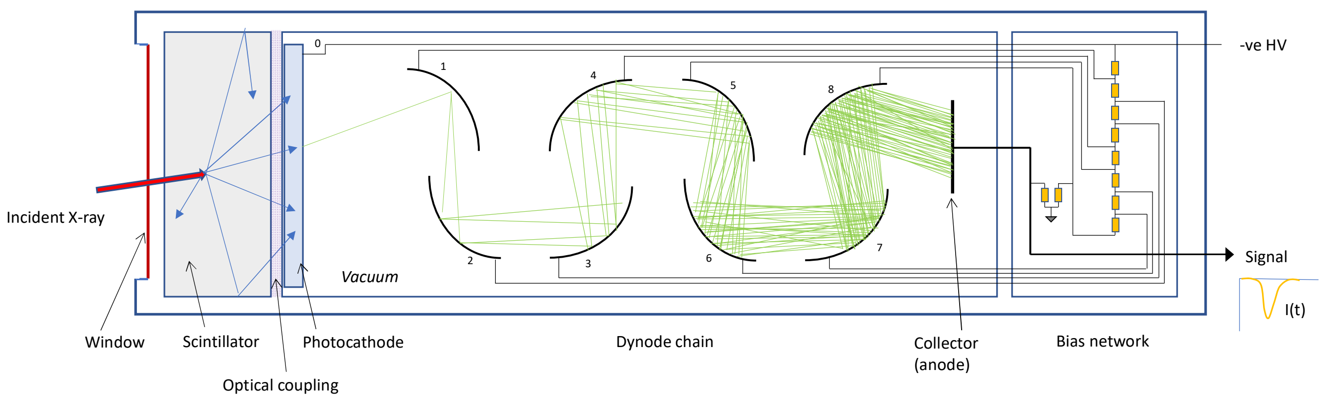
TN0015

Pulse measurement using sodium iodide scintillation detectors

Sodium iodide detectors

The doped sodium iodide or NaI(Tl) scintillation detector is the workhorse radiation detector for X-rays and gamma rays with energies of a few keV and upwards. Other scintillator materials offer higher speed or greater light output, but at much greater cost.

When a photon interacts with the scintillator material its energy is converted mainly to blue light that reaches the photocathode of a photomultiplier. The light releases a few electrons, and these are accelerated towards the first of a series of dynode electrodes. At each dynode the arriving electrons release a larger number of electrons that are accelerated to the next dynode. This multi-stage exponential gain process results in a pulse of charge at the output that can contain between 1e5 and 1e8 electrons. The ability to detect individual incoming photons is achieved this way.



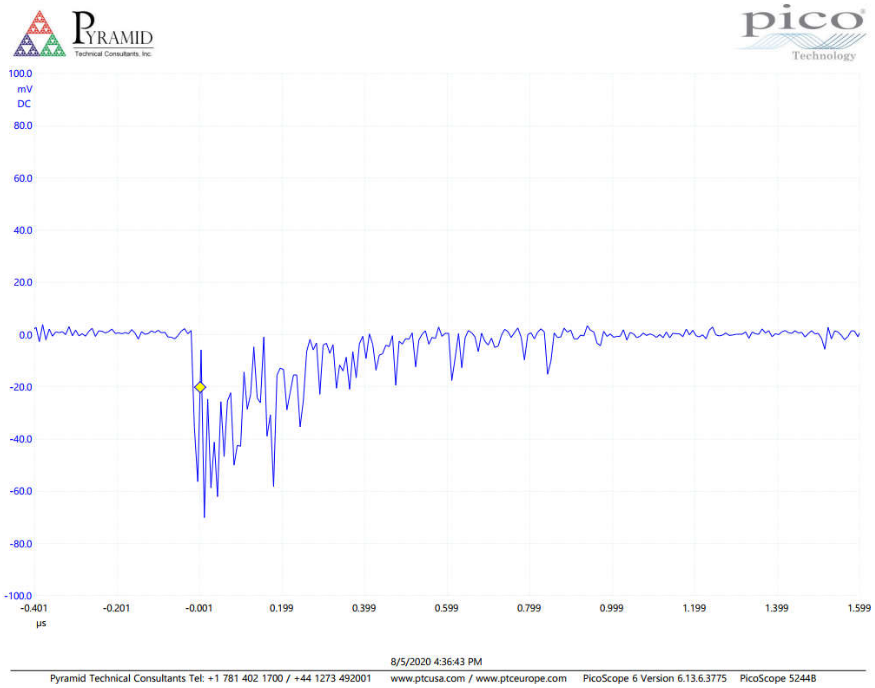
Types of measurement

The detector can make two types of measurement which differ only in the emphasis placed on the performance parameters. For pulse counting measurements the count rate of the pulses is the required data. In this case the speed of counting is usually most important – events should be counted individually even when they occur close in time. Alternatively, in pulse height analysis measurements the important data is the amount of charge in each pulse, a function of the amount of energy deposited in the scintillator. Here the precision and accuracy of measuring the pulse size is paramount. There is overlap between the performance parameters. In pulse counting it is generally necessary to count only pulses with a certain range of sizes, to allow background to be rejected. In pulse height analysis the measurement process must be fast enough to allow reasonable count rates to be processed.

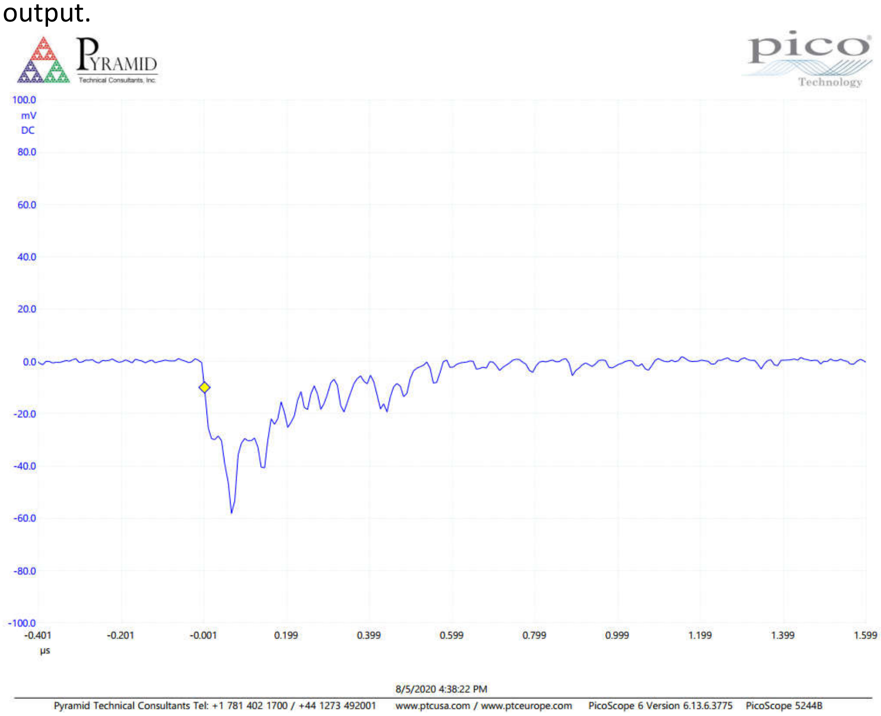
Pre-amplification

It is important to choose pre-amplification suited to the detector and the type of measurement. The sodium iodide detector responding to a single X-ray or gamma photon produces a complex burst of charge at the detector output.

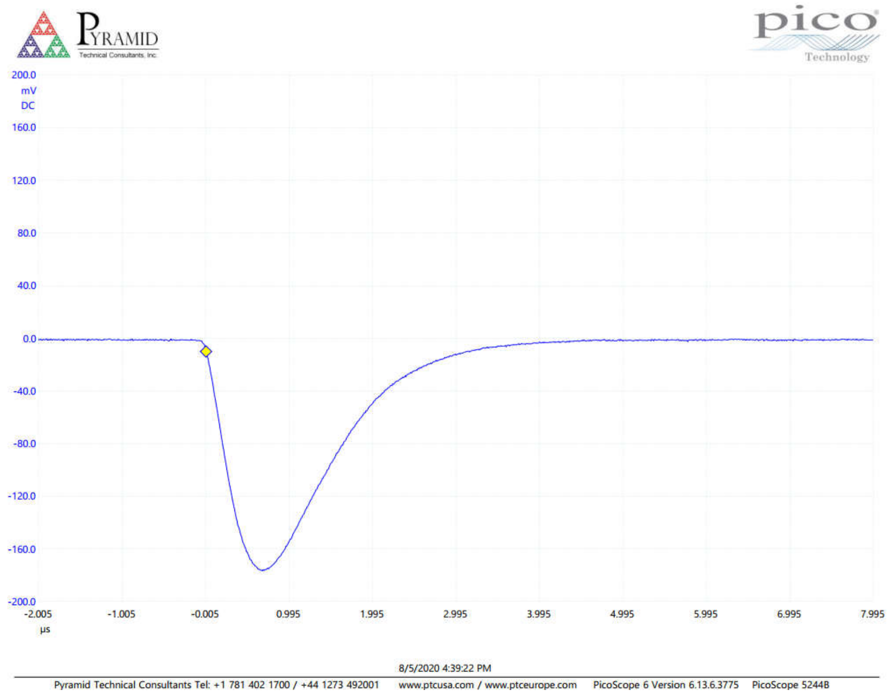
This is revealed if the signal is passed through a very fast pre-amplifier like the CP-10B. The trace below is the output from a NaI detector for a single 59.6 keV gamma event. There are fast bursts of charge over about 1 µsec duration due to the light emission and electron avalanche processes.



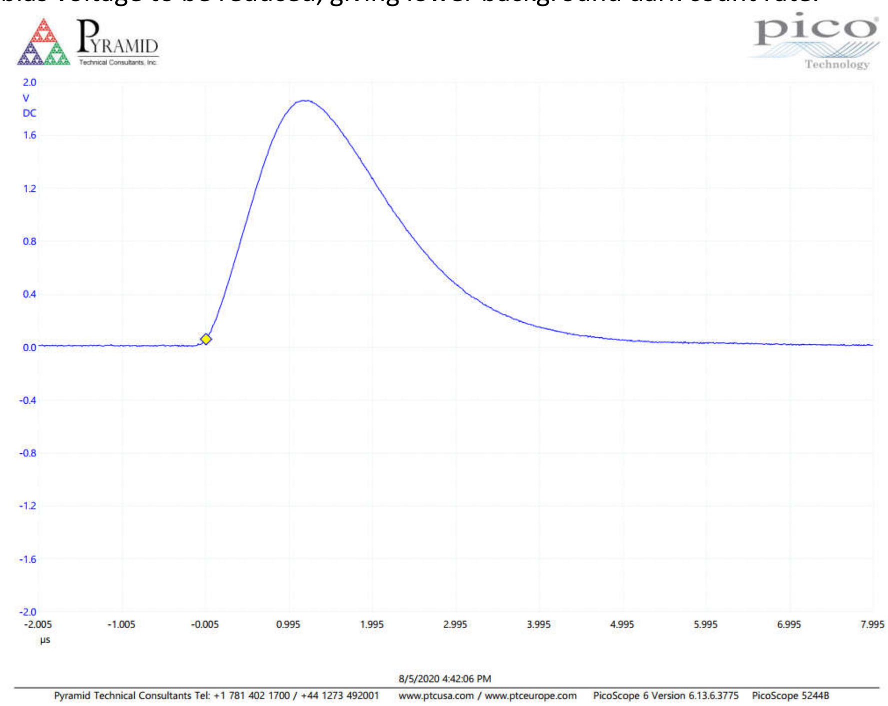
Such a signal is clearly unsuited to either pulse counting or pulse height analysis. A lower bandwidth preamplifier like the CP-10A is a good choice for fast scintillation detectors, but still reveals too much detail in a NaI detector output.



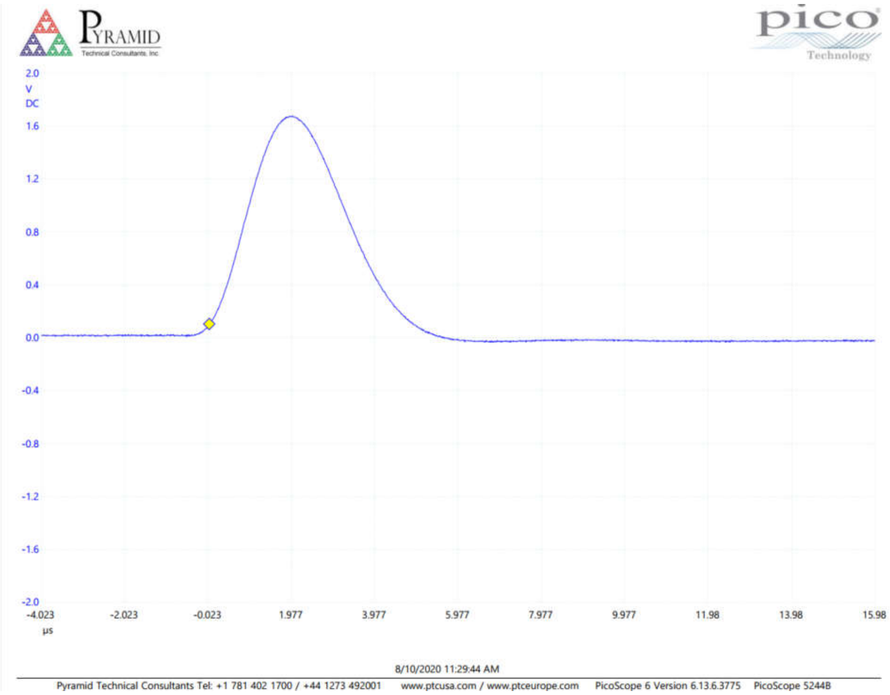
The Pyramid CP10AF preamplifier adds filtering to eliminate the detailed time structure and leave a single clean pulse.



The CP-15AF provides additional gain and optional inversion of the signal. Higher gain allows the photomultiplier bias voltage to be reduced, giving lower background dark count rate.



The classic solution is to first integrate the charge, then use a shaping amplifier to form a clean pulse whose height represents the amount of charge. The Pyramid CR-10 product uses this approach. The pulse shown below is the result of a 1 µsec shaping time constant. The CR-10 allows flexibility in choice of shaping time constant and a wide range of gain settings. It is physically larger than the CP-10 or CP-15.



Pulse height analysis

The low noise specification of the CR-10 and the choice of shaping times allows its use for a range of pulse height analysis applications. A sodium iodide scintillation detector provides a high signal charge per incident photon and has moderate photon energy resolution, so the performance of the CR-10 is not fully exploited. The CP-15AF is specifically designed to complement the performance of NaI detectors to enable pulse height analysis performance similar to the CR-10 but in very small and cost-effective package.

The spectra below were recorded with a FMB-Oxford C30NA20B sodium iodide detector measuring gamma rays from Am241. The photopeak at the high energy end of the spectrum is from 59.6 keV gammas. The gains of a CR-10 configured with 1 µsec time constant and a CP-15AF were approximately matched so that the two spectra could be overlaid. The yellow spectrum was recorded with the CP-15AF, the magenta spectrum with the CR-10.