DESIGN AND CONSTRUCTION OF AN ELECTRONIC THERMOSTATIC CONTROL FOR HEATING SYSTEMS

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CERTIFICATION

This is to certify that this project "Electronic thermostatic control for heating systems" was designed and constructed by EMAJEMITE WILLIAM for the award of bachelor degree in Electrical/Computer Engineering Federal University of Technology, Minna Niger State, Nigeria.

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DEDICATION

This project is dedicated to Almighty to God, who through his infinite mercy saw me through this grate institution of life.

ACKNOLEDGEMENT

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

Special thanks to my supervisor Engr.J.Tsado,for his tireless assistance,constructive ideas,encouragement,time spent and his guidance.My thanks alsogoes to my lecturers Engr Attah who gave me the basic background on analogue electronics,Egr Rumala who built self confidence in me through his lectures and my Engr.M.N. NWOHU for his fatherly advice to us. I also want to thank the present and past Dean of Egineering,Prof.FAkinbode, Prof.R.H.Khan and every member of my department and the entire school for their efforts and encouragement for me during the course of my study.

Words are not enough to say thanks to God who gave me the best parents in the world the, person of late Mr.Emajemite Aguonefe and my beloved mother who took care of me from childhood and gave me the opportunity to be educated.

I wish to express my deep appreciation and gratitude my brothers and sisters,Mr Michael Aguonefe, Mr. Peter Emajemite and Mrs Julie Eshaka for giving support and love throughout my academic pursuit.

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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 thermostatic 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 under heating or overheating. Internal heat gain 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 achieve 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 trigger automatically when the temperature inside a house, oven, kiln, incubator or any heating environment exceeds the required temperature. Generally, this equipment controls one or more heating source to maintain a desire 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 main spring for the operational outline of the control.

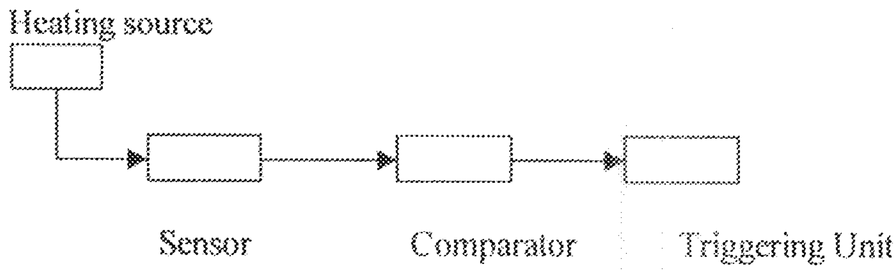


Fig. 1.1 Block Diagram of Thermostatic Control

The sensor; for this project, is a thermistor which is used as the sensing device that detects the changes in temperature and produces a desired effect. The comparator; compares the signal with the reference voltage, when input signal exceeds or less than the reference signal the output of the comparator changes from its value. The comparator thus, detects two input voltages and provides an output that has two discrete states.

The thermostatic control for heating system is a feedback control that reacts to
a change in temperature; the change of temperature affects the sensor, which in turn sends back an electrical signal to control the heating system.

1.2 LITERATURE REVIEW

It is on record that researchers and implementation of thermostatic control itself did not seriously take off until in the 80s when the needs 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 patent on what he called a heat responsive element consisting of steel bar 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 values or dampers to control heating system.

For the purpose of this project a number of text was consulted, one of these texts is merit student Encyclopedia by William. Hasley and Emmanuel Friedman where J.J.Jaklitsh.Jr dealt with the kind of thermostatic control for heating systems and give 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 1880s thermostatic control was defined and he 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 Dreddel,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 is extremely accurate when connected to electronic equipment, that only minute adjustment 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 equivalent, which is fed into the display unit from where the temperature variation may be read.

In addition to getting 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 makeup 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 OBJECTIVES AND MOTIVATION

The main purpose of this project is to design and construct an Electronic thermostatic control for heating systems. The system is designed 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 interfaced with wider variety of heating equipment.

(ii) The project has to be inexpensive.

(iii) The project should be easily setup and should require minimum maintenance.

Over heating a particular environment, being it a house, oven,kinl,incubator e.t.c 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 encompasses the general introduction where a brief knowledge of the history of electronic thermostatic control for heating system is discussed 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 into 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 component used, implementation and mode of operation of the thermostatic control were discussed

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

Finally, the last chapter (five), which is the conclusion summarizes the whole project and recommendation to further improvement on the design

CHAPTER TWO: DESCRIPTION OF DESIGN

The design of this project is limited to a closed 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 transducer unit, comparator unit and the switching unit.

The main component used in this project is the transducer bridge with its sensor (thermistor) whose function is to detect the present of heat within its vicinity. The thermistor is placed in a bridge circuit and the voltage drop across it, which is directly proportional to the instantaneous temperature of the heated environment, is fed to a comparator input.

A comparator is a two input 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 (Vref) with the help of a variable resistor V_R ,while the other input terminal is placed at a varying voltage which depends on the temperature of the thermistor.

The output of the comparator is then passed onto a switching unit comprises of a transistor and a relay. The NPN transistor is used as a current amplifier 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 of the heater.

The units consideration that make-up this project are explain below.

2.1 THE TRANSDUCER UNIT

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

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

2.2 HEAT 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, most temperature sensor may be used. The thermocouple and the platinum resistance are relatively expensive, while the semiconductor types of sensor are not easily obtainable. Due to low cost and availability. The thermistor is used for this project 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 output of the comparator, V_{out} changes from its value when V_{in} is less than or equal to V_{ref}.

A comparator circuit exhibits non-linear operational amplifier characteristics, whereas 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 amplifier, it should be noted that voltage comparator is just one of the areas of amplification of operational amplifier. A comparator thus performs the following functions:

(i) Detects two input voltage.

(ii) Provides an output that has two discrete 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.

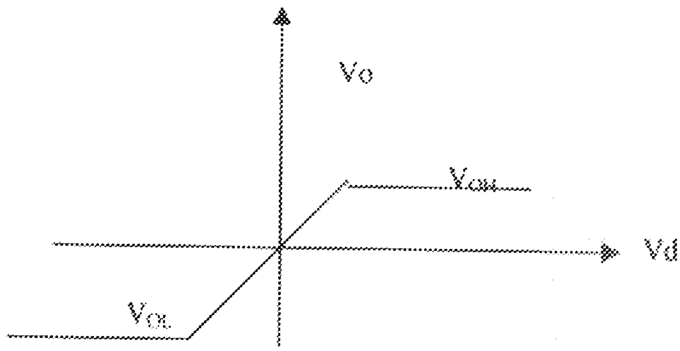


Fig.2.4 Comparator Voltage Transfer.

The Comparator operation is expressed as

$V_O = V_{OL}$, where $V_{ref} > V_{in}$

$V_O = V_{OH}$, where $Vref < V_{in}$

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 topped.

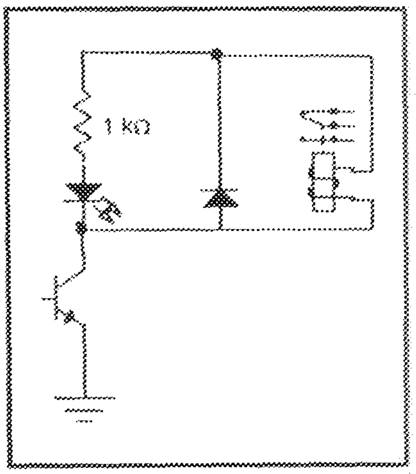


Fig 2.5 Block Diagram of Switching unit.

CHAPTER THREE: DESIGN ANALYSIS.

The detail design consideration for each component used in this project is analysis in this chapter.

3.1 THERMISTOR

The thermistor is the transducer (sensor) used in the project, it is made basically of sintered oxides of nickel and manganese, it is a device that undergoes a change in resistance with rise in temperature, most of the types have a negative temperature coefficient (NTC), their resistance fall with rise in the temperature of their surrounding, while some are positive temperature coefficient (PTC), their resistance increase with rise in temperature of their surrounding. For the purpose of this project the NTC type is used.

3.2 THE OP- AMP – AS A COMPARATOR

The 741IC OP-AMP is used in this project as a differential voltage comparator circuit operation on whether one of the inputs is greater or less than the other. So the two output voltage levels therefore represent the output voltage of decision. This is mostly determined by the saturation position of the op-amp. When the sampled input voltage by more than a few hundred of milivolts, the output is driven to negative saturation. It is the magnitude of the differential input voltage that detects the magnitude of the output voltage, so the absolute value of input voltage is of little importance.

The circuit thus function as a precision voltage comparator or balance detector.

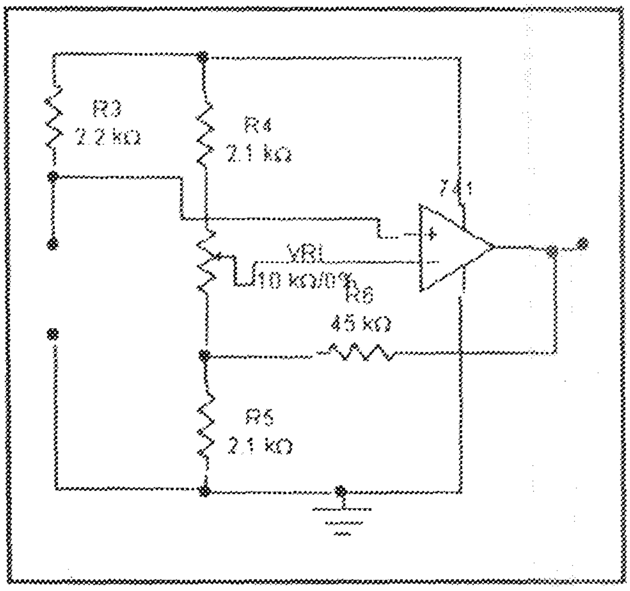


Fig 3.2 THE COMPARATOR CIRCUIT.

It is required to design a comparator circuit that will compare two signals (one from the thermistor and the other from the variable resistance V_R to give an output when the thermistor temperature is at the critical temperature and to give zero output when it is above the critical temperature. For the purpose of this project the critical temperature is at 45^0C.

The inventing input of the 741IC is held at a fixed reference voltage V_{ref}, the other terminal is connected to the thermistor.

Since the thermistor is an NTC, its resistance decreases with rise in temperature and increases with decrease in temperature.

The resistance(R_{Th}) of the thermistor corresponding to the critical temperature is 2.2kΩ.

The output of the comparator circuit is given by

$V_0 = A_0$ (Vin – Vref) ....(1)

Where A_0 = the open loop gain of the op-amp.

Vin = the input voltage at the non-inventing input

Vo = Aodi ---------(2)

Vin = $R_3 / (R_3 + R_{Th})$*Vcc................(3)

Voltage across variable resistor V_R is given by

Vref = (V_{R02} + R_2)/ [(V_{R02} + R_2) + (V_{R01} + R_1)]* Vcc.........(4)

Where , V_{R01} = resistance between the inventing input of the comparator and R_4

V_{R02} = resistance between the inventing input of the comparator and R_5 .V_{R01} and V_{R02} are determined, when the variable resistor V_{R1} is adjusted to a point in such a way that the thermistor is heated to the critical temperature range of 45 °C

V_{in} = (R_3)*Vcc/(R_3+R_{Th}) ,R3 =2.2kΩ ,R_{Th} = 2.2kΩ

= (2.2kΩ * 9 V)/(2.2kΩ+2.2kΩ)

= 4.5V

From equation (4)

$R_4 = R_5$ =2.1kΩ ,V_{R01} = 5.1kΩ,V_{R02} = 4.9kΩ

$Vref = (7k\Omega*9)/14.2k\Omega$

$= 4.44V$

Current through V_R (Vref) $= (4.44)/14200$

$= 0.3171mA$

The voltage (V_{in}) applied at the non – inverting input of the comparator is higher than Vref at the inverting input of the comparator. This indicates the ON mode of the heating device. If the thermistor is heated above the critical temperature the resistance falls causing output voltage to go high again. This indicates the ON mode of the heating device while the later denotes the OFF state.

From equation (1)

$Vo = Ao(4.5 - 4.44)$

$= Ao(0.06)$

where $Ao = 1+(R_6)/R_5$, $R_5 = 2.1k\Omega$, $R_6 = 45k\Omega$

$1+(45/2.1) = 22.43$

$Vo = 22.43*0.06$

$= 1.3V$

3.3 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 used for switching and other purposes. Germanium and silicon are commonly used material for the production of a transistor. The transistor is two types that is NPN and PNP.

For the purpose of this project, the NPN type of BC184L is used for current amplification, and provides the switching effect for the relay.

The NPN BC184L has the following specifications

I_{Cmax} = 0.1A

V_{BE} = 5V

V_{CE} =50V

h_{fe} = 400

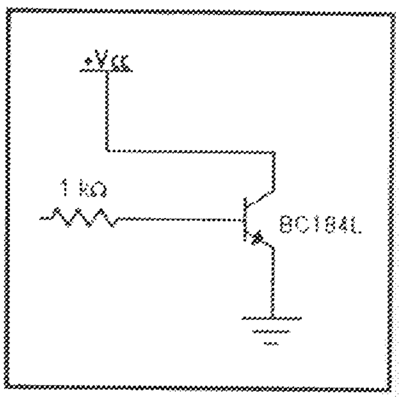


Fig.3.3 The Transistor Switch

The output of the Op- amp is fed into the base of the transistor. When this transistor is saturated a current flows through the collector to the coil of the relay, when the relay is energized it switches open and the heating stopped

The base voltage is given as,

$V_{Rb} = (1.3*1000)/5700$

$= 0.23V$

$I_{Rb} = 0.23mA$

The base current I_B required for saturation is calculate from

$I_B = Ic/\beta$

$= Ic/h_{fe}$ .... (1)

Equation (1) gives

$I_B = 0.1/400$

$= 0.25mA$

For the transistor not to breakdown the minimum base current is used to

drive transistor to saturation.

The collector current that is required to energize the relay coil is given by

$I_B(min) = Ic/h_{ef}$

$0.23mA = Ic/400$

$Ic(min) = 0.0023*400$

$= 0.92A$

3.4 RELAY SWITCH

A relay is an electromagnetic switch, a movable spring armature is mounted above the core of an electromagnetic, when the core is energized, the armature is altered and the contact points open or close by responding to the change in physical quantities such as current, voltage frequency, temperature e.t.c. A relay in a normally closed position opens when activated while normally open relay closed when energized. When energizing potential is removed, the spring action returns the armature to its normal original state. 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 exceeds its operating point or peak value. An under current under voltage relay operates when the actuating quantity falls below the reset value. An under current and under voltage relay operates when the actuating quantity falls below the reset value.

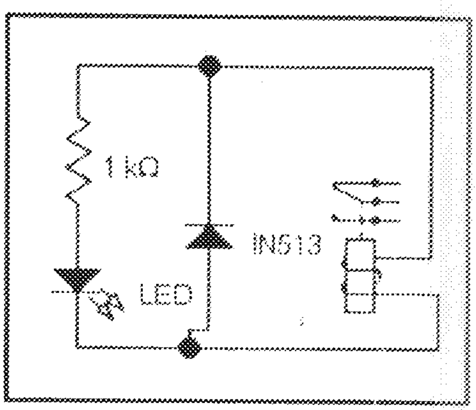


Fig 3.4 Relay Switch.

A relay switch of normally closed type is used in this project, so that at a particular point when it opens it trips off the heating circuit. Since the circuit is operating at 9V and with a maximum collect current of 0.1A (from transistor rating).

The relay selected has a resistance of 120 Ω; the relay current is given as

$$I_{relay} = 9V/120$$

$$= 0.075A.$$

This is the maximum current that can flow through the coil; hence the forward current should be greater than the relay current.

The diode connected in parallel to relay is a protection diode that prevents back e.m.f from burning the transistor. While the green LED (light emitting diode) that is connected in series with the 1kΩ resistor indicates the ON and OFF mode of the

comparator. The resistor also limits the current that flows through the LED.

3.5 POWER SUPPLY UNIT

The D.C power supply is a basic electronic system, generally consisting of a transformer, capacitor, resistor, rectifier 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.

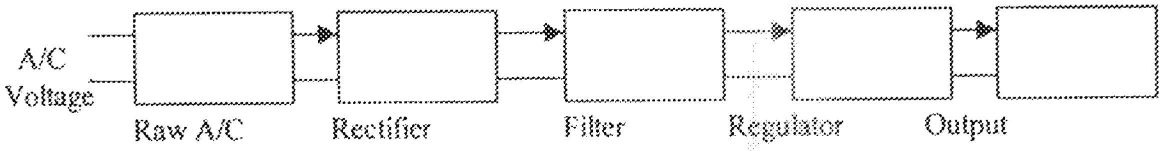


Fig 3.5 Block Diagram of power Supply system

Most electronics system cannot operate successfully and effectively with A.C power supply because this is always fluctuating. This implies that at sometimes there will be a response and sometimes later no response, most electronics system operates on a low D.C voltage supply, which is usually derived from an alternating current source like N.E.P.A supply because it is more economical than investing on batteries.

3.6 TRANSFORMER

Since the voltage supply from the mains cannot be used directly, transformer is used to step down or step up the A.C voltage to suit the requirement of the solid state electronic devices and circuits fed by D.C power supply. It also provides isolation from the supply line to the load, the connection with power line is through the magnetic field linking the primary and the secondary windings, thus this eliminates the risk of electric shock when working with semi-conductor devices. If the number of turns of the primary and the secondary windings are known, the output voltage from the primary side can be calculated from the following equations.

$V_2/V_1 = N_2/N_1 = K$..............(1)

Where, K is known as the voltage transformer ratio

N_1 = no. of turns in the primary
N_2 = no. of turns in the secondary

V_1 = primary voltage

V_2 = secondary voltage

From equation (1)

(i) If $N_2>N_1$, that is K<1, then the transformer is called a step- up transformer.

(i) If N2<N1, then the transformer is called a step-down transformer

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

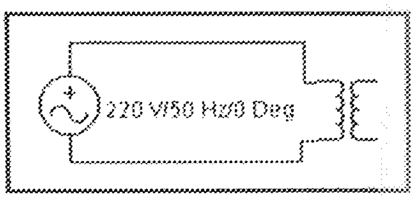


Fig 3.6 circuit diagram of a transformer.

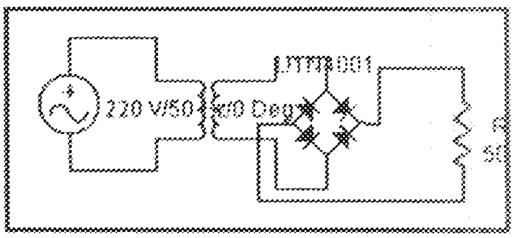
3.7 RECTIFIER.

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.

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

THE BRIDGE RECTIFIER: The full- wave bridge rectifier is the most frequently circuit for electronics d.c power supply, it consists of four diodes, a transformer not center-tapped and has a maximum voltage of V_m.

The circuit diagram is as shown in fig 3.7(a)



(a)

MODE OF OPERATION

During the positive input half-cycle, terminal M of the secondary voltage is positive and N is negative.

Diodes D_1 and D_3 become forward-biased (ON) while D_2 and D_4 reverse-biased (OFF). Hence, current flows along MEABCFN producing a drop across R_L and the wave-form is as shown in fig 3.7.1(b)

During the negative input half-cycle, secondary voltage terminal N becomes positive and M negative; D_2 and D_4 are forward-biased and circuit current flows through NFABCFM the resulting waveforms is as shown in fig3.7.1(c). Combining the resulting waveforms in (b) and (c) gives the full-wave rectification of the sinusoidal voltage.

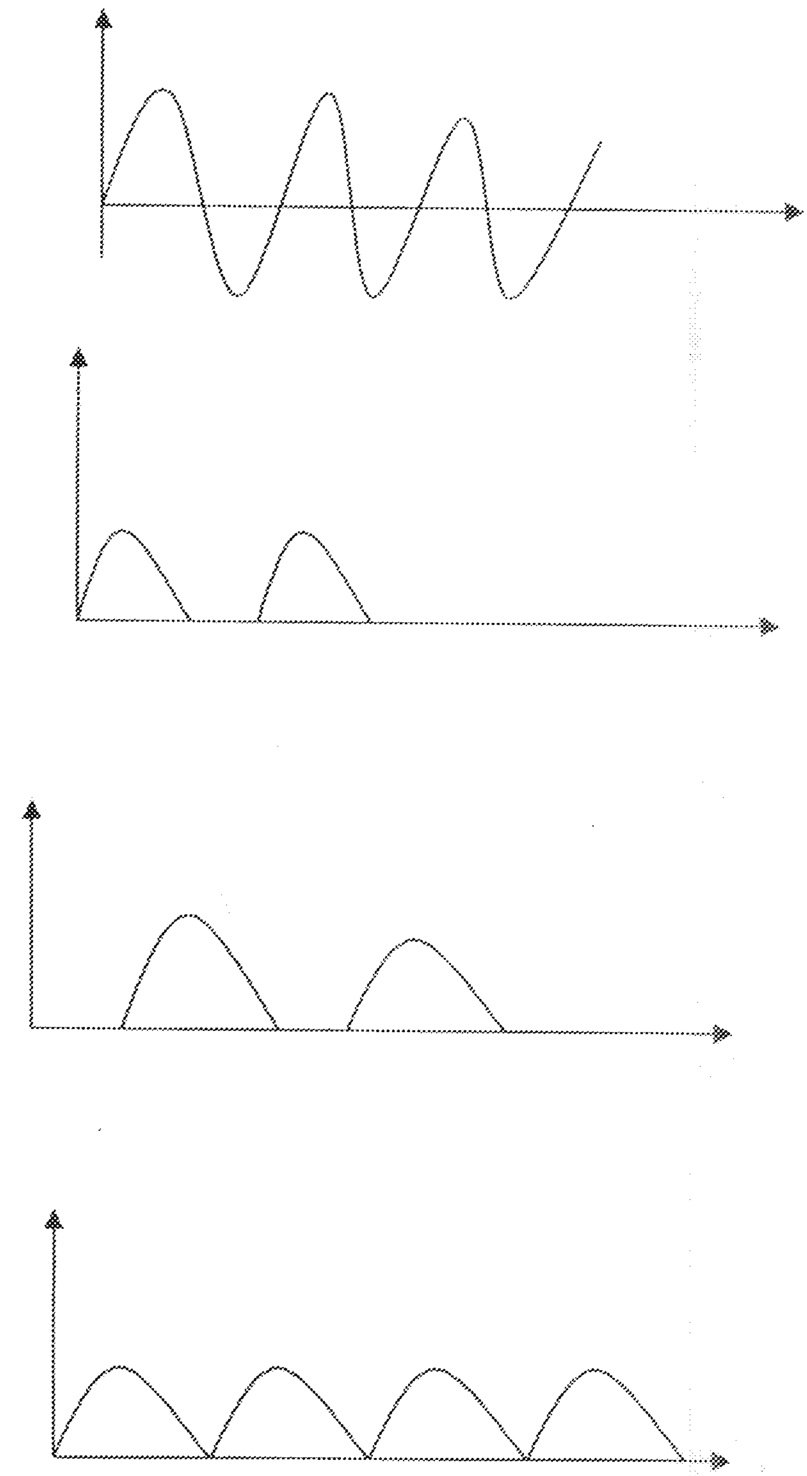


Fig 3.7.2 Full-wave rectifier waveform

3.8 FILTER CIRCUIT

The main function of the filter circuit is to minimize the ripple content in the rectifier output. As seen, output of various rectifier circuit is pulsating, that is it has a d .c value and some a .c components called ripples. In order to convert the pulsating output from the rectifier into a steady d .c level a filter circuit is required. There are various types of filters, but for the purpose of this project the series capacitor filter is used as shown in fig. 3.8(a)

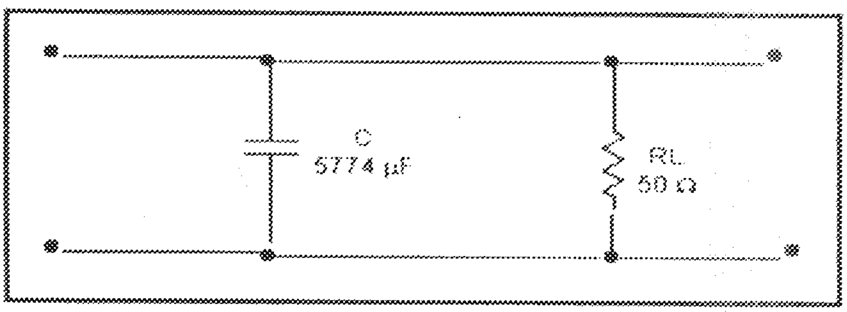


Fig 3.8.1(a) the diagram of the filter circuit.

3.9 FILTER DESIGN considering the filter circuit shown in fig3.8.1 (a). It is required to calculate the value of the capacitor that will help to reduce the magnitude of the ripple voltage, since capacitor has a basic property of opposing charges in voltage. This can be calculated by chosen a suitable value of a load resistor R_L. The ripple voltage, which occurs under this load conditions, can be approximated by a triangular wave, which has a peak – to – peak value of Vr (p-p) and a time period of Tr.

Where Vr(P-P) is the amount by which the capacitor voltage falls during discharge period Tr. This discharge actually is exponential, but can be approximated by a straight line discharge if we assume the discharge rate to remain constant at the dc level I_{dc} . In this case, charge lost dQ in time Tr is IdcTr

Therefor, Vr(P-P) = dQ / C = IdcTr /C……………(1)

= Vdc / FrCRL

Note that Idc = Vdc/R_L

The triangle ripple has an rms value given by

Vr(rms) =Vr(p-p)/2*$3^{1/2}$

= (Vdc)/2* $(3FrCR_L)^{1/2}$ ………………(2)

γ =Vr(rms)/dc = 1/2*$(3FrCR_L)^{1/2}$

Where Fr is the ripple voltage. For full-wave rectifier Fr is 2F, if F is the line frequency, then

γ = Idc/4*(3FC)[1/Vip -1/Vdc] … ……………(3)

=1/4*(3FCR^{L}) = Idc/4*$(3FCVip)^{1/2}$

It is seen from above that ripple increases with increase in load that output current.

Incindentall, Vdc = Vip – Vr$(p-p)^{1/2}$

Where Vip = Peak rectifier out put voltage, Substituting the value of $Vr(p-P) = Vdc/FrCR_L$ we have,

$Vdc = Vip - Vdc/4FrCR_L$ or $Vdc = Vip/[1+1/(4FrCR_L)]$

Therefore $Vdc = Vip[4FCRL/1+4FCR_L]$..............(4)

Let the value of the chosen load resistor $R_L = 50\Omega$, $Vip = 12.2V$ at 50Hz

To determine the value of the shunt capacitor to give 1% ripple factor and the resulting d.c voltage across the load resistor can be calculated using equations (3) and (4)

$\gamma = 1/4*(3FCR_L)$

Substituting the given values, we have

$0.01 = 1/(4*1.732*50*50*C)$

$C = 54774\mu F$

Therefore, $Vdc = Vip/[1+1/(4FCR_L)]$

$12.2/[1+1/(4*50*5774*10^{-6}*50)]$

$= 12V$

3.10 VOLTAGE REGULATOR

Voltage regulator is used to regulate unregulated power supply and to keep the terminal voltage of the d.c supply constant even when an a.c input voltage to the transformer varies or the load varies.

The value of voltage regulator used in this project is L78M09, it is used maintain the rectified voltage constant at 9V

The % regulation of power is given by

% Regulation = (Vmax – Vmin)/(Vmax)*100

Where, Vmax = 12V, Vin = 9V

% Regulation = (12-9)/(12)*100

= 25%

3.11 CIRCUIT MODE OF OPERATION

The circuit is set up as shown in Fig 3.11 When the 9V power supply is applied to the control circuit, the heater triggered ON, since the relay is a normally closed type. The variable resistor V_R is used to preset the reference voltage Vref so that the comparator output voltage Vo, cannot bias the transistor. At this point Vref > V_{in}.

As heating continues the resistance of the thermistor is also decreasing, causing a rise in the input voltage V_{in} until the resistance of the thermistor is just the same as R_3,at this point V_{in} has risen to a value of 4.5V with a corresponding temperature of 45°C measured with a thermometer. This is the critical temperature of the project.

Now,

Vref < V_{ni}.

The rise in Vin causes the comparator to swing high and the output voltage Vo is just sufficient to bias the transistor. The green LED turns ON to indicate that collector current is flowing into the relay coil

energize it, the relay switch which is normally closed becomes open thereby triggering the heater and the LED OFF. This indicates the OFF mode of the heater.

As temperature increases past the critical temperature, the resistance of the thermistor decreases below that of R_3 this causes a fall in Vo. At this time Vref $>V_{in}$, and the output voltage of the comparator Vout becomes low, which is not sufficient to bias the transistor thereby cutting off the transistor and no current flows through the transistor to the relay.

As the temperature decreases the resistance of the thermistor will begin to rise until it's resistance is equal to R_3, also the relay coil becomes denergized and the switch returns to its original position thereby switching ON the heater again.

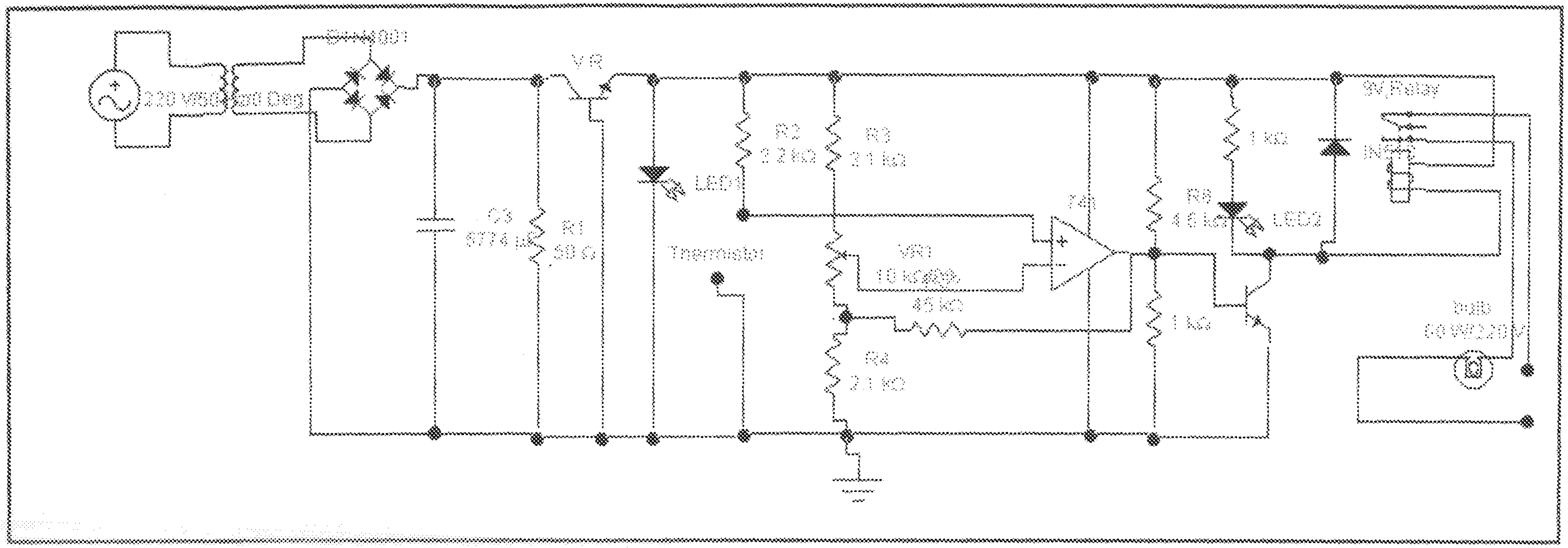


Fig.3.11 Circuit For The Eletronic Thermostatic Control For Heating Systems.

CHAPTER FOUR: CONSTRUCTION

The construction was undertaken by testing the designed outline stage, in this regard the power supply section was first connected as indicated in the design and then tested on the breadboard, the desire result was obtained as the components were connected correctly. The components were then transferred to a Vero board, care was taken in the course of soldering to avoid short circuit. The circuit was tested again and then placed in a casing.

4.1 TESTING AND MEASUREMENT

In testing and calibrating the system, power was applied to the circuit input terminals and V_R was adjusted to set the reference voltage Vref at a fixed value, in such a way that the comparator output voltage V_{out} is not sufficient to bias the transistor, at this point $V_{ref} > Vin$

As heating continues the resistance of the thermistor also decreases, causing a rise in the input voltage V_{in} until the resistance of the thermistor becomes equal to R_3, at this time V_{in} has risen to half V_{cc} and the corresponding temperature of the thermometer dipped into the heated water where the sensor is attached, with series adjustment of the potentiometer the value of the critical temperature of the project was obtained (45°C). At this temperature,

$V_{ref} < V_{in}$

Further increase in the temperature above the critical will cause a decrease in the thermistor resistance causing V_{in} to fall again. This indicates the on/off of the heating device.

CHAPTER FIVE: CONCLUSION

5.1 CONCLUSION

The design and construction of this project has not been an easy task in any way, it demands precision, and 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 (thermistor), the thermistor is placed in the heating environment and the detection is through photoelectric effect through a switching unit which s indicated with LED as indicator.

The main aim of this project, which is to produce a proto type 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 desire output at the switching unit due to temperature variation at the transducer was satisfactorily obtained.

5.2 RECOMMENDATION

To bring this work toward better temperature control, a more sensitive and reliable temperature transducer that is more sensitive than the thermistor should be used.

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