

TROUBLESHOOTING GUIDE FOR AMPTEK DIGITAL PULSE PROCESORS

This guide is intended to help users through the most common difficulties associated with Amptek's current family of digital pulse processors (DPPs). These units include the DP5 and X123 (running FW6) and all models of the PX5, the Gamma-Rad5, and the MCA8000D.

1 General advice

- 1) Each Amptek DPP comes with its own "Quick Start Guide". A paper copy was shipped with your product, while an electronic copy is on the installation CD. Follow the instructions for your product.
- 2) Incorrect installation of the application software or USB drivers is the most common source of problems with Amptek's DPPs. Software installation is simple but must be done correctly. It is described in a document entitled "Amptek DPP Software Installation"
- 3) Cables and connections are the second most common source of problems. Check that all necessary connections are made and that power has been turned on. Double check connections: cables can sometime be partially inserted, so they fail to make electrical contact. Remove connectors and reinsert to check. Pins can get bent or broken, so visually check connectors if needed.
- 4) The third most common problem is an incorrect configuration setting. There are many configuration parameters in Amptek's digital processors. Each user can optimize the system for a particular application but one can also configure the system so that it takes no meaningful data.
 - a. We provide default configuration files for Amptek's standard system. If you get no spectrum, load the default to get to a functional baseline. We also provide, for each system, a paper with a printout of a spectrum with a listing of the parameters used at the factory. Loading these parameters can also get one back to a functional baseline.
 - b. If you have the system basically working but the performance is not what you expect, then adjusting configuration parameters is likely important. Amptek's DPPMCA software includes an extensive online HELP function, with many "How To" guides and several "FAQ" items.
- 5) If everything seems to be installed, connected, and configured properly but the resolution is poor, then electromagnetic interference is a frequent problem. Ground noise is the most common culprit. Refer to section 9 of this guide. For Amptek's Peltier cooled detectors (XR100, PA210, X123, etc) proper heat sinking is vital; improper heat sinking is also a frequent cause of poor resolution.

2 Technical support

- If you cannot solve the problem after following the proper "Quick Start Guide" and the instructions in this document, then please contact Amptek, Inc., at 781-275-2242x132 or at sales@amptek.com.
- When you contact us, please have some critical information ready. First, we need to know the system that you have: e.g. an X123, an XR100 with a PX5, a PA210 with a DP5, etc. Second, we need to know what type of detector you have. On the detector hybrid is a set of letters and numbers, e.g. FSG32MD-G3SP. Please have this number ready. Third, we usually need you to connect to the processor, take a spectrum, and save it as a .MCA file. Even if there are no counts, all zeroes, save this file because it includes configuration settings and other details we can read.

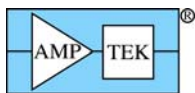
3 If the DPPMCA software does not run, then ...

3.1 Copy the DPPMCA folder onto the hard drive.

DPPMCA.EXE cannot be run from the installation CD, because it must write to files in the same directory. Copy the entire *DPPMCA* folder from the installation CD, or download it from the website, and place it on your hard drive. We recommend creating an Amptek folder in the Program Files folder. We recommend placing a shortcut to DPPMCA.EXE on your desktop.

3.2 Put necessary files into the same directory as DPPMCA.EXE.

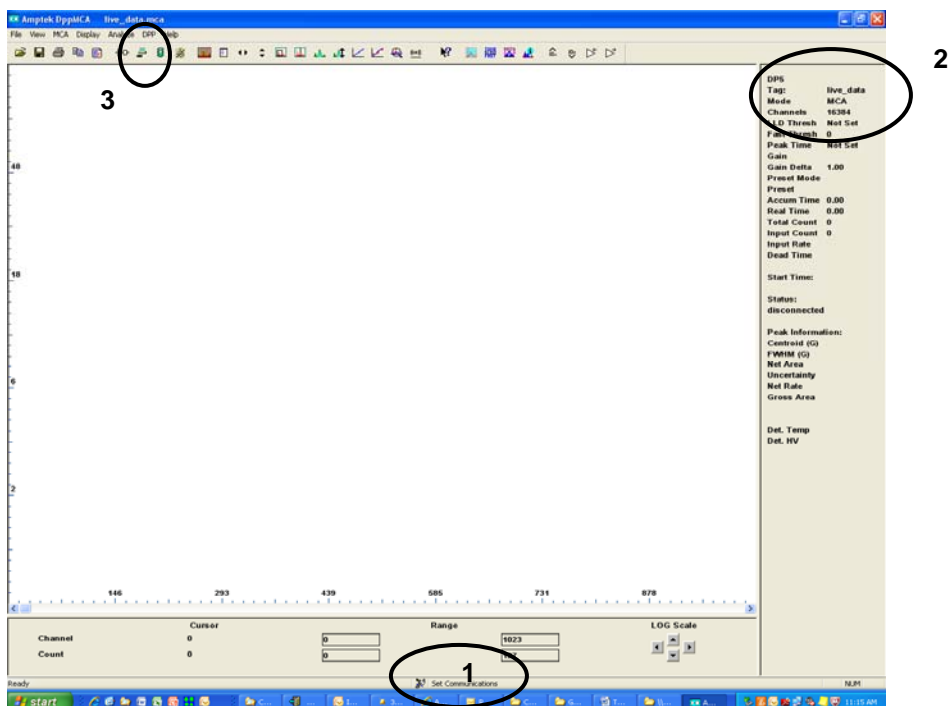
DPPMCA.EXE must read from and write to files in the same directory. Copy the entire *DPPMCA* folder from the installation CD, or download it from the website, and place it on your hard drive.



4 If the DPPMCA software runs but I cannot connect to my DPP, then ...

How to tell it is not connected:

- 1) It says "Set Communications" (a green USB symbol or an IP address indicate a connection).
- 2) There is no serial number for the DPP and the parameters in the info pane are incorrect.
- 3) The "Connect/Disconnect" toolbar button does not show a connection.



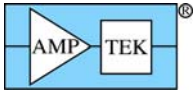
4.1 Press the "Connect" button in the software.

When DPPMCA launches, it will usually launch the "Select communication port" box. In this box, you can choose to connect via USB, Ethernet, or RS232. You must select the appropriate one, then click OK. If you launched without connecting, try again to connect, by pressing the "Connect/Disconnect" button on the toolbar, then "Find device" on the proper port.

4.2 Check cables and connections.

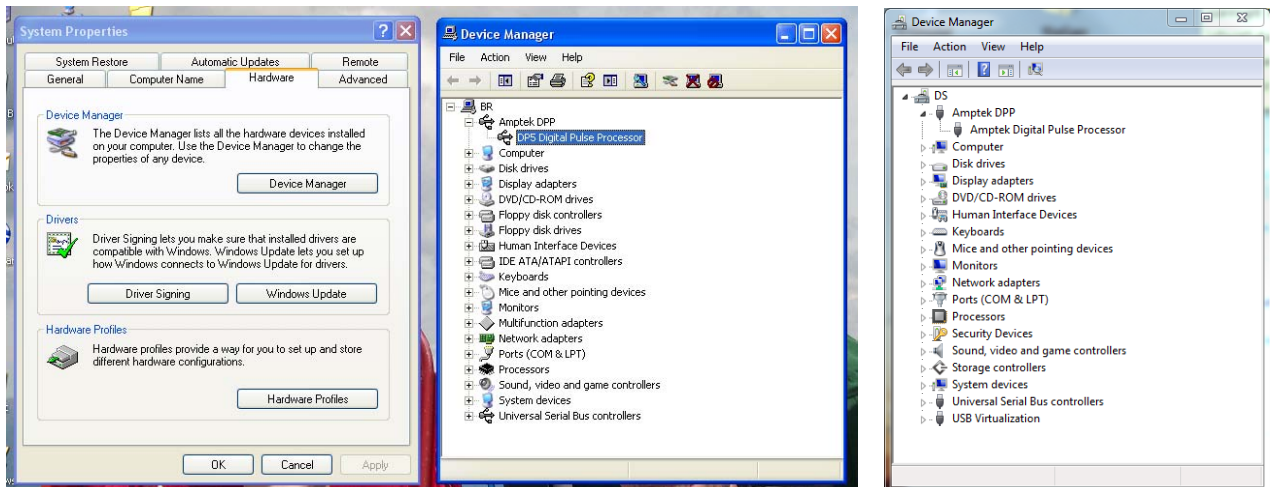
The connection requirements depend on which product you have selected, so refer to the appropriate Quick Start guide. You must have a communication cable (USB, Ethernet, or serial) connected. Your device may require a separate power plug or may be powered over USB or Ethernet.

- **Check power.** If the unit is powered, then an LED on the Ethernet connector will light. For the PX5 and MCA8000D, a front panel LED is also lit. Some Amptek DPPs have a power switch, some are turned on by plugging in the AC/DC adapter, and some are powered over USB, so refer to the "Quick Start Guide" for powering your unit.
- **Check communication cables.** For USB, the processor connects directly to a USB port on the computer. The computer will automatically detect the port. For Ethernet, the processor must be connected to a hub, and then the hub connected to the computer (you cannot connect directly to a computer via Ethernet). For RS232, connect from the serial port on the computer to the stereo jack on the processor. You must select the correct serial port in software.
- If all cables seem to be in place and it still does not communicate, then remove each of the cables and try to reseal them. Sometimes they are mechanically engaged but not making an electrical connection. Check also for bent pins. Sometimes, the cables themselves have problems. If you have tried everything else, try replacing the cables.



4.3 For USB, check driver installation.

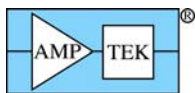
- If you are using USB, it is important to install the correct driver. A table showing compatibility for different situations is at <http://www.amptek.com/winusb.html#fw>.
- The simplest way to check if the correct driver was installed is to go to "Control Panel", then "System". Select the "Hardware" tab, then "Device Manager". The screen capture below shows what you will see, with the DPP connected.
- Amptek's current generation of products (DP5 and X-123 with FW6, PX5, Gamma-Rad5, DP5G, and MCA8000D) should list "Amptek Digital Pulse Processor".
- A DP5 with the FW5 firmware (backward compatible with Amptek's older DPPs) or an older device (DP4 or PX4) with update firmware will list "DP4 Digital Pulse Processor".
- A DP4 or PX4 as originally shipped will list "Amptek Legacy Digital Pulse Processor". These DPPs will not work on a 64 bit operating system.
- If you installed the incorrect driver, then refer to the instructions on the installation CD for manually removing USB drivers. Follow these instructions carefully!



4.4 Check software versions.

Amptek has released two different versions of the data acquisition and control software, ADMCA.EXE and DPPMCA.EXE.

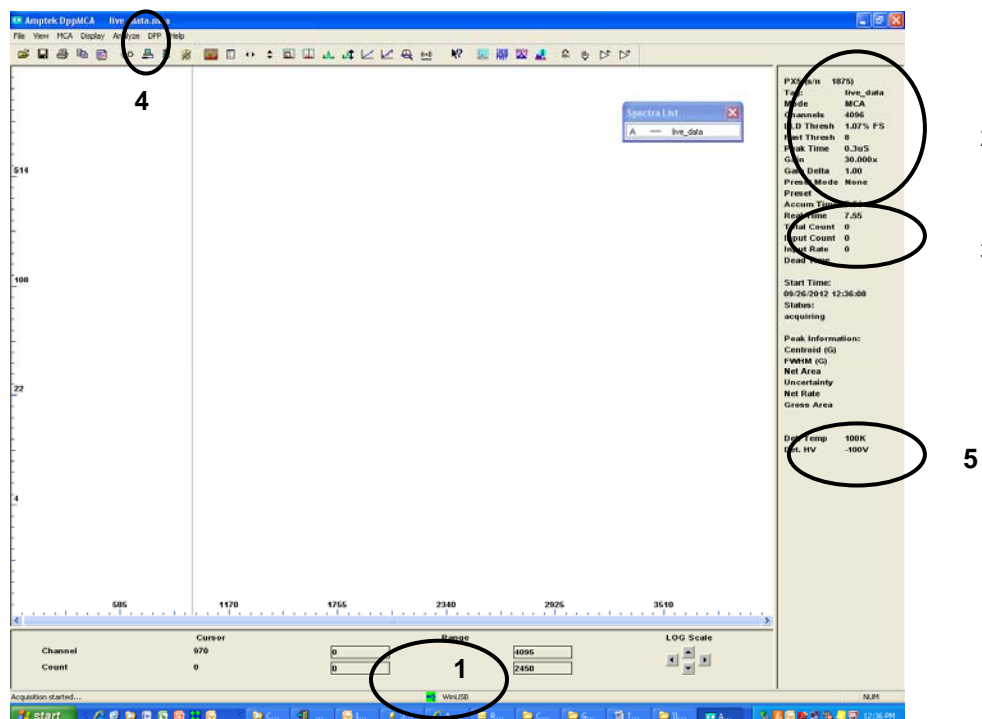
- ADMCA was used with Amptek's older processors, including the DP4, PX4, and the original release of the DP5 (which ran the FW5 firmware).
- DPPMCA is used with Amptek's current processors, including DP5s and X-123s with new firmware (FW6), the PX5, the Gamma-Rad5, and the MCA8000D.



5 If the DPP is connected but you don't see any counts, then ...

How to tell it is connected but getting no counts

- 1) There is a green USB icon indicating a valid connection. For Ethernet, the IP address is shown. For RS232, a green icon is shown with the port number.
- 2) In the Info Pane, the serial number is shown, along with valid values for gain, peaking time, etc.
- 3) The counts in the info pane are, however, zero and nothing is seen in the spectrum.



5.1 Start acquiring data

To record a spectrum and see counts, one must start acquiring data. Press the button on the toolbar which looks like a stoplight (number 4 above). When acquiring data, it will be red and you press it to stop. When not acquiring data, it will be green and you press it to start. When acquiring data, the acquisition time should be changing.

5.2 Make sure a source is present.

Make certain you have placed your isotopic source in front of the detector or turned on the X-ray tube. This may seem obvious but many users have forgotten this.

5.3 Check cables and connections.

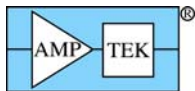
In some DPPs (e.g. the PX5 with XR100), there are communication and power connections to the processor and also connections to the preamp and detector. You may have connected the processor but not the preamp power or the signal. Double check all connections.

5.4 Check key parameters:

First, check the info pane (number 2). The top row will show the type of device and its serial number. Make sure it matches your DPP.

Second, check the high voltage (in number 5). Each type of detector has a different optimal HV bias, so make sure it is correct.

If the high voltage is zero, and you are using this to bias your detector, it will not function. Turn on the HV. In many Amptek DPPs, the HV can be set to either polarity. The polarity is set by a



hardware jumper. There is also a software polarity setting, and the DPP checks to see if the two match. If they do not match, then HV is disabled, so confirm the polarity. In the PX5-HPGe, there is also a HV Disable signal (and a polarity jumper for this signal) which should be checked.

Third, check the temperature. For a Peltier cooled system, the detector temperature is regulated to a value set in software, usually 220K to 250K. A temperature outside of this range usually indicates a problem. In the screen capture above, the reported temperature is 100K; this indicates that no detector is attached. If the temperature in a Peltier cooled system is at room temperature, e.g. 290K then either the cooling is not turned on or the detector has been damaged (there is vacuum in the hybrid, and if the Be window is broken, it will not cool).

Fourth, check the voltage to the preamplifier. Press the "Acquisition Setup" button, then the "Power" tab. For an X123 or system with a PC5, it should read "ON". For a PX5 system, it should read either "8.5V" or "5V", depending on the preamplifier.

5.5 Load the default configuration

The input polarity, the input offset, thresholds, gain, gate settings, and various other configuration parameters can, if set incorrectly, lead to no counts in the spectrum.

5.6 Look for damage to the detector.

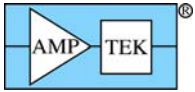
For products using Amptek's thermoelectrically cooled detectors, inspect the hybrid package for damage. There is vacuum inside the enclosure. If there is any damage at all to either the Be window or to the Ni cover, even a small crease, then air will leak inside and it will not work. Shake the detector and preamplifier very gently next to your ear. If you hear a rattle, then something has broken inside. In either case, you will need to contact Amptek.

5.7 Look at the preamp outputs.

If you have a system with a separate preamplifier, an XR100 or PA210 or CoolFET, then connect the preamplifier output to an oscilloscope. If you see the correct out, then the detector and preamplifier are working and the problem is in the processor, probably in its configuration (polarity, gain, etc).

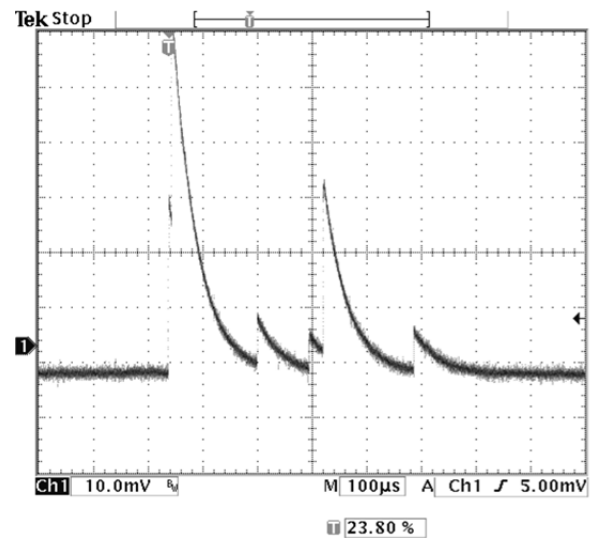
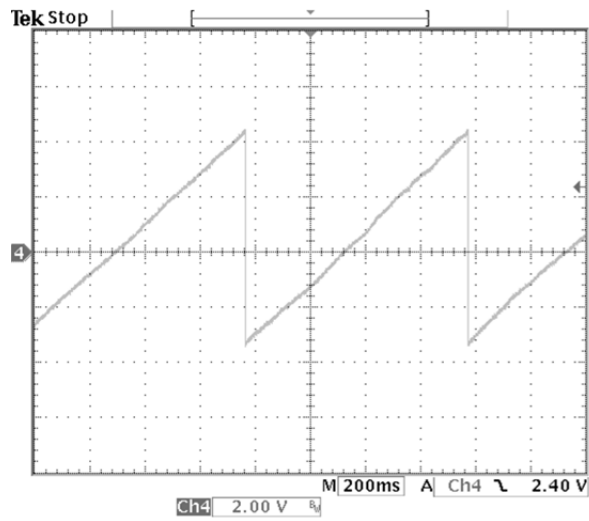
For reset-style preamplifiers, you should see a sawtooth, where the signal charge is integrated on the feedback capacitor until it resets. The sawtooth covers several volts with a period that can be tens of seconds, at full cooling and with no source. If you see this sawtooth, then put a source in front of the detector and the reset frequency should increase.

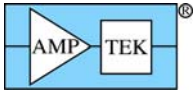
For continuous feedback preamplifiers, you should see a waveform like that displayed on the right below. The output has some DC offset (often negative and possibly hundreds of millivolts). Every X-ray interaction yields a small pulse with an exponential tail. This plot is from an HPGe gamma-ray detector, so pulses are large and the tail has a 50 μ s time constant. In X-ray detectors, the pulse may only be millivolts in amplitude and have a time constant of milliseconds. If you put a source in front and see tail pulses, then the detector and preamplifier are working.



www.amptek.com

AMETEK
MATERIALS ANALYSIS DIVISION

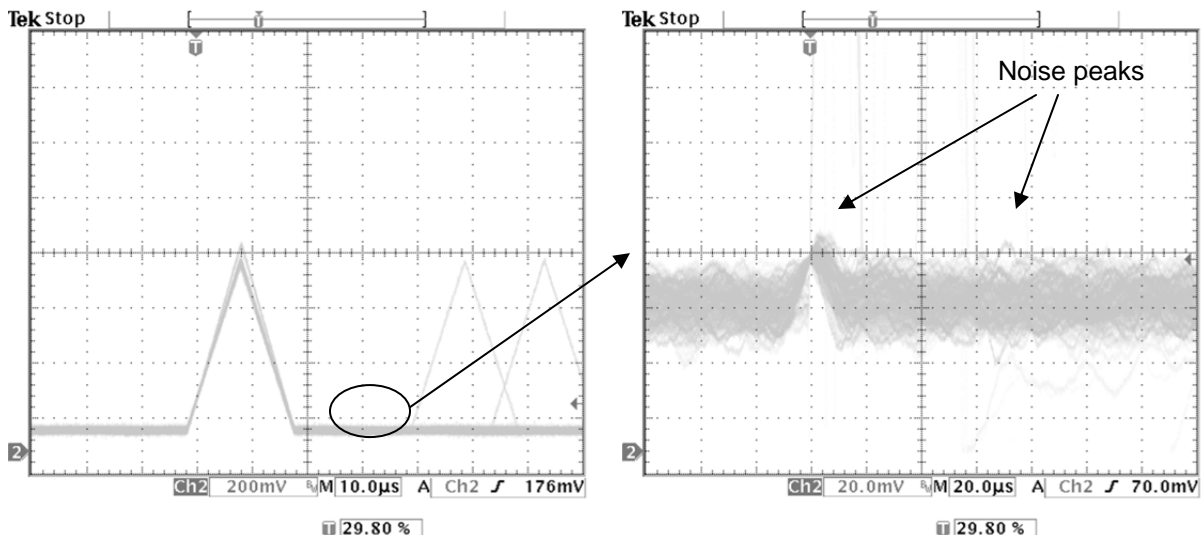
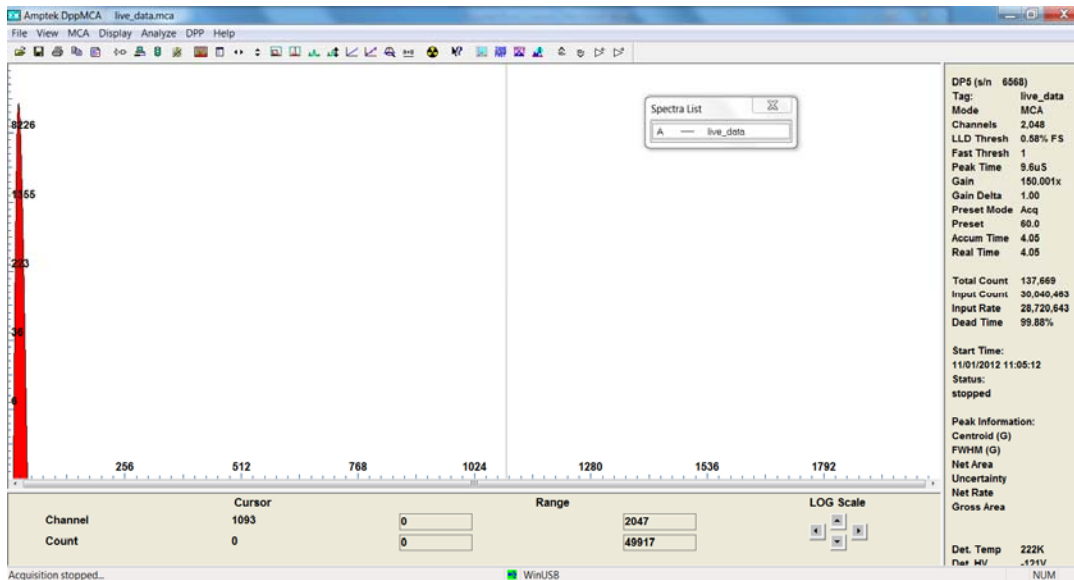




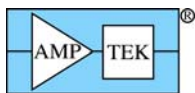
6 If the spectrum only shows a big spike in the lowest channels, then ...

What you will see for this case

The plot below shows a typical DPPMCA screen for this case. There is a large spike at the low end, a very high count rate, and a huge dead time. The problem is that peaks of the electronic noise exceed the thresholds, as shown in the oscilloscope traces. This may be because (1) a system parameter (such as gain or peaking time) was changed, which increased the noise, and the thresholds were not adjusted, or (2) because there is no radiation source so the only peaks are from noise, or (3) because a problem in the system is causing excessive noise. You may see only high counts in the fast channel, or in the slow channel, depending on the settings.



Left: Oscilloscope trace of normal pulses. Right: Intrinsic noise, observed by zooming in on the baseline. If the noise is large, relative to the threshold, then the noise peaks are measured and show up in the spectrum as a high rate of counts.



6.1 Set the thresholds.

If you changed the gain, peaking time, or virtually any parameter, then the thresholds need adjusting. Remove the source or turn off the X-ray tube, start a data acquisition, then press the "Tune Fast/Slow Threshold" button, while acquiring data, then try again.

Note: The "Tune Fast/Slow Threshold" algorithm sets the thresholds to give about 1 count per second in each channel. The fast channel is tuned by first reducing the threshold to zero, which causes a very high count rate, and then raising it until a 50 millisecond interval passes with no count. The slow threshold is tuned by reducing the threshold to zero, taking a 1 second spectrum, then computing the channel with only one count above. If you have a source present, then the count rate will never drop to one per second, so the algorithm fails. In some detectors, e.g. the Gamma-Rad5, background radiation will often keep the count rate above 1 cps. In these cases, you can manually adjust the thresholds to get a constant count rate. You can also manually adjust the threshold after auto-tune, if you want to. Many customers find it convenient to manually raise them slightly.

6.2 Make sure a source is present.

If your source is not present or the X-ray tube is off, then there is no signal, only noise, so the noise spike will be the only thing visible. Make sure you are exciting the detector.

6.3 Check for proper cooling and bias

If the detector is not cooling properly or is not properly biased, you may get excessive noise, so check these parameters on the display. Check connections as well: some customers have turned on the high voltage or cooling in the power supply but had poor connections to the preamplifier. This is particularly likely with OEM systems using the PA210 type preamplifiers.

6.4 Check the configuration parameters

If the gain is much higher than expected, then the noise will appear too high. If the peaking time is far different than expected, the noise will appear too high. Check the gain. In general, review the configuration parameters and consider using a default set.

6.5 Check for interference

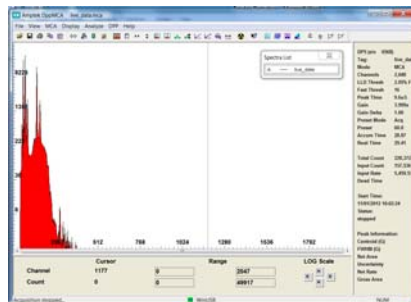
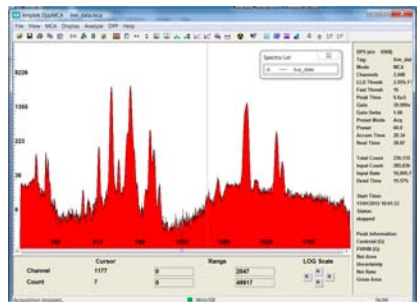
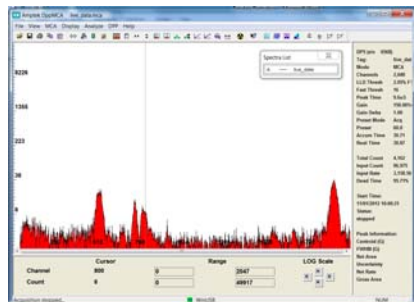
See section 9.

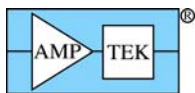
7 If the spectrum is far different than you expect, then ...

There are many different causes for a spectrum to be different than expected! We cannot cover all possible cases in this brief note, but the following are the most common issues.

7.1 Check the gain

The plots below show spectra measured from solder (Pb-Sn peaks) under the same conditions, except with three different gain settings: very high (left), correct (middle), and very low (right). If the gain is way off, you will not see the peaks you expect. We recommend setting the gain so that the largest amplitude pulses are near the upper channels. For more information on setting the gain, refer to the FAQ in DPPMCA Help.





7.2 Check the fast and slow counts

Do you see many fast counts, but nothing in the spectrum and no slow counts?

The root problem here is that the fast threshold is too low. It is triggering often on noise. Pile-up rejection will veto any pulse followed by a fast pulse; if the fast threshold is always firing on noise, it will veto everything. The simplest solution is to raise the fast threshold.

However, it is possible that you have too much noise in the fast channel. You can check the fast channel peaking time. You can review the configuration parameters in general. You can turn off pile-up rejection, so the extra counts are ignored. You may have high frequency electromagnetic interference (the fast channel is sensitive to > 1 MHz, while the slow channel is more sensitive to 20-100 kHz). So this may point to deeper issues.

Do you see more counts in the slow channel than in the fast channel?

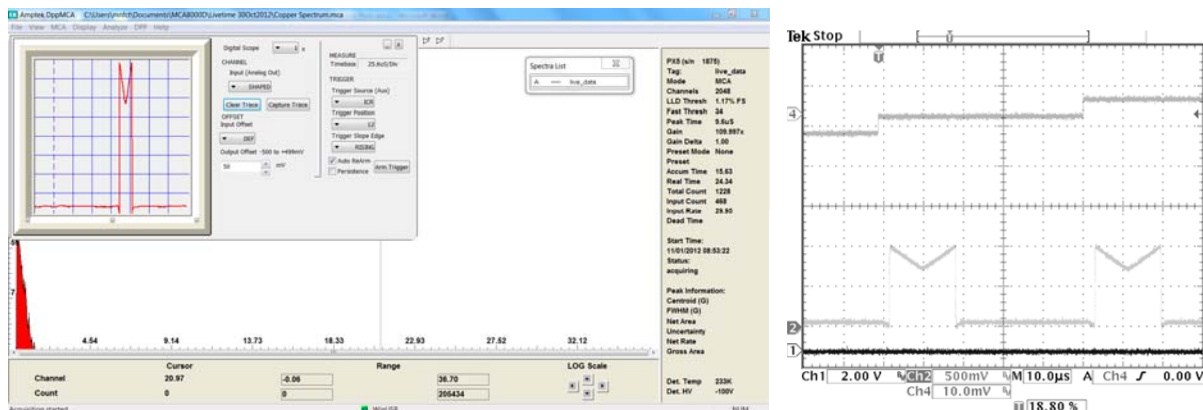
This is caused by improper threshold setting. The fast and slow thresholds and channels are discussed in the FAQ in DPPMCA Help.

Are you operating at a high count rate?

We strongly recommend doing initial setup and checkout at a very low count rate and then increasing. High count rates introduce the possibility of many additional issues so start simple.

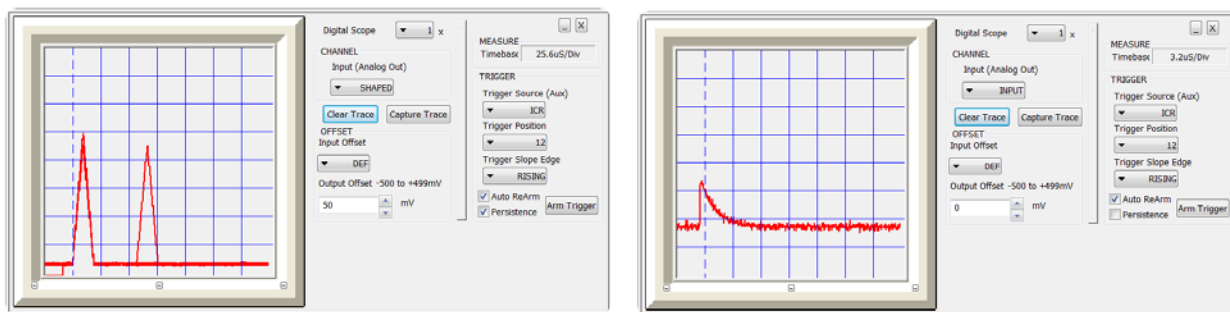
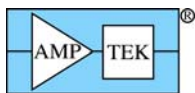
7.3 Check input polarity

The plots below show what one observes if the input polarity is wrong. The plot on the left shows both the spectrum and "oscilloscope mode" display, while the plot on the right is from an oscilloscope. The "peaks" are now negative going. The odd looking trace in the scope arises because the DAC output wraps around: instead of dropping below zero, it goes to the maximum and then drops. In the spectrum, the processor is not finding true peaks and so the resulting spectrum is incorrect.

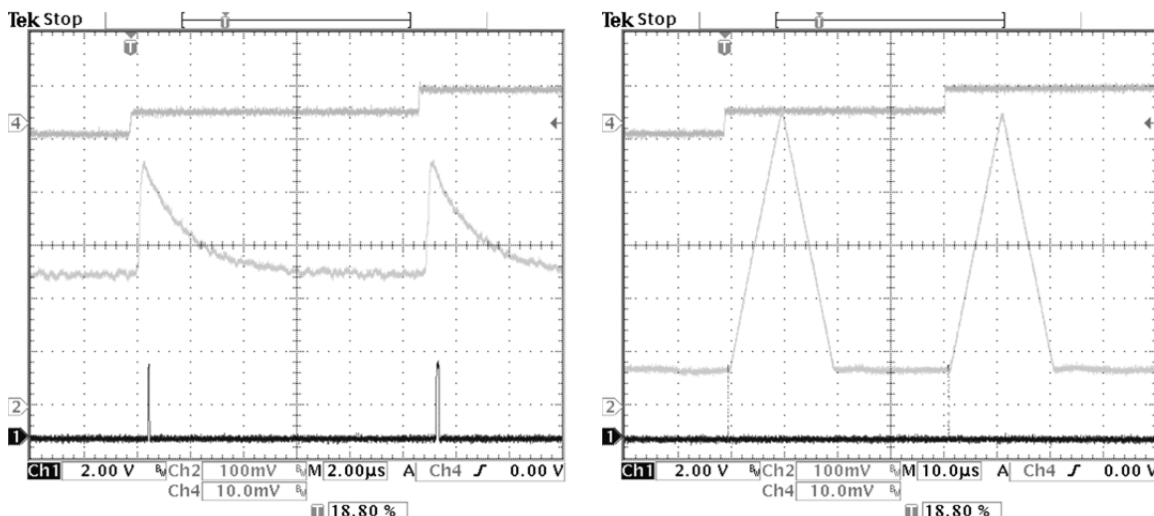


7.4 View the pulses

There are two different ways to look at the pulses in the processor. The DPPMCA software includes an oscilloscope mode, which displays the pulses on the computer. You can use this to view the shaped, input, or fast pulses to make sure parameters are set right. You can trigger this internal scope using the fast channel (ICR) or the other logic signals. Note that you must click the "Arm Trigger" button. The plot on the left below shows the shaped pulses, while the plot on the right shows the input (this is the input to the ADC). The input is very useful, since you can check polarity, for overshoot/undershoot, and to verify the DC offset (if you set the output offset to zero, it shows you the actual DC offset into the ADC, which must be large enough that the input never goes negative).



Although oscilloscope mode is convenient, it does not really provide all the capabilities of a true oscilloscope. You cannot adjust vertical or horizontal scales and you must trigger using a logic output (and the system must be close to correct to get these). If you have a system which produces a diagnostic analog output (such as the DP5, PX5, or Gamma-Rad5), then you can view the diagnostic output with an oscilloscope. The exact shape depends strongly on the processor, the type of detector, and the configuration parameter. The plot below shows typical pulses.



7.5 Check performance over count rate.

Do you see the photopeaks shifting as you increase count rate?

With most solid state detectors, such as the SDDs, the SiPIN detectors, and HPGe detectors, the problem lies in BLR settings. The BLR has separate slew rate settings for UP and DOWN corrections. If you observe the photopeaks to shift up with increasing count rate, then increase the DOWN slew rate or decrease the UP slew rate.

Amptek's CdTe detectors are available with three different options: transistor feedback (-T), resistive feedback (-R), or reset (-CR). The -T feedback provides excellent energy resolution but the gain will shift at count rates above a few kcps.

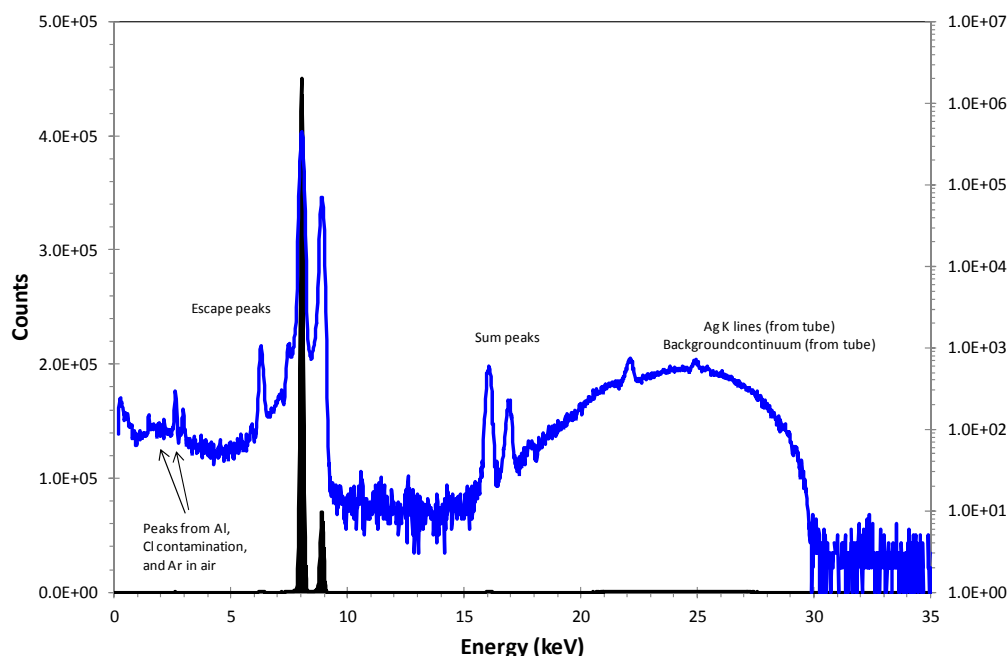
Customers using the DP5G with their own scintillator/PMT system must make sure that their components are stable. The resistive divider used with most PMTs results in significant changes in gain at high count rates. Amptek's Gamm-Rad5 uses an active divider for enhanced stability.

Do you see need to operate at a very high rate, e.g. 1 Mcps?

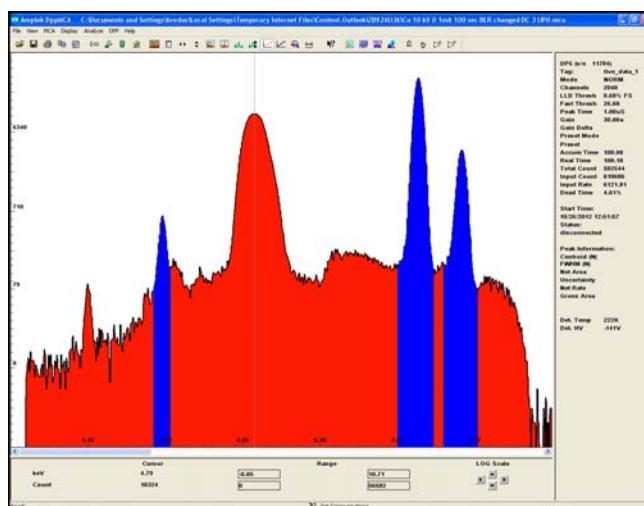
At the very highest rates (typically around 1 Mcps) and at short peaking times, the pile-up at the ADC input can cause the input to exceed the ADC's range. This leads to several odd artifacts throughout the spectrum. Amptek can tailor your processor for these conditions. Contact Amptek for support.

7.6 Make sure you know what to expect.

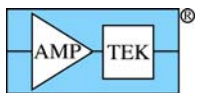
In many cases, when a user observes features in the spectrum which he/she does not expect to be there, the spectrometer is correctly measuring its input spectrum, but the spectrum includes second order features which the user did not expect. The plot below shows the spectrum measured from a pure copper target, excited by an X-ray tube at 35 kVp, in both a linear and a logarithmic scale. The Cu K_{α} and K_{β} lines are clearly dominant but there are many secondary features which may surprise users. This is discussed in a separate application note, but some of the key features include: (1) escape peaks located 1.74 keV below the primary peaks, (2) sum peaks due to pulse pile-up, (3) a peak at the Ar K_{α} line (due to Ar in air), (4) a peak at the Al K_{α} line (due to Al used in constructing the detector), and (5) a peak due to the Compton scattered Ag K X-rays (from the Ag anode in the tube). Diffraction peaks, which have a distinctly non-Gaussian shape are often very puzzling.



Typical spectrum measured from a pure copper sample.

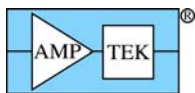


Left: Plot showing a diffraction peak from a copper sample. Note the broad peak away from any expect characteristic X-ray lines.



www.amptek.com

AMETEK[®]
MATERIALS ANALYSIS DIVISION



8 If the resolution is worse than you expect, then ...

8.1 Check for good cooling

In Amptek's thermoelectrically cooled detectors, the back of the detector is the heat sink. In Amptek's XR100 and X123 products, this is connected to the case. The detector is cooled relative to the back of the detector. If the back of the detector gets warm, so will the detector, and resolution will be degraded. It is very important to provide a good heat sink from the preamp case or detector back to ambient. Many customers have found that much more heat sinking was required than they initially expected.

8.2 Check the bias voltage

Each detector has a specified bias voltage. Either over-voltage or under-voltage can affect the resolution. Make sure you bias your detector correctly. Please refer to the specifications for your detector or to the datasheet supplied with your detector, which will show the bias used at the factory.

8.3 Compare the measured resolution to theory

Check resolution and energy

Monoenergetic X-rays or gamma-rays in solid state detectors have a theoretical resolution of

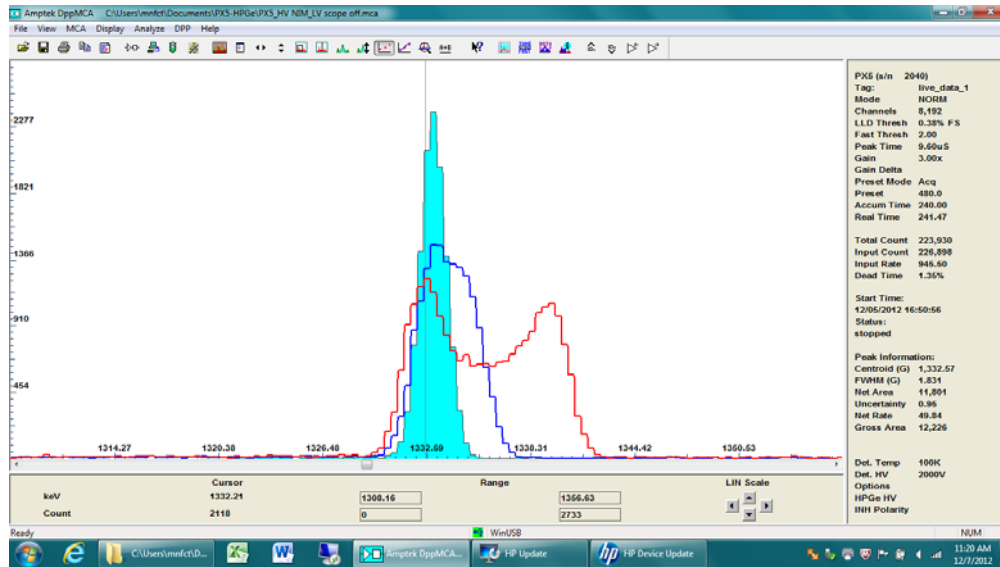
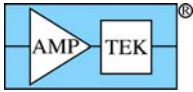
$$R = [ENC^2 + F \cdot E]^{1/2} \quad [1]$$

where R is the resolution (in eV FWHM), ENC is the electronic noise contribution (in eV FWHM), E is the energy (in keV), and F is a constant, equal to 2404 (in the units used here). The ENC term is due to intrinsic noise (thermal noise in the JFET, shot noise in the detector, etc) while the F·E term is due to statistical fluctuations in the production of charge.

If there were no additional sources of noise and peak broadening, and you measure the resolution of monoenergetic peaks over an energy range, it would follow Eqn. [1]. Amptek's Si-PIN and SDD X-ray systems are close to Eqn [1]. If you observe a significant deviation, then something is not right. But it is very important to use monoenergetic photopeaks for this comparison! In X-ray spectroscopy, peak splitting can be important. For example, the $K_{\alpha 1}$ and $K_{\alpha 2}$ lines are distinct and will cause what appears to be a single K_{α} peak to be broader than expected.

8.4 Check the peak shape

- The shape of a photopeak is a very useful diagnostic tool. Monoenergetic X-rays or γ -rays usually yield a peak with a very nearly Gaussian shape, with a FWHM given by the equation above. There will be a slight tail to lower energies (along with a background continuum and the other features mentioned in section 7.6). Deviations from a Gaussian shape can indicate the source of a problem.
- The plot below shows the result of electromagnetic interference. The filled blue trace shows the peak with no interference. The red trace shows significant interference: the pulses are superimposed on a sinusoidal baseline; the maximum and minimum of the sine yields two peaks with a valley between. The dark blue trace shows moderate interference; there is only a single peak but it is clearly non-Gaussian. When interference is present, the width of the peak does not depend on energy as Eqn [1]. See section 9 for more information on interference.

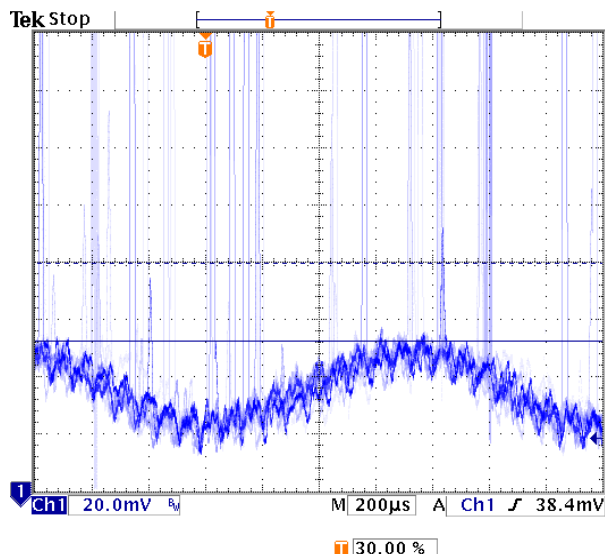


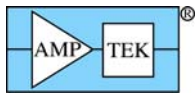
- An improper reset lockout period or an incorrect baseline restorer setting will cause a visible asymmetry on the upper or lower sides. Pulses are being measured when the amplifier output has not returned completely to ground.

9 If you are concerned about interference, then ...

9.1 Assess if interference is the problem.

- If the energy resolution is worse than it should be, and everything else is correct (voltage, peaking time, etc), then interference should be suspected. Interference noise is usually independent of amplitude, so adds in quadrature with the Fano broadening and intrinsic noise (ENC) of Eqn. [1].
- If the photopeak is not Gaussian, then interference should be suspect. Spectra taken in the presence of interference are shown in section 8.4.
- Interference is usually periodic while intrinsic noise is broadband. If you see a clear periodic signal on the oscilloscope, then interference should be suspected. Be careful, however: the pulse shaping gives an output with a characteristic frequency and this can be confused with interference. The plot below shows a scope trace in which two different periodic signals are present, one with a period of about 1200 μ s (0.8 kHz) and one about 100 μ s (10 kHz).





- Because interference is usually narrowband, when its frequency matches that of the shaping amplifier, it gets much worse. A 50 kHz power supply will strongly degrade resolution near $T_{peak}=20\ \mu s$. Intrinsic noise varies smoothly with peaking time, with a nearly flat minimum. If you sweep across T_{peak} values and see a sharp increase, interference should be suspected.
- Inspect the slow channel, the fast channel, and the input. Because the frequency responses of the fast and slow channels are different, interference may show up very clearly in one and not in the other. Note that you may have high frequency interference (e.g. 1 MHz) which increases fast channel noise greatly (leading to a high fast threshold) while slow channel resolution is unaffected.
- Interference always arises from some source; interference involves the coupling of energy from outside the circuit into it. If you turn off the source, the interference will go away. If you remove the coupling mechanism, the interference will go away. So if you suspect interference, then turn off possible sources and see if there is a difference.
 - A specific common concern is the HVPS of X-ray tubes, which are often 50-100 kHz and located near the detector. To test for this, put an isotopic source in front of the detector and record resolution with the tube off. Turn the HVPS on but leave the current off or low and see if the resolution gets worse. Then put an absorber in front of the tube and step up the current, seeing if the resolution gets worse.
 - Grounding is a very common source of interference noise. If you suspect interference, then try changing the grounds. Try different connection schemes.
 - Do not assume anything. We have found many oscilloscopes to emit at 50 kHz, so your scope may be the source of your noise. We have seen the transformers in low voltage power supplies which “buzzed” above >20 kHz. They are not audible but their acoustic energy can interfere with the detector. When in doubt, turn off everything except the detector and processor (you can start an acquisition, then disconnect and remove the computer). Turn off all external electronics and power from battery if you need. If the resolution gets better, then the problem is interference. Start turning things back on, one at a time.

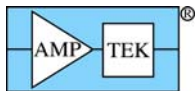
9.2 What should I do if there is interference?

- Interference involves a source, a coupling medium, and a receiver. To solve the problem, the key to solving interference is to identify the source, the coupling, and the receiver. Then determine which is easiest to reduce: emissions from the source, the coupling, or the sensitivity of the receiver.
- Interference is usually categorized by the coupling mechanism: conducted through grounds, conducted through some other line, capacitively coupled, magnetically coupled, or acoustically coupled. The best solution generally depends on the category.

Grounding

Grounding is a subject which is surprisingly complicated and is often poorly understood. Improper grounds are responsible for more interference problems than any other condition. The key recommendations are:

- You should always have a connection to earth ground, for personnel safety
- Avoid ground loops. Single point or star grounds are usually best for low frequency noise while ground planes are best for high frequency noise.
- Avoid common ground leads between sensitive and noisy and/or high current equipment.
 - Separate the signal processor ground from the power return for high current equipment, e.g. X-ray tubes or stepper motors, and the ground of fast digital systems.
 - When using a separate preamp, e.g. the XR100 or PA210, ensure that noisy ground currents do not flow through the preamp ground.



- Identify both power return paths and signal reference paths. Both of these are often called “ground”, depicted as the same on schematics, and are usually tied together at some node. The impedance between ground points is the cause of most grounding difficulties and makes the actual current paths important. Understand and control the paths of “ground” currents.
- Laptop power supplies often cause noise, injecting large current spikes into ground. We recommend isolating the laptop power supply from earth ground.
- If the detector and preamp are separate from the signal processor (e.g. when using an XR100 or PA210 preamp), connect the signal ground of the preamp to the signal ground of the processor using the lowest impedance feasible. It is usually best to connect the signal and chassis grounds to earth ground at the detector or preamplifier and isolate them elsewhere.
- Use low impedance ground connections (short cables, low wire gauges or braid, good connections).

There are a few reasons why grounds are the source of so many problems. First, the “ground” in a circuit serves three distinct roles: it provides a safe path to earth for high currents, it is a reference for signals, and it is a return path for power currents. A single connection can provide all of these roles but this will often cause problems. Second, when you see “ground” symbol in a circuit, it is typical to assume that all of them can sink arbitrary amounts of currents while all remaining at exactly the same voltage. This would be the case if the “ground” had zero impedance at all frequencies. But this is not the case, and therefore currents flowing through the ground cause the different “ground points” to be at different voltages. The most important thing you can do is to identify both the power return path and the signal reference path and separate them. Make sure that power return paths in your system do not affect the signal reference zero. In generally, keep the return paths far from the X-ray detector.

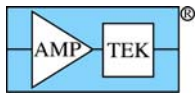
The term “ground” too often seems to be associated with a sort of cure-all concept, like snake oil, money, or motherhood. If you are one of those who regards ground with the same sort of irrational reverence that you hold for your mother, remember that while you can always trust your mother, you should never trust your “ground.” Examine and think about it. From Brokaw, referenced below.

Suppress noise at the source

- Enclose noise sources in a grounded, shielded enclosure.
- Keep the frequency of noise sources (power supplies, digital logic, etc) at least 10x higher or lower than the signal processor frequency (roughly $1/T_{\text{peak}}$ to $1/T_{\text{fast}}$).
- Provide good filtering on power supplies to Amptek's products. This is particularly important for customers providing power directly to the preamp.
- Provide good decoupling on the power supplies for all parts of the system.
- When laying out noisy circuits, e.g. switch mode power supplies or digital circuits, follow the manufacturer's advice and example circuits and layouts closely.

Suppress noise coupling

- Keep cables as short as feasible, particularly for sensitive leads or those with noisy currents.
 - Leads between the preamp (e.g. XR100 or PA210) and signal processor are sensitive.
 - High speed digital lines and power lines to/from high current equipment are likely noisy.
- Separate noisy leads from leads with sensitive signals, e.g. the preamp output.
- Twist together noisy shields and their returns. Consider shielding them. Also twist together low level signal leads or use coax, e.g. for the preamp output.
- Shielded cables used to protect low-level signals should be grounded at one end only, usually the source end (e.g. the preamp).
- Use low impedance power distribution lines.



www.amptek.com

AMETEK
MATERIALS ANALYSIS DIVISION

- Place sensitive equipment in a shielded enclosure. This is particularly important for Amptek's board level products, e.g. the PA210 preamp and DP5 signal processor.

EMI References

- Ralph Morrison, Ground and Shielding Techniques in Instrumentation, 4th edition, Wiley, 1998.
- Helmuth Spieler , Radiation Detectors and Signal Processing Lecture Notes - VII. Heidelberger Graduate Lectures in Physics , University of Heidelberg -- Oct. 8 - 12, 2001 , at http://www-physics.lbl.gov/~spieler/Heidelberg_Notes/pdf/VII_Why_Things_don't_Work.pdf
- P. Brokaw, *An IC amplifier user's guide to decoupling, grounding, and making things go right for a change*, Application Note AN-202, Analog Devices, www.analog.com
- Alan Rich, *Understanding interference type noise* (pp 120-123) and *Shielding and guarding* (pp 124-129), in *The Best of Analog Dialogue*, Analog Devices, 1991