





## High Voltage Fast Pulse Coaxial Components

## ESD Test Systems & Instrumentation



Barth Electronics, Inc.

“The Measurement Guys”

[www.BarthElectronics.com](http://www.BarthElectronics.com)

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Barth Electronics, Inc.

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## Company Background - Pulse Power Division

Barth Electronics, Inc. has been designing and manufacturing "state of the art" sub-nanosecond high energy, pulse power coaxial components since 1964. Our first high voltage pulse instrumentation hardware was designed for underground nuclear testing, and taught us much about reliable wideband HV attenuators. These "special" products have become "STANDARDS" and are used every day for reliable pulse measurements in physics and pulse power laboratories around the world. Our instrumentation advances developed as high voltage pulse technology evolved, (and has been consistently faster than pulses that could be generated). We stay at the leading edge of this technology by constantly creating innovations in component design that you require now, or will need tomorrow.

The resistor used in our attenuators, terminators, and voltage probes has many capabilities designed specifically for high voltage pulse use. It has a very low voltage coefficient of resistance, which is why our components provide the same accurate measurements at millivolt or kilovolt signal levels. Their low temperature coefficient of resistance also provides minimal attenuation change with temperature and our resistors are held to 50 ohms  $\pm 0.5$  ohms for accurate and repeatable attenuation measurements.

Our microwave and HV design capabilities have enabled us to put our resistors into coaxial housings that provide the best pulse response possible for their rated energy. The combination of these capabilities provides you with the fastest pulse rated components available.

Our attenuator design capability continues to evolve and has resulted in improved pulse response, voltage rating and in greatly increased average power rating. Our components remain the best high voltage coaxial devices available anywhere.

We strive to minimize your problems in interconnection of measuring instrumentation by providing many different coaxial connectors with close tolerances on our products. We offer type "SMA", "TNC", "BNC", "N", "SHV" and "HN" connector selections on many of our standard products.

We are working on the design of new and higher voltage connectors for use with your constantly increasing pulse voltages.

Our high voltage probes are usually designed to meet specific requirements of resistance, voltage, pulse width, risetime, and physical dimensions for each application. They are presently being used in air, vacuum, and water systems, with risetimes as fast as 100 picoseconds, and voltages as high as 500kV.

Our line of pulse transformer components has less loss and narrower bandwidth than resistive units for dividing, combining, or signal sampling. We make several extremely wide bandwidth reactive units that have high energy capability as well. We have developed a 50 picosecond risetime pressurized reed switch pulse generator that has an output voltage that is adjustable from 100 to 2500 volts.

Our waveform modification capabilities include impulse, linear ramp, stairstep generators and risetime spoilers and positive exponential generators. Units have been produced that can operate up to 10kV and are as fast as sub-nanosecond or as slow as 100 ns risetimes.

**We are continuously investigating new technologies that can be applied to EM measurements and are designing new products as needs arise. If we have not already designed what you need, we have other sources that may be helpful with your high voltage measurements. Call us to discuss your pulse measurement needs.**



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Barth Electronics, Inc.

## Company Background - ESD Division

Barth Electronics, Inc. is a high technology company specializing in designing and manufacturing “state of the art” sub-nanosecond high energy, pulse power instrumentation since 1964. Originally moving from Ohio to Boulder City, Nevada in 1976 during the days of weapons testing at the Nevada Test Site, we designed and manufactured very special test hardware for EG&G in Las Vegas as well as the National Laboratories. In 1997, Barth test equipment engineers developed the first commercial Transmission Line Pulser (TLP) for the Electrostatic Discharge (ESD) industry, using unique technology developed for high speed, high voltage test equipment.

As the operating transistors inside IC’s have become smaller and more sensitive to ESD, each pin on every IC is now protected to provide the reliability demanded in the digital world. By beating our swords into plowshares, weapons testing hardware was changed into the development and manufacture of the highest quality ESD test equipment available today. The reliability demanded in weapons testing was also transferred into our commercial ESD test equipment. High reliability test equipment is needed to design and test semiconductors to ensure their high reliability. Accurate and dependable TLP testing is vital to identifying electrical characteristics of silicon IC’s.

We are continuously investigating new technologies that can be applied to ESD and are designing new products as the need becomes apparent. Barth Electronics offers a complete line of ESD test systems as well as device testing as a service. We have always offered an UNCONDITIONAL guarantee on every product we sell. We provide solutions to the ever growing needs of the ESD industry.

Barth Electronics, Inc. - Setting the Standard in High Speed ESD Testing!



# TECHNICAL SPECIFICATIONS

## TESTING FOR GUARANTEED PERFORMANCE

Components are 100% tested with 1000 pulses at their rated voltage and pulse width. The resistance of all ports is measured before and after HV testing. Each unit passes this test only if its resistance, after HV pulsing, increases less than 0.04%. Any higher increase indicates a breakdown, and that unit is rebuilt and retested. In addition to the DC resistance measurements, each unit is also tested for pulse response and reflection coefficient to be certain they meet our specifications. The pulse amplitude and width capability of a unit listed as 5kV/400ns means that it is guaranteed to withstand 5kV rectangular pulses that are 400ns long. **We recommend that DC resistance tests be performed regularly on all of your resistive attenuators, of any make, as an easy detection of resistor failure.** All of our products are guaranteed to perform to their specifications indefinitely when used within its specifications.

## MAXIMUM INPUT LIMITATION

The voltage specification of our products is sometimes limited by the breakdown characteristics of the connectors. The voltage limits we use for our specifications are 4kV for the "N" connector, 6kV for the GR 874 connector and 13kV for the "HN" connector. These limitations are for DC, and provide a safety factor for our pulse length ratings. The "N" connector, for instance, can pass 10kV at short (10ns) pulse widths.

The breakdown limitations of our film resistors are related to pulse energy. A unit that has been tested to withstand 5kV, 400ns FWHM rectangular pulses should be able to withstand 10kV, 75ns FWHM rectangular pulses. While this general "rule of thumb" has been found to be useful in practice, we cannot guarantee higher voltages or pulse widths unless we test the particular unit to your pulse specification.

Some units have been designed and rated to withstand exponentially decaying pulses and are listed with a  $1/\epsilon$  notation. An exponentially decaying pulse with a  $1/\epsilon$  time constant has half the energy of a rectangular pulse, with the same FWHM time. Therefore, our resistive units can withstand exponential pulses that have a time constant twice as long as a rectangular pulse.

Please call if your pulse measurement requirements cannot be met by the standard product specifications.

## VOLTAGE COEFFICIENT OF RESISTANCE

The voltage coefficient error of our resistive components is less than 1 % at their rated voltage. It is usually significantly lower than this but we cannot specify it any better because of present measurement limitations. **See our Application Note for further information regarding the importance of Voltage Coefficient in pulse voltage measurement.**

## PULSE RISETIME

The 10%-90% risetime through our attenuators is listed as  $\tau$  (tau). It is calculated by taking the square root of the difference between the observed risetime squared and the input risetime squared. This would be the risetime out of our attenuator with a perfect (zero risetime) input. Our risetime and reflection coefficient measurements are made with a 54120A HP digital sampling system that can be normalized to as fast as 10ps.

## ATTENUATORS ENERGY RATINGS

Attenuator Model	Pulse Energy Rating	
BEI 2	1 mJ	Tight resistance tolerance low voltage MW attenuator
BEI 141	10 mJ	Medium voltage 3 GHz bandwidth
BEI 142	50 mJ	Higher voltage and >12 GHz bandwidth
BEI 102	50 mJ	Higher voltage and 7 GHz bandwidth
BEI 202	200 mJ	Maximum N connector voltage 17 GHz bandwidth
BEI 2237A	800 mJ	HN connector 7 GHz bandwidth
BEI 2239A	2050 mJ	HN connector 3.5 GHz bandwidth
BEI 2536	400 mJ	HN connector, 200 watt average power

# VOLTAGE COEFFICIENT OF RESISTANCE

## Application Note #1

The purpose of this application note is to describe some important considerations in high voltage pulse measurements with resistors as dividing elements. The term "**Voltage Coefficient of Resistance**" has been around for a long time<sup>1</sup>; but is seldom used or well understood. As high voltage pulse measurements improve, and higher accuracy becomes available, voltage coefficient errors that could once be ignored now must be considered.

It is well known that the resistance increases with temperature rise of nearly all resistors, including the commonly encountered carbon composition resistor. The temperature **coefficient of resistance** (of a resistor) may be expressed as the ratio of the resistance change to the temperature rise. Such a temperature coefficient classification is useful if the resistance changes uniformly with temperature rise and fall.

Resistors undergo temperature variations not only due to changes in ambient temperature, but also due to dissipation of electrical energy when current is passed through them. It is desirable in measurements using resistors, that their temperature coefficient be small to minimize errors. One can see, for example, that when a measurement apparatus involving resistors is calibrated at low signal levels, the calibration may be invalid at higher signal levels if the resistance values change.

It has also been known for a long time<sup>1</sup> that the resistance of a resistor can change due to a change in the voltage applied to it, even though the temperature may be held constant. The **voltage coefficient of resistance** may be expressed as the ratio of the resistance change in ohms to the corresponding increase in applied voltage in volts when the temperature is held constant. Such voltage coefficient of resistance definition is useful to characterize the resistance change with an increase in applied voltage. Of course, for any useful resistor material, the resistance returns to its original value when the applied voltage is removed.

When a steady voltage is applied to a resistor, it normally undergoes resistance changes due to both applied voltage and temperature increase. The temperature increase is caused by the dissipation of electrical energy in the resistor due to current flow. At low voltages the temperature coefficient is usually larger than the voltage coefficient. This change in resistance is almost entirely due to a temperature change in the resistor.

When a short pulse is applied to a resistor, and very little average power is dissipated in the resistor, its temperature will not rise appreciably. Most of the resistance change of a low temperature coefficient resistor will be due mainly to the application of voltage, and limited to the time when the voltage is applied. When high voltage pulses are applied to low value resistors, the change in resistance can be appreciable, and can be very important in measurement applications.

Measurement of short high voltage pulses are made in investigations of the effects of lightning strikes, EMP testing on electrical equipment, instrumenting underground nuclear tests, and the pulse power industry.

Most resistors have a negative voltage coefficient, which means that at higher voltages, the resistance decreases during the pulse. If the resistance increases with voltage, the resistor has a

positive voltage coefficient. This voltage dependent change of resistance happens instantaneously and can be observed to occur in less than 1 nanosecond. If the period of voltage application is too long, the temperature may rise and cause large resistance changes that can mask voltage coefficient effects.

Short pulses applied to many resistors will show voltage coefficient effects during the time the voltage is applied. Although a resistor may not burn out during extensive pulsing, or have a permanent resistance change, it can have significant voltage coefficient changes during the time of the pulse.

The voltage coefficient varies with different resistive materials, and seems to be greatest for materials that are composed of a granular conglomeration of resistive material held together with an insulating binder. Carbon composition and cermet film resistors use these types of resistive materials.

Nonlinear resistivity can easily be displayed by placing a small amount of finely powdered conducting or semiconducting material between two skewed small diameter wires. Graphite, shaved from a pencil or from a carbon composition resistor displays this effect nicely. The effect can be observed using as little as 1 volt between the two wires. The nonlinear voltage versus current ratio can easily be seen on a simple transistor/ diode curve tracer as a nonlinear slope. This nonlinear resistance occurs for both positive and negative voltages and is symmetrical if there is no rectifying contact. Of course, resistors of a few thousandths of an inch in length are not used in high voltage applications; but if you put 1,000 of these small resistors mentioned above, that are three thousandths of an inch long, in series, you would have a resistor three inches long. This resistor, assembled from many low voltage nonlinear junctions, would have a nonlinear resistance when used at 1,000 volts.

The voltage coefficient of resistance of the resistor depends not only upon the length of the resistor, but also upon the conductive interfaces between the resistive particles that make up the resistor. These interfaces result in emission current (tunneling) across microscopic gaps between conductive particles such as graphite. It is complicated by many factors such as size of particles, their size distribution, and electron emission coefficients. If resistance can be obtained without resorting to high resistance contacts between granular low resistivity materials, then low voltage coefficients can be achieved.

Bulk metal resistors have almost unmeasurable voltage coefficients. However, due to the low resistivity of metals, wire wound resistors must be used to achieve reasonable resistance values. The combined inductance and capacitance effects of wire wound resistors prevent their use either at high frequencies or with fast pulses.

Thin metal film can also be used to achieve reasonable resistance values, but these resistors have a high voltage coefficient. This may result from the extremely thin metal film deposited on a very rough ceramic substrate, that allows tunneling or current flow across the ceramic valleys.

Carbon composition resistors are made with powdered or granular graphite material, which has a relatively low bulk resistivity.

# VOLTAGE COEFFICIENT OF RESISTANCE

## Application Note #1

Many different resistivity compositions are made to cover the 10 ohm to 10 megohm resistor range. The graphite/insulator compositions are held in place with a phenolic binder that also anchors the wire terminals into the carbon resistance element. This is the original construction method for carbon composition resistors and creates a robust and inexpensive resistor.

Ordinary carbon composition resistors normally are made in 1/4, 1/2, 1, and 2 watt sizes. Our measurements found the 2 watt size to have a much higher voltage coefficient than the 1 watt size, and the 1/2 watt size to have the lowest voltage coefficient over all. It was also found that the voltage coefficient of any particular wattage rating is not much different between manufacturers. This would lead us to believe that something in the basic manufacturing process of this type of resistor may be responsible for its very high voltage coefficient.

In order to increase the surface area of a carbon composition resistor and allow it to dissipate more energy, the size of the resistor is increased. Increasing the size of the resistor will usually decrease its resistance unless one increases the resistivity of the bulk material to compensate for the increase in cross sectional area. For example a typical 1/2 watt resistor,  $P^{2P}$  has a length of 0.375 inch and a diameter of 0.140 inch. The typical 2 watt resistor has a length of 0.688 inch and a diameter of 0.318 inch. The length has been increased by a factor of 1.8, and the diameter by a factor of 2.27, so that the cross sectional area has increased by a factor of 5.2. The resistance of a cylindrical resistor would be  $R = r l/A$ , where  $r$  is the resistivity of the bulk material,  $l$  is the length, and  $A$  is the cross sectional area. The resistance would be increased by a factor of 1.8 due to the longer length, and decreased by a factor of 5.2 due to the larger cross sectional area. This example assumes parallel end terminals, although commercial carbon composition resistors have very non-uniform end terminals.

In order to maintain the same resistance, in going from 1/2 watt size to the 2 watt size, the resistivity of the bulk material must be increased by a factor of 2.9. The resistivity depends upon the ratio of graphite particles (and their size distribution) to the insulating binder material. A higher resistivity is achieved by decreasing this ratio, using more binder or less graphite in the mixture. Therefore, the resistance material of a 2 watt resistor has a smaller percentage of graphite, than a 1/2 watt resistor with the same value. Fewer contacts between granular resistor particles results in more tunneling, causing a higher voltage coefficient.

The mechanism that causes resistors to change value with the application of voltage is difficult to define with certainty. However, the evidence for such a change is real, and substantial changes in resistance can be observed. In one of our tests, the resistance of a 2 watt carbon composition resistor was observed to decrease from 390 ohms to 200 ohms during pulse testing. The high voltage resistance was approximately 51% of the resistance at low voltage during

application of a 2kv, 100ns wide pulse. In pulse tests at 3kV with the same value resistors, a 1 watt resistor decreased approximately 15%, and a 1/2 watt resistor decreased approximately 6%.\*

An additional factor that probably contributes to a decrease in resistance upon the application of high voltage is the effect of the swaged tinned metal contacts of these resistors. They protrude into the bulk resistive material in such a way as to cause non-uniform current distribution at both ends of the resistor.

In high voltage pulse testing, inaccurate results are obtained when high voltage coefficient resistors are used for voltage division or attenuation measurements. The measurement of voltage coefficient of resistance can be accomplished at audio and radio frequencies by measuring the production of harmonic signals due to resistor nonlinear behavior<sup>3P</sup>. We have developed additional measurement methods using voltage pulses, and will continue resistor and attenuator testing.

We hope this information helps provide a better understanding of voltage coefficient and the causes of resistance changes at high voltage. Reduced accuracy is the result of using common resistors in high voltage pulse measurements. The effect of voltage coefficient and the importance of using resistors with a low voltage coefficient in high voltage measurements is gradually becoming more widely appreciated.

Because future designs are based on voltage measurements made today, it becomes obvious that the use of low voltage coefficient resistive instrumentation is essential for tomorrow's designs.

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\*This agrees within the limit of 0.02 percent per volt quoted by G.W.A. Dummer<sup>4P</sup>. The results quoted for 1 megohm resistors of 1/4 to 2 watt ratings by F. LangfordSmiths<sup>5P</sup> cannot be compared to those obtained at Barth Electronics, Inc., because there is no information on the dimensions of the resistors, and because Barth Electronics test resistors had lower resistance values.

### REFERENCES

- <sup>1</sup> "Measurements of Nonlinearity in Cracked Carbon Resistors", G.H. Millard, Proc. I.E.E. (London) Vol.106B, Jan. 1959, pp.31-34.
  - <sup>2</sup> "Electronic Designers Handbook", L.J. Giacoletto, Editor, Second Edition, McGraw-Hill Book Co. 1977, pp.3-B.
  - <sup>3</sup> "Harmonic Testing Pinpoints Passive Component Flaws", V. Peterson and P. Harris, Electronics, July 11, 1966, pp. 93-100.
  - <sup>4</sup> "Materials for Conductive and Resistive Functions", G.W.A. Dummer, Hayden Book Co., 1970, p.279.
  - <sup>5</sup> "Radiotron Designer's Handbook", F. Langford Smith, Editor, Fourth Edition, Electron Tube Div. RCA, 1953, p.188.
- Barth Electronics, Inc. © "VCADV" 5/3/88

## Information on HN and Barth HNB Connectors:

The Barth HNB connector was specifically designed to provide both high voltage pulse capability and fast rise time performance in an HN compatible connector. These two characteristics are not available, both together in any other commercially available HN connector.

While the HN connector interface is not quite as good as the precision N connector, it is still a very respectable connector and has the advantage of withstanding much higher voltages. The HN connector to connector interface will handle 15kV DC at sea level and somewhat higher pulse voltages.

However all HN connector to cable interfaces are not created equal, some are capable of handling high voltages and others are not! The high voltage limitations of a cable connector, or any connector for that matter, are often limited by the transitions on the end of the connector opposite the connector to connector interface. This is especially true of cable connectors, where the center conductor to outer conductor air gap spacing at the cable to connector transition is often not designed for high voltage, that is, it is shorter than the connector interface air gap spacing. A real danger in this is that breakdown can be occurring inside a connector and it will most likely not be apparent at the connector interface.

The Amphenol UG-59B/U male HN cable connectors as well as the Barth 401-HNB male HN cable connectors have a cable to connector interface (center conductor to outer conductor) air path which is 50% longer than the HN to HN interface air path, and thus gives these connectors good high voltage capability. The easiest, and typical design, (as used in the Amphenol UG-59B), to make an HN cable connector handle high voltage is to cut the cable insulation off square and then have the connector insulator overlap the cable insulation by a length which is longer (commonly 50%) than the connector to connector interface air gap path. While this does a good job of providing high voltage capability, it causes a severe discontinuity which limits the bandwidth of this connection.

The Barth 401-HNB male HN cable connector is designed to handle high voltage and provide the best possible bandwidth. The way we provide both high voltage capability and wide bandwidth is to cut down the diameter of the insulation, in the cable to connector interface area, with a special hand tool. The connector insulator will then overlap this area to provide the high voltage capability, and it is made the correct diameter to also provide the correct impedance, which eliminates the discontinuity and therefore the bandwidth limitations inherent of the typical dielectric overlap used in the typical high voltage HN connectors.

Other HN Connectors such as the Kings KH-59-19 male HN cable have an improved RF specification. This improved bandwidth typically is the result of shortening of the dielectric overlap area, and thus creates a reduction in the length of mismatched impedance. This improvement for bandwidth comes at the expense of lower voltage handling capability in the cable to connector interface. In the case of the Kings KH-59-19 male HN cable connector, the cable to connector interface (center conductor to outer conductor) air path is 50% shorter than the HN to HN interface air path, and thus makes this connector unsuitable for high voltage applications. The shorter air gap in the coax to connector interface will almost always break down before break down occurs in the connector interface (where it would be more easily detected).

The Barth HNB interface is completely compatible with the standard HNB interface and when 2 HNB connectors are mated you have the best available match for HN type connectors. If your fast pulse rise times are slower than 0.5ns, you probably wouldn't benefit from the advantages of the Barth HNB connectors, but if your pulse rise times are on the order of 200-300ps then you would see some benefit, and if your rise times are faster than 100ps the HNB connectors are a must.

If your application does not need the wide bandwidth of the HNB connectors, just insure that the HN connectors you are using have a cable to connector interface that will handle your highest pulse voltage pulses.

We hope this information will help you to achieve good test results using HN connectors.



## Information on Barth BE 40kV Connectors:

The Barth BE connector is a unisex connector with a mating bullet that was specifically designed to address the Pulse Power need for a connector that will take higher voltage than an HN connector, and can still pass fast sub-ns pulse rise times. While the HN connector to connector interface will handle 15kV DC at sea level and somewhat higher pulse voltages. The BE connector to connector interface will handle 40kVDC, at sea level and somewhat higher pulse voltages. The BE connector provides both fast rise time performance, and high voltage pulse capability, for applications up to 40kV. These two characteristics are not both together available in any other commercially available connector at this voltage rating.

Most high voltage connectors are not designed to be wide bandwidth; likewise most RF connectors are not designed to handle high voltage. There are a few RF connectors on the market that will handle 20 to 25kV pulses, and some are matched better than others for rise time performance. Most are limited to a particular cable type, and others are only found on pulse generators and are supplied with the mating connector on a piece of coax.

The high voltage limitations of a coaxial cable connector are often determined by the cable to connector transition, the end of the connector opposite the connector to connector interface. Coaxial cable connectors are typically designed for RF performance, and not with high voltage in mind. Most often the center conductor to outer conductor air gap spacing at the cable to connector transition is not designed for high voltage, that is, it is shorter than the connector interface air gap spacing. A real danger in this is that breakdown can be occurring inside a connector and it will most likely not be apparent at the connector interface.

The coaxial connector, cable to connector interface air path (center conductor to outer conductor), for a well-designed high voltage connector, is made to be longer than the connector to connector interface air path, and thus gives the connectors reliable high voltage capability. The easiest, and typical design to make a cable connector handle high voltage is to cut the cable insulation off square and then have the connector insulator overlap the cable insulation by a length which is longer (commonly 50%) than the connector to connector interface air gap path. While this does a good job of providing high voltage capability, it causes a severe discontinuity which limits the bandwidth of these connectors.

The Barth BE connector is designed to provide the best possible bandwidth and to also reliably handle high voltage. The way we provide both is to cut down the diameter of the cable insulation in the cable to connector interface area with a special hand tool. The connector insulator will then overlap this area to provide the high voltage capability. This allow us to also maintain the correct dielectric diameter to provide the correct impedance, which eliminates the discontinuity and therefore the bandwidth limitations inherent of the typical dielectric overlap design used in most high voltage connectors.

The Barth BE interface is now standard on many of our higher voltage products, and we offer a cable version for RG-214 cable. Other versions will soon be available for RG-217, other high performance low-loss cables, as will be adapters to HN, N, bulkhead feedthroughs and bulkhead flange to transmission line versions. A hermetic feedthrough for vacuum applications is also being planned.

When 2 BE connectors are mated you have the best available match for your high voltage pulse system. If your fast pulse rise times are slower than 1ns, you may not benefit much from the advantages of the Barth BE connectors, but if your pulse rise times are faster than 500ps then you would see some benefit, and if your rise times are faster than 100ps, the BE connectors are a must.

If your application does not need the wide bandwidth of the BE connectors, just insure that the high voltage connectors you are using have a cable to connector interface that will handle your highest pulse voltage pulses. We hope this information will help you to achieve good test results using BE connectors.

# COAXIAL COMPONENTS

MODEL 1400-1 Test Kit

## ADVANTAGES

- ⊗ Pulse tested and characterized for time domain applications
- ⊗ Wide bandwidth, triple shielded, flexible, high performance cable
- ⊗ Rugged stainless steel connector construction for long life

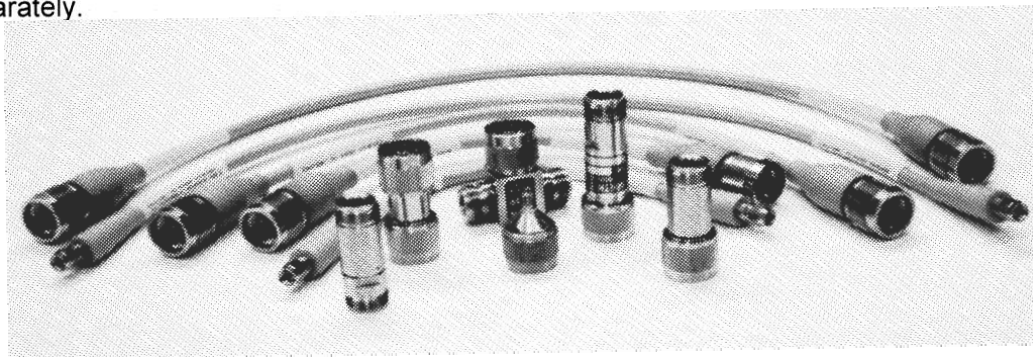
## DESCRIPTION

Barth Model 1400-1 test kit contains cable assemblies, adapters, attenuators and dividers.

The cable assemblies feature minimal fast pulse distortion to provide the fastest possible risetime response for 1GHz or 3.5GHz bandwidth oscilloscopes. The cables are constructed with precision "SMA" or "N" type connectors for minimum reflection losses.

The coaxial adapters, attenuators and divider are used for coaxial interconnections of sub-nanosecond risetime pulse information during high performance CDM and ESD testing.

Each component is TDR tested for low reflection, and pulse tested for risetime response to ensure minimal degradation of sub-nanosecond pulses. The kit contains the cable assemblies, connector adapters, attenuators, and power dividers listed below and all components are also available separately.



Quantity in kit	Description	Model
2	10" SMA plug-SMA plug picosecond cable assembly	460-MMP-10
2	15" SMA plug-SMA plug picosecond cable assembly	460-MMP-15
2	20" SMA plug-SMA plug picosecond cable assembly	460-MMP-20
2	10" N plug-N plug picosecond cable assembly	460-NMP-10
2	15" N plug-N plug picosecond cable assembly	460-NMP-15
2	20" N plug-N plug picosecond cable assembly	460-NMP-20
1	36" N plug-SMA plug picosecond cable assembly	460-NMMMP-36
2	N plug to N jack precision adapter	420-NMF
2	N plug to N plug precision adapter	421-NMM
2	N jack to N jack precision adapter	422-NFF
6	N plug to SMA jack adapter	423-NMMF
2	10/1 VR 20ps time domain attenuators - low voltage	2-20
2	2 way resistive divider - low voltage	1506A

# HIGH VOLTAGE PULSE TERMINATOR

## ADVANTAGES OVER STANDARD RF TERMINATORS

- ⊕ Low reflection coefficient
- ⊕ Withstands high voltage pulses
- ⊕ Pulse power rated
- ⊕ Low voltage coefficient
- ⊕ High reliability
- ⊕ Impedance held very close to nominal

## DESCRIPTION

Barth High Voltage Pulse Terminators are designed to terminate 50 ohm systems with a very low reflection coefficient. High voltage pulses are terminated with characteristics as good as, or better than, most instrument loads. These units are ideal for use in nuclear and high energy experiments. Extensive testing during manufacturing insures very high reliability for single-shot experiments. A voltage coefficient of the resistive film of less than .0001 %/V allows low voltage calibration of most systems.

## TERMINATOR MODEL COMPARISON

Model	Peak Voltage	Maximum Input* @ Pulse width ns	Input reflection coefficient at 100ps $\tau$	Connectors
101-xxx	2,500	400	< 1%	**
201 A-xxx	5,000	400	< 1%	**
201-BMP	3,000	250	< 1%	BNC male
2033-HFP	10,000	250	< 4%	HNB female
2051-GHMP	10,000	100	< 3%/100ps $\tau$	GHV male
2051-GHFP	10,000	100	< 3%/100ps $\tau$	GHV female
223-BMFP	4,000	100	< 5%	BNC male/female

NOTE: Our type HN (HNB) connectors are specially designed to obtain the minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or Model 402-HNB female cable connector for RG214/U coax should be used for interconnection.

\* Please refer to the Technical Specifications (Maximum Input Limitations) page for a full explanation of voltage and pulse width ratings.

\*\* Any male or female (GR, N, HNB) can be supplied. Units with N connectors are limited to a 4kV rating. The Model 101 is not supplied with HNB connectors to avoid voltage capability confusion. These are our most popular terminators, and are stocked for immediate delivery.

# HIGH VOLTAGE PULSE TERMINATOR

MODEL 101-xxx, 201A-xxx

## DESCRIPTION

50  $\Omega$  High Voltage Pulse Terminator



Model 101-GLP



Model 201A-NMP

## SPECIFICATIONS

<b>Maximum Input:</b>	101-xxx:	2.5kV, 400ns FWHM Pulse
	201A-xxx:	5kV, 400ns FWHM Pulse **
<b>Peak Input Power:</b>		125kW at rated pulse width
<b>Average Input Power:</b>		4W maximum
<b>Impedance:</b>		50 $\Omega \pm 0.5\%$
<b>Reflection-TDR:</b>		< 1% to a 100ps risetime step function
<b>Voltage Coefficient:</b>		< 1% at rated voltage
<b>SWR:</b>		DC-4GHZ < 1.005 +.013f GHZ DC-6GHZ < 1.005 +.013f GHZ
<b>Connectors:</b>	101/201A-GP	GR 874 Non locking
	101/201A-GLP	GR 874 Locking
	101/201A-NMP	N male **
	101/201A-NFP	N female **
	201A-HMP	HNB male ** (201A only)
	201A-HFP	HNB female ** (201A only)
<b>Dimensions:</b>		2.5" long, 1.25" dia. max.
<b>Weight:</b>		.2 lbs.

NOTE: Our type HN (HNB) connectors are only available in 201A series and are specially designed to obtain the minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or Model 402-HNB female cable connector for RG214/U coax should be used for interconnection.

-xxx Connector identifier, see list under connector heading for our standard (stocked) configurations. Call for connector configurations not shown.

\*\* Units with N connectors are limited to a 4kV rating.



# HIGH VOLTAGE PULSE TERMINATOR

## MODEL 201-BMP



Model 201-BMP

### DESCRIPTION

50  $\Omega$  High Voltage Pulse Terminator

### SPECIFICATIONS

<b>Maximum Input:</b>	3kV, 250ns FWHM Pulse
<b>Peak Input Power:</b>	200kW at rated pulse width
<b>Average Input Power:</b>	1W maximum
<b>Impedance:</b>	50 $\Omega \pm 0.5\%$
<b>Reflection-TDR:</b>	< 1% to a 100ps risetime step function
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connector:</b>	BNC male
<b>Dimensions:</b>	1.5" long x 19/32" dia. max.
<b>Weight:</b>	<1 oz.

# HIGH VOLTAGE PULSE TERMINATOR

MODEL 2033-HFP, 2035-HFP



Model 2033-HFP



Model 2035-HFP

## DESCRIPTION

50  $\Omega$  High Voltage Pulse Terminator

## SPECIFICATIONS

<b>Maximum Input:</b>	2033	12kV, 400ns FWHM Pulse
	2035	14kV, 400ns FWHM Pulse
<b>Peak Input Power:</b>	2033	2MW at rated pulse width
	2035	2MW at rated pulse width
<b>Average Input Power:</b>	2033	4W Maximum
	2035	8W Maximum
<b>Impedance:</b>		50 $\Omega \pm 0.5\%$
<b>Reflection-TDR:</b>		< 4% to a 100ps risetime step function
<b>Voltage Coefficient:</b>		< 1% at rated voltage
<b>Connector:</b>		HNB female
<b>Dimensions:</b>	2033	4.8" long x 1.3" wide x 1.3" high
	2035	10.4" long x 1.3" wide x 1.3" high
<b>Weight:</b>	2033	1 lb.
	2035	2 lb.

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection.

# HIGH VOLTAGE PULSE TERMINATOR

MODEL 2051-GHMP, 2051-GHFP



Model 2051 – GHMP  
(Male Version Shown)

## DESCRIPTION

50  $\Omega$  High Voltage Pulse Terminator

## SPECIFICATIONS

<b>Maximum Input:</b>	10kV, 100ns FWHM Pulse
<b>Peak Input Power:</b>	2MW at rated pulse width
<b>Average Input Power:</b>	2W maximum
<b>Impedance:</b>	50 $\Omega \pm 0.5\%$
<b>Reflection-TDR:</b>	< 3% to a 100ps risetime step function
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connector:</b>	GHV male, or GHV female
<b>Dimensions:</b>	3.2" long x 1" dia. max.
<b>Weight:</b>	< 1/3 lb.

# HIGH VOLTAGE PULSE ATTENUATOR

## DESCRIPTION

Barth High Voltage Pulse Attenuators are matched impedance coaxial attenuators for use primarily in pulsed 50 ohm systems, or where occasional transients would damage ordinary units. The attenuator design closely matches the impedance around each resistor, to that resistor. These attenuators feature an input impedance very close to 50 ohms, with characteristics as good or better than most microwave attenuators. These units are ideal for use in nuclear and high energy experiments. Extensive testing during manufacturing insures very high reliability for single-shot experiments. A voltage coefficient of the resistive film of less than .0001 %/V allows low voltage calibration of most systems.

## ADVANTAGES OVER STANDARD RF ATTENUATORS

- ⊗ Low reflection coefficient
- ⊗ Withstands high voltage pulses
- ⊗ Pulse power rated
- ⊗ Low voltage coefficient
- ⊗ High reliability
- ⊗ Input/Output impedance held very close to nominal

## MAXIMUM INPUT CONSIDERATIONS

The breakdown limitations of our film resistors are related to pulse energy. A unit that has been rated and tested to withstand 5kV, 400ns FWHM rectangular pulses should be able to withstand 10kV, 75ns FWHM rectangular pulses. While this general "rule of thumb" has been found useful in practice, we cannot guarantee higher voltages or pulse widths unless we test the particular unit to your pulse specification.

NOTE: We will only guarantee other voltages and pulse widths or shapes if we life test a unit for that particular pulse specification.

Our standard units are all 50 ohm impedance. We do, however, manufacture and stock many 100 ohm impedance units. If we are unable to meet your requirements with a stock unit, call, as other types and impedance's can be designed to your specifications.

## SPECIAL USE CONSIDERATIONS

Attenuators purchased at list price can be used at higher voltages and shorter pulse width ratings but are not guaranteed.

Guaranteed pulse energy performance is available with a nominal additional cost for special testing at specified voltage & pulse width.

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## HIGH VOLTAGE PULSE ATTENUATOR MODEL COMPARISON

Model	Average input power	Voltage ratio dB	Maximum Input*		Reflection coefficient at 100ps	Risettime through unit ps	Effective bandwidth DC to	Connectors
			Maximum peak voltage	Input @ pulse width ns				
102-GP-20	5W	20	2,500	400	< 2%	< 50	7 GHz	GR 874 non-locking
102-GLP-20	5W	20	2,500	400	< 2%	< 50	7 GHz	GR 874 locking
102-NMFP-20	5W	20	2,500	400	< 2%	< 50	7 GHz	N Male/Female**
102 with CF Option	10W	20	2,500	400	< 2%	< 50	7 GHz	See available configurations above
142-xxx-3	2W	3	2,500	400	< 3%	< 10	30 GHz	***
142-xxx-4	2W	4	2,500	400	< 3%	< 10	30 GHz	***
142-xxx-6B	2W	6	2,500	400	< 3%	< 10	30 GHz	**
142-xxx-8B	2W	8	2,500	400	< 3%	< 10	30 GHz	***
142-xxx-10B	2W	10	2,500	400	< 3%	< 10	30 GHz	***
142-xxx-14B	2W	14	2,500	400	< 3%	< 10	30 GHz	***
142-xxx-20B	2W	20	2,500	400	< 3%	< 10	30 GHz	***
142-xxx-26B	2W	26	2,500	400	< 3%	< 10	30 GHz	***
202B-GLP-N	2W	8	5,000	400	< 5%	< 20	17 GHz	GR 874 locking
202A-GLP-T	2W	14	5,000	400	< 5%	< 20	17 GHz	GR 874 locking
202A-GLP-X	2W	20	5,000	400	< 5%	< 20	17 GHz	GR 874 locking
202B-NMFP-N	2W	8	4,000	400	< 5%	< 20	17 GHz	N female/male
202-NMFP-T	2W	14	4,000	400	< 5%	< 20	17 GHz	N female/male
202-NMFP-X	2W	20	4,000	400	< 5%	< 20	17 GHz	N female/male
2237A-HFNFP	2.5W	26	10,000	400	< 4%	< 50	7 GHz	HNB female input
2239A-HFNFP	2.5W	26	16,000	400	< 4%	<100	3.5GHz	N female output
2240-BENFP	2.5W	26	25,000 50,000	160 40	<4% @ 1ns	<100	7 GHz	Barth 454 Input N Female Output
2511-30F	25W	30	8,000	150	< 5% @ 1ns	< 1ns	0.35 GHz	Fischer input BNC output
2536-HFP-3	200W	3	7,000 15,000	400 75	< 5%	35	10 GHz	HNB female****
2536-HFP-6	200W	6	7,000 15,000	400 75	< 5%	35	10 GHz	HNB female****
2536-HFP-10	200W	10	7,000 15,000	400 75	< 5%	35	10 GHz	HNB female****
2536-HFP-20	200W	20	7,000 15,000	400 75	< 5%	35	10 GHz	HNB female****

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection.

- \* Please refer to the Technical Specifications (Maximum Input Limitations) page for a full explanation of voltage and pulse width ratings.
- \*\* Units with N connectors are limited to a 4kV rating.
- \*\*\* Any male or female (GR, N, HNB, GHV) can be supplied.
- \*\*\*\* Unit is supplied with a Barth Model 404-HMM low reflection HNB male to male adapter, so that either the input or output can be adapted to a male connection.

# HIGH VOLTAGE PULSE ATTENUATOR

## MODEL 102 Series

### ADVANTAGES

- ⊕ High voltage pulse rated
- ⊕ Least expensive high voltage coaxial attenuator available
- ⊕ Small dimensions
- ⊕ Higher average power than 142 series



Model 102-NMFP-20

### DESCRIPTION

This unit utilizes a patented design, which provides for maintaining good HV capabilities and good power dissipation. While this unit has a simpler housing design than our precision attenuators, for better heat dissipation, it still provides a very respectable and clean 50 ps output risetime.

### SPECIFICATIONS

<b>Voltage Ratio:</b>	10.0/1 Vr (20dB)
<b>Maximum Input:</b>	5.0kV, 80ns FWHM Pulse, 500kW Peak Power** 2.5kV, 400ns FWHM Pulse, 125kW Peak Power 1.25kV, 1600ns FWHM Pulse, 31kW Peak Power
<b>Average Input Power:</b>	5W maximum <b>10W with optional fins (Model CF) for external cooling</b>
<b>Impedance:</b>	50 $\Omega \pm 1\%$
<b>Risetime through Unit:</b>	< 50ps
<b>Bandwidth (-3dB):</b>	DC to 7GHz
<b>Reflection-TDR:</b>	< 4% to a 100ps risetime step function
<b>SWR:</b>	< 1.05 to 1GHz < 1.30 to 4GHz
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	102-NMFP-20 N Male/Female** 102-GLP-20 GR 874 locking 102-GP-20 GR 874 non-locking
<b>Dimensions:</b>	102-NMFP-20 5" long x .8" dia. 102-GP-20 4.5" long x 0.625" dia. 102-GLP-20 4.5" long x 1.01" dia.
<b>Weight:</b>	3/8 lb.

\*\* Units with N connectors are limited to a 4kV rating.

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# HIGH VOLTAGE PULSE ATTENUATOR

MODEL 202 – XXX

## ADVANTAGES

- ⊕ High voltage pulse rated
- ⊕ High voltage precision coaxial attenuator
- ⊕ Small dimensions



Model 202B-NMFP-N

## DESCRIPTION

The Model 202 utilizes our original patented design, which still provides the best high voltage attenuator available. This unit withstands 5kV, 400ns FWHM pulses into either end and has a 20ps risetime.

## SPECIFICATIONS

<b>Voltage Ratio:</b>	202-xxx-N	2.5/1 Vr (8dB)
	202-xxx-T	5.0/1 Vr (14dB)
	202-xxx-X	10.0/1 Vr (20dB)
<b>Maximum Input:</b>	5.0kV, 400ns FWHM Pulse **	
<b>Peak Input Power:</b>	500kW at rated pulse width	
<b>Average Input Power:</b>	2W maximum	
<b>Impedance:</b>	50 $\Omega$ $\pm$ 1%	
<b>Risetime through Unit:</b>	< 20ps	
<b>Bandwidth (-3dB):</b>	DC to 17GHz	
<b>Reflection-TDR:</b>	< 5% to a 100ps risetime step function	
<b>SWR:</b>	< 1.05 to 1GHz < 1.30 to 4GHz	
<b>Voltage Coefficient:</b>	< 1% at rated voltage	
<b>Connectors:</b>	202-NMFP-y	N male/female
	202-GLP-y	GR 874 Locking
	202-HMFP-y	HNB male/female
<b>Dimensions:</b>	4.1" to 3.3" long x 1.2" wide x 1" high depending on value	
<b>Weight:</b>	< 1/2 lb.	

-xxx Connector identifier, see list under connectors heading for our standard (stocked) configurations. Call for connector configurations not shown.

-y Attenuation value identifier

\*\* Units with N connectors are limited to a 4kV rating.



# HIGH VOLTAGE PULSE ATTENUATOR

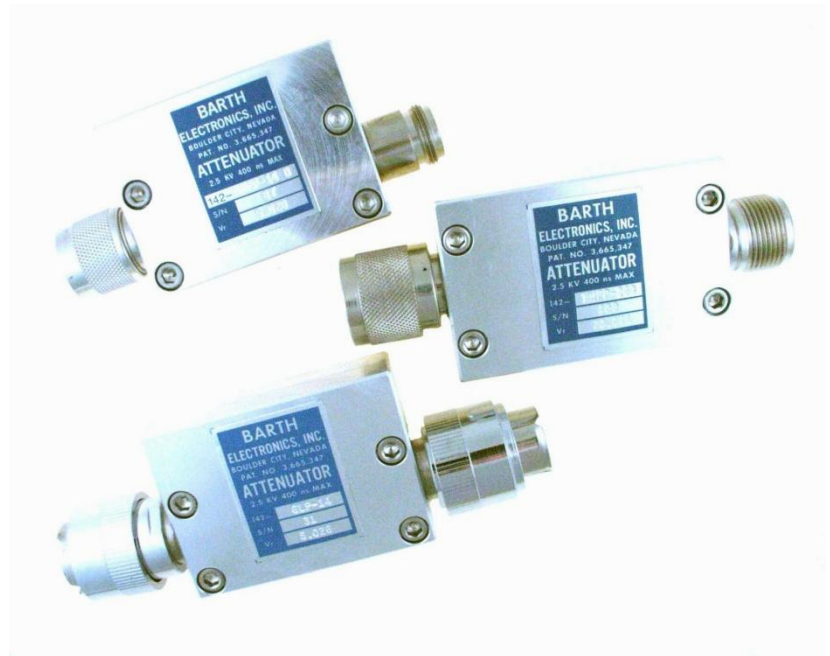
## MODEL 142 SERIES

### ADVANTAGES

- ⊕ High voltage pulse rated
- ⊕ Wide range of standard attenuation values, custom values available
- ⊕ Units with standard connector combinations are available from stock
- ⊕ Custom connector combinations can be manufactured from standard parts.

### DESCRIPTION

The 142 series attenuators are available in 8 standard attenuator values and are rated for 2.5Kv/400ns wide rectangular pulse. Any non standard value, between 1.2 and 20dB, can be manufactured.



### SPECIFICATIONS

#### Voltage Ratio - Attenuation dB:

142-xxx-3:	1.4/1 Vr (3dB)
142-xxx-4:	1.5/1 Vr (4dB)
142-xxx-6B:	2.0/1 Vr (6dB)
142-xxx-8B:	2.5/1 Vr (8dB)
142-xxx-10B:	3.2/1 Vr (10dB)
142-xxx-14B:	5.0/1 Vr (14dB)
142-xxx-20B:	10.0/1 Vr (20dB)
142-xxx-26B:	20.0/1 Vr (26dB)

**Maximum Input:** 2.5kV, 400ns FWHM Pulse

**Peak Input Power:** 125kW at rated pulse width

**Average Input Power:** 2W maximum

**Impedance:**  $50 \pm 1\%$

**Risetime through Unit:** < 10ps

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*Specifications are continued on the next page*

# HIGH VOLTAGE PULSE ATTENUATOR

## MODEL 142 SERIES

*SPECIFICATIONS continued*

<b>Bandwidth (-3dB):</b>		DC to 30GHz
<b>Reflection-TDR:</b>		< 3% to a 100ps risetime step function
<b>Voltage Coefficient:</b>		< 1% at rated voltage
<b>Connectors:</b>	142-NMFP-yy 142-GLP-yy 142-HMFP-yy 142-GHMFP-yy 142-SPJ 142-SPJP 142-SHV	N male/female * GR 874 Locking HNB male/female GHV male/female *** SHV male/female ***
<b>Dimensions:</b>		Outline drawings available
<b>Weight:</b>		3/4 lb max.
<b>Ordering Information:</b>		142-xxx-yy

-xxx Connector identifier, see list under connectors heading for our standard (stocked) configurations. Call for connector configurations not shown.

-yy Attenuation value in dB, see list of standard values under Voltage Ratio heading, or call for nonstandard values.

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection.

Actual measured voltage ratio is recorded on each nameplate.

\* Most popular general purpose lab items, in stock for immediate delivery.

\*\*\* Connector has risetime limitations; please specify test pulse risetime.

# HIGH VOLTAGE PULSE ATTENUATOR

MODEL 2237A-HFNFP, 2239A-HFNFP

Model 2237A-HFNFP



Model 2239A-HFNFP



## DESCRIPTION

26dB attenuators with HN female input connectors.

## SPECIFICATIONS

<b>Voltage Ratio:</b>	20/1 Vr (26dB)
<b>Maximum Input:</b>	2237A 10kV/400ns FWHM Pulse 2239A 16kV/400ns
<b>Peak Input Power:</b>	2237A 2MW at rated pulse width 2239A 5.12MW at rated pulse width
<b>Average Input Power:</b>	2.5W maximum
<b>Impedance:</b>	50 $\Omega$ $\pm$ 1%
<b>Risetime through Unit:</b>	2237A < 50ps 2239A <100ps
<b>Bandwidth (-3dB):</b>	2237A DC to 7.0GHz 2239A DC to 3.5GHz
<b>Reflection-TDR:</b>	Input < 4% to a 100ps risetime step function Output < 3% to a 100ps risetime step function
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	HN female input N female output
<b>Dimensions:</b>	2237A 4.8" long x 1.250" wide x 2" high 2239A 10.5" long x 1.250" wide x 2" high
<b>Weight:</b>	2237A 1 ¼ lbs. 2239A 1 ¾ lbs.

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection. A RG214/U coax "pigtail" input is also available and can be supplied with a HNB male connector on the coax. We have found that the best HN Connector pair cannot withstand 25kV at 10ns pulse width for more than 1000 shots. We have to limit the maximum pulse voltage of any attenuator with HN connectors. They can withstand 25 or 30kV at much shorter pulses. But we cannot specify what that pulse width limit may be.

# Barth Model 2240A-BENFP



## **DESCRIPTION:**

The 2240A-BENFP is an ultra wide band high voltage attenuator designed for measurement of signal rise times as fast as 100ps

## **SPECIFICATIONS:**

<b>Voltage Ratio:</b>		20/1 +/- 5% (26dB)
<b>Maximum Input Voltage:</b>		25kV, 160ns FWHM 50kV, 40ns FWHM
<b>Peak Input Energy:</b>		2.0 Joules (Watt Seconds)
<b>Average Input Power:</b>		2.5W Maximum
<b>Impedance:</b>		50 Ohm +/- 1%
<b>Risetime through Unit:</b>		<100ps
<b>Bandwidth</b>		DC to 3.5GHz
<b>Reflection - TDR:</b>	<b>Input</b>	<4% to a 100ps rise time step
	<b>Output</b>	<3% to a 100ps rise time step
<b>Voltage Coefficient:</b>		<1% at any voltage
<b>Connectors:</b>		Barth BE Series Input N Female Output
<b>Available Mating Connector:</b>		454-BE Series for RG-214 Cable (Call us for other configurations)
<b>Dimensions:</b>		10.5" long x 1.25" wide x 2" high
<b>Weight:</b>		1.5 lbs.

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 Barth Electronics, Inc.



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[www.BarthElectronics.com](http://www.BarthElectronics.com)

# Barth Model 454-BE Connector

## DESCRIPTION:

The Barth 454-BE Connector is for use with RG-214 Coax



## SPECIFICATIONS:

<b>Maximum Input Voltage:</b>		40 kV DC
<b>Full Width Half Max:</b>		100 kV, 20ns FWHM
<b>Impedance:</b>		50 Ohm +/- 1%
<b>Risetime through Unit:</b>		<100ps
<b>Bandwidth:</b>		DC to 7.0GHz
<b>Reflection - TDR:</b>	<b>Input</b>	<4% to a 100ps risetime step
	<b>Output</b>	<3% to a 100ps risetime step
<b>Connector:</b>		Barth BE RG-214 pigtail unterminated
<b>Dimensions:</b>		Connector body approx. 1.6" Dia. x 4" long + cable length
<b>Weight:</b>		Approx. 1 lb. (Connector + 1M RG-214 coax)

# Barth Model XXX-BE Connector

**\*NOTE:**  
**Additional Connectors  
Coming Soon.**



## **DESCRIPTION:**

The Barth XXX-BE Connector  
is for use with TBD Coax

## **SPECIFICATIONS:**

<b>Maximum Input Voltage: Full Width Half Max:</b>		40 kV DC 100 kV, 20ns FWHM
<b>Impedance:</b>		50 Ohm +/- 1%
<b>Risetime through Unit:</b>		<100ps
<b>Bandwidth:</b>		DC to 7.0GHz
<b>Reflection - TDR:</b>	<b>Input Output</b>	<4% to a 100ps risetime step <3% to a 100ps risetime step
<b>Connector:</b>		Barth BE
<b>Dimensions:</b>		Connector body approx. 1.6" Dia. x 4" long + cable length
<b>Weight:</b>		Approx. 1 lb. (Connector)

# HIGH VOLTAGE PULSE POWER ATTENUATOR

MODEL 2511-30F

## ADVANTAGES

- ⊕ Used for high voltage, high repetition rate testing of sources
- ⊕ Electrical Fast Transients pulse sources

## DESCRIPTION

The Model 2511-30F has a medium power rating that allows for high repetition rate testing of EFT generators, at their high voltage rating.



## SPECIFICATIONS

<b>Voltage Ratio:</b>	30dB	31.6/1 Vr
<b>Maximum Input:</b>	8 kV @ 50 ns FWHM Pulse, 100 ns 1/e Exponential decay	
<b>Peak Input Energy:</b>	64 mJ @ 50 ns Pulse Width	
<b>Average Input Power:</b>	25 W	
<b>Impedance:</b>	50 Ω	
<b>Risetime through Unit:</b>	1 ns	
<b>Bandwidth (-3dB):</b>	350 MHz	
<b>Reflection-TDR:</b>	< 5% @1ns	
<b>Voltage Coefficient:</b>	< 1% at 10 kV	
<b>Connectors:</b>	Fischer 103 receptacle input; BNC receptacle output	
<b>Dimensions:</b>	5.5" long x 4.2" wide x 3.5" high	
<b>Weight:</b>	2.8 lbs.	

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# Barth Model 2248

## DESCRIPTION:


The 2248-BENFP is an ultra wide band high voltage attenuator designed for measurement of signal rise times as fast as 100ps



## SPECIFICATIONS:

<b>Voltage Ratio:</b>		20/1 +/- 5% (26dB)
<b>Maximum Input Voltage:</b>		5kV, 4 $\mu$ s FWHM
<b>Peak Input Energy:</b>		2.0 Joules (Watt Seconds)
<b>Average Input Power:</b>		10W Maximum
<b>Impedance:</b>		50 Ohm +/- 1%
<b>Risetime through Unit:</b>		<100ps
<b>Bandwidth</b>		DC to 3.5GHz
<b>Reflection - TDR:</b>	<b>Input</b>	<4% to a 100ps rise time step
	<b>Output</b>	<3% to a 100ps rise time step
<b>Voltage Coefficient:</b>		<1% at any voltage
<b>Connectors:</b>		HN Female Input (Recepticle) N Female Output (Recepticle)
<b>Dimensions:</b>		8.25" long x 1.50" wide x 2" high
<b>Weight:</b>		1.5 lbs.

ZAPLESS®

 Barth Electronics, Inc.



1589 Foothill Drive  
Boulder City, NV 89005  
Phone 702.293-1576  
Fax 702.293.7024  
[www.BarthElectronics.com](http://www.BarthElectronics.com)

# HV Pulse Power Attenuator Model 2536

## DESCRIPTION:

A high voltage pulse/high power microwave (HPM) attenuator that contains a liquid dielectric coolant. It has an integral coolant pump, heat exchanger, and fan, which enables this unit to dissipate high average power.

\*\*Note: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection. The unit is supplied with a Model 404-HMM low reflection male to male adapter, so that either the input or output can be a male connector.

The Model 2536-HFP-X is warranted to perform to its specifications for a period of 1 year. This warranty does not apply to units subjected to input power higher than a 200W average or being used without the cooling pump being in operation for the minimum time as specified on the operations tag. A unit determined to have failed under normal operating conditions without excess power or voltage, will be repaired under warranty.



## SPECIFICATIONS:

<b>Voltage Ratio:</b>	2536-3 2536-6 2536-10 2536-20	1.4/1 Vr (3 dB) 2.0/1 Vr (6 dB) 3.2/1 Vr (10 dB) 10.0/1 Vr (20 dB)
<b>Maximum Input:</b>		7kV/400ns, 15kV/75ns, 30kV/15ns, 60kV/2ns FWHM Pulse
<b>Peak Input Power:</b>		72MW at rated pulse width
<b>Average Input Power:</b>		200W Maximum
<b>Impedance:</b>		50 $\Omega$ +/- 1% (output terminated with 50 $\Omega$ )
<b>Risetime through Unit:</b>		35ps
<b>Bandwidth (-3dB):</b>		DC to >10GHz
<b>Reflection - TDR:</b>		<5% to a 100ps risetime step function
<b>Voltage Coefficient:</b>		<1% at 25kV
<b>Connectors:**</b>		HNB Female
<b>Dimensions:</b>		$\approx$ 5"(12.7 cm) wide x 6"(15.3 cm) high x 12"(30.5 cm) deep
<b>Weight:</b>		$\approx$ 17 lbs. (7.8 kg)
<b>Power Requirements:</b>		115V/60Hz, 4 Amp to power cooling pump, fan and highly visible "power on" light (240V/50-60Hz model available for export)

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# WIDE BAND IMPEDANCE MATCHING COMPONENTS

MODEL 220-NFP, 220-MMFP

## DESCRIPTION

A 50  $\Omega$  series high voltage pulse resistor for a one way match of 100  $\Omega$  components, to 50  $\Omega$  components.



Model 220-NFP

## SPECIFICATIONS

<b>Input-Output Impedance:</b>	100 $\Omega$ to 50 $\Omega$ (50 $\Omega$ series resistor)
<b>Input-Output Voltage Ratio:</b>	2/1 (6.02dB)
<b>Maximum Input:</b>	2.5kV, 250ns FWHM Pulse
<b>Peak Input Power:</b>	62.5kW at rated pulse width
<b>Average Input Power:</b>	2W maximum
<b>Risetime:</b>	< 400ps
<b>Bandwidth (-3 dB):</b>	DC-1GHz
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	50 $\Omega$ N female

# Barth Model 5101-MMFP-1

## 50 Ohm Series Resistor



The Barth Model 5101-MMFP-1 is a 50 Ohm Series High Voltage Pulse Resistor designed for a one way match of 100 ohm components to 50 ohm components.

### Similar Products

- 220-NFP 50 ohm Series Resistor
- 220a-GLP 50 ohm Series Resistor

### Specifications:

Input Output Resistance:	100 ohm to 50 ohm (50 ohm Series Resistor)
Maximum Peak Input Voltage:	1.5kV/100ns FWHM rectangular pulse
Input-Output (VR):	2/1 (-6.02 dB)
Input-Output 10-90% Risetime:	< 400ps
Bandwidth (- 3dB):	DC - 1GHz
Maximum Peak Power (kW):	22.5kW at rated pulse width
Maximum Average Input Power:	1 Watt Maximum
Voltage Coefficient:	< 1% at rated voltage
Connector Configuration:	SMA male / SMA female - bidirectional

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# WIDE BAND IMPEDANCE MATCHING COMPONENTS

## MODEL 224A-GLP

### DESCRIPTION

Model 224A-GLP, 50  $\Omega$  to 100  $\Omega$  resistive matched attenuator

### SPECIFICATIONS

<b>Input-Output Impedance:</b>	50 $\Omega$ to 100 $\Omega$
<b>Voltage Ratio:</b>	3.035 Vr (9.64dB) 50 $\Omega$ to 100 $\Omega$ direction 7.07 Vr (16.99dB) 100 $\Omega$ to 50 $\Omega$ direction
<b>Maximum Input:</b>	2.5kV, 250ns FWHM Pulse
<b>Peak input Power:</b>	62.5kW at rated pulse width
<b>Average Input Power:</b>	2W maximum
<b>Risetime:</b>	< 20 ps
<b>Bandwidth (-3 dB):</b>	DC - 18GHZ
<b>Voltage Coefficient:</b>	< 1 % at rated voltage
<b>Connectors:</b>	GR 874 locking 50 $\Omega$ - GR 874 locking 100 $\Omega$



Model 224A-GLP

# HAND HELD HIGH VOLTAGE HIGH FREQUENCY VOLTAGE PROBE

MODEL 2440 - 6 GHz

## DESCRIPTION

The Model 2440 Hand Held, High voltage, High Frequency voltage probe, is intended for passive probing of high speed, high voltage pulse circuits. The probe kit contains one 450 ohm resistive probe for a 10:1 voltage ratio (20dB), one 950 ohm resistive probe for a 20:1 voltage ratio (26dB), and one each 450 and 950 ohm replacement resistors.

The probe is designed to have the output terminated into a 50 ohm system. It is intended for output into an attenuator or 50 ohm scope input. The probe's specified response is for the probe connected with the included low loss coaxial cable.



## SPECIFICATIONS

<b>Maximum Input:</b>	10:1 probe	3kv, 500ns 1/e Exponential decay pulse
	20:1 probe	5kv, 500ns 1/e Exponential decay pulse
<b>Risetime:</b>		< 60ps Typical
<b>Bandwidth:</b>		DC to 6GHz Typical Risetime and bandwidth can be limited by the physical structure surrounding the measurement point.
<b>Input Resistance:</b>	10:1 probe	500 ohm - when probe is terminated
	20:1 probe	1k ohm - into nominal 50 ohm load
<b>Voltage Coefficient:</b>		< 1 % at rated voltage
<b>Connectors:</b>		SMA female on probe bodies SMA male on both ends of 36" long low loss cable for connection of probe to measurement system.

Note: The probe ratings are for use with the supplied 36" long low loss cable. Use of longer or higher loss cable will degrade the risetime of the measured pulse.

# HAND HELD HIGH VOLTAGE HIGH FREQUENCY VOLTAGE PROBE

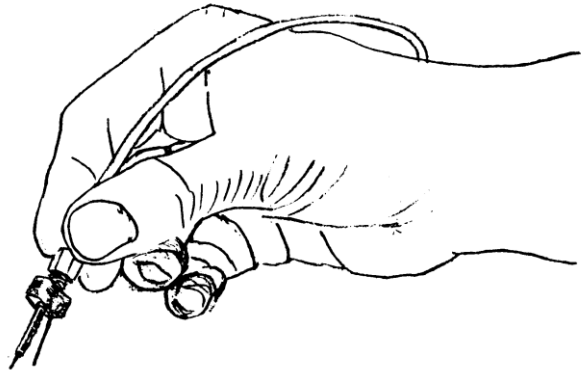
MODEL 2440 - 6 GHz

## WARNING / SAFETY

The Model 2440 Voltage Probe is designed for the measurement of short high voltage pulses on open transmission structures in a laboratory environment. General laboratory safety procedures for working on active High Voltage systems should be followed. Only personnel experienced in the safe operation of high voltage research and development laboratory type equipment should use this probe.

## OPERATION NOTE

Appropriate precautions must be taken to discharge the probe and connecting cable when the probe is being connected to sensitive sampling scope inputs, because they are very susceptible to electrostatic damage. Any Teflon dielectric coaxial cable can easily become statically charged and can hold a charge for a long period of time. Failure to discharge a piece of coax before connecting it to the sensitive scope inputs can easily damage the expensive front end electronics of these sensitive instruments.



The coax cable included with the probe can easily be discharged from either end by connecting a short or providing a resistive connection from the center conductor to the ground conductor.

Touching your finger between the center conductor and outer (ground) conductor on the SMA cable connector is a simple effective method to remove any charge on the probe cable.

The output of the probe must be connected with the included low loss coaxial cable to a 50 ohm system, for instance to an attenuator or directly to a 50 ohm scope input. The correct method for holding the probe when making measurements, is to hold the probe body by the SMA connector in your hand between your thumb and fingers in the same manner that you would hold a pencil. Placing your hand or fingers closer to the probe tip will add capacitance to the probe and will degrade the risetime of the probe output. The probe risetime specification includes the use of the supplied low loss 36" long cable. Use of longer or higher loss cable will degrade the probe's response.

## AVERAGE POWER RATING WARNING

The peak, or average power rating, only applies to a well terminated load. Any reflection greater than 10% will significantly add to the power the DC-20Ghz bandwidth resistor will have to absorb.



## CUSTOM HIGH VOLTAGE PROBES FOR DEDICATED LOCATION PULSE MEASUREMENTS

### Output risetime depends on housing construction around these resistors.

When used in the proper/optimum housing, the assembly has <100ps risetime ( $\tau$ ).

The resistors listed here are examples made specifically for fast HV pulse measurement application. They were designed and tested inside a specific metal housing that accurately simulates their final application use. They are located in special gas insulation, HV dielectric material, or were potted in place to provide the required pulse amplitude and risetime response characteristics. They were constructed to produce repeatable sub-nanosecond response which requires that the resistor remains attached to the pulse voltage terminal being measured. We welcome requests for specific pulse voltage measurement applications.

If you have a need for a high voltage probe we can design a specific resistor and housing to fit your requirements.

### Examples:

Model	Maximum peak voltage	Resistance	@ pulse width ns	Risetime of resistive output ps	Terminals
VP1E3-20-1E3	20,000	1000 $\Omega$	1 $\mu$ s	**	8-32 female thread ***
VP5E2-28-8R2	28,000	500 $\Omega$	800	**	HNB female
VP2E3-35-1R2N	35,000	2000 $\Omega$	100	**	N female
VP2E3-35-1R2H	35,000	2000 $\Omega$	100	**	HNB female

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or Model 402-HNB female cable connector for RG214/U coax should be used for interconnection.

\*\* The output risetime will be dependent on the housing.

\*\*\* Consult factory for optimum installation assistance for your application. Custom connector mounted probes can usually be designed for specific measurement requirements.

**DISCLAIMER:** These resistors were designed for special uses in special housings; **these resistors are not hand held voltage probes.**

## HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

Barth High Voltage Resistive Power Dividers are matched impedance coaxial devices for use primarily in pulsed 50 ohm systems, or where occasional transients would damage ordinary units. These units are ideal for use in nuclear and high energy experiments. These dividers feature input and output impedance very close to 50 ohms. Extensive testing during manufacturing insures very high reliability for single-shot experiments. A voltage coefficient of the resistive film of less than .0001%/V allows low voltage calibration of most systems.

### ADVANTAGES OVER STANDARD RF POWER DIVIDERS

- ⊗ Withstands High Voltage Pulses, Low Voltage Coefficient, as well as a Low Reflection Coefficient
- ⊗ Input/Output impedance held very close to nominal
- ⊗ High Reliability, and Pulse Power Rated

### MATCHED RESISTIVE POWER DIVIDER MODEL COMPARISON

Model	# of output ports	Voltage ratio dB	Maximum peak voltage	@ pulse width ns	Input reflection coefficient at 100ps $\tau$	Risetime through unit ps	Connectors
151-xxx	2	6.0	2,500	400	< 4%	< 40	**
251-xxx	2	6.0	5,000	400	< 4%	< 40	**
2642-MMFP	2	6.0	1,000	400	< 1%	< 35	SMA female/SMA male
2642-MFP	2	6.0	1,000	400	< 1%	< 35	SMA female
2702-BFP	2	6.0	2,500	250	< 5%	< 65	BNC female
2703-BFP	3	9.5	2,500	250	< 5%	< 65	BNC female
2704-BFP	4	12.0	2,500	250	< 5%	< 65	BNC female
2705-BFP	5	14.0	2,500	250	< 5%	< 65	BNC female
2706-BFP	6	15.6	2,500	250	< 5%	< 65	BNC female
2746-NFMF	6	15.6	4,000	100	< 4%	< 45	N female/SMA female
2812-NFP	2	6.0	2,500	250	< 2%	< 50	N female
2813-NFP	3	9.5	2,500	250	< 2%	< 50	N female
2814-NFP	4	12.0	2,500	250	< 2%	< 50	N female
2815-NFP	5	14.0	2,500	250	< 2%	< 50	N female
2816-NFP	6	15.6	2,500	250	< 2%	< 50	N female
281x-NMFP	***	***	2,500	250	< 2%	< 50	N male/N female
281x-HFNFP	***	***	5,000	100	< 2%	< 50	HN female/N female
281x-UNFP	***	***	10,000	25	< 3%	< 50	UHLC/N female
2825-NFP	5	14.0	4,000	100	< 2%	< 75	N female
2828-NFP	8	18.1	4,000	100	< 2%	< 65	N female
2830-NFP	10	20.0	4,000	100	< 2%	< 70	N female
2832-NFP	12	21.6	4,000	100	< 2%	< 75	N female

-xxx Connector identifier, see connector list heading above for our standard (stocked) configurations; call for connector configurations not shown

\*\* Any male or female (GR, N, HNB) can be supplied. Units with N connectors are limited to 4kV.

\*\*\* Refer to similar – NFP model above for # of Output Ports, and Voltage Ratio.

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 151-XXX



Model 151-NFP

## DESCRIPTION

High Voltage 2 Way Matched Power Divider (3 resistors)

## SPECIFICATIONS

<b>Voltage Ratio:</b>	2.0/1Vr (6dB)
<b>Maximum Input:</b>	2.5kV, 400ns FWHM Pulse
<b>Peak Input Power:</b>	125kW at rated pulse width
<b>Average Input Power:</b>	2W maximum
<b>Impedance:</b>	50 $\Omega$ $\pm$ .25 $\Omega$
<b>Reflection-TDR:</b>	< 4% to a 100ps risetime step function
<b>Risetime through Unit:</b>	< 40ps
<b>Bandwidth:</b>	DC to 9GHz
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	151-GP GR 874 Non locking 151-GLP GR 874 Locking 151-NMP N male 151-NFP N female
<b>Dimensions:</b>	4" long x 2.5" wide x 1" high
<b>Weight:</b>	Approx. 1/2 lb.

-xxx Connector identifier, see connector list heading above for our standard (stocked) configurations; call for connector configurations not shown.

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 251-XXX



Model 251-NFP

## DESCRIPTION

High Voltage 2 Way Matched Power Divider (3 resistors)

## SPECIFICATIONS

<b>Voltage Ratio:</b>	2.0/1 Vr (6dB)
<b>Maximum Input:</b>	5kV, 400ns FWHM Pulse **
<b>Peak Input Power:</b>	500kW at rated pulse width
<b>Average Input Power:</b>	2W maximum
<b>Impedance:</b>	50 $\Omega$
<b>Reflection-TDR:</b>	< 4% to a loop risetime step function
<b>Risetime through Unit:</b>	< 40ps
<b>Bandwidth:</b>	DC to 9GHz
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	251- GP GR 874 non-locking 251- GLP GR 874 locking 251- NMP N male ** 251- NFP N female ** 251- HMP HNB male 251- HFP HNB female
<b>Dimensions:</b>	4" long x 2.5" wide x 1" high
<b>Weight:</b>	Approx. 1/2 lb.

-xxx Connector identifier, see connector list heading above for our standard (stocked) configurations; call for connector configurations not shown.

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection.

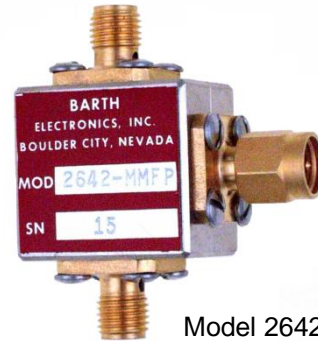
\*\* Units with N connectors are limited to 4kV rating.

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 2642-MMFP, 2642-MFP

## DESCRIPTION

High Voltage 2 Way Matched Resistive Power Divider with SMA Connectors



Model 2642-MMFP

## SPECIFICATIONS

<b>Voltage Ratio:</b>	2.0/1 Vr (6dB)
<b>Maximum Input:</b>	1kV, 400ns FWHM Pulse
<b>Peak Input Power:</b>	20kW at rated pulse width
<b>Average Input Power:</b>	1W maximum
<b>Impedance:</b>	50 $\Omega$
<b>Reflection-TDR:</b>	Input < 1% to a 100ps risetime step function Output < 2% to a 100ps risetime step function
<b>Risetime through Unit:</b>	< 35ps
<b>Bandwidth:</b>	DC to 10GHz
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	2642-MMFP SMA male in, 2 SMA female out 2642-MFP SMA female
<b>Dimensions:</b>	1.560" long x 1.370" wide x .640" high
<b>Weight:</b>	Approx. 2.3 oz.

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 2700 SERIES



Model 2706-BFP

## DESCRIPTION

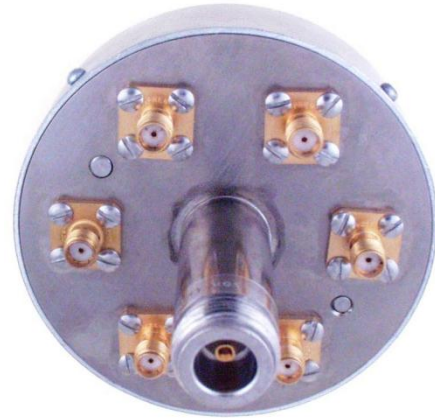
The 2700 series High Voltage Power Dividers offer 2, 3, 4, 5, or 6 output ports and are designed for use primarily in pulsed 50 ohm systems, or where occasional transients would damage ordinary units. These dividers feature input and output impedance very close to 50 ohms.

## SPECIFICATIONS

<b>Voltage Ratio:</b>	2702-BFP	2.0/1 Vr (6.02dB)
	2703-BFP	3.0/1 Vr (9.54dB)
	2704-BFP	4.0/1 Vr (12.04dB)
	2705-BFP	5.0/1 Vr (13.98dB)
	2706-BFP	6.0/1 Vr (15.56dB)
	2710-BFP	10.0/1 Vr (20.0 dB)
<b>Maximum Input:</b>	2.5kV, 250ns FWHM Pulse	
<b>Peak Input Power:</b>	125kW at rated pulse width	
<b>Average Input Power:</b>	8W maximum	
<b>Impedance:</b>	50 $\Omega$	
<b>Input Reflection-TDR:</b>	< 5% to a 100ps risetime step function	
<b>Risetime through Unit:</b>	< 65ps	
<b>Bandwidth:</b>	DC to 6GHz	
<b>Voltage Coefficient:</b>	< 1% at rated voltage	
<b>Connectors:</b>	BNC female	
<b>Dimensions:</b>	2.9' x 3" dia. + (2) 8-32 mounting studs	
<b>Weight:</b>	1 lb.	

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 2746-NFMF



## DESCRIPTION

High Voltage 6 Way Matched Resistive Power Divider

## SPECIFICATIONS

Model 2746-NMFP

<b>Voltage Ratio:</b>	6.0/1 Vr (15.56dB)
<b>Maximum Input:</b>	4kV, 100ns FWHM Pulse
<b>Peak Input Power:</b>	125kW at rated pulse width
<b>Average Input Power:</b>	4W Maximum
<b>Impedance:</b>	50 $\Omega$
<b>Reflection-TDR:</b>	< 4% to a 100ps risetime step function
<b>Risetime through Unit:</b>	< 45ps
<b>Bandwidth:</b>	DC to 8GHz
<b>Voltage Coefficient:</b>	< 1% at rated voltage
<b>Connectors:</b>	N female input, SMA female output
<b>Dimensions:</b>	2.9" x 3" dia. + (2) 8-32 mounting studs on 2" Centers
<b>Weight:</b>	1 lb.



# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER MODEL 2810 SERIES



## DESCRIPTION

The 2810 series 50 ohm matched resistive power divider equally divides and distributes signals in high voltage pulse applications.

## SPECIFICATIONS

### Voltage Ratio:

2812-NFP/NMFP	}	2 WAY DIVIDER
2812-HFNFP		2.0/1 $V_r \pm 2\%$ (6.02dB)
2812-UNFP		
2813-NFP/NMFP	}	3 WAY DIVIDER
2813-HFNFP		3.0/1 $V_r \pm 2\%$ (9.54dB)
2813-UNFP		
2814-NFP/NMFP	}	4 WAY DIVIDER
2814-HFNFP		4.0/1 $V_r \pm 2\%$ (12.04dB)
2814-UNFP		
2815-NFP/NMFP	}	5 WAY DIVIDER
2815-HFNFP		5.0/1 $V_r \pm 2\%$ (13.98dB)
2815-UNFP		
2816-NFP/NMFP	}	6 WAY DIVIDER
2816-HFNFP		6.0/1 $V_r \pm 2\%$ (15.56dB)
2816-UNFP		

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 2810 SERIES

## SPECIFICATIONS continued

<b>Maximum input:</b>	281x-NFP/NMFP	2.5kV, 250ns FWHM Pulse
	281x-HFNFP	5.0kV, 100ns FWHM Pulse
	281x-UNFP	10.0kV, 25ns FWHM Pulse
<b>Peak Input Power:</b>	281x-NFP/NMFP	125kW at rated pulse width
	281x-HFNFP	500kW at rated pulse width
	281x-UNFP	1.0MW at rated pulse width
<b>Average Input Power:</b>	8W maximum	
<b>Impedance:</b>	50 $\Omega \pm 1\%$	
<b>Reflection-TDR:</b>	281x-NFP	Input < 2% to a 100ps risetime step function Output < 6% to a 100ps risetime step function
	281x-UNFP	Input < 3%
<b>Risetime through Unit:</b>	< 50ps	
<b>Bandwidth:</b>	DC to 7GHz	
<b>Maximum Precursor:</b>	< $\pm 0.1\%$ for a 100ps risetime pulse	
<b>Time Domain Overshoot:</b>	< 2% overshoot for a 100ps risetime input pulse with no ringing	
<b>Time Match between Ports:</b>	$\pm 10$ ps maximum time difference between any/all output ports	
<b>Attenuation Matching:</b>	$\pm 1.0\%$ between ports from DC to 300MHz minimum	
<b>Voltage Coefficient:</b>	< 1% at rated voltage	
<b>Connectors:</b>	281x-NFP	N female (standard stocked configuration)
	281x-NMFP	N male input, N female output
	281x-HFNFP	HN female input, N female output
	281x-UNFP	Ultra fast BE50 input, N female output
	Note: Inputs are labeled, outputs are numbered.	
<b>Dimensions:</b>	Outline drawings available	
<b>Weight:</b>	2812-NFP	approx. $\frac{1}{2}$ lb.
	2813-NFP	approx. $\frac{3}{4}$ lb.
	2814-NFP	approx. $\frac{7}{8}$ lb.
	2815-NFP	approx. 1 lb.
	2816-NFP	approx. $1 \frac{1}{4}$ lb.

X = number of outputs (2, 3, 4, 5 or 6)

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER DIVIDER

MODEL 2825-NFP, 2828-NFP, 2830-NFP, 2832-NFP

## DESCRIPTION

The 2820/2830 Series Power Dividers are designed to equally divide and distribute signals in high voltage pulse applications.

## SPECIFICATIONS

<b>Voltage Ratio:</b>	2825-NFP	5.0/1Vr (13.98dB)
	2828-NFP	8.0/1Vr (18.06dB)
	2830-NFP	10.0/1Vr (20.00dB)
	2832-NFP	12.0/1Vr (21.58dB)

**Maximum Input:** 4kV, 100ns FWHM Pulse

**Peak Input Power:** 320kW at rated pulse width

**Average Input Power:** 10W maximum

**Impedance:** 50 Ω

**Reflection-TDR:** < 2% to a 100ps risetime step function

<b>Risetime through Unit:</b>	2825-NFP	< 75ps
	2828-NFP	< 65ps
	2830-NFP	< 70ps
	2832-NFP	< 75ps

<b>Bandwidth:</b>	2825-NFP	DC to 4.5GHz
	2828-NFP	DC to 5.4GHz
	2830-NFP	DC to 5.0GHz
	2832-NFP	DC to 4.5GHz

**Voltage Coefficient:** < 1% at rated voltage

**Connectors:** N female

**Dimensions:** Outline drawing available

<b>Weight:</b>	2825-NFP	1 1/8 lbs.
	2828-NFP	2 1/4 lbs.
	2830-NFP	3 lbs.
	2832-NFP	3 3/4 lbs.



Model 2820/2830 Series

# HIGH VOLTAGE PULSE 9 PORT POWER DIVIDER

MODEL 6419-NFP

## ADVANTAGES

- ⊕ Specifically designed for maximum amplitude output with fixed duration flat top, while maintaining a fast clean risetime.
- ⊕ Outputs are very consistent from port to port, with respect to risetime, amplitude, and delay.
- ⊕ Similar dividers with different number of outputs, other input voltages, pulse widths, or risetime specifications can be designed to meet a customers requirements.



## DESCRIPTION

9 Output High Voltage Pulse divider specifically designed for use with 10 kV, 250 ps risetime high voltage pulses.

## SPECIFICATIONS

<b>Number of Outputs:</b>	9 Outputs
<b>Input-Output Voltage Ratio:</b>	2.94:1 / 3.21:1 (9.75dB +/- 0.38 dB)
<b>Output Pulse Risetime:</b>	280 ps for a 250ps Input Risetime
<b>Maximum Input Pulse Amplitude:</b>	10 kV/10 ns, Rectangular Pulse
<b>Input Reflection Coefficient:</b>	+ 1.6%, - 3.0%, to a 250 ps Risetime Step Function
<b>Maximum Pulse Droop:</b>	6% @ 16 ns
<b>Connectors:</b>	Type "N" Receptacle (female) on Input and Outputs
<b>Dimensions:</b>	Approx. 7.3" x 7.3" x 3" Height
<b>Weight</b>	4.5 lbs.

# HIGH VOLTAGE PULSE 100 PORT POWER DIVIDER

MODEL 9201-GMF

## ADVANTAGES

- ⊗ Specifically designed for maximum amplitude output with fixed duration flat top, while maintaining a fast clean risetime.
- ⊗ Outputs are very consistent from port to port, with respect to waveshape, risetime, amplitude, and delay.
- ⊗ Similar dividers with different number of outputs, pulse width, voltage, or risetime specifications can be designed to meet a customer's requirements.



## DESCRIPTION

100 Output High Voltage Pulse Divider specifically designed for use with a fast rise high voltage pulse generator such as Barth Model 731, (2kV output with < 50ps rise time).

## SPECIFICATIONS

<b>Number of Outputs:</b>	100 Outputs
<b>Input-Output Voltage Ratio:</b>	> 14:1
<b>Output Voltage Example:</b>	> 138V x 2ns flat top for a 2kV x 2ns, 50ps risetime input
<b>Input-Output Risetime:</b>	< 60 ps
<b>Output Risetime Example:</b>	< 74ps for 2ns wide, 50ps risetime input
<b>Maximum Input Voltage:</b>	2.5kV, 0.75ns to 2ns pulse width
<b>Output Time Variation between ports:</b>	< 5ps, typically < 2ps
<b>Output Amplitude Variation between ports:</b>	< 15%
<b>Connectors:</b>	Input - General Radio Type 874/Output - SMA Female
<b>Dimensions:</b>	Approx. 7.64' (2.33m) long x 6" (15.3 cm) Outer Diameter 12" Tapered Input Section - 8" long 100 way Output Section
<b>Weight:</b>	45 lbs./20.4 Kilos

Note: Other High Voltage Pulse Dividers are available; call us with your needs.

# MODEL 691- MFBM BALANCED PROBE COMBINER

## ADVANTAGES:

- o High sensitivity, for accurate differential measurements, in the presence of high common mode noise levels.
- o Very wide bandwidth for fast risetime measurements of power supplies to the fastest digital systems.



## DESCRIPTION:

Barth Model 691 balanced probe combiner is designed for making fast risetime pulse differential measurements. This combiner provides wide bandwidth with high Common Mode Rejection (CMR). Features include 50 Ohm "+" and "-" SMA Jack inputs with a BNC Plug output for direct attachment to an oscilloscope.

## SPECIFICATIONS:

<b>Input/Output Voltage Ratio:</b>	2.0:1, -6.0 dB (When used as a differential combiner)
<b>Impedance:</b>	50 +/- 1/2 ohm
<b>Risetime:</b>	350ps
<b>Droop:</b>	7% at 1 $\mu$ s
<b>Frequency Range:</b>	15kHz to 1GHz
<b>CMR:</b>	> 40 dB 100kHz to >1GHz > 30 dB 20kHz to >1GHz
<b>Input Connectors:</b>	SMA Jacks
<b>Output Connector:</b>	BNC Plug
<b>Dimensions:</b>	4.75"l x 1.25"dia.
<b>Weight:</b>	8 oz., 225 g.

# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER COMBINER

MODEL 2921-HFP

## DESCRIPTION

2 Input 4 Output Combiner

## SPECIFICATIONS

<b>Voltage Ratio:</b>	2.0/1 Vr
<b>Maximum Input:</b>	2kV, 500ns FWHM Pulse
<b>Connectors:</b>	HNB female
<b>Dimensions:</b>	4 3/8 " long x 4 5/8 " wide x 1 1/4 " high
<b>Weight:</b>	1.5 lbs.



# HIGH VOLTAGE PULSE MATCHED RESISTIVE POWER COMBINER

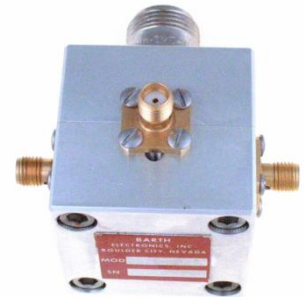
MODEL 2934-MFNF

## DESCRIPTION

4 Way Broadband High Peak Resistive Combiner

## SPECIFICATIONS

<b>Voltage Ratio:</b>	1.0/1 Vr
<b>Maximum Input:</b>	2kV, 10ns FWHM Pulse
<b>Average Input Power:</b>	1W Maximum
<b>Impedance:</b>	50 $\Omega$
<b>Risetime through Unit:</b>	< 30ps
<b>Connectors:</b>	SMA female inputs - N female output
<b>Dimensions:</b>	2.2" long x 2.2" wide x 2.2" high
<b>Weight:</b>	1/2 lb.





## WIDE BAND HIGH VOLTAGE TRANSFORMER TRANSFORMER COMPONENT MODEL COMPARISON

Transformer Type Model #	Maximum peak voltage	Maximum energy without saturation	Input reflection coefficient @ 100ps $\tau$	Risetime through unit mainline ps	Risetime of coupled output ps	Connectors
<b>PULSE INVERTERS</b>						
6115-BMFP	1,000	45 V $\times$ $\mu$ s	< 4%	< 400 *	n/a	BNC male/female
621A-GLP	2,000	250 V $\times$ $\mu$ s	< 5%	< 70	n/a	GR 874 locking
621A-MFP	2,000	250 V $\times$ $\mu$ s	< 5%	< 70	n/a	SMA female
621-NFP	2,000	250 V $\times$ $\mu$ s	< 5%	< 70	n/a	N female
<b>BALUNS</b>						
650A-NFT	300	30 V $\times$ $\mu$ s	< 1%	n/a	< 60	N female input- N female output
651-NFP	1,000	500 V $\times$ $\mu$ s	< 1%	n/a	< 90	N female input- N female output
652-NFP	1,000	100 V $\times$ $\mu$ s	< 1%	n/a	< 50	N female input- N female output

\* Input Reflection Coefficient rated at 500ps $\tau$ .

# WIDE BAND HIGH VOLTAGE PULSE INVERTER

## MODEL 6115-BMFP

### DESCRIPTION

50  $\Omega$  High Voltage Pulse Inverter



Model 6115-BMFP

### SPECIFICATIONS

<b>Voltage Ratio:</b>	1/(-1)
<b>Maximum Input:</b>	1kV, 45Vx $\mu$ s Pulse
<b>Impedance:</b>	50 $\Omega$
<b>Risetime:</b>	< 400ps, inverted pulse >98% at 1 $\mu$ s
<b>Bandwidth (-3dB):</b>	700MHz
<b>Droop:</b>	<10% at 1 $\mu$ s
<b>Reflection-TDR:</b>	< 4% to a 500ps risetime step function
<b>Connectors:</b>	BNC male/female
<b>Dimensions:</b>	2.8" long x 0.725" diameter
<b>Weight:</b>	2 oz.

# WIDE BAND HIGH VOLTAGE PULSE INVERTER

MODEL 621A-GLP, 621A-MFP, 621-NFP

## DESCRIPTION

50  $\Omega$  High Voltage Pulse Inverter



Model 621A-GLP

## SPECIFICATIONS

<b>Voltage Ratio:</b>		1/(-1)
<b>Maximum Input:</b>		2kV, 250V $\times$ $\mu$ s Pulse
<b>Impedance:</b>		50 $\Omega$
<b>Risetime:</b>		< 70ps, inverted pulse >94% at .5ns
<b>Bandwidth (-3dB):</b>		5GHz
<b>Droop:</b>		2% at 100ns
<b>Reflection-TDR:</b>		< 5% to a 100ps risetime step function
<b>Connectors:</b>	621A-GLP 621A-MFP 621-NFP	GR 874 locking SMA locking N female
<b>Dimensions:</b>	621A-GLP 621A-MFP 621-NFP	7.12" x 1.5" dia. 7.12" x 1.5" dia. 6" x 1.5" dia.
<b>Weight:</b>		1 lb.

# WIDE BAND HIGH VOLTAGE BALUN

MODEL 650A-NFT, 651-NFP, 652-NFP



Model 652-NFP

## DESCRIPTION

50  $\Omega$  Balun with (+) and (-) N female inputs

## SPECIFICATIONS

<b>Voltage Ratio:</b>		1.0 when used as a differential combiner
<b>Maximum Input:</b>	650A-NFT	$\pm 300V$ , 100ns (30Vx $\mu$ s)
	651-NFP	$\pm 1kV$ , 500ns (500Vx $\mu$ s)
	652-NFP	$\pm 1kV$ , 100ns (100Vx $\mu$ s)
<b>Impedance:</b>		50 $\Omega$
<b>Risetime:</b>	650A-NFT	< 60ps
	651-NFP	< 90ps
	652-NFP	< 50ps
<b>Bandwidth (-3dB):</b>	650A-NFT	8.75GHz
	651-NFP	3.8GHz
	652-NFP	3.5GHz
<b>Droop:</b>	650A-NFT	5.0% at 100ns
	651-NFP	0.5% at 100ns
	652-NFP	1.5% at 100ns
<b>Voltage Coefficient:</b>		< 1% at rated voltage
<b>Connector:</b>		N female
<b>Dimensions:</b>		7.12" x 2.25" dia.
<b>Weight:</b>		1.8 lbs.

# Bias-T Model 45350 (10 kV), 45355 (5 kV)

## Design and Performance

### APPLICATION

Electron Lenses in RHIC are designed with a series of biased drift tubes through which the electron beam propagates in the opposite direction of the RHIC ion beams. The image currents induced on the drift tubes are detrimental to the electron & ion beams. The Barth Bias-T is a custom HV RF system that was developed to measure beam loss signals.

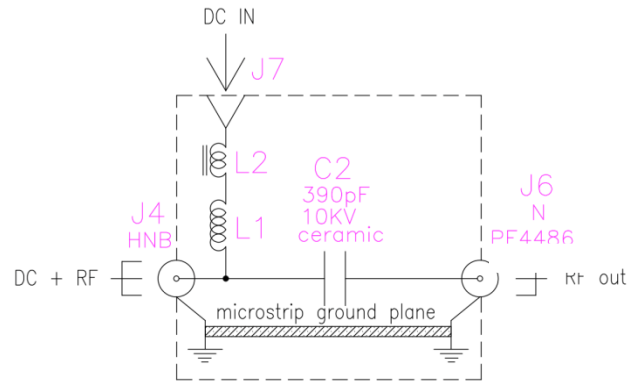
### Production Design

To produce a final design to pass greater than 90% of RF energy from 50 to 1000 MHz through a Bias T requires a special inductor and capacitor design. Moreover, each of the elements of the Barth Bias-T is designed to withstand 10kV or 5kV bias voltage, depending upon model.

Contact us for additional information or to discuss your application.

### Bias-T Design

While Bias tees rated for 100 V are common, HV Bias Tees rated up to 10kV have not been available until now. The Barth Bias-T is designed to handle up to 10 kV of DC bias while simultaneously passing up to 20 W of RF power in the frequency range of 50-500 MHz. (A simplified circuit is shown to the right.)



### Specifications:

Maximum Input:	45355:	5Kv
	45350:	10Kv
Impedance:		50 Ohm
Risetime:		<100PS
Drop:	45355:	1/ε decay = 88ns
Connectors:	DC+ RF/Pulse:	HN female
	RF/Pulse:	N female
	DC Bias:	AMP-LGH*

\* Unit supplied with mating HV connector, HV flying lead of customer specified length can also be provided.

Barth Electronics has been the worldwide leader in High Voltage pulse instrumentation since 1964. All of our products are unconditionally guaranteed to perform exactly to our listed specifications. Call or email us for additional information or to discuss your application.

 Barth Electronics, Inc.

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# High Voltage Pulse Generator Model 731



## DESCRIPTION

The Model 731 high voltage pulse generator provides pulses of < 200ps risetime, 500 volts through 3kV amplitude, to drive into any load impedance through 50 ohm coax.

The generator is capable of a minimum pulse width of 1.5ns and a maximum of 400ns. The rectangular output pulse width is determined by charge line length. HPM, impulse driven antennas, dry run simulation, and HV pulse testing are just a few of the uses for this HV pulse generator. Unit comes standard with 10ns charge line, and (1) additional charge line of customer's choice.

## PRELIMINARY SPECIFICATIONS

- Output Pulse:** < 200ps risetime at all output voltages
- Output Amplitude:** Continuously adjustable from < 500 volts output to > 3kV output
- Output Pulse Width:** 1.5ns to 400ns
- Output Pulse Rep Rate:** Single pulse / internal repetitions / external trigger modes  
Internal mode adjustable from >20 sec between pulses to 10Hz repetition
- Trigger Input:** 5V at 1mA through a grounding switch, or a 1V, 1 $\mu$ s input trigger pulse
- Mechanical Switch Life:** > 3,000,000 pulses at 2kV/400ns pulse width  
(switch life is energy dependent)
- Connectors:** HN female output and charge line connectors
- Input Power:** Standard 120 volt/60Hz line power at 10 amps  
(50Hz model available for export)
- Dimensions:** 19" wide (rack mount) x 5 1/4" high x 15" deep
- Weight:** 24 lbs.
- Accessories:**

<u>Model:</u>	<u>Description:</u>
464-HMP-5ns	5ns charge line
464-HMP-10ns	10ns charge line
464-HMP-20ns	20ns charge line
464-HMP-50ns	50ns charge line
464-HMP-100ns	100ns charge line
464-HMP-200ns	200ns charge line
464-HMP-400ns	400ns charge line

Any Value from 1.5ns to 400ns available

Contact us for additional information or to discuss your application.

 Barth Electronics, Inc.



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# High Voltage Pulse Generator Model 733



## DESCRIPTION

The Model 733 high voltage pulse generator provides pulses of < 200ps risetime, 500 volts through 5kV amplitude, to drive into any load impedance through 50 ohm coax.

The generator is capable of a minimum pulse width of 1.5ns and a maximum of 400ns. The rectangular output pulse width is determined by charge line length. HPM, impulse driven antennas, dry run simulation, and HV pulse testing are just a few of the uses for this HV pulse generator. Unit comes standard with 10ns charge line, and (1) additional charge line of customer's choice.

## PRELIMINARY SPECIFICATIONS

- Output Pulse:** < 200ps risetime at all output voltages
- Output Amplitude:** Continuously adjustable from < 500 volts output to > 5kV output
- Output Pulse Width:** 1.5ns to 400ns
- Output Pulse Rep Rate:** Single pulse / internal repetitions / external trigger modes  
Internal mode adjustable from >20 sec between pulses to 10Hz repetition rate
- Trigger Input:** 5V at 1mA through a grounding switch, or a 1V, 1 $\mu$ s input trigger pulse
- Mechanical Switch Life:** > 3,000,000 pulses at 2kV/400ns pulse width  
(switch life is energy dependent)
- Connectors:** HN female output and charge line connectors
- Input Power:** Standard 120 volt/60Hz line power at 10 amps  
(50Hz model available for export)
- Dimensions:** 19" wide (rack mount)
- Weight:** 24 lbs.
- Accessories:**

<u>Model:</u>	<u>Description:</u>
464-HMP-5ns	5ns charge line
464-HMP-10ns	10ns charge line
464-HMP-20ns	20ns charge line
464-HMP-50ns	50ns charge line
464-HMP-100ns	100ns charge line
464-HMP-200ns	200ns charge line
464-HMP-400ns	400ns charge line

Any Value from 1.5ns to 400ns available

Contact us for additional information or to discuss your application.

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# Ultra Linear Ramps

## Any Ramp Time, Any Voltage (mV to kV)

### SELECTABLE RAMP RATES

Rates are selectable in 2:1 steps. Steps can be made very small or very large to fit the application.

### ANY VOLTAGE / POLARITY

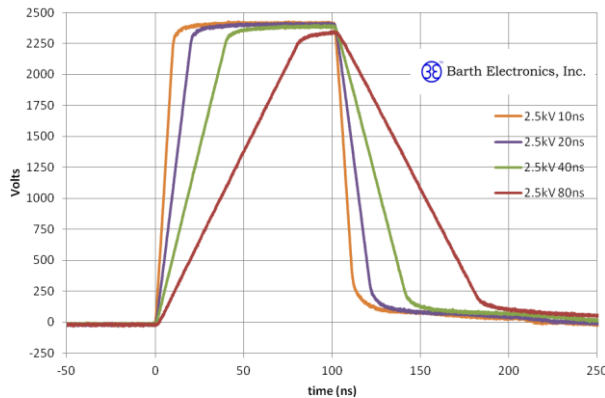
The maximum voltage we have used in our ramp circuits has typically been 5 kV. Higher voltage ramps to 100kV or above can be built. HN connectors will allow peak voltages to about 15 kV; while our BE 100 connector will allow peak voltages reaching 100 kV.

### EXTREMELY LINEAR

Linearity is only limited near the top by whatever rounding of the step function is present. The 10 ns flat top of the pulses shown have the same rounding as the pulse source. Better than 1% linearity is possible with this invention.

Contact us for additional information or to discuss your application.

Selectable Ramp Rates



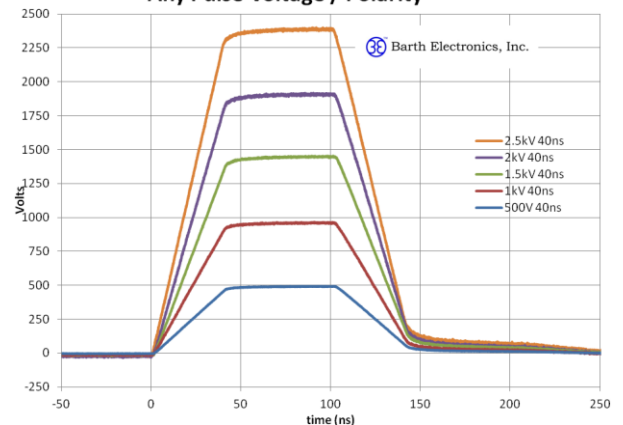
Barth Electronics latest invention turns step functions into ramp functions

These ramps are generated by special circuits we have developed that convert a rectangular pulse into a ramp. This is accomplished with 50 ohm impedance circuits which allow ordinary cables and connectors to deliver the ramp with minimal distortion.

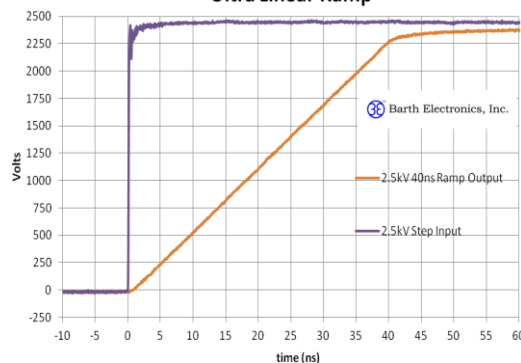
Ramp times from picoseconds to microseconds can be built for step function input.

Note that the ramp time is independent of the pulse voltage, so various dV/dt rates can easily be generated by varying the pulse voltage.

Any Pulse Voltage / Polarity



Ultra Linear Ramp



This ramp generator design is very scalable allowing fast to slow ramp rates in 2:1 steps, and outputs from very low voltages, to very High voltages, positive and negative polarity, limited only by the connector and cable capabilities.

The waveforms shown were produced using our prototype ramp generator system which was driven by our Model 731 pulse generator. Measurements were made on a Tektronix TDS-6604 6GHz scope.





# 5081-P Ramp Generator + 731 3kV Pulse Generator



## Ultra Linear Variable dV/dt Ramp Generator System

### Description:

The Barth Model 731 3kV Pulse Generator + 5081-P Ramp Generator Module combines our high voltage fast rise time pulse generator with a multi ramp module to produce a selectable fixed rate linear rise ramp pulse.

### System Components

- ⊗ Barth 731 High Voltage Fast Rise Time Pulse Generator
- ⊗ Barth 5081-P Multi-Ramp Module
- ⊗ 100ns Pulse Charge line
- ⊗ Output cable and control box to ramp module interconnect cables
- ⊗ Optional Exponential decay Pulse shape module with 50 ohm termination

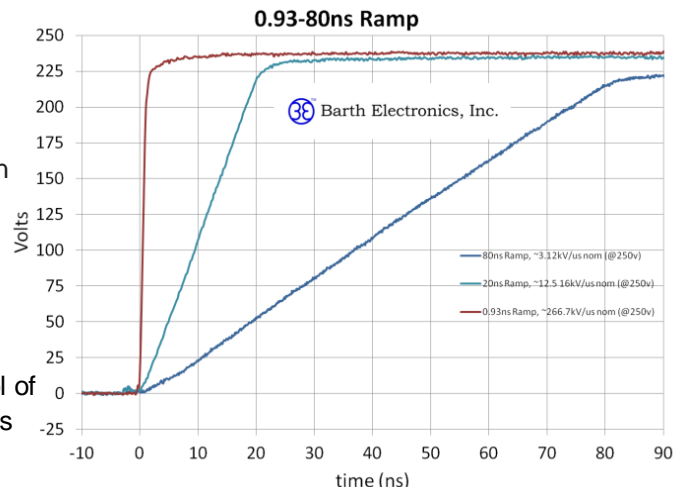
### How It Works

The Barth Model 731 3kV High Voltage Pulse Generator produces a fast rise time high voltage rectangular pulse. This pulse is then passed through the Barth 5081-P Multi Ramp generator module to create a linear ramp.

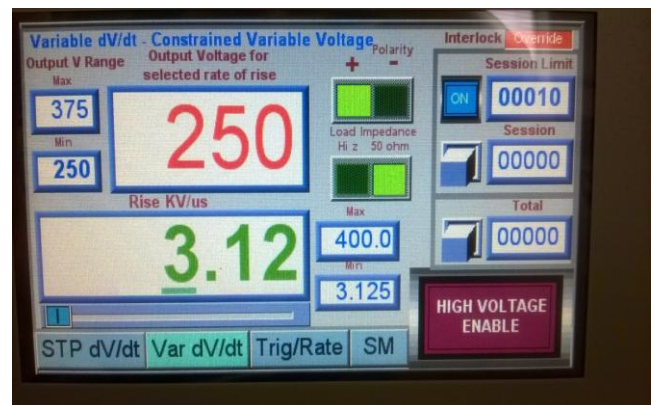
### Operation

Quick interactive and intuitive control of the generator operational parameters is provided via a touch screen interface. The test system provides interactive control of the two variables that define the dV/dt rate, the pulse voltage and ramp rate, to achieve specific kV/us rate pulses. The control also allows the user to interactively increase, or decrease the dV/dt rate which is applied to the DUT.

The 2 basic operational modes are: The “STP” stepped mode which features user adjustable voltage and 14 stepped dV/dt selections based on the 14 fixed ramp rates, and the “VAR” variable dV/dt mode which features a more continuously variable dV/dt selectable by the user. This mode is accomplished by varying the output voltage within an output voltage range and jumping to the next ramp selection as required automatically.



Samples of 0.93ns, 20ns, and 80ns ramp output showing Leading edge of pulse into matched 50 ohm load

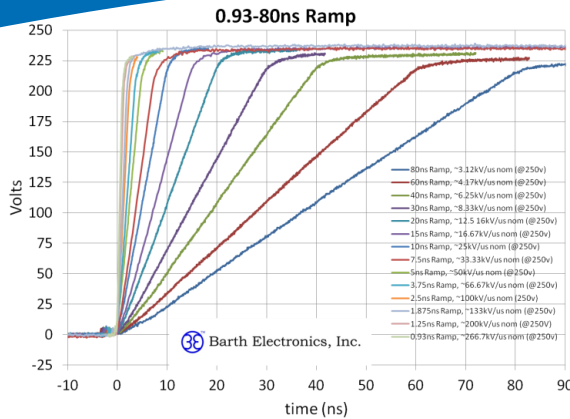


“VAR” variable dV/dt mode shown features a continuously variable dV/dt selectable by the user.

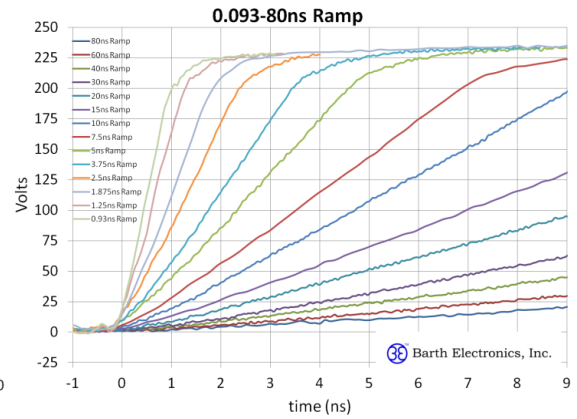
# 5081-P Ramp Generator + 731 3kV Pulse Generator

## Features

- ⊞ Interactive control allows the user to gradually increase, or decrease the  $dV/dt$  rate applied to a DUT
- ⊞ Stepped mode features user adjustable constant voltage and 14 stepped  $dV/dt$  selections
- ⊞ Variable  $dV/dt$  mode features a more continuously variable  $dV/dt$  selectable by the user.
- ⊞ 3.12 to 1600V/ $\mu$ s can be delivered into 50 ohm loads
- ⊞ 6.25 to 3600kV/ $\mu$ s can be realized into high impedance loads.
- ⊞ Touch screen interface allows quick interactive and intuitive control.
- ⊞ Internal rate and external triggering capability
- ⊞ Designed for Common-Mode Transient Immunity (CMTI) testing
- ⊞ Optional Exponential decay Pulse shape module with 50 ohm termination
- ⊞ Provision for external switch Interlock
- ⊞ One year warranty on the entire system



Sample pulse outputs showing Leading edge of pulse into matched 50 ohm load for all 14 ramp selections.

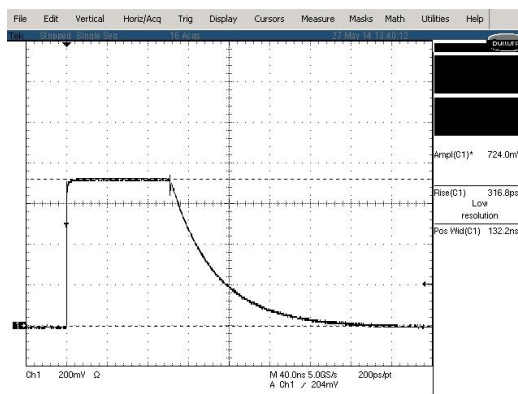


Same Sample Pulse Outputs with expanded time scale.

## Operation (cont.)

Specific  $kV/\mu s$  rate pulses between 3.12 and 1600V/ $\mu s$  can be achieved into 50 ohm loads. Rates between 6.25 and 3600kV/ $\mu s$  can be realized into high impedance loads.

The fall time mirrors the rise time, and with optional pulse shape module a long exponential decay fall time is also available as shown below.



Fast Ramp with Pulse Shape module (adds Exponential decay on falling edge) into matched 50 ohm load.

## Pulse Rate and Triggering:

The pulse rate and triggering is similar to the 731/733 modes including internal triggering for single shot or repetitive pulsing. Repetition rates to 10Hz are selectable. External triggering capability is also included.

## Interlock:

The interlock provision provides a means to prevent pulsing when a test fixture with a lid or other movable safety is employed. This requires a switch on the fixture that will close to indicate the closed lid position.

## Stand alone operation:

Stand alone operation of the 731 pulse generator is supported.

## Size and Weight

System is approximately 19" w x 13 h" x 15" Total weight is approximately 55 lbs.


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This Product Features  
Barth Designed ZAPLESS®  
High Speed Measurement  
Components

 Barth Electronics, Inc.

## MODEL 790 0 to +/- 200 Volt TRANSIENT PULSE GENERATOR



### DESCRIPTION

The Model 790 Transient Pulse Generator is a combined Latch Up sensitivity tester and a power supply load response tester. The generator uses a mechanical reed switch and a custom network to create the single clean fast risetime transient pulses. The power supply test alternates a resistive load on a power supply between 510 ohms and 10 ohms to allow observation of supply recovery parameters.

# 1 GHz RISETIME FILTER

## MODEL 1090-350NF

### ADVANTAGES

- ③ Get 7104 comparable data from your SCD 5000.
- ③ Easily connects to the SCD 5000 input, in series with the input signal.
- ③ Get instant waveform data without mathematical or software waveform conversions.



### DESCRIPTION

Barth Model 1090-350NF Risetime Filter is designed to be connected in series with the input of a TEK SCD 5000 digitizer to spoil the waveform to what would be observed on a TEK 7104 Oscilloscope. This filter enables the SCD 5000 user to obtain directly comparable waveforms on the SCD 5000 without need of a 7104, thus enabling supplier and user to obtain comparable results for various testing scenarios. Special Barth construction techniques utilized in this risetime filter have been developed over the past 31 years designing products for government laboratories in time domain applications.

### SPECIFICATIONS

<b>Input Impedance:</b>	50.0 Ohms +/- 5%
<b>Output Impedance:</b>	50.0 Ohms +/- 5%
<b>Input/Output Risetime:</b>	90ps Input / 350ps Output
<b>Input Connection:</b>	Type "N" Female (jack) connector
<b>Output Connector:</b>	Type "N" Female (jack) connector*
<b>Dimensions:</b>	Length: 3.625" Width: 1.5" body 3-3/8" across connectors w/ Male to Male adapters) Height: 1.25"
<b>Weight:</b>	< 0.50 lb., 226 g.

\*Supplied with "N" Male (Plug) to "N" Male (Plug) adapter for direct connection to the SCD 5000 input connector.



# TEM TIME DOMAIN ANTENNA

## MODEL 3004



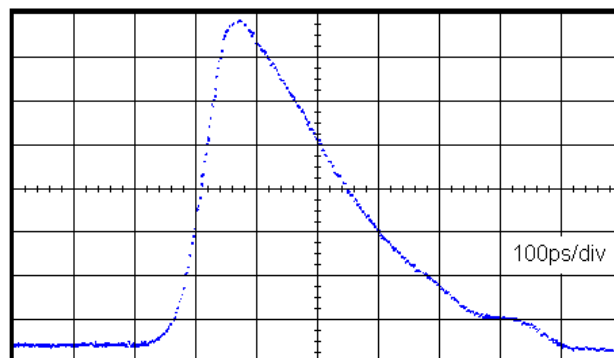
The Model 3004 is a 50 ohm impedance time domain antenna used to make measurements directly in the time domain. Use of this antenna for transmitting and receiving allows simple calculations of impulse amplitudes and risetimes. This "direct" method of measurement avoids the transformation between the frequency and time domains and minimizes the errors that can arise when basic assumptions are made about a radiating source. We have found time domain measurements to be much more reliable when made with this "time domain antenna", to eliminate frequency domain conversions.

The antenna has a balanced 50 ohms construction to allow maximum bandwidth and minimum reflection, fed with an integral 50 ohm wide band balun to allow the direct connection between the balanced antenna structure and ordinary coaxial line.

The good balun prevents off-axis radiation errors from unbalanced currents when used either for transmitting or receiving. The pulse response between two identical antennas is included below and shows a 75.6 PS. risetime followed by a slow decay. One antenna was fed with a 50 PS risetime step function of 5 ns. pulse length generated by our Model 731 reed switch pulse generator fed through low loss BFT4 coax for minimal pulse distortion. The very flat top from this pulse generator minimizes additional distortion of the antenna pulse decay after the initial rise.

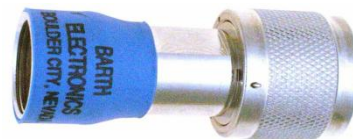
The Model 3004 receiving antenna was fed directly into to a HP 54120A digital sampling oscilloscope through low loss coax. A pulse response through two antennas was 75.6 ps, or for each antenna an individual risetime of about 53.5 PS. The pulse decay through the pair of antennas to 50% amplitude was about 242 Ps. The antennas were spaced 20 feet apart for this measurement and the pulse response would be slightly better at wider separations.

The antenna framework is 48 inches long by 39 inches wide by 15 inches high. The complete antenna weighs 22 pounds. We are designing some smaller time domain antennas for smaller aperture use, at closer spacings. We are also designing some larger time domain antennas with higher directivity/gain for use with air propagation or ground penetrating radar. If you require time domain pulse radiation measurements, our commercial time domain antenna hardware, high voltage pulse generators, and high voltage pulse experience is available for you.



# CONNECTORS/ADAPTERS HIGH VOLTAGE PULSE

MODEL 401-HNB, 402-HNB, 401-371



## DESCRIPTION

Model 401-HNB, HNB Male cable connector for RG214/U coax; designed for low reflection coefficient.

Model 402-HNB, HNB Female cable connector for RG214/U coax; designed for low reflection coefficient.

## SPECIFICATIONS

**Maximum Input:** 15kV, 1 $\mu$ s FWHM Pulse

**Impedance:** 50 $\Omega$

**Reflection-TDR:** < 4% at 100ps risetime

**Risetime:** < 20ps

For optimum reflection, the use of Model 401-371 connector installation tool is suggested.

Note: Model 401-HNB or 402-HNB cable connectors are also available assembled onto a user specified length of RG214/U coax (standard length is one meter).



## DESCRIPTION

The Model 401-371 HNB trim tool is used for preparing RG214/U coax for installation of a 401-HNB / 402-HNB cable connector.

## SPECIFICATIONS

Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or 402-HNB female cable connector for RG214/U coax should be used for interconnection.

# CONNECTORS/ADAPTERS HIGH VOLTAGE PULSE

MODEL 404-HFF, 404-HMM, 404-HFNF, 404-HMNM

## DESCRIPTION

**404-HFF** HNB female to female adapter specifically designed to maintain high voltage hold off and provide a low reflection coefficient.

**404-HMM** HNB male to male adapter specifically designed to maintain high voltage hold off and provide a low reflection coefficient.



## SPECIFICATIONS

**Maximum Input:** 15kV, 1 $\mu$ s FWHM Pulse

**Impedance:** 50  $\Omega$

**Reflection-TDR:** < 2% at 100ps risetime when mated with Barth HNB connector

**Risetime:** < 20ps

**Connectors:** 404-HFF HNB Female, HNB Female  
404-HMM HNB Male, HNB Male



## DESCRIPTION

**404-HFNF** HNB female to N female adapter specifically designed to maintain high voltage hold off and provide a low reflection coefficient

**404-HMNM** HNB male to N male adapter specifically designed to maintain high voltage hold off and provide a low reflection coefficient

## SPECIFICATIONS

**Maximum Input:** 4kV, 1 $\mu$  FWHM Pulse

**Impedance:** 50  $\Omega$

**Reflection-TDR:** < 2% at 100ps risetime when mated with Barth HNB connector

**Risetime:** < 20ps

**Connectors:** 404-HFNF HNB Female, N Female  
404-HMNM HNB male, N male



# CONNECTORS/ADAPTERS HIGH VOLTAGE PULSE

MODEL 421-NMM, 422-NFF, 423-NFMM, 423-NMMM, NMBF, 444-HMSP, 472-HMNF

## MODELS

**421-NMM**, N male to N male adapter; 3kV dc

**422-NFF**, N female to N female adapter; 3kV dc

**423-NFMM**, N female to SMA male adapter; 1.5kV dc

**423-NMMM**, N male to SMA male adapter; 1.5kV dc

**423-NFMF**, N male to SMA female adapter; 1.5kV dc

**423-NMMF**, N male to SMA female adapter; 1.5kV dc

**NMBF**, N male to BNC female adapter; 3kV dc

**MODEL 444-HMSP**, HN male to SHV plug adapter

**Maximum Input:** 10kV

**Impedance:** 50Ω

**Reflection-TDR:** ± 5% at 100ps

**Connectors:** HN male and SHV plug

**MODEL 472-HMNF**, HN male to N female adapter

**Maximum Input:** 4kV, 1μs FWHM Pulse

**Impedance:** 50 Ω

**Connectors:** HN male, N female



# CONNECTORS/ADAPTERS HIGH VOLTAGE PULSE

MODEL HNL, HNT, EL-L, QHPB

## DESCRIPTION

HNL: HNB right angle adapter

## SPECIFICATIONS

**Maximum Input:** 15kV, 1 $\mu$ s FWHM Pulse  
**Impedance:** 50  $\Omega$   
**Connectors:** HNB male/female



## DESCRIPTION

HNT: HNB unmatched "T"

## SPECIFICATIONS

**Maximum Input:** 15kV, 1 $\mu$ s FWHM Pulse  
**Impedance:** 50  $\Omega$   
**Connectors:** HNB female

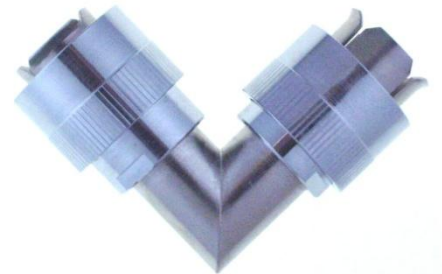


## DESCRIPTION

EL-L: 50  $\Omega$  90 deg. Elbow (Gilbert/GR part #0874-9527)

## SPECIFICATIONS

**Maximum Input:** 5kV, 1 $\mu$ s FWHM Pulse  
**Impedance:** 50  $\Omega$   
**Reflection-TDR:** < 1% at 100ps risetime  
**Risetime:** < 30ps  
**Connectors:** GR 874 locking



## DESCRIPTION

QHPB: HNB male to GR 874 locking adapter (Gilbert/GR part #0874-9804 w/added locking nut)

## SPECIFICATIONS

**Maximum Input:** 5kV, 1 $\mu$ s FWHM Pulse  
**Impedance:** 50  $\Omega$   
**Reflection-TDR:** < 4% at 100ps risetime  
**Risetime:** < 20ps



# CONNECTORS/ADAPTERS HIGH VOLTAGE PULSE

## MODEL 0874 SERIES

### GR to N ADAPTERS

<u>Model</u>	<u>Connectors</u>
0874-9710	GR 874 non-locking/N female
0874-9711	GR 874 locking/N female
0874-9810	GR 874 non-locking/N male
0874-9811	GR 874 locking/N male



### GR to BNC ADAPTERS

<u>Model</u>	<u>Connectors</u>
0874-9700	GR 874 non-locking/BNC female
0874-9701	GR 874 locking/BNC female
0874-9800	GR 874 non-locking/BNC male
0874-9801	GR 874 locking/BNC male



### GR to SMA ADAPTERS

<u>Model</u>	<u>Connectors</u>
0874-QMMP	GR 874 to SMA male
0874-QMMJ	GR 874 to SMA female



## CABLE ASSEMBLIES - RG214/U

### MODEL 463 Series

RG214/U: Low loss coaxial cable with double shield. 50  $\Omega$  Impedance. Available configurations shown below. NOTE: Base price assemblies include up to one meter in length of RG214/U coax. Longer length assemblies are available.

**463-GLP** One (1) GR Type 874 Locking connector assembled on RG214/U coax; max voltage specification is 5kV DC.

**463-HFP** One (1) 402-HNB Female connector assembled on RG214/U coax; max voltage specification is 15kV DC.

**463-HMP** One (1) 401-HNB Male connector assembled on RG214/U coax; max voltage specification is 15kV DC.

**463-HMFP** One (1) 401-HNB Male connector and one (1) 402-HNB Female connector assembled on RG214/U coax; max voltage specification is 15kV DC.

**463-HMMP** One (1) HN Male connector assembled on each end of RG214/U coax; max voltage specification is 15kV DC.

**463-NMMP** One (1) N Male connector assembled on each end of RG214/U coax; Maximum voltage specification is 3kV DC.

# HIGH VOLTAGE RESISTIVE SIGNAL/TRIGGER TAP OFF

## DESCRIPTION

Barth High Voltage Resistive Signal Tap Offs are useful for signal monitoring or device triggering. They are constructed using our voltage probes incorporated into a unit with connectors to allow easy insertion into a coaxial system. This arrangement is very useful in a laboratory setup, and for system monitoring.

## HIGH VOLTAGE RESISTIVE SIGNAL/TRIGGER TAP OFF COMPARISON

Model	Maximum Input*		Risetime through mainline ps	Voltage Ratio Tap Off	Risetime of Resistive Output	Connectors
	Maximum Peak Voltage	@ Pulse width ns				
241-NMFFP-11	2,500	400	< 30	11:1	<60ps	N male/female mainline
245-NMFFP-100	2,500	400	< 30	100:1	<60ps	N female tap off
242-GLBFP-100	5,000	400	< 30	100:1	<900ps	GR874 locking mainline/BNC female tap off
242-GLBFP-50	5,000	400	< 30	50:1	<400ps	GR874 locking mainline/BNC female tap off
242-GLBFP-25	5,000	400	< 30	25:1	<215ps	GR874 locking mainline/BNC female tap off
243-HMFNFP-100	15,000	2 $\mu$ S	< 30	100:1	<1.5ns	HNB male/female

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast rise times. For best pulse response, our Model 401-HNB male or Model 402-HNB female cable connector for RG214/U coax should be used for interconnection.

\* Please refer to the Technical Specifications (Maximum Input Limitations) page for a full explanation of voltage and pulse width ratings.

# HIGH VOLTAGE RESISTIVE SIGNAL/TRIGGER TAP OFF

## MODEL 241-NMFFP-11, MODEL 245-NMFFP-100

### ADVANTAGES

- ⊗ High Voltage Pulse rated
- ⊗ N mainline and tap off connectors
- ⊗ Wide bandwidth

### DESCRIPTION

A High Voltage resistive signal tap off useful for signal monitoring or device triggering.



Model 241-NMFFP-11

### SPECIFICATION

<b>Voltage Ratio:</b>	241-xxx-11	1:1 mainline into a 50 Ω load 11:1 tap off into a 50 Ω load
	245-xxx-100	1:1 mainline into a 50 Ω load 100:1 tap off into a 50 Ω load
<b>Maximum Input:</b>		2.5kV @ 400ns rectangular pulse on mainline*
<b>Peak Input Power:</b>		125kW at rated pulse width
<b>Average Input Power:</b>		1W maximum
<b>Mainline Risetime:</b>		< 30ps
<b>Tap Off Risetime:</b>	241-xxx-11	< 60ps
	245-xxx-100	< 60ps
<b>Bandwidth (-3dB):</b>	241-xxx-11	Tap off 5GHz, mainline 10GHz
	245-xxx-100	Tap off 5GHz, mainline 10GHz
<b>Impedance:</b>	241-xxx-11	50Ω with 450 Ω tapoff
	245-xxx-100	50Ω with 4950 Ω tap off
<b>Voltage Coefficient:</b>		< 1% at rated voltage
<b>Connectors:</b>	245-NMFFP-xxx	Mainline N male/female
	241-NMFFP-xxx	Tap off output N female
	241-GLNFP-xxx	Mainline GR 874 Locking Tap off Output N female
<b>Dimensions:</b>		Approx. 3 9/16" wide (9.1 cm) x 2 3/8" high (6.0 cm) x 3/4" deep (1.9 cm)
<b>Weight:</b>		1/2 lb.

NOTE: Other configurations-voltage ratio/tap off can be obtained. User must specify desired tap off voltage ratio or resistance value, voltage, and risetime requirements. BNC female is optionally available for tap off connector. The risetime and voltage specifications are dependent on, and in some cases limited by, the resistance value selected.

\* Maximum rating requires mainline be terminated into 50 Ω.

# HIGH VOLTAGE RESISTIVE SIGNAL/TRIGGER TAP OFF

MODEL 242-SPJBFP-25, 50, 100, MODEL 242-GLBFP-25, 50, 100



Model 242-SPJBFP-50



Model 242-GLBFP-100

## DESCRIPTION

A High Voltage resistive signal tap off useful for signal monitoring or device triggering on a coaxial cable system.

## SPECIFICATIONS

<b>Voltage Ratio:</b>		1:1 mainline, into a 50 Ω load
	242-XXXXX-25	25/1 (27.96dB) into a 50 Ω load
	242-XXXXX-50	50/1 (33.98dB) into a 50 Ω load
	242-XXXXX-100	100/1 (40dB) into a 50 Ω load
<b>Maximum input:</b>		5kV, 400ns FWHM Pulse*
<b>Peak/Average Input Power:</b>		500kW at rated pulse width, 1W
<b>maximum* Impedance:</b>	242-XXXXX-25	50Ω with 1200 Ω tap off
	242-XXXXX-50	50Ω with 2450 Ω tap off
	242-XXXXX-100	50Ω with 4950 Ω tap off
<b>Mainline Risetim:</b>		< 30ps
<b>Tap Off Risetim/ Bandwidth (-3db):</b>	242-XXXXX-25	< 215ps      1.6GHz
	242-XXXXX-50	< 400ps      870 MHz
	242-XXXXX-100	< 900ps      450MHz
<b>Voltage Coefficient:</b>		< 1% at rated voltage
<b>Reflection-TDR:</b>		< 3% to a 100ps rise time step function
<b>Connectors:</b>	242-GLBFP-XX	Mainline GR 874 locking, N male/female, HN male/female - BNC Tap Off
	242-SPJBFP-XX	Mainline SHV Plug/SHV Jack, GHV male/female - BNC Tap Off
<b>Dimensions:</b>	242-GLBFP-XX	Approx. 3.6 long x 2.2" wide x 1" high
	242-SPJBFP-XX	Approx. 5.6" long x 2.25" wide x .78" high
<b>Weight:</b>	242-GLBFP-XX	Approx. 5 oz.
	242-SPJBFP-XX	Approx. 8 oz.

\* Maximum rating requires mainline be terminated into 50 Ω.

# HIGH VOLTAGE RESISTIVE SIGNAL/TRIGGER TAP OFF

## MODEL 243-HMFNFP-100

### ADVANTAGES

- ⊗ High Voltage Pulse Rated
- ⊗ HN Mainline Connectors

### DESCRIPTION

A High Voltage resistive signal tap off useful for signal monitoring or device triggering.

### SPECIFICATIONS

**Voltage Ratio:** 1:1 mainline, into a 50  $\Omega$  load  
100:1 (40dB) tap off, into a 50  $\Omega$  load

**Maximum Input:** 15kV, 2us FWHM Pulse \*

**Peak Input Power:** 4.5MW at rated pulse width \*

**Average Input Power:** 1W maximum \*

**Mainline Risetime:** < 30ps

**Tap Off risetime:** < 1.5ns

**Bandwidth (-3dB):** Tap off 250 MHz, Mainline 10 GHz

**Impedance:** 50  $\Omega$  with 5k  $\Omega$  tap off  
(This provides 1/100 of the amplitude of the main line voltage on the sampled signal output connector)

**Voltage Coefficient:** < 1% at rated voltage

**Connectors:** Mainline HN male/female, Tap off output N female\*

**Dimensions:** Approx. 3 3/4" (9.5 cm) wide x 3" (7.6 cm) high x 3/4" (1.9 cm) deep

**Weight:** Approx. 5/8 lb.

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or Model 402-HNB female cable connector for RG214/U coax should be used for interconnection; available in our Pulse Catalog.

Other configurations-voltage ratio/tap off can be obtained. User must specify desired tap off voltage ratio or resistance value, voltage and risetime requirements, and desired sampled signal output connector. N female and BNC female are currently available. The risetime and voltage specifications are dependent on, and in some cases limited by, the resistance value selected.

\* Maximum rating requires mainline be terminated into 50  $\Omega$ .



Model 243-HMFNFP-100

# WIDE BAND HIGH VOLTAGE TRANSFORMER

## TRANSFORMER COMPONENT MODEL COMPARISON

### SIGNAL PICKOFFS

Model	Maximum Peak Voltage	Maximum Input*			Risettime of coupled Output ps	Connectors
		Energy without saturation	Reflection coefficient at 100ps $\tau$	Risettime through unit mainline ps		
CT5-GLP	5,000	800Vx $\mu$ s	< 5%	< 70	350	GR 874 locking
CT5-GLBFIP	5,000	800Vx $\mu$ s	< 5%	< 70	350	GR 874 locking Mainline/BNC female isolated
CT6-NFP-8	4,000	135Vx $\mu$ s	< 5%	< 70	< 300	N female
CT20B-HFNFP-20	15,000	1,300Vx $\mu$ s	< 5%	< 70	<170	HN female mainline/N female output
CT20B-HFNFP-8	15,000	135Vx $\mu$ s	< 5%	< 70	300	HN female mainline/N female output**

NOTE: Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB connector or Model 402-HNB female cable for RG214/U coax should be used for interconnection; available in our Pulse Catalog.

\* Please refer to the Technical Specifications (Maximum Input Limitations) page for a full explanation of voltage and pulse width ratings.

\*\* Input Reflection Coefficient rated at 500 ps $\tau$



# WIDE BAND HIGH VOLTAGE TRANSFORMER

## MODEL CT5-GLP, CT5-GLBFIP

### DESCRIPTION

High Voltage 50 Ohm Transformer Coupled Signal Pickoff

### SPECIFICATIONS

<b>Voltage Ratio:</b>	10.0/1
<b>Maximum input:</b>	5kV, 800Vx $\mu$ s Pulse
<b>Impedance:</b>	50 $\Omega$
<b>Mainline Risetime:</b>	< 70ps
<b>Tap Off Risetime:</b>	< 350ps
<b>Droop:</b>	< 5% at 1 $\mu$ s
<b>Bandwidth (-3dB):</b>	Mainline 5GHz, tap off 1GHz
<b>Reflection-TD R:</b>	< 5% to a 100ps risetime step function
<b>Connectors:</b>	CT5-GLP GR 874 locking CT5-GLBFIP GR 874 locking mainline, BNC female isolated output
<b>Dimensions:</b>	4" long x 3.150" wide x 1" high
<b>Weight:</b>	5/8 lb.



Model CT5-GLBFIP

# WIDE BAND HIGH VOLTAGE CURRENT TRANSFORMER

MODEL CT6-NFP-8

## DESCRIPTION

Transformer Coupled Signal Pickoff without direct connection to main transmission line



Model CT6-NFP-8

## SPECIFICATIONS

<b>Voltage Ratio:</b>	8.0 + 10%, 2ns after 50% amplitude
<b>Maximum Input:</b>	4kV, 135Vx $\mu$ s Pulse
<b>Impedance:</b>	50 $\Omega$
<b>Mainline Risetime:</b>	< 70ps
<b>Tap Off Risetime:</b>	< 300ps
<b>Bandwidth (-3dB):</b>	Mainline 5GHz, tap off 1.2GHz
<b>Reflection-TDR:</b>	< 5% to a 100ps risetime step function
<b>Connectors:</b>	N female
<b>Dimensions:</b>	2.8" long x 2.5" wide x 1" high
<b>Weight:</b>	1/2 lb.

# WIDE BAND HIGH VOLTAGE CURRENT TRANSFORMER

MODEL CT20B-HFNFP-20, MODEL CT20B-HFNFP-8

## DESCRIPTION

High Voltage Transformer Coupled Signal Pickoff without direct connection to main transmission line.



Model CT20B-HFMNFP-20

## SPECIFICATIONS

<b>Voltage Ratio:</b>	CT20B-HFNFP-20 CT20B-HFNFP-8	20.0/1 Vr 8.0/1 Vr
<b>Maximum Input:</b>	CT20B-HFNFP-20 CT20B-HFNFP-8	15kV, 1300Vx $\mu$ s Pulse 15kV, 135Vx $\mu$ s Pulse
<b>Impedance:</b>		50 $\Omega$
<b>Mainline Risetime:</b>		< 70ps
<b>Tap Off Risetime:</b>	CT20B-HFNFP-20 CT20B-HFNFP-8	< 170ps < 300ps
<b>Bandwidth (-3dB):</b>	CT20B-HFNFP-20 CT20B-HFNFP-8	Mainline 5GHZ, tap off 2GHZ Mainline 5GHZ, tap off 1.2GHZ
<b>Reflection-TDR:</b>		< 5% to a 100ps risetime step function
<b>Connectors:</b>		HN female mainline, N female tap oft output **
<b>Dimensions:</b>		3" long x 3.3" wide x 1.5" high
<b>Weight:</b>		1 lb.

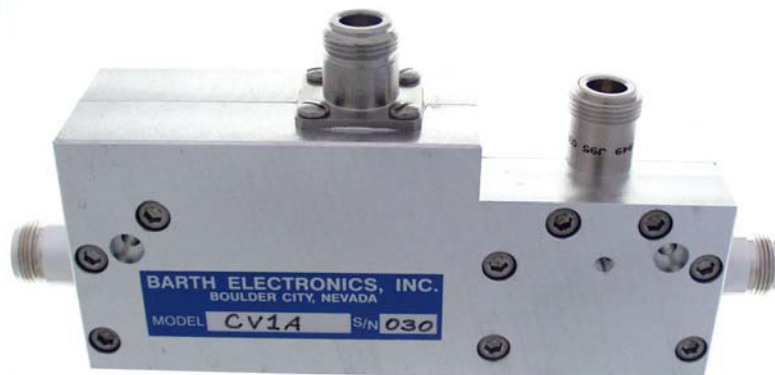
NOTE: The response is fairly flat from 40kHz to 950 MHz with the -3dB point at 16 kHz.

Our type HN (HNB) connectors are specially designed to obtain minimum reflection coefficient for fast risetimes. For best pulse response, our Model 401-HNB male or Model 402-HNB female cable connector for RG214/U coax should be used for interconnection, available in our Pulse Catalog. Unit is supplied with a Barth Model 404-HMM low reflection male to male adapter, so that either the input or output can be adapted to a male connection.

\*\* BNC female tap off output is optionally available.

# Wide Band High Voltage Resistive Voltage Tap Off And Resistive Current Monitor

MODEL CV1A



Model CV1A Current and Voltage Probe

## ADVANTAGES

- ⊗ Highest speed coaxial current sensor for time domain measurements
- ⊗ Flat pulse response extending to microseconds
- ⊗ Clean Response

## DESCRIPTION

Precision Coaxial Current Sensor, a completely new patented design providing precise current measurements from sub-nanosecond to microseconds. This complementary voltage and current probe can provide precise measurements of incident and reflected energy for time domain pulses as fast as 30 picoseconds. The CV1A is a combination voltage, tap off, and current monitor. This product presently covers the tremendously wide measurement range of  $3 \times 10^5$ , which can be extended.

## SPECIFICATIONS

**Voltage Sensor Ratio:** 100:1 tap off, into 50Ω load

**Maximum Input:** 2.5kV @ 400ns rectangular pulse on mainline\*

**Peak Input Power:** 125kW at rated pulse width

**Average Input Power:** 100W maximum\*

\* Maximum rating requires mainline be terminated into 50 Ω.

# Wide Band High Voltage Resistive Voltage Tap Off And Resistive Current Monitor MODEL CV1A

## SPECIFICATIONS Continued

**Mainline Risetime:** < 20ps

**Voltage Tap Off Risetime:** 30ps

**Voltage Coefficient:** < 1% at rated voltage and current

**Current Sensitivity Volts/Amp:** 0.5V/A

**Current Sensitivity Droop:** 1% in 1 $\mu$ s

**Maximum Current:** 300A

**Average power:** 100 watts

Mainline N male/female Tap off N female

**Dimensions:** Approx. 6.8" w (17.3cm) x 2.9" h (7.3cm) x 1.5" d (3.8cm)

**Weight:** 1.6lb. (.72kg)

NOTE: Other configurations-voltage ratio/tap off can be supplied. User must specify voltage ratio, Current ratio, voltage, and risetime requirements. The risetime and voltage specifications are Dependent on, and in some cases limited by, the resistance sensitivities selected.

\* Maximum rating requires mainline be terminated into 50  $\Omega$ .



# Barth Electronics, Inc. Device Testing Services available...

C  
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Barth Electronics, Inc. offers complete ESD Testing Services to the semiconductor industry. Nothing is outsourced - all testing is performed at our factory in Boulder City, Nevada. We provide device testing for each of our ESD test systems.



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1589 Foothill Drive, Boulder City, Nevada 89005

## What is TLP?

TLP is a short pulse (50ns to 200ns) measurement of the current-voltage (I/V) characteristics of the ESD protection built into an integrated circuit. The short TLP pulses are used to simulate the short ESD pulse threats that the input-output (I/O) pins of an IC must withstand without damage being caused to the complex silicon structures.

The TLP acronym stands for Transmission Line Pulse testing. A constant impedance transmission line is used as a pulse source because it can create a constant amplitude rectangular pulse shape. A flat top rectangular pulse is used because the amplitude at different points along its length can be measured more accurately than can be done with other pulse shapes.

The TLP cable used to generate the rectangular pulse for testing is usually 50 ohm because of the universal availability of coaxial cables and matched coaxial connectors. The coaxial cable is charged with a DC power supply to the desired voltage and then quickly discharged with a low inductance switch. The fastest pulses are made with a switch that is placed in a constant impedance coaxial housing to preserve the fastest possible risetime. A fast pulse can be made into a slower Gaussian risetime by using a matched impedance risetime filter. Such filters slow the pulse risetime without causing any other distortions. This concept is covered more fully in our Application Note #3.

TLP testing is done by applying the rectangular test pulse to the two pins of the Device Under Test (DUT) to be tested. The most common method of introducing the pulse to the DUT has been to split the pulse between a grounded 56-ohm resistor and a 500 to 1500 ohm resistor in series with the DUT pin to be tested. The common pin is connected to the ground lead to provide a return path for the pulse current.

TLP testing typically begins with low voltage pulses that are successively increased in amplitude to provide sufficient points to fill out an I/V plot. Higher or lower amplitude steps can be chosen to provide more or less data points for the areas of interest on the I/V plot. Usually the amplitude of the test pulse is increased until the DUT is damaged to learn its precise pulse current limit. The TLP pulse amplitude increases can be made smaller to add additional test points to some particular area of interest.

Damage to the DUT will occur when the test pulse amplitude becomes high enough to produce enough heat in the DUT to melt some structure and cause a permanent change in the device. Damage is usually accompanied by an immediate increase in the leakage current between the two pins.

A TLP test system includes a leakage measurement after each test pulse as a sensitive monitor of DUT damage. It helps identify precisely which test pulse created sufficient damage to increase the leakage current.

The precise current and voltage amplitudes of the pulse that cause damage to the DUT are then identified by the increased leakage current.

The TLP level of damage information can be compared to HBM damage levels found for the same type of device. TLP testing allows more precise information on damage levels than can be obtained from HBM testing. It allows precise comparisons between different test/production structures as well as providing an I/V plot of the complete electrical operation of the structure throughout its' full range.

The different (I/V) data points are plotted by measuring the pulse current through the device and the voltage across the device near the end of the test pulse. The testing is done near the end of the pulse after the current through the device and voltage across the device have stabilized. Damage to the device will occur near the end of the test pulse that causes enough heating/melting to effect a permanent change. An advantage of TLP testing is to identify the exact test pulse that caused damage to occur.

The temperature, in the silicon structure that absorbs the ESD threat, increases during the rectangular test pulse. The hottest temperatures will be found at the end of the pulse. As the amplitude of each pulse is increased, damage to the device will occur near the end of the test pulse if the step increases in amplitude are made sufficiently small. The goal is to measure the I and V near the end of the pulse to identify the exact pulse where the damage occurred.





Evaluating a TLP system for purchase decision should be done with a known circuit element. When we developed the *first* commercial TLP system many of our customers tested their devices with TLP trying to evaluate its quality. We recognized the need for an element with known and repeatable electrical characteristics to verify the accuracy of any TLP system. That is why we developed the SOLZ unit. It consists of a short, an open, a load resistor and a few Zener diodes. We measure these repeatable circuit elements to verify their I-V characteristics and provide them to anyone in the industry who wants to verify the accuracy of any TLP system. The short and the open are very simple; but we selected a special Zener diode that has repeatable turn-on sharp knee characteristics. One unit turns on about 7 volts, adding the second one causes turn on to occur at about 14 volts and adding the third Zener diode provides a 21 volt calibration point.

The Zener diodes are calibrated and their individual calibration voltages are provided with each SOLZ unit. We use a SOLZ calibration with each of our TLP systems to insure that the voltage measured is within 2% of the Zener calibrated voltage at three voltage levels.

The L in SOLZ is an accurate value Load resistance element. Measuring it can be used to verify the resistance (I/V) measurement capability of any TLP system. When the I/V data is known and the V data is known (from the Zener diodes) the accuracy of the current measurement can also be identified.

The Barth Model 4002/4003 TLP+™ system measures dynamic resistance value, typically, within 3%.

Before you decide on which TLP system to purchase please ask the other TLP manufacturers to measure our SOLZ unit. They can also construct and calibrate the individual elements in their own SOLZ unit.

You cannot evaluate a TLP system based on someone's opinion. It cannot be based on measuring unknown silicon elements that may or may not fail or change with testing. The evaluation of *any* TLP system must be based on measured data of four different known value elements.

If you have any questions on TLP calibration or verification please ask. I have spent many hours with the ESDA working group on TLP explaining and including the use of the SOLZ unit into our standard.

The data is found in ANSI/ESD SP5.5.1-2004 document. Section 7.3 under Tester Verification Methodology explains the methods of its use.

Jon Barth Chief  
Engineer

**The Barth SOLZ Kit**  
(For evaluation of TLP test systems)

**INSTRUCTIONS FOR USE**

The Barth Electronics' SOLZ Kit is used to evaluate the ability of TLP test systems to accurately measure known elements. These elements are a "**Short**", an "**Open**", a "**Load**", and a "**Zener**" diode (hence the acronym **SOLZ**).

The SOLZ Kit is an assembly of six known, measurable elements (including 3 Zener diodes of different voltages) which are stable, repeatable, and affordable. The six elements have been combined into a handy 16 pin DIP package. The six elements, measured by a TLP test system, will reveal basic information about the test system.

**Short:**

Measuring the short (pins 1 & 16 on the DIP package), will reveal the total internal series resistance of the system (typically ~2 ohms for the Barth Model 4002/4003 TLP test system). Note that the Barth Model 4002/4003 allows the operator to 'compensate' for the series resistance by entering a 'cal value' (see the document "TLP Compensation Procedure" used to calibrate the Model 4002/4003, copy enclosed).

**Open:**

Measuring the open (pins 2 & 15 on the DIP package), will reveal the total internal shunt resistance (or series conductance) of the system (typically -75 micromhos for the Barth Model 4002/4003 test system). Note that the Barth Model 4002/4003 allows the operator to 'compensate' for the shunt resistance by entering a 'cal value'.

**Load (5 ohm resistor):**

Measuring the resistor (pins 3 & 14 on the DIP package), will reveal the TLP test system's ability to produce a smooth slope showing a voltage / current ratio of 5 ohms. Five ohms has been chosen to most closely simulate the "on" resistance of a modern protection device. To obtain a full scale slope for the Barth Model 4002/4003, set the pulse voltage scale to 0 to 50 volts, and the current scale to 0 to 10 amps. If the Barth Model 4002/4003 has been 'compensated' by entering 'cal values', the accuracy of the measured resistance is warranted to be within 3%.

**Zener (diodes):**

Measuring the three Zener diodes' turn-on voltages will reveal the accuracy of **pulse** voltages. Use pin 4 for the negative lead and use pins 13, 12, or 11 for the positive lead (for the 7v, 15v, and 24v Zeners, respectively). To measure system accuracy, compare the TLP systems' measured turn-on voltages with the SOLZ Kits' labeled voltage values (typically 1 to 2% accuracy for the Barth Model 4002/4003 test system). The Barth system accuracy is warranted to be within 3%.

Please contact [beisales@barthelectronics.com](mailto:beisales@barthelectronics.com) for further information.

# Barth Model 4003 TLP+™

## Pulse Curve Tracer



### System Components

- ☞ Tektronix 1 GHz, 2 channel, digitizing oscilloscope
- ☞ High reliability Barth Electronics control box/pulse generator
- ☞ Keithley Picoammeter/voltage source
- ☞ Dell Precision Workstation - Test control computer
- ☞ LabView® runtime control and analysis software
- ☞ One year warranty on the entire system
- ☞ One year BSSP Barth Software Subscription Program

### Accuracy

Special Barth wide bandwidth pulse current and voltage sensors provide a high standard of measurement capability for ESD test equipment.

The complete system has been built with special attention paid to minimizing losses in the test circuitry and the coaxial cable connections. This results in low internal resistance at the device under test (DUT), for high accuracy measurements.

Barth's software allows users to make manual leakage delay adjustments, and allow for leakage test voltages up to 500V.

The software includes voltage & current waveform capture, automatic calibration / compensation, automatic data save, save / recall operator set-ups, auto or manual axis scaling, single or multi-point leakage testing (configurable), adjustable measurement window, dynamic resistance calculator, recall data function for compare & analyze of multiple tests, 2 channel scope (4 channel optional), save / recall pulsing "profiles", scope auto-SPC (signal path compensation), and numerous other features.

The BSSP (Barth Software Subscription Program) provides periodic software updates and improvements. This assures your system is in peak operating condition. Test speed increases and efficiency improves. Improve system capability with regard to calibration, reporting, and system diagnostics; all available with BSSP.

The Barth Model 4003 TLP+™

Pulse Curve Tracer precisely characterizes the ESD robustness of silicon chip protection circuitry.

Programmed rectangular pulses are applied to the device under test, resulting in a computerized plot of current vs voltage.

A leakage measurement can be made after each pulse to obtain the leakage evolution current versus pulse voltage.

Set up for packaged device testing; an optional dual wafer probe (Model 45003WP), permits wafer level testing. Other options and accessories are also available.

### How It Works

To use the Pulse Curve Tracer, the operator enters the desired test parameters via keyboard, such as starting voltage, current and voltage limits, voltage step increments, pulse risetime, leakage test voltage, and pulse width. The test then proceeds automatically, controlled by Barth software developed with National Instruments Labview®. The operator can halt and resume the testing and can view the plotted test data points as the test proceeds. The operator can also view (during testing or afterward), voltage & current waveforms, single point or multi-point leakage evolution, test set-up parameters, or numerical data information. The active test and several previous tests' data points may be viewed simultaneously on the I/V plot.

Hardcopy printouts listing data point values and showing plotted results using operator selected scaling are immediately available in a presentation ready format at the end of a test.

# Barth Model 4003 TLP+™

## Specifications

- ❷ Pulse current: 20 amps @ short circuit; 0-10 amps @ 50Ω load, 30A options available
- ❷ Pulse width: 75ns to 150ns standard; 500 ns option available
- ❷ Standard pulse width of 100ns (and 75ns) is supplied with the tester. Pulse width is manually selectable
- ❷ Pulse voltage: 0-500 v @ 50Ω load, 1000 v @ open circuit (step increments: ≥0.05v)
- ❷ Pulse risetime: (10-90%): 0.2, 2, 10 ns (built-in, software selectable) optional rise time filter values are available
- ❷ Pulse rate: Up to 20 test pulses per minute
- ❷ Leakage voltage: 0 to +/-500v (Model 6487), +/-200v (Model 2400),
- ❷ Leakage current sensitivity: 10-12 to 2.5 x 10<sup>-3</sup> amps (Model 6487)
- ❷ Source impedance: 50Ω
- ❷ Load Impedance: any load
- ❷ Selectable mains power: 100,120 vac@5amps; 220,240 vac@3amps, 50 to 60 Hz (USA default: 120 vac; 60 Hz)
- ❷ Switching control for 2 external channels is standard; switching control allows bias voltages to be applied or removed during the leakage test.

## Features and Benefits

### 50 Ohm Test System

Controlled 50-ohm impedance throughout the complete measurement chain of the test system minimizes the measurement errors associated with the usual 500-ohm resistor connections for ordinary TLP testers. Making measurements at 50-ohm impedance minimizes the effects of parasitics.

Just as the Barth 4003 TLP Pulse Curve Tracer connections to the packaged device sockets are constructed with a controlled 50-ohm impedance, the Barth TLP wafer probe also has a controlled 50-ohm impedance throughout its connections to the two needle contacts at any two pads.

Testing the DUT directly from an, inherently low 50-ohm source impedance provides inherently higher pulse currents from a clean test pulse with no ringing or overshoot. A perfect sub nanosecond risetime pulse generator combined with low distortion measurement probes and controlled impedance connections allows the Barth Pulse Curve Tracer test system to gather accurate TLP data either on wafer or on packages.

### Screen Displays

One of the 8 display screens is shown below.

All 8 screens display the active I-V test data and data for up to 5 recalled tests (on the left half of the screen).

The left side display shows both the I/V curve and leakage evolution. The right side display can also show: V & I waveforms, single or multi-point leakage evolution, operator info, test parameters, numerical test-point data, or calibration values.

### Data Storage

Data is automatically stored to hard disk in comma delimited format and can be recalled for viewing or transferring to disk. Data is automatically time/date stamped when saved.

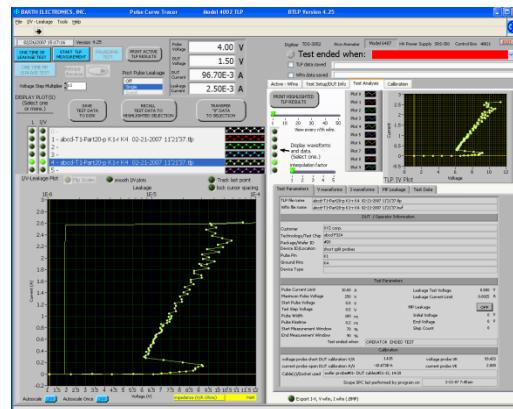
### Hardcopy Printout

Hardcopy color printouts list data point values and show plotted results using operator selected scaling; they are immediately available in a presentation ready format at the end of a test.

### Size and Weight

System is approximately 19" x 19" x 19" w/scope. Total weight including Control Box and scope is approximately 75 lbs. (Weight does not include computer.)

- ❷ Options and Accessories are available.



**This Product Features  
Barth Designed ZAPLESS®  
High Speed Measurement  
Components**

 Barth Electronics, Inc.



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## Pulse Curve Tracer Options

### Barth Model 4003 TLP+™

- ⊗ The Pulse Curve Tracer precisely characterizes the ESD robustness of silicon chip protection circuitry.
- ⊗ Programmed rectangular pulses are applied to the device under test, resulting in a computerized plot of current vs. voltage.
- ⊗ A leakage measurement can be made after each pulse to obtain the leakage evolution current versus pulse voltage.
- ⊗ Set up for packaged device testing; an optional dual wafer probe permits wafer level testing

### **500ns Wide Pulse Option – Model 4003-02**

The Wide Pulse Option is up to 500ns pulse width and provides one (1) External Charge Line (length of your choice). Note: the control box will need to be returned to factory for modification.

### **30 Amp Option Bundle – Model 4003-05**

The 30A Option Bundle provides “True 30 Amp” pulse capability and provides 1,500 volts to an open and 30 Amps through a short. Note: the control box will need to be returned to Barth for modification.

- ⊗ The 30A Option Bundle includes a CPU with T3600 specifications or higher and is required to run the 30A option software, DELL Precision T3600 with Xenon Processor, 4GB Ram, 500GB hard drive, 19” Flat Screen Monitor, Keyboard, Mouse, Windows® 7 OS, and the latest version of BSSP (1 yr subscription).
- ⊗ This option also allows user to analyze HBM and/or HMM circuits for operation characteristics and immunity.

### **Pulsed Bias Option – Model 4003-07**

The Pulsed Bias Option is AC Powered and provides an automatic bypass connection to preserve the leakage test capacity that occurs between TLP stress pulses. Note: the control box will need to be returned to factory for modification.

### **1500ns Wide Pulse Option – Model 4003-08**

Requires -02 500ns Wide Pulse Option; Includes (1) 1000ns Charge Line that is used with the external 500ns (425ns actual) Charge Line to achieve the 1500ns pulse width. 1500ns Wide Pulse Option is limited to below 10 Amps max.

### **Keithley Model 2400 Upgrade Option - 4003-11**

Replaces the Keithley 6487 Model.

### **580-NFT**

80 ns Ramp Generator. Call our office for details.



## Pulse Curve Tracer Options

### Barth Model 4002 TLP+™

- ⊗ The Pulse Curve Tracer precisely characterizes the ESD robustness of silicon chip protection circuitry.
- ⊗ Programmed rectangular pulses are applied to the device under test, resulting in a computerized plot of current vs. voltage.
- ⊗ A leakage measurement can be made after each pulse to obtain the leakage evolution current versus pulse voltage.
- ⊗ Set up for packaged device testing; an optional dual wafer probe permits wafer level testing

### **20 Amp Option – Model 4002-01**

The 20A Option is “True 20 Amp” pulse capability and provides 1,000 volts to an open and 20 Amps through a short. Note: the control box will need to be returned to factory for modification.

- ⊗ This option also allows user to analyze HBM and/or HMM circuits for the operation characteristics and immunity.

### **500ns Wide Pulse Option – Model 4002-02**

The Wide Pulse Option is up to 500ns pulse width and provides one (1) External Charge Line (length of your choice). Note: the control box will need to be returned to factory for modification.

### **1500ns Wide Pulse Option – Model 4002-08**

Requires 4002-02 500ns Wide Pulse Option; Includes (1) 1000ns Charge Line that is used with the external 500ns (425ns actual) Charge Line to achieve the 1500ns pulse width. 1500ns Wide Pulse Option is limited to below 10 Amps max.

### **Combo Option – Model 4002-0102**

The combo Option includes both the 20A and wide pulse options, above. Note: the control box will need to be returned to factory for modification.

### **Negative Pulse Option – Model 4002-03**

The Negative Pulse Option adds an inverter to the pulse circuit; this option is easily installed by user.

### **30 Amp Option Bundle – Model 4002-05**

The 30A Option Bundle provides “True 30 Amp” pulse capability and provides 1,500 volts to an open and 30 Amps through a short. Note: the control box will need to be returned to Barth for modification.

- ⊗ The 30A Option Bundle includes a CPU with T3600 specifications or higher and is required to run the 30A option software, DELL Precision T3600 with Xenon Processor, 4GB Ram, 500GB hard drive, 19” Flat Screen Monitor, Keyboard, Mouse, Windows® 7 OS, and the latest version of BSSP (1 yr subscription).
- ⊗ This option also allows user to analyze HBM and/or HMM circuits for operation characteristics and immunity.

### **Pulsed Bias Box Option – Model 4002-07**

The Pulsed Bias Box Option is AC Powered and provides an automatic bypass connection to preserve the leakage test capacity that occurs between TLP stress pulses. This option is user installed.

### **Keithley Model 2400 Upgrade Option - 4002-11**

Replaces the Keithley 6487 Model.

## Pulse Curve Tracer Accessories

### **20ns Risetime Filter – Model 40010-U**

The 20ns risetime filter provides 20ns up to 30 amp system.

### **30ns Risetime Filter – Model 40010-WC**

The 30ns risetime filter provides 30ns up to 30 amp system.

### **40ns Risetime Filter – Model 40010-VC**

The 40ns risetime filter provides 40ns up to 30 amp system.

### **Aluminum Test Stand – Model 43002**

The aluminum test stand is to stabilize DUT cables during use

### **DUT Cable for Test Stand – Model 43102**

Test stand DUT cable (Section 1; 18" length)

### **DUT Cable, 2 leads – Model 44202**

DUT cable with 2 leads, for 48 pin DIP Zip test fixture (Multiple ground pin)

### **DUT Cable, 3 leads – Model 44203**

DUT cable with 3 leads, for 48 pin DIP Zip test fixture (Multiple ground pin)

### **DUT Cable, 4 leads – Model 44204**

DUT cable with 4 leads, for 48 pin DIP Zip test fixture (Multiple ground pin)

### **HBM Dual Wafer Probe – Model 45003WP**

The HBM dual wafer probe includes 2 DUT cables, needles and accessories

### **HBM Dual Wafer Probe 3<sup>rd</sup> Arm Assembly – Model 46010**

The 3<sup>rd</sup> arm assembly is for use with the HBM Dual Water Probe, it is a single probe, and includes a leakage box kit.

### **High Z Set**

This High Z accessory is for use with the HBM Dual Wafer Probe; each set includes three (3) resistor sets for each Model of High Z, shown below:

- ⊗ Model 47150 = 50 ohm (set of 2), Source Z = 150 ohms
- ⊗ Model 47250 = 100 ohm (set of 2), Source Z = 250 ohms
- ⊗ Model 47450 = 200 ohm (set of 2), Source Z = 450 ohms

**Needle: Osmium tipped – Typically used for wafer pad probing (can be used with care for BGA)**  
**Model 45121** - Improved strength Osmium tipped needle (.026" dia. shank, 15 degree included angle to tip, 12.7 micron (0.0005") tip radius. Sold in sets of (4).

**Needle: Chisel tipped – Typically used for BGA and other package devices (dead bug style)**  
**Model 45104** - Chisel tipped needle (0.026" dia.shank, wide chisel = .026" ≈660 micron tip width)  
**Model 45106** - Chisel tipped needle (0.026" dia. shank, narrow chisel = .010" ≈254 micron tip width)  
**Model 45108** - Chisel tipped needle (0.026" dia. shank, very narrow chisel = .006/.008" ≈152-203 micron tip width)



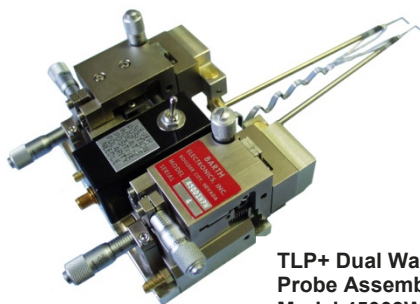
Barth Electronics, Inc.



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# Barth Model 45003WP, Model 45010

## Dual Wafer Probe Model 45003WP



**TLP+ Dual Wafer  
Probe Assembly  
Model 45003WP**

The Barth Model 45003WP Dual Wafer Probe accessory is designed to be used with the Barth Model 4003 TLP+™ Pulse Curve Tracer for pulse testing of the ESD protection circuit I/V characteristics at the wafer level.

It has two separate needles and isolated probe connections that can be independently positioned with no interaction between them.

### Specifications:

- ⊞ Dual Wafer Probe High Z Set; each set includes three (3) resistor sets for each Model of High Z.
- ⊞ Needle: Osmium Tipped - Model 45121
- ⊞ Needle: Chisel Tipped - Model 45104
- ⊞ Controlled 50 ohm impedance throughout the complete measurement chain of our test system minimizes the measurement errors associated with the usual 500 ohm resistor connections for ordinary TLP testers. Making measurements at 50 ohm impedance minimizes the effects of parasitics.

### Accuracy

The Barth Model 45003WP Dual Wafer Probe accessory has been specially designed to provide the same accuracy as when testing packaged devices in a socket. Testing the TLP characteristics of the device on wafer and later when it is packaged, can provide significantly more information than is available with pass or fail testing with human body model or machine model. Either manner of connecting to the DUT allows very repeatable measurements at high pulse currents.

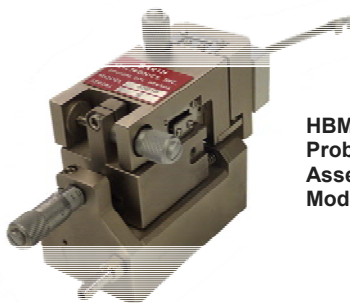
To minimize the mechanical problems of crossed needles in connecting to the pads to be tested, a specially designed constant impedance-reversing switch allows easy selection of the TLP pulse polarity at the pads. A user selectable magnetic or vacuum base allows this TLP probe to be easily moved while maintaining a secure position on the table.

Just as the Barth TLP Test System connections to the packaged device sockets are constructed with a controlled 50 ohm impedance, the Barth Model 45003 Dual Wafer Probe accessory also has a controlled 50 ohm impedance throughout its connections to the two needle contacts at any two pads.

Testing the DUT directly from an inherently low 50 ohm source impedance provides inherently higher pulse currents from a clean test pulse with no ringing or overshoot. A perfect sub nanosecond risetime pulse generator combined with low distortion measurement probes and controlled impedance connection allows the Barth Model 4003 TLP+™ Pulse Curve Tracer test system to gather accurate TLP data either on wafer or packages.

## 3rd Arm Probe Model 45010

The Barth Model 45010 3rd. Arm Probe has been specially designed for applying additional grounds or bias voltages to your devices.



**HBM Dual Wafer  
Probe 3rd Arm  
Assembly  
Model 45010**

 Barth Electronics, Inc.

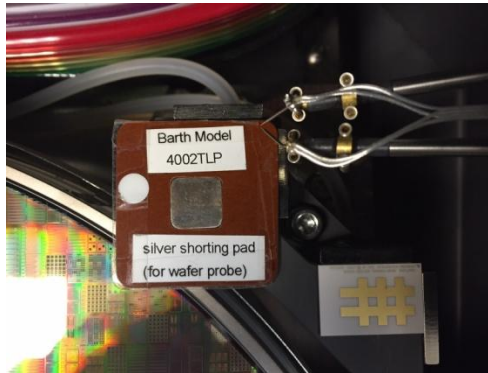


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# Silver Shorting Pads 45201 and 45202

## 45201 Design and Performance



### Specifications:

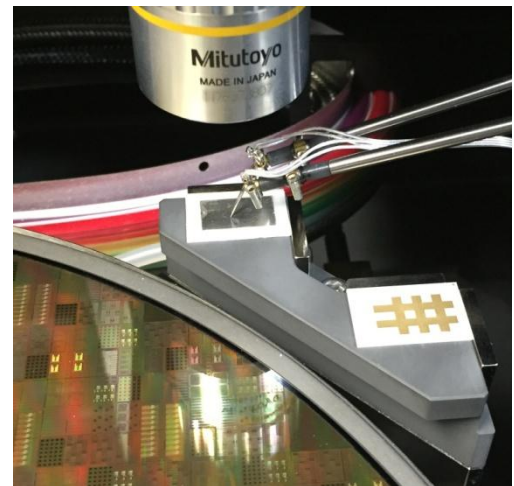
Standard shorting pad supplied with the 4002-TLP and 4003-TLP Test Systems

Silver pad located on larger composite back for placement on wafer chuck to provide a calibration short to the Dual wafer probe needles.

### APPLICATION

4002-TLP Wafer Probe  
Short Calibration

## 45202 Design and Performance



### Specifications:

This is an optional shorting pad for use with the 4002-TLP Test System

A Silver pad is located on small alumina base intended for permanent mounting on a probe station frame to allow a short calibration or verification without removal of the DUT wafer from the platen.

Barth Electronics has been the worldwide leader in High Voltage pulse instrumentation since 1964. All of our products are unconditionally guaranteed to perform precisely to our listed specifications. Call or email us for additional information or to discuss your application.

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# Pulsed Bias Box- Model 45320

## TLP Pulsed Bias Accessory for 4002-TLP

### APPLICATION

4002-TLP biasing of the TLP pulsed pin



Pulsed Bias accessory  
for 4002-TLP Pulsed  
Curve Tracer

Unit shown mounted; replaces original "Remote Switches / To DUT" panel on front of 4002-TLP rack chassis.



The Pulsed Bias unit incorporates a wide bandwidth DC blocking capacitor to allow application of bias voltage on the TLP pulsed pin, with built in switching to preserve normal leakage measurement capability; leakage measurements are made in between TLP pulses. Accessory is supplied with a Keysight low voltage power supply which is set up and controlled by the TLP test system over GPIB bus.

Barth Electronics has been the worldwide leader in High Voltage pulse instrumentation since 1964. All of our products are unconditionally guaranteed to perform exactly to our listed specifications. Call or email us for additional information or to discuss your application.

Contact us for additional information or to discuss your application.



# Ramp Module 580-NFT

## 40ns and 80ns Ramp Pulse



Linear Ramp accessory  
for 4002-TLP Pulsed  
Curve Tracer

### APPLICATION

4002-TLP Pulsed Curve  
Tracer – Ramp generator  
(rise time spoiler)

Unit shown mounted; tucks  
inside top rear of 4002-TLP  
rack chassis at top of rack  
inside rear compartment door



Unit connects to the external rise time spoiler  
connections on the 4002-TLP to provide both 40 and  
80ns rise time linear ramp function to the TLP test  
system.

Barth Electronics has been the worldwide leader in High Voltage pulse instrumentation since 1964. All of our products are unconditionally guaranteed to perform exactly to our listed specifications. Call or email us for additional information or to discuss your application.

Contact us for  
additional information  
or to discuss your  
application.



# Barth Model 4002/4003 TLP+™

## Pulse Curve Tracer Rental and Rent-to-Own Systems

The Barth Electronics Model 4002/4003 TLP+™ test system is a complete turnkey TLP test system featuring a Barth Model 40021 TLP Control Box or 40031 TLP Control Box, which includes built in software selectable rise time filters for pulse rise time values of 200ps, 2ns, and 10ns.

Unless otherwise requested, rental unit is shipped configured for the TLP standard 100ns pulse width, and can be easily re-configured by the user for a 75ns pulse width. A control computer is also provided.

Additionally, Barth offers a Model 4002/4003 rent-to-own program. Please contact our office for further details.

### System Components

- Ⓢ Tektronix 500 MHz, 2 channel, digitizing oscilloscope
- Ⓢ High reliability Barth Electronics control box/pulse generator
- Ⓢ Keithley Picoammeter/voltage source
- Ⓢ Main power switch/power distribution panel
- Ⓢ Test control computer
- Ⓢ LabView® runtime control and analysis software

### Rental system includes:

- Ⓢ 1 day training on site at the Barth Electronics factory in Boulder City, NV; (travel costs are not included),
- Ⓢ Additional training days are available
- Ⓢ Phone and email support
- Ⓢ Portable TLP+ system which includes:
  - Tektronix® oscilloscope (2 channel)
  - Keithley Picoammeter
  - SRS HV power supply
  - LabView® runtime control and analysis software
  - Control computer with the latest version of Barth test computer software
  - 48 pin DIP zip test fixture (includes DUT cable and accessories)

### Available True 30 Amp System:


- Ⓢ The 30 amp system has “True 30 Amp” pulse capability and provides 1,500 volts to an open and 30 amps through a short. This option also allows user to analyze HBM and/or HMM circuits for operation characteristics and immunity.

Currently, systems are only available for rent within the USA.

System availability is limited and subject to prior rental.

**This Product Features**  
**Barth Designed ZAPLESS®**  
**High Speed Measurement**  
**Components**

**94**

 Barth Electronics, Inc.



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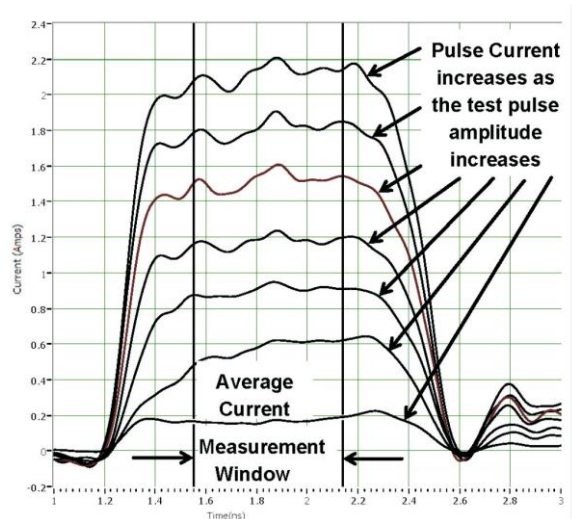
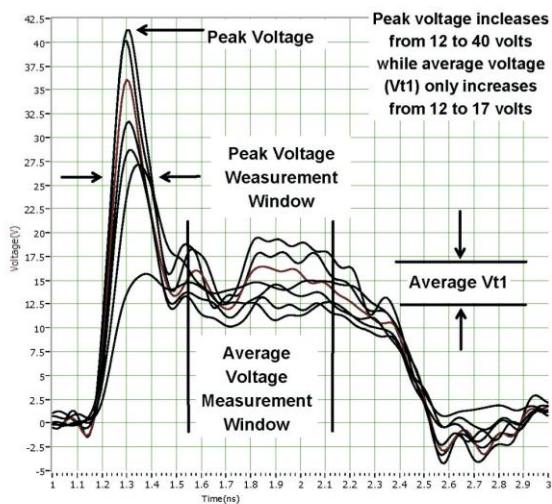


# Measure your CDM protection with VFTLP+

Would you like to see the subnanosecond operations of your CDM protection?



VFTLP+ now provides revolutionary improvement in understanding CDM effects inside the package. This test is now available to help you analyze your CDM circuit design. Very Fast test pulse and Measurements simulate the very fast CDM event. Understand the very fast operation of your voltage clamping circuits for the first time.



The voltage and current waveforms shown above are of a snapback device. The Voltage waveforms show the Vt1 voltage increasing from 12V to 17V while the peak voltage added threat to the Gate Oxide increases from 12 to 40 Volts. Measurements on wafer; and of packaged devices provides a completely new understanding of CDM circuit operation inside the package.

# Barth Model 4012 VFTLP+™

## Very Fast High Speed Pulse Curve Tracer



### System Components

- ☞ Tektronix 6GHz digitizing oscilloscope
- ☞ High reliability Barth Electronics control box/pulse generator
- ☞ Keithley Picoammeter/voltage source
- ☞ Test control computer
- ☞ LabView® runtime control and analysis software
- ☞ One year warranty on the entire system
- ☞ One year BSSP Barth Software Subscription Program

### How It Works

To use the Pulse Curve Tracer, the operator enters the desired test parameters via keyboard, such as starting voltage, current and voltage limits, voltage step increments, pulse risetime, and pulse width.

The test then proceeds automatically, controlled by Barth software developed with National Instruments LabView®.

The operator can halt and resume the testing and can view the plotted test data points as the test proceeds.

The operator can also view (during testing or afterward), voltage & current waveforms, single point or multi-point leakage evolution, test set-up parameters, or numerical data information.

The active test and several previous test data plots may be viewed simultaneously on the I/V plot.

Hardcopy prints are immediately available; this includes both the active I/V plot plus leakage vs. average current plot.

### Screen Displays

Eight display screens all display the active test and up to 5 recalled tests (on the left half of the screen).

The left side display shows the I/V curve and leakage evolution.

The right side display can also show: V & I waveforms, single or multi-point leakage evolution, operator info, test parameters, numerical test-point data. or calibration values.

The Barth Model 4012 VFTLP+™ Very Fast Pulse Curve Tracer is built with specially designed high speed hardware.

Its test pulse simulates the CDM speed and its current and voltage sensors capture the very fast response of ESD circuits necessary for CDM design.

Barth manufactured hardware has the fastest instrumentation of any system and corrects for losses inherent at these picosecond speeds. This system is the first to add accurate peak TDDDB oxide threat data to the usual I-V data plot. It is used to analyze the gate oxide threat produced by ESD protection structures. This system captures both voltage and current waveforms at silicon level before packaging for first silicon CDM success.

### Software

The software includes voltage & current DUT waveform capture, automatic calibration / compensation (and save / recall), save / recall operator set-ups, auto or manual axis scaling. Single or multi-point leakage testing (configurable), adjustable measurement window, dynamic resistance plots with values, compare & analyze multiple tests, save / recall pulsing "profiles", multi pulsing capability (between data collection points), and scope auto-SPC (signal path compensation), to aid your CDM design effort.

The BSSP (Barth Software Subscription Program) provides periodic software updates and improvements. This assures your system is in peak operating condition. Test speed increases and efficiency improves. Improve system capability with regard to calibration, reporting, and system diagnostics; all available with BSSP.

## Features and Benefits

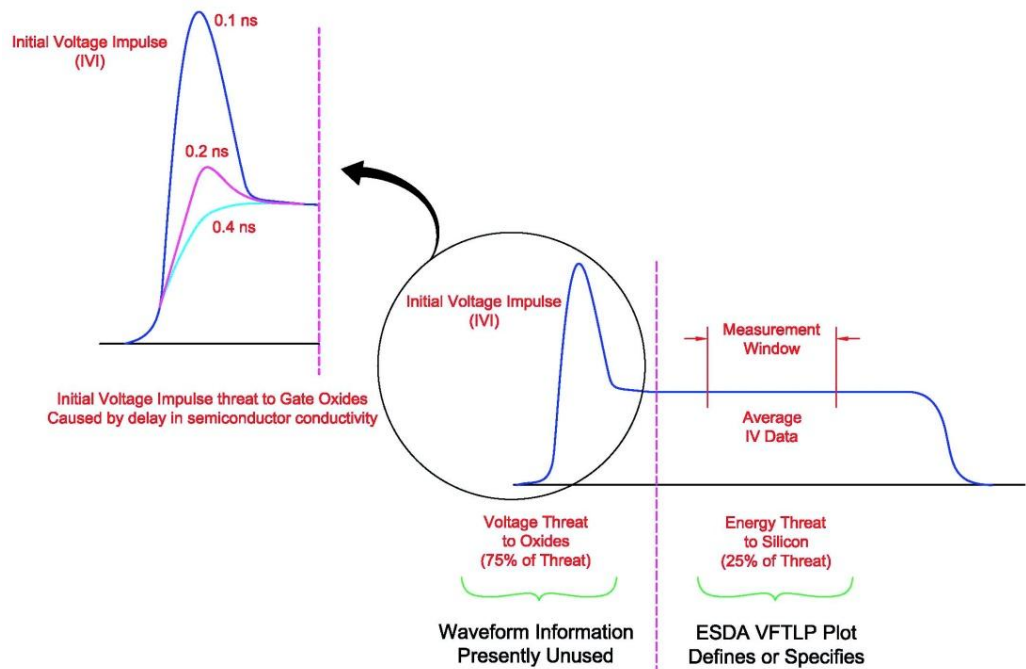
### Specifications

Output to DUT (program driven)

- Ⓢ Pulse width: 1ns, 2ns, 5ns, and 10ns standard. Pulse width is software selectable.
- Ⓢ Pulse voltage: 0-500 v @ 50Ω load, 1,000 v @ open circuit
- Ⓢ Min. Pulse Voltage; 1.0V into Open Load  
Min. Step Voltage; 0.2V into Open Load
- Ⓢ Pulse current: 0-10 amps @ 50Ω load, 20 amps @ short circuit
- Ⓢ Pulse risetime: 100ps, 200ps, 400ps (built-in, software selectable)
- Ⓢ Pulse rate: ≈ 10 test pulses per minute
- Ⓢ DUT voltage sensor risetime: 30ps
- Ⓢ DUT current sensor risetime: 35ps
- Ⓢ Leakage voltage: 0 to 100v (0.1 v increments)
- Ⓢ Leakage current sensitivity: 1 pA to 2.5 mA
- Ⓢ Source impedance: 50Ω
- Ⓢ Load Impedance: any silicon ESD voltage clamp circuit
- Ⓢ Factory Selectable power: 100,120 vac @ 1.5amps; 220,240 vac @ .75amps, 50 to 60 Hz (USA default: 120 vac; 60 Hz)

### Accuracy

Special Barth wide bandwidth pulse current and voltage sensors provide a high standard of measurement capability for ESD test equipment. The complete system has been built with special attention paid to minimizing losses in the test circuitry and the coaxial cable connections. This results in accurate measurements of low dynamic resistance CDM protection circuits directly at the silicon pads.



### Options and Accessories

- External Parametric Tester Option  
Allows connection of an external tester for more extensive characterization or functional testing of DUT in between pulse tests
- BGA-TF Test Fixture – Model 40312  
BGA-TF Test Fixture (includes one BGA probe)
- RF Probe Head  
RF Probe Head for use with either the Vacuum or Magnetic VFTLP+ Wafer Probe Positioner; (xxx= micron spacing).  
Manufactured by Cascade Microtech®
- VFTLP+ Wafer Probe Positioner, Magnetic  
Manufactured by Cascade Microtech®
- VFTLP+ Wafer Probe Positioner, Vacuum  
Manufactured by Cascade Microtech®
- Silver Shorting Pad - Silver Short with 15ea. 5.5Ω resistors on alumina base to allow a short calibration or verification of system

### Data Storage

Data is automatically stored to hard disk in comma delimited format and can be recalled for viewing or transferring to disk. Data is automatically time/date stamped when saved.

### Hardcopy Printout

Hardcopy printouts on a color printer listing data point values and showing plotted results using operator selected scaling are immediately available in a presentation ready format at the end of a test.

### Size and Weight

System is 19"W x 11"H x 20.5" D (total height with a Tektronix Model DPO70604 is 21"). 147 lbs (not including external PC, monitor, or packing materials).

**This Product Features Barth  
Designed ZAPLESS®  
High Speed Measurement  
Components**





## VFTLP+ BGA-TF Test Fixture



The Model 4012 Very Fast TLP Plus (VFTLP+) system required 5 years to create a system which can simulate the CDM test in the time domain. This very fast hardware capture the fastest parts of the high speed waveforms never quantitatively identified before. The instrumentation developed for this system provides accurate waveform measurements of circuits needed for both a very fast pulse source and extremely fast response current and voltage sensors. In addition to the well-known I-V data used for analysis of electrical characteristics of ESD protection structures, the VFTLP+ system captures both voltage and current waveforms at the Device Under Test (DUT).

The BGA-TF Test Fixture is designed to be used with the VFTLP+ system. It provides high pulse current measurements of CDM type protection directly to two balls with minimum inductance without an expensive BGA high speed socket. With the DUT isolated about ground planes, there is no capacitance to ground effects on the current and voltage waveforms; measured directly at the package terminals.

While of limited value, this test is as close to the internal circuit operation as it is possible to achieve from the outside. This DUT fixture allows two pin testing to determine the amount of correlation with CDM.

To minimize the parasitic inductance from connections to the VFTLP+ system, this test will be most effective only when testing closely spaced balls. Metal and silicon failures from high currents at CDM pulse widths will be achieved; but internal GOX stress may not closely simulate the CDM test.

Metal/Silicon failure levels with this fixture combined with gate oxide failure levels using direct VFTLP+ failure measurements, can be combined to improve correlation with CDM. Continuous leakage monitoring through the measurement connection allows the test pulse failure level to be constantly monitored in between pulse measurements.

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Revised 03/07/07

## CDM Circuit Turn-On Analysis Using Very Fast TLP (VFTLP+) Waveforms

The 4012 Very Fast TLP (VFTLP+) system captures DUT voltage and current waveforms in addition to generating I/V data. The machine was built with the best possible hardware so that software could analyze and extract accurate data from these captured waveforms. This machine has the ability to capture and save waveforms for both the current through the DUT and the voltage across the DUT. The number of I-V waveforms displayed on the waveform screen is determined by the position of two cursors on the I-V plot screen. By moving each of the two cursors the user can display one or many DUT voltage and current waveforms.

The position of the pads for this test chip, required that we use the negative test pulse. Future software will allow the I-V data to be put into the first quadrant and display all waveforms as positive going for ease of visual analysis.

The I-V plot in Figure 1. shows three I-V characteristics of an excellent CDM protection circuit at different pulse widths. We made all three pulse width measurements on one CDM protection structure avoiding failure levels known from previous tests of identical test structures. The green data points are from the 1 ns long test pulse which didn't fail at the maximum test pulse amplitude which produced 18 amps at 17 volts in the DUT. The blue I-V data points from 2 ns pulse testing was terminated at about 12 Amps to avoid failure which occurs at about 16 amps. Because the 5 ns long test pulse was the last test on this structure it was taken to failure, which occurred at about 7 amps. This particular CDM test structure was very robust and provides an excellent demonstration of the capabilities of our 4012 VFTLP+ machine.

These structures had gate monitors to simulate the sensitive gate in the core being protected, and are the failure level indicators when leakage current increases. There is a way to make certain that the greatly increased leakage current was caused by gate monitor failure. If a retest of the test structure produces the same I-

V characteristics, this indicates that the protection circuit was unchanged, and undamaged.

Failures current levels of devices at different pulse widths will be more thoroughly analyzed in the future. The ability of the VFTLP+ to provide actual DUT voltage amplitude waveforms into the core will allow more precise analysis of how gate oxide failures compare to Time Dependant Dielectric Breakdown measurements made with flat top pulses.

Measuring the same CDM test structure at three different pulse widths is useful because it shows how the circuit conductivity changes with shorter and longer pulses.

The 1 ns (blue), 2ns (red), and 5 ns (green) long test pulse I-V data shows how multiple I-V plots are displayed on the same screen.

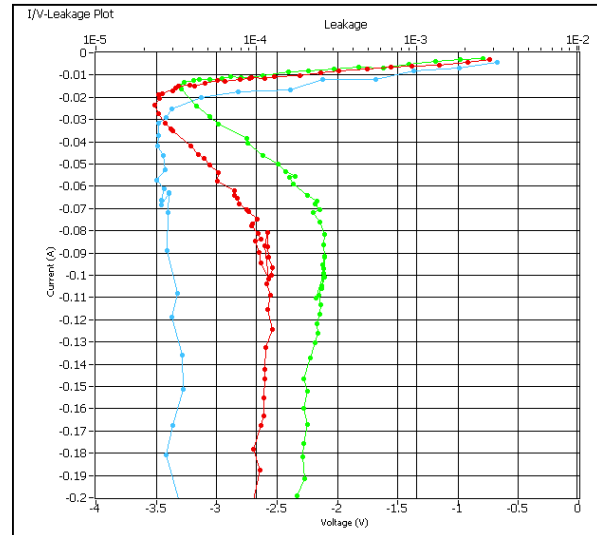


Fig. 1

The blue plot shows how the device turns on at 1 ns pulse width. The pulse is so short that the circuit doesn't have sufficient time to fully conduct into its snap-back mode. An approximate measure of the negative resistance at the slight snap-back conditions indicate that it would be about -0.60 ohms. This short pulse test shows that the circuit cannot get into its higher conduction mode to cause the



## Barth 4012 Application note #1

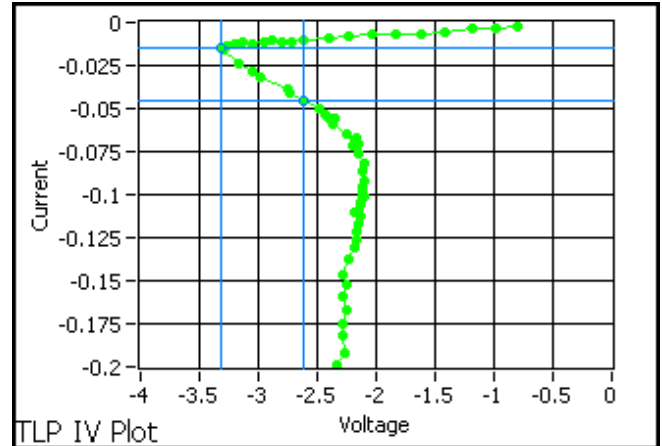
voltage decrease to amplitudes it will have when the test pulse is longer; but although the voltage remains higher throughout increasing current pulses, the shorter pulse width does not cause this gate monitor to fail at the maximum test pulse amplitude.

The red plot is made with the 2 ns long test pulse and shows the beginning of the snap-back operation. It shows a noticeable decrease in DUT voltage after snapback. Its snap-back negative resistance can now be measured at about -16.7 ohms.

The green plot is made with the 5 ns long test pulse and shows a more conductive snap-back operation that holds the voltage at even lower levels. The negative resistance during snap-back is now noticeably higher at -23 ohms. Again this test structure is an excellent example of a very well designed test structure that turns-on as desired for CDM protection.

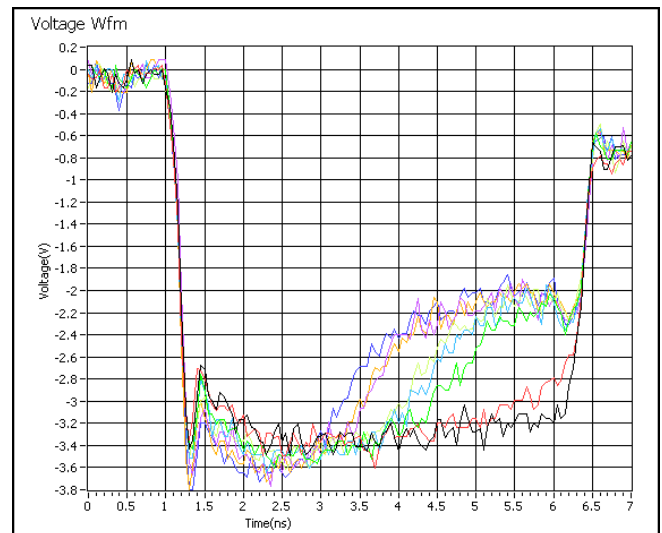
The user can display many different color plots on this screen but keeping them to 8 or 10 plots on one screen limits data confusion when the complete I-V range is displayed. When current and voltage scales are expanded, however, the difference between multiple plots becomes very clear. Subtle differences in multiple similar plots I-V plots can be clearly identified in this way. Although the noise levels in VSTLP increases above a few amps there is a significant advantage in data analysis when using a TLP systems with accurate measurements at all time ranges. Lower accuracy VFTLP systems will provide lower accuracy information on the differences between minor changes in ESD circuit design.

The green data points below form the I-V plot of the 5 ns long test pulse data in the low current region of a CDM circuit where turn-on begins.



The 4012 VFTLP+ software uses two blue cursors used to select two I-V data points which includes all the data points between them. The seven (7) green DUT data points select the all the voltage and current waveforms to be displayed on two more screens for analysis of turn-on characteristics.

The **voltage waveforms** below show a number of interesting facts.



1. The lowest voltage data point is the black trace where it is relatively constant throughout the length of the five (5) nanosecond test pulse.

2. The second higher voltage waveform point is shown as red. It shows a slight decrease in voltage near the end of the 5 ns pulse as the circuit starts to conduct in a nonlinear fashion.

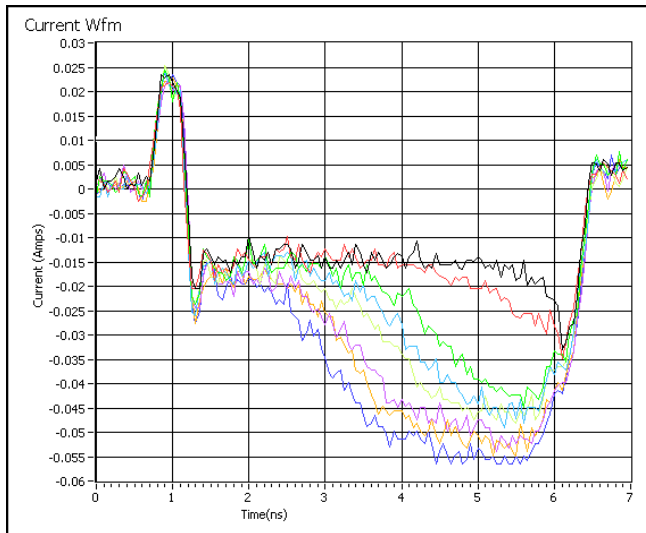


## Barth 4012 Application note #1

3. The next higher voltage waveform is shown in green. It also shows a significant decrease over the last nanosecond of the 5 ns long pulse.

4. The highest current point between the two green cursors on the I-V plot is shown in blue on both the DUT Voltage and Current plots. Here the voltage has started to decrease after about 3 ns and shows major voltage decrease during the last 1.5 ns of the 5 ns long test pulse. The current increase after a few nanoseconds occurs at the same time as the decreasing voltage.

The **current waveforms** between the two selection cursors are shown below.



1. Again the lowest test pulse amplitude is the black trace which is relatively constant throughout the length of the five (5) nanosecond test pulse.

2. The second higher current waveform is shown in red. It shows a slight increase in current near the end of the 5 ns pulse as the circuit starts to conduct in a nonlinear fashion.

3. The next higher current waveform is shown in green. It also shows a significant, linear increase over the last nanosecond of the 5 ns long pulse.

4. The highest current point between the two green cursors on the I-V plot is shown in blue on this DUT Current waveform. Here the

current has started to increase after just 1 ns and shows a major linear current increase during the middle ns of the 5 ns long test pulse. The current increase after a few nanoseconds occurs at the same time as the decreasing voltage.

These are just seven waveforms for this particular CDM protection circuit during its interesting turn-on phase. The waveforms at all the higher currents with voltage and current amplitudes during the pulse are also available. Many more details beyond this cursory analysis will certainly be extracted from accurate waveforms, when studied by ESD designers.

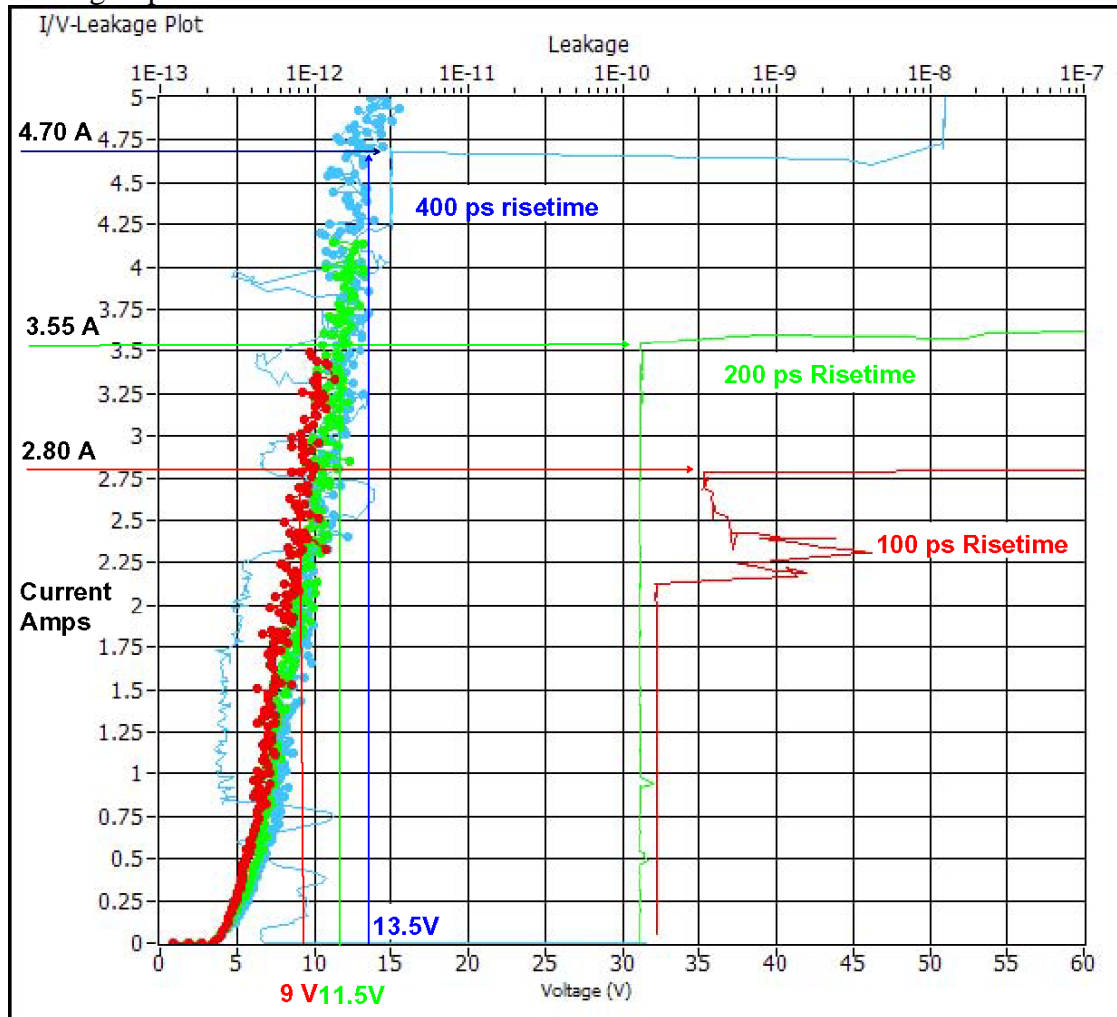
One of our associates in ESD design commented that a Very Fast TLP (VFTLP+) system would not show any useful CDM design information. He must have forgotten the limited understanding of early TLP data, with the limited accuracy available from early crude machines. Today TLP data has such extreme value that all ESD design tutorials make specific demands that it must be used if efficient and good ESD protection is to be achieved.

Barth Electronics has complete confidence that intelligent ESD designers will devise methods to extract, and expand on the preliminary analysis of VFTLP+ waveforms made here. That is why we have invested so much time in developing the most accurate fast pulse hardware and waveform capture software for sub nanosecond time analysis of CDM protection circuits. Improvements in protection circuit design can grow rapidly when accurate sub-nanosecond voltage and current waveforms details are used.

An analysis of all the waveforms, at increasing amplitudes can now identify how the CDM protection circuit turns on during the test pulse time. Knowing the dynamic conductivity at each period of time can now provide the CDM designer with details impossible to measure previously. The data shown here was taken at 100 ps risetime. What additional design data may be able to be extracted from VFTLP+ data taken at slower risetimes of 200 and 400 ps?

## Barth Plots the “Real” CDM Killer of Gate Oxides

Being able to measure and provide the total voltage over time in an ESD test is a significantly new advancement in ESD design. This is especially true for CDM design because voltage kills Gate Oxides. Modern oxides are thinner and have greater sensitivity to over-voltage. The extremely short but very high voltage requires a new test to measure this High Speed threat.



This above plot shows the ordinary I-V plot of a protection circuit which begins conduction at 4 volts and reaches 10 or 15 volts at currents where the gate oxide fails. The ordinary I-V data averaged during the measurement window at late time doesn't provide the data needed. Current, is not what damages gate oxides however; the short impulse of voltage is the real threat.

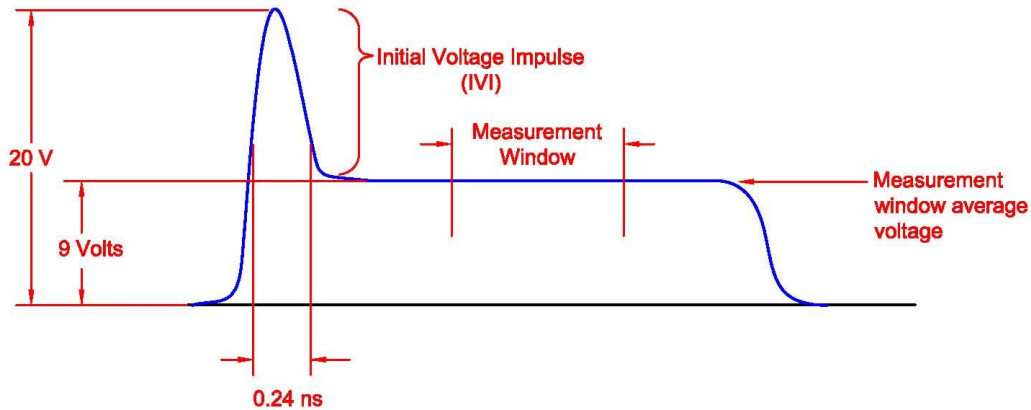
Until recently the true parameters of the very fast voltage waveform threat to gate oxides was unavailable. Because CDM can be as fast as 100 ps risetime, this very fast risetime must be available to simulate the real CDM event. Sensors to measure any rate of rise must be at least three (3) times as fast as the risetime being measured. Barth Electronics has recently developed sub-nanosecond sensors which allow accurate measurements of both the very fast risetime current and voltage in CDM protection circuits.

# Barth Plots the “Real” CDM Killer of Gate Oxides

Sensors to measure any rate of rise must be at least three (3) times as fast as the risetime being measured. Barth Electronics has recently developed 30 ps risetime capable voltage and current sensors to provide accurate measurements of the very fast risetimes inherent in CDM protection circuits.

We capture all High Speed data in the current and voltage waveform. The very fast voltage which results from that current pulse is the important parameter needed for CDM protection design. Without 30 ps risetime sensor response, the true voltage threat information necessary for CDM design is not available. The Barth Model 4012 now uses 30 ps risetime I & V sensors to provide accurate measurements of 100 ps risetime pulse used to simulate the CDM event threat.

The drawing below shows a typical DUT voltage waveform on wafer which ultimately damages the gate oxide.

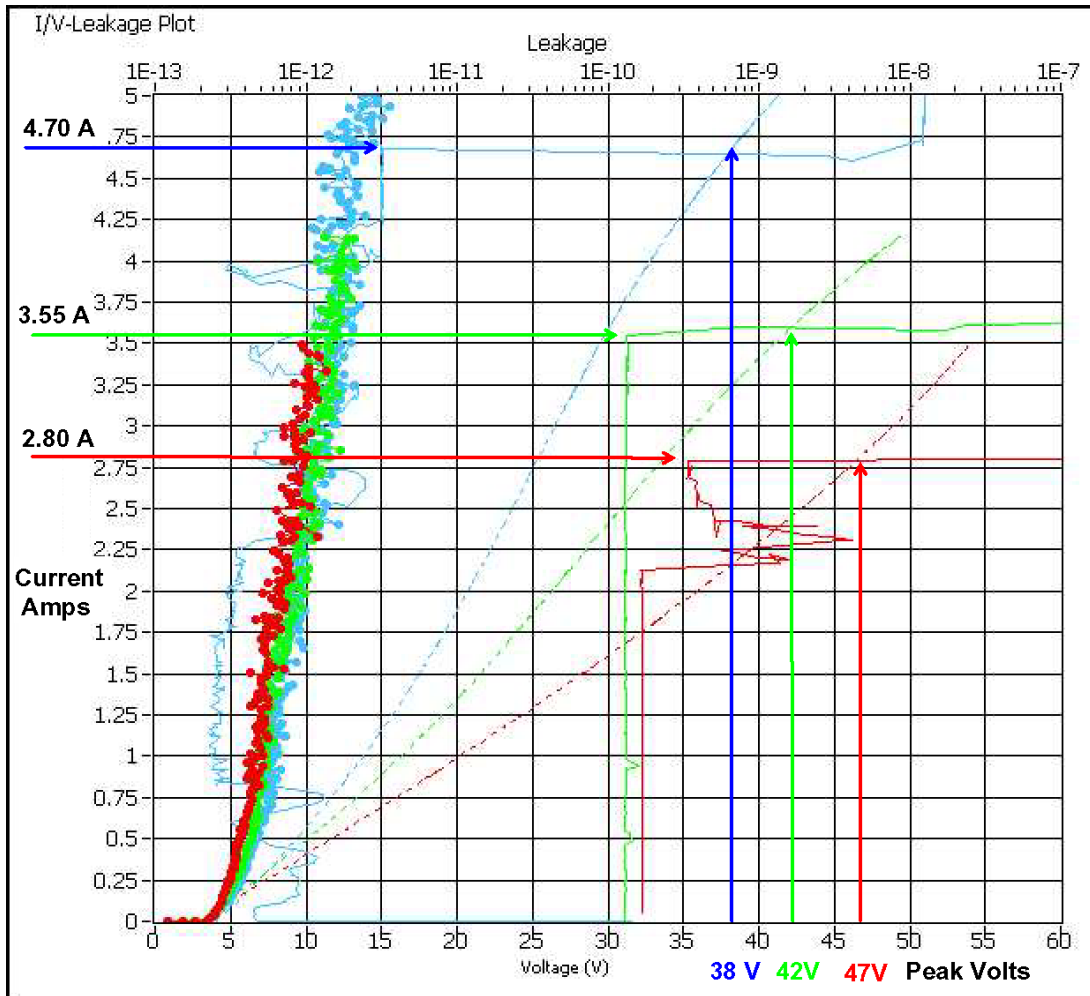


Initial Voltage Impulse threat to Gate Oxides  
Caused by delay in semiconductor conductivity

The average voltage in the measurement window occurs long after the all important initial impulse voltage. The peak voltage amplitude and its width can now be accurately measured with the High Speed Barth Model 4012 VFTLP+ system. It can measure the sub-nanosecond voltage impulse threat to gate oxides.



## Barth Plots the “Real” CDM Killer of Gate Oxides



The above I-V plot made with the Barth Model 4012 VFTLP+ shows not only the voltage averaged during the measurement window, it shows the much higher peak voltage that is the primary threat to gate oxides. The much higher initial peak voltage is a much greater threat than the average voltage measured after the semiconductor has fully turned on.

The Barth Model 4012 system is the only VFTLP+ with extremely fast sensors which can measure this extremely short voltage and identify the dangerous sub-nanosecond peak amplitude. From the sub-nanosecond to many nanoseconds, the 4012 system is fast enough to show both the amplitude and width of over-voltage threats to gate oxides. Gate oxides can be killed by voltages too fast and too short to be accurately seen by ordinary VFTLP systems. Can your VFTLP system show the true data that is this fast?

Does your designer have enough time to design CDM with a VFTLP system which isn't fast enough to show the Real threats? This VFTLP provides the data you need to determine how your CDM protection responds to the real threat. Real analysis for real first time design, the Barth Model 4012 VFTLP+ can do it!!

## Barth 4012 Application note #2

### Introduction to VFTLP+

VFTLP was originally developed to provide I-V characteristics of CDM protection and its analysis has been similar to that of TLP data used to analyze HBM protection circuits. VFTLP and TLP data are an average of the voltage and current waveforms taken in the measurement window. TLP for HBM circuit analysis provides very reasonable average voltage and current data after their waveforms have settled down and are relatively constant.

HBM failures are primarily the result of energy dissipation in silicon protection elements. CDM threats are 1 to 2 ns long, while HBM threats are about 100 to 200 ns long. CDM is different from HBM in two important respects. First, CDM currents create voltages which are applied to gate oxides. Oxides fail when their voltage capability is exceeded.

The second major difference is that HBM testing specifies 2 to 10 ns current risetimes while the CDM event is extremely fast. Its risetime is as fast as 100 ps and the length of its pulses are much shorter. In order for VFTLP to simulate CDM events its test pulse risetimes be as fast as this 100 ps. The original VFTLP test system used shorter pulses with the intention of simulating CDM. However this test still uses the I-V data averaged in the measurement window. Although averaged data is useful in understanding the basic I-V characteristics of the CDM protection element, it misses time varying information. The high speed CDM event creates rapidly changing current and voltages in the silicon protection elements or circuits. Understanding their high speed response introduces a new and very important indicator of CDM protection circuit operation, that is impossible to identify using only current and voltage data averaged during a measurement window.

Because the primary cause of failure with CDM is gate oxide failure, voltage is the

primary information needed to understand protection elements or circuits. The high speed CDM event creates very fast rates of current and voltage rise inside high speed IC's. We have developed special 30 ps risetime voltage and current sensors to identify the total DUT response with our VFTLP system. Measuring the high speed operation of silicon elements or circuits on wafer provides a new insight into previously un-known details of protection element operation.

Our VFTLP also adds true 100 ps risetime test pulse capability to simulate the CDM testing and CDM events. To deliver the high speed test pulse to the DUT, we always use very low loss transmission lines. Our very high speed wafer probes achieve extremely low inductance connections to the wafer. We identify this carefully engineered CDM circuit analysis tool as VFTLP+.

Our measurements of protection circuits on wafer have identified oxide threat Time Dependent Dielectric Breakdown (TDDB) voltages. Until now this measurement has been made with rectangular pulses to identify oxide voltage sensitivities to relatively short pulses. We have found that the first part of the oxide voltage threat is the initial voltage impulse. We identify this as the Initial Voltage Impulse (IVI) because it occurs in every VFTLP+ and CDM event. It is caused when extremely fast CDM events create very narrow voltage impulses, typically being 150 to 200 picoseconds wide. More complex protection circuits take additional time to turn-on and the IVI fall time can be as long as 5 ns. The IVI precedes the average steady state voltage identified in the measurement window. The IVI voltage has been referred to in previous papers although the true peak voltage has not been available. With both limited risetime test pulses and limited DUT response risetime measurement systems, the real silicon IVI cannot be determined.

## Barth 4012 Application note #2

The total oxide threat can now be identified by measurements of the voltage created by silicon protection circuits during the total time the threat is applied.

Diodes are a common element used for CDM protection. To demonstrate how voltage developed across a protection element varies during the test, we measured some micro-miniature silicon signal diodes. These diodes are only one mm long and have very low package inductance. The inductance is low enough that it does not become noticeable until the VFTLP+ current increases to a level high enough to increase the L/R effect. At this time the voltage impulse from  $-L \cdot di/dt$  effects become visible. We identify this as the Secondary Voltage Impulse (SVI) because the negative polarity inductive voltage “kick” from fast risetime current flowing through an inductance occurs when chips are packaged.

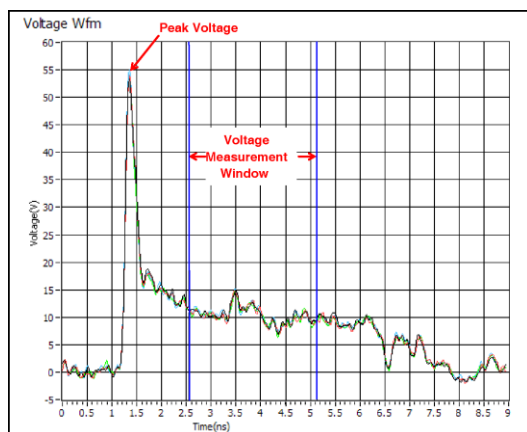


Figure 1. Voltage waveform showing voltage averaged over the measurement window and peak value

Semiconductors have an inherent delay between the time a voltage is applied and the current flow completes the silicon path. Our VFTLP+ system has permitted us to investigate high speed physics of semiconductors. The time delay between the application of voltage and carriers completing their path through silicon is typically identified as being 10 to 20 picoseconds. This time delay is dependent

on the path length through the semiconductor and the applied voltage. Higher voltages increase the speed of carriers in semiconductors until the saturation velocity limit is reached.

These introductory measurements of commercial diodes were made on 1N4148 diodes soldered directly to the end of a time calibrated piece of 0.085 inch diameter semi-rigid coaxial cable. The cable is connected to the VFTLP+ tester with an integral SMA connector. Great care must be made to assure that the measurement reference location is positioned at the end of the coaxial test cable where the DUT is located. These measurements can be made with any VFTLP machine on similar diodes. Accurate information on the voltage overshoot which occurs before the current carriers complete the circuit path through the silicon must be made with 100 ps risetime. Simulating the CDM event is of paramount importance if VFTLP is to provide its inherent capability.

### Diode Turn-on Time Measurements

Note: The first measurements made of the 1N4148 miniature size package were made at the end of the two wires, which extend about 0.095 inch past the end of the 0.085” dia. copper jacket.

We also made tests of the inductance of these two wires by placing a 0.040 wire short between them 0.070” from the body to simulate the 1N4148 diode position. These relatively short wires extending out from the coaxial cable added a significant amount of inductance.

To remove as much lead inductance as possible we connected the much shorter leads in micro-miniature 1N4448 diodes directly at the end of the Teflon. It was placed between the 50 ohm inner conductor and its Copper jacket. Removing the wire leads and moving the diode 0.095 inch closer to the timing short reference end of the coaxial cable shows noticeably less inductance.



## Barth 4012 Application note #2

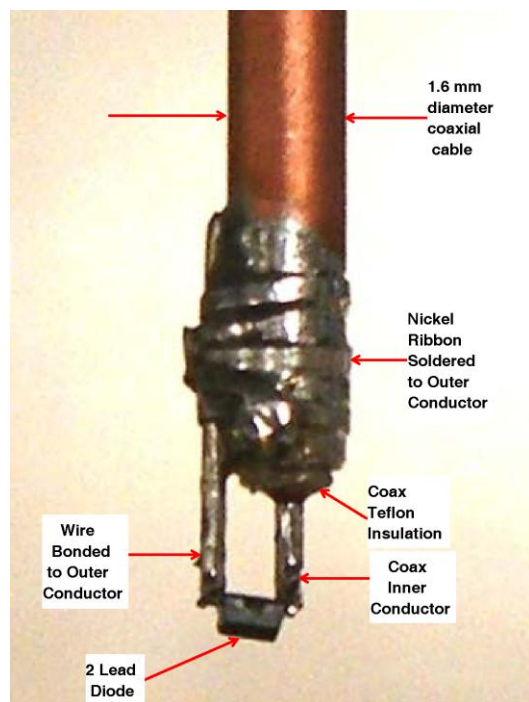


Figure 2. 1N4148 diode mounted on coax

This second diode has the shortest total package lead length and therefore has much less inductance. It is a Digi-key part number MMBD4448HTADICT-ND. The manufacturer's part number is MMBD4448HTA-7. It is in a SOT-523, 3 lead packages but only one of the two diodes in the packages are used. It is rated at 80V; and 150 mW. Measurements of this small diode positioned directly at the zero time location of the DUT coaxial cable, minimizes the parasitic lead inductance. When measuring packaged parts, the leads out side the package can be made short, but the lead frame and bond-wires to the chip add measurable inductance. The total inductance creates a significant  $-L \cdot di/dt$  voltage impulse at the beginning and end of the test pulse. This voltage impulse is added to the Initial Voltage Impulse (IVI) of the semiconductor makes the exact time delay difficult to establish.

These first examples are used to emphasize the rate of silicon conductivity increase possible to measure with fast rising test pulses on commercial diodes. The voltage

IVI and the rate of current increase are similar to some CDM protection circuits which use SCR elements.

The first voltage waveform in Figure 3 (black trace) is at about 1 volt and draws no current for the same trace in Figure 4. The voltage is constant at 1 volt. The second test pulse is about 2.5 volts (red) and remains at that level for about 1.5 ns; then begins to decrease to the 1 volt constant silicon conductivity level in 3 or 4 nanoseconds. The 100 ps risetime test pulse creates the high amplitude voltage across the diode. The peak voltage created when using slower risetime test pulses of 200 and 400 picoseconds create lower peak voltages. These large diodes provide excellent examples of the slowly increase in silicon conductivity. After they reach the peak voltage they begin an immediate but slow decrease toward 1 volt over a similar 3 to 4 nanoseconds time period.

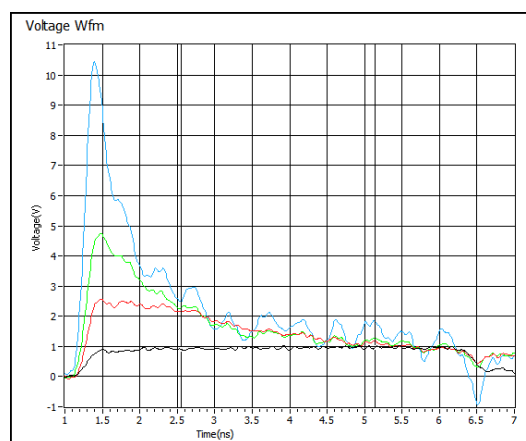


Figure 3. Voltage waveforms of 1N4448 diode from 0 to 0.27 Amps

There is no current created when the 1 volt test pulse is applied to the diode, as shown in the black trace. The slow increase in current is obvious in the next test pulse (red) as the current requires almost 4 nanoseconds to reach its constant amplitude.

## Barth 4012 Application note #2

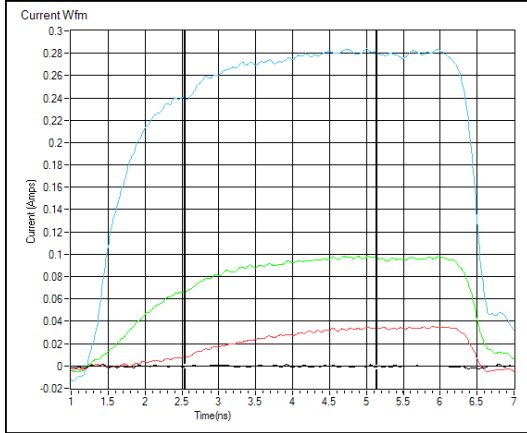


Figure 4. Current waveforms of 1N4448 diode from 0 to 0.27 amps

At higher pulse currents the dynamic resistance of the diode becomes lower and increases the  $-L \cdot di/dt$  IVI effect. This is shown for higher amplitude pulses as the pulse voltage increases, creating higher currents (green, and then blue). Higher test pulse voltages cause the carriers to move more rapidly and the steady state current is reached more rapidly until carrier velocity reaches saturation.

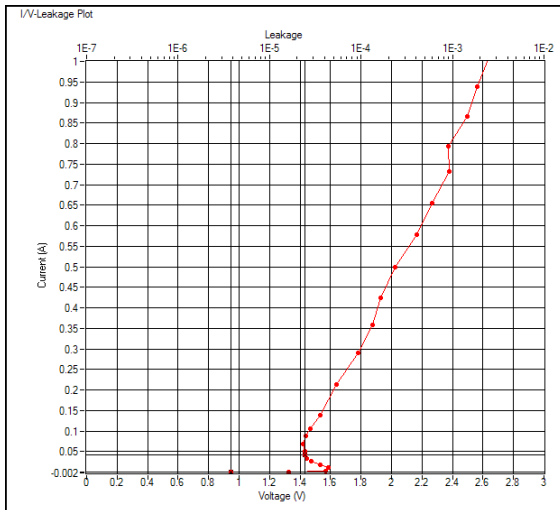


Figure 5. Snap-back suggested by this I-V plot of an ordinary diode.

By examining the voltage waveforms below in Figure 6, we can see that the Initial Voltage Impulse is immediately followed by decreasing voltage. The measurement window indicated by the heavy black lines at 2.5 ns and 5.1 ns shows the average (Vt1)

of the decaying voltage being less than the peak voltage of about 2 volts.

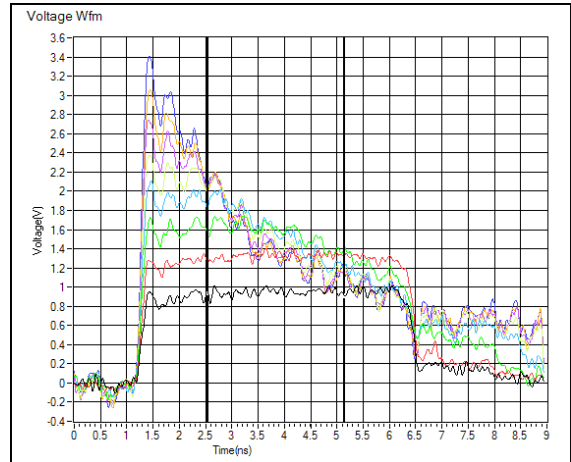


Figure 6. Voltage waveforms measured over 0 to 1 amp range. For clarity only every third waveform is shown.

By replacing the diode package with a conductor having the same dimensions as the diode package leads, the  $-L \cdot di/dt$  voltage impulses at the beginning and end of the test pulse can be identified. This is only approximate however, because the physical dimensions of the bond wire from the lead frame to the chip inside the package are only estimated.

### Measurement Window Location?

The plot in Figure 5 would normally indicate a snapback element. However the diode we are testing does not exhibit a snapback characteristic.

The waveforms show that the voltage is not a snap-back condition. Because the average voltage in the measurement window is temporarily lower than the average of earlier test pulse voltages, an average measurement gives a false indication of snap-back.

Measurements of the 1N4448 diode were made with a 5 ns long pulse. As shown in figure 6, the first three test pulses produce very low current and immediately fall to zero at the end of the pulse.

## Barth 4012 Application note #2

At higher amplitude test pulses the voltage and current are seen to continue after the end of the 5 ns long test pulse. This is the stored charge effect in the diode. Depending on the silicon protection element characteristics, this voltage sometimes continues at a significant amplitude. This can add voltage for some part of a nanosecond to the TDDDB threat. If the length of time a voltage is unexpectedly extended across a gate oxide, during either VFTLP or CDM test pulses, GOX failures can be lower than expected.

To display both the average and peak voltage we introduce the dual voltage plot shown below in Figure 7. It displays the total voltage threat very clearly by adding the peak voltage to the usual VFTLP I-V average current and voltage plot shown in Figure 5 above.

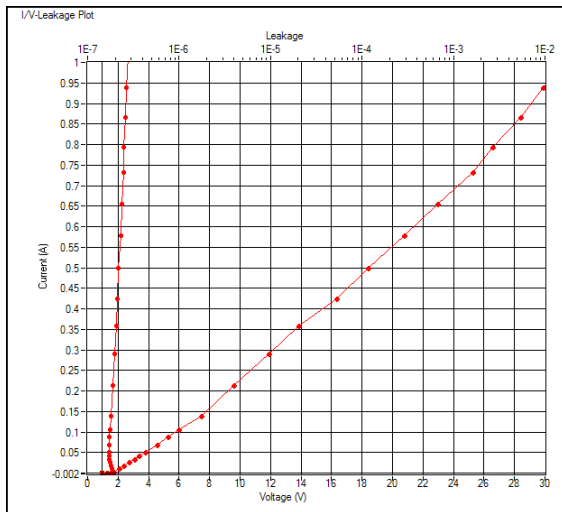


Figure 7. I-VV plot from 0 to 1 amp adds the peak voltage measurements to the standard VFTLP Plot .

The total voltage threat in a single display provides a simple but effective graphical presentation. The ordinary I-V data in this plot is the same as that shown in Figure 5.

By adding the peak voltage to the I-V plot, both threats produced by CDM protection circuits can be rapidly analyzed.

We identify this as an I-VV plot because both the average and peak voltage are measured and graphically displayed.

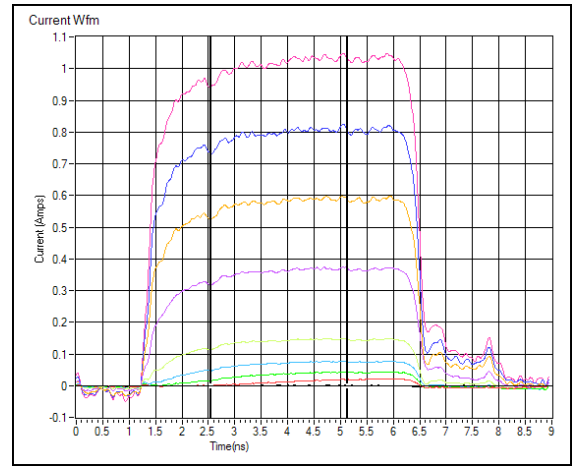


Figure 8. Current waveforms from 0-1A

This figure shows the current waveforms increasing more rapidly as the test pulse amplitude increases. Increasing test pulse voltages increase the speed of the carriers through the silicon element. The large path length in the individual diodes tested here creates a longer path than is found in ESD protection elements. Therefore the IVI in simple ESD diodes is much lower; however more complex ESD protection elements such as an SCR can have very similar rates of voltage decay with very high peak voltages.

### Conclusions

The ability to simulate CDM rates of rise and measure its effect on silicon protection circuits is provided in the VFTLP+ test. While we measured diodes larger than those used in ESD protection, it demonstrates the high speed measurement capabilities needed to understand the high speed operation of silicon. Commercial diodes such as the ones we tested do not fail at the highest pulse current and longest pulses. They are readily available and their time delay characteristics are very repeatable.

## Barth 4012 Application note #2

The waveform and I-VV plot data provided by this VFTLP+ test adds completely new analysis to the original VFTLP system. Improving CDM protection is important because the sensitivity of gate oxides continues to increase.

We are eagerly searching to test CDM protection on wafers. This new analysis tool can provide an important data base for ESD design. This information will be the first time manufacturers of wafers will be able to see the complete protection element characteristics at the high speeds which simulate the CDM test.

The wafer information we measure and publish will be isolated from other manufacturers, because this type data has never been published previously. We need to measure more silicon elements or circuits on wafer to assemble VFTLP+ information as an introduction for the industry.

This data is the first of our application notes for this VFTLP+ test system. Those who supply wafers for this testing will be the first to receive full information time history on their CDM protection design details and the effects geometry variations have on gate oxide failures.

We will continue to publish application notes to develop a better understanding of circuit response to high speed threats. This test method can begin a correlation between voltage response and variations in geometry. Voltage and current waveforms on future silicon CDM protection will become more analytical as dimensional details are better understood.

We can provide this information to begin a better understanding of previously hidden operational parameters of high speed ESD protection.

This first presentation demonstrates how ordinary VFTLP has been improved to expand design data it is now possible to extract from CDM protection elements. We

have devoted over two years to this test system and will continue to expand the value of this new analysis tool.

Our measurements of actual CDM protection circuits and individual test structures data will continue in future application notes. The generosity of potential customers, in providing silicon protection elements on wafer has been most helpful in understanding the basics of high speed silicon protection. The small amount of data we have recently measured provided the basic requirements needed for CDM design. This new source of data begins a new ability to analyze the high speed operation of silicon elements and circuits in continuous time detail.

Jon Barth  
Chief Engineer  
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 =One Barth TLP Test System

 =One Barth VFTLP Test System

 =One Barth HMM Test System



## No Gun IEC Device Testing Model 4702 IEC-50



### **Eliminate gun testing problems**

- No large gun tip
- No separate Ground Return Cable
- No special test setup with Coupling Planes

### **No excess gun radiation**

- Easy, repeatable connection to Device Testing Fixture Boards

### **Direct probes to pads for Wafer Level Testing**

- Optional wafer probes and cable available

### **Complete testing in one step**

- Direct cable connections to DUT, leakage test after each test pulse, computer controlled test level steps for automated testing

### **Verifiable testing**

- All current pulses recorded from oscilloscope

The ESD gun has now been replaced by a stationary, computer controlled source feeding the IEC test pulse into a coaxial cable. Now, instead of moving the gun from point to point, the pulse itself is directed from the test pulse point to test point through a switching matrix.

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# Barth Model 4702 HMM+™

## 50Ω HMM Pulse Test System



### Preliminary Specifications

Output to DUT (program driven)

- ⊗ Pulse Rise Time: 0.7 - 1.0 ns
- ⊗ I<sub>PEAK</sub>: 3.75 A/kV\* +/-10%
- ⊗ I<sub>30ns</sub>: 2.0 A/kV\* +/-20%
- ⊗ I<sub>60ns</sub>: 1.0 A/kV\* +/-20%
- ⊗ Voltage Range: 500V-27kV\*
- ⊗ Max Current: 100A PEAK; = IEC gun current @ 27kV
- ⊗ Pulse Rate: ~10 test pulse series per minute
- ⊗ Leakage Voltage: 0V to 100V in 0.1V increments
- ⊗ Source Impedance: 50Ω
- ⊗ Load Impedance: Any load
- ⊗ Size: 19"W x 20.5"D x 11"H control unit, 18"H includes Tektronix oscilloscope
- ⊗ Weight: ~130lbs total system weight plus shipping materials

\*IEC Equivalent Voltage

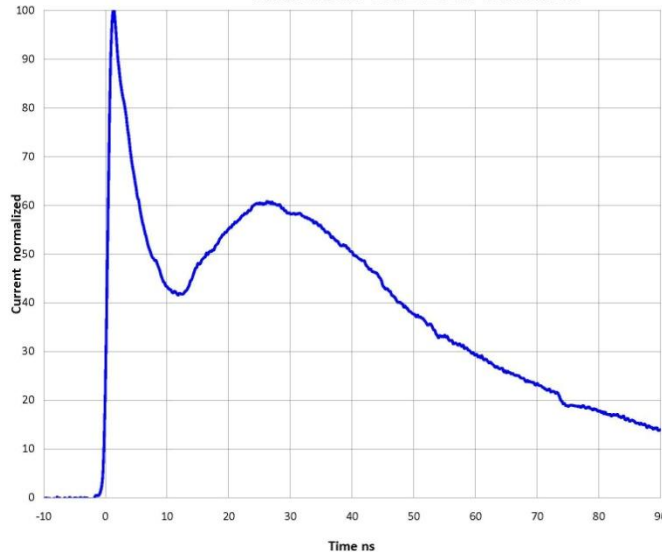
The Barth Model 4702 HMM+™ 50 Ω HMM Pulse Test System was designed and built to eliminate the common problems that are found with IEC gun testing. Gone are the interfering electromagnetic pulses that are induced with gun testing, and the system removes other undesirable effects that result from the gun's separate ground return cable. The test system also solves the large gun tip interconnect issues, providing a very easy connection to test fixture boards.

### Connection and Operation

Tester is connected to the DUT with a single 50Ω coax which delivers the IEC-HMM pulse and provides connection for leakage measurements in between IEC stress pulses. This method provides a ready and convenient connection for both system type and component level IEC testing. Wafer level testing is also supported.

Testing is computer controlled, allowing the user to gradually increase the HMM delivered threat, while checking the DUT leakage, measured in between threat pulses, to develop information on DUT failure levels and signatures. will include references to this 50 ohm source test method. The IEC pulse is defined by the basic immunity test method for personal ESD Specification, IEC 61000-4-2:2008. A new version of this standard is currently under development and will include references to this 50 ohm source test method.

Barth Model 4702 IEC-50 Waveform



Pulse voltage and current delivered to the DUT are measured with custom Barth wide bandwidth voltage and current probes for accurate waveform measurement. Waveforms are digitized and downloaded to the control PC for processing. Our measurements provide the ESD chip designer with the detailed waveform information, which allows for assessment of effectiveness of the ESD protection circuitry, and to verify compliance to the desired ESD immunity level.

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**This Product Features**  
**Barth Designed ZAPLESS®**  
**High Speed Measurement**  
**Components**

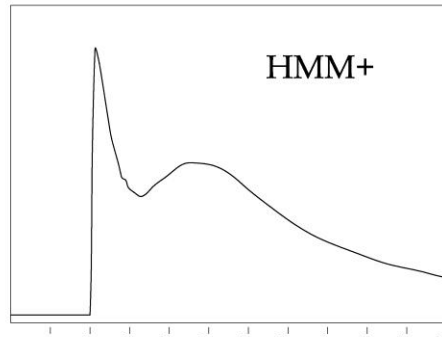


## HMM+ Pulse Test System Options

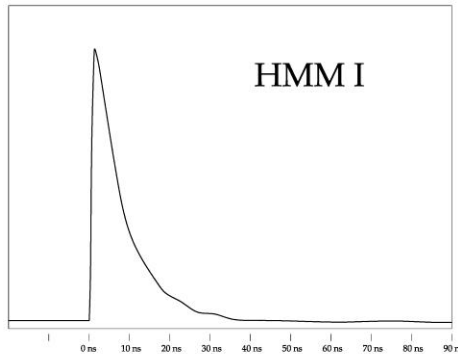
### HMM +I/-I Option - Model 4702-02

The HMM +I/-I option provides the capability to also test your device with just the fast rise impulse threat portion of the HMM waveform, or just the slow rise wider pulse, energy threat portion of the HMM waveform.

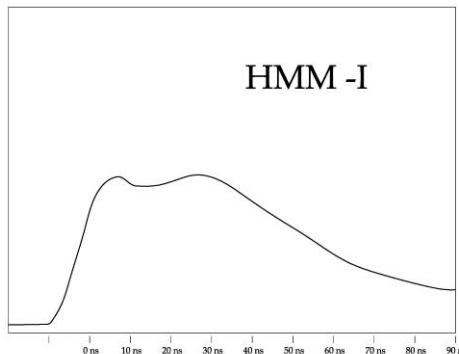
Testing of your devices with these different type threats provides you with additional information allowing you to better understand actual performance of specific portions of your design, allowing you to more quickly quantify performance and pinpoint potential issues with your protection structures.



**HMM+ ; Standard HMM waveform**



**HMM I ; Impulse only waveform - contains only the high speed "Impulse" portion of the HMM waveform threat**



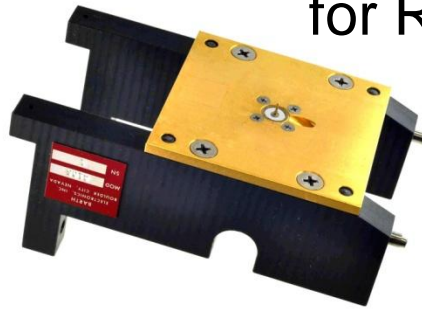
**HMM -I ; Minus impulse waveform – contains only the slow rise time "Energy " portion of the HMM waveform threat**

Contact us for additional information or to discuss your application.



# Barth Model 4106

## Wide Bandwidth Current Sensor for RCDM-3



The Barth Model 4106 CDM current Sensor is designed to be used with the RCDM-3 Test Systems to improve the quality of measurements, especially when used with greater than 1GHz bandwidth scopes. Barth Model 4118 for Orion Test Systems is also available.

### Features:

- ③ Designed to be used with the RCDM-3 Test systems
- ③ Supports use of wide bandwidth scopes.
- ③ Addresses the need for accurate, repeatable measurements
- ③ Enables comparable measurements from tester to tester

### Specifications:

**A/V Sensitivity variation:** -0.2 dB/+0.6dB 500 to 3000 MHz

**Resistive Impedance:** 1.0 ohm +/- 0.3 ohm 500 to 3000 MHz.

**Meets Current JS-002 and Q100-011 Specifications**

**User Replaceable Pogo Pin**

### Improve Your Test Accuracy and Repeatability

The 20 year wait for improvements in CDM test accuracy and repeatability between testers is over. We at Barth have used our experience in producing high speed measurement components to design a new current sensor with uniform frequency response.

Many years after identifying the primary cause of CDM repeatability error, expectations that manufacturers would provide better measurement components remained unanswered. Our long term goal was to improve CDM data measurement correlation between all RCDM3 testers with individually calibrated current sensors. Adding tight specifications to the CDM standard will insure that data measured with 3 GHz or higher bandwidth scopes will produce accurate data that the industry requires.

Our work on these products began with detailed time and frequency domain measurements of existing CDM components. Our analysis determined that the existing time domain specifications ignore frequency parameters necessary for accurate measurements of actual CDM discharges. Holding tight tolerance specifications in the CDM discharge frequency range allows our Model 4106 current sensor to provide a new level of data accuracy. When all RCDM3 test systems produce accurate data, these new components in turn will automatically provide repeatable and comparable test data. Tight specifications for this current sensor frequency response and a true one ohm discharge resistance will lead the way to improved repeatability and accurate device failure levels.

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# Barth Model 4181A

## CDM Triple Verification Module for Calibration of RCDM-3 Sensors



The Barth Model 4181A Triple Verification Module accessory is designed to be used with the Barth Model 4106 CDM current Sensor for the RCDM-3 Test systems to improve the quality of measurements, especially when used with greater than 1GHz bandwidth scopes.

Its low profile design allow it to be used without removal of the FR-4 base making calibration verification easy and convenient.

### Complimentary Accessories

- ③ Designed to be used with the RCDM-3 Test systems
- ③ Module includes three (3) verification values for quick system verification.
- ③ Indexed module alignment allows storing x-y location for quick discharge pin alignment.
- ③ Supports use of wide bandwidth scopes.
- ③ Addresses the need for accurate, repeatable measurements
- ③ Enables comparable measurements from tester to tester

### Specifications:

<b>Capacitance values:</b>	55 pF +/- 0.2% + 0.2 pF 6.8 pF +/- 1% + 0.2 pF 1.0 pF +/- 0.2% + 0.2 pF
<b>Temperature stability:</b>	+/- 0.1% 50°F to 120°F (10°C to 49°C)
<b>Dielectric stability:</b>	<0.01%, 5% to 95% humidity (40°F to 100°F, 4°C to 38°C) dew point.
<b>Capacitance Variation:</b>	< 1% DC to 3 GHz
<b>Dielectric Loss Variation:</b>	< 0.0003 DC to 3 GHz

### Improve your test Accuracy and Repeatability

Barth introduces a new precision verification module for the RCDM3 tester in a convenient package for quick alignment and use. This new triple verification module provides an accurate and stable discharge source as an accessory for our Model 4106 current sensor.

The new verification modules use >99% alumina ceramic dielectric to eliminate the variable parameters of the presently used FR4 capacitor dielectric. We determined FR4 to be completely unsuitable as reference capacitors when improved accuracy measurement components are available. Alumina eliminates the variable discharge parameters of the FR4 hygroscopic effects, its variations with frequency, and its excessive high frequency loss properties. The triple verification module also eliminates additional variables caused by air gap differences with each placement. The results of these variations have been mostly hidden by inconsistencies in the original CDM measurement components and specified methods.

The new construction with greatly improved dielectric material makes this triple verification module a simple, but very effective, CDM tester verification source that will be part of the overall improvement possible with the Barth Model 4106 wide bandwidth current sensor.

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## **CREDIT CARDS**

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Discounts for quantities are available. Call factory for quantity discount pricing.

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We stand behind every high quality product we manufacture. Our commitment to quality and workmanship are among the highest in the world. Quality does cost and all high voltage pulse power items produced by Barth Electronics Inc. are buy it once use it forever, *when used within catalog specifications*. **Note:** Tampering of any Barth pulse product in *any way* will void the warranty.

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## **TECHNICAL QUESTIONS**

For technical support email [beitechsupport@barthelectronics.com](mailto:beitechsupport@barthelectronics.com) , or call 1-702-293-1576

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