DESIGN AND CONSTRUCTION OF AN AUTOMATIC HEATER CONTROLLER SYSTEM

BY

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Dedication

This project is dedicated to my parents, my uncle, Alh. Ibrahim Abdullahi Aliero (sponsor), who care much and hope for me a beautiful future. Also to my beloved wife who gave me a full courage on everything I do.

CERTIFICA TION

this is to certify that this project, titled: DESIGN AND CONSTRUCTION OF AN AUTOMATIC HEATER CONTROLLER SYSTEM was carried out by Lawai Idris under the supervision of Engr. M.S. Ahmed and submitted to the Electrical and Computer E engineering Department.Federal University of Technology, Minna in partiaJ fulfilment of the requirement of Bachelor of Engineering (B.Eng.) degree in electrical 'and computer engmeermg.

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Declaration

I, Lawai Idris, hereby declare that this project is an original concept of mine. It was designed, constructed and tested under the supervision ofENGR. M. S. AHMED.

This project has not been presented in any form for the award of diploma or degree certificate. All information extracted and derived from published work has been duly acknowledged.

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Sign and Date

Acknowledgement

My sincerest appreciation must be extended to my supervisor, Engr. M.S. Ahmed who has checked the text and sent in comments, corrections and suggestions. I also want to thank Dabo Mato *T/wada* for his editorial support of this project. I wish to thank the countless individuals who have shared their suggestions on evaluation of this project throughout its edition.

ABSTRACT

Electrical and electronics circuits are always designed to solve social problems. This leads to the invention of an automatic heater controller system.

The system was design to switch ON the heater automatically at preset time, monitor the temperature and switch it off automatically when the preset temperature is reach.

This consists ofa clock that supplies a voltage to the input of the level shifter. The level shifter inverts and re invert the input signal and to which the output of the level shifter serves as the clock pulse for the time detector. The output of the time detector serves as one of the two input signals to the switching circuit.

The second input signal to the switching circuit comes from the output of the temperature sensor and controller.

The automatic reset circuit was also designed to resets the system when the water is heated without been fetched. A manual reset was designed to reset the system manually.

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Chapter one

General Introduction

1.1 Introduction

One of the most important discoveries man has made is the form of energy called Electricity, this energy has revolutionized almost all aspect of life. Electricity or rather electrical energy has the advantage of being transformable into many forms of energy that are employed in various fields. Man has numerous objectives to accomplish, and the means of achieving these objectives usually involve the need for control system. Recently, control system; have assumed an increasing important role in the development and advancement of modern civilizations and technology. Practically, every aspect of human day-to-day activities is affected by some types of control system. For example, in the domestic domain, automatic control of heating, cooling and air conditioning system regulate the temperature and humidity of homes and buildings for comfortable living.

Automatic heater controller is the automatic control of the temperature of a given hot device (especially heater) for the comfort of human being. Human beings are born into a hostile environment, with the degree of hostility varying with the season of the year and with geographical locations. This suggests that the argument for automatic heater controller switch might be based solely on surge damages and climatic conditions. These may be valid in areas where electric current is not stable.

1.2 Aims and Objectives

Automatic heater controller is a circuit system designed to switch water heater at preset times, monitor the temperature of the water and switch off the heater when a preset temperature on the device is reached, wait to reheat the water if it was not used and switch itself after three successive switching without the water being used by the user. The system uses local water heating element, a discrete logic IC, comparator, transistor, triac and other passive components.

1.3 Limitations

For this circuit to be working properly, the following limitations must be considered.

I. There must be constant supply of water in the container where the heater element is to be inserted and the water level should be appropriate so that the heating element of the heater is well dipped into the water.

2. The thermistor must be attached to the container.

3. Power supply capable of operating the heater must be available at the set time of switching.

Chapter two

Literature review

As weather changes throughout the year, temperature changes day by day out. This therefore, result in desire for thermal management .for many system, this means using heater or air condition and fans. Unfortunately, with the use of these systems come the problem of mechanical failure, not forgetting unwanted destruction of life and properties. Automatic heater controller switch and monitoring can ease some of these problems, resulting in more reliable and efficient systems.

2.1. Temperature

This is the degree of hotness or coldness of an object. Hence, temperature tells how hot or cold a body. is, the temperature of a body determines the direction of flow of heat between the body and its surrounding. Temperature is very important in human lives. Human body must keep a constant temperature. If man becomes ill, the man's body temperature may rise, the man is then said to have a fever. If heat flows away from a body, its temperature is above that of the surrounding and if heat flows towards the body, its temperature is lower than that of the surrounding [1].

An English thinker John Locke in 16th century discovered that man's sense are poor in determining level of temperature .consequently, scientists went into investigation to discover better ways of measuring temperature. An Italian scientist Galileo discovered the first thermometer (air thermometer).

Gabriel Daniel Fahrenheit, (A German instrument maker and physicist), invented the first accurate thermometer in the early 1799's.in 1742, a Swedish astronomer, Anders Celsius devised a new temperature scale and in the mid 1800 lord Kelvin (William Thomson),a British scientist suggested another scale for the temperature measurement[I].

Almost everyday, people use the word "hot" and "cold" the room is hot the water is cold, the weather is hot or the tea is cold. In every day usage "hot" implies "having a lot of heat" many people think that "cold "is something completely separate from heat. But cold simply implies having very little heat even though the first engines were built in the Iih century people were stiII wondering about the nature of heat.

2.1.1 Temperature measuring devices

There are various means of measuring temperature. This is normally achieved by using temperature measuring devices and element. These devices and elements are employed to read or study the temperature. The following is a brief summary of some common temperature measuring devices with no attempt made to be comprehensive.

2.1.1.1 Liquid-In-Glass Thermometer

This thermometer represents the oldest and perhaps most common practical thermometer. They come in many different form and qualities with variety of different liquids, although mercury is the choice for accurate application. A very good liquid in glass thermometer contains (mercury, alcohol, or toluene) which is connected to a capillary tube or a bourdon tube. The former produces a linear motion to make contact or more a flapper, in response to thermal expansion, where it ranges of application is -45 degree to 650 degree Celsius [1].

2.1.1.2 Vapour Pressure Thermometer

A liquid vapour interface exits in a bulb and the saturation vapour pressure transmitted along a capillary depends only on the temperature at the bulb. It ranges of suitability is from -35 degree to 300 degree Celsius [I].

2.1.1.3 Thermistor

The measuring elements are oxides of metals with an inverse exponential relation between temperature and electrical resistance. Although their response is non-linear possible to reduce the non-linearity by combining them with resistors. Application is limited to a maximum temperature of 100 degree Celsius [1].

2.2 Power Supply

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 a D.C voltage [3]. The block diagram below shows the basic part of a simple power supply.

AC
VOLTAGE

RAWAC RI!CllPI!R F1LTIR R!GULATOR OUTPIIT

Fig. 2.2a a block diagram of power supply unit.

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 .no response; most of the electronics system operates on a low D.C. voltagesupply, which is usually derived from an A.C. current source such as PHCN supply because it is more economical than investing on batteries. The section consists of rectified D.C. supply from mains using 12v transformer and rectifier arrangements plus filtering network to remove ripples of the A.C. supply.

These are arranged as shown in the diagram below:

01

Fig. 2.2b: rectification and liltcring circuit

The transformer steps down the incoming supply according to the ratio of its turns as shown by the equation:

The operation of the circuit is as follows. when the circuit is powered on, a pulse from power on resetting circuit applied a logic high signal to resets input R of the flip flop causing Q to go low and Q' to go high. When the preset time from mechanical clock is reached it send a 1.5v pulse to the level shifter. This is shifted to Vee level and applied to the clock input of the flip flop. This cause the data present at D input (high) to be transferred to the Q output of the flip flop thus triggering the device. A logic high from auto reset or manual reset transfer s the outputs to their pre-triggered condition of Q-Iow and Q-high[5].

3.3 Temperature Sensor and Control

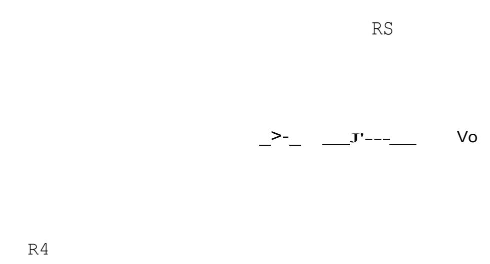
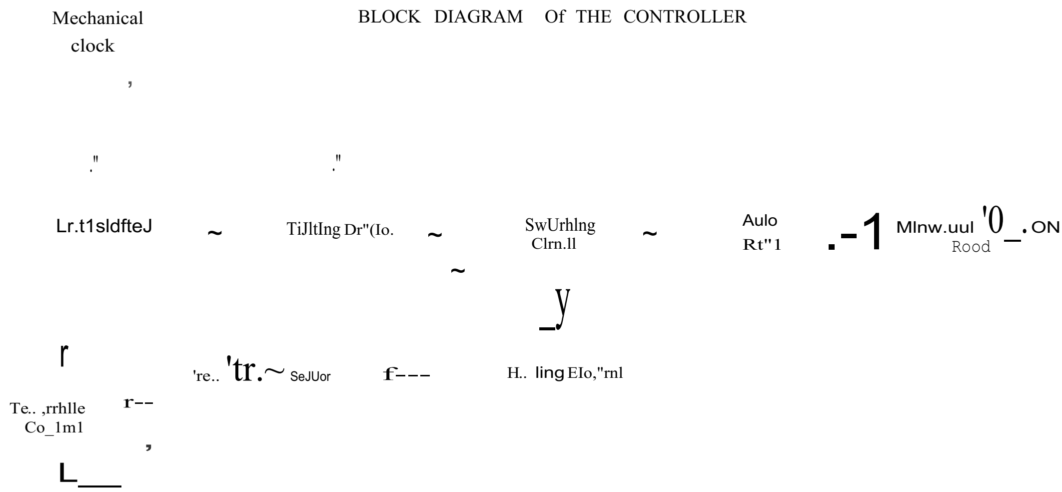


Fig. 3.3a: Temperature sensor and Control circuit.

The temperature sensing and control circuit is achieved by using a comparator (voltage comparator) LM 358 to sense the variation of its terminal voltages and switches when a predetermined value is reached either in positive or negative direction. The voltages of the terminals - inverting and noninverting inputs are fixed using resistor networks and a Thermistor as the temperature sensing element[5]. The network is shown below:

it on so that the voltage at the collector terminal (the reset line) is the supply voltage (Vcc) thus resetting the line while circuit at the brief instant.

BLOCK DIAGRAM Of THE CONTROLLER



:~-'

S1

Vee

R4-

RS

--::r:- 1.SV

OA

..,Q

R

o ~Q

'p

|CL|<

1/24$20

RQ2

RS

RES

L

WAD

Q4

1/24.520

TRIAC

RQ2

N

Cl

R17

Fig.2.9: The Circuit Diagram of the Automatic Heater Controller System.

3.6 The values of the components used in the project.

R_1=10K	C_1 = 3.3 j.l farad
R_2=L100K	C_2 = 0.0 Ij.l farad
R_3=IOK	C_3 = 0.0 I~l farad
Itt = lOOK	Ql = *C268*
Rs=IOK	Q2 = C268
R6 = tOOK	Q3 = C268
R7 = tOOK	Q4 = C268.
SS = 2.7K	
R9 = lOOK	
RIO = tOK	
RII=4.7K	
RI2 = 3.3K	
RI3 = 10K	
RI4 = 2.7K	
R1S = 4.7K	
R_{16}= lOOK	
R17 = 3.3K	
RI8 = 2.2K	
R19 = 10K	
Y_{R1} = 10K	
Rj= lOOK	

3.7 Design calculation

The design procedure and calculations are carried out to determ ine the values of parts and levels and also to determine the values of the critical components of the project. The calculations of the various sections are as follows:

3.7.1 Level shifter

Select transistor QI and Q2 that has a current gain suitable to allow the 1.5v trigger pulse from the clock to saturate it without drawing much current from the clock supply. in this case, transistor Be 458 that has forward current gain p of 150 typical is chosen for both 01 and 02. Therefore to determine the current flowing into the base of 02, choosing 10k as the base resistor use equation:

$$1.5v = I_BR_s + 0.7V$$

$$I_sR_s = 1.5V - 0.7V$$

$$= 0.8V$$

$$I_s * 10 * 10^3 = 0.8V$$

$$= 0.8/10*10^3$$

With $P = 150$

$$I_e = I_s P$$

$$= 0.8 * 10^{-3} * 150$$

$$= 0.12A$$

This is the current flowing through collector- emitter junction with QI fully on .when, Q2 is ofT, current flowing between collector and emitter is zero. When 01 is off, current flowing into the base of 02 with Vee of6V,

$$= 6/ (22* 10^3) = 0.27mA$$

And with P of 150, collector current of Q2, B

Fig. 3.3b:resistor network of the temperature sensor and controller circuit.

The combined resistance of arm A-A is given by:

Considering arm 8- B'

The combined resistance of the ann is given by

.... 3

The voltage at terminal A with variable resistor at its maximum setting i.e

VR = R2 is given by

..4

$$VAR = \frac{\left(\frac{IUxR4}{F2+R4} + R3\right)}{\left(\frac{R2XR4}{IU+R4} + R3 + Rl\right)} x\ Vcc$$

.... 5

When VR is at minimum setting, VR = 0

Therefore, voltage at terminal A, VA is given by:

V_{AO}= {R3/(R2+R3)}*Vcc 6

In the equation, V_{AR} represent the maximum setting of the control voltage which in tum represent the maximum temperature setting, while V_{AO} represent the minimum setting.

Considering arm B- B', R, is the temperature sensing Thermistor which has value R_{BC} when it is at normal temperature (27°C and RBII when inserted into a boiling water of temperature 100°C).

The voltage at terminal B when R, = RBC is given by:

$$YBC = \{R61\ (RBC + R6)\} * Ycc \quad ..7$$

This is the minimum setting of the voltage at the terminal B (i.e. when the water is cold).when the water is hot; the voltage at terminal B is given by:

$$Yh = \{(R6/Rr+R6)\} * Yout \quad . \quad ..8$$

The final circuit of the temperature sensor and control is shown below:

Rf

Fig. 3.3c: Final circuit of the temperature sensor and control.

3.4 switching circuit

L

RJ

MTI

Timing VI

Comparator V'2

Q1 G

liulu

N

Fig. 3.4: Switching circuit.

The switching circuit utilizes two NAND gates A and B to achieve AND function and its inputs are V_1 which is the timing signal from the timing detector and V_2 which is the temperature signal from the comparator. When both V_1 and V_2 is high, gate A, output goes low and since it is connected to both input of gate B, this gate goes high switching transistor Q which in turn triggers triac which switched on the heater element. If either Vl or V-both-goes low, the whole circuit is switched off]«].

The voltage at the base of the transistor Q is given by:

.. 9

The voltage at emitter terminal of the transistor and consequently the gate terminal of the triac is giv~n by: .

$V_E = V_{BE} - 0.6$ 10

$= \{(R_2/(R_1 + R_2)) V_0\} - 0.6$ 11

3.5 Resetting Circuit

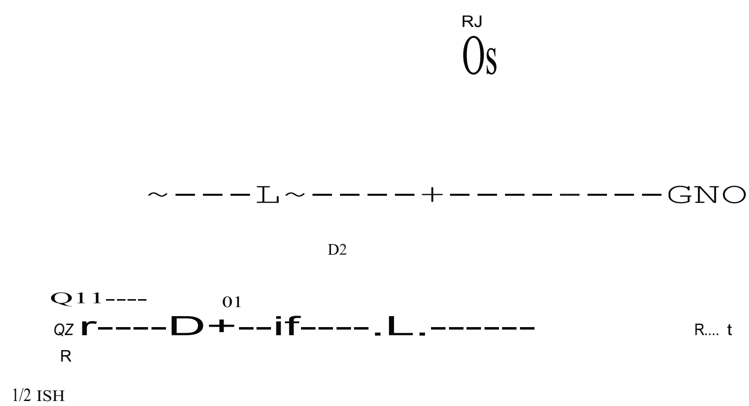


Fig.3.5: Resetting Circuit

The resetting circuit consists of the three units:

1. The automatic resetting;
2. The manual resetting,
3. The power on resetting.

3.5.1 The automatic resetting

The automatic resetting circuit switches off the timing circuit and itself after the water has been heated up and the heater temperature control has switched on and off. If the manual control has not been pressed and the heated water has not been fetched within the period. This is to avoid continues switching on and off of the heater as the water cools down after heating. The circuit is realized using 4520 dud decade counter that is clock by the output of the switching circuit as tlie water heats and cools. After three such operations, the Q2 output of the counter goes high, thus resetting the timing flip flop and consequently disabling the switching circuit. The pulse also reset the counter by asserting its reset input R high[7].

3.5.2 The manual resetting

The manual.resetting work by applying the voltage supply through resistor R3 for the reset line when normal switches (non-latching) S is c1osed[7].

3.5.3 The power on resetting

The power on reset circuit works by briefly switching transistor QI output high thus resetting the circuit when power was first applied. This is done to avoid untimely switching of the timing detector due to supply transient as the voltage rises[7].

The circuit works as follows:

When supply (Vee) was first switched on, capacitor C_1 charges through resistor R, for a period given by:

.... 12

After the period the capacitor will be charged to supply voltage and this allows current flowing through R, to pas through the base- emitter junction of the transistor Q to ground. This current is chosen to saturate QI, and thus allowing 0.2v across its collector-emitter terminals. This voltage holds the line low. Diode D2 is used to isolate the circuit from the rest. During this period of charging, the voltage at the base of QI is insufficient to switch

$Ie = Is\ P$

$= 0.27 * 10_{-3} * 150$

$= 40.9mA$

This amount is sufficient to trigger flip flop 4013 which has minimum logic I input current ofO.OOlmA.

3.7.2 Timing detector

Since the collector is to be switched on constantly from our supply line, power consumption is the optimum consideration in selecting the timing controller IC.A CMOS IC is selected due to its extra low power consumption when on stand by.

Select CMOS IC 40 13 flip flop from data sheet:

Minimum supply voltage = 3v,

Maximum supply voltage = 15v.

We select a Vee of9v,

Minimum logic 1 input voltage = 2/3 * Vee, in this case equals 2/3 * 9V, which is 6v.

Maximum logic 0 input voltage - 1/3 * Vee = 1/3 * 9V = 3V

3.7.3 Temperature sensor and controller

In this section, an operational amplifier LM 358 which has differential input voltage from VCC to ground and which can operate with a single or double rail supply is selected due to the above mentioned reason. The operational amplifier has an added advantage of good slow rate characteristics. A thermistor, load with the following values determined through experimentation is selected for temperature sensing:

I. at room temperature and thermistor in open air is 5 to 10k

2. at room temperature dipped in cold water - 4.00k

3. at boiling temperature of water (100°C) - 5500

In the diagram, select arbitrary value of Ro to be 2.7k R_t when dipped in cold water.

R_{IC} = 2.7 + 4.0k = 6.7k

When dipped in hot water,

R_{IC} = (2.7 + 0.550) k = 3.25k

Terminal voltage at point when water is cold equal to:

$V_{TRC} = \{(2.7/(94.0 + 2.7))\} * 6$

When the water is hot

$V_{BII} = \{(2.71\ (0.55 = 2.7))\} * 6 = 16.2/3.25 = 4.99V$

Considering the voltage divider network shown below:

,-- V«

R2

L__ GND

R4 is given an arbitrary value of2.7k

R3 is variable resistor with setting at 0 - RIO k

Since the terminal is that of the non-inverting (positive) input of our comparator, the voltage at room temperature must be higher than that of the inverting (inverting) input while at highest temperature its voltage must be lower.

Set VA_{COLD} at a value of 2.7V and R3 = 0 there value of resistor R_I is determined by:

$$2.7 = 2.7 + \frac{\frac{0XR2}{0 + R2}}{2.7 + R\boldsymbol{R} + \frac{0XR2}{0 + R2}} xV('C$$

$$2.7 = \frac{2.7 + 0}{2.7 + RII + 0} x6$$

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Manual operation of the automatic heater controller system

1. Parts identification: the device has three outer parts viz:
Socket, Temperature Control knob, Power Cord, and Temperature Sensor.

2. Operation:

The system was designed to switch ON the heater automatically at preset time, monitor the temperature and switch it off automatically when the preset temperature is reached. This consists of a clock that supplies a voltage to the input of the level shifter. The level shifter inverts and re invert the input signal and to which the output of the level shifter serves as the clock pulse for the time detector. The output of the time detector serves as one of the two input signals to the switching circuit.

The second input signal to the switching circuit comes from the output of the temperature sensor and controller.

The automatic reset circuit was also designed to resets the system when the water is heated without been fetched. A manual reset was designed to reset the system manually. The socket is used to plug the heating element (especially water heater), power cord is used to plug the device to the A.C. power mains *(220/240V)* for supply voltage to trigger the system ON. While the temperature control knob is used to calibrate the system to a desired temperature, turning the knob anticlockwise increases the temperature and in clockwise decreases the temperature. the temperature ~ensor, senses the preset temperature to cause the system to trip on or trip off based on the temperature of the water set by the used of the temperature control knob.

3. Precautions: power supply capable of operating the heater must be available at the set time of switching, the thermistor must be attached to the container and there must be constant supply of water in the container where the heater element is to be inserted and the water level should be appropriate so that the heating element of the heater is well dipped into the water.

$$2.7 = \frac{2.7}{2.7+R''} x6$$

$2.7x6 = 2.7(2.7 + Rn)$

$16.2 = 7.29 + 2.7 RII$

$8.91 = 2.7Rn$

$\therefore R» = 8.9112.7 = 3.3$

$R'' = 3.3K$

Choose the terminal voltage at VA when the water is at its highest temperature to be at 4.68V. Determine the RrR3 combination that will give this terminal voltage using:

Therefore, $(R2 \, // \, RJ) = 11.88/1.32$

$(R2 \, //R_J)$ is a parallel combination of variable resistor R3 and fixed resistor R2 using variable resistor R3 of lOOk, R2 can be determine as follows:

$900 + 9R_2 = 100R_2$

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R2=900/91 =9.89::::::10K

Determining hysteresis value that will give excellent switching when the set values are passed, a value ofO.63v was selected for the operational amplifier being used.

Determining Rr

0.63 = {(9+ 2.7)/ (9+ 2.7+ Rr)} * 6

= (11.7/11.7 + Rr) * 6

Therefore Rr = 99. 7k, Rr is chosen to lOOk as the nearest standard resistor.

3.7.4 Decoding and switching

In this section, 40 II NAND gate was used to decide the signal from the comparator and the timing detector and its output tri&ger a triac through a transistor buffer Q,.

The trigger voltage is calculated by:

V_{TR}= {(R2/(RI +R2» * V_{OUT}} -0.6

= 3.02v - O.Sv = 2.43v, therefore, V_{TR} = 2.43v.

3.7.5 Resetting circuit

For the reset line to operate properly, the rise time of the signal must be greater than 210ns for the CMOS IC families. Considering the power on reset time constant circuit, the rise time of this, is given by:

T =0.693 * RC

= 0.693 * 10 * 10^3 * 3.3 * 10^{-6}

= 220mS

These are the values of the parts and components used in practical realization of the project.

Chapter four

Construction, testing and observation

4.1 Construction

In constructing this project the components were checked at first to confirm rating and terminals. All resistors are firstly checked to ensure correct values and all transistors are checked to ensure that they are not burnt out and diodes and triac are also checked.

Then, the layout of the IC on the bread board are planned so that as much as possible signals go from left to right as they do on schematics. This helps tracing during testing. All the ICs are pointed in the same direction to reduce the chance of one being put in backwards, making sure that there is enough room for connecting wire and other needed components.

Solder IC holder first on the planned positions and make other connections using colour-coded wire (telephone wires) e.g. red for $V_{ce.}$ black for ground connections, green for clock and yellow for reset etc.

As each section is wired, trace the corresponding line of the circuit on the schematic with marking pen to keep track of what has been completed. Follow through until all components are placed in order. Check and recheck the breadboard to ensure that all points that need to be connected together are alright and those that need to be separated are so done.

4.2 Testing

In testing this circuit, the following instruments were needed:

1. Digital Multimetre
2. Logic probe
3. 9 bolt battery
4. Wire jumper
5. Thermometer
6. Schematic diagram of the circuit

Firstly, connect the 9 volt battery to the Y_{ee} and ground of the circuit board before inserting the IC and check the voltages using the multimeter in 20Y range. Check all pins (16 in all) of the 4520 counter IC holder, Y_{ec} should be observed. Then connect it to pin 14 of the 4013, also, Y_{ee} should be observed.

Next, connect to the pin 8 of the LM 398, here also Y_{ee} be observed. Then remove the supply and insert the various integrated circuits in their respective integrated circuit holders.

Now turn on the power and observe the various voltages at all the marked points on the schematic, the following readings should be observed.

4.3 Result

Table 4.3: measured values of voltages at various points

POINTS	CONDITION		COMPARATOR	
State	Asserted	Non Asserted	Hot	Cold
A	1.5V	OV	-	-
B	8.96V	O.IV	-	-
C	8.96V	O.IV	-	-
O	-	-	0.3V	9.0V
E	2.2V	OV	-	-
F	9V	0	-	-
G	-	-	Variable 1.5-4V	Variable 1.5-4.5V
H	-	-	3.45V	1.0V
I	8.72V	0.3V	-	-

Remove the thermistor form the circuit and measure its resistance using the Multimetre. After this the thermistor is inserted into water and water is heated after its initial temperature was recorded using the thermometer. The thermistor resistance was continued to be recorded after each ten degree Celsius (10° C) rise in the water temperature until the water reaches its boiling point. The water is then allowed to cool back.

Chapter five

Conclusion and recommendation

5.1 Conclusion

The project was to design a digital electronic temperature switch that will control and measure temperature of a hot or cold body from 0° C to 100°C, which was achieved.The operation of this system completely depends on the time detector, temperature sensor and controller circuit. This is because, it is these circuits that provide the triac, and automatic reset circuit with the triggering signal which initiate the operation. The temperature sensor and the controller circuit depend on the capability of the thermistor to sense the temperature of the water and also the slow rate of the comparator. The time detector circuit depends on the capability of the level shifter to provide the required signal when the preset time is reached.

Some of the problems include the multiple triggering and also caused by the mechanical-switch when the circuit is in operation, to become part of the AC mains due to the lack of isolation between AC and DC signals at the gate of the triac. This problem can be overcomed by the use of apto-isolation circuit.

5.2 Recommendation

To bring this work towards better temperature control, a more sensitive and reliable temperature transducer that is more sensitive than the thermistor could be used.also iam recommending the department to find the means of educating students about the electrical application softwares, so that the students will be more copmpasant with them.