

# Development of Auto Thermal Control Device For Space Air - Conditioning

Akinde Olusola Kunle<sup>1\*</sup>, Maduako Kingsley Obinna<sup>2</sup>, Akande, Kunle Akinyinka<sup>2</sup>  
and Adeaga Oyetunde Adeoye<sup>3</sup>

<sup>1</sup>Department of Electrical and Electronic Engineering, First Technical University, Ibadan, Nigeria.

<sup>2</sup>Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, Nigeria.

<sup>3</sup>Department of Mechanical and Agricultural Engineering, First Technical University, Ibadan, Nigeria.

## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Auto Thermal Control device is an electronic based device which employs the application of temperature sensors to controlling household appliances without human interference directly. In this work, thermal source is used to regulate electrical fan and room heater depending on ambient temperature. The room heater, which is adjusted to a set temperature, switches 'ON' when the temperature of a room is low (cold). While the same is switches 'OFF' with increase in the room temperature. This triggers 'ON' an electric fan at different speeds, and thus cools the room. A temperature sensor, thermistor, monitors change in room temperature. Two types of thermistor exists: Positive Temperature Coefficient, PTC. An increase in the resistance of PTC results in increase in temperature). In the Negative Temperature Coefficient, NTC; a decrease in resistance yields to temperature increase. This article explored a NTC thermistor. The design could be a ready product in the market of the developing nation where environmental automation is yet fully deployed.

*Keywords: NTC thermistor; wheatstone bridge; voltage comparator; switching circuit.*

## 1. INTRODUCTION

Temperature is an indispensable fundamental quantities in the cosmos world. Thermal control, viz-a-viz devices automation could be challenging in some fields like: Industrial applications, environmental monitoring, biomedical diagnostics, communications, computing, and aerospace applications, food processing and storage etc. [1]. Often, there is the desire to prevent undue exposure or possible deterioration as a result of harshness of from the weather. Auto Thermal Control device aims at such application where a room is conditioned for optimal temperature.

Auto Thermal Control system takes over the task of automatically controlling the ambient condition (cold or hot) of children's room for comfort and well-being of inhabitants. The auto control task is made possible with the help of a thermistor which varies in resistance with changes in the ambient. This controlling feature of the device functions alongside other electronic arrangement like Wheatstone bridge, switching circuit, comparator and dual power supply [2]. The thermistor (temperature sensor) senses change in ambient temperature and gives output which is fed to a Wheatstone bridge. The Wheatstone bridge, which is a dual voltage divider circuit, gives out two outputs that are fed to inputs of comparators (741 Op-Amp). At hot temperature, the comparator compares the unknown voltage and the reference voltage to produce an output that is fed to a switching circuit to close the electrical contact which leads to an electric fan thereby switching the fan ON and controlling it at different speeds. At cold temperature, the thermistor produces an output signal that also goes to the comparator which compares the unknown voltage and the reference voltage. The output from the comparator is used to switch ON a room heater by closing the electrical contact of the room heater. The main objective of this design is the automatic control of the speed of a fan at temperature variation in a room. Besides, the device switches ON or OFF an electric room heater at extreme temperatures.

Auto Thermal Control device is indispensable when monitoring children's room become critical, especially for an extended periods of time. Unnecessary energy or resource wastage is equally prevented when a room's temperature

is congenial and does not require extra cooling from fan. In addition, it assists physically challenged persons to adjust a fan's speed automatically. Furthermore, it helps to monitor children with asthmatic condition in order to prevent a worst situation [3,4]. Energy or resource wastage is equally prevented when ambient temperature is auspicious, and no extra cooling from the fan is required

## 2. REVIEW

Angela Chioma Ibeawuchi in 2007, designed and constructed a Temperature Control Electric Fan. This work achieved the automatic switching ON and OFF of an electric fan rated at 60 watts, 240 volts A.C [5]. A thermistor was used as a temperature sensor with one comparator circuit which could only produce one output at a time (high or low) to switch ON or cut OFF a rotating fan. However, the work could not be used to regulate the speed of the fan. Using more than one comparator will give advantage to the designer to design a system that can regulate the speed of the fan during mild or hot temperature and switch ON a room heater during cold temperature as in this project.

Also, in September 2010, Nnamdi Uzoechi C. of the Department of Electrical/ Electronics in the School of Engineering, Madonna University, Anambra State, Nigeria designed Automatic Temperature Control Fan with Auto Switch ON/ OFF. He improved on the result achieved by Mrs Angela Chioma Ibeawuchi. By combining a timing selector and temperature sensor he was able to control the operation of a DC powered fan rated at 6 watts, 12 volts. The design was set at switching ON a fan once an environment was hot after 30 minutes of operation, the rotation of the fan turned to half of its initial speed [6]. It was an appreciable improvement except that the speed of the fan's rotation was not determined by the ambient temperature but on a pre-time set up. The design could not be used to sufficiently cool a hot room since the speed of the fan will be reduced to half of its initial speed after 30 minutes of operation. Furthermore, the fan will not be needed in a very cold weather which will require the use of a room heater to be put ON as in this project.

## 2.1 Theory of Basic Components Review

### 2.1.1 Resistors

Resistors are materials that restrict the flow of electrons passing through them. They are mainly used to control the flow of electric current and provide the desired amount of voltage in electric or electronic circuits. There are two types of resistors namely:

- (i) Linear resistors and
- (ii) Non-linear resistors.

In linear resistors, current is directly proportional to the applied voltage and the resistance of such resistors do not change with the variation in applied voltage, temperature or light intensity. While in non-linear resistors current is not directly proportional to the applied voltage. Such resistors have a property that their resistance values change with the variation in applied voltage, temperature or light intensity. The non-linear resistors are of three types namely thermistor, photo-resistor and varistor [7]. The pictorial and circuit symbol are shown in Image 1.



Image 1. Circuit symbol of a resistor

### 2.1.2 Thermistors

Thermistors are temperature-sensitive devices that change in resistive values due to variation of temperature. They are frequently used as temperature sensors generally, in the range of -100 to +300°C. It is a metal oxide (aluminium, nickel, copper, zinc, manganese, cobalt, etc.) and is semiconductor by nature, the resistivity varying between 0.1 to  $10^9 \Omega\text{-cm}$  depending on the material. They are rated by their resistive value at room temperature (usually at 25°C), time constant (the time to react to the temperature change) and power rating with respect to the current flowing through them. The main advantage of thermistor is the speed of response to any changes in temperature, accuracy and repeatability. The response characteristic is non-linear and can be expressed as:

$$R_T = R_0 e^{\beta \left( \frac{1}{T} - \frac{1}{T_0} \right)} \quad (1)$$

Where  $R_0$  and  $R_T$  are the resistance values at temperatures  $T$  (degree Kelvin),  $T_0$  (reference temperature), and  $\beta$  is a constant of the material. The two types of thermistors include:

- i. Negative Temperature Coefficient (NTC)
- ii. Positive Temperature Coefficient (PTC)

In NTC, increase in temperature results to decrease in resistance and decrease in temperature results to increase in resistance. While in PTC the reverse is the case. The application of thermistors includes air conditioners, fire detectors, water level sensor, gas flow indicators, etc. In this project; thermistor is used as a temperature sensor [8-12]. Fig. 2 shows the circuit symbol of a thermistor.



Fig. 1. Circuit symbol of a thermistor

### 2.1.3 Capacitors

These are components that can store charges in an electric field. They consists of two metal plates close together but separated by an insulating material called a dielectric.

If a potential difference is established across the terminals, charge  $Q$  is stored on the plate. The ratio of the charge to the potential difference is a constant.

$$Q/V = C \quad (2)$$

Where  $C$  is a constant known as capacitance of the capacitor and it is measured in Farads;  $Q$  is a charge measured in coulombs and  $V$  is the supplied voltage measured in volts.

Capacitors are essential in nearly every circuit application. They are used for waveform generation, filtering blocking, and bypass applications. Capacitors do not dissipate energy even though current can flow through them. This is because the voltage and current are 90 degrees out of phase. A capacitor is more proportional to the voltage but rather to the rate of change of voltage. Capacitors come in

amazing variety of shapes and sizes. But they are basically under two classes:

- I. Electrolytic capacitor
- II. Non-electrolytic (electrostatic) capacitor

The electrolytic capacitor is polarized with higher capacitance values the non-electrolytic is not polarized and has smaller capacitance values [7]. The symbols of capacitor are shown in Fig. 2:



**Fig. 2. (a) Non Polarised; (b) Polarised Capacitors**

### 2.2.4 Power diodes

Diodes are semiconductors that allow easy flow of current in one direction. It is made from positively doped P-type and negatively doped N-type materials of either silicon or germanium. They are passive non-linear devices having polarized terminals. The forward bias voltage of a diode is 0.3V for germanium or 0.6V for silicon material. But a very high voltage, up to 50V and above is required to reverse-bias the device. The positive terminal is called the Anode while the negative terminal is the Cathode. Diodes are used as rectifiers – changing A.C. to D.C. [13]. In this design, they were used at the dual power supply unit for rectification purposes. Fig. 3 shows the circuit and pictorial symbols of a diode.



**Fig. 3. (a) Circuit and (b) pictorial symbol of a diode**

### 2.2.5 Zener diode

A zener diode also called a voltage reference, voltage regulator or breakdown diode. It is a silicon PN junction diode that can be operated in the breakdown region. The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture. Fig. 4 shows a schematic symbol for a zener diode [7,12].



**Fig. 4. Zener diode symbol**

### 2.2.6 Bipolar transistors

A Bipolar Transistor is an active device that has three terminals: Emitter, Base and Collector. There are two types of Bipolar Transistors:

- i. NPN Transistor
- ii. PNP Transistor

Both of these types of transistors operate the same way, except in their circuit connections. The NPN collector is connected to the positive part of the source, while the Emitter is connected to the negative part of the source. PNP transistors have the opposite connections as compared to NPN. The Base is a small region that allows electrons generated from the Emitter to flow to the Collector when a bias voltage is applied. Transistors are used for switching or amplification purposes. However, their application in this project is for switching. The three operating regions of transistors include:

- i. Cut Off region
- ii. Saturation region
- iii. Active region

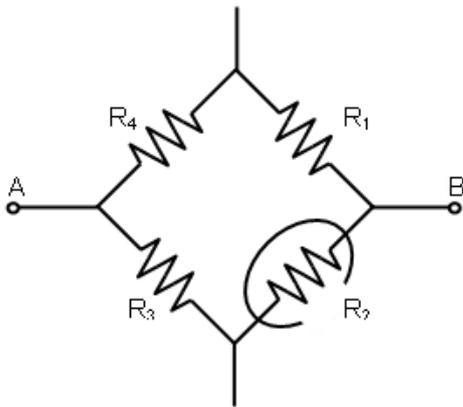
At Cut off, the transistor is at OFF position. The voltage between the Collector and Emitter terminals is high ( $V_{CE} = V_{CC}$ ) while the Collector current is zero. The reverse is the case when the transistor is saturated. Between the Cut Off and the Saturation regions, the variation of the transistor is active ( $V_{CE} > 0$ ) [14]. The symbols of the transistor are shown in Fig. 5 below:



**Fig. 5. Symbol of (a) NPN and (b) PNP transistors**

### 2.2.7 Wheatstone bridge

A Wheatstone bridge is a circuit for measuring resistance accurately. This circuit was devised in 1843 by Charles Wheatstone – a Professor of Physics at King’s College, London. In this project, a thermistor is connected in one arm of the Wheatstone bridge. Fig. 9 shows the circuit arrangement of a Wheatstone bridge.

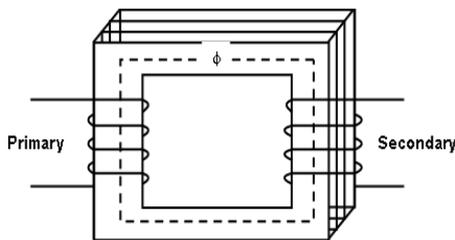


**Fig. 6. A Circuit arrangement of a wheatstone bridge**

The Wheatstone bridge is balanced when  $R_1/R_2 = R_4/R_3$ . At this stage, Terminals A and B are at the same potential, and since it is ratio metric, the null effect created when it is balanced does not shift with variations in supply voltage [12,13].

**2.2.8 Transformer**

A transformer consists of a laminated iron core wound with two coils – the primary and the secondary. The primary coil is connected to a source of alternating voltage which builds up a changing magnetic field and sets up same type of voltage at the secondary. This is done through mutual inductance between the coils by magnetic flux linkage. It is called a step-down transformer when the number of turns in the primary is more that of the secondary, But otherwise, it is called step-up transformer. A step-down transformer is used in this design to transform the high voltage to a very low Alternating Current (A.C.) output [13]. Fig. 7 shows an Iron-Core Transformer.

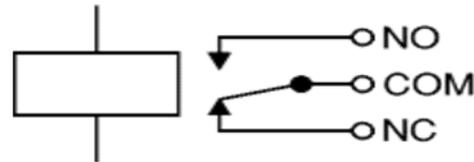


**Fig. 7. Iron-core transformer**

**2.2.9 Relay**

Relay is an electromagnetic switching device consisting of coil part and the contacts part. Direct current source connected to the coil part sets up a steady magnetic field around a soft

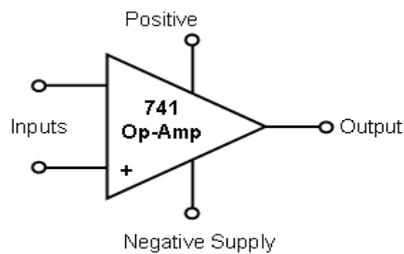
iron spring to open or close contacts. With the removal of the source, the magnetic field built up collapses, releasing attracted spring. Relay is used to switch ON high-voltage powered devices from very low Direct Current (D.C.) Voltage connected to the coil terminals [15]. Fig. 8 shows the circuit symbol of a relay.



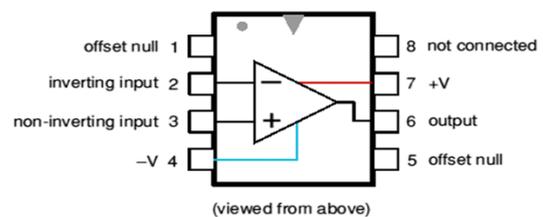
**Fig. 8. Relay circuit symbol**

**2.2.10 Operational amplifier (741 OP-AMP)**

Operational amplifier is a device that accepts varying input signal and produces a similar output signal with larger amplitude. The input terminals are the inverting and non-inverting input. 741 Op-Amp has high input impedance and low output impedance with a very high voltage gain. It compares between a known and unknown values applied at the input terminals. In this work, it is used as a voltage comparator [16]. Fig. 9 shows the circuit and pictorial symbol of 741 Op-amp.



**Fig. 9. (a) Circuit of 741 Op-Amp**



**Fig. 9. (b): 741 Op-Amp Symbol [17]**

**2.2.11 Seven segment led display**

Seven segment LED display consists of seven rectangular LEDs which can form the digits 0 to 9. The seven LED segments are labeled 'a' to

'g'. Each of these segments is controlled through one of the display LEDs. Seven segment displays come in two types:

- i. Common cathode type;
- ii. Common anode type.

In the common cathode display, the entire cathode connections of the LED's are joined together to logic "0" and the individual segments are illuminated by application of a "HIGH", logic "1" signal to the individual Anode terminals.

The common anode display has all the anode connections of the LED's are to logic "1" and the individual segments are illuminated by connecting the individual Cathode terminals to a "LOW", logic "0" signal. Fig. 10 shows a schematic diagram of a seven segment LED display [18].

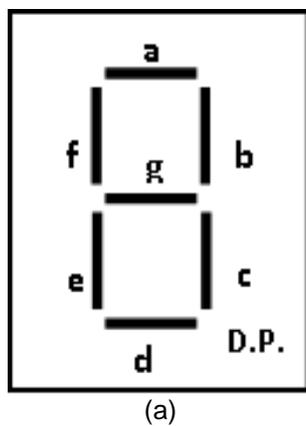


Fig. 10. Seven-Segment LED display

It is obvious that to display any digit from 0 to 9 or letter from A to F, we would need 7 separate segment connections plus one additional connection for the LED's "common". Also as the segments are basically a standard light emitting diode, the driving circuit would need to produce up to 20mA of current to illuminate each individual segment [8,18] and to display the number 8, all 7 segments would need to be lit resulting to total current of nearly 140mA (7 x 20mA).

### 3. METHODOLOGY OF AUTO THERMAL CONTROL DEVICE DESIGN

A modular design approach was employed towards the development of the Auto Thermal Control device. The design and construction of the device for room conditioning was achieved in modules. Successful implementation and

integration of the various modules produced the complete design.

The primary objectives driving the design consist of the following:

- i. Designing of a prototype system for room temperature conditioning;
- ii. Interfacing of the output of a temperature sensor using a comparator in order to control the switching of a room heater and speed of electrical fan;
- iii. Designing a device that assists children immune system to maintain normal body temperature to avoid blockage of blood flow and tissue damage of the lungs that can lead to pneumonia.

A lot of factors were put into consideration to achieving the design. Some of these are stated as:

(i) **User Target:** Two electrical appliances were installed, and are expected to be activated separately at different times of need. The room heater was to come ON any time the temperature of the room becomes cold (26°C) and the fan was to be switched ON once the room's temperature goes a little above the normal room temperature (28°C), and even faster if the temperature increases up to 32°C.

(ii) **Availability of Materials:** As a temperature dependent device, the need for a highly sensitive heat sensor was obvious. Notable among temperature sensor include thermostats, thermocouples and thermistors. Whereas thermostats and thermocouples sense heat to break-open already closed contacts, thermistors produce varying electrical resistance when there are changes in temperatures [11]. This feature of a thermistor was best fitted in the design structure of the undertaken project. Presently, there are even more temperature sensitive sensors (ICs) that produce changes in output resistances as compared to thermistors. But sourcing such component in the local markets was difficult. Thus, the best types of thermistor that responds quickly to temperature changes were picked up for the work. The same measure was adopted in making sure that other components used were easily available.

(iii) **Output Loads:** Although this design purely achieved at a prototype level, it is necessary to state that high voltage electrical appliances like electric room heater and fan that operate at

220V A.C. were connected to the device output as loads. Industrial relays which were energized with D.C. voltages and could open or close high voltage A.C. lines for the connected loads were used for the design.

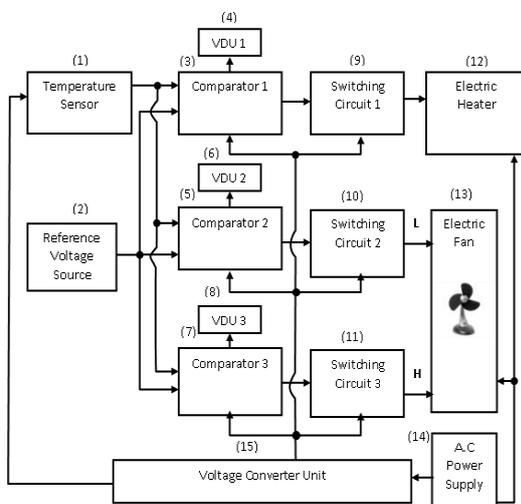
### 3.1 Design Specifications

This project was designed to specifically switch ON an electric room heater once the temperature of a room meant for children goes (cold). In addition, it was to put off the room heater, switch ON an electric fan at different speeds needed to cool the room if the temperature goes above the normal safe level. In achieving these, the various power ratings of the components used in the design were chosen to be high above that required for safe circuit operations. The power requirements were easily checked out from the manufacturer's data books.

### 3.2 Description of the Block Diagram

There are a total of 15 blocks representing the complete designed work. Fig. 11 shows the layout structure of the interconnected blocks labeled "1" to "15".

Block 1 is the temperature sensor unit. It produces electrical resistance as a result of temperature change. It has a common output that is fed to three other blocks – 3, 5 and 7. Block 2 has a reference voltage source that completes the comparative values of blocks 3, 5 and 7.



**Fig. 11. Block diagram of thermal auto control system**

Each of the three comparators produces an output depending on the set temperature. Comparator 1 (block 3) produces a high output when the room temperature is cold (26°C), while Comparator 2 (block 5) produces a high output when the temperature goes above normal (28°C). Comparator 3 (block 7) produces a high output if the room temperature increases to 32°C. To this end, the visual display units (blocks 4, 6, and 8) connected to the comparator outputs indicate the various temperature numerical values at which these changes occur.

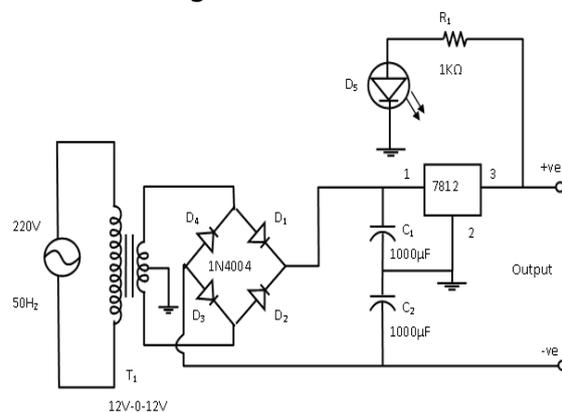
In like manner, transistor switching circuits (blocks 9, 10 and 11) are directly connected to these comparators. The switching circuits energize the interfacing relays which close up or open contacts of the A.C. supply to the loads.

### 3.3 Design details of the units

The complete design of Thermal Auto Control for children's room is shown in Fig 16. The design is divided into five different units as follows:

- (i) Voltage Converter
- (ii) Wheatstone Bridge
- (iii) Comparator
- (iv) Active Switching Circuit
- (v) Outputs

#### 3.3.1 The voltage converter



**Fig. 12. Circuit diagram of the voltage converter unit**

The circuit diagram of the voltage converter unit is depicted in Fig. 12. It is made up of a centre tapped transformer (12V-0-12V). It steps down the A.C. power supply to a low value of 24V splitted into two equal parts of 12V each. A bridge rectifier network consisting of four diodes

(D<sub>1</sub>-D<sub>4</sub>) converts the A.C to a pulsating D.C. The ripples of the two pulsating D.C. outputs are further filtered off using a low pass capacitor filters (C<sub>1</sub> & C<sub>2</sub>). After filtration, the D.C. outputs are +15V and -15V respectively. A linear voltage regulator, IC<sub>1</sub> (7812) is connected to the +15V output to produce a constant D.C of 12V. There is an LED indicated, D<sub>5</sub> connected in series with a limiting resistor R<sub>1</sub> across the positive D.C. output. The component values required are calculated as follows:

**Chosen Values**

(a) Secondary voltage of the transformer, T<sub>1</sub> is 24V (V<sub>rms</sub>).

The peak voltage,  $V_P = V_{rms} \times \sqrt{2} = 33.94V$

The peak inverse voltage (PIV) of the diodes is given by

$PIV = V_{P(out)} + 0.7V = 34.64V.$

From a semiconductor data book, power diode 1N4004 was taken since it has a PIV of 50V and current capacity of 2A.

Therefore: D<sub>1</sub>= D<sub>2</sub>=D<sub>3</sub>=D<sub>4</sub> = 1N4004

Input frequency,  $f_{in} = 50Hz;$   
 Output frequency,  $f_o = 2 \times \text{input frequency} = 100Hz$

Making the following assumptions of ripple voltage, V<sub>r</sub> = 5mV and reflected load resistance, R ≤ 500Ω. And using ripple factor formula for full wave rectifier;

$$V_{r(pp)} = \left( \frac{1}{fR_L C} \right) V_{p(rect)} \tag{3}$$

$$C = \frac{V_{p(rect)}}{V_{r(pp)}} \times \frac{1}{fR_L}$$

C = 577µF.

For the indicator circuit: V<sub>s</sub> = 12V

Forward biased voltage of D<sub>5</sub> = 2V and current of about 10Ma;

$$V_S = V_{R1} + V_{D5} \tag{4}$$

$$12 = V_{R1} + 2$$

V<sub>R1</sub> = 10V

Also:  $V_{R1} = I_{LED} \times R_1 \tag{5}$

10 = 10mA X R<sub>1</sub>

R<sub>1</sub> = 1KΩ

The component values thus used in the design consist of the following:

T<sub>1</sub> = 220V/12V-0-12V (step down)

D<sub>1</sub> = D<sub>2</sub> = D<sub>3</sub> = D<sub>4</sub> = 1N4004

C<sub>1</sub> = C<sub>2</sub> = 1000ΩF, 35V

IC<sub>1</sub> = 7812

D<sub>5</sub> = Red LED

R<sub>1</sub> = 1KΩ

**3.3.2 Wheatstone bridge**

A Wheatstone bridge comprises two parallel voltage divider circuits. The bridge is balanced when the ratio of resistances at the opposite arms are equal. The resistance value of the thermistor connected on one arm of the bridge at room temperature (25<sup>0</sup>C) is 200Ω. A negative temperature coefficient (NTC) thermistor was used, so when its temperature gets lower than the room temperature it resistance output increases. Reverse case occurs when the temperature is higher. All the resistors in the bridge with the semiconductor diodes produces fixed voltages of 2.2V, 2.9V and 3.6V that were used as reference values for the respective comparator inputs. Voltage across the thermistor was fixed at 3.5V (V<sub>RTH</sub>).

$V_{R2} = V_s - V_{RTH} = 12 - 3.5 = 8.5V$

From  $V_{R2} = 8.5V \tag{6}$

R<sub>2</sub> = 485Ω

R<sub>2</sub> was made to be the same with R<sub>3</sub> in forming the first parts of the bridge.

i.e. R<sub>2</sub> = R<sub>3</sub> = 485Ω

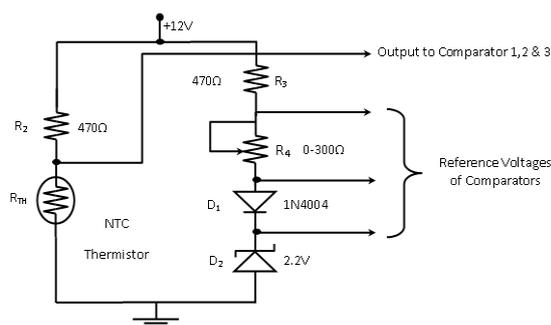
D<sub>6</sub> = 1N4001 (power diode).

Therefore, V<sub>D6</sub> = 0.7V;

D<sub>7</sub> = zener diode (2.2V)

But the standard value chosen was 470Ω.

Only the resistor R<sub>4</sub> was made to vary from 0-300Ω. The circuit diagram for the Wheatstone bridge is drawn in Fig. 13:



**Fig. 13. Circuit diagram of wheatstone bridge**

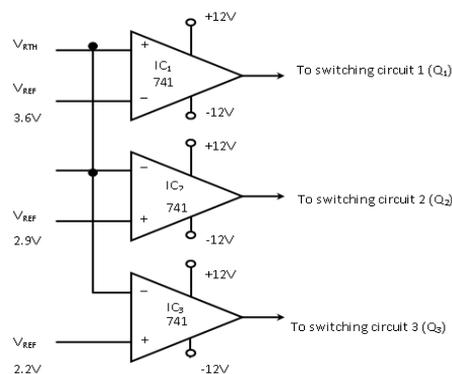
### 3.3.3 The comparators

Op-Amp 741 IC was used for each of the comparators. Normally, a comparator has two inputs – one variable and the other a reference value. It produces either a high or low output. When the voltage of its inverting input (pin2) is lower than the one at its non-inverting input (pin3), a high output is produced. The output is low if the reverse is the case. Reference voltages of 3.6V, 2.9V and 2.2V were connected to pin 2 of IC<sub>2</sub>, pin3 of IC<sub>3</sub> and pin3 of IC<sub>4</sub> respectively. The varying voltage of the thermistor was connected to the remaining input terminals of the Op-Amp. When the room is very cold, the voltage at pin3 of IC<sub>2</sub> goes up higher than the one of pin2. A high output voltage is produced from the pin 6 terminal of IC<sub>2</sub>. But once the room is heated up, the thermistor's voltage falls until it is lower than the voltage at pin3 of IC<sub>3</sub>, producing a high output at pin6 of the second comparator (IC<sub>3</sub>). If the room gets hotter, voltage at pin2 terminal of IC<sub>4</sub> will be lower than that of pin3, again resulting to a high output of the third comparator (IC<sub>4</sub>). It is important to understand that these changes happen at different times. Variable resistors  $V_{R1}$ ,  $V_{R2}$  and  $V_{R3}$  were connected between pin terminals 1 and 5 of the Op-Amps respectively to clear up the offset voltages; thus making them very sensitive to the changes that were occurring. The Fig. 14 shows the circuit diagram of the comparator unit.

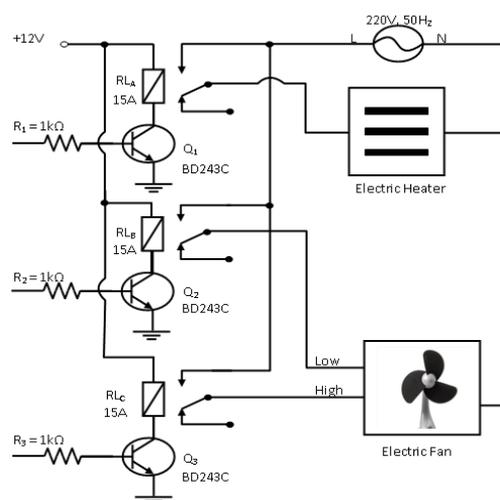
### 3.3.4 The active switching circuits

Bipolar transistors, NPN type were active switching components used for the energizing of the relays connected to close or open power lines for the A.C. loads. At the base of these transistors (Q<sub>1</sub>, Q<sub>2</sub> and Q<sub>3</sub>) were fixed resistors (R<sub>5</sub>, R<sub>7</sub> and R<sub>9</sub>) of value 1KΩ meant to stabilize the biasing current. Once any transistor is biased, the associated relay will be energized

and this happens when the comparator 1 output is high. All the relays are at their normally open contacts, expected to be closed when their coils are energized. The transistors are all high power rated and strong enough to carry the energizing current of the relays. Q<sub>1</sub> = Q<sub>2</sub> = Q<sub>3</sub> = BD243C. The diagram is shown in Fig. 15.



**Fig. 14. Diagram of the three comparators**



**Fig. 15. Diagram of switching circuit**

### 3.3.5 Output unit

Two major electrical appliances – the electric room heater and fan were used for testing, as A.C. loads for the device. Energizing relay R<sub>L</sub>A was to switch ON the room heater. Energizing relays R<sub>L</sub>B and R<sub>L</sub>C were to switch ON the electric fan at different speeds. The relays had current capacity of 15A to carry any of the electrical appliances. Three (3) seven segment display unit were used as visual indicators to show the temperature values at which the appliances were put ON or OFF.

### 3.4 Functional Circuit Design and Description

The transformer ( $T_1$ ) steps down the AC input voltage (220V) to 24V which is shared into two equal parts of 12V each. Diodes ( $D_1$ - $D_4$ ) used as bridge rectifier converts the alternating current (AC) to a pulsating direct current (DC). Capacitor,  $C_2$  filters one part of the transformer output and supplies the filtered negative voltage (-15V) to the comparators ( $IC_2$ ,  $IC_3$  and  $IC_4$ ). Capacitor,  $C_1$  filters the remaining part of the transformer output voltage and supplies the filtered positive voltage (+15V) to the voltage regulator,  $IC_1$  (7812).  $D_5$ , a Light Emitting Diode (LED) indicator, arranged in series with the current limiting resistor ( $R_1$ ) and are connected to the output of  $IC_1$ . The regulated voltage (+12V) is supplied to the Wheatstone bridge. The thermistor based Wheatstone bridge produces two types of voltages; one, fixed voltages (2.2V, 2.9V and 3.6V) and variable voltages as a result of temperature changes. A common variable voltage from the thermistor is transferred to pin 3 of  $IC_2$ , pin 2 of  $IC_3$  and  $IC_4$ . The function of  $IC_2$  is to compare the variable and fixed voltage (3.6V) to produce an output. The output of  $IC_2$  is high, when the temperature is 24°C and low when the temperature is 30°C.  $IC_3$  compares the variable and fixed voltage (2.9V) to produce an output. The output of  $IC_3$  is high when the temperature is 28°C and low when the temperature is 26°C.  $IC_4$  compares the variable and fixed voltage (2.2V) to produce an output. The output of  $IC_4$  is high when the temperature is 32°C and low when the temperature is 26°C.

Transistor,  $Q_1$  switches ON the relay ( $RL_A$ ) which is energized as current passes through its coil.  $RL_A$  closes the contact to the electrical heater to switch it ON when the temperature is 26°C. Transistor,  $Q_2$  switches ON the relay ( $RL_B$ ) which is energized as current passes through its coil.  $RL_B$  closes the electrical contact of the fan. Thus, switches ON the fan at low speed when the temperature is 28°C. Transistor,  $Q_3$  switches ON the relay ( $RL_C$ ) which is energized as current passes through its coil.  $RL_C$  closes the electrical contact of the fan's speed. Thus, the speed of the fan is increased when the temperature is 32°C.

## 4. IMPLEMENTATION AND TESTING

The design was first carried out on a project board with every detail specification of the circuit

strictly followed. Testing was carried out on each section of the project in order to examine and observe the level of performance of the various units. Prior to this, each component was tested for continuity using a digital ohmmeter. The results of each stage was satisfactory and in line with the design specification; except few areas where adjustments was made to close up for the targeted outputs. All the components were transferred from the bread board, assembled on a project board and carefully soldered. The soldering iron used was 40W capacity to prevent excess overheating of components' assemblage. The lead was a good quality type that got easily melted once in contact with heat. Extra case was used to avoid short or open circuits on the soldered board. The soldering pattern was formed around the terminals of the components with concave shape. Hardware like switches and indicators were not soldered on the project board but rather mounted on the casing panel.

**Table 1. Terminal voltages of comparators at room temperature**

741Comparator	ICComparator		ICComparator		ICComparator	
Pins	Pin2	Pin3	Pin2	Pin3	Pin2	Pin3
TestPointVoltage	3.5V	2.2V	2.9V	3.6V	3.6V	3.6V

## 4.1 Testing And Results

### 4.1.1 Voltage converter unit

The assembled circuit was once more re-checked for any shaky terminals. The power supply unit was first tested. Upon activation of the power unit, a digital voltmeter was used in measuring the terminal voltages of capacitor  $C_1$  and  $C_2$  with the ground terminal as the common. The positive of  $C_1$  read +15.8V while the negative terminal of  $C_2$  read -13.2V. Another reading was taken from the output of the voltage regulator, and it was a constant +12V in value with the LED indicator fully ON.

### 4.1.2 The wheatstone bridge/comparator unit

At normal room temperature of about 27°C, terminal voltage inputs of the comparator were measured as shown in Table 1.

From the above table, only  $IC_2$  comparator was expected to produce a high output. Other comparator  $IC$ 's voltage would give out low or zero outputs at room temperature. A heater bulb was switched ON over the thermistor, the

terminal voltage of the thermistor got reduced drastically, bringing the voltage reading at pin2 of IC<sub>4</sub> as low as 2.5V. This puts off comparator IC<sub>3</sub>, made comparator IC<sub>4</sub> to produce high output. But even with these values, IC<sub>2</sub> comparator remained low until; the environment became very cold to increase the terminal thermistor voltage up to 3.8V. It was then the heater came ON, to warm up the room.

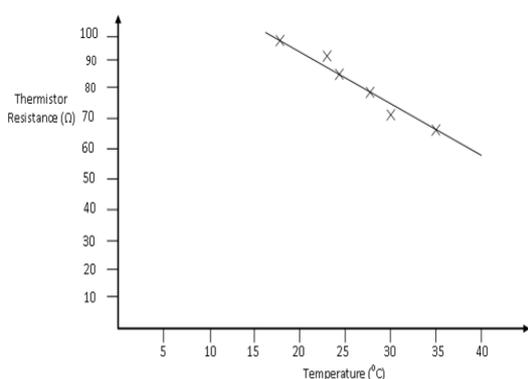
#### 4.1.3 Thermistor resistance at different temperature

Careful observation was made with application of heat over thermistor and the resulting resistance values recorded as shown in the table below.

**Table 2. Thermistor resistance at different temperature**

Temperature	Thermistor's Resistance
36%	74
30	79
27	85
24	90
23	94.5
18	98.2

The table above shows that as the values of the temperature decreases the resistance of the thermistor increases. This linear relationship can be plotted graphically as shown below:



**Fig. 16. A graph of thermistor resistance against temperature**

#### 4.2.4 Output unit

At room temperature, it was observed that the fan was ON but at low speed. When the heater was switched ON, although it was not immediate, the fan's rotation became faster. And when the thermistor's surrounding became cold,

the fan went off, the heater came up automatically. The two appliances were coming ON at the level required due to the changing ambient temperatures.

#### 4.2.5 Casing and packaging

A rectangular plastic box beautifully made was picked up for the components housing. The dimension of the box was 30cm x 15cm x 10cm. The project board containing the soldered components was inside the box; while the heating bulbs, switches and indicators were on the plastic panel. The arrangements were compact to produce a good finish. After the packaging, the device was re-tested again. It was working as designed.

### 5. CONCLUSION

Excessive use of electric fan, especially when the weather gets very cold and particularly around children can lead to serious health hazards like dry skin, blockage of blood flow, tissue damage on the lungs which can lead to pneumonia.

This project has been designed, constructed and packaged to regulate the rotation of the fan's speed at different speed required by the surrounding temperatures so that at extreme cold environment, the fan is automatically switched off and the heater is activated to warm up the room. Auto thermal control system can also be used in the industrial where temperature plays a vital role.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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