Development of New Peak Detection method for Nuclear Spectroscopy

[1]Nirja Sindhav, [2]Arpit Patel, [3]Dipak Kumar Panda, [4]Paresh Dholakia
[1]PG Student, [2]Scientist, [3]Scientist, [4]Assistant Professor
[1]Electronics and Communication Dept.,
[1]V.V.P. Engineering College, Rajkot, India

Abstract— ***Gamma ray is a well-established technique to measure the chemical composition of planetary surface. These high energetic gamma radiations are mostly are detected either by semi-conductor detector or scintillation detector. The interaction of Gamma radiations with the scintillation detector produces visible lights. This visible light is guided to photo-multiplier tube (PMT) through light guide to produce a bunch of electrons. CSPA (charge sensitive pre-amplifier) has been used to converts these electrons to voltage. To achieve an optimized the resolution the signal from the preamplifier is shaped and amplified to Gaussian shape. The pulse height information can be deduced by either detecting the peak of the pulse or digitizing through successive ADC. But in this paper we have presented new peak detection method. The peak of the amplified Gaussian shaped signal has been discharged linearly to fetch the maximum energy and time information. Conversion of the analog signal is to be done in digital through comparator and the measurement of the pulse width is carried out. This width gives the energy of the signal and ultimately the counter starts counting the pulses in the defined time. This count provides the information related to the energy of the gamma ray and from these the abundance of the element can be calculated. The output of the system is gathered in the data acquisition system. This design needs some controlling signal for initiating and fetching data which will be generated through FPGA. The coding for the FPGA is to be done in the VeriLOG language. FPGA has an internal PLL which generates clock at 320 Mhz. we are measuring the pulse width with help of PLL clock in counting mode.***

IndexTerms—Gamma Ray Spectrometer, Peak Detection Techniques, FPGA, Mixed Pulse Processing

I. INTRODUCTION

Gamma ray has deep penetrating power and hence is generally used for nuclear spectroscopy. The energy photons emitted by the electronics transition (x-ray) are not suitable for this purpose [1]. Gamma ray spectrometer is a well-established technique to measure the elemental abundance of elements like Si, K, Al, O, Ca, Mg, Fe, Ti, U & Th. GRS has been flown in various planetary mission like moon (Lunar Prospector, Selene, Change' etc), mars (Mars Odyssey) and asteroid. Though high purity Ge (HPGe) preferred because of its high resolution still scintillation detector like CsI(Tl), NaI(Tl) and BGO detector are used because of their temperature independency.

Out of the various scintillation detectors NaI(Tl) is most commonly used for the detection of the Gamma rays because of good resolution provided by it and it is economical too. When Gamma rays interact with the detector and emit visible light. This visible light is guided to a photomultiplier tube (PMT). When these light photons strike the photocathode one electron is ejected via photoelectric effect. These electrons are then guided by the electron multiplier to finally to anode to bunch of electrons. The output pulse from PMT is converted into corresponding voltage by a preamplifier which is then amplified to Gaussian shaped pulse. Finally the peak of the Gaussian is detected and then discharges linearly to obtain the energy and time information. The overall pulse height is directly proportional to the Gamma ray energy absorbed in the crystal. Pulse height analyzer measures the height of the input pulses.

In conventional gamma ray spectrometer the peak height information is generally obtained by detecting the peak using a peak detector then this information is digitized by an ADC to get the gamma spectrum. But use of Peak detector is both costlier and very carefully has to be handled. Also controlling the peak detector also is not so simple. Therefore we have opted a new methodology for the same purpose. Here the signal processing involved is Analog and Digital Signal Processing. Before implementing the design and fabrication of the hardware the concept has been verified through simulation. Finally, this design will be implemented through FPGA coding by VeriLOG.

A. Gamma Ray Spectroscopy (GRS)

Gamma ray spectrometer well established technique used in both laboratory for measurement of geological sample as well as a remote sensing tool in planetary science. Planetary bodies without any atmosphere with very thin atmosphere can emit gamma ray from their surface. There are in all two main sources of gamma rays Galactic Cosmic Rays. (GCR) and decay of natural radioactive element like K (^{40}K), U (^{235}U, ^{238}U), Th (^{232}Th).

Gamma Ray Spectroscopy is the study of interaction of Gamma rays between matter and radiated energy. Scintillation detector is one of the detector which is used to detect the Gamma rays. Sodium iodide detectors are mainly used because of their availability in large size, high interaction of gamma rays and high density of material.

Figure 1: 2" x 2" NaI(Tl) Gamma ray detector.

B. Operation of detector with PMT

Gamma ray strikes the surface of the detector the charge gets accumulated and then it passes through the photomultiplier tube (PMT). PMT is consists of a photo cathode, dynode and an anode. When the photons from the scintillator strike the photocathode it emits one electron by photoelectric effect. The dynodes in the PMT are connected to gradually higher potential corresponding to its preceding one. The ejected photoelectron from the cathode is guided to the first dynode to produce secondary electrons. These secondary electrons are the guided to series of dynode and finally to the anode. The large number of electrons reaching the anode results in a sharp current pulse. This pulse is then connected to a charge sensitive preamplifier (CSPA) to converts the collected charge to the proportional voltage pulse. The preamplifier output generally of few tens of mV to max 100 mV [2]. The pulse is of ~300 ns rise time with 100 µs fall time for NaI(Tl). To measure accurately and optimize the energy resolution the pulse has to be amplified and shaped to a Gaussian pulse. The amplified pulse height is directly proportional to the Gamma ray energy absorbed in the crystal. Further process is to be continued with the signal processing electronics.

C. Pulse Height Analyzer

The function of the pulse height analyzer is to measure the height of the input pulse. The pulse height distribution is based on the interaction of the Gamma rays with the detector. The portable gamma-ray spectrometer [1] is a necessary tool for radioisotope identification in radiation safety, security inspection and environmental surveying, as well as for a variety of other scientific and industrial applications [3].

II. PULSE SHAPING TECHNIQUE

The pulse shaping method is explained below:

- ***CR and RC Shaping***
  The pre-amplifier output pulse is passed through a CR (Differentiator) (basically shorten the fall time) and then passed through a RC (Integrator) (which increase the rise time). In frequency domain the CR is high pass filter and RC is the low pass filter.
- ***Pole-Zero cancellation***
  The overshoot and undershoot of the signal are removed by setting the value of Pole-Zero cancellation in processing.
- ***Baseline shift***
  The amount of the signal which is suppressed below the baseline level is called the baseline shift. Baseline shifts can be eliminated using the bipolar pulse shape but the SNR characteristic is better using the mono polar pulse shape.
- ***Double differentiation***
  This is in general a second differentiation state added to the CR-RC stage. It is used at high counting rates and even used for achieving the bipolar shape of the pulse [4].
- ***Single delay line shaping***
  The single delay line uses the shorted transmission line for the shaping of the pulse. The coaxial cables are also used for the same.

- ***Double delay line shaping***
  The double delay line shaping gives the output as the bipolar signal which was the drawback of the single delay line shaping. The entire information of the signal is stored in its amplitude.

For our development we have used first pole zero and then CR-(RC)^2 method. The peak of the signal is detected and given to the comparator which compares the input with the reference voltage and provides the digital output, it works as ADC. The width of the linear discharged pulse is measured where counting is carried out through the counter using the clock pulses. This gives the number of counts which will be displayed on the system. The count Vs time graph will give the abundance of the element. FPGA has been used to generate time control signals.

III. Conceptual Proposed Method

This work has been in inspired from the Wilkinson ADC [5]. The detail schematic block diagram is shown fig 2. The conceptual design of the circuit has been developed on the basis of the switch and the discharge capacitor. The Wilkinson-type ADC determines the amplitude of the pulse by first converting the amplitude to time and then measuring time [5].

The comparator is there which compares the shaping amplifier output with discharge output which is having small delay. This delay can help us to identify the peak of shaped pulse. The comparator output pulse is given to a switch to initiate the discharge process.

Another comparator will compare the discharge output with reference voltage and will generate the pulse which is having the timing information of discharge. The pulse will be given to FPGA to measure the width using counter based algorithm. The higher discharge time can help to cover a wide energy range and also the resolution can be improved. The figure given below depicts the idea behind the design of the circuit.

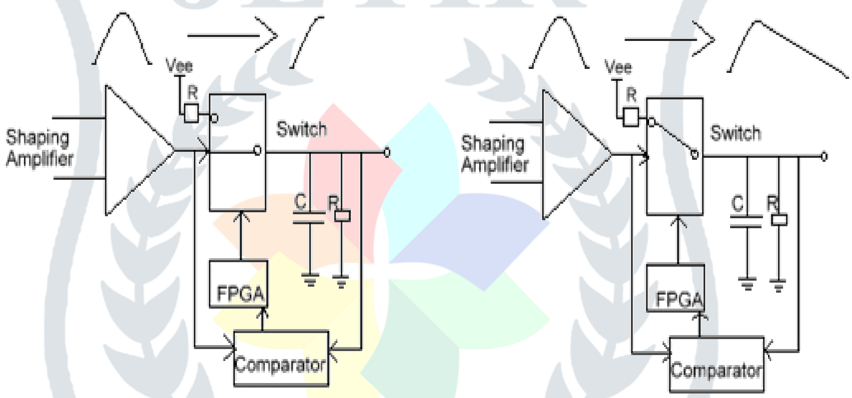

Figure 2: Conceptual method for the discharge of the signal.

The peak detection and linear discharge circuit board has been made as given in the figure below:

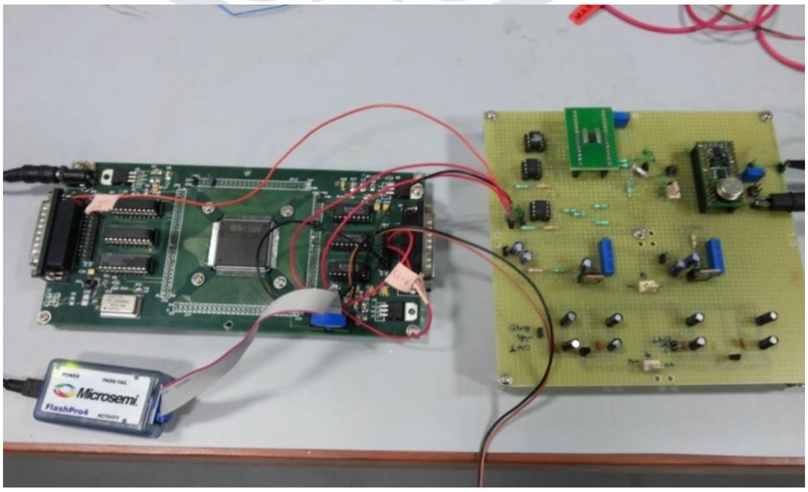

Figure 3: Circuit board of the proposed desig.

The above figure shows the GP (general purpose) board consists of the Shaper circuit, the Switch and the Comparator Circuit. Actel made FPGA is used for processing and data storage.

IV. Results and Their Analysis

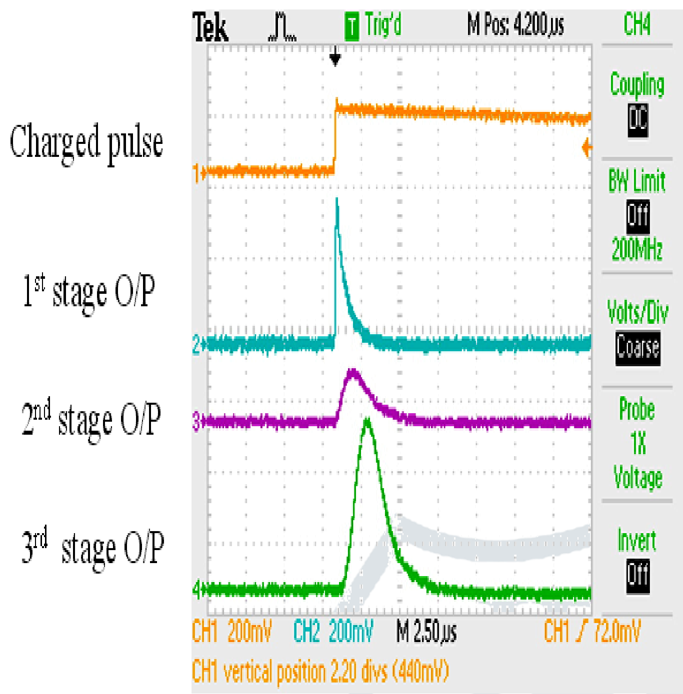

Figure 4: Shaper Output-Gaussian.

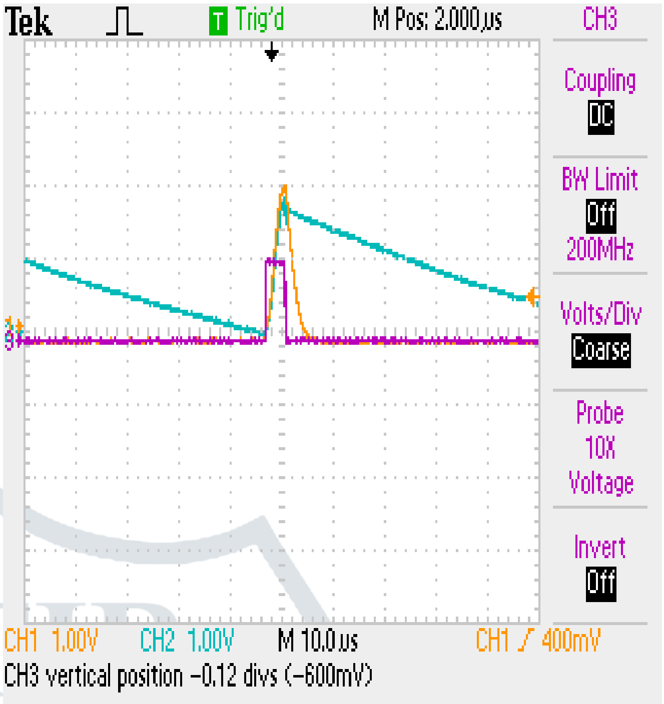

Figure 5: Peak Detected with the Comparator Output.

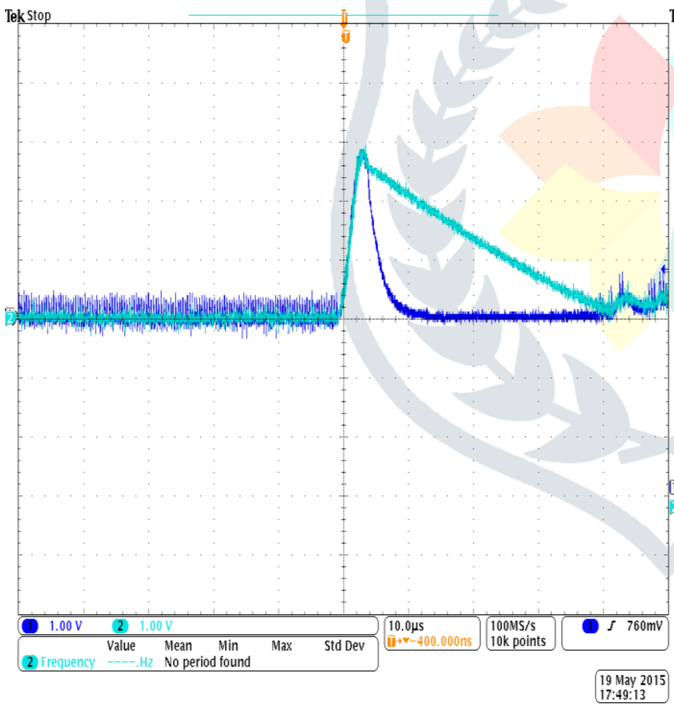

Figure 6: Peak detected pulse and comparator output.

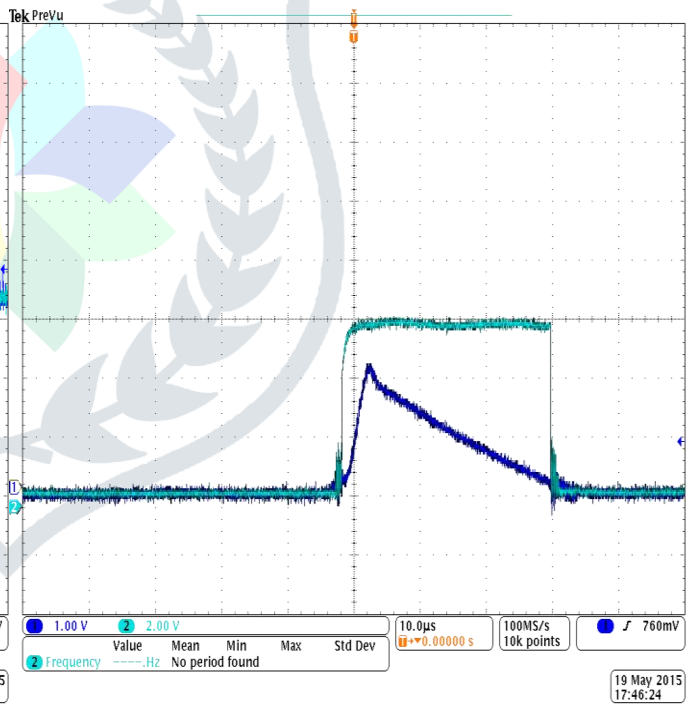

Figure 7: Linear Discharge and Comparator Output till the end of the pulse.

As shown in the figure 5, Channel-1 gives the Gaussian pulse output from shaping amplifier and Channel-2 is the linear discharged pulse whereas the Channel-3 gives the indication of the peak. This indication of peak detection can be realized by the comparator output. And the width (active high) of the comparator output will be measured by counting the number of clock pulses assimilated in the entire width of it. This pulse is given as an input signal to the FPGA where the logic is implemented to count the number of clocks within the entire width till the next pulse. The Counter clock is at 320 MHz which is generated using FPGA internal PLL block.

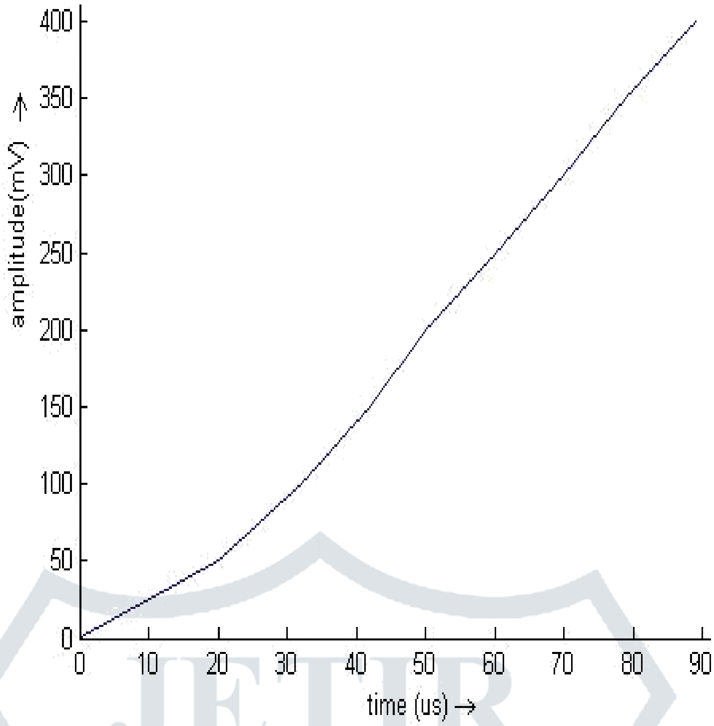

Figure 8: Graph of Linearity.

The graph in figure-8 shows the linearity of the system where as per the increment in the input voltage directly increases the linear discharge of the pulse. The discharge time is kept long so the nonlinearity of system cannot affect the resolution of system. Ultimately it is like, more discharge, more information. More improvement can be achieved in linearity as well as resolution in breadboard model

As shown in the figure 9 the front window of the software Libero includes the design entry tools where we have the HDL editor as well as the smart design. We are using smart design as it is more compatible in the design. Followed by the simulation block which gives timing waveforms of the signals coded in the HDL.

Again there is a place and route option which gives the pin assignment of the FPGA to the peripheral components and a flashpro block for the programming.

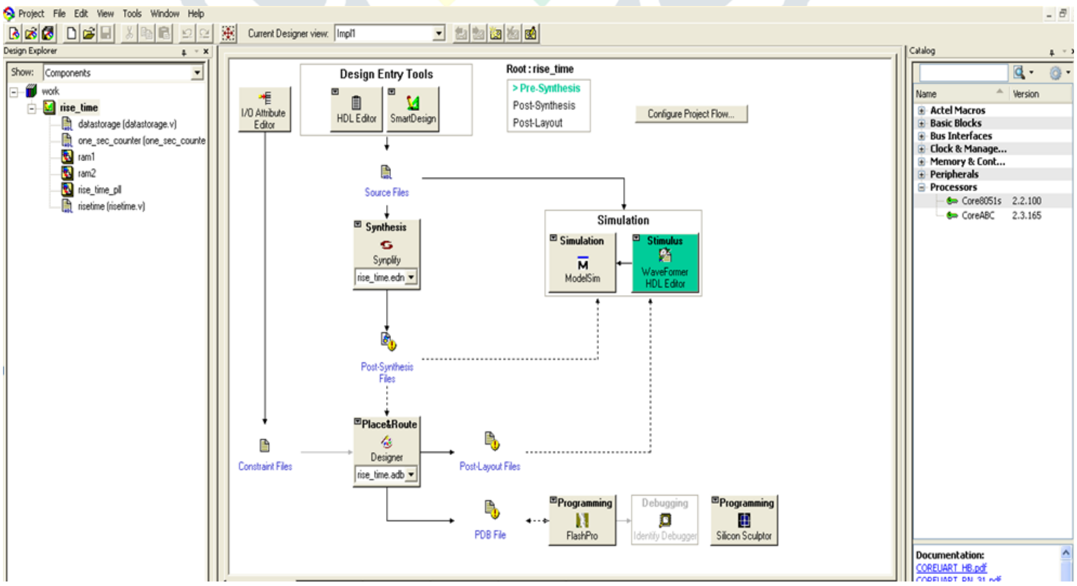

Figure 9: Front window of the Software Libero.

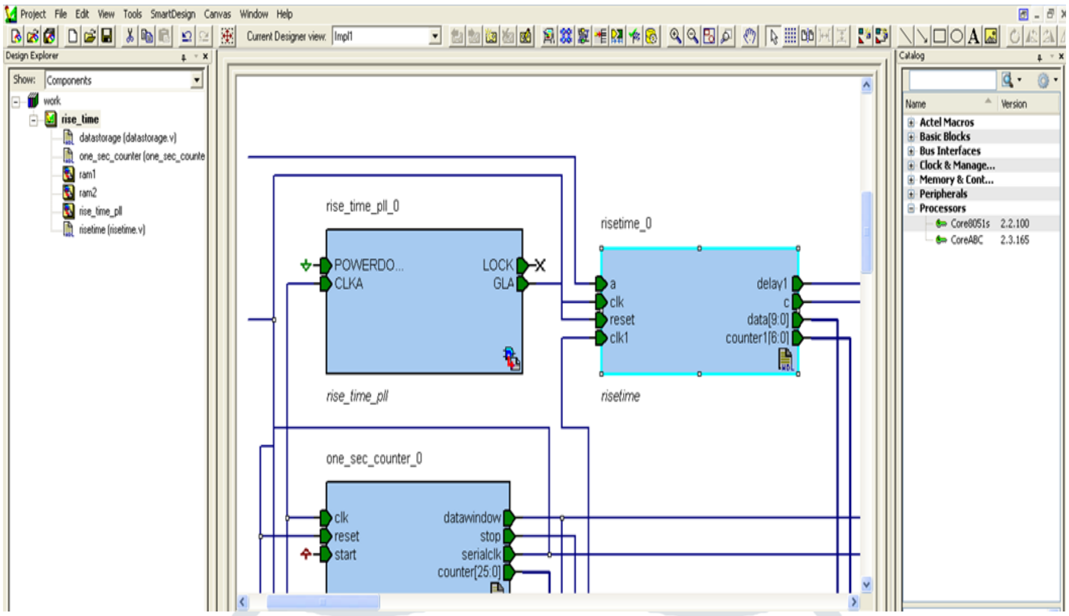

Figure 10: PLL and Pulse width Counter block interfaced.

The above figure 10 shows the interfacing of the PLL which generates frequency of 320 MHz and the counter of the pulse width measurement block. In figure 11 the first signal is the input signal which is random followed by the second signal as the clock of the PLL which is 320 MHz, fast clock while the fourth input is the clock of the FPGA of 40MHz.

Here when reset is high every signal gets reset and gives no output but when the reset is low the system starts giving the number of counter clock pulses. These number of counter clock pulses are to be stored into some storage. Once the data is accumulated the RAM is connected with the system itself which provides the storage where the data of all the individual pulse at specific time are stored. When the peak is detected and the comparator gives input to the FPGA the collection of data for the counter starts from the starting of the pulse to the ending of the comparator width till the next pulse arrives.

In figure 11, there is a data of 717 and 215 which gives the number of clock pulses of the linearly discharged pulse from when its peak is detected and it goes to zero cross over line. 717 is of one pulse and 215 is of another pulse at different times. The resolution is 3.125 ns for the pulse width measurement.

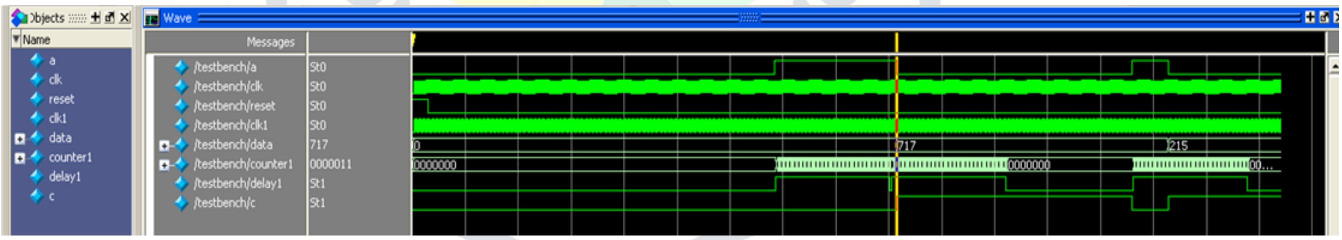

Figure 11: Waveforms of the fast clock, slow clock and counter.

V. Conclusion

The conventional method introduced us with the peak detector hardware which is to be replaced by the new method which is easy to operate, economical and less power consuming. So the new method is using the CR-(RC)^2 method for the pulse processing. The detected peak of the signal gives the voltage level at which the gamma ray is observed. The entire work gives new method for the detection of the peak of gamma ray. FPGA is also used for the counting the clock pulses which are assimilated in the linear discharge width.

VI. Acknowledgment

I am a M.E. student from EC department, V.V.P. Engineering College, Rajkot, Gujarat. The work presented in this paper is part of my dissertation work. For the guidance to carry out this dissertation work, I am highly obliged to Scientist Dipak Kumar Panda and Scientist Arpit Patel, Physical Research Laboratory, Ahmedabad, Gujarat. It has been an honor to work with them. Also Prof. Paresh M. Dholakia, V.V.P. Engineering College, Rajkot, for his esteem support and help to accomplish the research work. I would like to express my gratitude to my Mother, family and friends for the moral support, strength and motivation which led me to reach to this stage. At last, special thanks to God.

.

REFERENCES

[1] Kamontip Ploykrachang, Decho Thong-Aram, Suvit Punnachaiya, Somchai Baotong, “Pocket PC based portable gamma-ray spectrometer”, Songklanakarin Journal of Science And Technology, 33(2),(2011) 215-219.

[2] W. Skulski, M. Momayezi, “Particle identification in CsI(Tl) using digital pulse shape analysis”, *Elsevier, Nuclear Instruments and Methods in Physics Research A* 458 (2001) 759-771.

[3] W.S. Wilburn, J.D. Bowman, S.I. Penttila, M.T. Gericke, “A low-noise current-mode preamplifier for gamma asymmetry measurements”, *Elsevier, Nuclear Instruments and Methods in Physics Research A* 540 (2005) 180-187.

[4] G.F. Knoll, Radiation Detection and Measurement, third edition ch 12, 16 to 18, Wiley, New York, 1999.

[5] Dusan Ponikvar, “Wilkinson-type ADC with short conversion time and low clock frequency”, *Elsevier, Nuclear Instruments and Methods in Physics Research A* 408 (1998) 523-529.