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Development of a Simulated Method for Continuous Monitoring of Radiation in the Nuclear Medicine Department (Wad Medani)

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ABSTRACT

Generally, radiations emit from different sources of energy. Some of these radiations are very dangerous. They may lead to many diseases like cancer. Many nuclear institutes over the world have been established for the purpose of diagnostic and treating by using radioisotopes. The optimization of staff protection is essential in the nuclear medicine department to minimize the effect of the radiation to the department staff and to other people. In all around the world, detectors are used to monitor the radiation.

This paper is discussing a microcontroller simulated system; the system was established by situating four detectors in the department of nuclear medicine to monitor the injected patients with Tc 99^m. Gamma photons are converted into pulses at the output of the detectors, and then they are transmitted to the microcontroller to define the radiated area. If any of this injected patient inter to a non-radiated area, the detector issues an alarm and red colour in the monitoring room. Moreover, the area number is displayed in the liquid cathode display (LCD) of the microcontroller.

Key words: gamma photons, Tc 99m, Microcontroller, PIN Photodiode, Radioisotope, Liquid Cathode Display (LCD).

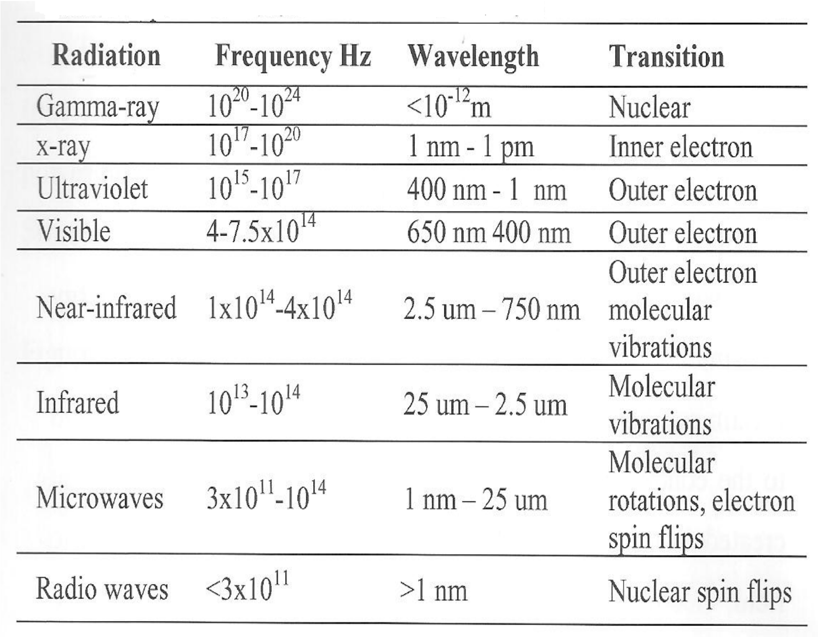
INTRODUCTION

The nuclear medicine department generally classified as controlled or supervised areas. The rooms for preparation, storage and injection of the radiopharmaceutical should be controlled areas. Due to the potential risk of contamination, the imaging room and waiting area should also be controlled areas. It might be convenient to classify the whole department as a supervised area mainly due to the risk of contamination [IAEA, 1989].

There are three different types of radiation decay; Alpha particle emission (alpha decay), beta particle emission (beta decay) and gamma photon emission (gamma decay). Each of these has its own energy, frequency and wavelength.

The energy of gamma ray (E h!) is the highest compared with other radiations and this is explicit in Table (l).

Table 1 Types of radiations and their characteristics



Radiation	Frequency Hz	Wavelength	Transition
Gamma-ray	10^{20}-10^{24}	$<10^{-12}$m	Nuclear
x-ray	10^{17}-10^{20}	1 nm - 1 pm	Inner electron
Ultraviolet	10^{15}-10^{17}	400 nm - 1 nm	Outer electron
Visible	4-7.5x10^{14}	650 nm 400 nm	Outer electron
Near-infrared	1x10^{14}-4x10^{14}	2.5 um – 750 nm	Outer electron molecular vibrations
Infrared	10^{13}-10^{14}	25 um – 2.5 um	Molecular vibrations
Microwaves	3x10^{11}-10^{14}	1 nm – 25 um	Molecular rotations, electron spin flips
Radio waves	<3x10^{11}	>1 nm	Nuclear spin flips

Radiation Detectors

The detector is a device in which the incident radiation can interact with its material to produce an observable effect, which may be a chemical change or creation of an electrical signal.

Each type of radiation has specific probability of interaction with the detector media. This probability varies with the energy of incident radiation and the characteristics of the detector. Detectors are characterized by the type of interaction and the way of operation.

There are three main types of radiation detectors, gas ionization detectors, scintillation detectors and semiconductors diode detectors.

In semiconductor detectors, the radiation is measured by means of the number of charges, which is arranged between two electrodes. Ionizing radiation produces free electrons and holes. The numbers of electron-hole pairs depend on the energy transmitted by the radiation to the semiconductor. As a result, a certain number of electrons are transferred from the valence band to the conduction band, and an equivalent number of holes are created in the valence band. Under the influence of an electric field, electrons as well as holes travel to the electrodes, where they give rise to a pulse that can be measured in the output circuit. The energy required for production of electron- hole- pairs is very low compared to the energy required for production of paired ions in a gas detector. Consequently, in semiconductor detectors, the statistical variation of pulse height is smaller and the energy resolution is higher. As the electrons travel fast, the time resolution is very good, compared with gas ionization detectors. The density of semiconductor detector is very high, and charged particles of high energy can give off their energy in a semiconductor of relatively small dimensions [P. Horowitz, W. Hill, 1994].

MATERIALS AND METHODS

The main components of this project are; the photo detector (pin diode), microcontroller, the display, LCD, alarm and the power supply.

Simulated Developed System

The block diagram of the developed system is shown in Figure (1).

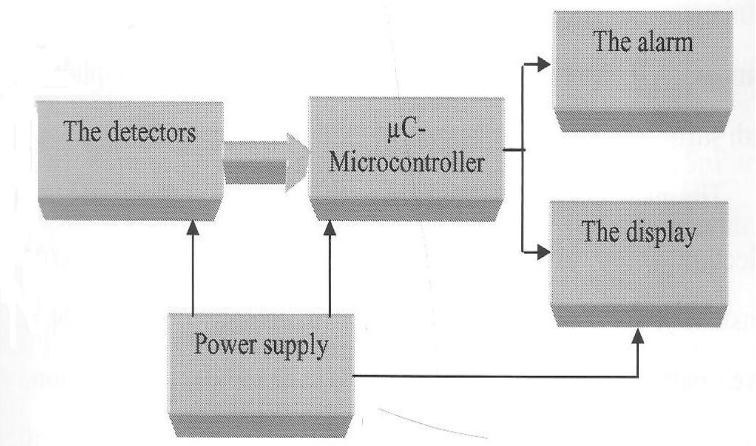


Figure (1) Block Diagram of the Simulated Developed System

Generally, the detectors detect the Gamma ray from injected patient and transmit the electrical signals to the microcontroller, the latter displays the received signals on the LCD. Also, there is an alarm shown by the light emitting diodes (LED) due the radiations. The details of the process are highlighted in following sections.

Detector Circuit

The PIN photodiode detects individual photons of gamma radiation. When a photon strikes a depletion region created by reverse bias on the photodiode, it produces a small amount of charge in proportion to the photon's energy. The resulting signal is then amplified and filtered by four amplifiers and a final comparator distinguishes between the signal and noise. The comparator output pulses go high each time a gamma photon with sufficient energy strikes the photodiode (see Fig 2).

The most critical component is the PIN photodiode, whose selection often involves conflicting considerations. Detector sensitivity, for example (the number of photons detected for a given radiation field)depends on the size of the depletion region, which in turn depends on the area of the diode and the amount of reverse bias applied to it. To maximize sensitivity, a large-area detector with high reverse bias should be chosen. However, both of these conditions add noise.

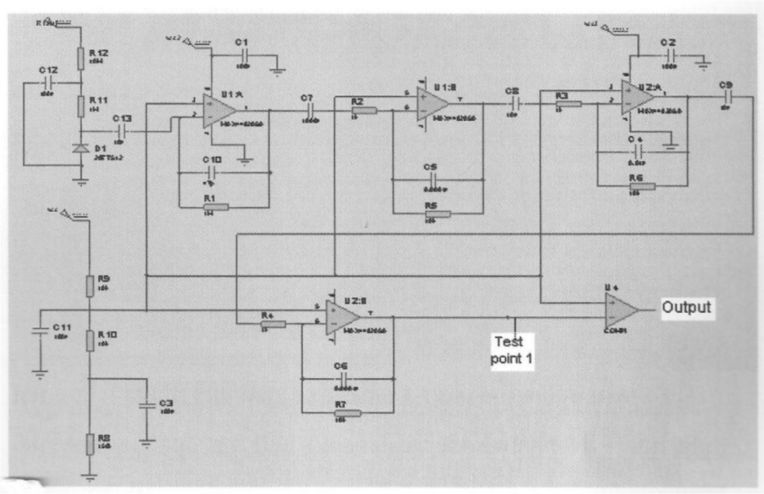


Figure (2) Simulated Detector Circuit

In order to minimize the noise, a detector with 25pF to 50pF of capacitance under reverse bias is used that can provide a fair compromise between sensitivity and noise.

Important considerations for the first-stage op amp include input-voltage noise, input-current noise, and input capacitance. Input-current noise is directly in the signal path, so the op amp should minimize that parameter. JFET- or CMOS-input op amps are a must. Also the op-amp's input capacitance should be small compared to the PIN photodiode's capacitance.

In this design, a high-quality PIN photodiode and an op amp with low current noise have been used. The limiting factor for noise should be the first-stage op amp's input-voltage noise multiplied by the total capacitance at the op amp's inverting node. That capacitance includes the PIN photodiode capacitance, the op-amp input capacitance, and the feedback capacitance Cl. Thus, to minimize circuit noise effect, it is necessary to minimize the op amp's input-voltage noise.

To insure that the circuit measures gamma radiation and not light, the PIN photodiode is covered with an opaque material.

Moreover, in order to block radiated emission from other sources such as power lines, computer monitors, etc., the circuit is shielded with a grounded enclosure. A simulated voltage (1m V)was applied to the input of the detector as should be if a similar signal could have been received by a real detector. Figure 3 shows the results of a typical gamma strike. The top waveform is taken from test point 1 (before the comparator), while the bottom waveform is taken from the comparator.

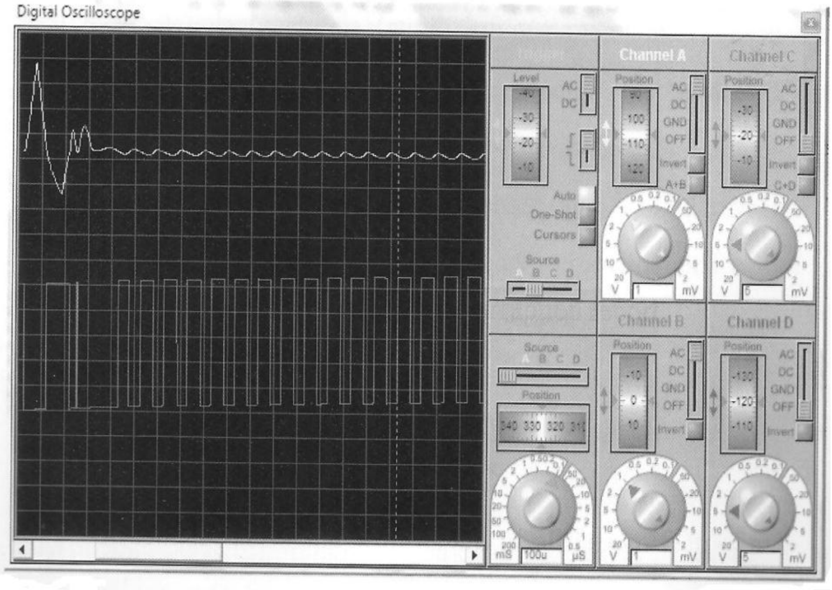


Figure (3) Output of the Detector Using a Digital Oscilloscope

Referring to figure 2, the top left of the oscilloscope shows a big signal that results in a big wide pulse at the bottom of the oscilloscope.

Microcontroller

ATmega 8535 microcontroller was used in the developed simulated system. The microcontroller contents four ports (A, B, C & D), each ports has 8 bits. It also includes internally an analog to digital converter. Bits 0, 1, 2, & 3 from port B were used as inputs to acquire digital simulated signals from four detectors.

Bits 0, 1, 2, & 3 from port A together with all bits from port C (except bit 3) are connected to the LCD (see Fig 4).

The software being used in the design was C++. The program was successfully written and it was compiled into the machine language. Then the program was loaded into the microcontroller.

Display Circuit

When a simulated source of radiation (injected patient with Tc^{99}m) moved to a non-radiated area, any of detectors 1, 2, 3, or 4 detects the radiation. The message (radiation area X) is displayed on LCD monitor. So it's easy then to control all a non-radiated area in the department by using this method.

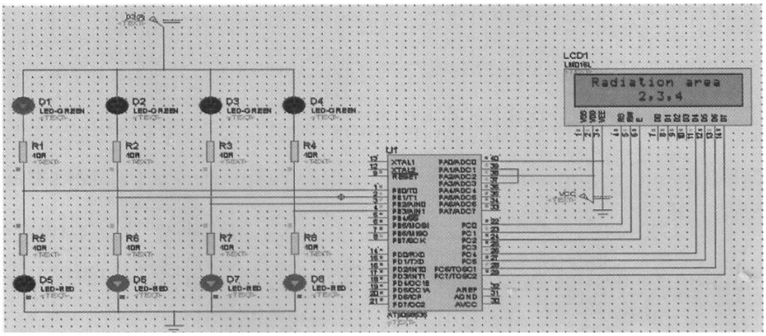


Figure (4) Display Circuit

Alarm Circuit

The alarm circuit produces sound when the source of radiation enters to a non-radiated area. The circuit was designed using 555 timer ICs in as stable multi-vibrator mode. See figure 5.

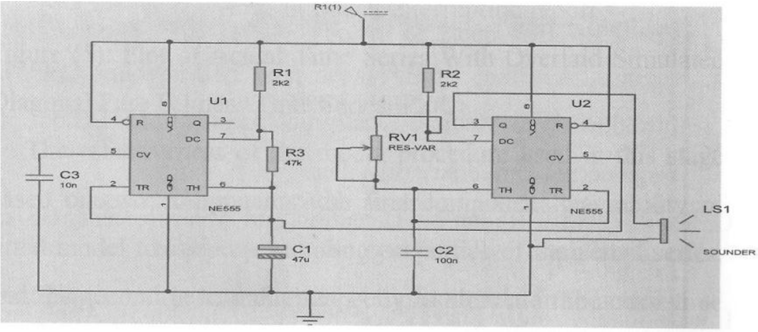


Figure (5) Alarm Circuit

CONCLUSION

A very simple, easily, friendly simulated radiation detector system was developed.The system can be applied in a real world if a transmitter and a receiver circuits are included in the design. All the components of the simulated system were connected perfectly and they were tested successfully using the PROTEUS program.

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