Technical Note

Development of RadRob15, A Robot for Detecting Radioactive Contamination in Nuclear Medicine Departments

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ABSTRACT

Accidental or intentional release of radioactive materials into the living or working environment may cause radioactive contamination. In nuclear medicine departments, radioactive contamination is usually due to radionuclides which emit high energy gamma photons and particles. These radionuclides have a broad range of energies and penetration capabilities. Rapid detection of radioactive contamination is very important for efficient removing of the contamination without spreading the radionuclides. A quick scan of the contaminated area helps health physicists locate the contaminated area and assess the level of activity. Studies performed in IR Iran shows that in some nuclear medicine departments, areas with relatively high levels of activity can be found. The highest contamination level was detected in corridors which are usually used by patients. To monitor radioactive contamination in nuclear medicine departments, RadRob15, a contamination detecting robot was developed in the Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC). The motor vehicle scanner and the gas radiation detector are the main components of this robot. The detection limit of this robot has enabled it to detect low levels of radioactive contamination. Our preliminary tests show that RadRob15 can be easily used in nuclear medicine departments as a device for quick surveys which identifies the presence or absence of radioactive contamination.

Keywords

Robot, Radioactivity, Contamination, Radiation Detection

Introduction

Unsealed radioisotopes are used in nuclear medicine departments. For any radionuclide, the level of radiation hazards is determined by the amount of radioactivity administered and the type of radionucleide [1]. According to IAEA, radioactive contamination can be defined as the deposition or presence of radionuclides on surfaces or within solids, liquids or gases, where their presence is unintended or undesirable. Contaminations with radioisotopes such as Tc-99m and I-131 are likely to occur in nuclear medicine departments, its adverse health risks depend mainly on some basic factors including the half life of the contaminant radioisotope and its decay type and radiation energy. Although common contaminations usually are not associated with severe acute health effects, long term adverse health effects such as malignancies, leukemia, genetic defects and congenital anomalies may occur [2]. Studies performed in IR Iran shows that in some nuclear medicine departments, areas with relatively high levels of activity can

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be found. The highest contamination level was detected in corridors which are usually used by patients [3]. It should be noted that in radioiodine therapy doses with activities as high as 7.4 GBq per patient are used [4]. To monitor radioactive contamination in nuclear medicine departments, RadRob15, a contamination detecting robot was developed in the Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC). The motor vehicle scanner and the gas radiation detector are the two main components of this robot. The detection limit of this robot has enabled it to detect low levels of radioactive contamination.

Scanner Robot

A smart robot has been developed in this project to carry a light weight radiation detector which has been optimized for detecting low levels of radioactive contamination. The main goal in designing this robot was development of an efficient carrier for RadRob15 detector with the ability of scanning indoor areas (such as corridors in nuclear medicine departments) without hitting any obstacles. To achieve this goal, a series of sensors and an 8-bit AVR micro-controller are utilized to measure the distance between the scanner robot and obstacles. The micro-controller is programmed by Atmel Software in such a method that the two wheels will guide the RadRob15 in the right path in search of radioactive contaminations.

Radiation Detector

To reach a better performance two single transistors (Q_1 and Q_2) are combined to form a Darlington Transistors as illustrated in Figure 1. The result is an improved component with a high input impedance, low output impedance and high current gain. However, it had some disadvantages such as higher V_{BE} (overall V_{BE} for the pair is 1.2 V to 1.4 V instead of the 0.6 V to 0.7 V for a single silicon BJT). Moreover, any leakage current from the first transistor was amplified by the second transistor therefore very precise measurements are performed in utilizing these transistors. As shown in Figure 2, two npn BJTs which are cascaded behave like a single npn transistor. Cascading two pnp BJTs yields similar characteristics. As illustrated in Figure 2, two npn BJTs which are cascaded behave like a single npn transistor. Assuming r_{O1} and r_{O2} are very large in both transistors, these resistors can be ignored and β_1 and β_2 are both much greater than one (i.e., $\beta_1 \approx \beta_{1+1}$ and $\beta_2 \approx \beta_{2+1}$), the ac small signal model of the npn version of each transistor is illustrated in Figure 3 and therefore the Darlington pair ac small signal model will be equivalent to the circuit shown in Figure 2. By making the assumption that emitter currents are approximately equal to collector currents (i.e., $\alpha_1 = \alpha_2 \approx 1$): $i_e = i_{e2} = \beta_2 i_{b2} = \beta_2 i_{e1} = \beta_2 \beta_1 i_{b1}$. The above formula demonstrates that the combination of Q_1 and Q_2 transistors behaves like a single high β ($\beta = \beta_1 \beta_2$) transistor. Although the effective collector current i_C is calculated by adding i_{C1} and i_{C2}, the multiplier of β_2 makes i_{C2} the dominant contributor to the sum. Schematic diagram of the circuit is shown in Figure 4. As illustrated in this figure, two npn and two pnp Darlington Transistors are connected to an ionization chamber consisting of an anode (a needle passing through the canister) and a cathode (the cylindrical canister). When radiation passes through the ionization chamber, it produces ions which are affected by the electric field created within the cham-

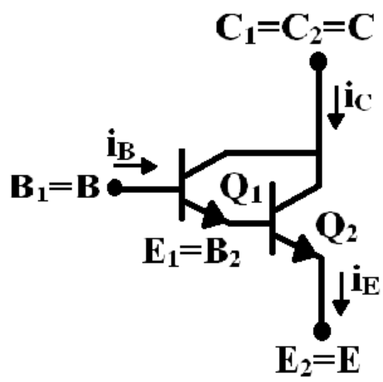

Figure 1: Two single transistors (Q_1 and Q_2) are combined to form Darlington Transistors

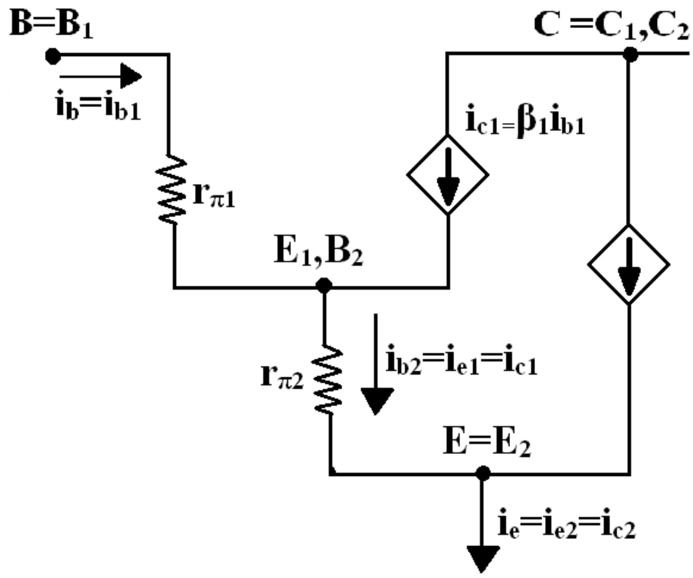

Figure 2: Two npn BJTs which are cascaded behave like a single npn transistor

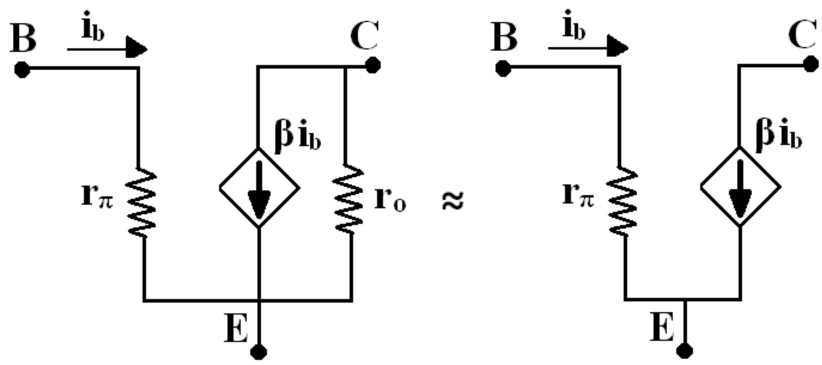

Figure 3: The ac small signal model of the npn version of each transistor

ber. These ions are then absorbed by the ionization chamber resulting in leakage current in the npn transistor base (I_2). Trimmer can be adjusted so that base currents of npn transistors are the same ($I_1=I_2$) and therefore due to the symmetry of the circuit collector currents of pnp transistors are equal (i=i') causing same voltages in terminals ($V_1=V_2$). When ionizing radiation changes the voltage of the right terminal, the voltage difference between terminals is measured via the analog port of Atmega8 which is programmed by BASCOM software tool. Therefore, when the voltage difference increases (as a response to higher intensities of ionizing radiation), more LEDs in the LED row will be turned on (visual alarm) and the frequency of the buzzer beeps will be increased (audio alarm).

Figure 4. Two npn and two pnp Darlington Transistors are connected to the ionization chamber consisting of an anode (a needle passing through the canister) and a cylindrical cathode (the canister).

Concluding Remarks

Accidental or intentional release of radioactive materials into the living or working environment may cause radioactive contamination [5]. Studies performed in IR Iran shows that in some nuclear medicine departments, areas with relatively high levels of activity can be found. The highest contamination level was

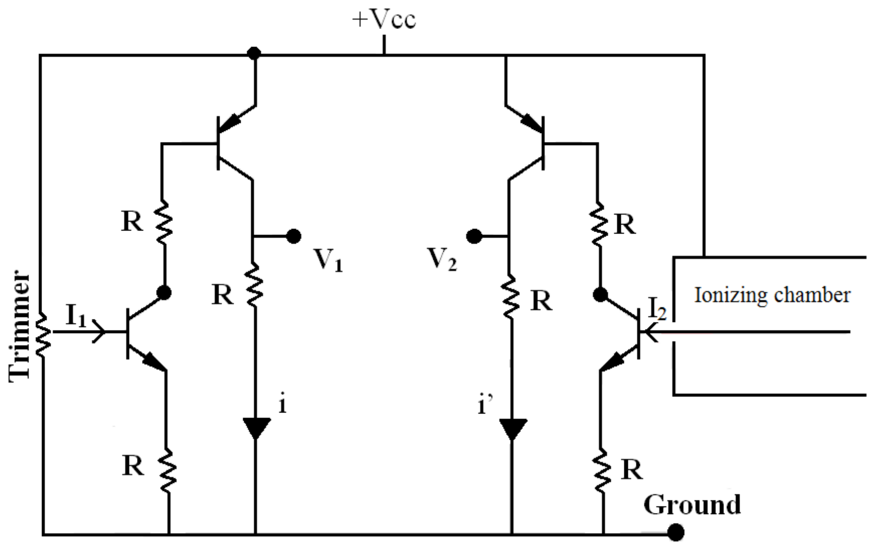

Figure 4: Two npn and two pnp Darlington Transistors are connected to the ionization chamber consisting of an anode (a needle passing through the canister) and a cylindrical cathode (the canister).

detected in corridors which are usually used by patients. RadRob15 is a scanner robot developed at INIRPRC for detecting radioactive contamination in nuclear medicine departments. The detection limit of RadRob15 has enabled it to detect low levels of radioactive contamination. Our preliminary tests show that RadRob15 can be easily used in nuclear medicine departments as a device for quick surveys which identifies the presence or absence of radioactive contamination.

Acknowledgment

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Conflict of Interest

None Declared

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