DESIGN AND CONSTRUCTION OF AUTOMATIC WATER HEATING REGULATING SYSTEM

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Dedication

This project is dedicated to my mother, Alhaja H.O.T Ibiyemi for her love, prayers, encouragement and support.

Declaration

I, Ali Gellal, 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 the Federal University of Technology, Minna.

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(Name of External Examiner)

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Acknowledgement

My profound gratitude goes to God Almighty for giving me life and grace to see this day. I also wish to express my thanks to my mother for her financial support, my siblings Fahd, Shelila, Labib, Idris and Hillal for their encouragement, My project supervisor Mr S.N. Rumala for his constant scrutiny, constructive criticism and advise, and my friends Florence, Usman, Bola, Doyin, Dammy, Umar, Solomon and Bulus for helping out in various ways.

Abstract

The automatic water regulating heating system is a form of automation that involves immediate switching OFF of a heating device when a desired temperature is reached. It works on the principle of an input temperature sensor (LM-35) which has a temperature-voltage relationship of 1°c to 10mV. The output is fed into the non-inverting terminal of a comparator. The inverting input terminal is referenced to the set-up so that any input voltage corresponds to a particular temperature according to the temperature-voltage relationship; hence comparator is high whenever input temperature is above referenced value. The control latch stores the result which triggers OFF the heating control relay (stops heating) and triggers ON an alarm oscillator. The mixer latch mixes the two audio frequencies generated and an NPN transistor circuit amplifies the signal.

The power supply involves a step down transformer and the resulting 12V is regulated to 5V by 7805. The regulated voltage provides stable operation of the system.

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CHAPTER ONE

1.0 Introduction

Engineering is all about making life easier through the application of science for the design and construction of machines and structures [14]. In a world where ease and comfort are some of man's basic desires, man's search for a method of perfection brought about what is now known as automation [15]. The word 'automatic' is an attachment to several machines and equipments in this present generation. It is the ability of a machine to perform a self oriented function thereby saving time and human energy dissipation.

Science and technology has rapidly advanced in the last few years, making it possible for man to get work done with ease and at a faster rate especially since recent development in solid state electronics is rapidly revolutionizing the field of control technology. Control techniques are now compact and very flexible and enabling modern machines and equipments to be self-oriented and perform predefined operations via the use of sensors, logical control units and transducers. These control techniques are being used in an ever widening variety of electronic products like the automatic electric kettle.

Woodword J. (1965) pointed out that the kind of technology employed by an organization would determine the structure of the organization [16]. Hickson D. et al (1969) viewed the automation of equipment as a factor of work- flow integration, which is a determinant of organizational effectiveness [16].

1.1 A Brief History on Energy

Energy in so many years, especially at post Second World War has become one of the most significant and important tool in the process of development both in the developed and developing nations of the world. Prior to this era, energy was not considered so important since production was to a large extent dependent on human and animal energy resources.

Heating of water is part of energy utilization and is a process that is as old as man. With passage of time and transformation, the mode of heating water has change from the use of sun to the modern day electricity. The rapid advancement in technology has however revealed that variety of energy sources ranging from the sun to the present day electricity can be use in one way or the other to accomplish this objective of water heating with greater efficiency.

Electricity can be converted into heat and used for raising body temperature using variety of equipments both domestically and industrially. In most of the developing countries, heating of water for bathing during the cold season and also for other purposes represents a significant portion of electricity consumption in the domestic sector. In Nigeria, especially in the urban areas, electricity has proven to be the most widely used source of energy in water heating. It is the most versatile form of energy and most easily distributed. [18].

A water heating system is a device use to heat water to a certain temperature, examples of such device are electric kettles and boiling rings. This project involves an automatic water heating unit which can be regulated, with alarm i.e. temperature can be adjusted to a desired degree. It is designed for water heating operation within the range of 0°c to 100°c. It corporate a precision temperature sensor for easy-to-use and accurate operation. The main method of use involves setting the device (the project) to a desired temperature before heating is set then connecting the electrical heating device to it and switch ON from an AC mains. When water reaches the desired temperature, heating is stopped immediately and an alarm triggers ON to alert the user.

1.2. Objectives of this Project

Some of the aims of this project are:

1. To reduce or even eliminate fire outbreaks due to electrical water heating devices either in a domestic setting or industrial.
2. To develop an affordable and cost effective way of monitoring heated water temperature.
3. To reduce the frequent visit to the venue where water is being heated due to anxiousness of wanting to attain a desired temperature.
4. To improve on the efficiency of water heater for domestically purpose.
5. To demonstrate the principle of controlling water heater temperature use especially in homes and industries.
6. To achieve a very portable and accurate means of maintaining water heater used for domestic and industrial purposes.

1.3 Methodology of this Project

The concept of design involves the use of a precision temperature sensor, LM-35. This is a well calibrated temperature sensor with temperature range between 0°c to 100°c. It possesses a particular voltage input terminal that corresponds with temperature change, that is, it has a relationship of 1°c to 10mV. Hence, for every one degree change, the sensor produces 10mV output, so 300mV corresponds to 30°c. This output of sensor is connected to the positive input of a comparator, the other input is referenced to a particular voltage through a variable resistor. Based on temperature-voltage relationship of the sensor, the output of the comparator can be adjusted to respond to the condition of its inputs. Therefore, a condition is set whenever the temperature is equivalent to the referenced voltage. This condition is used for switching a power relay. The relay supplies current to the heating element of the unit. The heating is automatically triggered OFF whenever the temperature of the heated water is going beyond the referenced value. The same input controls the triggering of the alarm. As the heating stops, the alarm triggers ON immediately. The alarm requires manual reset. It has to be reset by the user for alarm to stop and original state of the system be attained. The unit is a mere water heating thermostat.

1.4. Scope of Work

As stated above, it is for heating of water within the range of 0°c to 100°c. The heating element is rated below 2000 watts. It is a home use device which required maximum heating temperature is adjustable. The heating element is controlled by a relay circuit as compared to modern triac control. The system was achieved by connecting various components together such as the temperature sensor, comparator, a step down transformer, heating element, a regulator, an oscillator, a relay, inverters, power switch, rectifying diodes, variable resistors, buzzer, transistors, resistors, light emitting diode, SR latch among others. They perform different functions ranging from stepping down of the AC to DC by the diodes, filtering and smothering of the DC component by capacitors and stability by the resistor. The system consists of an automatic temperature switch that can control a powerful heater in a hot water storage vessel. It generally has two fixed temperature settings, one to switch the water heater ON and another to switch it OFF.

1.5 Need For Automatic Control

The subject of automatic controls is enormous, covering the control of variables such as temperature, pressure, flow, level and speed. There are three major reasons for automatic control:

1 . Safety

2. Stability

3. Accuracy

Temperature data is very helpful when availability Manufacturers of certain goods and most especially geographers need it for their data bank. Temperature studies are also very useful for hydrological data and in the study of how plants can survive. Before the construction of power stations, temperature studies used to be carried out so as to know the estimated water level for hydro dams, know the estimated temperature before the design and construction of solar stations. [2,3].

This project can be used in households, offices, industrial plants, cafeterias, manufacturing process, shower room, laundry and so many places.

CHAPTER TWO

2.0 Literature Review

The early attempts to deal with temperature are really dated back in time. At the ancient times, people heated water in many ways like from stove to storage tank. [1]. When wood and coal were the prevalent fuels, water was usually heated in a pot over the fire or in a kettle over a cooking stove. Heating enough water for a bath was a time-consuming ordeal. Later, when running water came indoors, a chamber or pipe loop called a water-back (or water-front) were installed in the fire box of stoves. Heated water moved by convention through this chamber to a storage tank. These tanks were called range boilers. The oldest water-back/front boiler still hooked up and in use dates back to early 1920`s. [2]. One of the most efficient water heaters available today, the Marathon, is an updated side-arm heater. It is very efficient due to its burner separation from storage tank which makes no flue to run through the stored hot water, hence standby heat loss from tank is greatly reduced. [3]. When the 'rain bath' or shower became common, tank-type heaters seemed to gain in popularity because of the water temperature fluctuations then. Innovative ideas of getting hot water from a tank within a few minutes begun. [4, 5].

Before any form of system control was achievable with temperature, temperature measuring instrument such as thermometer had to be invented.The earliest form of thermometer is the simple air-thermoscope which traps air in a bulb so that the air expands or contracts in response to a temperature increase or decrease; it moves a liquid column in a long tube. Thermoscope is the not a thermometer but is its predecessor. The logical distinction between the two is that the thermometer possesses a scale, while a thermoscope does not. Therefore, thermoscope did not go far in use because of this limitation. [21].

The first practical temperature measuring instrument was attributed to physiologist Santorio Santorii (Sanctorius) of Padua would be regarded as the discoverer of the thermometer, for he published the earliest account of it in Part III of his commentaria in artem Medicinalem Galenis (Venice,1612),of which the Imprimatur is dated 1611.Santorio claimed he had adapted thermometer from Heron. He used the instrument to estimate the heat of a patient's heart by measuring the heat of the expired air. Galileo Galilei invented a rudimentary water thermometer in 1593 which, for the first time, allowed temperature variations to be measured. In 1714, Gabriel Fahrenheit invented the first mercury thermometer, the modern thermometer. [25]. Many other contributions were made to the development of temperature measuring devices especially for defined functions. Through the recent capabilities of semiconductor fabrication, modern temperature controllers are during their work beyond expectation. In old thermostats, the temperature sensors were mere coiled bimetallic strip. A bimetallic strip is made by many layers of metal (especially iron and copper) of different expansibilities. The metals that make up the strip get bigger or smaller when they are heated or cooled. When the strip cools off, one side of the metal on the inside of the coil gets smaller and the strip will wind more tightly. When the coil tightens, the circuit is completed by a switch attached to the coil, and the related heating element is supplied with electricity. The switch in the circuit is typically a mercury switch .As the temperature rises, the opposite occurs, and the coil unwinds, opening the circuit and the heater is cut-off. This simple configuration is attributed to applications such as pressing iron .Sometimes; the switch is in form of mercury in tube. [22].

Modern, operations are computer-based for increased flexibility, accuracy, and overall performance.

2.1 Theoretical Background

A reset able water thermostat comprises the following:

1. A temperature sensor (a simple thermometer).
2. A control unit
3. Heating element

The temperature medium usually converts temperature into corresponding electric circuit. The relationship is good to be in a linear scale for acceptable accuracy.

In this situation, where a certain required temperature is needed, within the range of 0°c to 100°c, a very good and sensitive temperature sensor is of great importance. Thermistors, bimetallic and silicon temperature sensors would not be able to keep to the task because they lack accuracy in temperature measurement, hence development of a more precise temperature sensor such as the LM-35 by natural semiconductors. The sensor is attributed to a lot of merits such as high temperature measuring linearity and a good temperature-voltage relationship. [20].

Accurately the sensor's output response to temperature with the relationship 1°c = 10mV. The linearity of this relationship covers the water heating temperature range i.e. 0°c to 100°c. Hence temperature can be measured with a voltmeter due to the relationship. Development of such integrated temperature sensor enhances easy attainability of practical reset able water heating devices. [21].

Due to the numerous advantages of this temperature sensor, I incorporated it into to this project to make my work easy and portable. A suitable component for enhancing the use of LM-35 is a comparator. Comparators compare two signals or voltage levels [28]. It serves as the control/switching unit of the project. The inputs being compared are non- inverting and inverting inputs. The output of comparator defines the input state digitally, for instance, for logical '1' and '0'; the output is logical '1' whenever the voltage at the non-inverting input is greater than the inverting input, and when the inverting input is equal or greater than the non-inverting input, comparator's output is logical '0'. [26]. These states are used for load or output switching operation of the altogether thermostat.

Basic switching is not directly done like older designs. The comparator is referenced with its inverting input to minimize switching errors. The referenced voltage of the aimed temperature to water ought to be in voltage, hence the relationship (1°c = 10mV) is in used i.e. for 60°c , the device is referenced to 600mV, so the heating of the water terminates as temperature is about leaving 60°c. Same response is true for every point within the water heating temperature range (0°c to 100°c) of the sensor.

An alarm is triggered ON to call the attention of the user in order to retain the required temperature of the water. Manual resetting is required to stop alarm and take back the system to its original state for another operation. The switching is carried out through an electromechanical device, a relay.

The project is really economical due to the limited amount of components used during design and quite simple for comprehension. It is robust for longer life.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.0 Block Module

The circuit is designed with high simplicity. The module diagram is shown below.

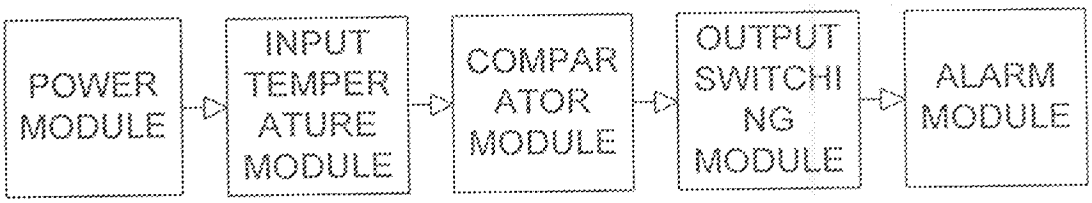

Fig 3.0 Block Module diagram of automatic water heating regulating system.

The major components are cheap and easy to get. The audio alarm is generated by a complementary metallic oxide semiconductor (CMOS) integrated circuit. It provided the circuit with a low power consumption, high compatibility, high fun-out, power supply voltage range and availability. Modern circuit design incorporates the leading logic by reason of the early. The design holds 4000 series complementary metallic oxide mode for implementing logic designs.

The project is divided into five modular designs. Each module is designed for a particular task. The overall operation of these different modules makes up the full circuit implementation. These modules are;

1. Power Module
2. Input Temperature Sensor Module
3. Comparator Module

4. Output Switching Module

5. Alarm Module

3.1 Power Module

The power unit is designed to supply the circuit with the required electrical current for operation, which involves operation of the step down of AC mains to the regulation of a rectified voltage. The main power supply comes from a 220/12V step-down transformer. The rectifier consists of a four-diode configuration with IN4001. It is quite a common rectifying diode. The ripple filtering is done by a 2200μf 35V electrolytic capacitor. The circuit representation is shown on fig.3.1

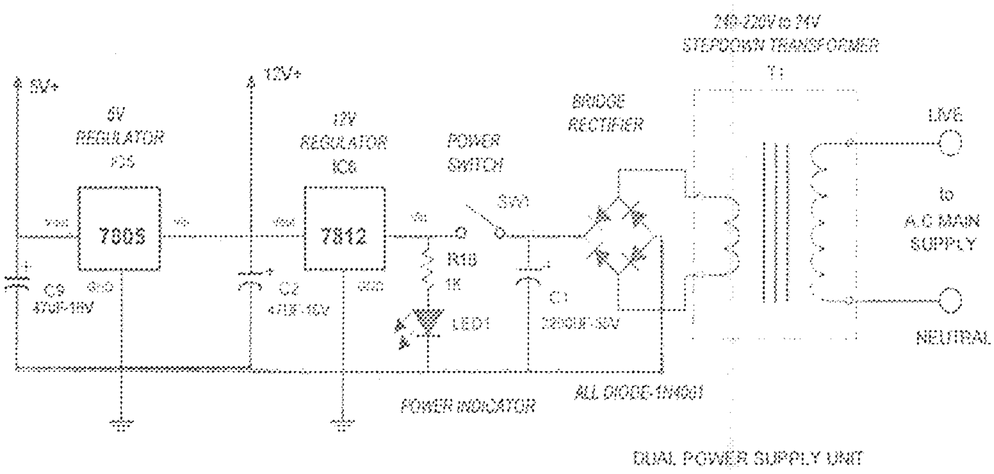

Fig. 3.1 Power supply circuit.

The alternating current from the mains is converted to a suitable form, used by the system components. It (alternating current) passes through the following processes;

1. Transformation
2. Rectification
3. Regulation

3.1.1 Transformation

The transformer of an A/C voltage of a known magnitude (240V) to a lower magnitude (12V) was achieved by using transformer rated 240/12V.

3.1.2 Rectification

This process was achieved by the use of a bridge rectifier, which involves four rectifying diodes connected in a bridge format. This connection allows only two diodes to be active (or in forward bias) at every half cycle of the input alternating current. This results in the rectification or conversion of the output of transformer from A/C to D/C. Due to voltage drop across the diodes, the rectified voltage is usually lower than the expected. The voltage drop is usually compensated during the design and construction of such transformers. It is a normal practice to make a transformer produce more voltage than the rated value so that in situations of voltage drop in course of rectification, the drop would be insignificant. Moreover, the application of a large electrolytic capacitor is required at the output of the rectifier due to the production of ripple in course of rectification. The capacitor usually ranges from 1000µf to 4700µf. Such values result to a reasonable ripple effect reduction at the power supply. A 2200µf, 35V capacitor is incorporated into the circuit. The voltage rating of the capacitor is 35V due to the expected output of around 24V at the rectifier's output.

3.1.3 Regulation

Two regulators are used for deriving lower voltages, but stable to different sections of the circuit. The regulators are 7812 and 7805 with voltage output of 12V and 5V respectively. The objective of the regulators is to stabilize the voltage in the circuit. The 12V regulator supplies a constant power to the relay part of the circuit while the 5V maintains steady voltage at the other parts of the circuit. The 7805 voltage regulator is three terminal positive regular and available the TO-220/D-pak package. The is made to easily protect against short circuits, overheating etc, with excellent properties as a voltage source (e.g. internal resistance measured). The use of 7805 regulator reduces the ripple voltage to a desired level. When adequate heat sinking is provided, it can deliver over 1A output current. Although designed primarily as fixed regulator, this device can be used with external components to obtain adjustable voltages and currents. The regulation to the comparator and CMOS ICs is kept at 5V as shown in fig 3.1 to ensure that the switching of the output device does not affect circuit operation and also to prevent damage to the ICs if any fault condition arises.

A 47µf 16V capacitor is usually in between a particular regulator's output and the ground. It provides more current stability to the output. A power switch is also incorporated into the circuit to open and close complete current flow. The switch's action is indicated through a light emitting diode (LED) indicator. It (LED) looks electrically like a diode with a forward voltage drop of about 2V. They are built with gallium Arsenide phosphate which has a larger band gap and hence a larger forward drop voltage than silicon. It is used as a power indicator.

The 7805 is designed for a supply voltage of about 35V. And it regulates a voltage of 5 at the pin 3 (input). The minimum and maximum output voltages are 4.8V and 5.2V respectively. [13].

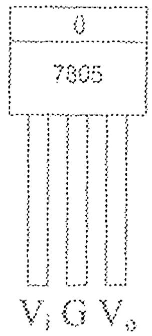

Fig 3.2 Pin layout of 7805 voltage regulator

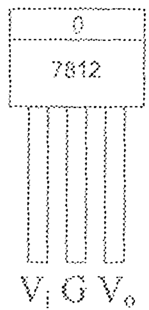

Fig 3.3 Pin layout of 7812 voltage regulator

The light emitting diode is connected in series with a 1kΩ resistor. The leading resistor serves as a current limiting device. It disallows damage to be done to the light emitting device.

The specified voltage for a light emitting diode is 2.3V, taken the supply voltage to be 12V. Therefore, voltage across the resistor for normal no-destruction flow is 12V-2.3V = 9.7V. Let's assume a current of 10mA for such a circuit. Therefore, the value of Ri is

$$V_{Ri}/I_i = 9.7/(10X\ 10^{-3}) = 970\Omega$$

A 1KV is quite suitable for a 970Ω design result. To add more weight, the 7805 (5V regulator) needs the other part if the circuit with a regulated supply of 5V from the rectified 12V supply provided to the transformer.

3.2 Input Temperature Sensor Module

The input temperature sensor used is the LM-35 integrated circuit. This three terminal TO-92 package device converts temperature into corresponding voltage with a precision relationship of 1°c to 10mV. Two of its terminal is usually for power supply while the third one is for temperature recognition. The temperature range is 0°c to 100°c and its overall error is around ±2°c.

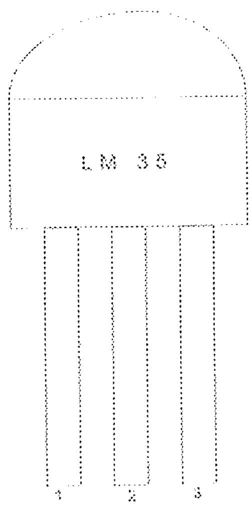

Fig 3.4 Pin assignment of the LM-35 temperature sensor

Key: 1 is voltage input

2 is voltage output

3 is ground

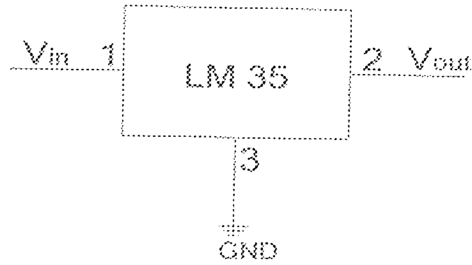

Fig 3.5 Typical circuit for LM-35

In the circuit, the LM-35 is used for monitoring temperature information of the surrounding. It is a preferable option to common thermistor in terms of calibration, linearity and overall result. It provides a easy way of valuating temperature into useable analogue signal, for instance, a temperature of 25°c is converted to 250mV by the sensor. The accuracy within the temperature range is quite remarkable. Its output is then fed to a comparator for further simulation.

3.3 Comparator Module

A voltage comparator is a circuit that compares input signal V_{in} with a referenced voltage V_r when the input signal exceeds the referenced signal. It detects two input voltages; the output of the circuit is proportional to the signal between the inputs.

3.3.1 LM-339 (quad-operational amplifier) as a comparator

The integrated circuit is a quad-comparator package with a four inbuilt unit; it is designed with the following features:

1. Single or split supply operation
2. Low input Bias current 25nA (typical)
3. Low input offset current ±5.0nA (typical)
4. Low input offset voltage
5. Input common mode voltage range to ground
6. Low output saturation voltage 130mV (typical) at 4.0mA
7. TTL and CMOS compatible
8. ESD clumps on the input increase reliability without affecting device operation

It is used in this project as digital voltage comparator circuit for monitoring a particular response of input from the temperature sensor. Hence, the output voltage level therefore represents the output voltage of decision. [7, 9, 10].

Each unit of the device possesses two inputs and a single output. The inputs are at the inverting ($V_{in(-)}$) and non-inverting($V_{in(+)}$) terminals. The output responses to the states of the inputs in the sense that the former is in its high (logical 1) state whenever the voltage at the non-inverting input is greater than that of the inverting input and it is close to the supply voltage (Vcc).The output changes to its low state (logical 0) or relatively zero voltage whenever the voltage at the non-inverting input is less than that of the non-inverting terminal. These results are used in any design involving a comparator.

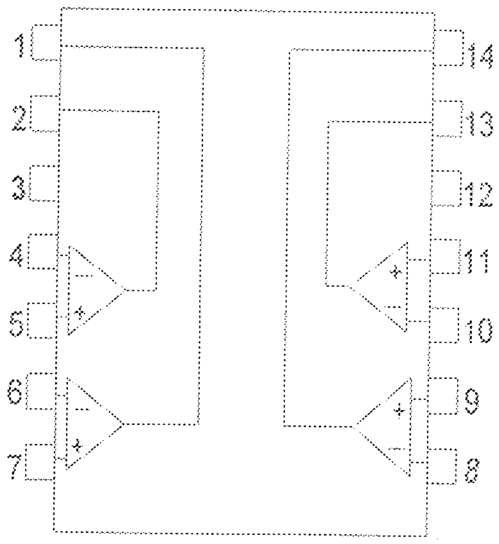

Fig 3.6 Pin assignment and internal circuitry of LM-339

Based on manufacturer's specification, the LM-339 integrated circuit's output which is an open collector terminal is usually loaded with 10kΩ. Single unit is used for the circuit.

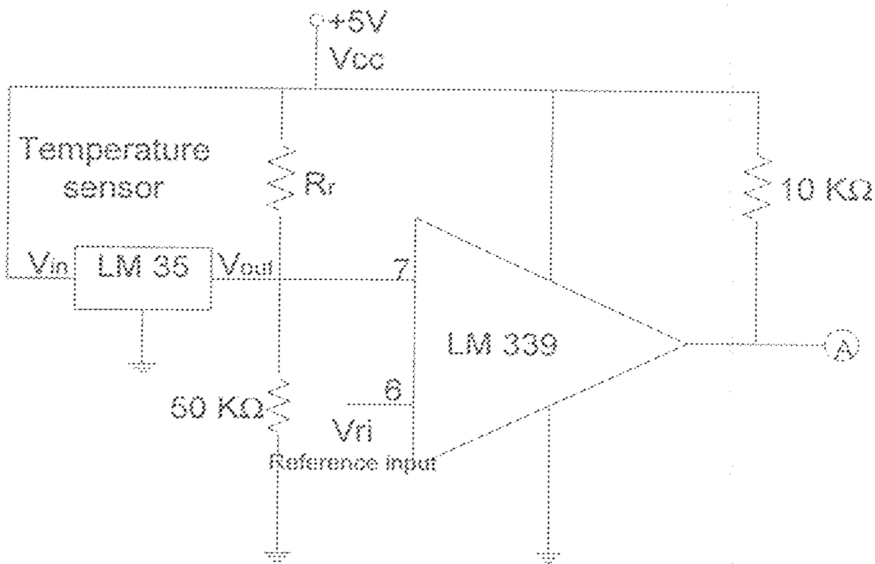

Fig 3.7 Comparator's circuit

The temperature sensor's output is connected to the non-inverting input of the comparator hence assumes voltage at this terminal ($V_{in(+)}$). The inverting input is referenced to a particular voltage usually greater than the value expected at the non-inverting input so that, the initial condition of the output terminal 'A' is logic '0' or relatively zero voltage. A value, R_r is required, to set the full range of VR_1 at 0mV to 1000mV, hence from the temperature-voltage relationship, the range corresponds (0mV-1000mV = 0°c-100°c).

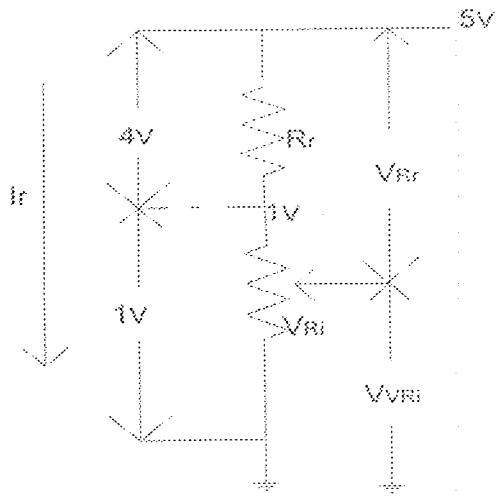

Fig 3.8 Reference resistance circuit

The series connected resistors are supplied with 5V; hence voltage expected at VR_1 is 1V. 4V is expected across R_r Current through resistors is given as

$$I_r = 5/(R_r + VR_1)$$

$$V_{VR1} = (5/(R_r + VR_1)) \times VR_1$$

$$1 = (5/(R_r + 50) \times 50$$

$$R_r + 50 = 250k\Omega$$

$R_f = 200k\Omega$

Therefore, R_f is 200kΩ for a voltage range of 0 to 1V at the inverting input of the comparator.

The reference input allows a particular temperature to be responded to by the circuit, that is, when the reference is set to 0.5V, the output changes from initial state of logical '0' to '1' as the voltage from temperature sensor is about leaving or going beyond 0.5V. Normally, the logical '1' output is to cut-off further temperature raise in heating effect. The result is temperature regulation within a particular or fixed range.

Terminal A is the control terminal. It is used for controlling the output switching unit. Power is supplied to an electrical plug or socket whenever the output of the comparator is low but cut as the output changes from logical '0' to '1'. [23, 26].

3.4 Output Switching Unit

This unit is designed to respond to input from the temperature sensor versa the comparator in controlling the flow of current through a particular terminal. The circuit mainly comprises of an SR latch, transistor and relay.

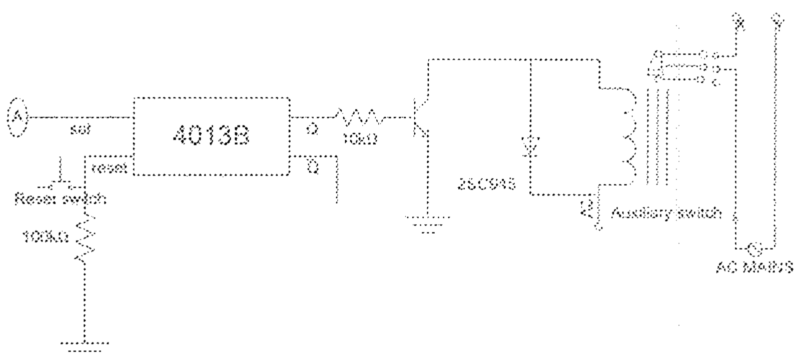

Fig 3.9 Output switching module.

3.4.1 The SR latch (4013B)

This device is designed with CMOS logic. It is responsible for the input latching of the circuit. The integrated circuit consists of two identical independent data-type flip-flops. Each flip-flop independent data-type, set, reset, and clock inputs and Q and Q (not Q) outputs. These devices can be used for shift register application input, for counter and toggle applications.

The logic input present at the data input is transferred to the Q output during the positive going transition of the clock pulse. Setting and resetting is independent of the clock and is accomplished by a high level on the set or reset line respectively. The flip-flop can be configured to work only as a SR flip-flop by grounding only data and clock inputs.

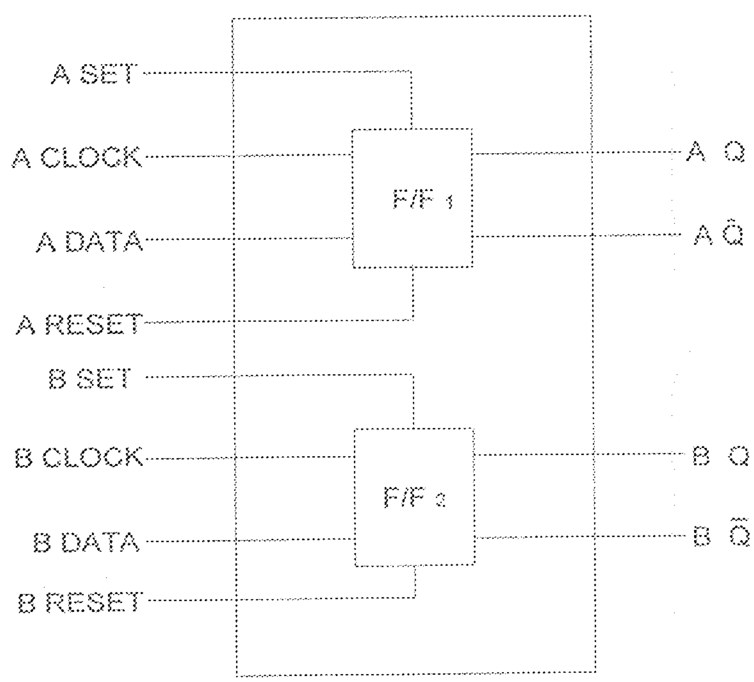

Fig 3.10. Functional diagram of 4013B

The signal of the comparator was connected to the set terminal of the SR latch. The main function of the latch is to hold or store the output condition of the comparator with respect to this project, the feature allows the heating of water to stop completely even when the water is dropping below the required heating temperature.

By setting, it changes Q input from logical '0' to 1'. The logical output is required for switching ON and OFF of an NPN transistor (25C945). The transistor is designed to control a 12V relay. The transistor is merely a switch for getting the relay with an open or close circuit is state. A reversed bias diode is usually incorporated into the circuit at the collector of the transistor to cancel out the effect of back e.m.f due to change of flux in the inductive component of the relay. The e.m.f could damage the transistor. The relay has a resistance of 400Ω. Therefore, the transistor saturation, the expected current at the collector is given below

$$I_c = 12/400 = 0.03A$$

25C945 NPN transistor has a typical current gain value or life of 100

Therefore, $I_B = 0.03A/100 = 0.3A$

The base resistance of the transistor is expected as:

$$R_B = (5\text{-}0.7)/\ (0.3 \text{ X } 10^{-3})$$

$$= 1433.33\Omega$$

3.4.2 The 2SC945 NPN transistor.

The 2SC945 is an NPN bipolar transistor designed for use in the driver stage of Audio Frequency (AF) amplifier and low speed switching applications. It has a current gain h_{fe} of 170 at 30^{o}c. Temperature affects the current gain of the device. [27]

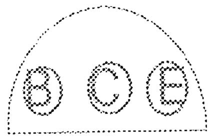

Fig 3.11 Pin layout of 2SC945 transistor

Where B is the base terminal,

C is the collector terminal and

E is the emitter terminal. [27]

To stabilize the concerned pin whenever the push button is inactive, a resistance value of 10kΩ is used due to expected drop in voltage at the Q input. [10]. This is attributed to impedance factor.

Moreover, the initial condition of the relay is terminal C making contact with terminal B so that when the auxiliary switch is closed, an AC mains voltage is set across points X and Y, that is, a plug heating device works by the condition. But when the transistor is saturated due to the high state at comparator's output, contact C is attracted to A. This results into breaking of the required current to the X and Y terminal. Heating definitely stops. To begin or resume current supply to the X and Y terminals, the reset button is pressed, in which the transistor is cut-off due to low logical level at its base. Terminal C returns back to B. The control latch also operates the alarm unit. [24].

Table3.1 SR flip-flop truth table

S	R	Q	$\bar{Q}$
1	0	1	0
0	1	0	1
1	1	1	1
0	0	Qx	$\bar{Q}x$

3.4.3 Transducer

It is a device that converts energy into electrical signals. There are of two types:

1. Input transducers (examples are Thermistor, Photocells, Thermocouple etc)
2. Output transducers (examples are loudspeakers, Motors, Solenoid, Electronic valves etc)

Transducers may be a small part of a system and they are very important device in electronics that especially in control system owing to the success of any control system in terms of its operation and performance which often depends on the quality, sensitivity and stability on the input sensor. This sensor has to pick up the small changes in the input qualities and translate these tiny changes into useful electrical signals. [18].

3.5 Alarm Module

It mainly involves an oscillator. A 4060B oscillator is used in the circuit. It is configured at the RC mode.

3.5.1 Oscillator (4060B)

It is a 14-stage binary ripple counter with an on-chip buffer. The oscillator configuration allows design of either RC or crystal oscillation circuits. Also included on this is a reset function which places all outputs into the new state and disables the oscillator. A negative transition on clock will advance the counter to the next state. Schmitt trigger action on the line permits very slow rise and full times. Although the device generates ten frequencies, only two are used in the circuit. The low frequencies are within the audio frequency range, one is relatively high and the other low. They are mixed together in a mixer latch to generate the needed alarm effect. The integrated circuit possesses fourteen binary internal dividers that breakdown a relatively high main frequency of which ten of the resulting frequency are fed out of the device.

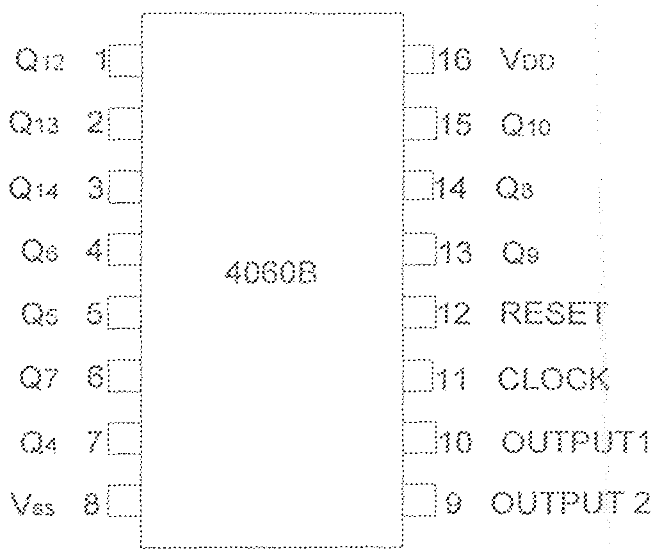

Fig 3.12 Functional Diagram of 4060B

Application of the oscillator includes time delay circuits, counters controls and frequency dividing circuits. The integrated circuit is fully static operation, diode protection or all inputs, supply voltage range from 3.0V to 18V, capable of driving two low-power TTL loads or one low-power TTL load over the rated temperature range, buffered outputs available from stage 4 through 10 and 11 through 14, common reset line. It is designed to have a main oscillation and ten frequency outputs from its pin. The integrated circuit holds sixteen pins in which ten of such are used for corresponding frequency outputs. The pin 12 is used for enabling and disenabling the integrated circuit so it has to be low. It is a control terminal. A specific resistor and capacitor are connected to the leading pins. [8].

The Q outputs have specified frequencies based on internal division of the integrated circuit. Output 1 and 2 are assigned for both RC and crystal oscillator mode. RC mode is used in the circuit which determines the oscillation frequency. Clocking of the device is done with negative pulse.

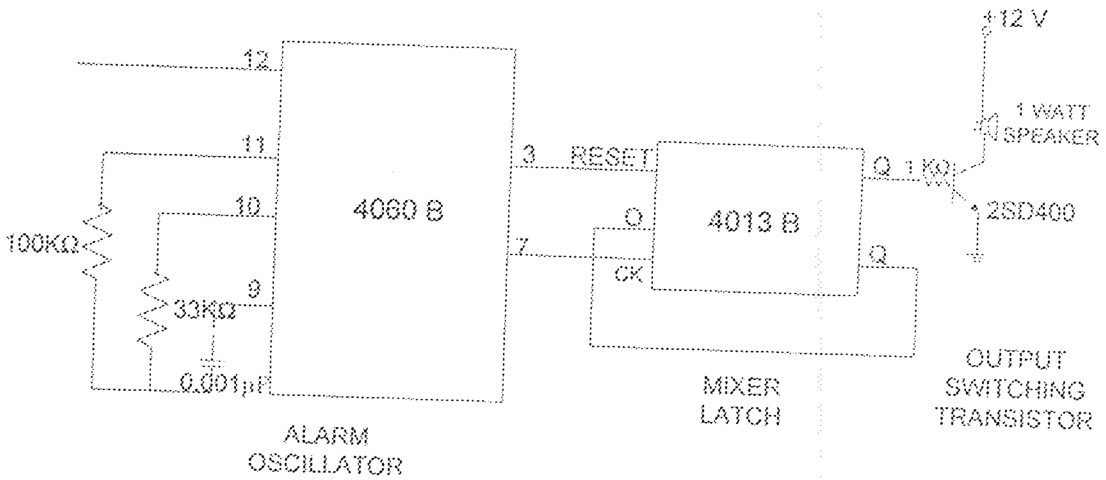

Fig 3.13 Functional diagram of the alarm unit

Base on the manufacturer's data sheet of the 4060B, the main frequency is

$$f_m = 1/(2.3RC)$$

$f_m = 1/(2.3 \times 33 \times 10^3 \times 0.001 \times 10^{-6})$

$f_m = 13.2kH_z$

The formula have a limited application for it only gives the idea or range of frequency operation of the device. The resistor at terminal 11 of the device must be atleast twice and less than ten times the value of the one at terminal 10.

$$2R2 \leq R1 \leq 10R2$$

Where f is in hertz, R in ohms and C in farads.

The values used in the circuit are quite common and typical. Formula for output is

$$f_x = f_m/2^x$$

Frequency output from pin 3 $= f_m/2^{14}$

$= (13.2 \times 10^3)/2^{14}$

$= 0.8H_z$

Frequency output from pin 7 $= f_m/2^4$

$= (13.2 \times 10^3)/2^4$

$= 825H_z$

The mixer latch mixes the two frequencies to generate an alarm result. The mixer latch is a toggled configured flip-flop. Its Q output is connected to the base of a 2SD400 transistor. The transistor was incorporated into the circuit to intensify the strength of the audio signal from the mixer latch.

Assuming is at the complete or full ON state, the expected current at the collector is given below:

$I_c = 12/8$

$= 1.5A$

The value is lower in real or more practical situation.

The transistor possesses a typical current gain or life of 100.

Therefore, I_b = 1.5/100

= 0.015A

Hence, base resistance R_b is (5-0.7)/0.015 = 286.7Ω

The oscillator produces the audio frequencies for the alarm and because the transistor has a maximum allowable collector current of 1A, the base resistor is increased to drop the expected voltage at the collector of the transistor.

3.5.2 The 2SD400 transistor.

The 2SD400 is a NPN epitaxial planar silicon transistor. It is a complement of the 2SB544, its PNP equivalent. it possesses a maximum collector to base voltage V_{cbo} and collector to emitter voltage V_{ceo} of 25V while it's emitter to base voltage V_{ebo} is 5V. The 2SD400 handles a maximum collector current I_c of 1A and can handle 2A when pulsed. It has a peak power output of 900mV at the effective operating temperature of 150^0 c ,therefore it is used for high current applications. [27]

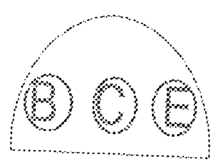

Fig 3.14 Pin layout of 2SD400 transistor.

Where B is the base terminal,

C is the collector terminal and

E is the emitter terminal. [27]

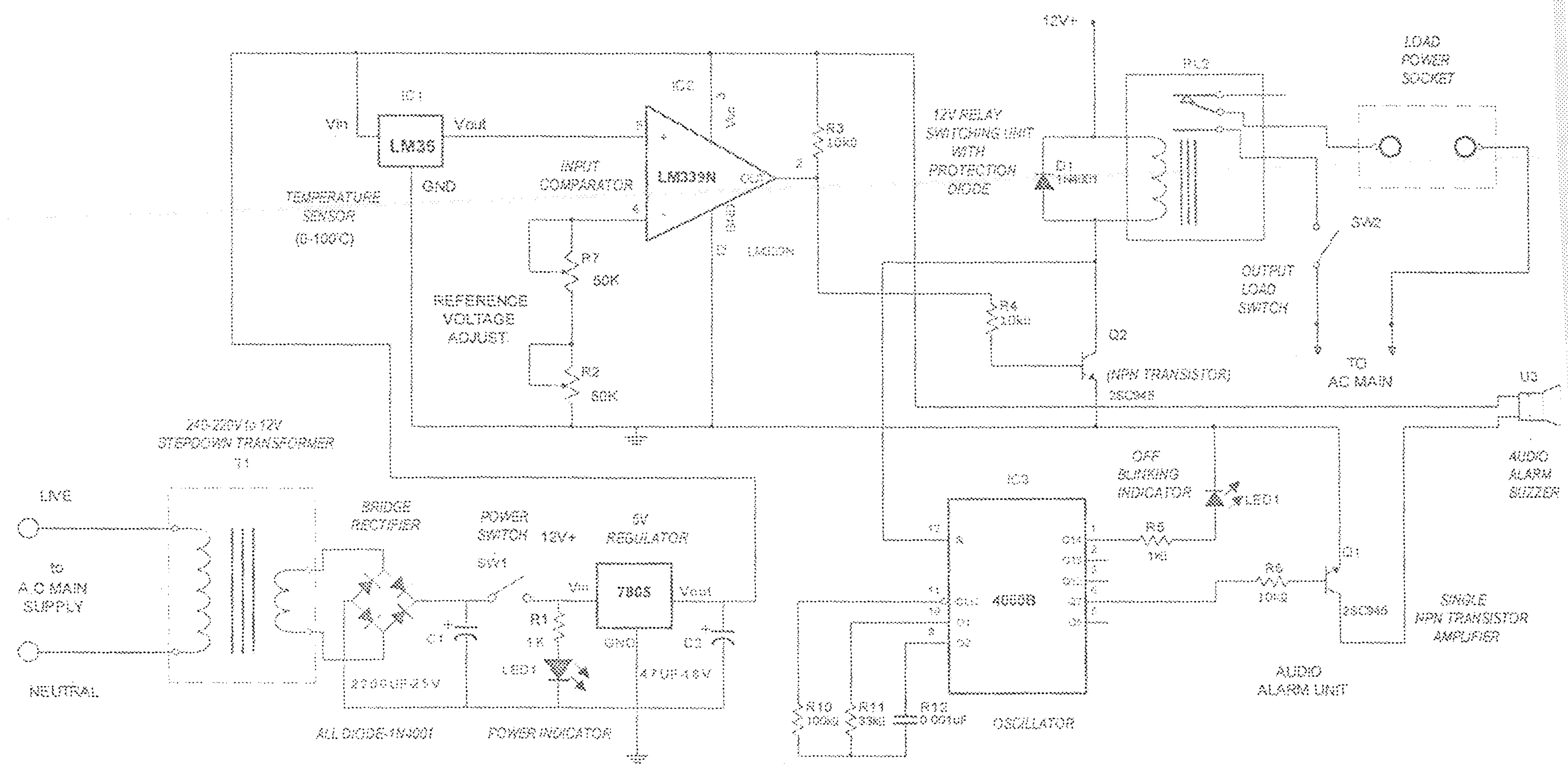

Fig 3.15 circuit diagram

CHAPTER FOUR

TEST, RESULTS AND DISCUSSION

The circuit connections of the Automatic Water Regulating Heating System were carefully constructed with durability in mind.

4.0 Circuit Construction

The circuit construction involved stages. A suitable Vero board was cut into a suitable size that should contain all components involved. The power circuit was first constructed on board after all metallic surfaces on the board were strictly scrapped with razor blade. The operation encourages smooth and neat soldering of the leading components on the Vero board because usually the surface of the board is covered with dirt which limits 'metal to metal' soldering contact. Utmost care was taken to avoid short circuit. The components were put in place using soldering iron and connected with jumper wires. Sub-circuits were interconnected, so that a whole new circuit was achieved. The circuit was set to meet the aim of the project by careful adjustment of the values of critical components like the resistor and capacitors towards the output section of the device. Soldering operation was carefully done to prevent destruction of components which were handled with care to avoid 'static electricity effect or damage'.

4.1 Arrangement

The assembling of components of this was straight forward and the design layout was carefully followed to avoid wrong connection of some of the components.

The assembling of these components was divided into two stages; the stage was an experiment which involved mounting of component on a breadboard. After undergoing this stage, necessary adjustment was made to the circuit so as meet the specification and standard required, then the circuit construction was mounted on a Vero board.

4.2 Soldering

Some soldering precautions taken are outlined below:

1. Little but enough solder was applied to any joint to ensure proper contact of the components.
2. Care was taken to ensure proper soldering of each joint, so that the lead of individual joint would not heat away
3. Heat sink was used to conduct heat away.
4. Ensured that soldering-iron temperature was not too high to avoid damage resulting from over-heating

4.3 Difficulties Encountered

Difficulty encountered during the construction of this project involved:

1. Unclose connection, which was bridge with a wire.
2. Short circuit that rises through de-soldering of concerned.
3. Re-adjustment or re-designing of the circuit to fit the real target.
4. Unavailability of some components, which resulted in looking for substitutes.

4.4 Testing

The testing was done in two stages, the initial testing stage and the final testing stage.

4.4.1 Initial Test

The system was powered from the 12V DC supply after the components have been mounted on the Vero board and proper safety precaution carried out. Heat was gotten from the soldering iron which was carefully placed very close to the temperature sensor so as to sense heat and activate the system. There was an audible beep sound from the loudspeaker when the temperature was up to the adjusted nub of the variable resistor according to the temperature-voltage relationship of sensor. Alarm stopped immediately heat was taken away.

4.4.2 Final Test

This was done by setting the preset temperature to a value while a boiling ring and temperature sensors were deep into water in a bowl. The device was ON. Heating effect on water was expected for a while before it was cut-off.

The boiling ring was supplied with electricity from the control device. Different temperatures were adjusted to in the testing to check the accuracy of response.

4.5 Discussion of Result

It was seen that the temperature output increased with increase in temperature. Although the involved device does not have a temperature display unit, the internal precision calibration of the involved temperature sensor made the heater switching of significant accuracy.

The result of the test was mainly based on the fact that the initial condition of the involved heater was ON. The heating effect raised temperature of water in the bowl and that of the temperature sensor. When the sensor attained the preset temperature, the heater was automatically switched OFF. The switching went on with the triggering on of the alarm which indicated that the water was at the required temperature.

It was observed that the device was not incorporated with a thermostat feature which involved the regulation of the temperature of water. By the moment the heater stopped working, the temperature of the water started dropping due to no heating effect.

4.6 Precautions

During the construction of this project, the following precautions were taken:

1. All integrated circuits were protected from heat related damage through the application of corresponding socket.
2. The temperature sensor is protected for liquid related damage by proper metallic sealing.
3. Sensitive parts of circuit were properly insulated to prevent short circuit.
4. The components were given reasonable space during soldering to prevent unwanted connections.
5. The circuit was firmly screwed to the casing for rigidity to prevent unexpected removal of wires.

4.7 Packaging

The complete unit was housed in a plastic case due to availability, conveniency and it was relatively cheap.

The side view of the casing is given below:

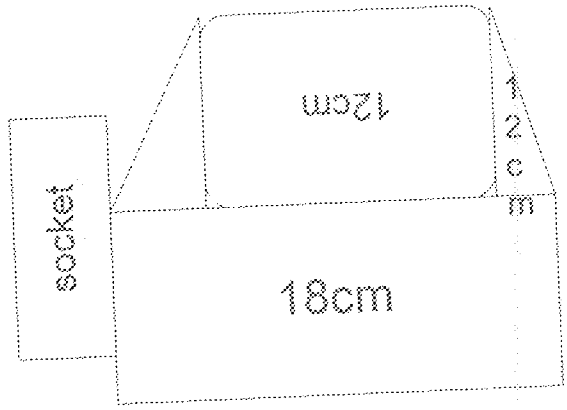

Fig 4.1 System packaging

Length = 18cm

Breath = 12cm

Height = 12cm

Total volume of casing is

$$18 \times 12 \times 12 = 2592cm^3$$

CHAPTER FIVE

CONCLUSION

The design and construction of this project was successfully carried out as described. The demonstration of the temperature control of water depends solely on the temperature sensor (LM-35) due to its temperature-voltage conversion ability and relationship. The aim of the project which is the ability of the device to be able to heat water to a certain desired temperature and alert the user immediately by alarming a sound was achieved.

Result obtained during final test may not be as accurate as that of initial test due to the metal steel used as protection for the temperature sensor so that the water to be heated would not damage it. The initial test might be more accurate because of the direct contact of temperature sensor and heat source. Unavailability of relatively tin steel that would conduct heat as fast as accurate was a contributing factor to the uncertainty on accuracy of the final test.

The project could be further worked upon. It can serve as a stepping stone for persons interested in designing and constructing modern water heating temperature control systems with sensitivity and lower rate of false alarm. Some recommendations are:

1. Incorporation with a thermostat effect in regulating the temperature of the water.
2. Incorporation of a digital temperature display to show the readings and preset of temperatures.
3. Modification for computer interfacing.
4. Usage of wide range temperature sensor for super-heating.

5. Incorporation with time based heating, for timing of the water for a specific heating.

Thus, it is hoped also that it will provide a solution to the difficulty of life in several places of work, houses and industries.

Older project involving thermostats could take advantage of this new technology because the use of the device in this project is an evident improvement to earlier related works.

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