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A FULLY DIGITALIZED, LABVIEW INTERFACED GEIGER-MÜLLER SCALAR UNIT FOR EDUCATIONAL NUCLEAR INSTRUMENTATION

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ABSTRACT

Nuclear technology is one of the most advance fields of science with numerous applications which are irreplaceable and unique. Yet, it can be extremely dangerous if handled without being careful. In Sri Lanka, nuclear technology is widely used in medical, scientific and industrial applications while having a power generation requirement after 2030 [1]. But, still the nuclear science education has limited to the theoretical concepts. As the local governing body of the nuclear technology, Sri Lanka Atomic Energy Board (SLAEB) has initiated a project to develop a low-cost educational tool for practical nuclear science[2]. The project was successfully completed and it is presented by this study. The goal of the project is to enhance the public awareness on nuclear technology and to improve the practical nuclear knowledge among advance and graduate level students. It is expected to launch this long-term plan in collaboration with the educational authorities. As the major component of the project, a scalar unit for a Geiger-Müller (GM) detector has been developed. The device has completed up to a factory ready prototype and tested for its performance.

Keywords: Nuclear instrumentation, GM counter, Nuclear awareness

1. INTRODUCTION

Number of nuclear disasters and accidents have happened within the last century, where the Fukushima-Daiichi incident (2011) is being the most recent one. Most of the nuclear accidents have caused due to the unawareness and ignorance. The importance of educating the community about the about nuclear sciences has been discussed extensively to avoid such incidents in the future [3]. Also, the threat of CBRN terrorism has emerged with the possibility of deploying Chemical, Biological, Nuclear and Radiation weaponry against people. In such a scenario, it is very important to have an educated society that can handle the chaos and minimize the ill-effects.

As a long-term plan, number of countries have developed educational kits to introduce the concepts, applications, detection methods and safety measures of nuclear physics. But, due to the extreme cost of these instruments, they are seldom used in Sri Lanka for educational purposes.

Geiger-Müller (GM) Counter is a basic detector used to investigate radiation. It is generally comprised of two major components; a GM probe and a Scalar. The scalar unit is consisted of a high-voltage (HV) driver, a pre-amplifier, a discriminator and a counter [4, 5].

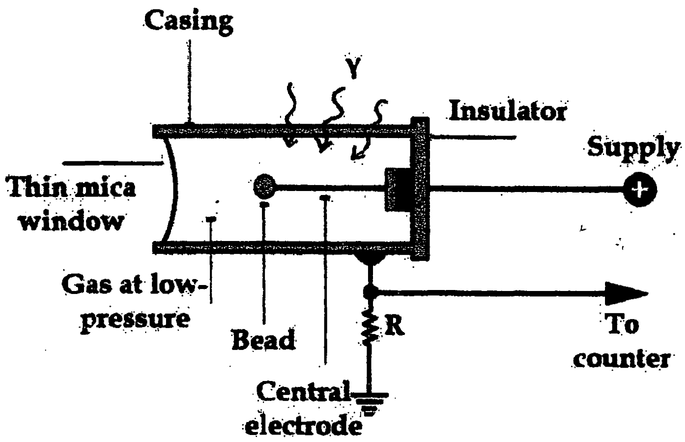

Figure 1: A GM probe

A GM tube/probe can detect ions produced when an ionizing radiation (α, β, γ or X-ray) interact with the gas at low pressure. Each ionizing burst produces a voltage pulse across the grounding resistor R (Fig. 1). Higher sensitivity to the low radiation doses is key advantageous of the GM detectors.

2. METHODOLOGY

For experimental purposes, the HV unit of the instrument has to be a variable one. Scalar unit was previously designed with a transformer based HV supply circuit. It had several limitations including higher loss, low-voltage range and lower processing power. A novel HV module was designed using switching technology that can controlled by Pulse Frequency Modulation (PFM). This is the central part of the scalar unit.

The pulse generated at the resistor R is then buffered, filtered, stretched and modulated with 2×10^3 Hz pulse using on-off keying modulation, to produce the iconic alarm sound of radiation detectors.

The processed and filtered pulses are counted by the micro-controller unit (MCU), which coordinates all the functions of the device, including HV controlling and data transmission. The complete block diagram of the device is given in the Fig. 2 [6].

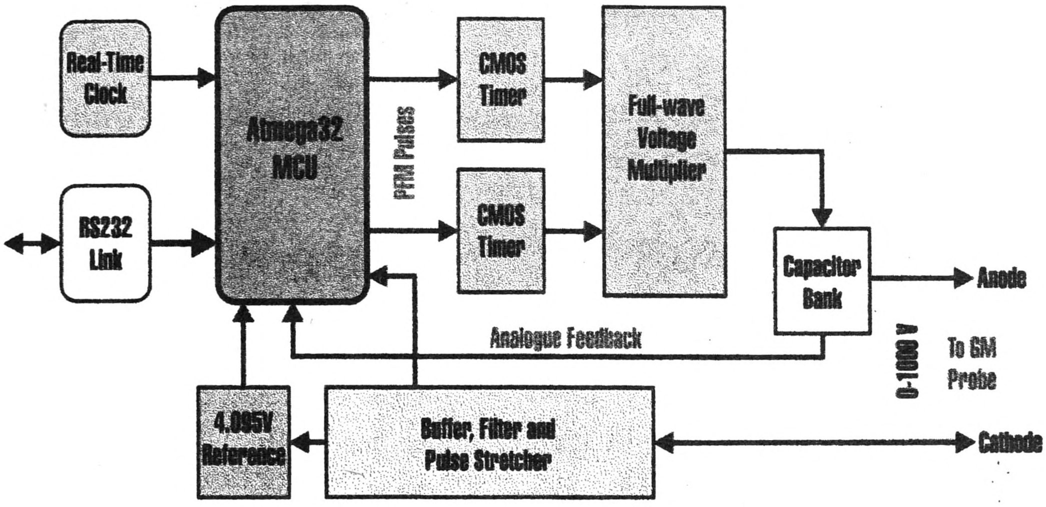

Figure 2: Block diagram of the scalar unit

An external real-time clock source has used for precise time measurements. An analogue feedback to the MCU is monitored constantly to maintain the required high-voltage value at the output. An RS232 serial-to-USB bridge is used for data communication between the LABVIEW interface and the device.

A separate container is used to place the radiation source varying the distance and shielding. The device functions in two operation modes; Radiation Counter and Ratemeter. A counter counts number of pulses for a given time period and the Ratemeter measures the rate of radiation exposure.

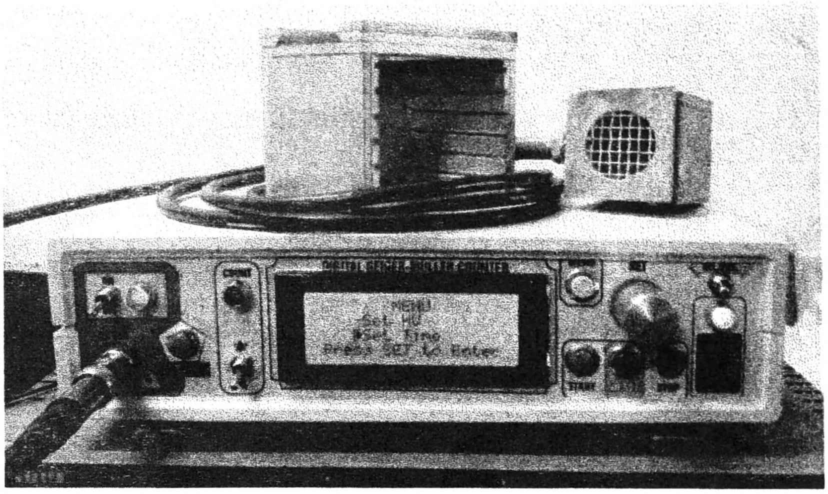

Figure 3: Completed device

3. EXPERIMENTAL

For experimental, the probe was irradiated using a low energy gamma (γ) source (Monazite sand sample). The experimental procedures were carried out in an environment with an average background radiation of 18 cpm. (counts per minute). Since the device was designed for educational demonstrations, data were obtained to verify two theoretical concepts. The experimental results are as follows.

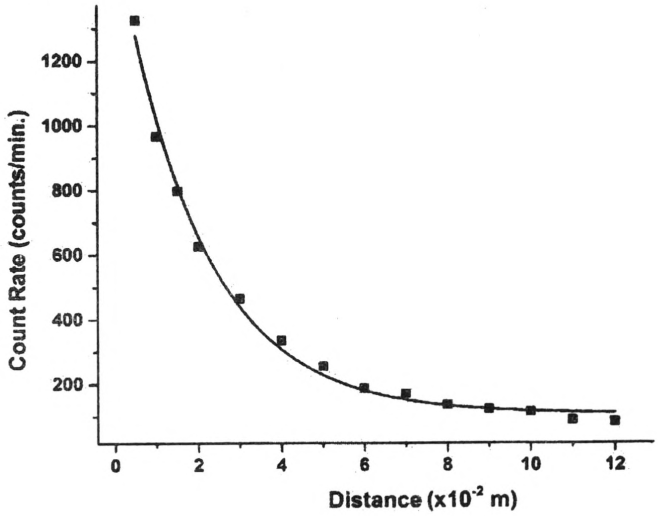

Figure 4: Demonstration of the inverse square law of radiation

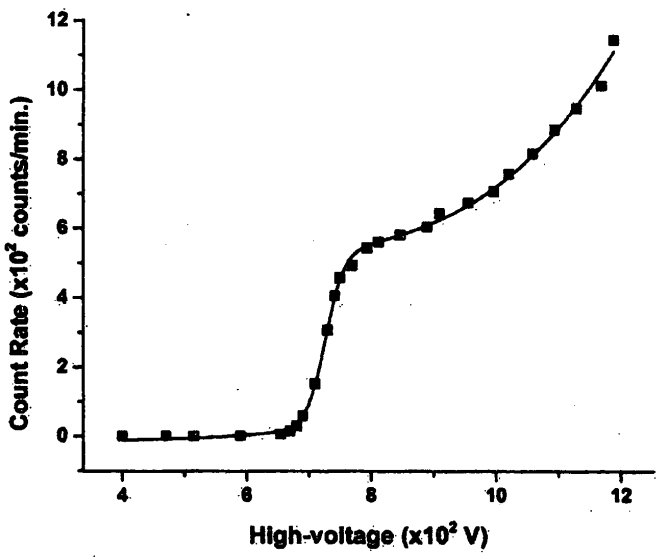

Figure 5: Characteristic curve of the Centronic ZP190 GM probe

4. RESULTS AND DISCUSSION

GM probes have different characteristics. Therefore, the operation parameters has to be able to adjust on the preference of the user and the probe parameters. The scalar unit is designed as a separate, standalone unit. Therefore, it can be used for any GM probe while the internal adjustments are set by the advance settings.

In the Ratemeter mode, the exposure rate is given in counts per seconds. Due to the randomness of radiation data the average of several adjacent readings has to be taken as the final reading. This data is plotted real-time in the LABVIEW interface. The interface is also usable to directly control the device, which is not available in the GM systems developed in previous efforts. This device can be used for number of basic experiments and demonstrations in nuclear science, including radiation protection methods (shielding), background radiation, counting statistics, dead-time, half-value thickness, backscattering and GM probe characterization. They are recommended to be taught in advance and undergraduate levels.

The GM probe is sensitive even for small radiation doses such as in the environment (background radiation). This is an important feature, which allows the use of low-dose, low-energy sources for the experiments. Thus ensures the safety of the users.

5. CONCLUSION

As an advance, useful technology, nuclear science has number of benefits that can be used for the economic and social development. The use of nuclear science has rapidly growing applications in Sri Lanka. But, with the unavoidable risk of the technology, it is extremely important to enhance the public awareness on the technology. For Sri Lanka the introduction of the practical nuclear physics to the education syllabi, will be an affordable initiative that deliver a priceless payback in long-term basis.

The device was fabricated at an affordable cost which is bearable by a developing country as ours. It has a fully functional setup that is expendable for several other applications. With minimum alterations, the system can be used for multiple applications such as multi-channel analysing (MCA) and ionizing chambers.

As an educational tool, the system has successfully tested in the prototype level. With an appropriate training (which can be conveyed by the SLAEB) the teachers will be able to deliver the practical knowledge on nuclear science to the next generation.

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- International Atomic Energy Agency, Vienna, Austria.

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