11547.40 | 11560.90 |
| 1080 | 11574.50 | 11588.00 | 11601.60 | 11615.10 | 11628.70 | 11642.30 | 11655.90 | 11669.40 | 11683.00 | 11696.60 |
| 1090 | 11710.20 | 11723.80 | 11737.40 | 11751.00 | 11764.60 | 11778.20 | 11791.80 | 11805.40 | 11819.00 | 11832.60 |
| 1100 | 11846.30 | 11859.90 | 11873.50 | 11887.20 | 11900.80 | 11914.40 | 11928.10 | 11941.70 | 11955.40 | 11969.00 |
| 1110 | 11982.70 | 11996.40 | 12010.00 | 12023.70 | 12037.40 | 12051.00 | 12064.70 | 12078.40 | 12092.10 | 12105.80 |
| 1120 | 12119.40 | 12133.10 | 12146.80 | 12160.50 | 12174.20 | 12187.90 | 12201.60 | 12215.40 | 12229.10 | 12242.80 |
| 1130 | 12256.50 | 12270.20 | 12284.00 | 12297.70 | 12311.40 | 12325.20 | 12338.90 | 12352.60 | 12366.40 | 12380.10 |
| 1140 | 12393.90 | 12407.60 | 12421.40 | 12435.10 | 12448.90 | 12462.70 | 12476.40 | 12490.20 | 12504.00 | 12517.80 |
| 1150 | 12531.50 | 12545.30 | 12559.10 | 12572.90 | 12586.70 | 12600.50 | 12614.30 | 12628.10 | 12641.90 | 12655.70 |
| 1160 | 12669.50 | 12683.30 | 12697.10 | 12710.90 | 12724.70 | 12738.60 | 12752.40 | 12766.20 | 12780.00 | 12793.90 |
| 1170 | 12807.70 | 12821.50 | 12835.40 | 12849.20 | 12863.10 | 12876.90 | 12890.80 | 12904.60 | 12918.50 | 12932.30 |
| 1180 | 12946.20 | 12960.00 | 12973.90 | 12987.80 | 13001.60 | 13015.50 | 13029.40 | 13043.30 | 13057.10 | 13071.00 |
| 1190 | 13084.90 | 13098.80 | 13112.70 | 13126.60 | 13140.50 | 13154.40 | 13168.30 | 13182.20 | 13196.10 | 13210.00 |
| 1200 | 13223.90 | 13237.80 | 13251.70 | 13265.60 | 13279.50 | 13293.40 | 13307.40 | 13321.30 | 13335.20 | 13349.10 |
| 1210 | 13363.10 | 13377.00 | 13390.90 | 13404.90 | 13418.80 | 13432.70 | 13446.70 | 13460.60 | 13474.60 | 13488.50 |
| 1220 | 13502.50 | 13516.40 | 13530.40 | 13544.30 | 13558.30 | 13572.20 | 13586.20 | 13600.20 | 13614.10 | 13628.10 |
| 1230 | 13642.10 | 13656.00 | 13670.00 | 13684.00 | 13697.90 | 13711.90 | 13725.90 | 13739.90 | 13753.90 | 13767.90 |
| 1240 | 13781.80 | 13795.80 | 13809.80 | 13823.80 | 13837.80 | 13851.80 | 13865.80 | 13879.80 | 13893.80 | 13907.80 |
| 1250 | 13921.80 | 13935.80 | 13949.80 | 13963.80 | 13977.80 | 13991.90 | 14005.90 | 14019.90 | 14033.90 | 14047.90 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 1260 | 14061.90 | 14076.00 | 14090.00 | 14104.00 | 14118.00 | 14132.10 | 14146.10 | 14160.10 | 14174.20 | 14188.20 |
| 1270 | 14202.20 | 14216.30 | 14230.30 | 14244.30 | 14258.40 | 14272.40 | 14286.50 | 14300.50 | 14314.60 | 14328.60 |
| 1280 | 14342.60 | 14356.70 | 14370.80 | 14384.80 | 14398.90 | 14412.90 | 14427.00 | 14441.00 | 14455.10 | 14469.10 |
| 1290 | 14483.20 | 14497.30 | 14511.30 | 14525.40 | 14539.50 | 14553.50 | 14567.60 | 14581.70 | 14595.70 | 14609.80 |
| 1300 | 14623.90 | 14638.00 | 14652.00 | 14666.10 | 14680.20 | 14694.30 | 14708.30 | 14722.40 | 14736.50 | 14750.60 |
| 1310 | 14764.70 | 14778.80 | 14792.80 | 14806.90 | 14821.00 | 14835.10 | 14849.20 | 14863.30 | 14877.40 | 14891.50 |
| 1320 | 14905.60 | 14919.70 | 14933.70 | 14947.80 | 14961.90 | 14976.00 | 14990.10 | 15004.20 | 15018.30 | 15032.40 |
| 1330 | 15046.50 | 15060.60 | 15074.70 | 15088.80 | 15102.90 | 15117.00 | 15131.10 | 15145.30 | 15159.40 | 15173.50 |
| 1340 | 15187.60 | 15201.70 | 15215.80 | 15229.90 | 15244 | 15258.10 | 15272.20 | 15286.30 | 15300.40 | 15314.60 |
| 1350 | 15328.70 | 15342.80 | 15356.90 | 15371.00 | 15385.10 | 15399.20 | 15413.40 | 15427.50 | 15441.60 | 15455.70 |
| 1360 | 15469.80 | 15483.90 | 15498.10 | 15512.20 | 15526.30 | 15540.40 | 15554.50 | 15568.70 | 15582.80 | 15596.90 |
| 1370 | 15611.00 | 15625.10 | 15639.30 | 15653.40 | 15667.50 | 15681.60 | 15695.70 | 15709.90 | 15724.00 | 15738.10 |
| 1380 | 15752.20 | 15766.40 | 15780.50 | 15794.60 | 15808.70 | 15822.90 | 15837.00 | 15851.10 | 15865.20 | 15879.30 |
| 1390 | 15893.50 | 15907.60 | 15921.70 | 15935.80 | 15950.00 | 15964.10 | 15978.20 | 15992.30 | 16006.50 | 16020.60 |
| 1400 | 16034.70 | 16048.80 | 16063.00 | 16077.10 | 16091.20 | 16105.30 | 16119.40 | 16133.60 | 16147.70 | 16161.80 |
| 1410 | 16175.90 | 16190.10 | 16204.20 | 16218.30 | 16232.40 | 16246.50 | 16260.70 | 16274.80 | 16288.90 | 16303.00 |
| 1420 | 16317.20 | 16331.30 | 16345.40 | 16359.50 | 16373.60 | 16387.70 | 16401.90 | 16416.00 | 16430.10 | 16444.20 |
| 1430 | 16458.30 | 16472.40 | 16486.60 | 16500.70 | 16514.80 | 16528.90 | 16543.00 | 16557.10 | 16571.20 | 16585.40 |
| 1440 | 16599.50 | 16613.60 | 16627.70 | 16641.80 | 16655.90 | 16670.00 | 16684.10 | 16698.20 | 16712.30 | 16726.40 |
| 1450 | 16740.50 | 16754.70 | 16768.80 | 16782.90 | 16797.00 | 16811.10 | 16825.20 | 16839.30 | 16853.40 | 16867.50 |
| 1460 | 16881.60 | 16895.70 | 16909.80 | 16923.90 | 16937.90 | 16952.00 | 16966.10 | 16980.20 | 16994.30 | 17008.40 |
| 1470 | 17022.50 | 17036.60 | 17050.70 | 17064.80 | 17078.90 | 17092.90 | 17107.00 | 17121.10 | 17135.20 | 17149.30 |
| 1480 | 17163.40 | 17177.40 | 17191.50 | 17205.60 | 17219.70 | 17233.70 | 17247.80 | 17261.90 | 17276.00 | 17290.00 |
| 1490 | 17304.10 | 17318.20 | 17332.20 | 17346.30 | 17360.40 | 17374.40 | 17388.50 | 17402.60 | 17416.60 | 17430.70 |
| 1500 | 17444.70 | 17458.80 | 17472.80 | 17486.90 | 17501.00 | 17515.00 | 17529.10 | 17543.10 | 17557.20 | 17571.20 |
| 1510 | 17585.20 | 17599.30 | 17613.30 | 17627.40 | 17641.40 | 17655.50 | 17669.50 | 17683.50 | 17697.60 | 17711.60 |
| 1520 | 17725.60 | 17739.70 | 17753.70 | 17767.70 | 17781.70 | 17795.80 | 17809.80 | 17823.80 | 17837.80 | 17851.80 |
| 1530 | 17865.90 | 17879.90 | 17893.90 | 17907.90 | 17921.90 | 17935.90 | 17949.90 | 17963.90 | 17977.90 | 17991.90 |
| 1540 | 18005.90 | 18019.90 | 18033.90 | 18047.90 | 18061.90 | 18075.90 | 18089.90 | 18103.90 | 18117.90 | 18131.80 |
| 1550 | 18145.80 | 18159.80 | 18173.80 | 18187.80 | 18201.70 | 18215.70 | 18229.70 | 18243.60 | 18257.60 | 18271.60 |
| 1560 | 18285.50 | 18299.50 | 18313.50 | 18327.40 | 18341.40 | 18355.30 | 18369.30 | 18383.20 | 18397.20 | 18411.10 |
| 1570 | 18425.10 | 18439.00 | 18452.90 | 18466.90 | 18480.80 | 18494.80 | 18508.70 | 18522.60 | 18536.50 | 18550.50 |
| 1580 | 18564.40 | 18578.30 | 18592.20 | 18606.10 | 18620.10 | 18634.00 | 18647.90 | 18661.80 | 18675.70 | 18689.60 |
| 1590 | 18703.50 | 18717.40 | 18731.30 | 18745.20 | 18759.10 | 18773.00 | 18786.80 | 18800.70 | 18814.60 | 18828.50 |
| 1600 | 18842.40 | 18856.20 | 18870.10 | 18884.00 | 18897.80 | 18911.70 | 18925.60 | 18939.40 | 18953.30 | 18967.10 |
| 1610 | 18981.00 | 18994.80 | 19008.70 | 19022.50 | 19036.40 | 19050.20 | 19064.10 | 19077.90 | 19091.70 | 19105.60 |
| 1620 | 19119.40 | 19133.20 | 19147.00 | 19160.80 | 19174.70 | 19188.50 | 19202.30 | 19216.10 | 19229.90 | 19243.70 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1630 | 19257.50 | 19271.30 | 19285.10 | 19298.90 | 19312.70 | 19326.50 | 19340.20 | 19354.00 | 19367.80 | 19381.60 |
| 1640 | 19395.30 | 19409.10 | 19422.90 | 19436.60 | 19450.40 | 19464.20 | 19477.90 | 19491.70 | 19505.40 | 19519.20 |
| 1650 | 19532.90 | 19546.60 | 19560.40 | 19574.10 | 19587.80 | 19601.60 | 19615.30 | 19629.00 | 19642.70 | 19656.40 |
| 1660 | 19670.20 | 19683.90 | 19697.60 | 19711.30 | 19725.00 | 19738.70 | 19752.40 | 19766.10 | 19779.70 | 19793.40 |
| 1670 | 19807.10 | 19820.80 | 19834.50 | 19848.10 | 19861.80 | 19875.40 | 19889.10 | 19902.80 | 19916.40 | 19930.00 |
| 1680 | 19943.70 | 19957.30 | 19970.90 | 19984.50 | 19998.20 | 20011.80 | 20025.40 | 20039.00 | 20052.60 | 20066.10 |
| 1690 | 20079.70 | 20093.30 | 20106.90 | 20120.40 | 20134.00 | 20147.50 | 20161.00 | 20174.60 | 20188.10 | 20201.60 |
| 1700 | 20215.10 | 20228.60 | 20242.10 | 20255.60 | 20269.10 | 20282.50 | 20296.00 | 20309.40 | 20322.90 | 20336.30 |
| 1710 | 20349.70 | 20363.10 | 20376.50 | 20389.90 | 20403.30 | 20416.70 | 20430.10 | 20443.40 | 20456.80 | 20470.10 |
| 1720 | 20483.40 | 20496.70 | 20510.00 | 20523.30 | 20536.60 | 20549.90 | 20563.10 | 20576.40 | 20589.60 | 20602.90 |
| 1730 | 20616.10 | 20629.30 | 20642.50 | 20655.60 | 20668.80 | 20682.00 | 20695.10 | 20708.20 | 20721.30 | 20734.40 |
| 1740 | 20747.50 | 20760.60 | 20773.70 | 20786.70 | 20799.80 | 20812.80 | 20825.80 | 20838.80 | 20851.80 | 20864.70 |
| 1750 | 20877.70 | 20890.60 | 20903.50 | 20916.40 | 20929.30 | 20942.20 | 20955.10 | 20967.90 | 20980.70 | 20993.60 |

## 62.19 S-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology (NIST) in the US for a metal pair of Platinum vs.Platinum-10% Rhodium referenced to a cold junction at 0°C. S is the letter designation approved by the American Institute for Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the µV produced in intervals of 1°C. For example -231.71 µV is produced at -49°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -50 | -235.69 | -231.71 | -227.69 | -223.65 | -219.57 | -215.46 | -211.32 | -207.15 | -202.94 | -198.71 |
| -40 | -194.44 | -190.14 | -185.81 | -181.45 | -177.06 | -172.64 | -168.19 | -163.71 | -159.20 | -154.66 |
| -30 | -150.09 | -145.49 | -140.86 | -136.20 | -131.52 | -126.80 | -122.06 | -117.29 | -112.49 | -107.66 |
| -20 | -102.80 | -97.91 | -93.00 | -88.06 | -83.09 | -78.10 | -73.08 | -68.03 | -62.95 | -57.85 |
| -10 | -52.72 | -47.57 | -42.38 | -37.18 | -31.94 | -26.68 | -21.40 | -16.09 | -10.75 | -5.39 |
| 0 | 0.00 | 5.41 | 10.85 | 16.31 | 21.80 | 27.31 | 32.84 | 38.40 | 43.99 | 49.59 |
| 10 | 55.23 | 60.88 | 66.56 | 72.26 | 77.99 | 83.74 | 89.51 | 95.30 | 101.12 | 106.96 |
| 20 | 112.82 | 118.71 | 124.62 | 130.55 | 136.50 | 142.47 | 148.47 | 154.49 | 160.53 | 166.59 |
| 30 | 172.67 | 178.78 | 184.90 | 191.05 | 197.21 | 203.40 | 209.61 | 215.84 | 222.09 | 228.36 |
| 40 | 234.65 | 240.96 | 247.29 | 253.64 | 260.01 | 266.40 | 272.81 | 279.24 | 285.69 | 292.16 |
| 50 | 298.64 | 305.15 | 311.67 | 318.22 | 324.78 | 331.36 | 337.96 | 344.58 | 351.22 | 357.88 |
| 60 | 364.55 | 371.24 | 377.95 | 384.68 | 391.42 | 398.19 | 404.97 | 411.77 | 418.58 | 425.41 |
| 70 | 432.26 | 439.13 | 446.02 | 452.92 | 459.84 | 466.77 | 473.72 | 480.69 | 487.67 | 494.68 |
| 80 | 501.69 | 508.73 | 515.78 | 522.84 | 529.92 | 537.02 | 544.14 | 551.27 | 558.41 | 565.57 |
| 90 | 572.75 | 579.94 | 587.14 | 594.37 | 601.60 | 608.85 | 616.12 | 623.40 | 630.70 | 638.01 |
| 100 | 645.34 | 652.68 | 660.03 | 667.40 | 674.79 | 682.18 | 689.60 | 697.02 | 704.46 | 711.92 |
| 110 | 719.38 | 726.87 | 734.36 | 741.87 | 749.39 | 756.93 | 764.48 | 772.04 | 779.62 | 787.21 |
| 120 | 794.81 | 802.43 | 810.05 | 817.70 | 825.35 | 833.02 | 840.70 | 848.39 | 856.10 | 863.81 |
| 130 | 871.54 | 879.29 | 887.04 | 894.81 | 902.59 | 910.38 | 918.18 | 926.00 | 933.83 | 941.67 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 140 | 949.52 | 957.38 | 965.26 | 973.14 | 981.04 | 988.95 | 996.87 | 1004.80 | 1012.75 | 1020.70 |
| 150 | 1028.67 | 1036.64 | 1044.63 | 1052.63 | 1060.64 | 1068.66 | 1076.69 | 1084.73 | 1092.79 | 1100.85 |
| 160 | 1108.93 | 1117.01 | 1125.11 | 1133.21 | 1141.33 | 1149.46 | 1157.59 | 1165.74 | 1173.90 | 1182.07 |
| 170 | 1190.24 | 1198.43 | 1206.63 | 1214.84 | 1223.05 | 1231.28 | 1239.52 | 1247.77 | 1256.02 | 1264.29 |
| 180 | 1272.56 | 1280.85 | 1289.14 | 1297.45 | 1305.76 | 1314.08 | 1322.41 | 1330.76 | 1339.11 | 1347.47 |
| 190 | 1355.83 | 1364.21 | 1372.60 | 1380.99 | 1389.40 | 1397.81 | 1406.23 | 1414.66 | 1423.10 | 1431.55 |
| 200 | 1440.01 | 1448.47 | 1456.95 | 1465.43 | 1473.92 | 1482.42 | 1490.93 | 1499.44 | 1507.97 | 1516.50 |
| 210 | 1525.04 | 1533.59 | 1542.14 | 1550.71 | 1559.28 | 1567.86 | 1576.45 | 1585.05 | 1593.65 | 1602.27 |
| 220 | 1610.89 | 1619.51 | 1628.15 | 1636.79 | 1645.44 | 1654.10 | 1662.77 | 1671.44 | 1680.12 | 1688.81 |
| 230 | 1697.51 | 1706.21 | 1714.92 | 1723.64 | 1732.37 | 1741.10 | 1749.84 | 1758.58 | 1767.34 | 1776.10 |
| 240 | 1784.87 | 1793.64 | 1802.42 | 1811.21 | 1820.01 | 1828.81 | 1837.62 | 1846.44 | 1855.26 | 1864.09 |
| 250 | 1872.93 | 1881.77 | 1890.62 | 1899.48 | 1908.34 | 1917.21 | 1926.09 | 1934.97 | 1943.86 | 1952.76 |
| 260 | 1961.66 | 1970.57 | 1979.49 | 1988.41 | 1997.33 | 2006.27 | 2015.21 | 2024.15 | 2033.11 | 2042.07 |
| 270 | 2051.03 | 2060.00 | 2068.98 | 2077.96 | 2086.95 | 2095.95 | 2104.95 | 2113.95 | 2122.97 | 2131.98 |
| 280 | 2141.01 | 2150.04 | 2159.08 | 2168.12 | 2177.16 | 2186.22 | 2195.28 | 2204.34 | 2213.41 | 2222.49 |
| 290 | 2231.57 | 2240.66 | 2249.75 | 2258.85 | 2267.95 | 2277.06 | 2286.17 | 2295.29 | 2304.42 | 2313.55 |
| 300 | 2322.68 | 2331.82 | 2340.97 | 2350.12 | 2359.28 | 2368.44 | 2377.61 | 2386.78 | 2395.96 | 2405.14 |
| 310 | 2414.33 | 2423.52 | 2432.72 | 2441.92 | 2451.13 | 2460.34 | 2469.56 | 2478.78 | 2488.01 | 2497.25 |
| 320 | 2506.48 | 2515.73 | 2524.97 | 2534.23 | 2543.48 | 2552.74 | 2562.01 | 2571.28 | 2580.56 | 2589.84 |
| 330 | 2599.12 | 2608.41 | 2617.71 | 2627.01 | 2636.31 | 2645.62 | 2654.93 | 2664.25 | 2673.58 | 2682.90 |
| 340 | 2692.23 | 2701.57 | 2710.91 | 2720.25 | 2729.60 | 2738.96 | 2748.31 | 2757.68 | 2767.04 | 2776.41 |
| 350 | 2785.79 | 2795.17 | 2804.55 | 2813.94 | 2823.33 | 2832.73 | 2842.13 | 2851.54 | 2860.95 | 2870.36 |
| 360 | 2879.78 | 2889.20 | 2898.63 | 2908.06 | 2917.49 | 2926.93 | 2936.37 | 2945.82 | 2955.27 | 2964.72 |
| 370 | 2974.18 | 2983.64 | 2993.11 | 3002.58 | 3012.05 | 3021.53 | 3031.02 | 3040.50 | 3049.99 | 3059.49 |
| 380 | 3068.98 | 3078.48 | 3087.99 | 3097.50 | 3107.01 | 3116.53 | 3126.05 | 3135.57 | 3145.10 | 3154.64 |
| 390 | 3164.17 | 3173.71 | 3183.25 | 3192.80 | 3202.35 | 3211.90 | 3221.46 | 3231.02 | 3240.59 | 3250.16 |
| 400 | 3259.73 | 3269.31 | 3278.89 | 3288.47 | 3298.06 | 3307.65 | 3317.24 | 3326.84 | 3336.44 | 3346.04 |
| 410 | 3355.65 | 3365.26 | 3374.88 | 3384.49 | 3394.12 | 3403.74 | 3413.37 | 3423.00 | 3432.64 | 3442.28 |
| 420 | 3451.92 | 3461.56 | 3471.21 | 3480.87 | 3490.52 | 3500.18 | 3509.84 | 3519.51 | 3529.18 | 3538.85 |
| 430 | 3548.53 | 3558.21 | 3567.89 | 3577.57 | 3587.26 | 3596.95 | 3606.65 | 3616.35 | 3626.05 | 3635.76 |
| 440 | 3645.46 | 3655.18 | 3664.89 | 3674.61 | 3684.33 | 3694.05 | 3703.78 | 3713.51 | 3723.24 | 3732.98 |
| 450 | 3742.72 | 3752.46 | 3762.21 | 3771.96 | 3781.71 | 3791.47 | 3801.23 | 3810.99 | 3820.75 | 3830.52 |
| 460 | 3840.29 | 3850.07 | 3859.84 | 3869.62 | 3879.41 | 3889.19 | 3898.98 | 3908.78 | 3918.57 | 3928.37 |
| 470 | 3938.17 | 3947.98 | 3957.78 | 3967.59 | 3977.41 | 3987.22 | 3997.04 | 4006.86 | 4016.69 | 4026.52 |
| 480 | 4036.35 | 4046.18 | 4056.02 | 4065.86 | 4075.70 | 4085.55 | 4095.40 | 4105.25 | 4115.11 | 4124.96 |
| 490 | 4134.83 | 4144.69 | 4154.56 | 4164.43 | 4174.30 | 4184.17 | 4194.05 | 4203.93 | 4213.82 | 4223.70 |
| 500 | 4233.59 | 4243.49 | 4253.38 | 4263.28 | 4273.18 | 4283.09 | 4292.99 | 4302.90 | 4312.82 | 4322.73 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 510 | 4332.65 | 4342.57 | 4352.50 | 4362.43 | 4372.36 | 4382.29 | 4392.22 | 4402.16 | 4412.11 | 4422.05 |
| 520 | 4432.00 | 4441.95 | 4451.90 | 4461.86 | 4471.82 | 4481.78 | 4491.74 | 4501.71 | 4511.68 | 4521.65 |
| 530 | 4531.63 | 4541.61 | 4551.59 | 4561.58 | 4571.57 | 4581.56 | 4591.55 | 4601.55 | 4611.55 | 4621.55 |
| 540 | 4631.55 | 4641.56 | 4651.57 | 4661.59 | 4671.60 | 4681.62 | 4691.64 | 4701.67 | 4711.70 | 4721.73 |
| 550 | 4731.76 | 4741.80 | 4751.84 | 4761.88 | 4771.93 | 4781.98 | 4792.03 | 4802.08 | 4812.14 | 4822.20 |
| 560 | 4832.27 | 4842.33 | 4852.40 | 4862.47 | 4872.55 | 4882.63 | 4892.71 | 4902.79 | 4912.88 | 4922.97 |
| 570 | 4933.06 | 4943.16 | 4953.26 | 4963.36 | 4973.47 | 4983.58 | 4993.69 | 5003.80 | 5013.92 | 5024.04 |
| 580 | 5034.16 | 5044.29 | 5054.42 | 5064.55 | 5074.69 | 5084.83 | 5094.97 | 5105.12 | 5115.27 | 5125.42 |
| 590 | 5135.57 | 5145.73 | 5155.89 | 5166.06 | 5176.22 | 5186.40 | 5196.57 | 5206.75 | 5216.93 | 5227.11 |
| 600 | 5237.30 | 5247.49 | 5257.68 | 5267.88 | 5278.08 | 5288.28 | 5298.49 | 5308.70 | 5318.91 | 5329.13 |
| 610 | 5339.35 | 5349.57 | 5359.80 | 5370.03 | 5380.27 | 5390.50 | 5400.74 | 5410.99 | 5421.23 | 5431.49 |
| 620 | 5441.74 | 5452.00 | 5462.26 | 5472.53 | 5482.79 | 5493.07 | 5503.34 | 5513.62 | 5523.91 | 5534.19 |
| 630 | 5544.48 | 5554.78 | 5565.10 | 5575.42 | 5585.74 | 5596.06 | 5606.39 | 5616.72 | 5627.06 | 5637.40 |
| 640 | 5647.74 | 5658.09 | 5668.44 | 5678.79 | 5689.14 | 5699.50 | 5709.86 | 5720.23 | 5730.60 | 5740.97 |
| 650 | 5751.34 | 5761.72 | 5772.10 | 5782.49 | 5792.87 | 5803.27 | 5813.66 | 5824.06 | 5834.46 | 5844.86 |
| 660 | 5855.27 | 5865.68 | 5876.10 | 5886.52 | 5896.94 | 5907.36 | 5917.79 | 5928.22 | 5938.65 | 5949.09 |
| 670 | 5959.53 | 5969.98 | 5980.42 | 5990.87 | 6001.33 | 6011.78 | 6022.25 | 6032.71 | 6043.18 | 6053.65 |
| 680 | 6064.12 | 6074.60 | 6085.08 | 6095.56 | 6106.05 | 6116.54 | 6127.03 | 6137.53 | 6148.03 | 6158.53 |
| 690 | 6169.04 | 6179.55 | 6190.06 | 6200.58 | 6211.10 | 6221.62 | 6232.15 | 6242.68 | 6253.21 | 6263.74 |
| 700 | 6274.28 | 6284.83 | 6295.37 | 6305.92 | 6316.47 | 6327.03 | 6337.59 | 6348.15 | 6358.72 | 6369.29 |
| 710 | 6379.86 | 6390.43 | 6401.01 | 6411.60 | 6422.18 | 6432.77 | 6443.36 | 6453.96 | 6464.56 | 6475.16 |
| 720 | 6485.76 | 6496.37 | 6506.98 | 6517.60 | 6528.22 | 6538.84 | 6549.46 | 6560.09 | 6570.72 | 6581.36 |
| 730 | 6592.00 | 6602.64 | 6613.28 | 6623.93 | 6634.58 | 6645.24 | 6655.90 | 6666.56 | 6677.22 | 6687.89 |
| 740 | 6698.56 | 6709.23 | 6719.91 | 6730.59 | 6741.28 | 6751.97 | 6762.66 | 6773.35 | 6784.05 | 6794.75 |
| 750 | 6805.45 | 6816.16 | 6826.87 | 6837.58 | 6848.30 | 6859.02 | 6869.75 | 6880.47 | 6891.20 | 6901.94 |
| 760 | 6912.67 | 6923.41 | 6934.16 | 6944.90 | 6955.65 | 6966.41 | 6977.16 | 6987.92 | 6998.69 | 7009.45 |
| 770 | 7020.22 | 7031.00 | 7041.77 | 7052.55 | 7063.34 | 7074.12 | 7084.91 | 7095.70 | 7106.50 | 7117.30 |
| 780 | 7128.10 | 7138.91 | 7149.72 | 7160.53 | 7171.35 | 7182.17 | 7192.99 | 7203.81 | 7214.64 | 7225.47 |
| 790 | 7236.31 | 7247.15 | 7257.99 | 7268.84 | 7279.69 | 7290.54 | 7301.39 | 7312.25 | 7323.11 | 7333.98 |
| 800 | 7344.85 | 7355.72 | 7366.59 | 7377.47 | 7388.35 | 7399.24 | 7410.13 | 7421.02 | 7431.91 | 7442.81 |
| 810 | 7453.71 | 7464.62 | 7475.53 | 7486.44 | 7497.35 | 7508.27 | 7519.19 | 7530.12 | 7541.04 | 7551.98 |
| 820 | 7562.91 | 7573.85 | 7584.79 | 7595.73 | 7606.68 | 7617.63 | 7628.58 | 7639.54 | 7650.50 | 7661.47 |
| 830 | 7672.43 | 7683.40 | 7694.38 | 7705.36 | 7716.34 | 7727.32 | 7738.31 | 7749.30 | 7760.29 | 7771.29 |
| 840 | 7782.29 | 7793.29 | 7804.30 | 7815.31 | 7826.32 | 7837.34 | 7848.36 | 7859.38 | 7870.41 | 7881.44 |
| 850 | 7892.47 | 7903.51 | 7914.55 | 7925.59 | 7936.64 | 7947.68 | 7958.74 | 7969.79 | 7980.85 | 7991.92 |
| 860 | 8002.98 | 8014.05 | 8025.12 | 8036.20 | 8047.28 | 8058.36 | 8069.45 | 8080.54 | 8091.63 | 8102.72 |
| 870 | 8113.82 | 8124.92 | 8136.03 | 8147.14 | 8158.25 | 8169.37 | 8180.49 | 8191.61 | 8202.73 | 8213.86 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 880 | 8224.99 | 8236.13 | 8247.27 | 8258.41 | 8269.55 | 8280.70 | 8291.85 | 8303.01 | 8314.17 | 8325.33 |
| 890 | 8336.49 | 8347.66 | 8358.83 | 8370.01 | 8381.18 | 8392.36 | 8403.55 | 8414.74 | 8425.93 | 8437.12 |
| 900 | 8448.32 | 8459.52 | 8470.72 | 8481.93 | 8493.14 | 8504.36 | 8515.57 | 8526.79 | 8538.02 | 8549.25 |
| 910 | 8560.48 | 8571.71 | 8582.95 | 8594.19 | 8605.43 | 8616.68 | 8627.93 | 8639.18 | 8650.44 | 8661.70 |
| 920 | 8672.96 | 8684.23 | 8695.50 | 8706.77 | 8718.05 | 8729.33 | 8740.61 | 8751.90 | 8763.19 | 8774.48 |
| 930 | 8785.78 | 8797.08 | 8808.38 | 8819.69 | 8831.00 | 8842.31 | 8853.63 | 8864.94 | 8876.27 | 8887.59 |
| 940 | 8898.92 | 8910.25 | 8921.59 | 8932.93 | 8944.27 | 8955.62 | 8966.97 | 8978.32 | 8989.67 | 9001.03 |
| 950 | 9012.40 | 9023.76 | 9035.13 | 9046.50 | 9057.88 | 9069.26 | 9080.64 | 9092.02 | 9103.41 | 9114.80 |
| 960 | 9126.20 | 9137.60 | 9149.00 | 9160.40 | 9171.81 | 9183.22 | 9194.64 | 9206.06 | 9217.48 | 9228.90 |
| 970 | 9240.33 | 9251.76 | 9263.20 | 9274.63 | 9286.07 | 9297.52 | 9308.97 | 9320.42 | 9331.87 | 9343.33 |
| 980 | 9354.79 | 9366.25 | 9377.72 | 9389.19 | 9400.67 | 9412.14 | 9423.62 | 9435.11 | 9446.60 | 9458.09 |
| 990 | 9469.58 | 9481.08 | 9492.58 | 9504.08 | 9515.59 | 9527.10 | 9538.61 | 9550.13 | 9561.65 | 9573.17 |
| 1000 | 9584.70 | 9596.23 | 9607.76 | 9619.30 | 9630.84 | 9642.38 | 9653.93 | 9665.48 | 9677.03 | 9688.59 |
| 1010 | 9700.15 | 9711.71 | 9723.28 | 9734.85 | 9746.42 | 9757.99 | 9769.57 | 9781.16 | 9792.74 | 9804.33 |
| 1020 | 9815.92 | 9827.52 | 9839.12 | 9850.72 | 9862.33 | 9873.94 | 9885.55 | 9897.16 | 9908.78 | 9920.40 |
| 1030 | 9932.03 | 9943.66 | 9955.29 | 9966.93 | 9978.56 | 9990.21 | 10001.90 | 10013.50 | 10025.20 | 10036.80 |
| 1040 | 10048.50 | 10060.10 | 10071.80 | 10083.50 | 10095.10 | 10106.80 | 10118.50 | 10130.20 | 10141.90 | 10153.50 |
| 1050 | 10165.20 | 10176.90 | 10188.60 | 10200.30 | 10212.00 | 10223.70 | 10235.50 | 10247.20 | 10258.90 | 10270.60 |
| 1060 | 10282.30 | 10294.10 | 10305.80 | 10317.50 | 10329.30 | 10341.00 | 10352.70 | 10364.50 | 10376.20 | 10388.00 |
| 1070 | 10399.70 | 10411.50 | 10423.30 | 10435.00 | 10446.80 | 10458.60 | 10470.30 | 10482.10 | 10493.90 | 10505.60 |
| 1080 | 10517.40 | 10529.20 | 10541.00 | 10552.80 | 10564.60 | 10576.40 | 10588.20 | 10600.00 | 10611.80 | 10623.60 |
| 1090 | 10635.40 | 10647.20 | 10659.00 | 10670.80 | 10682.60 | 10694.40 | 10706.30 | 10718.10 | 10729.90 | 10741.70 |
| 1100 | 10753.60 | 10765.40 | 10777.20 | 10789.10 | 10800.90 | 10812.70 | 10824.60 | 10836.40 | 10848.30 | 10860.10 |
| 1110 | 10872 | 10883.80 | 10895.70 | 10907.60 | 10919.40 | 10931.30 | 10943.20 | 10955.00 | 10966.90 | 10978.80 |
| 1120 | 10990.70 | 11002.50 | 11014.40 | 11026.30 | 11038.20 | 11050.10 | 11062.00 | 11073.80 | 11085.70 | 11097.60 |
| 1130 | 11109.50 | 11121.40 | 11133.30 | 11145.20 | 11157.10 | 11169.10 | 11181.00 | 11192.90 | 11204.80 | 11216.70 |
| 1140 | 11228.60 | 11240.50 | 11252.50 | 11264.40 | 11276.30 | 11288.20 | 11300.20 | 11312.10 | 11324.00 | 11336.00 |
| 1150 | 11347.90 | 11359.90 | 11371.80 | 11383.70 | 11395.70 | 11407.60 | 11419.60 | 11431.50 | 11443.50 | 11455.40 |
| 1160 | 11467.40 | 11479.40 | 11491.30 | 11503.30 | 11515.20 | 11527.20 | 11539.20 | 11551.10 | 11563.10 | 11575.10 |
| 1170 | 11587.10 | 11599.00 | 11611.00 | 11623.00 | 11635.00 | 11647.00 | 11658.90 | 11670.90 | 11682.90 | 11694.90 |
| 1180 | 11706.90 | 11718.90 | 11730.90 | 11742.90 | 11754.90 | 11766.90 | 11778.90 | 11790.90 | 11802.90 | 11814.90 |
| 1190 | 11826.90 | 11838.90 | 11850.90 | 11862.90 | 11874.90 | 11887.00 | 11899.00 | 11911.00 | 11923.00 | 11935.00 |
| 1200 | 11947.10 | 11959.10 | 11971.10 | 11983.10 | 11995.20 | 12007.20 | 12019.20 | 12031.30 | 12043.30 | 12055.30 |
| 1210 | 12067.40 | 12079.40 | 12091.40 | 12103.50 | 12115.50 | 12127.60 | 12139.60 | 12151.60 | 12163.70 | 12175.70 |
| 1220 | 12187.80 | 12199.80 | 12211.90 | 12223.90 | 12236.00 | 12248.10 | 12260.10 | 12272.20 | 12284.20 | 12296.30 |
| 1230 | 12308.40 | 12320.40 | 12332.50 | 12344.50 | 12356.60 | 12368.70 | 12380.70 | 12392.80 | 12404.90 | 12417.00 |
| 1240 | 12429.00 | 12441.10 | 12453.20 | 12465.30 | 12477.30 | 12489.40 | 12501.50 | 12513.60 | 12525.60 | 12537.70 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1250 | 12549.80 | 12561.90 | 12574.00 | 12586.10 | 12598.20 | 12610.20 | 12622.30 | 12634.40 | 12646.50 | 12658.60 |
| 1260 | 12670.70 | 12682.80 | 12694.90 | 12707.00 | 12719.10 | 12731.20 | 12743.30 | 12755.40 | 12767.50 | 12779.60 |
| 1270 | 12791.70 | 12803.80 | 12815.90 | 12828.00 | 12840.10 | 12852.20 | 12864.30 | 12876.40 | 12888.50 | 12900.60 |
| 1280 | 12912.70 | 12924.80 | 12936.90 | 12949.00 | 12961.10 | 12973.30 | 12985.40 | 12997.50 | 13009.60 | 13021.70 |
| 1290 | 13033.80 | 13045.90 | 13058.10 | 13070.20 | 13082.30 | 13094.40 | 13106.50 | 13118.60 | 13130.80 | 13142.90 |
| 1300 | 13155.00 | 13167.10 | 13179.20 | 13191.40 | 13203.50 | 13215.60 | 13227.70 | 13239.90 | 13252.00 | 13264.10 |
| 1310 | 13276.20 | 13288.40 | 13300.50 | 13312.60 | 13324.70 | 13336.90 | 13349.00 | 13361.10 | 13373.20 | 13385.40 |
| 1320 | 13397.50 | 13409.60 | 13421.80 | 13433.90 | 13446.00 | 13458.10 | 13470.30 | 13482.40 | 13494.50 | 13506.70 |
| 1330 | 13518.80 | 13530.90 | 13543.10 | 13555.20 | 13567.30 | 13579.40 | 13591.60 | 13603.70 | 13615.80 | 13628.00 |
| 1340 | 13640.10 | 13652.20 | 13664.40 | 13676.50 | 13688.60 | 13700.80 | 13712.90 | 13725.00 | 13737.20 | 13749.30 |
| 1350 | 13761.40 | 13773.60 | 13785.70 | 13797.80 | 13810.00 | 13822.10 | 13834.20 | 13846.40 | 13858.50 | 13870.60 |
| 1360 | 13882.80 | 13894.90 | 13907.00 | 13919.20 | 13931.30 | 13943.40 | 13955.60 | 13967.70 | 13979.80 | 13992.00 |
| 1370 | 14004.10 | 14016.20 | 14028.40 | 14040.50 | 14052.60 | 14064.80 | 14076.90 | 14089.00 | 14101.20 | 14113.30 |
| 1380 | 14125.40 | 14137.50 | 14149.70 | 14161.80 | 14173.90 | 14186.10 | 14198.20 | 14210.30 | 14222.50 | 14234.60 |
| 1390 | 14246.70 | 14258.80 | 14271.00 | 14283.10 | 14295.20 | 14307.30 | 14319.50 | 14331.60 | 14343.70 | 14355.80 |
| 1400 | 14368.00 | 14380.10 | 14392.20 | 14404.30 | 14416.40 | 14428.60 | 14440.70 | 14452.80 | 14464.90 | 14477.00 |
| 1410 | 14489.20 | 14501.30 | 14513.40 | 14525.50 | 14537.60 | 14549.80 | 14561.90 | 14574.00 | 14586.10 | 14598.20 |
| 1420 | 14610.30 | 14622.40 | 14634.50 | 14646.70 | 14658.80 | 14670.90 | 14683.00 | 14695.10 | 14707.20 | 14719.30 |
| 1430 | 14731.40 | 14743.50 | 14755.60 | 14767.70 | 14779.80 | 14791.90 | 14804.00 | 14816.10 | 14828.20 | 14840.30 |
| 1440 | 14852.40 | 14864.50 | 14876.60 | 14888.70 | 14900.80 | 14912.90 | 14925.00 | 14937.10 | 14949.20 | 14961.30 |
| 1450 | 14973.40 | 14985.50 | 14997.50 | 15009.60 | 15021.70 | 15033.80 | 15045.90 | 15058.00 | 15070.10 | 15082.10 |
| 1460 | 15094.20 | 15106.30 | 15118.40 | 15130.50 | 15142.50 | 15154.60 | 15166.70 | 15178.70 | 15190.80 | 15202.90 |
| 1470 | 15215.00 | 15227.00 | 15239.10 | 15251.20 | 15263.20 | 15275.30 | 15287.40 | 15299.40 | 15311.50 | 15323.50 |
| 1480 | 15335.60 | 15347.70 | 15359.70 | 15371.80 | 15383.80 | 15395.90 | 15407.90 | 15420.00 | 15432.00 | 15444.10 |
| 1490 | 15456.10 | 15468.20 | 15480.20 | 15492.20 | 15504.30 | 15516.30 | 15528.40 | 15540.40 | 15552.40 | 15564.50 |
| 1500 | 15576.50 | 15588.50 | 15600.60 | 15612.60 | 15624.60 | 15636.60 | 15648.70 | 15660.70 | 15672.70 | 15684.70 |
| 1510 | 15696.70 | 15708.80 | 15720.80 | 15732.80 | 15744.80 | 15756.80 | 15768.80 | 15780.80 | 15792.80 | 15804.80 |
| 1520 | 15816.80 | 15828.80 | 15840.80 | 15852.80 | 15864.80 | 15876.80 | 15888.80 | 15900.80 | 15912.80 | 15924.80 |
| 1530 | 15936.80 | 15948.80 | 15960.80 | 15972.70 | 15984.70 | 15996.70 | 16008.70 | 16020.60 | 16032.60 | 16044.60 |
| 1540 | 16056.60 | 16068.50 | 16080.50 | 16092.50 | 16104.40 | 16116.40 | 16128.30 | 16140.30 | 16152.30 | 16164.20 |
| 1550 | 16176.20 | 16188.10 | 16200.10 | 16212.00 | 16224.00 | 16235.90 | 16247.80 | 16259.80 | 16271.70 | 16283.60 |
| 1560 | 16295.60 | 16307.50 | 16319.40 | 16331.40 | 16343.30 | 16355.20 | 16367.10 | 16379.00 | 16391.00 | 16402.90 |
| 1570 | 16414.80 | 16426.70 | 16438.60 | 16450.50 | 16462.40 | 16474.30 | 16486.20 | 16498.10 | 16510.00 | 16521.90 |
| 1580 | 16533.80 | 16545.70 | 16557.60 | 16569.50 | 16581.40 | 16593.20 | 16605.10 | 16617.00 | 16628.90 | 16640.70 |
| 1590 | 16652.60 | 16664.50 | 16676.30 | 16688.20 | 16700.10 | 16711.90 | 16723.80 | 16735.60 | 16747.50 | 16759.30 |
| 1600 | 16771.20 | 16783.00 | 16794.90 | 16806.70 | 16818.60 | 16830.40 | 16842.20 | 16854.00 | 16865.90 | 16877.70 |
| 1610 | 16889.50 | 16901.30 | 16913.20 | 16925.00 | 16936.80 | 16948.60 | 16960.40 | 16972.20 | 16984.00 | 16995.80 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1620 | 17007.60 | 17019.40 | 17031.20 | 17043.00 | 17054.80 | 17066.60 | 17078.40 | 17090.20 | 17101.90 | 17113.70 |
| 1630 | 17125.50 | 17137.20 | 17149.00 | 17160.80 | 17172.50 | 17184.30 | 17196.10 | 17207.80 | 17219.60 | 17231.30 |
| 1640 | 17243.10 | 17254.80 | 17266.60 | 17278.30 | 17290.00 | 17301.80 | 17313.50 | 17325.20 | 17336.90 | 17348.70 |
| 1650 | 17360.40 | 17372.10 | 17383.80 | 17395.50 | 17407.20 | 17418.90 | 17430.60 | 17442.30 | 17454.00 | 17465.70 |
| 1660 | 17477.40 | 17489.10 | 17500.80 | 17512.50 | 17524.20 | 17535.80 | 17547.50 | 17559.20 | 17570.80 | 17582.50 |
| 1670 | 17594.20 | 17605.80 | 17617.50 | 17629.10 | 17640.80 | 17652.40 | 17664.00 | 17675.70 | 17687.30 | 17698.90 |
| 1680 | 17710.50 | 17722.20 | 17733.80 | 17745.40 | 17757.00 | 17768.60 | 17780.10 | 17791.70 | 17803.30 | 17814.90 |
| 1690 | 17826.40 | 17838.00 | 17849.50 | 17861.10 | 17872.60 | 17884.10 | 17895.70 | 17907.20 | 17918.70 | 17930.20 |
| 1700 | 17941.70 | 17953.20 | 17964.70 | 17976.10 | 17987.60 | 17999.00 | 18010.50 | 18021.90 | 18033.30 | 18044.80 |
| 1710 | 18056.20 | 18067.60 | 18079 | 18090.40 | 18101.70 | 18113.10 | 18124.40 | 18135.80 | 18147.10 | 18158.40 |
| 1720 | 18169.80 | 18181.10 | 18192.40 | 18203.60 | 18214.90 | 18226.20 | 18237.40 | 18248.70 | 18259.90 | 18271.10 |
| 1730 | 18282.30 | 18293.50 | 18304.70 | 18315.90 | 18327.00 | 18338.20 | 18349.30 | 18360.40 | 18371.50 | 18382.60 |
| 1740 | 18393.70 | 18404.80 | 18415.80 | 18426.90 | 18437.90 | 18448.90 | 18459.90 | 18470.90 | 18481.90 | 18492.80 |
| 1750 | 18503.80 | 18514.70 | 18525.60 | 18536.50 | 18547.40 | 18558.30 | 18569.10 | 18580.00 | 18590.80 | 18601.60 |

## 62.20 T-type thermocouple tables

The following table is as compiled by the National Institute of Standards and Technology (NIST) in the US for a metal pair of Copper Vs. Copper-Nickel referenced to a cold junction at 0°C. T is the letter designation approved by the American Institute for Standards (ANSI). The column to the left is temperature in °C. The columns to the right are the μV produced in intervals of 1°C. For example -6256.38 μV is produced at -269°C.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -270 | -6257.58 | -6256.38 | -6254.82 | -6252.94 | -6250.74 | -6248.25 | -6245.49 | -6242.46 | -6239.17 | -6235.62 |
| -260 | -6231.83 | -6227.79 | -6223.50 | -6218.98 | -6214.21 | -6209.20 | -6203.95 | -6198.46 | -6192.72 | -6186.75 |
| -250 | -6180.53 | -6174.06 | -6167.36 | -6160.41 | -6153.22 | -6145.79 | -6138.13 | -6130.22 | -6122.08 | -6113.70 |
| -240 | -6105.09 | -6096.25 | -6087.18 | -6077.89 | -6068.37 | -6058.64 | -6048.69 | -6038.53 | -6028.16 | -6017.58 |
| -230 | -6006.80 | -5995.82 | -5984.64 | -5973.27 | -5961.71 | -5949.97 | -5938.04 | -5925.93 | -5913.64 | -5901.18 |
| -220 | -5888.54 | -5875.74 | -5862.77 | -5849.63 | -5836.33 | -5822.88 | -5809.26 | -5795.49 | -5781.56 | -5767.48 |
| -210 | -5753.25 | -5738.87 | -5724.34 | -5709.67 | -5694.85 | -5679.88 | -5664.77 | -5649.52 | -5634.13 | -5618.59 |
| -200 | -5602.92 | -5587.10 | -5571.15 | -5555.05 | -5538.82 | -5522.45 | -5505.95 | -5489.30 | -5472.52 | -5455.61 |
| -190 | -5438.55 | -5421.37 | -5404.04 | -5386.59 | -5368.99 | -5351.27 | -5333.40 | -5315.41 | -5297.28 | -5279.02 |
| -180 | -5260.62 | -5242.10 | -5223.44 | -5204.64 | -5185.72 | -5166.66 | -5147.47 | -5128.16 | -5108.71 | -5089.12 |
| -170 | -5069.41 | -5049.57 | -5029.60 | -5009.50 | -4989.27 | -4968.91 | -4948.43 | -4927.81 | -4907.07 | -4886.20 |
| -160 | -4865.20 | -4844.07 | -4822.81 | -4801.43 | -4779.93 | -4758.29 | -4736.53 | -4714.64 | -4692.63 | -4670.49 |
| -150 | -4648.23 | -4625.84 | -4603.33 | -4580.69 | -4557.92 | -4535.03 | -4512.02 | -4488.88 | -4465.62 | -4442.23 |
| -140 | -4418.72 | -4395.08 | -4371.32 | -4347.44 | -4323.43 | -4299.30 | -4275.05 | -4250.67 | -4226.17 | -4201.55 |
| -130 | -4176.81 | -4151.94 | -4126.95 | -4101.83 | -4076.60 | -4051.24 | -4025.76 | -4000.16 | -3974.43 | -3948.59 |
| -120 | -3922.62 | -3896.54 | -3870.33 | -3844.00 | -3817.56 | -3790.99 | -3764.30 | -3737.49 | -3710.57 | -3683.52 |
| -110 | -3656.36 | -3629.07 | -3601.67 | -3574.15 | -3546.52 | -3518.76 | -3490.89 | -3462.90 | -3434.80 | -3406.58 |
| -100 | -3378.24 | -3349.79 | -3321.22 | -3292.54 | -3263.74 | -3234.83 | -3205.80 | -3176.66 | -3147.41 | -3118.04 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| -90 | -3088.56 | -3058.96 | -3029.26 | -2999.44 | -2969.50 | -2939.46 | -2909.30 | -2879.03 | -2848.65 | -2818.16 |
| -80 | -2787.55 | -2756.84 | -2726.01 | -2695.08 | -2664.03 | -2632.87 | -2601.61 | -2570.23 | -2538.74 | -2507.14 |
| -70 | -2475.44 | -2443.62 | -2411.70 | -2379.67 | -2347.52 | -2315.27 | -2282.92 | -2250.45 | -2217.88 | -2185.20 |
| -60 | -2152.41 | -2119.52 | -2086.52 | -2053.42 | -2020.21 | -1986.89 | -1953.47 | -1919.94 | -1886.31 | -1852.58 |
| -50 | -1818.74 | -1784.80 | -1750.75 | -1716.61 | -1682.36 | -1648.01 | -1613.55 | -1579.00 | -1544.34 | -1509.59 |
| -40 | -1474.73 | -1439.77 | -1404.72 | -1369.56 | -1334.30 | -1298.94 | -1263.49 | -1227.93 | -1192.27 | -1156.52 |
| -30 | -1120.67 | -1084.71 | -1048.66 | -1012.51 | -976.26 | -939.91 | -903.47 | -866.92 | -830.28 | -793.54 |
| -20 | -756.70 | -719.76 | -682.73 | -645.59 | -608.36 | -571.04 | -533.62 | -496.10 | -458.49 | -420.78 |
| -10 | -382.98 | -345.09 | -307.10 | -269.03 | -230.86 | -192.61 | -154.26 | -115.83 | -77.31 | -38.70 |
| 0 | 0.00 | 38.77 | 77.62 | 116.53 | 155.51 | 194.56 | 233.68 | 272.88 | 312.15 | 351.49 |
| 10 | 390.91 | 430.41 | 469.98 | 509.64 | 549.37 | 589.18 | 629.06 | 669.03 | 709.09 | 749.22 |
| 20 | 789.43 | 829.73 | 870.11 | 910.57 | 951.11 | 991.74 | 1032.46 | 1073.25 | 1114.14 | 1155.10 |
| 30 | 1196.16 | 1237.29 | 1278.52 | 1319.82 | 1361.22 | 1402.70 | 1444.26 | 1485.92 | 1527.65 | 1569.48 |
| 40 | 1611.38 | 1653.38 | 1695.46 | 1737.63 | 1779.88 | 1822.22 | 1864.64 | 1907.15 | 1949.74 | 1992.42 |
| 50 | 2035.19 | 2078.04 | 2120.97 | 2163.99 | 2207.10 | 2250.29 | 2293.56 | 2336.92 | 2380.36 | 2423.88 |
| 60 | 2467.49 | 2511.18 | 2554.96 | 2598.81 | 2642.75 | 2686.77 | 2730.88 | 2775.06 | 2819.33 | 2863.68 |
| 70 | 2908.11 | 2952.62 | 2997.21 | 3041.88 | 3086.63 | 3131.46 | 3176.37 | 3221.36 | 3266.43 | 3311.57 |
| 80 | 3356.80 | 3402.10 | 3447.48 | 3492.94 | 3538.48 | 3584.09 | 3629.78 | 3675.55 | 3721.39 | 3767.31 |
| 90 | 3813.30 | 3859.37 | 3905.51 | 3951.73 | 3998.03 | 4044.40 | 4090.84 | 4137.35 | 4183.94 | 4230.61 |
| 100 | 4277.34 | 4324.15 | 4371.03 | 4417.99 | 4465.01 | 4512.11 | 4559.28 | 4606.52 | 4653.83 | 4701.21 |
| 110 | 4748.67 | 4796.19 | 4843.78 | 4891.45 | 4939.18 | 4986.98 | 5034.86 | 5082.80 | 5130.81 | 5178.89 |
| 120 | 5227.03 | 5275.25 | 5323.53 | 5371.89 | 5420.30 | 5468.79 | 5517.35 | 5565.97 | 5614.65 | 5663.41 |
| 130 | 5712.23 | 5761.12 | 5810.07 | 5859.09 | 5908.18 | 5957.33 | 6006.54 | 6055.83 | 6105.17 | 6154.59 |
| 140 | 6204.06 | 6253.60 | 6303.21 | 6352.88 | 6402.62 | 6452.42 | 6502.28 | 6552.21 | 6602.20 | 6652.25 |
| 150 | 6702.37 | 6752.55 | 6802.79 | 6853.10 | 6903.47 | 6953.90 | 7004.39 | 7054.95 | 7105.57 | 7156.25 |
| 160 | 7206.99 | 7257.80 | 7308.66 | 7359.59 | 7410.58 | 7461.63 | 7512.74 | 7563.92 | 7615.15 | 7666.45 |
| 170 | 7717.80 | 7769.22 | 7820.69 | 7872.23 | 7923.83 | 7975.49 | 8027.20 | 8078.98 | 8130.82 | 8182.71 |
| 180 | 8234.67 | 8286.68 | 8338.76 | 8390.89 | 8443.08 | 8495.33 | 8547.64 | 8600.01 | 8652.44 | 8704.92 |
| 190 | 8757.47 | 8810.07 | 8862.73 | 8915.44 | 8968.22 | 9021.05 | 9073.94 | 9126.89 | 9179.89 | 9232.95 |
| 200 | 9286.07 | 9339.24 | 9392.48 | 9445.76 | 9499.11 | 9552.51 | 9605.96 | 9659.48 | 9713.04 | 9766.67 |
| 210 | 9820.35 | 9874.08 | 9927.87 | 9981.71 | 10035.60 | 10089.60 | 10143.60 | 10197.60 | 10251.80 | 10305.90 |
| 220 | 10360.20 | 10414.40 | 10468.80 | 10523.20 | 10577.60 | 10632.10 | 10686.60 | 10741.20 | 10795.90 | 10850.60 |
| 230 | 10905.40 | 10960.20 | 11015.00 | 11069.90 | 11124.90 | 11179.90 | 11235.00 | 11290.10 | 11345.30 | 11400.50 |
| 240 | 11455.80 | 11511.10 | 11566.50 | 11621.90 | 11677.40 | 11732.90 | 11788.50 | 11844.10 | 11899.80 | 11955.50 |
| 250 | 12011.30 | 12067.10 | 12123.00 | 12178.90 | 12234.90 | 12290.90 | 12347.00 | 12403.10 | 12459.30 | 12515.50 |
| 260 | 12571.70 | 12628.00 | 12684.40 | 12740.80 | 12797.30 | 12853.80 | 12910.30 | 12966.90 | 13023.50 | 13080.20 |
| 270 | 13136.90 | 13193.70 | 13250.50 | 13307.40 | 13364.30 | 13421.30 | 13478.30 | 13535.40 | 13592.40 | 13649.60 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 280 | 13706.80 | 13764.00 | 13821.30 | 13878.60 | 13936.00 | 13993.40 | 14050.80 | 14108.30 | 14165.90 | 14223.50 |
| 290 | 14281.10 | 14338.80 | 14396.50 | 14454.30 | 14512.10 | 14569.90 | 14627.80 | 14685.70 | 14743.70 | 14801.70 |
| 300 | 14859.80 | 14917.90 | 14976.10 | 15034.30 | 15092.50 | 15150.80 | 15209.10 | 15267.50 | 15325.90 | 15384.30 |
| 310 | 15442.80 | 15501.30 | 15559.90 | 15618.50 | 15677.20 | 15735.90 | 15794.60 | 15853.40 | 15912.20 | 15971.10 |
| 320 | 16030.00 | 16089.00 | 16148.00 | 16207.00 | 16266.10 | 16325.20 | 16384.30 | 16443.50 | 16502.80 | 16562.10 |
| 330 | 16621.40 | 16680.70 | 16740.10 | 16799.60 | 16859.10 | 16918.60 | 16978.20 | 17037.80 | 17097.40 | 17157.10 |
| 340 | 17216.80 | 17276.60 | 17336.40 | 17396.30 | 17456.20 | 17516.10 | 17576.10 | 17636.10 | 17696.10 | 17756.20 |
| 350 | 17816.40 | 17876.50 | 17936.80 | 17997.00 | 18057.30 | 18117.60 | 18178.00 | 18238.40 | 18298.90 | 18359.30 |
| 360 | 18419.90 | 18480.40 | 18541 | 18601.70 | 18662.40 | 18723.10 | 18783.80 | 18844.60 | 18905.40 | 18966.30 |
| 370 | 19027.20 | 19088.10 | 19149.10 | 19210.10 | 19271.20 | 19332.20 | 19393.40 | 19454.50 | 19515.70 | 19576.90 |
| 380 | 19638.20 | 19699.40 | 19760.70 | 19822.10 | 19883.50 | 19944.90 | 20006.30 | 20067.80 | 20129.30 | 20190.80 |
| 390 | 20252.30 | 20313.90 | 20375.50 | 20437.20 | 20498.80 | 20560.50 | 20622.20 | 20683.90 | 20745.70 | 20807.40 |

# Revision histories

## Controlled document revision histories

The following technical notes have been modified since the previous release of the Applications Handbook:

- TEC/NOT/072 - Time and leap seconds
- TEC/NOT/076 - Using the KAD/HBM/102

Documents which have been updated are marked by a ●.

| **TEC/NOT/001** | | **Strain gages and ideal bridges** |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 11 Apr. 2017 | Applied Defense Solutions template features. | |
| 6 Jul. 2012 | Removed reference to TEC/NOT/002 which is obsolete | |
| 4 Dec. 2009 | Update to format only | |
| 7 Sep. 2005 | Added equation to Section 1.2 for clarity<br>Corrected error in Figure 1.6 | Customer feedback<br>Documentation error |
| 1 Oct. 2003 | Corrected equation | Consistency error |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/003** | | **IRIG-B** |
| **Date** | **Action** | **Reason** |
| 17 May 2017 | Applied Defense Solutions template features. | |
| 1 Mar. 2004 | Corrected errors in Figure 5.3 | Documentation error |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/004** | | **MIL-STD-1553** |
| **Date** | **Action** | **Reason** |
| 7 Jun. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/006** | | **ARINC-429** |
| **Date** | **Action** | **Reason** |
| 7 Jun. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/008** | | **Panavia** |
| **Date** | **Action** | **Reason** |
| 19 Jun. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |

| TEC/NOT/009 | | Panavia and the KAM/PBM/001 |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 19 Jun. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/010** | | **Thermocouples** |
| **Date** | **Action** | **Reason** |
| 9 Nov. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/011** | | **Synchros** |
| **Date** | **Action** | **Reason** |
| 9 Nov. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/012** | | **Piezoelectric effect and charge amplifiers** |
| **Date** | **Action** | **Reason** |
| 9 Nov. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/013** | | **3-Phase power monitoring** |
| **Date** | **Action** | **Reason** |
| 9 Nov. 2017 | Applied Defense Solutions template features. | |
| 29 Jan. 2008 | Reformatted technical note | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/014** | | **Linear variable differential transformer (LVDT)** |
| **Date** | **Action** | **Reason** |
| 23 Jan. 2023 | In section 11.4 Half-bridge LVTD basics, changed KAM/CDC/001 typo to KAD/LDC/101. | |
| 18 Dec. 2017 | Applied Defense Solutions template features. | |
| 29 Jan. 2008 | Issued first release of technical note | |
| **TEC/NOT/015** | | **CVSD modulation of audio signals** |
| **Date** | **Action** | **Reason** |
| 18 Dec. 2017 | Applied Defense Solutions template features. | |
| 3 Aug. 2004 | Corrected error in Figure 23.2 | Documentation error |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/016** | | **Power dissipation** |
| **Date** | **Action** | **Reason** |
| 18 Dec. 2017 | Applied Defense Solutions template features. | |
| 4 Mar. 2003 | Added equation describing heat transfer due to natural convection in still air | Documentation error |

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|---|---|---|
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/019** | | **An introduction to digital filtering** |
| **Date** | **Action** | **Reason** |
| 18 Dec. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/023** | | **Resistance temperature detectors** |
| **Date** | **Action** | **Reason** |
| 22 Dec. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/024** | | **Evolution of pulse code modulation (PCM)** |
| **Date** | **Action** | **Reason** |
| 22 Dec. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/026** | | **A dictionary of telemetry terms** |
| **Date** | **Action** | **Reason** |
| 22 Dec. 2017 | Applied Defense Solutions template features. | |
| 1 Aug. 2003 | Updated references section | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/027** | | **IRIG 106-96 chapter 4** |
| **Date** | **Action** | **Reason** |
| 22 Dec. 2017 | Applied Defense Solutions template features. | |
| 20 Nov. 2002 | Issued first release of technical note | |
| **TEC/NOT/035** | | **Rules of PCM placement** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 20 Jul. 2012 | Reworded Rule 1 about Bus monitors and removed the warning note. Corrected table titles in table 18-3 and 18-4. | |
| 1 Feb. 2012 | Technical note made obsolete; after consideration made active again | |
| 1 Dec. 2004 | Issued first release of technical note | |
| **TEC/NOT/037** | | **Using the KAD/ADC/008** |
| **Date** | **Action** | **Reason** |
| 27 May 2022 | Updated this technical note to state that the ACC/TRF/002 is recommended for new programs. It is still noted that both the ACC/TRF/001/B and the ACC/TRF/002 can be used with the KAD/ADC/008. | |

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| 15 May 2020 | In Table 20-1: Output registers, in the RMS Register, updated the formulas in the Description column. In section 20.5 Calculating the parameter from the measured count, removed the duplicate “RMS voltage” equation. | |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 9 Sep. 2011 | Changed ACC/TRF/001 ratio from 23 to 19.6 and updated to the new template | |
| 11 Dec. 2007 | Changed to indicate “40 parameters” not “45 parameters”; reformatted technical note | Documentation Error |
| 1 Jun. 2005 | Overview: Clarified description of algorithm used in the ADC/008<br>Output registers: Corrected errors in output register table | Customer feedback<br>Documentation Error |
| 1 Apr. 2005 | Issued first release of technical note | |
| **TEC/NOT/045** | | **Using the BIT/101** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 16 Sep. 2009 | Issued first release of technical note | |
| **TEC/NOT/046** | | **Using the KAD/EBM/101** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 10 Jan. 2017 | Added instructions to cover using the KAD/EBM/101 with DAS Studio 3. | |
| 28 Jul. 2009 | Update to format only | |
| 11 May 2009 | Issued first release of technical note | |
| **TEC/NOT/047** | | **Using the KAD/DSI/002** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 26 Nov. 2014 | Issued first release of technical note | |
| **TEC/NOT/048** | | **Format select** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 28 Jul. 2009 | Update to format only | |
| 26 May 2009 | Issued first release of technical note | |
| **TEC/NOT/049** | | **Power estimation** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 17 Jan. 2012 | Added PSU/012/B limitations to section 43.3.3, 43.4 and 43.5 | |

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|---|---|---|
| 14 Mar. 2011 | Updated section 43.5 Example of power estimation | |
| 22 Aug. 2008 | Issued first release of technical note | |
| **TEC/NOT/051** | | **Ethernet frames, Wireshark® and FAT32** |
| **Date** | **Action** | **Reason** |
| 28 Dec. 2017 | Applied Defense Solutions template features. | |
| 9 Feb. 2012 | Changed all references to iNET and xNET to iNET-X | |
| 22 Mar. 2010 | Issued first release of technical note | |
| **TEC/NOT/052** | | **Using the KAD/ARI/001** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 24 Jan. 2012 | Issued first release of technical note | |
| **TEC/NOT/053** | | **Using the KAD/BCU/105** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 16 Sep. 2009 | Issued first release of technical note | |
| **TEC/NOT/054** | | **Using the KAD/ETH/101** |
| **Date** | **Action** | **Reason** |
| 13 Oct. 2022 | Specified that Table 29-1: KAD/ETH/101 to PC port RJ-45 wiring is (cross-over). | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 22 Dec. 2015 | Removed the “PC-to-Ethernet interface” section and replaced it with the “KAD/ETH/101 to PC port RJ-45 wiring” table. In the “Connecting the PC and the KAM-500Acra KAM-500 chassis to a network” section, updated the procedure for setting up a network. Removed the “Setting parameters” section. Added a Glossary. | |
| 4 Nov. 2009 | Issued first release of technical note | |
| **TEC/NOT/055** | | **Using the KAD/VID/103** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |

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|---|---|---|
| 14 Dec. 2016 | Separated “Video compression” section into subsections.<br>In “Camera selection” table, corrected all pins so that GND are now NC and vice versa.<br>In “Audio compression” section, clarified how ADPCM encodes differences between predicted and current audio sample.<br>In Setup tab description table, added rows to describe “Video Parameter’s Prefix name” and “Max thread threshold”.<br>Added new “Prefixing of the video parameter name” section.<br>In “Using video over Ethernet” section, added a bullet point to clarify use of the Video Parameter’s Prefix Name field. | |
| 16 Sep. 2009 | Issued first release of technical note | |
| **TEC/NOT/056** | | **Using the KAD/CBM/102** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 12 Jan. 2017 | Added instructions to cover using the KAD/CBM/102 with DAS Studio 3. | |
| 18 Nov. 2009 | Issued first release of technical note | |
| **TEC/NOT/058** | **Overview of SNMP and using third party SNMP tools** | |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 9 Jan. 2017 | Throughout the document, applied style changes.<br>In “MIBs” section, added an example for accessing the hierarchy.<br>In “Example of reading the MIB file” section, made modifications.<br>Added a new “Settings subtree section” section.<br>Added a new “Time subtree section” section.<br>Added a new “Device Identifiers section” section.<br>In “SNMP software” section, added addtional items.<br>In “Installation and setup of Net-SNMP” section, made modifications.<br>In “Using Net-SNMP” section, added additional examples.<br>Added a new “Troubleshooting” section. | |
| 21 Feb. 2012 | Issued first release of technical note | |
| **TEC/NOT/059** | **KAD/TDC/107 cable assembly using ACD/CJB/002 reference junction block** | |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 12 Jun. 2012 | Removed reference to KAD/TDC/107 in title of technical note; reworded any sections that implied this technical note is only for KAD/TDC/107 modules. | Technical note required to be generic as it applies to multiple modules rather than just the KAD/TDC/107. |

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| 20 Feb. 2012 | On page 1, corrected CON/KAD/010 connector image to show screws attached; added new step 15 to show CON/KAD/010 screws being removed; step 25, corrected image to show the two UNC 4-40 screws clamp bar connected to backshell are hex-socket-head and not slot-head as previously shown | Customer feedback |
| 3 Jun. 2010 | Issued first release of technical note | |
| **TEC/NOT/060** | | **Using the KAM/TCG/102** |
| **Date** | **Action** | **Reason** |
| 12 Jan. 2023 | In section 34.6 Tips, removed the “External battery” item. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 19 Aug. 2014 | Added content for using the KAM/TCG/102 with DAS Studio 3. Removed the Glossary section. | Glossary terms defined on first use. |
| 6 Jan. 2011 | Issued first release of technical note | |
| **TEC/NOT/062** | | **Using the KAD/UAR/102** |
| **Date** | **Action** | **Reason** |
| 24 Jun. 2023 | In section 35.6.6 Parsing messages without a unique start sequence, corrected the second paragraph to state “The Sync Interval can also be used if the value of the Start Sequence is also defined in the message payload” not “only defined”. | |
| 22 Apr. 2021 | Removed the Note from section “35.6.6 Parsing messages without a unique start sequence”. Added a new section “35.6.7 Using wildcard in Start Sequence”. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 15 Jun. 2015 | Updated technical note to include settings configured using DAS Studio 3 | |
| 5 Nov. 2013 | In section 56.6.3, clarified that Start/Stop Sequences for both MSGA and MSGB are defined in Figure 56-12. | |
| 15 Oct. 2013 | Sections “56.6.4 Length” and “56.6.5 Stop byte” incorrectly stated Length or Stop Byte is used to allocate the message ID/parser slot. Corrected this and combined these sections to new section “Using End of Message values to stop parsing”. For consistency, renamed most headings in this technical note. | |
| 24 Jan. 2012 | Issued first release of technical note | |
| **TEC/NOT/063** | **Grounding and shielding of the Axon and Acra KAM-500** | |
| **Date** | **Action** | **Reason** |
| 7 Dec. 2017 | Technical note has been reorganized and text and illustrations have been updated to ensure grounding requirements for Axon hardware are covered. Title has been modified to include Axon. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |

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|---|---|---|
| 8 Nov. 2012 | Format updates applied | |
| 14 Mar. 2011 | Issued first release of technical note | |
| **TEC/NOT/064** | | **Using the KAM/MEM/103** |
| **Date** | **Action** | **Reason** |
| 2 Sep. 2019 | Changed references to *KAM/MEM/103* data sheet to *CompactFlash cards* data sheet.<br>In Table 37-3: Memory module history, added references to DAS Studio 3 in the Software required column. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 7 Jan. 2017 | Added instructions to cover using the KAM/MEM/103 with DAS Studio 3. | |
| 19 May 2014 | Issued first release of technical note | |
| **TEC/NOT/065** | | **Using the KAD/SWI/101** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 4 Oct. 2010 | Issued first release of technical note | |
| **TEC/NOT/066** | | **Using the KAD/DEC/103** |
| **Date** | **Action** | **Reason** |
| 31 Jul. 2017 | Added instructions to cover using the KAD/DEC/103 with DAS Studio 3. | |
| 18 Feb. 2011 | Issued first release of technical note | |
| **TEC/NOT/067** | | **IENA and iNET-X packet payload formats** |
| **Date** | **Action** | **Reason** |
| 10 Feb. 2023 | In the section 40.3 iNET-X packet header, under the “PTP Time (64 bits):” element, specified that the time is TAI. | |
| 21 Aug. 2018 | In Figure 40-2, changed Packet Length to “Sequence Number (2B). In section 40.4 IENA packetization, changed Key Status (8 bits to “This field is reserved for future use.” In section 40.6 Recommended reading, changed the three SSR/to modules KAD/; changed Recorder Studio 3 to DAS Studio 3. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |

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|---|---|---|
| 25 Nov. 2015 | Updated the two figures on page 2.<br>In "iNET-X and IENA packetization rules and recommendations" table, clarified that fragmentation is not supported by the INET-X standard.<br>At the end of "iNET-X packet header" section, added a note to clarify timeout being reduced.<br>In "iNET-X payload structure overview" table, added Example products column; changed Max payload length to 1,444 bytes.<br>In "IENA positional packet format for analog" section, removed first paragraph.<br>Deleted the following sections:<br>IENA positional packet format for bit stream payloads<br>IENA positional packet format for video<br>IENA positional packet format for parser-aligned payloads<br>IENA positional parser-aligned payload format for ARINC-429<br>IENA positional parser-aligned payload format for MIL-STD-1553<br>IENA positional packet format for errors and events<br>Added new section "IENA". | |
| 7 Feb. 2012 | Issued first release of technical note | |
| **TEC/NOT/068** | | **Network MCS in KSM-500** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 19 Apr. 2012 | Issued first release of technical note | |
| **TEC/NOT/069** | | **Xbar Switches - Filtering and Forwarding** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 16 Apr. 2012 | Issued first release of technical note | |
| **TEC/NOT/071** | | **Using the KAD/DSI/003/B** |
| **Date** | **Action** | **Reason** |
| 6 Oct. 2022 | In the "43.5.4 Channels 0 to 23 discrete status with time tagging in KSM-500" section, in the STATUS registers table, corrected the description for "DSI3_ST_LO_12B0_Jx" to read "Bit 4 to bit 15". In the "43.5.5 Channels 0 to 23 discrete status with time tagging in DAS Studio 3" section, in the Event related registers table, added "Discrete24Hi" and "Discrete24Lo" registers. | |
| 11 Apr. 2018 | Issued first release of technical note | |

| ● TEC/NOT/072 | | Time and leap seconds |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 7 Dec. 2023 | In Section “44.1 Time standards available for use with Curtiss-Wright products” made some changes regarding leap time. Changed all instances of “PTPv1” to “PTP”.In the “Examples of leap seconds and year settings” added multiple notes regarding the modules supported. Added two new sections “44.4.1 Leap year on the KAM/TCG/10x” and “44.5 Axon and time”. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 3 Aug. 2016 | Issued first release of technical note | |
| **TEC/NOT/073** | | **Using the KAD/VID/106** |
| **Date** | **Action** | **Reason** |
| 27 Aug. 2019 | In the 44.2.2.2 KSM-500 Setup tab settings table and the 44.2.2.3 DAS Studio 3 Settings tab settings table, under the row Input Video Bitrate, added rates for KAD/VID/106/B. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 13 Dec. 2016 | Added instructions to cover using the KAD/VID/106 with DAS Studio 3. | |
| 6 Oct. 2016 | Issued first release of technical note | |
| **TEC/NOT/074** | **Using DAS Studio 3 to configure the KAD/CBM/103** | |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 21 Nov. 2013 | Issued first release of technical note | |
| **TEC/NOT/075** | **Using DAS Studio 3 to configure the KAD/EBM/102** | |
| **Date** | **Action** | **Reason** |
| 26 Apr. 2023 | Removed all references/screens to Auto Configure as no longer supported in DAS Studio. At the end of “47.7 Scenario 3” section, removed the Important and Note regarding parsing rules. In step 1 of “47.8.13 Step-by-step instructions” section, deleted the text regarding parsing rules and deleted the Note. At the end of the same section, deleted the last sentence regarding packet filter destination. | |
| 30 Jun. 2021 | Technical note has been reorganized and had multiple new sections added due to new features added in DAS Studio 3 configuration software. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 28 Jul. 2015 | Applied Curtiss-Wright template features. In the Configuring the KAD/EBM/102 to transmit Ethernet data into a PCM stream.section, updated the notes on Mac Address to include ‘The first three bytes for Curtiss-Wright MAC Addresses are 00-0C-4D (see Figure 69-2 on page 3).’ Corrected the MAC Address example used in Figure 69-2. | |

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|---|---|---|
| 3 Dec. 2013 | Issued first release of technical note | |
| **TEC/NOT/076** | | **Using the KAD/HBM/102** |
| **Date** | **Action** | **Reason** |
| 13 Dec. 2023 | Removed all references to Garmin G1000 from text and figures. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 30 Jan. 2014 | Issued first release of technical note | |
| **TEC/NOT/077** | | **Using shunting processes in Ethernet systems** |
| **Date** | **Action** | **Reason** |
| 3 Sep. 2019 | In the 48.3.2 Summary section, added information for enabling Shunt or Classic Shunt for newer modules; and in shunt format 0, 4, and 8 whether a resistor is added or removed. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 19 Feb. 2014 | Issued first release of technical note | |
| **TEC/NOT/078** | | **Using the KAD/UBM/104** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 29 Apr. 2014 | Issued first release of technical note | |
| **TEC/NOT/079** | | **Using the KAD/UBM/103** |
| **Date** | **Action** | **Reason** |
| 26 Jun. 2023 | In section 51.5.2 Setting up the incoming signal, corrected the third paragraph to state "negative input must be left unconnected". | |
| 14 Jun. 2021 | Technical note has been reorganized and had multiple new sections added due to new features added in DAS Studio 3 configuration software. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 9 Sep. 2014 | Issued first release of technical note | |
| **TEC/NOT/081** | | **Visualization effects while reconstructing time waveforms from sampled data** |
| **Date** | **Action** | **Reason** |
| 8 Mar. 2018 | In the "Sampling: square wave visual effect" section, removed the link to Wikipedia. Rewrote the introductory paragraph for the "Sampling: screen effect" section. | |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 9 Sep. 2015 | Issued first release of technical note | |

| TEC/NOT/082 | | Analog modules specifications explained |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 23 Jan. 2023 | At the end of section 53.1 DC error: primary gain vs. secondary gain, added a new section: Example of digital gain calculation for KAD/ADC/135. | |
| 19 Jun. 2020 | On page 2, gain calculations for a KAD/ADC/109 corrected so that primary gain is 10 and the digital gain is 3.2. | |
| 25 Dec. 2017 | Applied Defense Solutions template features. | |
| 25 Sep. 2017 | Issued first release of technical note | |

| TEC/NOT/083 | | Using the KAM/MEM/113 |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 27 Apr. 2023 | In section “54.4.3 Always log”, added a note to clarify that in DAS Studio 3, the KAM/MEM/113 is configured to start recording after 10 acquisition cycles. | |
| 10 Oct. 2022 | At the end of “54.3.1 Format a CF card using the erase format from the KAM/KAM/MEM/113” section, specified that a CF card cannot be formatted on a KAM/MEM/113 when using a KAD/BCU/105 module. In the “54.4.4 How to fix a corrupted PCAP file” section, included references to IADS RT Station. In section “54.4.10 PCAP replay” added references that Data Exporter can be used as an extraction tool. | |
| 3 Mar. 2020 | In section 53.1.2 Triggers, clarified steps 7 and 8.<br>In section 53.3.2 Formatting a CF card in DAS Studio 3 specified “on a KAM/MEM/113” in heading title.<br>Added section 53.3.3 Formatting a CF card on a KAM/MEM/113 using fixed data in DAS Studio 3.<br>Modified section 53.4.2 Power loss or power off during recording.<br>Added the following sections:<br>53.4.12 Reading a CF with Windows 10<br>53.4.13 IENA timestamp and PCAP timestamp<br>53.4.14 Recording packetizers<br>53.4.15 KAM/MEM/113 and mode select | |
| 9 Jul. 2018 | In section 53.1.4, deleted the Warning at the end of the section.<br>In section 53.4.4, added a Note regarding Wireshark versions.<br>In section 53.4.5, added condition for KAM/MEM/113 formatted using ssrformat.<br>Added a new section 53.4.11 No date on first PCAP recorded. | |
| 18 Jan. 2018 | Issued first release of technical note | |

| TEC/NOT/084 | | Using the KAM/WSI/104 |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 27 May 2020 | Issued first release of technical note | |

| TEC/NOT/085 | Using the KAM/TCG/105 and KAM/TCG/106 | |
|---|---|---|
| **Date** | **Action** | **Reason** |
| 14 Jun. 2021 | Issued first release of technical note | |
| **TEC/NOT/086** | **Using the KAD/ABM/103** | |
| **Date** | **Action** | **Reason** |
| 24 Jun. 2021 | Issued first release of technical note | |
| **TEC/NOT/087** | **Using the AXN/ABM/401** | |
| **Date** | **Action** | **Reason** |
| 13 Jan. 2023 | Issued first release of technical note | |
| **TEC/NOT/089** | **Using DAS Studio to configure the AXN/ENC/402** | |
| **Date** | **Action** | **Reason** |
| 30 Mar. 2023 | Issued first release of technical note | |
| **TEC/NOT/091** | **Using the AXN/TCG/401** | |
| **Date** | **Action** | **Reason** |
| 14 Mar. 2023 | Issued first release of technical note | |
| **TEC/NOT/092** | **AXN capabilities and FAQ** | |
| **Date** | **Action** | **Reason** |
| 8 Aug. 2023 | Issued first release of technical note | |
| **QD/HW/SPF/M/0001** | | **Reference Chapter** |
| **Date** | **Action** | **Reason** |
| 29 Dec. 2017 | Applied Defense Solutions template features. | |
| 9 Dec. 2015 | Applied Curtiss-Wright template features.<br>Removed references to obsolete *TEC/NOT/002 - Bridge balancing and shunt calibration*. | |
| 15 Nov. 2002 | Issued first release of technical note | |

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**Document part number:** **DOC/HBK/001**

***This document was reviewed on 03/11/2020 and does not contain technical data.***

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