International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 12, December-2014

Optical Smoke Detector

(Using Arduino Uno)

Bhaskar Jyoti Borah
Department of Physics
Tezpur University, Napaam
Tezpur - 784028

***Abstract*—I design a prototype which is capable of detecting smoke present nearby. The sensor designed for this device is based on the principle of scattering of light. Light from a blue LED is sent to an LDR through a multimode fiber optic cable. Presence of smoke particles between the LED and the front end of the optical fiber cable leads to the scattering effect which results in a change in the light intensity incident on the LDR. This change in light intensity again causes change in the resistance and hence in the voltage drop across the LDR. In this prototype I have used Arduino Uno (ATMEGA 328P-PU) microcontroller board for processing the voltage drop across the LDR.**

Keywords— scattering of light; LED (Light Emitting Diode); LDR (Light Dependent Resistance); Arduino Uno; ATmega 328P-Pu; Microcontroller.

I. INTRODUCTION

Fire accidents occur mostly due to carelessness of people. Every year thousands of people die from fire accidents. Fire kills an estimated 4,000 Americans every year. Another 30,000 people are seriously injured by fire each year. Property damage from these fire accidents costs at least $11.2 billion per year. Most of the fire accidents occur in residential buildings during the time when occupants are more likely to be asleep. More than 90% of fire deaths in buildings occur in residential dwellings. Such terrible fire accidents can be avoided and can be reduced to some minimal level if the detection of fire is possible at the early stage. Smoke detectors are devices used for the detection of smoke or other products of combustion. It warns people early enough about a fire, and thus helps to avoid unwanted destruction of properties.

In this proposed design I am using a simple technique for detecting the presence of smoke. Principle of light scattering [1] is used here. The scattering effect is higher for lower wavelength of light. Due to this fact blue LED [2] is chosen for this purpose (has lower wavelength; 475 nm). Light from this LED is incident on the front end of an optical fibre cable. *[Reason for choosing optical fibre is that it has a certain maximum value for incident angle. Light incident on the fibre beyond this maximum limit can't propagate through it. This angle is the 'angle of acceptance [3]'. Thus, usage of this fibre optic cable basically helps to reduce the effect of surrounding light sources]*. At the other end of the cable an LDR [4] is fixed. The presence of smoke particles basically leads to the increase in the potential drop across the LDR. For detecting these changes I am using a programmed microcontroller (ATMEGA 328P-PU).

II. HARDWARE CONSTRUCTION

The major hardware components are described below →

A. Arduino Uno

Arduino Uno [5] is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. (Shown in fig. 1)

1) Programming

The Arduino Uno can be programmed with the Arduino IDE. The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol.

2) Basic details

Microcontroller	ATmega328
Operating Voltage	5 volt
Input Voltage (recommended)	7-12 volt
Input Voltage (limits)	6-20 volt
Digital I/O Pins	14
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328)
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16Hz

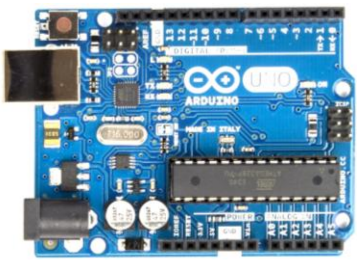

Fig. 1. Arduino Uno

B. Nokia 5110 LCD

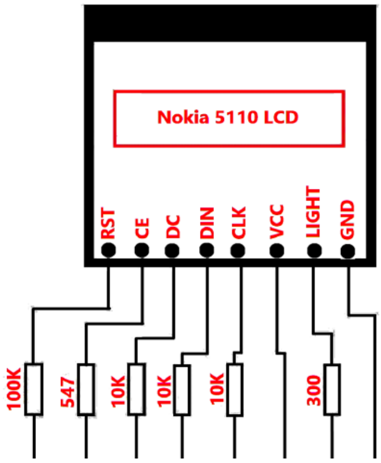

Fig. 2. Schematic for Nokia 5110 LCD

Fig. 2 shows a graphic LCD screen (used in Nokia 5110) which uses the PCD8544 controller. This LCD screen has 48X84 pixels. The PCD8544 is a low power CMOS LCD controller [6]. This LCD screen works best at 3.3V supply. We are using some resistors in order to protect this LCD from high voltage (Since this microcontroller operates at 5V).

Table 1: Pin details for Nokia 5110 LCD

Pin	Name	Function
1	RST	Reset pin – active low
	CE	Enable pin – active low
3	DC	Data/Command selection pin “0” – Write data “1” – Write command
4	DIN	Serial data input pin
5	CLK	Clock input pin
6	VCC	Supply voltage +2.7 to 3.3V
7	LIGHT	Backlight LED control pin
8	GND	Ground

Table 2: Connections to the LCD with resistors

LCD pin	Arduino pin	Resistor used (ohm)
RST	3	100K
CE	4	547
DC	5	10K
DIN	6	10K
CLK	7	10K
VCC	3.3 Volt	No resistor
GND	Ground	No resistor

C. Multimode Optical Fiber

Fig. 3. Multimode fiber optic cable

Multimode optical fibers [7] are basically used for communication purposes over short range of distance (e.g. in a building, in a small campus etc). These fibers are designed to carry multiple modes or light rays simultaneously which are incident on the cable at different angles. There are two types of multimode fibers:

1) Step-index multimode fiber: Used for imaging and illumination. (Fig. 4)

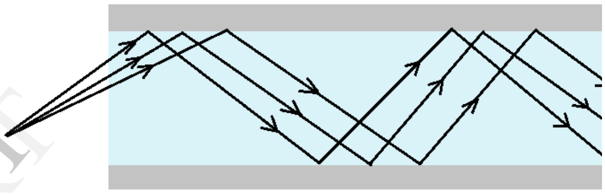

Fig. 4. Propagation in step-index multimode fiber

2) Graded-index multimode fiber: Used for data communications and networks. (Fig. 5)

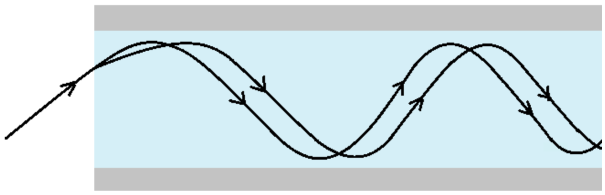

Fig. 5. Propagation in graded-index multimode fiber

In this prototype I am using a step index optical fiber cable for transferring light from the blue LED to the LDR (which is placed in a dark chamber). Reason for choosing the fiber optic cable is to minimize the unwanted effect of surrounding light. Rays falling at the front end of the fiber optic cable making larger angle than the angle of acceptance [3] can’t propagate through the fiber. This helps to eliminate the light from the surrounding sources. The acceptance cone as well as the angle of acceptance is shown in Fig. 6.

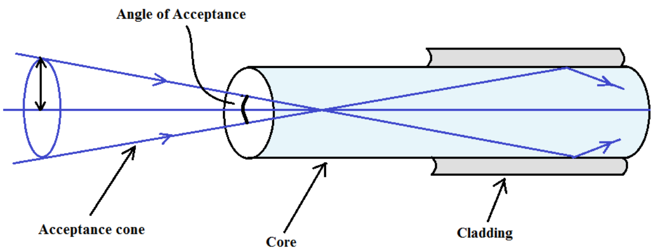

Fig. 6. Angle of Acceptance

D. Light Dependent Resistor

A light-dependent resistor (LDR) [4] is a light-controlled variable resistor. Its resistance decreases with increasing incident light intensity and hence it exhibits photoconductivity. It is made of a high resistance semiconductor. In absence of light, its resistance is in the range of megaohms (MΩ) and in presence of light its resistance goes down to a few hundred ohms.

When light is incident on the LDR, the electrons get excited (by the high energy photons) and jump from the valance band to the conduction band. The resulting electron and hole pairs conduct electricity which leads to the lowering of resistance. An LDR along with its characteristic curve is shown in Fig. 7.

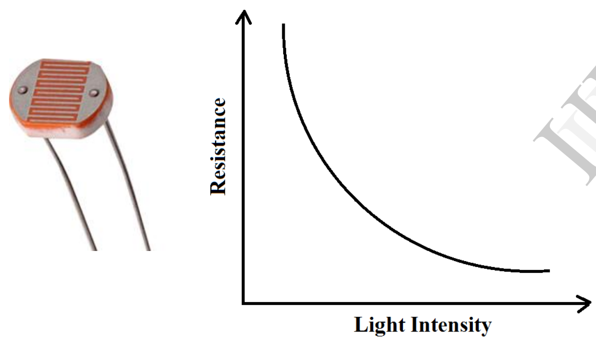

Fig. 7. LDR and its characteristic curve

E. Block Diagram

The basic working process of this device is shown in the block diagram (Fig. 8)

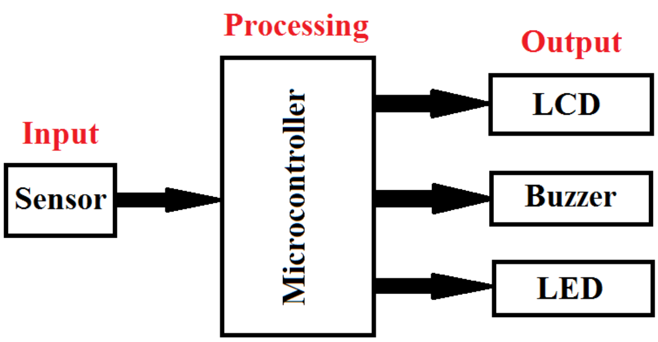

Fig. 8. Block Diagram

F. Circuit Diagram

Circuit diagram of this prototype is shown in Fig. 9.

III. SOFTWARE DESCRIPTION

The programming for this device is done in C++ language. The ATmega328 on the Arduino Uno comes preburned with a bootloader that makes it possible to upload new code into the microcontroller without the use of an external hardware programmer.

A. Arduino Integrated Development Environment

For developing the software for this smoke detector I am using Arduino IDE (Arduino 1.0.5) [8]. Programming is done using C++ language in order to control the I/O pins of the Arduino [9]. Arduino software is available for all the platforms (Windows, MAC, LINUX). After downloading the suitable software it has to be installed on the computer.

- Steps to be followed:

(a) Arduino IDE is to be executed.

(b) Necessary Libraries are to be added (described later).

(c) The board “Arduino Mega 2560” is to be selected.

Tools → Board →Arduino Uno

(d) Driver for the Arduino Board is to be installed. It can be found inside the Arduino folder located in the program files.

(e) After connecting the Board to the computer (through USB), Serial Port is to be selected properly.

Tools → Serial Port → COM3 / COM4 etc

(f) Now the program (to be uploaded in the microcontroller) has to be typed / copied.

(g) Clicking the ‘verify’ option, the program should be checked for errors.

(h) After successful verification it can be uploaded to the microcontroller by clicking on the ‘upload’ option.

B. Library used

For controlling the LCD, I have designed a simple library [10] (‘lcd’) with some basic functions.

- Installation details (for Windows OS):

(a) ZIP files should be downloaded and extracted.

(b) The folder obtained after extraction should be moved to the following path:

C:\Users\User_name\Documents\Arduino\libraries

(c) The library should be imported in the IDE.

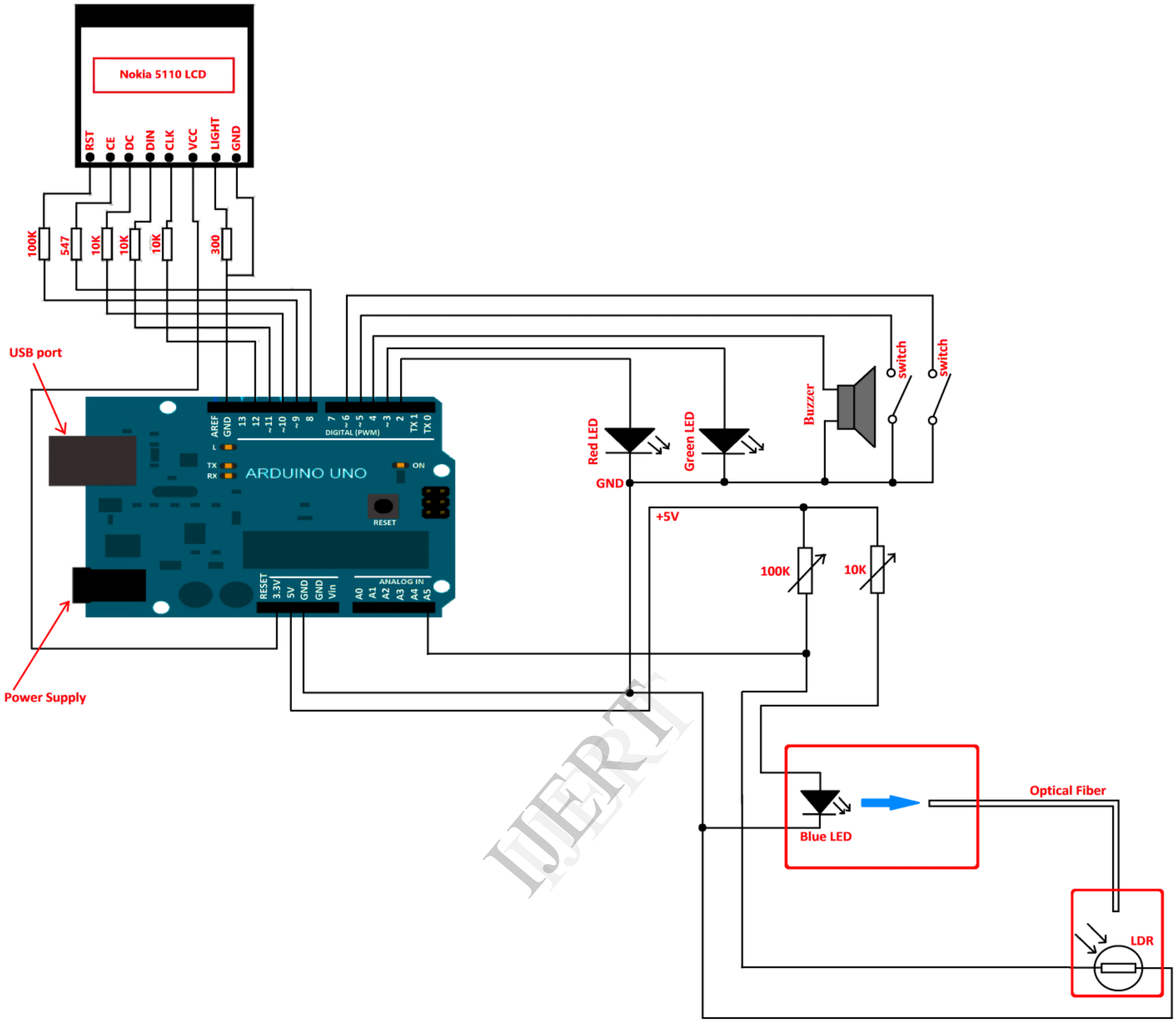

Fig. 9. Circuit Diagram

(d) Finally Arduino IDE should be restarted.

This process may vary for other Operating Systems.

IV. WORKING PRINCIPLE

The sensor designed for this device is based on scattering phenomenon of light. Light from a blue LED is sent to an LDR through a multimode fiber optic cable. Reason for choosing an optical fiber cable is that it has a maximum possible value for incident angle. Light incident on the front end of the fiber beyond this maximum limit (angle of acceptance) can't propagate through it. Thus, usage of this fiber optic cable helps to reduce the effect of surrounding light sources.

The reason behind using blue LED is that its wavelength (475 nm) is smaller than the other typically available LEDs.

Since the scattering phenomenon is inversely proportional to the 4th power of the wavelength of light, hence blue light is scattered more effectively by the smoke particles in comparison to the other lights.

The other end of the fiber is placed inside a dark chamber, where an LDR is fixed for taking the readings of light intensity. When light falls on the LDR, its resistance gets reduced. By Ohm's law [11], we have: ***V=I.R*** (where, **V** is potential drop across two points; **I** is current through the conductor; **R** is the resistance between these two points). Thus due to the decrease in resistance, the voltage drop also decreases. When the smoke particles come in between the path of the blue LED and the front end of the fiber, then scattering effect takes place. Due to this phenomenon the light intensity being incident on the fiber gets reduced which leads to the increase in the resistance across the LDR. Thus, presence of smoke particles results in the increase in the voltage drop across the LDR (according to Ohm's law). For detecting these changes I am using a programmed microcontroller (ATMEGA 328P-PU) [12]. The LDR is connected to the 'A5' analog pin of the microcontroller board as shown in the circuit diagram (figure 9). In the programming part, I am basically processing the voltage drops across the LDR. A reference value for the voltage drops is fixed within the program (which can be changed by pressing the up/down keys). If the voltage reading from the LDR goes above this reference voltage, the microcontroller immediately starts the alarming as well as LED blinking process simultaneously. Calibration of this prototype can be done by changing the resistance of the 100K potentiometer. Besides this analog calibration feature, two push button switches are also provided which enables the user to change the reference voltage (already fixed within the program). Thus this device can be calibrated very accurately.

V. RESULT AND DISCUSSION

I have tested this prototype in various conditions using different smoke sources and found it working properly. Its sensitivity is found to be high enough which can be adjusted by varying the variable resistor (100K) and by pressing the 'up' / 'down' buttons. So long as the smoke particles are present inside the container, its alarming process continues. At normal condition green LED remains on. When smoke is present, it turns off and the red LED starts blinking. Simultaneously a smoke level is also displayed over the display panel. By properly calibrating this device it is possible to detect the presence of smoke in parts per million unit (ppm). Proper calibration will also enable us to distinguish some other hazard gases present in the atmosphere.

There are many future scopes for this prototype. It is possible to connect a temperature sensor to the microcontroller (ATMEGA 328P-PU). This will provide the current temperature along with the detection of smoke. By interfacing a GSM circuit with the Arduino Uno, it is possible to control this device using a cell phone. This kind of system will be very useful in large industries, where possibility of fire accident is very high.

VI. CONCLUSIONS

In this project I have designed an optical smoke detector using *Arduino Uno* board (Microcontroller: *ATMEGA 328P-PU*). Presence of smoke particles between the LED and the front end of the optical fiber cable causes scattering to take place resulting in a change in the incident intensity of light. Which again causes change in the resistance and hence in the voltage drop across the LDR. Voltage drops are measured and processed with the help of Arduino Uno. The proposed design is shown in fig. 10.

Detection of smoke is very helpful for avoiding the unwanted destructions due to fire accidents. Every year thousands of people die from fire accidents. By using a smoke detector, it is possible to detect a fire accident at its beginning stage and thus it becomes possible to minimize the destruction.

Fig. 10. Optical Smoke Detector

VII. REFERENCES

[1] H. C. van de Hulst, Light scattering by small particles, New York: Dover. ISBN 0-486-64228-3, December 1981.

[2] E. Fred Schubert, Thomas Gessmann, Jong Kyu Kim, "Light Emitting Diodes", DOI: 10.1002/0471238961.1209070811091908.a01.pub2, July 2005.

[3] James N. Downing, Fiber-optic Communications, Cengage Learning, 2004 - Technology & Engineering, pp. 67-69.

[4] B. P. Singh, Rekha Singh, Electronic Devices and Integrated Circuits, Pearson Education India, January 2009, pp. 864-869

[5] http://arduino.cc/en/Main/arduinoBoardUno (Accessed on 17th December, 2014).

[6] Baker, R. Jacob, "CMOS: Circuit Design, Layout, and Simulation", Third Edition- 2010, Wiley-IEEE, pp. 1174, ISBN 978-0-470-88132-3.

[7] Ajoy K. Ghatak, K. Thyagarajan, Optical Electronics, Cambridge University Press- 1989, pp. 364-399.

[8] Monk Simon, Programming Arduino Getting Started with Sketches, McGraw-Hill Professional- 2011; ISBN: 978-0-07-178423-8, MHID: 0-07-178423-3, pp. 15-25.

[9] McRoberts Michael, Beginning Arduino, Paul Manning- 2010, ISBN: 978-1-4302-3240-7, pp. 12-20.

[10] Bjarne Stroustrup, Libraries, "The Design and Evolution of C++", Pearson Education India- 1994, ISBN: 978-81-317-1608-3, pp. 181-194.

[11] John Avison, The World of Physics, Nelson Thornes- 1989, pp. 236.

[12] Dale Wheat, Arduino Internals, Apress, November- 2011, pp. 39-64.

Author Biography:

Bhaskar Jyoti Borah passed Higher Secondary from Pragya Academy, Jorhat, India in 2012. He has been pursuing Integrated M.Sc. in physics in Tezpur University, Napaam, India since 2012. He has been obtaining INSPIRE (Innovation in Science Pursuit for Inspired Research) scholarship under the scheme of DST (Department of Science & Technology, India) since 2012.