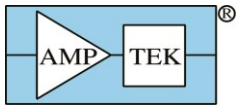


## User Manual for Amptek’s DP5 Product Family

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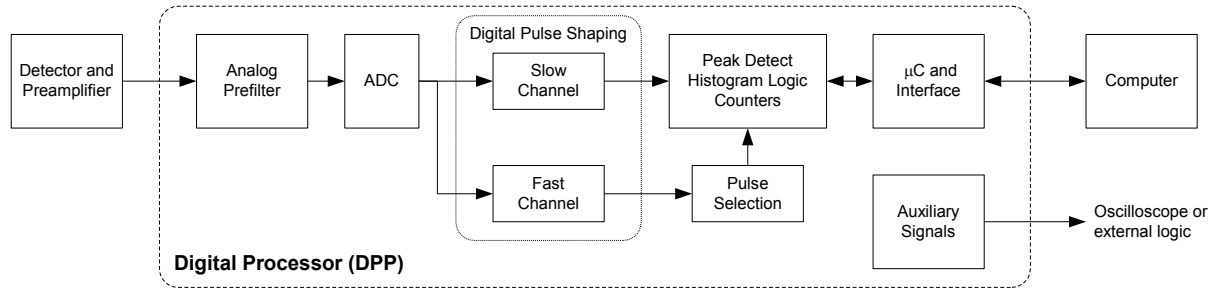


# 1 Introduction

## 1.1 DP5 Family

Amptek has a family of products based on its core DP5 digital pulse processing technology. This “family wide” user manual describes those elements which are common across the product family; each product has its own specification and user manual, which describes those elements unique to it.

The DP5 technology is 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 sensor (a.k.a. detector), a charge sensitive preamplifier, analog prefilter circuitry, an ADC, an FPGA which implements pulse shaping and multichannel analysis, a communications interface, power supplies, data acquisition and control software, and analysis software.



The core technology shared by all the family of products 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), run the same firmware (FW6), 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.

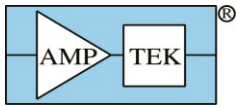
The products in the DP5 family differ in the sensor for which they are designed, which leads to changes in the analog prefilter, power supplies, and form factor. They also differ in their completeness: some of Amptek’s products are “complete”, while others offer only a portion of the functionality for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

The first product Amptek developed in this family was the DP5, a digital pulse processor optimized for high performance semiconductor X-ray detectors. A variety of other products was spun out of this core, which is why we call it the “DP5 family”. These products do not contain the DP5 itself and in fact some are quite different. They all use the same communication protocol (known as “FW6”) so an alternate name would be the “FW6 family,” but for historical reasons we call them the “DP5 family”.

## 1.2 DP5 family documentation

This “family wide” user manual will focus on the digital signal processing and the communication interface which are common to the entire DP5 family of products.

The document “Understanding the DP5 Processor” provides much background information, applicable to the entire DP5 family. The HELP file of the DPPMCA software also has valuable “family wide” information. Further documentation is provided in the SDK for custom software and in the “DP5 Programmer’s Guide” (which provides details of the software interface).



Each product has a “product specific” user manual. These focus on the sensor and preamplifier either included or intended for use, the analog prefilter, the power supplies, the form factor of the specific product, and application suggestions.

On the Installation CD is a section of “application notes.” Two are of special note, being applicable across the entire family. These include the “Trouble-shooting guide to Amptek’s digital pulse processors” and “Interference.” There is also a folder with additional help topics, which is recommended.

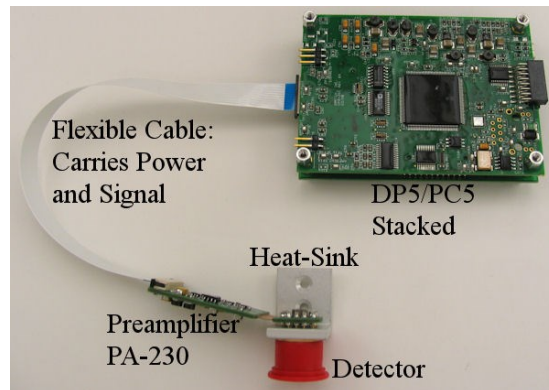
### 1.3 DP5 Core Technology

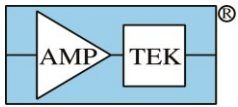
The DP5 is a second generation digital pulse processor (DPP) which replaces both the shaping amplifier and MCA found in analog systems. The digital technology improves several key parameters:

- 1) Better performance, specifically better resolution, higher count rates, better pileup rejection, and more accurate measurement of input count rates
- 2) Greater flexibility since more configuration options are available, selected by software,
- 3) Improved stability and reproducibility.

A 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. In addition to the spectrum, various other data streams are available in the DP5 family (counts, MCS mode, list mode, SCA outputs, various auxiliary signals, etc).

The DP5 products require a serial communication (USB, RS232, and Ethernet are all supported) and power (which can be via USB, PoE in some products, or DC power (typically +5V)). The DP5 products interface with the DPPMCA data acquisition and control software, along with an SDK of interface routines, to integrate the unit with custom software. Optional accessories include software for analyzing X-ray spectra, software for analyzing gamma-ray or alpha particle spectra, several collimation and mounting options, and X-ray tubes to complete a compact system for X-ray fluorescence.





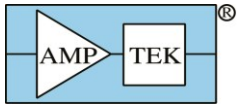
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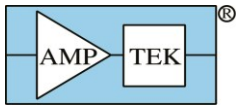


## 2 DP5 Product Family

The table below lists the DP5 family of products, as of Feb 2015.

Product Name	Primary Application	Type <sup>1</sup>	Variants	Comments
X-123	X-ray spectroscopy	System	SDD, FastSDD <sup>®</sup> , Si-PIN, CdTe	Available with vacuum adapters, with several length extenders, and in various other options
DP5	Semiconductor detectors	Board	Analog prefilter can be adapted widely	Available with PC5, which provides power to detectors and preamplifiers
DP5 & PA210	X-ray spectroscopy	Board level system	SDD, FastSDD <sup>®</sup> , Si-PIN, CdTe	Designed for OEMs embedding in an instrument
PX5	Semiconductor detectors	Module		Primarily for laboratory users
PX5-HPGe	$\gamma$ -ray spectroscopy	Module		For use with customer-supplied HPGe detector
Gamma-Rad5	$\gamma$ -ray spectroscopy	System	Nal(Tl) is standard but many options available	Includes scintillator and PMT
TB-5	$\gamma$ -ray spectroscopy	Module		User provides scintillator and PMT.
DP5G	$\gamma$ -ray spectroscopy	Board		Available with PCG, which includes low voltage power supplies and communication connectors
MCA8000D	Spectroscopy	Module		Does not include pulse shaping but only the MCA function.
MCA8000D - PA	Particle counting	Module		

<sup>11</sup> A “system” includes all elements above, including detector. A “module” is only a part of the system (usually excluding at least the detector) but is packaged. A “board” is a part of the system but is not packaged; it is a printed circuit board.



### 3 Quick Start Instructions

Each DP5 product has its own, specific quick start instructions yet they all share a common core:

#### 3.1 Precautions

- **DO NOT TOUCH THE THIN WINDOWS.** Many of these products contain delicate windows, which may be made of a few microns beryllium or even 20 nanometers of silicon nitride. Any contact with the windows may destroy them. Such damage is not covered by warranty.
- **HIGH VOLTAGE MAY BE PRESENT.** Most radiation detectors require bias voltages, from 100 to 5,000V. Current limiting is generally used but high voltage remains possibly dangerous.
- **IONIZING RADIATION IS HAZARDOUS.** Although these products do not produce ionizing radiation, they are generally used to detect it. It is the customer's responsibility to meet the radiation safety requirements of his/her institution and to be mindful of radiation safety.

#### 3.2 Install software

- Software is provided on your installation CD. A current version of all software is also available from <http://www.amptek.com/software-download-page/>
- Installation instructions are at <http://www.amptek.com/dpp-installation-instructions/>

#### Step 1: Install WinUSB Drivers

- 1) IT IS STRONGLY RECOMMENDED THAT YOU USE WINDOWS UPDATE TO INSTALL THE WINUSB DRIVERS, IF YOUR DEVICE SUPPORTS THIS. Manual installation is possible; see the instructions.
- 2) The actual screens look slightly different for Win7, XP, etc. See the instructions for details.

#### Step 2: Install the DPPMCA data acquisition and control software

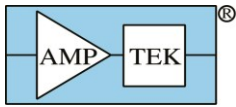
DPPMCA.EXE is the primary data acquisition and control software used with all products in the DP5 family (with one exception noted below). This program is on the installation CD that was provided with your system or can be downloaded from Amptek's website.

- 1) Locate the DPPMCA directory and copy and paste it to your local machine. Then run the executable in the directory. There is no "setup," it is a simple copy and paste to the local computer. Amptek recommends copying the software to "Program Files/Amptek."
- 2) TIP: Right click on the DPPMCA.EXE file and select create shortcut. Then drag the shortcut to your desktop for easy access.
- 3) You must have full read/write access to the DPPMCA directory. These programs cannot be run from the CD.

#### Step 3: Launch the DPPMCA program

#### Step 4: Connect to the DPP

- 1) The connection dialog will appear when DPPMCA is launched.
- 2) Select which interface you will use (USB, Ethernet, or RS232).
- 3) If more than one device is available, select the device you want.
- 4) Click "connect". You can tell if you connected because the software will show the serial number of the processor at the top right and will show an icon (USB, Ethernet, etc) at the bottom.



### 3.3 *Configure the device*

- The DPP stores its configuration, so when powering the system initially, the factory configuration is loaded. If you modify the configuration, the last configuration is loaded. For the PX5, hold the power button down until it beeps twice to use the configuration in memory.

**TIP:** We recommend that you save the initial configuration, which was used at the factory to test the unit, before making changes so you can return to it if necessary. Open DPP Setup and click "Save configuration to file".

- The most commonly changed parameters are the gain and the thresholds.
  - To quickly change the gain, use the gain increment (decrement) buttons on the toolbar.
  - After changing the gain, remove all excitation sources, start an acquisition, then click the "Tune Slow/Fast Thresholds" button on the toolbar.
  - Refer to the DPPMCA Help for further suggestions.

### 3.4 *Acquire data*

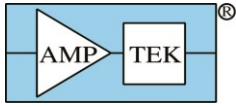
- 1) Place a source in front of the detector.
- 2) To start or stop acquisition, toggle the "traffic light" icon in the toolbar or press the space bar.
- 3) To clear the data and time, press the icon to the right of the "traffic light" or press "A".

#### Data Acquisition Tips

- It can take minutes for an Amptek detector to stabilize after power has been applied or a configuration changed. If the spectrum looks odd, clear the data and restart.
- You can tell that data are being acquired if (a) the spectrum appears in the window, (b) the input and total counts are increasing, (c) the accumulation time is increasing, and (d) the "status" in the right hand Info Panel reads "acquiring".

### 3.5 *Display, analyze, save data*

- The spectrum, counts, and accumulation time are automatically displayed as data are acquired. If a region of interest is defined and selected, its net area and other properties are also shown.
- DPPMCA includes basic spectrum analysis functions: defining regions of interest, calibrating the energy scale, simple mathematical expressions, and a simple peak search algorithm. For more sophisticated spectrum analysis, additional software must be used. For XRF, the XRS-FP analysis software package can be purchased from Amptek.
- To calibrate the system, you must first acquire a spectrum with two or more photopeaks of a known energy. DPPMCA will perform a linear regression between the centroids of these peaks and the known energies.
- To save a data file, press "Ctrl-S" or click the "File Save" icon. Data are saved in an ASCII file format, described below, which includes the counts in each channel, slow and fast counts, ROI and calibration data, and the DPP configuration parameters.
- DPPMCA's Help File contains more information on regions of interest, energy calibration, etc.
- A "Troubleshooting Guide" is contained on your CD and is on the Amptek website, in case you have difficulties.



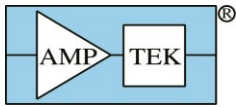
## 4 Specifications

### 4.1 Specification table

<b>Pulse Processor</b>	
Applies to all DP5 products except MCA8000D	
Gain	Product of coarse gain (from amplifiers) and fine gain (in FPGA)
Coarse Gain Values	Depends on product
Fine Gain	Software selectable, 0.75 to 1.25, 13 bit resolution
Full Scale	1000 mV at ADC. Corresponding processor input depends on gain
Gain Stability	20 ppm/°C (typical). This is the stability of the DPP. Sensors, preamplifiers, and other components may exhibit much larger temperature coefficients.
Pulse Shape	Trapezoidal
ADC Clock Rate	20 or 80 MHz, 12 bit ADC
Peaking Time	Software selectable peaking times between 0.05 and 102 $\mu$ s, corresponding to semi-Gaussian shaping times of 0.02 to 45 $\mu$ s. ADC clock (20 or 80 MHz) determines the range; <0.8 $\mu$ s requires 80 MHz.
Flat Top	63 software selectable values for each peaking time (depends on the peaking time), > 0.05 $\mu$ s.
Baseline Restoration	Asymmetric, 16 software selectable slew rate settings
Fast Channel Peaking Time	0.05, 0.1, 0.2, 0.4, 0.8 $\mu$ s (80 MHz) and 4x at 20 MHz
Fast Channel Pulse Pair Resolving Time	$T_{fast}$ plus pulse risetime
Dead Time Per Pulse	1.05 times the $T_{peak} + T_{flat}$ . No conversion time.
Maximum Count Rate	$8 \times 10^6 \text{ sec}^{-1}$ (periodic). Output count rate of $1.4 \times 10^6 \text{ sec}^{-1}$ for a random input of $3.8 \times 10^6 \text{ sec}^{-1}$ (80 MHz)
Dead Time Correction	Manual correction based on Fast Channel measurement of ICR. Accurate to 1% for ICR < 1 Mcps under typical conditions.
Pulse Selection Options	Pile-up rejection, risetime discrimination, gate

<b>Multichannel Analyzer</b>	
Applies to all DP5 products.	
Number of channels	256, 512, 1024, 2048, 4096, or 8192 channels.
Bytes per channel	3 bytes (24 bits) - 16.7M counts
Acquisition Time	10 ms to 466 days

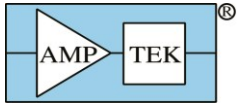




Data Transfer Time	1k channels in 5 ms (USB), 35 ms (Ethernet) or 280 ms (RS-232) See DP5 Programmer's Guide for further details
Conversion Time	None
Presets	Time, total counts, counts in an ROI, counts in a channel
MCS Timebase	10 ms/channel to 300 s/channel
External MCA Controls	Gate input: Pulses accepted only when gated on by external logic. Input can be active high or active low. Software controlled.
Counters	Slow channel events accepted by MCA, Incoming counts (fast channel counts above threshold), SCA8 counts, event rejected by selection logic, and external event counter. Sixteen ROI counters.

<b>Operating Modes</b> Applies to all DP5 products.	
MCA mode	Most common operating mode. The DPP acquires a pulse height spectrum, using the MCA in the FPGA, and reads this to the computer, over one of the interfaces, one software request. Readout intervals usually range from 0.1 s to a few seconds.
MCS mode	The DPP acquire a "multichannel scaling (MCS)" histogram, which has the number of counts in successive time bins. Used for measuring count rate versus time with high precision
Counting mode	By reading only the status packet over one of the interfaces, one can obtain the input and output count rates at much shorter intervals than the entire spectrum can be read. Requires custom software.
SCA mode	
List mode	
Streaming mode	
External counters	

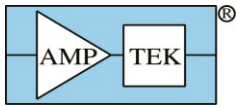
<b>Auxiliary Inputs/Output</b> The availability and connectors depend on the product	
Single Channel Analyzers	8 SCAs, independent software selectable LLDs and ULDs, LVCMOS (3.3V) level (TTL compatible)
Digital Outputs	Two independent outputs, software selectable between 8 settings including INCOMING_COUNT, PILEUP, MCS_TIMEBASE, etc. LVCMOS (3.3V) levels (TTL compatible).
Digital Inputs	Two independent inputs, software selectable for MCA_GATE, EXTERNAL_COUNTER
Digital Oscilloscope	Displays oscilloscope traces on the computer. Software selectable to



show shaped output, ADC input, etc., to assist in debugging or optimizing configurations.

<b>Communications</b> Applies to all DP5 products.
USB 2.0 full speed (12 Mbps)
RS-232 at 115.2k or 57.6k baud
Ethernet (10base-T)

<b>Hardware</b> Applies to all DP5 products.	
Microprocessor	Silicon Labs 8051F340 (8051-compatible core)
External Memory	512kB low-power SRAM
Firmware	Signal processing is programmed via firmware, which can be upgraded in the field.



<b>General &amp; Environmental</b>	
Operating temperature	-40 °C to +65 °C (for the electronics)  All electronic components in the DP5 family are rated for the industrial range, up to +85°C. Components are warmer than the ambient and thus we recommend limiting the ambient temperature to <65°C.  Some detectors may have tighter temperature limits; even where they operate over a wide range, performance is usually a strong function of detector temperature.
Warranty Period	1 Year
Typical Device Lifetime	5 to 10 years, depending on use
Storage and Shipping	Long term storage: 10+ years in dry environment Typical Storage and Shipping: -40 °C to +85 °C, 10 to 90% humidity non condensing
Compliance	RoHS Compliant

Power and physical specifications vary with the product so the power specifications are included in each product's user manual.

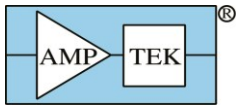
#### 4.2 *Performance*

##### *Energy resolution*

The energy resolution is not specified for the processor family; it depends most strongly on the detector, the type of radiation, and on the exact configuration settings of the processor. In general:

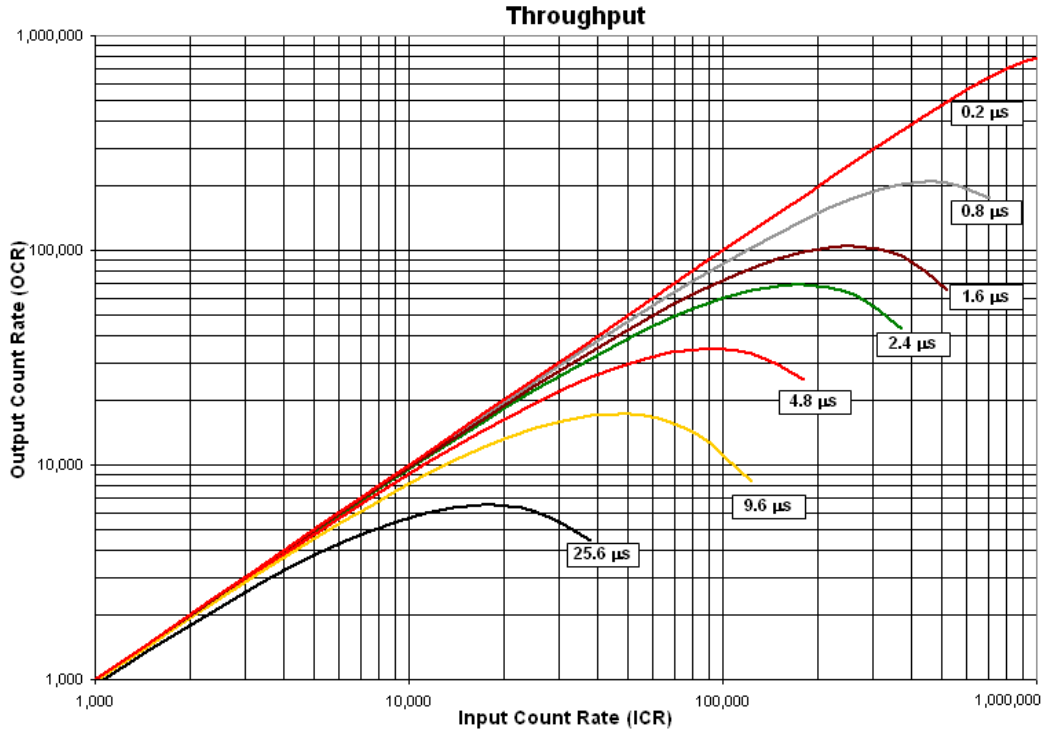
- In many detectors, the resolution is dominated by the interaction of the particle with the detector so is independent of the electronics. In semiconductor X-ray and gamma-ray detectors, Fano broadening which arises from fluctuations in the radiation interaction often dominate resolution. In a scintillator, Poisson fluctuations in the photon production dominate the energy resolution.
- In many systems, electronic noise is also important. The output electronic noise depends on many parameters: the design of the pulse shaper, the peaking time of the pulse shaper, the detector's capacitance, leakage current, and temperature, the design of the preamplifier, etc.
- There are additional factors which impact resolution: charge loss, ballistic deficit, and others.

The noise filtering properties of the DP5 family are discussed in the document entitled "Understanding the DP5 Processor Family". The other factors depend on the detector and preamplifier so are discussed in each product's user manual.



Count rates

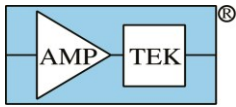
Unlike the resolution, the dead time per pulse is independent of the detector (assuming the detector's risetime is negligible) and so can be specified for the entire DP5 family. The curves below show the output count rate versus input count rate, for several different peaking times.



If  $R_{in}$  is the input count rate,  $R_{out}$  is the output count rate,  $T_{peak}$  is the peaking time, and pile-up rejection is enabled, these curves follow closely the equation

$$R_{out} = e^{(-2R_{in}T_{peak})}$$

For further information on input count rates, output count rates, and dead times, refer to "Understanding the DP5 Processor Family".



## 5 Electrical Interfaces

### 5.1 Serial Communications

#### 5.1.1 USB

- The USB interface follows the USB 2.0 Full Speed (12 MBPS) specifications.
- The USB transceiver is internal to the C8051F340 from Silicon Laboratories. If technical specifications are required, please refer to the Silicon Laboratories website.

#### 5.1.2 Ethernet

- The DP5 products incorporate a 10base-T Ethernet controller and embedded TCP/IP stack to provide internet support via a standard RJ45 jack.
- The DP5 supports auto-negotiation for half- and full-duplex. Only 10 Mbit/s is supported.
- By default, the DP5 products are configured to use a dynamic IP address from a DHCP server. A fixed IP address can be programmed via any of the interfaces (USB, RS232, or Ethernet). For more information, refer to the application note "Using Ethernet with Amptek Digital Devices".
- The DP5 products work poorly when connected directly to a PC's Ethernet port. Communication is much more reliable if connected via an Ethernet hub or switch.

#### 5.1.3 RS232

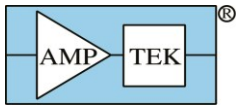
RS-232	Symbol	Min	Typ	Max	Units	Conditions
RX input range		-25		+25	V	
RX threshold low		0.6	1.2		V	
RX threshold high			1.5	2.4	V	
RX hysteresis			0.5		V	
RX input resistance		3	5	7	K $\Omega$	
TX voltage swing		+/- 5	+/- 5.4		V	3 K $\Omega$ to ground
TX output resistance		300	10 M		$\Omega$	Unpowered
TX short-circuit current				+/- 60	mA	
baud rate		57.6		115.2	Kbaud	
baud rate accuracy				$\pm 1.5\%$		

- The RS232 interface uses only RXD/TXD lines (no hand-shaking).
- The transceiver is a MAX3227. Please refer to the MAXIM data sheet for further specifications.

#### 5.1.4 Data transfer times

This is discussed in detail in the DP5 Programmer's Guide and is only summarized here.

- When the computer requests a spectrum, the DPP briefly shuts off data acquisition to make a copy of spectrum memory; when the copy is complete, acquisition is re-enabled. The duration of this deadtime is a function of the number of channels selected and FPGA clock speed; with common settings it is about 1 ms. The acquisition time is stopped during this readout.
- There is also a time duration required to transfer the data from the DPP to the PC. This depends on the number of channels, clock speed, and interface chosen. For 2k channels via USB at 80 MHz, it is 7.5 ms. Ethernet takes about 10x as long and RS232 about 5x longer still.



### 5.2 *Input Signal Interface*

The input signal interface varies considerably from one product to the next so is discussed in each product’s user manual.

### 5.3 *Power Interface*

The power interface varies considerably from one product to the next so is discussed in each product’s user manual.

### 5.4 *Auxiliary I/O*

The DP5 family can route any one of several signals to the auxiliary input and output connectors. Instructions on configuring the auxiliary outputs, through DPPMCA, are found on the installation CD, under the DPPMCA “Additional Help” folder. The complete list of possible signals is contained in the DP5 programmer’s guide. Each product uses different physical connectors and places them in different locations but all share the same set of signals, described here. Refer to your product’s manual for the actual connectors and pinouts for your product.

#### *AUX\_OUT\_1 and \_2*

- Each of these lines can be configured, via software, to output any one of several logic signals in the FPGA. These logic signals are associated with pulses processed by the FPGA.

#### *AUX\_IN\_1 and \_2*

- Each of these two lines can be configured, via software, to input any one of several logic signals in the FPGA. These logic signals are associated with pulses processed by the FPGA.

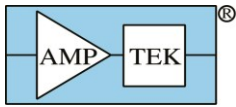
#### *Single Channel Analyzers (SCAs)*

- 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.
- In “streaming mode”, the SCA outputs are re-assigned for use as a parallel data bus. Please refer to the Programmer’s Guide for more information.

#### *Analog Output*

- The analog output is used to display diagnostic signals. Various points in the FPGA processing pipeline are connected to a multiplexer. Any of these lines can be selected and sent to the DAC producing the analog output.
- The same signal which goes to the analog output also goes, via the selected communications interface, to the diagnostic oscilloscope mode in DPPMCA. Though the data are the same, DPPMCA’s internal oscilloscope has limited triggering and other capabilities. Connecting a real oscilloscope to the analog output is the best tool for analyzing pulse shapes.

<b>ANALOG OUT</b>					
Output Range	$V_{DAC}$	+1.0	0		V
Output Impedance		499			$\Omega$



## 6 Software Interface

### 6.1 *Embedded firmware*

There are two types of firmware embedded in the DP5 digital processors: an FPGA image and code running on the microcontroller. There are product specific versions of these, that is, the FPGA image differs between that running on the DP5, used with most X-ray detectors, and that on the PX5, and that on the DP5G for scintillators.

The “DP5 Programmer’s Guide” contains much detailed information on the interfaces to these two firmware packages. Amptek updates both on occasion, to fix bugs and to add features. The latest versions can always be found on Amptek’s website. The Firmware Manager program, described below, permits the user to upload new versions of both packages in the field.

### 6.2 *DPPMCA*

DPPMCA is a Windows software application that provides data acquisition, display, and control for the DP5 family of Amptek’s signal processors. Features include:

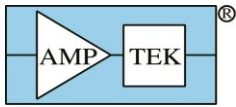
- Full control of all hardware features. Typically includes acquisition presets, gain, peaking time, detector HV, detector temperature, number of channels, risetime discrimination parameters, and many more.
- Live display of the spectrum with many options. Includes linear and logarithmic vertical scaling, manual or auto-ranging, and zoom on the horizontal scale. Displays live spectrum and multiple stored or processed spectra.
- Spectral analysis features include energy calibration, setting regions of interest (ROI), computing ROI information (centroid, total area, net area, FWHM), spectrum smoothing, summing of spectra, subtraction and scaling of background spectra.
- Active link to the XRS-FP Quantitative Analysis Software Package using fundamental parameters, which can be purchased separately.
- Supports Microsoft Windows XP, Vista, and Windows 7.

### 6.3 *FW5 vs FW6*

When the DP5 was first released, it used a software interface which was almost backward compatible with Amptek’s prior digital pulse processor technology, the DP4 and PX4. This provided a convenient bridge for users. This version of the firmware was known as FW5 and it used the ADMCA.EXE data acquisition and control software package, with an associated DLL and API. But FW5 was limited to supporting only those features found in the older generation. Sometime later, we added quite a few features and capabilities and fixed various bugs. The new firmware is called FW6. This has a completely different communications protocol. What this means is that new interface software is required: the DPPMCA.EXE software package and an associated SDK.

The software to communicate with the two versions is completely incompatible. The DP5 can still be programmed with FW5 and the old software used but it has greatly limited features. The performance at high count rates is particularly limited. The communication protocol is far less robust (much less error checking). It does not support Ethernet. And Amptek no longer supports FW5.

FW5 only works with the DP5 processor board and the products using it, e.g. the X-123. The PX5, the GammaRad-5, TB-5, DP5G, and MCA8000D are not compatible with FW5, only FW6.



#### 6.4 *Firmware manager*

Firmware manager is used to update the FPGA and  $\mu$ C code. It can upgrade a DP5 from FW5 to FW6, or downgrade from FW6 to FW5, or to install newer releases of the firmware. Firmware manager works over all interfaces (RS232, USB, and Ethernet). But it is fastest and most reliable over USB. Also note that upgrading from FW5 can only be done via RS232. Firmware manager can be downloaded from Amptek's website. By default, when it is used, it checks Amptek's website for the latest firmware versions and will indicate if a new version is available.

#### 6.5 *Analysis software (XRS-FP, SODIGAM, and GAMMA-W)*

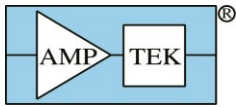
XRS-FP is used for X-ray fluorescence (XRF) analysis. XRF is a common and powerful tool for elemental analysis: X-rays excite the atoms in a sample, causing them to emit characteristic X-rays. The energy of the X-ray indicates the elements; the intensity of the X-ray lines indicates the amount of that element present. XRS-FP takes the raw spectra, processes the spectra to correct for a host of processes, fits the photopeaks, and then uses the intensities of the photopeaks to identify the elements present and to quantify the concentrations of the elements. XRS-FP is a very powerful tool. It supports the "fundamental parameters" analytical method, support standardless and calibrated methods, and various other options. It is provided by CrossRoads Scientific and sold by Amptek.

SODIGAM and GAMMA-W are used for gamma-ray analysis with scintillators and high purity germanium (HPGe) detectors, respectively. The spectrum of gamma-rays emitted from a radioactive sample is measured. These software packages also process the raw spectra, fit the photopeaks, and use the intensities to identify the radioisotopes present and to quantify the concentrations. This software is provided by Dr. Westmeier, GmbH, and sold by Amptek.

#### 6.6 *Software developer's kit*

Along with the compiled, executable, DPPMCA software, Amptek provides a software developer's kit (SDK) with examples of the code used to connect to, control, and read data from the DP5 products. This software is generally used by customers who need to embed the DP5 interface in their own analysis or display software. The SDK includes examples in several different languages and several operating systems.





## 7 Application Notes

### 7.1 Selection Advice

Amptek, Inc. has several different signal processing and power supply options available, and each can be configured for use with each of the different detectors and preamplifiers. They all share the same core functions but are packaged differently and provide different auxiliary outputs (for advanced interfacing) and may have more flexible controls.

All of Amptek's signal processors provide trapezoidal pulse shaping, with commandable peaking times from 0.1 to 100  $\mu$ s and commandable flat top durations. They support up to 4 Mcps (periodic). They include pile-up rejection and measurement of the incoming count rate through a fast channel. They support 1k to 8k MCA channels.

All of Amptek's signal processing support USB, Ethernet, and RS232 interfaces. Their primary output is the MCA spectrum along with some key status data (total counts, fast counts, etc). But all the processors provide many configurable inputs and outputs. This includes a "list mode" (useful for high time resolution measurements), several hardware single channel analyzers, timing signals, a gate, etc. All the processors run from 5 VDC, drawing about 0.5A for 2.5W dissipation. Amptek supplies a 5V AC/DC wall adapter.

Amptek's DPPMCA software, which can be downloaded from the website, provides a complete data acquisition and control interface. It provides access to all functions in the processors and the same software package works with all of Amptek's current generation of processors. Amptek also provides a software developer's kit (SDK) for users wanting to interface to the processor from their own software environment.

#### *PX5*

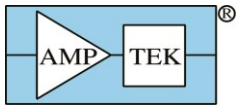
The PX5 is recommended for most laboratory users. It is a benchtop module, 6.5 x 5.5 x 1.5 inches in size. It includes the signal processing (pulse shaping and MCA) and the power supply functions. Of Amptek's processors, it is the easiest to configure for special applications and provides the easiest access to all of the auxiliary functions. A single PX5 can be readily used with Amptek's SDDs or Si-PINs. The PX5 can be used with other detectors also. A special PX5 configuration, the *PX5-HPGe*, has been developed for use with HPGe and Si(Li) cryogenic detectors. The input to the PX5 must be the output of a charge sensitive preamplifier.

#### *X123*

The X123 is recommended when a compact system is most important. It is a compact module, 2.7 x 3.9 x 1 inches. It includes the detector and preamplifier along with the signal processing and power supply functions. As a single module, one need only plug in the 5 VDC and the communication connector and it is ready to run. But because the detector and preamplifier are integrated, changing detector and preamplifier are difficult, so it is less flexible for research. It also has fewer auxiliary I/O signals available and fewer configuration options.

#### *DP5 and PC5*

The DP5/PC5 module is recommended for OEM applications involving semiconductor detectors, where the units will be built in a complete system. The DP5 is a board level signal processor. The PC5 is a board level power supply. The two are used in the X123 so together provide the same functionality as the X123. But since they are printed circuit boards, the user is responsible for packaging and for providing appropriate grounding, EMI shielding, thermal dissipation, etc.



A user can purchase the DP5 and provide his/her own power supplies or can purchase the PC5 and provide his/her own pulse processing. The DP5 can also be configured for use with many different detectors, e.g. HPGe, Si(Li), proportional counters, etc. Amptek has a special variant of the DP5, the DP5G, for use with scintillator/PMT systems. The input to the standard DP5 must be the output of a charge sensitive preamplifier.

#### *MCA8000D*

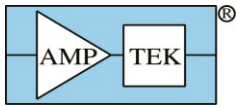
The MCA8000D is recommended for use with analog pulse shaping electronics. This product only implements the multichannel analysis function and does not include pulse shaping.

#### *DP5G*

The DP5G is recommended for OEM applications in scintillation spectroscopy. It is a variant of the DP5 which includes a charge amp suitable for use with scintillator/PMT systems. The DP5G is used in Amptek's TB5 and Gamma-Rad5 products.

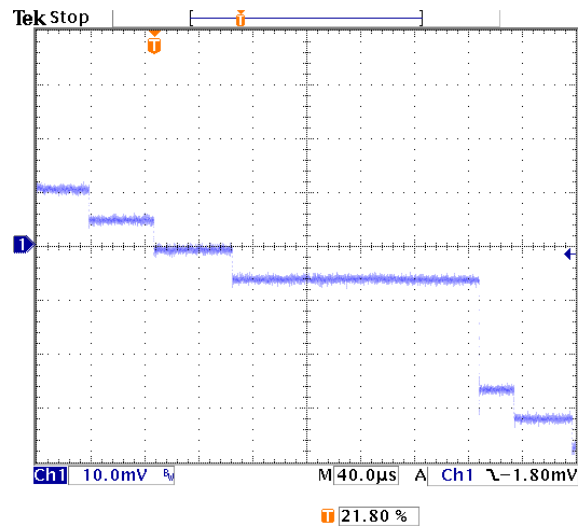
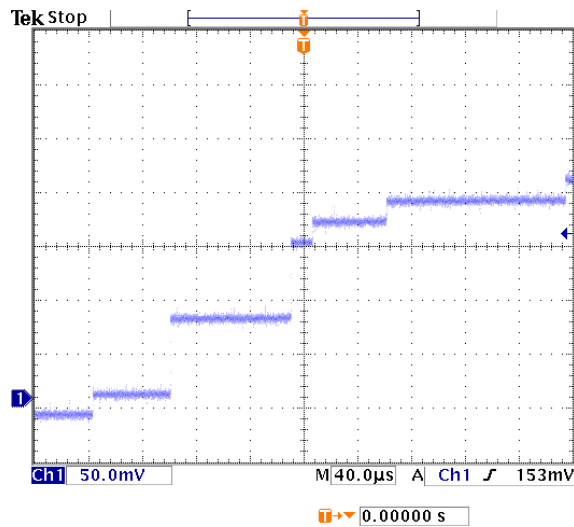
#### *TB5 and Gamma-Rad5*

The TB-5 is recommended for scintillation spectroscopy for customers providing their own scintillator and PMT while the Gamma-Rad5 is recommended for customers needing a complete scintillation spectroscopy system.

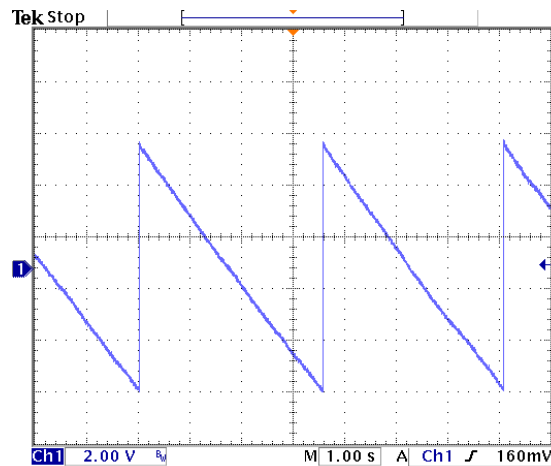
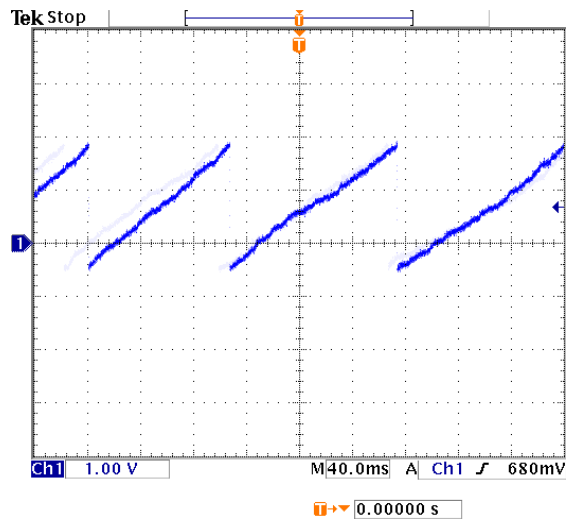


7.2 Typical Oscilloscope Traces

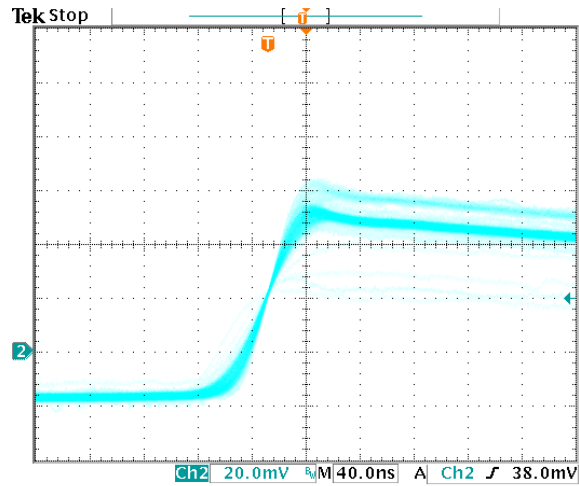
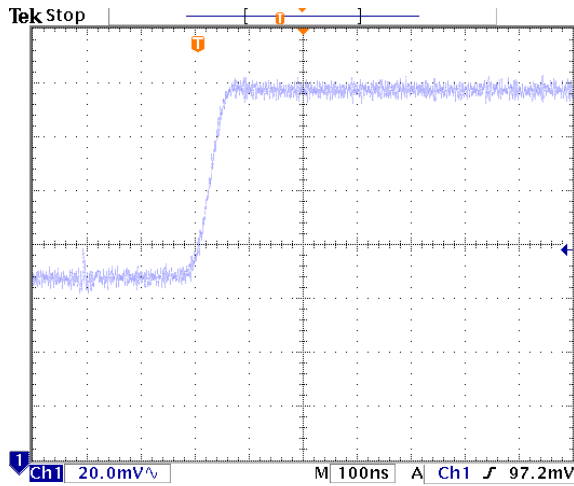
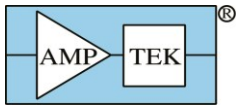
The following images show typical oscilloscope traces for various detectors and signal processors. They cannot capture every instance but do show common examples.



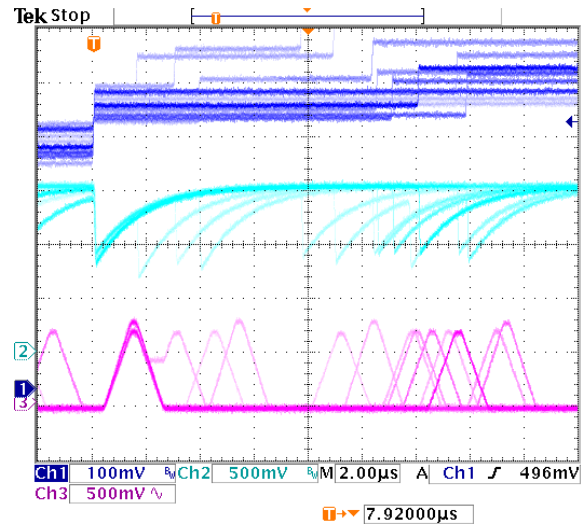
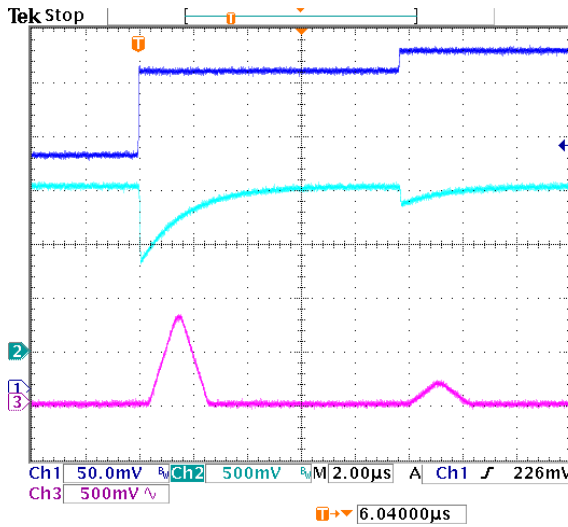
**Preamplifier outputs.** These traces illustrate typical output pulses with Amptek's X-ray detectors, which use reset preamps. The plot on the left is for a FastSDD<sup>®</sup> detector; each X-ray interaction results in a positive going step of  $\sim 3.7$  mV/keV. One can distinguish the 5.9 and the 22.1 keV steps. The plot on the right is for a Si-PIN, which produces negative going pulses with a gain of 1 mV/keV.



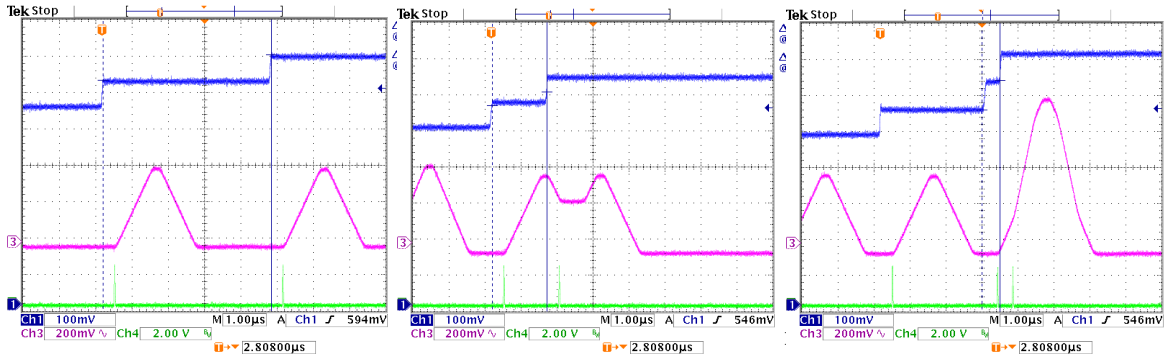
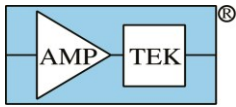
**Preamplifier output.** These traces also shows the preamp output but on a different voltage and time scale to illustrate the reset. The small steps from each signal integrate towards the rail, where a reset signal is generated. This results in a sawtooth of several volts amplitude. The period depends on the total current through the detector (signal current plus leakage current). The plot on the left (right) is for a FastSDD<sup>®</sup> with PA210, that on the right for a Si-PIN with an XR-100.



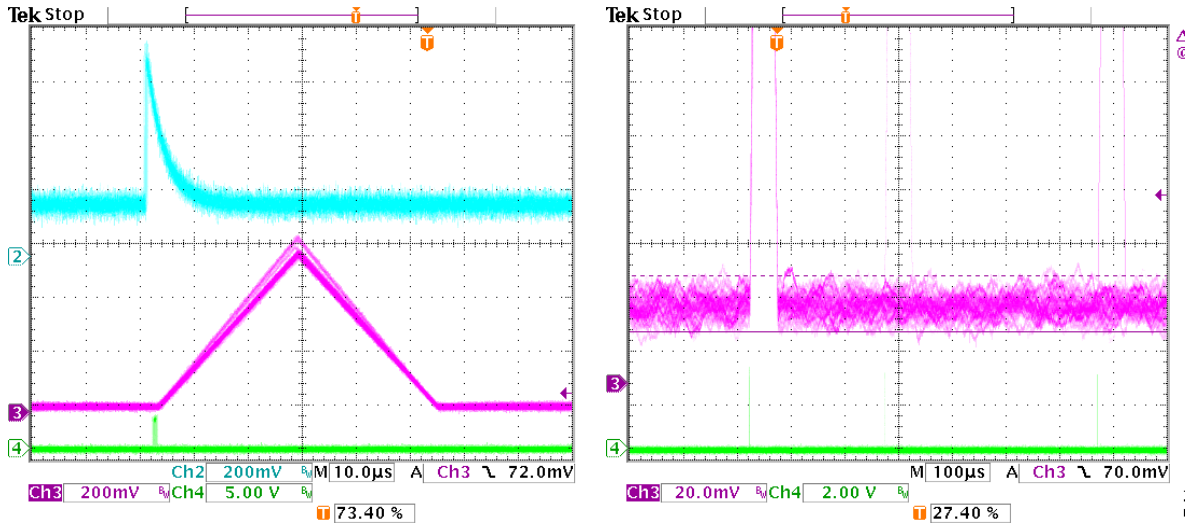
**Preamplifier risetime.** The plot on the left shows the trace from the preamplifier for a single pulse at a short time scale, while the trace on the right shows the input to the ADC from several pulses. These are for a FastSDD<sup>®</sup> with <sup>55</sup>Fe. The distinct traces for the  $K_{\alpha}$  and  $K_{\beta}$  energies are visible.



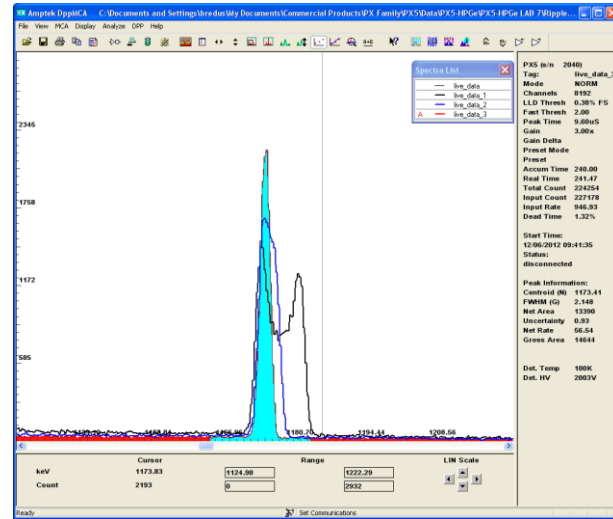
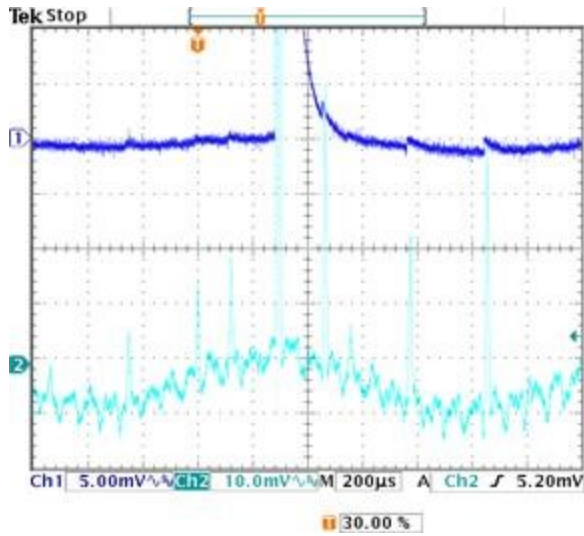
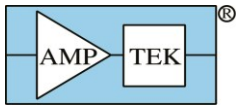
**Signals.** These traces show the preamplifier output (dark blue), the input to the ADC (light blue) and the shaped output (magenta) for typical pulses. The shaped output is on the DAC output. The trace on the left shows two pulses which are well separated in time. The plot on the right shows several pulses, illustrating the random timing and occasional pulse pileup.



**Pileup and deadtime losses.** These traces illustrate pulse pile-up. On the left, the two interactions are well separated in time. Both are counts and both amplitudes are measured accurately. In the middle trace, two pulses are closer in time. The shaped pulses overlap but they are far enough apart, more than  $T_{peak} + T_{flat}$ , so their pulse heights are not affected. Both amplitudes are measured accurately. In the right trace, two pulses are close enough together that the peak shape is affected. This is termed pile-up. They are far enough apart in time that the logic can detect the pile-up and reject the signals, avoiding an erroneous pulse height. If two pulses are so close together that they overlap in the fast channel, which yields a shaped pulse height equal to the sum of the individual heights, this will be recorded.

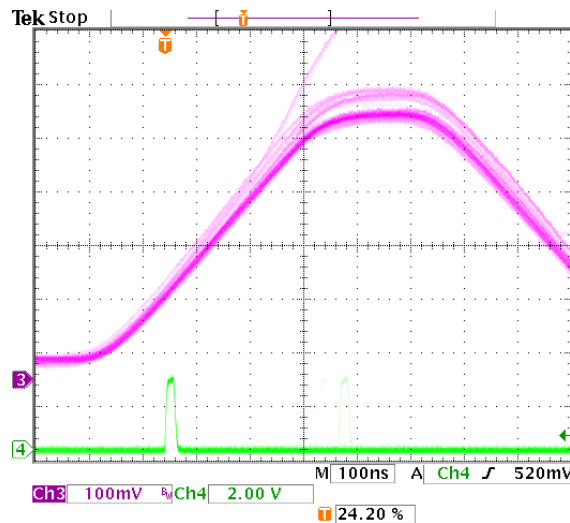
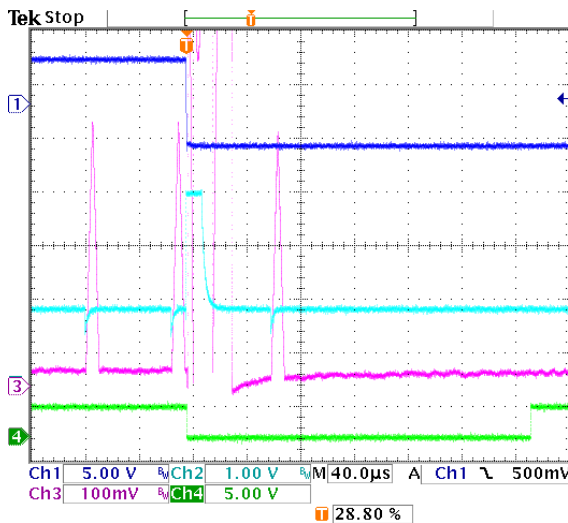


**Noise.** These traces illustrate intrinsic noise. The very small current pulses from the detector are superimposed on a signal which varies randomly in time, due to intrinsic noise: shot noise in the detector, thermal noise in the input FET, etc. This noise degrades resolution and affects counting thresholds; the pulse shaping filters the noise. In the plot on the left, the blue trace shows the input to the ADC. The band is wide because of the wideband input noise. The shaped output, the triangle, is much shaper because the noise has been filtered. This is a low pass noise filter. The separation between the  $K_{\alpha}$  and  $K_{\beta}$  lines is clear in the shaped output but not visible before shaping. The plot on the right shows the noisy baseline on which the signal is superimposed; the pulse height cannot be measured more accurately than the width of this band. This also affects counting and thresholds: if the threshold were placed in the noise band, say 5 mV here, the system would be constantly triggered due to noise fluctuations.

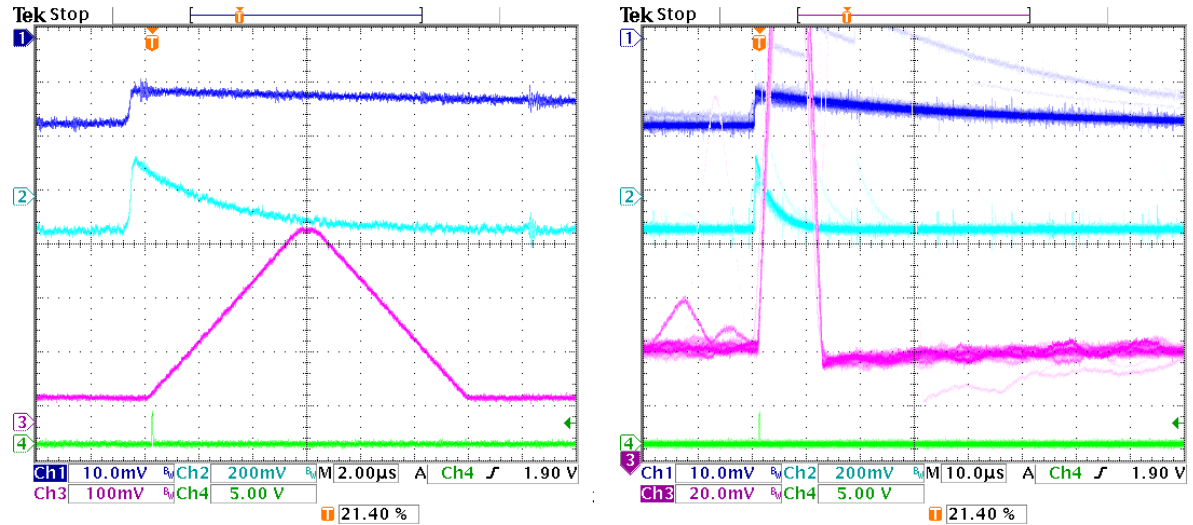
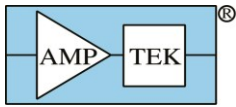


**Interference.** The trace on the left illustrates interference: since the detector produces very small current pulses, even a small amount of ripple coupling in via a ground path or radiated to the signal line can degrade performance. This plot shows both high and low frequency interference. Every time the baseline peaks, the system records a pulse, so the measured count rate is very high, with many counts in the low channels (the left edge of the histogram). Moreover, since the peak amplitude is shifted up and down, resolution is degraded. The plot on the right shows photopeaks with no interference (filled), a little interference (blue) and then with ripple exceeding intrinsic noise (the double peak).

**Reset:** The trace below left shows the output for an SDD after a preamp reset (dark blue trace). When it resets, the ADC input (light blue) has polarity opposite that of the signal and is very large, so the amplifiers saturate. The signal requires some time to recover, as can be seen in the magenta trace: the pulse occurring 60  $\mu$ s after reset starts from a low baseline yielding an incorrect pulse height. Acquisition should be shut off until the baseline recovers (this is the “reset lockout period”). The green trace is the output of the DETRES from AUX2, showing the lockout period.



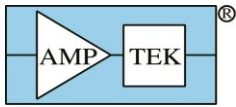
**Ballistic Deficit and Trapezoidal shaping:** The magenta trace above right shows the shaped pulse for a detector with a risetime which varies and is longer than 100 ns. Notice the variation in the shape of the rising edge: some of the pulses require a longer time to peak. These are pulses with a slower charge collection time. If  $T_{flat}$  is shorter than the charge collection time, the pulse does not reach full amplitude, resulting in an error in pulse measurement (termed “ballistic deficit”). It is important to set  $T_{flat}$  longer than the charge collection time of the slowest pulses. The effect is more important at short  $T_{peak}$ .



**Pole zero correction:** The traces above show signals from a detector with resistive feedback, in this case an HPGe detector with a 50  $\mu$ s tail. The dark blue trace, the preamp output, drops exponentially to baseline rather than exhibiting the steps of the reset preamplifier. Circuitry in the DP5 cancels this tail (known technically as pole-zero cancellation) so that the light blue trace exhibits a strictly exponential recover, yielding the magenta trapezoid.

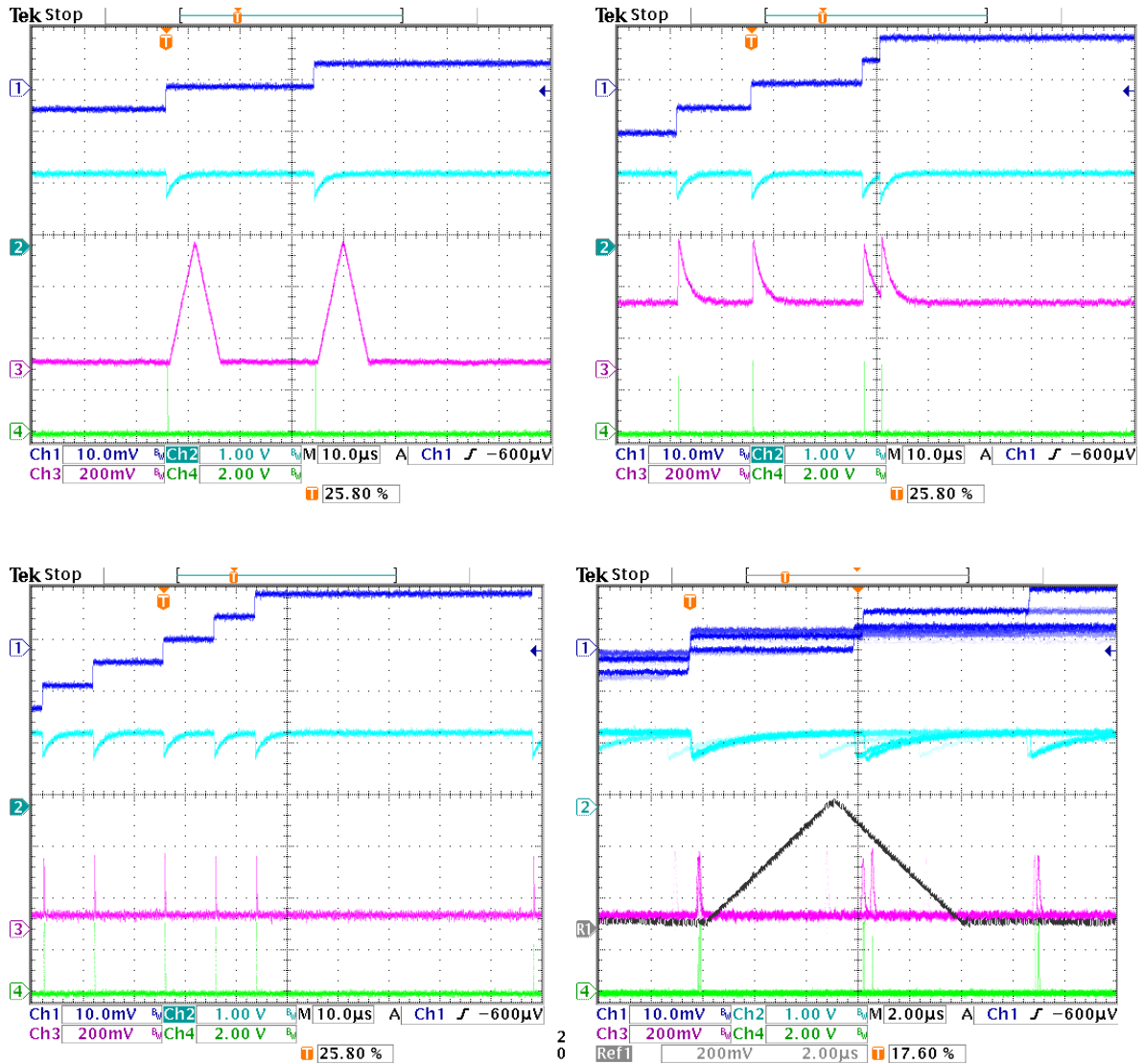
The plot on the right shows the result of incorrect pole cancellation: the magenta trace overshoots, dropping below baseline, and then recovering. If a pulse occurs shortly after another, the second starts from the incorrect baseline, leading to an erroneous pulse height measurement. This causes loss of resolution at high count rates.

There are several time constants in the digital processor which must be correctly adjusted for proper operation. Incorrect adjustment leads to the response seen here or else to an undershoot with a slow recover.



### 7.3 Auxiliary Output Signals

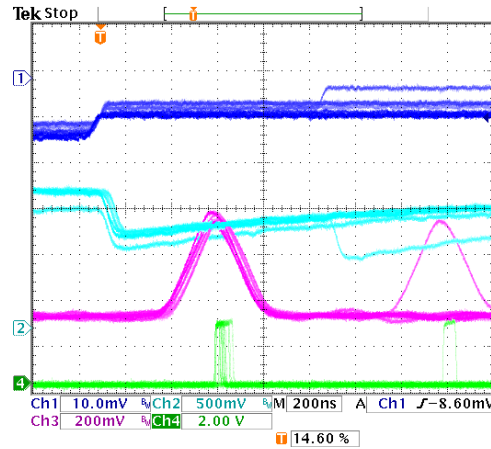
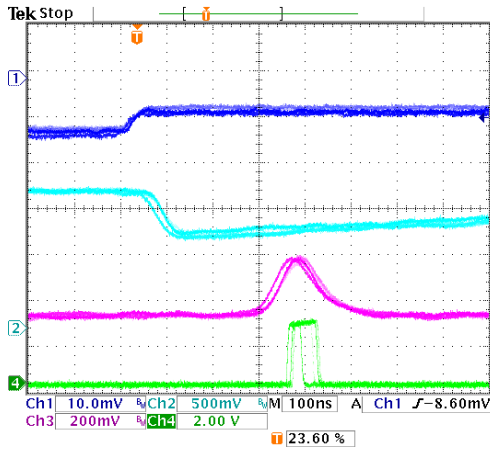
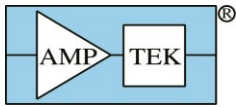
These traces show the most commonly used auxiliary outputs.



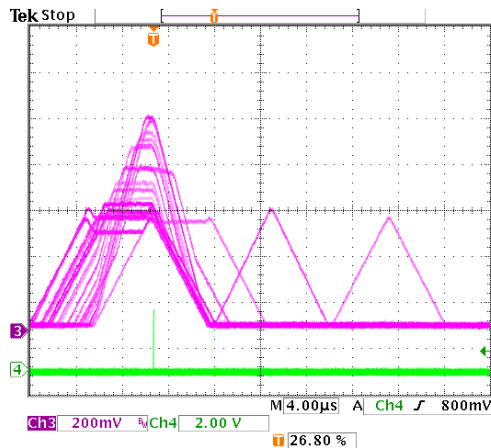
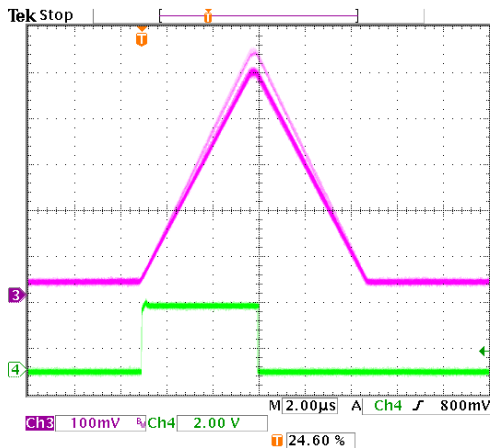
**DAC (analog) outputs:** The analog, DAC output is used to show diagnostic signals representing the waveform during the signal processing. In all these plots, the dark blue trace shows the preamp output and the light blue trace shows the ADC input.

At the top left, the magenta trace shows the **shaped pulse**. In the top right, the magenta trace shows the signal labeled **input** (note that the polarity and offset have been adjusted to keep the signal in range). At the bottom left, the magenta trace shows the **fast pulse**: it is shaped but with a much shorter peaking time. This allows the fast channel to detect piled up pulses and to accurately count pulses but at the cost of higher noise bandwidth. The bottom right trace compares fast and slow signals.



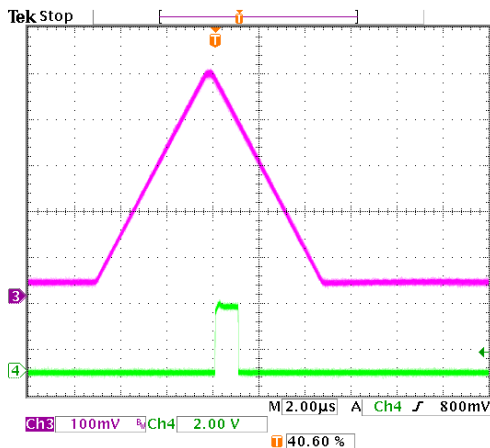


**ICR:** These traces illustrate the ICR (Incoming Count Rate) pulse. This is produced by a comparator operating on the fast channel. Any pulses which exceeds the fast threshold will generate an ICR pulse. This is used to produce the fast or input count rate and in the pile-up reject logic.



**Peak Hold:** The green trace on the left shows the peak hold signal, indicating when the logic was searching for the peak.

**Pileup:** The green trace on the right is produced when two pulses pile-up, at the time of the peak of the second pulse.



**SCA8:** The green trace shows the output of an SCA, in this case SCA 8. It is produced by a pulse with a peak amplitude within the SCA range (set in software). Its rising edge is at the time the peak is detected. Its width is commandable to 0.1 or 1 µs.