DESIGN AND CONSTRUCTION OF AN ELECTRONIC THERMOSTATIC CONTROL FOR HEATING SYSTEMS

BY

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90/1665

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DECLARATION

I OBANOVWE GLORY hereby declare that this project is an original concept which was totally designed, modelled and constructed by me under the supervision and guidance of my supervisor, Engr. Shehu Ahmed.

STUDENT

21/1/98

DATE

CERTIFICATION

This is to certify that this project "Electronic thermostatic control for heating systems" was designed and constructed by OBANOVWE GLORY for the partial fulfillment of the award of bachelor degree in Electrical/ Computer Engineering.

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ENGR. SHEHU AHMED DATE

PROJECT SUPERVISOR

______________________ ______________

PROF. S.O AJOSE DATE

______________________ ______________

EXTERNAL EXAMINER DATE

DEDICATION

This project is dedicated to Almighty God, my beloved mother Mrs Roseline Obanovwe and my late father Mr. Joseph Obanovwe.

ACKNOWLEDGEMENT

My humble and honest gratitude goes to Almighty God, his son Jesus Christ for his divine provisions, protection and guidance throughout the course of my study.

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Words are not just enough to say thanks to my prestigious mother MRS ROSELINE OBANOVWE, who single handedly bore the bulk of my financial and moral responsibilities.

I wish to express my deep appreciation and gratitude to my brothers, sisters, aunts and cousins, Mr. Akpobome Obanovwe, Erhire Obanovwe, Miss Tivere Obanovwe, Miss Bluff Akpeyi, Mr Kingsley Oba for giving me the support and love throughout my academic career.

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TABLE OF CONTENT

ABSTRACT

The design and construction of an electronic thermostatic control for heating systems is described in this report. The project is limited to a closed loop system so as to demonstrate heat detection in an environment. The detection is via a switching unit which is indicated with an LED indicator.

This project is intended to produce an output which depends solely upon the temperature of the sensor device (thermocouple). The design is therefore based on the principle of using temperature transducer (sensor) that converts heat variation of an environment into electrical signal, which is then used to control the switching unit. The design and numerical analysis, circuit, block diagrams and values are provided to give readers adequate knowledge and information about the system.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION:

In the world today, most heating system, whether direct or indirect are governed by some form of thermostatic control, designed to maintain a desired temperature set by a thermostat, which regulates the input of heat. In the early days, control is often by water temperature, the adjustment being made according to outside weather. Alternatively, control may be by room thermostat.

Thermostatic control has the objective of economizing heat as far as possible while avoiding underheating or overheating. Internal heat gains and solar gain may often contribute significantly to the total daily heat requirement of any heating environment and, superimposed on the normal designed output of a heating system, can lead to uncomfortably high internal temperature. A quickly responsive system is therefore desirable. To achieved this, the turn on and off type of thermostatic control is considered in this project.

The turn on and off type of thermostatic control is an electronic equipment to triggered automatically when the temperature inside a house, oven, kiln, incubator or any heating environment exceed the required temperature. Generally, this equipment control one or more heating source to maintain a desired temperature.

To perform this function a thermostatic control must have a sensor, comparator and a triggering unit. The block diagram in fig 1.1 summarizes the mainspring for the operational outline of the control.

1.2 LITERATURE SURVEY

It is on record that researchers and implementation of thermostatic control itself did not seriously take off until in the 80s when the need to automatically control for heating systems become very important. Hence there are still relatively few text that deals extensively with important aspect of Electronic Engineering.

However, the device for controlling heating system was first introduced in 1830 by Andrew Ure, a Scottish Professor of Chemistry, who issued a pattent on what he called a heat-responsive element consisting of a bar steel united to zinc by numerous rivets, this bimetallic bar bends with temperature change because of the different expansion rate of the metal strip, and the bending can be used to actuate valves or dampers to control heating system.

For the purpose of this project a number of texts was consulted, one of these text is merit students Encyclopedia by William .D. Hasley and Emmanuel Friedman where J.J. Jaklitsch Jr. dealt with the kinds of thermostatic control for heating systems and gives the operation of their functional parts. He however, did not delve into the process of designing the device.

According to Nathaniel Robbins Jr. in the late 1880's thermostatic control was defined and went further to explain the types, the principle of operation, and the merits and demerits over the conventional control system. He also mentioned areas where this device is applicable.

In a text of science and invention by Cornelius Drebbel, a Ducthman living in London dealt extensively on the types and the essential features of thermostats and went further to say that resistance-based thermostatic control are extremely accurate when connected to electronic equipment, that only minute adjustments could be made to the temperature regulating system.

Other heat controlling equipment (thermostat) exist that basically uses almost the same type of principle but different types of input and output units, though there are some whose principle is drastically different from that used in this project. Some systems are based on the principle of analog to digital converter. Where the analog voltage produced by the sensor is converted into its digital equivalence, which is fed into the disply unit from where the temperature variation may be read.

In addition to gettting information on the working principles of the thermostatic for heating system itself, which is the main objective of this project, it is necessary to have vividly knowledge of the working condition of the various components which make up this device, which the texts mentioned above omitted. It is in this light that practical electronics (second edition) by Barry Woolland was consulted.

1.3 **OBJECTIVE AND MOTIVATION**

The main purose of this project is to design and construct an Electronic thermostatic control for heating systems. The system is design to be automated by switching on and off.

To achieve this aim, the objective considered to form the entire system design and development are:-

i) the control system should be easily interface with wider variety of heating equipments.

ii) the project has to be inexpensive

iii) the project should be easily set-up and should require minimum maintainance.

Overheating a particular environment, being it a house, oven, kiln, incubator etc. is very dangerous hence the main motivation in embarking on this project is to design a system that maintain a required temperature for safety and to be used with minimum possible human attention.

1.4 PROJECT LAYOUT

This project write-up is in five chapters for easy comprehension.

Chapter one encompases the general introduction where a brief knowledge of the history of Electronic thermostatic control for heating systems is dicussed also mention is the need for this control system and the type of thermostatic control designed.

In addition, the texts consulted in the course of this project were highlighted.

The objective and motivation in embarking on this project is also mention.

In chapter two, the project is sub-divided in three major units that constitute the design of this work for easy and logical explanation of each function.

Chapter three, the general consideration of each components used, implementation and the mode of operation of thermostatic control is discussed in this chapter.

Chapter four deals with the construction, constraints encountered during the course of this project, measurement and testing of the control system.

Finally, the last chapter (five), the conclusion which summerizes the whole project and recommendation to further improve on this design were discussed.

CHAPTER TWO

DESCRIPTION OF DESIGN

2.1 DESIGN CRITERIA:

The design of this project is limited to a close-loop system so as to demonstrate heat detection in an environment. The detection is then indicated with the aid of a light emitting diode (LED) as indicator. The design comprises of three units, the tranducer unit, comparator unit and the switching unit.

The main component used in this project is the transducer bridge with its sensor (thermocouple) whose function is to detect the present of heat within its vicinity. The thermocouple is placed in a bridge circuit and its voltage which is directly proportional to the instatenous temperature of the hot junction is amplified by voltage amplifier (amplification is necessary to improve the sensitivity).

A quad LM324 operational amplifier (OP. amp.) is connected as a voltage amplifier and as a comparator. The voltage amplifier has two inputs and one output. One terminal of the thermocouple is connected to the inverting input and a variable resistor (potentiometer) V_{R1} is connected to the non-inverting input of the dc amplifier. The output of the amplifier is fed into the comparator unit.

A comparator is a two inputs and one output voltage comparing device that is capable of high gain, high input resistance and low output. One input terminal is placed at a fixed voltage (V_f) with the help of a variable resistor (potetiometer) V_{R2}, while the other input terminal is placed at a varying voltage which depends on the voltage from the amplifier. The output of the comparator is then passed onto a switching unit comprises of transistor and a relay.

The npn transistor is used as a current amplification and to provide switching effect for the relay. The relay on the other hand is an electromagnetical device which is used to switch on and off the heater. A light emitting diode (LED) is used to indicate the on and off mode.

The units consideration that make up this project are explain below:

2.2 THE TRANSDUER UNIT

The word transducer means any device which converts energy from one form into another such as heat energy into electrical energy into electrical signals. Typical input transducers are thermocouple, thermistors, photocells, strain guage and typical output transducers are loudspeakers, motors, selenoids and valves.

While a transducer may be in a small part of a system, they are very importance devices in electronics, of utmost importance is the success of any control system, interms of its operation and performance, which will often depend on the quality, sensitivity and stability on the input sensor. The sensor have to pick up the small change in the input qualities and translate this often tiny changes into useful electrical signals.

2.2.1 HEAT (TEMPERATURE) SENSOR

Heat sensor or transducer is a device that senses heat (temperature) variation in an environment to give useful electrical signal. Different sensors are made from different materials, but generally, their properties changes with rise or fall in temperature.

The useful temperature range for this project is between 38° - 80°c, hence most temperature sensor may be used. The thermistor and the platinium resistance are relatively expansive, while the semiconductor types of sensor are not easily obtainable. Due to low cost and availbilty, the thermocouple is used as the heat sensor.

2.3 THE VOLTAGE COMPARATOR UNIT

The voltage comparator is a circuit which compares input signal (voltage) and the reference voltage, the ouput of the comparator, V_{out} changes from its value when V_{in} is less than or eqaul to V_f.

A comparator circuit exhibits a non-linear operational amplifier characteristics, whereas a differential amplifier behaves linearly. A comparator is therefore a two inputs, one output voltage comparator device that is capable of high gain, high input resistance and low output. While this may be taken as the definition of an operational amplifiers, it should be noted that voltage comparism is just one of the areas of amplification of operational amplifiers. A comparator thus performs the following function:

(i) detects two input voltage

(ii) provides an output that has two descrete state.

The differential voltage comparator is operated via a dual power supply with a common ground, thus enabling the output to swing either to positive or negative with respect to ground.

The OP. amp. gives a voltage gain of about 10^3 between input and output. One input terminal is denoted negative, it gives an inverting output i.e. the inverting terminal and the other is denoted positive, it gives non-inverting output i.e. the non-inverting terminal. The output of the device is ideally zero, when identical signal are simultaneously applied to both inputs since the two signals are cancelled out by the differential outcome of the amplifier. The output of the circuit is protional to the differential signal between the inputs and it given by

$$V_{out} = A_o(V_{in} - V_{ref})$$

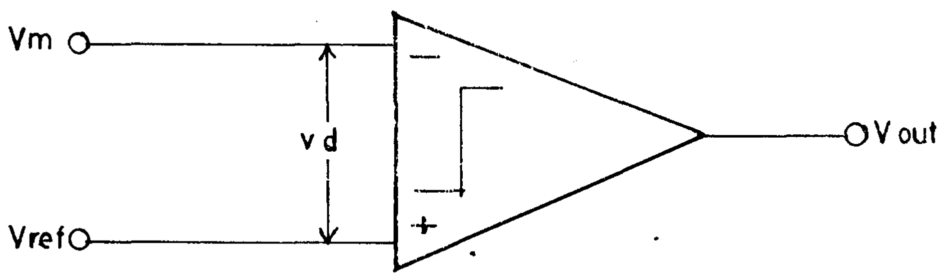


Fig 2.1 Voltage Comparator Symbol

from the fig above, $V_{out} = A_o(V_{in} - V_{ref})$

$V_{out} = A_oV_d$

where A_o = the open loop of the OP-amp. (Gain)

V_{in} = the input signal at the inverting terminal

V_{ref} = the reference voltage at the non-inverting terminal

V_d = differences between the inverting and the non-inverting terminals.

V_{out} = the output voltage.

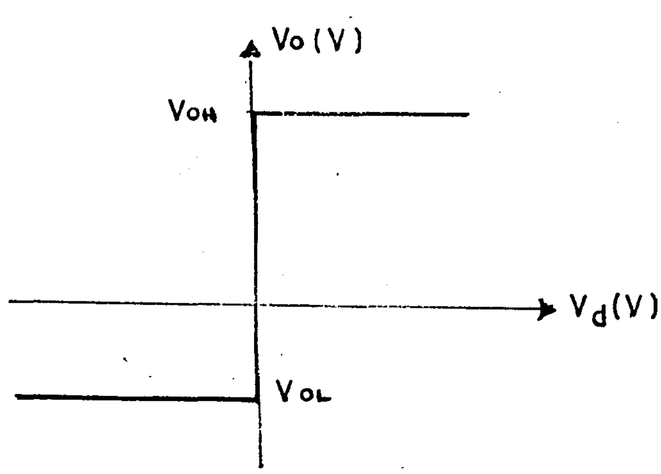


Fig 2.2 Comparator Voltage Transfer Curve

The comparator operation is express as

$V_o = V_{oL}$ when $V_{ref} > V_{in}$

$V_o = V_{oH}$ when $V_{ref} \geq V_{in}$

2.4 THE SWITCHING UNIT

The switching operation is achieved with the aid of a transistor and a relay. The transistor is used to amplify current to the relay which eventually switches off and on the heater.

When the output of the comparator is fed to the base of the transistor, the transistor goes to its saturation point thereby making current to flow through the relay coil which is connected to the transistor collector region. The collector current I_c energized the coil of the relay thereby opening the relay switch and heating is stopped.

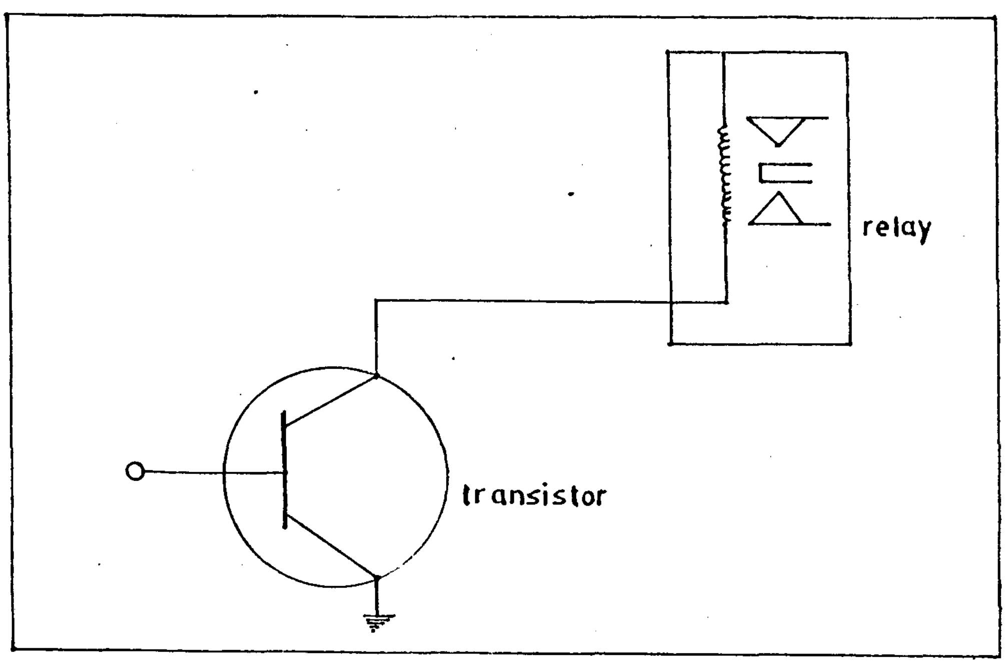


Fig 2.3 Block Diagram of Switching Unit

CHAPTER THREE

GENERAL DESIGN ANALYSIS

The detail design consideration for each components used in this project are analized in this chapter.

3.1 THE THERMOCOUPLE

A thermocouple is the transducer (sensor) used in this project, it consist of two wires of dissimilar metals or alloys joined together to form a junction. If this junction is heated, a voltage is developed between the free ends of the wires called the hot and cold junction respectively, the dissimilar metals used are copper and constantan wires, its a low temperature thermocouple and the best for measuring temperature below 0° - 600°c. It has an average output of 2.50 mV/100°F and has an accuracy of ¾%. The temperature of the hot junction is determined by measuring the potential drop between the junctions which usually increases as the temperature of the hot junction is raised.

The disadvantage of the thermocouple is that it produces fairly small voltage, this voltage is thus, amplified with the aid of voltage amplifier (OP. amp.).

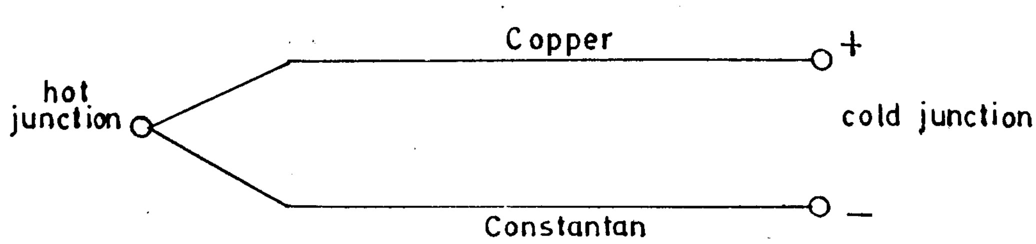


Fig 3.1 Copper-Constantan Thermocouple

Sensitivity is imposed by making five junctions (hot and cold). This multiply the transduced E.m.f by five.

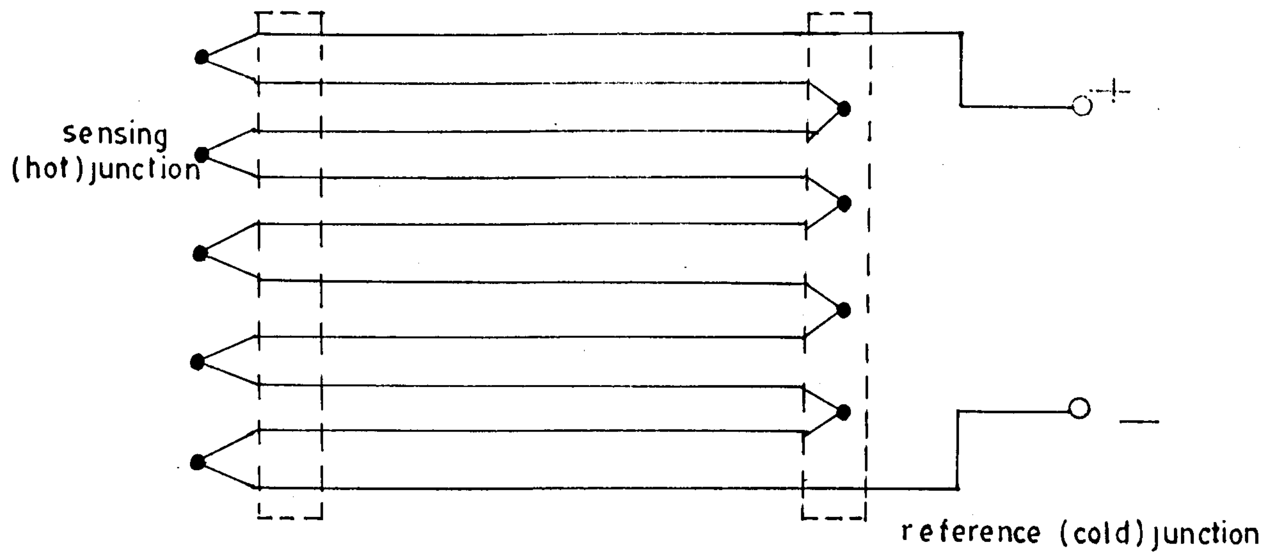


Fig. 3.1.2 Five junction copper-constatan thermocouple schematic

The E.m.f generated by the thermocouple is the difference between two E.m.fs V' and V acting in the junctions.

Thus

$$E = V' - V.$$

HOW THE EMF IS GENERATED:

When the hot junction of a thermocouple is placed within the heating environment, a charge Q flows round the circuit, at the hot junction heat energy V'Q is absorbed and at the cold junction, the current is in opposition to the E.m.f V, therefore heat energy VQ is evolved. The difference between V'Q and VQ (V' - V)Q is the electrical energy (Emf) available in the circuit. The Emf generated is not more than a few milivolts for temperature difference between the junction of 100k.

of the voltage amplifier. Terminal 4 goes to the positive of the supply source (+Vcc) and terminal 11 goes to the ground (GND). A feed-back network is connected to the inverting input and the output OP. amp. This connecton enable the OP. amp. to amplifier both negative and positive dc voltage with respect to the common reference level.

The circuit below shows the arrangement of the thermocouple and voltage amplifier as the transducer unit.

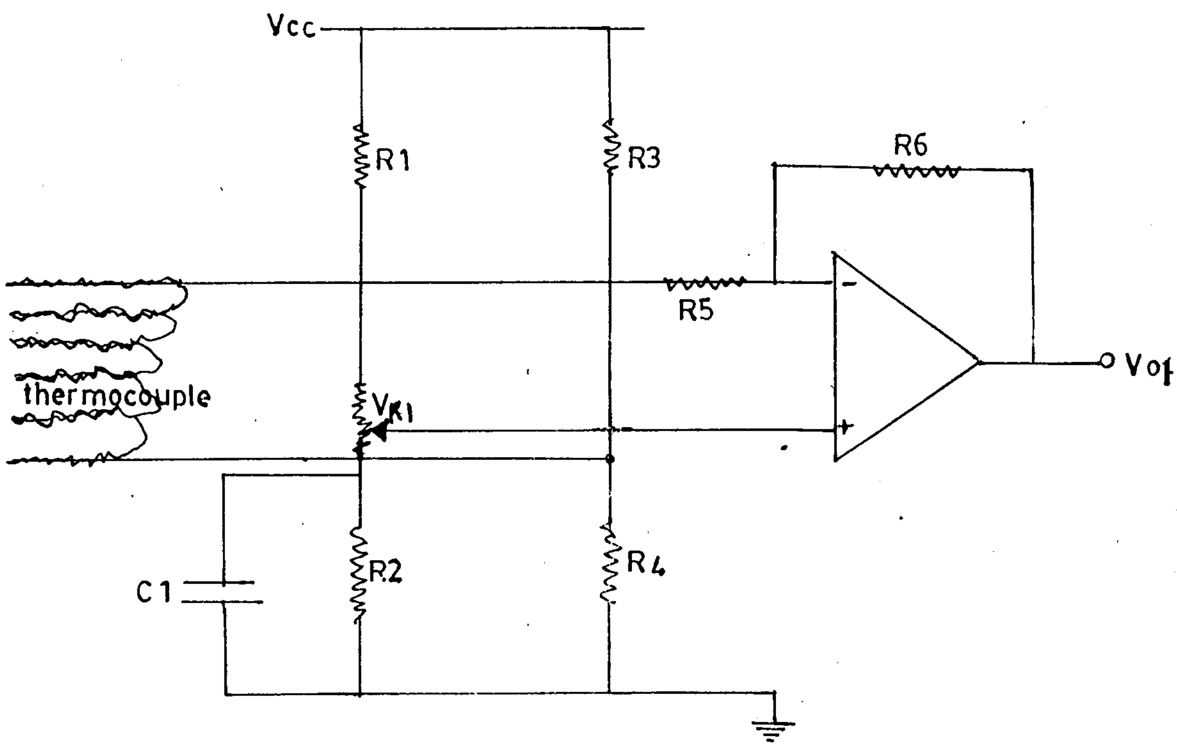


Fig 3.2.1 the transducer circuit.

The output of the circuit above is given by

$$V_{o1} = A_o (V_{ref} - V_{in}) \qquad 3.2.1$$

$$V_{o1} = A_o V_{d1} \qquad 3.2.2$$

where $V_{d1} = (V_{ref} - V_{in})$

$$\text{Gain } (A_o) = \frac{-R_6}{R_5} \qquad 3.2.3$$

Vin = transducer Emf + mid-voltage

$$\text{mid-volt} = \frac{R_3 \times V_{cc}}{R_3 + R_4} \qquad 3.2.4$$

Voltage drop (V_{ref1}) across ... is given by

$$V_{ref1} = \frac{V_{RO2} + R_2}{(V_{RO2} + R_2) + V_{RO1} + R_1} \times Vcc \qquad 3.2.5$$

where V_{RO1} = resistance between the non-inverting input terminal and R_1

and V_{RO2} = resistance between the non-inverting input terminal and R_2

V_{RO1} and V_{RO2} are determined when the variable resistor (V_{R1}) is adjusted to a precise position for easy setting of the high gain OP. amp.

equation above gives

$$\text{mid-volt} = \frac{R_3 \times V_{cc}}{R_3 + R_4} \qquad R3 = R4 = 2.2K\Omega \quad Vcc = 9V$$

$$= \frac{2.2K}{2.2K + 2.2K} \times 9V = 4.5V$$

$$\text{current through mid-volt} = \frac{\text{midvolt}}{2.2k} \Rightarrow \frac{4.5V}{2.2k} \Rightarrow 2mA$$

R1 = R2 =2.2K, VRO1 = 94.2Ω, VRO2 = 105.8Ω

∴ from equation 3.4.5

$$Vref1 = \frac{2305.8}{4600} \times 9V = 4.5113V$$

$$\text{current through } V_{R1} \text{ (Vref1)} = \frac{4.5113}{4600} = 0.98mA$$

$$\therefore I_{VR1} = 0.98mA$$

Vin = 4.5 + transducer Emf

where transducer Emf = 6.6mV (measured value)

Vin = 4.5 + 6.6mV = 4.5066V

Vd1 = 4.5113 - 4.5066 = 0.0047 => 4.7mV

equation 3.2.3 gives

$$Ao = \frac{R6}{R_5} \qquad R_5 = 1k\Omega,\ R_6 = 1m\Omega$$

$$Ao = \frac{1000000}{1000} = 1000$$

Vo1 = 1000 x 4.7mV = 4.7V (from equation 3.2.2)

V_{o1} is now the test voltage to the comparator.

3.3 **OP. AMP. AS A COMPARATOR (Lm324)**

The Lm324 is a quad type of comparator, it is used in this project is a differrential voltage circuit on whether one of the input is greater or less than the other, so that the two input voltage level therefore represents the output voltage of decision. This is mostly determined by the saturation position of the operational amplifier. When the input voltage V_{in} (V_{o1}) is greater than that of the reference by more than a few hundred micro-volts, the output is driven into saturaton positively, and when the sample voltage is few hundred less than the reference voltage, the output is driven too negative saturation. It is the magnitude of the differential input voltage that dictates the magnitude of the output voltage, so the absolute value of input voltage are of little importance. The circuit thus function as a precision voltage comparator or balance detector.

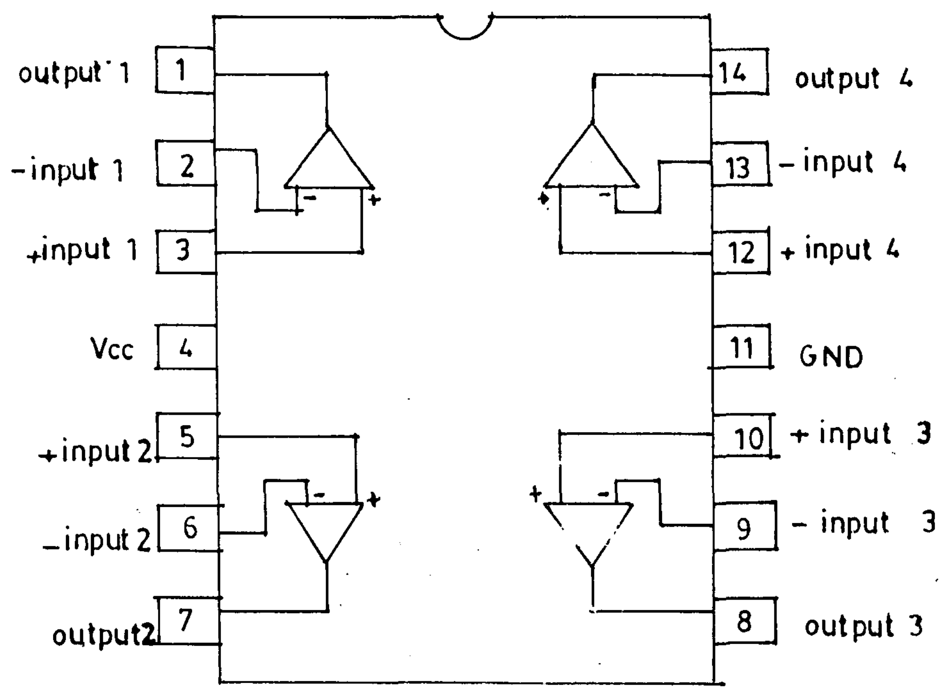


Fig 3.3 Pin-out of the Quad Lm324 OP. amp.

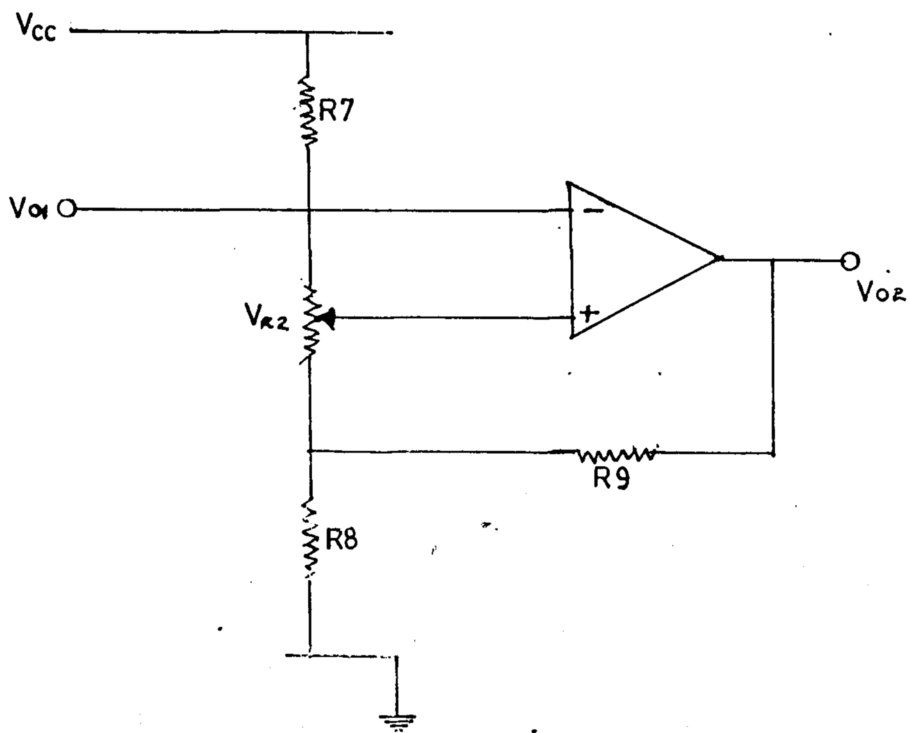


Fig 3.3.1 The Comparator Circuit.

The positive feed-back in the circuit transform the OP. amp. from the becoming a linear differential OP. amp. but to a more digitalized quantised amplifier.

The output of the comparator circuit is given by

$V_{o2} = a \ (V_{o1} - V_{ref2})$

$$V_{o2} = a\, V_{d2} \qquad 3.3.1$$

voltage across variable resistor V_{R2} is given by

$$V_{ref2} = \frac{V_{Rb} + R_8}{(V_{Rb} + R_8) + (V_{Ra} + R_7)} \times V_{cc} \qquad 3.3.2$$

where

V_{Ra} = resistance between the non-inverting input of the comparator and R_7

V_{Rb} = resistance between the non-inverting input of the comparator and R_8

V_{Ra} and V_{Rb} are determined, when varaible resistor V_{R2} is adjusted to a point in such a way that the heating environment is heated to a temperature range of 45°c.

datas,

$R_7 = R_8 = 560\Omega$, $V_{Ra} = 2.62k\Omega$, $V_{Rb} = 2.28K\Omega$

$R_9 = 1.5K\Omega$, $V_{o1} = 4.7V$

from equation 3.3.2

$$V_{ref2} = \frac{3180}{6120} \times 9 = 4.6765V$$

current through V_{R2}

$$IV_{R2} = \frac{4.6765}{6120} = o.76mA$$

The voltage (V_{o1}) applied at the inverting input of the comparator is higher than V_{ref2} at the non-inverting input of the comparator, this indicate the off mode of the heating device.

As temperature decreases, the Emf generated by the thermocouple also decreases.

For the heating device to trigger on again V_{ref2} must be higher than V_{o1}

thus, transducer Emf becomes 7,7mV

V_{in} = 4.5V + 7.7mV

= 4.5077V

V_{d1} = 4.5113 - 4.5077V

= 3.6mV

V_{o1} becomes

$$V_{o1} = 1000 \times 3.6mV$$
$$= 3.6V$$

Since V_{ref2} is now higher than the new V_{o1}, this indicates the on mode of the heating device. Temperature begins to increase as the transducer Emf continue to increase until V_{ref2} is exceeded again.

from equation 3.3.1

$$V_{o2} = a\ (4.7 - 4.6765)$$
$$= a\ (0.0235)$$

where $a = 1 + \frac{R_9}{R_8}$ $\qquad R_9 = 1.5k,\ R_8 = 560\Omega$

(Gain) $a = \frac{1 + 1.5k}{560} = 3.67857$

V_{o2} = 3.67857 x 0.0235

= 0.0864V

3.4 **TRANSISTOR AMPLIFIER**

It is an active semi-conductor device. Transistor switch has three electrodes. These electrodes are named base, emitter and collector, It can amplify, oscillate and can be use for switching and other purposes. Germinium and silicon are commonly used material for the production of a transistor. The transistor are two types i.e. NPN and PNP.

For the purposes of this project the NPN MRF 581 type is used for current amplification and to provide the switching effect for the relay.

The NPN MRF 581 has the folloeing specification

$I_{cmax} = 2A$

$V_{Bcmax} = 36V$

$V_{BE} = 4V$

$V_{CE} = 18V$

$h_{fe} = 25$

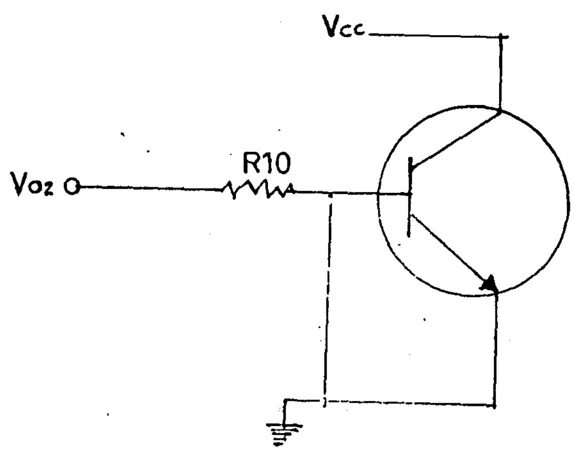


Fig. 3.4 The Transistor Switch.

The output of the OP amp V_{o2} s fed to the base of the transistor. When this transistor is saturated a voltage is fed to energise the relay coil thereby opening the relay switch and heating is stop.

current through R_{10}. $R_{10} = 100\Omega$,

$$I_{R10} = \frac{V_{o2}}{R_{10}} = \frac{0.0864V}{100}$$

I_{R10} = 0.864mA

Voltage drop across R_{10}

$$V_{R10} = I_{R10} \cdot R10$$
$$= 0.864mA \times 100$$
$$V_{R10} = 0.0864V$$

The base current I_B required for saturation is specified from the formular

$$I_B = I_c/ß = I_c/h_{fe} \qquad 3.4.1$$

from the circuit diagram (fig 3.4)

$$I_B = \frac{V_{cc} - V_{BE}}{R_B}$$

V_{cc} = 9V, V_{BE} = 4 and R_{10} = 100

on substitution

$$I_B = \frac{9 - 4}{100} = 0.05A$$

equation 3.4.1 gives

$I_B = I_c/h_{fe}$

h_{fe} for mRf 581 = 25, I_B = 0.05A

0.05A = $I_c/25$

= 0.05 x 25

= 1.25A

this is the required current to energize the coil of the relay.

3.5 **RELAY SWITCH**

A relay is an electromagnetic switch, a movable spring armature is mounted above the core of an electromagnet, when the core is energized, the armature is altered and the contact points open or close by responding to change in some physical quantities as current, voltage frequency, light sensitivity, temperature, pressure etc. A relay in a normally closed position opens when activated and normally open relay closed when energized. When energizing potential is removed, the spring action returns the amature to its original state, switch point and move complicated switching operations. Relay can be categorized as an under current and over voltage relay.

An over current relay and over voltage relay operates when the actuating quantity (current or voltage) exceeds its operating or pick values. An under current and under voltage relay operates when the actuating quantity (of current or voltage) falls below the reset or drop out value.

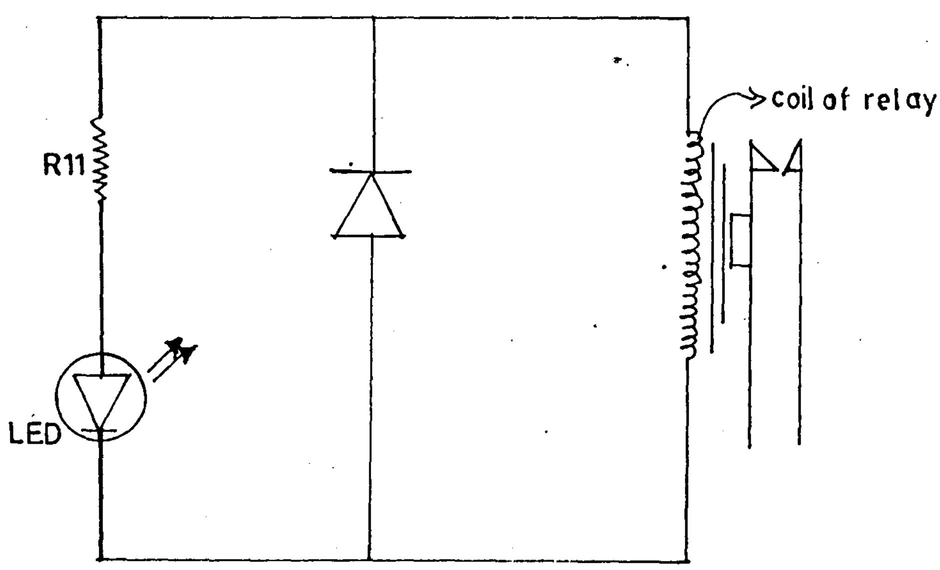


Fig 3.5 Relay Switch.

A relay switch of normally closed type is used in this project, so that at a point when it opens it trips off the heating circuit. Since the circuit is operating at 9V and a current rating of 2A maximum (I_{cmax}, from transistor rating).

The relay selected has a voltage of 9V and a resistance of 115Ω.

therefore I_{relay} = 9V/125Ω = 0.07A

This is the maximum current that can follow through the coil, hence the forward current has to be greater than the relay current.

The diode connected in parallel with the relay is a protection diode, the protection diode prevent back Emf from burning the transistor i.e. at any point in time where there is back Emf on the relay coil the voltage is not exceeded.

The LED (Light emitting diode) in series with R_{11} and parallel to the protection diode indicated on and off mode of the comparator, R_{11} limit the current that flows through the LED.

The amber (LED) light emitting diode has a forward voltage of 5V and forward current I_f . of 4mA.

$$R_{11} = \frac{V_{cc} - V_f}{I_f} = \frac{9-5}{4mA} = \frac{4}{4mA} = 1000$$

R_{11} = 1kΩ

3.6 THE POWER SUPPLY

The D.C. power supply is a basic electronic system, generally consisting of a transformer, a rectifier, a filter and a regulator to convert A.C. voltage to D.C. voltage. The block diagram below shows the basic part of a simple power supply.

galvanic seperation between the mains [a.c input] and the d.c output. In a brief a transformer is a device that:

(i) Transfers electric power from one circuit to another.

(ii) It does so without a change of frequency.

(iii) It accomplishes this by electricmagnetic induction and

(iv) where the 2 electric circuit are in are in mutual inductive influence of each other.

A trnsformer can be either centre-tap or non-centre-tap.

The figure below shows the basic circuit diagram for a transformer.

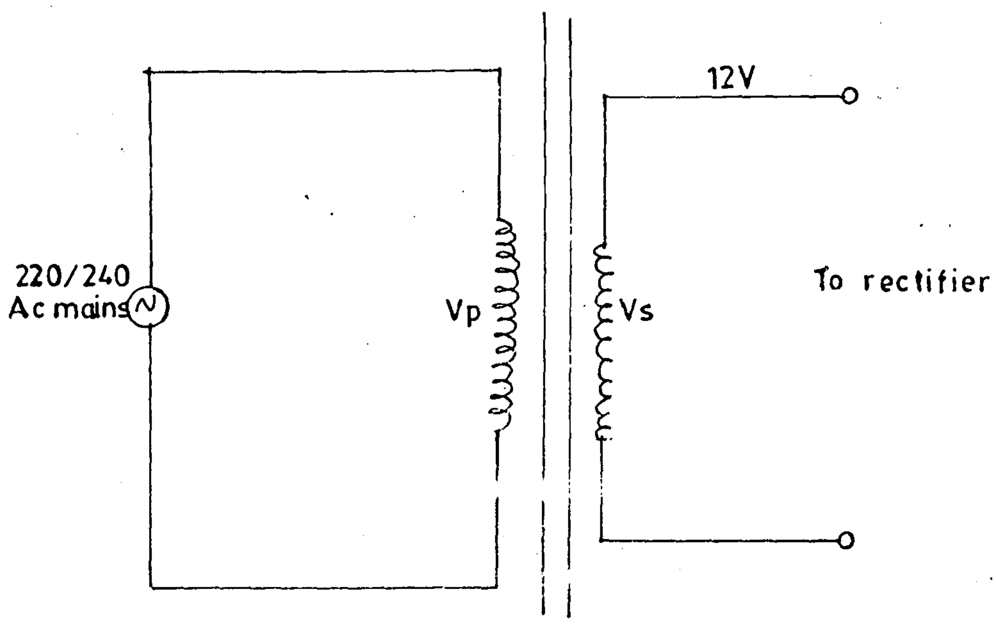


Fig 3.6.1 Circuit Diagram of a Transformer.

RECTIFIER:

A rectifier is a circuit which employs one or more diodes to convert a.c voltage into pulsating d.c voltage. There are several types of rectifiers;

1. half-wave rectifier
2. full-wave biphase rectifier
3. full-wave bridge rectifier

For the purpose of this design the full-wave bridge rectifier is considered because it is the most common and is more suitable for high-voltage applications.

THE BRIDGE RECTIFIER

The full-wave bridge rectifier is often useful to be able to produce using a full-wave ractified waveform without using a centre-tapped (bi-phase) transformer. The bridge rectifier is connected to a transformer which is used to obtain the desired a.c voltage to be rectified. This type of rectifier is the most efficiently used circuit for electronics d.c supply, the output terminals of the bridge rectifier are completly independent. There are two d.c terminals; neither is common to the a.c voltage. With bridge rectifier both positive and negative d.c supply voltage can be produced. Connecting the +d.c terminal to the ground yeilds a negative supply. While connecting the -d.c terminals to the ground yeilds a positive supply.

The full-wave bridge rectifier is available in 3 distinct forms namely:-

1. four discrete diodes
2. one device inside a four terminal case
3. As part of an array of diodes in an Ic

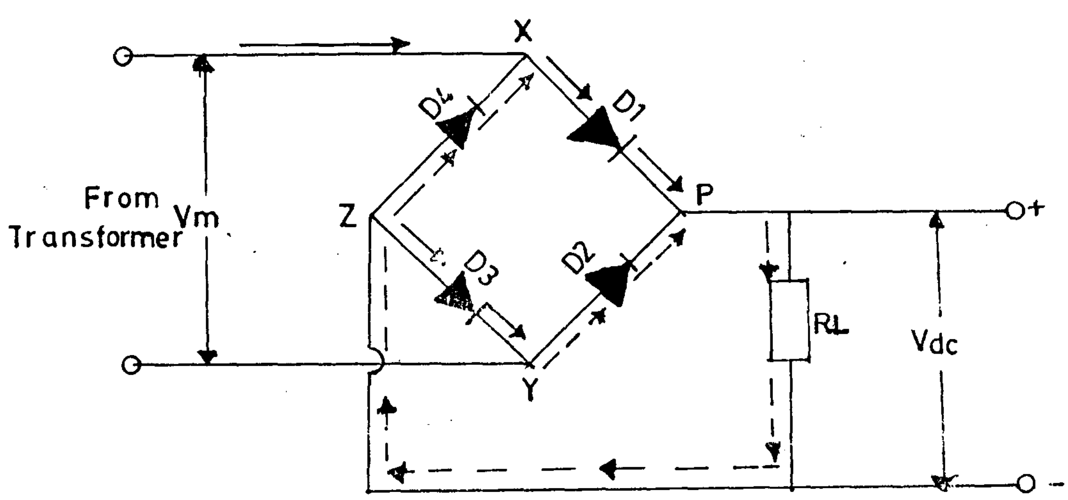


Fig 3.6.2 (a) Full-Wave Rectifier Diagram.

3.6.3 FILTER CIRCUIT

The purpose of this circuit element is to remove fluctuations or pulsations [ripples] in the output voltage supplied by the rectifier. Practically no filter can give an output voltage as ripple free as that of a d.c battery but, it approaches it so closely that the power supply perform well i.e. the main function of a filter is to minimize the ripple content.

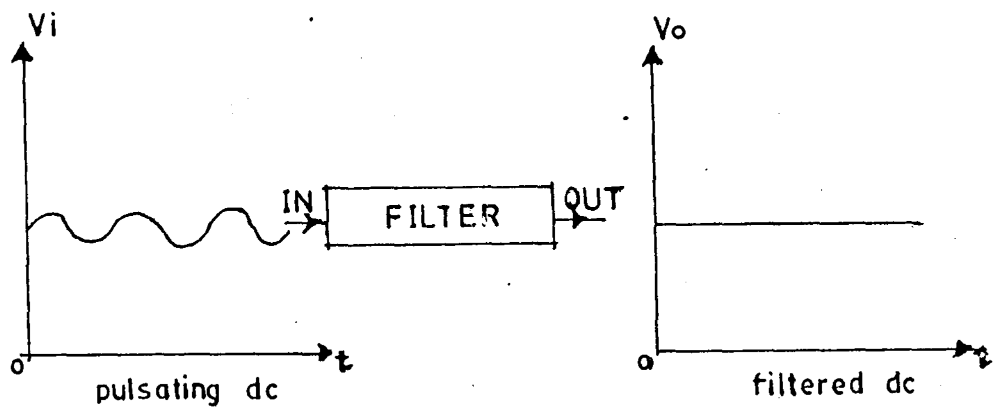


Fig 3.6.3 Pulsating dc to Filtered dc Supply.

Output at various rectifier circuits is pulsating. It has a d.c value and some a.c components. This type of output is not used for driving sophisticated electronic circuits and devices. There are 2 main types of filters employed to smoothen-out pulsating in the output namely: the shunt and the series capacitor filter.

For this project, the shunt capacitor filter is used, the capacitor is connected across the rectifier and in parallel with the load R_L to achieve filtering action.

fig 3.6.3(a) - fig 3.6.3(c) below shows the filter circuit and its filtering action illustrrated in the wave forms.

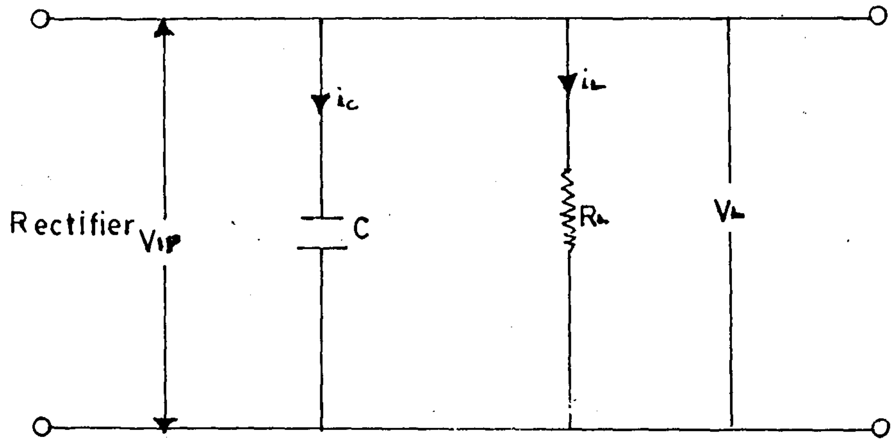


Fig. 3.6.3 (a).

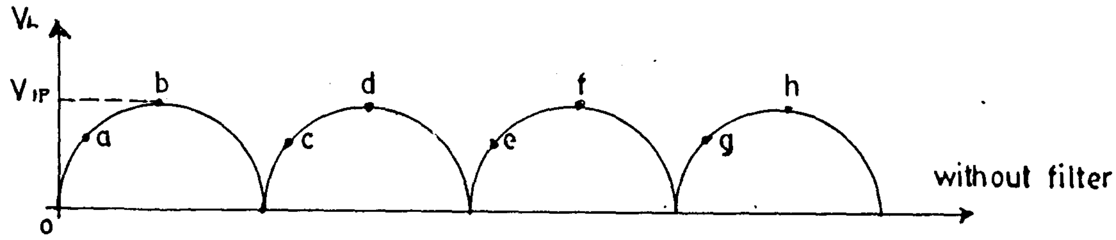


Fig. 3.6.3 (b).

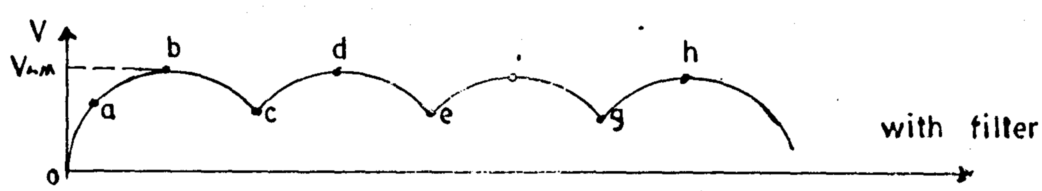


Fig. 3.6.3 (c).

An open circuit Point P is at positive potential with respect to Y and Z is at zero potential (but will be more positive than point Y at full negative half cycle potential when it will be held held at positive potential with respect to point y). D_2 is cut-off while D_3 conducts, making a complete path of unidirectional current through R_L across which a voltage V_{dc} is developed.

During the second half cycle, D_2 and D_4 passes a unidirectional current through R_L to develop a voltage while D1 and D_3 are open-circuited. The cummulative effect is that current flows throughout the complete cycle to produce a d.c voltage as the rectifier output.

ADVANTAGES OF FULL-WAVE BRIDGE RECTIFIERS

1. It gives twice the efficeincy of half-wave
2. It is more efficient
3. It gives twice Vdc for half-wave
4. It's output is much easier to filter because it has less amount of ripples.

FULL-WAVE ANALYSIS

$$V_{dc} = \frac{2Vmax}{A} = 0.636\ Vmax$$

$$V_{rms} = \frac{Vmax}{\sqrt{2}} = 0.707\ Vmax.$$

Output frequency = Twice input frequency. Hence $F_o = 2fi$

This increase in output frequency makes it easier to filtered, and also it contains only even harmonics.

Piv = Vmax (Bridge rectifier)

Piv = This is the maximun voltage appearing across the rectifier diodes during the time of non-conduction

Ripple Voltage (Vrip) = i/Fc.

FILTERING ACTION OF A SHUNT CAPACITOR.

When +ve half cycle of the a.c. input is applied to bridge rectifier [fig. 3.6.2], diode 1 and 3 are forward biased. This allows capacitor C to quickly charge up to peak value of input voltage VIP [point 6 in fig. 3.6.3b] because charging time constant is approximately 0.

Hence capacitor C follows the charging voltage as shown. After being fully charged, the capacitor holds the charge till input a.c. supply to the rectifier goes -ve.

During the -ve half cycle the capacitor attempts to discharge through D1 and D2 but cannot because they are now reverse biased. Therefore it discharges through RL from point b to c in fig. 3.6.3(c) and its voltage decreases somewhat. The discharging time constant [CRL] is usually 100 times more than the charging time. Hence C does not have sufficient time to discharge appreciably.

During the next +ve half cycle, when rectifying voltage exceed the capacitor voltage represented by point in fig 3.6.3(C), the capacitor C is again charge quickly Vip as represented by point d. In this way, RL sees nearly constant d.c. voltage across it at all times.

3.6.4 VOLTAGE REGULATOR

In an unregulated power supply, output changes when ever input supply voltage or load resistance changes. It is never constant. The change in voltage from no-load to full-load condition is called voltage regulation. The aims of a voltage regulator is to reduce these variation to zero or at least, to the minimum possible value.

In brief the main function of a voltage regulator is to keep the terminal voltage of the d.c. constant even when:

(i) a.c input voltage to the transformer varies

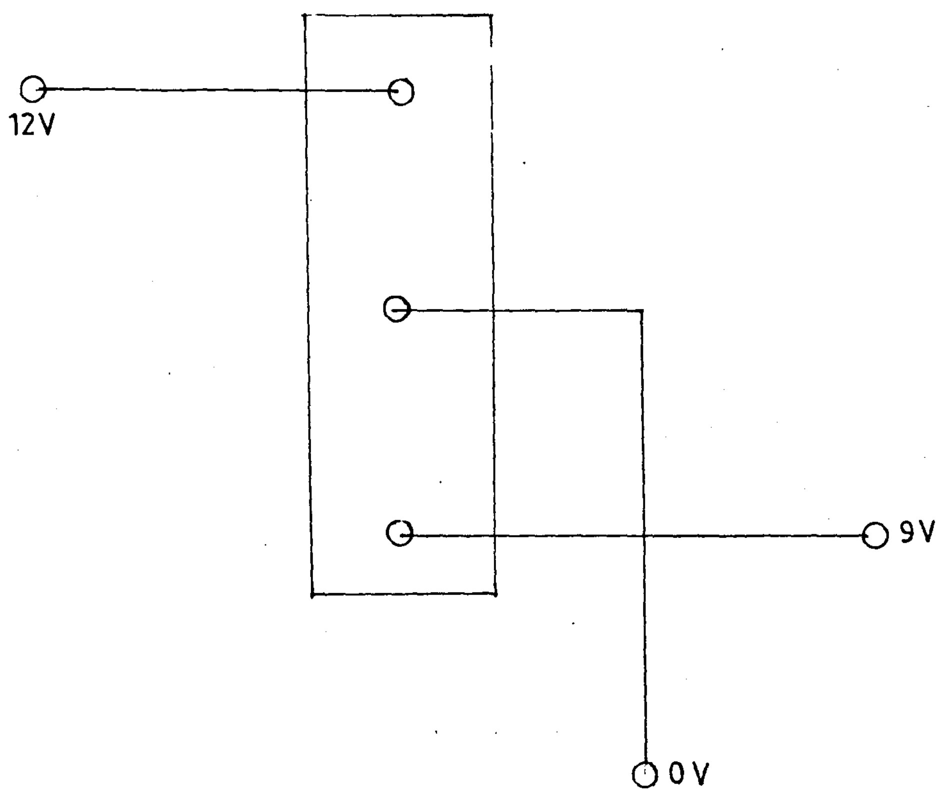
(ii) The load varies.

The value of regulator used in this project is L78m09, it is used to maintain the rectified voltage at constant 9 volts.

Percentage (%) regulator = (Vmax - Vmin/Vmax) x 100

Vin = 12 and Vout = 9 when there is no fluctuation in voltage supply.

Voltage drop across the regulator = 12 - 9 = 3V



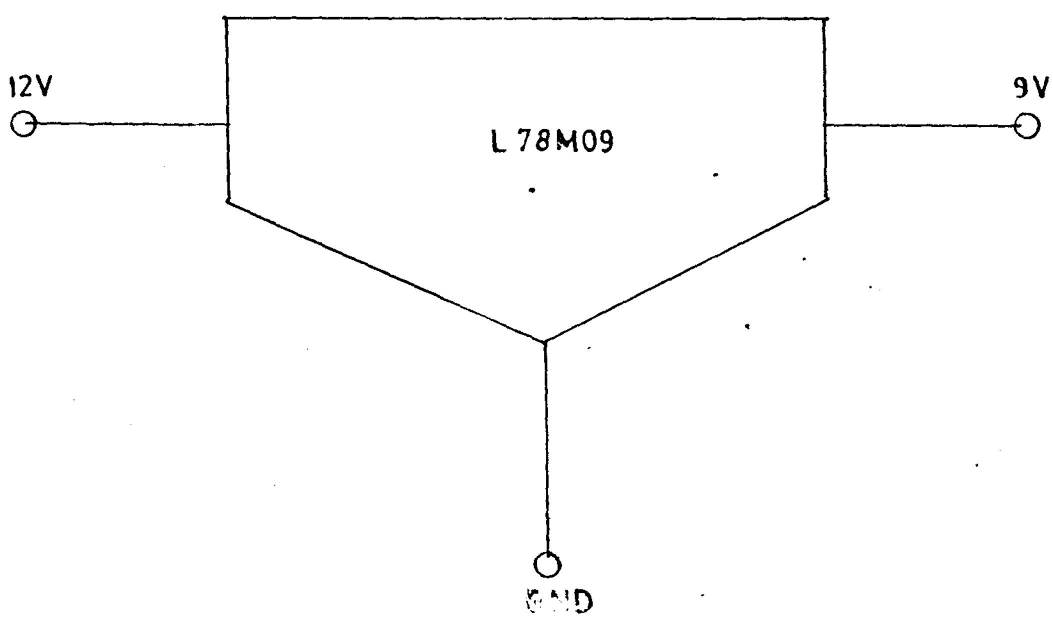


Fig. 3.6.4 Voltage regulator diagram.

The regulator allows for stability to the limit as follows

240 --> 12V = 240/12 = 20 times.

∴ for supply to be as low as 9V then mains must be as low as 9 x 20V = 180V. Expect mains fluctuation gets below 180V before there will be malfunctioning in the system (i.e. before supply can drop below 9V).

Also connected at the extreme end is a light emitting diode (LED) to indicate that there is voltage across the circuit. It is connected in parallel to the voltage regulator. The complete power supply is shown below.

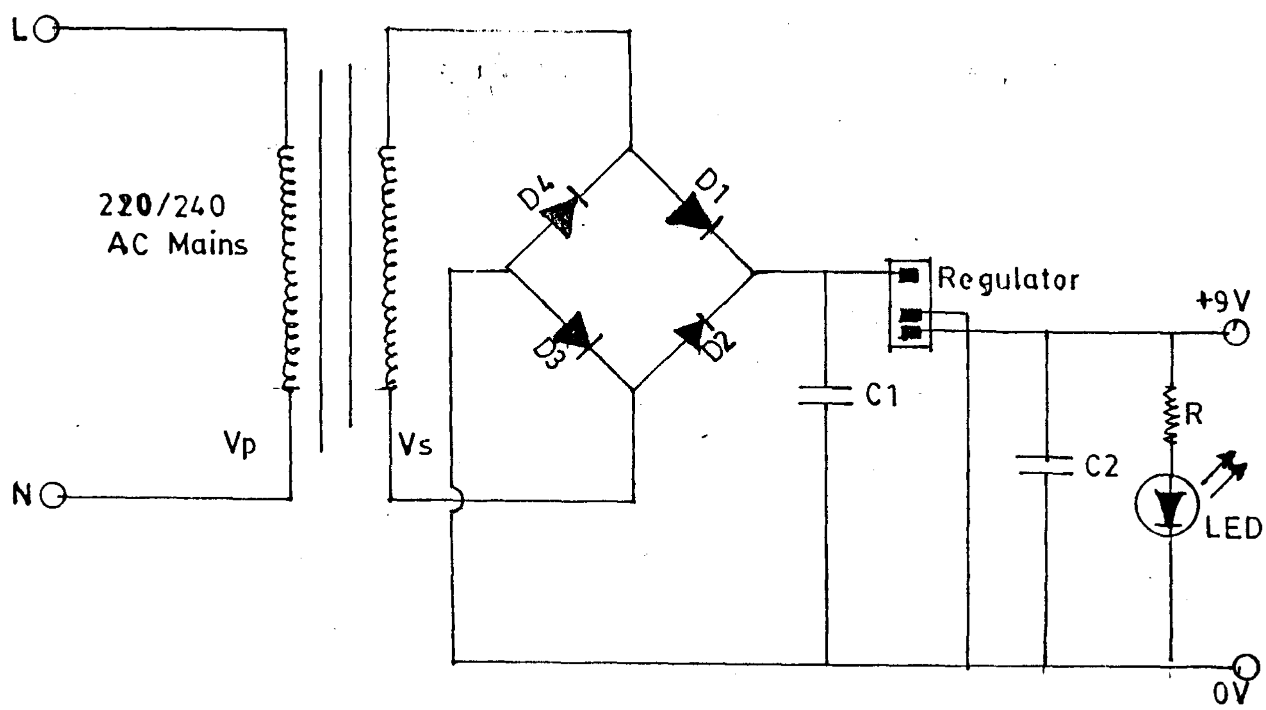
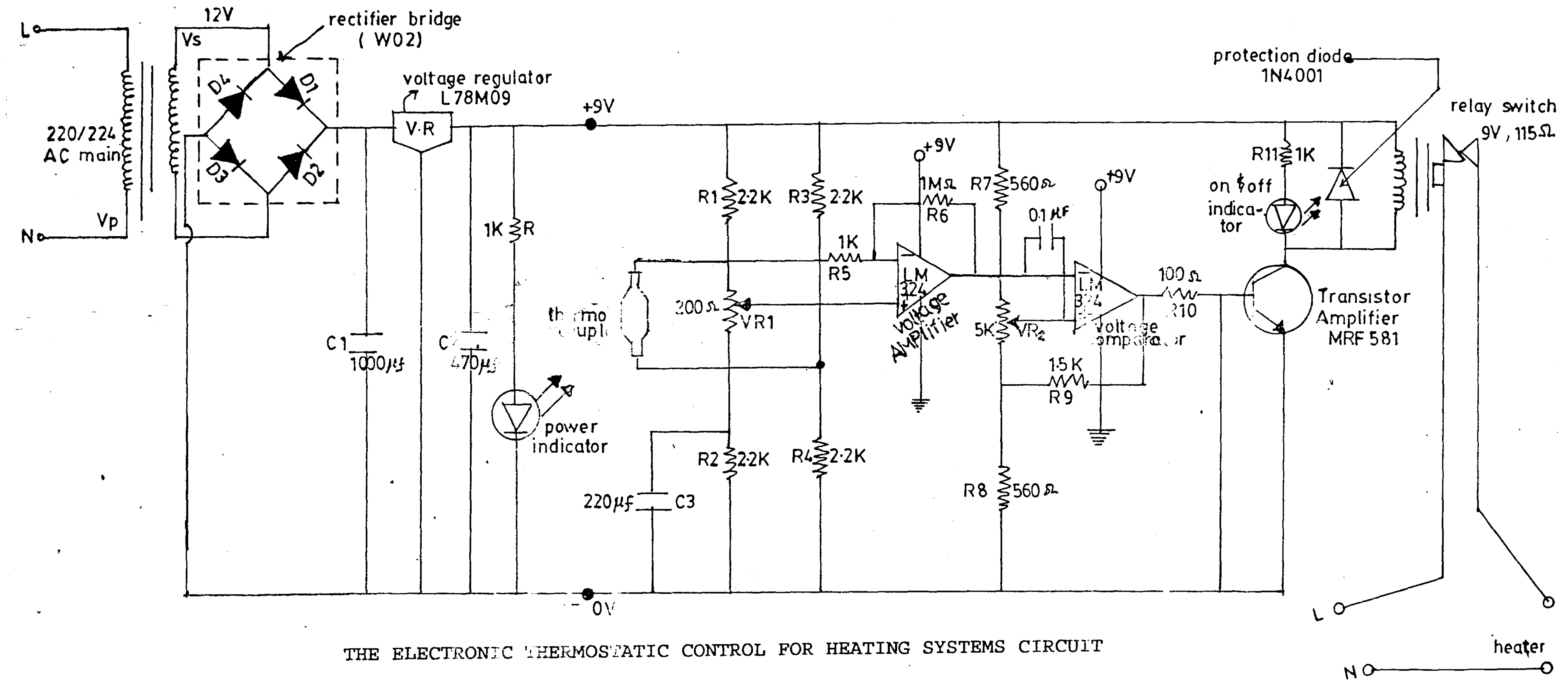


Fig. 3.7 Power Supply Circuit



THE ELECTRONIC THERMOSTATIC CONTROL FOR HEATING SYSTEMS CIRCUIT

3.7 **CIRCUIT MODE OF OPERATION**

The 220/240 a.c mains (N.E.P.A.) was stepped down using a 12 volts step-down transformer and then rectified to 12v dc power supply using a full bridge rectifier (Wo2), the ripples associated with this 12v dc supply is taken care of with a smoothing capacitor c_1. The dc supply is further regulated to a constant dc 9v supply and also associated with this dc supply is ripples which eventualy was cleared with a filtering capacitor c_2, the light emitting diode indicates the existence of power.

The 9v power supply is fed into the control circuit and the heater is triggered on, V_{R1} is used to preset the inverting dc amplifier in such a way that output v_{o1} doesn't saturate within the temperature range this project is designed for . VR2 is used to maintain a desired temperature (38° - 80°) and also set a reference voltage (V_{ref2}) to the comparator.

As temperature increases, the e.m.f generated by the thermcouple also increases, this (e.m.f) is however very low (mVolt), therefore the voltage amplifier (Lm324) amplifies the e.m.f by gain of 1000 and the output of the amplifier Vo1 is then fed into the inverting input of the voltage comparator (Lm324) which compares the voltage Vo1 and the reference voltage Vref2 set by the variable resistor VR2. When this Voltage (V_{o1}) exceeds the V_{ref} the output V_{o2} of the comparator after suitable voltage division is applied to the base of the transistor (mRf 581) amplifier, with V_{o2} high the transistor is driven into saturation and the current flows through the collector region to energized the relay coil, then the relay switch which is normally closed becomes open thereby triggering the heater off.

As temperature decreases, the emf generated by the thermocouple also decreases, therefore V_{o1} decreases and the output of the voltage comparator V_{o2} becomes low and fed to the base of the transistor, this V_{o2} is not high enough to bias the transistor thereby cutting off the transistor and no current flow through the transistor to the relay, the relay coil becomes de-energised and relay switch return back to its original positon therby switching on the heater.

This circuit is an automatic system, as the operation process continue to repeat the loop.

constant positon. In such a way that V_{o1} dosen't get saturated within the temperature range of the project, while a multimeter was placed at the output of the dc amp. V_{o1}, which is the test voltage to the comparator and a thermometer was placed at the hot junction of the thermocouple and then, V_{R2} was adjusted until the relay turn on the heating device for about a minute and then turn it off again, the temperature reading at which the heating device turns off and the corresponding voltage (Emf) generated by the thermocouple was noted to be 38° and 4V respectively.

On readjusting the V_{R2} further, the corresponding temperature and voltage are 45° and 4.85V respectively, and it was observed that the heating device remain in the on and off state for quite a long period of time compared to when it was at the on/off state for the previous setting (38°). By so doing a turn on state is achieved when the voltage applied at the inverting input is less than reference voltage (V_f) at the non-inverting input of the comparator

i.e. On state indicate that $V_{ref} > V_{test}$
and Off state indicate that $V_{ref} < V_{test}$

Conclusively, it was observed that as temperature increases the voltage (Emf) generated by the thermocouple increases.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION:

The design and construction of this project has not been an easy task in anyway, it calls for precision, hence a functioning electronic thermostatic control had successfully been carried out as described. The demonstration of the detection of heat which depends solely upon the temperature of the sensor device (thermocouple), the thermocouple here, is placed in the heating environment and the detection is through photoelectric effect via a switching unit which is indicated with a LED as indicator.

The main aim of this project which is to produce a phototype control circuit for heating systems that could accept an input signal from a sensor and then gives an output to indicate the condition at the input has been fulfilled. With this regard it can be said that the desired output at the switching unit due to temperature variation at the transducer was satisfactorily abtained.

5.2 RECOMMENDATION

To bring this work toward better temperature control, a more sensitive and reliable temperature transducer that is more sensitive than the thermocouple should be used. Sophisticated signal processing techniques using analog to digital converters is recommended in other to display the actual temperature at which the environment is been heated. Moreso, a microprocessor base system is also recommended.

Since this design can still be inproved upon, it will serve as a stepping stone, for whoever is interested in building a modern electronics thermostatic control.

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