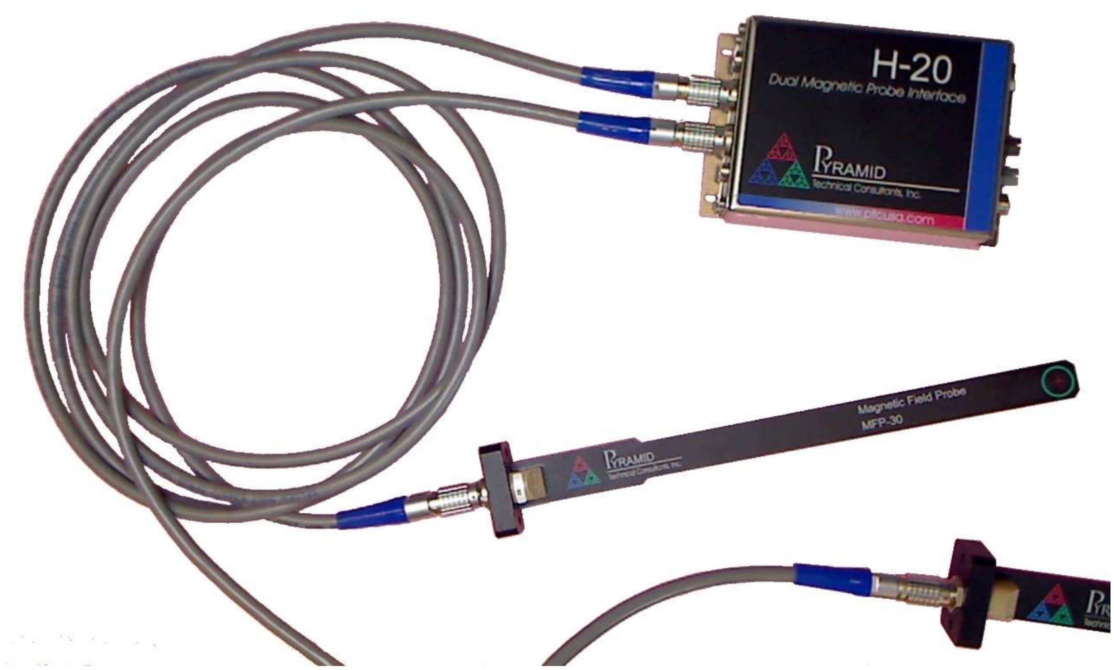
H20
MFP-30

Precision Magnetic Probe System

User Manual



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3 Safety Information

This unit is designed for compliance with harmonized electrical safety standard EN61010-1:2000. It must be used in accordance with its specifications and operating instructions. Operators of the unit are expected to be qualified personnel who are aware of electrical safety issues. The customer's Responsible Body, as defined in the standard, must ensure that operators are provided with the appropriate equipment and training.

The unit is designed to make measurements in **Measurement Category I** as defined in the standard.

Although the H20 does not generate dangerous voltages, nor is it designed to measure directly such voltages, in your application it may be measuring the field in electromagnets with high voltages present. Appropriate precautions must be taken.

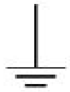
The unit must not be operated unless correctly assembled in its case. Only Service Personnel, as defined in EN61010-1, should attempt to work on the disassembled unit, and then only under specific instruction from Pyramid Technical Consultants, Inc. or their authorized distributors.

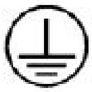
The H20 unit is designed to operate from +24 VDC power, with a maximum current requirement of 250 mA. The MFP-30 probes are powered by the H20. A suitably rated power supply module is available as an option.

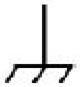
The H20 unit must be grounded by secure connection to a grounded conducting surface. If the unit is mounted on an insulating surface, then one of the four mounting screws must be re-assigned as a grounding connection.

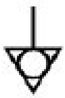
Some of the following symbols may be displayed on the unit, and have the indicated meanings.

 Direct current

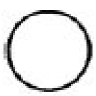
 Earth (ground) terminal

 Protective conductor terminal

 Frame or chassis terminal

 Equipotentiality

 Supply ON

 Supply OFF

 CAUTION – RISK OF ELECTRIC SHOCK

 CAUTION – RISK OF DANGER – REFER TO MANUAL

4 Models

4.1 Components

H20-CTRL	H20 control unit
H20-CTRL-S2	H20 control unit with field control servo feature
MFP-30	MFP-30 field probe
PSU24-40-1	Power supply, 24 VDC, 40W for H20
CAB-H20-9	Connection cable between H20 and MFP-30, 9' (2.7 m)
CAB-H20-15	Connection cable between H20 and MFP-30, 15' (4.6 m)
CAB-H20-22	Connection cable between H20 and MFP-30,22' (6.7 m)

4.2 Pre-configured system examples

H20-SYS1-9	H20 system comprising H20 control unit, one MFP-30 magnetic field probe and 9' (2.7 m) cable, PSU24-40-1 power supply
H20-SYS1-22	H20 system comprising H20 control unit, one MFP-30 magnetic field probe and 22' (6.7 m) cable, PSU24-40-1 power supply
H20-SYS2-9	H20 system comprising H20 control unit, two MFP-30 magnetic field probes and two 9' (2.7 m) cables, PSU24-40-1 power supply
H20-SYS2-22	H20 system comprising H20 control unit, two MFP-30 magnetic field probes and two 22' (6.7 m) cables, PSU24-40-1 power supply
H20-SYS2-S2-22	H20 system comprising H20 control unit with field control feature, two MFP-30 magnetic field probes and two 22' (6.7 m) cables, PSU24-40-1 power supply

5 Scope of Supply

H20 system model as specified in your order. The field control option is an additional option.

MFP-30 probes as specified in your order.

Interconnecting signal cables as specified in your order.

USB memory stick containing:
- User manual
- PTC Diagnostic software installation file
- PSI DiagnosticG2 software installation file
- Power supply

Optional items as specified in your order.

OEM customers may not receive all the items listed.

6 Optional Items

6.1 Power supplies

PSU24-40-1. +24 VDC 1.6 A PSU (100-250 VAC, 50-60 Hz, IEC C14 3-pin plug receptacle) with output lead terminated in 2.1mm threaded jack.

6.2 Data cables

CAB-ST-P-x-ST Fiber-optic cable, 1 mm plastic, ST terminated, x feet long.

CAB-ST-HCS-x-ST Fiber-optic cable, 200 um silica, ST terminated, x feet long.

6.3 Fiber-optic loop

A360 fiber-optic loop controller / Ethernet adaptor.

A500 intelligent real-time controller with Ethernet interface.

A560 intelligent real-time controller with Ethernet interface.

6.4 DIN rail mount

MTG-DIN35-11462. Mounting adaptor for 35mm standard DIN rail. H20 control unit can be mounted along or across the rail.

6.5 Magnetic shield

CAL-MFPB0. Double mu-metal shield for probe zero offset checking and calibration.

7 Intended Use and Key Features

7.1 Intended Use

The H20 system is intended for magnetic field measurement, particularly in electromagnets. The field can be monitored at rates sufficient for real-time monitoring and for field control, and the probe design eliminates magnetic materials or conducting surfaces that would distort the measurement of AC fields. The MFP-30 probe is particularly suited to measure the magnetic fields typical of ion beamlines which use conventional (non-superconducting) electromagnets, and has the range and precision to perform well in many general field measurement applications. The probe is thin (less than 2.5 mm) but nevertheless stiff enough to allow it to be placed at a known and stable location in the field.

The H20 has design features which make it tolerant of electrically noisy environments, but the place of use is otherwise assumed to be clean and sheltered, for example a laboratory or light industrial environment. The unit is typically integrated into a larger system, using fiber optic communication links. It can be operated independently, if combined with a suitable fiber optic loop controller and host computer. Users are assumed to be experienced in the general use of precision electronic circuits for sensitive measurements, and to be aware of the dangers that can arise in high-voltage circuits.

7.2 Key Features

Two-channel magnetic field measurement.

Probes designed to measure correctly in AC fields.

High performance HE244 Hall effect device (MFP-30).

Probe temperature sensor and compensation (MFP-30).

Analog voltage monitor outputs for high-speed representation of the measured field, or magnet power supply programming.

Field control feature when used together with a suitable electromagnet power supply.

Analog voltage inputs for field settings or general purposes.

Analog bandwidth DC to > 10 kHz.

Can be operated in a fiber-optic serial communication loop with up to fifteen other devices.

100BaseT Ethernet interfacing to a host computer available through the A360, A500 and A560 loop controllers.

8 Specification

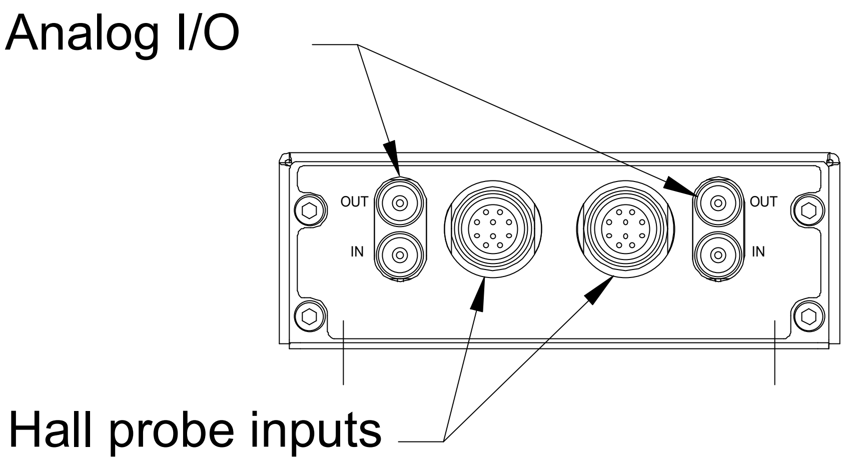
H20 System	
Number of channels	Two fully parallel field measurement channels with temperature measurement and compensation
Measurement ranges	Not less than +/- 2.5 T (25 kGauss) on x1 range x1, x4, x10 and x40 software-selectable ranges.
External accuracy	0.05 % maximum deviation relative to full scale of any point from linear fit to at least 10 points over a 1 T span
Temperature coefficient of gain	< 100 ppm C-1 within +10C / -5C of the calibration temperature
Temperature coefficient of offset	< 0.01 Gauss C-1 within +10C / -5C of the calibration temperature
Noise	< 0.1 Gauss rms with 1 msec averaging
Step response	Better than 100 µsec to within 0.1% of full scale deviation from target setting for any instantaneous field step. Observed step depends on selected downsampling and readout method.
Field control	Optional field control feature on each channel. Field target can be provided as a numeric value via the communications interface, or as an analog voltage. Process control output is analog voltage, maximum range +/- 10 V.

MFP-30 probe	
Analog signals	Magnetic flux density Probe temperature
Field range	>= +/- 2.5 Tesla (+/- 25 kGauss) nominal on x1 gain setting Gain settings x1, x4 (these combine with x1 and x10 settings in the H20 control unit to give four field ranges)
Hall element sensitive area	< 1 mm square (1 mm^2)
Hall element position	7.5 mm from probe tip, 1.17 mm below probe top surface, position marked on casing.
Temperature sensor	Thermistor in probe tip, calibrated measurement range 5C to 60C
Probe tip thickness	< 2.3 mm (0.091")
AC field compatibility	Probe body materials non-conductive. Hall voltage and current leads are small-pitch twisted pairs.

Radiation resistance	Only passive components are located at the probe tip. Tested with 0.75 mC of 230 MeV protons delivered to a neutron producing target close to the probe, with no measurable change in performance. Corresponds to 1-2 years of typical particle therapy beamline dose.
Connector	Lemo 10-way EXG.1B.310
Probe body materials	Glass-reinforced polycarbonate, FR4 fiberglass epoxy.
Weight	40 g (1.4 oz)
Dimensions	(see figure 3)
Operating environment	0 to 35 C (15 to 25 C recommended to reduce drift and offset) < 80% humidity, non-condensing vibration < 0.2 g all axes (1 to 100 Hz)
Shipping and storage environment	-10 to 50C < 80% humidity, non-condensing vibration < 2 g all axes, 1 to 100 Hz

H20 control unit	
Analog inputs	
Number	Six: - two field measurements - two temperature measurements - two general purpose inputs (+/- 10 V).
Field gain settings	Gain settings x1, x10 (these combine with x1 and x4 settings in the MFP-30 probe to give four field ranges)
Digitization	16 bit successive approximation over full range
Sample rate	250 kSa s-1
Downsampling	Selectable block averaging from 25 to 62500 conversions per reading
Calibration	Gain and offset values for each analog signal and each range stored in EEPROM.
Analog outputs	
Number	Two, +/- 10V. Used for field control if optional feature is in use.
Resolution	16 bit over +/- 10V
Transition noise	<= 25 mV typical at updates
Communications	

Communications to loop controller	Fiber optic (10 Mbit/sec)
Data rate through to host computer	1 kHz typical, up to 10 kHz in lightly-loaded networks.
Physical features	
Probe connector	Lemo 10-way EXG.1B.310
Controls	16 position rotary switch for loop address selection
Displays	Four LEDs (power, activity, network, device).
Power input	+24 VDC (+12 V, -4 V), 120 mA typical with two probes, 200 mA maximum.
Case	Stainless steel.
Dimensions	(see figures 1 and 2).
Case protection rating	The case is designed to rating IP43 (protected against solid objects greater than 1mm in size, protected against spraying water).
Weight	0.33 kg (0.72 lb).
Operating environment	0 to 35 C (15 to 25 C recommended to reduce drift and offset) < 80% humidity, non-condensing vibration < 0.2 g all axes (1 to 100 Hz)
Shipping and storage environment	-10 to 50C < 80% humidity, non-condensing vibration < 2 g all axes, 1 to 100 Hz



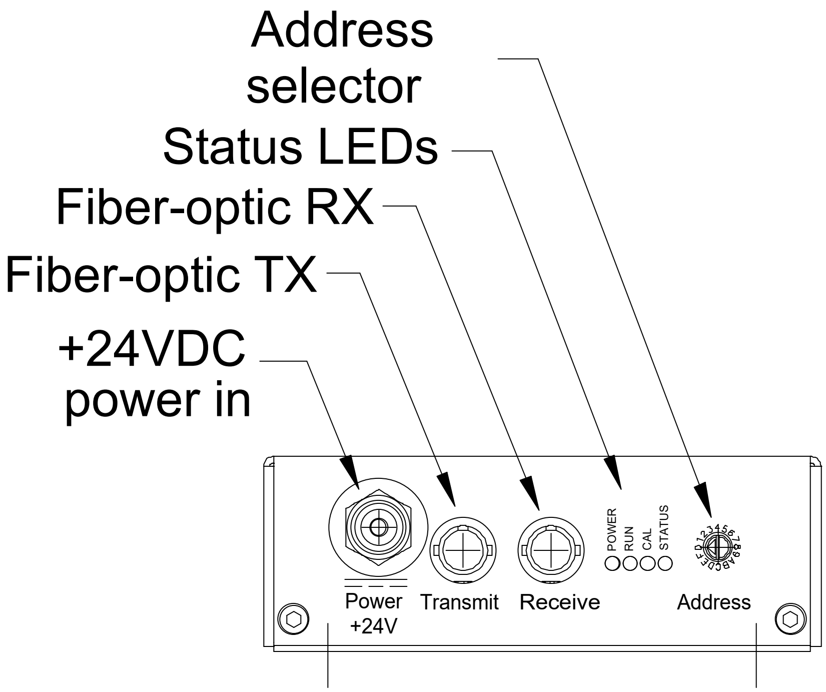


Figure 1. H20 control unit end panels.

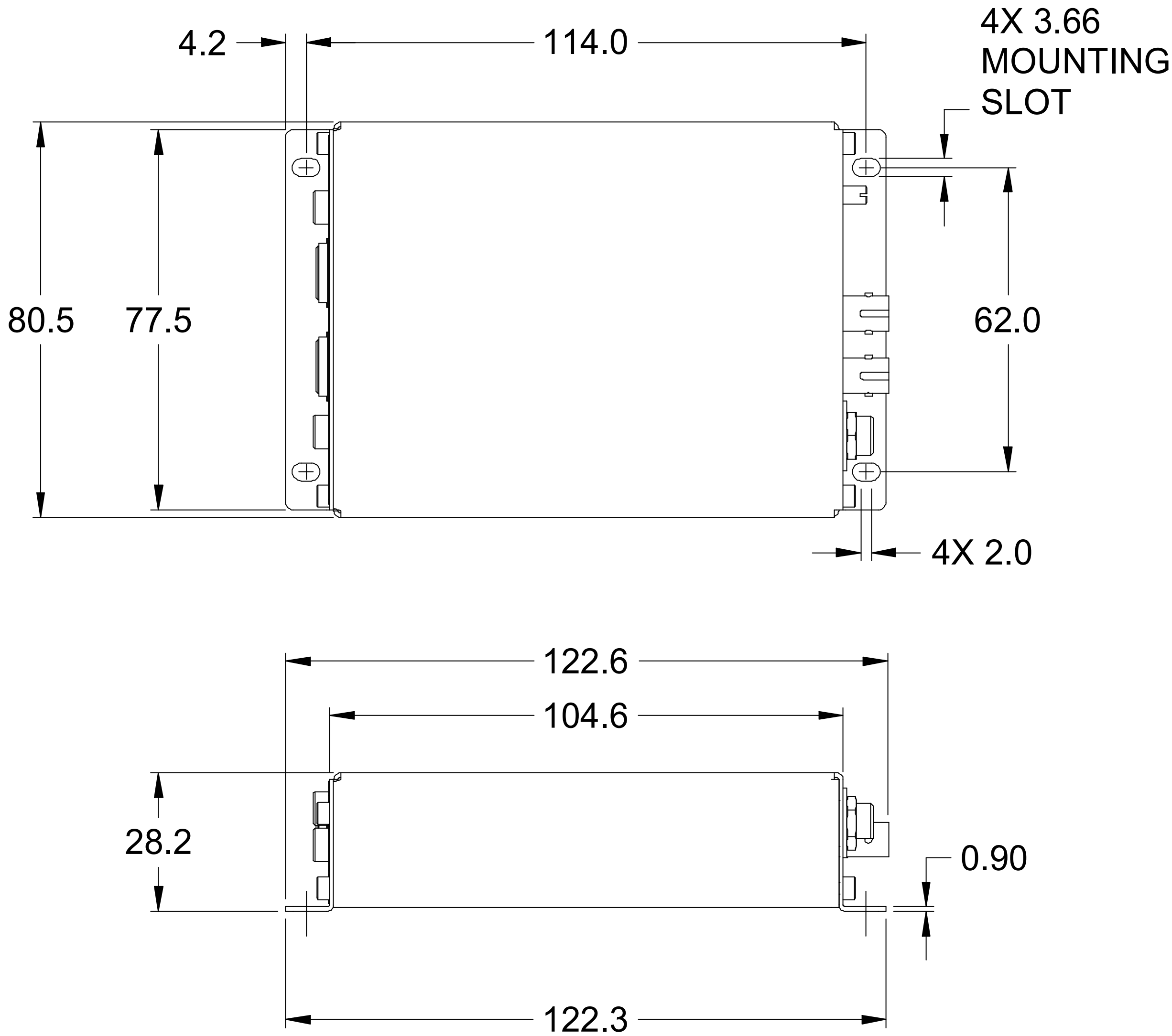


Figure 2. H20 control unit plan and side views. Dimensions mm.

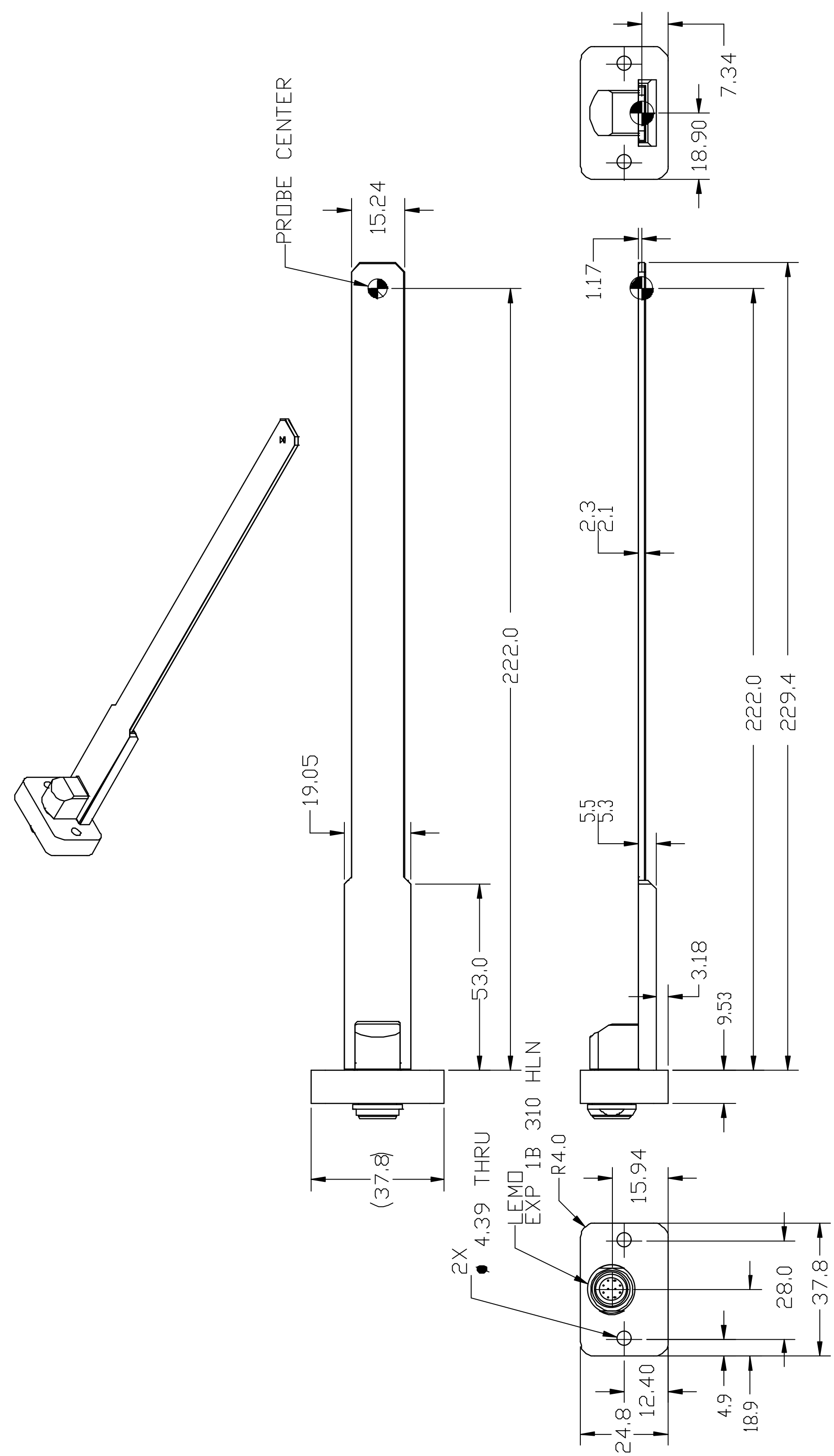


Figure 3. MFP-30 probe geometry Dimensions mm.

9 Installation

9.1 Mounting

The probe should be mounted so that the sensitive spot is located in the field you want to measure. Two clear holes suitable for M4 screws are provided on the probe mounting flange. The MFP-30 probe will measure the field component normal to the flat, and will show a positive value for a field vector entering on the center of the bullseye pattern.

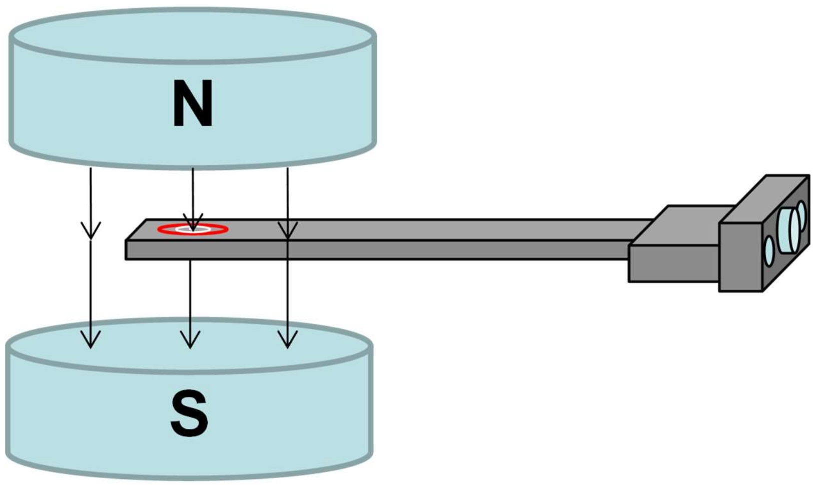


Figure 4. Probe orientation for a positive field reading (MFP-30 probe; +ve gain coefficient).

The mounting should prevent any tendency for movement or vibration, especially if the probe is measuring a fringe field where there is field curvature. If the field has significant AC components, the mounting should be non-conducting to avoid measurement errors due to eddy currents.

The H20 control unit must be mounted within cable reach of the MFP probe. Three standard cable lengths are available, 9 foot, 15 foot and 22 foot, with the shorter cable preferred for best noise performance. Longer cables can be supplied on request. The control unit may be mounted in any orientation, or may be simply placed on a level surface. Four M3 clear holes are provided in the base flange on a 62 mm by 114 mm rectangular pattern (see figure 2). A DIN rail adaptor is available for the H20 control unit.

The mounting positions for probe and control unit should allow sufficient access to connectors and cable bend radii. Leave 60mm clearance at either end for mating connectors and cable radii.

H20 system includes temperature compensation, but you will get maximum precision if the control unit, and particularly the probe, are in a temperature-controlled environment. No forced-air cooling is required, but free convection should be allowed around the case.

9.2 Grounding and power supply

A secure connection should be made via the H20 control unit mounting flange to local ground potential. If the unit is mounted on an insulating surface, then one of the four mounting screws must be re-assigned as a grounding connection.

+24 VDC power should be provided from a suitably-rated power supply with the following minimum performance. If you purchased your H20 as an end-user, a compatible power supply will have been provided.

Output voltage	+24 +/- 0.5 VDC
Output current	300 mA minimum, 2000 mA maximum
Ripple and noise	< 100 mV pk-pk, 1 Hz to 1 MHz
Line regulation	< 240 mV

The H20 is tolerant of line voltage in the range 22 VDC to 26 VDC, although we recommend using a 24 V supply with reasonable accuracy, as noted above. The H20 includes an internal automatically re-setting PTC fuse rated at 200 mA. However the external supply should in no circumstances be rated higher than the H20 connector limit of 5 A, and a maximum of 2.0 A is recommended.

9.3 Connection to equipment

9.3.1 Typical setup

Figure 5 shows a typical installation to monitor a magnetic field, in schematic form. An MFP-30 probe is measuring a field component normal to the flat face of the probe. It is connected to the H20 control unit via the cable included with the H20 system. Note that this cable can be connected either way round. The H20 is on a fiber-optic communication loop, under control of one of the Pyramid Technical Consultants, Inc. loop controllers (A360, A500, A560). The choice of controller depends on the overall system requirements; any of them allows the full capability of the H20 and MFP-30 to be exploited. Software on the host computer displays the field readings and controls provided by the H20. This may be the Pyramid diagnostic programs provided with the product, or custom software that connects to the Pyramid devices via abstraction layers like the IG2 package.

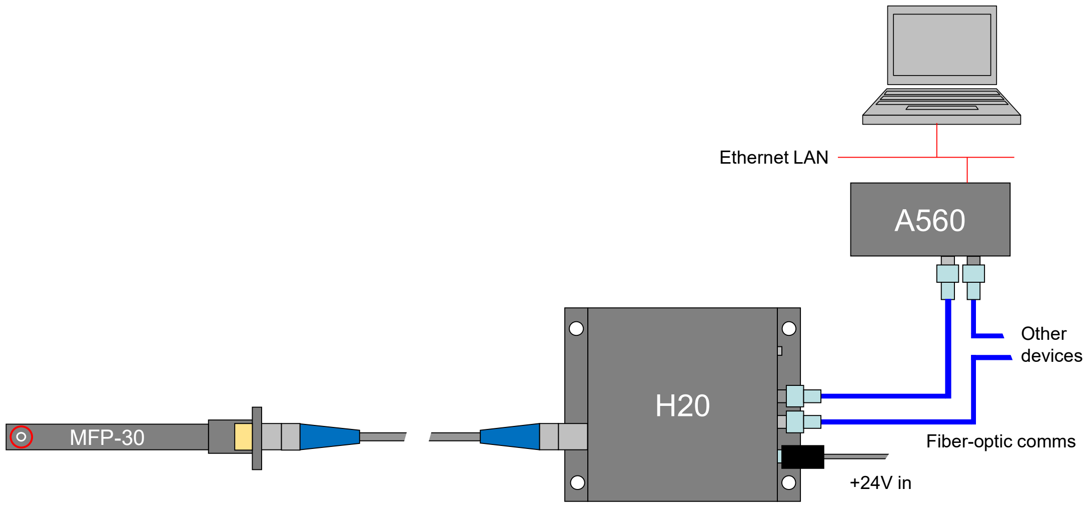


Figure 5. Schematic example H20 setup.

The use of the closed loop field control option is illustrated in figure 6. The PC provides a field target over the communication channel. A PID control algorithm in the H20 computes a control setting for the magnet power supply to minimize the error between the target field and the measured field.

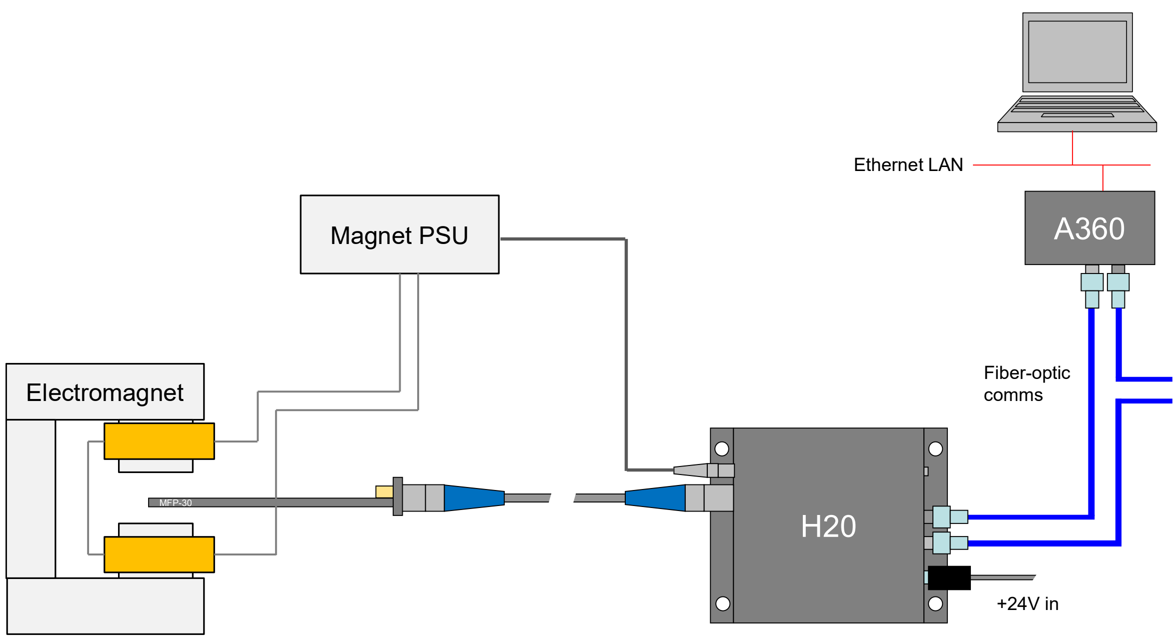


Figure 6. Schematic example setup for electromagnet field control.

In an alternative arrangement, the field setting targets can be provided as analog voltages from an independent source.

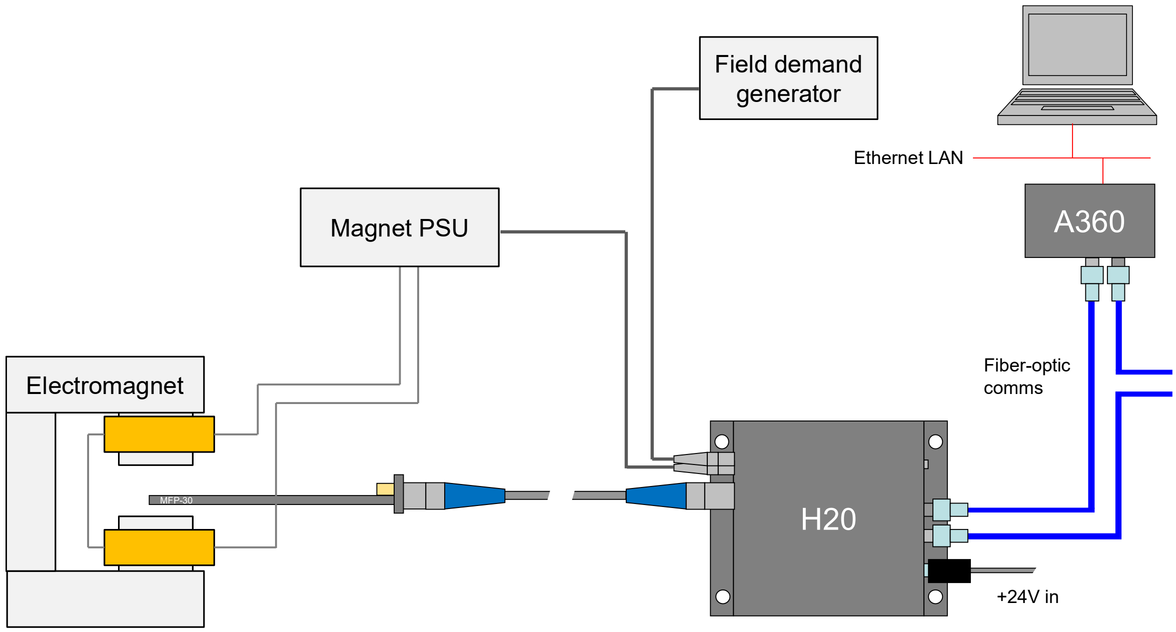


Figure 7. Schematic example setup for electromagnet field control with independent field programming.

The two inputs of the H20 are independent. You can measure two unrelated fields, and, if you have the field control option, run an independent field control servo on each. A typical application is the control of a two-dimensional magnetic beam scanning system, such as those used in particle therapy beamlines and semiconductor ion implanters.

10 Getting Started using the Pyramid Diagnostic Host Programs

Usually you will use a custom application to communicate with the H20, either one you write yourself using the software interfaces available from Pyramid Technical Consultants, Inc., or one that is supplied by Pyramid. However you can get started immediately using one of the Pyramid Diagnostic host programs. These are available for free download from www.ptcusa.com, and are provided with the H20 for end-user customers. There are two generations of the Diagnostic software, and the H20 is a G1 device that is compatible with both.

PSI Diagnostic. This software supports all Pyramid products, apart from G2 devices. It allows you to connect the H20 via an A500 controller. Ethernet communications use UDP with an added reliability layer.

PTC DiagnosticG2. This software supports all G2 devices such as the A560, I128 and C400, plus a growing selection of other Pyramid devices, including the H20. It allows you to connect the H20 via an A360, A500 or A560 controller, or other Pyramid G2 products such as the I128, F460 and C400 that support fiber optic slave devices. It uses TCP/IP and UDP Ethernet communications when connected to G2 loop controllers.

The PTC DiagnosticG2 is recommended for the H20 as all new G2 devices are compatible with it. Both Diagnostics are standalone Windows programs which allow you to set outputs and read, graph and log data from the H20. Their user interfaces are similar. The PTC DiagnosticG2 is also available for Linux – call Pyramid Technical Consultants for further details.

For some applications one of the Diagnostic programs may be adequate for all of your data acquisition needs. In any event it is useful to understand what you can do with the Diagnostic programs, because they expose all of the functions of the devices they connect to. Application programmers will find this useful to help decide which functions to implement in their own host software.

10.1 Preparing the H20 and MFP-30 for operation

Inspect the unit carefully to ensure there is no evidence of shipping damage. If there appears to be damage, or you are in doubt, contact your supplier before proceeding.

Connect one or two probes to the H20 control unit using the cable(s) supplied. Connect 24 V DC power. The LEDs will go through a startup sequence when the power is applied. All four LEDs light, then the power LED stays lit while the other three indicators light in sequence. When the H20 has started correctly and prior to connecting to a controller, the power LED will remain lit and the device LED will flash, showing that the device has automatically started measuring data.

It is simplest to start with to connect the H20 directly to a loop controller as the only device on the loop, and with the loop controller connected directly to a PC by an Ethernet patch cable. Figure 8 shows such a connection to an A360 which we shall use to illustrate operation with the PSI DiagnosticG2 software. The H20 fiber-optic loop address switch can be set to anything between 0 and 15 (F). If you have more than one device on the loop, then they must all have unique settings.

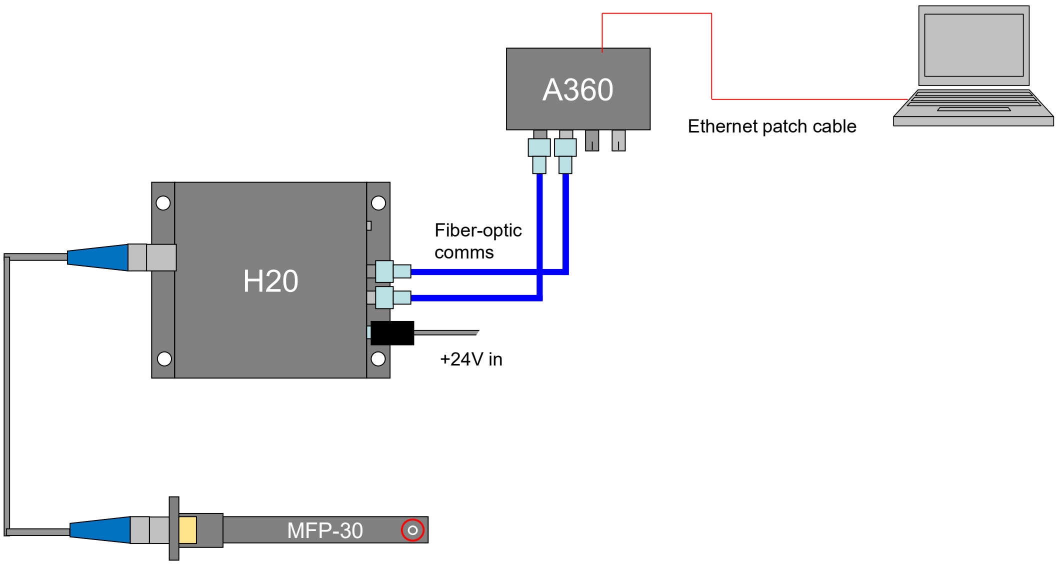


Figure 8. Example of a direct connection to the H20 via an A360 and Ethernet.

The A360 loop controller has an IP address stored in its non-volatile memory, or it can be set for DHCP address allocation by a router. It is simplest to start with if you set the A360 and your PC to a non-conflicting IP4 static addresses in the same subnet range. For example if the A360 has known IP address 192.168.1.68, then the PC could be 192.168.100.77, with subnet mask 255.255.255.0. The address of the PC is set up using the Local Area Connection Properties or Ethernet Properties dialog in Windows.

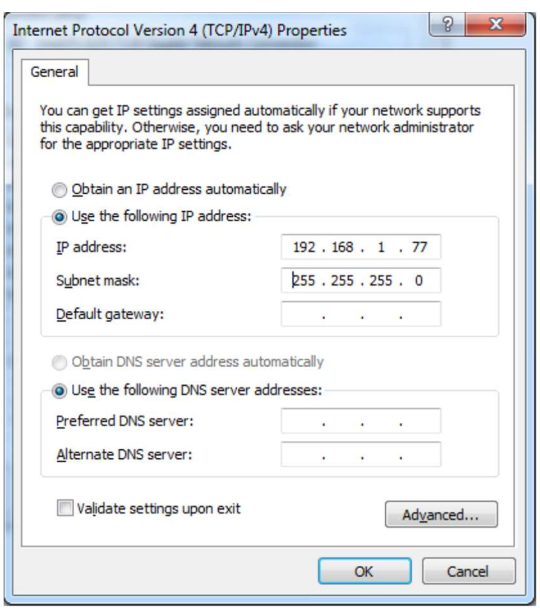


Figure 9. Setting up a Windows PC with a static IP address

Having set up the simple network shown, check that you can ping the loop controller.

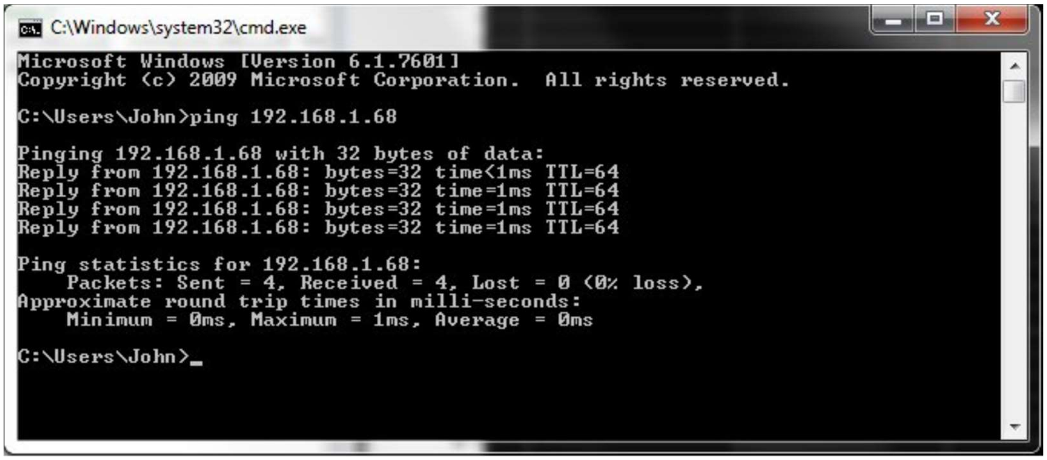


Figure 10. Pinging the loop controller.

Now you are ready to communicate with the H20 via the loop controller. For this you will need to install a host program like the PTC DiagnosticG2.

10.2 Installing and using the PTC DiagnosticG2 Program

If you are an end-user, your H20 was shipped with a USB memory stick with the installation files you need. We recommend that you copy the files into a directory on your host PC. Check the Pyramid Technical Consultants, Inc. web site at www.ptcusa.com for the latest version.

The program runs under the Microsoft Windows operating system and has been tested on Windows XP, Windows 7 and Windows 8.

Install the PSI DiagnosticG2 by running the PTCDiagnosticSetup.msi installer, and following the screen prompts. Once the program has installed, you can run it at once. It will allow you to connect to the H20, and, depending upon your setup, multiple additional devices at the same time.

10.2.1 Establishing communication with the H20

We'll work through an example where the connection to the H20 is via an A360 at IP address 192.168.1.68. Start the PSI DiagnosticG2; the Discover Devices dialog will open. Clicking the Discover Controllers button (

) will make the program search the accessible local area network through all active network interfaces for loop controller devices.

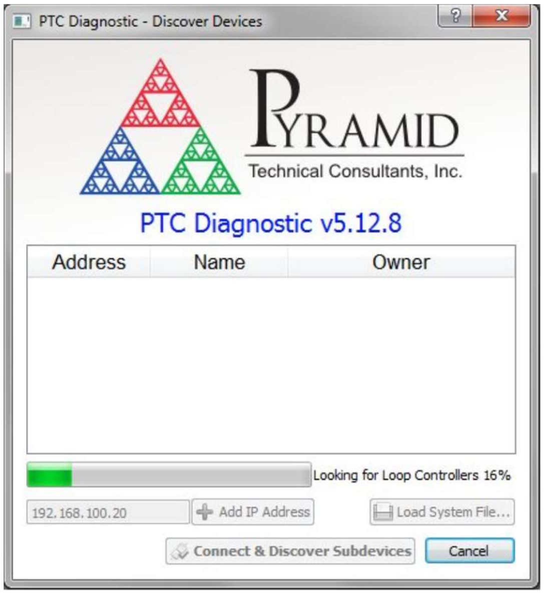


Figure 11. PTC DiagnosticG2 device discovery

In this example we discover the A360, and a recovery utility that can be ignored.

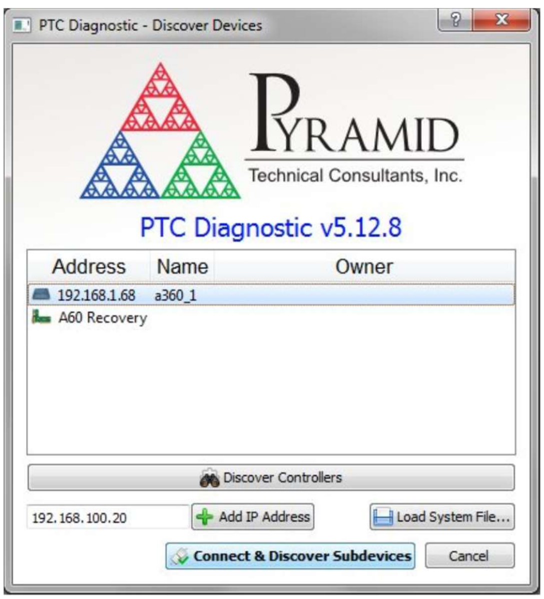


Figure 12. PTC DiagnosticG2 device discovery – discovered loop controllers

Now highlight the A360 and click Connect & Discover Subdevices. After a few seconds the program should find the H20 plus any other devices you may have connected, and show the connection tree in the system pane. In this example there is an H20 and an M10 device on loop 1 of the A360. On the H20 control unit itself you should see the network LED illuminate regularly to show that loop messages are being processed.

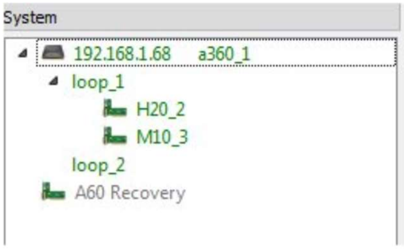


Figure 13. Discovered devices

Double-click the H20 entry in the list to open the H20 window. You will see a message in the message area at the bottom showing that the H20 (described as a “PTCboard”) has been connected. You will see the field reading from connected MFP-30 probes. If you have a permanent magnet to hand, you can place it near a probe tip to get a response.

Figure 14. H20 connected and reading magnetic field

The H20 user interface window is divided into two halves, graphics and data on left and right respectively, plus a top banner area. Below the graphic is a message window which reports all the commands issued to the H20 by the PTC Diagnostic program, and the corresponding acknowledgements. Generally you can ignore this display when taking data, but it will be valuable for diagnosis if you have any operating problems. The data area on the right changes according to which display tab option you select with the option buttons at the bottom.

10.3 Screen Layout - Top banner

Figure 15. Top banner display

The top banner is always visible. It contains the following indicators and controls.

Comms bar	When moving, this indicates that messages from the H20 are being received by the PTCDiagnosticG2. The message frequency is displayed.
Connected LED	When lit, this indicates that communications are valid and the system is not in error.
Busy LED	When lit, this indicates the H20 is busy and cannot respond to inputs, for example while writing to NVR.
Measuring LED	When lit green, this indicates that data acquisition is occurring.
Error LED	When lit, the H20 has logged an error. The details are displayed in the message area.
Auto Initiate	Checking this box causes the software to automatically initiate a new acquisition whenever you change any acquisition parameter.
Initiate	This button starts data acquisition.
Abort	This button terminates any acquisition in progress.

10.4 Screen layout – Message Log area

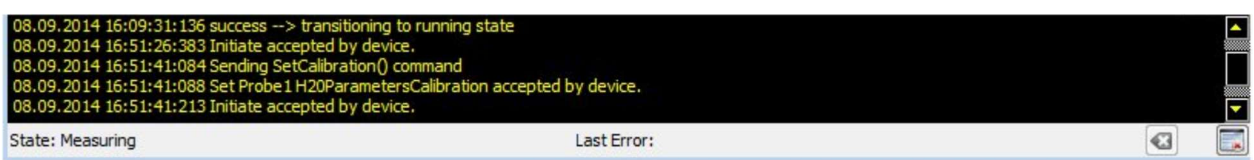


Figure 16. Message area

This area shows all the commands and responses between the H20 and the host system, plus any H20 errors, which are shown in red. You can clear the messages with the Clear Log Display button ( ) and you can clear latched errors with the Clear Last Error button ( ).

10.5 Screen layout – Right hand tabs

10.5.1 Data tab

The Data tab displays the instantaneous values of all analog input and output values, including the two measured magnetic fields. There are duplicate displays for the two probe channels.

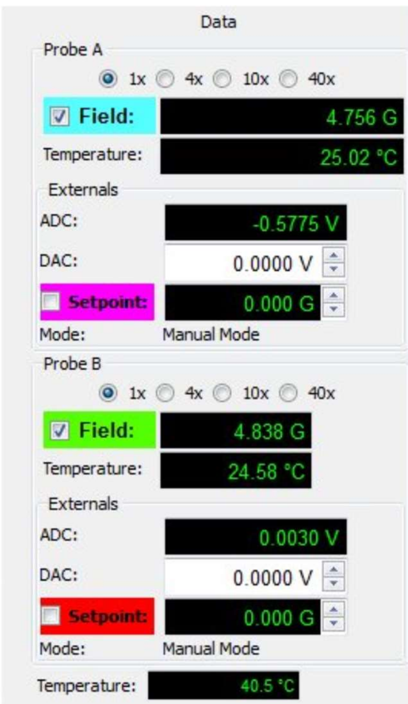
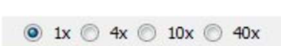


Figure 17. H20 data tab

If either field reading is close to overrange, it is highlighted in red. If an input has no probe connected, then the values have no meanings and should be ignored. In this situation the field will read close to zero and the temperature will show an obviously excessive reading around 120 C.

Range setting 	These radio buttons set the combined gain of the MFP-30 probe and H20 unit for the channel.
Field	The readings in Gauss for a probe connected to the channel. If no probe is connected, the reading will be close to zero. The graph trace

	corresponding to a field reading is color-coded. Unchecking Field for a probe removes its trace from the graph.
Temperature	The reading in centigrade for the channel from the thermistor in a connected MFP-30 probe. If no probe is connected, the reading will be high, and should be ignored.
ADC	The voltage reading on the analog input (Lemo coax connector) for the channel in volts.
DAC	The voltage setting on the analog output (Lemo coax connector) for the channel in volts. The control is only enabled when the mode setting is Manual.
Setpoint	The field target value in Gauss for the channel for closed loop control (-S2 field control option only). In Digital Closed Loop mode, the field becomes an edit box for the field in Gauss. In Analog Closed Loop mode, the field is a read only display of the field target calculated from the analog input voltage and the Setpoint Gain value on the Field Control Parameters tab. The setpoint is plotted on the graphic if the box is checked.
Mode	The selected mode selection for the channel for the analog inputs and outputs. See section 15 for more details.

Temperature	The temperature reading from the thermistor on the H20 PCB.

10.5.2 Setup tab

The Setup tab provides acquisition controls and settings for the analog input and output functions.

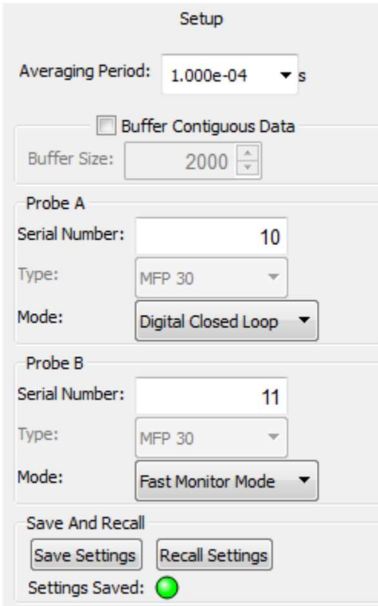
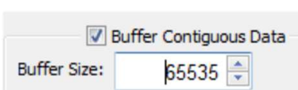
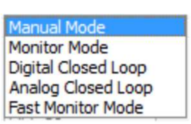


Figure 18. H20 setup tab

Averaging period	The H20 converts the incoming analog data at 250 kHz, but the data is averaged (downsampled) to increase the signal to noise ratio. The averaging can be varied between 100 µsec (25 samples averaged) and 0.25 seconds 62,500 samples averaged). The drop-down control offers some pre-set averaging periods, but other valid values can be entered directly.
Buffering 	Checking the Buffer Contiguous Data box sets up a data buffer in G2 loop controllers that support the function. This allows you so acquire time-contiguous data at rates that exceed the capacity of the communication channels. The maximum available buffer size is 65535 readings.
Serial number	You can assign and store the serial number of probe A and B, which will be associated with the calibration values.
Type	Select probe type. The H20 only supports the MFP-30 probe at the time of writing.
Mode 	Select the function of the analog inputs and outputs. The closed loop field control modes are only available if you have the –S2 option installed. See section 14 for more details on the mode selections.
	Pressing the Save Settings button copies all current acquisition settings, probe serial numbers, calibration values and field servo settings (-S2 option only) into non-volatile memory. The Recall Settings button recovers the values from NVR and makes them the

	working settings. The green LED turns on to show when the saved settings and the current working settings are the same.

10.5.3 Calibration tab

The Calibration tab provides access to the H20 and probe calibration settings. There are three sub-tabs, covering the H20 settings, the probe settings and the temperature compensation settings. All the values are determined in the factory and generally you should not need to change them unless you replace the probes. See section 14 for more details on calibration.

10.5.3.1 Calibration sub-tab: H20

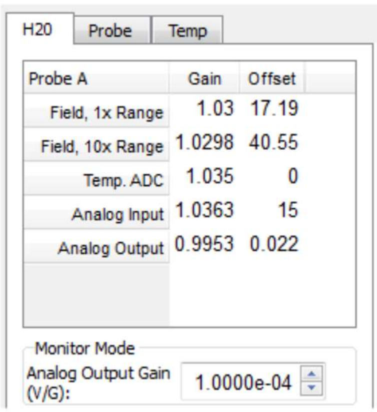


Figure 19. H20 calibration sub-tab

Probe A, B	Gain and offset parameters for each H20 channel, for the field input, temperature input, analog input and analog output.
Analog output gain (V/G):	The conversion factor that is used to create the output voltage from the measured field in monitor mode.

10.5.3.2 Calibration sub-tab: Probe

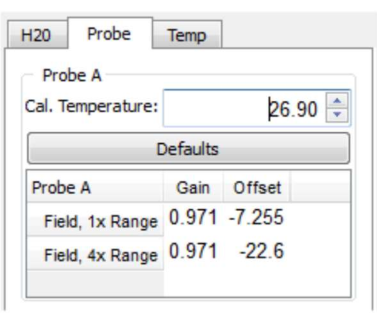


Figure 20. Probe calibration sub-tab

Cal: Temperature	The temperature measured by the probe in centigrade when it was calibrated, used for temperature compensation.
Probe A,B	The gains and offsets associated with the probe.

10.5.3.3 Calibration sub-tab: Temp

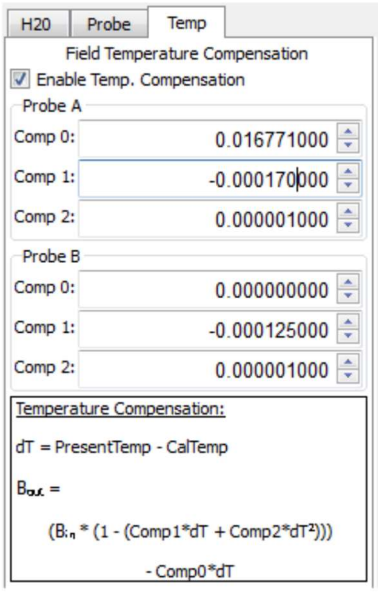


Figure 21. Temp calibration sub-tab

Enable Temp. Compensation	Set whether temperature compensation is used. The default setting is checked.
Probe A,B	The offset (Comp0 = a_{off}) and gain (Comp1 = a_{gain1}, Comp2=a_{gain2}) terms of the probe temperature compensation.

10.5.4 Field Control Parameters tab

The inputs fields on this tab are enabled if your H20 system has the –S2 field control option installed. The fields are also presented on the PID A, B graphic screens. See section 16 for more details on field control.

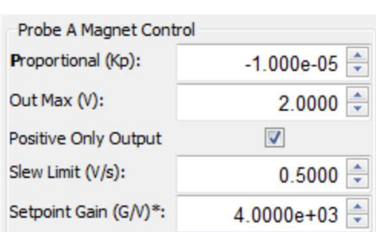


Figure 22. Field Control Parameters tab

Proportional (Kp):	The proportional term that determines how responsive the control loop is.
Out Max (V):	The maximum absolute value of analog output voltage (the control voltage for the electromagnet power supply) that can be sent out.
Positive Only Output	Check if the magnet system is unipolar only. The control voltage output range is limited 0 V to Out Max V (no negative control voltages).
Slew Limit (V/s):	The maximum rate of change allowed for the control voltage output.
Setpoint Gain (G/V)*:	The scaling that is applied to a voltage input to the H20 to give a target for the field control loop when in Analog Closed Loop mode.

10.5.5 Properties tab

This tab gives access to the embedded firmware update utilities, and shows the currently installed versions. The Update PIC Code and Update FPGA Firmware buttons start the update processes for the microcontroller and FPGA respectively. See section 19 for details of the update process.

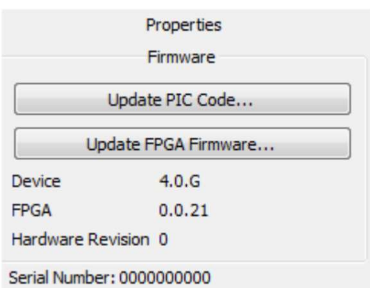


Figure 23. Properties tab

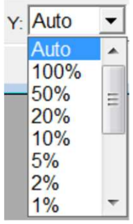
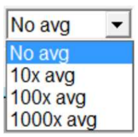
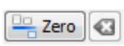
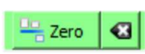
10.6 Screen layout – Graphics area

There are three ways of displaying incoming field data in a graphical way: as a rolling strip chart, as a scope display and as a histogram 

. Only the checked channels are displayed (but both channels are always measured and logged). You can plot the field target values also if your H20 has the –S2 option.

Most controls are common to the plot types.

Y:	This drop-down controls the vertical scaling of the data plot. You can select automatic scaling or various fixed proportions of the nominal full scale. The channel that is selected for plotting and which has the

	greatest full scale setting (smallest range multiplier) will determine the value of full scale.
Display only positive values 	This control is enabled for fixed vertical scaling. It toggles the graphic from a display that is symmetric around 0 to one that shows only 10% of the vertical scale in the negative direction.
Filtering 	The PSI Diagnostic can apply a filter to the plotted data to allow you to pick small signals out of noise. This filter is independent of, and additional to, the block averaging filtering implemented by the H20 itself. The PSI Diagnostic filter is a simple IIR type, $Y_{plot\_N} = Y_{new}/A + (1-1/A)Y_{plot\_N-1}$, where Y_{new} is the latest reading, Y_{plot_N} is the current value to be plotted, Y_{plot_N-1} is the prior plotted value and A is the averaging value from the pull-down menu. The filtering affects the graphed data and digital displays. If you choose to save the buffered data, you will have the opportunity to save the raw values or the filtered values.
Zero correction  / 	When you press zero, the current values are captured and subtracted from all subsequent readings as displayed on all the graphic and digital displays, until you press the clear zeroes button . If you choose to save the buffered data, you will have the opportunity to save the raw values or the zero offset corrected values.
	Clear buffered data. Values are cleared from the PSI Diagnostic data buffer, but any acquisition in progress continues and timestamps are not reset.
	Save data buffer contents to csv file.

10.6.1 Strip display

Data from the selected channels, with the selected averaging, is plotted onto a rolling strip chart as it is acquired. The model for the display is a chart recorder. The horizontal axis is a timestamp the vertical (y) axis is the field in Gauss.

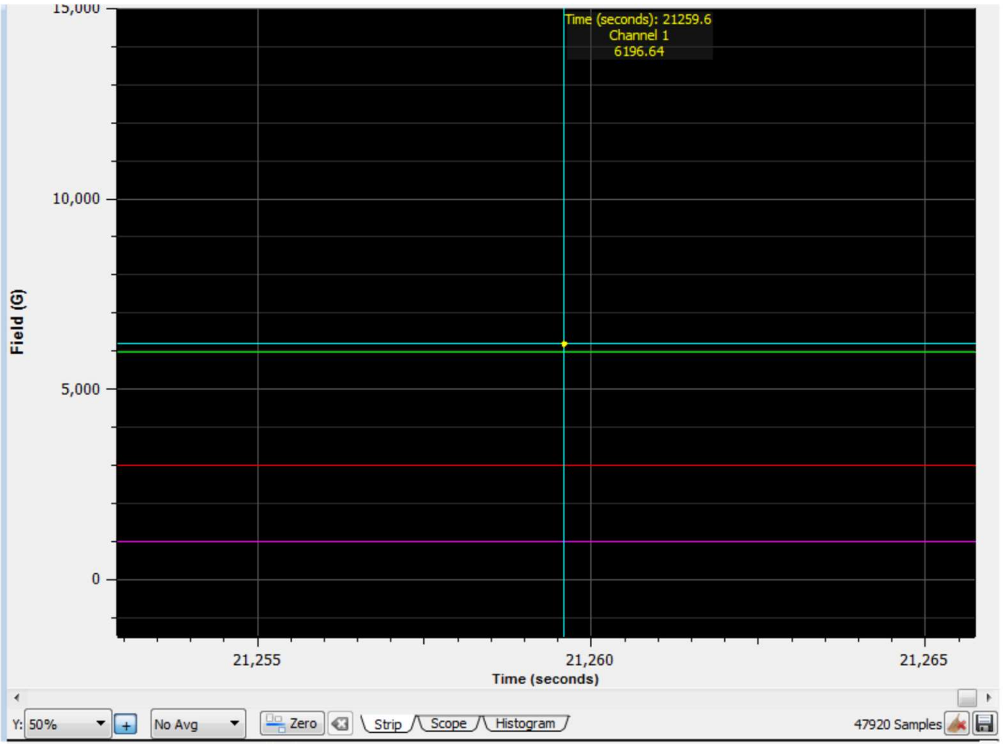


Figure 24. Strip chart display

You can place a cursor on the plot by clicking near one of the traces. When the data you have acquired exceeds the horizontal axis capacity, a scroll bar appears below the graphic. This allows you to move backwards and forwards in the data that has been buffered by the PTC DiagnosticG2. You can do this while the acquisition is taking place, and after it has completed.

10.6.2 Scope display

Data is plotted onto the display after every 256 readings. Otherwise the display is identical to the Strip plot. This mode is most useful when using buffered acquisitions. The model for the display is an oscilloscope.

10.6.3 Histogram display

The signal from each channel (A,B) and the field targets (C,D; -S2 option only) are displayed as vertical bars. This mode emulates a graphic equalizer or rate meter, and can be useful for instrument tuning. You can place a cursor on the plot by clicking on one of the bars.

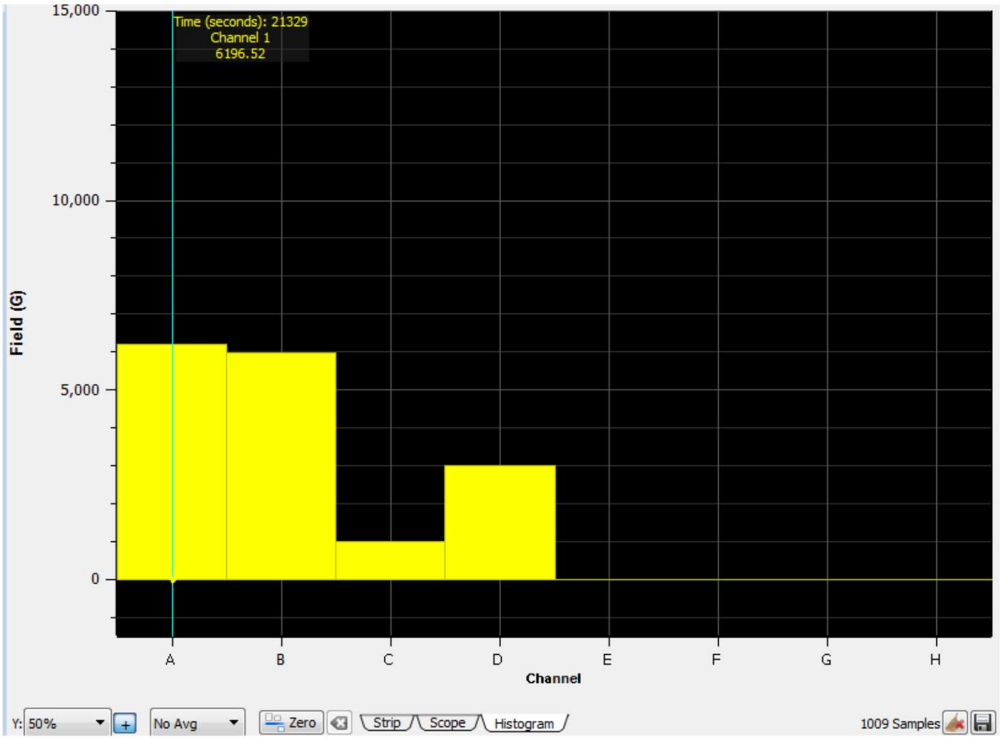


Figure 25. Histogram display

10.7 Installing and using the PSI Diagnostic Program

If you have an A500 loop controller, then the H20 can also be connected via the earlier PSI Diagnostic host program. This Windows program requires the Microsoft .net framework to be installed on your computer. Otherwise the installation process is similar to the DiagnosticG2 installation. The screen controls and readbacks are the same, although the layout is different. The software is not compatible with G2 devices including the A360 and A560 loop controllers.

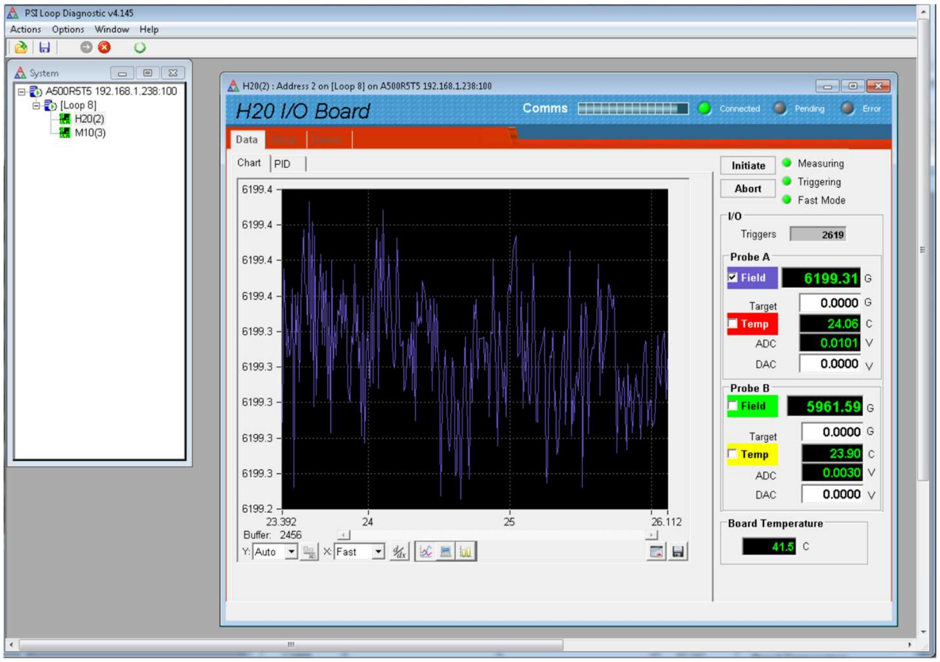


Figure 26. H20 connection to the PSI Diagnostic via an A500 loop controller

11 Connecting to Host Software Systems via IG2 and EPICS

1.1 What is EPICS?

The Experimental Physics and Industrial Control System (EPICS, http://www.aps.anl.gov/epics/) is:

"A set of Open Source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as particle accelerators, telescopes and other large scientific experiments. EPICS uses Client/Server and Publish/Subscribe techniques to communicate between the various computers. Most servers (called Input/Output Controllers or IOCs) perform real-world I/O and local control tasks, and publish this information to clients using the Channel Access (CA) network protocol. CA is specially designed for the kind of high bandwidth, soft real-time networking applications that EPICS is used for, and is one reason why it can be used to build a control system comprising hundreds of computers."

Pyramid supplies an executable called IG2 which embeds an open source Channel Access Server from the EPICS community. This allows connection via the Ethernet interface. IG2 is configured for the devices you wish to connect using editable xml files. Once IG2 is running on a computer in your network, then any other computer can run a client program which can display and control the process variables for the devices. In the simple network in figure 27, the process variables of an H20 attached to an A360 via fiber optics, are exposed to the network by the IG2 service running on a server computer. One or more client GUI computers can then access the values.

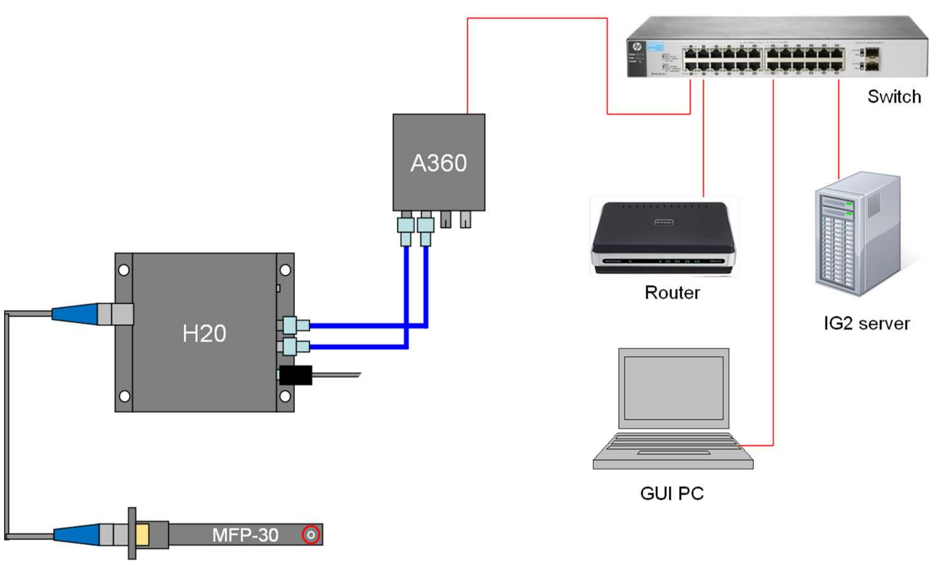


Figure 27. Example network for EPICS communications.

There is a wide range of client interfaces from the EPICS community, including interfaces for C++, C#, Java, Python, Labview ™, and Matlab ™. The Control System Studio, or CS Studio, (http://controlsystemstudio.github.io/) is a set of ready-made tools built on Java and Eclipse (http://www.eclipse.org/) that allows users to get started with little or no programming required. There are various logging, plotting, post-processing and alarm point tools. A fully-featured "drag and drop" user interface editor (BOY) allows quite complex customized user interfaces to be created with minimum development time. As an example, the following screenshot shows a simple user interface created in the CS Studio BOY OPI editor.

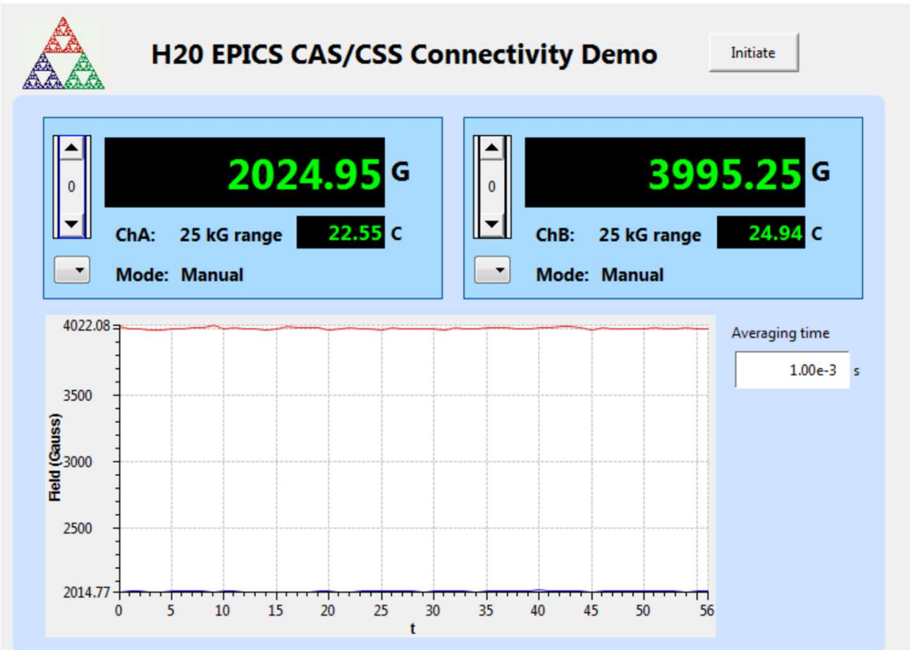


Figure 28. Example user screen created using CS Studio BOY.

1.2 Installing and Configuring IG2

The IG2 package is available to users of Pyramid products. It is supplied as a zip file which should be de-compressed and the entire folder moved to the computer that will act as the server. The server and the user interface computer can be the same machine. The loop controller, the server and the user interface computer should be able to communicate with each other over your network.

In the folders you have saved, there is an xml files in the \service subdirectory that need to be edited to customize your particular setup. IG2 looks for the file "system.xml" in the \service subdirectory to establish the configuration of the system. You can locate system.xml elsewhere than the default location, or give it a different name, in which case you need to specify the path and file name by means of an argument in the command line that launches IG2.

The system file comprises a header section on the xml schema, which does not need to change. Then comes a description of the user interface host computer, descriptions of the fiber optic loop controller devices in your system and descriptions of the devices attached to loops. You don't have to describe every device and every input/output point that is present in your system, but only the ones that you expose in the system file will be visible to EPICS.

The simplified example in figure 29 shows the xml schema. Two field measuring channels and two range controls only are exposed on the H20; normally you would expose a much more complete set of process variables. The A360 is supporting the H20 as the only looped device.

The convention of "wires" for Pyramid device process variables, and the fixed names of those wires for each supported product, are described in the document "ig2_scripting_v#.#.pdf", where #.# is the document revision number, included with each release. The document also describes how you can scale the values, for example to convert voltages from general purpose I/O devices to physical units relevant to the item they are controlling, and how you can set up monitoring against tolerance bands.

The choice of a corresponding working name for each wire is up to the user; you may wish to choose something descriptive that is relevant to what you are measuring or controlling. We nevertheless recommend a naming convention that makes it clear whether a value is a readback or control (the prefixes c_ and r_ are used in the example), which particular device the value is associated with, and a number or letter to indicate the channel for multichannel devices.

```
<?xml version="1.0" encoding="iso-8859-1"?>
<system
  xmlns="http://www.ptcusa.com"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.ptcusa.com A510.xsd" type="pyramid" >
  <hosts>
    <host ip="192.168.1.77" name="PTCE_Server" localhost="true" />
  </hosts>

  <loopcontrollers>
    <loopcontroller type="A360" name="A360_1" ip="192.168.1.68" >
    <loops>
        <!-- A1:LOOP1 ***********************************************************************-->
         <loop number="1" name="Slave_device_loop">
          <boards>
           <board type="H20" name="H20_1" address="2">
              <channels>
                <channel name="r_h20_1_field1" wire="analog_in_field_1" />
                <channel name="r_h20_1_field2" wire="analog_in_field_2" />
                <channel name="r_h20_1_temp1" wire="analog_in_temp_1" />
                <channel name="r_h20_1_temp2" wire="analog_in_temp_2" />
                <channel name="c_h20_1_range1" wire="int_out_range_1" />
                <channel name="c_h20_1_range2" wire="int_out_range_2" />
                <channel name="c_h20_1_monitor" wire="int_out_monitor"/>
                <channel name="c_h20_1_init" wire="digital_out_initiate"/>
              </channels>
           </board>
         </boards>
       </loop>
      </loops>
    </loopcontroller>
  </loopcontrollers>

  <interpreter>
    <devices>
        <epicscas type="epicscas" name="epics_server" />
    </devices>
  </interpreter>

 </system>
```

Figure 29. Example xml system configuration file for IG2 / EPICS.

Once you have created and saved your system file, you can run the IG2 service executable. If the server has a display, you will see a console window that shows the connection process and then records subsequent control value changes sent to the H20. The names you declared will now be recognized as process variables by any EPICS-compatible client program.

CAUTION

Don't try to control the H20 simultaneously from an EPICS client and from the PTC DiagnosticG2. The results will be confusing. In particular, if you attempt to run the IG2 service and PTC DiagnosticG2 on the same computer, the communications will conflict.

12 Magnetic Measurements

12.1 Measures of Magnetic Field Strength

Hall probes measure the magnetic flux density (also called magnetic induction), but it is useful to see how this is related to other measures of the magnetic field.

There is a field around a current carrying conductor or a permanent magnet that exerts a force on other current carrying conductors, moving charged particles, and compass needles. The force is proportional to a measure of the field called the magnetic flux density. This is measured in tesla (T), or kg m s-2 A-1 m-1 = kg s-2 A-1 in SI base units. One tesla is a high field by everyday standards, and is typical of the field in the air gap of a particle beamline bending dipole electromagnet. The old cgs unit is the Gauss, and this is still widely used.

1 T = 10e4 Gauss

1 T = 10 kGauss

The Earth's magnetic field is around 0.5 Gauss at the surface of the Earth, varying with location from about 0.25 to 0.65 Gauss.

It is common to describe the resistance of an energetic charged particle to being deflected by a magnetic field by its magnetic rigidity, measured in tesla meters (Tm). A one Tm beam in a one T dipole field will bend with a radius of one m. An example of a one Tm beam would be 46.75 MeV protons.

The magnetic flux Φ which gives rise to the magnetic flux density is measured in Webers.

1 T = 1 Wb m-2

The old cgs unit of magnetic flux is the maxwell, but this is rarely used (1 Wb = 10e8 Mx).

You can consider that the magnetic field arises from a magnetizing field, H, which is due to the motion of charged particles, usually electrons. In the SI system H is measured in amp per meter. A magnetizing field H produces a magnetic flux density

$B = \mu H$

where μ is the permeability of the local medium. In vacuum the permeability $\mu_0 = 4\pi \times 10^{-7}$ henry m-1. The permeabilities of other materials are expressed relative to this. In ferromagnetic materials the relative permeability may be hundreds or thousands. Air has a relative permeability of very nearly one, however, thus when you measure the B field with the H20 system, you also get the H field in A m-1 after division by μ_0.

The old cgs unit for magnetizing field is the Oersted.

1 Oe = 1000/4π A m-1

and in vacuum 1 Oe creates 1 Gauss.

12.2 Field vectors

The B field is a vector field, which you can decompose at any point into three orthogonal components. Magnetic field lines are assumed by convention to point from the north pole to the south pole of a magnet, A compass will point to the south pole of a magnet (thus there is a south magnetic pole at the Earth's magnetic north pole).

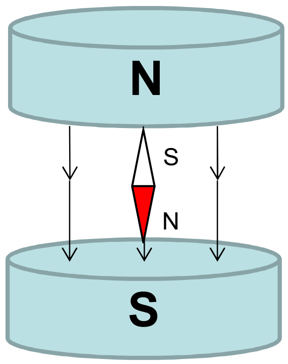


Figure 30. Direction convention for magnetic field lines

The MFP probe measures the field component that is perpendicular to the flat face of the probe, at the position of the bulls eye mark. If you orient the MFP-30 probe so that the field vectors point into the bulls eye, you will get a positive field reading, as shown in figure 31, where you can also see the deflection direction of a positive ion beam for the illustrated field direction, and the current direction in the coils of an electromagnet producing the field.

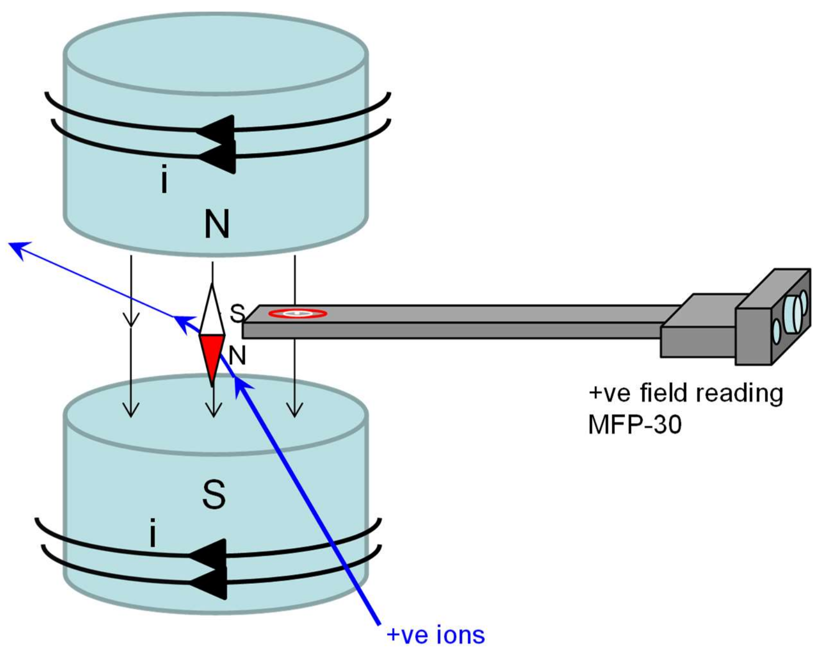


Figure 31. Direction convention for magnetic field lines

The sign of the field reading assumes you have a positive calibration gain value. Should you wish to reverse the directionality, then you must make the gain factor negative.

12.3 Rate of Change of Magnetic Flux Density

Any conductor loop which encloses an area through which the magnetic flux is changing with time will have a current induced in it. If the loop is not shorted, there will be a voltage induced across the terminals that is the negative of the rate of change of B integrated over the surface area of the loop.

$$V = -\frac{d}{dt}\int_S B.ds$$

We can assume that the loop area is small enough that B is constant over its area, so we have

$$V = -\frac{dB}{dt}A$$

where is the area of the loop.

The resulting induced current magnitude and time profile will depend on the impedance of the loop. This effect is important when you are measuring AC fields. The MFP-30 is carefully designed to prevent circulating induced currents that might affect its readings. You should take care that the position of the probe is not near conductive plates or loops that could affect the field reading, unless you are deliberately trying to survey induced currents.

13 Circuit overview

13.1 MFP-30 Probe

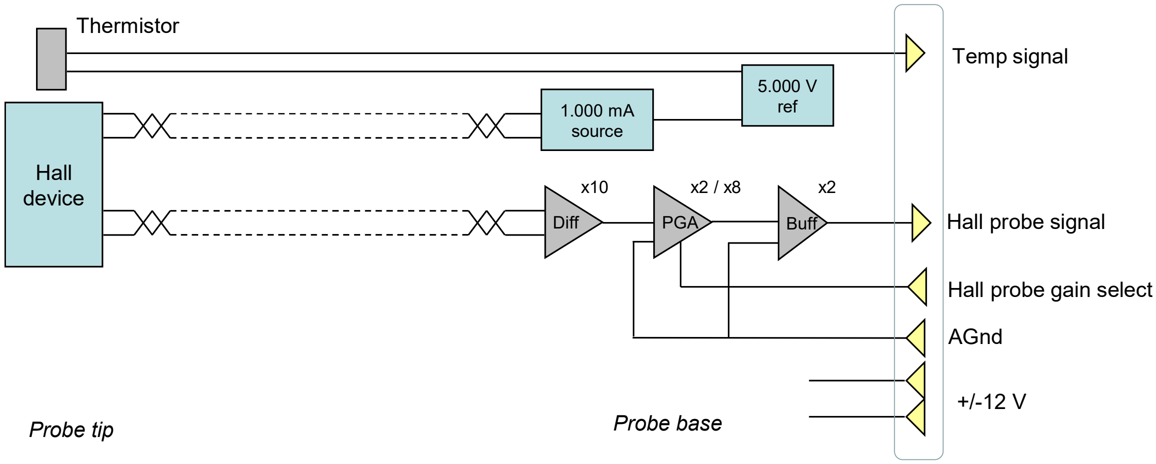


Figure 32. MFP-30 probe block schematic.

The MFP-30 probe uses the very high performance HE244 Hall device, which provides extremely low noise and drift. A 1.000 mA constant current is provided from a current source. Current stability is ensured by a precision bandgap voltage reference and high precision resistor. The very small Hall effect voltage is amplified x10 by a differential instrumentation amplifier. The following programmable gain amplifier can be set to x2 or x8 gain. A line driver buffer amp with x2 gain sends the signal along the cable to the H20.

Connections to the Hall device at the probe tip are made using tightly twisted pairs. A thermistor temperature sensor is located at the probe tip close to the Hall device.

+/-12V power is provided by the H20 and filtered at the probe.

13.2 H20 Control Unit

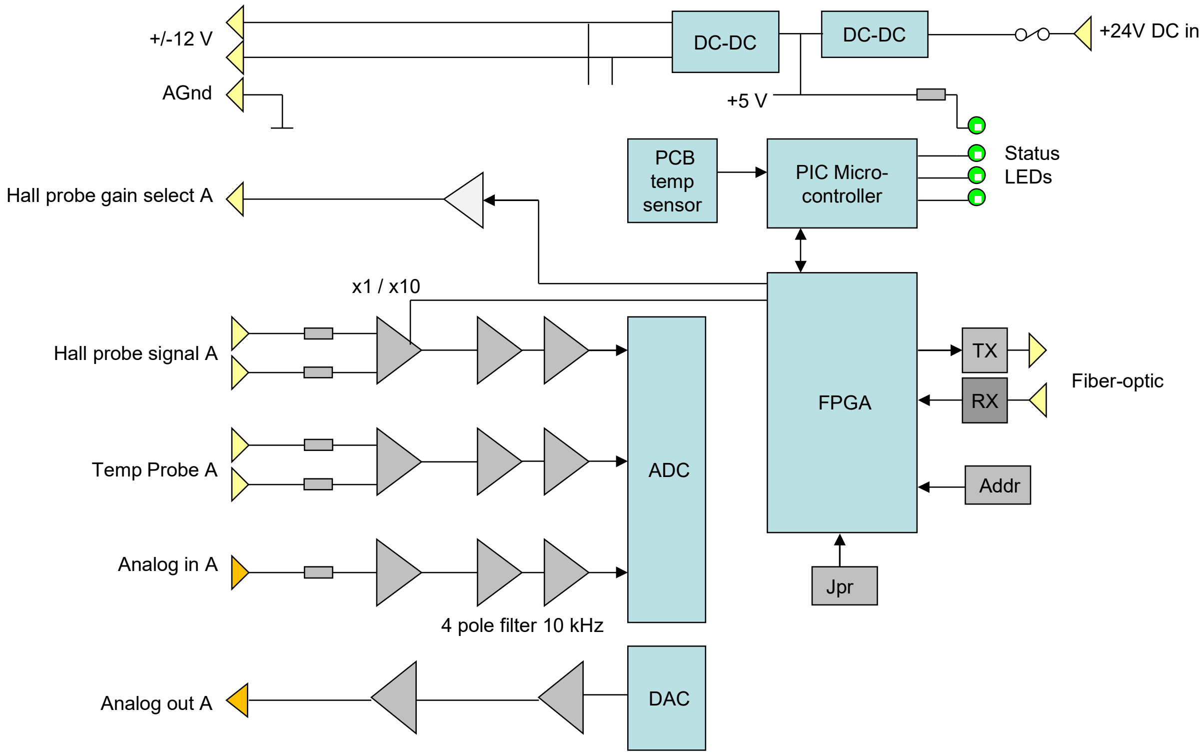


Figure 33. H20 control unit block schematic (channel A shown).

The simplified block schematic above shows the channel A connections on the left. These are duplicated for channel B. The H20 control unit is derived from the widely-used M40 general purpose I/O device. A field programmable gate array (FPGA) handles all input output and digital filtering, and converts raw ADC numbers to physical units. It communicates with the PIC microcontroller via an internal bus. The microcontroller stores calibration values and reads an on-board thermistor to monitor the H20 internal temperature.

The Hall probe and temperature inputs are connected to differential amplifiers. The input amplifier for the Hall probe can be set to x1 or x10 gain. Thus there are the following overall gain options for the combination of MFP-30 and H20:

MFP 30 gain stages			*H20 gain stages*	*Overall gain*	*Bits / Gauss*	*Range designation*	*Nominal full scale*
10	2	2	1	40	1.1	x1	25 kGauss
10	8	2	1	160	4.5	x4	6.25 kGauss
10	2	2	10	400	11.2	x10	2.5 kGauss
10	8	2	10	1600	44.8	x40	625 Gauss

All analog inputs are filtered by 4-pole low-pass filters with 10 kHz roll-off (-3 dB). The filter passband can be altered to special order at build time. A fully parallel 250 kSa/sec 16-bit bipolar ADC reads all the analog inputs. Any ADC over-ranges are flagged and communicated to the host computer along with the digital input bit pattern.

Incoming 24V power is fused, polarity protected and filtered. It is used to supply isolation DC-DC converters which create the internal voltage rails, and provide +/-12 VDC for the probes.

14 Calibration

14.1 Overview

The calibration scheme assumes you may need to swap probes between H20 channels or H20 units. Therefore there are separate calibration settings for the H20, which ensure it is an accurate voltage measurement device, and for the probe, which ensures it is an accurate field to voltage conversion device. The probe serial number is stored along with the calibration parameters to allow you to keep the correct probe and calibration together.

We recommend that you keep an independent record of the calibration values in case the sotred values are accidentally overwritten.

14.2 H20 calibration

The H20 is calibrated in the factory using a precision traceable voltage source. You should not need to change the settings. All the analog inputs have an offset expressed in ADC bits, and a gain. The corrected reading is given by

Reading = Gain*V_{meas} – Offset

where V_{meas} is the measured signal at the ADC The gain value that is displayed is normalized to the nominal gain of the H20, so that a setting of 1.00 gives a roughly correct readout.

The analog output has a gain and offset expressed in volts.

Voltage out = Gain * (V_{DAC} – Offset)

where V_{DAC} is the DAC output voltage before correction, and the gain is normalized as described above.

14.3 MFP-30 probe calibration

The MFP-30 is calibrated in the factory for a specified H20 input channel using a magnetic shield for the zero offset and an electromagnet and a high accuracy factory reference probe that is placed in the same field. The reference probe is calibrated against an NMR probe. The gains are normalized to the nominal conversion gain of the probe, so that a setting of 1.00 gives a roughly correct readout.

You should not need to change the settings. However you would need to transfer the settings and the probe serial number if you move the probe to another H20 channel, either on the same H20 or another.

If you have the CAL-MFPB0 shield for the probe, however, you will be able to check and if necessary adjust the zero offset value. This should only be done when the H20 and probe have been powered and allowed to stabilize for at least 30 minutes, and the averaging should be high (0.1 seconds) for best signal to noise ratio. The reading with the probe shielded should be less than 0.1 Gauss on x1 and x4 ranges. If it is not, and you wish to adjust it, then alter the offset parameter for the relevant MFP-30 probe and relevant gain setting until the reading is close to zero. The probe temperature should be close to that used for the factory calibration to avoid temperature compensation errors.

Figure 34. MFP-30 probe in CAL-MFPB0 shield.

14.4 Temperature Coefficients

Hall probes work due to migration of electrons in a bulk semiconductor, and thus the signal for a given field depends on the mobility of these electrons which in turn depends upon temperature. The MFP-30 probe includes a separate temperature sensor in close thermal proximity to the Hall device, and the compensation is carried out in real time using coefficients stored by the H20 control unit.

There are two components to the temperature compensation; a zero field offset coefficient and a gain correction. The gain correction provides a first and second order term. A reference temperature is recorded as part of the factory calibration. The factory calibration is linked to the serial number of the probe. You should be sure that the probe you have connected matches the serial number shown on the Setup tab. The green LED on the Setup tab of the PTC DiagnosticG2 illuminates when the probe serial number and calibration coefficients are saved or recalled as a matched set.

Measurements then use the difference ΔT between the measured temperature and the reference to correct the measured field

$$B_{corr} = B_{meas}*(1 - (a_{gain1}*\Delta T + a_{gain2}*\Delta T^2)) - a_{off}*\Delta T$$

where B_{meas} is the field reading before compensation, a_{gain1} and a_{gain2} are the first and second order gain coefficients and a_{off} is the offset coefficient. Figure 35 illustrates the effect of the a_{off} parameter over a typical temperature range when measuring close to zero field. Note that even before compensation the MFP-30 has a smaller temperature coefficient than a typical commercial Gaussmeter. Figure 36 illustrates the effect of using a_{gain1} and a_{gain2} gain correction parameters for the measurement of a -3 kGauss fixed field over a typical operating temperature range.

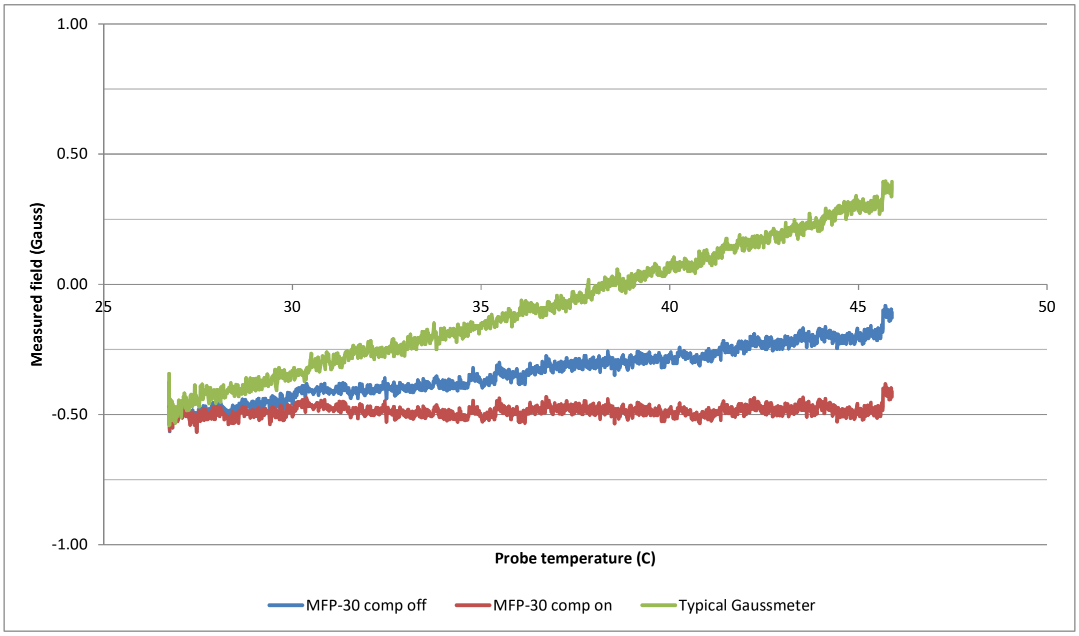


Figure 35. Typical MFP-30 temperature compensation – zero offset.

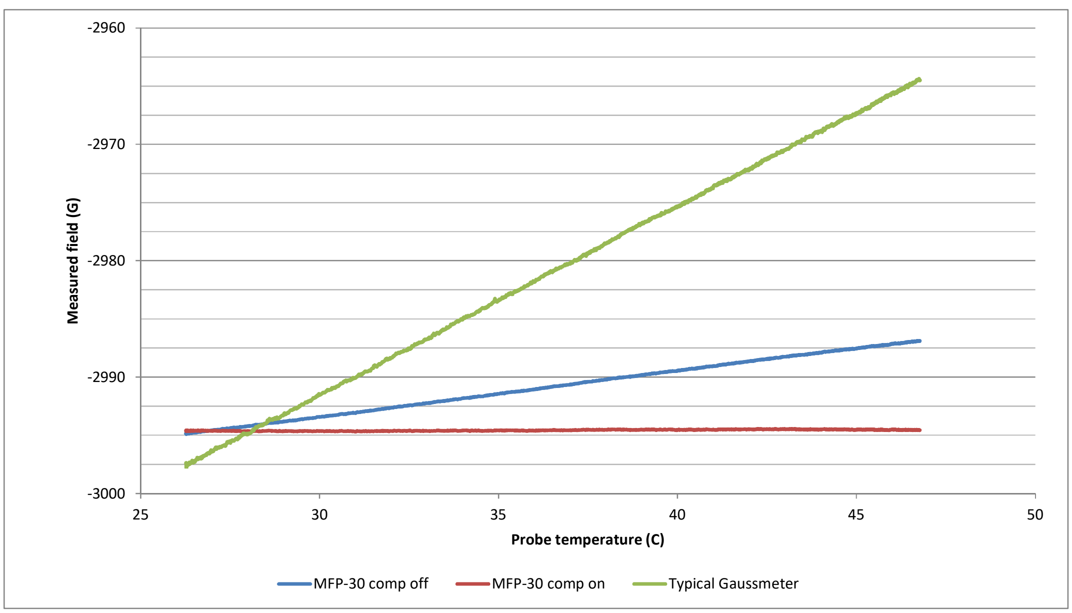


Figure 36. Typical MFP-30 temperature compensation – gain.

A typical value of a_{gain1} for the MFP-30 is about -0.00013 C^{-1}, with a_{gain2} close to zero. The absolute accuracy of the H20 and MFP-30 is more than sufficient for most measurement and control applications with the normal factory temperature compensation. The gain factors do vary slightly over the full field measurement range, however. If you require the best possible accuracy in the face of temperature variation over a more limited range of fields, then you may request that the temperature compensation is optimized for that range as a special calibration order.

15 Monitor Outputs

15.1 Overview

The analog outputs can be used to provide a real-time indication of the measured field, suitable for connection to a voltmeter or oscilloscope. There are two monitor modes, normal and fast. The two channels are independent, and can operate in different modes.

If the analog output is being used as a monitor, then it is not available for direct manual setting or for field control.

15.2 Monitor mode

If you select Monitor, then the field output as averaged and read form the calibration curve is converted to a voltage using the Analog Output Gain parameter, and this voltage is delivered to the relevant Out Lemo coaxial connector.

V = (Measured Field in Gauss) * (Analog Output Gain)

The limiting output voltage is +/-10.0 V.

This mode is suited to readout by a precision DVM or digitizer.

15.3 Fast Monitor mode

If you select Fast Monitor, then the raw ADC conversions are scaled directly into output voltage.

V = ((ADC reading) / 32768) * 10

Accuracy is lower than normal monitor mode because the calibration is not used, but the response to field changes is very fast, limited only by the analog bandwidth of the H20 and MFP-30, because there is no averaging. This mode is suited readout by an oscilloscope.

16 Field Control

16.1 Benefits of field control

The response of an electromagnet with a ferromagnetic return yoke is non-linear if the steel starts to saturate, so a simple linear relationship between coil current and field is not reliable. This could in principle be handled using a non-linear calibration curve. However all electromagnets with ferromagnetic iron return yokes also exhibit some hysteresis. The observable result is that simply setting the coil current accurately does not guarantee that the magnet air gap field is reproducible. It depends of the recent history of magnet excitation. It is not always possible or practicable to trace out the same history to overcome hysteresis.

If a magnetic field probe is used to measure the field in the air gap, however, then a servo control loop can be used to drive the power supply current as necessary in order to achieve the target field, despite the hysteresis. The H20 system with the –S2 option provides this capability.

Example setups for current programming and field programming of an electromagnet are shown in the following figures. In the first figure a series of current steps is programmed by a function generator. The H20 simply measures the resulting field steps. An M10 is also shown that interfaces the power supply (it could also provide the current program if required).

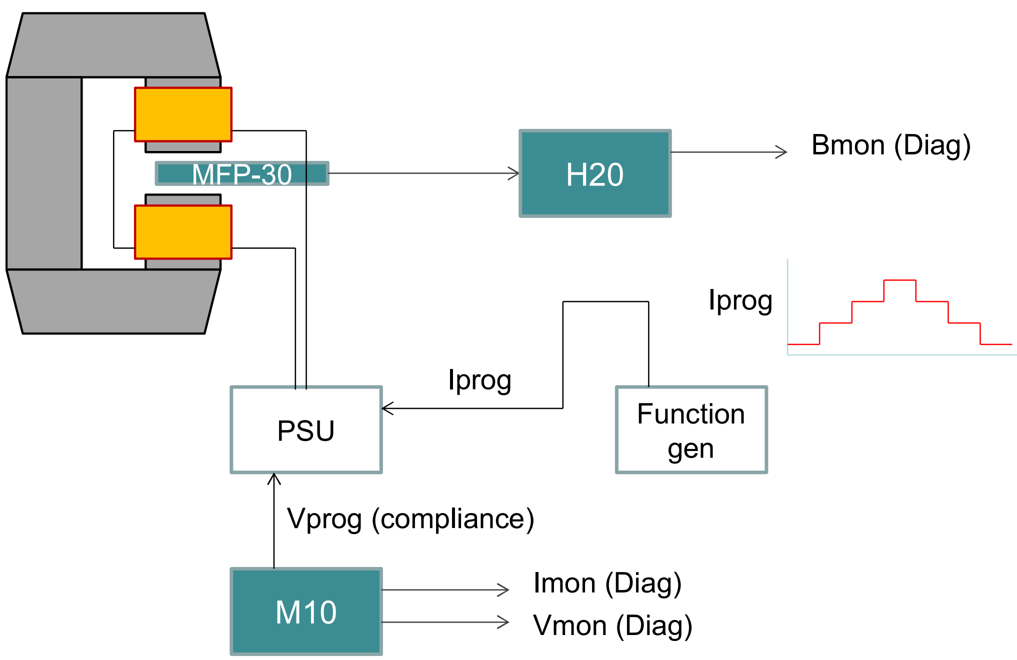


Figure 37. Example setup for current control.

In the second figure the function generator voltage steps are used as field program steps, with the field values given by Bprog * Setpoint Gain. The H20 compares the actual measured field with the target field and adjusts the current demand Iprog to drive the difference to zero.

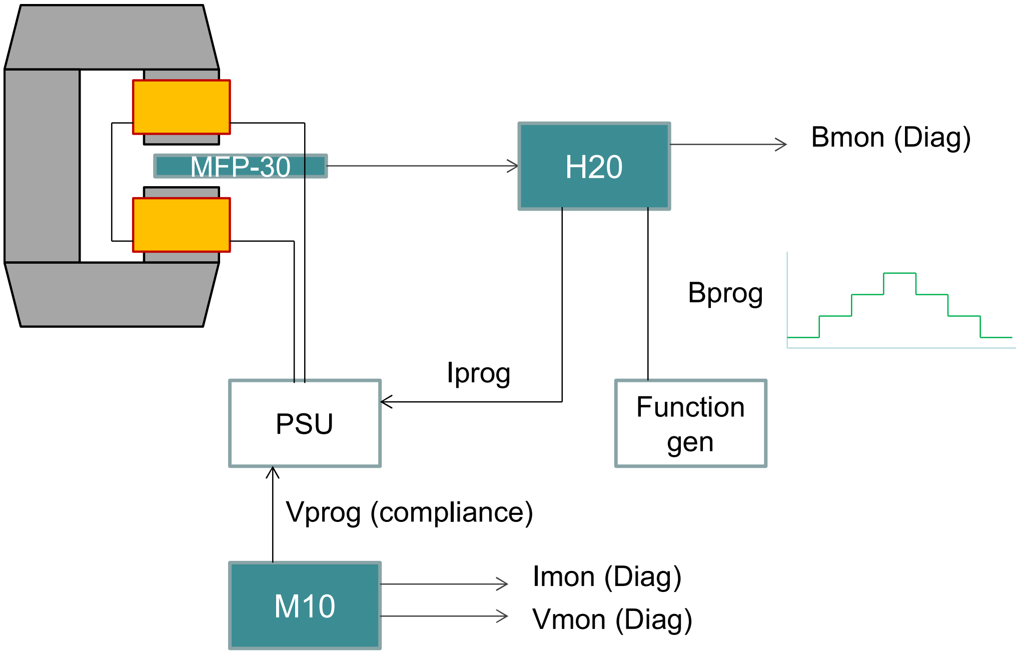


Figure 38. Example setup for field control.

Th difference between the two methods is illustrated below. The fields with increasing current steps are clearly different from the fields at the same current setting when descending, due to magnet steel hysteresis. Under field control there is some initial overshoot at each step, but the fields are identical on the way up and the way down.

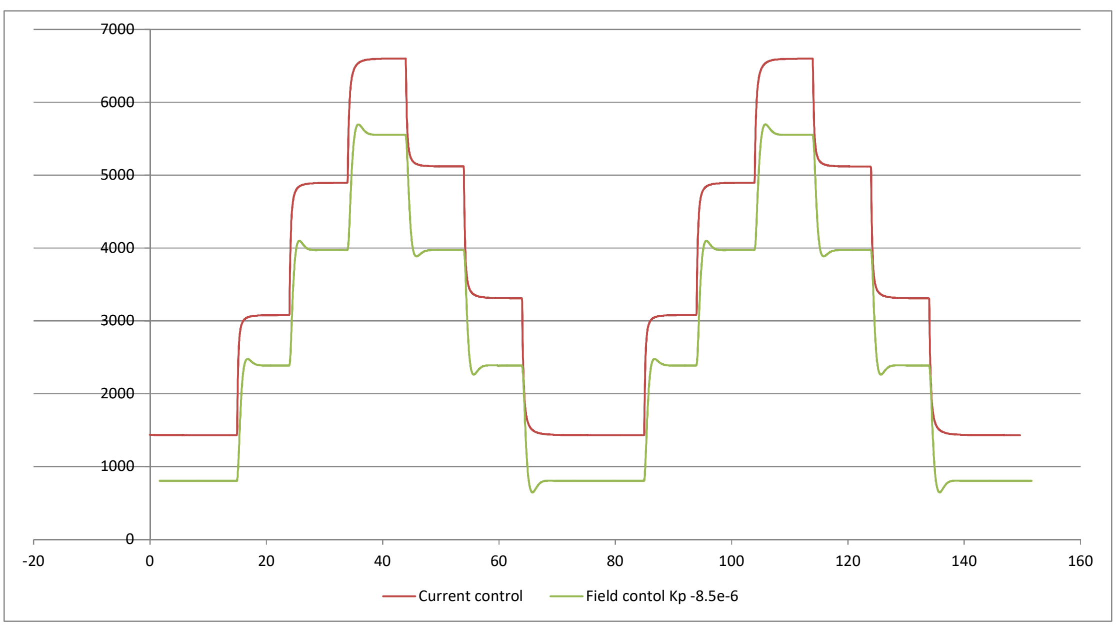


Figure 39. Response to setpoint steps under current control and field control.

16.2 Field servo algorithm

The H20 algorithm is a simple proportional controller which runs at the same rate as the averaging period. Enhanced controllers to suit particular applications will be added in future software updates. The field setpoint can be provided as a value in Gauss over the communication channel from the host computer (Digital Closed Loop mode) or as an analog voltage (Analog Closed Loop mode).

The action is easy to understand using the PID graphics screens from the PTC Diagnostic G2 program. In the example the H20 is using Analog Closed Loop mode.

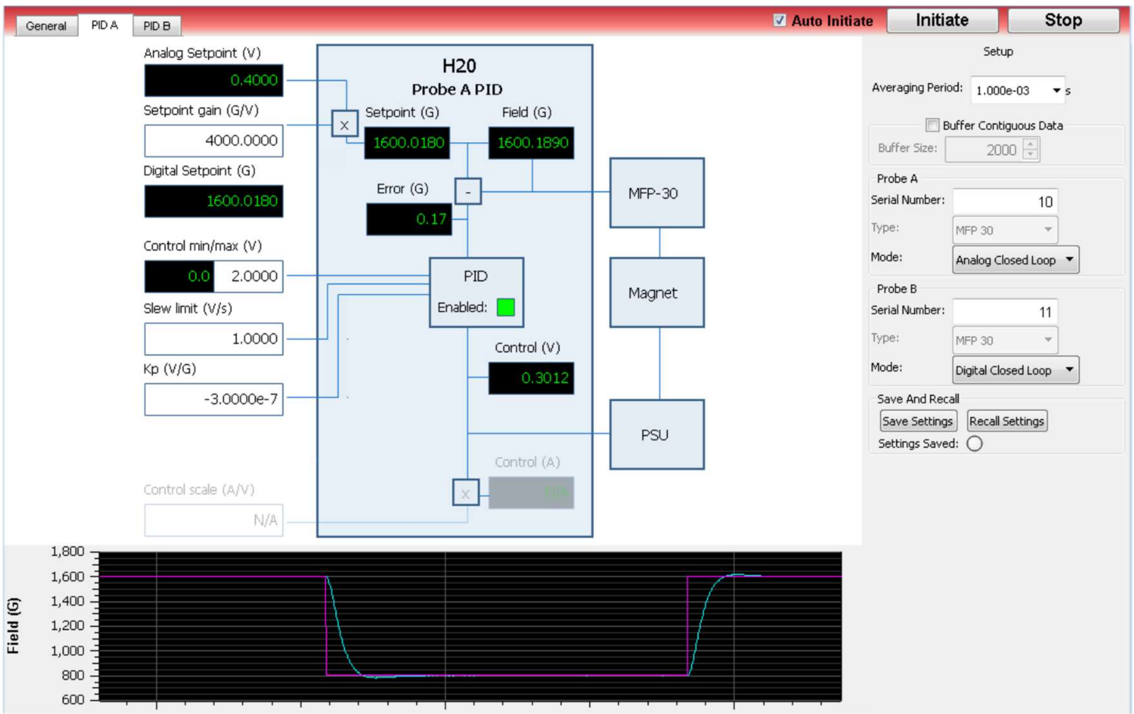


Figure 40. Field control graphic display.

A setpoint voltage of 0.4 V is being measured by the H20 which is operating in Analog Closed Loop mode. This is converted to a field setpoint by multiplying by the Setpoint Gain, which is 4000 Gauss per volt in the example. Thus the field target is 1600 Gauss. Every servo period, which equals the averaging time period (1 msec in the example), the error between the measured field and the setpoint field is used with the Kp term to give a new output control voltage to be sent to the power supply:

```
Err = (Bmeas - Btarget)

dVctrl = Kp*Err

Vctrl(t) = Vctrl(t-1)+dVctrl
```

The size of the change in control voltage dVctrl is limited to the Slew Limit setting times the servo period. The control voltage range is limited by the Control min/max setting. If the Positive Only Output box is checked on the Field Control Parameters tab, then the range is 0V to

+ Control min/max. The power supply and magnet now respond to the new control voltage, the field changes, and the process repeats.

The sign of the Kp parameter depends on the orientation of the probe. If the measured field vector becomes more positive with increasing control voltage, then Kp must be negative to stabilize the loop. If it becomes more negative with increasing control voltage, then Kp must be positive.

16.3 Tuning the control loop

In any servo loop you need to find a good compromise between stability and speed. The faster the servo responds, the more likely it is to become unstable and oscillate in some circumstances. The speed that the servo can respond will depend strongly on the characteristics of the magnet such as inductance and eddy current decay, and the bandwidth and voltage compliance of the power supply. In the case of a standard unipolar single-quadrant power supply, the response can be different for increasing and decreasing current.

Fortunately it is relatively simple to tune the H20 servo loop. The objective is to ensure that the loop is unconditionally stable, and that the system achieves a new setpoint in acceptable time. Set the voltage Slew Limit so that the power supply will stay within its voltage compliance limit when driving the magnet load. The maximum rate of change of current due to the Slew Limit is

$$dI/dt_{max} = (\text{Slew Limit}) * (\text{PSU conversion gain in A V-1})$$

The maximum voltage required to achieve this rate of change of current is, in the absence of severe magnet yoke saturation

$$V = L*dI/dt_{max} + I_{max}*R$$

where L and R are the inductance and resistance of the magnet load, and I_{max} is the maximum current delivered. You should reduce the Slew Limit, and therefore dI/dtmax so that V will not exceed the power supply voltage compliance limit. In addition, set the Control min/max if you wish to limit the maximum control voltage that the H20 servo controller can send to the power supply.

Set the H20 averaging time to suit the noise levels in your system and the servo loop rate you require. Now you should deliver a low frequency sequence of typical upward and downward setting steps and gradually increase the absolute value of Kp and watch how the system responds. The following examples are for a particularly slow magnet with high hysteresis and a slow unipolar power supply. Some overshoot is necessary to get an acceptable step response time. When Kp is made too high the system becomes unstable.

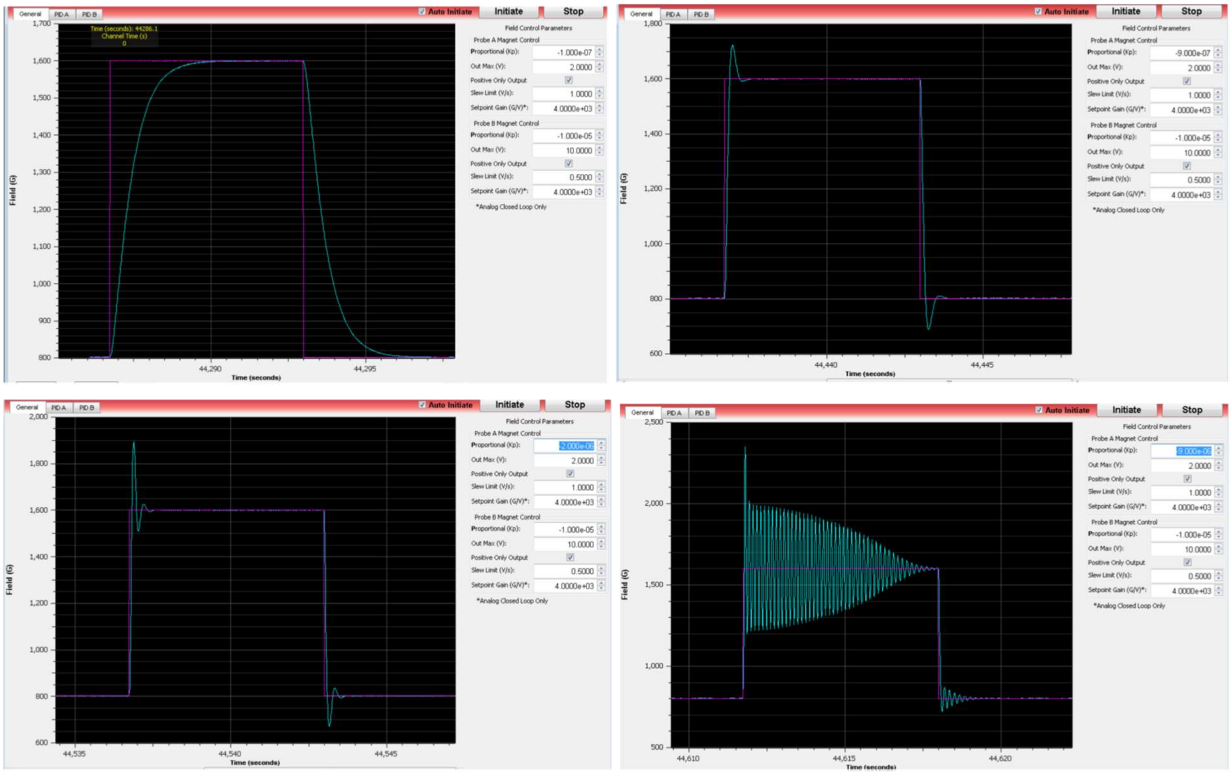


Figure 41. Step response at increasing Kp setting.

So long as we can tolerate some overshoot, then we can look in more detail at the settling after a step to choose the Kp value which gives the fastest convergence within an acceptable tolerance band. The following example was recorded for a 20 msec averaging period in the H20 and various values of Kp. The mauve curve is probably the best overall, although the green curve at higher Kp would be faster if a wider tolerance band is acceptable.

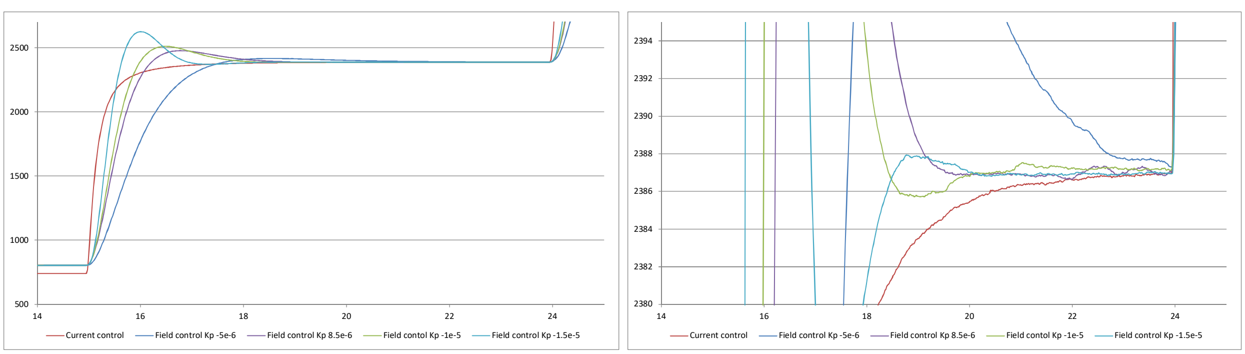


Figure 42. Step response detail at increasing Kp setting (magnified field scale on right).

17 Connectors

17.1 H20 control unit front panel connectors

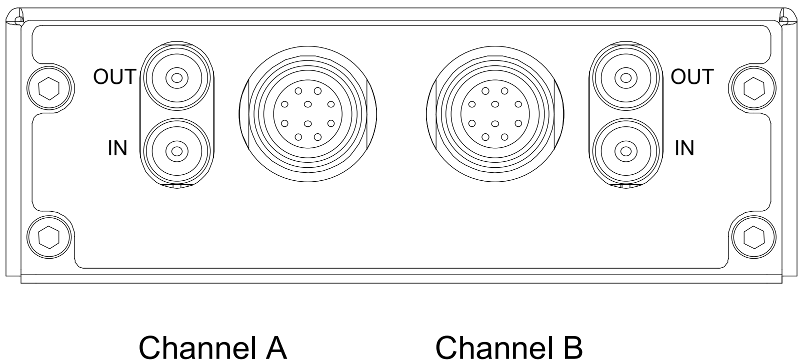
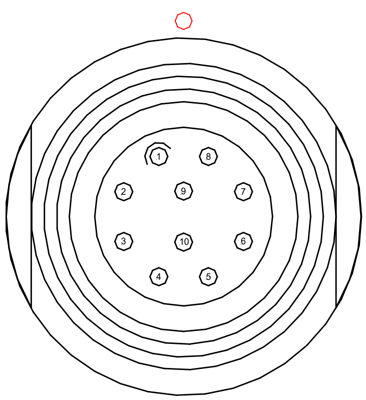


Figure 43. H20 front panel signal connections.

17.1.1 Probe connections

Two ten pin Lemo EXG.1B.310 female. The connector on the MFP-30 probe is identical.



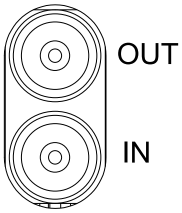
External view on connector / solder side of mating plug. Pins numbered anticlockwise from top left, with 9 and ten in the center.

MFP-30 probe

1	Cable shield	6	Analog ground
2	Analog ground	7	Temperature signal
3	Hall sensor signal	8	Analog ground
4	Hall signal gain select	9	+12 VDC
5	Digital (not used)	10	-12 VDC

17.1.2 Analog signals

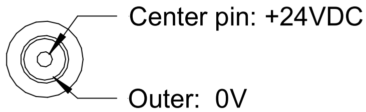
Four Lemo 00 50 ohm coaxial, one output (upper connector) and one input (lower connector) associated with each channel. Suitable cable type RG-173 or RG-316. Impedance matching is not required.



17.2 Rear panel connectors

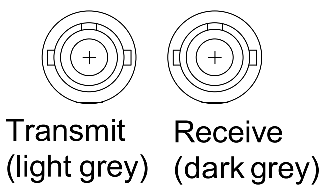
17.2.1 Power input

2.1 mm threaded jack. To mate with Switchcraft S761K or equivalent



17.2.2 Fiber-optic communications

ST bayonet. To mate with ST male terminated fiber optic cable. Recommended cable types 1 mm plastic (such as Avago HFBR-EUS-500) or 200 µm silica (such as OCS BC03597-10 BL). Signal: 650 nm light (red).



18 Controls and Indicators

18.1 Front panel controls

None.

18.2 Rear panel controls

18.2.1 Address switch

16 position rotary switch setting device address. Choice of address is arbitrary, but each device in a fiber-optic loop system must have a unique address.

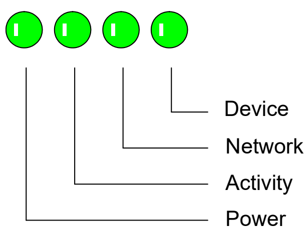
Setting	Function
0-F (decimal 1 to 15)	Available address settings.

18.3 Front panel indicators

None.

18.4 Rear panel indicators

Quad green LED.



18.4.1 Power

Green LED. On = input power is present; internal DC-DC converters are running.

18.4.2 Activity

Green LED. Flashes for 100 msec when H20 has received digital output setting such as gain change.

18.4.3 Network

Green LED. Flashes when H20 is processing messages on the fiber-optic channel.

18.4.4 Device

Green LED. Flashes on for 100 msec with period (250 msec + averaging time) when H20 is initiated and acquiring data.

18.5 Internal settings

We do not recommend that you open the H20 case unless specifically instructed to do so by your supplier or Pyramid Technical Consultants, Inc. There are no user-serviceable parts inside.

18.5.1 JPR1 settings

Internal jumper JPR1 is reserved for future configuration settings.

Links	Function
1	Reserved
2	Reserved

19 Software updates

The H20 has three embedded firmware releases.

Firmware	Function
FPGA (.fhex file)	General logic, loop message passthrough, ADC reading and averaging
PIC Boot (.hex file)	Boot up, code upload
PIC Application (.hex file)	Main application; calibration, range control, host communications, SCPI instrument model.

The PIC boot code is unlikely to require updating. It requires use of an Altera programming adaptor. A factory recall will be issued if an update is ever necessary. The two other codes can be updated by upload from the host computer via the normal communications link. The FPGA code, in a file version with .pof extension, can also be loaded using an Altera adaptor. This is only necessary in the event that the code has become corrupted. Contact Pyramid Technical Consultants, Inc. for more advice in this case.

19.1 FPGA firmware updates

To update the FPGA, click the “Update FPGA Firmware…” button on the PTCDiagnosticG2 Properties tab, and navigate to the relevant file. The code will then load. The process takes about 30-40 seconds.

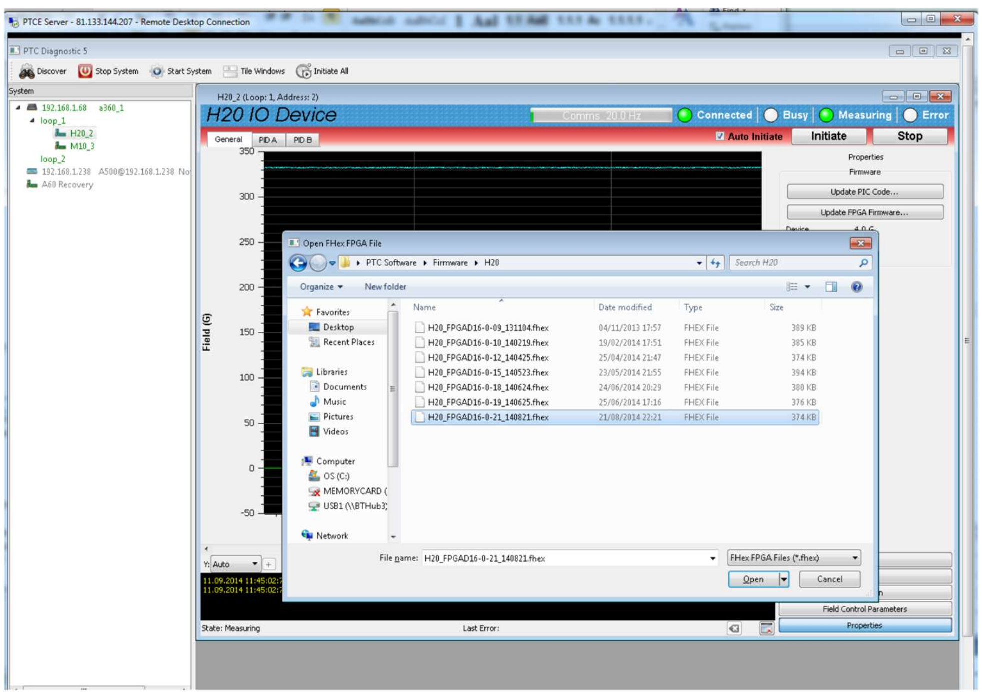


Figure 44. Selecting the fhex file to load.

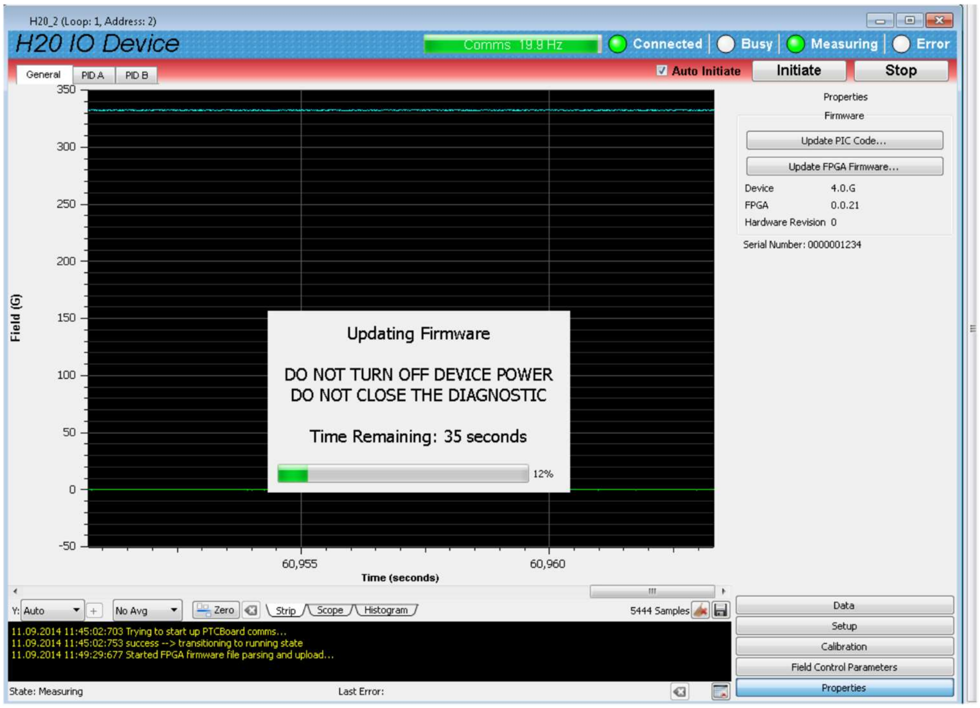


Figure 45. FPGA update in progress.

When the upload is complete, you will get a prompt to power cycle the H20 in order to load the new code.

Figure 46. Reboot prompt.

If the FPGA upload fails for any reason such as loss of power during the upload, or data corruption, then the H20 may not be able to communicate. In the unlikely circumstance that this happens, it can be recovered using an FPGA programming tool and the .pof version of the FPGA code. Contact your supplier or Pyramid Technical Consultants who will arrange for the unit to be repaired.

19.2 PIC microcontroller firmware updates

The PIC microcontroller application code may be updated periodically to add new operating features. New code releases will be provided by your supplier, or can be downloaded from the Pyramid Technical Consultants, Inc. website. The hex file can be loaded using the PTC DiagnosticG2 host. “Update PIC Code…” button on the PTCDiagnosticG2 Properties tab and navigate to the relevant file. The process takes about one minute, and the new code will load and run automatically.

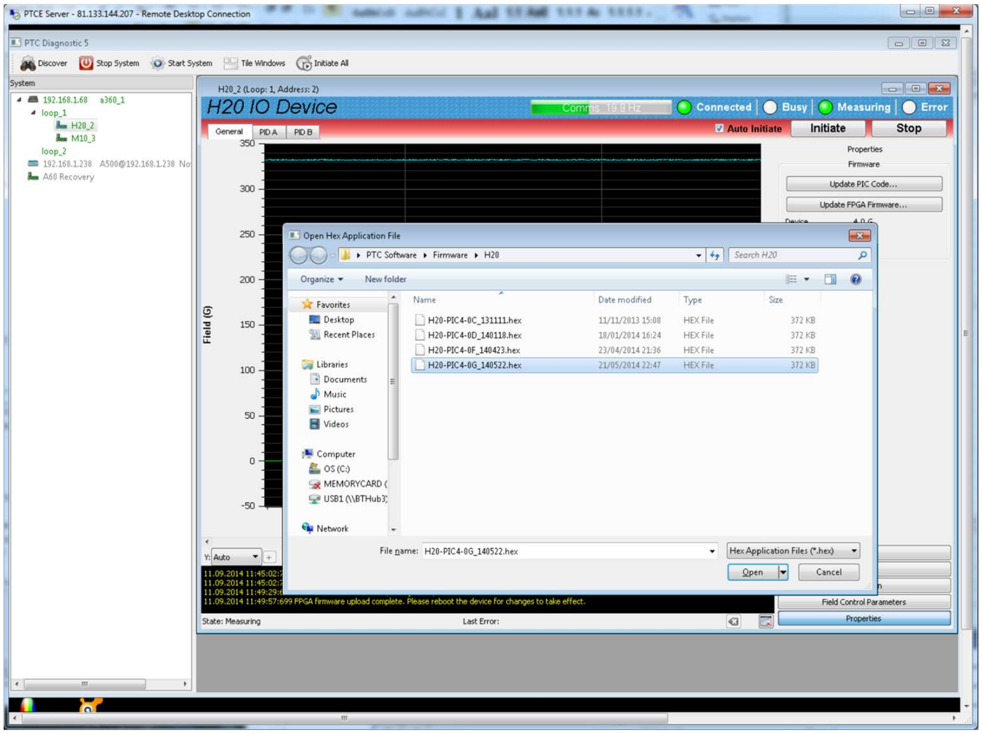


Figure 47. Selecting the hex file to load.

20 Fault-finding

Symptom	Possible Cause	Confirmation	Solution
Incorrect field readings	Probe orientation not as expected	Check orientation of the probe relative to the expected field direction.	Orient and secure the probe.
	Probe out of position	Check probe position	Locate and secure the probe.
	Calibration incorrect or corrupted	Check calibration values for erratic values.	Contact supplier or Pyramid Technical Consultants, Inc. to arrange recalibration
	Default calibration has been loaded.	Gains are all 1.00 and offsets 0.00.	Reload the saved calibration.
	Temperature compensation not in use.	Check compensation parameters.	Use factory compensation values.
	Mechanical stress on probe.	Check mounting arrangement.	Mount the probe securely by without applying bending force.
	Probe and H20 control unit are not a matched pair.	Check serial numbers against shipping documentation.	Use matched pairs. Return to Pyramid Technical Consultants, Inc. for recalibration if necessary.
	No probe connected	Temperature reading is unrealistic (> 100C)	Connect a probe
Unstable field reading	Field is actually changing	Check field by independent means.	

	Probe position is unstable in a spatially varying field.	Check field by independent means, or by placing the MFP in a known stable field.	Provide a mechanically stable probe mounting.
High noise levels	Integration time too short for signal being measured	Noise level reduces with integration period	Use an appropriate integration time for the signal level.
	H20 case not grounded.	Check continuity to local ground.	Make dedicated ground connection if mounting does not provide this.
	Field has unsuspected AC components.	Check field by independent means, or by placing the MFP in a known stable field.	
	Line voltage pickup	Noise level drops sharply if averaging period is 16.7 msec (60 Hz), 20 msec (50 Hz) or 100 msec (50 or 60 Hz)	Keep H20 and signal cable clear of unscreened high current mains voltage. If possible use integration periods (N/line frequency).
Analog signals respond very slowly	Averaging period has been set very high.	Reduce period	Set averaging appropriate to the required time resolution and noise levels
	Filtering is enabled in the Diagnostic host program.	Check averaging setting on the Data tab.	Use the correct filtering setting.
Unable to communicate with H20	Duplicate address setting	Check address against expected address in host software.	Use correct switch setting. Switches can be changed while the unit is operating.
	Communication link timeout		Investigate and fix communications issue. Use a longer timeout setting if necessary.

	RX and TX cables cross connected somewhere in loop.	Network LED not lit.	Correct cabling.
	Fiber optics are damaged	Inspect fibers, especially the connectors. Check light can be seen through fiber. Exchange fibers and retry	Fit new fibers or re-terminate as necessary.
Communications interruptions	Other processes on PC host interfering with comms ports.		Use a dedicated PC with simple configuration and minimum number of processes running.
PSI Diagnostic will not connect to devices	Two copies of program running		Run a single instance only
Random changes to parameters	Another host program is interacting with the same H20.	Check software running on hosts that could access the H20.	Run a single host program only.
Field control does not function	-S2 option is not installed	Check H20 configuration	Upgrade H20 if required.
Field control unstable	Kp value too high	Reduce Kp	Re-check tuning for the setup.
	Kp value needs to change because averaging period has changed	Reduce Kp	Re-check tuning for the setup.
Field control very slow	Kp too low	Increase Kp	Re-check tuning for the setup.
	Kp value needs to change because averaging period has changed	Increase Kp	Re-check tuning for the setup.
	Slew limit too low	Increase to suit power supply compliance	Re-check tuning for the setup

Field control runs immediately to output limit	Kp wrong sign	Check value	User correct Kp polarity
	Probe is inverted in the field	Check orientation	User correct Kp polarity
Unable to set low field in a unipolar system	Magnet remnant field exceeds the setting	Check actual field at minimum	De-gauss the magnet if lower setting is needed.

21 Maintenance

The H20 does not require routine maintenance or calibration. There are no user-serviceable parts inside the case of the control unit.

If you require re-calibration of the unit, contact Pyramid Technical Consultants to arrange a return for calibration. We recommend that the H20, the MFP-30 and the connecting cable are all returned together for maximum calibration accuracy.

The H20 is fitted with a 1.1 A automatically resetting positive temperature coefficient (PTC) fuse in the 24 VDC input. No user intervention is required if the fuse operates due to overcurrent. The fuse will reset when the overcurrent condition ends.

22 Returns procedure

Damaged or faulty units cannot be returned unless a Returns Material Authorization (RMA) number has been issued by Pyramid Technical Consultants, Inc. If you need to return a unit, contact Pyramid Technical Consultants at support@ptcusa.com, stating

- model
- serial number
- nature of fault

An RMA will be issued, including details of which service center to return the unit to.

23 Support

Manual and software driver updates are available for download from the Pyramid Technical Consultants website at **www.ptcusa.com**. Technical support is available by email from support@ptcusa.com. Please provide the model number and serial number of your unit, plus relevant details of your application.

24 Disposal

We hope that the H20 gives you long and reliable service. The H20 is manufactured to be compliance with the European Union RoHS Directive 2002/95/EC, and as such should not present any health hazard. Nevertheless, when your device has reached the end of its working life, you must dispose of it in accordance with local regulations in force. If you are disposing of the product in the European Union, this includes compliance with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC. Please contact Pyramid Technical Consultants, Inc. for instructions when you wish to dispose of the device.

25 Declaration of Conformity

Declaration of Conformity

Issued by: Pyramid Technical Consultants, Inc.
1050 Waltham Street, Lexington MA 02421, USA

The undersigned hereby declares, on behalf of Pyramid Technical Consultants, Inc. that the referenced product conforms to the provisions as listed. Refer to the document: *Extension of testing and analysis to the PTC product line, December 10, 2007,* and its continuations, and the *I400 Technical Construction File* for detailed testing information.

Product:	H20 Dual Hall Probe Controller & MFP-30 probe
Year of initial manufacture:	2014
Applicable Directives:	73/23/EEC Low Voltage Directive: Laws for electrical equipment within certain voltage limits 89/336/EEC – EMC Directive: Laws relating to electromagnetic compatibility
Applicable Standards:	IEC 610101:2002 (2nd Edition) UL 61010-1:2004 EN 61326: 1997+A1:1998+A2:2001 EN 55011:1998, A2:2002 EN 61000-6-2:2001 – Electromagnetic Compatibility Generic Standard, Immunity for Industrial Applications
Issuing Agencies:	Safety: TUV Rheinland North America. 12 Commerce Rd, Newtown, CT 06470 USA EMC: TUV Rheinland North America. 12 Commerce Rd, Newtown, CT 06470 USA
Applicable Markings:	TUV, FCC, CE
Authorized by:	R.P. Burr President, Pyramid Technical Consultants, Inc.
Date:	28 July 2014

The Technical Construction File required by theses Directives are maintained at the offices of Pyramid Technical Consultants, Inc, 1050 Waltham Street, Lexington MA 02421, USA
A copy of this file is available within the EU at the offices of Pyramid Technical Consultants Europe, Ltd, Suite 3 Unit 6-7 Henfield Business Park, Henfield BN5 9SL, United Kingdom.

26 Revision History

The release date of a Pyramid Technical Consultants, Inc. user manual can be determined from the document file name, where it is encoded yymmdd. For example, M10_UM_080105 would be a M10 manual released on 5 January 2008.

Version	***Changes***
H20_UM_140911	First general release
H20_UM_171214 V2.0	Moved to document control repository.