



(RESEARCH ARTICLE)



## Hangar fire detection alarm with algorithm for extinguisher

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### Abstract

A fire alarm is a high-performance system that detects smoke, heat or flames and actuates fire suppression system, for the protection of lives and property. It is employed in aircraft hangars for the protection of aircraft, personnel as well as the hangar structure. The need for a fire alarm in a hangar with algorithm for extinguishers cannot be overemphasized.

The structure of the hangar building, type of aircraft housed in the hangar and activities carried out at the hangar such as inspections, overhauls and modifications of aircraft, determine the type of fire alarm to be used, whether it should be automatic or manual [2]. The detection employed, be it smoke detection, heat sensing or both and the process of extinguishing in the face of a fire threat or hazard is equally important.

The effectiveness of the alarm is dependent on genuine alerts and not false alarm triggers, hence in this research paper, the employment of intelligent detection using comparators in programmed IC, the Micro-controller, was interfaced with a 555 Timer, a multi-vibrator for generating aural sound for alarm, LCD Display for indicated readings as well as algorithm for extinguishing using water or foam via sprinklers. The basic work started with a block diagram representation, thereafter, individual subsystems, which form the building blocks were analyzed and the components parts identified. A circuit diagram for the project was analyzed and built using Proteus. This was simulated and found to be achievable, hence a program was written in C++ for the micro-controller using Arduino Language known as the source code. The results show hangar fire detection alarm with algorithm for extinguishing and was investigated as an effective means of suppressing fire threat in the hangar [4].

**Keywords:** Algorithm; Sprinklers; Fire Alarm; Comparators; Micro-controllers; Artificial Intelligence

### 1. Introduction

Fire detection alarms are often found in workplaces and can be triggered by smoke where they are referred to, as smoke detectors. This may be true because there is no fire without a smoke. However, fire alarms can also be identified or made to trigger if the sensing temperature of a known sensor can be pre-set to a value so as would be enough to trigger an alarm system. A fire detection and alarm system is a system with sub systems and devices designed to work together to detect and warn of a fire outbreak through visual and aural indications like sounds. The detection can be triggered through the presence of smoke, heat or rise in temperature depending on the type of detector sensor employed.

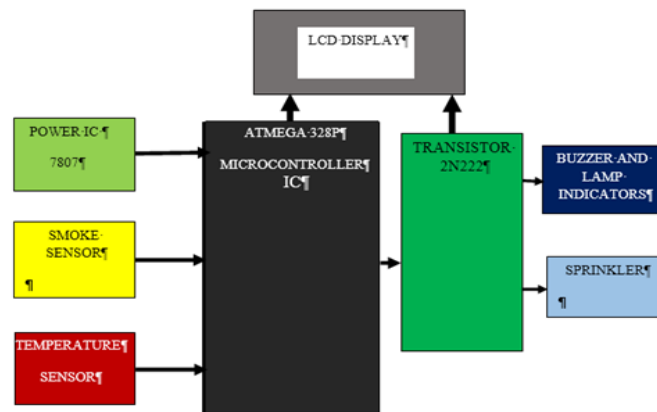
Aircraft hangars pose unique challenges for fire protection because of large open floor areas with tall roof decks to house high-value aircraft contents. Large quantities of liquid jet fuel are present, and aircraft maintenance activities offer potential ignition sources. Another characteristic that differentiates aircraft hangars from most other occupancies are

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the large aircraft wings and fuselages that create obstructions to both fire detection and fire suppression, sometimes, there are large scaffolds, which create further obstructions [2].

Naturally, hangars come in all shapes and sizes hence the type of fire protection employed. A 6,000 ft<sup>2</sup> (560 m<sup>2</sup>) shelter for small aircraft poses different challenges than a 150,000 ft<sup>2</sup> (14,000 m<sup>2</sup>) maintenance complex for overhauling commercial jets. The main fire threat is posed by a fuel spill finding an ignition source, leading to a challenging fire. For example, a 50-foot (15 m<sup>2</sup>) diameter pool of burning Jet-A fuel can produce a heat release rate in the order of 300 megawatts (Mw) and a few gallons or litres of ignited fuel is enough to destroy just about any facility that is not properly protected. Large hangars, therefore, need fire detection systems that must function over unusual heights and distances where sensitivity is needed for fast response.

The most suitable detection in the face of outbreak in a hangar is smoke due to the easy diffusion of smoke. Hence a PIC micro-controller was used for the intelligent detection by designing it to suit the desired output using C++ programming language as the design language, and the algorithm for extinguishing. In this research paper, the possibility of an active fire detection system capable of protecting, detecting and suppressing a fire, when activated and operated manually or automatically to alert occupants of a hazard, as well as suppress the fire using either foam or water in sprinklers or overhead form was designed[4].



**Figure 1** Block diagram of the fire alarm design with sprinkler.

## 2. Types of fire alarm

Though fire alarms are devices designed to detect an unwanted presence of fire by monitoring environmental changes associated with combustion, either smoke, heat or flames, an alarm can either be classified as manually or automatically activated, or both. Manually activated alarms are break glass stations. Buttons and manual fire alarm activation are constructed to be readily located by personnel near the exits or unambiguous places where it can be identified, and operated. Automatically activated alarms on the other hand take many forms in order to respond to any number of detectable physical changes associated with fire. Such as convector thermal energy, heat detection, combustion products, smoke detection, energy radiation; flame detector, fire gas detector, water-flow detector and release of extinguishing agents [3].

These has made fire alarm systems to be classified by designated letters as L fire alarm systems which are concerned primarily with preserving life and enabling all occupants other than those immediately affected by the fire, to make good of their escape from the building. These systems are designed primarily to evacuate the building and prevent loss of life or injury. The system may not automatically call for the brigade and protection of property. M fire alarm systems are manual call points recommended where alarms are raised throughout the building. There are usually found on the escape routes staircases etc. There is no automatic fire detection built in and are operated by someone raising the alarm suitable for working places e.g, hand bells. P fire alarm systems denote an automatic fire detection system installed to take on the additional task of not only preserving life but protecting the building and contents as well when the building is quite unoccupied. The system should automatically dial out to the brigade as a matter of urgency as early as possible for minimal damages [8].

Despite fire been of different classes, ranging from class A, B, C, D and K, the research work is done based on P fire alarm systems for all classes of fire.

### 3. Building the smoke and fire detection circuit

In building the smoke and fire detection circuit, multiple sensors; LM35 heat sensor and MQ-2 smoke sensor were utilized instead of one sensor. Processing of the dual information using ARTMEGA328 microprocessor for effective determination of a fire by comparing the sensor feeds was not a challenge because the step-by-step algorithm using the C++ language was embedded in the microcontroller using ARDUINO technology. This gave out a good result. Optimization of all designs of the circuit using PROTEUS was carried out in validation of circuit.

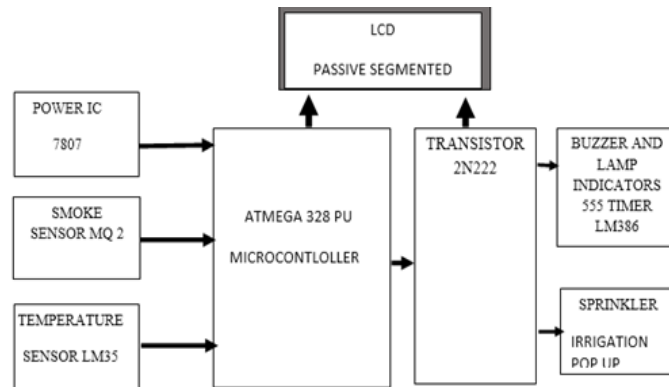


Figure 2 Components used during the construction work

#### 3.1. Power circuit

The build up to the alarm system started with the power supply from the voltage regulator 7807 IC, where a 12V battery, 2 filtering capacitors C1 = 10 $\mu$ f and C2 = 100 $\mu$ f were used. The 100-micro farad ( $\mu$ f) capacitor was connected between the input and ground pin of the voltage regulator IC to prevent ripple from the supply circuit getting into the main circuit, then connection to the voltage source of 12-volt supply. The 10-micro farad ( $\mu$ f) capacitor connects between the output and ground pin of the voltage regulator 7807 IC to prevent fluctuation in voltage supply to load due to a varying load impedance.

The voltage regulator IC (7807), a three-terminal device, made up of input terminal, output terminal and the ground regulates the voltage supply to 7V needed by the microcontroller and some other circuit elements [6].

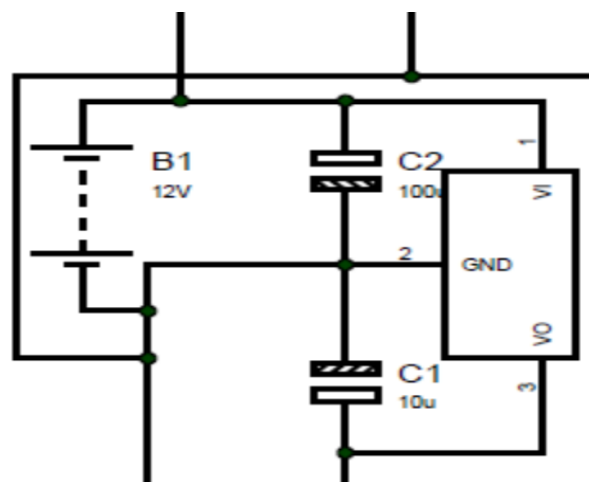


Figure 3 Power supply circuit design for the fire alarm

#### 3.2. Smoke detection

The smoke detector senses smoke, typically as an indication of fire. Since Smoke can be detected either optically (photoelectric) or by physical process (ionization), we selected a detector that uses both methods. The Smoke detectors are to be powered with power supply from a DC source, individual battery-powered units, and interlinked power from

the mains-power unit AC supply from the building, if any unit detects smoke, all will trigger, even, in the absence of electricity.

Its circuit diagram identifies the internal components put together to allow the gas/smoke sensor to effectively perform its task. The smoke sensor is powered using a 7V supply connected on the positive terminal 1, ground negative terminal 2 and display output terminal 3. Though in the original design, 12v smoke detector sensors were considered, the final implementation was a 5v smoke sensor that was used [6].

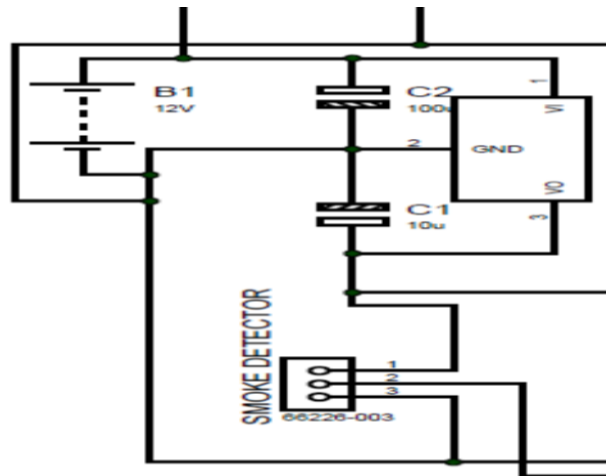


Figure 4 Smoke Detection Circuit for the alarm

### 3.3. Heat detection

The heat detector circuit is designed to respond when the thermal energy of a fire increases the temperature of a heat sensitive element by convection. The thermal mass and conductivity of the element regulate the rate flow of heat into the element. It has two main operations, checking the “rate of rise” and a “pre-set or fixed temperature”. It triggers when temperature increases beyond the pre-set or fixed value. The LM35 used is a rate-of-rise type sensor that ranges from -55°C to 150°C beyond which it is configured to trigger.

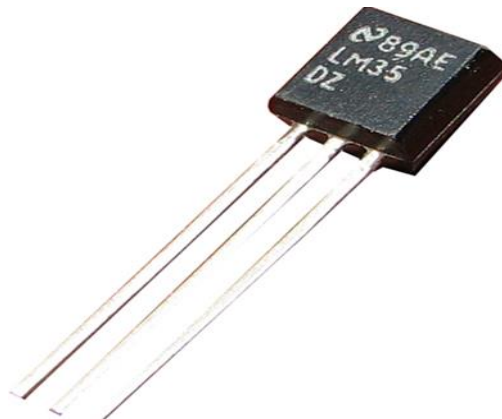


Figure 5 LM35 Precision Centigrade Temperature Sensors

The choice of LM35 is because of its advantage over other linear temperature sensors calibrated in kelvin since it is linearly proportional to the centigrade temperature scale where there is no need to subtract a large constant voltage from the output to obtain convenient centigrade scaling. Measurements are taken directly so no external calibration or trimming to provide typical accuracy of  $\pm 1/4^\circ\text{C}$  at room temperature and  $\pm 3/4^\circ\text{C}$ , over a full  $-55^\circ\text{C} - 150^\circ\text{C}$  temperature range. Thus, its low-output impedance, linear output, and precise inherent calibration made it easier to be interfaced with the microcontroller circuit, by connecting its output to analogue pin A0 of the microcontroller which has an in-built analogue to digital converter and a comparator to test and measure the change in the temperature value [4].

### 3.4. The atmega328-p IC

The Atmega328-p IC is the microcontroller used for the research work. It is a programmable integrated circuit (microcontroller) used to hold algorithm then monitor the environment to check for the presence of both smoke and heat. It also provides information to the LCD and uses this information to switch on an indication lamp, alarm sound as well as provide a switch to turn on or initiate an extinguishing system to douse the fire. A circuit was built around the IC using a 22-pf capacitor together with a 16 MHz crystal oscillator to provide its operating frequency of 16MHz for its effective operation.



Figure 6 ATMEGA328-PU

### 3.5. Mapping of the microcontroller pins

Mapping of a microcontroller, in a design is essential because of its many programmable features. A typical mapping architecture for the atmega328-pu is shown in Figure 6.

Pin 19 in the mapping was used to switch on the alarm circuit, Pin 4 was used to switch the lamp circuit while Pin 5 was used as switch to initiate an extinguishing system. Pin 13 was connected to the reset (RS) pin of the LCD, Pin 14 was connected to the enable (E) pin of the LCD, Pin 15 was connected to data, Pin 4 (D4) of the LCD, Pin 16 was connected to data Pin 5 (D5) of the LCD, Pin 17 was connected to data Pin 6 (D6) of the LCD, Pin 18 was connected to data Pin 7 (D7) of the LCD. Meanwhile, Pins 9 and 10 were connected to the crystal oscillator circuit and Pin 1 of the IC was connected to 10k resistor to create a pull up effect and to a push button connected to ground to provide a reset switch for the IC.

Pin 23 was connected to the LM35 IC to collect temperature data which is sent through an analogue to digital converter within the microcontroller, the converted digital data processed and used the data to determine an adverse change in temperature.

Pin 24 was the one used to collect data from the smoke detector which is also sent through an analogue to digital converter within the microcontroller, the converted digital data is processed and used to determine the presence of smoke within the environment. Pins 7, 20 and 21 were connected to VCC and finally, Pin 8 was connected to ground [4].



Figure 7 Atmega168/328 IC Architecture Layout

### 3.6. Fire alerting unit and alarm circuit

The fire alerting unit consists of the visual indicating unit and the sound alerting section. These enable the system to alert the personnel when there is fire either by making sound in form of alarm or switching on a light through the display board. The two circuits that make up the fire alerting units are the alarm circuit and the display circuit. The alarm circuit gives an audio signal to the operator in case of smoke detection or fire outbreak [7].

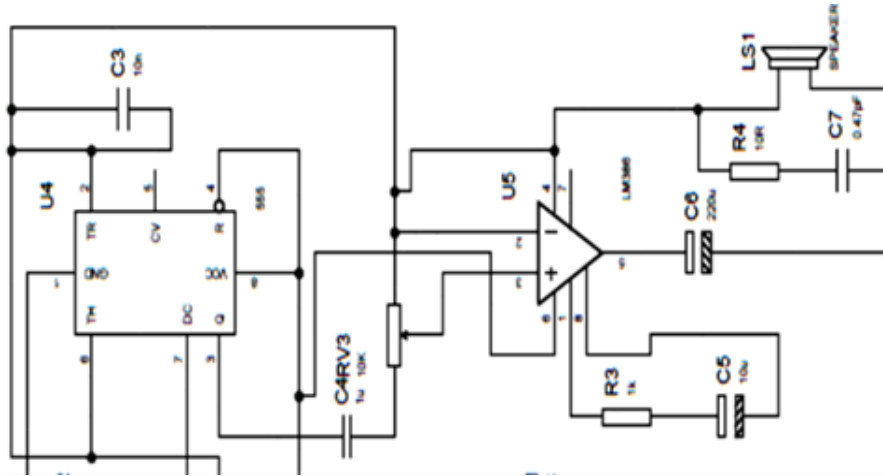


Figure 8 Alarm circuit

### 3.7. Implementing the audio circuit

The 555-timer circuit was used here to design the aural tone required to be fed into the speaker circuit when an aural or audio warning is initiated due to the presence of fire or smoke during testing of the system. The 555-timer circuit was designed as a multivibrator to continuously provide oscillation at its output port when it is triggered.

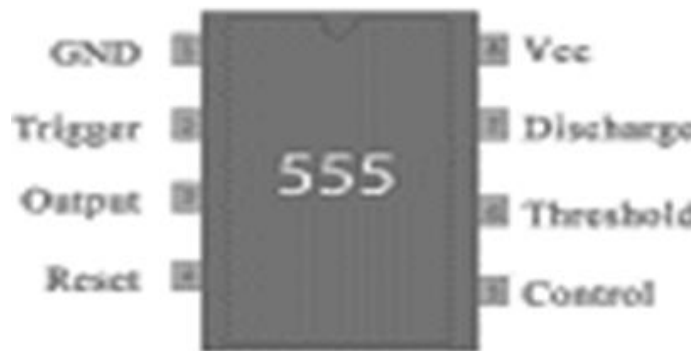


Figure 9 555 Timer IC and pin mapping Architectural Layout

The circuit built around the 555 timer IC to enable it to perform the specified purpose was as follows. Pin 1 and Pin 8 of the IC were connected to a 5-volt (V) power supply switch using a 2N2222 transistor to control the power source to the 555 timer IC. Pin 2 was connected through a 10-nano farad (nf) capacitor to the circuit ground, which is required to set the oscillating frequency, Pin 3 was connected through a 1micro farad (uf) capacitor to the output port, Pin 4 was connected to the voltage source (VCC) However, Pin 5 was not connected, it is supposed to be the switch to initiate the extinguishing system. Pin 6 was looped with Pin 2 to ground and Pin 7 was connected to 50 kilo-ohm pre-set or pot resistor which was required to set the oscillating frequency of the IC [6].

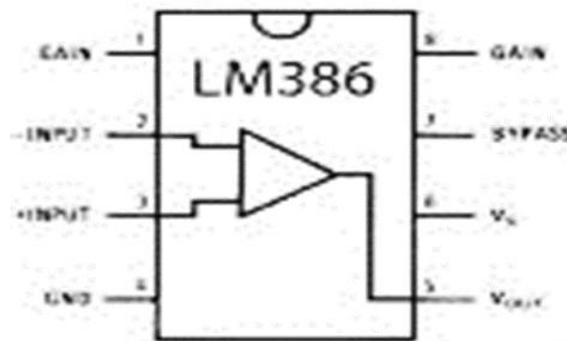
### 3.8. Lm386 IC audio power amplifier IC

LM386 IC is a mono low voltage audio power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between Pins 1 and 8 was used to increase the gain to any value from 20 to 200. The inputs are ground referenced while the

output automatically biases to one-half the supply voltage. The quiescent power drain is only 24 mW when operating from a 6-V supply, making the LM386M-1 and ideal for battery operation in this circuit.



**Figure 10** LM386 IC audio power amplifier



**Figure 11** LM386 IC audio power amplifier and pin mapping

To make the LM386 a more versatile amplifier, two pins 1 and 8 are provided for gain control. With Pins 1 and 8 open, the 1-k $\Omega$  resistor sets the gain at 20 (26 dB). A capacitor was shunted from Pins 1 to 8, bypassing the 1-k $\Omega$  resistor, where the gain went up to 200 (46 dB). If a resistor is placed in series with the capacitor, the gain can be set to any value from 20 to 200. Gain control can also be done by capacitive coupling of resistor (or FET) from Pin 1 to ground. Additional external components can be placed in parallel with the internal feedback resistors to tailor the gain and frequency response for individual applications. For example, we can compensate poor speaker bass response by frequency shaping the feedback path. This is done with a series RC from Pins 1 to 5 paralleling the internal 15-k $\Omega$  resistor. If Pins 1 and 8 are bypassed, then R as low as 2 k $\Omega$  can be used. This restriction is because the amplifier is only compensated for closed loop gains greater than 9. The design shows that phenomenon when one of the inputs was biased to ground with a 10 k $\Omega$  resistor.

Also, since the base current of the input transistors was about 50 nA, the inputs were at about 12.5 mV when left open. If the dc source resistance driving the LM386 was higher than 250 k $\Omega$  it would have contributed very little additional offset (about 2.5 mV at the input and 50 mV at the output). If the dc source resistance was less than 10 k $\Omega$ , then shorting the unused input to ground will keep the offset low (about 2.5 mV at the input, 50 mV at the output). Thus, for dc source resistances between these values we eliminated excess offset by putting a resistor from the unused input to ground, which was equal in value to the dc source resistance. Though all offset problems were eliminated if the input was capacitively coupled. Therefore, it should be noted that when using the LM386 with higher gains bypassing the 1k $\Omega$  resistor between Pins 1 and 8, it will be necessary to bypass the unused input, preventing degradation of gain and possible instabilities.

### 3.9. Alarm speaker design

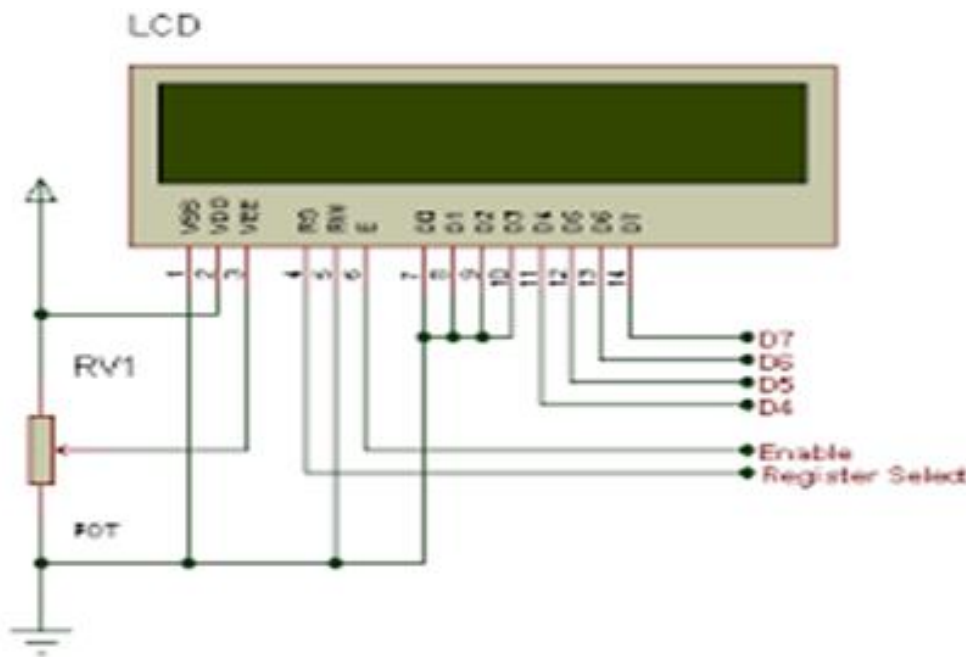
The design for alarm speaker used an 8  $\Omega$  speaker to produce an aural sound of 35KHZ. The speaker was interfaced with the output of the LM386 amplifier using a 10  $\Omega$  resistor and a 0.47pF capacitor connected in series to the input of the speaker. The speaker provided a very loud sound when smoke/gas was detected, the speaker was powered with a 12V DC supply from main source [7].



**Figure 12** an 8Ω alarm speaker

### 3.10. The display circuit

The liquid crystal display (LCD) used was a 16 by 2 LCD which indicated the number of rows to be 16 and the number of columns to be 2. The LCD is required to provide information to the operator circuit, such as, the condition and response of the electronic to various functions programmed into the microcontroller. A circuit was built around the LCD to make it operational as shown in Figure. 13.



**Figure 13** Display unit of the fire alarm detection

The pot resistor was used to preset the contrast of the LCD that is brightness of the screen. The register selects (RS) pin which was connected to the microcontroller Pin 13, provided a 5 volt (V) signal to activate the RS port, the enable pin was connected to Pin 14 of the microcontroller which also enables the LCD with a 5 volt (V) signal to its port. Pins 7 to 10 which corresponds to D0 to D3 of the LCD was not used while D4 to D7 was used to collect data from the microcontroller. The LCD requires a 5-volt (V) power supply feed through Pin 1 (VSS) connected to ground and Pin 2 (VDD) connected to source. In fact, the LCD also displayed fire safety tips, circuit fault, sensor condition and warning indication.

### 3.11. Encoding the microcontroller ICs used in the design

The source code used in programming the IC is Arduino programming language. The flow chart is shown in Figure. 14 and the generated source code for the IC to control its input and output registers is shown in Appendix A



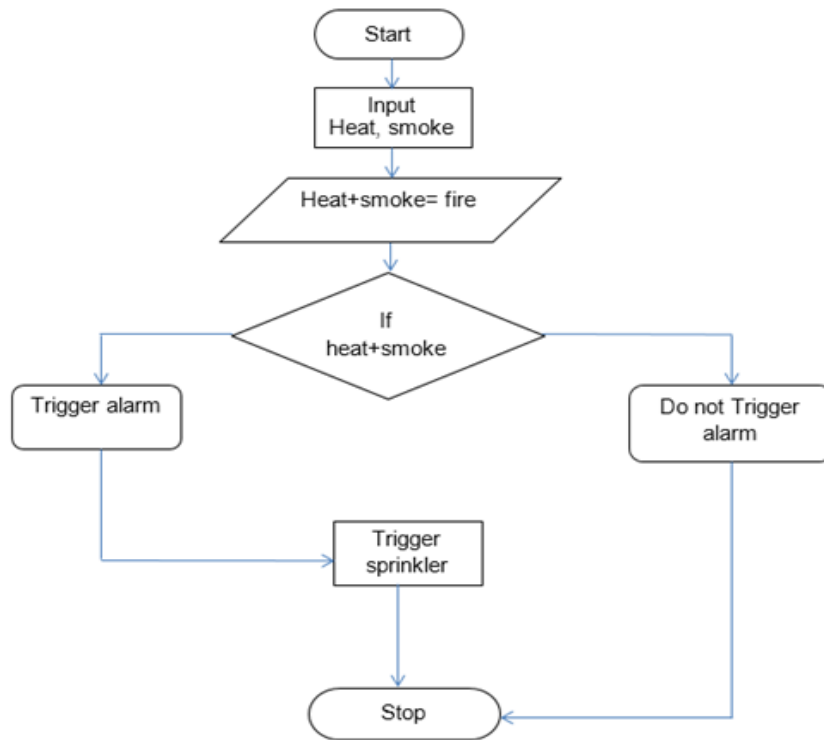


Figure 14 Flow Chart for encoding the microcontroller

#### 4. Circuit integration and implementation

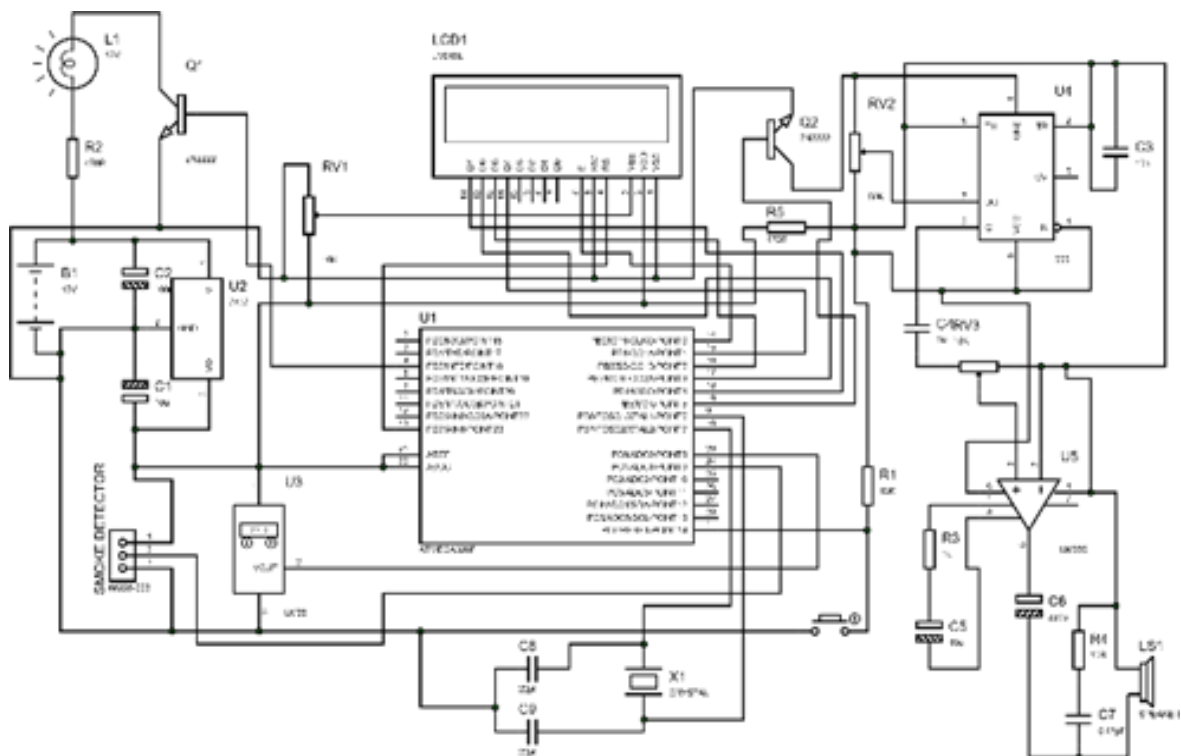


Figure15 Circuit diagram of Hangar fire detection alarm with algorithm for extinguisher

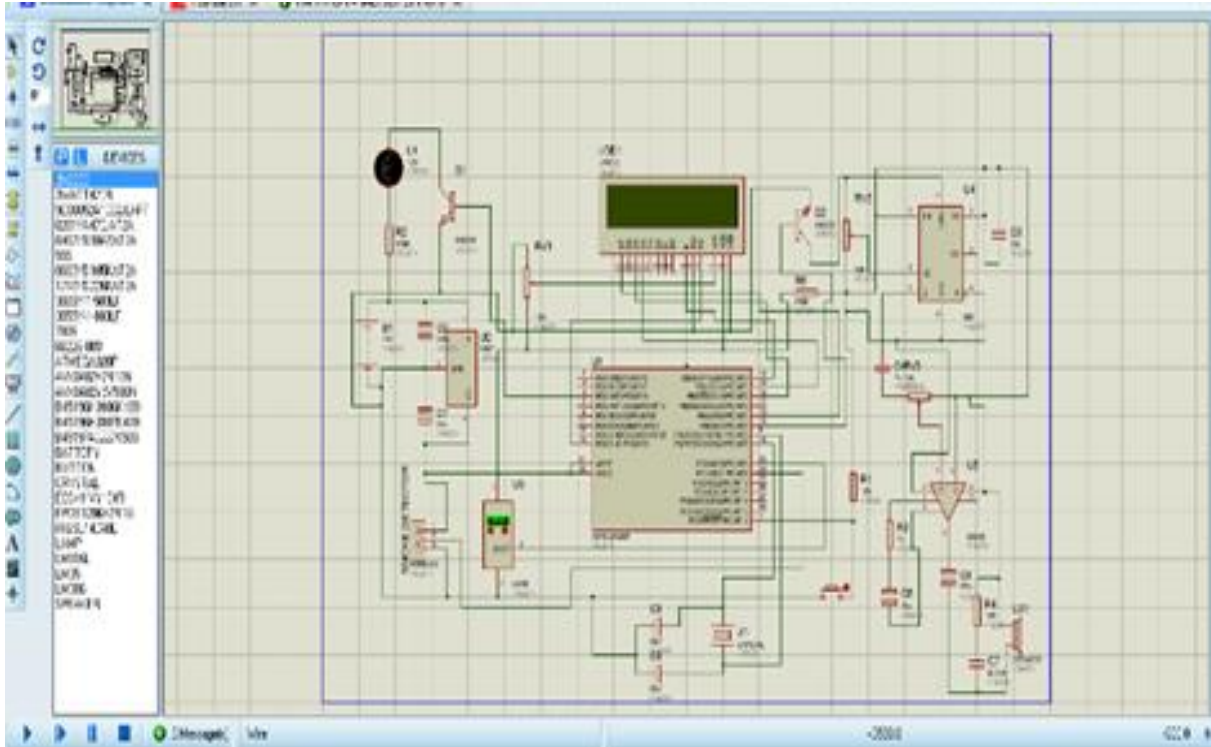


Figure 16 Proteus Simulation

#### 4.1. Results obtained

The microcontroller Atmega328-p IC is the heart of the fire alarm system built; therefore, more attention was given to the microcontroller because it integrated other part of the circuits together. The results obtained after integrating all parts of the circuit are as follows:

#### 4.2. Heat detection output

The heat detector sensed the temperature ranges from 0 – 10230C into voltage values ranges from 0 - 5V. The microcontroller calculates the float temperature as

$$\text{FLOAT TEMP} = \text{TEMPERATUREVALUE} \times (5.0/1023.0) \quad (1)$$

Equation 1 Detection output temperature value

If the voltage value is greater than or equal to 4 then the temperature is high.

#### 4.3. Smoke detection output

The smoke detector sensor reading ranges from 0 – 1023 and it is converted into voltage values ranges from 0 - 5V. The microcontroller calculates the float smoke as;

$$\text{FLOAT SMOKE} = \text{SMOKEVALUE} \times (5.0/1023.0) \quad (2)$$

Equation 2: Smoke detection output value

If the voltage value is greater than or equal to 4 then there is a presence of a smoke.

#### 4.4. Liquid crystal display (LCD) output

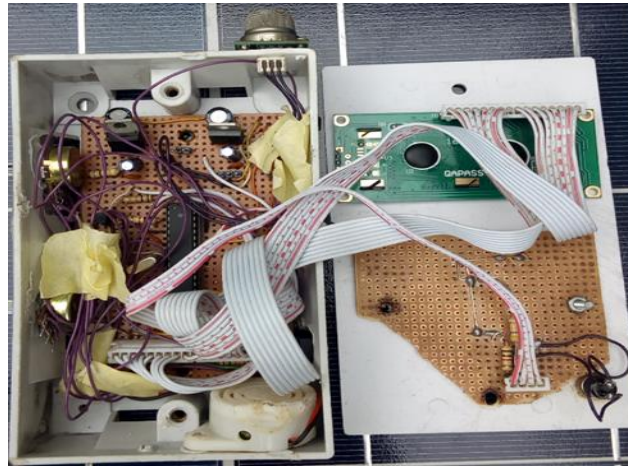
When the system is been activated by putting on the fire alarm system power, the LCD displayed output are shown sequentially as follow.

- 'SYSTEM ACTIVATED' as a start-up notification

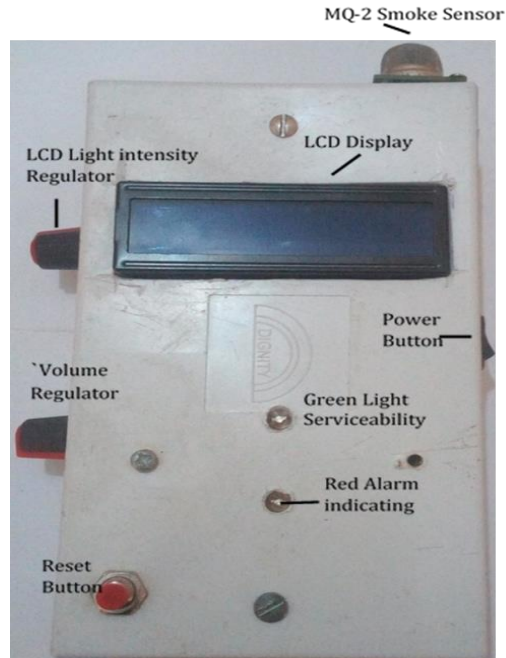
- 'FIRE ALERT SYS'
- 'BY NAMES OF DESIGNER'
- 'ADDRESS OF COMPANY OR DESIGNERS'
- 'TEMPERATURE VALUE'

#### 4.5. Fire alarm section output

When the voltage level is high or the smoke level is greater than or equal to 4, the alarm system turned on and sound produced by the 555 timers was heard loud enough.



**Figure 17** Internal Components of the built-up circuit



**Figure 18** Coupled and finished product

## 5. Conclusion

Since the atmega328-pu microcontroller is a programmable, integrated circuit used to hold algorithm then monitor the environment to check for the presence of both smoke and heat at the same time, it provides information to the LCD. It uses this information to switch on an indication lamp, alarm sound and provide a switch to turn on or initiate an extinguishing system to take out the fire.

### *Recommendation*

The knowledge of artificial intelligence or embedded systems would find a place in this work where the exact direction and location of the triggered alarm or sensor would also indicate the position where the sprinklers will be directed. The automatic extinguishing sprinkler system would be made up of water pressure pumps and sprinklers and the hangar designs would support wet water system of pipe laying. The research work applications are essential in situations where the fire outbreak occurs at a time people or fire brigade may not be around to douse it off. For instance, in the dead hours of the night.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

There is no conflict of interest.

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