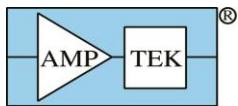


MCA8000D User Manual

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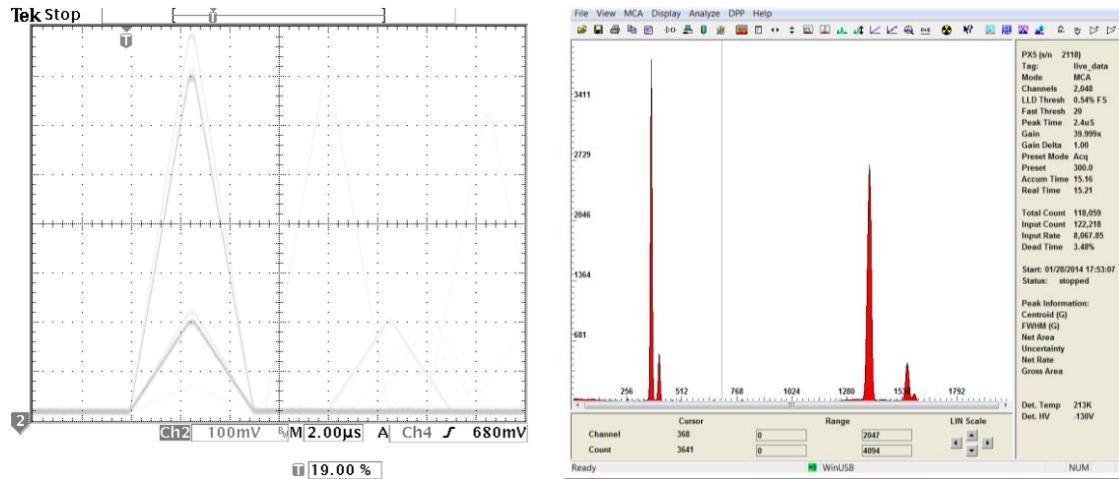
1 Introduction

1.1 MCA8000D Description

The MCA8000D is a modern, high performance *multichannel analyzer* (MCA). It is a replacement for Amptek's MCA8000A. The MCA8000A has provided very high performance for spectroscopic applications for 15+ years but its architecture was designed around computer interfaces and hardware now obsolete. Amptek has designed the MCA8000D to use modern, digital signal processing technology and to use modern, high speed USB and Ethernet interfaces.

An MCA is one component in a complete instrumentation system. In most applications, a sensor produces as its signal a series of current pulses. Signal processing electronics produce "shaped" pulses, where the peak voltage is proportional to the deposited energy, size of the particle, or another quantity of interest. The MCA outputs the pulse height spectrum, a histogram of the pulse heights.

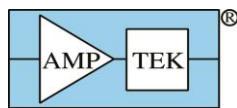
The MCA detects the peak voltage of each shaped pulse and obtains the digital value; this digital value is proportional to the peak voltage. At 10 bits, for example, there are 1024 digital values (a.k.a. channels), so for a gain of 1V full scale, a 0.5V input pulse is in channel 512. Each time a pulse peaks in a given channel, the MCA increments a counter for the corresponding channel. This array of integer counter values is the pulse height spectrum which is the primary output of the MCA. This is sent to a display or to spectrum processing software. Along with the histogram, the MCA outputs the measurement time, a dead time correction, and total counts.



A typical MCA input, a series of shaped pulses, is shown on the left while the MCA output, the pulse height spectrum, is shown on the right.

Figure 1 shows sample pulses, as seen on an oscilloscope (left), and the corresponding pulse height spectrum (right). For Fig. 1, two different sources were used, a ⁵⁵Fe source emitting 5.9 and 6.5 keV X-rays and a ¹⁰⁹Cd source emitting 22.1 and 25.0 keV X-rays. Each X-ray produces a pulse with height proportional to its energy. The different pulse heights seen on the scope trace correspond to these energies, as do the peaks in the pulse height spectrum on the right. In this application, the pulse heights correspond to energy deposited in a radiation detector. In other applications, the pulse height may correspond to the size of a dust particle, to the time between two events, or to other physical quantities. The role of the MCA is to output the pulse height spectrum and the count rates.

Note that the MCA8000D discards overrange events – over 1V for the 1V scale, or over 10V for the 10V scale. The input can safely handle larger events.



MCA or DPP?

In many modern sensor systems using digital technology, the pulse shaping function is combined with the MCA. The preamplifier signal is digitized, the pulse shaping is done digitally, and the already digital peak is found by the MCA portion of the signal processor. Such a device is properly called a “digital pulse processor” or DPP. Many people (incorrectly) refer to a digital processor which does both the shaping and MCA function as an MCA. The MCA8000D does no digital shaping. It requires analog pulse shaping circuitry to produce its input; it only carries out the functions of digitizing the peak and acquiring the histogram. Amptek, Inc. makes a whole family of digital signal processors which combine the shaping and MCA functions, designed for a range of products and applications (the DP5, PX5, DP5G, TB-5, PX5-HPGe, and others). If you need a full digital signal processor rather than just the MCA function, please contact Sales@amptek.com.

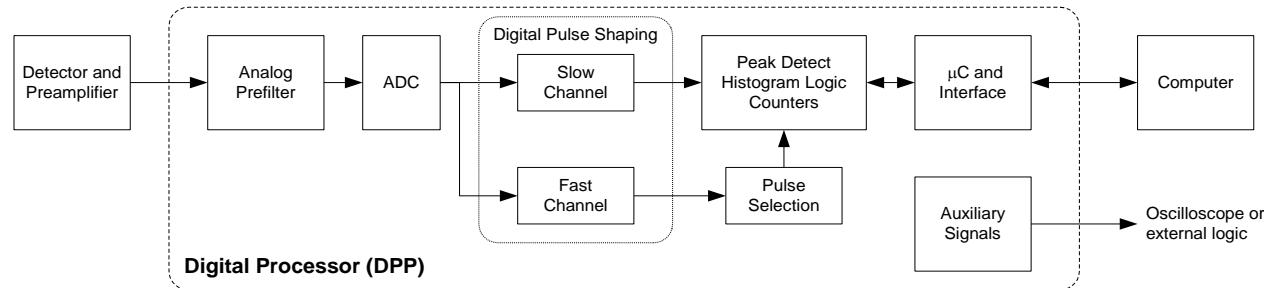
1.2 MCA8000D vs MCA8000A

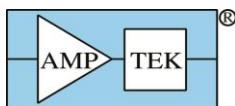
There are a few important differences between the MCA8000D and the MCA8000A

- The MCA8000A only supported an RS232 interface (and required the handshaking signals to be present). Most modern computers do not contain RS232 hardware; most RS232 to USB adapters do not work with the MCA8000A and it does not work with Win7. The MCA8000D supports RS232, USB, and Ethernet, making it compatible with modern computers.
- The MCA8000A used an analog peak hold and the MCA8000D uses a digital peak hold. The most important consequence, for the user, is that the MCA8000A could support a pulse with a 250 ns time to peak while the MCA8000D requires at least a 500 ns time to peak (Gaussian) for best performance.
- The MCA8000A drew 200 mW (it could run for a day from two AA batteries) while the MCA8000D draws 2 W. It can be powered from USB, unlike the MCA8000A.
- The MCA8000A interfaced to Amptek's ADMCA software while the MCA8000D interfaces to Amptek's DPPMCA software. These look similar to the user but are different programs. If a customer wrote custom software, this will need to be revised using a new SDK.
- The physical size and mass of the MCA8000D are about half that of the MCA8000A.

1.3 DP5 Family

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





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

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

1.4 Options and Variations

The MCA8000D is available in two different configurations: the standard configuration is optimized for nuclear spectroscopy, while the "Option PA" configuration is optimized for particle size and counting applications. These applications are discussed further in the applications notes (section 6).

In terms of hardware the only difference is that the nuclear configuration (standard) has 1 k Ω input impedance while option PA units have 100 k Ω input impedance. In addition, option PA units are calibrated, in terms of the voltage input, using a NIST traceable calibration. The "absolute peak mode", selectable in software, is more common for particle applications.

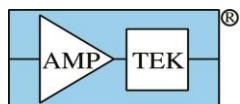
Option PA

The Option PA package has been developed to facilitate the use of the MCA8000D for particle counting in airborne¹ (Size Calibration) and liquid suspended (Number Calibration) particle applications. The unit is calibrated and certified traceable to the National Institute of Standards and Technology (NIST).

The Option PA package is capable of detecting pulses from 5 mV to 10 V. The MCA8000D is typically connected to the output of a particle sensor. It detects and displays a spectrum of pulse heights allowing the user to determine if a given particle size is producing the correct voltage. The software included with the MCA provides information on the peak center (centroid and mean calculation) making it easy to determine if the peak is in the correct position. The MCA is internally calibrated to convert the MCA channel scale to a mV scale. This calibration is loaded automatically in the DPPMCA application, making it unnecessary to load calibration files manually.

- Pulse detection from 5 mV to 10 V
- 2 Voltage scales: 0-1 V and 0-10 V
- 100 k input impedance
- NIST Traceable calibration
- Certificate of calibration
- Absolute peak or separate peak detection modes (absolute mode typical for PA)

¹Sommer, H.T. "IMPLEMENTING PARTICLE COUNTER CALIBRATION PER ISO 11171-1999."; TEAM Service, Inc., P.O. Box 220, Merlin, OR 97532, (541)476-4744, HolgerTSo@aol.com; Copyright Society of Automotive Engineers



2 Specifications

2.1 Spectroscopic Performance

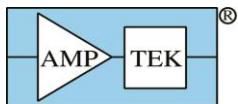
This is dependent upon the detector and the shaping amplifier. The MCA8000D does not affect the spectroscopic performance.

2.2 Processing, physical, and power

The processing specifications of the MCA8000D are quite different from those of the other members of the DP5 family, due to its fundamentally different function in a spectroscopy system.

General Characteristics

Pulse-Height Digitizer	High speed 100 MHz, 14 bit ADC with digital pulse height measurement
Input Ranges	0 to 1 V or 0 to 10 V (software selectable) (over-range events are discarded)
Number of Channels	256, 512, 1k, 2k, 4k, or 8k (software selectable)
Minimum input risetime	≥ 500 ns to meet specifications
Dead Time per pulse	10 ns plus pulse shaping time
Peak Detection Modes	Separate peaks (V1): Standard to nuclear instrumentation MCAs. Absolute Peak Above Threshold (V2): Typically used in airborne particle sizing analyzers, in environmental air monitoring systems and in aerosol research.
Acquisition Modes	MCA and MCS (multichannel scaling) down to 10 ms/channel
Differential Nonlinearity	$<\pm 0.6\%$ from 5 mV to full scale
Integral Nonlinearity	$<\pm 0.02\%$ over full scale
Gain Stability	± 10 ppm/ $^{\circ}$ C (typical)
Zero drift	± 10 ppm/ $^{\circ}$ C (typical)
Low Level Discriminator	Software selectable threshold, in increments of one channel.
Counts per Channel	Maximum = 16.7×10^6 counts (3 bytes)
Real and Live Timers	Data acquisition real or live time preset. Maximum preset time 4,294,967.29 seconds (10mS precision), or 999,999.999 seconds (1mS precision). Shorter accumulation times can be achieved by gating the input signal with Gate 1 or Gate 2
Real and Live Time	4,294,967.295 s (0.001 s precision)
Acquisition Time	1,677,721.599 s (0.001 s precision)
Preset Counts	$4,294,967,295 (2^{32}-1)$ in channel or ROI
Interface	RS232: 115.2 or 57.6 Kbaud. USB: Standard 2.0 full speed (12 Mbps). Ethernet: Standard 10base-T (UDP).
Operating Temperature	-20 $^{\circ}$ C to +60 $^{\circ}$ C
TUV Certification	Certificate #: CU 72131640 01 Tested to: UL 61010-1:2012 CAN/CSA-C22.2 NO. 61010-1-12

*Exterior Controls and Indicators*

Status Light	Steady red light: power is ON and no data acquisition in progress Flashing red light: data acquisition in progress. [Same as amber light on Ethernet connector.]
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Power

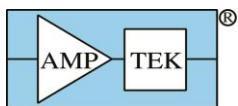
Operating Power	2W
Input Power	+5 V at 0.4 A
Input Power Range	+4 V to +5.5 V (0.5 to 0.4 A typical)
Input Power Sources	USB power or AC/DC adapter (supplied)

Connections

Input	The analog input accepts positive unipolar or bipolar semigaussian type pulses of shaping time constants ≥ 200 ns or peaking time ≥ 500 ns. The dynamic range is 0 to +1 V or 0 to +10 V, software selectable. Minimum pulse height is 5 mV. Input impedance is 1 k Ω or 100 k Ω (options at purchase). The input has overload protection up to ± 20 V. The DC level of the input signal must be zero.
Gates	The MCA8000D has two logic gates: GATE1 is used to synchronize acquisition with external hardware. GATE2 is used for pileup rejection. Each gate can be commanded to ACTIVE HIGH, ACTIVE LOW, or DISABLED. When set to ACTIVE HIGH, if the input is high, then pulse heights are recorded and the live time clock runs. The active state of each GATE input is evaluated at the time the peak of the input analog pulse is detected.
Interface (I/O)	USB: Standard USB Mini-B jack. Ethernet: Standard RJ45 Ethernet jack. RS232: Standard 2.5 mm stereo audio jack. Power Plug mates with 3.5 mm x 1.3 mm x 9.5 mm female barrel, center positive, plug connector.

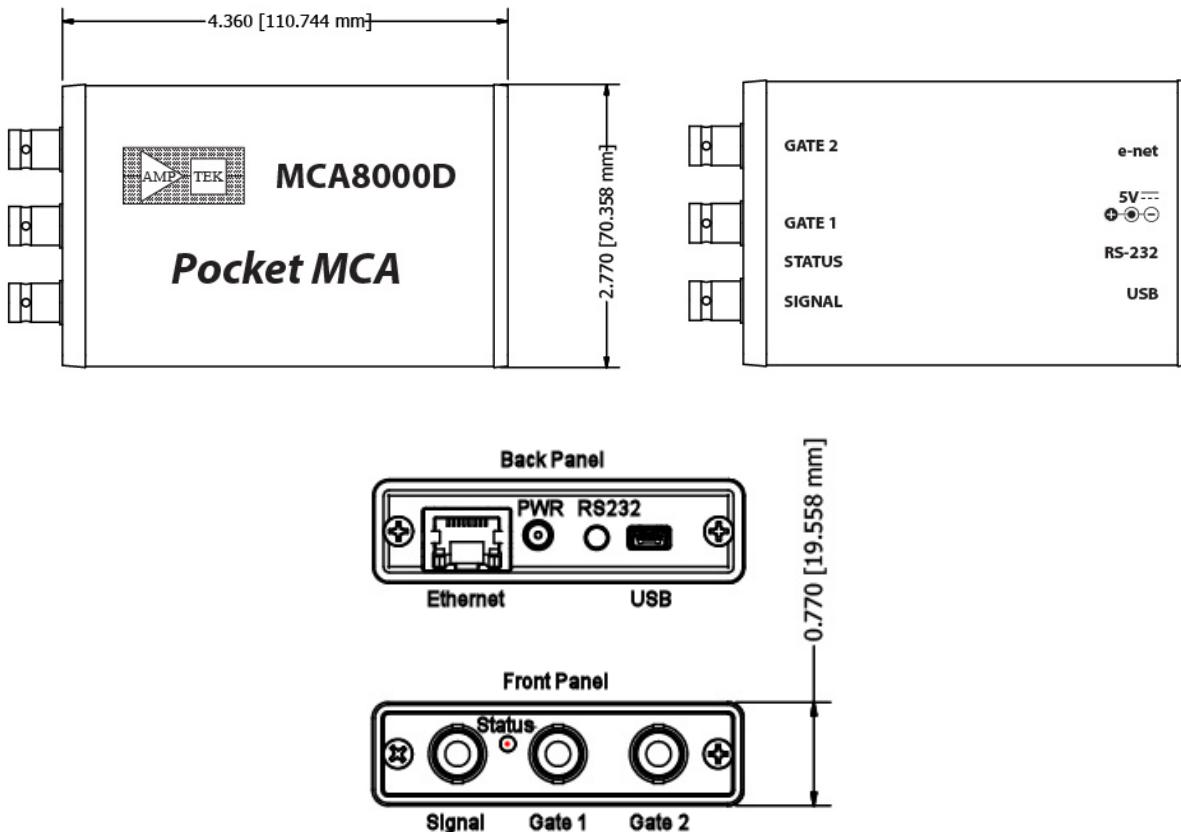
Mechanicals

Weight	<165 g
Dimensions	5 x 2.8 x 0.8 in (125 x 71 x 20 mm)



3 Mechanical Interface

3.1 Dimensions



3.2 Connectors

Input

Standard BNC Coax

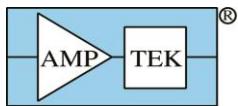
Gate 1, Gate 2

Standard BNC Coax

Power

Power jack: 3.5 mm x 1.3 mm x 9.5 mm female barrel, center positive.

Mating plug: Kobiconn #171-PA35135-E (or equiv.)



Products for *Your* Imagination

AMETEK[®]
MATERIALS ANALYSIS DIVISION

Ethernet (J2)

Standard Ethernet connector (RJ-45)

USB

Standard USB 'mini-B' jack. MCA8000D can be powered from the USB bus.

RS-232

Standard 2.5 mm stereo audio jack.

Contact	Signal
Tip	TXD (from MCA8000D)
Ring	RXD (to MCA8000D)
Sleeve	GND

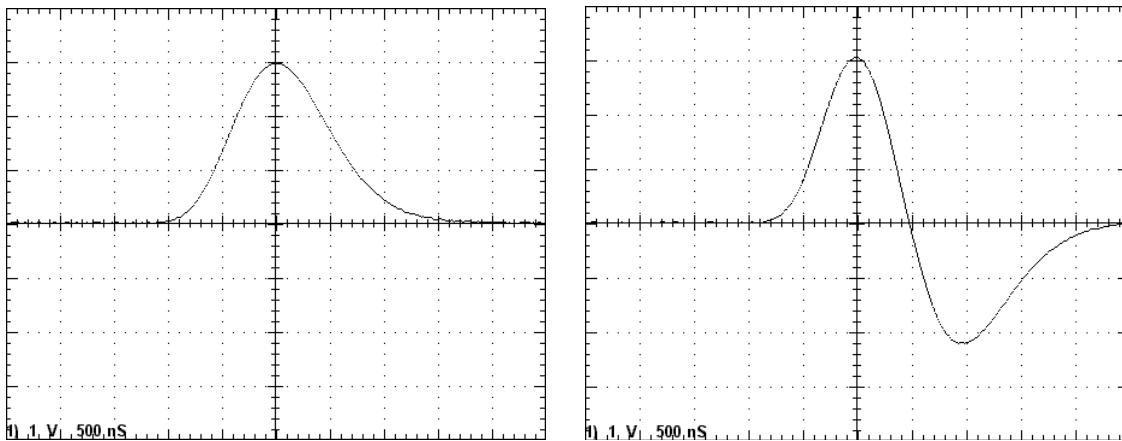
4 Electrical Interface

4.1 Communications Interface

Common to DP5 family and described in the DP5 family manual.

4.2 Input signal interface

Signal type: Shaped pulse. Typical examples shown below.

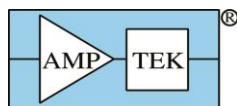


Oscilloscope traces illustrating typical pulses input to the MCA8000D.

Input polarity: Must be positive: the MCA8000D finds the peak of the positive going signal.

Pulse risetime: Must be >500 ns for full accuracy and resolution. Shorter risetimes will be measured but the accuracy or pulse height resolution may be compromised.

Input ranges: The MCA8000D supports two allowable input ranges, 0 to +1V and 0 to +10V, selectable by software command. As discussed below, when the 10V range is selected, a precision 10:1 divider brings the signal into the 0 to +1V range of the ADC. The minimum pulse height that can be detected is 5 mV.



4.3 GATE Interface

The input is 5V-tolerant and the thresholds are compatible with TTL and 3.3V CMOS

4.4 Power Interface

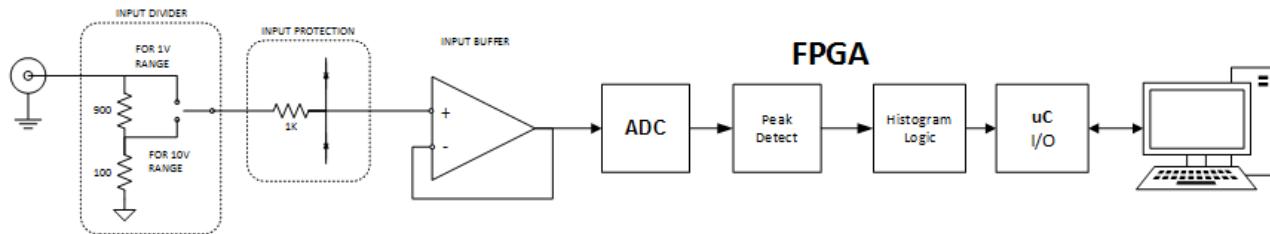
Absolute Maximum Power Supply Voltage +6.0 VDC

Absolute Minimum Power Supply Voltage +4.0 VDC

Input power outside this range will damage MCA8000D components.

5 Design

5.1 Block diagram



A block diagram of the MCA8000D is shown above. It includes (a) an analog prefilter, (b) a 100 MHz, 16 bit ADC, (c) an FPGA, (d) a microprocessor and I/O components, and (e) power supplies (not shown).

The analog prefilter consists of (a) a switchable attenuator, (b) input protection circuitry, and (c) a unity gain buffer. The ADC has a range corresponding to 1 volt full scale. To handle a 10V input, the signal is sent to a precision divider. This resistance of this divider is typically 1 kohm for nuclear measurements (shown above) and 100 kohm for particle analyzers (Option PA).

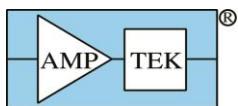
The two resistance values are available because the analog circuitry of most particle analyzers is designed to drive a high impedance; if the impedance is too low, then the series resistance of the analyzer attenuates the signal and degrades accuracy. Many shaping amplifiers for nuclear applications are specified for lower impedance. But Amptek can supply a 100 kohm unit for nuclear applications or a 1 kohm unit for particle analyzers. Contact Amptek for details. The buffer keeps the impedance of the rest of the circuit from loading the input, which is important for accuracy and linearity.

The FPGA implements the peak detect function and then bins the data into the histogram memory. The peak detect includes a low pass filter to minimize the effects of timing jitter (the pulse is not synchronous with the clock). Sliding scale linearization is used to assure the required linearity. The logic tracks the rising edge of the pulse to a peak and then requires the value to fall by a threshold which can be configured via software.

The FPGA stores the pulse height spectrum as a histogram in its memory, along with counter values. This is periodically read by the microcontroller, which then formats the data into the appropriate packets and transmits them over the selected interface. The microcontroller also accepts commands from the attached computer to configure the hardware. The microcontroller is only used for serial interface; all acquisition, counting, and timing are carried out in the FPGA.

5.2 Peak detect modes

The MCA8000D supports two different peak detect modes, selectable by software command:



- In Mode 1, the MCA8000D tracks the signal when it passes a threshold (the “slow threshold”, set in software) up to the first peak and then detects that a peak has occurred when the input has fallen by a certain value (also the “slow threshold”). If a second peak occurs before the signal has fallen back to threshold, then this second peak is also detected and recorded in the spectrum. Each of the separate peaks are recorded, unless vetoed by a pile-up reject logic signal into a GATE. Mode 1 is common in nuclear instruments, where the two peaks occur due to discrete radiation interactions occurring closely in time and both may be valid. Note that a pile-up rejection circuit external to the MCA can be used to gate off such pulses (discussed below).
- In Mode 2, the MCA8000D tracks the signal when it passes the slow threshold. If it detects that a peak has occurred, but then the signal rises to a second (or third or fourth or ...) peak before returning to threshold, it is the largest peak which is output from the peak detector. The largest value between slow threshold crossings is the output. Mode 2 is common in particle sizing analyzers, where the shape of the particle can cause the light curve to exhibit multiple peaks but the largest peak is the quantity of interest.

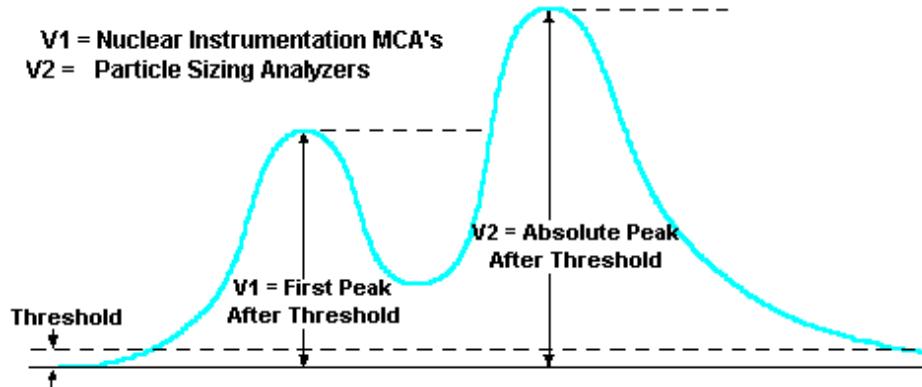


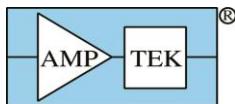
Figure 3. Illustration of the two peak detection modes available.

5.3 Thresholds

The MCA8000D includes a threshold parameter which can be set in software. Its primary function is in the peak detect logic: the pulse height must be greater than the threshold, then the pulse must fall below its peak by the threshold before the system recognizes that a peak occurred. Usually, the MCA will only record pulses above this threshold but, with some bipolar pulses, it is possible to have below threshold pulses recorded. The MCA8000D also include a separate parameter, the LLD (low level discriminator). This functions purely as a lower threshold, only recording pulse heights which exceed the LLD.

5.4 Livetime

In the MCA8000D, there is a livetime clock. This clock is stopped whenever (a) the input is over the slow threshold or (b) GATE1 or GATE2 disables acquisition.



6 DPPMCA Software Interface

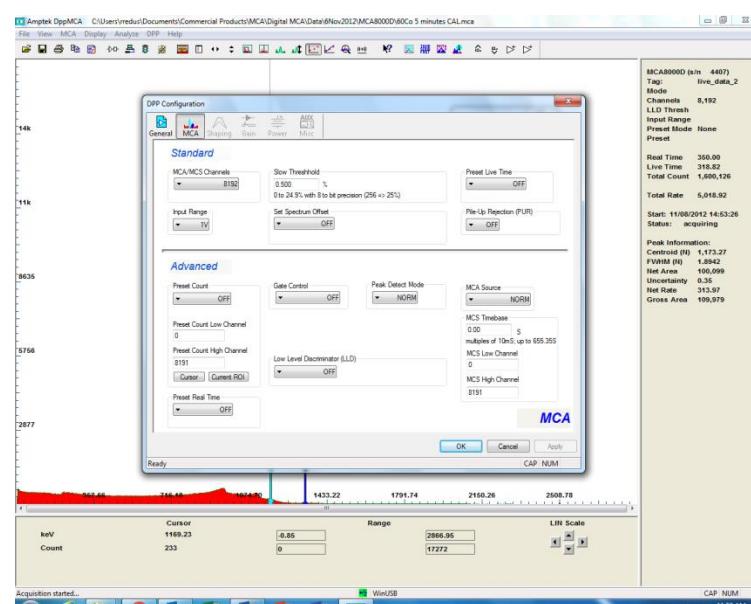
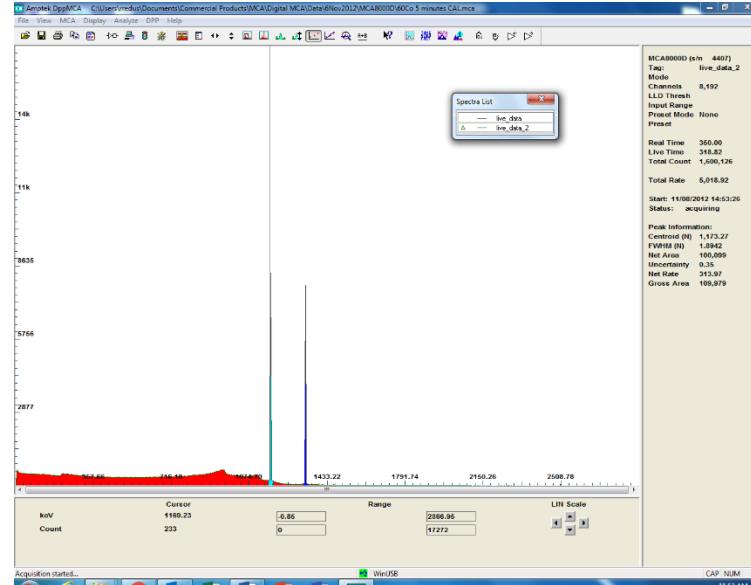
The MCA8000D uses the same DPPMCA software, with the same FW6 communication protocol, as the other members of the product family. It's the same basic software interface, but because the MCA8000D has a much more limited set of configuration options (only those related to the MCA rather than to signal processing and power supplies), the interface looks slightly different. The DPPMCA Help File remains accurate but the accessible parameters are much more limited.

When connected to and acquiring data from the MCA8000D, the main screen (shown to the right, top) is almost unchanged. The only difference is that, in the "Info Pan" on the right, DPPMCA does not show the gain, peaking time, HV, detector temperature, or the other parameters shown with the digital processors. In addition, it shows the live time and real time, rather than accumulation time, because the MCA8000D uses different clocks, as discussed elsewhere in this manual.

When configuring the MCA8000D, (shown to the right, bottom) only the MCA tab is available, because none of the parameters listed on the other pages are present in the MCA8000D. These parameters all have their usual meanings, as discussed in the DPPMCA help file and in this user manual.

- To use an external gate, connect the logic signal to GATE1, then set the "Gate Control" to HIGH or LOW (depending on the signal polarity).
- To use pileup rejection, connect the logic signal to GATE2, then set "PUR" to HIGH or LOW (depending on the signal polarity).

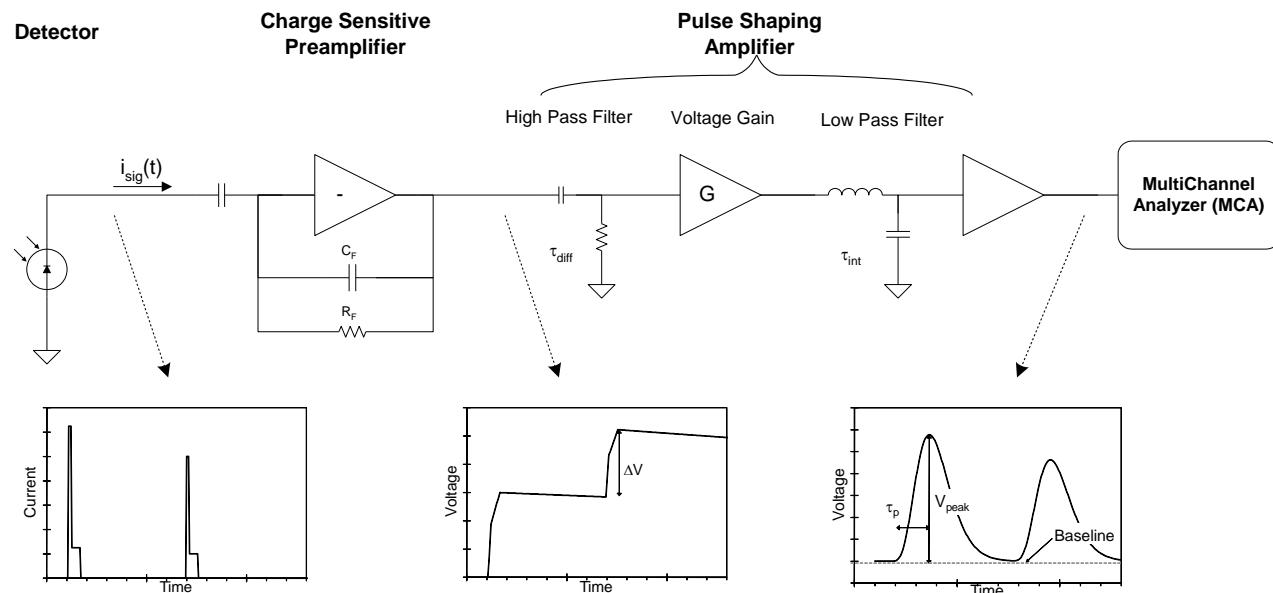
The digital oscilloscope still functions but the only valid trigger signal is PEAKH (the other triggers are generated by DPP logic in Amptek's other products).



7 Application Advice

7.1 MCA800D in Radiation Detection

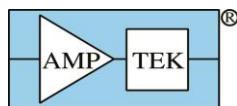
The figure below illustrates a typical spectrometer used in detecting ionizing radiation – X-rays, gamma-rays, alpha particles, etc. When ionizing radiation interacts in the detector, charge is liberated. The total amount of charge is proportional to the energy deposited. The ratio depends on the detector but in many applications, the total charge may only be a few thousand electron-ion pairs. The signal current is input to a charge sensitive preamplifier, which produces a voltage pulse where the step, ΔV is proportional to the charge in the input pulse and hence to the energy.



The step from the preamplifier is usually very small and is superimposed on a baseline which is much larger, varies with time, and has wideband noise present. The preamplifier output thus goes to a shaping amplifier which filters the noise, stabilizes the baseline, and provides enough gain for accurate measurement. The MCA does two things: (1) it digitizes the voltage of the peak of the shaped pulses and (2) from the many pulses it produces a pulse height spectrum. This is a histogram.

In most radiation detection systems, the quantity of interest is the system conversion gain in eV/channel. This depends on many factors: detector material, preamp conversion gain, shaping amplifier gain, and a pulse peaking factor related to the shaping network. In most radiation detection applications, one sets up the complete system and then uses monoenergetic radiation sources to calibrate the system conversion gain. There are many excellent calibration sources, e.g. characteristic X-ray lines and gamma-ray lines. These are constant and do not depend on any external conditions. The absolute calibration of the MCA, in volts/channel, is not needed for most radiation detection applications because the system gain depends on so many factors and excellent, traceable calibration sources are readily available.

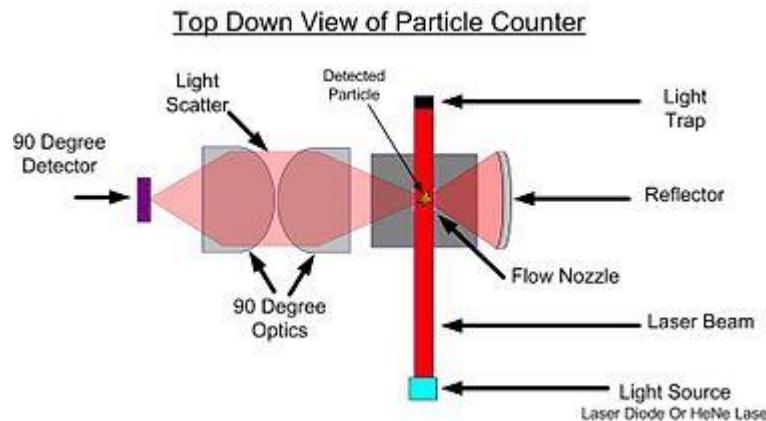
Because radioactive decays are random processes, they occur at random times. Among other things, because the pulse shaping electronics give a finite time to process each pulse (a dead time per pulse), two pulses can overlap or pile-up. They will be input to the circuit as a single pulse. The MCA8000D includes a dead time clock to estimate the true, incoming rate from the number of measured pulses and the total time the system was dead. This is discussed in more detail below. The MCA8000D also includes a Gate input which can be used to stop acquisition for piled up pulses. The



shaping amplifier or other circuitry preceding the MCA8000D must be used to generate the Gate signal. The MCA8000D cannot detect pile-up but it can reject pulses when external circuitry signals.

7.2 MCA8000D in Particle Counting

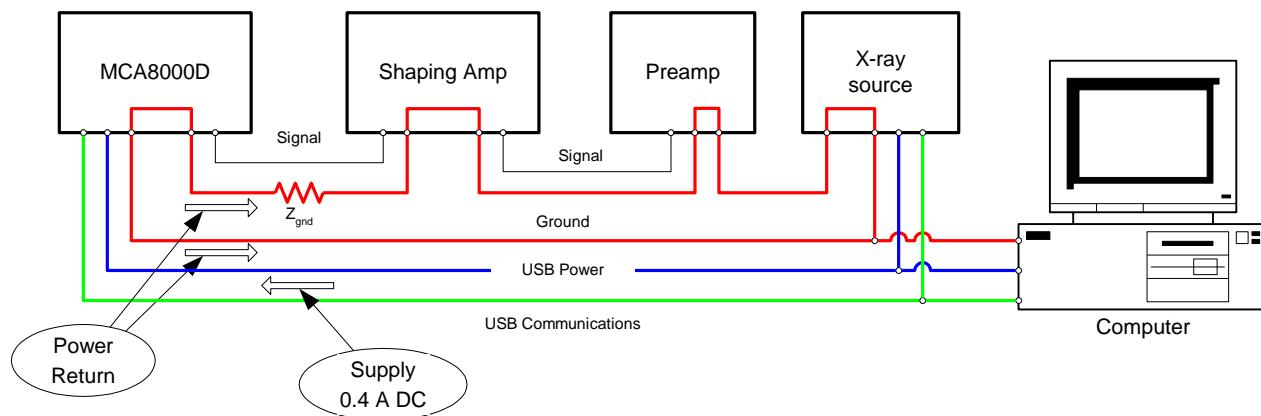
The figure below (from *Wikipedia*) illustrates a typical particle counter system. A light shines on a region through which dust passes. When a dust particle passes in front of the light source, light reflects into the detector, producing a current pulse. The current profile may have a very erratic shape depending on the shape of the particle. By measuring the distribution of peak values, one determines the distribution of particle sizes.

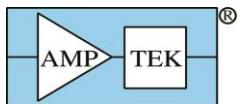


The manufacturer will provide a calibration value: a 0.1V output pulse corresponds to a given particle size. An MCA then measures the distribution and number of these pulses. Note that the particle analyzer requires the MCA's calibration, in volts per channel, to be known. This is unlike the nuclear system where the characteristics of ionizing radiation can be used for very accurate calibrations. The MCA8000D for particle analyzers, Option PA, includes a NIST certified voltage calibration. In the calibrated MCA8000D, channel 512 corresponds to 0.5 (5) volts in the 0-1 (0-10) voltage range. Amptek guarantees the calibration to +/- 1% but it is usually much better.

7.3 Grounding and measurement errors

Grounding is very important for accurate, small signal measurements. Customers have reported errors which arise from return currents when powering the unit via USB. The drawing below illustrates the problem.





The problem arises because “ground” has two distinct roles in most circuits. The ground connection is usually both a signal reference and a power return path. If there is significant current in the power return, then the impedance of the ground leads to voltage differential which causes errors if the same ground path is used as the signal reference.

In the sketch above, the red trace illustrates the ground connection in a common arrangement. The preamp signal passes to the shaping amp and its output to the MCA8000D. There is a ground connection between them, so the preamp output voltage is referenced to ground and the shaping amp output is referenced to ground.

In this sketch, the 0.4A of USB power must return to the computer. There are two parallel paths, the ground in the USB cable but also the signal ground. The 0.4A current will be divided between the two paths and this current, across the resistance in the ground path between the amplifier and the MCA8000D will cause an error. Even 50 mΩ of resistance in the cables will lead to a 20 mV error.

The best solution is to separate the signal ground from the power return path. In this particular case, using the MCA8000D’s AC/DC power supply accomplishes this. The AC/DC supply is not grounded, so the return current is entirely contained in the power supply wire. The separation between signal reference and power return is usually recommended and will help with measurement accuracy.

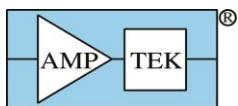
7.4 Calibration

General Information

Calibration of the MCA8000D is simple yet is the source of much confusion for novice users, so will be discussed in some detail. To calibrate the MCA, whatever the application, one needs to inject into the MCA a set of pulses of known, discrete amplitudes. A spectrum is then acquired and these discrete amplitudes appear as discrete peaks in the spectrum. The centroid of each peak is measured, often using the DPPMCA software. A calibration dialog in DPPMCA lets one enter the measured centroids (in channels) and the corresponding known amplitudes (in volts, keV, electrons, nanoseconds, or whatever unit is appropriate). The software then implements a correlation using these (amplitude, channel) pairs. The MCA8000D hardware is linear to within 0.6% full scale but many sensors are not linear, so the software permits either linear or quadratic regressions. The DPPMCA software uses the values entered into the calibration dialog to show the scale of the horizontal axis in its display. The use of the calibration dialog is discussed in more detail in the DPPMCA Help File but, at its core, it implements a regression on a set of measured (amplitude, channel) pairs.

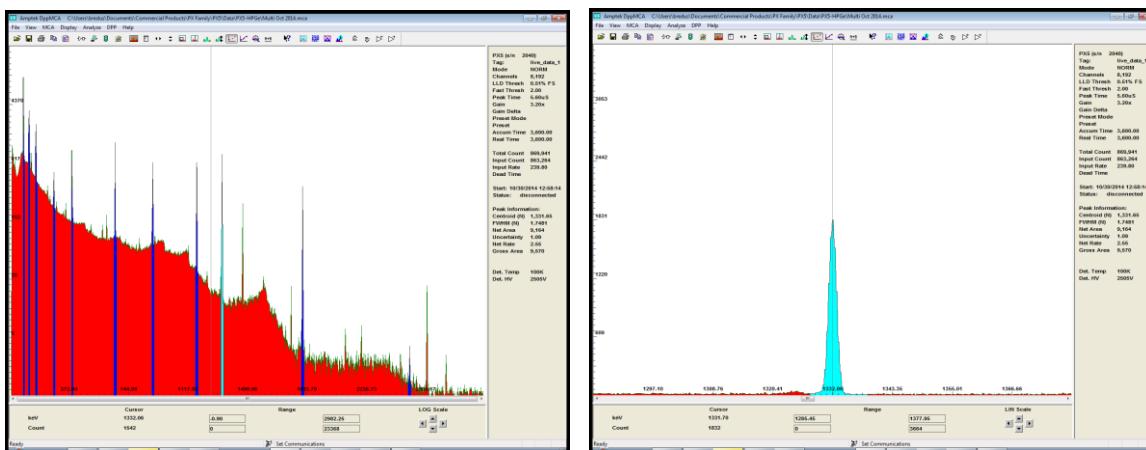
Nuclear Instruments

In a nuclear instrument, one typically measures the spectrum from a sample with at least two peaks of known energies. The energy of the incident particles is correlated with the measured centroids; this calibrates not only the MCA but the entire signal processing chain (detector, preamp, shaping amp, etc). Because the characteristic energies of X-rays and gamma-rays are physical constants, there is no need for NIST traceable calibrations: one is calibrating the system to constants. But one does need a spectrum with peaks of known energies. The plot below shows the spectrum measured from an HPGe gamma-ray detector and shows a zoomed in photopeak; the software computes the centroid channel of this peak. The table below that shows a set of calibration values, (energy, channel) pairs, and the result of a linear regression. Note that channel zero is not zero energy; this is typical, since real amplifiers have nonzero offset.



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	Energy (keV)	Centroid	Fit Energy	Δ Energy	
241Am	59.537	172.63	59.610	0.073	0.073
57Co	122.061	351.29	122.153	0.092	0.092
57Co	136.474	392.43	136.554	0.080	0.080
133Ba	276.404	791.76	276.346	-0.058	0.058
133Ba	356.014	1,019.24	355.979	-0.035	0.035
133Ba	383.859	1,098.74	383.810	-0.049	0.049
137Cs	661.661	1,891.92	661.475	-0.186	0.186
60Co	1,173.238	3,353.57	1,173.150	-0.088	0.088
60Co	1,332.513	3,808.60	1,332.441	-0.072	0.072

$$\begin{array}{lll} \text{slope (keV/channel)} & 0.350 & \pm 1.2E-05 \\ \text{offset (keV)} & -0.822 & \pm 0.035 \end{array}$$

Particle Analyzers

For a particle analyzer, Amptek provides a NIST traceable calibration. We use a DC voltage source and a special calibration mode to trigger the ADC on each of two DC voltage levels. This produced the centroid channel for each of the two voltages.

At Amptek, we program into each MCA8000D (Option PA) the two (voltage, channel centroid) pairs. Amptek's DPPMCA software reads these two pairs and does a linear regression to obtain the mV/channel and mV offset; these are used in the display of the horizontal axis. Amptek guarantees the accuracy of this Option PA calibration to within +/-1% and the offset to be within 0.02 mV (0.2 mV) for the 1 (10V) range. A customer can do a calibration check (using a calibrated pulser and recording centroids) or can acquire additional calibration points using the calibration dialog in DPPMCA.