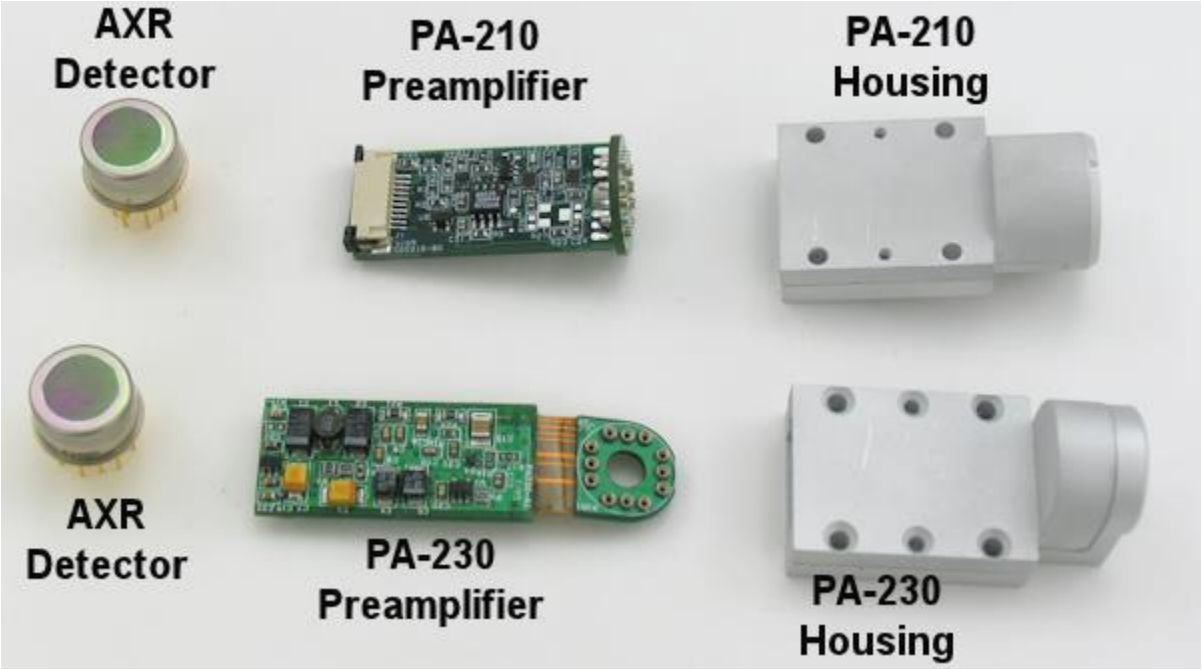
User Operating Manual

OEM Preamplifiers for Amptek X-ray Detectors



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1 Warnings and Precautions

CAUTION: READ MANUAL BEFORE USING THE DETECTOR AND PREAMP

DO NOT DROP THE DETECTOR, CAUSE MECHANICAL SHOCK TO THE DETECTOR, OR CAUSE DAMAGE TO THE DETECTOR

- Mechanical shock can damage components inside the TO-8 package.
- There is vacuum inside the TO-8 for cooling. Damage to the package can cause a vacuum leak, preventing good cooling. DAMAGE TO THE PACKAGE IS NOT COVERED UNDER WARRANTY.

DO NOT TOUCH THE THIN WINDOW ON THE END OF THE DETECTOR

- **BROKEN WINDOWS DAMAGED BY IMPROPER HANDLING WILL NOT BE COVERED BY WARRANTY.**
- The detector window is made from either thin beryllium (13 µm or less) or thin Si_3N_4 (as thin as 40 nm). The windows are extremely brittle and shatter easily.
- Do not permit any object to come into contact with the window.
- The window cannot be repaired or replaced. If the window breaks, the detector must be replaced.
- Keep the red protective cover installed when not in use.

AVOID RADIATION DAMAGE TO THE DETECTOR

- **A RADIATION DAMAGED DETECTOR WILL NOT BE COVERED UNDER WARRANTY.**
- The detector will experience radiation damage if it is exposed to a high flux environment, e.g. directly from a synchrotron.
- If the flux is low enough for spectroscopic operation, e.g. a count rate of a few hundred kcps, there will be no radiation damage in many years of continuous operation. But there are beams that produce a flux many orders of magnitude higher than this, and these will cause damage.
- Also, avoid radiation exposure to the electronics, the preamplifier and signal processor.

High voltage is present inside the preamplifier. This is typically -130 to + 180 V (depending on the detector). The current is limited to <100 µA so is not a personnel hazard.

For best performance the detector and preamplifier should be mounted to a heat sink. They should be kept away from incandescent lamps and not held in the hand. The thermoelectric cooler dissipates up to 2 W. A low thermal resistance path to a heat sink is needed to keep the detector cool, which is needed for the lowest electronic noise and for spectrum stability.

For best performance pay attention to possible sources of electromagnetic interference. Use a single point electrical ground, use the shortest length cables possible, and keep the system far from sources of electromagnetic interference, such as computer monitors, high power high voltage power supplies, etc. The signals from the detector are very small so performance can be degraded by EMI.

WARNING

This product contains the following chemicals, which are known to the State of California to cause cancer, birth defects or other reproductive harm if exposed to them through improper use, storage, or disposal of the product:

Prop 65 Chemical	Type of Toxicity	CAS No.	Product part containing the chemical
Beryllium	Cancer	--	Detector window

Please consult this owner's manual for proper use, storage, care and disposal of the product. For more information, go to: www.p65warnings.ca.gov

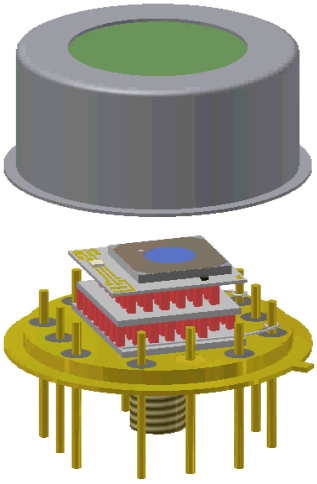
2 Document applicability

Amptek, Inc. provides a family of semiconductor X-ray detectors: SiPIN, SDD (silicon drift detectors), FAST SDD® (SDD with a special input FET), and CdTe. These different detectors have different performance specifications. Moreover, each detector type requires a different preamplifier circuit: there is a preamp circuit for the SiPINs, one for the SDDs, one for FAST SDD®, and one for CdTe.

Amptek offers three different preamp form factors for each detector type. The XR100 is most common for laboratory use; there is an XR100 for SiPINs, one for SDDs, etc. The PA210 and PA230 are much smaller preamps, optimized for OEM use. This manual describes the generic form factor and interface for the OEM preamps, the PA210 and PA230. It does not cover the specifications for the detectors; these are described elsewhere.

3 Description

3.1 Core detector technology



Amptek provides a family of high performance, compact X-ray detectors and associated signal processing electronics. The radiation detectors are custom photodiodes, including the traditional Si-PIN diodes, **S**ilicon **D**rift **D**etectors (SDDs), and CdTe Schottky diodes. The detector is mounted on a two-stage thermoelectric cooler along with the key preamplifier components. The cooler keeps the detector and key components at -25°C or below, reducing electronic noise without cryogenic liquid nitrogen and drawing <1W. This cooling permits high performance in a compact, convenient package, and has been critical to the development of portable XRF analyzers and of high performance, benchtop XRF and EDS systems.

Amptek's detectors represent the state-of-the-art in X-ray spectroscopy, delivering the best energy resolution, best efficiency at low energies, highest count rates, highest peak to background ratios, all at low cost and suitable for portable systems, vacuum systems, etc. They are used by OEMs and by laboratory researchers. The core enabling technologies include the detectors themselves (which are designed and manufactured by Amptek), the low noise JFET and CMOS technology, and the packaging which enables good cooling in a robust system.

The sketch above illustrates a detector mounted on a thermoelectric cooler, on a TO-8 header. The input FET and other components are also mounted on the cooler. A nickel cover (also shown) is welded to the TO-8 header with vacuum inside the enclosure for optimum cooling. In the cover is a window (shown green above) to enable soft X-ray detection. This is typically beryllium for energies > 2 keV, with Si_3N_4 available for lower energies. The entire assembly shown above is sometimes called the "detector", though strictly speaking it is the photodiode which detects the X-rays.

3.2 Preamplifiers and signal processors

The detector assembly shown above must be connected to a preamplifier (a circuit board containing those portions of the preamp not in the TO-8). Amptek uses reset-style charge sensitive preamplifiers for the lowest noise and highest count rates. Each type of Amptek detector (FAST SDD®, SDD, Si-PIN, and CdTe) requires its own preamp circuit. These are available in several different standard package options: as an XR100 box, as a standard OEM preamp (PA210 or PA230) or in a custom board.

The output of the preamplifier must be connected to signal processing electronics (which includes pulse shaping and a multichannel analyzer) and power supplies. Amptek has several different options for these, including the X123 (where all are integrated in a single, small box), the DP5/PC5 board stack (bare boards, for integrating into customer systems), and the PC5 module (usually used in the laboratory). Please refer to Amptek's website for more information.

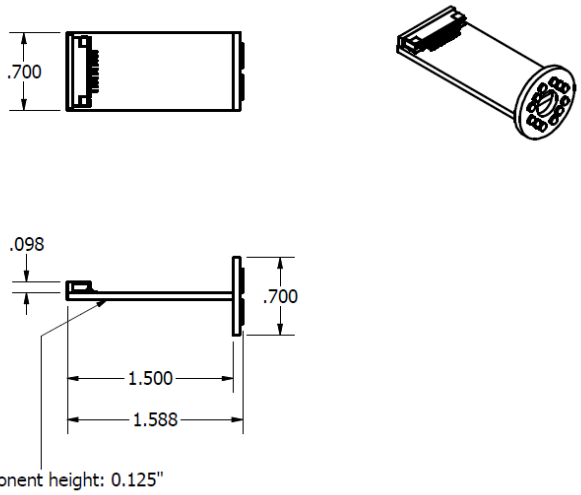
4 OEM Preamplifier Specifications

General	
Preamp Type: Reset style charge sensitive preamplifier	
Power	
Max cooling power	3.5 V / 0.45 A
Temperature monitor	Diode (1N914)
Low voltages	+/- 4.75 to 5.25 V @15 mA. No more than 50 mV p-p
HV Bias	
SiPIN	+180V @ <1 μA
SDD & FAST SDD	-100 V to – 180V @ 25 μA
CdTe	+500V to 800V @ 25 μA
Preamp Sensitivity	
SiPIN	1 mV/keV
SDD	0.8 mV/keV
FAST SDD®	3.6 mV/keV
CdTe	0.8 mV/keV
Tolerance (all)	+/- 10%
Reset range	
SiPIN, SDD, CdTe	- 2.5V to + 2.5V
Fast SDD	-0.05 V to + 2.5V

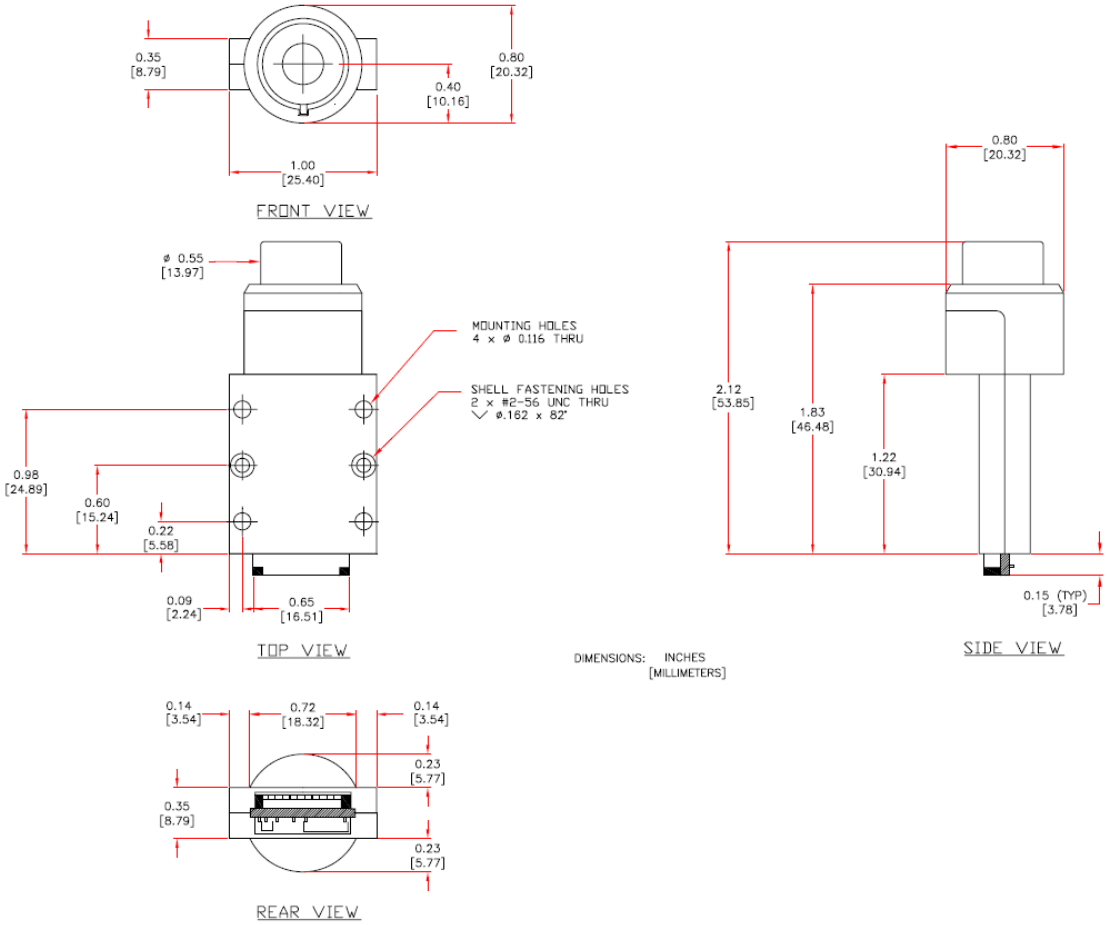
Connector (for SiPIN, SDD, FAST SDD®)	
Type	10 Pin Flat Flex Connector TE Connectivity 1-84953-0
Mating FFC Cable	Amptek ACH-421S (shielded)
Pin 1	Cooler power return
Pin 2	Cooler power
Pin 3	+5V power
Pin 4	-5V power
Pin 5	Signal Ground
Pin 6	Signal Out
Pin 7	Temperature monitor
Pin 8	Signal Ground
Pin 9	N.C.
Pin 10	HV Bias
Power Connector (for CdTe)	
Type	6 Pin RA Molex 0022288062
Mating connector	Amptek ACH-440
Pin 1	Temperature monitor
Pin 2	HV Bias
Pin 3	-5V power
Pin 4	+5V power
Pin 5	Cooler power return
Pin 6	Cooler power
Signal & Ground (coax)	RG178B/U Amptek ACH-499
Other	
Operating range	-35 °C to +80 °C @components
Storage & shipping	-40 °C to +85 °C, 10% to 90% RH noncondensing
RoHS	Compliant
Warranty Period	1 year

5 Preamplifier Mechanical Specifications

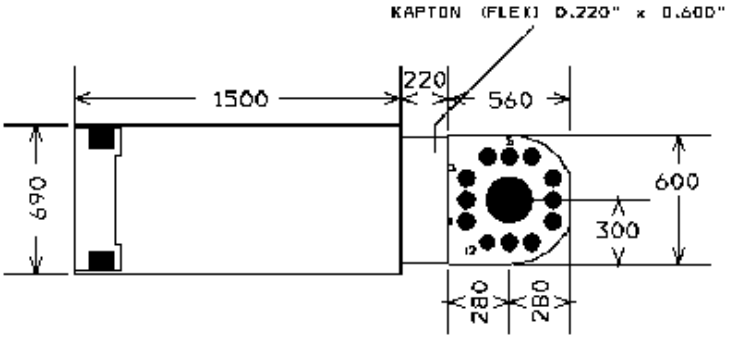
5.1 PA210 Circuit Board



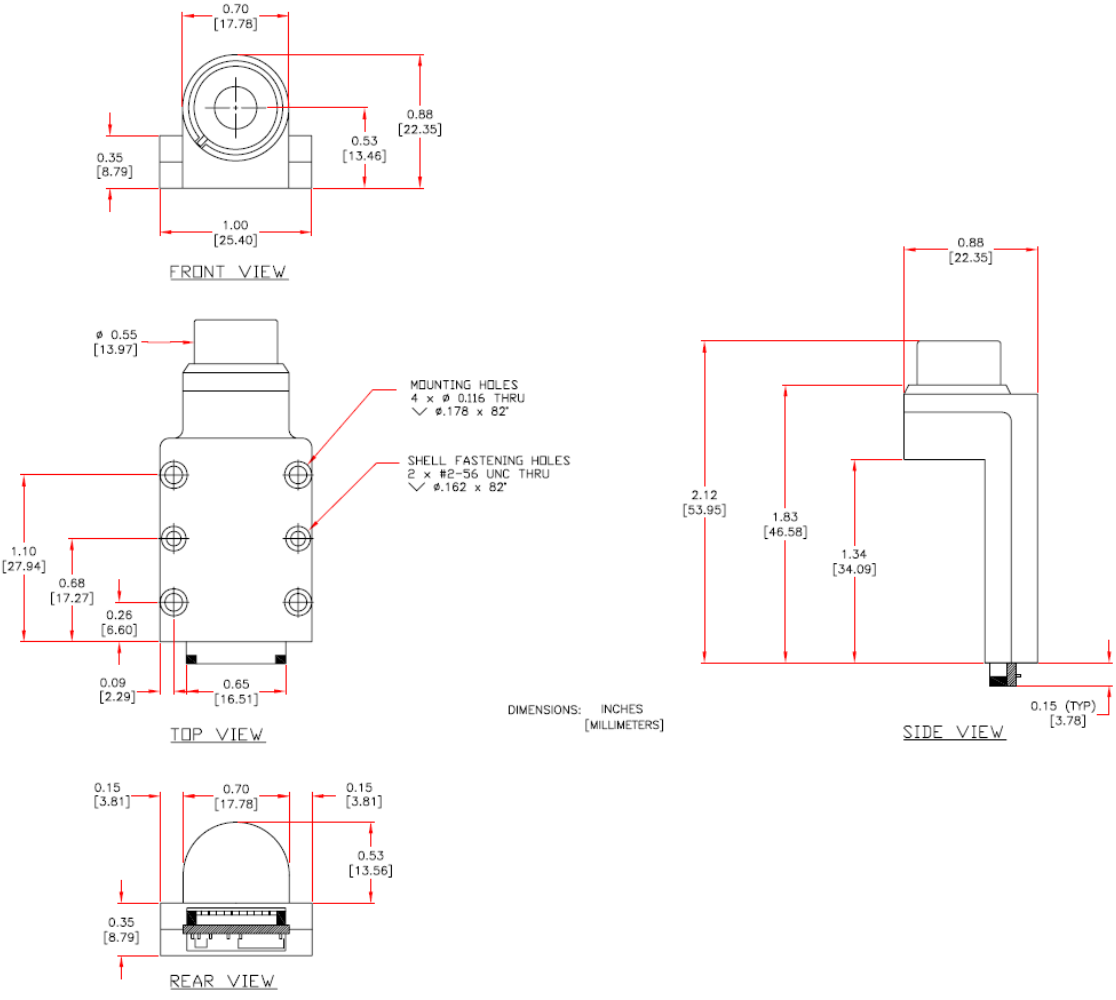
5.2 PA210 in cover



5.3 PA230 Circuit Board



5.4 PA230 in cover



6 Electrical Interface

6.1 Connection Diagram

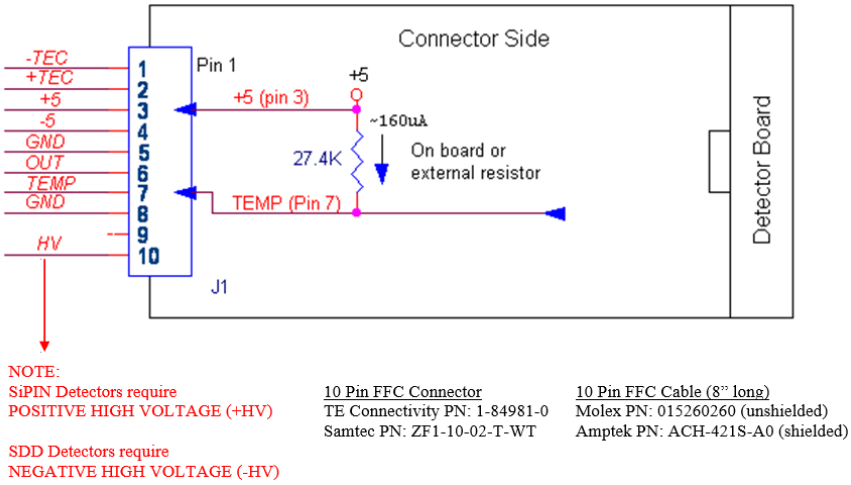


Figure 1. Block diagram of detector and preamp connections for SiPIN, SDD, and FAST SDD®.

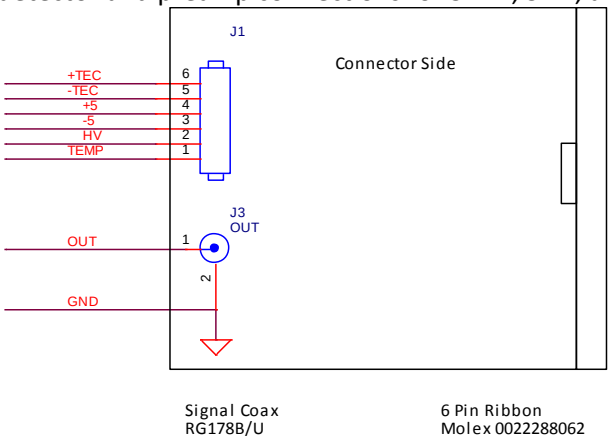


Figure 2. Block diagram of detector and preamp connections for CdTe.

6.2 Preamplifier Output Signal

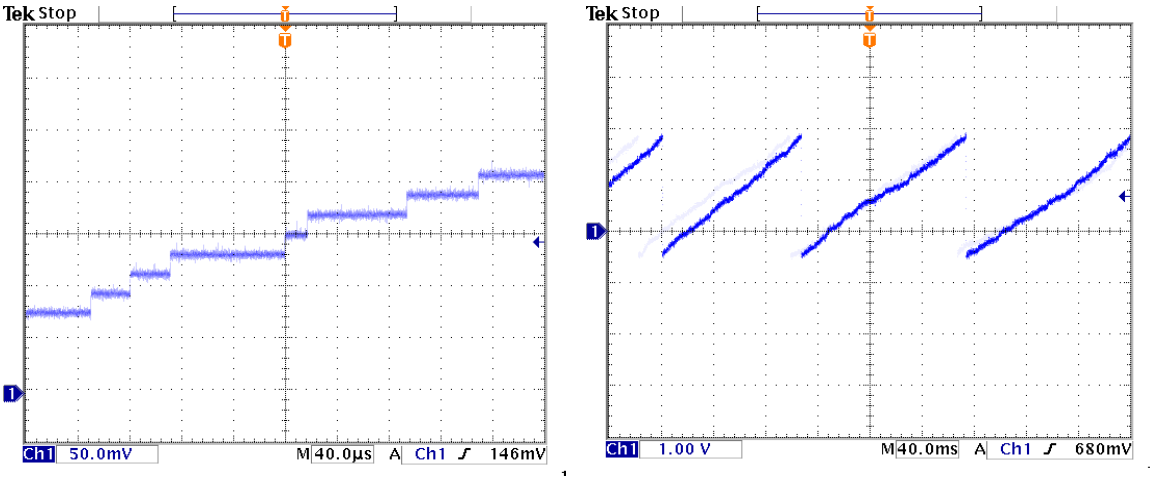


Figure 3. FAST SDD® signal output. Left: Typical signals seen from a FAST SDD® preamplifier. Each X-ray interaction results in a positive going step of ~3.6 mV/keV. Right: Typical full reset ramp

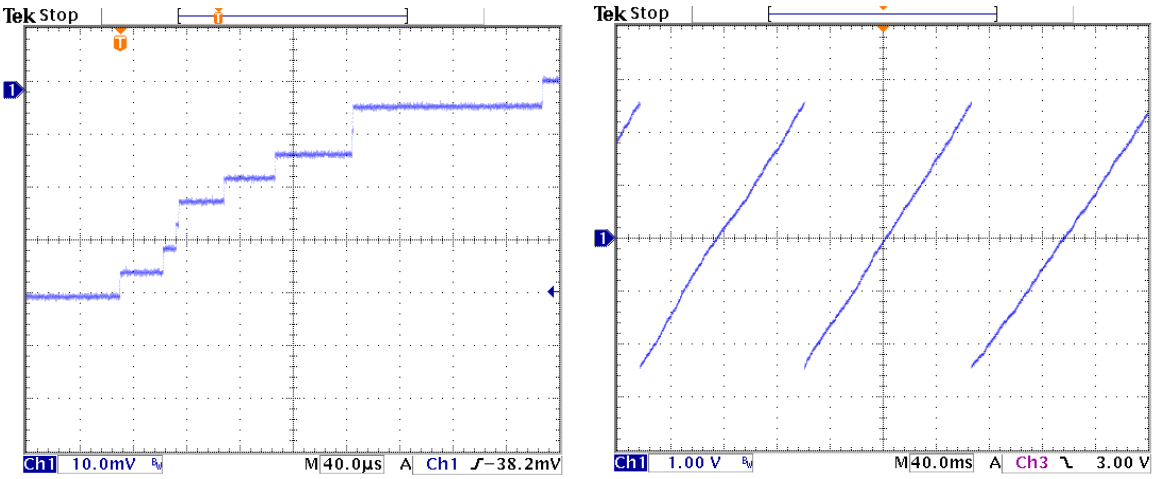


Figure 4. SDD signal output. Left: Typical signals seen from a SDD preamplifier. Each X-ray interaction results in a positive going step of ~0.8 mV/keV. Right: Typical full reset ramp

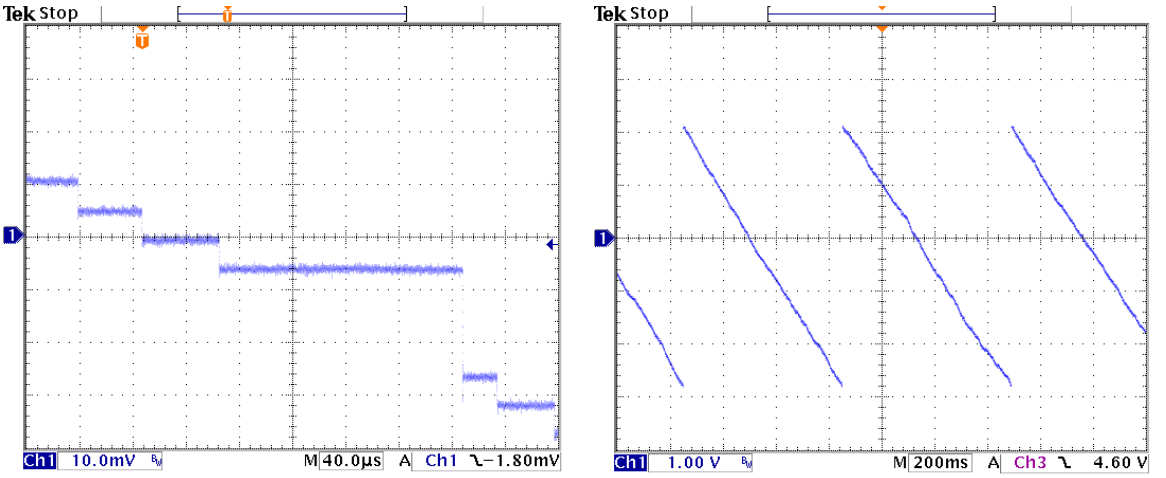


Figure 5. SiPIN signal output. Left: Typical signals seen from a SiPIN preamplifier. Each X-ray interaction results in a negative going step of ~1 mV/keV. Right: Typical full reset ramp

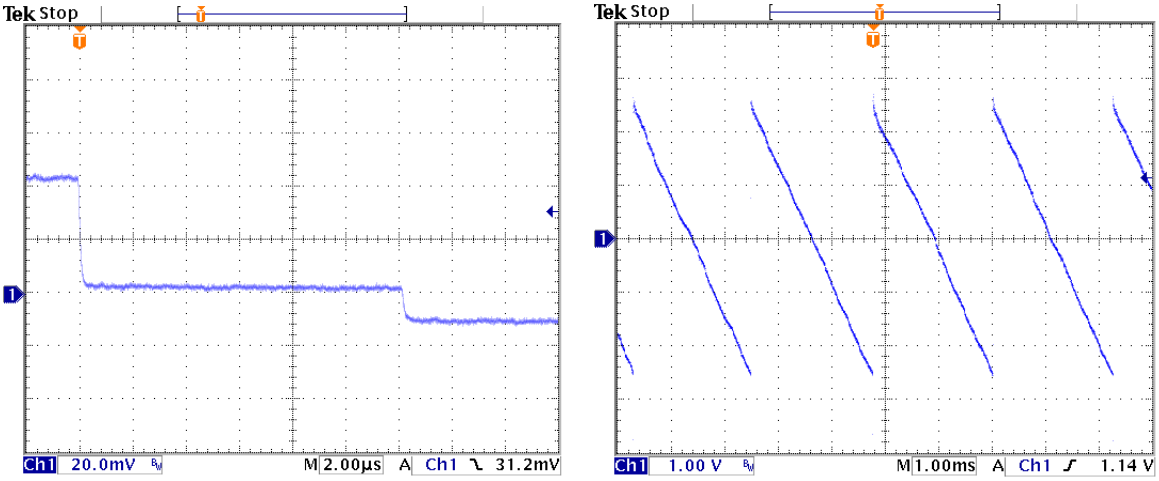


Figure 6. CdTe signal output. Left: Typical signals seen from a FAST SDD® preamplifier. Each X-ray interaction results in a negative going step of ~0.8 mV/keV. Right: Typical full reset ramp

6.3 Cooling

Recommended temperature

What is the recommended operating temperature for the detector (i.e. the photodiode itself)? The electronic noise is improved as cooling is reduced. If the goal is the best possible energy resolution, the lowest possible noise, then operate the detector as cold as possible, with the maximum voltage across the cooler. But this has a couple of disadvantages: (1) power dissipation (and heat sink requirements) increase rapidly as the detector is cooled, and (2) the detector temperature will vary as the ambient temperature varies, and gain is a function of detector temperature, so the stability of the spectrum suffers.

For most users, stability and power are more important than achieving the absolute minimum noise. For the best stability run the detector at the maximum ambient temperature that is expected (e.g. 35 °C) at full cooling. Note the temperature the detector reaches (perhaps 236 K in this example). Then use a set point that is slightly higher (240 K in this example). That way, the detector temperature is as cold as feasible, for stability, in this particular instrument.

Temperature sensor

The temperature sensor in Amptek's detectors is a forward connected 1N914 diode. At a fixed current the forward voltage is a function only of temperature as shown below. Amptek's standard processors use a 730 µA current; some OEMs use 160 µA. These yield the calibration curves shown. The calibration will change if a different current is used.

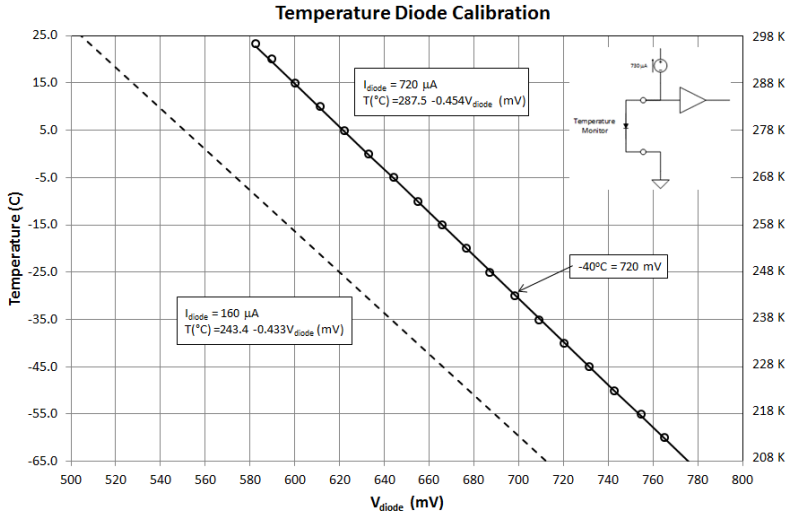


Figure 7. Temperature diode calibration curves at two diode currents, 720 and 160 µA

Thermoelectric cooler

The plot below shows the typical voltage across the cooler and the current through the cooler, as a function of the temperature across the cooler at a base temperature of 30 °C. Cooling is improved at a higher base temperature.

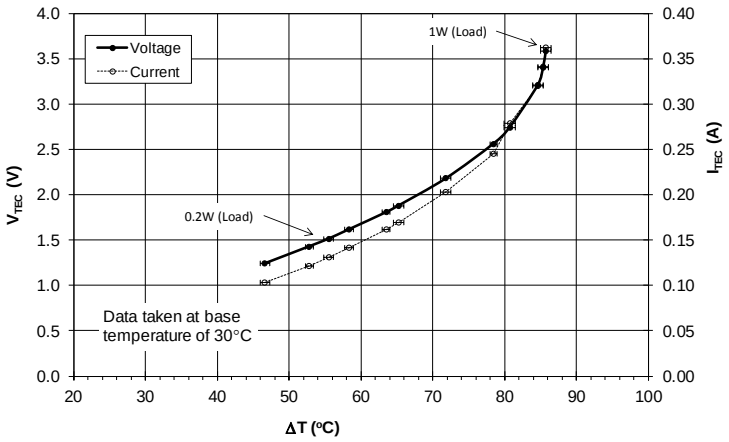


Figure 8. Thermoelectric cooler typical voltage and current curves.

Note that ΔT is difference between the temperature of the detector and that of the base, the TO-8 header and stud. This is typically warmer than the ambient environment. Good performance requires the base to be kept as cold as feasible. Note that the power drawn by the cooler decreases rapidly with ΔT. If maximum cooling (ΔT = 85 °C) occurs at 1 W, at 0.5 W ΔT is about 78 °C, and at 0.2 W, ΔT is 55 °C.

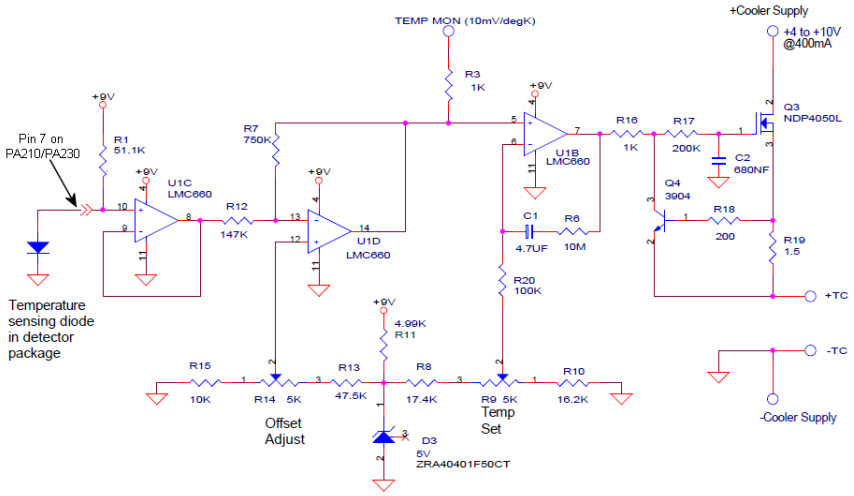


Figure 9. This example temperature control circuit supplies 160 uA through the temperature diode, corresponding to the Temperature Diode Calibration Curve for I=160 uA. If this circuit is used to control the PA-210/PA-230 preamp, DO NOT install R19 on the preamplifier since the current is set through R1 on the temperature controller circuit. Instead, connect Pin 7 on the PA-210/PA-230 to the input of the temperature controller circuit as shown in this schematic.

6.4 Supply Voltages

High Voltage

There must be very low noise and ripple on the HVPS. Amptek's power supplies include several low pass filter stages.

SDD and FAST SDD®: The recommended bias voltage for Amptek's SDD and FAST SDD® units is typically -130 V at a current of 25 µA. Any single FAST SDD® will operate with bias voltages over a large range, a factor of two, with little variation in performance. The upper and lower limits will vary from one unit to the next, so a high voltage power supply should be adjustable over a range of -100 to -180V.

SiPIN: The recommended bias voltage for Amptek's SiPIN units is typically +180 V at a current of <1 μA. The performance changes little over a fairly wide range, from the depletion voltage (typically 150V or less) up to a value above 220V, but performance is measured and guaranteed at 180V.

CdTe: The recommended bias voltage for CdTe detectors is generally between +500V and +800V. The performance of a CdTe detector does vary with bias; increasing the bias voltage improves charge collection efficiency but at the cost of increased noise. This tradeoff is discussed in more detail in the XR100-CdTe manual.

Low Voltage Supplies

The preamp power should be between +/- 4.75 and 5.25 VDC at 15 mA. There must be < 50 mV p-p noise (lower noise is recommended).

7 Operating Notes with Amptek power supply

If the unit is to be used with a power supply from Amptek, e.g. a PX5, PC5, or X-123, then follow the instructions in the "Quick Start" guide provided to you and in the "User Manual" for your power supply.

- If you have a PX5, make sure that the "preamp power" is set, via software, to 5V (rather than the 8.5V used by an XR100). Also make sure that the HV polarity is set correctly. As discussed in the PX5 manual, there is a jumper on the bottom of the unit that determines the HV polarity; one must also set the HV polarity in the software, and the PX5 verifies that the software and hardware settings agree.
- If you have a PC5, make sure that the low voltage has been configured, in hardware, to 5V and that the HV polarity is set correctly, in hardware.

8 Operating Notes without Amptek power supply

If the unit is to be used with your own power supplies, then follow these instructions.

8.1 Equipment Required

- Power Supplies
  - A dual power supply, +/-5 VDC @ 35 mA, with voltage meter & current limit
  - A power supply, zero to +3.5 VDC @ 0.7 A, adjustable with voltage and current meter
  - An HV power supply meeting the requirements of your detevctor
- Multimeter with high input impedance (>1000 MΩ).
- Signal processing electronics. For a FAST SDD®, a digital pulse processor such as Amptek's PX5 or DP5 is strongly recommended. The signal processing electronics should include pulse shaping and multichannel analysis functions.
- Oscilloscope
- Low energy radioactive x-ray source (preferably ^{55}Fe for Si detectors and ^{57}Co or ^{241}Am for CdTe)
- AC power outlet strip (preferably with surge suppression & EMI/RFI filtering).

8.2 Absolute Maximum Ratings

- Cooler power.....+0.7 AMPS
- Preamp power.....+/- 5.5 VOLTS
- Detector Bias (HV).... Depends on detector

8.3 Connections and Turn-On Procedure (without PX5 or other Amptek DPP/supply)

1) Turn all power supplies OFF. Plug all equipment to be used into one common AC power outlet strip. This will help prevent ground loops, which is crucial in getting good performance.
2) Set voltages and current limits on all power supplies as noted above. Turn supplies off.
3) Connect the flex cable to the preamp, according to the pin assignments given in section 4.
4) Attach the preamp OUTPUT to the INPUT of the signal processor.
5) Attach the preamp OUTPUT one oscilloscope input and the OUTPUT of the shaping amplifier to a second oscilloscope input.
6) Turn ON the +/-5 VDC power supplies to power the charge sensitive preamplifier
7) Increase the HV supply to its nominal value. The output of the preamplifier should exhibit a sawtooth waveform as in section 6.2 at a fairly high frequency.
8) Power the temperature sensor using a current source, as shown in section 6.3, and monitor $V_{temperature}$ (mV) with a meter.
9) While observing the meter slightly increase the cooler supply current until the temperature reading starts to change on the meter. Observe that the voltage is increasing, indicating that the temperature is decreasing. The reset frequency will decrease as the detector cools.
10) Once the temperature gets below -40 °C the performance will not change with a temperature variation of a few degrees. Now the unit is fully operational.
11) THE COOLER IS FRAGILE AND WILL BE PERMANENTLY DAMAGED IF EXCESSIVE CURRENT OR IF REVERSE POLARITY IS APPLIED. THE WARRANTY WILL BE VOID IF THE COOLER IS DAMAGED DUE TO EXCESSIVE CURRENT OR REVERSE POLARITY, OR IF THE THIN Be WINDOW IS DAMAGED.
12) Remove the red protective cover from the detector of the XR-100FastSDD. Place the X-ray source in front of the detector.
13) The output of the signal processor should show the X-ray pulses as shown in section 6.2.
14) Once the temperature has stabilized (about one minute), start taking data on the MCA. For normal operation there is no need to monitor the temperature.

9 Troubleshooting

The units has undergone extensive testing and burn-in before leaving the factory. If the performance of the system is not similar to the one recorded at the factory before shipping please perform the following tests:

If no spectrum is observed and no counts are observed:

- Double check all the power supply voltages and the signal connection.
- Make sure the preamp output is connected to a high impedance (not 50 Ω).
- Using an oscilloscope verify the presence of the periodic reset signal shown in section 6.2. If there is no reset sawtooth the detector is not functioning.
- Verify that the reset period decreases when you place a source in front of the detector.
- Check your signal processor. There are many settings in a modern signal processor (gain, input offset, thresholds, etc.) which can prevent the processor from observing the X-rays.

If a spectrum is observed but the resolution is worse than expected or the spectrum is otherwise distorted:

- Check the detector temperature and the heat sink.

  First, make sure that cooling is properly enabled. Observe the temperature the detector reaches.

  Second, check the heat sink. The thermoelectric cooler draws up to 1.5 W from the detector; if itis thermally isolated, it will heat up and the detector will heat up.

  Third, inspect the Be window on the detector. There is vacuum inside the detector. If the seal on the window is damaged and air enters the detector will not cool fully.

- Look for interference noise.

  The detector produces very small signals which are susceptible to electromagnetic interference. Connect the preamp output to its signal processor and this to an oscilloscope. Remove all X-ray sources.

  Look for periodic noise pick-up on the scope by changing the time-base dial on the scope back and forth. If you find any periodic signal on the scope (other than the Reset Waveforms), try to eliminate its source or place the XR-100FastSDD away from the pick-up area. Any periodic signal detected on the scope will degrade the resolution of the XR-100FastSDD.

- If you are using an Amptek signal processor and/or power supply refer to its User Manual and to Amptek's "Troubleshooting guide" and to Amptek's "Grounding and shielding" application note.

- IF ANY QUESTIONS REMAIN CONTACT THE FACTORY FOR FURTHER ASSISTANCE AND RETURN PROCEDURES. If you are using an Amptek signal processor please follow the instructions for "Saving a .MCA file and obtaining diagnostic data," which can be found on your installation CD.

10 Warranty and Technical Questions

10.1 Warranty

AMPTEK, INC. warrants to the original purchaser this instrument to be free from defects in materials and workmanship for a period of one year from shipment. AMPTEK, INC. will, without charge, repair or replace (at its option) a defective instrument upon return to the factory. This warranty does not apply in the event of misuse or abuse of the instrument or unauthorized alterations or repair. AMPTEK, INC. shall not be liable for any consequential damages, including without limitation, damages resulting from the loss of use due to failure of this instrument. All products returned under the warranty must be shipped prepaid to the factory with documentation describing the problem and the circumstances under which it was observed. The factory MUST be notified prior to return shipment. The instrument will be evaluated, repaired, or replaced, and promptly returned if the warranty claims are substantiated. A nominal fee will be charged for unsubstantiated claims. Please include the model and serial number in all correspondence with the factory.

10.2 Technical Questions

- Please refer to http://amptek.com/technical-support/
- Please have the model and serial numbers of your Amptek device(s) available. Please have available a description of the signal processing and other electronics used with the device.
- Contact Amptek at amptek.sales@ametek.com or +1 781-275-2242.