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Radiation monitoring and detection using economical open-source components

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Abstract: The recent advances in radiation technology led to the use of ionizing radiation in the health and industrial sector. However ionizing radiation represents a hazard to living organisms at higher doses, it can disrupt the cellular functions by breaking DNA strands leading to symptoms of radiation sickness complications including skin erythema, internal bleeding and consequently death. The use of radiation detectors to alert the user of the presence ionizing radiation is therefore vital to avoid excessive exposure to radiation. Electronic Pocket Dosimeters (EPDs), an example of these radiation detectors, are worn by radiation workers. They provide real-time exposure readings unlike the film badges and TLDs which are commonly used in the Philippines. This study aims solve the issue of costly radiation detectors by building an economical Geiger counter that is modulable and can be further modified and improved. This is done by using an Arduino™ microcontroller, a Geiger tube, and simple high voltage circuitry. The device was first tested for radiation detection and was then calibrated using a Cs-137 gamma source at Philippine Nuclear Research Institute - Secondary Standard Dosimetry Laboratory (PNRI - SSDL). The result of the calibration was within 6.5% deviation from the actual exposure value which complies with the tolerance of 20% set by PNRI.

Keywords: Radiation monitoring; Arduino; Electronic Pocket Dosimeter; Geiger tube.

1. INTRODUCTION

Due to the ionizing nature of radiation that causes breaks in the DNA strands, it is important for individuals working in radiation risky environments to be able to detect radiation levels and be alerted in case they are exposed to radiation. That is in order to avoid radiation sickness symptoms and further health complications. Electronic Pocket Dosimeters (EPD) are small radiation devices that integrate an LCD screen and an audiovisual alarm to provide an accurate and practical method of detecting radiation in real time for radiation workers. In the Philippines, film badges and thermoluminescent dosimeters are available, but these do not provide real time detection.

The recent advance in technology has made the procurement of microcontrollers at very easy and at low prices, an example of that is the Arduino™ microcontroller which can be programmed and connected to interact with different electronic components using I/O pins. One of its advantages is that it can easily be connected to a computer in order to program it to properly interact with a Geiger tube or other desired detectors.

2. MATERIALS AND METHODS

The Geiger counter was built by using an Arduino™ ATMEGA 2560 Microcontroller which was connected to a simple high-voltage circuitry and an imported Geiger-Muller (GM) tube, the tube requires high voltage in order to operate since high voltage is needed to facilitate the flow of electrons in the tube when the gas inside the tube is ionized by a radiation event. The high voltage circuitry comprises a 15 mH inductor, a 1 kV ceramic capacitor, 4.7 MΩ, 100KΩ and 10KΩ resistors (O. Vagle, 2007). A 1N4007 diode, a high voltage transistor (MPSA-44) and an NPN amplifier Transistor (2N3904) used to amplify the counted events by the GM tube (Arduino.cc 2014), it is based on a square wave driven step-up boost converter design and provides the necessary voltage for the Geiger tube to operate. The HV circuitry was assembled as shown in Figure 1. The pulse out of the circuit was connected to the Arduino on pin 2 which counts the events and display them on a monochrome 16x2 LCD panel, the pulse in was connected to pin 9 which provides a square wave at 1.9 kHz in order to drive the high voltage circuitry, the capacitor eliminates the voltage ripple at around 400 V. The LCD panel is connected to pins 3,4,5,6,8, and 12 for data and was provided with 5 V regulated voltage from the Arduino board (Arduino.cc, 2005), after boot up the board starts a loop function to pulse a square wave at pin 9 for the high voltage circuitry and read-out the incoming pulses on pin 2, these pulses originate from radiation events in the GM tube. Every two seconds the board updates the counts accumulated in that period and displays them in CPM and µSv/h.

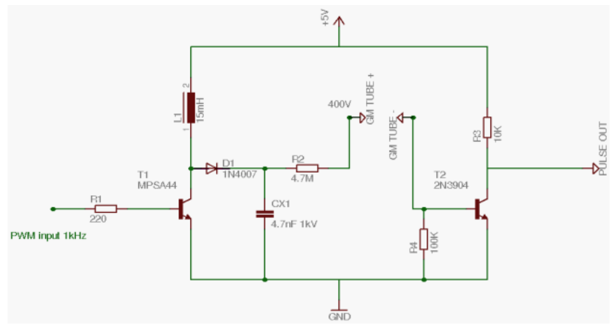

Figure 1 schematic of the high voltage circuitry

3. RESULTS AND DISCUSSION

The device was tested at different exposure rates of 10,20,40,60,80,100 and 200 µSv/h on a testing bench against a Cs-137 radioactive source with an activity of 44 GBq. A lead absorber was used in order to attenuate the beam for lower dose calibration. Results of the calibration were compliant with the 20 % tolerance set by PNRI (PNRI, 2004). The readings were accurate with a percent error of 6.5 % from actual exposure dose at maximum. The data from readings vs. actual exposure was plotted for a linearity test (Figure 2) giving the two lines, one for the expected reading and another for actual readings. At 400 µSv/h and higher the GM tube was saturated and gave erroneous readings, this is naturally due to the dead-time of the GM tube.

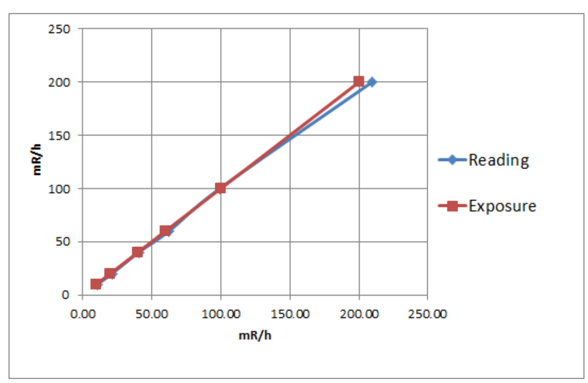

Figure 2 the linearity of the reading versus actual dose

4. CONCLUSIONS

The results of this study conclude that it is possible to assemble an accurate open-source Geiger counter using readily available materials and is able to detect radiation dose exposure accurately using inexpensive components. The results of the calibration were at 6.5 % maximum error which is well within the 20 % maximum deviation value set by PNRI. The total costs of the acquired materials amounted to less than 2000 Philippine pesos which is several times less than the cost of a commercial grade radiation dosimeter.

5. ACKNOWLEDGMENTS

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