Gamma Spectroscopy with a digital oscilloscope

Tuhin Malik[1], Krithika Raman[3], Rutuparna Rath[2], Rohan Biswas[4], Dibyadyuti Pramanik[5] Abhijit Bisoi[5], Shinjinee Dasgupta[6], M. Saha Sarkar[6]
[1]BITS-Pilani, K.K.Birla Goa Campus, Zuarinagar, Goa 403726 INDIA
[2] Stella Maris College, Chennai, Tamil Nadu 600086 INDIA
[3]North Eastern Hill University, Shillong, Meghalaya 793022 INDIA
[4]IISER Kolkata, Mohanpur West Bengal 741252 INDIA
[5]Indian Institute of Engineering Science and Technology, Shibpur, Howrah - 711103, INDIA
[6]Saha Institute of Nuclear Physics, Bidhannagar, Kolkata - 700064, INDIA
*· * email: maitrayee.sahasarkar@saha.ac.in*

Introduction

Digital Signal Processing (DSP) is one of the most versatile and powerful technologies that is presently bringing in revolutionary changes in a wide variety of fields, ranging from communications, medical imaging, astrophysics to nuclear spectroscopy.

The output signals of the detectors used in gamma spectroscopy studies are analogue in nature. In commercial DSP units, these analogue signals from the preamplifiers are converted to equivalent digital signals using an ADC (Analogue to Digital Converters). The resultant digitised signal is analysed later without any analogue electronic units like amplifier, pulse shape analysers etc. DSP techniques are utilised to replace hardware with software. An efficient DSP system therefore warrants development of a variety of mathematical algorithms. In contrast to the analogue regime, in DSP, the challenges lies in developing a system with enough speed and an efficient enough algorithm to measure the necessary properties of the pulses from the detector, event by event.

Rapid development of fast digital oscilloscopes gives us an opportunity to utilise digital signal processing to improve and simplify the experimental setup at small laboratories. It has been demonstrated that several modules of the analogue electronics can be replaced by only one fast digital storage oscilloscope.

The aim of this work is to utilize a digital oscilloscope for digital pulse processing and perform standard measurements of energy signals from different gamma detectors. The results have been compared with those obtained with standard methods of pulse processing and analysis.

Experimental Details and Analysis

In the present work, a DPO 4032 Tektronix Digital Oscilloscope [1] has been used as an ADC to digitise the preamplifier pulses from different gamma detectors. This is a 350MHz oscilloscope with 2.5 GS/s (400ps time resolution) horizontal resolution and its vertical resolution is 8 bits (11 bits with Hi Res option). This oscilloscope collects data on an event by event basis and can store information corresponding to each pulse in different formats. We have coupled this oscilloscope via USB and /or LAN connection to a Desktop PC and continuously acquired data. Performance of several scintillators, like NaI(Tl), $LaCl_3$ and BaF_2 have been tested using this method.

We have usually acquired data in two modes from this oscilloscope. These are:

1) Automatic Measurements mode: - vendor pre-defined properties of any pulses, like amplitude, rise time, delay etc are measured and saved in a file.
2) The oscilloscope can also store waveforms in terms of data (voltage vs. time for detector pulses) in ascii files, and screen images.

The amount of charge deposited in the detector by the radiation is given by the area under the peak in the voltage vs. time plot. When acquiring real time singles data during an experiment, enormous amount of events are usually generated by a single detector. In such cases, it is often cumbersome as well as time consuming for the oscilloscope to write full waveform information for each and every pulse. The oscilloscope in this case may miss many events resulting in dead time in acquisition. In order to overcome such difficulties, in these cases automatic measurement modes appear to be more useful. Three measurements were chosen for this purpose namely- maximum, amplitude and peak to peak measurements. Histograms of these data were later generated using Excel, MATLAB and plotted to get energy spectra and resolution of the detectors.

However, these measurements are pre-defined by the manufacturer and it is imperative to understand the measurements fully before drawing conclusions on the detector behaviour from these data. It also does not provide any scope of testing different algorithms to get best energy resolution of a particular detector.

In order to obtain a more complete picture of the energy of the photons, the method of charge integration was applied on the waveform data by developing a few algorithms with and without subtracting the contribution of noise. The results are compared with those from measurement modes as well as from data acquisition with conventional electronics.

We have also initiated to study the effect of high count rate and pile-up in the present measurements. The gamma source (Co-60) is kept at three different distances (close, mid and far) from the NaI(Tl) detector to quantify the effects of pile-up. Pile-up events have been identified by checking for more than one peak in the single event window.

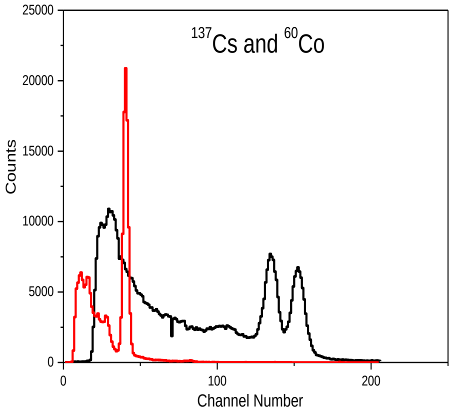

Fig. 1 Typical energy spectra generated for a NaI(Tl) detector using data recorded by an oscilloscope.

Table 1: Variation in pile-up events.

Distance	**Total no. of events**	**No. of events with single pulse**	**Ratio**
far	282581	163052	0.577
mid	45182	22408	0.4959
close	183895	71803	0.3904

Discussion and Summary

The importance of proper choice of bin width while drawing the energy histogram (energy spectrum) has been tested. We have compared the usefulness and the limitations about the various pre- defined measurements of the oscilloscope. It has been found that the peak to peak measurement of the preamplifier pulses gives the best energy resolution of any scintillator detector. We have also tested a HPGe detector with this oscilloscope and understood the necessity of an ADC of higher vertical resolution for obtaining proper energy resolution of a HPGe detector. Charge Integration of the waveforms were found to give accurate results irrespective of the settings of the oscilloscope. Hence the reliability of the waveform data was found out.

Hence a fast digital oscilloscope was found to be a good substitute for the complex analog circuitry as it gave more or less the same energy resolution for different types of scintillators.

Acknowledgement

The authors gratefully acknowledge Profs. Maitreyee Nandy, Chandi Charan Dey and PMG. Nambissan for providing the detectors.

References

[1] DPO4032 Tektronix Users Manual