# NEAR EAST UNIVERSITY

## Faculty of Engineering

## Department of Electrical and Electronic Engineering

## SYNCHRONOUS ON-OFF CONTROL PROJECTS

Graduation Project
EE – 400

Student: Mehmet Başar Özdikici (990446)

Supervisor: Mr. Özgür Cemal Özerdem

Lefkoşa – 2004

# ACKNOWLEDGEMENT

First I want to thank Özgür Cemal Özerdem to be my Supervisor. Under this guidance, I successfully overcome many difficulties and learn a lot about Power Electronics with EE433 and with EE222 courses. Power Electronics depends greatly on technology. In each discussion, he explained my questions patiently and answered my questions quickly and in detail. He always help me a lot either in my study.

Thanks to faculty of Engineering for having such a good computational environment. I want to thank all my student friends in NEU. Being with them make my during educational in NEU full of fun.

Also I want to thank my friends mentioned as Hisham Mahmud Tariq, Ali Kurttekin, Cem Aksu, Murat Çuhadar and Sercan Gündeş who helped me a lot in making of this project.

Finally I want to thank especially my family. Without their endless support and love for me.

## ABSTRACT

In this project the operation of synchronous thermostat was explained. Along with this the electronic elements used in this type of circuits and the connections of resistors, triac, transistors, capacitors, heater and thermostat in the circuit of synchronous thermostat were also showed. Also the full details of these elements' structure are explained in my project. As it is known that in all the temperature applications the thermostat is the main component that controls the whole system automatically according to the required conditions. And the process of operation of a thermostat is also explained in detail.

# TABLE OF CONTENTS

# INTRODUCTION

This project is about the synchronous on-off controlling system. In this project we have discussed about the operating principles and the circuit details of the synchronous on-off control system in full details. The main aim of this project is to control a heater circuit by using a synchronous thermostat.

This project is divided into five parts. The first part is the first chapter that explains about the full description of thermostat. The details of operations, replacement, limit, applications, features and the key specifications are explained.

The second part is the second chapter in which we describe the effects on this synchronous system like the noise and mounting in typical applications used.

The third part is chapter three which includes the details of all the electronic components used in this synchronous system and their features.

The fourth part is chapter four of this project which explains the performance measurements of the thermostat and heaters.

The fifth part is chapter five which is the main circuit designing and implementation of this circuit.

# Chapter 1

## INTRODUCTION TO SYNCHRONOUS THERMOSTAT

### 1.1 Replacing the Thermostats

The temperature of the air inside the drum is regulated using thermostats. Thermostats open and close an internal switch with respect to the temperature of their environment. There are two different thermostats in your dryer: the operating thermostat(s) and the limit thermostat. The only difference in these thermostats is their opening and closing temperatures.

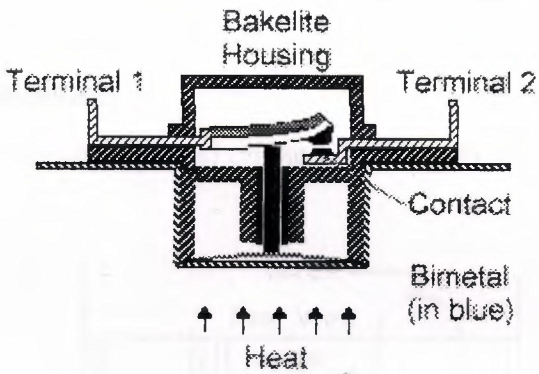



Figure 1.1 Structure of Thermostat

### 1.1.1 Operating Thermostats

Operating thermostats control the temperature of the air inside the drum. You may have one or more operating thermostats mounted on the exhaust side of the blower housing. One may be used for the "Normal" drying cycle and will open at the highest temperature. The thermostat for "Permanent Press" or "Gentle" will open at a lower temperature. The operating thermostats are in series with the heater element. Operating thermostats normally open from 120 to 170 degrees and are always closed at room temperature. The following picture shows the thermal fuse and the operating thermostat.

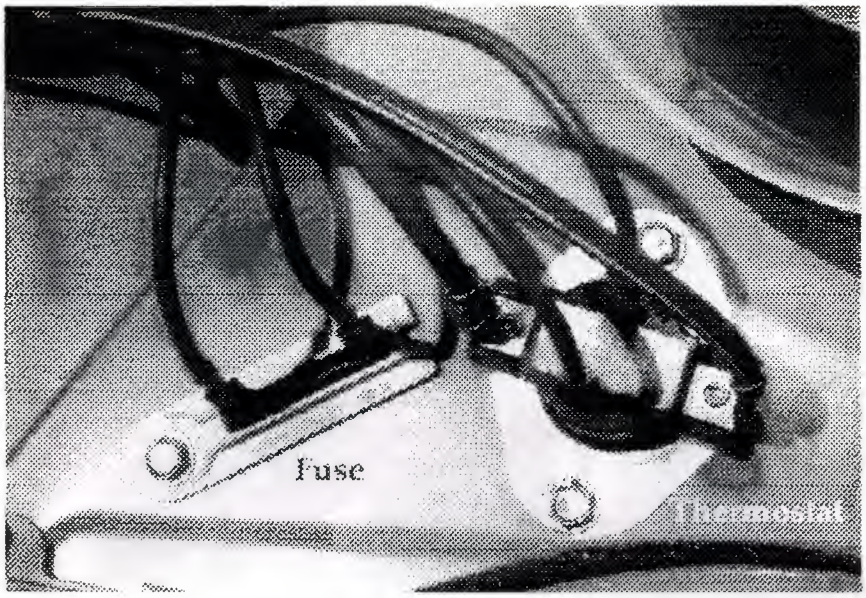



Figure 1.2 operational thermostat

### 1.1.2 Limit Thermostats

The limit thermostat is located on the side of the heater chimney.

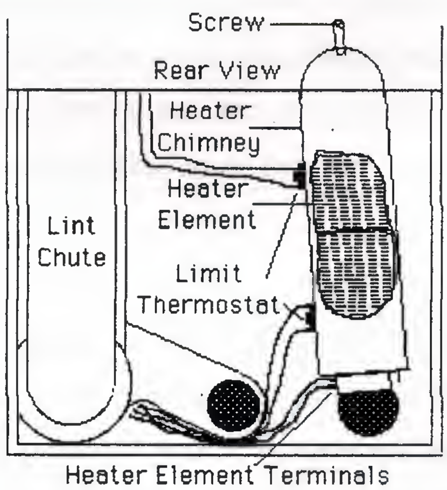



Figure 1.3 Limit thermostat

As its name implies, this thermostat shuts off the heater element if a dangerously high temperature is reached. This can happen if the operating thermostat fails (welds closed) and demands heat constantly. When this happens, the limit thermostat becomes the operating thermostat. Unfortunately, the limit thermostat cycles at a temperature almost 100 degrees higher than the high temperature operating thermostat! This does your clothes absolutely no good. You should be able to smell that something is wrong. The following is a picture of a high limit thermostat.

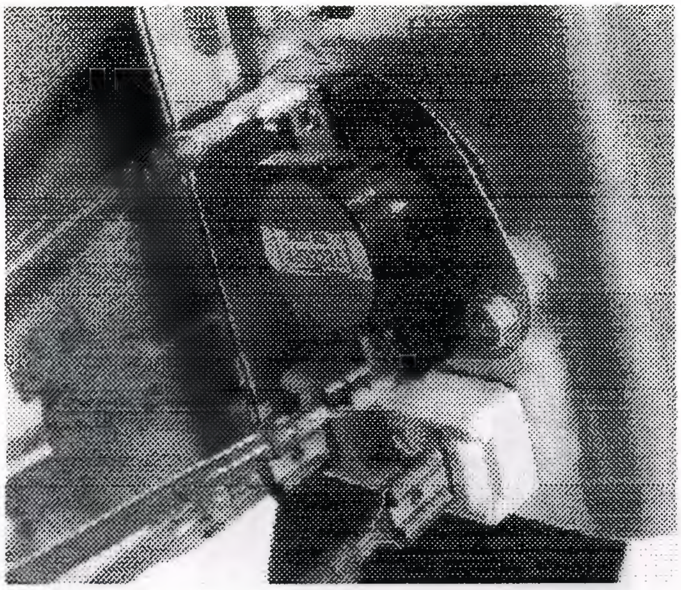


Figure 1.4 high limit thermostats

Sometimes the terminals on the high limit thermostat burn or char. This problem starts with oxidation of the spade terminals on the end of the red wires leading to and from the thermostat. The oxidation process is accelerated by the heat from the heater element. The oxidized contacts generate heat when the high heater current flows throught them. The high heat increases the contact resistance and the heat goes higher. This causes the terminals to get hotter and hotter until the bakelite case of the thermostat breaks down and the spade terminal and the wire insulation turns black. When this occurs, the high limit thermostat and the spade terminal should be replaced.

### 1.1.3 Thermal Cutoffs

Whirlpool installed thermal cutoffs near the top of the chimneys. They provide additional protection in the event that the heat generated by the heater coil does not move out into the drum fast enough. A picture of a thermal cutoff is shown below.

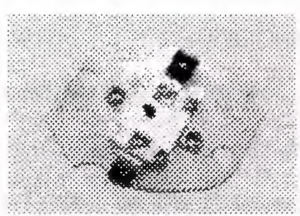


Figure 1.5 Thermal cutoffs

The following picture shows the thermal cutoff installed on the heater chimney.

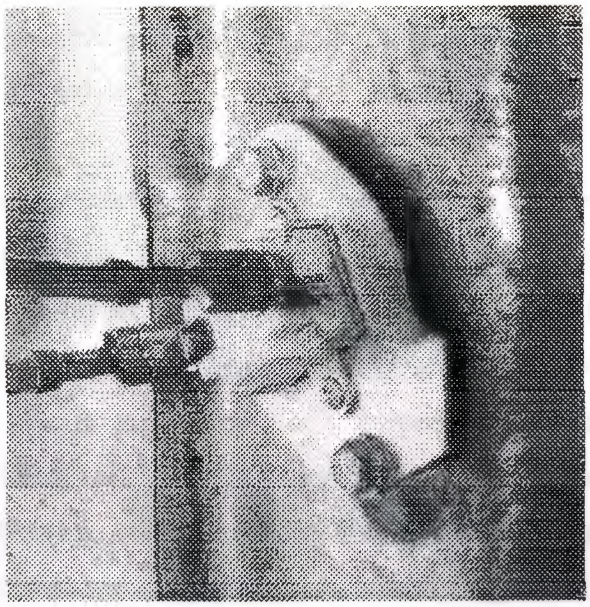


Figure 1.6 thermal cutoff installed on the heater chimney

The frustrating feature of a thermal cutoff device is that it opens when its operating temperature is reached but then it stays open and will not close when the temperature drops down. In other words, the cutoff works once and then has to be replaced. Look for a reason for the elevated temperature in the heater chimney. Check for a blocked vent or an operating thermostat that is running hot. When you are ready to replace the thermal cutoff, obtain Part 279769 which contains a new thermal cutoff AND a high limit thermostat.

If you want to check the thermostats, follow this procedure. Disconnect the power cord and move the dryer far enough away from the wall that you can disconnect the dryer vent hose. Remove the 5/16" sheet metal screws securing the rear access panel. Save the top, middle screw for last. Set the panel aside.

Visually inspect the operating thermostats on the blower housing. Do any of the paper labels look charred? If they do, replace them. Set your ohmmeter at its lowest scale and confirm that they are closed by measuring less than 1 ohm. If a thermostat is not charred and it is closed it is usually OK. However, a thermostat's contacts can weld together and pass this test. They will usually get very hot before they weld and char the paper label. If you noticed charred paint on the rear access panel, just behind the heater chimney, suspect a welded operating thermostat. Replace them if the ohmmeter shows an open circuit at room temperature. The thermostat's operating temperature (temp that it will open) is stamped on its base. An L155 thermostat will open at 155 degrees. If you want your dryer to operate at a higher temperature, replace its operating thermostat with one bearing a higher L number.

Perform the same checks on the limit thermostat as for the operating thermostats in the preceding step. You should have smelled the problem with a failed limit thermostat. A limit thermostat will not cycle unless the selected operating thermostat has failed closed. If the dryer is operating on the limit thermostat, it has transformed into an oven and is baking your clothes in a convection chamber at a temperature of about 250 degrees! Limit thermostats cycling at these elevated temperatures are prone to failing closed. Of course things really get hot with all thermostats failed closed and the heater element constantly on. I have seen one dryer go this far. It had melted the plastic console down and was close to igniting the lint ( and probably the clothes). This is a very dangerous situation because dryers are usually operated unattended. You can order a replacement limit thermostat using the model number of your dryer. Take all suspect thermostats to your nearest appliance store and purchase new ones. If the paper labels are charred and illegible, remember whether they were operating thermostats or the limit thermostat. If you are replacing one of two operating thermostats, determine from the wiring diagram on the back of the dryer whether you are replacing a high (Cottons) or low (Permanent Press) temperature thermostat. Or If you had two operating thermostats and one was charred beyond recognition, copy the numbers off the one that checked out OK and purchase the other one from the parts list. Take your dryer model number along. Another approach is to use generic Gemline thermostats and purchase them by their operating temperatures. Use an L155 for cottons and a L135 for permanent press.

Replace the thermostats (you can reverse the wires on a two-terminal thermostat with no ill effects). Replace the rear access panel and check for proper operation.

## 1.2 Thermostat

The explaination of thermostat is given below:

### 1.2.1 General Description

The LM27 is a precision, single digital-output, low-power thermostat comprised of an internal reference, DAC, temperature sensor and comparator. Utilizing factory programming, it can be manufactured with different trip points as well as different digital output functionality. The trip point (TOS) can be preset at the factory to any temperature in the range of +120°C to +150°C in 1°C increments. The LM27 has one digital output (OS/OS/US/US), one digital input (HYST) and one analog output (VTEMP). The digital output stage can be preset as either open-drain or push-pull. In addition, it can be factory programmed to be active HIGH or LOW. The digital output can be factory programmed to indicate an over temperature shutdown event (OS or OS) or an under temperature shutdown event (US or US). When preset as an overtemperature shutdown (OS) it will go LOW to indicate that the die temperature is over the internally preset TOS and go HIGH when the temperature goes below (TOS−THYST). Similarly, when preprogrammed as an undertemperature shutdown (US) it will go HIGH to indicate that the temperature is below TUS and go LOW when the temperature is above (TUS+THYST). The typical hysteresis, THYST, can be set to 2°C or 10°C and is controlled by the state of the HYST pin. A VTEMP analog output provides a voltage that is proportional to temperature and has a −10.7mV/°C output slope.Currently, there are several standard parts available, see ordering information for details. For other part options, contact a National Semiconductor Distributor or Sales Representative for information on minimum order qualification. The LM27 is currently available in a 5-lead SOT-23 package.

### 1.2.2 Applications

- Microprocessor Thermal Management
- Appliances
-Portable Battery Powered Systems
- Fan Control
- Industrial Process Control
- HVAC Systems
- Electronic System Protection

### 1.2.3 Features

-Internal comparator with pin selectable 2°C or 10°C hysteresis
- No external components required
- Open-drain or push-pull digital output; supports CMOS logic levels

- Internal temperature sensor with VTEMP output pin
- VTEMP output allows after-assembly system testing
- Internal voltage reference and DAC for trip-point setting
- Currently available in 5-pin SOT-23 plastic package
- Excellent power supply noise rejection

### 1.2.4 Key Specifications

- Power Supply Voltage 2.7V to 5.5V
- Power Supply Current 40µA(max) 15µA(typ)
- Hysteresis Temperature 2°C or 10°C(typ)
- Temperature Trip Point Accuracy ±3°C (max)

## Chapter 2

## FUNCTIONAL DESCRIPTION

### 2.1 AFTER-ASSEMBLY PCB TESTING

The LM27's VTEMP output allows after-assembly PCB testing by following a simple test procedure. Simply measuring the VTEMP output voltage will verify that the LM27 has been assembled properly and that its temperature sensing circuitry is functional. The VTEMP output has very weak drive capability that can be overdriven by 1.5mA. Therefore, one can simply force the VTEMP voltage to cause the digital output to change state, thereby verifying that the comparator and output circuitry function after assembly. Here is a sample test procedure that can be used to test the LM27CIM5X-2HJ which has a 140°C trip point.

1.Turn on V+ and measure VTEMP. Then calculate the temperature reading of the LM27 using the equation:

$$VO=(-3.552x10-6x(T-30)2)+(-10.69576x10-3x(T-30))+1.8386V$$

2. Verify that the temperature measured in step one is within (±3°C + error of reference temperature sensor) of the ambient/board temperature. The ambient/board temperature (reference temperature) should be measured using an extremely accurate calibrated temperature sensor, which is in close proximity to and mounted on the same PCB as the LM27 perhaps even touching the GND lead of the LM27 if possible. The LM27 will sence the board temperature not the ambient temperature.

3. A. Observe that OS is high.
   B. Drive VTEMP to ground.
   C. Observe that OS is now low.
   D. Release the VTEMP pin.
   E. Observe that OS is now high.

4. A. Observe that OS is high.
   B. Drive VTEMP voltage down gradually.
   C. When OS goes low, note the VTEMP voltage.

D. VTEMPTrig = VTEMP at OS trigger (HIGH->LOW)

E. Calculate Ttrig using Equation.

5. A. Gradually raise VTEMP until OS goes HIGH. Note VTEMP.

B. Calculate THYST using Equation.

## 2.1.1 VTEMP LOADING

The VTEMP output has very weak drive capability (40μA source, 1μA sink). So care should be taken when attaching circuitry to this pin. Capacitive loading may cause the VTEMP output to oscillate. Simply adding a resistor in series will prevent oscillations from occurring. To determine the value of the resistor follow the guidelines given. The same value resistor will work for either placement of the resistor. If an additional capacitive load is placed directly on the LM27 output, rather than across CLOAD, it should be at least a factor of 10 smaller than CLOAD.

## 2.1.2 NOISE CONSIDERATIONS

The LM27 has excellent power supply noise rejection. Listed below is a variety of signals used to test the LM27 power supply rejection. False triggering of the output was not observed when these signals where coupled into the V+ pin of the LM27.

- square wave 400kHz, 1Vp-p
- square wave 2kHz, 200mVp-p
- sine wave 100Hz to 1MHz, 200mVp-p

Testing was done while maintaining the temperature of the LM27 one degree centigrade way from the trip point with the output not activated.

## 2.1.3 MOUNTING CONSIDERATIONS

The LM27 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface. The temperature that the LM27 is sensing will be within about +0.06°C of the surface temperature to which the LM27's leads are attached to. This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature measured would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity, the backside of the LM27 die is directly attached to the GND pin (pin 2). The temperatures of the lands and traces to the other leads of the LM27 will also affect the temperature that is being sensed.

Alternatively, the LM27 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM27 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to ensure that moisture cannot corrode the LM27 or its connections. The junction to ambient thermal resistance (θJA) is the parameter used to calculate the rise of a part's junction temperature due to its power dissipation. For the LM27 the equation used to calculate the rise in the die junction temperature where TA is the ambient temperature, V+ is the power supply voltage, IQ is the quiescent current, IL_TEMP is the load current on the VTEMP output, VDO is the voltage on the digital output, and IDO is the load current on the digital output. Since the LM27's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the LM27 is required to drive summarize the thermal resistance for different conditions and the rise in die temperature of the LM27 without any loading on VTEMP and a 10k pull-up resistor on an open-drain digital output with a 5.5V power supply.

## 2.2 Typical Applications

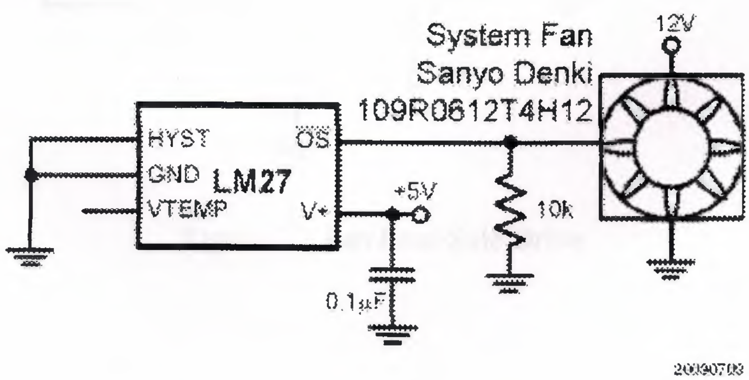



Figure 2.1 Two Speed Fan Speed Control

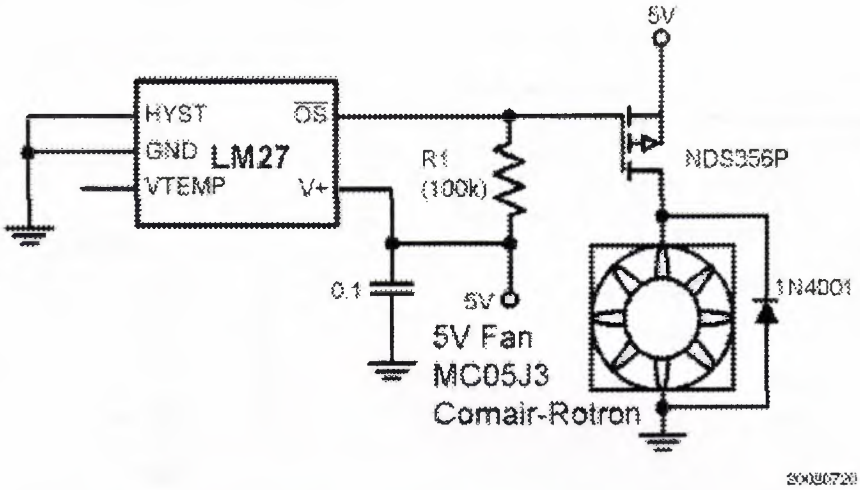



Figure 2.2 Fan High Side Drive

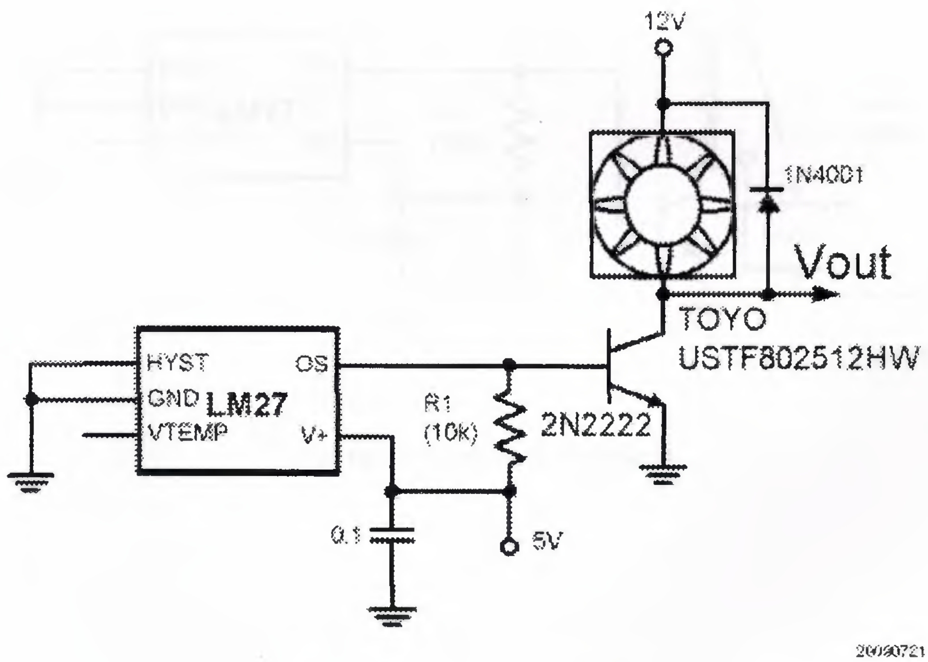



Figure 2.3 Fan Low Side Drive

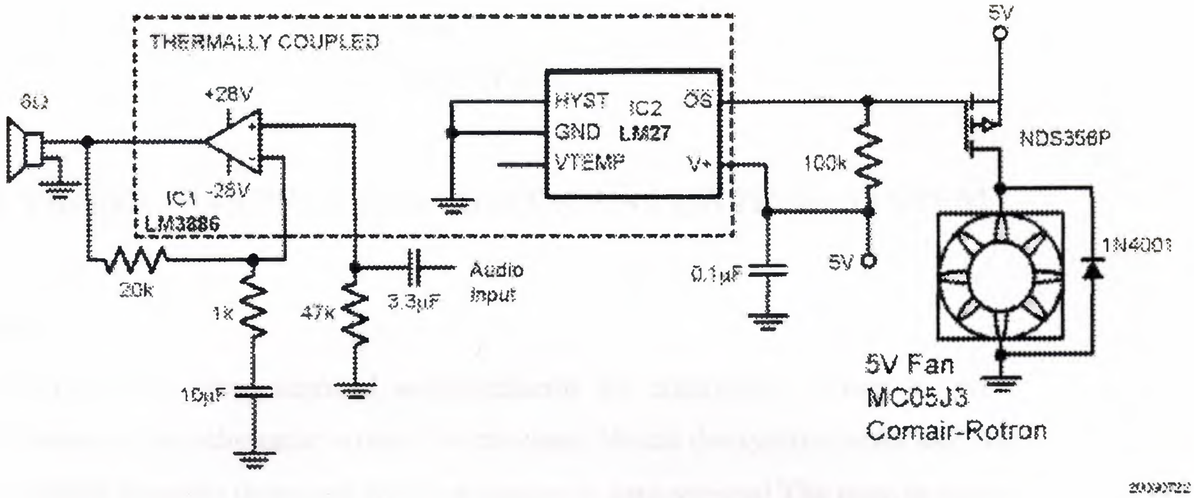



Figure2.4 Audio Power Amplifier Thermal Protection

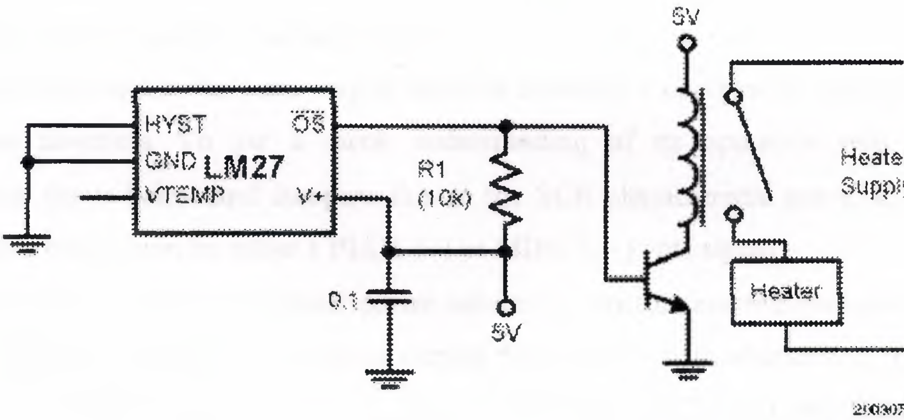



Figure 2.5 Simple Thermostat

# Chapter 3

# ELECTRONIC PARTS IN SYNCHRONOUS CONTROL SYSTEM

## 3.1 Triac

The triac is a three terminal semiconductor for controlling current in either direction. Below is the schematic symbol for the triac. Notice the symbol looks like two SCRs in parallel( opposite direction) with one trigger or gate terminal.The main or power terminals are designated as MT1 and MT2 . (See the schematic representation below) When the voltage on the MT2 is positive with regard to MT1 and a positive gate voltage is applied, the left SCR conducts. When the voltage is reversed and a negative voltage is applied to the gate, the right SCR conducts. Minimum holding current, Ih, must be maintained in order to keep a triac conducting.

A triac operates in the same way as the SCR however it operates in both a forward and reverse direction. To get a quick understanding of its operation refer to its characteristic curve below and compare this to the SCR characteristic curve. It can be triggered into conduction by either a PLUS (+) or MINUS (-) gate signal.

The TRIAC is a three-terminal device similar in construction and operation to the SCR. The TRIAC controls and conducts current flow during both alternations of an ac cycle, instead of only one. The schematic symbols for the SCR and the TRIAC are compared in figure 3-23. Both the SCR and the TRIAC have a gate lead. However, in the TRIAC the lead on the same side as the gate is "main terminal 1," and the lead opposite the gate is "main terminal 2." This method of lead labeling is necessary because the TRIAC is essentially two SCRs back to back, with a common gate and common terminals. Each terminal is, in effect, the anode of one SCR and the cathode of another, and either terminal can receive an input. In fact, the functions of a TRIAC can be duplicated by connecting two actual SCRs as shown in figure 3-24. The result is a three-terminal device identical to the TRIAC. The common anode-cathode connectionsform main terminals 1 and 2, and the common gate forms terminal 3.

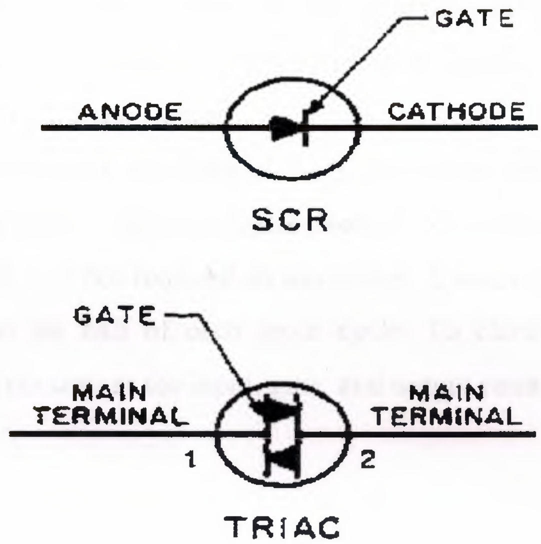



Figure 3.1 Comparison of SCR and Triac

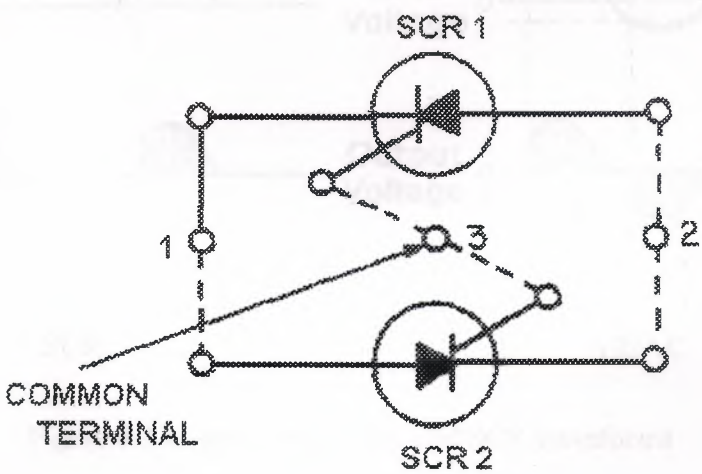



Figure 3.2 Back to back SCR equivalent circuit

The difference in current control between the SCR and the TRIAC can be seen by comparing their operation in the basic circuit shown in figure 3.1. In the circuit shown in view A, the SCR is connected in the familiar half-wave arrangement. Current will flow through the load resistor ($R_L$) for one alternation of each input cycle. Diode CR1 is necessary to ensure a positive trigger voltage.

With the TRIAC inserted in the place of the SCR, current flows through the load resistor during both alternations of the input cycle. Because either alternation will trigger the gate of the TRIAC, CR1 is not required in the circuit. Current flowing through the load will reverse direction for half of each input cycle. To clarify this difference, a comparison of the waveforms seen at the input, gate, and output points of the two devices is shown in figure 3.3.

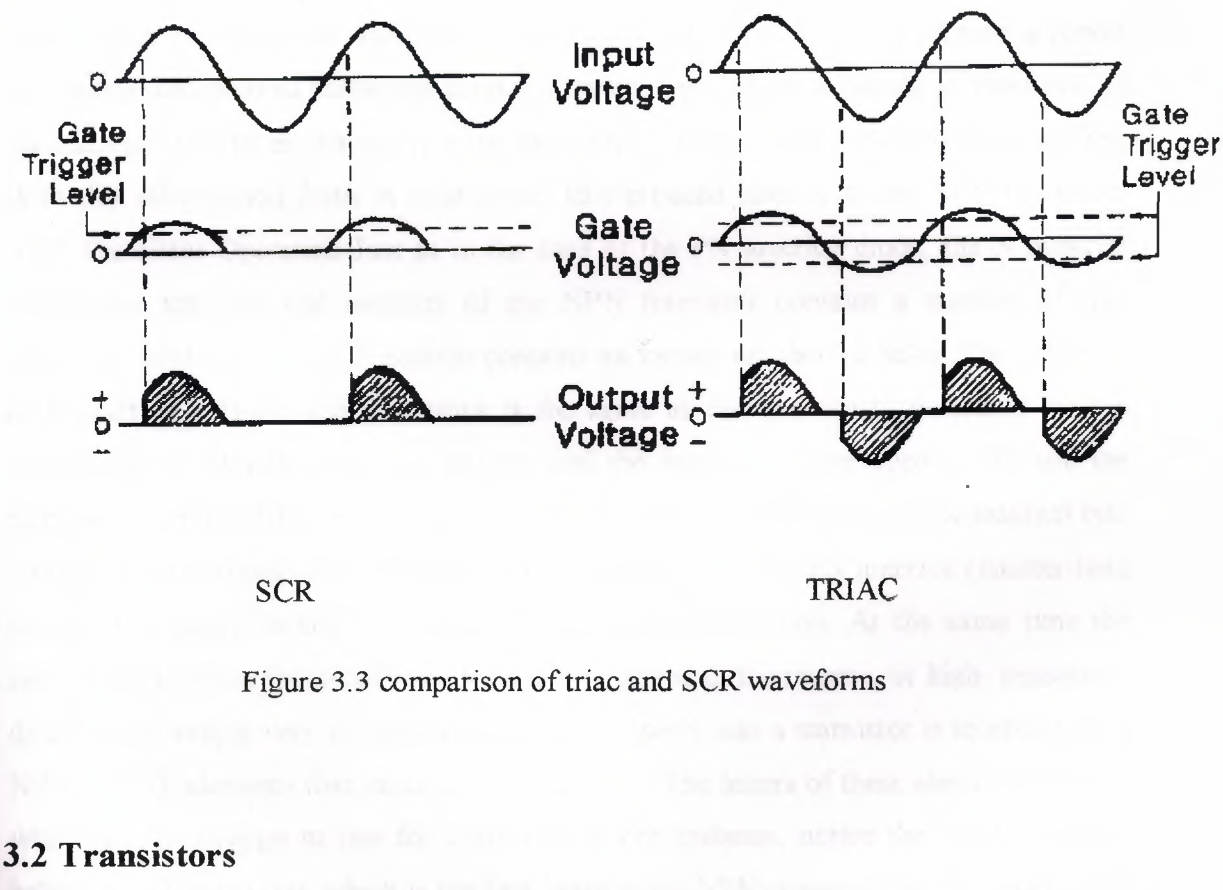



Figure 3.3 comparison of triac and SCR waveforms

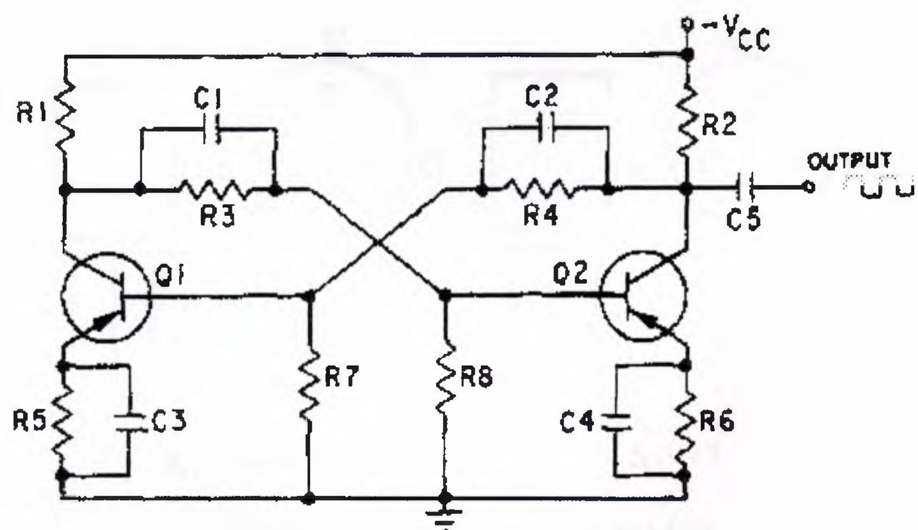
### 3.2 Transistors

Transistors are semiconductor devices with three or more terminals. The operation of normal transistors has already been discussed, but there are several transistors with special properties that should be explained. As with diodes, a discussion of all the developments in the transistor field would be impossible. The unijunction transistor (UJT) and the field effect transistor (FET) will be discussed because of their widespread application in Navy equipment. Many other special transistors have been developed and will be discussed in later NEETS modules.

TRANSISTOR THEORY, you should recall from an earlier discussion that a forward-biased PN junction is comparable to a low- resistance circuit element because it passes a high current for a given voltage. In turn, a reverse-biased PN junction is comparable to a high-resistance circuit element. By using the Ohm's law formula for power ($P = I^2R$) and assuming current is held constant, you can conclude that the power developed across a high resistance is greater than that developed across a low resistance. Thus, if a crystal were to contain two PN junctions (one forward-biased and the other reverse-biased), a low-power signal could be injected into the forward-biased junction and produce a high-power signal at the reverse-biased junction. In this manner, a power gain would be obtained across the crystal. This concept, which is merely an extension of the material covered in chapter 1, is the basic theory behind how the transistor amplifies. With this information fresh in your mind, let's proceed directly to the NPN transistor. NPN Transistor Operation Just as in the case of the PN junction diode, the N material comprising the two end sections of the NPN transistor contains a number of free electrons, while the center P section contains an excess number of holes. The action at each junction between these sections is the same as that previously described for the diode; that is, depletion regions develop and the junction barrier appears. To use the transistor as an amplifier, each of these junctions must be modified by some external bias voltage. For the transistor to function in this capacity, the first PN junction (emitter-base junction) is biased in the forward, or low-resistance, direction. At the same time the second PN junction (base-collector junction) is biased in the reverse, or high- resistance, direction. A simple way to remember how to properly bias a transistor is to observe the NPN or PNP elements that make up the transistor. The letters of these elements indicate what polarity voltage to use for correct bias. For instance, notice the NPN transistor below: 1. The emitter, which is the first letter in the NPN sequence, is connected to the negative side of the battery while the base, which is the second letter (NPN), is connected to the positive side. 2. However, since the second PN junction is required to be reverse biased for proper transistor operation, the collector must be connected to an opposite polarity voltage (positive) than that indicated by its letter designation(NPN).

### 3.2.1 The Unijunction Transistor (UJT)

The UNIJUNCTION TRANSISTOR (UJT), originally called a double-based diode, is a three-terminal, solid-state device that has several advantages over conventional transistors. It is very stable over a wide range of temperatures and allows a reduction of components when used in place of conventional transistors. A comparison is shown in figure 3.4. View A is a circuit using conventional transistors, and view B is the same circuit using the UJT. As you can see, the UJT circuit has fewer components. Reducing the number of components reduces the cost, size, and probability of failure.




A. TRANSISTOR

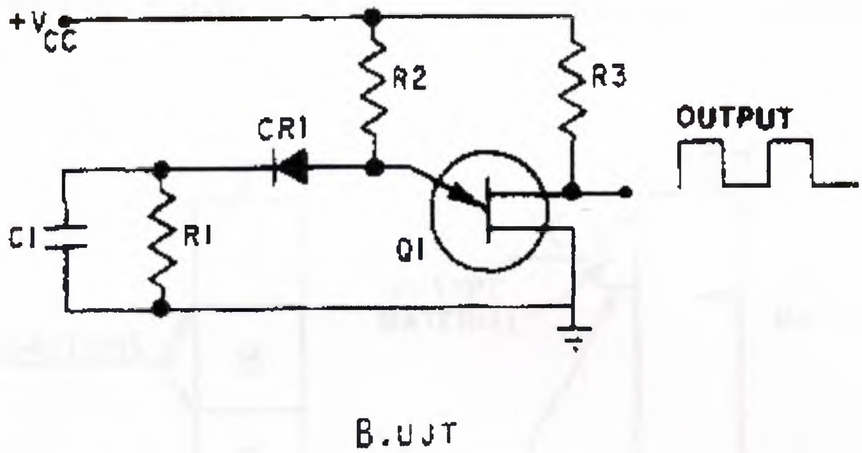



Figure 3.4 comparisons of conventional transistors and UJT circuits

The physical appearance of the UJT is identical to that of the common transistor. As shown in figure 3.5, both have three leads and the same basic shape; the tab on the case indicates the emitter on both devices. The UJT, however, has a second base instead of a collector.

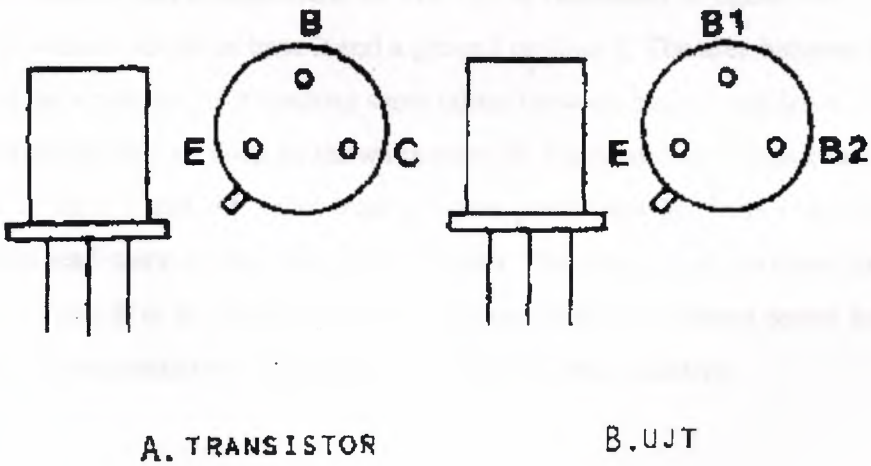



Figure 3.5 Figure of transistor and UJT

As indicated in the block diagram shown in views A and B of figure3.6, the lead differences are even more pronounced. Unlike the transistor, the UJT has only one PN junction. The area between base 1 and base 2 acts as a resistor when the UJT is properly biased. A conventional transistor needs a certain bias level between the emitter, base, and collector for proper conduction. The same principle is true for the UJT; it needs a certain bias level between the emitter and base 1 and also between base 1 and base 2 for proper conduction.

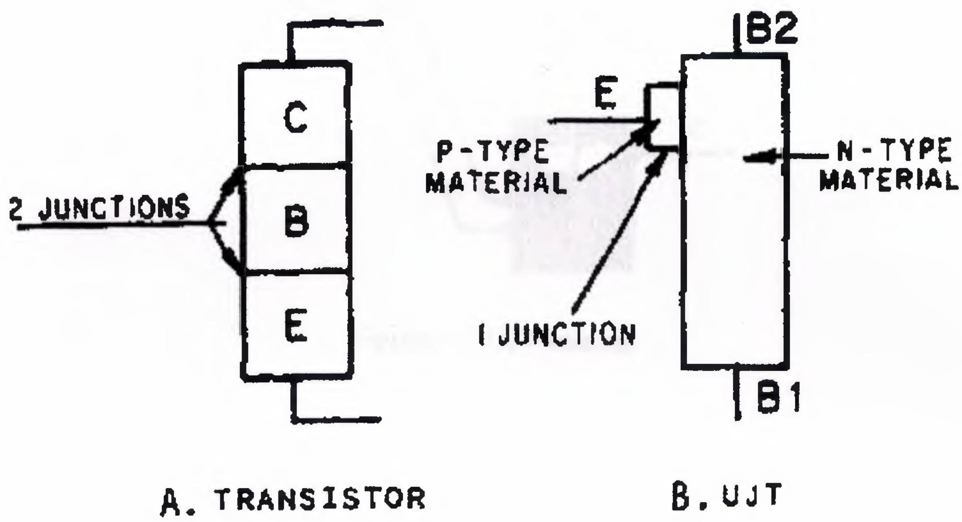
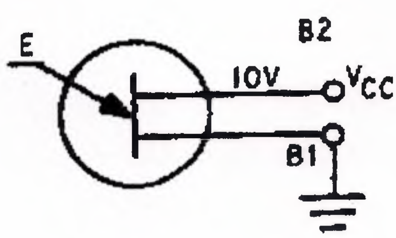



Figure 3.6 Transistor and UJT structure

The normal bias arrangement for the UJT is illustrated in figure 3-41, view A. A positive 10 volts is placed on base 2 and a ground on base 1. The area between base 1 and base 2 acts as a resistor. If a reading were taken between base 1 and base 2, the meter would indicate the full 10 volts as shown in view B. Theoretically, if one meter lead were connected to base 1 and the other lead to some point between base 1 and base 2, the meter would read some voltage less than 10 volts. This concept is illustrated in figure 3-42, view A. View B is an illustration of the voltage levels at different points between the two bases. The sequential rise in voltage is called a voltage gradient.



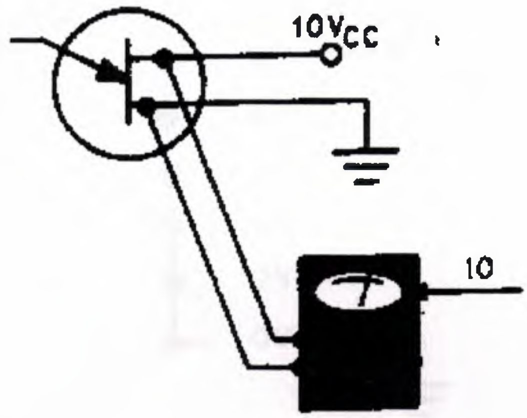
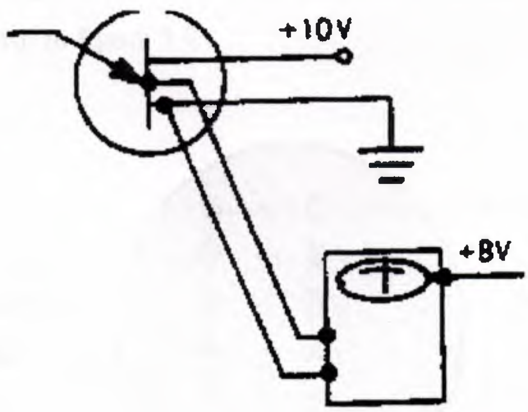


Figure 3.7 UJT biasing



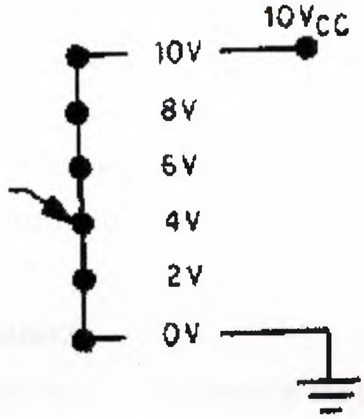



Figure 3.8 UJT voltage gradient.

The emitter of the UJT can be viewed as the wiper arm of a variable resistor. If the voltage level on the emitter is more positive than the voltage gradient level at the emitter-base material contact point, the UJT is forward biased. The UJT will conduct heavily (almost a short circuit) from base 1 to the emitter. The emitter is fixed in position by the manufacturer. The level of the voltage gradient therefore depends upon the amount of bias voltage, as shown in figure 3.9.

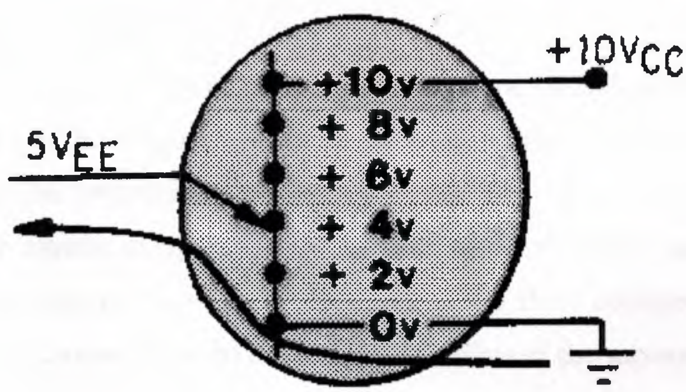



Figure 3.9 Forward bias point on UJT voltage gradient.

If the voltage level on the emitter is less positive than the voltage gradient opposite the emitter, the UJT is reverse biased. No current will flow from base 1 to the emitter. However, a small current, called reverse current, will flow from the emitter to base 2. The reverse current is caused by the impurities used in the construction of the UJT and is in the form of minority carriers.

More than 40 distinct types of UJTs are presently in use. One of the most common applications is in switching circuits. They are also used extensively in oscillators and wave-shaping circuits

### 3.2.2 Field Effect Transistors

Although it has brought about a revolution in the design of electronic equipment, the bipolar (PNP/NPN) transistor still has one very undesirable characteristic. The low input impedance associated with its base-emitter junction causes problems in matching impedances between interstage amplifiers.

For years, scientists searched for a solution that would combine the high input impedance of the vacuum tube with the many other advantages of the transistor. The result of this research is the FIELD-EFFECT TRANSISTOR (FET). In contrast to the bipolar transistor, which uses bias current between base and emitter to control conductivity, the FET uses voltage to control an electrostatic field within the transistor. Because the FET is voltage-controlled, much like a vacuum tube, it is sometimes called the "solid-state vacuum tube."

The elements of one type of FET, the junction type (JFET), are compared with the bipolar transistor and the vacuum tube in figure 3-44. As the figure shows, the JFET is a three-element device comparable to the other two. The "gate" element of the JFET corresponds very closely in operation to the base of the transistor and the grid of the vacuum tube. The "source" and "drain" elements of the JFET correspond to the emitter and collector of the transistor and to the cathode and plate of the vacuum tube.

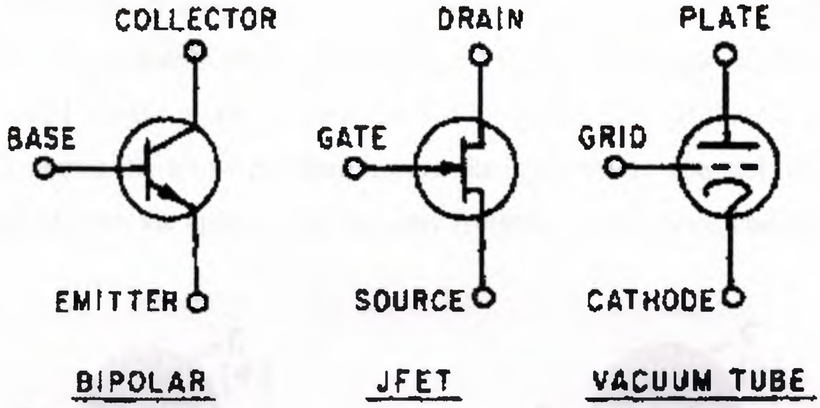



Figure 3.10 Comparison of JFET, transistor, and vacuum tube symbols.

The construction of a JFET is shown in figure 3-45. A solid bar, made either of N-type or P-type material, forms the main body of the device. Diffused into each side of this bar are two deposits of material of the opposite type from the bar material, which form the "gate." The portion of the bar between the deposits of gate material is of a smaller cross section than the rest of the bar and forms a "channel" connecting the source and the drain. Figure 3-45 shows a bar of N-type material and a gate of P-type material. Because the material in the channel is N-type, the device is called an N-channel JFET.

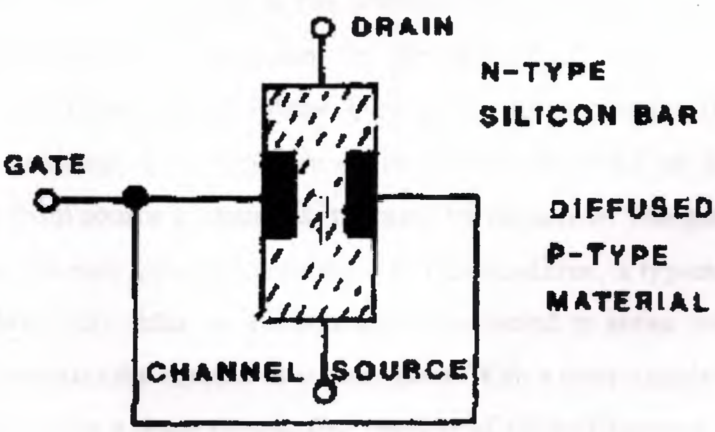



Figure 3.11 JFET structure.

In a P-channel JFET, the channel is made of P-type material and the gate of N-type material. In figure 3-46, schematic symbols for the two types of JFET are compared with those of the NPN and PNP bipolar transistors. Like the bipolar transistor types, the two types of JFET differ only in the configuration of bias voltages required and in the direction of the arrow within the symbol. Just as it does in transistor symbols, the arrow in a JFET symbol always points towards the N-type material. Thus the symbol of the N-channel JFET shows the arrow pointing toward the drain/source channel, whereas the P-channel symbol shows the arrow pointing away from the drain/source channel toward the gate.

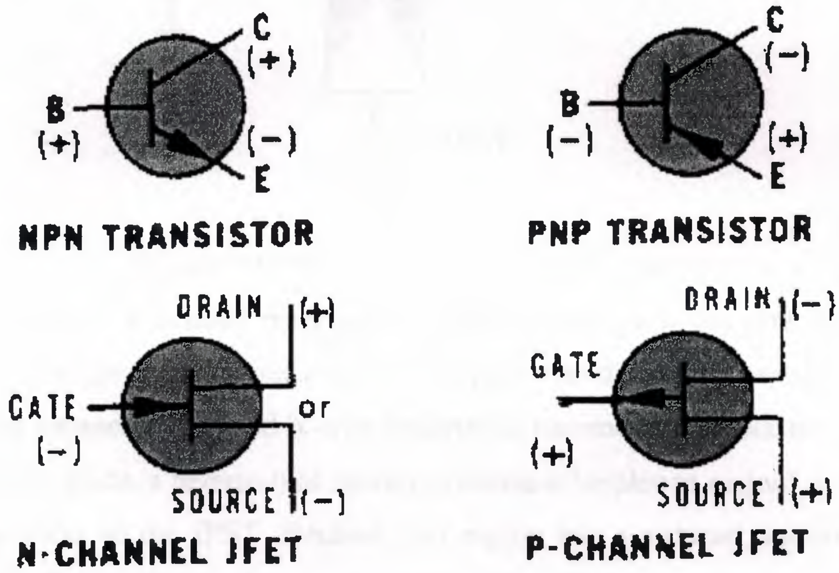



Figure 3.12 Symbols and bias voltages for transistors and JFET

The key to FET operation is the effective cross-sectional area of the channel, which can be controlled by variations in the voltage applied to the gate. This is demonstrated in the figures which follow. Figure 3.12 shows how the JFET operates in a zero gate bias condition. Five volts are applied across the JFET so that current flows through the bar from source to drain, as indicated by the arrow. The gate terminal is tied to ground. This is a zero gate bias condition. In this condition, a typical bar represents a resistance of about 500 ohms. A milliammeter, connected in series with the drain lead and dc power, indicates the amount of current flow. With a drain supply ($V_{DD}$) of 5 volts, the milliammeter gives a drain current ($I_D$) reading of 10 milliamperes. The voltage and current subscript letters ($V_{DD}$, $I_D$) used for an FET correspond to the elements of the FET just as they do for the elements of transistors.

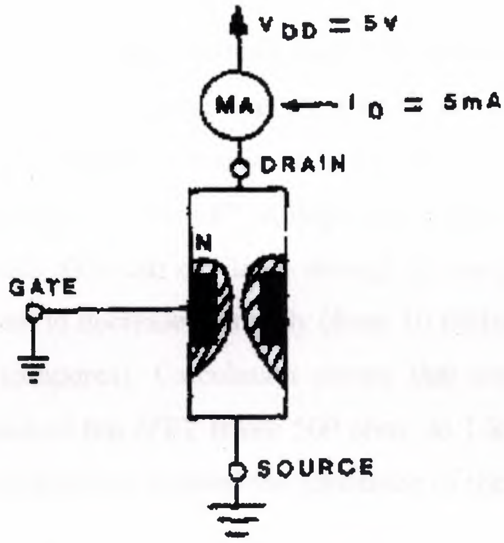



Figure 3.13 JFET operation with zero gate bias

In figure 3.14, a small reverse-bias voltage is applied to the gate of the JFET. A gate-source voltage ($V_{GG}$) of negative 1 volt applied to the P-type gate material causes the junction between the P- and N-type material to become reverse biased. Just as it did in the varactor diode, a reverse-bias condition causes a "depletion region" to form around the PN junction of the JFET. Because this region has a reduced number of current carriers, the effect of reverse biasing is to reduce the effective cross-sectional area of the "channel."

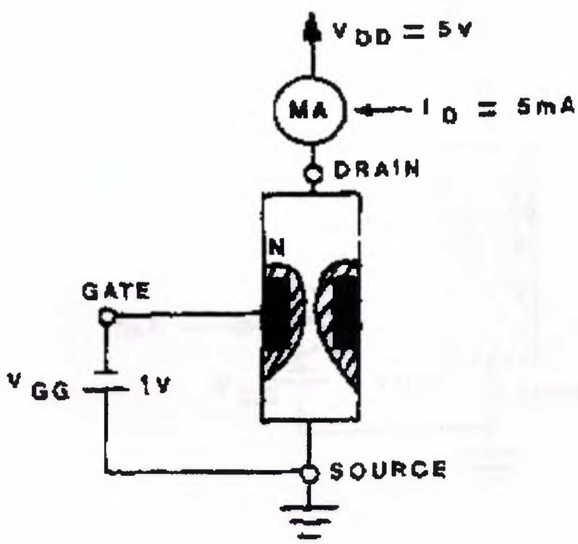



Figure 3.14 JFET with reverse bias

The application of a large enough negative voltage to the gate will cause the depletion region to become so large that conduction of current through the bar stops altogether. The voltage required to reduce drain current ($I_D$) to zero is called "pinch-off" voltage and is comparable to "cut-off" voltage in a vacuum tube. In figure 3-48, the negative 1 volt applied, although not large enough to completely stop conduction, has caused the drain current to decrease markedly (from 10 milliamperes under zero gate bias conditions to 5 milliamperes). Calculation shows that the 1-volt gate bias has also increased the resistance of the JFET (from 500 ohms to 1 kilohm). In other words, a 1-volt change in gate voltage has doubled the resistance of the device and cut current flow in half.

These measurements, however, show only that a JFET operates in a manner similar to a bipolar transistor, even though the two are constructed differently. As stated before, the main advantage of an FET is that its input impedance is significantly higher than that of a bipolar transistor. The higher input impedance of the JFET under reverse gate bias conditions can be seen by connecting a microammeter in series with the gate-source voltage ($V_{GG}$), as shown in figure 3.15.

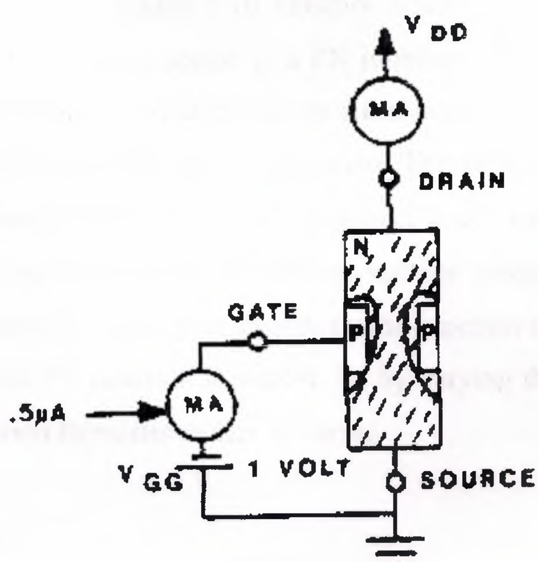



Figure 3.15 JFET input impedance

With a $V_{GG}$ of 1 volt, the microammeter reads .5 microamps. Applying Ohm's law illustrates that this very small amount of current flow results in a very high input impedance (about 2 megohms). By contrast, a bipolar transistor in similar circumstances would require higher current flow (e.g., .1 to -1 mA), resulting in a much lower input impedance (about 1000 ohms or less). The higher input impedance of the JFET is possible because of the way reverse-bias gate voltage affects the cross-sectional area of the channel. The preceding example of JFET operation uses an N-channel JFET. However, a P-channel JFET operates on identical principles.

### 3.3 Diode

The chareacteristics of the different types of diodes are explained below:

### 3.3.1 Varactor Diode

The varactor diode symbol is shown below with a diagram representation.

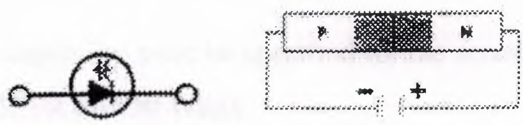


Figure 3.16 Varactor diode

When a reverse voltage is applid to a PN junction , the holes in the p-region are attracted to the anode terminal and electrons in the n-region are attracted to the cathode terminal creating a region where there is little current.This region ,the depletion region, is essentially devoid of carriers and behaves as the dielectric of a capacitor.

The depletion region increases as reverse voltage across it increases; and since capacitance varies inversely as dielectic thickness, the junction capacitance will decrease as the voltage across the PN junction increases. So by varying the reverse voltage across a PN junction the junction capacitance can be varied.

### 3.3.2 Zener Diode

Refer to the characteristic curve of a typical rectifier(diode) in the figure below. The forward characteristic of the curve we have previously described above in the DIODE section. It is the reverse characteristics we will discuss here.

Notice that as the reverse voltage is increased the leakage current remains essentially constant until the breakdown voltage is reached where the current increases dramatically. This breakdown voltage is the zener voltage for zener diodes. While for the conventional rectifier or diode it is imperative to operate below this voltage; the zener diode is intended to operate at that voltage, and so finds its greatest application as a voltage regulator.

The basic parameters of a zener diode are:

**(a)** Obviously,the zener voltage must be specified. The most common range of zener voltage is 3.3 volts to 75 volts, however voltages out of this range are available.

**(b)** A tolerance of the specified voltage must be stated. While the most popular tolerances are 5% and 10%, more precision tolerances as low as 0.05 % are available . A test current (Iz) must be specified with the voltage and tolerance.

**(c)** The power handling capability must be specified for the zener diode. Popular power ranges are: 1/4, 1/2, 1 , 5, 10, and 50 Watts

- **SUMMARY**

This chapter introduced you to a representative selection of solid-state devices that have special properties. The basic operating principles of the devices discussed in this chapter are summarized in the following paragraphs for you to use as a review and a future reference.

The **ZENER DIODE** is a PN junction that is designed to operate in the reverse-bias breakdown mode. When the applied voltage reaches the breakdown point, the Zener diode, for all practical purposes, becomes a short circuit. The reverse bias and breakdown mode of operation cause the Zener diode to conduct with (in the direction of) the arrow in the symbol as shown.

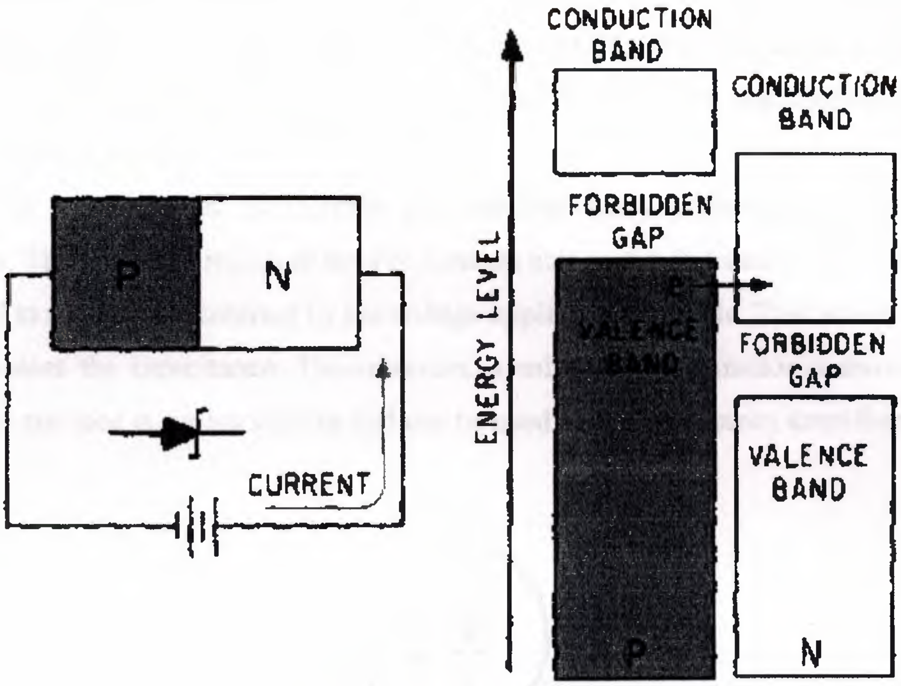



Figure 3.17 diagram of zener diode

Two theories are used to explain the breakdown action of Zener diodes. The ZENER EFFECT explains the breakdown of diodes below 5 volts. The heavy doping used in these diodes allows the valence band of one material to overlap the energy level of the conduction band of the other material. This situation allows electrons to tunnel across the PN junction at the point where the two energy bands overlap. Zener diodes that operate above 5 volts are explained by the AVALANCHE EFFECT in which free electrons colliding with bound electrons cause an ever-increasing number of free current carriers in a multiplying action. The Zener diode is used primarily as a voltage regulator in electronic circuits.

The TUNNEL DIODE is a heavily doped PN junction that exhibits negative resistance over part of its range of operation, as can be seen in the curve in the illustration. The heavy doping causes the tunnel diode to have a very narrow depletion region and also causes the valence band of one of the semiconductor materials to overlap the energy level of the conduction band of the other semiconductor material. At the energy overlap point, electrons can cross from the valence band of one material to the conduction band of the other material without acquiring any additional energy. This action is called tunneling. Tunnel diodes are used as amplifiers, oscillators, and high-speed switching devices.

The VARACTOR is a diode that exhibits the characteristics of a variable capacitor. The depletion region at the PN junction acts as the dielectric of a capacitor and is caused to expand and contract by the voltage applied to the diode. This action increases and decreases the capacitance. The schematic symbol for the varactor is shown below. Varactors are used in tuning circuits and can be used as high-frequency amplifiers.

Figure 3.18 schematic symbol of varactor

The SILICON CONTROLLED RECTIFIER (SCR) is a four-element, solid-state device that combines characteristics of both diodes and transistors. The symbol for the SCR is shown below. A signal must be applied to the gate to cause the SCR to conduct. When the proper gate signal is applied, the SCR conducts or "fires" until the bias potential across the device drops below the minimum required to sustain current flow. Removal of the gate signal does not shut off the SCR. In fact, the gate signal is often a very narrow voltage pulse or trigger. The SCR is ideal for use in situations where a small, low-power gate can be used to turn on larger currents, such as those found in rectifier and switching circuits. SCRs are used extensively in power supply circuits as rectifiers.

OPTOELECTRONIC DEVICES are of two basic types: light producers or light users. The LED is the most widely used light-producing device. When the LED is forward biased it emits energy in the form of light. LEDs are used in several configurations as digital equipment readout displays. The PHOTODIODE, the

PHOTOTRANSISTOR, and the PHOTOCELL are all devices that use light to modify conduction through them. The SOLAR CELL uses light to produce voltage.

The UNIJUNCTION TRANSISTOR (UJT) is a three-terminal, solid-state device with only one PN junction. The block diagram below shows the difference in construction between normal transistors and the UJT. The area between base 1 and base 2 of the UJT acts as a variable resister. The emitter of the UJT acts as the wiper arm. The sequential rise in voltage between the bases is called a voltage gradient. The UJT conducts when the emitter is more positive than the voltage gradient at the emitter/base contact point. There are many variations of the UJT which are used in switching circuits, oscillators, and wave-shaping circuits.

The FIELD-EFFECT TRANSISTOR combines the high input impedance of the vacuum tube with all the other advantages of the transistor. The elements of the FET are the gate, source, and drain, which are comparable to the base, emitter, and collector of a standard transistor. The JFET or "junction FET" is made of a solid bar of either P- or N-semiconductor material, and the gate is made of the opposite type material, as illustrated below. The FET is called P-channel or N-channel depending upon the type of material used to make the bar between the source and drain. Voltage applied to the gate controls the width of the channel and consequently controls the current flow from the source to the drain. The JFET is normally operated with reverse bias that controls the channel width by increasing or decreasing the depletion region.

The MOSFET is an FET that has even higher input impedances than the JFET because the gate of the MOSFET is completely insulated from the rest of the device. The MOSFET operates in either the depletion mode or the forward-bias enhancement mode and can be either N-channel or P-channel. The induced-channel and the dual-gate MOSFETs are variations of the basic MOSFET.

## 3.4 Resistors

**The resistor on the side of +12 V** is the resistor to make temperature setting voltage smaller than the maximum output voltage of the voltage converter.The output voltage of the voltage converter doesn't become a power supply voltage even if it maximum. A few electric currents flow through the input of the comparator. With this electric current, the voltage drop occurs with the resistor which connects with the collector of the voltage converter. When making temperature setting voltage a power supply voltage, the temperature setting voltage always becomes higher and it becomes not possible to do a temperature adjustment. The relay always becomes an operating state. **The resistor on the side of the grounding** is the resistor which decides the upper limit with setting temperature.

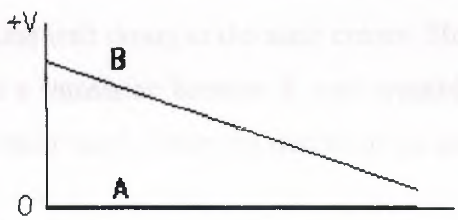



Figure 3.19 voltage flows with temperature setting

When making temperature setting maximum when there is not this resistor, the positive terminal of the comparator becomes 0 V. Therefore, until the output voltage of the voltage converter becomes 0 V, the relay doesn't work. At the circuit this time, the output voltage of the voltage converter doesn't become 0 V. Because it is, after never, the relay works.

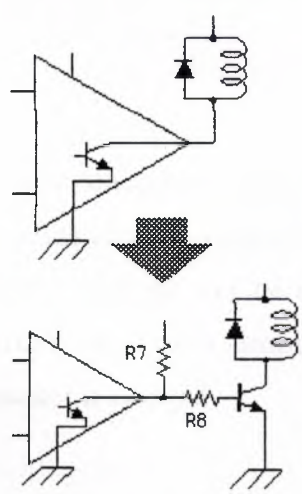



Figure 3.20 Relay circuit

When a maximum temperature is guarded with the other equipment, this resistor isn't needed. When there is not a limitation receptacle, a resistor is needed so as not to become above the upper limit temperature. You consider a maximum temperature and must fix an appropriate resistance value. Relay drive circuit the output of the comparator is an open collector(Type which supplies a power supply to the collector from outside). In case of LM319, the maximum permission loss electric power of the built-in transistor is 500 mW. Because it is, the small relay can be directly driven. The circuit this time isn't doing to the such circuit. However, I changed into the drive circuit which used a transistor because it was unstable that the relay works. It wasn't worked when it should work.When the output of the comparator is ON(It detects below the setting temperature), the base of the drive transistor becomes grounding voltage approximately. Therefore, the electric current doesn't flow through the base of the drive transistor and the transistor becomes OFF condition. The relay doesn't work.When the output of the comparator is OFF(It detects above the setting temperature), the electric current flows through R7 and R8 into the base of the drive transistor and the transistor becomes ON condition. The relay works.When not using an drive transistor, the operating state of the relay becomes opposite.

## 3.5 Capacitor

A capacitor consists of two conductive metal plates separated by an insulating dielectric. The dielectric can be made of glass, ceramic, Tantalum oxide, or plastics such as polyethylene or polycarbonate. Even air can be used as the dielectric. When the capacitor holds some energy in the form of extra electrons on one plate and electron holes on the other we say that the capacitor is charged.

### 3.5.1 Farads

Capacitance (C) is the amount of charge per volt of potential that a capacitor holds. (C =Q/V where Q = coulombs (the unit of charge) and V = Volts)
Capacitance is measured in farads, but most often a small fraction of a farad thus:

-micro-farads uF millionths ($10^{-6}$) farads

-pico-farads pF ($10^{-12}$) farads (sometimes called 'puffs' in engineering slang)

The energy stored in a capacitor is $E = CV^2/2$ $E$ is in joules.

Thus, the average power in watts is $P_{av} = CV^2/2t$ where $t$ = time in seconds.

The maximum voltage rating and its capacitance determine the amount of energy a capacitor holds. The voltage rating increases with increasing dielectric strength and the thickness of the dielectric. The capacitance increases with the area of the plates and decreases with the thickness of the dielectric.

Thus, the capacitance of a capacitor ($C$) is related to the plate area ($A$), plate separation distance ($d$) and permittivity ($\varepsilon$) of the dielectric by the following equation:

$C = \varepsilon A/d$ Here $A$ and $d$ are based on meters as the unit and $\varepsilon$ is in coulombs squared per Newton-meters squared notice the force unit involved - it explains why capacitor microphonics (remember the good old condenser microphone?) and a mechanical failure mode of capacitors).

### 3.5.2 Dielectric Constants

Dielectric constant ($k$) gets it's value by comparison of the charge holding ability of a vacuum where $k = 1$. Thus, $k$ is the ratio of the capacitance with a volume of dielectric compared to that of a vacuum dielectric. $K = \varepsilon_d/\varepsilon_0$ Where $\varepsilon_d$ is the permittivity of the dielectric and $\varepsilon_0$ is the permittivity of free space. Air has nearly the same dielectric value as a vacuum with $k = 1.0001$. Teflon, a very good insulator, has a value of $k = 2$ while the plastics range in the low 2s to low 3s. Mica gets us a $k = 6$. Aluminum oxide is 7, Tantalum's $k$ is 11 and the Ceramics range from 35 to over 6,000.

Dielectric constants vary with temperature, voltage, and frequency making capacitors messy devices to characterize. Whole books have been written about choosing the correct dielectric for an application, balancing the desires of temperature range, Temperature stability, size, cost, reliability, dielectric absorption, voltage coefficients, current handling capacity (ESR). (Ivan Sinclair wrote a nice book on passives; unfortunately, it is out of print. This points to the fact that our universities are no longer teaching this material).

### 3.5.3 Dielectric strength

Dielectric strength is a property of the dielectric that is usually expressed in volts per mil (V/.001") or volts per centimeter (V/cm). If we exceed the dielectric strength, an electric arc will 'flash over and often weld the plates of a capacitor together.

### 3.5.4 Q or Quality Factor

The $Q$ of a capacitor is important in tuned circuits because they are more damped and have a broader tuning point as the $Q$ goes down. $Q = 1/RX_C$ where $X_C$ is the capacitive reactance ($X_C = 2\pi FC$) and $R$ is the soon to be defined term of ESR. $Q$ is proportional to the inverse of the amount of energy dissipated in the capacitor. Thus, ESR rating of a capacitor is inversely related to its quality.

### 3.5.5 Dissipation Factor

The inverse of Q is the dissipation factor (δ). Thus, $\delta = ESR/X_C$ and the higher the ESR the more losses in the capacitor and the more power we dissipate. If too much energy is dissipated in the capacitor, it heats up to the point that values change (causing drift in operation) or failure of the capacitor.

### 3.5.6 Ripple Current Rating

The ripple current is sometimes rated for a capacitor in RMS current. Remembering that $P = I^2R$ where R in this case is ESR it is plain to see that this is a power dispassion rating.

### 3.5.7 Dielectric Absorption

This is the phenomenon where after a capacitor has been charged for some time, and then discharged, some stored charge will migrate out of the dielectric over time, thus changing the voltage value of the capacitor. This is extremely important in sample and hold circuit applications. The typical method of observing Dielectric Absorption is to charge up a cap to some known DC voltage for a given time, then discharge the capacitor through a 2 ohm resistor for one second, then watch the voltage on a high-input-impedance voltmeter. The ratio of recovered voltage (expressed in percent) is the usual term for Dielectric absorption.The charge absorption effect is caused by a trapped space charge in the dielectric and is dependent on the geometry and leakage of the dielectric material.

### 3.5.8 ESL (Equivalent Series Inductance)

ESL (Equivalent Series Inductance) is pretty much caused by the inductance of the electrodes and leads. The ESL of a capacitor sets the limiting factor of how well (or fast) a capacitor can de-couple noise off a power buss.The ESL of a capacitor also sets the resonate-point of a capacitor. Because the inductance appears in series with the capacitor, they form a tank circuit.

### 3.5.9 ESR Defined

ESR is the sum of in-phase AC resistance. It includes resistance of the dielectric, plate material, electrolytic solution, and terminal leads at a *particular frequency*. ESR acts like a resistor in series with a capacitor (thus the name Equivalent Series Resistance). This resister can cause circuits to fail that look just fine on paper and is often the failure mode of capacitors.To charge the dielectric material current needs to flow down the leads, through the lead plate junction, through the plates themselves - and even through the dielectric material. The dielectric losses can be thought of as friction of aligning dipoles and thus appear as an increase (or a reduction of the rate of decrease -- this increase is what makes the resistance vs freq line to go flat.) of measured ESR as frequency increases.

As the dielectric thickness increases so does the ESR. As the plate area increases, the ESR will go down if the plate thickness remains the same. To test a Capacitors ESR requires something other than a standard capacitor meter. While a capacitor value meter is a handy device, it will not detect capacitor failure modes that raise the ESR. As the years go by, more and more designs rely on low ESR capacitors to function properly. ESR failed caps can present circuit symptoms that are difficult to diagnose.

# Chapter 4

# PERFORMANCE AND MEASURMENTS OF ELEMENTS

## 4.1 Performance measurement of the thermostat

I will show the result which measured the relation with the axis angle of the variable resistor for the temperature setting and the temperature of the heating element which was controlled with the thermostat which was made this time below.

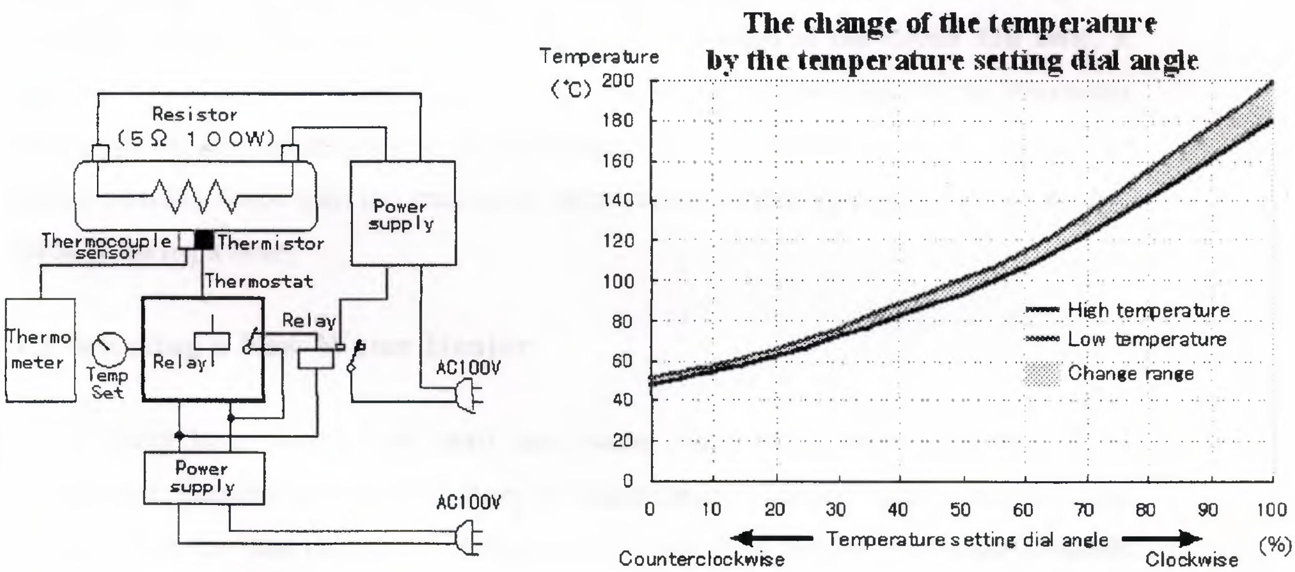



Figure 4.1 the change of the temperature

I used the wirewound resistor of 5-ohm 100-W as the heating element which is the same as the case to have measured the change of the thermistor resistance value by the temperature. I made the thermistor to control the temperature and the thermocouple thermometer sensor to do the thermometry touch the surface of the resistor by the point. The wirewound resistor is heated by the electric power from the stabilised power supply. The temperature of the resistor is controlled by ON/OFF of the AC input of the stabilised power supply by the output of the thermostat.

The temperature change(Maximum temperature and the minimum temperature) at the specific temperature is changed by the quantity with the electric power which is supplied to the resistor, the thermal capacity of the heating element, the radiation quantity of the heating element and so on. In the graph on the left, the blue line shows the temperature that the relay of the thermostat became OFF and the red line shows the temperature that the relay became ON. The temperature of the resistor continues to rise in a little time even if the power supply stops. The red line shows the temperature that the rise of the temperature stopped.

In the range which is shown in the green, the temperature repeats the rise and the fall. The range of the change gets widely when the provision with the electric power increases. When making the temperature setting maximum at the circuit this time, it becomes 180 to 200°C. There is fear with the degrading characteristic of the thermistor when applying this temperature to the thermistor long. I think that it had better make the setting possible range with the maximum temperature narrow by making the resistance value of R6 big a little.

## 4.2 Selecting a New Water Heater

Many homeowners wait until their water heater fails before shopping for a replacement. Because they are in a hurry to regain their hot water supply, they are often unable to take the time to shop for the most energy-efficient unit for their specific needs. This is unfortunate because the cost of purchasing and operating a water heater can vary greatly, depending on the type, brand, and model selected and on the quality of the installation.

To avoid this scenario, you might want to do some research now before you are faced with an emergency purchase. Familiarize yourself today with the options that will allow you to make an informed decision when the need to buy a new water heater arises.

## 4.3 Types of Water Heaters Available

Within the last few years, a variety of water heaters have become available to consumers. The following types of water heaters are now on the market: conventional storage, demand, heat pump, tankless coil, indirect, and solar. It is also possible to purchase water heaters that can be connected to your home's space-heating system.

### 4.3.1 Storage Water Heaters

A variety of fuel options are available for conventional storage water heaters electricity, natural gas, oil, and propane. Ranging in size from 20 to 80 gallons (75.7 to 302.8 liters), storage water heaters remain the most popular type for residential heating needs in the United States. A storage heater operates by releasing hot water from the top of the tank when the hot water tap is turned on. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full.

Because the water is constantly heated in the tank, energy can be wasted even when no faucet is on. This is called standby heat loss. Newer, more energy-efficient storage models can significantly reduce the amount of standby heat loss, making them much less expensive to operate. To determine the most energy-efficient model, consult the EnergyGuide label required on storage water heaters. EnergyGuide labels indicate either the annual estimated cost of operating the system or energy efficiency ratings.

### 4.3.2 Demand Water Heaters

It is possible to completely eliminate standby heat losses from the tank and reduce energy consumption 20% to 30% with demand (or instantaneous) water heaters, which do not have storage tanks. Cold water travels through a pipe into the unit, and either a gas burner or an electric element heats the water only when needed. With these systems, you never run out of hot water. But there is one potential drawback with demand water heaters -- limited flow rate.

Typically, demand heaters provide hot water at a rate of 2 to 4 gallons (7.6 to 15.2 liters) per minute. This flow rate might suffice if your household does not use hot water at more than one location at the same time (e.g., showering and doing laundry simultaneously). To meet hot water demand when multiple faucets are being used, demand heaters can be installed in parallel sequence. Although gas-fired demand heaters tend to have higher flow rates than electric ones, they can waste energy even when no water is being heated if their pilot lights stay on. However, the amount of energy consumed by a pilot light is quite small.

### 4.3.3 Heat Pump Water Heaters

Heat pump water heaters use electricity to move heat from one place to another instead of generating heat directly. To heat water for homes, heat pump water heaters work like refrigerators in reverse.

Heat pump water heaters can be purchased as integral units with built-in water storage tanks or as add-ons that can be retrofitted to an existing water heater tank. These systems have a high initial cost. They also require installation in locations that remain in the 40 degree to 90 degree F (4.4 degrees to 32.2 degrees C) range year-round and contain at least 1000 cubic feet (28.3 cubic meters) of air space around the water heaters. To operate most efficiently, they should be placed in areas having excess heat, such as furnace rooms. They will not work well in a cold space.

### 4.3.4 Tankless Coil and Indirect Water Heaters

A home's space-heating system can also be used to heat water. Two types of water heaters that use this system are tankless coil and indirect. No separate storage tank is needed in the tankless coil water heater because water is heated directly inside the boiler in a hydronic (i.e., hot water) heating system. The water flows through a heat exchanger in the boiler whenever a hot water faucet is turned on. During colder months, the tankless coil works well because the heating system is used regularly. However, the system is less efficient during warmer months and in warmer climates when the boiler is used less frequently.

A separate storage tank is required with an indirect water heater. Like the tankless coil, the indirect water heater circulates water through a heat exchanger in the boiler. But this heated water then flows to an insulated storage tank. Because the boiler does not need to operate frequently, this system is more efficient than the tankless coil. In fact, when an indirect water heater is used with a highly efficient boiler, the combination may provide one of the least expensive methods of water heating.

### 4.3.5 Solar Water Heaters

Through specially designed systems, energy from the sun can be used to heat water for your home. Depending on climate and water use, a properly designed, installed, and maintained solar water heater can meet from half to nearly all of a home's hot water demand Two features, a collector and a storage tank, characterize most solar water heaters. Beyond these common features, solar water-heating systems can vary significantly in design. The various system designs can be classified as passive or active and as direct (also called open loop) or indirect (also called closed loop).

Passive systems operate without pumps and controls and can be more reliable, more durable, easier to maintain, longer lasting, and less expensive to operate than active systems. Active solar water heaters incorporate pumps and controls to move heat-transfer fluids from the collectors to the storage tanks.

Both active and passive solar water-heating systems often require conventional water heaters as backups, or the solar systems function as preheaters for the conventional units.

A direct solar water-heating system circulates household water through collectors and is not appropriate in climates in which freezing temperatures occur. An indirect system should not experience problems with freezing because the fluid in the collectors is usually a form of antifreeze.

If you are considering purchasing a solar water-heating system, you may want to compare products from different manufacturers. The Solar Rating and Certification Corporation (SRCC -- see Source List at the end of this publication) provides a benchmark for comparing the performance of some solar water heating systems.

The SRCC publishes performance ratings of both solar water-heating systems and individual solar collectors. These published ratings are the results of independent, third-party laboratory testing of these products. All systems and collectors that have been certified by the SRCC will bear the SRCC label.

Keep in mind, though, that simply having an SRCC label does not imply that the product has a superior performance. Carefully compare SRCC label information on different brands and models to ensure that you are fully aware of projected performance.

The Florida Solar Energy Center (FSEC -- see Source List) also provides information on solar manufacturers and contractors. It also maintains solar equipment testing facilities and publishes performance ratings for solar water heating systems. Just choosing a solar water heater with good ratings is not enough, though. Proper design, sizing, installation, and maintenance are also critical to ensure efficient system performance. Although the purchase and installation prices of solar water heaters are usually higher than those of conventional types, operating costs are much lower.

### 4.4 Criteria for Selection

As with any purchase, balance the pros and cons of the different water heaters in light of your particular needs. There are numerous factors to consider when choosing a new water heater. This publication has already described different system configurations. Some other considerations are capacity, efficiency, and cost.

#### 4.4.1 Determining Capacity

Although some consumers base their purchases on the size of the storage tank, the peak hour demand capacity, referred to as the first-hour rating (FHR) on the EnergyGuide label, is actually the more important figure. The FHR is a measure of how much hot water the heater will deliver during a busy hour, and it is required by law to appear on the unit's EnergyGuide label. Therefore, before you shop, estimate your household's peak hour demand and look for a unit with an FHR in that range.

Gas water heaters have higher FHRs than electric water heaters of the same storage capacity. Therefore, it may be possible to meet your water-heating needs with a gas unit that has a smaller storage tank than an electric unit with the same FHR. More efficient gas water heaters use various nonconventional arrangements for combustion air intake and exhaust. These features, however, can increase installation costs.

#### 4.4.2 Rating Efficiency

Once you have decided what type of water heater best suits your needs, determine which water heater in that category is the most fuel efficient. The best indicator of a heater's efficiency is its Energy Factor (EF), which is based on recovery efficiency (i.e., how efficiently the heat from the energy source is transferred to the water), standby losses (i.e., the percentage of heat lost per hour from the stored water compared to the heat content of the water), and cycling losses. The higher the EF, the more efficient the water heater. Electric resistance water heaters have an EF between 0.7 and 0.95; gas heaters have an EF between 0.5 and 0.6, with some high-efficiency models around 0.8; oil heaters range from 0.7 to 0.85; and heat pump water heaters range from 1.5 to 2.0. Product literature from manufacturers usually gives the appliance s EF rating. If it does not, you can obtain it by contacting an appliance manufacturer association.

Some other energy efficiency features to look for are tanks with at least 1.5 inches (3.8 centimeters) of foam insulation and energy efficiency ratings shown on the EnergyGuide labels.

### 4.4.3 Comparing Costs

Another factor uppermost in many consumers' minds is cost, which encompasses purchase price and lifetime maintenance and operation expenses. When choosing among different models, it is wise to analyze the life-cycle cost -- the total of all costs and benefits associated with a purchase during its estimated lifetime. More information on conducting life-cycle cost analyses is available from EREC. Units with longer warranties usually have higher price tags, though. Often, the least expensive water heater to purchase is the most expensive to operate.

# Chapter 5

## PHOTOGRAPH AND CIRCUIT DIAGRAM OF SYNCHRONOUS THERMOSTAT

### 5.1 CIRCUIT DIAGRAM

The circuit diagram of the synchronous thermostat system is given below in figure 5.1.

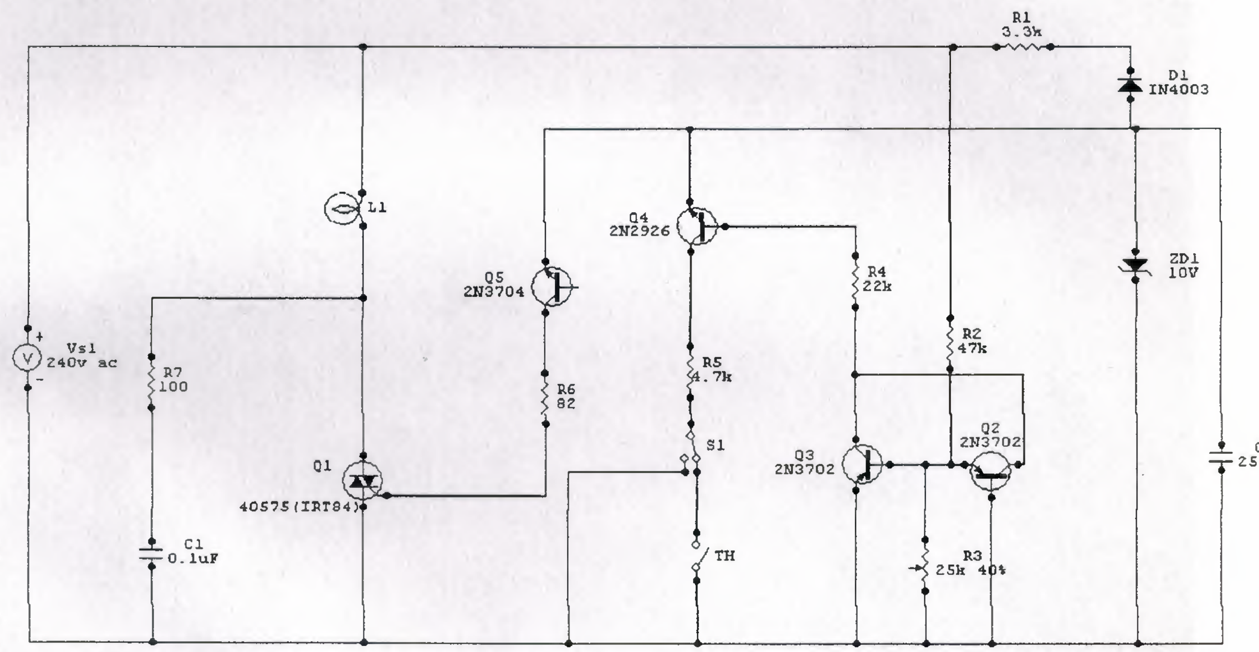



Figure5.1 circuit of a synchronous thermostat controlled heater

In this circuit the VS1 is the 240V AC current source, L1 is the lamp, Q1 is the Triac, Q2 and Q3 are the PNP transistors, Q4 and Q5 are the NPN transistors, TH is the thermostat, S1 is the switch, D1 is diode, ZD1 is Zener diode, C1 and C2 are capacitors and R are the resistances with assigned values. The photographs of this circuit practically adjusted on the circuit board are given below.

## 5.2 PHOTOGRAPHS

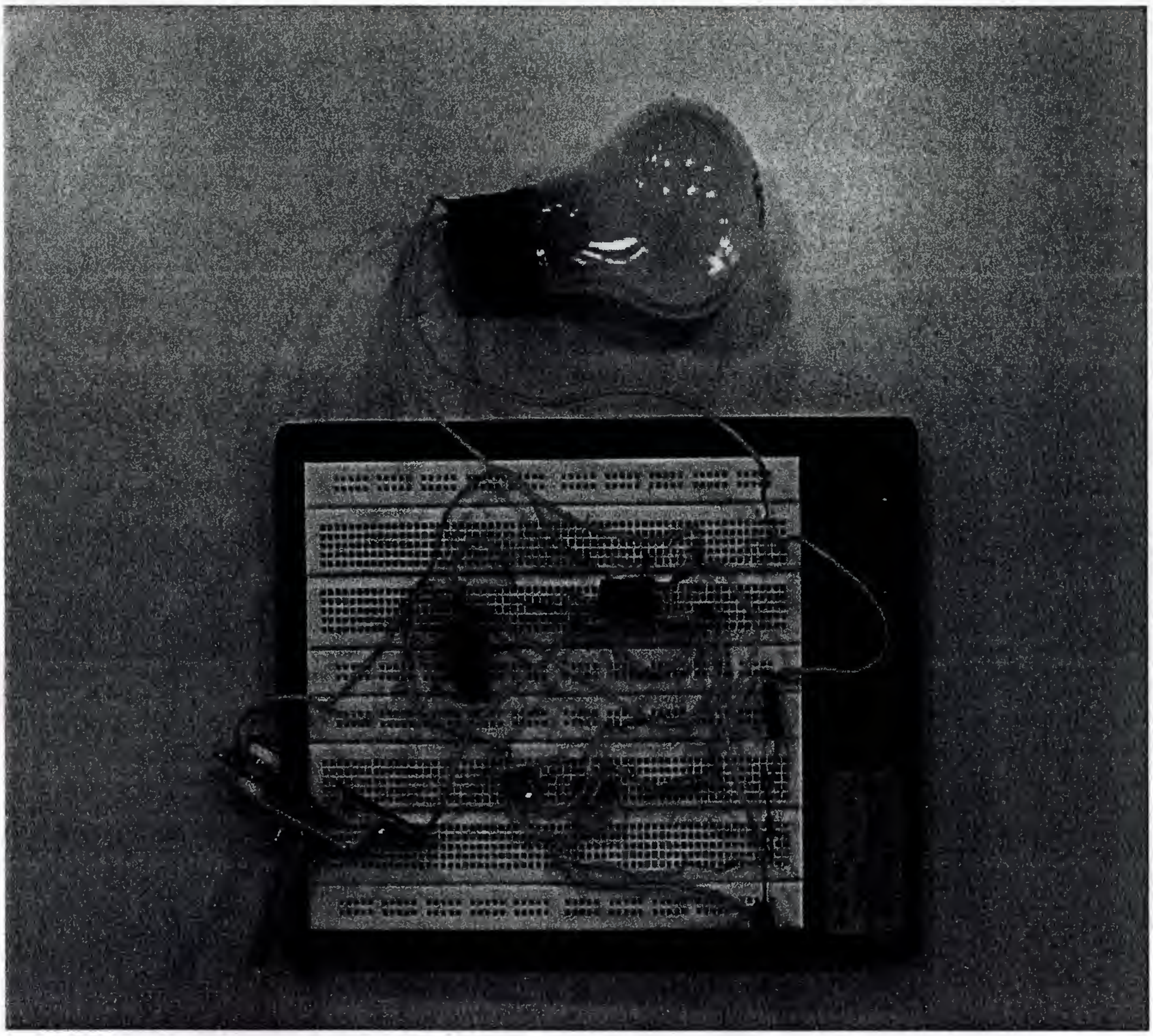


Figure 5.2 horizontal view of the circuit

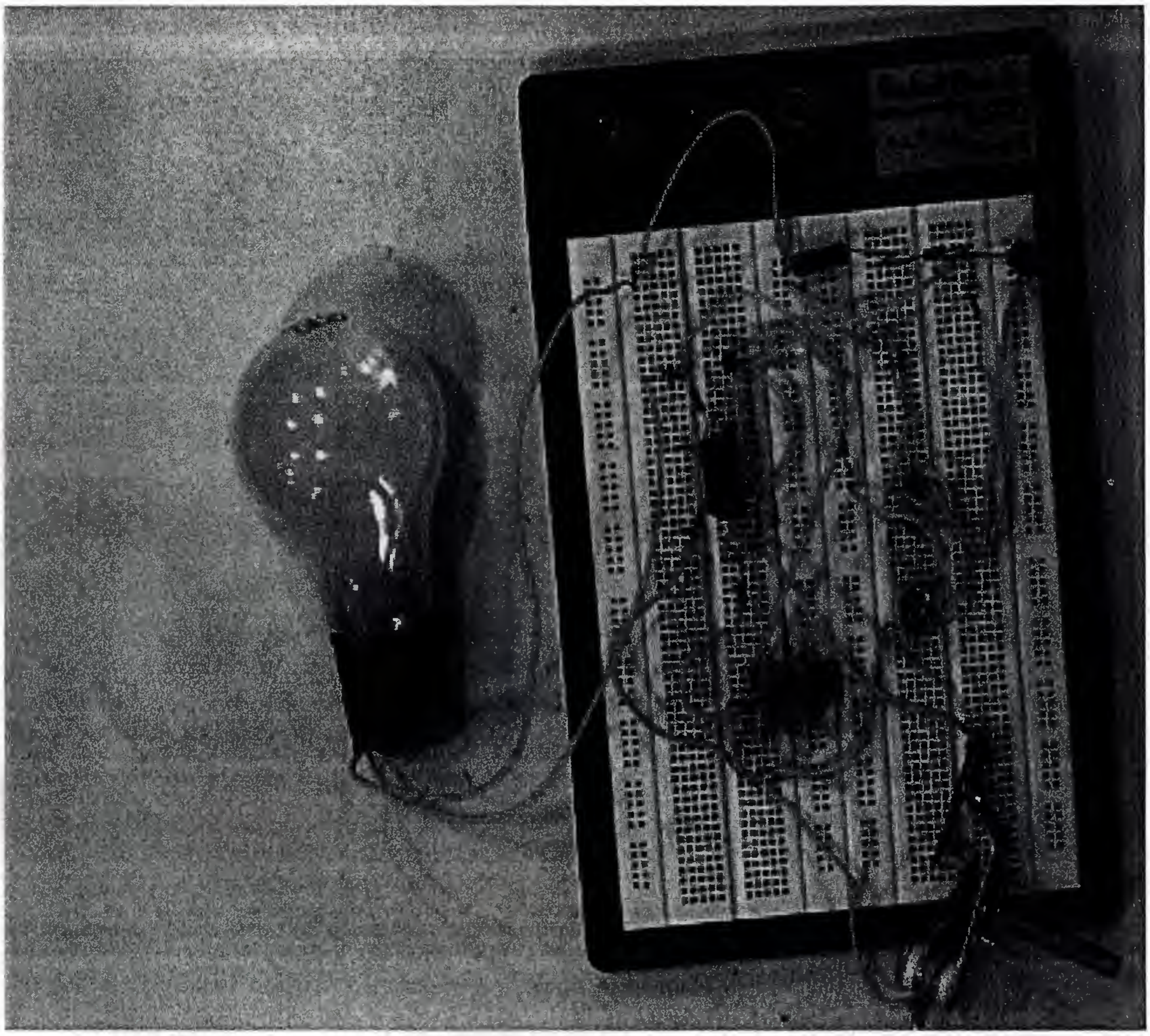


Figure 5.3 vertical view of the circuit

## 5.3 Explanation of Whole Process

Figure 5.1 shows the practical circuit of a synchronous thermostat-controlled heater regulator of this type.

A full description of the operating principles and circuit details of this unit are given in Chapter 5.Briefly, Q2 and Q3 are wired as a zero-crossing detector that is driven from the a.c. power line, and the outputs of Q2 and Q3 provide a control signal to the Q4-Q5 triac gate-drive network. Q4 and Q5 are powered from a 10V d.c. supply delivered from the power line via R1-D1-C1 and zener diode ZD1.

The circuit action is such that heavy pulse of gate drive is applied to the triac only when the instantaneous line voltage is close to zero at the cross-over points near the beginning and end of each half-cycle, and when base drive is available to Q4 via R5.The circuits thus gives r.f.i. free operation of the heater , and can be inhibited or turned off by simply removing the R5 current. In figure 5.1 thermostat TH is wired in series with R5, and thus gives automatic on-off control of the heater.

At low temperatures the thermostat is closed and circuits gives synchronous operation of the heater. At high temperatures the thermostat is open and the circuit is inhibited, so the heater is off. The circuit can be turned on and off manually if required, via S1.

The figure 5.1 circuit is very easy to setup, since R3 is the only adjustable component in the design (apart from the thermostat). It should be noted, however, that this component must be adjusted to suit the particular resistive load that is used with Triac. If a multi-value load, such as a two or three-bar heater is used, the R3 adjustments must be made with the load in its minimum-load position, i.e., with only one of the heater bars turned on. Once the initial R3 adjustment has been made the circuit will function correctly in all positions of the multi-value load.

The R3 adjustment is in practice very simple. The selected heater is simply connected in place (turned to its minimum load position), R3 is set to give maximum resistance, and S1 is turned to ON position. The R3 value is then gradually reduced until it is just past the point at which the heater turns full on; the R3 adjustment is then to ensure that it does not fall below the nominal 10V value. The circuit is then ready for use.

# CONCLUSION

In this synchronous ON-OFF control project when we apply 240V AC voltage the current will start passing through circuit elements and the heater will start heating the water. As soon as the temperature of water will increase so the thermostats temperature also increases then the thermostat will cut off the electricity automatically.

We have practical examples of this type of thermostats in our normal life like the electric water geezers in houses also we can see this same type of system in home air-conditioners when the room temperature increases the thermostat of the air-conditioners senses the temperature and it will cut off the electricity automatically. There are synchronous ON-OFF control systems in these two examples.

This system the synchronous ON-OFF control system can be used in many parts of the electrical devices

# REFERENCES

[1] Jasprit Singhn, *Semiconductor Devices* McGraw-Hill International Edition.

[2] Clyde F. Coombs,Jr. *Electronic Instrument Hand Book Second Edition.*

[3] Muhammed H. Rashid *Power Electronics Circuits, Devices and Applications,* Prentice Hall international editions.

[4] Joseph Vithayathil, *Power Electronics Principal and Applications.*

[5] www.americanmicrosemi.com

[6] www.tpub.com/neets/book7/26e.htm

[7] www.teccor.com/web/menuitems/products/triac.htm