DESIGN AND CONSTRUCTION OF AN AUTOMATIC FIRE ALARM SPRINKLER SYSTEM

BY

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(2006/24442EE)

A Thesis submitted to the Department of Electrical and computer Engineering in partial fulfillment of the requirements for the award of Bachelor of Engineering degree (B.Eng) in Electrical/computer Engineering, Federal University of Technology Minna, Niger State, Nigeria.

November, 2011.

DECLARATION

I, Anigbo Hilary declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to Federal University of Technology, Minna.

9/11/2011

Anigbo Hilary
(Student)

Signature and Date

CERTIFICATION

This is to certify that this project titled "Design and Construction of a Automatic fire alarm sprinkler system" was carried out by Anigbo Hilary with matriculation number 2006/24442EE, and submitted to the Department of Electrical and Electronics Engineering, Federal university of Technology of Minna in partial fulfillment of the requirements for the award of Bachelor degree in Engineering (B.Eng).

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DEDICATION

This project is dedicated to the glory of Almighty God who is my source of sustenance and gave me the ability, guidance and knowledge during and indeed after my studies.

ACKNOWLEDGEMENTS

I want to give thanks to Almighty God for His grace upon my life. I sincerely thank my project supervisor, Mr. Enesi A. Yahaya for his guidance, help and inspiration. Apart from supervising my work, I learnt how to be hard working no matter the challenges in order to achieve a goal.

This project would not have been possible without the confidence, endurance and support from my family members especially Chief & Mrs. I.N. Anigbo, Dr. Chris Anigbo and Dr. Gideon Anigbo who have always been my benefactors.

ABSTRACT

This project presents the design and construction of a fire alarm sprinkler system with delay circuit. The system senses high temperatures of about 60°C that may lead to fire outbreak with the aid of a sensing circuit made up of an integrated temperature sensing unit. The sensory circuit is connected to circuit breaker to disconnect the electrical main supply and a delay circuit to cause a delay for about 60seconds, after which if the heat detected persists; the sprinkler system is activated to sprinkle water over the area. The sensory circuit is powered using a 12V D.C regulated power supply. This system improves the chances for reducing the risks to life and property.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

This chapter entails the motivation behind the development of the project, the problem definition and methodology used in the project, and finally the outline of the chapter composition of this project report.

1.2 Project Motivation And Objective

The outbreak of fire has a harmful effect on live and property in any society. Most fire detecting devices just detect the presence of fire and raise an alarm to call the attention of people, without attempting to combat the fire. Also, most fire detecting devices are not intelligent enough to detect false alarms in that they detect the presence of heat and just raising an alarm with no additional circuitry to check whether it was actually a fire outbreak or a false alarm.

The basic objective of this project is to detect the presence of heat or fire outbreak by sensing the heat in the area for temperature above 60 °C, create a time delay to make sure it is not a false alarm, and with the help of the circuit breaker and sprinkler system, automatically attempt to suppress the fire by sprinkling water over the area and also disconnect the electrical mains supply should it be electrically caused.

1.3 Problem Definition And Methodology

Having completely understood the component characteristics configured to make up the circuit design, the problem is the design of a fire detector and water sprinkler system with delay so as to detect the presence of fire in the surrounding environment and also to combat it. In the course of solving the problem, the following methodology will be used.

- Design of power supply unit
- Design of the heat detector circuit
- Design of the delay circuitry(consisting of the 555 Astable Multivibrator and the two(2) MOD-10 counters)
- Design of the circuit breaker
- coupling of the water pump and the sprinkler system
- A study of the varying input and output characteristics
- Providing of a case for the fire detection and sprinkler-control system

1.4 Project Outline

The project comprises of five chapters. Introduction, literature review and theoretical background of the components used in the project, system design, calculation and decisions taken on selecting the appropriate components of the circuit, circuit construction and testing, and finally the general conclusion, problems encountered limitation area of application and possible recommendation for further work.

CHAPTER TWO

2.1 Introduction

The design and construction of the fire detector and fighter device is done due to the incorporation of different electronic components and sub circuits. This chapter is going to discuss the literature review, the basic theoretical aspect on which the various part and sub-units of the project are based.

2.2 Literature Review

Heat detectors are the least expensive fire detectors having the lowest false alarm rate of all the fire detectors, but are also the slowest in detecting fire. Heat detectors are best suited for fire detection in small confined spaces where rapid fire with high heat output are expected and in other areas where ambient conditions would not allow the use of other fire detection devices or where speed of detection of life safety are not a consideration. One example of this would be low value products where fire could cause minimum damage to the structure or contents. Automatic fire alarms with water sprinkler system is an active fire protection measure and are most effective during the fire's initial flame growth stage.

Today 80% of deaths in building fires are caused by smoke inhalation. In a matter of minutes, the victims are dead before the fire ever reaches them. Being a vital aspect of several industrial and residential processes, research works have been carried out to solve the problems of late detection of fire outbreak and the subsequent control of the fire outbreak. This was achieved by using some basic electronic components like temperature and heat sensors which senses potential heat in the environment that can lead to fire outbreak. [1]

Amao designed, constructed and tested a micro-controller based temperature controller using temperature sensor IC. The output voltage of the sensor varies proportionally to the temperature in degree centigrade (°C). [2]

Adisa designed a temperature measuring sensor device using thermistor, potentiometer and Opamp as comparator. [3]

Gwamziti Ponsah designed and constructed and tested a non- latching fire using thermistor and microcontroller based which senses temperature above 41 °C [4]

For the control of fire in this project, an automatic sprinkler system is interfaced to the circuit together with a circuit breaker to sprinkle water over the area and also to disconnect the mains supply. This helps reduce the risk of life and properties to a reasonable extent.

2.3Theoretical background

2.3.1 Transformer

A transformer is a device that transfers electrical energy through inductively coupled conductors (the transformers coils). Mostly, in electrics, AC voltage is stepped down to suit the requirement of the solid state devices and circuits fed by the DC supplier in an ideal transformer. The induced voltage in the secondary winding (Vs) is in proportion to the primary voltage (Vp) and is given by the ratio of the number of turns in the secondary (Ns) to the number of turns in the primary (N_p) as follows:

$$\frac{Vs}{Vp} = \frac{Ns}{Np} = K \qquad (2.2)$$

This gives the basic equation for stepping up or stepping down the voltage, where K is the voltage transformer ratio.

2.3.2 Rectification

Rectification is a process by which alternating current (AC), which periodically reverses direction to DC current, which flows in one direction. Devices that conduct such kind of conversions are called rectifiers. There are different forms to which rectifiers may take, and these include: Vacuum tube diodes, Mercury arc valves, Solid state diodes, Silicon-controlled rectifiers e.t.c.

The process of rectification is carried out in two major ways namely:

- Half wave rectification
- Full wave rectification

1N 4001 General Purpose Rectifier

This is a low voltage drop, high surge current capability rectifier used for converting AC current to an appropriate DC voltage value. It is commonly used in many electronic circuits.

2.3.3 D.C. Voltage Regulators

A regulator is an electronic device that controls the voltage level to a given value. There are several types of regulators depending on the output voltage /regulated voltage given by the regulator. Some examples of common power regulators are:

- 7805 power regulator
- 7812 power regulator

However, the regulator used in this project is the 7812 regulator which is described below.

7812 Regulator

The 7812 regulator is a three (3) terminal device that produces an output of 12v when connected. Thus, input voltages to the regulator greater than 12 volts are regulated by the regulator to produce an output of 12v.

The 7812 regulator belongs to the 78XX family of self-contained linear voltage regulator circuits which can support voltages of up to 35 to 40 volts and currents of 1 to 1.5 amperes. They are Positive voltage regulators, i.e. they are designed to produce voltage that is positive relative to the ground. They also have a minimum voltage drop of 1.7V across them.

The diagram of the 7812 regulator pin out is as shown in fig 2.1 and 2.2 respectively.

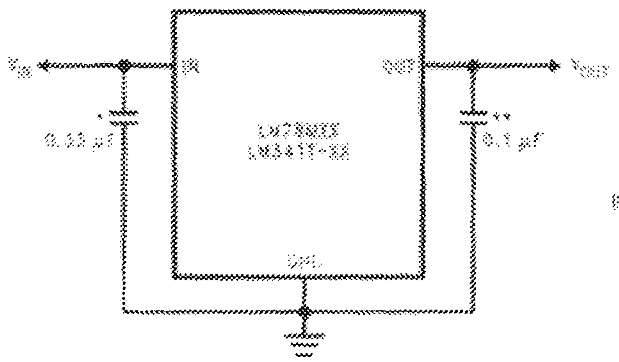

Fig. 2.1: 7812 Regulator circuit

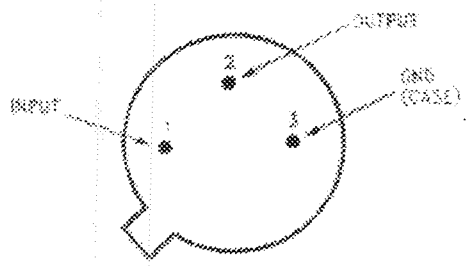

Fig. 2.2: 7812 Regulator Pin-out

2.3.4 LM35 (Temperature Sensor)

The LM35 temperature sensor is a three terminal device whose output is linearly proportional to the Celsius (centigrade) temperature. The sensor is an integrated circuit temperature sensor whose major advantage over other sensors is that it does not require external calibration or timing to provide typical accuracies of ¼ degrees at room temperature and ¾ degrees over a full -55^0C to 150^0C Temperature range. The sensor is also a low self heating device and draws 60μF from its supply. They are used in oven controllers and resistor temperature sensing.

There are certain behaviors of the LM35 temperature sensor that makes it have advantages over the normal thermistor.

1. LM35 temperature sensors are linear in its behavior while thermistors are nonlinear
2. Outputs of the sensor are directly in Celsius. Thus there is no need for conversion to centigrade unlike the thermistor whose output needs to be converted to Celsius.
3. Easier interfacing or readout due to low output impedance and linear characteristics.
4. You can measure temperature more accurately than a using a thermistor.
5. The sensor circuitry is sealed and not subject to oxidation, etc.
6. The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

The temperature sensor LM35 in Fig. 2.3 below shows the various components comprising it which are transistors, resistors, an operational amplifier and a diode for rectification purposes.

The LM35 sensor has eight pins where only three (3) of them perform important tasks. The pin layout diagram of the temperature sensor is as shown in Fig 2.4

The circuit diagram of the LM35 temperature sensor is as shown in Fig. 2.3.

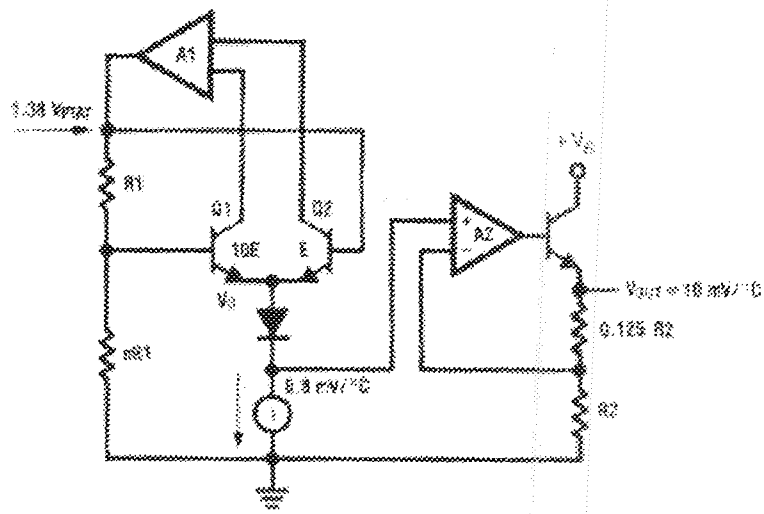

Fig. 2.3: LM35 Temperature sensor internal circuit schematic

From the figure in 2.4 below, the pins 1, 4 and 8 are the active pins and are used as output, ground and supply respectively. The other pins are inactive and are ignored or connected to ground.

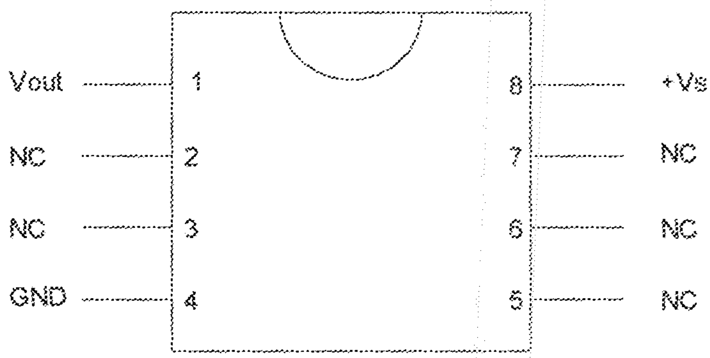

Fig. 2.4: LM35 temperature sensor pin layout

The calculation for the conversion of temperature to voltage by the temperature sensor is given by a simple direct conversion formula (because of the sensors linear behavior). This formula is given as:

- Temperature (°C) = V_{out} × (100 °C/V) . . . .(2.1)

Substituting the value of the temperature, which is surrounding the sensor, we can get the output voltage of the sensor which would determine whether or not the sprinkler/ circuit-breaker alert would be turned-on.

2.3.5 Operational Amplifier (OpAmp) comparator

A comparator circuit is a circuit building block that compares the strength (usually in volts) of the two signals and provides an output signal when one is bigger than the other. The large output gain of an operational amplifier makes it ideal for comparing two voltages.

The circuit in Fig. 2.5 consists of two inputs, one is called an inverting input while the other a non-inverting input. It also has an output to which the result of the compared voltage signals of the two inputs is gotten. The Op Amp can be configured in two ways: the inverting and the non-inverting configuration.

The operational amplifier used as a comparator circuit is as shown in Fig. 2.5.

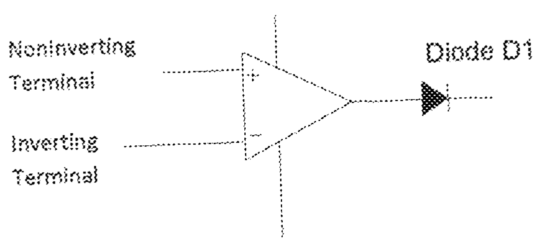

Fig. 2.5: Op Amp Comparator

2.3.6 Transistors

The transistor is a semiconductor device commonly used to amplify or switch electronic signals. A transistor is made up of either silicon (si) or germanium (ge) with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistors terminal charges the circuit following through another pair of terminals, because the control (output) power can be much more controlling than the power, the transistor provides amplification of a signal. It can also be used to turn current on and off in a circuit like an electrical controlled switch, where the amount of current is determined by other circuit elements. There are basically two types of transistors, the bipolar junction (BJT) and the FET transistor. In this project, the BJT is use. The BJT is a three terminal electric device constructed of doped semiconductor material, they are so named because there operation involves both electrons and holes. The three terminal of the BJT are emitter, base and collector. The BJT consist of two junction diodes which are NPN and PNP. NPN transistor consists of a layer of P doped semiconductor (base) between two N doped layers, while PNP consist of N doped semiconductor between two P doped layers.

Current entering the base i.e. collector mode is amplified in the collector output. In other terms, an NPN transistor is "on" when its base is pulled high relative to the ammeter.

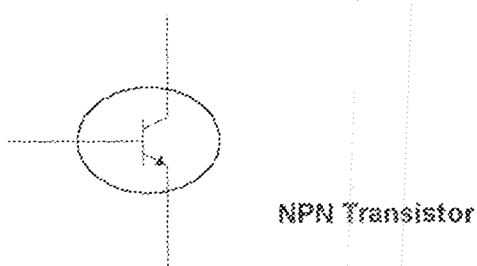

Fig. 2.6: Symbol for NPN bipolar junction transistor

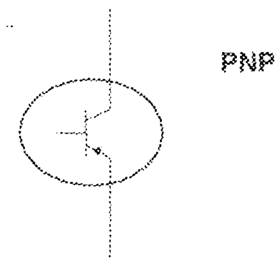

Fig. 2.7: Symbol for a PNP bipolar junction transistor.

There are basically two types of BJT transistors namely

- NPN Transistor
- PNP Transistor

In this project, the transistors used are the C1815 and TIP41C NPN transistor.

2.3.7 555 Timer Astable Multivibrator

The 555 timer astable multivibrator is an astable multivibrator connected using a 555 timer as the hearth of the oscillator. It produces a square wave with sharp transitions between its low (0V) and high ($+V_s$) state. It is a highly stable oscillator for generating accurate time delays or oscillations, with additional terminals for triggering and resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and a capacitor, while in the astable mode of operation, the free running and delay circle are accurately controlled with two external resistors and one capacitor. The circuit can be triggered and reset on falling waveforms, and output can source or sink up to 200mA or drive TTL circuits.

The connection diagram of the astable 555 timer is as shown in fig 2.8 below

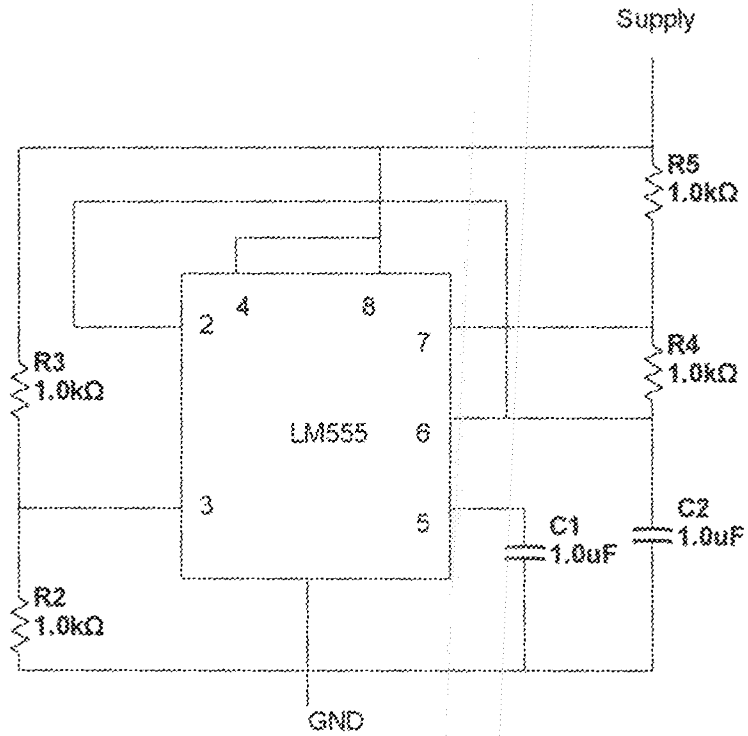

Fig. 2.8: Connection diagram for LM555 astable multivibrator using 555 timer

2.3.8. Decade Counter

A decade counter, unlike other counters is a counter that counts in decimals rather than binary. A decade counter may have each digit binary encoded (that is, it may count in binary-coded decimal, as the 7490 integrated circuit did) or other binary encodings (such as the bi-quinary encoding of the 7490 integrated circuit). Alternatively, it may have a "fully decoded" or one-hot output code in which each output goes high in turn (the 4017 is such a circuit). The latter type of circuit finds applications in multiplexers and demultiplexers, or wherever a scanning type of behavior is useful. Similar counters with different numbers of outputs are also common. The decade counter is also known as a mod-counter when it counts to ten (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). This project design utilizes the CD4017 decade counter for its counting operations which is explained below.

CD4017 Decade Counter

The CD4017 is a 5-stage divide-by-10 Johnson counter with 10 decoded outputs and carry out bit. Its counting sequence is taken from one to ten (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). The configuration of the CD4017 decade counter is such that each of its decade outputs is normally In its 0 state and go to the logical 1 state Only at its respective time slot.

This counter is cleared to its zero count by a logical '1' on its reset line On pin 15 and advance on the positive edge of the clock signal when the clock enable signal on the clock input pin, i.e. pin 14, is in its logical '0' state. Then, each decoded output then remains high for 1 full cycle For every 10 clock input cycles and is used as a ripple carry signal to any Succeeding stages. The connection /pin-out diagram of the counter CD4017 dual inline package is as shown in fig 2.9 below.

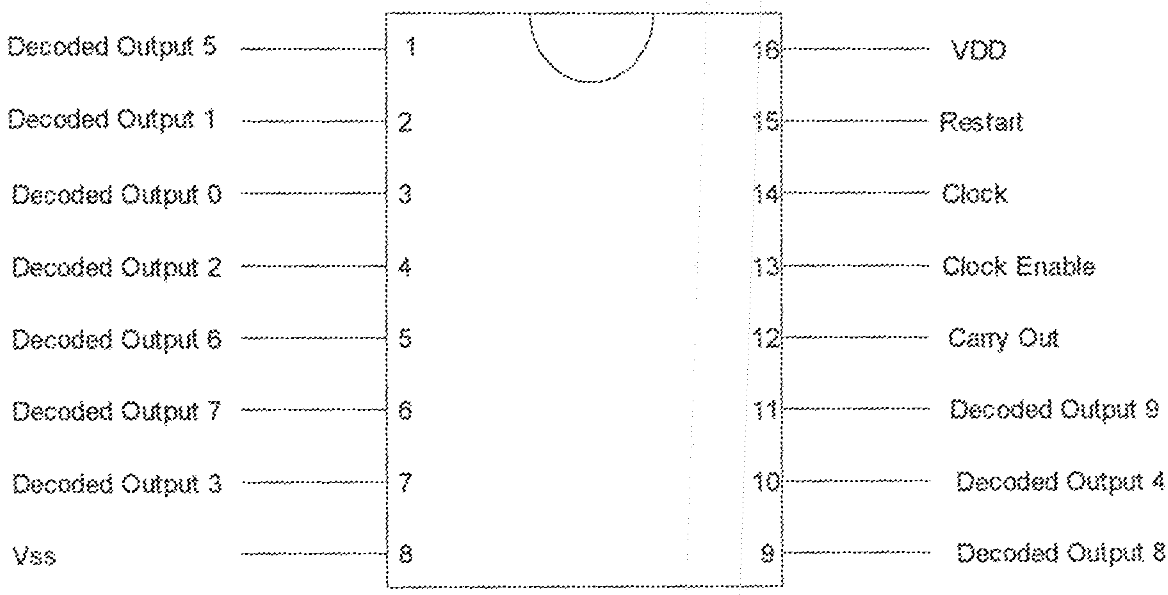

Fig. 2.9: pin-layout diagram for CD4017 Decade counter

CHAPTER THREE

SYSTEM DESIGN AND IMPLEMENTATION

3.1 Introduction

In this chapter, the main consideration is that of the design and different calculations that make up the detector and fighter by the general circuit diagram and the principle of operation.

The project design comprises six units which include:

i. Power supply unit
ii. Sensory unit
iii. Comparator unit
iv. Delay unit
v. Circuit breaker unit
vi. Alarm/Pump (water sprinkler unit)

The system block diagram of the project design is shown in Fig. 3.1.

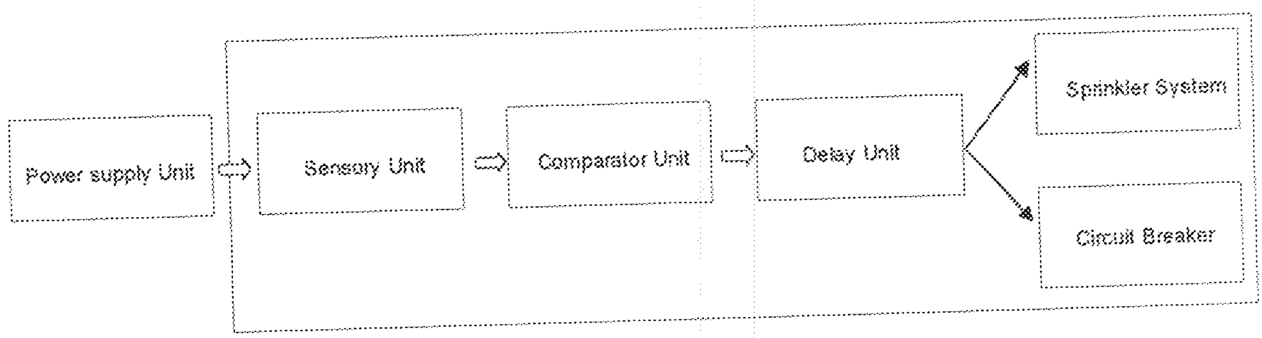

Fig. 3.1: block diagram for automatic fire alarm sprinkler system

In the block diagram as described in Fig 3.1, the power supply unit supplies power to all the other peripheral components of the design. The sensory unit senses the temperature of the surrounding environment and passes it onto the comparator unit that compares the incoming voltage signal with a reference voltage. The delay unit is activated by the comparator unit which controls the sprinkler system and the circuit breaker system connected to it.

3.2 The Design of the Power Supply Unit

The power supply unit is designed using the figure shown in fig 3.2

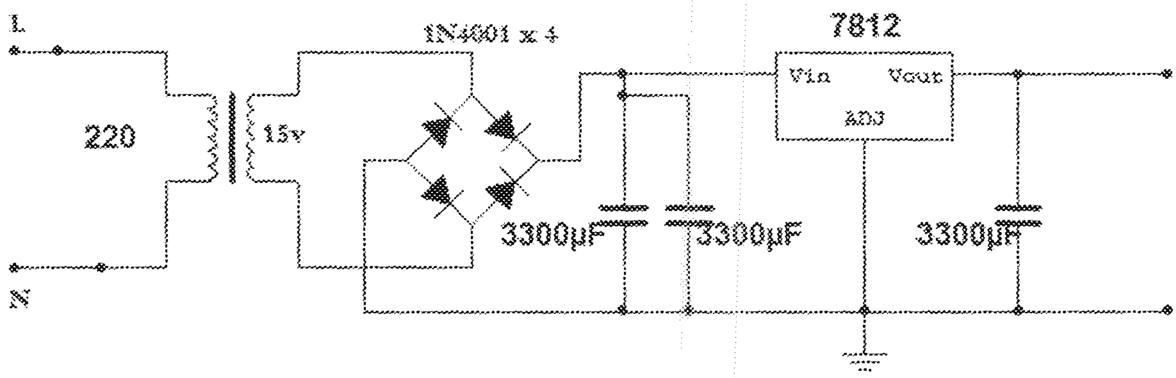

Fig. 3.2: Power supply unit

The power supply system is one of the fundamental components of this project design and whose major function is to provide the design with a reliable source of DC, from the AC power supply input. This DC voltage is then used in the circuit for its operations. The conversion process of A.C. power (220V, 50Hz) to a D.C voltage supply is through the various conversion processes.

3.2.1 Transformer selection

The following electrical conditions are required by the power supply

- 12Volts DC supply by the project circuit for its operation.
- 1.800A DC current supply

The voltage required by the circuitry of the project is a 12V D.C supply obtained from the rectification and filtering of the output of a 220/15V step down transformer. Therefore, the specification of the chosen transformer is as follows:

primary voltage = 220V

secondary voltage = 15V

AC current I_{ac} = 2A

DC current $I_{dc} = \frac{2 \times Irms \times \sqrt{2}}{\pi} = \frac{2 \times 2 \times \sqrt{2}}{\pi}$

I_{dc} = 1.801A = 1800mA

3.2.2 Filter Parameter Selection

The purpose of the capacitor is to act as a filter thereby producing a steady state direct current supply by smoothening the output of a rectifier and eliminating the A.C. components. Having known the supply frequency from the supply mains power supply, which is $50H_z$ the smoothening capacitor can thus be chosen properly.

$$C = \frac{I_{dc}}{4\sqrt{3} \times f \times \gamma \times V_p} \qquad (3.2)$$

Where;

- C = Filter capacitor
- F = input frequency for a full-wave rectifier

- V_p = Ripple voltage
- γ = Ripple factor of 2.5%

$$V_p = \frac{\sqrt{2}}{1} \times V_{rms} = \frac{\sqrt{2}}{1} \times 15 = 21.21$$

Hence, from the equation 3.2 above,

$$C = 1.801 / 4\sqrt{3} \times 50 \times 21.21 \times 0.025 = 16 \times 10^{-4} = 9800\mu F$$

This is the optimal value of the capacitor to be used for the design. However, the value of capacitor chosen is 9900µF because of the following reasons:

- A large capacitor value has a larger electron-storage capability thereby producing lesser ripples
- Value of the Load

3.2.3 Selection of Bridge Rectification Components

The bridge rectifier used in this circuit utilizes four 1N4001 rectifier diodes which has the following electrical characteristic ratings:

Maximum voltage rating = 60V

Maximum forward current = 1.5A

Root Mean Squared Voltage (V_{rms}) = 15V

The value of the maximum reverse voltage above which break down may occur is given from the datasheet of the 1N4001 as:

$V_{maxReverseVoltage}$ = 50V

The maximum reverse voltage is related to the peak voltage as in fig 3.2:

$V_{maxReverseVoltage} = 2 \times V_p$ .... (3.3)

But V_p = peak voltage $= \frac{\sqrt{2}}{1} \times Vrms$

From the electrical characteristics rating $V_{rms} = 15V$

Thus, $V_p = \frac{\sqrt{2}}{1} \times 15V = 21.21V$

Thus, $V_{maxReverseVoltage} = 2 \times V_p$

$V_{maxReverseVoltage} = 2 \times 21.21Volts = 42.42V$

This means that the maximum voltage above which breakdown may occur causing large current to flow in the reverse direction thereby damaging the diode is 42.42Volts.

The 1N4001 rectifier diode has its maximum reverse voltage as given from the datasheet as 50V. This value is larger than the maximum reverse voltage calculated above and this feature makes it suitable for use in the project circuit.

After the rectification circuit, the waveform of the bridge rectifier is as shown in Fig. 3.3

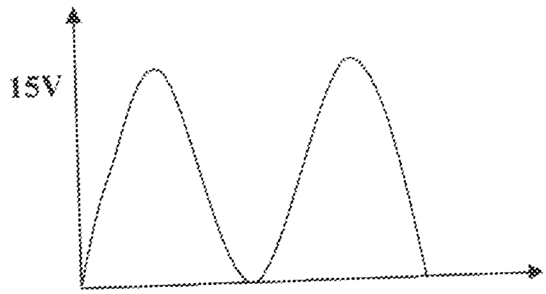

Fig. 3.3: Waveform of the rectifier

3.2.4 Selection of a regulator

The voltage required by the circuit is 12V DC supply, thus the voltage regulator to be used in this project is taken from the 7800 series regulator, specifically the 7812 voltage regulator. This is because it takes whatever input voltage given to it and produces a constant 12V DC supply. Therefore, the 7812 is good for handling the 12V circuit. The following reading are given from its datasheet

- The maximum supply voltage:40v
- The maximum supply current:1.5A

3.3 The Comparator Circuit/ Sensor Circuit

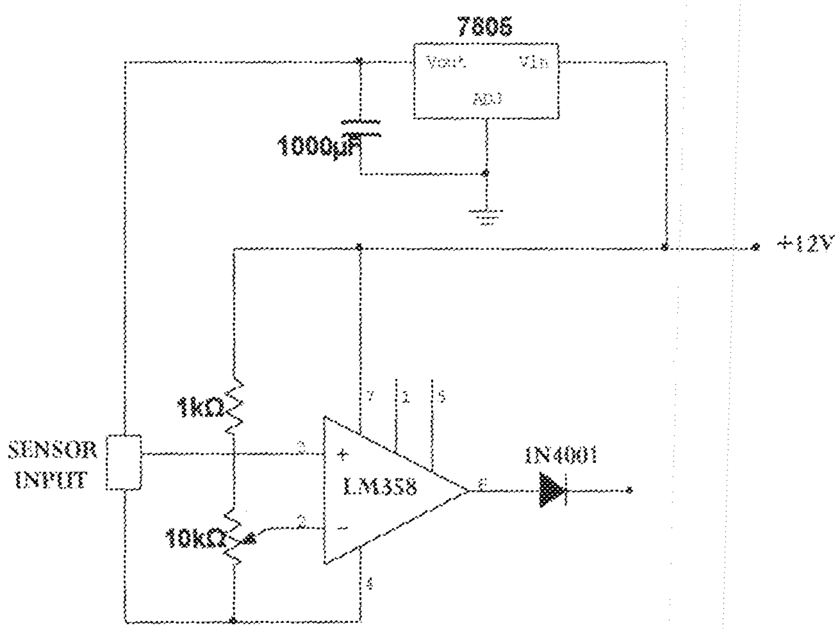

Fig. 3.4: Diagram of the sensor/comparator circuit

This is responsible for obtaining voltage signal from the temperature sensor device and comparing it with the reference voltage signal gotten from the voltage divider of two resistors connected in series. The comparator circuit is design using OP-AMP LM358 which is shown in the Fig.3.4

It is configured in non inverting configuration, the reference input is selected to be half of the supply voltage and one of the resistors in potential divider mode is choosing as 1KΩ and the other is calculated using

$$V_4 = \frac{R_2}{R_1+R_2} V_{CC} \quad (3.11)$$

The temperature-voltage equation for the OPAmp is given as:

Temperature (^{o}C) = V_{out} × (100 ^{o}C/V)

The estimated minumum heat temperature for fire is given as:

(^{o}C)$Fire_{min}$ = 60 ^{o}C

Thus, the voltage the temperature sensor (LM35) is given as:

$$Vout = \frac{(\text{ oC})\text{Fire(min)}}{100}$$

Thus, V_{out} = 60/100Volts = 0.6V

Hence, the implication of this is that the voltage coming out of the voltage divide of the two resistors R1 and R2 should be 0.6V.

Thus, $V_4 = \frac{R_2}{R_1+R_2} V_{CC} = 0.6V$

Therefore $\frac{R_2}{R_1+R_2} * 12Volts = 0.6V$

Therefore $\frac{R_2}{R_1+R_2} = \frac{0.6}{12} = 0.05$

Therefore $\frac{R_2}{1000+R_2} = 0.05$

Therefore $R_2 = 52\Omega$

The following constraints are required by the LM358 Operational Amplifier

- Input current should not be less than 0.06mA
- Input voltage should not exceed 80V

Choosing value of R1 and R2 to be 1000Ω and 52Ω respectively,

- The current input to the OPAmp would be

Input Current $\sim \frac{Vcc}{R1+R2} \sim \frac{12}{1052} = 0.0114A = 11.4mA$

Which is in accordance with the conditions described above?

- Also, the condition $\frac{R_2}{R_1} = 0.052$ Is satisfied

Hence R1 = 1000 Ohms R2 = 52Ohms

3.4 The delay circuit

The delay circuit in this project consists of the following components:

- The NE555 Astable Multivibrator Circuit
- Two MOD10 counters (CD4017)

3.4.1 The Astable Multivibrator (NE555)

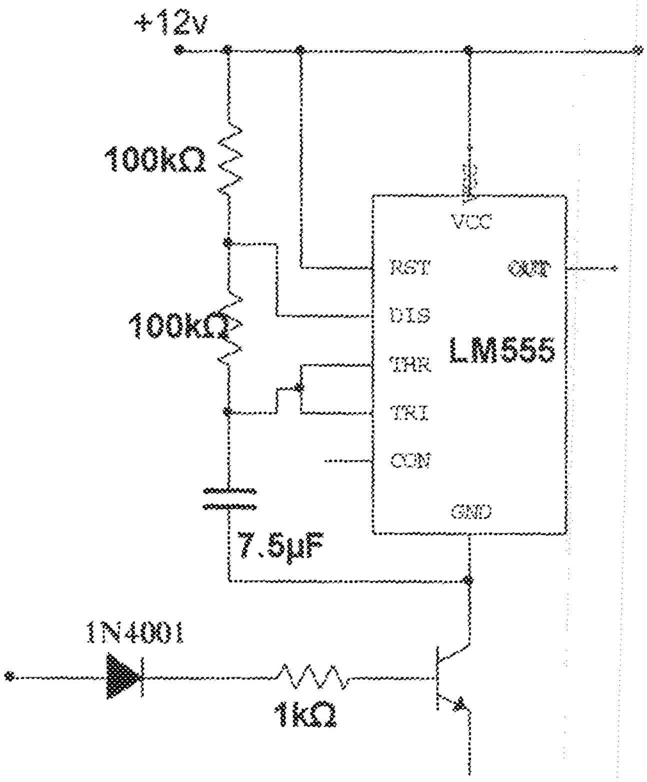

Fig. 3.5: Diagram for Astable Multivibrator

Fig 3.5 shows the connection diagram of the NE555 astable multivibrator circuit.

The subcomponents of the circuit as shown below are:

- Astable 555 multivibrator timer circuit
- Two external resistors (R1 and R2)
- One external capacitor (C1)

The required current and voltage ratings of the multivibrator are given as shown:

- Supply voltage = 12V
- Supply current = 12A
- Output voltage drop = 2.5

$T1 = (R1 + R2) \times C$

And $T2 = (R2) \times C$

Charge time is given by:

$$T1 = 0.693(R1 + R2) \times C \quad \text{......(3.4)}$$

Since it passes through R1 and R2 to the C.

Discharge time is given by:

$$T2 = 0.693 \times (R2) \times C \quad \text{......(3.5)}$$

Since it passes through R2 only.

Thus, the total period $(t_1 + t_2)$ is given by

T(total) = $t_1 + t_2$

$$= 0.693(R1 + 2 \times R2) \times C \quad \text{......(3.6)}$$

F(Total Frequency) = 1/T

$$F = \frac{1}{0.693(R1 + 2 \times R2) \times C}$$

Alternatively, instead of using the calculation method as described in eqn 3.3 above to determine the safe values of R_1, R_2 and C, the graph as shown in fig 3.3b can be used.

Fig 3.3b shows a graph illustrating the safe operating values for C given a particular running frequency.

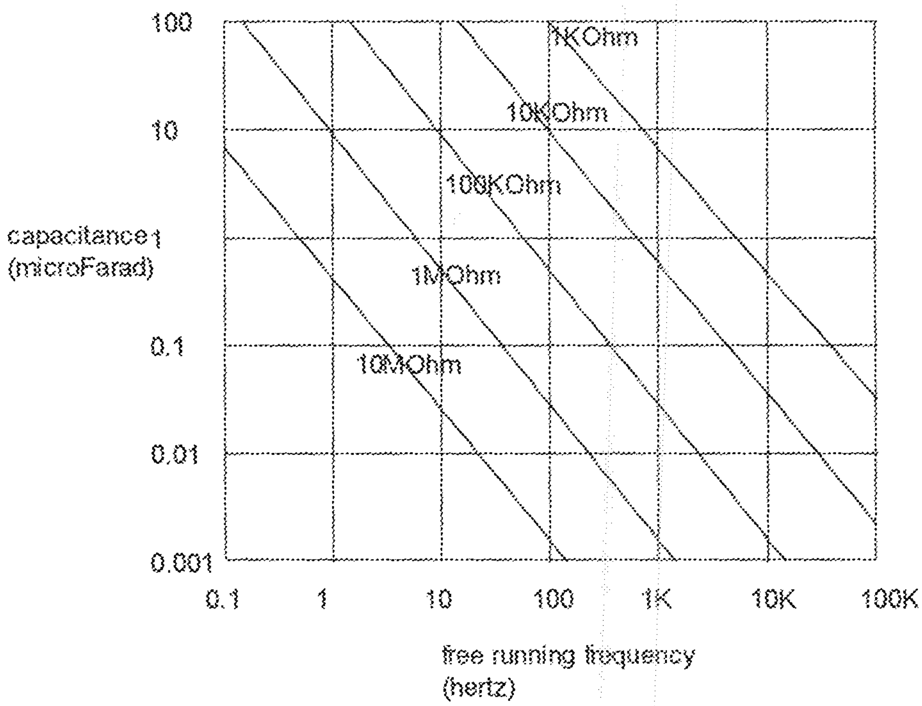

Fig. 3.6: Safe plotted graph of Values for 555 timer

The diagram above shows a graph plot for obtaining the values of Rand C to obtain safe working data environment for the 555 timer circuit. From the plot, a given required running frequency of the timer is traced on the x axis and the appropriate capacitance and restator values are gotten from the graph through the diagonal lines and the vertical (y) axis respectively.

In this project, however, the delay period to turning on the sprinkler after the fire has been observed is 60 seconds.

To obtain a total number of 60 clock pulses from the multivibrator in approximately 60sec., the 555 timer must have a period of

T (Period) = 60sec ÷ 60 pulses

T (Period) = 1sec/pulse

Thus, from the formula in 3.4 and 3.5,

$$T \text{ (Period)} = T1 + T2 = 0.693(R1 + 2\times R2)\times C \text{..........................(3.7)}$$

$$T \text{ (Period)} = T1 + T2 = 0.693(R1 + 2\times R2)\times C = 1\text{sec./pulse} \text{............(3.8)}$$

The conditions for the values of the R and C are given as follows:

- C must be greater than 500pF to avoid any stray capacitances
- R1 and R2 must be greater than 1KΩ each to avoid damage due to over current
- R1 and R2 must be less than 3.3MΩ
- Also, the load current on the IC is about 100mA

Thus taking values of R1 = 10kΩ, R2 = 70kΩ, C = 10μF

The formula to give the desired total period is obeyed, and the conditions stated for the values of R and C are obeyed.

Thus substituting the values of R1, R2 and C in the equation 3.9 and 3.10 above, the

Values of T_{charge} and $T_{discharge}$ are given as

$$T_{charge} = 0.693(R1 + R2)\times C \text{..(3.9)}$$

$$= 0.693(10K + 70K)\times 10\mu F$$

$$= 0.693 \times (80 \times 10\hat{}3) \times (10\times 10\hat{}6)$$

$$= 0.5544 \text{ sec.}$$

$$T_{disharge} = 0.693(R2)\,C \text{..(3.10)}$$

$$= 0.693(10k)\times 10\ \mu F = 0.693 \times (70 \times 10\hat{}3) \times (10\times 10\hat{}6)$$

= 0.4851 sec

The figure 3.7 above shows the output voltage waveform of the astable multivibrator.

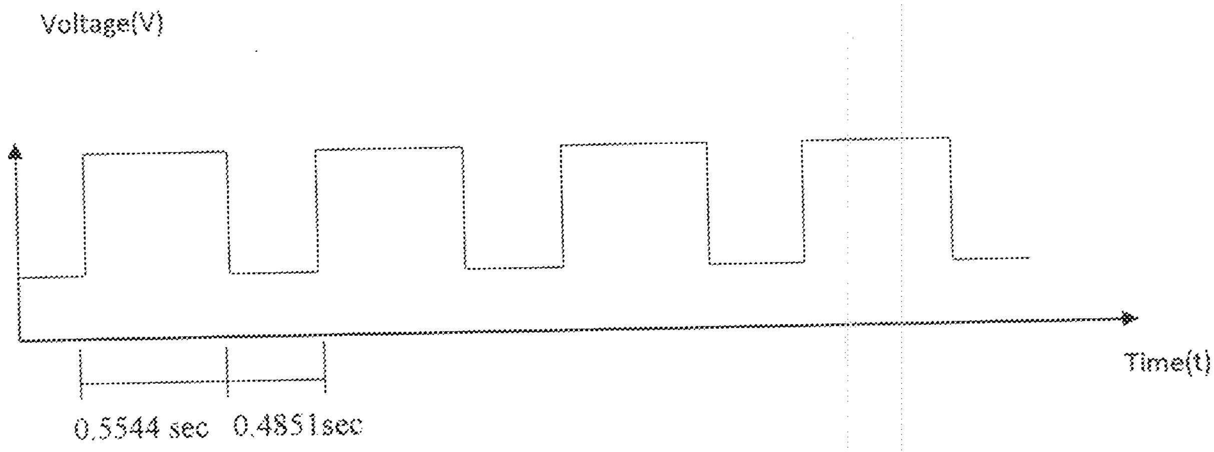

Fig. 3.7: Output Waveform of the Astable

The waveform of the voltage output of the capacitor of the astable multivibrator is as shown in fig 3.7 below.

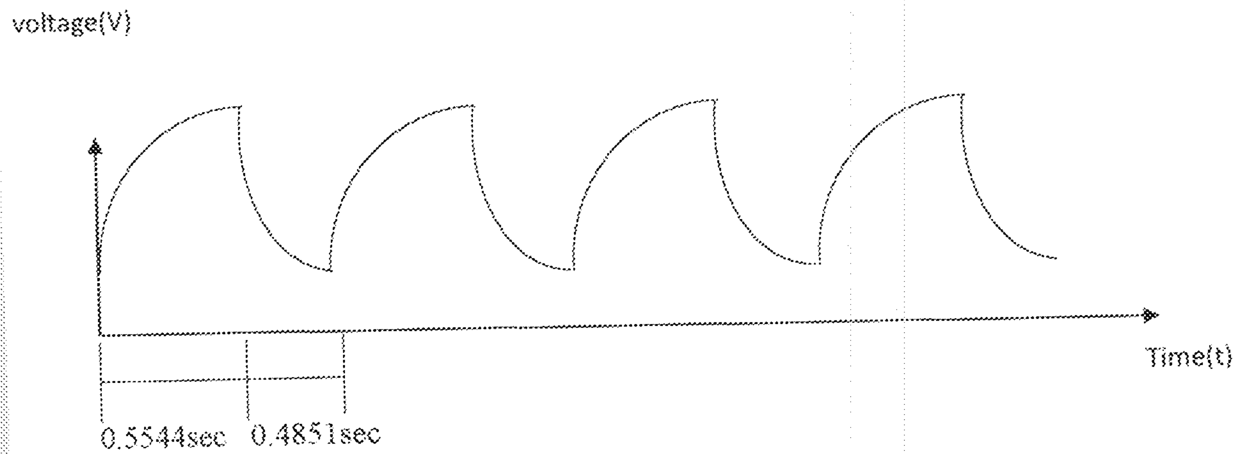

Fig 3.8: Output Waveform of Capacitor C1

The figure below shows the voltage output waveform of the capacitor (C) of the astable multivibrator. The waveform is a sawtooth waveform because of the rising and falling nature of the voltage in the capacitor when connected.

After the astable multivibrator has been setup, the measured data taken with voltameter and ammeter are given as:

- Sink current output from NE555 = 189mA.
- Voltage output from NE555 = 12.1 V.

Thus, voltage drop = (15 - 12.1) = 2.9 V.

3.4.2 The MOD-10 decade counter (CD4017)

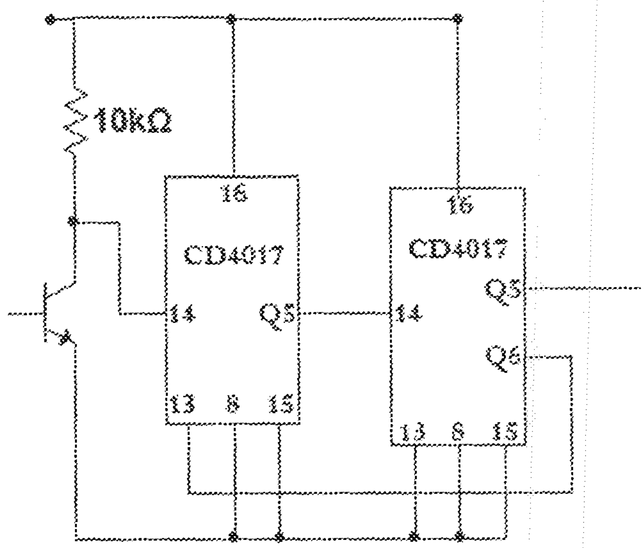

Fig: 3.9 Diagram of clock pulse generators (Two CD4017)

The input voltage from the CD4017 is equal to the output voltage from the NE555 timer which is equal to 12.1volts from measurement.

Supply voltage and current to the decade counter are given as follows:

- Supply Voltage = V_{cc} = 12 V (at pin 16)
- Supply Current = I_{cc} = 0.1mA
- Normal operating temperature = 26°C(room temperature)

The pin connection of the CD4017 timer is as shown:

- Pin 5 : An output of the counter (O_5)
- Pin13 and Pin 8 : connected to ground
- Pin 14: Input clock pulse to the counter.
- Pin 15: connected to Ground

Since Q5 is the 6_{th} output of counter C1, the number of pulses to be supplied to the input of the first counter (CD4017-01) for the output Q5 (of C1) to go high again is:

= 10 Clock Pulses

The number of clock pulses required for the output of the second counter (*CD4017-02*) to be high at Q_5 is:

= 6 Clock Pulses

From these two calculations, it can be seen that the total number of pulses which should be produced by the NE555 astable timer circuit required for the output of C2 to go high at pin 5 is given as:

= 10 clock pulses × 6 clock pulses = 60 clock pulses which when multiplied by the period of the circuit gives the required delay timing for the delay Circuit.

T (Period) = 60 sec ÷ 60 pulses

1.5sec/pulse = Delay Period ÷ 60 pulses

Delay Period = 1 sec/pulse × 60 pulses

Delay Period = 60 sec.

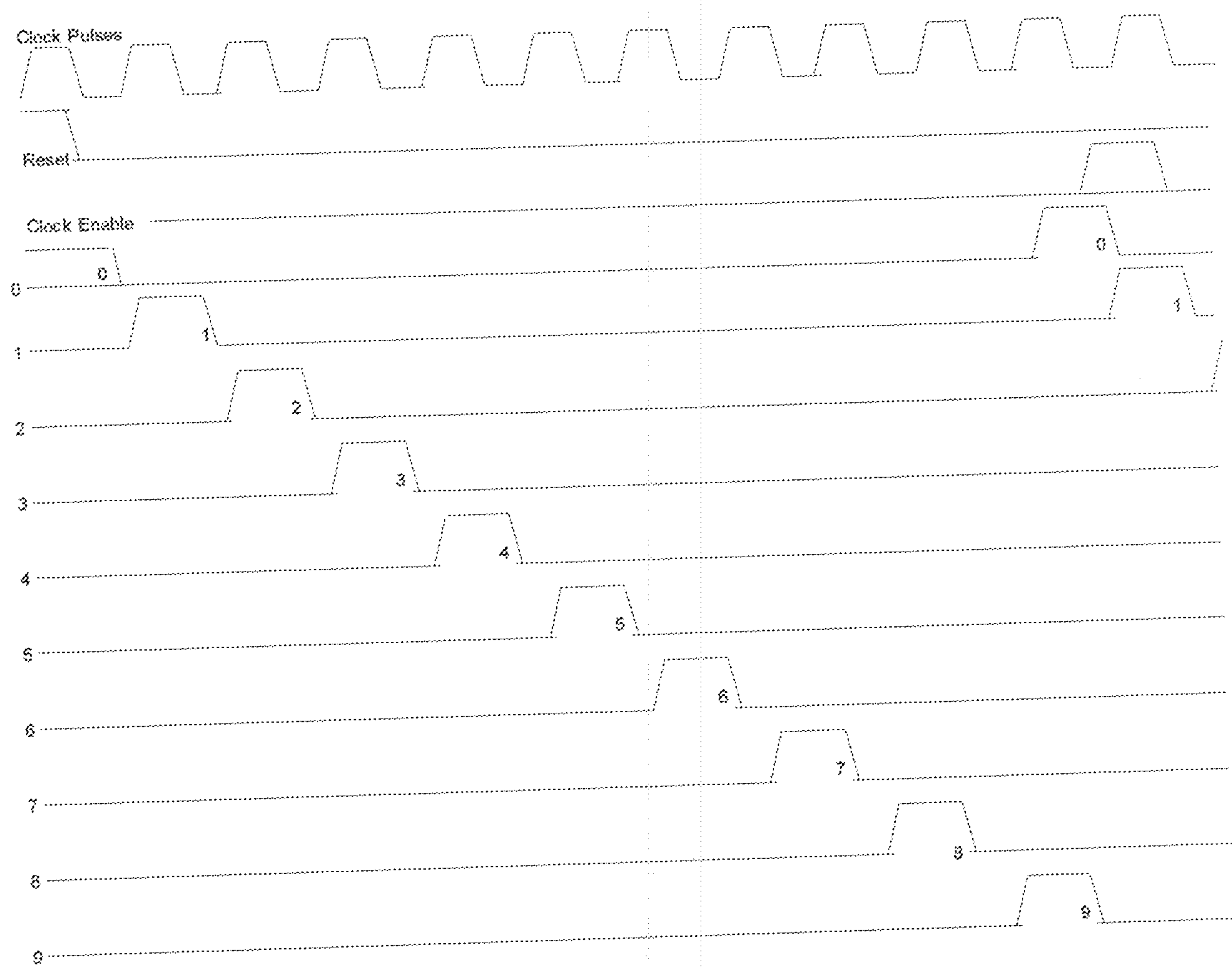

Fig 3.9.1: Timing diagram of a mod-10(decade)

3.5 Sprinkler/Buzzer unit And Circuit Breaker Unit

3.5.1 Design of the relay driver stage

The relay driver stage consist a protective diode, SPST (normally close) relay, NPN transistor. The transistor acts as a switch that controls the relay coil current meant to energize the relay. Figure 3.9.1 and fig 3.9.2 on next page shows the relay driver circuit for the circuit breaker and sprinkler system.

The relay selected is an SPST (normally close) relay of rating 12V/400Ω.

The current the relay must draw to be energized;

$$I_c = \frac{12v}{400\Omega} \cong 30mA$$

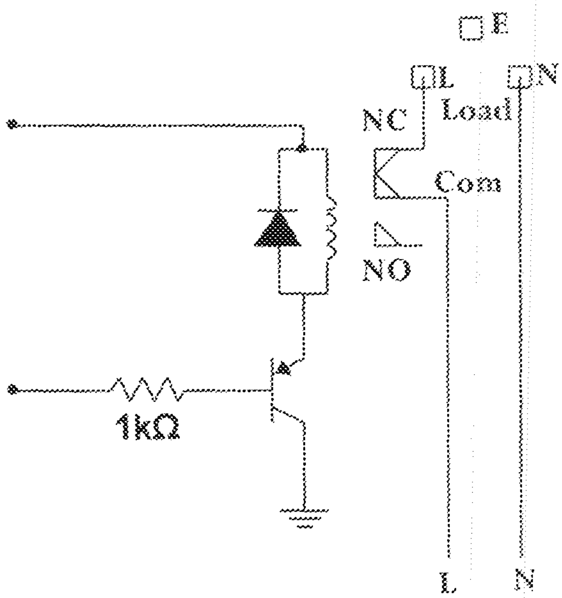

Fig: 3.9.2 Diagram of circuit breaker

3.5.2 Electric Water Pump

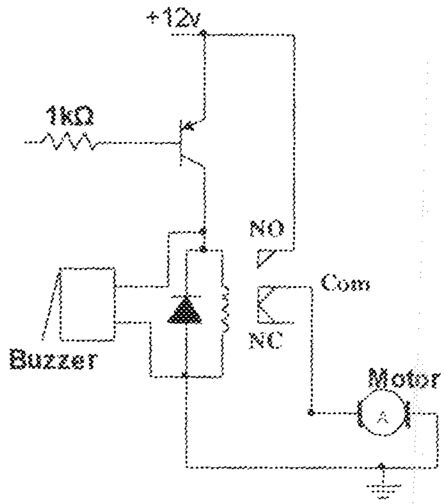

Fig: 3.9.3 Diagram of Sprinkler/Buzzer Unit

The water pump is a mechanical device with an inbuilt electric motor which produces a rotational motion when there is signal input voltage to its input terminals. This signal causes a rotational electromagnetic motion which causes its internal rotor to run thereby pulling water from a water supply to spray to the area. It is used to incorporate a sprinkler which is used as the fire-combater in this project. The relay used here is SPST (normally open).

Let's determine the value of R_B (base resistor) that is used to set the current used in driving the transistor into saturation.

$V_{BB} = V_{BE} + I_B R_B$ 3.11

$I_C = h_{FE} I_B$ 3.12

Where, V_{BB} = 12V (output voltage from comparator when HIGH)

$V_{BE} = V_{BE(ON)}$

$I_C = 30mA$ (the current the relay must draw to be energized)

$$I_B = \frac{30mA}{110} \cong 273\mu A$$

We will choose I_B to be roughly double of the calculated value to ensure the transistor stays in saturation and allow enough current to pass through the relay coil in order it's energized when the temperature persist and to switch on the motor and buzzer .

Choosing, $I_B = 545\mu A$

$$R_B = \frac{12v - 0.7V}{545\mu A} \cong 20.7K\Omega$$

R_B is chosen to be 1KΩ, a standard resistor of 5% tolerance.

The project circuit design shown in fig 3.9.1 below shows the overall circuit schematic of the entire project with the sensory unit, the power supply unit, the delay unit and the circuit breaker unit all connected together to perform the task of automatic fire detection.

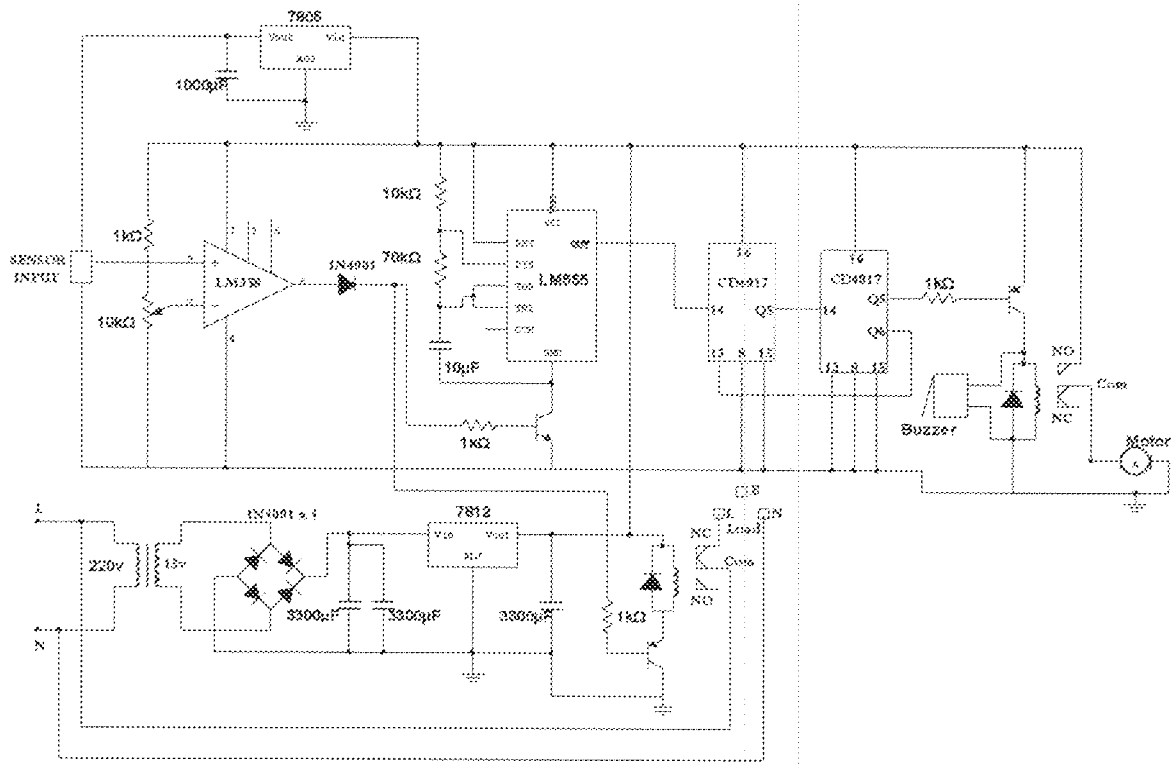

Fig. 3.9.4: Automatic fire sprinkler system with delay and breaking circuit

CHAPTER FOUR

TESTING, CONSTRUCTION AND DISCUSSION

4.1 Introduction

This chapter contains the construction of the system hardware, and testing of the entire system and also the casing of the entire system hardware.

4.2 Construction

The system construction was achieved by first placing the components temporary on the breadboard to actually test the system hardware, after which all the electrical component makeup of the project circuit was later transferred to the veroboard and soldered 3mm wires were used in the wiring connection of the project. The circuit was then cased in a black casing with the temperature sensor brought to the outside of the plastic casing. The sprinkler system was constructed using a small 0.7W water pump with a nozzle for the sprinkle water to the outside. This was placed on the plastic casing containing the project circuit. The plastic casing was painted black using a brush color paint and a tube outlet to the sprinkler system was provided to enable extension of length.

4.3 System Testing

The system hardware was tested by placing the built fire detection and control circuit in a caged environment and bringing out the cord connected to the sensor to the outside. The sensor was above the water sprinkler and shielded from the sprinkler to prevent water from affecting it. The sprinkler system was connected to a feed water tank which served as the water supply. The circuit breaker was connected to control the mains supply.

The procedure for the testing of the Fire Alarm Sprinkler System was carried out as described:

1. Water was fed into the water sprinkler tank till it was half full of water to activate the water sprinkling action by the sprinkler when needed.
2. The two external circuit breaker connector wires from the project circuit were carried out and connected to the test bulb to illustrate the circuit breaking action. Polarities were not considered during the connection.
3. The external DC power connection wires were carried out and connected to a 12V DC voltage power supply with the positive and negative terminals connected properly.
4. The project circuit was now setup. A pressing iron was placed near the heat sensor, and after a while the bulb tripped off. This indicates that heat or fire is being detected.
5. The pressing iron was withdrawn from the heat sensor and the bulb tripped on again. This indicates that the initial detection was merely a false alarm.
6. The pressing iron was now placed near the sensor again for awhile again without withdrawal and for about 60 seconds after the bulb switched off, the sprinkler was activated and began to sprinkle water over the area.

4.4 Casing

This is the final appearance given to the system hardware. the system circuit was housed in a plastic casing with the following factors taken into considerations

- Space occupied
- Allowance for heat dissipation
- Ease of insulation
- Thermal conductivity

- Portability of the project

The dimensions of the casing are:

- Height= 10cm
- Length=8cm
- Width= 6cm

The veroboard was screwed on the plastic casing.

The control circuit is attached to a board placed in the house while the circuit breaker is connected to the mains supply of the house. The water sprinkler and heat sensing unit is attached to the area of the house whose fire is to be detected.

The connection diagram illustrating how the Fire Alarm Sprinkler system is connected and wired in a house is as shown in fig 4.1.

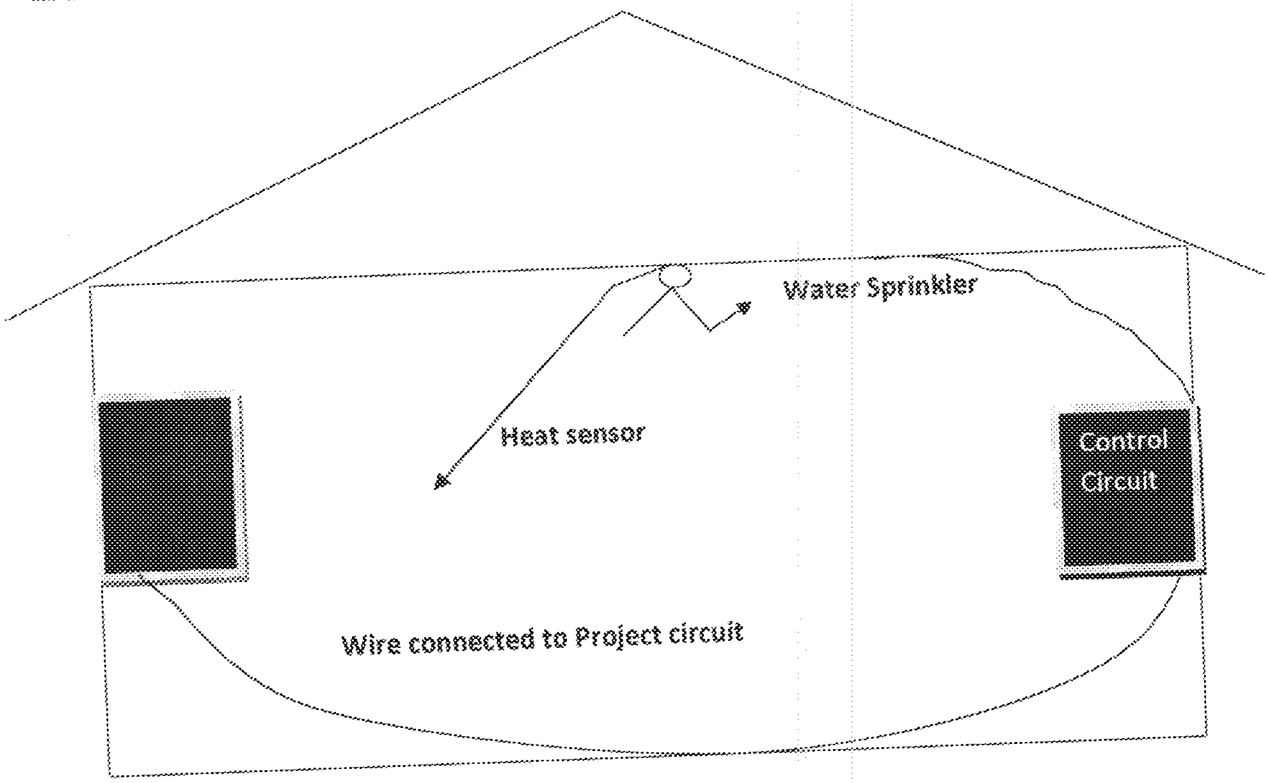

Fig. 4.1: wiring the sprinkler circuit

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter shows the conclusion that were drawn from this project, some of the limitations that were encounter in the course of the project work and also some recommendations that could be useful to the prospective designer of a project of this type.

5.2 Conclusion

The design, construction and testing of the fire detection and control system with delay system has been successfully carried out as described. The primary objective of this project was to produce a temperature detector circuit which would detect the fire, wait for a period of 60 seconds to ensure it is not a false alarm, and trigger a sprinkler pump and circuit breaker to attempt to control the fire. This was achieved by using a delay circuit interfaced to the temperature detector circuit so as to provide a delay timing after which the fire control system is setup.

This project is of great significance to the world in that it enables the saving of lives and property from fire outbreak to a reasonable extent.

5.3 Limitation

i. The water sprinkler system is a D.C motor which may not be totally efficient in combating the source of fire outbreak. Also, the water sprinkler is not rotational so it only attempts to combat the detected fire in a geographical spread only.

ii. The system's operation is completely dependent on the presence of light (electricity). Thus, the system does not operate during power failure.

iii. There is also the problem of interruption of power supply during construction.

iv. As the delay timing circuit is fixed and not adjustable, the system can only be used in geographically large fire monitoring areas where the delay timing of 60 seconds would not be enough to cause a major fire catastrophe.

v. The timing attitude of the project is carried out using digital decade counter devices, thus, the use of A.C voltage to power these devices may cause inaccuracy in the timing behavior of the circuit.

5.4 Recommendations

1. Future work can be done on this fire detection and control system using a smoke detector.
2. A practical fire extinguisher should be incorporated in the system.
3. There should be the provision of a backup power supply during interruption of the PHCN (power holding company of Nigeria) supply.

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