International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 9 Issue 10 October - 2025, Pages: 336-349

A Fire-Alarm Detector and Suppression System's Design for Prevention and Control of Fire Outbreaks

***[1]Abdullahi Dahiru, [2] Abdulrazaq Muhammad Ahmad, [2]Huzaifa Ahmad Ibrahim, [1]Haruna Isyaku, and [1]Idris Sani Salisu**

[1]Department of Science Laboratory Technology (SLT), Kano State Polytechnic, Kano State, Nigeria
[2]Department Electrical Engineering, Bayero University Kano (BUK), Kano State, Nigeria
**Correspondingauthor'se-mail:shubigaida2022@gmail.com,+2349091853667*

Abstract: *Fire Outbreak is a major concern at homes, offices, schools, hospitals, industries etc. It is dangerous and requires high security and control to avoid destruction of lives and property. Fire alarm is an electronic device that is stored in a building to detect the presence of fire accident. An automatic fire-alarm system is design to detect the unwanted presence of fire by monitoring environmental changes associated with combustion. A lack of safety measure may result in material and financial losses, as well as loss of life. A preventive measure to avoid the risks involved in a fire outbreak is the installation of an automatic fire alarm detector in a building to automatically detect fire, alert the personnel with an audible sound to exit the building and sprinkle water to reduce the intensity of the fire hence the fire alarm and suppression system was designed and constructed. The system comprised of sub units which are power supply, photoelectric smoke sensor, audio alarm system, delay timer and suppression unit designed and coupled together to make up the complete fire alarm system. The sub units were designed using active and passive electronic components such as resistor, capacitor, LDR, LED, op-amp, water pump, 555 timer, transistor, buzzer etc. Components were interconnected to make up the final and completed fire alarm and suppression system. Testing was carried out on the whole system and it worked satisfactorily. It was observed that only dark smoke and high intensity smoke triggers the smoke sensor which is the limitation of the system as not all burning particles emit dark smoke. For further work on this system to enhance the versatility and adequate operation of the system it is recommended to use other types of smoke sensors as they more reliable and sensitive to any kind of smoke.*

Keywords: *Fire-alarm detector, Building automation system***,** *Suppression system, Fire outbreak.*

1.0 INTRODUCTION

Fire Outbreak is a major concern at homes, offices, schools, hospitals, industries etc. It is dangerous and requires high security and control to avoid destruction of lives and property. Fire is a rapid self-sustaining oxidation process accompanied by the evolution of heat and smoke in varying intensities. Fire is believed to be based on three elements being present: fuel, ignition source, oxygen. Some of the factors that contribute to spread fire easily are delay in discovery of the fire, inadequate personal fire protection, delay in raising the fire alarm, inadequate water distribution system etc. (Emmanuel, 2016). Several attempts have been made over the years to mitigate the effect of fire outbreak such as establishment of firefighting agencies, public education on fire safety, installation of fire hydrants, formation of community fire volunteers, provision of fire extinguishers, etc yet such measures were ineffective because of poor funding from the relevant authorities, use of obsolete equipment and in some cases lack of technical know-how to operate the equipment (Abubakar, 2013).

Avillo (2014) highlights that fire alarm systems play a crucial role in building fire safety strategies, with the main function of detecting fires at an early stage and providing warnings. Christopher J. Naum explains that a fire alarm system is an important component of building safety designed to detect fires and provide early warning to occupants and firefighters. Naum emphasized the importance of integrating fire alarm systems with other building safety systems to ensure effective and efficient responses to fire incidents (Naum, 2016). The Fire Alarm System has two main systems, namely the detection system and the alarm system. The detection system uses detectors in the form of heat detectors and smoke detectors. Heat detectors are used to detect a significant increase in temperature which may indicate a fire will occur and smoke detectors are used to detect particles in the form of gas around the room, where the detector will give a signal to the control center when it detects an indication of a fire then the alarm system will give a warning to take immediate evacuate action (Ali, 2016).

Fire alarm system is defined as a system designed to detect the first signs of fire through the use of various sensors and communication technologies. This system aims to provide early warning so that building occupants can vacuate safely (Hidayat, 2021). Based on the explanation in the journal, a fire alarm system is a device used to detect fires and provide warnings to immediately evacuate if a fire occurs.

In research related to making a Fire Alarm System, it is known that the device that has been made can detect fires in several rooms by using fire sensors, smoke sensors, and temperature sensors whose values will be monitored on a 16x2 LCD where the buzzer used as an alarm will active if the sensor detects a fire in the room. The Fire Alarm System in other research also detects potential fires by using PLC-controlled smoke detectors and heat detectors, and the water pump will be activated if a fire occurs (Darmawan *et al.*, 2022). In other research, it was also explained that the device that has been created will provide notifications to Telegram if the sensor used detects a fire (Osamah Ibrahim Khalaf, 2019).

Fire is one of the deadliest risks that any individual can face. In the unfortunate event of fire in a building, you risk losing your life and most of your property, if not all. A lack of safety measure may result in material and financial losses, as well as loss of life. A preventive measure to avoid the risks involved in a fire outbreak is the installation of an automatic fire alarm detector in a building to automatically detect fire, alert the personnel with an audible sound to exit the building and quench the fire using the appropriate quenching fluid; hence the fire alarm and suppression system is being proposed. The system is capable of automatically detecting a smoke in a given environment, sound a beeping alarm and also sprays water quickly to reduce the intensity of the fire.

In the view of the above, a safety measure can be designed to curtail the risk involved in a fire accident; hence this project proposes a design of a reliable and effective fire alarm and suppression system. Having a fire alarm and suppression system is an excellent idea to keep you and your property safe. The system gives an early warning of the threat and allows enough time to evacuate the premises and also spray water to reduce the intensity of the fire.

2.0 Materials and Methods

The design of an electronic circuit depends mainly on the rating of components, the required voltage of components and the output the circuit should generate. In this chapter, materials chosen were based on calculation and/or datasheet and simple methods were employed according to the standard methods of the following researches; Daniel, (2005); Jorn, (2008) and Paulison, (2005), to realize practical values of components used in the construction of the fire alarm system. This section is divided into five units; Power supply unit, Smoke detecting circuit, Alarming circuit, Timing circuit and Fire suppression unit

2.1 Power Supply Unit

The fire alarm system requires a DC voltage source for its operation. Therefore, for the purpose of this design, an alternating (AC) voltage source of 220V will be used, where the AC voltage must be converted to DC voltage by rectification. Thus the process of converting the AC voltage to the DC voltage was accomplished with the help of a rectifier, filter and voltage regulator. For the system to be functional at all time, an uninterruptible power supply (UPS) with battery charger was designed where a battery will be used as a backup in the absence of power from the mains. The steps in designing a UPS is illustrated in figure 2.1 below.

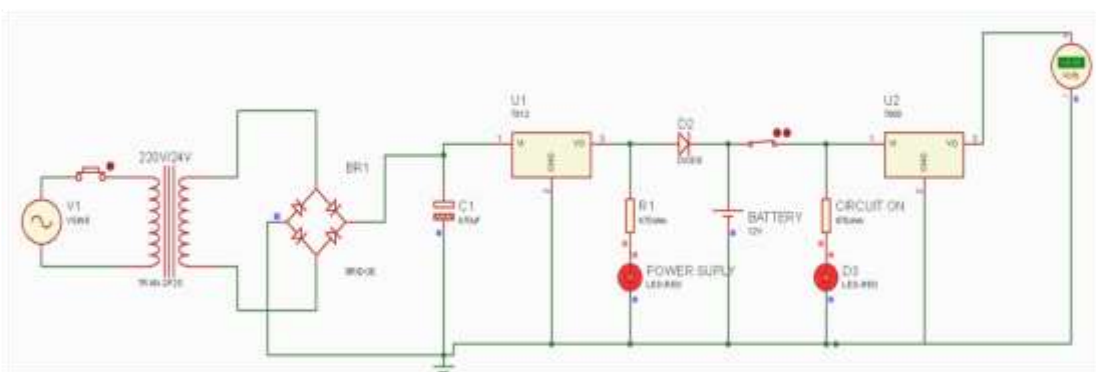


Figure 2.1: Uninterruptible power supply circuit diagram

2.1.1 Transformer

The transformer used is a step-down transformer which receives ac voltage of 220V at 50Hz frequency from the ac input and steps it down to another ac voltage suitable for the bridge rectifier. The voltage across the secondary side of the transformer was calculated to accommodate the rectifier minimum voltage and voltage regulator. From datasheet:

- ✓ The voltage drop across a bridge rectifier is 1.4V.
- ✓ The maximum voltage and current of IC7812 are: 12.6V, 5mA-

1.0A

Therefore, the total sum of voltage of rectifier and IC7812 is

$$1.4 + 12.6 = 14V$$

The voltage across the secondary side of the transformer is 14V. The step-down transformer as calculated is a 220/14V step-down transformer. Availability in market is a 220/24V step-down transformer and it will serve the same purpose.

2.1.2 Rectifier

The rectifier designed is a bridge rectifier consisting of four 1N4001 diodes all connected in forward biased. 1N4001 diode was chosen because it is cheaper and it has a low reverse voltage.

2.1.3 Filter capacitor

The smoothing capacitor is used to filter out the AC ripple contents into DC and its value is calculated using the formula below $C = \frac{1}{\sqrt[4]{3} * F * RF * R_l}(F)$, where RF is the ripple factor, F is frequency=50Hz and R_l is the resistive load. From datasheet, the ripple factor of a bridge rectifier is 0.48

$$R_l = \frac{V}{I} = \frac{12V}{1A} = 12\Omega$$

$$C = \frac{1}{\sqrt[4]{3} * 50 * 0.48 * 12} = 5.012\varepsilon^{-4}F$$

$$C = 501.2\varepsilon^{-6}F = 501.2\mu F$$

The calculated value of the capacitor is $501.2\mu F$ but the secondary side of our transformer is 24v thus we need an electrolytic capacitor with 25v working voltage and a standard value of capacitor with 25v working voltage starts at $1000\mu f$, $3300\mu f$, $5000\mu f$, $10000\mu f$. . etc. $3300\mu f$ was bought because of availability in the market.

2.1.4 IC Regulator

The system requires +9V as calculated and as such an IC7809 voltage regulator was chosen to give a regulated +9V constant DC supply. The back-up battery used was 12V and as such IC7812 was used to charge the battery at constant 12v to prevent the battery from overcharging. Also the water pump requires 12v dc hence the need for 7812.

2.1.5 Battery

The back-up battery was designed to operate at 12v because batteries discharge over time since the system requires 9v the battery will not go below 9v before it gets recharged again. Three 3.7v lithium ion batteries were bought and connected in series to give a total voltage of 11.1v.

2.1.6 Diode

A 1N4001 diode was connected in forward biased at the output of the IC7812 to prevent the battery voltage going back to the supply. Two red LEDs were used to indicate when the power supply is active and when the circuit is switched on.

2.2 Smoke Detecting Circuit

The smoke detecting circuit designed was a photoelectric smoke detector comprised of photoelectric transmitter (LED) and a photoelectric receiver (LDR). An LDR is a resistor whose resistance depends on light intensity hence the name light dependent resistor. RV1 is a variable resistor used to adjust the sensitivity of the circuit, R1 is a resistor and RV2 is the variable resistor used to set the reference voltage at the inverting terminal. A positive voltage comparator is used to compare the voltage from the input (LDR) at the non-inverting terminal and the reference voltage at the inverting terminal and sets it output to saturate towards the positive supply $+V_{cc}$ when voltage at the non-inverting terminal is greater than the inverting terminal. From the figure 3.2 below, the light from the LED falls directly on the LDR making the resistance of the LDR low. This ensures the set reference voltage is greater than the voltage from input thus making the output of the comparator to saturate towards the negative supply $-V_{cc}$. When there is smoke, the light emitting from the LED to the LDR is obstructed, this increases the resistance of the LDR which increases the voltage at the non-inverting terminal and it exceeds the voltage at the inverting terminal causing the output of the comparator to saturate towards the positive supply $+V_{cc}$ this action turns the transistor switch to trigger the monostable configured 555 timer to activate the audio alarm for the calculated duration of time and subsequently activating the water pump to suppress the fire for the calculated duration of time.

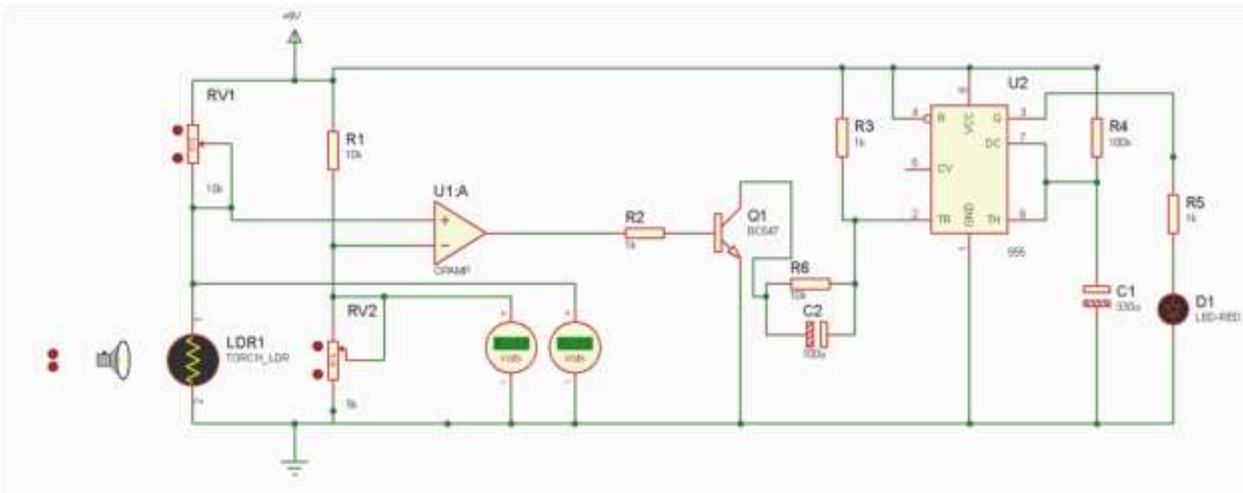


Figure 3.2: Smoke Detecting Circuit

2.2.1 Op-amp

An LM358 dual op-amp was chosen because of the following reasons:

i. Two operational amplifiers are compensated internally hence probability of multi-sensor (smoke & heat detector) is applicable and it will be added in conclusions and recommendations chapter.

ii. It is more linear and compatible with all forms of logic.

iii. It is more flexible for real life applications like shock alarm circuits and dark sensor circuits.

2.2.2 Transistor

BC547 transistor was used for quick switching of the trigger circuit.

2.2.3 Trigger circuit

The trigger circuit has a capacitor and resistor to reduce the voltage at the pin 2 (trigger) for triggering the monostable 555 timer. The capacitor gets charged to reduce the voltage and discharges through the resistor.

2.2.4 Calculations for smoke detecting circuit

Voltage at the inverting terminal (V_-), it is the reference voltage (V_{ref}) set up by the two resistors that form the voltage divider.

$$V_{ref} = V_{cc} * \frac{RV_2}{R_1 * RV_2};\ \ V_{cc}$$

$$= 9V;\ R_1 is\ chosen\ as\ 10k\Omega \text{ and } V_{ref}\ is\ chosen\ as\ 2.6V\ , RV_2\ is\ calculated\ below$$

$2.6V = 9 * \frac{RV_2}{10k+RV_2}$ $by\ cross\ multiplication, simplification\ and$ making RV_2 subject of the formula, $RV_2 = 4062.5\Omega\ calculatedand\ 5k\Omega\ variableresistorwasobtained$. Voltage at the non inverting terminal (V_+), it is the input voltage from the smoke sensor. When there is no smoke (light from LED is casting on LDR) it's resistance is 0.

$$V_+ = V_{cc} * \frac{R_{ldr}}{RV_1 + R_{ldr}};\ R_{ldr} = 0\Omega\ ; V_+ = 0V$$

When there is smoke (light from LED is obstructed on LDR) it's resistance from datasheet is between [5k 10kohms], RV_1=10kohms

$$V_{smoke} = 9 * \frac{5k}{10k + 5k} = 3V$$

2.3 Alarming Circuit

The alarming circuit was designed to produce a beeping sound when smoke is detected. This process was achieved using 555timer IC configured as both monostable and astable multivibrator to sound a beeping sound for 15 seconds as calculated. An astable multivibrator has an output which is not stable, it keeps fluctuating between stable and unstable state when energized and therefore when a buzzer is connected at the output of the astable multivibrator, it generates a beeping sound thus forming the alarming circuit. The monostable was designed to generate the alarm for 15 seconds while conseqeuently providing delay of 15 seconds to activate the relay to switch on the suppression unit.

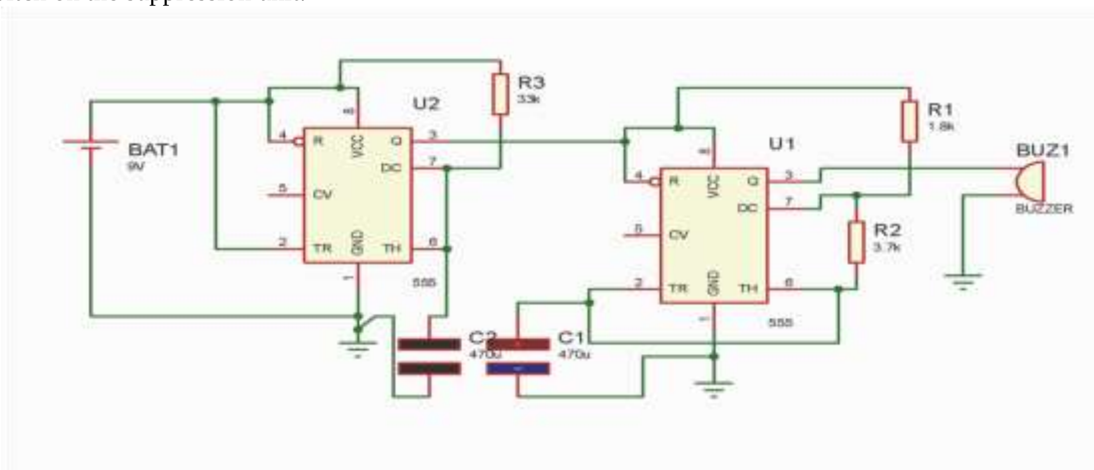


Figure 3.3: Alarming Circuit Principle operation of a Stable Multi-vibrator

An astable multivibrator is designed using the 555 timer IC as shown in the figure above. During operation, Supply voltage is applied to the trigger input in pin 2 of the 555 timer. The capacitor C charges through R_1 and $R_2$with a time constant of $0.693(R_1+R_2)C$ when the voltage across the capacitor reaches $2/3V_{cc}$ then the capacitor discharges through resistor R_2 with time constant $0.693R_2C$ until it reaches $1/3V_{cc}$ and the process starts all over again. During charging, the output pin is always high while during discharging, the output is always low. A 9V piezoelectric buzzer was chosen because of availability in market and the system operates at 9V.

2.3.1 Calculations of resistors R1, R2 and capacitor C

The values of resistors R1, R2 and C are calculated using the formula for charging time and discharging time of the capacitor below;

$$T_{charge} = 0.693(R_1 + R_2) * C \quad - eqn\ 1$$

$$T_{discharge} = 0.693 * R_2 * C \quad - eqn\ 2$$

The duty cycle of this stable multi-vibrator is 60% and the desired period T= 3 seconds.

$$D = 60\% = \frac{60}{100} = 0.6$$

$$D = \frac{T_{charge}}{T}\ , T_{charge} = DT, = 0.6 * 3 = 1.8\ seconds$$

$$T = Tcharge + Tdischarge, Tdischarge = T - Tcharge = 3 - 1.8 = 1.2\ seconds$$

$$T_{charge} = 1.8\ seconds$$

$Tdischarge = 1.2\ seconds$, Adding eqn 1 & 2

$$T = Tcharge + Tdischarge = 0.693(R1 + 2R2) * C$$

$$choosin\ gc\ to\ be\ 470\mu f and\ substituting\ in\ eqn\ 2,_2\ can\ be\ calculated$$

$$R_2 = \frac{T_{discharge}}{0.693 * 470 * 10^{-6}} = \frac{1.2}{0.693 * 470 * 10^{-6}} = 3.7k\Omega$$

Substituting R_2 and C in eqn 1, R_1 can be calculated;

$$R_1 + 3700 = \frac{T_{charge}}{0.693 * 470 * 10^{-6}} = \frac{1.8}{0.693 * 470 * 10^{-6}} = 5526.4$$

$$R_1 = 5526.4 - 3700 = 1826.4\Omega$$

R2 was calculated as 3.7kohms, 4kohms was chosen because of availability in market.
R1 was calculated as 1.8kohms, 2kohms was chosen because of availability in market.

2.3.2 Calculations for R and C time constant

The RC time constant set up the duration for the alarm as well as the delay between subsequent operation of alarm and suppression unit. The formula for the time constant is shown below;

$$T = 1.1RCeqn\ 1$$

The desired duration of time is 15 seconds, we can choose a standard value of one component and calculate for the other. Choosing a standard value of capacitor of $470\mu f$, the resistor value can be calculated from eqn 1.

$$T = 1.1RC$$

$$R = \frac{T}{1.1C} = \frac{15}{1.1 * 470 * 10^{-6}} = 29k\Omega$$

$$R = 33\Omega\ was\ chosen\ because\ of availability\ in\ the\ market$$

2.4 Timing circuit

The timing circuit was designed to produce a delay between subsequent operation of the alarm and the suppression. The timing circuit was designed using 555 timer IC configured to operate in the monostable (one-shot) mode and a single pole single throw (SPST) electromechanical relay.

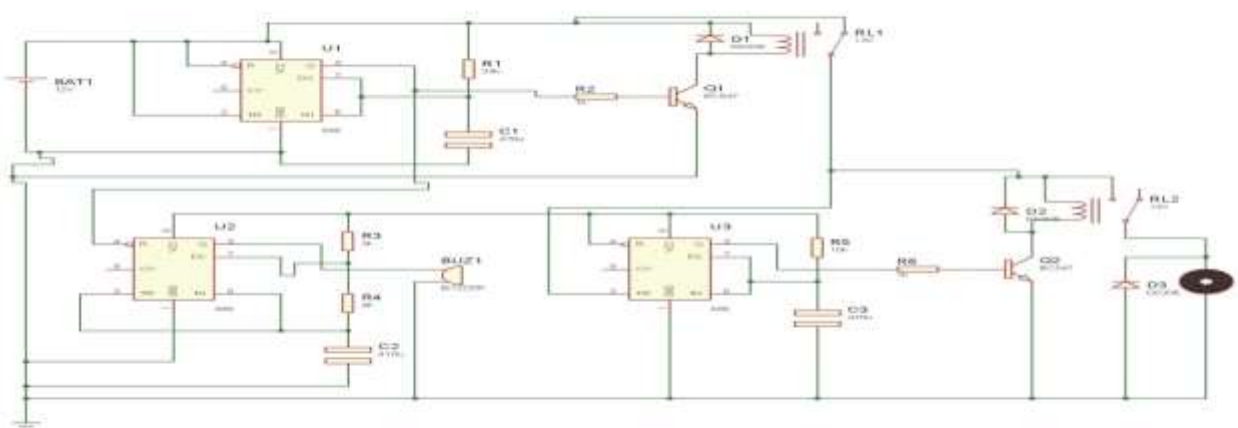


Figure 2.4: Timing Circuit

From the figure above, when the smoke is detected the output of the monostable 555 timer connected to the astable 555 timer will generate the alarm and also control a transistor to energise and switch a relay to disable the water pump when the alarm is active. After the alarm has finished beeping for the calculated duration of time then automatically the relay will return to its original position to enable the water pump to suppress the detected fire.

3.4.1 Calculations for R1 and C

The intended delay is 15 seconds for the subsequent operation and the known time constant equation is; $= 1.1 * R1 * C$, $15 = 1.1 * R1 * C$. Choosing a standard value of capacitor,= $470□^{-6}$ = 470□□. The value of R1 can be calculated using the time constant equation;

$$= 1.1 * R1 * C$$
$$15 = 1.1 * R1 * 470\varepsilon^{-6}$$

$$making\ R1\ subject\ of\ the\ formula$$

$$R1 = \frac{15}{1.1 * 470\varepsilon^{-6}} = 29013.53\Omega = 29k\Omega$$

$$R1 = 29k\Omega\ as\ calculated$$

3.5 Fire suppression unit

The main component of the fire suppression unit is the water pump. Other components include the reservoir tank, pipe and a sprinkler. The inlet of the water pump is fixated at the bottom of the reservoir tank while the outlet is connected to a pipe of low diameter to provide high pressure; a sprinkler is connected to the pipe to suppress the detected fire. The fire suppression unit is designed using monostable 555 timer to sprinkle water for a calculated duration of time.

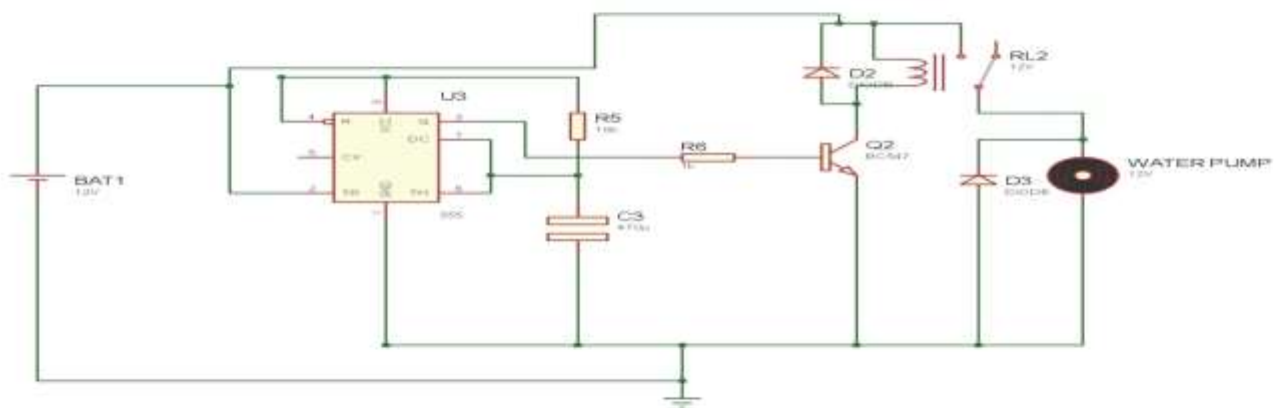


Figure 2.5: Fire suppression unit

From the figure above, after smoke has been detected and an alarm has been generated for the 15 seconds as calculated the timing circuit relay will return to its original position consequently activating the monostable 555 timer which will trigger a transistor to energize and switch a relay to activate the water pump to suppress the fire for the calculated time. Principle of operation of monostable multivibrator. The Monostable multivibrator triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully. Once triggered, the 555 Monostable will remain in this "HIGH" unstable output state until the time period set up by the Rand C network has elapsed. The amount of time that the output voltage remains "HIGH" or at a logic "1" level, is given by the following time constant equation: $t = 1.1 * R*C$

2.5.1 Calculations for R and C time constant

The calculated duration for the water pump is 5 seconds, choosing a standard value of capacitor 470□□ the value of resistor can be calculated from the time constant below.

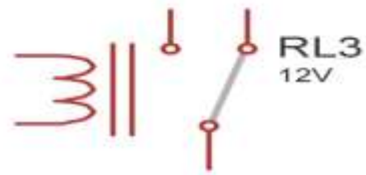
$$t = 1.1 * R * C$$
$$5 = 1.1 *R * 470 * 10^{-6}$$

$$R = \frac{5}{1.1 * 470 * 10^{-6}} = 9671.2\Omega$$

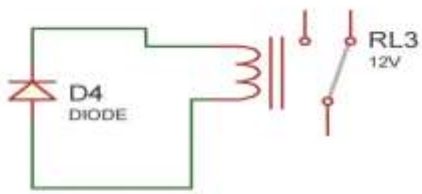
$$R = 10k\Omega$$

2.5.2 Transistor and Relay

Bc547 transistor is used to energize and switch the relay, the relay used is a single pole single throw (SPST) normally opened (NO) electromechanical relay. When it is energized, it generates an electromagnetic field that pulls the switch to the normally closed (NC) position which then completes the circuit and activates the water pump.



A relay has the disadvantage of producing a back EMF when de-energized and this back EMF can produce high voltage spikes which can damage the circuit. To overcome this, a freewheeling diode is used to suppress the back EMF. A diode only allow current to flow in one direction (from anode to cathode), the diode is connected in reversed bias to provide a path for the relay coil to dissipate its energy safely.



3.5.3 Water Pump

A DC water pump uses DC power such as battery, solar to energize the electric motor of the water pump for pumping huge amount of water. The internal coils of the electric motor will burn if there is no water available in the reservoir tank hence a water-level sensor will be incorporated to deactivate the water pump whenever the reservoir tank is empty.

Figure 2.5 Water Pump

A freewheeling diode is connected in reversed biased to suppress the back EMF produced by the internal coils of the electric motor of the water pump. The water pump is a DC device operating at 12v dc.

3.5.4 Water-level sensor

A water-level sensor was designed to check the level of water in the reservoir tank when low it will deactivate the water pump to avoid the internal coils of its electric motor from burning. The water-level sensor was designed using a TTL NOT gate (Inverter).

An inverter or NOT gate is a logic gate whose output is the opposite of the input. That is, a “LOW” input (0) gives a “HIGH” output (1), and vice versa.

A TTL logic gate has voltage levels associated with each level state. From 0-0.8 is LOW and from 2.4-5 is HIGH. Using these voltage levels aided in designing the water-level sensor.

A voltage divider was used to set the input voltage of the NOT gate. From the figure below, when there is no water in the reservoir tank the circuit is incomplete, thus $V_{cc}=V_{in}=5v$ and $V_{out}=0v$.

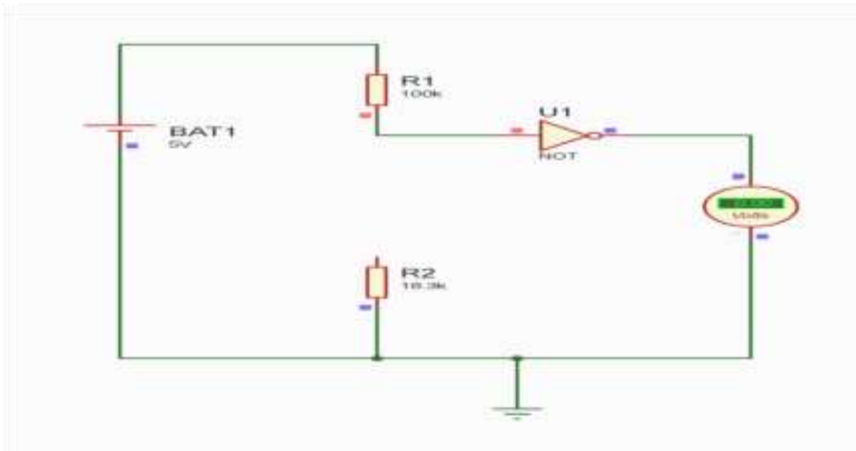


Figure 3.6: Water-level Sensor Circuit

When there is water in the reservoir tank, the circuit then becomes complete and thus the voltage divider rule applies to get the V_{in}.

$$V_{in} = V_{cc} * \frac{R_{water}}{R_1 + R_{water}}$$

$V_{cc}=5v$; resistance of water depending on temperature and salt contents inside it is 50kohms; choosing $V_{in}= 0.7v$, R_1 can be calculated using the above formula.

$$0.7 = 5 * \frac{50k}{R_1 + 50k}; by\ cross\ multiplication\ and$$

$$0.7R_1 + 35k = 250k$$
$$0.7R_1 = 215k;\ R_1 = {}^{215k}/_{0.7} = 307k \cong 300k$$

The output of the NOT gate is connected to the RESET pin (pin 4) of the monostable configured 555 timer of the suppression unit.

- When there is no water (output of NOT gate is low); 555 timer will not be activated
- When there is water (output of NOT gate is high); this output will set the monostable 555 timer which in turn will switch the relay of the water pump to suppress the fire detected.

International Journal of Academic and Applied Research (IJAAR)
ISSN: 2643-9603
Vol. 9 Issue 10 October - 2025, Pages: 336-349

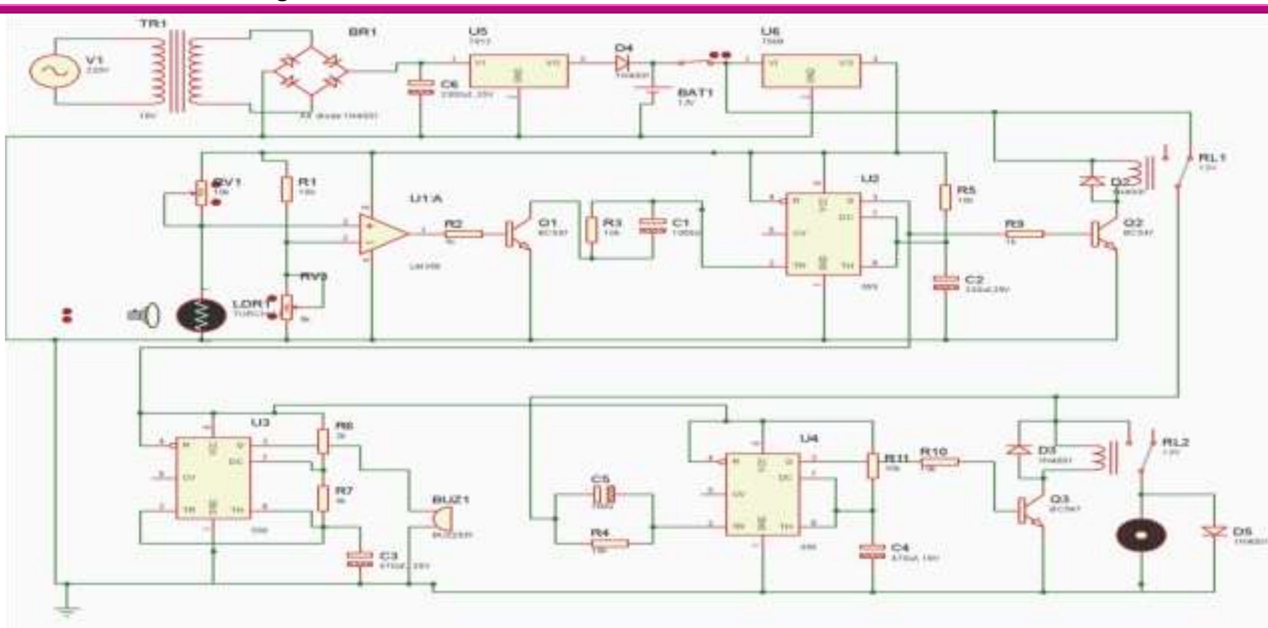


Figure 3.7: Fire Alarm Complete Circuit Diagram

3.0 RESULTS AND DISCUSSION

The components were interconnected to make up the final and completed prototype fire alarm and suppression system. This chapter however is basically on the construction and testing of each unit of the system to confirm its functionality.

3.1 Construction

The main constructional elements of the circuit are LED, LDR, LM-358 op-amp, 555 timer, relay and other discrete components such as diode, capacitor, resistor etc.

3.1.1 Arrangement of circuit components:

There were four stages involved in assembling the circuit components. These are

- ✓ Testing of the components
- ✓ Arrangement of the components in position
- ✓ Soldering
- ✓ Final testing to confirm functionality. Components were firmly fixed on the veroboard and their continuity and polarity was noted.

3.1.2 Laying of components on Vero-board

The laying out of components was first done for each unit on the breadboard as a temporary circuit layout so as to ascertain that the circuit diagram for the construction of each unit of the fire alarm and suppression system can work effectively. Corrections to be made during the construction were made on the breadboard before it was transferred to the veroboard with fine soldering as a permanent construction. Care was taken not to allow the soldering iron to be too hot as it can damage some components such as IC regulator, Transistor, LED etc. All distance connection was made using jumper (connection) wires. This includes buzzer, LEDs, water pump etc. In the smoke detector sensor, connecting wires were used to supply the LED and LDR (adopted method of Suryani and Wijaya, 2019)

3.1.3 Soldering

Soldering is a process of joining two or more metals together by application of heat and solders to the joint. A correctly made joint provides a low resistance which gives good electrical continuity and has a fair degree of mechanical strength in a soundly made joint, the parts to be joined were linked by a thin film of solder.

3.1.4 Casing and Testing

Adaptable plastic casing of 150 x 150 x 70mm was used in this project with little construction on it to suit my application. After completion of the construction, testing was carried out to observe the performance of the circuit. Testing was first done on each unit of the system (unit testing) before finally testing the complete system (system testing).

3.2.1 Power Supply Unit Testing

Here the regulated power supply of the system was tested to ensure that the desired 9v DC was produced and how regulated the output was. Below is the test and the result obtained. Different loads were connected to the power supply for testing purposes these includes LED, 9V Relay, 9V transistor radio battery etc.

Table 3.1: Shows Power Supply Testing

S/N	Condition	Output (V)
1.	No load connected	9.03V
2.	Load connected	9.0V
3.	Load connected	8.94V
4.	Load connected	9.01V

3.2.2 Smoke Detecting Circuit testing

Testing was carried out on this unit to observe the output of the circuit at different light intensity including darkness. The output is a physical property (i.e. Buzzer).

Table 3.2: Shows Smoke Testing

S/N	Reference Value	Condition	Result
1.	2.6V	When there is no smoke	Buzzer off
2.	2.6V	Case is covered with smoke	Buzzer comes on

From the table above, the result is okay because, when smoke is detected the buzzer gives an alarm while the alarm is silent when there is no smoke as designed and expected. Therefore, following the design procedures, the circuit was constructed and its performance was achieved. From the results obtained in this study (table 3.1), it was revealed that the power supply operated satisfactorily as the voltage regulation is considerably okay. Also, from table 3.2, it was seen that when there is no smoke around the sensor, the output of the op-amp is low and the buzzer remains off. When there is smoke in the sensor, the LDR resistance increases and the voltage at the non-inverting terminal is greater than the reference voltage which makes the output of the op-amp high thus activating the alarming circuit and an audible sound was heard through the buzzer. This agrees with findings of the following researchers (Domingues *et al.*, 2016; Fraden, 2016; and Groover, 2015). It was also observed that the level of smoke that can trigger circuit has to be reasonable high and preferably burnt particles that emit dark smoke. The alarming circuit was active for the calculated time and deactivated after the time has elapsed. Also the pump was activated after the delay time was set and deactivated for the calculated time period. The reservoir tank was filled with water and the water-level sensor activated the water pump then the reservoir tank was emptied and the water-level sensor sensed this action and deactivated the water pump to avoid it from damaging itself.

3.2.3 Timer Circuit testing

Here the time set or produced by the alarm circuit, delay timer circuit, and suppression unit were tested and it was found that the time is not exactly the same as calculated time desired, which may be due to variation in component value or settling time of electrolyte capacitors. The following tables show the desired calculated time versus the result obtained in the timer circuits.

Table 3.3: Alarm and Delay Circuit-timer Testing

S/N	Calculated Value	Stopwatch-timer	Results

1.	15 seconds	18.5 seconds	Buzzer on and delay activated
2.	15 seconds	19 seconds	Buzzer on and delay activated
3.	15 seconds	19.01 seconds	Buzzer on and delay activated

3.2.4 System testing

After all the units testing have been carried out, the whole system testing was carried out i.e. when all the units are interconnected (working together). Smoke was introduced in the smoke detecting circuit and alarm was generated subsequently the smoke was suppressed then the reservoir tank was emptied and smoke was reintroduced again, alarm was generated and the water pump was not activated thus the system was found to respond satisfactorily. Finally, testing instruments were carried out using DC digital Multi-meter and Stop-watch.

Table 3.4: Suppression Unit Testing

S/N	Calculated value	Stopwatch timer	Result
1.	5 seconds	4.54 seconds	Pump activated
2.	5 seconds	5.59 seconds	Pump activated
3.	5 seconds	4.81 seconds	Pump activated

The prototype fire alarm and suppression system only detects smoke of certain intensity from a burning particle, generates an alarm and subsequently sprinkle water to suppress the smoke only if water is available in the reservoir tank else it will only detect the smoke and generate an alarm. This is the limitation of this system. From here, it can be concluded that, the design and construction of the prototype fire alarm and suppression system has been achieved satisfactorily with few encountered challenges along the way which have been overcome and it is hoped that this designed prototype system will find useful application in homes, offices, hospitals etc. to reduce the effect of fire outbreak by detecting smoke released as a result of burning from fire and also prevent lives and properties from being engulfed by the fire.

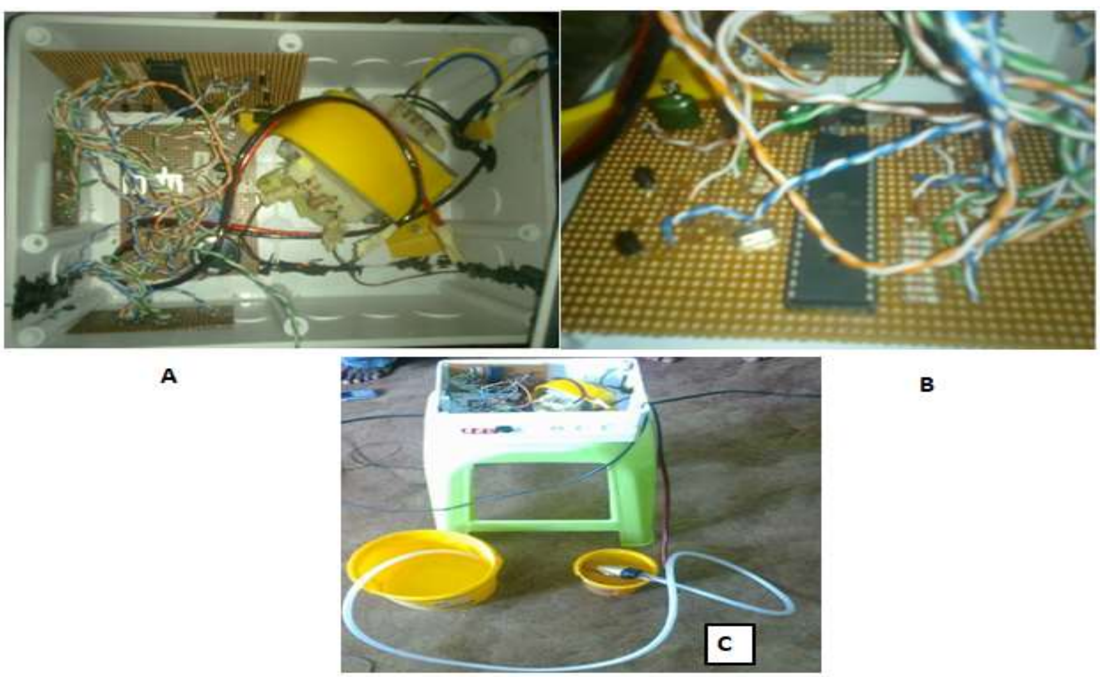


Figure 3.1: Shows Automatic Fire control system (A), Microcontroller view onboard (B) and overview of the System Testing (C)

4.0 CONCLUSION AND RECOMMENDATIONS

In this chapter, conclusion and recommendations for further work were made.

4.1 Conclusion

Based on the experimental research of the project, report has been meticulously organized to mirror the project's onboard structure. Chapter 1 provides an overview of the work, and Chapter 2 presents the project's design and construction, including the analysis of its various components and the procedures involved in mounting the components on vero board. The project's performance, test, and cost evaluation were included in Chapter 3 of this journal write up.

The findings of this research contribute immensely to the growing body of knowledge on utilizing the fire alarm systems with building automation technologies. The device not only demonstrated high functionality and feasibility but also showcased successful suppression system, supported by expert validation. These results are consistent with global research trends, further cementing the system's potential for real-world applications. In this research, the author succeeded in designing a Fire Alarm System with Arduino UNO as a microcontroller that works according to the design that has been made and knows how to make a design for this device.

This research presents several notable benefits that contribute to both education and practical applications. This enhances students' understanding of fire safety and building automation, making complex systems more accessible and comprehensible. Additionally, the research contributes greatly to improve safety by simulating realistic fire detection and automation scenarios, thus preparing students to handle such situations in actual environments. Furthermore, cost-effective nature of the system makes it a perfect teaching tool, especially for institutions with limited funding, and its scalability guarantees that other educational institutions, training facilities, or industries can use it. Thus, Fire-Alarm detector could be used as a preventive measure in the case of fire-outbreaks when used at homes, offices, schools, hospitals, industries etc.

4.2 Recommendations

The following recommendations for further work on this project will enhance the versatility and adequate operations of this system;

1. The project was carried out based on research on the major constituents of fire and therefore making the device a good and effective firefighting tool. More study can be done to enhance to improve and broaden the project's technology and application. Additional technological advancements include adding an SMS alert system to the device, which notifies owners and users in the event of a fire outbreak that occurs and no one is nearby where the device is located.

2. The sensor detector designed in this project is photoelectric smoke detector, though it is very sensitive but needs relatively high level of dark smoke to trigger the alarm and this is a limitation as not all particles emit dark smoke therefore it is recommended to use other types of smoke sensors E.g MQ-2 smoke sensor, ionization smoke sensor etc. as they more reliable and sensitive to any kind of smoke.

3. This system is an analog system and it was observed that it activates the circuit and has false triggering immediately the ON switch is active. It is recommended to incorporate a microcontroller to the system to improve the accuracy, this eliminates the false triggering and it will activate the circuit only when a smoke is detected.

4. The system can be modified if features like a talking Artificial intelligence are added to the system to utter "Smoke detected, please exit the building" whenever smoke is detected and also send a fire alert SMS message to all people's phone in the building. Further research must be done to achieve these features.

5. In the suppression unit of this designed system, the sprinkler is adjusted to face only one direction in a building and fire may spread all over the place inside a building. An electric motor maybe used to connect the sprinkler so that the sprinkler is rotating and spraying water in motion or more sprinklers maybe attached to the common pipe and inserted in different locations inside the building so that it will spray water effectively.

Conflict of Interest

The authors declared no conflict of interest.

Acknowledgements

The authors are THANKFULL to the management of Kano State Polytechnic and Tertiary Education Trust Fund (TETFUND), Nigeria for sponsoring the research project.

CONFLICTS OF INTEREST

No competing interests exist.

REFERENCES

Ali, K. (2016). Fire Alarm System. 0, 1–23.

Avillo, A. V. (2014). Fireground strategies (3rd ed.). Fire Engineering Books & Videos.

Daniel U. A. (2005). *Design and Construction of a Reflector Type Smoke or Fumes Alarm System*. B. Eng. Unpublished Thesis, Electrical and Electronics Engineering Department, Federal University of Technology, Yola, Nigeria. Pp 1 -10.

Darmawan, H., Yusiana, V., & Siregar, H. (2022). Rancang Bangun Fire Alarm dan Smoke Detector Berbasis Programmable Logic Controller (PLC) Tyfe SR3B261BD. Journal of Electrical Power Control and Automation (JEPCA), 5(2), 58. https://doi.org/10.33087/jepca.v5i2.77.

Domingues, P., Carreira, P., Vieira, R., & Kastner, W. (2016). Building automation systems: Concepts and technology review. Computer Standards & Interfaces, 45, 1–12. https://doi.org/10.1016/J.CSI.2015.11.005.

Fraden, J. (2016). Handbook of modern sensors: Physics, designs, and applications (5th ed.). Springer.

Groover, M. P. (2015). Automation, production systems, and computer-integrated manufacturing (4th ed.). Pearson.

Hidayat, N. (2021). Analysis of IoT-Based Fire Alarm Systems for Office Buildings. Journal of Computer Technology and Systems.

John W. Cowart (2008). *Heroes All: A History of Firefighting in Jacksonville.* Bluefish Books. Florida. Pp13 -20.

Naum, C. J. (2016). Building construction for the fire service (4th ed.). Jones & Bartlett Learning.

OBI, I (2022). Design And Construction Of A Fire Alarm Detector System. Repository.mouau.edu.ng: Retrieved Oct 20, 2025, from https://repository.mouau.edu.ng/work/view/design-and-construction-of-a-fire-alarm-detector-system-7-2.

Osamah Ibrahim Khalaf (2019). IOT_fire_detection_system_using_sensor_w.74–78. https://doi.org/10.4206/aus.2019.n26-7/.

Paulison, R. D. (2005). Course of Action**,** *fire chief magazine*, [ONLINE]. Pp 1-2 Available from: http://firechief.com/health_safety/firefighting_courses_action. [Accessed 17 July 2012].