DESIGN AND CONSTRUCTION OF AN AUTOMATIC ROOM FAN REGULATOR

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DECLARATION

I hereby declare that this project was wholly designed and constructed by me under the able supervision of Mr. S. N. Rumala, Department of Electrical and Computer Engineering, Federal University of Technology, Minna, Niger State.

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Date

DEDICATION

I dedicate this thesis to the MOST HIGH GOD, the Supreme Commander of the universe, on whose mercy ticket I live.

ACKNOWLEDGEMENT

I appreciate the Giver of Life for the gift of life, for counting me worthy to be called His brother and a joint heir of the Father.

I am grateful to my parents, Evang. and Evang. Mrs. David O. Amedari for their unquantifiable love, sacrifice and care for me. You are role models for posterity. My ever-supportive siblings are worthy of mention here, Zion, Shekinah, Mcking, and God'sfavor. My thanks go to my supervisor, Engr. S. N. Kumala for his detailed supervision and sincere assistance. Thanks for believing in me, Sir. Mummy Elizabeth Angulu, thanks so much for taking me into your house and accepting me as I am. I appreciate Pastor Simeon Yeesuf for his care. Your generosity and kindness to me is noted be God. I am grateful to Engr. Salihu for providing excellent reference materials for my work. Mr. Emma, you have been so supportive and caring. May the Lord God remember you for good.

I would not forget my wonderful family, Fellowship of Christian Students (FCS) – I'll miss you all. I appreciate all my friends and I will not fail to mention some of them: Ashem, Chinwe, Andy, Kunle, Emma, Blessing, Ehimen, Kaase, Okechukwu, Femi and Irene. Thanks for been there for me.

ABSTRACT

The fan was invented to produce air currents to make man more comfortable especially in uncomfortably hot weather conditions. Control of the speed of the fan has hitherto been manual, based on the discretion of man.

This project serves to offer an alternative by providing automatic fan speed control based on the direct sensing of the environment's ambient temperature. The design incorporates a thermistor as its temperature sensor

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

In a world where comfort and ease constitute some of man's basic desires, the electronic world has not in anyway been overwhelmed in its level of contribution to achieving these desires. This project is another step further in the quest for the improvement of man's living conditions.

This project provides a circuit for the automatic linear control of a fan speed using an adequate temperature transducer. In other words, the circuit monitors the ambient temperature of the room and controls the speed of the fan in accordance with the room temperature. Thus, temperature changes of the room result in a proportionate change in the speed of the fan. The speed of the fan in proportion to the ambient temperature can be easily set by the user without altering the circuit. Although, the level of control by the user is defined by an upper limit and lower limit so that the fan and the control circuits are not stretched beyond their operating limits.

Transducers form the interface between the world that we sense and the realm of electronics. In order for this circuit to act on temperature information, it must be converted into electrical signals by a transducer. The transducer used in this project is a negative temperature coefficient (NTC) thermistor.

The major units of this project are briefly outlined as follows:

The current to voltage converter converts the current passing through the thermistor into a proportional voltage.

The instrumentation amplifier has a high sensitivity and is used to increase the voltage and power levels of the transducer output and to prevent excessive loading of the transducer by the measurement system.

The comparator in the circuit compares the input voltage with a reference voltage. The output from the comparator is coupled to the optocoupler which in turn outputs a control signal that regulates the AC power to the fan by means of a trial.

The complete circuit operation is explained in chapter two. Chapter three contains the procedure for construction of the device and the layout of the components.

1.2 LITERATURE REVIEW

With fan use comes the usual fan headaches of mechanical failures, increased power consumption and noise. Fan speed control can ease some of these headaches resulting in quieter, more reliable fans that use less power. Fan speed and therefore cooling efficiency can slowly degrade or fail completely without adequate speed control.

There are many ways to control the speed of a fan. Controlling the speed of a fan can range from as simple as regulating the input voltage to the fan to using more complicated digital microprocessor input.

Linear Regulation

The linear regulation option is designed for applications where the input power may fluctuate at different voltage levels. As the term implies, linear regulation adjusts the voltage across the fan by using a linear regulator. Unfortunately, linear regulation has its drawbacks: mainly power dissipation in the pass element (linear regulator) as well as startup and stalling issues.

Linear regulators work by controlling the voltage across the fan. They do this by dissipating power in the form of heat. During maximum and minimum cooling, power dissipation will be ideally is fully on, so the voltage across it is nearly zero. Zero volt means zero power dissipation. During minimum cooling, the pass element is off (zero current flows), so again power dissipation is zero. Thus the current draw of the fan can be approximated as a linear function of the voltage applied, making it look resistive. Maximum heat dissipation in the fan circuit occurs during minimal cooling requirements.

Fans require a certain voltage before they will start. This is called "startup voltage". Once a fan is already spinning, decreasing the voltage below the stall voltage will cause the fan to stop. The startup voltage is equal to or (usually) greater than the stall voltage. Typically they are 25% to 50% of the rated voltage for the fan. And when linear regulation is used without speed monitoring, there is no way of knowing if the fan has stalled or even started for that matter.

Selecting the correct voltage to ensure proper startup for all fans can be difficult. And this could limit the useful range of speed control [14].

DC-DC Regulation

DC-DC regulation is similar to linear regulation in that it controls the speed of the fan by adjusting the DC voltage across the fan. However, unlike a linear regulator, a DC-DC regulator uses a switch mode power supply. Because both methods control speed by adjusting the voltage, both tend to have the same advantages and disadvantages. The one exception, however, is that DC-DCs are ideally 100% efficient and don't generate any heat. Although in reality, efficiencies tend to be around 75% to 95%. The penalty for this efficiency is increased cost and complexity [14].

Programmable speed control

Programmable fans allow you to control the speed of the fan by developing simple circuits that can either pulse width modulate, vary the voltage or vary the resistance [12].

Pulse-width modulating (PWMing) the fan directly involves turning the fan's power supply on and of at fixed frequency. Duty-cycle adjustments are made to control the speed of the fan. The larger the duty cycle, the faster the fan spins. The PWM rise and fall times must be sufficiently slow to ensure long-term reliability of the fan.

PWMing has its advantages and disadvantages. The Advantages include a very simple drive circuit, good startup characteristics, and minimal heat dissipation in the pass transistor. A major disadvantage is increased stress on the fan.

Thermal speed control

Thermal speed control option uses a thermistor or thermostatic switch to monitor the temperature and regulate the speed accordingly. As the name implies, the thermostatic switch turns the fan on and off depending on the temperature. This switching usually causes a sudden switching from peace to noise and vice versa which could be rather disturbing. The thermistor metal properties allow it to change its resistance at different temperatures, thus creating a variable voltage divider circuit [14].

1.3 BENEFITS OF FAN SPEED CONTROL

Reduced audible noise

One of the most immediately noticeable advantages of fan speed control comes in the form of relief for the human ear. Fans running at full speed when not required can be a significant source of annoyance especially in quiet environments.

Reduced power consumption

In situations where minimization of power cost is of paramount importance, fan speed control is quite appreciated. Power consumption can be approximated as the square of the fan`s speed

Increased lifetime

Reducing fan speed when necessary also decreases the wear on the fan. Fan wear is a rough function of the absolute number of revolutions of the fan. Reduced wear translates into increased lifetimes and therefore greater meantime between failures (MTBFs). Because fans are mechanical, they tend to be one of the more common failures in a system [14].

CHAPTER 2
CIRCUIT OPERATION, DESIGN AND ANALYSIS

2.1 OVERVIEW OF CIRCUIT OPERATION

This is a circuit by which the speed of a fan can be linearly controlled automatically; depending on the ambient room temperature. The circuit uses a triac for power control. In this circuit, the temperature sensor used is an NTC thermistor, that is, one having a negative temperature coefficient. The value of the thermistor resistance at 25°C is about 1kΩ.

Op-amp A1 essentially works as a current to voltage converter and converts temperature variations into voltage variations. To amplify the change in voltage due to temperature, an instrumentation amplifier formed by op-amp A2, A3 and A4 is used. Resistor R4 and diode D2 combination is used for generating reference voltage since we want to amplify only changes in voltage due to changes in temperature.

IC2 works as a comparator. One input to the comparator is the output from the instrumentation amplifier while the other input is the stepped down, rectified and suitably attenuated sample of AC voltage. This is a negative going pulsating DC voltage. With increase in temperature, pin 2 of IC2 goes more and more negative and hence the width of the positive going pulses increases linearly with temperature. The output from the comparator is coupled to an optocoupler, which in turn controls the AC power delivered to the load.

2.2 CHOICE OF TEMPERATURE SENSOR

A variety of temperature sensors are available in the market today for various applications. The most common of which include thermocouples, thermistors, resistance temperature detectors (RTDs), pyrometers and IC sensors. With an almost daily advancement in the field of electronics, newer series of these sensors are manufactured offering improved characteristics and features designed to meet the diversified individual needs of designers and engineers.

Thus, in handling any project, a careful selection of the right temperature sensor has to be made with a view to meeting the requirements of the project and making efficient use of the sensor.

In choosing the sensor for this project, an analysis of the characteristics and features of the available sensors was carried out to choose the sensor that would most appropriately fit the needs of the project.

Due to the fact that every sensor has its advantages and disadvantages, a careful balance had to be made in choosing a sensor that had the maximum applicable advantages and minimum deterring disadvantages.

Thermocouples are not well suited for this project because the measurement must be relative to a fixed cold junction temperature making implementation impractical. The accuracy of the thermocouple has been found out to decrease over long period of use and thus maintaining stability in thermocouples could be much of a burden. The materials of which thermocouple wires are made are not inert and are subject to instability resulting from a variety of factors such as the atmosphere to which they are exposed. Also, if there is significant distance between the point in the process where the temperature measurement must be made and the electronic measuring instrument, the cost of the thermocouple wire connecting the two becomes an important consideration[18].

Resistance temperature detectors (RTDs) are made of platinium or nickel which are very expensive materials culminating in expensive products. They are also susceptible to shock and vibration.

IC sensors are known to have low sensitivity to temperature changes[8].

Pyrometers are only applicable in radiation detection and will not be considered since the temperature range being considered is a little above and below room temperature[8].

Thermistor are well suited for use as component parts of this project. Their small size and mass means that they can be packaged in a wide variety of thermal sensing packages. Thermistors are smaller, more rugged and offer significant cost advantages over other sensors since they do not require expensive metals such as platinium[7].

Thermistors provide higher resolutions than RTDs or thermocouples because their resistance vs. temperature change is significantly large. Their low mass and small size gives them quick response to temperature changes. Their higher resistance values allow them to be used with longer lead wires without requiring lead wire compensation[8].

2.3 THE CURRENT TO VOLTAGE CONVERTER

Another name for the current to voltage converter is the current controlled voltage source. It is so called because an input current controls an output voltage.

The input current is determined by the feedback resistor which in this circuit is a negative temperature coefficient (NTC) thermistor. The thermistor gives current that is proportional to the ambient temperature of the environment. This current which is limited by resistors R1 and R2 is converted to voltage by the current to voltage converter.

The major characteristics of the current to voltage is that it has a very low input impedance and a very low output impedance too[16].

With the inverting input at virtual ground, all of the input current flows through the feedback resistor which is the thermistor. So for different values of the thermistor resistance, a proportional value of voltage is obtained.

But the voltage drop across the thermistor does not vary with the current.

Thus the output voltage V_{OUT}.

$$= I_{in} R_T (A_{ol}/1+A_{ol}) \quad \ldots\ldots (2.1)$$

Where Aol = open loop gain

Iin = input voltage

Rt = resistance of thermistor

Because Aol is much greater than unity, the equation simplifies to

$$V_{out} = I_{in} R_t \quad \ldots\ldots (2.2)$$

The closed loop gain of the converter is given by

$$A_v = R_t/R_2 \quad \ldots\ldots (2.3)$$

$$R2 = 1\ K\Omega$$

Because Rt can vary from 100Ω to 1kΩ the maximum gain of the converter =

1000/1000 = 1

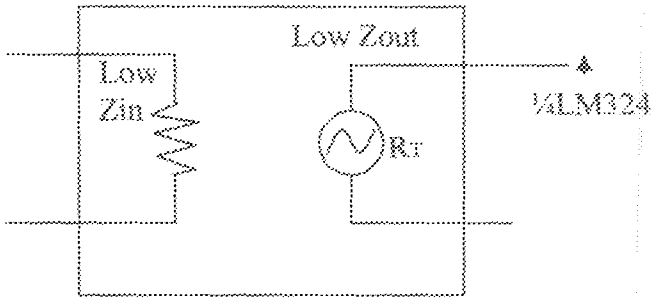


Fig 2.1 Current – controlled voltage source

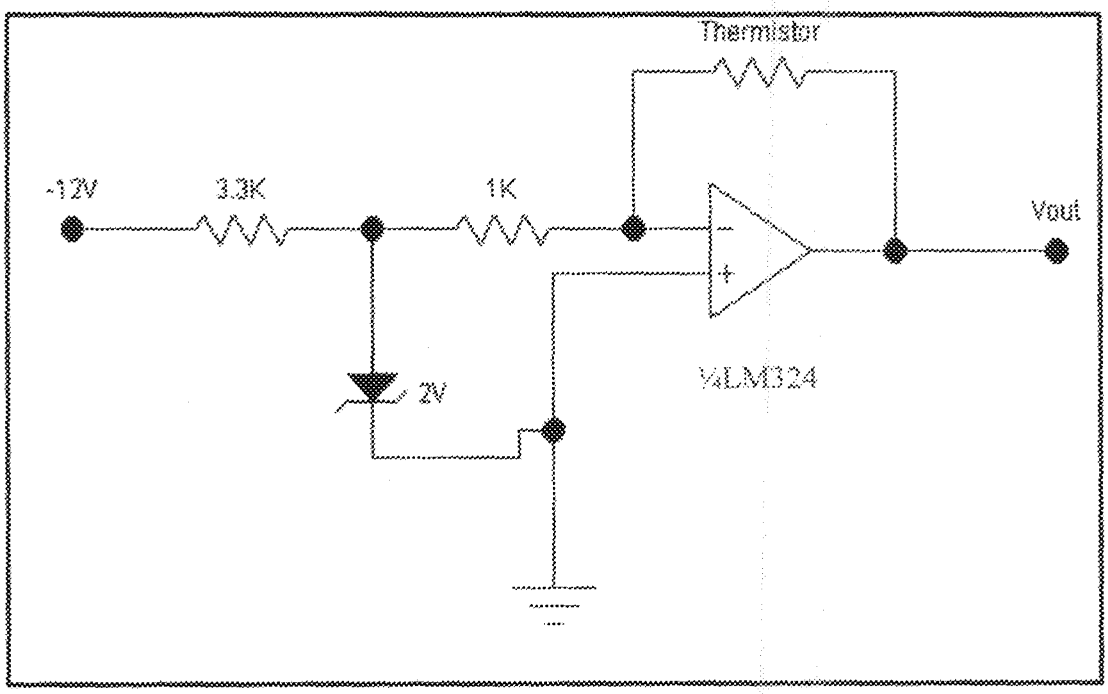


Fig 2.2 The current to voltage converter circuit

Zener diode, D1 ensures that the voltage appearing at the inverting input terminal is maintained at 2V

2.4 THE INSTRUMENTATION AMPLIFIER

The essential characteristics of the instrumentation amplifier are high gain, high input resistance, low offset and high common mode rejection ratio (CMRR). The high gain is necessary because the amplifier has to be sensitive to the low voltage signals from the current to voltage converter. Minimum loading on the signal source requires a high-input resistance. The low offset is necessary for accuracy in the measurement being made. A high value of CMRR is required to ensure that only the differential input is amplified and the common mode signal is greatly attenuated[17].

The instrumentation amplifier is made up of three operational amplifiers. The circuit has two gain stages. The first stage being a pre-amplifier and the second stage a post-amplifier. The first stage consists of A2, A3, R6, VR1 and R7 as in fig 2.3. The second stage composed of A4, R8, R9, R10 and R11 represents a standard differential amplifier configuration. All the resistors are of equal value, which is 10kΩ except for VR1. The negative feedback of A3 causes the voltage on top of VR1 to be equal to the voltage at the non-inverting input terminal of A3. Similarly, the voltage below VR1 is held to a value equal to the voltage at the non-inverting input of A2. This establishes a voltage drop across VR1 equal to the voltage difference between voltages at the non-inverting input terminals of A2 and A3. This voltage drop causes a current through VR1, and since the feedback loops of the two input op-amps draw no current, that same amount of current through VR1 goes through R8 and R9. This produces a voltage drop across these resistors. The differential amplifier, A4 takes this voltage drop and amplifies it by a gain of 1 since R10 and R11 are of the same value[19]. Also any common mode signal is rejected by the differential amplifier A4.

The voltage appearing at the non-inverting terminal of A3, which is pin 5 of the LM324, is the output voltage of the current to voltage converter. This voltage, as stated earlier, is dependent on the current through the thermistor and varies between 0.20V and 1.85V.

The voltage at the non-inverting terminal of A2, which corresponds to pin 3 of the LM324 IC, is maintained at 2.1V by the zener diode, D2. The voltage across resistor, R4 which is a current limiting resistor (because it limits the zener current to less than its maximum current rating) equals the difference between the source voltage which is 12V and the zener voltage which is 2.1V.

That is, 12-2.1 = 9.9V.

Therefore the current through the resistor is,

$$Is = Vs - Vz/R4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.4)}$$

$$\frac{12-2.1}{3.3K\Omega} = 0.03A$$

Vs = source voltage

Vz = zener voltage

R4 = 3.3kΩ

The zener diode D2 operates in the breakdown region. For breakdown to occur, Vth, that is, the Thevenin voltage facing the zener diode must be greater than the zener voltage.

$$Vth = \frac{R5Vs}{R5+R4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.5)}$$

$$= \frac{1M\Omega * 12}{1M\Omega + 3.3k\Omega}$$

This value is far greater than the zener voltage of 2.1V, thus breakdown occurs.

Since operational amplifiers have DC offsets, this was taken into account during design. To minimize this DC effect, shunt resistors were connected between the non-inverting input terminals of A2 and A3 and ground. The value of the resistors used is 1MΩ. These resistors compensate for the DC offsets caused by the op-amp, thus improving accuracy in measurements to be made.

The differential gain for the pre-amplifier stage is given by

$$\frac{\Delta Vout}{\Delta Vin} = 1 + \frac{2R6}{VR1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

$= 1 + 20000/1000 = 1 + 20$

$= 21$

The overall gain of the two stage cascade is

$$\frac{\Delta Vout}{\Delta Vin} = \left[1 + \frac{2R6}{VR1}\right]\frac{R11}{R9} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.7)$$

$= 21(1000/1000) = 21$

This implies that the gain of the second stage of the instrumentation amplifier is unity.

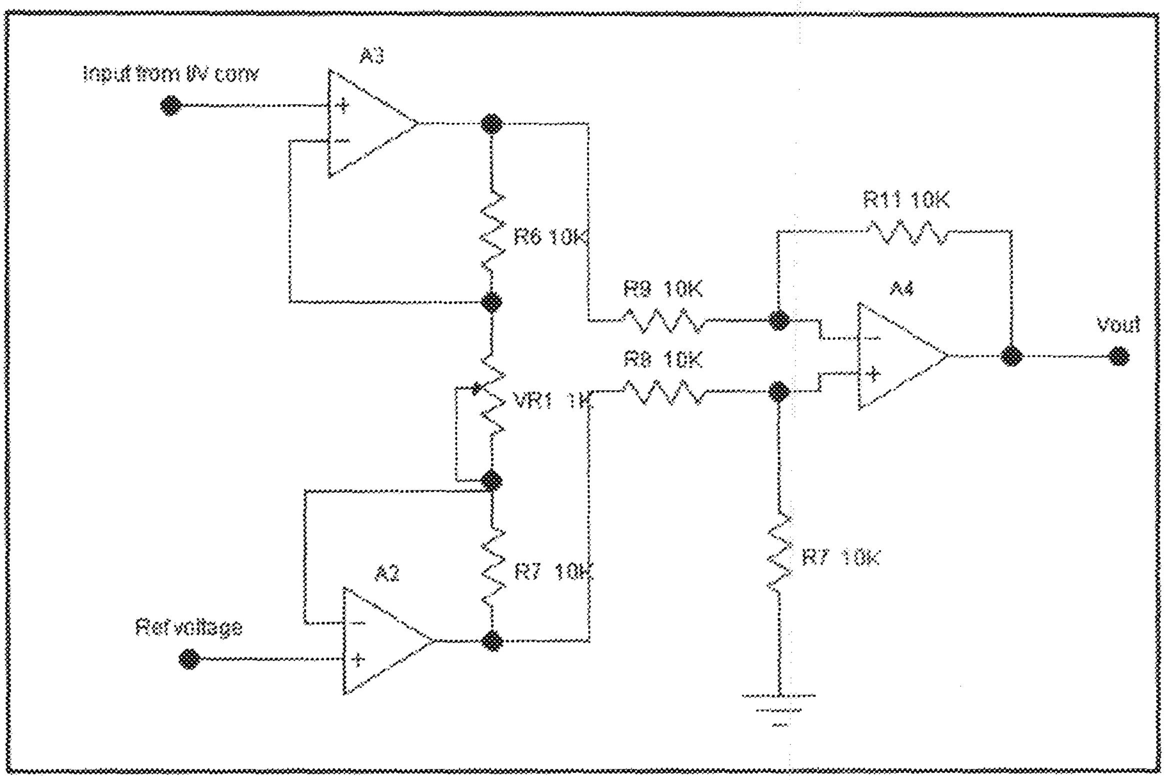


Fig2.3 The Instrumentation amplifier with 3 operational amplifiers

2.6 THE COMPARATOR

The integrated circuit used for the comparator is the µA741. This is a high performance monolithic operational amplifier constructed on a single silicon chip. It has a high gain of up to 200,000 and a wide range of operating voltage.

The comparator function is realized by using the operational amplifier in its high gain differential mode. This is required because the smallest possible difference between signals at the input have to be amplified to produce an output.

This comparator like any other one, will be saturated fully positive if the voltage at the non-inverting input terminal is more positive than that at the inverting terminal and saturated fully negative if the voltage at the non-inverting input terminal is less positive than that at the inverting input terminal[3]. Thus, the comparator compares the input from the inverting terminal and a reference voltage applied to the non-inverting input terminal. This reference voltage is a stepped down, rectified and suitably attenuated sample of AC voltage. The output of the comparator changes when one input exceeds the other in magnitude.

This comparator circuit is also called a square-wave converter. The output voltage transitions between the opposing states of saturation whenever the input voltage equals to the reference voltage. The result is a square wave[3].

Adjustments to the potentiometer setting, VR2, would change the reference voltage applied to the non-inverting input, which would change the points at which the wave would cross, changing the on/off times, or duty cycle of the square wave.

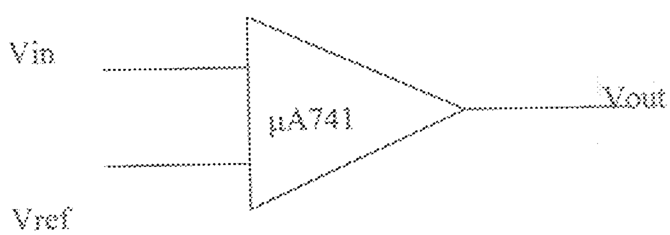


Fig 2.4 The Comparator

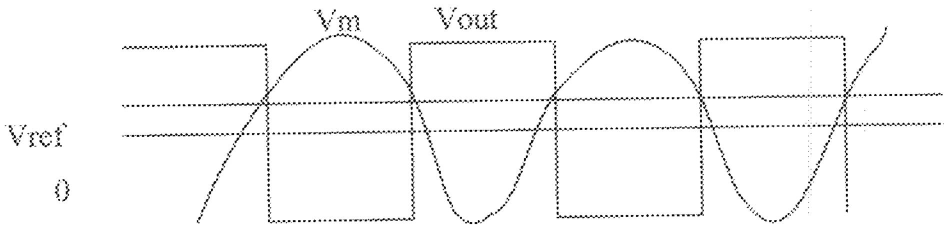


Fig 2.5 Comparator Waveform

This technique is also called pulse-width modulation (PWM) because a waveform is varied according to a controlling signal.

The input into the non-inverting input terminal of the comparator is a negative voltage which depending on the potentiometer, VR2, varies between -8.33 to -10.90. R14 and R16 form a voltage divider network.

$$Vref = \frac{R16V}{R16 + (R14 + VR2)} \quad \text{......................... (2.8)}$$

Resistor R15 limits the current to the comparator to about -1.86mA. This is to provide a safe operating current for the comparator.

The input to the inverting input terminal from the instrumentation amplifier varies from 10.72 to -11.49V.

No external compensating capacitor is used so that the slew rate of about 0.5V/μs is not reduced.

Zener diode, D7 and resistor R13 which have values of 5.1V and 2.2kΩ respectively, in the output circuit convert the full range output swing to digital levels.

2.6 THE ISOLATION AND TRIGGER CIRCUIT

Isolation circuit

This part of the circuit plays a key role in the overall circuit especially as regards the safety of the circuit and quality of signal the triac receives.

The main component of the isolation unit is the optocoupler. This is an isolating device consisting of an LED infra-red emitting diode in the same package as a light sensitive transistor or swiching device. The input and output circuits are electrically isolated from each other since the signal connection is via the optical link between the LED and the sensor.

Isolation of the input and the output circuit is done for a number of reasons:

1. Interference: One part of the circuit may be in a location where it picks up a lot of interference such as from electric motors or even the fan being controlled. Since the output of this circuit goes through an optocoupler, only the intended signal will pass through the optocoupler. The interference signal will not have enough strength to activate the LED in the optocoupler and thus they are eliminated.
2. High voltage separation: Since the LED is completely separated from the photosensitive triac, the optocoupler can exhibit voltage isolation of up to 7500V or any voltage that may approach from the triac.
3. Simultaneous separation and intensification of signals: The optocoupler could prevent attenuation of the signal strength and even amplify the current of the signal[13].

The optocoupler used in this circuit is MOC3011 which is constructed from a Gallium Arsenide Infrared Emitting Diode and Silicon Triac Bi-directional Detector, housed in a plastic package. The detector has an on-state RMS current of 100mA which is sufficient as gate trigger current to the main triac.

When the infra red LED is forced to conduct, a light beam is sent across the gap to the photo sensitive triac inside the MOC3011. This triac fires as the main voltage increases and forces the external main triac to also conduct. Power is applied to the load as long as the LED sends light.

Trigger circuit

The trigger circuit in this project makes use of a triac as the semi conductor power switching device.

The triac is a three terminal device which can be regarded as a bi-directional thyristor because it conducts in both directions. Current flows in either directions between the main terminal MT1 and MT2 is initiated by a small signal current applied between MT1 and the gate terminal. Therefore, triacs are used to provide full wave ac power switching and ac power control[11]. For this reason it is used in this project. The triac used in the project is BT136 which is rated 500-800V, Igt < 70mA, holding current = 30mA.

Turn on of the triac occurs when the gate current is between 30mA and 60mA. Turn off of the triac is achieved at the end of the conducting half cycle.

Triggering of the triac can occur in four quadrants because the triac can be triggered by positive or negative currents. But for this project, triggering occurs in the 1st quadrant, that is, the triac is triggered by a positive gate current from the optocoupler.

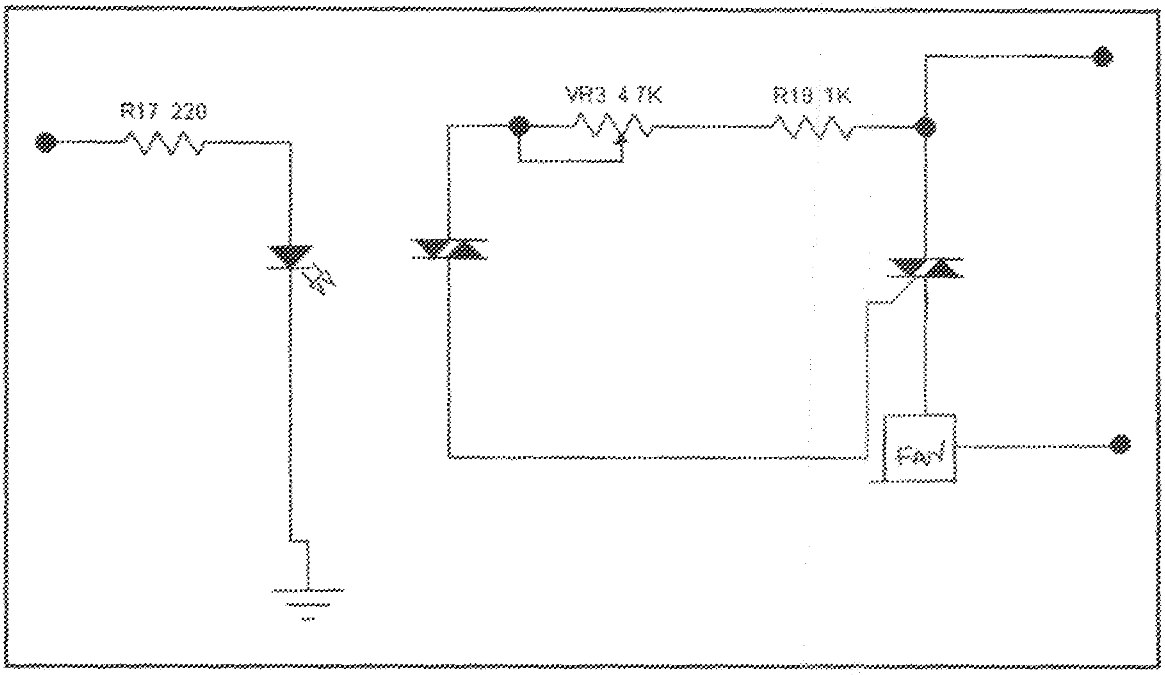


Fig 2.6 Isolation and trigger circuit

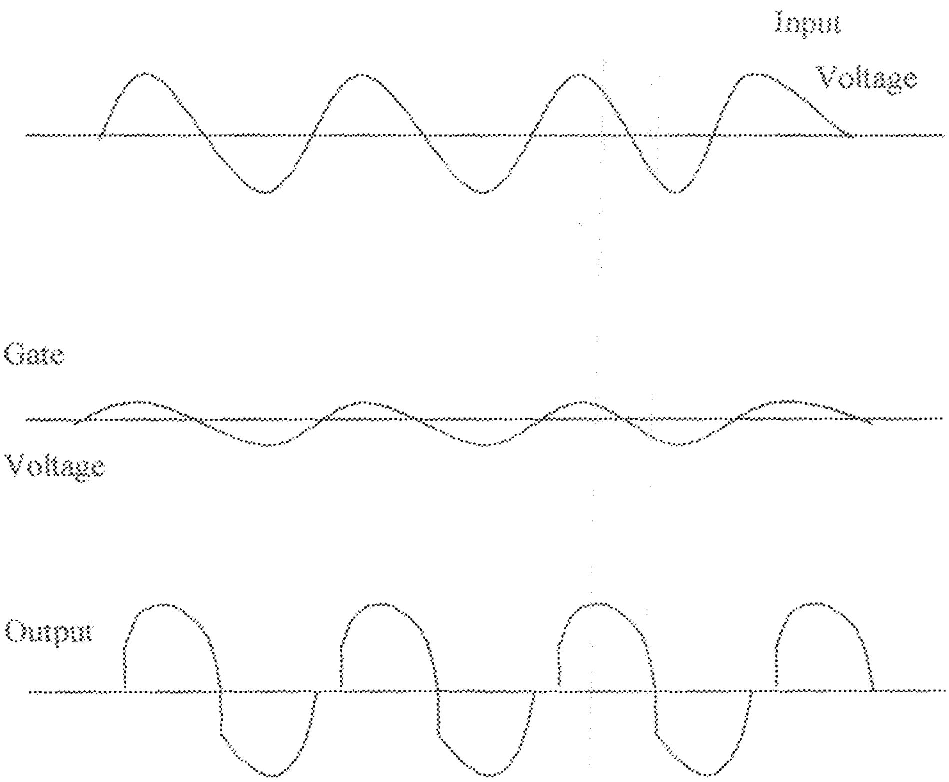


Fig 2.7 Triac waveform

2.7 THE REGULATED DC DUAL POWER SUPPLY

Virtually every piece of electronic equipment and their peripherals are powered from the DC power source. Most of there equipment, this project not being an exception, required not only DC voltage but voltage that is also well filtered and regulated.

More over this is a project that indirectly makes use of DC power to control AC power. This power supply performs the following functions at high efficiency and low cost:

1. Reflection
2. Voltage transformation
3. Filtering
4. Regulation
5. Isolation
6. Protection

The power supply module supplies +12VDC to the quad operational amplifier, LM324, +12VDC and -12VDC to the μA741 operational amplifier. It also supplies positive and negative DC voltages to the input terminals of the LM324 as well as the reference voltage to the non-inverting input terminal of the comparator (μA741) which has been passed through a voltage divider to give a value of about -7.45V

The transformer serves two main purposes:

- it isolates the equipment DC power lines from the main supply and
- it changes the level of the AC main voltage to a lower value.

The bridge rectifier converts the AC voltage from the transformer secondary winding into pulses of unidirectional or DC current.

Following the rectifier is the capacitive input filter. It serves to smooth out the pulses received from the rectifier.

Two linear voltage regulators are used. LM7812 provides a fixed positive voltage of 12V and LM7912 provides a fixed negative voltage of -12V.

The linear voltage regulator behaves as a variable resistance between the input and the output as it provides the precise output voltage. The output is continuously controlled to give good stabilization against main input changes and good regulation against load current changes[5].

One of the limitations to the efficiency of this circuit is that the linear devices must drop the difference in voltages between the input and the output. Consequently the power dissipated by the linear device is

(Vinput – Voutput) * I output ………………. (2.9)

This power is usually dissipated in the form of heat. Thus the regulators are provided with heat sinks to absorb the dissipated heat.

A 15V centre-tapped transformer is used to compensate for voltage drop across the bridge rectifier and losses in the regulators. This ensures that an output of 12V is obtained at the output terminal of the LM7812 and -12V at the output terminal of the LM7912.

The input capacitors, 1000µF 25V between pin 1 of the LM7812 and ground and between pin 2 of the LM7912 and ground prevent oscillations that might occur at the input voltage. The output capacitors, 0.1µF 50V, pin 3 of the LM7812 and ground and pin 3 of the LM7912 and ground improve transient response of the regulators

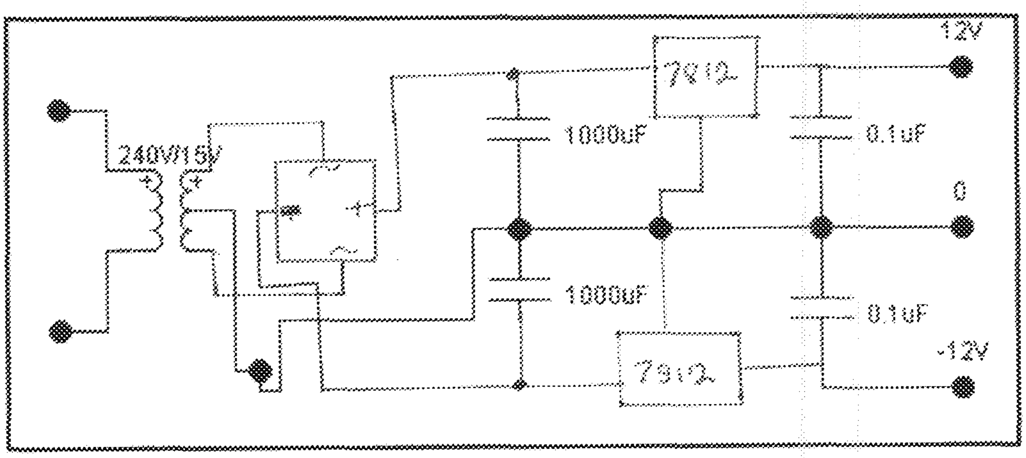
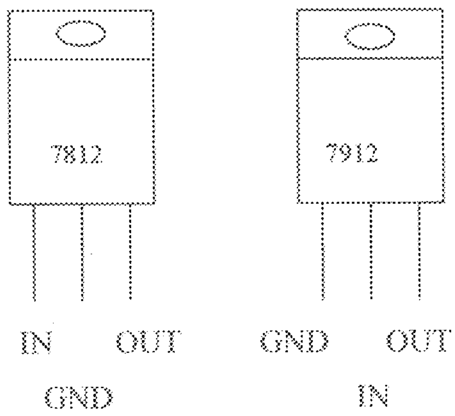


Fig 2.8 Dual Regulated Power Supply



Positive Regulator   Negative Regulator

Fig 2.9 The LM7812 and LM7912 IC regulators

CHAPTER 3

CONSTRUCTION AND TESTS

3.1 CONSTRUCTION PROCEDURE

The full schematic of the automatic room fan regulator device is shown in figure 3.1

List of Components

Resistors

R1, R4, R12, R15, R16 – 3.3kΩ

R2, R18 – 1kΩ

R3, R5 – 1MΩ

R6, R7, R8, R9, R10, R11 - 10kΩ

R13 - 2.2kΩ

R14 - 390Ω

R17 - 220Ω

Diodes

D1 - 2V zener diode

D2 - 2.1V zener diode

D3-D6 - IN4002 rectifier diode

D7 - 5.1V zener diode

D8 - IN4002 rectifier diode

Capacitors

C1, C3 - 1000μF electrolytic capacitor

C2, C4, - 0.1μF electrolytic capacitor

Semiconductors

IC 1 LM324 Quad operational amplifier

IC 2 μA741 Operational amplifier

IC 3 MOC3011 Optocoupler

IC 4 LM7812 +12 volt regulator

IC 5 LM7912 -12 volt regulator

Traic BT 136

RT NTC Thermistor

Miscellaneous

240V/12V transformer

14 pin IC socket

8 pin IC socket

Vero board

Heat sink

Jumper wires

During the course of design and construction of this project the following were taken into consideration:

1. The ambient temperature range to which the device would be sensitive to
2. Selection of reference voltage of the comparator
3. Selection of suitable components to reduce bulkiness of the device
4. Determination of gain for the instrumentation amplifier to provide minimum input to comparator
5. Isolation of circuit from the main AC supply to be controlled.

Step 1

I conducted an electronic simulation of the circuit to check its workability using Electronic Workbench 5.0 software. During simulation the output at different stages were recorded for comparison and analysis with the figures got during actual testing.

Step 2

All the components were carefully selected with values chosen on the basis of the simulation results. Each component was tested individually to confirm its working status.

Step 3

The circuit was constructed on a breadboard taking note of polarities and pin numberings. Tests were conducted at different stages and readings recorded. This gave room for corrections and modifications.

Step 4

A detailed paper drawing was made of the circuit including its power supply with the layout of the Vero board in mind. Components were virtually put in their real Vero board positions on the drawing. This was done to prevent desoldering and resoldering of components on the Vero board which could make the work look dirty and damage components as well.

Step5

The dual DC power supply was first constructed on the Vero board. A bridge rectifier was used for the full wave rectification instead of two diodes as earlier intended. Also, it should be noted that the power supply provided the reference voltage to the comparator thus saving extra components, space and cost. A decent heat sink was attached to each of the regulators because they draw appreciable current and this causes them to dissipate a lot of power via heat.

Step 6

The IC sockets were soldered unto the Vero board next, followed by the other components excluding IC1, IC2 and IC3. Jumper wires were used were necessary to bridge connections.

For soldering, an alloy of 60% tin: 40%lead was used. The solder both mechanically bonds the components to the PC board and provides electrical continuity between the devices and the board.

Step 7

IC1, IC2, and IC3 were then placed into the sockets. The LM324 quad operational amplifier is a single chip implementation of four operational amplifiers. This was preferred to the discrete implementation of individual operational amplifiers for the following reasons:

1. The amplifiers and other components are naturally matched and their specifications tend to track better with temperature since they share a common substrate.
2. Cost and space is saved by using one IC instead of four ICs.

3.2 COMPONENT LAYOUT AND CASING

Only one Vero board was used in the design. The Vero board takes care of all the units of the device and the power supply except the transformer which was placed directly in the casing.

Power railings of +12V and -12V were provided on the right side of the Vero board while the ground railing was done on the left side. This made it easier to provide power supply to different sections of the circuit.

Jumper wires were used to link points that the provisions on the Vero board could not handle. Also, the thermistor was placed away from the transformer so that, the temperature sensing would be more accurate. That is, the temperature of the air is taken and not of the transformer.

The casing is made of plastic which is strong and durable. Its rectangular shape is based on the Vero board shape and the transformer. It feature holes on the sides so that air currents can move in and out of the casing. The holes also make it possible for easy dissipation of heat generated by the transformer.

3.3 TEST AND CALIBRATION

Test and calibration of negative temperature coefficient thermistor

The NTC thermistor exhibits a decrease in electrical resistance with increasing temperature. The resistance value of the thermistor is usually referenced at 25°C (abbreviated as R25)[9].This device is supposed to be placed in a room and it is expected that the temperature of the air in the room should be between 25°C and 40°C maximum.

Considering the above facts, a thermistor having an R25 value of 1kΩ was chosen. This implies that at temperatures above 25°C, the resistance of the thermistor would be below 1kΩ.

A test was carried out to determine the resistance value of the thermistor at different temperatures.

The thermistor was placed in a beaker containing water which had been cooled to 25°C and the temperature of the water was gradually increased by heating it to about 50°C. The resistance of thermistor was measured using a multimeter. Readings were taken at intervals of 5°C by touching the leads of the thermistor with the multimeter probes and monitoring the multimeter display.

The result of the test is as shown below:

T (°C)	R (Ω)
25	1000
30	800
35	640
40	510
45	420
50	360

The resistance vs. temperature (R/T) characteristic (also known as R?T curve) of the NTC thermistor forms the 'scale' that allows its use as a temperature sensor. This characteristic is a non-linear, negative exponential function[9].

CHAPTER 4
CONCLUSION

4.1 Precautions taken in constructions

1. The Vero board or printed circuit board (PCB) was cleaned and scraped to remove any oxidation before the components were soldered unto it
2. I made sure I paid close attention to the pin numberings of the ICs and the polarities of the electrolytic capacitors used in the power supply.
3. Heat sinks were attached to the heat dissipating components, that is the voltage regulators to enhance heat transfer from the device to the atmosphere.
4. During soldering, excessive heating of the components was avoided by making the soldering process as quick as possible. Too much heat applied could lead to damage of the internal circuitry of the components.
5. I used IC sockets to hold the ICs instead of directly soldering the ICs unto the PC board. This was done to make the changing of ICs easier and to prevent damage to the ICs during soldering.

4.2 RECOMMENDATIONS AND CONCLUSION

RECOMMENDATION

In the course of design and construction, I discovered that this project could be further worked on in future and enhanced to be of more benefit to the society. Thus I recommend the following:

1. A circuit to handle automatic switching in response to presence or absence of people in the room
2. A timing device can be incorporated so that the duration of operation of the fan could be regulated also.

3. A more recent optocoupler should be used because the MOC3011 might soon be replaced in the market.

CONCLUSION

This project has successfully being used to control the power supply to a room fan in direct response to the ambient temperature, thus doing away with manual fan speed control. It worked efficiently with a temperature range of 25° to 40°C.

The usual characteristics and features of any project or assignment have not been lacking in this project. There were a few challenges and hitches which required deep thinking and reasoning.

This project has utilized DC power to control AC power supply and thus expanded the possibilities of power control.

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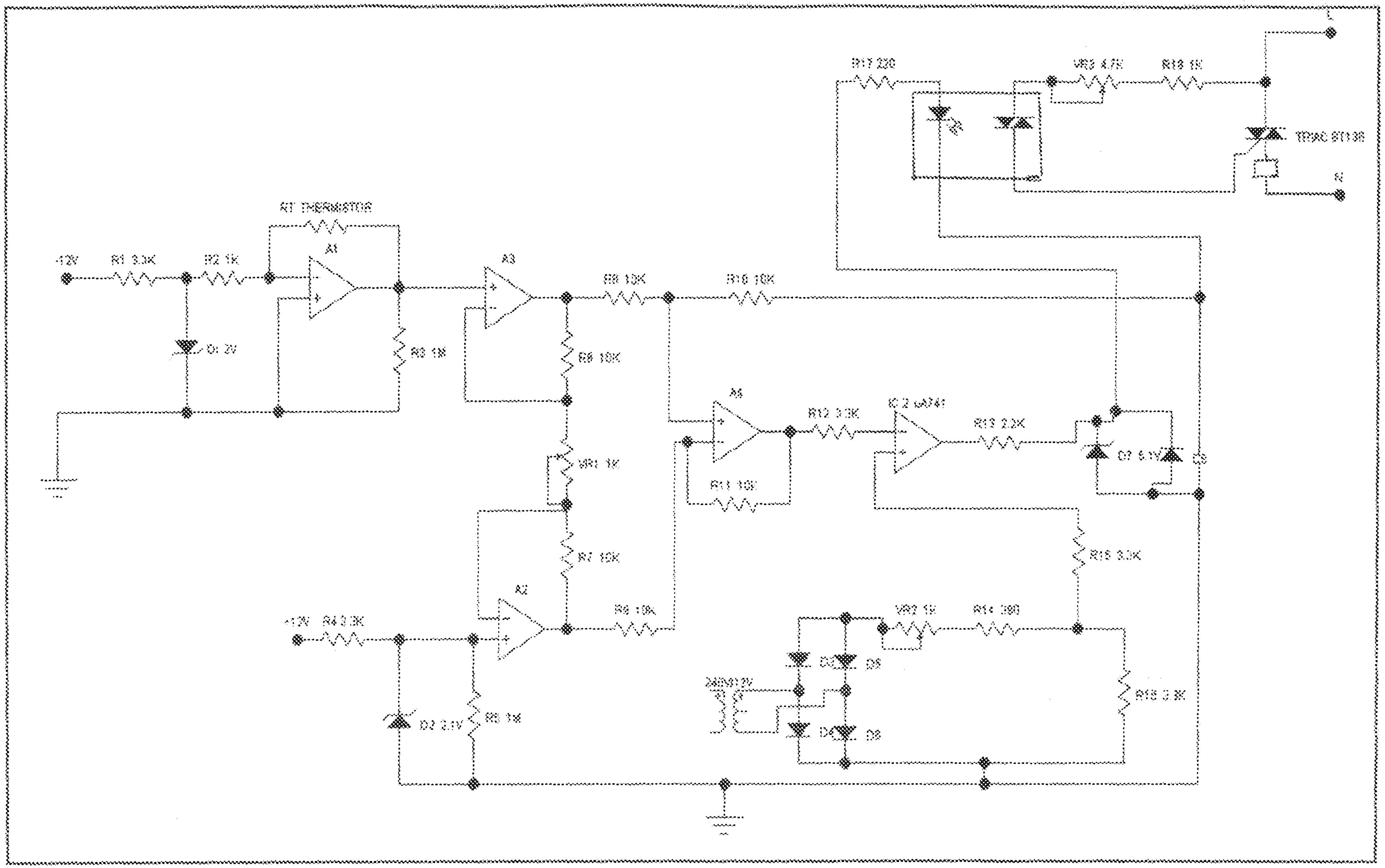

Fig3.1 Complete circuit diagram