PX4 Frequently Asked Questions (FAQ)

What is the PX4?

The PX4 is a component in the complete signal processing chain of a nuclear instrumentation system. It replaces many different components in a traditional instrumentation system: the shaping amplifier, the multichannel analyzer, logic devices, high voltage power supplies, and several auxiliary components.

The input to the PX4 is the preamplifier output. The PX4 digitizes the preamplifier output, applies real-time digital processing to the signal, detects the peak amplitude (digitally), and bins this value in its histogramming memory, generating an energy spectrum. The spectrum is then transmitted over a serial interface (USB or RS232) to the user's computer. The PX4 generates, from a single low voltage power input, the high voltage to bias the detector, power to operate a thermoelectric cooler, and the various low voltages required by the preamplifier as well as the PX4's own circuitry.

Figure 1 and Figure 2 show block diagrams of a traditional analog system and the PX4, a digital system. They include the same basic elements and implement the same functions. The PX4 implements the pulse shaping digitally rather than using analog components, providing considerable performance advantages. Further, the PX4 is a single, compact, integrated unit with digital control of all parameters, making it much more convenient.

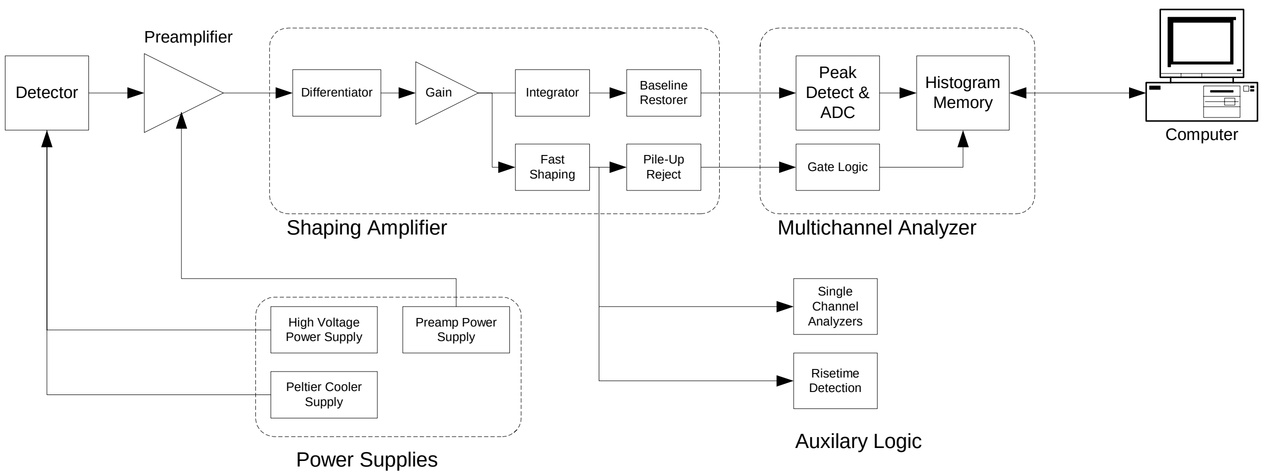


Figure 1. Bock diagram of a traditional analog spectroscopy system. In addition to the detector and preamplifier, it includes a shaping amplifier, an MCA, power supplies, and auxiliary logic function. These are generally separate modules.

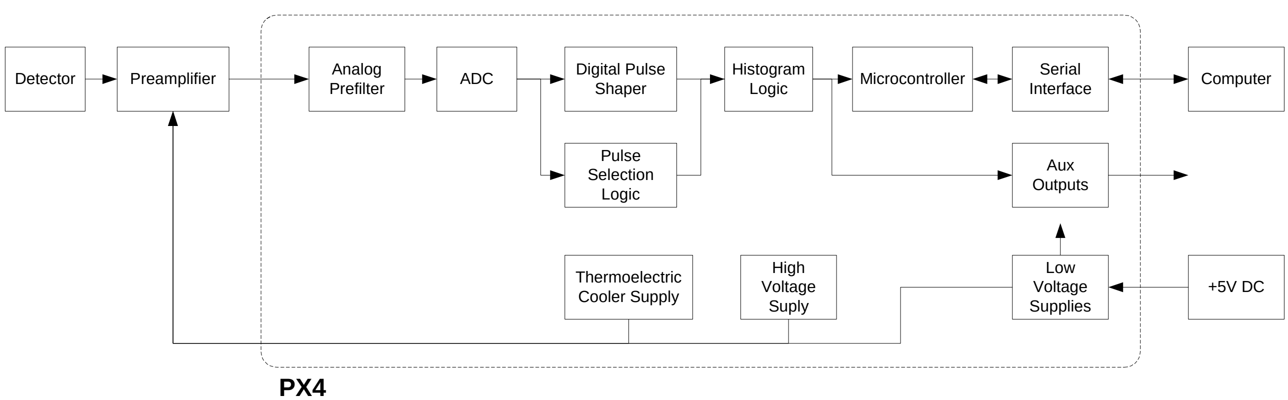


Figure 2. Block diagram of the PX4. It includes the same functions as a traditional system, but in a single, compact module. Digital processing permits greater flexibility in the configurations and makes changing configurations easier.

What is "digital pulse processing" and how does it differ from analog processing?

The output from the preamplifier (a charge sensitive preamplifier) is a small, fast voltage step. With Amptek's XR100, the gain is 1 mV/keV, so for X-rays the preamp output signal is tens of mV. The goal is to measure this with a resolution of a couple hundred eV, or <0.2 mV. The signal has a risetime of 100 nsec or so and a decay time of milliseconds or more. This signal is superimposed on a variable DC baseline and has considerable white noise due to thermal noise in the preamplifier, shot noise in the detector, etc. The signals occur at random time intervals, often at tens of thousands of events per second.

In both analog and digital pulse processing systems, this preamplifier output goes to a shaping amplifier and then to a multichannel analyzer (MCA). The shaping amplifier's purpose is to permit an accurate determination of the peak height. The pulse shaping removes the DC baseline, reduces distortions due to overlapping pulses, and filters out the broadband noise. The shaping amplifier also amplifies the pulse to permit accurate measurements. Both digital and analog systems have this same purpose and include similar elements: a differentiator (or high pass filter), an integrator (or low pass filter), voltage gain, baseline restoration, etc. In both systems, the pulse amplitude is ultimately obtained in a digital form, yielding an energy spectrum in the MCA memory.

The difference is that the analog processor uses analog circuitry to perform the pulse shaping, then digitizes the peak of the final shaped pulse. The pulse shaping is implemented using op-amps, resistors, and capacitors. The digital processor digitizes the preamplifier output, then shapes the pulse with a digital filter running in an FPGA. The functions are the same, but the digital pulse processor moves the digitization earlier in the signal processing chain.

What are the advantages of digital pulse processing?

There are three primary advantages: better performance, greater flexibility, and greater stability and reproducibility.

1. Researchers derived long ago the ideal filters for use in nuclear electronics, e.g. for the best signal-to-noise ratio at a given count rate. The transfer function cannot easily be produced in practical op-amp circuits. But digital processors have fewer restrictions and so can more closely approximate the ideal transfer functions. This improves performance.
2. There is no dead time associated with the peak detect and digitization, so a digital processor has considerably higher throughput than an analog system. Further, since it has a finite impulse response, pile-up and other pulse overlap effects are reduced. The digital processor's performance is particularly good at high count rates.
3. In an analog pulse processor, most parameters are determined by resistors and capacitors. In a pseudo-gaussian shaper, shaping time is determined by a set of fourteen resistors and capacitors, for example. It is impractical to have many different configuration options in an analog system. In a digital system, shaping time is set by the length of digital delay. In a digital system, one can easily have many more parameters and configuration options. These parameters include not only the shaping time but baseline restoration parameters, pile-up rejection parameters, etc. A digital system has far more configuration options so the user can readily tailor a system to the needs of an application, resulting in better performance.
4. Because the analog system relies on resistors and capacitors, its stability is limited to the stability of these components and its reproducibility to their tolerances. In a digital system, the stability and the reproducibility are much better, because they derive from a few very accurate references, e.g. the crystal oscillator to set timing. In an analog system, fine gain usually comes from a pot and it is difficult to return to a previous setting, but in a digital system, one can go back to exactly the same parameters.

What are the advantages of the PX4 over the PX2?

The PX4 has two major advantages.

1. The PX4 is a digital system, so offers all of the advantages listed above for digital systems: more flexibility, better stability and reproducibility, and better performance. One can adjust the PX4 parameters to optimize separately for low and high count rates, obtaining better performance in each than the PX2's single setting. It has lower noise (for low count rates), better baseline stability (at high count rates), a lower temperature coefficient, and various other performance advantages.

2. The PX4 is more convenient. It is a single, compact, light-weight package. With the PX2, you need not only the PX2 but also the MCA, power cables for each, etc. The PX2 requires 110VAC while the PX4 does not need line voltage. A single PX4 can be used for all of the detectors in Amptek's inventory, Si and CdTe.

What do I need along with the PX4?

1. A detector and preamplifier.

   Amptek has a series of detector/preamplifier units for which the PX4 was specifically designed. Designated XR100s, this includes thermoelectrically cooled Si detectors for X-ray spectroscopy and thermoelectrically cooled CdTe detectors for higher energy X-rays and for γ-rays. These are all easily configured for use with the PX4.

   The PX4 can be used with most other standard detectors and preamplifiers used in the nuclear industry – other solid state detectors, scintillators, etc. The PX4 can be configured for use with these various detectors, as discussed in the PX4 User's Guide.

2. A computer (with interface software) and a power supply (one is provided with the unit).

   The PX4 requires a computer for data acquisition and control. Amptek provides the necessary PC software (it can be downloaded from our website, free of charge), suitable for PCs running Windows. Amptek also provides a library of subroutines for interfacing to the PX4 from within a user's custom software. The standard PX4 includes a USB and an RS232 interface.

   The PX4 requires a 5V DC power supply. It is supplied with a standard transformer to produce 5V from 120 VAC. It can be operated from other supplies. USB does not specify enough current to run the PX4 with an XR100 thermoelectric cooler. Battery packs may also be used. Please refer to the PX4 specifications.

Will the PX4 work with an MCA?

The PX4 includes an MCA internally. It is possible to use the PX4 as a shaping amplifier only but not recommended. One can send the preamp signal to the PX4, use it for pulse shaping, then send this (digital) shaped pulse to the PX4's DAC, and connect this with the user's external MCA. However, some loss of performance is often observed, due to grounding issues and to the digital nature of this shaped output. We recommend use of the PX4's internal MCA, since it is available anyway and will generally provide the best performance.

Will the PX4 work with a traditional shaping amplifier? Can the PX4 be used as an MCA only?

The PX4 replaces a traditional shaping amplifier. It is not possible to connect the output of a traditional shaping amplifier to the PX4 and use it as an MCA only. The circuitry before the ADC will further shape the input, resulting in a highly distorted (not useful) pulse.

Will the PX4 work with Amptek's XR100 detectors?

Yes. It was optimized for use with them.

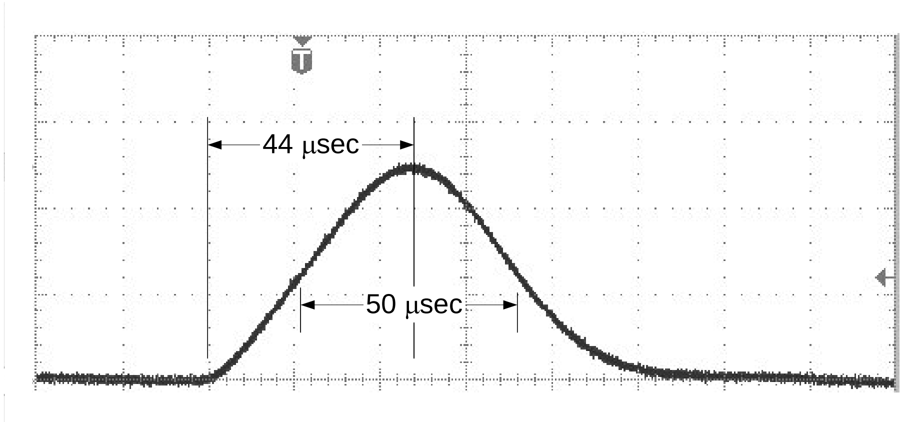
Will the PX4 work with all detectors and preamplifiers?

It will certainly work with most standard detectors and preamplifiers. We hesitate to say "all" because such a wide variety is in use.

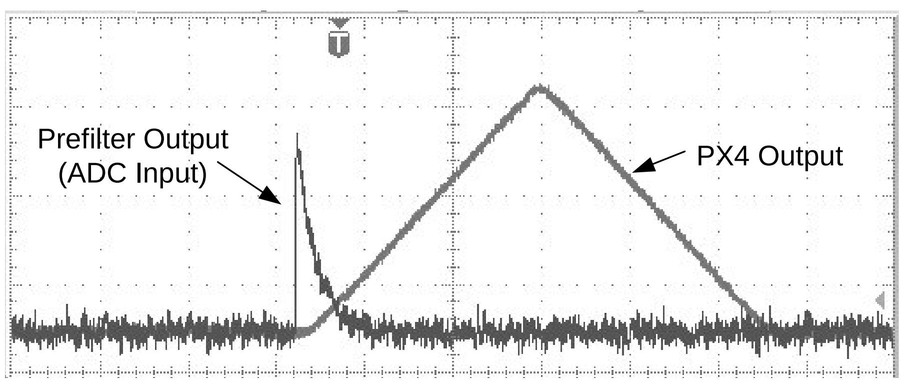
What is the difference between "peaking time" and "shaping time"?

This is the source of much confusion, in both analog and digital pulse processing. The simple answer is that the PX4 with peaking time T_P will have performance similar to that of an analog shaper with shaping time constant τ, where $2.2\tau=T_P$.

For the longer answer, we must recognize that τ is related to the time constant of the low pass filter stages and so is also related to the peaking time of the output pulse, to the pulse duration, and to the noise bandwidth (in the frequency domain). The relationship between these quantities depends on the details of the transfer function of the filter which does the pulse shaping. Shown below is an oscilloscope trace of a quasi-triangular shaped pulse from an analog pulse shaper, an Amptek PX2, with $\tau = 20$ μsec (the horizontal axis is 20 μsec/div). This is considered the shaping time it is the real component of the poles of the transfer function. The risetime is 44 μsec, or 2.2τ. The pulse is slightly asymmetric, with a settling time slightly longer than its rise time. The FWHM is about 50 μsec.



An oscilloscope trace of a PX4 shaped pulse is shown below (20 μsec/div). The risetime is well defined at 51 μsec. The pulse is triangular, so is symmetric and has duration 51 μsec (FWHM). The noise bandwidth is comparable to that of a quasi-triangular shaper with the same risetime, so 23 μsec. It will have pile-up properties similar to those of the PX2 output above, but slightly larger noise bandwidth and therefore lower noise.

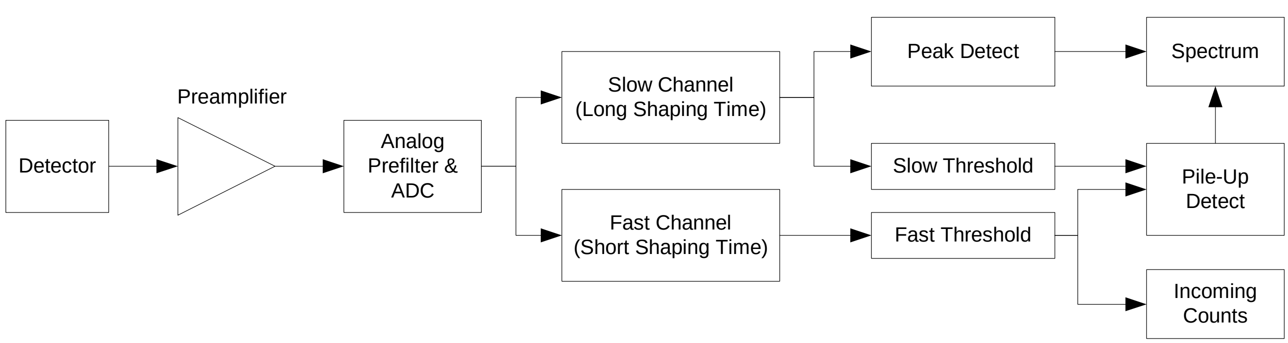


What is the difference between the "fast channel" and the "slow channel"?

What is the difference between the "fast threshold" and the "slow threshold"?

What is the difference between the "counts" and the "incoming counts"?

The "fast" and "slow" channels are two parallel signal processing paths inside the PX4, operating at different shaping times. They are optimized to obtain different data about the incoming pulse train. The "slow" channel, which has a long shaping time constant, is optimized to minimize electronic noise, to obtain an accurate pulse height. The "fast" channel, which has a short shaping time constant, is optimized to detect pulses which are closely spaced in time and so overlap (or pile up) in the slow channel.



For most detectors, electronic noise is minimized at a fairly long shaping time constant. For Amptek's XR100 Si detectors, minimum noise is found with a peaking time of 20 to 50 μsec. So the slow channel is operated at this long time constant, and its output is connected to the peak detect circuit and used to obtain the energy spectrum.

Since radiation interacts in the detector at random intervals, it is possible to have two interactions occur within the processing time of the slow channel. Even at low count rates this will occur occasionally and in most applications, it is useful to operate at a high count rate to minimize data acquisition time. Two problems occur when the pulses overlap in time: only a single pulse is recorded rather than two, and the detected peak has an incorrect amplitude. To address this, there is a fast channel with a peaking time of 0.4 μsec. Pulses which overlap in the slow channel but not in this fast channel may be rejected from the spectrum, to minimize the distortions. If pile-up reject (PUR) is turned on, then they are rejected. Further, the fast channel is used to measure the true incoming count rate (ICR), where far fewer pulses are rejected. Additional information on pulse pile-up can be found in the PX4 User Manual.

Note that separate thresholds are used in the fast and slow channels. Since the fast channel is usually operated further from the noise corner, it has a much higher noise level and so the threshold must be higher. The "counts" recorded by the PX4 are those in the spectrum, those detected in the slow channel. The "incoming counts" recorded by the PX4 are those detected in the fast channel, where the dead time is much less.

What is the dead time for the PX4?

The dead time is the duration of time following a valid event during which a subsequent event will not be measured. For the fast channel in the PX4, the dead time is 400 nsec. For the slow channel, if pile-up reject is disabled, the dead time is 1.25*peaking time. With PUR on, then it is 2.5*peaking time. Technically, this is a pulse pair resolving time, i.e. the amount of time that elapses before you can count the next pulse. There is no dead time as in an analog system (associated with the peak detect and digitization), so a digital processor has considerably higher throughput than an analog system.

Will the PX4 work with a MAC computer?

All Amptek supplied software will only work on Windows based machines. We do provide the complete communication protocol so that a user could write their own drivers and software.

Will the PX4 work with a computer running LINUX?

All Amptek supplied software will only work on Windows based machines. We do provide the complete communication protocol so that a user could write their own drivers and software.

How do I configure the PX4 for an Amptek XR100 detector?

The easiest way is to select a predefined configuration file based on your XR100 detector type from the General tab of the DP4/PX4 properties dialogue in the ADMCA software.

How do I configure the PX4 for a detector and preamp from another manufacturer?

This can be fairly complex. Please refer to the PX4 user's guide.

Who are typical users of the PX4?

How quickly can it be set up?

The PX4 is very easy to set up. All you need to do is connect the USB port to your PC, plug in the AC power adapter, and connect your detector.

How long does it take to stabilize?

It is the detector not the PX4 that must stabilize when powered on. Amptek detector have internal thermoelectric coolers that take about 1 minute to stabilize.

Can my old PMCA files be used in the ADMCA software?

The ADMCA software can open all old PMCA files.