
Development of a Low-End Real-Time Radon Detector

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ABSTRACT

Radon is an invisible, odorless, and chemically inactive radioactive gas produced by the decay of uranium ore. Various types of equipment and components have been proposed for use in effective radon detection. In this paper, we describe a low-end real time radon detector that uses a PIN photodiode radon-sensor module. It was calibrated using the RAD7 by virtue of a linear regression analysis. Based on our studies, we believe that this system would be helpful in protecting many people from the dangers associated with radon exposure.

Keywords: radon, low-end, radon detector, PIN photodiode.

I. INTRODUCTION

Radon is a chemical element with symbol Rn and atomic number 86. It is a radioactive, colorless, odorless, tasteless noble gas. It occurs naturally as an intermediate step in the normal radioactive decay chains through which thorium and uranium slowly decay into lead; radon, itself, is a decay product of radium. Its most stable isotope, ^{222}Rn , has a half-life of 3.8 days. Since thorium and uranium are two of the most common radioactive elements on Earth, and since their isotopes have very long half-lives, on the order of billions of years, radon will be present long into the future. Unlike all the other intermediate elements in the decay chains, radon is, under normal conditions, gaseous and easily inhaled. Radon gas is a health hazard. It is often the single largest contributor to an individual's background radiation dose, but due to local differences in geology, the level of the radon-gas hazard differs from location to location. Despite its short lifetime, radon gas from natural sources can accumulate in buildings, especially, due to its high density, in low areas such as basements and crawl spaces. Radon can also occur in ground water - for example, in some spring waters and hot springs.

There are many commercial instruments and techniques available for measuring radon indoors. Most detectors for evaluating indoor radon levels are passive in that they do not require external power. The principal drawback of passive detectors is that they only measure radon concentration at one specific location for a specific period. Because many variables influence radon concentration levels, a single estimate of radon concentration is likely to have a significant error. In [1], highly sensitive, electrostatic collection chambers using Columbia Resin 39 (CR-39) plastic track detectors were developed for measuring low-level radon. In [2], the unique characteristics and the shortcomings of track detectors for neutron and radon dosimetry is described and compared with those of alternative detector systems. In [3], low-cost alpha-particle sensor systems using special Positive Metal-Oxide Semiconductor (PMOS) transistors in a floating n-well were developed for radon and radon-daughter monitoring and dosimetry. In [4], a radon detector employed an electrically charged, pressed, porous metal filter that permitted radon-gas diffusion while blocking ambient light. It readily trapped both attached and unattached Polonium-214 (Po-214) and Polonium 218 (Po-218) ions present in gas passing through the filter. The filter was positively charged relative to the unbiased PN junction of a photo-diode detector within a detection chamber. In [5], an alpha particle detector was designed using a commercial silicon photodiode. An application of a silicon photodiode detector for radon progeny measurements is presented in [6].

In this paper, we describe a low-end real time radon detector that uses a PIN photodiode radon-sensor module. It was calibrated using the RAD7 by virtue of a linear regression analysis.

II. LOW-END REAL TIME RADON DETECTOR

2.1. PIN photodiode, Arduino Microprocessor Control Unit, and liquid crystal display modules

A commercial PIN photodiode can be used to detect radiation, and particularly, alpha particles. It is low cost, has good quantum efficiency, and good energy resolution. It can also work with a low bias voltage. A PIN photodiode is more widely used than a conventional photomultiplier tube (PMT) because it requires less biasing to operate and it is very compact. The PIN photodiode sensor module shown in Fig. 1 was used to detect radon gas in our tests.

Figure:

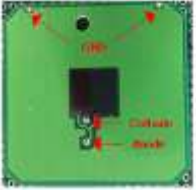
	module size	43 x 43 mm
	sensor size	10 x 10 mm

Fig. 1 PIN photodiode sensor module

The Mega 2560 is a microcontroller board based on the Atmega2560. It has 54 digital input/output pins (of which 15 can be used as Pulse Width Modulation (PWM) outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB port, a power jack, an in-circuit serial programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller; it just needs to be connected to a computer with a USB cable or powered with an AC-to-DC adapter or battery. The Mega 2560 board is compatible with most shields designed for the Uno and the older Duemilanove and Diecimila boards. The board is shown in Fig. 2

Figure:



Fig. 2 Arduino Mega 2560 board

A liquid crystal display (LCD) screen is an electronic display module found in a wide range of applications. The 16x2 LCD display, the most basic, most commonly used module is found in many different devices and circuits. These modules are preferred over the 7-segment and other multi-segment light-emitting diodes (LEDs) because LCDs are economical; easily programmable; and they have no limitations when it comes to displaying special characters, custom characters, and animations. A 16x2 LCD is a 16-character by two-line display. We used an LCD with a 5x7-pixel matrix in our experiments. The LCD has two registers: Command and Data. The Command register stores the instructions sent to the LCD. A command is an instruction sent to the LCD telling it to perform a predefined task, such as initializing the screen, clearing the screen, setting the cursor position, controlling the display, etc. The Data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed. The LCD display shown in Fig. 3 is an LCD module (BC4915AYPLEH) that shows the level of radon gas in pCi/L. The display range is from 0.0 to 999.9. The radon counter we developed was designed to notify a user of the level of radon gas. It is updated every hour that there is a change in the level of radon gas.

Figure:



Fig. 3 LCD module (BC4915AYPLEH)

2.2. Assembling of modules.

In our experiments, we used a radon counter assembled from very low-cost consumer electronics. The circuit designs for the power, high voltage generator, LCD, switch, LED, buzzer, microprocessor control unit (MCU), and sensor circuit are shown in Fig. 4. Using these circuit diagrams, we developed the PIN photodiode radon-counter printed circuit board (PCB) layout shown in Fig. 5 (a). We then assembled the PIN photodiode radon counter shown in Fig. 5 (b).

Figure:

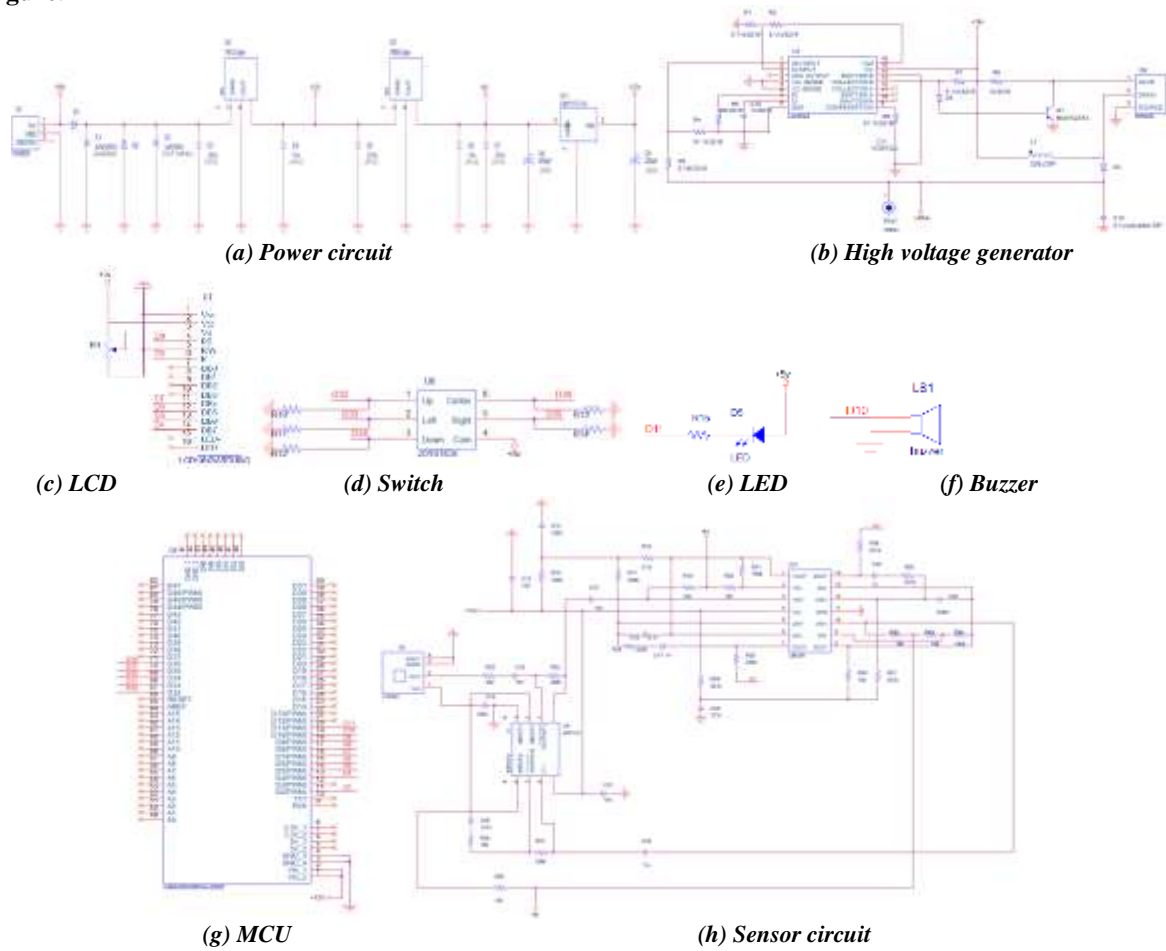


Fig. 4. Power, high voltage generator, LCD, switch, LED, buzzer, MCU, and sensor circuit

Figure:

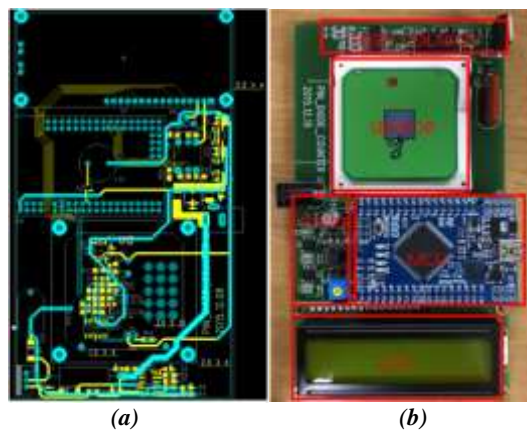


Fig. 5. PCB layout (a) and assembled PIN photodiode radon counter (b)

III. EXPERIMENTAL RESULTS

3.1 Radon measuring apparatus RAD7 :

The RAD7 radon detector, manufactured by DurrIDGE Company in the United States, is a highly versatile instrument that forms the basis of a comprehensive radon measurement system. It is used in many different modes for different purposes. The PIN photodiode radon counter used in our tests was calibrated using the RAD7 electronic radon detector shown in Fig. 6. The RAD7 uses an air pump and a solid-state alpha detector that is made of semiconductor material that converts alpha radiation directly into an electrical signal. It has desiccant (CaSO_4) tubes and inlet filters (pore size $1\ \mu\text{m}$) that block fine dust particles and radon daughters from entering the radon test chamber. The RAD7's internal sample cell is a 0.7-liter hemisphere coated on the inside with an electrical conductor. A silicon alpha detector occupies the center of the hemisphere.

Figure:



Fig. 6. RAD7 electronic radon detector

3.2 Radon concentration calibration

The methyl methacrylate box made for radon concentration calibration is shown in Fig. 7. The calibration experiments were conducted for 72 h using a varied concentration of radon gas. Using a linear regression-analysis technique, the radon counts per hour of the implemented PIN photodiode radon counters were calibrated to pCi/L which is a unit of radon concentration as shown in Fig. 8. For the first PIN photodiode radon counter, the root mean square error (RMSE) was 1.496 pCi/L and the correlation coefficient R^2 was 0.8614, as shown in Fig. 8. The experiment result suggests that the implemented PIN photodiode radon counters could prove useful for measuring and monitoring radon concentration of the indoor air in a house or a workplace.

Figure:



Fig. 7. Methyl methacrylate box made for radon concentration calibration

Figure:

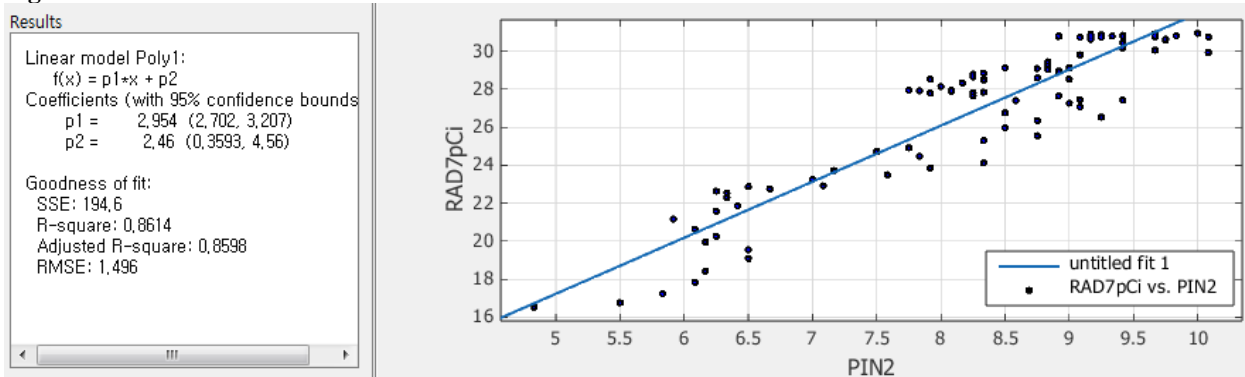


Figure 8. Linear regression analysis

IV. CONCLUSION

In this paper, a low-end radon counter using a PIN photodiode radon-sensor module was discussed. Using a linear regression analysis technique, the measured radon counts per hour of the implemented PIN photodiode radon counters could be calibrated to pCi/L which is a unit of radon concentration by comparing with the measured radon concentration data of RAD7. This low-end real time radon counter can be used to measure radon concentration of the indoor air in houses and workplaces.

V. ACKNOWLEDGEMENTS

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