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AMETEK MATERIALS ANALYSIS DIVISION

PX5-HPGe User Manual

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1 Introduction

1.1 PX5-HPGe Description

The PX5-HPGe is a modified version of Amptek's PX5 signal processor and power supply. It was designed to support solid state detectors requiring (a) HV bias exceeding the 1.5kV limit of the standard PX5, (b) preamplifiers built to the NIM standard so needing +/- 12VDC and/or +/- 24VDC, and (c) requiring precise cancellation of resistive tails in the 50 to 100 μs range. High purity germanium (HPGe) and lithium-drift silicon (Si(Li)) detectors, both cryogenically cooled, are the most common detectors requiring the customization of the PX5-HPGe.

A custom power supply board is installed in a standard PX5, providing the higher bias voltages needed by an HPGe detector along with the higher preamp power voltages and currents required by most HPGe preamplifiers. A custom front panel is also installed to mate with industry-standard connectors on HPGe detector/preamp modules. The only change to the signal processing circuitry is a modification to the pole-zero cancellation circuit, which provides more precision but limits the time constant to a range of 40 to 100 μs.

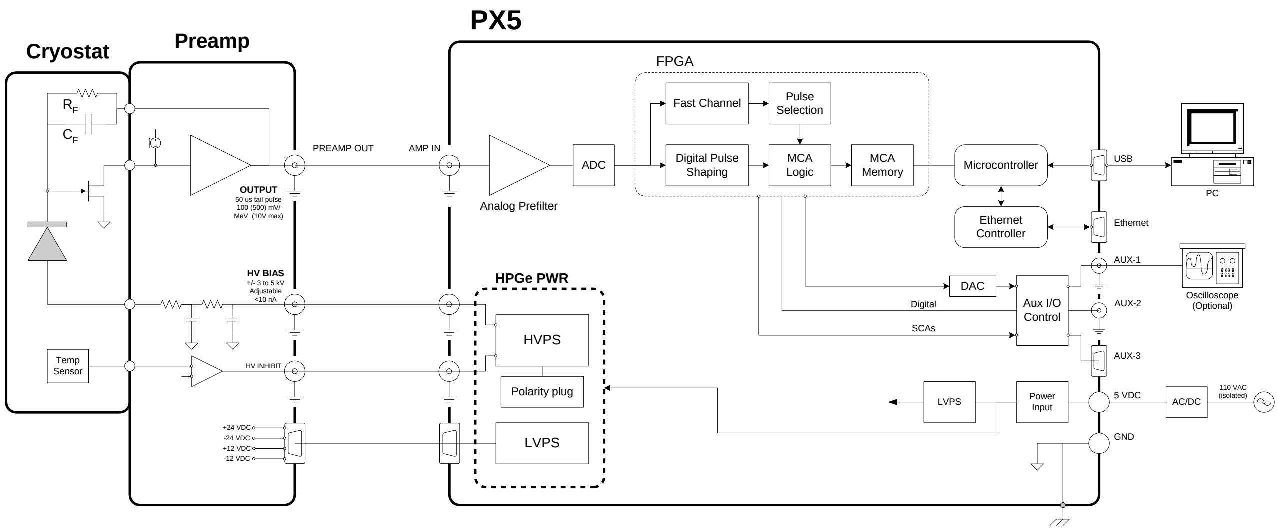
This user manual describes the custom power interfaces of the PX5-HPGe and how to configure the system. There exists an extensive set of documentation for the PX5, including specification sheet, user manual, and programmer's guide. The user should refer to the standard PX5 documentation for the core signal processing and software.

1.2 Standard PX5

The PX5 is a high performance digital pulse processor and power supply module. It is a component in a complete nuclear spectroscopy system, which must also include a detector and preamplifier. A complete system can be assembled by combining the PX5 with one of Amptek's detectors and preamps (several options and configurations may be used) or a user can supply his own detector and preamplifier, and/or power supply. The PX5 is similar in many ways to a combination of Amptek's DP5 signal processor and PC5 power supply module, but has several enhancements and is packaged for laboratory use. The DP5 and PC5 are printed circuit board assemblies, suited primarily to OEM applications as part of a complete system.

The PX5 is a digital pulse processor (DPP) which replaces both the shaping amplifier and MCA found in analog systems. The digital technology improves several key parameters: (1) better performance, specifically better resolution and higher count rates; (2) greater flexibility since more configuration options are available, selected by software, and (3) improved stability and reproducibility. The DPP digitizes the preamplifier output, applies real-time digital processing to the signal, detects the peak amplitude, and bins this in its histogram memory. The spectrum is then transmitted to the user's computer. The PX5 supports USB, RS232, and Ethernet, and the auxiliary connectors provide several additional inputs and outputs. This includes a DAC output, an MCA gate, timing outputs, eight SCA outputs, and others. The PX5 is supplied with the DPPMCA data acquisition and control software, along with interface subroutines to integrate the unit with custom software (DPP FW6 SDK).

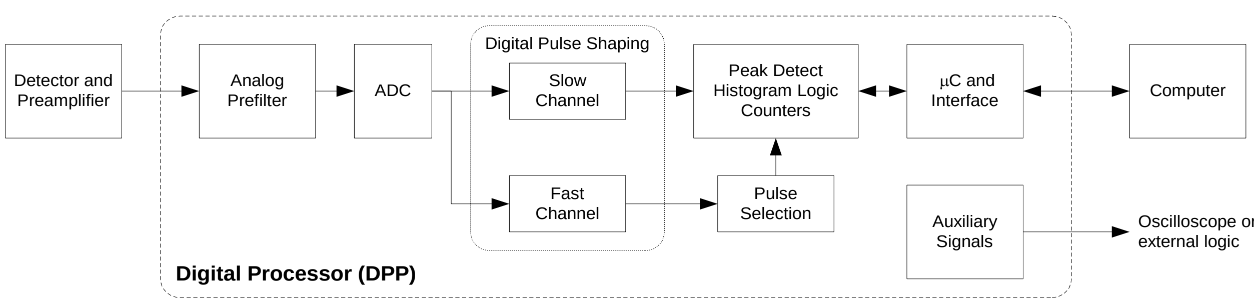
Photograph of PX5 front panel.



Block diagram of PX5-HPGe used with a standard cryogenic HPGe detector and preamplifier. The HPGe PWR module, located inside the PX5 enclosure, is unique to the PX5-HPGe.

1.3 DP5 Family

Amptek has a family of products built around its core DP5 digital pulse processing technology, designed for pulse height spectroscopy. It was originally designed for the detection of ionizing radiation, principally X-ray and gamma-ray spectroscopy. A generic system, illustrated below, includes (a) a sensor, a.k.a. detector, (b) a charge sensitive preamplifier, (c) analog prefilter circuitry, (d) an ADC, (e) an FPGA which implements pulse shaping and multichannel analysis, (f) a communications interface, (g) power supplies, (h) data acquisition and control software, and (i) analysis software.



The core DP5 technology shared by all the systems includes the ADC, the FPGA, the communication interface, and the data acquisition and control software. All products in the DP5 product family include nearly the same digital signal processing algorithms, the same communication interfaces (both the primary serial interfaces and the auxiliary I/O), and use the same data acquisition and control software. The DPPMCA software package is a complete, compiled data acquisition and control software package used across the family; Amptek also offers an SDK for custom software solutions.

The products in the DP5 family differ in the sensor for which they are designed, which leads to changes in the analog prefilter, power supplies, and form factor. They also differ in their completeness: some of Amptek's products are "complete" while others offer only a portion of the functionality for the user to integrate into a complete system.

Amptek has written a "User Manual for Amptek's DP5 Product Family" which summarizes those characteristics which are common across the entire DP5 family. This manual concentrates only those aspects which are unique to the PX5-HPGe.

2 Specifications

The PX5 specification table is identical to that found in the "User Manual for Amptek's DP5 Product Family". The physical and power specifications are listed below.

Physical	
Dimensions	6.5" x 5.5" x 1.5" / 165 x 135 x 40 mm
Weight	1.6 lbs / 750 g

Power	
Nominal Input:	+5 VDC at 500 mA (2.5 W) typical. Current depends strongly on the preamplifier's DC current requirements.
Input Range:	+4 V to +5.5 V (at 0.4 to 0.27 A typical)
Initial transient:	2 A for <100 μs
Power Source:	External supply

Preamp power		
	+/- 12 VDC	+/- 24 VDC
I_{max} (mA)	80	40
Accuracy	2%	2%
Regulation	5%	5%
Frequency (kHz)	600	600

3 Mechanical Interface

3.1 Dimensions

6.5” x 5.5” x 1.5” / 165 x 135 x 40 mm (excluding connectors)

3.2 Control

Front Panel ON/OFF: This switch turns the PX5 on and off. If the PX5 is off and you hold the switch down for >3 seconds (when it beeps a second time), then the PX5 returns to the configuration settings that were in use when it was powered off (stored in EEPROM), which includes turning on the preamp supplies, if they were previously on.. If you hold the switch for <3 seconds, the PX5 boots unconfigured. In either case, HV will be off until explicitly commanded on.

3.3 Front Panel Indicators

HV POL +/-

These LEDs indicate if the hardware jumper in the PX5 HV power supply is set to positive or negative. One LED or the other will be active. These LEDs are active whether or not the HV power supply is on.

HV FAULT

This LED is active when the "HV INH" signal from the HPGe is disabling the HV power supply.

HV ON

This LED is active when there is actually high voltage at the HV output connector. For HV to be on, (1) the HV must be commanded ON in software, (2) the hardware polarity jumper and the software polarity setting must match, (3) the HV Inhibit input must be inactive (high or low, depending on switch setting), and (4) the case must be closed.

3.4 Connectors

Power

Power Plug mates with 3.5 mm x 1.3 mm x 9.5 mm female barrel, center positive, plug connector.

Pin #	Name
1	VIN (+5 V DC)
2	GND

USB

Standard USB 'mini-B' jack.

Ethernet

Standard Ethernet connector (RJ-45)

Analog In

Standard BNC connector.

Pin	Signal	Comment
1	Input	IN+ of input amplifier
2	GND	Can jumper to IN- of amplifier

Preamp Power

DB9-F

1	GND
2	GND
3	NC
4	+12V
5	NC
6	-24V
7	+24V
8	NC
9	-12V

HV

SHV output of the high voltage power supply. This should usually be connected to the "HV" on the HPGe detector's preamplifier. Polarity is set by a hardware jumper. The HV bias is commandable in software over a +/- 5kV range.

HV INH:

BNC input to the HV power supply. This should usually be connected to the "HV INH" output from the HPGe detector's preamplifier. The HV supply in the PX5 is shut down if this is active. The output from the HPGe becomes active if the detector gets warm. A switch sets this input to "active high" or "active low" since different manufacturers use different logic states to disable the HV. A pull-up or pull-down resistor pulls the input to the inhibited state if no input is provided.

See section 6.1 for details and for instructions on changing the polarity.

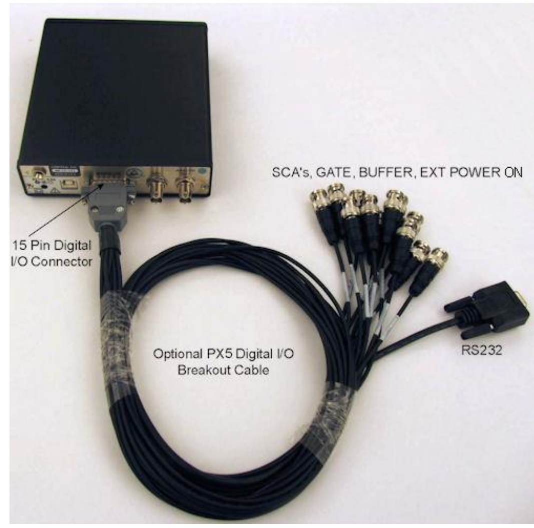
AUX1 and AUX2

Standard BNC connectors. See electrical interface for signals.

AUX 3

Digital I/O: 15 pin D connector (female). Mates with Amptek breakout cable assembly or customer-supplied cable

Pin #	Name	Pin #	Name
1	Gnd	9	SCA 8 Out
2	RS232 - TX	10	External Power On
3	RS232 -RX	11	SCA 7 Out
4	SCA 6 Out	12	SCA 1 Out
5	SCA 5 Out	13	SCA 2 Out
6	Gnd	14	SCA 3 Out
7	Aux 3	15	SCA 4 Out
8	Aux 4		



4 Electrical Interface

4.1 Power Interface

Absolute Maximum Power Supply Voltage +5.5 VDC

Absolute Minimum Power Supply Voltage +4.0 VDC

Input power outside this range will damage PX5 components.

4.2 Analog Input Interface

Absolute Maximum Input Voltage Range -11V to +11V.

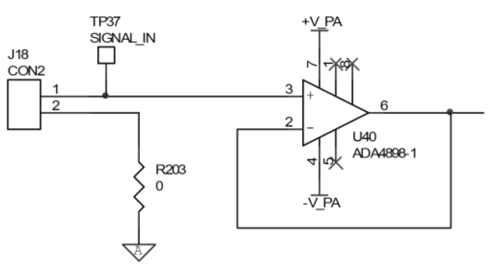
Input voltages outside this range will damage PX5 components.

Polarity: Either positive or negative. Configure in software

Tail pulse with decay time constant of 30-100uS. Configure in software

Step size: 5 mV to 1V.

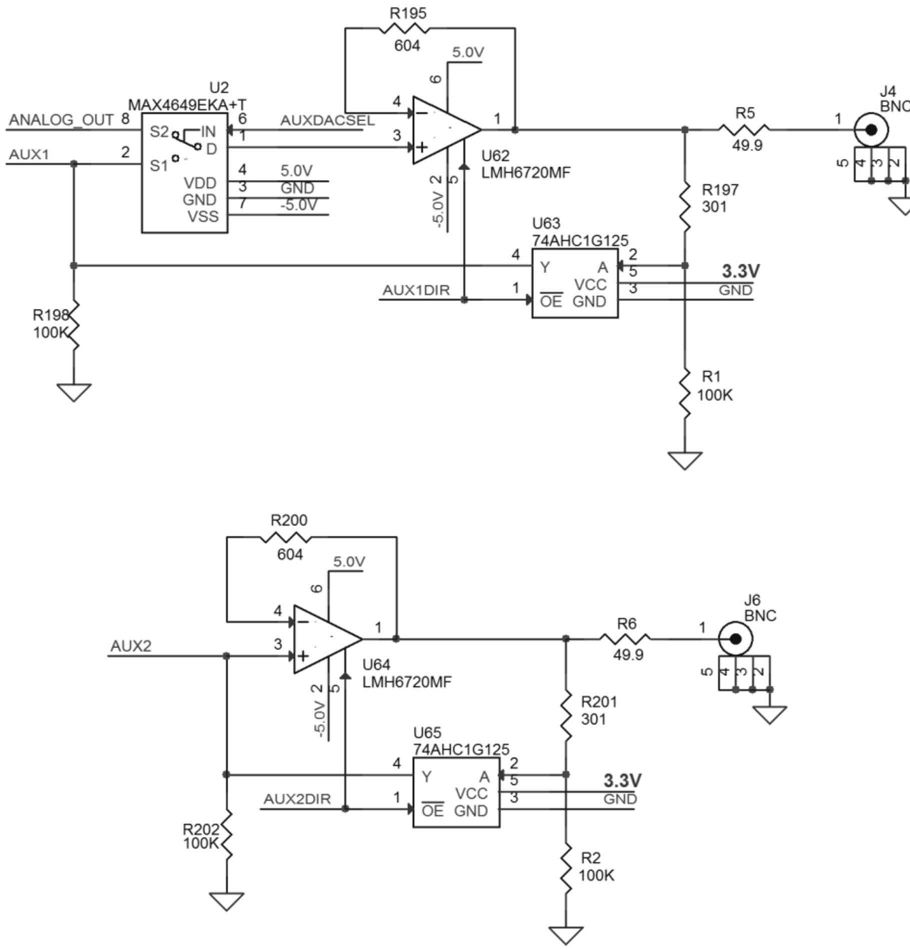
Shown below is a simplified schematic of the analog input. There are several jumpers on the board which permit this front end to be reconfigured for use with a variety of different detectors and preamplifiers. Contact Amptek to discuss these options



V_PA can be set to +/-5V or to +/- 8.5V. The input amplifier's output voltage swing is +/- 3.3V or +/- 6.8V, depending on V_PA. The absolute max is +11 to -11V.

4.3 AUX1 and AUX 2 Interface

The schematic below illustrates the AUX1 and AUX2 interfaces. Based on software commands, AUX-1 can be used to (a) output diagnostic analog signals showing pulse shapes, (b) output logic signals, or (b) input logic signals for COUNTER. In software, one first selects which of the three functions is used, and then must select which signal is used for the DAC output, for the AUX-1 logic output, or for the input. The AUX-2 BNC can be used to input or output digital signals, including the GATE function.



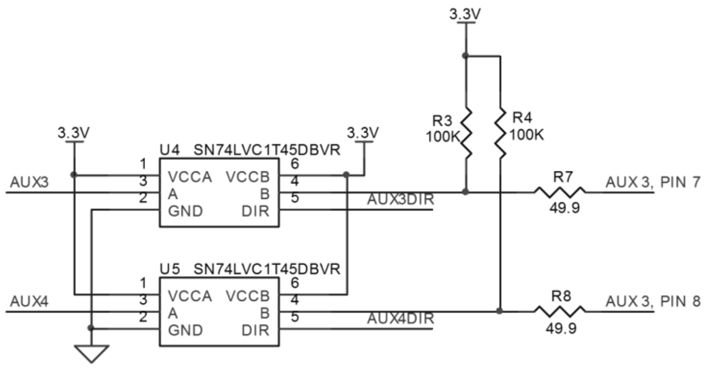
Schematic for AUX-1 BNC connector (top), and AUX-2 BNC connector (bottom)

The AUX signals have an unusual characteristic when used as inputs, due to clamping from the op amp. They are compatible with 3V/5V CMOS. They may be compatible with TTL with an appropriate pull-up resistor. The minimum input 'high' voltage is about 2.6V-2.7V, and the input will draw about 1mA briefly until it switches state - then the current will drop. The input acts like a flip-flop - if the input is disconnected the input will remain in its previous state.

4.4 AUX3 Interface

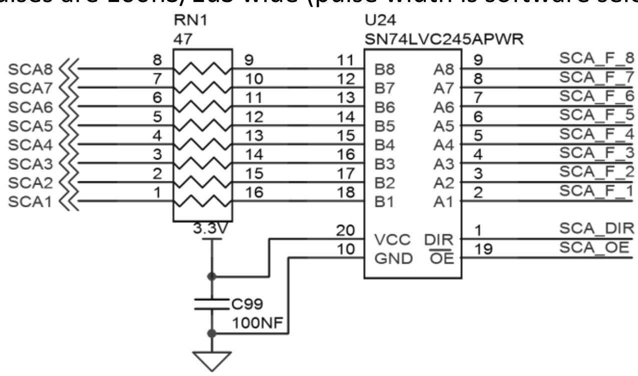
AUX3 and AUX4

These auxiliary connections can be used to input or output logic signals. The circuit is shown below.



Single Channel Analyzers (SCAs)

- Each of the eight SCAs has an independently assignable LLD and a ULD. If the shaped pulse peaks within the range of an SCA, between its LLD and ULD, then a logic signal is output.
- These output pulses are 100nS/1uS wide (pulse width is software selectable.)



5 PX5-HPGe Design

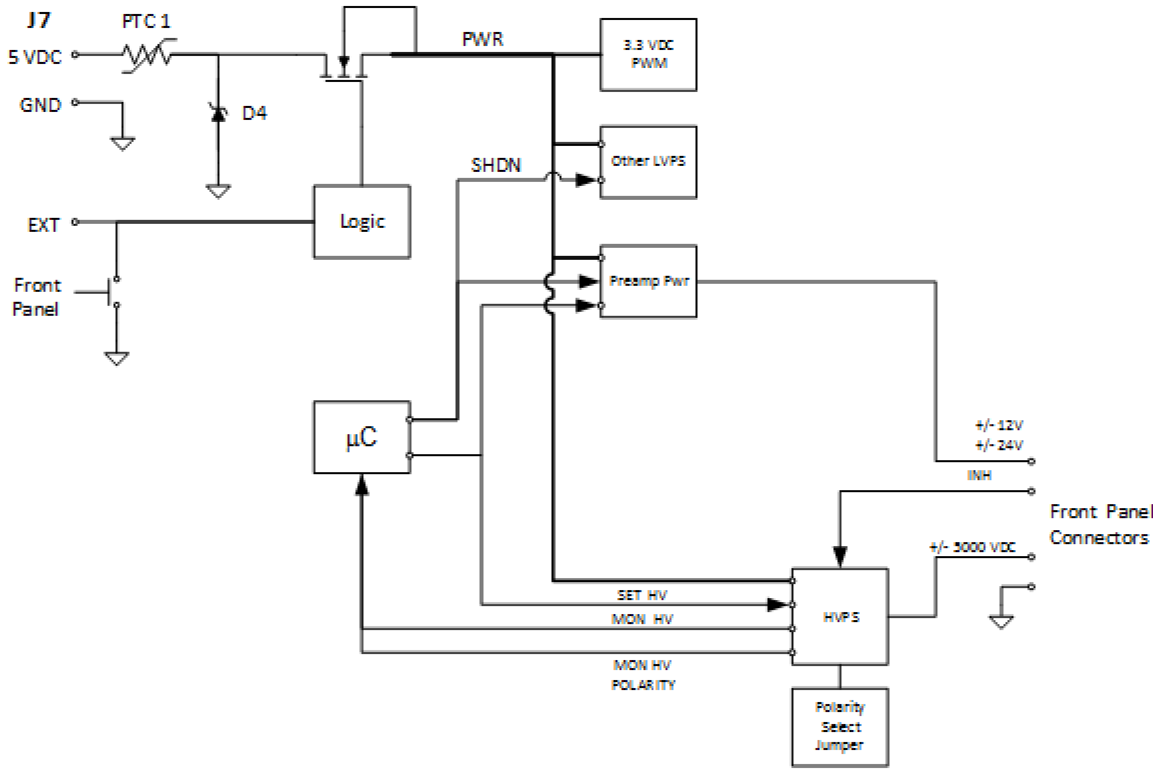
5.1 Signal Processing

The PX5-HPGe's signal processing chain differs from the standard PX5 in only one way: it uses a different digital pot for pole-zero cancellation. The PX5-HPGe has a more limited range of values it can cancel, from 30 to 100 μs, but it provides much higher resolution in this range, which is important for the line width of the HPGe response.

There are three components to the signal processing chain: an analog prefilter, an ADC, and the FPGA. The ADC and the FPGA are identical to those of the DP5. The analog prefilter has a wider input gain range, a switch to change the input high pass filter (to optimize for the highest count rates), and a digital pot to cancel the tail of resistive preamplifiers. But the overall architecture is unchanged from the DP5 and that described in the "User Manual for the DP5 Product Family".

5.2 Power Supply Architecture

The PX5 has several different switch-mode power supplies. A block diagram is shown below.



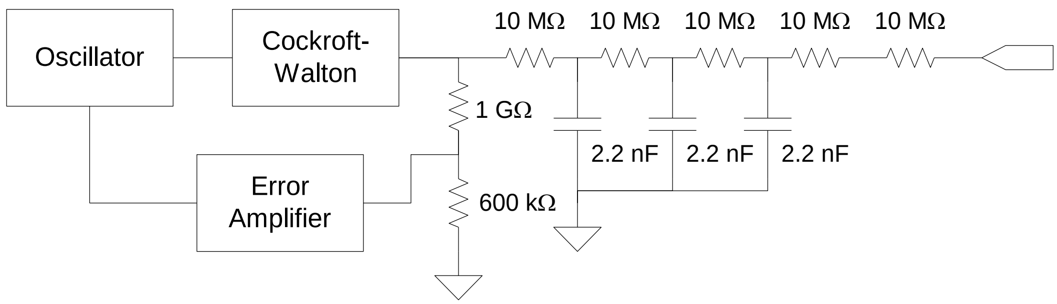
Some key points of the overall architecture are as follows:

- The input power is nominally +5 VDC (4 V to 5.5 V acceptable).
- Reverse polarity protection is provided by PTC1 and D4
- The FET controller will not allow the PX5 to turn on if the input voltage is below 3.25V or above 5.8V. If the PX5 is on, and the input power drifts outside this range, then the PX5 will switch off.
- F1 is a polyfuse, i.e. a resettable fuse. It goes to a high impedance with very high current but returns to low impedance after power is removed. It does not need replacing after use.
- The front panel switch is a momentary switch. When the switch is depressed, the edge is detected by the logic and the MOSFET switches open or closed. The EXT line on J3 permits the user to switch the power off or on remotely.
- When power is applied, the 3.3V supply turns on and the digital circuitry is powered. When the PX5 is configured, the microcontroller turns on its low voltage supplies. Based on the configuration choices, the preamp power, 9VDC supply, and the HV supply may be enabled.
- There are several different pulse width modulated power supplies used in the PX5. Nominal switching frequencies are >1 MHz, except for the HVPS, which runs at about 60 kHz. The HPGe preamp power supplies operate at 600 kHz.

5.3 High voltage power supply

WARNING: Using the wrong polarity will destroy the detector and will NOT be covered under warranty. Always check that the correct HV polarity is set before turning on the PX5.

The block diagram below illustrates the operation of the HV supply. There is a fixed frequency oscillator (60 kHz) which drives a Cockcroft-Walton multiplier. The output of this multiplier is divided into the error amplifier, which regulates the amplitude of the oscillator output.



- □ The HV control circuit has a 10 sec time constant, so in a minute the HV is within 0.2% of its final value.
- □ There is 60 MΩ series resistance after the feedback point. The HV supply regulates the voltage at the output of CW multiplier. The bias applied to the detector is reduced by the load current multiplied by this series resistance.
- □ The high voltage power supply can provide positive or negative polarity, at voltages up to 5000 VDC and currents up to 30 μA. It is suitable for solid state detectors.
- □ The polarity is changed by a jumper on a board internal to the PX5. The procedure for changing this is discussed in section 6.1. The polarity is indicated by the color of the LED ring on the front panel power switch: green (red) for positive (negative).
- □ The polarity is set in hardware. There is also a polarity flag in software. The PX5 μC compares the hardware jumper with the software flag. If they do not agree, then HV supply is disabled. To enable, change one or the other to make them agree.
- □ The magnitude of the power supply is controlled by a DAC so can be commanded in software from about 50 to 5000 VDC. The output is monitored by an ADC (it typically reads a few volts when the HV is turned off).

5.4 Preamp power supplies

- □ The preamp power supplies are located on the same board as the HVPS. They provide +/- 12 VDC and +/- 24 VDC, per the NIM preamp standard.

6 PX5 Applications

6.1 Changing the HV Bias Polarity

It is very important to use the correct polarity for the HV power supply! Applying the wrong bias, at several kV, can destroy a very expensive detector. There are a few key points regarding the HV bias polarity in the PX5-HPGe:

- The HV polarity is set in hardware, by a jumper on the HPGe PWR board inside the PX5.
- There is also an HV polarity command in the software. The μC in the PX5 compares the polarity set in software with that set in hardware. It only turns on the HVPS if these two agree.

  Note that the software command does not actually change the HV polarity; the hardware jumper changes the polarity.
- To change the polarity, you must turn off the PX5, open the cover, move the jumper, reinstall the cover, turn on the PX5, and send the software command to change the polarity. These steps are described in more detail below.
- A pair of LEDs on the front of the PX5 indicates the setting of the HV polarity jumper. These LEDs do not indicate the state of the HV; the appropriate LED will be lit whether or not the HV bias is actually turned on.

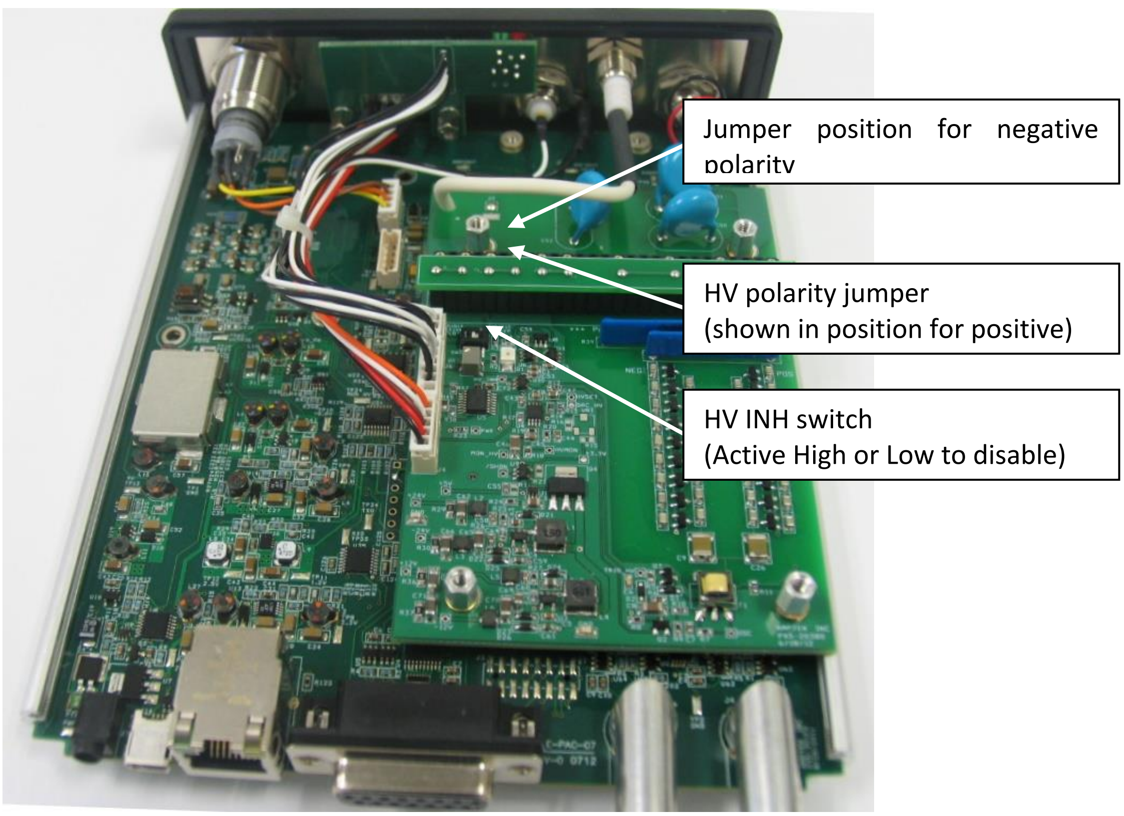


Figure 1. Photograph of PX5-HPGe (with cover removed) showing location of HV polarity jumper and inhibit switch.

6.2 Changing the HV Inhibit

- There is an *HV Inhibit* input on the front the PX5-HPGe. It is very important that an HPGe detector be fully cooled before HV bias is applied. If bias is applied before cooling, the detector can be destroyed. Most HPGe detector manufacturers provide an HV Inhibit output signal which becomes active when the detector is warm. However, some manufacturers utilize "active high" to disable while others utilize "active low". A switch inside the PX5 (SW2) selects inhibit active high or low.

Manufacturer	INH voltage when warm	INH voltage when cold	SW2 setting
	Disables HV on PX5 *HV Fault* LED is ON	Enables HV on PX5 *HV Fault* LED is OFF	
Canberra, BSI	<0.5V	>2.5V	"Active Low"
EG&G Ortec	>2.5V	<0.5V	"Active High

- Some manufacturers do not provide an INHIBIT output. To use the PX5 for these detectors, set SW2 to "Active High" and put a 50Ω terminator on the BNC to pull the signal low.
- The SW2 setting, i.e. whether a HIGH or LOW signal will disable the HV, is read by the PX5 and displayed in DPPMCA.
- The state of the HV Inhibit is also read by the PX5 and displayed in DPPMCA.
- A front panel LED, *HV Fault*, turns on (yellow) if the HV Inhibit signal is disabling the HV bias.

6.3 Additional HV Inhibit Logic

- In addition to the hardware controller, there is also a software HV inhibit command. The HV supply can be commanded off in software.
- The HPGe PWR board contains an phototransistor which detects if the PX5 case is open. It disables the HV supply, to prevent one from accidentally turning on the 5 kV supply with the case open. The PX5 case must be closed before HV can be turned on. Power should never be connected while the case is open.
- The *HV On* LED on the front panel indicates there is actually HV bias at the output. This implies that the HV has been commanded ON in software, the hardware and software polarity settings match, the HV Inhibit input is appropriate (high or low, depending on SW2), and the case is closed.

6.4 Procedure to change HV settings

1) Turn off PX5 (via front panel switch).
2) Remove all cables from back panel (power, USB, Ethernet, etc.).
3) Remove the two screws at either end of the back panel and the two jack posts on the DB15 connector.
4) Remove the back panel and the black plastic trim.
5) Slide back the top cover. You should see the PX5 and HPGe PWR board, as shown in Figure 1.
6) Remove the polarity jumper and place it into the correct position.
7) SW2 can be set to "Active high" or "Active low"
8) Slide the top cover back in place. Reinstall the black trim and the back panel.
9) Replace the two screws on the side and the two jack posts.

10) Reinstall the power, communication, and other connectors on the back panel.
11) Suggested: remove the HV cable from the front panel until the software is configured correctly.
12) Power back on the PX5. Using DPPMCA, connect to the PX5. Reload the prior configuration but do not yet click "Apply"
13) Under Acquisition Set-up, Power, change the HV polarity. Set the HV to some low value, to check it. Click "apply".
14) The software should show the desired polarity and set point. If it is correct, then
15) Turn off the HV in software. Reinstall the HV cable. Set the HV to its desired value, then click "apply".

6.5 Configuring the PX5-HPGe

Digital processors provide many more configuration options than are available for a typical analog pulse shaping and MCA system. These permit the user to better tailor the system for a particular application, providing much higher performance than the older systems, but require the user to understand how to set the parameters. The PX5 configuration options are described in the PX5 User Manual and in the online help available with the DPPMCA software. In this section, we will describe a few of the parameters which are usually most critical for users of HPGe detectors.

Gain

The ADC of the PX5 has a full scale signal input of about 1 volt. This is much lower than that of older analog MCAs, so the gain of the PX5 will usually be smaller than that of traditional shaping amplifiers.

A typical preamp for an HPGe detector might have a charge sensitivity of 100 mV/MeV. To measure γ-ray spectra of 2.5 MeV full-scale, with input signals of 0.25 V full scale, the PX5 gain should be set to about 4. To measure 1 MeV full scale, the PX5 gain should be set to about 10.

Some HPGe preamps have a charge sensitivity of 500 mV/MeV. With such a preamp, a 2.5 MeV γ-ray yields an input signal of 1.25V, exceeding the range of the PX5. The PX5 has a maximum full scale energy of 2 MeV with this preamplifier, with a PX5 gain of 1.

The resolution of the system will depend somewhat on the gain setting: at low gain, the noise of the PX5 circuitry becomes more important. The table below shows results measured at Amptek with a typical detector, a Canberra GC1020. The resolution matched that measured by Canberra at the factory at appropriate gain settings.

	Full scale energy (MeV)	Gain	Resolution (keV FWHM)			
			Noise	122 keV	662 keV	1332 keV
Amptek HPGe			0.65	0.78		1.61
PX5	1.0	9.3	0.66	0.79	1.25	
PX5	1.6	6.0	0.70	0.83	1.30	1.62
PX5	3.1	3.0	0.90	1.00	1.41	1.78

Preamplifier Pole Zero Cancellation

The PX5-HPGe does not support reset-type preamplifiers.

The PX5–HPGe fully supports tail pulse preamplifiers, using resistive feedback. The standard PX5-HPGe will cancel preamplifier time constants from 35 to 103 μs. For time constants outside this range, contact Amptek when ordering to receive the correct components.

To obtain good resolution with a tail pulse preamplifier it is critical that the preamplifier pole be properly cancelled. IMPROPERLY CANCELLING THE PREAMPLIFIER TAIL IS THE MOST COMMON CAUSE OF POOR PERFORMANCE WITH THE PX5-HPGe. Given the narrow line photopeak widths of an HPGe detector, even a very small error in pole zero cancellation will significantly affect resolution. We recommend the following procedure:

1) Set the "reset lockout" parameter to "OFF" and set the "pole-zero" parameter to a value equal to the time constant of the preamplifier. Note that the actual pole may differ somewhat from the nominal value given by the manufacturer, due to the tolerances of the components in the preamplifier, so we recommend checking and tuning the value after setting it. A 50 μs preamp may have the best performance with a setting of 45 μs, for example. The pole zero circuit in PX5-HPGe differs from a standard PX5 to provide fine resolution over a range of 35 to 103 μs. The precision varies logarithmically from about 0.1uS at the low end, to about 1uS at the high end.

2) To check the pole zero setting, on the AUX tab set the Analog Out to "Shaped" and Connector 1 to "DAC". If you have access to an oscilloscope, connect it to the AUX-1 connector on the back of the PX5, as shown in Fig 4. You can use DPPMCA's oscilloscope mode to view the pulses but a real oscilloscope will make fine adjustments much easier. When the pole is set correctly, the flat top is truly flat and there will be no undershoot or overshoot after the trapezoid, as shown below. Note: After the pulse looks pretty good, expand the vertical scale to look for smaller under/overshoots.

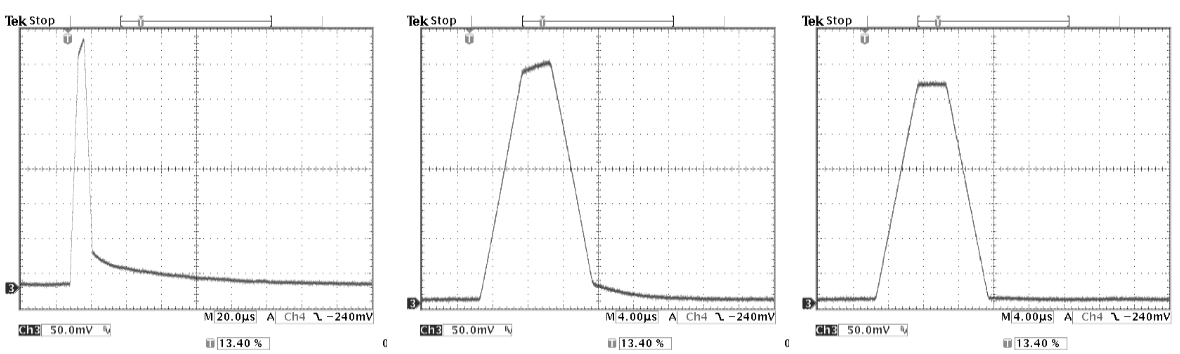
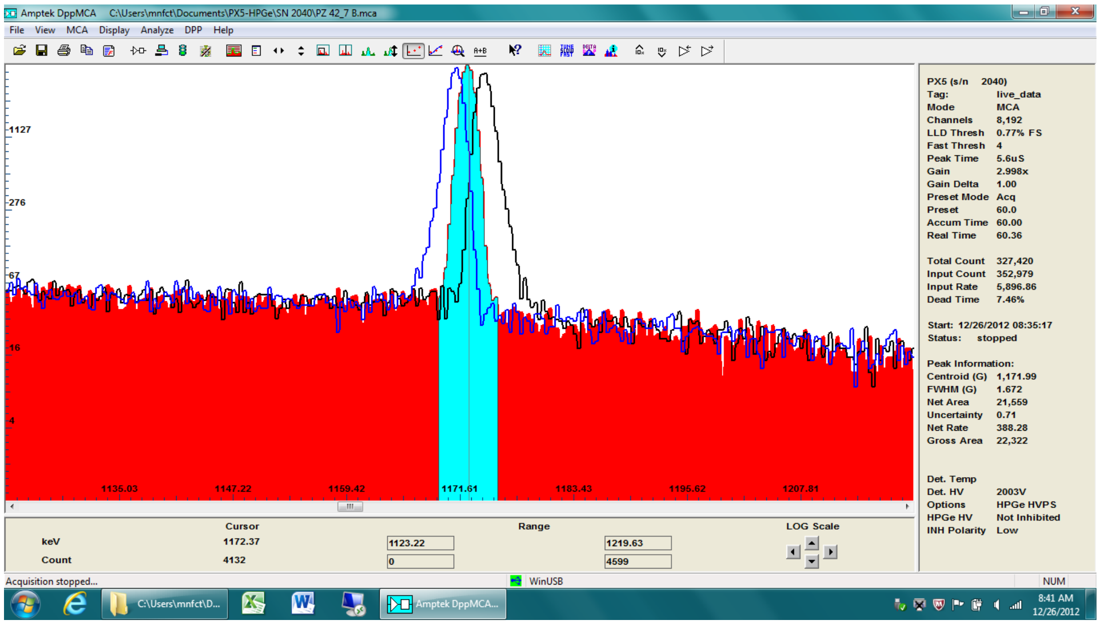


Figure 2. Scope traces showing the adjustment of the pole-zero setting.

3) After the pulse shape looks good with an oscilloscope, you should measure a spectrum and inspect the photopeak. Small errors in the setting will lead to degraded resolution with an asymmetric peak, particularly at high count rates, as shown in Fig 5.



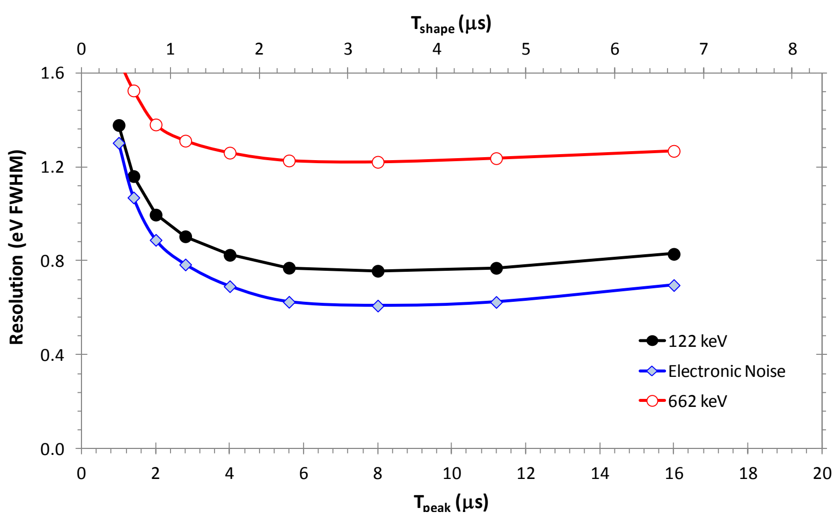
Three spectra of the 1.173 MeV peak of ^{60}Co, taken with differing pole-zero settings (41.9, 42.7, and 43.1 µs) with resolutions of 1.67, 1.65, and 1.69 eK FWHM, respectively. An incorrect setting leads to degraded resolution with an asymmetric photopeak.

Shaping Time Constant and Peaking Time

There are three different parameters related to pulse shaping: peaking time, flat top duration, and fast channel peaking time. Their selection impacts performance quite a bit and differs from analog shaping:

Peaking Time:

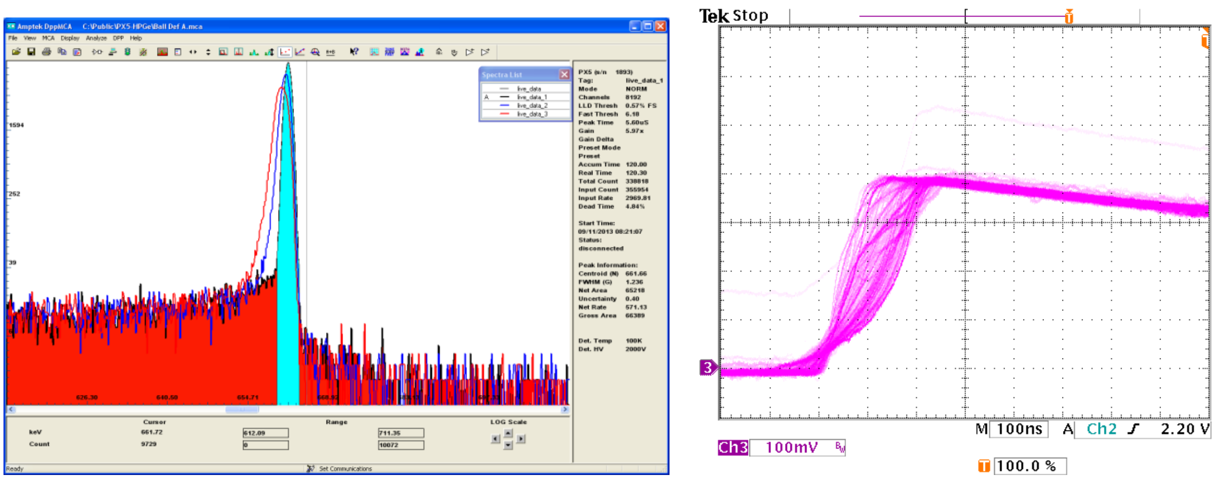
The peaking time largely determines the rms electronic noise and the pulse duration, hence throughput and pile-up. A digital processor with peaking time T_{peak} has characteristics similar to, and slightly better than, that of an analog shaper with time constant 2.4 T_{peak}. The plot below shows the electronic noise and the FWHM of the 122 and 662 keV peak measured with an HPGe detector at Amptek.



Plot showing rms noise and energy resolution measured with the PX5-HPGe and a Canberra GC1020 HPGe.

Flat Top:

The flat top duration should exceed the maximum charge collection time in the detector (this varies with the detector and the bias voltage). If the charge collection time exceeds the flat top duration, the system measures a smaller pulse height, degrading resolution and yielding a tail on the lower side of the pulse (an effect called ballistic deficit). A digital processor has two advantages over the analog system: (1) ballistic deficit can be completely eliminated (by setting the flat top longer than maximum collection time), and (2) the flat top can be adjusted separately from the peaking time, so one can optimize for charge collection independently of optimizing for noise/dead time.



Left: Measured ^{137}Cs photopeak with T_{flat}=0.6 μs and shorter, showing the ballistic deficit tail when the flat top duration is too short. Right: Oscilloscope trace showing the varying risetimes which cause this effect.

The plot on the left above illustrates the importance of this setting. It shows ^{137}Cs spectra taken with flat tops of 0.10, 0.15, and 0.60 μs. The FWHM resolution is 2.4, 1.8, and 1.2 keV, respectively. The plot on the right shows oscilloscope traces of the preamplifier output for the detector used to take the data on the left. The risetime is clearly varying between 100 and 400 ns. We recommend observing the preamplifier pulse shapes on an oscilloscope to determine the maximum duration and then setting the flat top to this value. If a tail is observed, then try increasing the flat top.

Fast Channel Peaking Time:

The PX5 uses a standard slow/fast channel system. The slow channel is optimized for spectroscopy; it has lower noise and lower ballistic deficit than the fast channel to accurately measure the pulse heights. The fast channel is optimized for measuring count rates and timing intervals. The fast channel resolves pulses which overlap in the slow channel. It is used in the pile-up reject logic (PUR) and to estimate the incoming count rate (ICR).

The fast channel peaking can be set to 50, 100, 200 or 400 nsec (200, 400, 800, 1600) for an 80 (20 MHz) ADC clock. Setting this to a short value will generally help the circuits to distinguish closely spaced peaks. However, there are a few disadvantages to setting it too short: (1) Electronic noise increases, so the noise threshold is higher, so both PUR and ICR circuits fail to detect small events. (2) The fast channel pulse duration becomes a strong function of the charge collection time so varies significantly from one event to the next. This can make understanding the throughput and pile-up more difficult. A setting of 100 ns is a good starting point.

ADC clock

The ADC in the PX5 can be operated at either 20 MHz or 80 MHz. We have found the resolution to be slightly better at 80 MHz for the peaking times typical of an HPGe detector. There is a different set of peaking times, flat top durations, and fast channel peaking times for each ADC clock rate.

Thresholds

The PX5 has low level thresholds on both the fast and slow channels. For the best performance, these thresholds are adjusted just above the noise in each channel. If you change anything which changes the noise (peaking time, gain, HV setting, etc) then you should adjust the thresholds immediately afterwards. We recommend removing all sources and pressing the “Tune Fast/Slow” button on the toolbar.

It is possible that this will return an error message. What this button does is, essentially, to set the thresholds to a very low value where there is a high rate of noise counts. It then finds the value where the rate of pulses falls to about one per second. This works if only noise pulses are present. If there are enough signal pulses present, e.g. due to gamma-rays in the background, the algorithm may fail to converge. In this case, you can manually set the thresholds to get about 1 count per second.

Baseline Restoration

The default baseline restoration setting has been found to work well in many situations but may not be ideal. You can adjust the Up and Down settings, or even turn it off, and see if improvement is found.

Auxiliary

We recommend connecting the shaped output to an oscilloscope while configuring the system but have observed a small resolution loss when the shaped output is connected to AUX 1. You may find a small improvement if this you turn the DAC “off” after you have configured the system.

6.6 PX5-HPGe Troubleshooting

The PX5 User Manual and the DPPMCA Help provide troubleshooting advice for the standard PX5. The most common issues for the PX5-HPGe are described there so will not be repeated here. The standard documents are on the CD shipped with the system and are also available at

http://www.amptek.com/documentation.zip

Installation and Setup

Installation of the software and drivers are described in the standard PX5 documentation. Refer to

http://www.amptek.com/winusb.html

High voltage power supply

The most common difficulty encountered with the high voltage is that it may not turn on when the user desires. The key is to recognize that, for the high voltage to turn on, the following conditions must be met:

- The high voltage polarity determined by the jumper must match that commanded in software. The jumper determines the polarity but the software setting is a check on this.
- The HV inhibit setting must match that selected by the switch. If the switch is set to "Active High", then the inhibit line must be low for the unit to turn on, and vice-versa.
- You must issue a software command to turn on the HV. When the PX5 is powered off and then powered back on, the high voltage will not come on automatically; you must set the high voltage value and command it on.

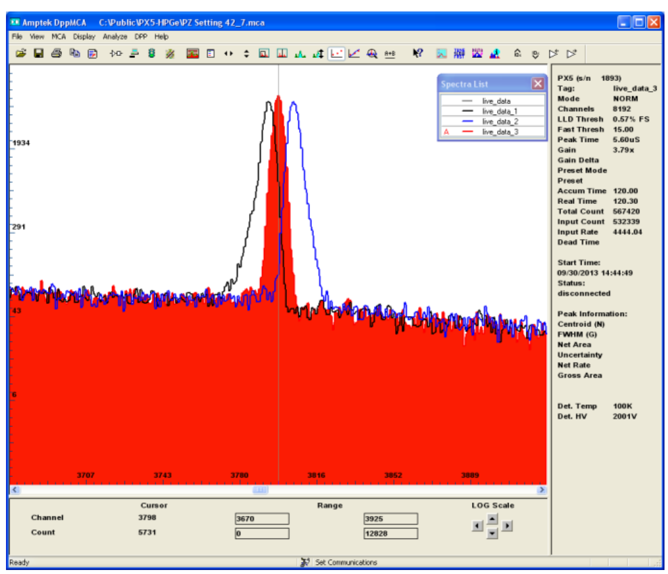
Refer to Section 6.2 for details.

Resolution

The key to diagnosing and solving resolution problems is to closely examine the shape of the photopeak: the photopeaks from an HPGe detector should be very close to Gaussian. Any distortion for a Gaussian shape helps indicate the source of the problem.

In addition, one should examine how the resolution depends on energy, on count rate, on peaking time, etc. The dependence on these parameters is well known for a properly configured system; any deviation from the expected curves usually indicates the source of the problem.

Pole-Zero Cancellation

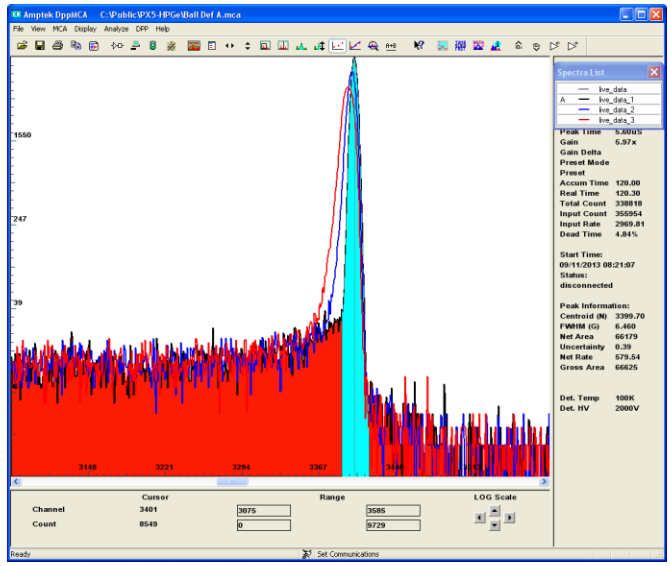


The plot to the right shows the photopeak of ^{60}Co with the pole-zero parameter set correctly (42.7 µs, giving the filled central symmetric peak at 1.6 keV FWHM) and with it about 1 µs longer and shorter (giving about 2 keV FWHM).

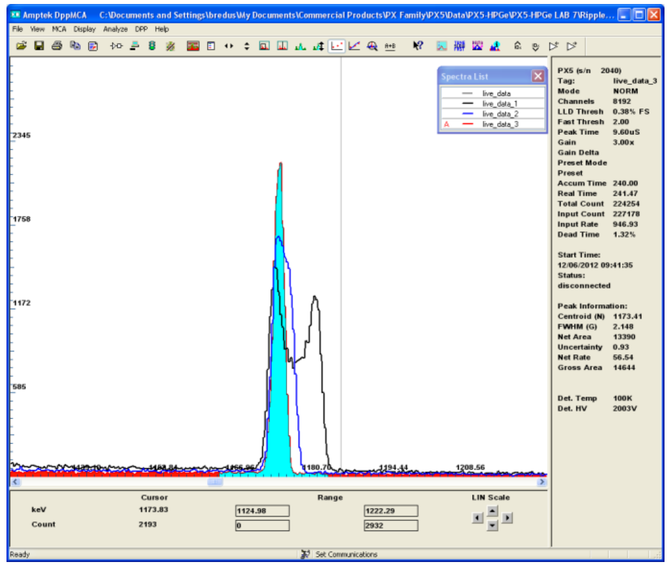
Note that the peak can have a tail in either direction, depending on whether there is residual undershoot or overshoot. If this parameter is set incorrectly, then the resolution will degrade with increasing count rates, as more pulses occur during the residual tail. Improperly setting this parameter is the leading cause of resolution loss with the PX5-HPGe. See section 6.5for more information.

Ballistic Deficit

The plot to the right shows photopeaks of ^{137}Cs in the present of ballistic deficit, when the flat top of the shaped pulse is shorter than the maximum charge collection time from the detector. Only a portion of the charge is integrated in the pulse, and this portion varies from one pulse to the next, degrading resolution. Note that this effect always causes a tail towards lower amplitudes. It is addressed by increasing the flat top duration.



Interference



The plot to the right shows the effect of electromagnetic interference, where the signal pulses ride on top of a baseline variation that arises from the interference.

This is the 1.1 MeV peak of ^{60}Co. The filled peak is in the absence of interference. The blue trace shows a small amount of interference: the peak is wider and visibly non-Gaussian. The black trace shows the result when the interference is larger than the peak width: two separate peaks are formed.

Interference has some important distinguishing properties. First, it adds broadening which is generally independent of energy. Second, the broadening depends strongly on peaking time: the interference is worst when the peaking time corresponds to the frequency of the interference. Third, when the source of interference is removed, the spectrum gets better.

When interference is suspected, the best approach is to view the shaped output with an oscilloscope. The frequency of the interference is often clear and this helps identify the source. Measuring resolution vs peaking time will also help identify the frequency and hence the source. Finally, trying to remove possible source and measuring the resulting resolution can be helpful. Some further suggestions on interference are found at the end of this document.

The spectrum above was measured with sinusoidal interference with a frequency near that of the pulse shaping. Pulsed or very low frequency interference can result in slow or occasional shifts in the spectrum; often, the result is a Gaussian sitting on a wider baseline. HPGe detectors are susceptible to acoustic vibrations which can cause this. The best solution is to remove the source of vibrations. If this is not possible, then changing the BLR settings may help. Try changing the “Up” and “Down” parameters. The baseline restoration will regard low frequency noise as a changing baseline and can reduce these changes.

Count rates and dead time

Obtaining an accurate incoming count rate is very important and is a challenge since pulses overlap in time and the pile-up rejection circuitry discards overlapping pulses. The PX5 use a different approach to determine the incoming count rate than does a traditional analog processor, using a fast channel to measure the incoming rate rather than the traditional livetime clock.

Additional Notes: Eliminating Interference

HPGe systems are susceptible to electromagnetic interference, e.g. ground loops. Defeating ground loops is challenging but important. When there is interference, the pulses from the signal ride on top of a sinusoidal baseline variation. The peak is broadened by the sinusoid and the peak is not Gaussian. If the peak-to-peak of the interference is larger than the FWHM due to Gaussian effects, one observes photopeak splitting. For weaker interference, one observes a single peak but with a noticeable flat top. The previous plot below shows measurements obtained when interference was present. The black trace shows the peak with no interference. The blue trace shows a moderate amount of interference; note that the peak is wider and no longer Gaussian. The red trace shows interference large enough to cause peak splitting. Interference also has the signature that the resolution is far worse at a shaping time associated with the frequency of the interference source.

Eliminating interference is often quite difficult; the signal currents are very small so it does not take much extra current to degrade resolution. As a general rule, we recommend the following:

- Improper grounding is the most common cause of interference with HPGe systems. Pay close attention to the grounds, to ground currents, and if you have a problem, try changing the ground.
  - If the return path for a power supply occurs along a signal ground, then this return current acts with the impedance of the ground path to degrade the signal. Isolate signal and power return currents as much as possible.
  - If the ground connections between multiple devices form a loop, a ground loop, then this loop will pick up radiated interference. Use a single ground point.
- Try to determine the frequency of the interference. Connect the shaped output to an oscilloscope and look for low level periodic signals. Try this also for the input signal.
- Many devices in a laboratory may radiate electromagnetic interferences; CRTs, high frequency digital circuits, and so on. We have seen oscilloscopes which generated noise, and power supplies for laptop computers generating large ground currents. If you can determine the frequency of the interference, this may help identify the source. In any case, try turning off various suspected sources of noise to see if they are the cause.