# Studies on the effect of digital data acquisition parameters on the neutron-gamma discrimination

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## Introduction

A radiation detection system often requires instruments capable of discriminating different kinds of radiation. The discrimination of radiation is done using various techniques. Pulse Shape Discrimination (PSD) is one technique that differentiates radiations based on their pulse shapes. PSD is employed in areas with a mixed radiation environment, such as nuclear reactors, space research, national security, medical physics, etc. PSD is commonly used for n-$\gamma$ discrimination. Discrimination of n-$\gamma$ using PSD can be carried out using analog and digital methods. The digital method is preferred over the analog method due to reduced hardware, multi-parameter analysis, increased throughput rate, fully computer-controlled operation, etc. PSD performance has significantly improved since the advent of fast digitizers and is characterized by the Figure of Merit (FoM) of the detector. FoM measurements using digitizer depends on several parameters such as interval of short and long gates, number of bits, sampling rate, etc. Even a slight increase in FoM is significant for experiments involving Triple PSD [1] where two bands lie close to each other, though it may not be significant much in cases involving only two types of radiation. The dependence of FoM on the digitizer parameters such as sampling rate and digitizer resolution ( e.g. 10-bit, 12-bit, etc.) has been studied earlier [2], and it has been reported that the best results are obtained using a 500 MHz/s sampling rate and a resolution equal to or better than 12 bits. The present work reports the studies on the dependence of the BC501A detector's FoM on pre-trigger and trigger holdoff for the first time. Pre-Trigger sets the portion of the waveform acquisition window to be saved before the trigger, whereas trigger holdoff is a programmable time during which the digitizer accepts no further trigger signals. A schematic of the acquisition window, showing both the parameters, is presented in fig.1.

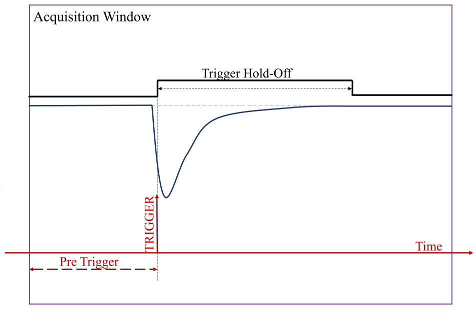

FIG. 1: Schematic of Acquisition window in Digitizer

## Experimental details

All the measurements were carried out at Radiation Detectors and Spectroscopy Laboratory, IIT Roorkee [3]. A 3″×3″ BC501A organic liquid scintillator coupled to a PMT supplied by Saint-Gobain was used for the measurements. The pulses due to gamma rays and neutrons were acquired using a $^{252}$Cf source. The detector was biased at − 1400 V. The anode signal from PMT was processed by CAEN fast desktop digitizer DT5751, with a 10-bit resolution and a sampling rate of 1 GS/s. The signal from the detector was fed to the digitizer via a 50 Ohm BNC to MCX coaxial connector cable of length 1 meter. DPP-PSD firmware, based on the charge integration method, was used for PSD. The onboard FPGA computes PSD online

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by employing two programmable charge integration gates. A short gate integrates the charge within the prompt light emission, and a long gate integrates the charge from the total light emission. Subsequently, PSD is calculated using the following formula.

$$PSD = \frac{Q_L - Q_S}{Q_L} \quad (1)$$

where $Q_L$ is charge within long gate and $Q_S$ is charge within short gate. A 2-D projection of the PSD versus entries (or counts) can be generated. To quantify the effectiveness of PSD, Figure of Merit (FoM), as defined below, is used.

$$FoM = \frac{\delta_{peaks}}{FWHM_\gamma + FWHM_n} \quad (2)$$

where $\delta_{peaks}$ is the separation between centroids of two peaks and $FWHM_{\gamma/n}$ is FWHM of gamma/neutron peak.

## Results and Discussion

In the present study, short and long gates were optimized and set to 30 and 100 ns, respectively. Fig.2 presents the plot of PSD as a function of the ADC channel number. Two distinct bands are clearly visible in the plot. The lower band corresponds to events due to $\gamma$-rays, and the upper band corresponds to events due to neutrons. Fig.3 presents the projection of the 2D plot on the PSD axis for the entire range. The curves were fitted with gaussian peaks using the ROOT package to get the centroid and FWHM of the peaks. FoM was calculated for different combinations of pretrigger and trigger holdoff values using eq.2. The calculated values of FoM were in good agreement with those published in the literature [4]. Table 1 shows the variation of FoM with pre-trigger when trigger holdoff was set at 144 nsec. Slight variations in FoM with pretrigger were observed. The best FoM value was obtained at a pre-trigger value of 48 ns.

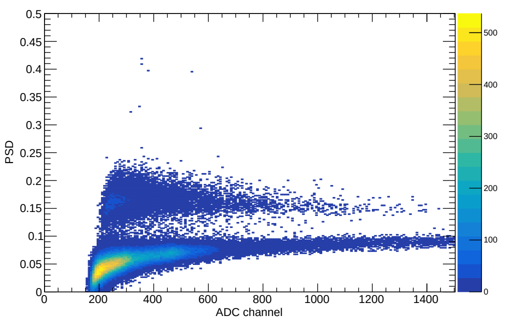


FIG. 2: 2-D PSD spectrum

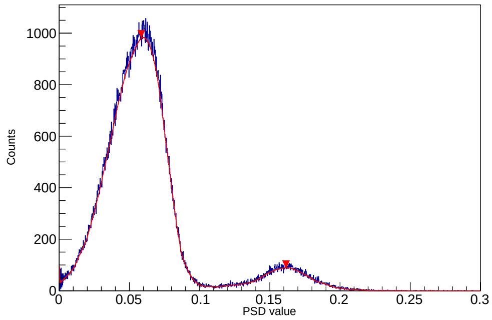


FIG. 3: Projection of the 2-D spectrum

TABLE I: Variation of FoM with Trigger-holdoff set at 144 nsec

| Pre-Trigger (nsec) | FoM |
|---|---|
| 32 | 1.131±0.004 |
| 40 | 1.162±0.005 |
| 48 | 1.220±0.005 |
| 56 | 1.140±0.002 |
| 64 | 1.138±0.004 |
| 72 | 1.184±0.006 |
| 144 | 1.125±0.004 |
| 248 | 1.121±0.004 |
| 400 | 1.109±0.006 |

Variation of FoM with trigger holdoff was also studied, with the pre-trigger set at 40 nsec. The best FoM value was found at a trigger holdoff value of 144 ns. Measurements are in progress to understand the dependence of FoM on digitizer parameters for alpha-gamma discrimination.

## References

[1] A. Giaz et al., Nucl Instrum Methods Phys Res A. **825**, 51 (2016).
[2] D. Cester et al., Nucl Instrum Methods Phys Res A. **748**, 33 (2014).
[3] https://rdslab.iitr.ac.in/index.html
[4] K.A.A et al., Nucl Instrum Methods Phys Res A. **642**, 78 (2011).