[Kim, 3(8): August 2016]
DOI-10.5281/zenodo.59610

ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

A STUDY ON RADON DETECTION USING ARDUINO BOARD

Gyu-Sik Kim
Department of Electrical Engineering, The Univ. of Seoul, Seoul, Korea

ABSTRACT

Radon is a natural, inert, invisible, odorless and chemically inactive radioactive gas emitted from the earth. It is produced by the decay of uranium ore, such as radium, actinium, or thorium. Because inhaling radon and its radioactive decay products causes irradiation of lung tissue, prolonged exposure to high concentrations of radon significantly increases the risk of developing cancer. Various types of equipment and components have been proposed to date for radon detection. In this paper, a radon counter using arduino MCU module is implemented. To demonstrate the practical significance of the results, some simulation and experimental results are presented.

Keywords*: radon, radon detection, arduino, MCU module*

I. INTRODUCTION

Radon is a natural, inert, invisible, odorless and chemically inactive radioactive gas emitted from the earth. It is produced by the decay of uranium ore, such as radium, actinium, or thorium. Because it is inert and does not chemically bond to elements, it is released from soil into the atmosphere. Radon is emitted almost everywhere on earth, but some geographical regions have higher concentrations than others. When radon decays, it released alpha particles with energy of 5.5 MeV. Because inhaling radon and its radioactive decay products causes irradiation of lung tissue, prolonged exposure to high concentrations of radon significantly increases the risk of developing cancer. It has been reported that the US. Environmental Protection Agency estimates exposure to naturally occurring radon leads to 21,000 lung cancer deaths nationwide each year, making radon the nation's primary environmental health threat and second only to cigarette smoking as a cause of fatal lung cancer.

Various types of equipment and components have been proposed to date for radon detection. In [1], highly sensitive, electrostatic collection chambers have been developed for low-level radon measurements using CR-39 plastic track detectors. In [2], a radon detector employs an electrically charged pressed, porous metal filter that allows radon gas diffusion, while blocking ambient light, so that it readily traps both attached and unattached Po-214 and Po-2l8 ions, that may be present in gas passing through the filter, the filter being charged positively relative to an unbiased PN junction of a photo diode detector within a detection chamber. In [3], a passive direct-reading radon monitor utilizing a custom α particle detecting MOS integrated circuit and electrostatic radon progeny concentrator has been designed. In [4], a silicon PIN photodiode was designed and fabricated in consideration of low-leakage-current and high-bias-voltage application. In [5], a fast-responding passive radon detector using electrostatic concentration and enhanced readout electronics has been designed. In [6], an electrostatic concentrator constructed by metalizing a plastic funnel is used to focus charged radon progeny onto the exposed surface of an optical image sensor from a webcam. Alpha particles emitted by the collected progeny strike the image sensor, generating sufficient charge to completely saturate one or more pixels.

In this paper, a radon counter using arduino MCU module is implemented. To demonstrate the practical significance of the results, some simulation and experimental results are presented.

II. ARDUINO MEGA 2560, RADON SENSOR, AND LCD DISPLAY

The Mega 2560 is a microcontroller board based on the ATmega2560 [7,8]. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila. The board and specifications are shown in Fig. 1 and Table 1, respectively.

[Kim, 3(8): August 2016] ISSN 2348 – 8034
DOI-10.5281/zenodo.59610 Impact Factor- 4.022

Figure:

Figure 1. Arduino MEGA 2560 board

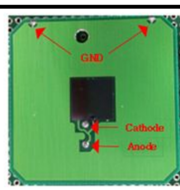
Table:

Table 1. Specs of Arduino MEGA 2560

Microcontroller	ATmega2560
Operating voltage	5v
input voltage(recommended)	7~12v
input voltage(limit)	6~20v
digital I/O pins	54 (of which 15 provide PWM output)
analog input pins	15
DC current per I/O pin	20mA
DC current for 3.3v pin	50mA
flash memory	256kB, (bootloader 8kB)
SRAM	8kB
EEPROM	4kB
clock speed	16Mhz
size	101.52 x 53.3 mm (length x width)
weight	37g

Radon is a radioactive gas that is colorless, odorless, and tasteless and is impossible to detect without the use of sensitive test equipment. Radon is a naturally occurring gas produced by the breakdown of uranium in soil, rock, and water. The EPA presently suggests that corrective action be taken to reduce the radon levels in your home if measured over the long term at 4 pCi/L or greater. Recently a PIN photodiode is more widely used than a conventional PMT, because it requires less bias to operate it and it is very compact. A PIN photodiode sensor module shown in Fig.2 was used for detecting of radon gas in this paper.

Figure:



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

Figure 2. PIN photodiode sensor module

Figure:

ISSN 2348 – 8034
Impact Factor- 4.022

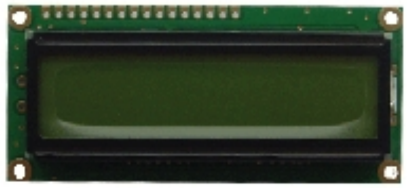


Figure 3. LCD module (BC4915AYPLEH) : 1602 character LCD

Table:

Table 2. Specs of LCD module (BC4915AYPLEH)

number of characters	16 characters x 2 lines
module dimension	80.0 x 36.0 x 12.1 mm
controller IC	*ST7066U*

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications [9]. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), anima tions and so on. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a prede fined task like initializing it, clearing its screen, setting the cursor position, controlling 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 on the LCD.

The LCD display in Fig. 3 is a LCD module (BC4915AYPLEH) that shows the level of radon gas in Pico Curies per liter (pCi/L). The display range is 0.0 to 999.9. The radon counter developed in this paper is designed to notify the user of the level of radon gas on either a short-term or long-term basis, and is updated every hour if there is a change in the level of radon gas.

III. SIMULATION STUDIES FOR RADON DETECTION

When a radon particle hits the PIN photodiode sensor, the output voltage level of the sensor will be slightly changed. In order to detect this voltage change for MCU, a pulse converting circuit is needed. Fig. 4 shows the pulse converting block diagram. Fig. 5 shows the pulse converting circuit.

Figure:

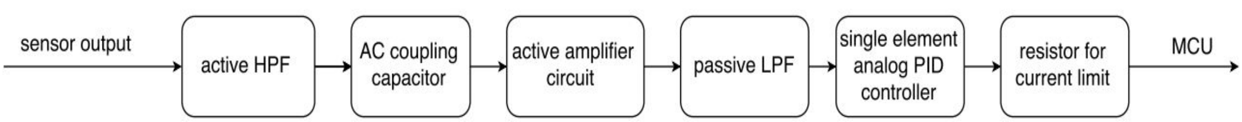


Figure 4. Pulse converting block diagram

Figure:

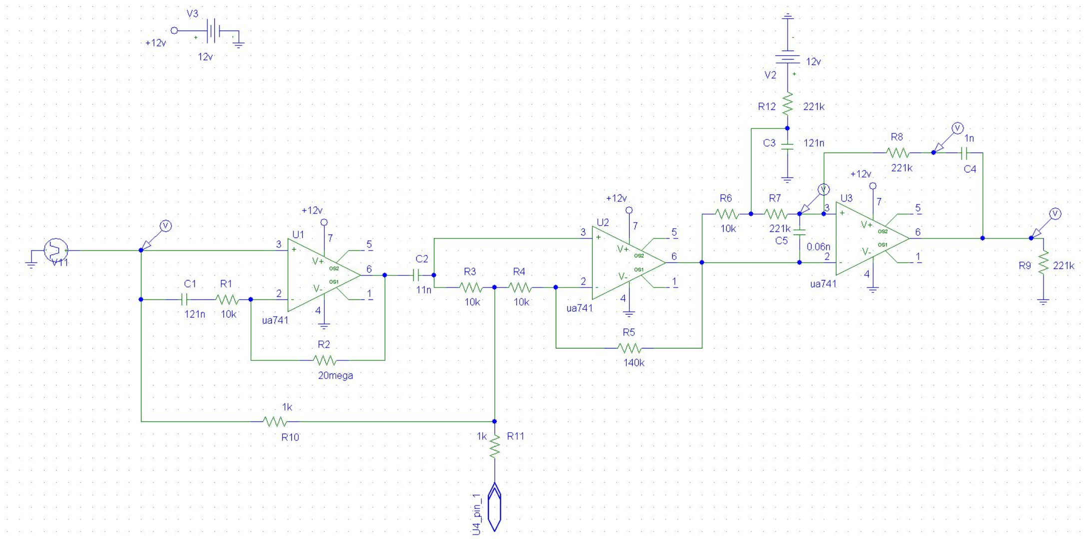


Figure 5. Pulse converting circuit for detected radon

Fig. 6 shows the simulation results I for the pulse converting circuit of Fig. 5. This circuit has the role of the maximum voltage limitation of 5V to arduino MCU pins. The upper figure of Fig. 6 shows the input voltage waveform with the range of -50V to +50V. Through simulation study, it is found that this high voltage can be limited to 5V. Fig. 7 shows the simulation results II for the pulse converting circuit of Fig. 5. Even though the input voltage of 50V is generated once, the final output pulses to arduino MCU pins might be generated several times. This is because the rise time of the input voltage is very slow to be 0.3msec.

Figure:

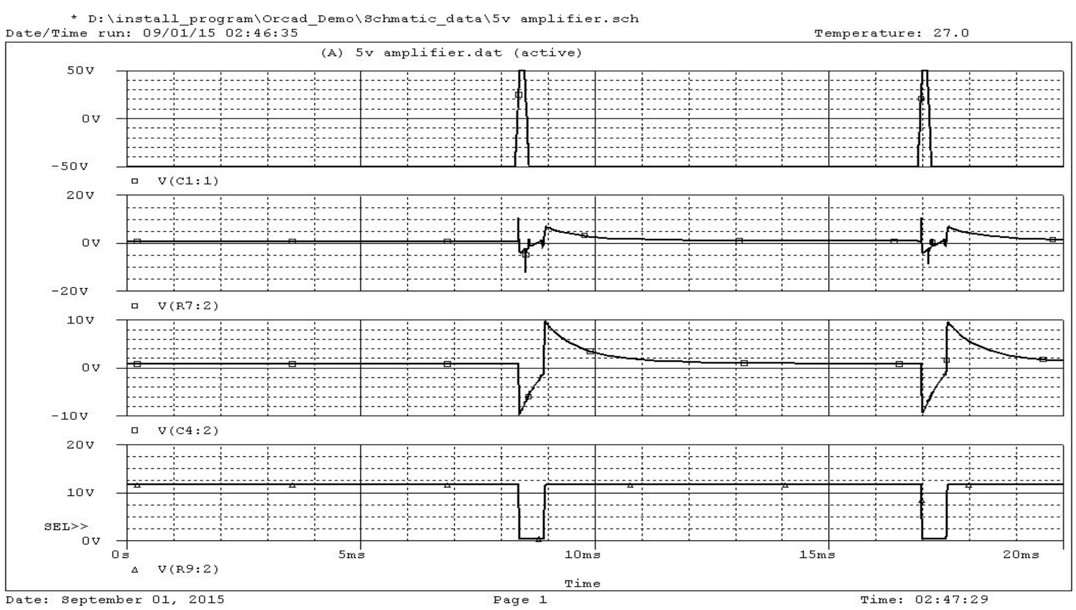


Figure 6. Simulation results I for the pulse converting circuit of Fig. 5

Figure:

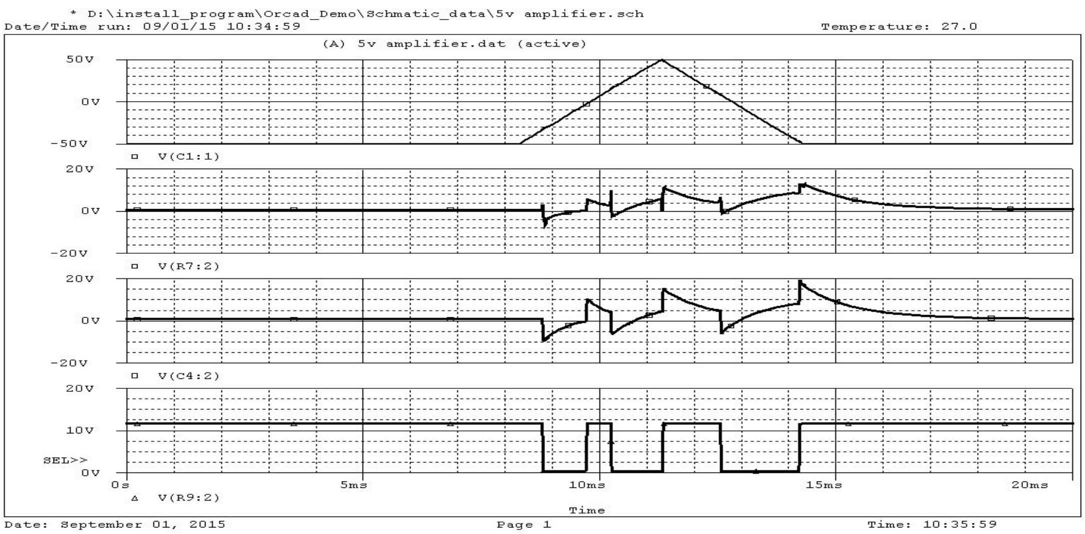


Figure 7. Simulation results II for the pulse converting circuit of Fig. 5

Figure:

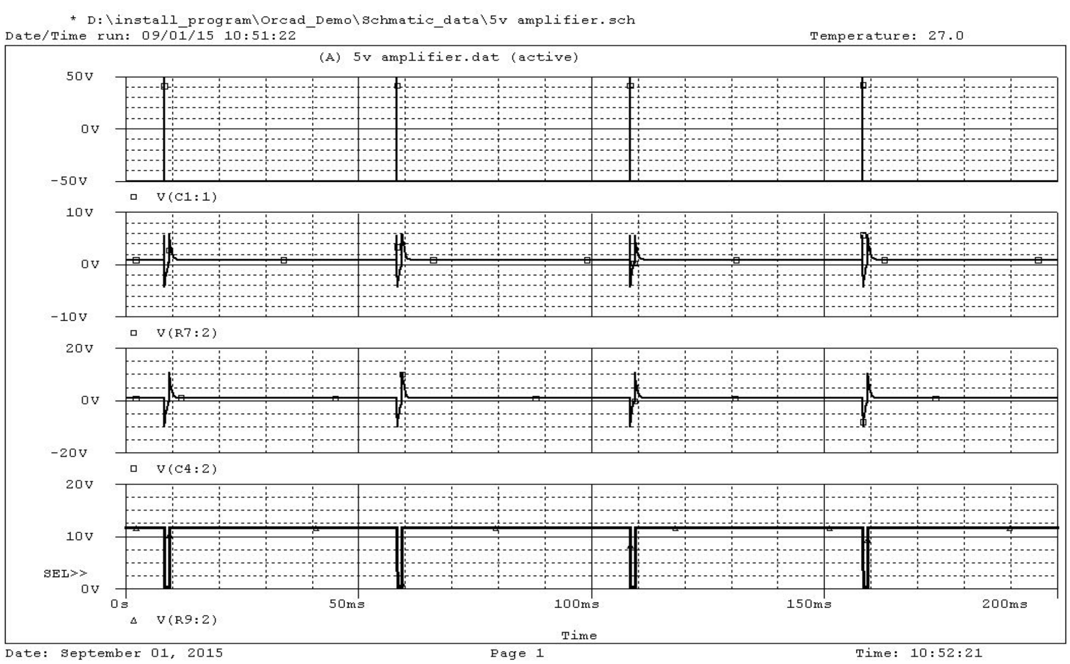


Figure 8. Simulation results III for the pulse converting circuit of Fig. 5

 ISSN 2348 – 8034
Impact Factor- 4.022

Fig. 8 shows the simulation results III for the pulse converting circuit of Fig. 5. These results show that if the pulse width of input voltage 50V is very short, the pulse width of output voltage would be also shortened. So, it was found that if the pulse width of input voltage 50V is shorter than 0.00001msec, the pulse width of output voltage would not be generated.

IV. EXPERIMENTAL RESULTS & DISCUSSION

Fig. 9 shows the radon counter implemented using an arduino MCU module. In order to investigate the performance of the implemented PIN photodiode radon counter, the experimental set-up was made. Radon emitting soil was placed on the shelf. Then, the radon counter was set under the shelf as shown in Fig. 10. The measurement result using the PIN photodiode radon counter is seen in Fig. 11. A Safety Siren Pro Series3 - HS71512 was used as a reference during this experiment. The Siren radon counter also adopts a pin-type photo diode for radon sensing. It has an electrostatic concentrator to deposit charged radon progeny onto the pin-type photo diode. It yields a count rate of about 2.8counts per hour. On the other hand, the radon counter developed in this paper yields a count rate of about 4.4counts per hour. This corresponds to 15.3pCi/L. This shows that the radon counter developed in this paper is superior to the Siren radon counter with respect to sensitivity.

Figure:

Figure 9. Radon counter implemented using an arduino MCU module

Figure:

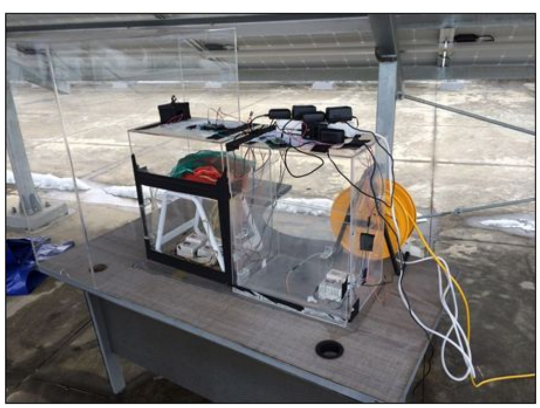


Figure 10. Experimental set-up for performance test

ISSN 2348 – 8034
Impact Factor- 4.022

Figure:

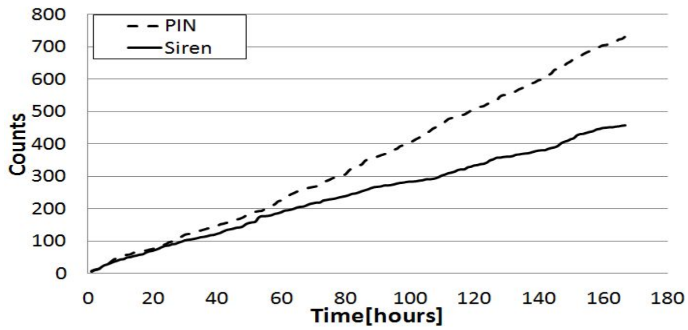


Figure 11. Measurement results showing the feasibility of pin photodiode-based radon counter

V. CONCLUSION

A radon counter using PIN photodiode sensor module is implemented in this paper. For radon emitting soil, a measured count rate of 4.4counts per hour was observed. This corresponds to 15.3pCi/L. This shows that the radon counter developed in this paper is superior to the Siren radon counter with respect to sensitivity. Through experimental studies, it was found that the PIN photodiode sensor module could be used for a radon counter. More studies, such as calibration of PIN photodiode sensor module and linear regression analysis should be followed.

VI. ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea governm ent (MSIP) (No. 2016011249).

REFERENCES

1. *Hiroshi Miyake, Keiji Oda and Masami Michijima, "Portable and High-Sensitive Apparatus for Measurement of Environmental Radon Using CR-39 Track Detector," Japanese Journal of Applied Physics, vol.26, No.4, pp.607-610, April, 1987*
2. *Peter J. Diamondis, "Radon gas measurement apparatus having alpha particle-detecting photovoltaic photodiode surrounded by porous pressed metal daughter filer electrically charged as PO-219 Ion accelerator," US patent, P.N. 5489780, Feb. 1996*
3. *R. H. Griffin, H. Le, D.T. Jack, A. Kochermin and N.G. Tarr, "Radon Monitor using Custom α - detecting MOS IC," in Proceedings of IEEE Sensors 2008, Lecce, Italy, pp.906-909, Oct. 2008.*
4. *Han Soo Kim, Se Hwan Park, Jang Ho-Ha, Dong-Hoon Lee, and Seung Yeon Cho, "Characteristics of a Fabricated PIN Photodiode for a Matching With a CsI(TI) Scintillator," IEEE Trans. Nucl. Sci., vol.57, NO.3, pp. 1382-1385, June, 2010*
5. *R.H. Griffin, A. Kochermin, N.G. Tarr, H.McIntosh, H.Ding, J.Weber and R.Falcomer, "A sensitive, fast-responding passive electrostatic radon monitor," in Proceedings of IEEE Sensors 2011, Limerick, Ireland, Oct., 2011*
6. *Ryan H. Griffin and N. Garry Tarr, "Optical image sensors and their application in radon detection," in Proceedings of SPIE Vol.8915, pp.8915C-1~7, Oct., 2013.*
7. *https://www.arduino.cc/en/Reference/HomePage#*
8. *http://www.hardcopyworld.com/gnuboard5/bbs/board.php?bo_table=lecture_begin*
9. *http://www.lcd-module.com/*
10. *http://www.axis.com/files/whitepaper/wp_ccd_cmos_40722_en_1010_lo.pdf*