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Portable Fire Detector

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Abstract: *This paper describes the design of a portable fire detector which can easily detect the sudden rate of change of temperature and sound an alarm if preset value are exceeded. The detector is said to be portable because it can be moved from one place to another. The design is meant to be less costly compared to other fixed fire alarm detectors and is also meant to use both batteries or be charged from AC mains supply. Fire has been causing fatalities and other casualties and losses to property and need to be detected at an early stage and put off immediately. The system incorporates a thermistor and the Arduino IDE which can be programmed using various languages such as C++. The circuit was designed and simulate, with simulation results showing that the system is able to fulfill its objectives. A prototype was built was demonstrated that the system is able to respond to rate of change of temperature. The work is still ongoing whereby future improvements involves utilizing solar energy and inbuilt photovoltaic system to power or charge detector battery.*

Keywords: *Portable detector, fire, arduino*

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I. Introduction

Fire detection systems are designed to identify a fire outbreak at its early development, so that occupants can safely evacuate from that place. Early detection also means that emergency personnel’s response could be made possible before any casualty occurs or property damaged. Some systems rely solely upon an occupant to discover the fire and press a switch to sound the alarm and this can cause a delay leading to loss of lives and property. Speed of detection is an important factor because to survive a fire outbreak an early fire detection is necessary. The choice of fire detectors is therefore affected by various factors such as property being protected. Example, A place such as a hospital can be expected to have fast response fire detectors as compared to a warehouse because in a hospital patients may not be able to evacuate on their own so early warning is required. According to Bukowski, four of every five fire deaths have occurred in U.S. homes [1]. Analysis by the National Fire Protection Association (NFPA) also indicates that when a fire occurs, detectors reduces the chances of dying nearly by 50 percent. It is therefore very vital that these systems be put in place to save lives and property.Residential fires can occur any time of day or night [2]. These fires can take the form of a smoldering or flaming fire. A smoldering fire is a slow burning, flameless form of combustion that produces a minimal amount of heat and large amounts of smoke. In comparison, a flaming fire is a free-burning fire that produces a flame, extreme heat, burns rapidly and creates minimal amounts of smoke. Both types of fires create hazardous conditions to everyone who is exposed within the structure. Hazardous conditions include poor visibility due to smoke obscuration, thermal effects including burns, irritation of the airway tract and narcosis from inhaling the toxic gases. One of the most lethal gases produced by both smoldering and flaming fires is Carbon Monoxide. In a smoldering fire, the incompleteness of the combustion process leads to high levels of Carbon Monoxide [3]. In comparison, flaming fires produce smaller amounts of Carbon Monoxide. Over the years, studies been completed to determine how smoke alarms react to these two types of fires.There are so many varieties of fire detection systems in the market. Example, the smoke detectors, which are best for early detection of fires in the home, however, their quick response nature makes them very expensive to install, about five to ten times costlier than heat detectors [4]. Their warning provides valuable time to safely escape a fire. Three types of smoke alarms include photoelectric, ionization and a combination of the two known as a dual sensor alarm. Both ionization and photoelectric smoke alarms are effective in detecting the presence of fire [5]. They are however, noticeably different in performance, including operation, response time and nuisance alarms. The second type is heat detectors: they are the slowest type but also the least expensive, they are also the most basic type [6]. Of this type, there are fixed temperature detectors; which operates at a specific temperature (a certain threshold is not to be exceeded), rate-of-rise detectors (which activate based on the speed of rise of temperature), or a combination of the two. Fixed temperature and rate-of-rise heat detectors are suited to detect in the presence of slow or fast rising temperatures due to burning combustibles. The construction of these models incorporate a thermistor heat element protected from damage by the built-in, durable plastic guard.

This paper is be based on heat detection principle, as it is the cheapest method of detecting fire, using almost less sophisticated technology. Interfacing it with the Arduino as the controller will make it a more accurate detector, being reliable at saving the lives of people who find themselves in a tragedy of a fire. It is intended to design and develop a portable fire detector which can easily be moved from one place to another. This will help those people who normally find themselves not staying permanently at one place. Example, people working in towns and cities but with their permanent places of residence somewhere else can own this portable fire detector and able to move with it as and when necessary.This paper is arranged according to the following sections: Section II deals with characteristics of Arduino board. Section III gives the details temperature correlation with thermistor resistance. Section IV deals with fire detection circuit while Section V deals with analysis and discussion while Section VI gives conclusion and future work.

1.1 Arduino Uno Board

Arduino is an open-source platform used for building electronics projects [7]. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board, figure 1 below. The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package. Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be powered from a USB cable coming from your computer or a wall power supply (like this) that is terminated in a barrel jack. [8]. The USB connection is how the code will be loaded onto the Arduino board. Power supply should not be greater than 20 Volts as it will overpower (and thereby destroy) the Arduino board. The recommended voltage for most Arduino models is between 6 and 12 Volts. The figure 1 below shows Arduino UNO Board

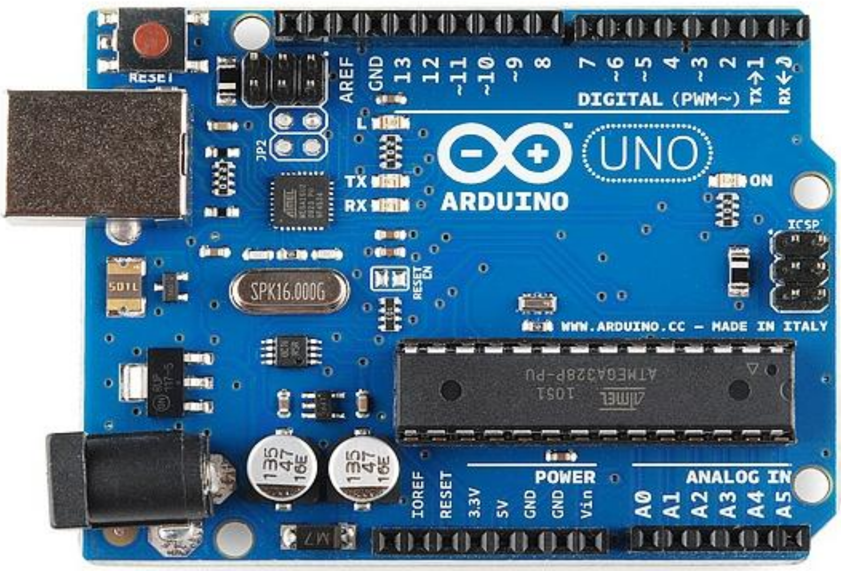

Figure 1 – Arduino Board

1.2 Temperature correlation with resistance

Thermistor resistance is related to temperature in degrees Kelvin by the following formula Steinhart-Hart equation [9]

$$\frac{1}{T} = A + B * \ln\left(\frac{R}{R_t}\right)^2 + D * lin\left(\frac{R}{R_t}\right)$$

$$where \quad A = 1.12924\, E_{03}, B = 2.34108E\_04, \;\; C = 0.87755\, E_{07}, D = 0.0$$

Thermally sensitive resistors (thermistor) are made up of solid semiconductor materials, whose resistance decreases by about 4% per centigrade degree in accordance with the Steinhart-Hart equation [9]. Figure 2 below shows relationship of thermistor resistance with temperature. At room temperature (around 25^{o}C) a thermistor rated 10kΩ has a resistance of about 10kΩ. When temperature increases, say up to 30^{o}C which corresponds to a change of 5^{o}C, the resistance drops by a factor equivalent to 5*4%=20%, which is 8kΩ.

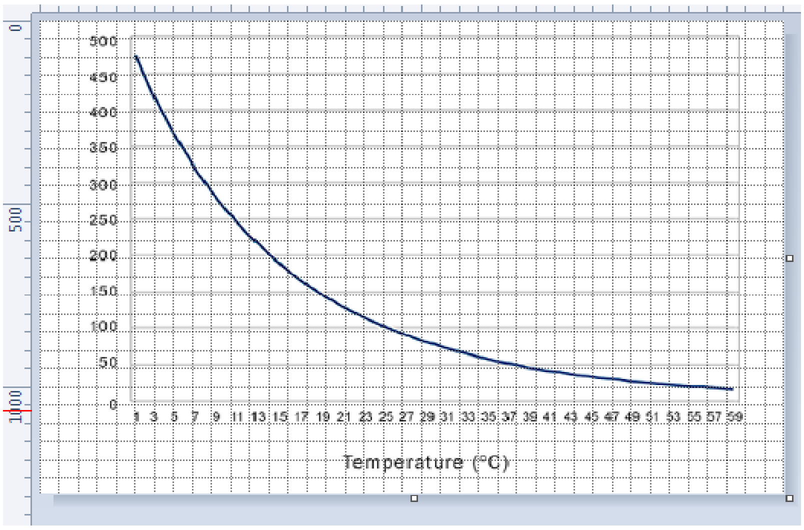

Figure 2 - Illustrates the resistance of the thermistor as a function of the temperature

1.3 Fire Detection Circuit- Thermistor Integrated With Arduino

1.4Circuit diagram of fire detector with series connected thermistor and smoke sensor

Various configurations of fire detection circuit can be made. One of the possible configuration is shown in figure 3 below. When the switch is on, in the absence of heat or smoke current runs through loop I1 which will be having the least resistance then, turning on the LED and indicating that the detector is in an ON state. Once the detector is activated, that is, when the thermistor resistance has been reduced due to the presence of heat, and the smoke sensor engaged, the loop I2 is activated providing the transistor base current. Now the transistor is active, so loop I3 takes over and the buzzer starts buzzing.

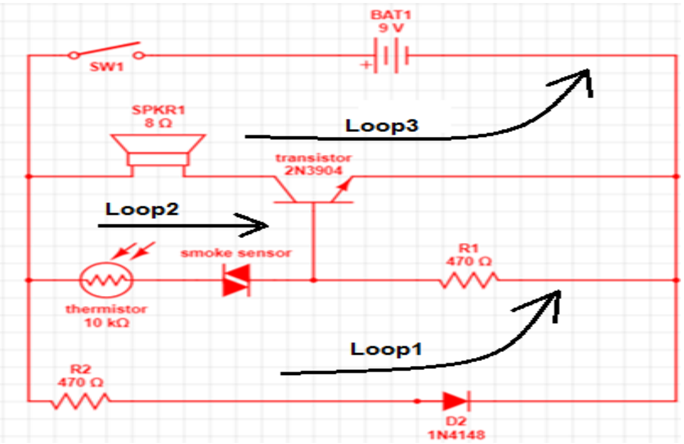

Figure 3 – Basic circuit diagram of fire detector with series connected thermistor and smoke sensor

In this circuit, instead of have two separate sensors for detecting temperature (thermistor) and smoke respectively on two separate lines, they are put together in series. However, they can be integrated together into a single sensor thus the thermistor characteristics gives the sensor properties of a switch by blocking the current passage due to its large resistance. Similarly the smoke detector characteristics give the sensor properties of a normally open switch because it only closes its contacts when it senses smoke particles. The advantage of this sensor is that number of false alarms are reduced, since if dust accumulates on the smoke sensor in the absence of fire, the thermistor will still retain its robust resistance hence stopping current to flow through it. The disadvantage of this design is that it does not however solve the case of seasonal changes. The system assumes a certain preset value as being normal or reference ambient temperature. Therefore as ambient temperature varies with seasons particularly in areas experiencing seasons such as winter and summer, the ambient temperature can be lower than preset value. While smoke detectors are rigorous in terms of fire detection their disadvantages are that they can provide false detection if used where volatile solvents, conductive material, dusts, or high humidity are present.

1.5 Experimental setup

This papers considers the configuration where a thermistor is integrated with Arduino. Figure 4 below shows an experimental setup of the portable fire detector under consideration. The desired setup is of this format, having in the input section of the detector, a 10kΩ resistor in series with a thermistor of the same resistance measured at room temperature (25^0C). When the condition in the program code is met the buzzer shows by producing a sound and the LED turns ON.

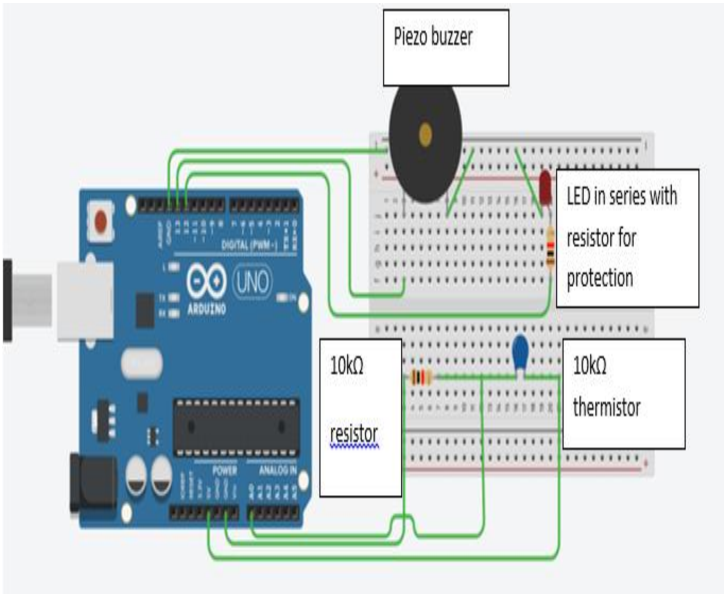

Figure 4 – Experimental setup of designed fire detector

a) Material and equipment

The following equipment and instruments are utilized in the experimental setup

1. The Arduino UNO board which is one of the main components, acting at the brains for this prototype to work efficiently.
2. Next up it's the breadboard which holds circuit components together.
3. The thermistor which will act as a heat sensor, but as mentioned before, for this project, a potentiometer was used instead.
4. An LED and a Buzzer both as output devices
5. Two resistors, one used in the voltage divider of the input circuit and the other, for limiting the current that goes to the LED.
6. And lastly a 9V battery to power the circuit.

B) Principle of operation

The programmed code assumes that a temperature change (rise) of 5^0C, should not occur in less than a minute. In the case where this happens then the model is programmed to immediately sound an alarm, thereby notifying occupants in a building of a fire danger. The system is programmed such that when a certain threshold is reached, that is if a certain temperature value is exceeded the buzzer sounds an alarm. The main component or sensor to be used is the thermistor because its resistance varies as it gets exposed to temperature variations. At room temperature (around 25^oC), the thermistor resistance is approximately equal to its rated resistance. Example, if it is rated at 10kilo ohms then it's resistance also about 10kilo ohms at room temperature. When exposed to heat the thermistor resistance drop significantly as low as below 4kilo ohms. In the circuit, the thermistor is connected in series with a resistor to form a voltage divider. Voltage is then allocated to the two components based on each one's respective resistance. When the thermistor is exposed to heat, its resistance drops and the Arduino board will recognize this (the sensor Pin representing the thermistor voltage divider is connected to analogue pin A0 on the Arduino board) and starts sounding the alarm if the threshold is exceeded.The program code for this project reads the value of the analogPin(A0), refer to figure 1 on previous pages, after one second of initialization and stores it on a variable named "a". The program then waits for five seconds, and reads the analogPin(A0) for the second time, this time, storing the value at variable named "b". It then calls a function called "an IF function" which tests whether the difference between "a" and "b" is greater than 170.7 in the 5 seconds time that elapsed, that is, the rate. The program however does not print out any readings but rather sounds an alarm and turn an LED ON.

b) Experimental model

A condition of fire outbreak was created using potentiometer as shown in figure 5 below in order to measure temperature rise with respect to time. Since it was not practically possible to create a real fire in the laboratory, a potentiometer was used instead of a thermistor so as to vary the resistance. Resistance variation simulated temperature variation which resembles normal ambient temperature rise or a fire outbreak.

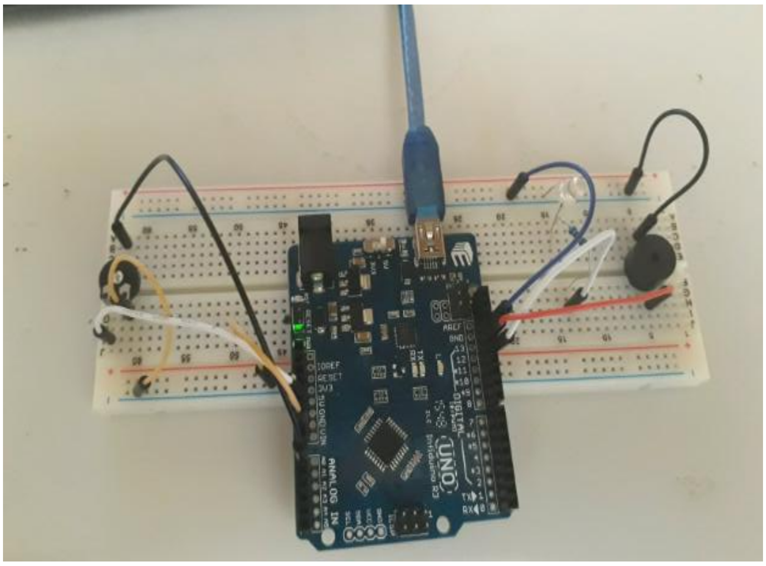

Figure 5 – Model of Arduino-integrated fire detector

II. Analysis And Discussion Of The Results

The results obtained for both scenarios 1 and 2 showed that the sensor responded in accordance with written code and expected results were obtained.

2.1 Scenario 1

When the potentiometer wiper is pointing in the centre position, the value of the voltage in bits, as read by the Arduino is 512, corresponding to ((512/1023)*5V=2.5V) as shown in figure 6. This is the expected reading of the analog Read (A0) because in this instance resistances of thermistor and resistor are of the same value and since they are in series. In this scenario the alarm did not activate as per developed program code

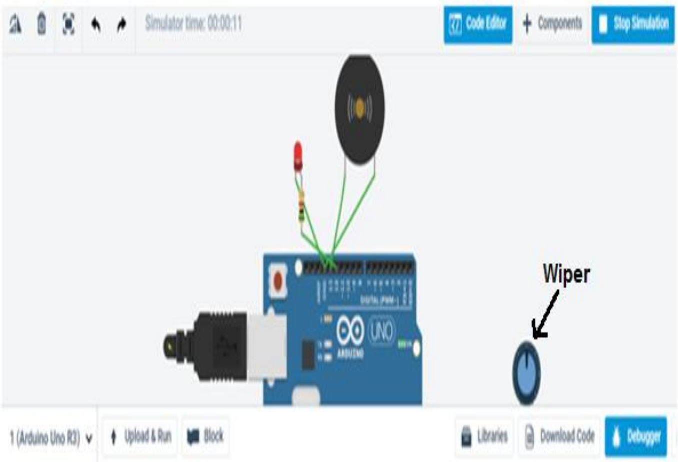

Figure 6 - Simulation circuit of the system

2.2 Scenario 2

According to program code this temperature change should not occur in less than 5 seconds. If it happens within 5 seconds the system interprets it as showing presence of fire hence causes the alarm to go on. The figure 7 below is for a running simulation which shows a rise equivalent to 170.7 bits after 5 seconds. The 170.7 bits which approximately equals 171 bits, is equivalent to

$$\frac{171}{2024}x5V = 0.835V$$

And this corresponds to $R_T = \frac{5x10k\Omega}{0.835} - 10k\Omega = 4.99k\Omega$ according to voltage divider rule. And a change in resistance making a percentage decrease of 50.1%. A 4% decrease in resistance corresponds to 1^oC rise, hence giving a temperature difference of

$$\frac{50.1}{4} = 12.525^oC$$

When the value of 12.525°C was reached after 5 seconds elapsed the alarm did not go on, interpreting that as a normal rise in ambient temperature. When the detector was set such that 12.525°C elapsed in less than 5 seconds the alarm was activated and released buzz sound interpreting the conditiont as detecting presence of fire.

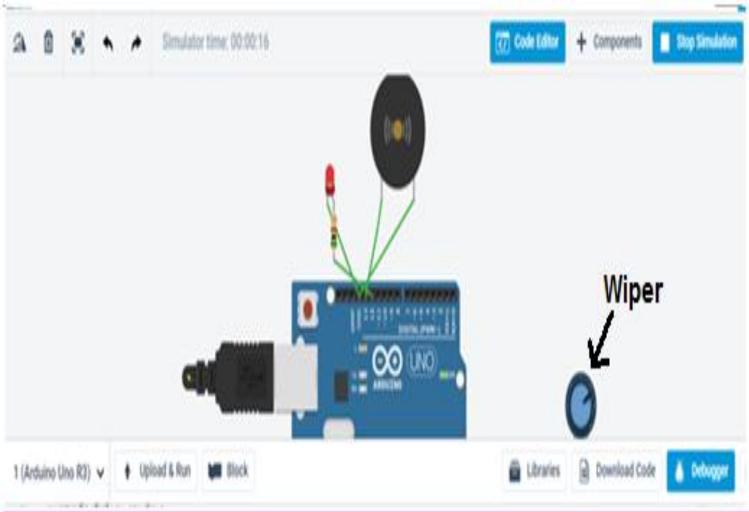

Figure 7 - The value of a =512

III. Conclusion And Future Work

The developed system was able to respond as expected. In figures 5 and 6 when the system detected higher voltage which showed increase in temperature, it did not activate the alarm when the 12.525°C was reached after five seconds elapsed. It interpreted this conditions as a normal ambient temperature rise. Operating the detector such that the 12.525°C was reached before five seconds elapsed triggered alarm to go on because it was interpreting the conditions as presence of fire, according to the program code. The work is still ongoing and for future the system will be improved by including solar charging system. Also, amplification of buzz sound would be incorporated so that the alarm could be audible from a defined minimum distance. A prototype will be built and test under real life conditions where the thermistor is used instead of potentiometer and be able to detect presence of fire.

References

[1]. R. Bukowski and V. Nuzzolese, "Performance-based Fire Protection of Historical Structures", Fire Technology, vol. 45, no. 1, pp. 23-42, 2008.

[2]. L. Montoya, M. Junger and Y. Ongena, "The Relation Between Residential Property and Its Surroundings and Day- and Night-Time Residential Burglary", Environment and Behavior, vol. 48, no. 4, pp. 515-549, 2014.

[3]. J. Quintiere, M. Birky, F. Macdonald and G. Smith, "An analysis of smoldering fires in closed compartments and their hazard due to carbon monoxide", Fire and Materials, vol. 6, no. 3-4, pp. 99-110, 1982.

[4]. B. Pless, "Smoke detectors and house fires", BMJ, vol. 325, no. 7371, pp. 979-980, 2002.

[5]. T. Fazzini, "Ionization and photoelectric smoke alarms in rural Alaskan homes", Western Journal of Medicine, vol. 173, no. 2, pp. 89-92, 2000.

[6]. T. Karsky, Smoke and heat detectors. [Moscow, Idaho]: University of Idaho, College of Agriculture, Cooperative Extension Service, Agricultural Experiment Station, 1978.

[7]. J. Younker and T. Ribaric, "Beyond Open Source Software: Solving Common Library Problems Using the Open Source Hardware Arduino Platform", Partnership: The Canadian Journal of Library and Information Practice and Research, vol. 8, no. 1, 2013.
[8]. P. Seneviratne, Building Arduino PLCs P. Kumar, "Reducing the Impact of Soiling on Solar Panel Using Automated Water Free Split Microfiber Cleaning System," Int. J. Mod. Trends Eng. Res., vol. 4, no. 3, pp. 84–87, 2017.
[9]. Ametherm Circuit Protection Thermistirs. Online, https://www.ametherm.com/thermistor/ntc-thermistors-steinhart-and-hart-equation

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