DESIGN AND CONSTRUCTION OF AN AUTOMATIC TEMPERATURE CONTROL FOR HEATING DEVICES WITH ALERTING SOUND SYSTEM

BY

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2003/15466EE

DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE, NIGERIA.

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A THESIS SUBMITTED TO THE

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DEDICATION

This project is dedicated to God Almighty and to my parents; Mr. and Mrs. Raiyetunbi.

DECLARATION

I, Raiyetunbi Simeon O.Bright, declare that this work was done by me and has never being presented for the awards of a degree. I also hereby relinquish the copyright to Federal University of Technology, Minna.

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ACKNOWLEDGEMENT

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ABSTRACT

This project is on the design and construction of an automatic temperature control for heating devices with alerting sound.

The motivation behind this project is to improve on the design and construction of a temperature controller incorporating visual indicator (visual alert) and audio (sound) alert as the desired temperature is reached.

The introduction of automatic control system brought about the elimination of human error during temperature control process.

This project makes use of LM35 (centigrade sensor) which senses temperature from the heating element and converted it to its equivalent voltages. The output of LM35 is compared with a reference voltage level by a comparator whose output controls the relay via the Schmitt trigger operation.

This project works perfectly within the room temperature and the boiling temperature of water.

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CHAPTER ONE

GENERAL INTRODUCTION.

1.0 BACKGROUND STUDY

Many methods have been developed for measuring temperature. Most of these rely on measuring some physical property of a working material that varies with temperature. Some of the common devices for measuring temperature are: glass thermometer, thermocouple, resistance temperature detector (RTD), thermostats, and infrared e.t.c [1] But the regulation and control of temperature for heating devices or a particular area (room) has been a great concern of electrical engineers over the years. The invention and application and of sensing devices with high precision such as silicon sensors have added to the beauty of modern technology, especially in electrical and computer (electronics) engineering aspect.

This project is aimed at designing and constructing an automatic temperature controller. It offers a high degree of flexibility and precision that simply cannot be matched by mechanical thermostats. The heart of the devices is a National semi conduct's linear /precision temperature sensor (LM35). A sensor is usually accompanied by set of specifications that indicate its overall effectiveness in measuring the desired variable. [2] The sensor is a transducer that is campable and converting physical quantity such as force, temperature, pressure e.t.c. into a more readily manipulated electrical quantity. It provides reasonable 6temperature monitoring technique and have a voltage output terminal that is linearly proportional to the Celsius temperature. The relationship is that every one degree centigrade is corresponding to "10mv" at the output; the relationship is quite precise because the sensor is already calibrated to standard Celsius temperature during its manufacturing procedure. [3]

Automatic temperature controller is used to control a relay to supply power to a small space heating devices through the relay contact. The circuit contained comparators circuit that compares the output from the temperature sensor with a referenced voltage and a sounder IC. The sensor detects temperature changes and the sounder sounds when present temperature is reached.

The referenced voltage is adjusted for different response and ranges. This is done through the variable resistor 9 with assumed values of 100kΩ) which alloOw the devices to adjust its hystersis range (temperature range when relay engages and disengages).

During operation, the resistor is adjusted so that the relay triggers off at a desired temperature and gives an alerting sound. After few centigrade drop in temperature, the relay triggers ON and remains ON until temperature again rise to preset (desired) level.

This circuit automatically converts changes in temperature sensed by the temperature sensor (LM35) from system into change of voltage. [4]

It compares the output dries with the voltage of the preset temperature using the comparators and finally drives the relay.

This project is suitably applicable fro boiling ring domestic heater, temperature fan, incubator, and every other heating device that operate within the specified range of voltage and temperature.

1.1 AIMS AND BENEFITS

- The introduction of an automatic control system brought about the elimination of human error during temperature control process.
- It reduces fire outbreak caused by heating devices
- It enables desired temperatures to be obtained with an alerting sound system

1.2 SCOPE AND LIMITATION OF THE PROJECT.

This design and construction of automatic temperature control system and alerting sound for heating devices that ranges between the temperature of 0°C and 100°C. hence, it is most suitable for domestic use not for industries that require high temperature application. Also, the heating control is done through relay switching, the frequent turning ON and OFF when it gets to the preset point may damage the motor.

1.3 METHODOLOGY

The method and procedures employed to carried out project is explained with the below block diagram below.

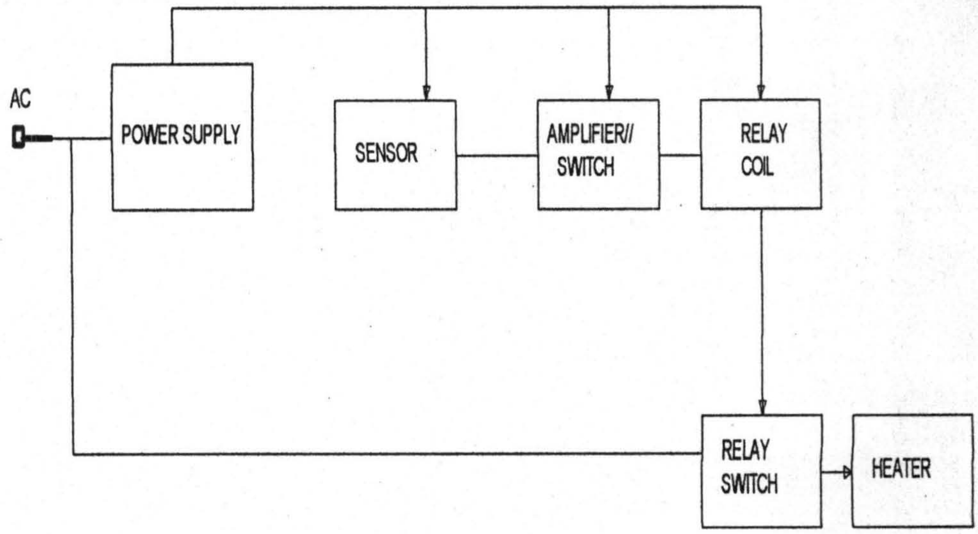


Fig.1.0 Block Diagram

A low voltage DC supply voltage of 9volts was chosen for system operation. This voltage was derived from 12v 0.5A step down transformer connected to a four diode full wave bridge rectifier (FWBR)

This project makes use of LM35 (centigrade sensor) which senses temperature from the heating element and converted it to its equivalent voltages. The output of LM35 is compared with a reference voltage level by a Schmitt trigger whose output controls the relay via the transistor operation.

1.4 PROJECT OUTLINE

This project thesis is grouped into five (5) chapters: the background study, the literature review, the project analysis and design, construction and testing a recommendation/ conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.0 TEMPERATURE HISTORY

The commonest measured parameter in the world so for is temperature because of its diverse applications to human life.

The knowledge about temperature had being in existence for ages people knew then that fire is hot and snow is cool. Actually, the knowledge about temperature grew as man attempted with metal through the gold, silver and bronze ages. Most of these technological processes really required some degree of regulation over temperature. But in order to regulate, the ability to measure what you are regulating is required.

Common sensor used for the measurement of temperature includes resistance thermometers, thermostat and thermocouple. Sensor is classified as analog and digital. Digital sensors have logic output level that can be directly interfaced to a computer. Analog sensor produces an output voltage that is proportional to the measured variable that required the use of analog to digital converter (ADC) to interfaces analog sensor to a computer.[3]

2.1 HISTORY OF TEMPERATURE MEASUREMENT

In the early 1600s an Italian physicist named santorio Santorio developed a crude thermometer-like device which he referred to as a "thermoscope". In some ways resembling type liquid filled thermometer of today, it lacked any sort of calibrated scale, and the tube was open to the atmosphere, which adversely affected its accuracy due to variations in barometric pressure. [1]

Also, in the early 1600s, among his other scientific credits, Galileo Galilei reportedly invented another style of thermoscope, sometimes referred to as a Galileo thermometer. This type of instrument, which is still available as more of a decorative item than a functioning thermoscope, operates on the principle of buoyancy. [4]

As the temperature of the clear fluid contained within its vertical glass cylinder increase, the fluid expands and that has a slightly specific density corresponding to fluid temperature, to sink within the cylinder as their density become greater than that of the fluid in which they are submerged. The temperature is read from a small engraved metal disc on each sphere. The current approximate temperature is indicated by the lowest floating glass sphere appearing in the thermoscope. [5]

Further development of temperature measurement still using as the indicator and a calibrated scale to measure the fluid displacement in relation to temperature is credited to such scientist as Ole Christensen Roemer, who in 1701 reportedly made one of the first practical thermometers, using red wine as the indicator, Daniel Gabriel Fahrenheit, who soon after developed a more accurate mercury filled thermometer and thermometer scale. And Celsius (also in the 1700s), who developed a metric scale of temperature measure. While Thompson (Lord Kelvin) and William Rankin were credited in the mid-1800s with having broadened the calibrate temperature measurement scale range to include "Absolute zero" thus, making it more useful for research purpose. [2].

As technology in the area of physics, metallurgy and electrical electronic engineering have progressed since 1800s, so has temperature measurement and control. Many applications that require remote monitoring and for remote control of thermocouple, thermistor, or resistance temperature detector (RTD). [6].

Automatic temperature controller is an instrument, which directly or indirectly control one or more source of heating to maintain a desired temperature. It is a device that monitor and automatically responds to change in temperature or air conditioner. The sensing element ensures change in the temperature and produces a desired effect on the transducer. The transducer converts the effect produced by the sensing element into a suitable control of the device or devices, which affect the temperature [7].

The most commonly used principle for sensing changes in temperature are;

i. Unequal rate of expansion of two dissimilar metals handed together (bimetals)

ii. Unequal expansion of two dissimilar metals (rod and tube).

iii. Liquid expansion (sealed diaphragm and remote bulb or sealed bellows with or without a remote bulb).

iv. Saturation pressure of liquid vapour system and

v. Temperature sensitive resistance element.

The most commonly used transducers are;

i. Potentiometer with a wiper that is moved by the sensing element.

ii. Switches that make or break an element circuit.

iii. Pneumatic actuator and

iv. Electronic amplifier.

CHARTER THREE

DESIGN ANALYSIS

3.0 CONSTRUCTION PROCEDURES

The automatic temperature control unit with audible alert system comprises the following sub systems;

i. System power supply
ii. LM35 temperature to voltage transducer
iii. 23 DC amplifier
iv. Schmitt trigger.
v. 6v 10A relay power switch

3.1 SYSTEM POWER SUPPLY

A low voltage DC supply voltage of 9volts was chosen for system operation. This voltage was derived from 12v 0.5A step down transformer connected to a four diode full wave bridge rectifier (FWBR) as diagrammed in fig 3.0

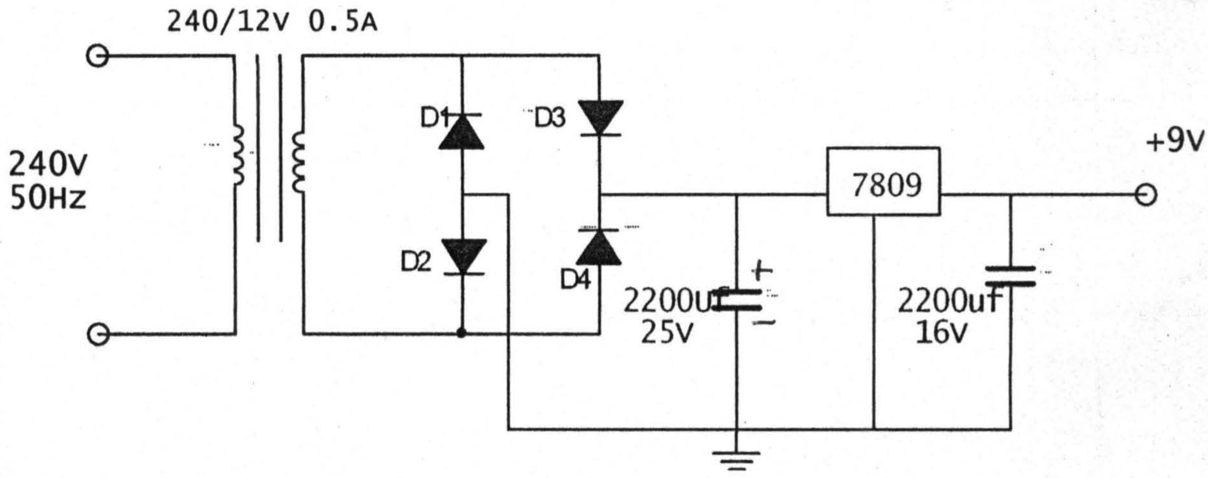


Fig. 3.0 system power supply

The 240v Ac mains supply was stepped down to a low voltage 12v Ac by a step down transformer with a 20:1 voltage transformation ratio. The 12v Ac voltage was converted to a pulsating Dc voltage with amplitude.

$$V_{DC} = V_{RMS}$$

This value of voltage was smoothed by a capacitor whose value was deuced from the expression.

$$Q = CV = It$$

$$C = \frac{It}{V}$$

Where

I = Maximum load current.

t = Period of the unsmoothed DC voltage

- 1/f = half wave rectifier

½ F = Full wave rectifier

C_f = 50Hz in Nigeria.

The 7809 regulator requires a minimum input voltage of 11 volts to maintain a regulated output on a 155v peak Dc voltage, the maximum allowable ripple voltage is then;

15.5 - 11 = 4.5V

The maximum current was computed by the addition of the operational current values of the components with system.

Power Led/ Load LED = (10mA + 12 mA) = 22mA

LM 35................Negligible

LM 35Q: 5mA

Putting (On) = 9/40Ω = 22.5mA

The total system current was thus fixed at 5mA

$$C = \frac{It}{V}$$

$$= \frac{0.05 \times 1/(2x5)}{4.5}$$

$$= \frac{0.05 \times 0.01}{4.5}$$

$$= \frac{5 \times 10^{-4}}{4.5}$$

$$= 1.1 \times 10^{-4}$$

$$= 110\mu F$$

The above value of capacitance is the minimum required on the DC output to ensure regulation. The value was increased to 2200μF to improve system operational characteristic at low AC input Voltages.

7809 9-Volt regulator

A 3- terminal fixed voltage regulator was used to provide a ripple free Dc output voltage. The device is capable of supplying an output current of 1A. The device is packaged in a TO220 package as shown below.

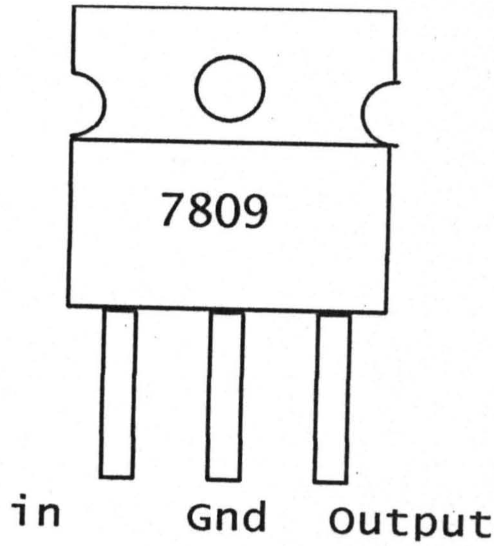
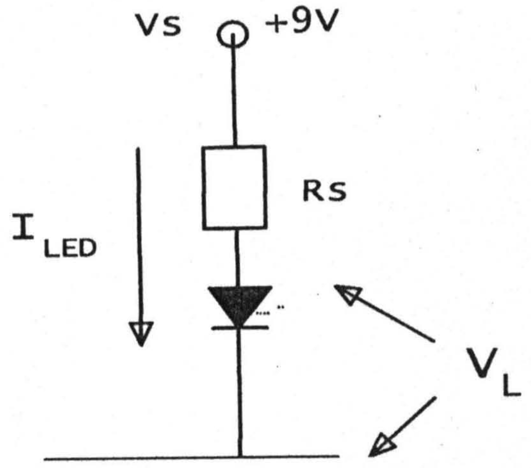


Fig 3.1 7809 regulator

A system power on indicator was provided on the unit to indicate the presence of local Ac main supply.



The Led was connected across the 9volt Dc output through a series current limiting resistance of value calculated from the expression.

$$R_s = \frac{V_s - V_{LED}}{I_{LED}}$$

V_{LED} = 1.7v

I_{LED} = 5mA

A 7Ma led forward current was selected for device longevity.

R_s = 9 – 1.7 = 7.3 = 1050kΩ = 1 kΩ

3.2 LM35 PRECISION CENTIGRADE TEMPERATURE SENSORS

LM 35 temperature to voltage transducer

A transducer was needed to interface the control unit with the temperature level of the surrounding. An Lm35 temperature sensor was used.

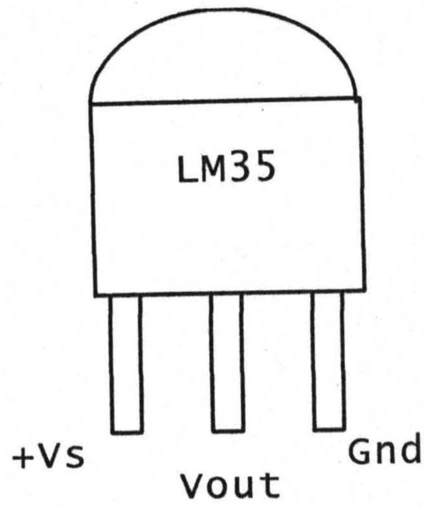


Fig. 3.2 a front view of LM35 temperature sensor

The LM35 is an integrated circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (centigrade) temperature. The Lm35 thus has an advantage over linear temperature sensor calibrated in Kelvin, as the user is not subtract a large constant voltage from its output to obtain convenient centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ¼ °C over a full -55 to + 150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry easy. It can be used with single power supplies or with minus supplies. As it draw only 60μa from its supply, it has very low self-heating, less than 0.1°C still air. The LM35 is rated to operate over a -55° to + 150°C temperature range, while the LM35C is rated for a – 40° to + 110°C range (-10° with improved accuracy). The LM35 series is available packaged in heretic TO-46 transistor packages, while the LM35C, LM35CA, and Lm35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-led surface mount small outline package and a plastic TO-220 packet.

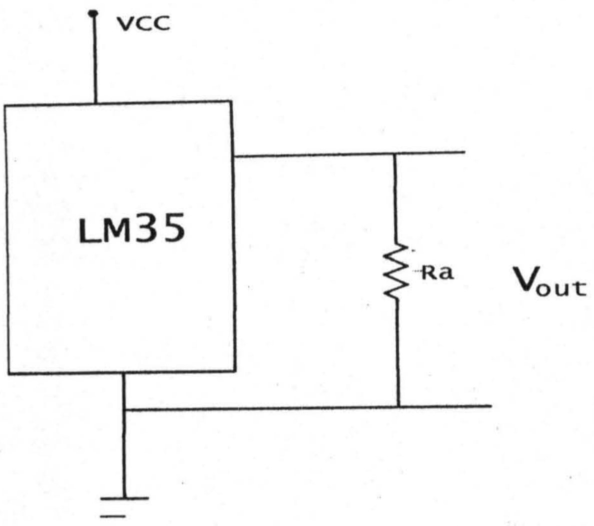


Fig 3.2 b Electrical connection of LM35

This device has the specifications listed below.

- The sensor has a sensitivity of 10mA/°C
- Use a conversion factor that is the reciprocal that is 100°C/V.
- Temperature equation used to convert output voltage to temperature is|: Temperature (°C) = Vout (100 °C/V).

  So if Vout is 1V, then, Temperature =100 C
- The output voltage varies linearly with temperature.
- Very low output impedance
- Supply current <1mA

The LM35 comes in many different packages, including the following

- TO-plastic transistor-like package,

- TO-46 metal can transistor-like package
- 8-lead surface mount SO-8 small outline package
- TO-202 package

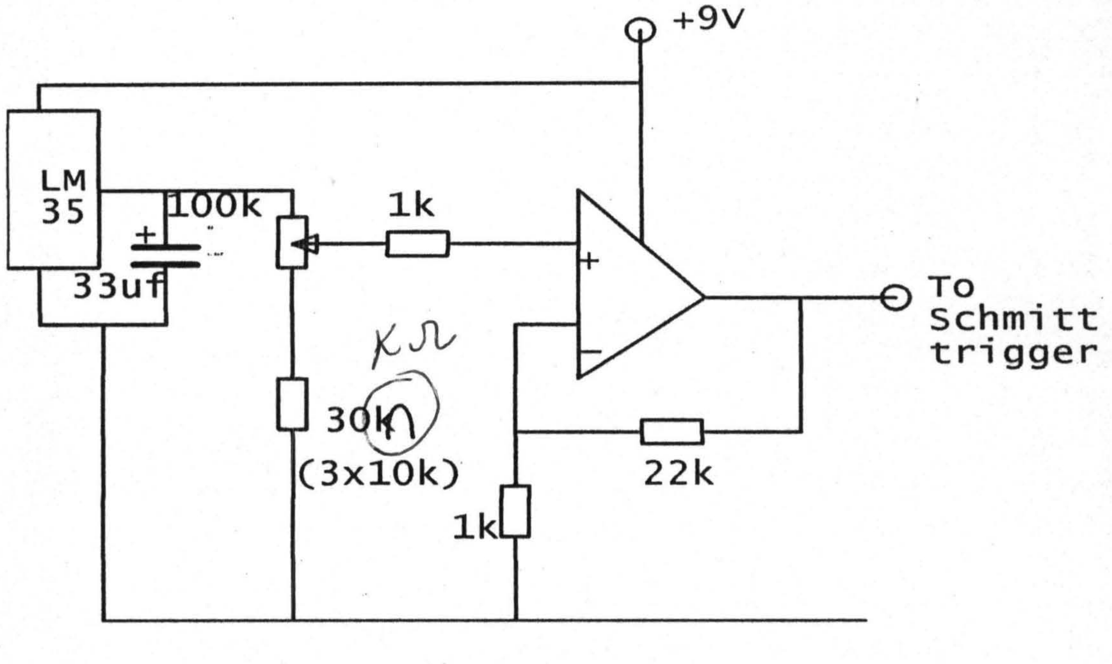


FIG 3.3 LM35- Amplifier interface.

The sensor's output was stabilized by a 33μF capacitance to prevent rapid output voltage charged. The buffered output voltage was led into a potential divider as shown in fig 3.3 to allow for variability of preset settings. The divider network was arranged to fix the maximum upper temperature limit at 100°C.

3.2 23 DC Amplifier

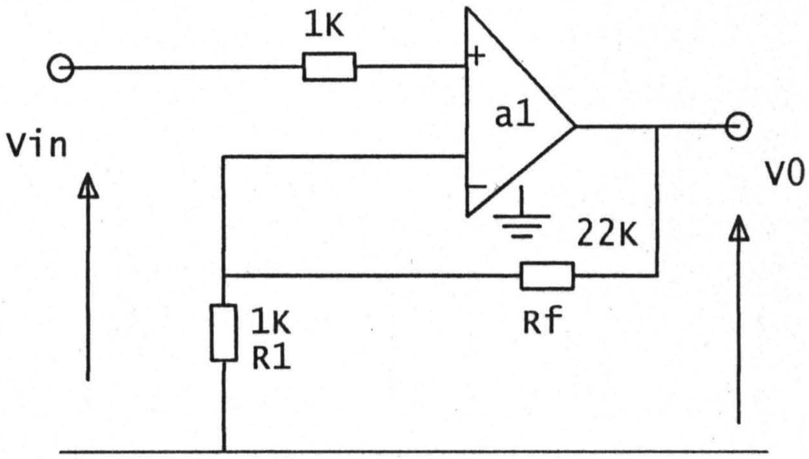


Fig. 3.4 DC *23 Amplifier

The gain of the amplifier is given by the

Expression:

$$\frac{V_{out}}{V_{in}} = \frac{1 + R_F}{R_F}$$

For the value calculated above.

$$\frac{V_{out}}{V_{IN}} = \frac{1 + 22}{1} = 23$$

The amplifier voltage was fed into the inverting input of a second operational amplifier configured as Schmitt trigger.

3.4 SCHMITT TRIGGER

A Schmitt trigger is an improved comparator with two well defined upper and lower switching thresholds, V_A and V_L.

The difference between VA and V_L is the hysterisis and is responsible for the stability inherent in Schmitt triggers.

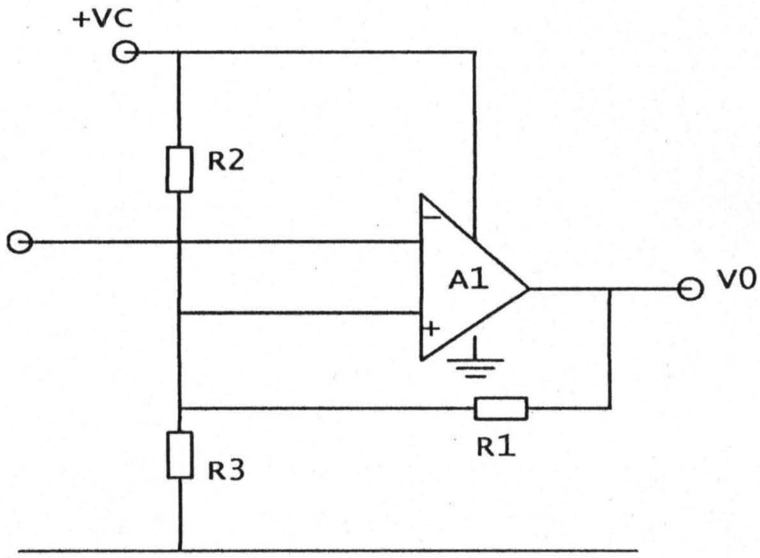


Fig.3.5 OP-amp Schmitt trigger

In fig 3.5 above, assure the output voltage is high i.e at + Vcc. The right most end of R_1 is pulled up to + Vcc, making it parallel with R_2. the voltage on the non-inverting input of A_1 is thus;

$$V+ = \frac{Vcc \times R_3}{(R_1 // R_2) + R_3.} = V_H$$

V_H = Value of Comparator turn on Voltage (Relative to the voltage on the input).

The output of the comparator remains high until the input voltage in V_ exceeds this value at which point output switches low.

With A_1 output low, the right most end of R_1 is connected to ground, making it parallel with R_3.

Thus;

$$V_T = \frac{Vcc \times (R_1 // R_3)}{R_2 + (R_1 // R_3)} = V_L$$

V_L is the value of input voltage below which the comparators switches from low back to high.

A symmetrical circuit operation was dewed desirable. On a +9v DC supply, the Schmitt trigger was biased as shown below;

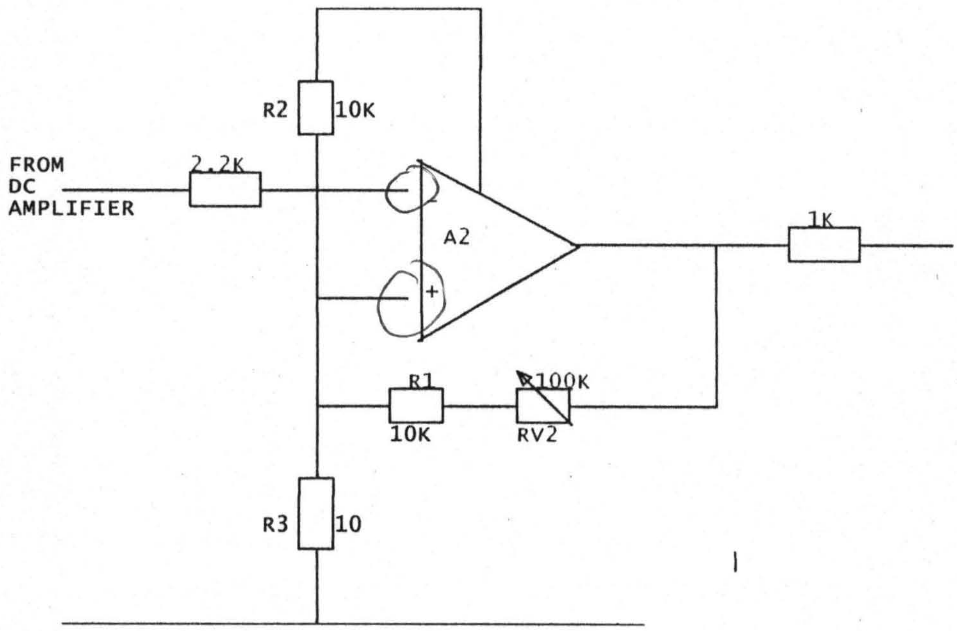


Fig 3.6 system Schmitt trigger.

On a 9V Dc supply, the Schmitt trigger has switching voltages centered around 4.5V. An 100kΩ adjustable resistance was introduced in series with R_1, as indicated above, to allow for a free turning of the hystersis voltage.

The 100kΩ resistance was adjusted to provide a hysterisis of about 500mV. Corresponding to a temperature difference of

$$\frac{500mV}{23} = \frac{22mV}{10mV} = 2.2\,^{\circ}C$$

That is, at a particular temperature, when the measured temperature exceeds that preset temperature the heating element is sensed off. The Unit remains off until the sensed the sensed temperature falls below the preset off temperature by 2°C.

3.5 6V 10A RELAY SWITCH

To provide an automatic connection and disconnection, a DC relay was used. A reley is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be double throw (change over) switches. Relay allow one circuit to switch a second circuit which can be completely separate from the first.

This relay in this project was controlled via the Schmitt trigger output as diagrammed below;

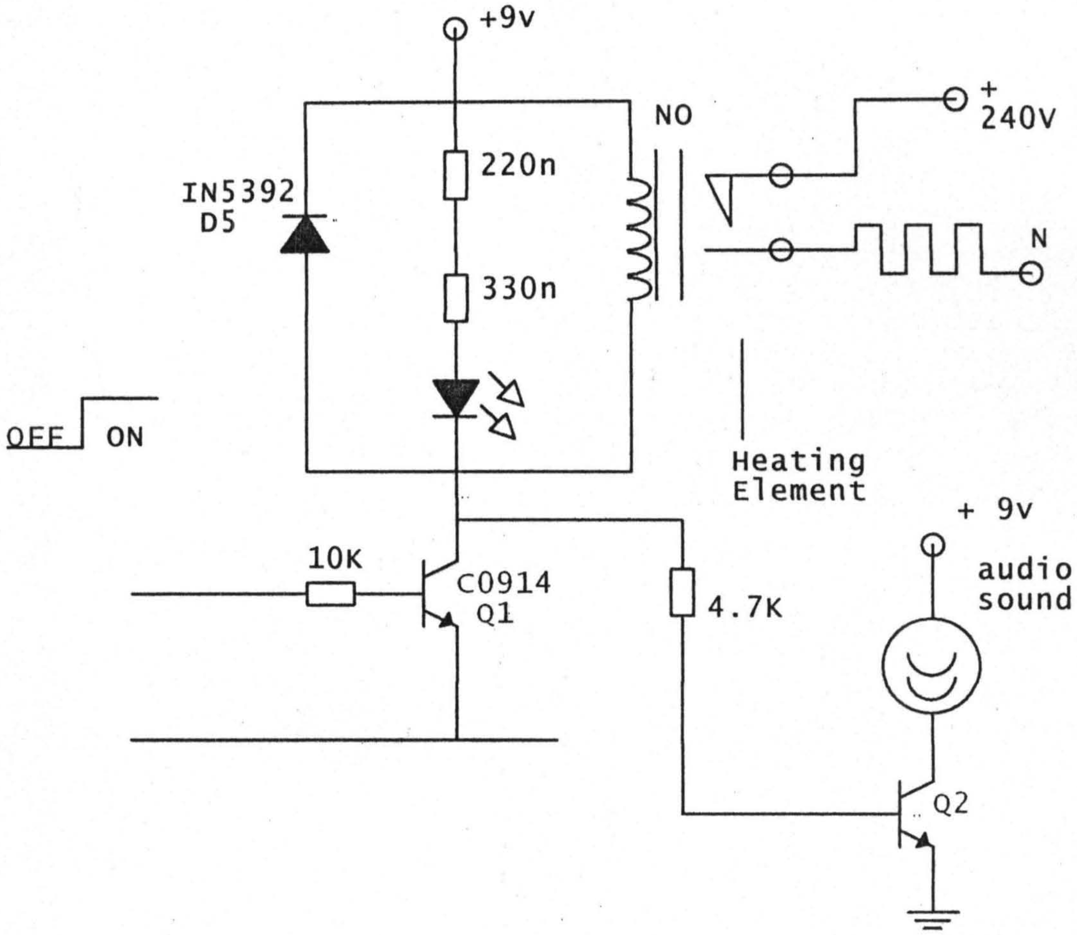


Fig 3.7a relay driver

T_l, an NPN Transistor was used to energized and denergized a 9v relay V_l a the Schmitt trigger. The delay draw a current is thus the Ic of the C 9014.

$$I_c = I_{load} = 22.5mA$$

The transistor has a gain of 200

$$I_B = I_C$$

$$\frac{22.5 \times 10^{-3}}{2 \times 10^{2}}$$

$$= 11.25 \times 10^{-3} = 113\mu A$$

$$R_B = \frac{Va - V_{BE}}{In} = \frac{9 - 0.7}{113\mu A}$$

$$= \frac{8.3 \times 106}{11.3} = 0.75 \times 10^6$$

$$= 750\ k\Omega$$

When this value of resistance was used, the relay would not energize smartly. A 1 kΩ base resistance was therefore used to allow for over drive.

Load-ON indication was provided by a yellow LED connected in parallel with the relay winding as shown above.

The value of R_s was deduced from the equation.

$$R_s = \frac{Vs - V_{LED}}{I_{LED}}$$

For a yellow LED, a forward current of about 0.12mA produces a bright enough brightness level, at a V_F of 1.7V.

$$R_s = \frac{9 - 1.7}{0.12} = \frac{7.3}{0.012} = 600\ \Omega$$

A 220 Ω / 330Ω series resistance was used instead.

The relay's switch connections are usually leveled 10m, μC and NO:

- COM = common, always connect to this, it is the moving part of the Switch.
- NC = Normally open, Com is connected to this when the coil is off
- NO = normally closed, Com is connected to this when the relay coil is on.

- Connect to Com and No if you want the switch circuit to be on when the relay coil is on.
- Connect to Com and NC if you want the switches circuit to be on when the relay coil is off.

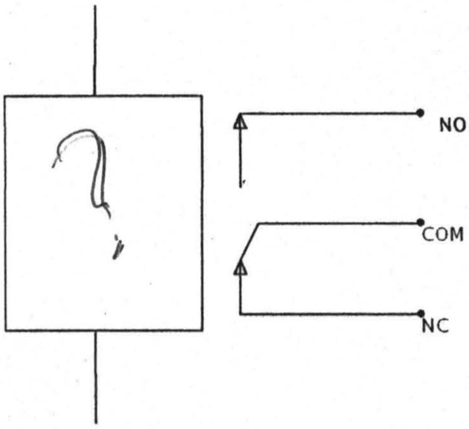


Fig 3.7b circuit symbol of a Relay

A relay is a switch operated by an electromagnet, it is useful if we want a small current in the circuit containing a devices such as lamp or electric motor which require a large current, or if we wish several different switch contacts to be operated simultaneously. The current needed to operated a rely is called the pull-in current in the when relay just stops working.

Note: If the coil resistance of a relay R and its operate voltage is V, then the pulled in current is;

$$I = V/R$$

Where $I =$ Relay coil current

$V =$ Coil Voltage and

$R =$ Coil resistance.

AUDIBLE ALERT

An audio alert mechanism was incorporated into the design implementation. The sounder was controlled by a NPN transistor T_2 as indicated in fig 3.7 a with T_1 On, T_2 as indicated in Fig 3.7a with T_1 ON, T_2 is at off and also the sounder. However, when the preset temperature limit is exceeded T_1 is switched off, T_2 ON, sinking current through the sounder and generating an audio signal. Sounders are output transducers which consist an electrical signal to sound. They require a drive circuit. Pie zo transducers require a small directly to the outputs of most ICs. They are ideal for buzze and beeps, but are noy sound, it can speech or music because they for detecting sudden loud noise or impacts effectively behaving as a crude microphone.

Using a transistor for switching the sounder. When a transistor is used as a witch it must be either OFF or fully ON. In the fully ON state, the voltage V_{CE} across the transistor is almost it cannot passage more collector saturated because it cannot pass any more collector current IC. The output device switched by the transistor is called the "load".

The power develop in a switching transistor is very small in the OFF state.

Power = IC x V_{CE}

But also

Ie = 0, so that

Power is zero

In the full ON state:

Power = IC x V_{CE}, but

V_{CE} = 0 (atmost)

So that power is very small

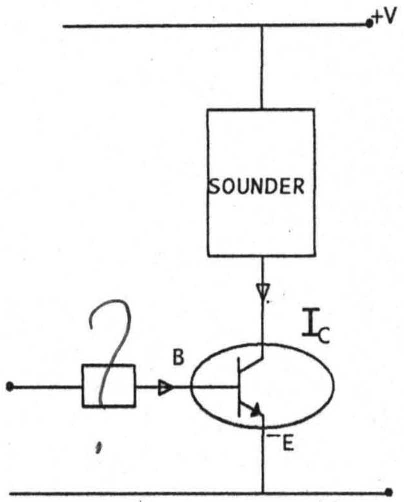


Fig.3.8 connection of Transistor.

$V_{CE} = 0$, when the transistor is ON,

This implies that

$V^+ = I_cR_c + V_{CE}$ 1.0

$V_{im} = IB_{RB} + V_{BE}$ 1.1

$I_c/I_b = hf_e$ 1.2

$R_b = \frac{V_{in} - V_{Bt}}{I_b}$ 1.3

Where

I_c = Collector current

I_b = Base content

V_{in} = Input voltage

V_t = Supply voltage

H_{ft} = Current gain

V_{BT} = Base emitter voltage

.

CHAPTER FOUR

CONSTRUCTION AND TESTING

4.0 CONSTRUCTION

The construction of this project is in two stages, the components and the coupling of the entire project.

The power supply stage was first soldered, and then the sensor and comparator stage and all the other stages were soldered. The circuit was soldered in a number of pattern that is, stage by stage. Each stage was tested using the multimeter to make sure it was working properly before the next stage was done. This helps to detect faults.

The soldering of the circuit was done on vero board. The second stage of the project construction is the casing of soldered circuit. The project was cased in light insulating materials which make the project portable and attractive.

4.1 CONSTRUCTION TOOLS AND EQUIPMENTS

A brief discussion of the construction tools is given below soldering iron; a modular soldering iron with 60watts heating element was used for the project.

Soldering stand: This was used for keeping the soldering iron in a save position.

Lead: Flux core type of lead was used for the soldering of the various components.

Lead sucker: This was used for sucking up Melting solder.

4.4 RESULTS

The system automatically switches off with alerting sound immediately after the heater (load) temperature equals the preset temperature and cools down for a while, it then automatically switches on. The process continues repeatedly as long as the preset temperature is reached.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION.

The system satisfied the expected mode of operation. The sensor has satisfactorily accommodated temperature range to 100 C. With the temperature controller, a desired temperature which falls within the range can be effectively controlled.

5.2 RECOMMENDATION

For subsequent works on the project, an IC temperature sensor (preferably LM35DT) may be used instead of increase temperature sensing efficiency.

The temperature monitoring and control system be modified to communicate with more than one sensing unit.

A display unit may also be incorporated to show the temperature of the heating element as the heat increases, the whole system may be modified to control much higher ranges of temperature.

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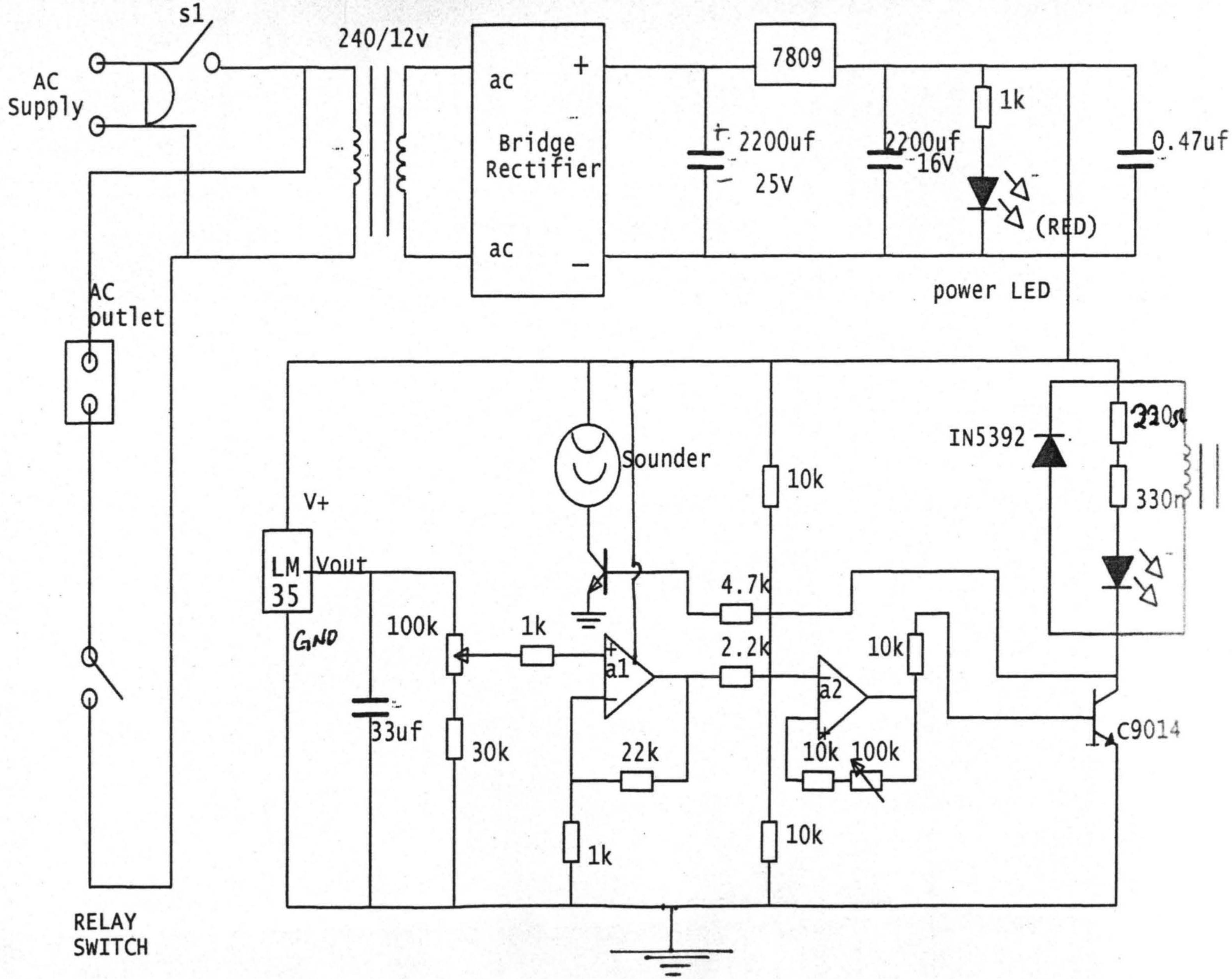
s1
240/12v
AC
Supply
ac
+
Bridge
Rectifier
ac
−
7809
2200uf
25V
2200uf
16V
1k
0.47uf
(RED)
power LED
AC
outlet
Sounder
10k
IN5392
330r
V+
LM
35
Vout
GND
100k
1k
4.7k
2.2k
a1
a2
10k
33uf
30k
22k
10k
100k
C9014
1k
10k
RELAY
SWITCH