Performance of Digitizers with HPGe and Scintillation Detectors

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Introduction

Recently, FPGA based digitizers have found attractive applications in signal processing for complex detector arrays in nuclear physics [1]. In the conventional analog electronics, energy and time signals from the preamplifiers are processed separately and involve a chain of electronics units. In a digitizer a flash ADC directly samples and stores the preamplifier output, which is then processed by pulse height analyzing algorithms to extract energy information. Since input data can be continuously acquired by a flash ADC and then processed by FPGA, the digitizer can work as a 'zero dead time' system. The digital signal processing (DSP) not only reduces requirement of electronics units and cabling, but also eliminates temperature related drifts to a large extent. In addition digitizers have better noise immunity. Thus, for long counting experiments like background studies for double beta decay [2], DSP is highly desirable.

This paper presents the performance of pulse height analyzing digitizer, CAEN N6724 for HPGe detectors and a charge integrating digitizer CAEN N6720 for high resolution scintillators like $CeBr_3$ [3]. Both these digitizers are NIM based and hence provide a compact, economical option for a few detector setups.

Experimental Details and Analysis

The CAEN N6724 unit is a 14 bit, 100 MS/s digitizer with input dynamic range 2.25 Vpp. The algorithm implemented for pulse height analysis is based on trapezoidal filter (moving window de-convolution). Digital filter parameters, namely, input signal decay time (T_{decay}), trapezoidal rise time (T_{rise}) and trapezoidal flat top time ($T_{flattop}$) are optimized for best resolution. The performance of CAEN N6724 digitizer has been studied with two different HPGe detectors. Table 1 gives details of detectors and preamplifier outputs.

Table 1: Detector specifications and parameters

Detector	Dia (mm)	L (mm)	t_{rise} (ns)	t_{fall} (μs)
Det 1 (30%) (Bruker Baltic)	53	63	140	120
Det 2 (70%) (Otrec)	78	63	400	150

Optimum pole-zero cancellation of trapezoidal signal is obtained by varying T_{decay}. It has been found that ballistic deficit error could be well compensated by setting $T_{flattop}$ equal to or greater than three times the rise time of input signal. Trapezoidal rise time (T_{rise}) is functionally equal to integration time of spectroscopic amplifier. It is kept as small as possible to get best energy resolution and minimum pulse pile-up. The optimum trapezoidal filter settings obtained for both detectors are given in Table 2. It can be seen that T_{rise} and $T_{flattop}$ is higher for the larger detector as expected.

Table 2: Trapezoidal Filter Parameters

Detector	T_{decay} (μs)	T_{rise} (μs)	$T_{flattop}$ (μs)
Det 1	70	3.5	0.5
Det 2	50	5.5	1.5

Figure 1 shows a spectrum of ^{152}Eu source for Det 2 recorded using the digitizer (top panel) and conventional analog electronics (bottom panel) and a comparison of energy resolution obtained is given in Table 3. It can be seen that the energy resolution obtained both DSP and analog processing is similar. Moreover peak positions shows excellent stability against thermal drift in the data recorded with the digitizer during long duration (24 hours). The digitizer has also been tested with a standard pulse generator and dead time is found to be nearly zero up to 50 KHz.

Table 3 A comparison of energy resolution with analog and DSP.

E_γ (keV)	FWHM (keV) Det 1		FWHM (keV) Det 2	
	Analog	Digitizer	Analog	Digitizer
121.8	1.40	1.68	1.44	1.67
778.9	1.86	1.97	1.87	2.03
1408.0	2.33	2.34	2.36	2.31

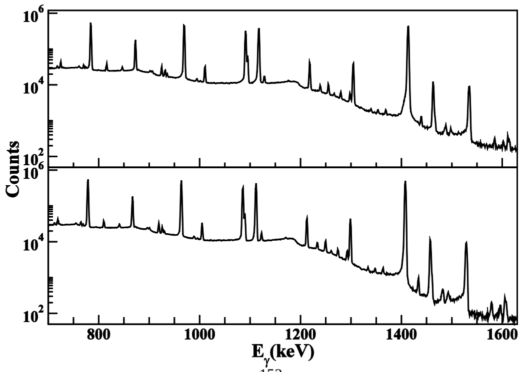

Figure 1: A comparison of ^{152}Eu Spectrum for Det 2 with the CAEN digitizer (bottom panel) and analog electronics (top panel)

Figure 2 shows a spectrum for high activity ^{54}Mn source (~30000 dps) in a close geometry with Det 2. The peak shape of 834.8 keV gamma ray with digitizer shows a considerable improvement. This clearly illustrates the advantage of the DSP particularly for large diameter detectors.

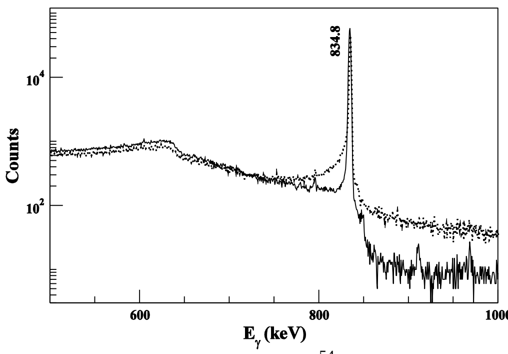

Figure 2: A comparison of the ^{54}Mn spectrum with the CAEN digitizer (solid line) and analog electronics (dotted line).

For processing signals from fast scintillator detectors like $CeBr_3$ or $LaBr_3$, the CAEN N6720 digitizer (12 bit) with a higher sampling rate (250 MS/s) and charge integrating option with input dynamic range ~2 Vpp is well suited. The charge integrating digitizer substitutes both QDC and CFD with integration and gate generation in the digital domain. Trigger and timing filters have been implemented completely in the digital domain, which replace the CFD and TAC in the conventional acquisition system. The N6720 has been tested with a $CeBr_3$ coupled to a Hamamatsu R6231 PMT, which has an anode output with ~20 ns rise time and a total pulse width ~100 ns. The energy spectrum of ^{60}Co with programmable gate width set at 150 ns is shown in Figure 3. The $CeBr_3$ has very good energy resolution ~ 4% at 1332 keV, similar to that of $LaBr_3$. The coincidence spectra for two $CeBr_3$ detectors have been successfully tested with this digitizer. Tests with BaF_2 detectors are in progress.

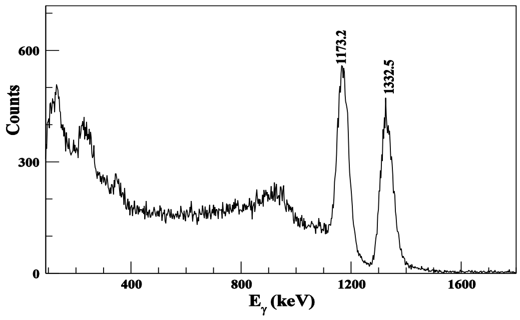

Figure 3: ^{60}Co Spectrum of a $CeBr_3$ detector with charge integrating digitizer CAEN N6720.

Summary

The performance of pulse height analyzing digitizer, CAEN N6724 for HPGe detectors and a charge integrating digitizer CAEN N6720 for fast scintillators $CeBr_3$ has been found to be excellent in terms of energy resolution and count rate handling. The long term stability is also found to be very good. These NIM units are ideally suited for small detector setups.

References

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