NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

0-3V DC STABILIZED POWER SUPPLY WITH CURRENT CONTROL 0.002-3 A

Graduation Project
EE - 400

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ABSTRACT

The sampling and reconstruction of power supply is one of the most important of information theory, upon which many technological advancement in electronic systems have been build.The project includes four parts, these are basic information about electronic components and general information about designing of power supply and information about printed circuit board(PCM) method.

You can learn how does electronic component works and how we can test the electronic component. You can learn information about their types and usage area.You can get these information about two PCB(printed circuit board) methods as the resistive pen method and the fabrication method .Also there are many information about power system designing in the project.You can get the information which parts has includes power supply .

Power supply is important section in the electronic systems. Applying the principles in the project can eliminate some of the missteps while putting you on the road to becoming a successful power-supply designer.

INTRODUCTION

The sampling reconstruction of basic of electronic element is one of the most important aspects of electronic circuit designing ,circuit processing and electronic systems.Every Electronic systems includes a power supply or power part . It is important part of the electronic systems.The Thesis is consists of the introduction four chapters and conclusion .

The chapter1 introduces information about resistors, capacitors, diodes, transistor, field effect tarnsistors,transformers, operational amplifier .These are main components of electronic systems.There are information about types and characteristic of electronic component in this chapter.

Chapter 2 We describe the procedure of the power supply.There are four main parts of power supply in this chapter .These are transformer part , rectifier part , filter and regulator part and working principle of these.We describe about types of rectifier system and AC and DC voltage stabilizers and types of regulator .

Chapter 3 consists of the information about printed circuit board (PCB) method.We describe how we build the PCB . There are information about creating layout scheme and transdering layout to PCB and chemical removal of unused Copper foil.

Chapter 4 includes the information about our the project.There is a power supply circuit We are explaining how it works and it's construction and technical specifications and characteristic of circuit. We describe the Resistive pen method for .We build the circuit of project with resistive pen method. There are information about montage of circuit .

1.ELECTRONIC COMPONENTS

1.1.Resistors

A resistor is a component of an electrical circuit that resists the flow of electrical current. A resistor has two terminals across which electricity must pass, and is designed to drop the voltage of the current as it flows from one terminal to the next. A resistor is primarily used to create and maintain a known safe current within an electrical component.

Resistance is measured in ohms, after Ohm's law. This rule states that electrical resistance is equal to the drop in voltage across the terminals of the resistor divided by the current being applied to the resistor. A high ohm rating indicates a high resistance to current. This rating can be written in a number of different ways depending on the ohm rating. For example, 81R represents 81 ohms, while 81K represents 81,000 ohms.

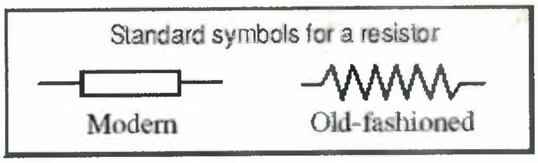


Figure 1.1 Symbol of Resistor

The amount of resistance offered by a resistor is determined by its physical construction. A carbon composition resistor has resistive carbon packed into a ceramic cylinder, while a carbon film resistor consists of a similar ceramic tube, but has conductive carbon film wrapped around the outside. Metal film or metal oxide resistors are made much the same way, but with metal instead of carbon. A wirewound resistor, made with metal wire wrapped around clay, plastic, or fiberglass tubing, offers resistance at higher power levels. For applications that must withstand high temperatures, materials such as cermet, a ceramic-metal composite, or tantalum, a rare metal, are used to build a resistor that can endure heat. A resistor is coated with paint or enamel, or covered in molded plastic to protect it. Because resistors are often too small to be written on, a standardized color-coding system is used to identify them.You can see the colour code for resistor in appendix A. The first three colors represent ohm value, and a fourth indicates the tolerance, or how close by percentage the resistor is to its ohm value. This is important for two reasons: the nature of resistor construction is imprecise, and if used above its maximum current, the value of the resistor can alter or the unit itself can burn up.

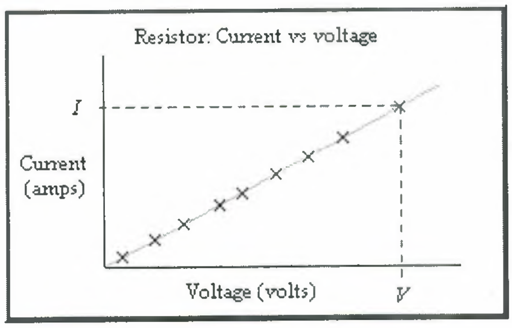


Figure 1.2 Resistor I-V characteristic

Every resistor falls into one of two categories: fixed or variable. A fixed resistor has a predetermined amount of resistance to current, while a variable resistor can be adjusted to give different levels of resistance. Variable resistors are also called potentiometers and are commonly used as volume controls on audio devices. A rheostat is a variable resistor made specifically for use with high currents.

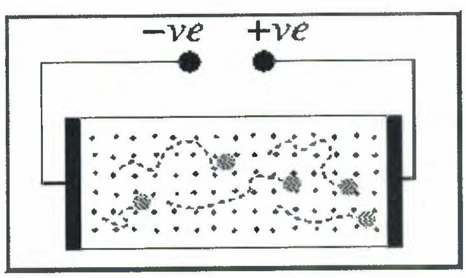


Figure 1.3 Metal oxide varistor

There are also metal-oxide varistors, which change their resistance in response to a rise in voltage; thermistors, which either raise or lower resistance when temperature rises or drops; and light-sensitive resistors. is the current, and R is the resulting resistance. It should be noted that the resistance of a real-world device is never exactly true to this law, as impurities in the conductor and the actual behavior of electrons affect the resistance. In practice, however, such discrepancies are negligible enough to be ignored, and Ohm's Law may be treated as true.

1.1.1 Multiplier band

Once you find the values for the first two bands, write them down. For example, if you have a red band and a black band, then the values will be 2 and 0. Put these two numbers together and you'll get the number 20. The third band is the multiplier band. This is the number you'll multiply the first two bands by to get the resistor's value. The color scheme for the third band is as follows:

Black = 1
Brown = 10
Red = 100
Orange = 1000 (or 1 K)
Yellow = 10,000 (or 10 K)
Green = 100,000 (or 100 K)
Blue = 1,000,000 (or 1 M)

Pretend that a resistor had red, black, yellow, and silver bands. I already explained that the red and black bands in the first two positions would translate into 2 and 0, which are joined to read as 20. The yellow band in the third position is a multiplier.The multiplication value is 10,000 (or 10 K). Now, multiply 20 by 10,000 and you'll get 200,000. This means that the resistor is rated at 200,000 ohms, more commonly expressed as 200 K ohms.You can see the tolerance and coclour code on the table 1.1 in Appendix A . .

1.1.2 TYPES OF RESISTOR

1.1.2.1 Carbon Film Resistors

The diagram shows the construction of a carbon film resistor in figure1.4:During manufacture, a thin film of carbon is deposited onto a small ceramic rod. The resistive coating is spiralled away in an automatic machine until the resistance between the two ends of the rod is as close as possible to the correct value.

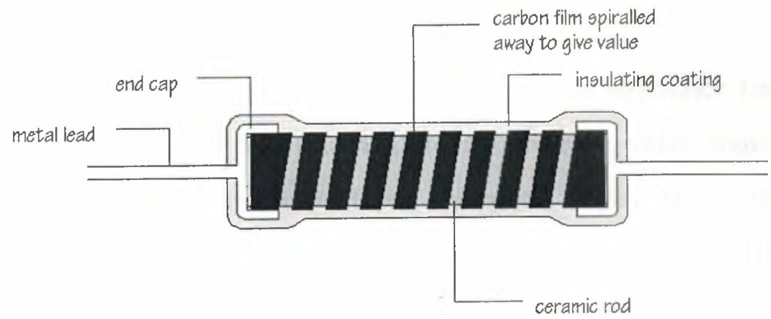


Figure1.4 Metai Resistor Basic

Metal leads and end caps are added, the resistor is covered with an insulating coating and finally painted with coloured bands to indicate the resistor value.Carbon film resistors are cheap and easily available, with values within ±10% or ±5% of their marked, or 'nominal' value. Metal film and metal oxide resistors are made in a similar way, but can be made more accurately to within ±2% or ±1% of their nominal value.Wirewound resistors are made by winding thin wire onto a ceramic rod. They can be made extremely accurately for use in multimeters, oscilloscopes and other measuring equipment. Some types of wirewound resistors can pass large currents wihtout overheating and are used in power supplies and other high current circuit.This resistor is called a Single-In-Line(SIL) resistor network. You can see in figure in1.5. It is made with many resistors of the same value, all in one package.

Figure1.5 Single in line resistor

One side of each resistor is connected with one side of all the other resistors inside. One example of its use would be to control the current in a circuit powering many light emitting diodes (LEDs).In the photograph on the left, 8 resistors are housed in the package. Each of the leads on the package is one resistor. The ninth lead on the left side is the common lead.

1.1.2.2 Metal Film Resistors

Metal film resistors are used when a higher tolerance (more accurate value) is needed. They are much more accurate in value than carbon film resistors. They have about ±0.05% tolerance. They have about ±0.05% tolerance. Resistors that are about ±1% are more than sufficient. Ni-Cr (Nichrome) seems to be used for the material of resistor. You can see ıt's picture in figure 1.6

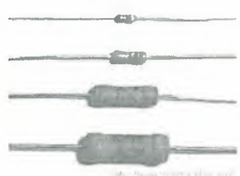


Figure 1.6 Metal film Resistor

The metal film resistor is used for bridge circuits, filter circuits, and low-noise analog signal circuits. Metal film resistors are recommended for use in analog circuits.

1.1.2.3 Variable Resistors

There are two general ways in which variable resistors are used. One is the variable resistor which value is easily changed, like the volume adjustment of Radio. The other is semi-fixed resistor that is not meant to be adjusted by anyone but a technician. It is used to adjust the operating condition of the circuit by the technician. Semi-fixed resistors are used to compensate for the inaccuracies of the resistors, and to fine-tune a circuit. The rotation angle of the variable resistor is usually about 300 degrees.

Some variable resistors must be turned many times to use the whole range of resistance they offer.

This allows for very precise adjustments of their value. These are called "Potentiometers" or "Trimmer Potentiometers." See the figure in 1.7

Figure 1.7 Types of Variable Resistors

In the photograph to the left, the variable resistor typically used for volume controls can be seen on the far right. Its value is very easy to adjust.

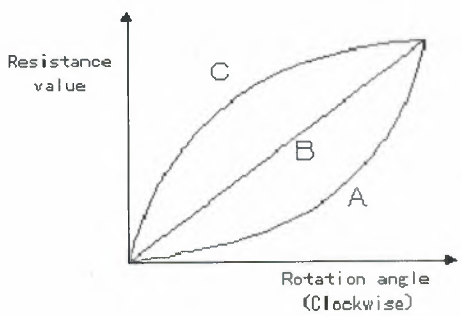


Figure 1.8 Variable Resistor rotationangle diagram

The four resistors at the center of the photograph are the semi-fixed type. These ones are mounted on the printed circuit board.The two resistors on the left are the trimmer potentiometers..There are three ways in which a variable resistor's value can change according to the rotation angle of its axisin figure 1.8 . When type "A" rotates clockwise, at first, the resistance value changes slowly and then in the second half of its axis, it changes very quickly.The "A" type variable resistor is typically used for the volume control of a radio, for exaple. It is well suited to adjust a low sound subtly. It suits the characteristics of the ear. The ear hears low sound changes well, but isn't as sensitive to small changes in loud sounds. A larger change is needed as the volume is increased. These "A" type variable resistors are sometimes called "audio taper" potentiometers. As for type "B", the rotation of the axis and the change of the resistance value are directly related. The rate of change is the same, or linear, throughout the sweep of the axis. This type suits a resistance value adjustment in a circuit, a balance circuit and so on..They are sometimes called "linear taper" potentiometers.

1.1.2.4 CDS Elements

Some components can change resistance value by changes in the amount of light hitting them. One type is the Cadmium Sulfide Photocell. (Cd) The more light that hits it, the smaller its resistance value becomes.. They vary according to light sensitivity, size, resistance value etc.

Figure 1.9 A typical CDS photocell

Pictured at the left is a typical CDS photocell in figure 1.9 . Its diameter is 8 mm, 4 mm high, with a cylinder form. When bright light is hitting it, the value is about 200 ohms, and when in the dark, the resistance value is about 2M ohms. This component is using for the head lamp illumination confirmation device of the car, for example.

1.1.2.5 Ceramic Resistor

There is another type of resistor other than the carbon-film type and the metal film resistors in figure 1.10 . It is the wirewound resistor.A wirewound resistor is made of metal resistance wire, and because of this, they can be manufactured to precise values. Also, high-wattage resistors can be made by using a thick wire material. Wirewound resistors cannot be used for high-frequency circuits. Coils are used in high frequency circuits. Since a wirewound resistor is a wire wrapped around an insulator, it is also a coil, in a manner of speaking. Using one could change the behavior of the circuit. Still another type of resistor is the Ceramic resistor.These are wirewound resistors in a ceramic case, strengthened with a special cement. They have very high power ratings, from 1 or 2 watts to dozens of watts. These resistors can become extremely hot when used for high power applications, and this must be taken into account when designing the circuit. These devices can easily get hot enough to burn you if you touch one. a typical CDS photocell

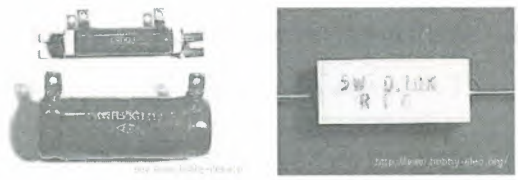


Figure 1.10 Wirewound resistors and Ceramic resistor

The upper one is 10W and is the length of 45 mm, 13 mm thickness. The lower one is 50W and is the length of 75 mm, 29 mm thickness. The upper one is has metal fittings attached. These devices are insulated with a ceramic coating.

1.1.2.6 Thermistor (Thermally sensitive resistor)

The resistance value of the thermistor changes according to temperature.This part is used as a temperature sensor.There are mainly three types of thermistor.You can see thermistor picture in figure 1.11

Figure 1.11 Termistor

The resistance value of the thermistor changes according to temperature.This part is used as a temperature sensor.

NTC(Negative Temperature Coefficient Thermistor): With this type, the resistance value decreases continuously as the temperature rises.

PTC(Positive Temperature Coefficient Thermistor): With this type, the resistance value increases suddenly when the temperature rises above a specific point.

CTR(Critical Temperature Resister Thermistor): With this type, the resistance value decreases suddenly when the temperature rises above a specific point.The NTC type is used for the temperature control.

The relation between the temperature and the resistance value of the NTC type can be calculated using the following formula in equation 1.1.

R : The resistance value at the temperature T

T : The temperature [K]

R0 : The resistance value at the reference temperature T0

T0 : The reference temperature [K]

B : The coefficient

$$R = R_0 \cdot \exp^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

Equation 1.1

As the reference temperature, typically, 25°C is used.The unit with the temperature is the absolute temperature(Value of which 0 was -273°C) in K(Kelvin).25°C are the 298 kelvins.

1.1.3 Testing Resistors

Now that you know how to read a resistor's estimated values and potential values, let's take a look at how to check for a bad resistor. Generally, resistors are pretty durable, but they can be cooked by excessive amounts of electricity. Back in my college electronics class, I remember more than one classmate cooking resistors with too much juice.Usually, the resistor gets hot, starts smoking, and makes a strange high-pitched squeal. Once a resistor has been blown, often no electricity can pass through it. Such resistors are said to have infinite resistance. At the same time, if the resistor was damaged by excessive voltage but not destroyed, the resistor may allow some electricity to pass but have an incorrect level of resistance. This is why it is so important to know about tolerances. For example, if you knew that a resistor was supposed to have a value of 200,000 ohms but tested the resistor at 180,000 ohm, you might assume that the resistor was bad. When testing a resistor, the multimeter is passing a known amount of electrical current through the resistor and then measuring the amount of current that actually makes it through. Since the multimeter is passing current through the resistor, you want to ensure that the device containing the resistor you are testing is unplugged and turned off. If a normal amount of current were flowing through the resistor and you tried to test the resistor, not only will your reading be inaccurate, but you could damage the resistor and other components. You could also damage your multimeter or receive a nasty electrical shock. With that said, multimeters are designed to use scales.

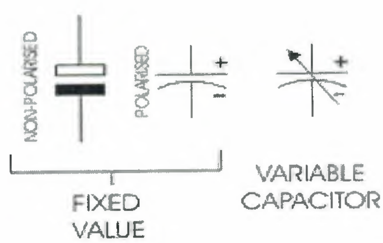
These scales determine how much current the multimeter will use during the test. For example, my multimeter has scales for 200 ohms, 2 K ohms, 200 K ohms, 2 M ohms, and 20 M ohms. If I were to test our fictitious 200 K ohm resistor with this particular meter, I would set the scale at 200 K ohms. However, it's purely a coincidence that my meter has a setting for 200 K ohms. Normally, there won't be a scale setting that matches the value of the resistor. In such situations, you'll want to go to the nearest scale value above the resistor's rating. For example, if you had a 100 K ohm resistor, you would use the 200 K ohm scale. If you had a 300 K ohm resistor, you'd use the 2 M ohm scale. The available scales will differ among brands and models of multimeters, but the concept remains the same operation in evertime.

Once you've verified that the device is unplugged and powered off and that your meter is set to the correct scale, it's time to take a measurement. Resistors aren't polarized, so it doesn't matter which side of the resistor you place the meter's red or black probes on. Once you place the probes against the resistor's leads, you should receive a value for the resistor.For demonstration purposes, I decided to use my meter to actually test a 200 K ohm resistor. The resistor tested at 197.6 ohms.

1.2 CAPACITORS

1.2.1 Basic of Capacitors

A capacitor is a tool consisting of two conductive plates, each of which hosts an opposite charge. These plates are separated by a dielectric or other form of insulator, which helps them maintain an electric charge. There are several types of insulators used in capacitors. Examples include ceramic, polyester, tantalum air, and polystyrene. Other common capacitor insulators include air, paper, and plastic. Each effectively prevents the plates from touching each other.The first capacitor was the Leyden jar, invented at the Netherlands University in the 18th century. This type of capacitor consists of a glass jar coated with metal on the inside and outside. A rod is connected to the inner coat of metal, passed through the lid of the capacitor, and topped off with a metal ball. As with all capacitors, the Leyden jar contains an oppositely charged electrode and a plate that is separated by an insulator. The Leyden jar has been used to conduct experiments in electricity for hundreds of years.A capacitor measures in voltage, which differs on each of the two interior plates. Both plates of the capacitor are charged, but the current flows in opposite directions. A capacitor contains 1.5 volts, which is the same voltage found in a common AA battery. As voltage is used in a capacitor, one of the two plates becomes filled with a steady flow of current. At the same time, the current flows away from the other plate. The capacitor also functions as a filter, passing alternating current (AC), and blocking direct current (DC). This symbol is used to indicate a capacitor in a circuit diagram.



Figıre 1.2.1 Circuit Symbole of Cpacitor

The capacitor is constructed with two electrode plates facing eachother, but separated by an insulator.When DC voltage is applied to the capacitor, an electric charge is stored on each electrode. While the capacitor is charging up, current flows. The current will stop flowing when the capacitor has fully charged.The value of a capacitor (the capacitance), is designated in units called the Farad (F).The capacitance of a capacitor is generally very small, so units such as the microfarad (10-6F), nanofarad (10-9F), and picofarad (10-12F) are used.

Recently, an new capacitor with very high capacitance has been developed. The Electric Double Layer capacitor has capacitance designated in Farad units. These are known as "Super Capacitors."Sometimes, a three-digit code is used to indicate the value of a capacitor. There are two ways in which the capacitance can be written. One uses letters and numbers, the other uses only numbers. In either case, there are only three characters used. The method used differs depending on the capacitor supplier. In the case that the value is displayed with the three-digit code, the 1st and 2nd digits from the left show the 1st figure and the 2nd figure, and the 3rd digit is a multiplier which determines how many zeros are to be added to the capacitance. Picofarad (pF) units are written this way.You can see the capacitor colour code table in Appendix A

For example : when the code is [103], it indicates 10 x 103, or 10,000pF = 10 nanofarad(nF) = 0.01 microfarad(μF).
If the code happened to be [224], it would be 22 x 104 = or 220,000pF = 220nF = 0.22μF.Values under 100pF are displayed with 2 digits only. For example, 47 would be 47pF.

The capacitor has an insulator(the dielectric) between 2 sheets of electrodes. Different kinds of capacitors use different materials for the dielectric.A capacitor is often used to store analogue signals and digital data. Another type of capacitor is used in the telecommunications equipment industry. This type of capacitor is able to adjust the frequency and tuning of telecommunications equipment and is often referred to a variable capacitor. A capacitor is also ideal for storing an electron. A capacitor cannot, however, make electrons

1.2.2 Capacitance Parallel Plate Capacitor Air

This formula is suitable for atmospheric pressure

C = 0.224[(K S (N - 1))\ d] .... Equaition 1.2.1

Where

C = Capacitance in picofarads

K = Dielectric Constant

S = Area of one plate in square inches

N = Number of plates

d = Distance between plates in inches

* You can see the Dielecteric constant table of material in Appendiz A

1.2.3 Capacitors in Series and Parallel

This is very similar to the resistors except the formula for series and parallel connections are interchanged.If Cab is the effective capacitance of a series or parallel combination then, it is given by.

1/Cab(series) = 1/C1 + 1/C2 + 1/C3 where C1,C2,C3 are individual capacitances.

Cab(parallel) = C1 + C2+ C3

1.2.4 Capacitor Charge And Discharge Current

The graph at the right shows the immediate rise in charging current when the switch is placed in the Charge position. The current then decays to zero amps as the capacitor becomes fully charged.

When the switch is moved to the Discharge po-sition, the current instantaneously reverses in direction and then decays to zero as the capacitor become fully discharged.Capacitive Reactance is the opposition to the flow of current in an electrical circuit due to capacitance and is measured in Ohms.

The symbol for reactance is X; capacitive reactance is represented by Xc. The formula for capacitive reactance is:

$$X_C = \frac{1}{2\pi f C}$$ **Eguation 1.2.2**

Where:

Xc = Capacitive reactance in ohms

f = Frequency in hertz

C = Capacitance in farads

2 π = 6.28 [Note: the value of pi (π) is 3.1416]

As illustrated by the formula above, capacitive reactance is inversely proportional to frequency.Direct Current (DC) will not flow through a capacitor because the frequency of pure DC (having no ripple or changes in amplitude) is zero hertz , therefore the value of capacitive reactance in ohms is, theoretically, infinite (there is always some small amount of leakage current through the capacitor dielectric). A capacitor is said to "block" direct current. Even though direct current will not flow through a capacitor, the impressed voltage will cause an electrostatic charge to accumulate on the plates and the capacitor will store an electrical charge according to the formula:

$$Q = CE$$ **Equation 1.2.3**

Where:

Q = Quantity stored in coulombs

E = Potential across the capacitor in volts

C = Capacitance in farads

1.2.5 Breakdown voltage

When using a capacitor, you must pay attention to the maximum voltage which can be used. This is the "breakdown voltage." The breakdown voltage depends on the kind of capacitor being used. You must be especially careful with electrolytic capacitors because the breakdown voltage is comparatively low. The breakdown voltage of electrolytic capacitors is displayed as Working Voltage.The breakdown voltage is the voltage that when exceeded will cause the dielectric (insulator) inside the capacitor to break down and conduct. When this happens, the failure can be catastrophic.

1.2.6 TYPES OF CAPACITOR

1.2.6.1 Electrolytic Capacitors (Electrochemical type capacitors)

Aluminum is used for the electrodes by using a thin oxidization membrane. Large values of capacitance can be obtained in comparison with the size of the capacitor, because the dielectric used is very thin. The most important characteristic of electrolytic capacitors is that they have polarity. They have a positive and a negative electrode.[Polarised] This means that it is very important which way round they are connected. If the capacitor is subjected to voltage exceeding its working voltage, or if it is connected with incorrect polarity, it may burst. It is extremely dangerous, because it can quite literally explode. Make absolutely no mistakes.Generally, in the circuit diagram, the positive side is indicated by a "+" (plus) symbol. Electrolytic capacitors range in value from about 1µF to thousands of µF. Mainly this type of capacitor is used as a ripple filter in a power supply circuit, or as a filter to bypass low frequency signals, etc. Because this type of capacitor is comparatively similar to the nature of a coil in construction, it isn't possible to use for high-frequency circuits. (It is said that the frequency characteristic is bad.)The photograph is an example of the different values of electrolytic capacitors in which the capacitance and voltage differ in figure 1.2.2.

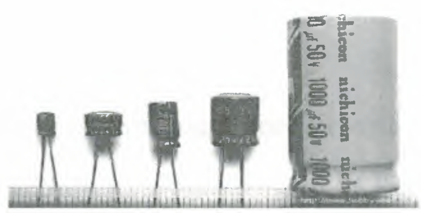


Figure 1.2.2 Electrochemical type capacitors

From the left to right:

1µF (50V) [diameter 5 mm, high 12 mm]

47µF (16V) [diameter 6 mm, high 5 mm]

100μF (25V) [diameter 5 mm, high 11 mm]
220μF (25V) [diameter 8 mm, high 12 mm]
1000μF (50V) [diameter 18 mm, high 40 mm]

The size of the capacitor sometimes depends on the manufacturer. So the sizes shown here on this page are just examples. In the photograph to the right, the mark indicating the negative lead of the component can be seen. You need to pay attention to the polarity indication so as not to make a mistake when you assemble the circuit.

1.2.6.2 Tantalum Capacitors

Tantalum Capacitors are electrolytic capacitors that is use a material called tantalum for the electrodes. Large values of capacitance similar to aluminum electrolytic capacitors can be obtained. Also, tantalum capacitors are superior to aluminum electrolytic capacitors in temperature and frequency characteristics.

When tantalum powder is baked in order to solidify it, a crack forms inside. An electric charge can be stored on this crack. These capacitors have polarity as well. Usually, the "+" symbol is used to show the positive component lead. Do not make a mistake with the polarity on these types.

Tantalum capacitors are a little bit more expensive than aluminum electrolytic capacitors. Capacitance can change with temperature as well as frequency, and these types are very stable.

Therefore, tantalum capacitors are used for circuits which demand high stability in the capacitance values. Also, it is said to be common sense to use tantalum capacitors for analog signal systems, because the current-spike noise that occurs with aluminum electrolytic capacitors does not appear.

Aluminum electrolytic capacitors are fine if you don't use them for circuits which need the high stability characteristics of tantalum capacitors.

Figure1.2.3 Tantalyum Capcitors

The photograph is illustrates the tantalum capacitor in figure 1.2.3. The capacitance values are as follows, from the left:0.33 μF (35V),0.47 μF (35V) ,10 μF (35V) .The "+" symbol is used to show the positive lead of the component. It is written on the body.

1.2.6.3 Ceramic Capacitors

Ceramic capacitors are constructed with materials such as titanium acid barium used as the dielectric.

Figure 1.2.4 Ceramic Capacitor

Internally, these capacitors are not constructed as a coil, so they can be used in high frequency applications. Typically, they are used in circuits which bypass high frequency signals to ground..These capacitors have the shape of a disk. Their capacitance is comparatively small.The capacitor on the left is a 100pF capacitor with a diameter of about 3 mm.The capacitor on the right side is printed with 103, so 10 x 103pF becomes 0.01 μ in figure 1.2.4 F. The diameter of the disk is about 6 mm.Ceramic capacitors have no polarity.

1.2.6.4 Multilayer Ceramic Capacitors

The multilayer ceramic capacitor has a many-layered dielectric. These capacitors are small in size, and have good temperature and frequency characteristics. Square wave signals used in digital circuits can have a comparatively high frequency component included. This capacitor is used to bypass the high frequency to ground.

Figure 1.2.5 Multilayer Ceramic Capacitors

In the photograph, the capacitance of the component on the left is displayed as 104 in figure 1.2.5. So, the capacitance is 10 x 104 pF = 0.1 μF. The thickness is 2 mm, the height is 3 mm, the width is 4 mm.The capacitor to the right has a capacitance of 103 (10 x 103 pF = 0.01 μF). The height is 4 mm, the diameter of the round part is 2 mm.These capacitors are not polarized. That is, they have no polarity

1.2.6.5 Electric Double Layer Capacitors (Super Capacitors)

This is a "Super Capacitor," which is quite a wonder. The capacitance is 0.47 F (470,000 μF) in figure 1.2.7.

Figure1.2.7 Super Capacitors

Care must be taken when using a capacitor with such a large capacitance in power supply circuits, etc. The rectifier in the circuit can be destroyed by a huge rush of current when the capacitor is empty. For a brief moment, the capacitor is more like a short circuit. A protection circuit needs to be set up.The size is small in spite of capacitance. Physically, the diameter is 21 mm, the height is 11 mm.Care is necessary, because these devices do have polarity.

1.2.6.6 Polyester Film Capacitors

This capacitor uses thin polyester film as the dielectric. They are not high tolerance, but they are cheap and handy.

Figure1.2.8 Polyester Film Capacitors

Their tolerance is about ±5% to ±10%..From the left in the photograph in figure 1.2.8

Capacitance: 0.001 μF (printed with 001K) [the width 5 mm, the height 10 mm, the thickness 2 mm].

Capacitance: 0.1 μF (printed with 104K) [the width 10 mm, the height 11 mm, the thickness 5mm].

Capacitance: 0.22 μF (printed with .22K) [the width 13 mm, the height 18 mm, the thickness 7mm]. Care must be taken, because different manufacturers use different methods to denote the capacitance values. Here are some other polyester film capacitors. Starting from the left

Capacitance: 0.0047 μF (printed with 472K) [the width 4mm, the height 6mm, the thickness 2mm]

Capacitance: 0.0068 μF (printed with 682K) [the width 4mm, the height 6mm, the thickness 2mm]

Capacitance: 0.47 μF (printed with 474K) [the width 11mm, the height 14mm, the thickness 7mm] .These capacitors have no polarity.

1.2.6.7 Mica Capacitors

These capacitors use Mica for the dielectric. Mica capacitors have good stability because their temperature coefficient is small. Because their frequency characteristic is excellent, they are used for resonance circuits, and high frequency filters. Also, they have good insulation, and so can be utilized in high voltage circuits. It was often used for vacuum tube style radio transmitters, etc. Mica capacitors do not have high values of capacitance, and they can be relatively expensive.

Figure1.2.10 Mica Capacitors

Pictured at the right are "Dipped mica capacitors." These can handle up to 500 volts.The capacitance from the left in figure1.2.10

Capacitance: 47pF (printed with 470J) [the width 7mm, the height 5mm, the thickness 4mm]

1.2.6.8 Metalized Polyester Film Capacitors

These capacitors are a kind of a polyester film capacitor.

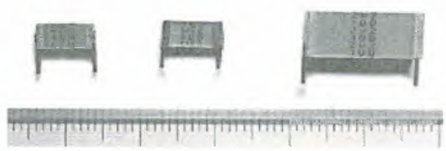


Figure1.2.11 Metallized Polyester Film Capacitors

Because their electrodes are thin, they can be miniaturized.From the left in the photograph in fifure 1.2.11

Capacitance: 0.001µF (printed with 1n. n means nano:10-9) Breakdown voltage: 250V [the width 8mm, the height 6mm, the thickness 2mm]

Capacitance: 0.22µF (printed with u22).Breakdown voltage: 100V [the width 8mm, the height 6mm, the thickness 3mm]

Capacitance: 2.2µF (printed with 2u2) ,Breakdown voltage: 100V [the width 15mm, the height 10mm, the thickness 8mm]

Care is necessary, because the component lead easily breaks off from these capacitors. Once lead has come off, there is no way to fix it. It must be discarded.These capacitors have no polarity.

1.2.6.9 Variable Capacitors

Variable capacitors are used for adjustment etc. of frequency mainly.On the left in the photograph is a "trimmer," which uses ceramic as the dielectric. Next to it on the right is one that uses polyester film for the dielectric. The pictured components are meant to be mounted on a printed circuit board.When adjusting the value of a variable capacitor, it is advisable to be careful.One of the component's leads is connected to the adjustment screw of the capacitor. This means that the value of the capacitor can be affected by the capacitance of the screwdriver in your hand. It is better to use a special screwdriver to adjust these components.Pictured in 1.2.12 the upper left photograph are variable capacitors with the following specifications: Capacitance: 20pF (3pF - 27pF measured) [Thickness 6 mm, height 4.8 mm] Their are different colors, as well. Blue: 7pF (2 - 9), white: 10pF (3 - 15), green: 30pF (5 - 35), brown: 60pF (8 - 72).

Figrure1.2.12 Variable Capacitors

In the same photographin figure 1.2.12, the device on the right has the following specificationsThe components in the photograph on the right are used for radio tuners, etc. They are called "Varicons" but this may be only in Japan. The variable capacitor on the left in the photograph, uses air as the dielectric. It combines three independent capacitors. For each one, the capacitance changed 2pF - 18pF. When the adjustment axis is turned, the capacitance of all 3 capacitors change simultaneously.Physically, the device has a depth of 29 mm, and 17 mm width and height. (Not including the adjustment rod.) There are various kinds of variable capacitor, chosen in accordance with the purpose for which they are needed. The pictured components are very small.To the right in the photograph is a variable capacitor using polyester film as the dielectric. Two independent capacitors are combined.

1.2.7 Teating Capacitor

With the microwave unplugged, use a metal (not the shiny chrome type) screw driver with a insulated handle to short across (touch both at the same time) the terminals of the high voltage capacitor to discharge it.This is a common way to do this. See the in figure 1.2.13

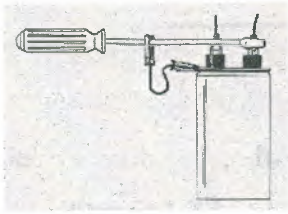


Figure 1.2.13 Capacitor shoet circuit methode as carefully

If the wire terminals and wires are coated (not bare metal) you can use a pair of needlenose pliers with insulated handles to short/discharge across the capacitor.Set your needle meter to an OHM scale, Touch your leads together and 0 (zero) out your meter with the adjustment wheel. With wires off of the capacitor (write down where they go first!)...touch the cap terminals (red lead on left and black lead on right)...the needle should move away from the infinity (probably left side) and move slightly (towards the right side) and go back to infinity...reverse leads and (red lead on right side and black lead on the left side) on the cap and the needle should move away from infinity even further and then go back to infinity = a good cap..

1.3 DIODES

1.3.1 Basic of diodes

Diodes allow electricity to flow in only one direction. The arrow of the circuit symbol shows the direction in which the current can flow. Diodes are the electrical version of a valve and early diodes were actually called valves.

a. Diode example

b. Circuit symbol

Figure 1.3.1

A semiconductor diode consists of a semiconductor PN junction and has two terminals, an anode (+) and a cathode (-). Current flows from anode to cathode within the diode (according to the high to low circuit analysis method), but only when there is at least a certain amount of forward voltage applied. When positive voltage is applied across the diode, it is called a forward bias, whereas a negative voltage is called a reverse bias.

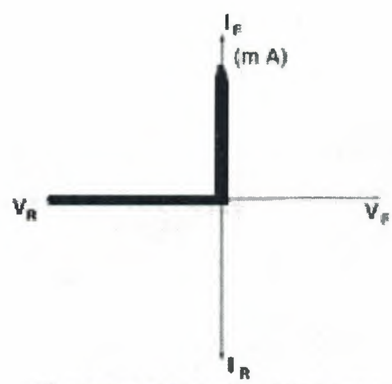


Figure 1.3.2 The Operation of an Ideal Diode

A diode is best described as a one way valve, since it only allows current to flow from anode to cathode. For example, if you applied a reverse bias to the diode with a magnitude of 5 volts, current would not flow. If you applied 5 volts with a positive bias, current would flow.

This seems pretty simple, but there are exceptions to the one way valve analogy. For example, diodes have a minimum forward voltage level to allow current to flow. In most cases, about .7 volts are needed to trigger current flow. You can see this in figure 1.3.3 . The current does not start to flow until a certain amount of forward voltage is applied. Another exception is the breakdown voltage. All diodes have a point where, if the reverse voltage is high enough, the semiconductor structure will break down, allowing current to flow. This value is usually fifty volts or higher and when the breakdown voltage is reached, it generally damages or destroys the diode.

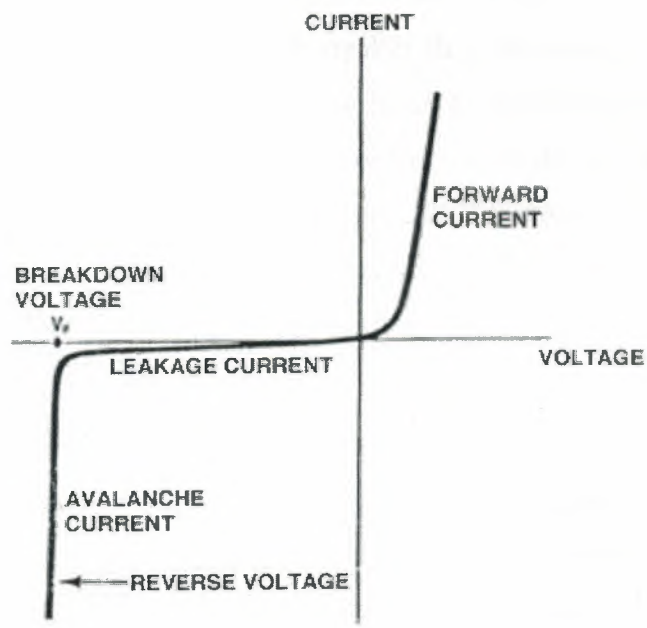


Figure 1.3.3 The Operation of a Real Diode

Why is a diode useful? Because it can be used for rectification, protection of components from reverse voltage, and creating interesting wave shapes. For example, say you have an electrolytic capacitor that can only withstand 10V of reverse bias voltage. All you have to do is place a diode in front of it and it will block most reverse voltages from destroying the capacitor.

Rectification is the process of converting an alternating current signal into a direct current signal and is used in all AC to DC converters and power supplies

1.3.2 Forward Voltage Drop

Electricity uses up a little energy pushing its way through the diode, rather like a person pushing through a door with a spring. This means that there is a small voltage across a conducting diode, it is called the forward voltage drop and is about 0.7V for all normal diodes which are made from silicon. The forward voltage drop of a diode is almost constant whatever the current passing through the diode so they have a very steep characteristic (current-voltage graph).

1.3.3 Reverse Voltage

When a reverse voltage is applied a perfect diode does not conduct, but all real diodes leak a very tiny current of a few µA or less. This can be ignored in most circuits because it will be very much smaller than the current flowing in the forward direction. However, all diodes have a maximum reverse voltage (usually 50V or more) and if this is exceeded the diode will fail and pass a large current in the reverse direction, this is called breakdown. Ordinary diodes can be split into two types: Signal diodes which pass small currents of 100mA or less and Rectifier diodes which can pass large currents.

1.3.4 Connecting and soldering

Diodes must be connected the correct way round, the diagram may be labelled a or + for anode and k or - for cathode (yes, it really is k, not c, for cathode!). The cathode is marked by a line painted on the body.Diodes are labelled with their code in small print, you may need a magnifying glass to read this on small signal diodes! Small signal diodes can be damaged by heat when soldering, but the risk is small unless you are using a germanium diode (codes beginning OA...) in which case you should use a heat sink clipped to the lead between the joint and the diode body. A standard crocodile clip can be used as a heat sink. Rectifier diodes are quite robust and no special precautions are needed for soldering them.

1.3.5 TYPES OF DIODE

1.3.5.1 Signal Diodes (small current)

Signal diodes are used to process information (electrical signals) in circuits, so they are only required to pass small currents of up to 100mA. General purpose signal diodes such as the 1N4148 are made from silicon and have a forward voltage drop of 0.7V. Germanium diodes such as the OA90 have a lower forward voltage drop of 0.2V and this makes them suitable to use in radio circuits as detectors which extract the audio signal from the weak radio signal. For general use, where the size of the forward voltage drop is less important, silicon diodes are better because they are less easily damaged by heat when soldering, they have a lower resistance when conducting, and they have very low leakage currents when a reverse voltage is applied .

1.3.5.2 Zener Diodes

Every diode leaks (allows a little amount of current to pass through) in the wrong direction, but when there is more then about 60 volts on the diode (in the blocking direction) it will let it all pass, and it often gets defective. This effect is used in zenerdiodes. In a zenerdiode the threshold is much lower, and the diode keeps working. Zenerdiodes are used a lot in power supplies to keep the voltage constant:

a Symbole of Zener diode **b.**Photo of Zener diode

Figure1.3.4

Example: Circuit symbol: a = anode, k = cathode

Zener diodes are used to maintain a fixed voltage. They are designed to 'breakdown' in a reliable and non-destructive way so that they can be used **in reverse** to maintain a fixed voltage across their terminals.

The diagram shows how they are connected, with a resistor in series to limit the current.

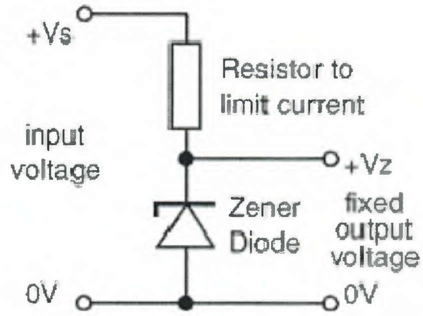


Figure1.3.5 Zener diode connection

Zener diodes can be distinguished from ordinary diodes by their code and breakdown voltage which are printed on them. Zener diode codes begin BZX... or BZY... Their breakdown voltage is printed with V in place of a decimal point, so 4V7 means 4.7V for example. Zener diodes are rated by their breakdown voltage and maximum power: The minimum voltage available is 2.7V. Power ratings of 400mW and 1.3W are common

1.3.5.3 LED (Light Emitting Diode)

LED stands for Light Emitting Diode. This is a very special kind of diode, which produces light. They are available in many different colors: red, green, and yellow. There are also blue and white LEDs, but they are produced in another way, and are much more expensive. LEDs don't act like a normal light bulb, they are still diodes. symbol of a led:

a.Symbole of LED

b.Picrure of LED

Figure 1.3.6

You can recognize the minus side of a led in multiple ways, you can see it by the inside of the LED, the longer pin and the dent in the casing. They way a LED makes light is very complex, na d hard to explain. LEDs are more economical then light bulbs. There are also components that contain two

LEDs, they can light up red, green or orange. These components are used in televisions, to indicate if it's on or stand-by.

1.3.5.4 LED Displays

LED displays are packages of many LEDs arranged in a pattern, the most familiar pattern being the 7-segment displays for showing numbers (digits 0-9). The pictures below illustrate some of the popular designs:

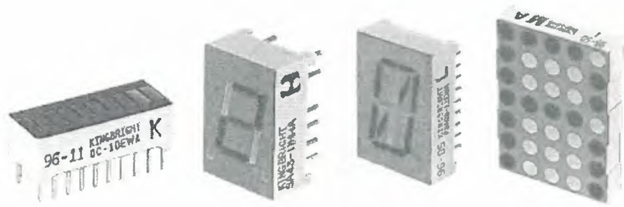


Figure 1.3.9 Types of Display

There are many types of LED display and a supplier's catalogue should be consulted for the pin connections. The diagram on the right shows an example. Like many 7-segment displays, this example is available in two versions:

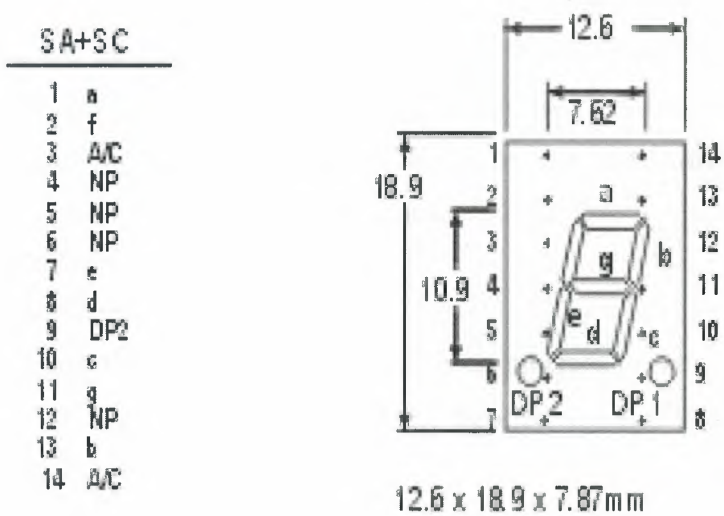


Figure 1.3.10 7Segment display Pin Configuration

Common Anode (SA) with all the LED anodes connected together and Common Cathode (SC) with all the cathodes connected together. Letters a-g refer to the 7 segments, A/C is the common anode or cathode as appropriate (on 2 pins). Note that some pins are not present (NP) but their position is still numbered..

1.3.5.5 Schottky Barrier Diode

A Schottky barrier diode attaches a Schottky gate electrode directly to a n-type semiconductor and makes use of the fact that reverse bias voltages are prevented from causing current flow across the junction of the metal and semiconductor. Some are for high frequencies and some are for general rectification.

Figure1.3.11 symbole of Schottky Barrier Diode

Those for high frequencies are often used in high-speed switching for wave detectors and mixers in the UHF and microwave bands.

Since the forward voltage is small and the reverse breakdown voltage cannot be made too high (currently, approx. 100 to 200 volts) compared to normal diodes for general rectification, Schottky barrier diodes for general rectification are used for the rectification of power supplies for low voltages and high currents, or power supply switching for the rectification of high frequencies with its small reverse recovery time

1.3.5.6 Varactor Diode

One characteristic of any PN junction is an inherent capacitance. When the junction is reverse biased, increasing the applied voltage will cause the depletion region to widen, thus increasing the effective distance between the two "plates" of the capacitor and decreasing the effective capacitance.

By adjusting the doping gradient and junction width, we can control the capacitance range and the way capacitance changes with applied reverse voltage.

Figure1.3.12 Symbol of Vractor Diode

A four-to-one capacitance range is no problem; a typical varactor diode (sometimes called a "varicap diode") might vary from 60 picofarads (pf) at zero bias down to 15 pf at 20 volts. Very careful manufacturing can get a capacitance range of up to ten-to-one, although this seems at present to be a practical limit.Varactor diodes are used in electronic tuning systems, to eliminate the use of and need for moving parts.

1.3.5.7 Tunnel Diode

As we mentioned in our discussion of semiconductor physics, the addition of either P-type or N-type impurities causes the Fermi level in the silicon crystal to shift towards the valence band (P-type impurities) or the conduction band (N-type impurities). The higher the doping level, the greater the shift. In the tunnel diode, the doping levels are so high that the Fermi levels in both halves of the crystal have been pushed completely out of the forbidden zone and into the valence and conduction bands.

Figure1.3.13 Symbol of Tunnel Diode

As a result, at very low forward voltages, electrons don't have to gain energy to get over the Fermi level or into the conduction band; they can simply "tunnel through" the junction and appear at the other side. Furthermore, as the forward bias increases, the applied voltage shifts the levels apart, and gradually back to the more usual diode energy pattern. Over this applied forward voltage range, diode current actually decreases as applied voltage increases. Thus, over part of its operating range, the tunnel diode exhibits a negative resistance effect. This makes it useful in very high frequency oscillators and related circuitry.

1.3.5.8 P-I-N Diode

The p-i-n diode doesn't actually have a junction at all. Rather, the middle part of the silicon crystal is left undoped. Hence the name for this device: p-intrinsic-n, or p-i-n. Because this device has an intrinsic middle section, it has a wide forbidden zone when unbiased. However, when a forward bias is applied, current carriers from the p- and n-type ends become available and conduct current even through the intrisic center region. The end regions are heavily doped to provide more current carriers.

Figure1.3.14 Symbole of P-I-N Diode

The p-i-n diode is highly useful as a switch for very high frequencies. They are commonly used as microwave switches and limiters. A PiN diode operates under what is known as high-level injection. In others words, the intrinsic "i" region is flooded with charge carriers from the "p" and "n" regions. Its function can be likened to filling up a water bucket with a hole on the side. Once the water reaches the hole's level it will begin to pour out. Similarly, the diode will conduct current once the flooded electrons and holes reach an equilibrium point, where the amount of electrons are equal to the amount of holes in the intrinsic region.

When the diode is forward biased, the injected carrier concentration is typically several orders of magnitudes higher than the intrinsic level carrier concentration.

1.3.6 Testing diodes

You can use a multimeter or a simple tester (battery, resistor and LED) to check that a diode conducts in one direction but not the other. A lamp may be used to test a rectifier diode, but do NOT use a lamp to test a signal diode because the large current passed by the lamp will destroy the diode!

On an (analog) multimeter , use the low ohms scale. A regular signal diode or rectifier should read a low resistance (typically 2/3 scale or a couple hundred ohms) in the forward direction and infinite (nearly) resistance in the reverse direction. It should not read near 0 ohms (shorted) or open in both directions. A germanium diode will result in a higher scale reading (lower resistance) due to its lower voltage drop. .

On a (digital multi meter) DMM, there will usually be a diode test mode. Using this, a silicon diode should read between .5 to .8 V in the forward direction and open in reverse. For a germanium diode, it will be lower, perhaps .2 to .4 V or so in the forward direction.

Using the normal resistance ranges - any of them - will usually show open for any semiconductor junction since the meter does not apply enough voltage to reach the value of the forward drop. Note, however, that a defective diode may indeed indicate a resistance lower than infinity especially on the highest ohms range. So, any reading of this sort would be an indication of a bad device but the opposite is not guaranteed.

1.4 TRANSISTORS

1.4.1 Basic of Transistors

The design of a transistor allows it to function as an amplifier or a switch. This is accomplished by using a small amount of electricity to control a gate on a much larger supply of electricity, much like turning a valve to control a supply of water.A junction transistor consists of a thin piece of one type of semiconductor material between two thicker layers of the opposite type in figure 1.4.1. For example, if the middle layer is p-type, the outside layers must be n-type. Such a transistor is an NPN transistor. One of the outside layers is called the emitter, and the other is known as the collector. The middle layer is the base. The places where the emitter joins the base and the base joins the collector are called junctions.

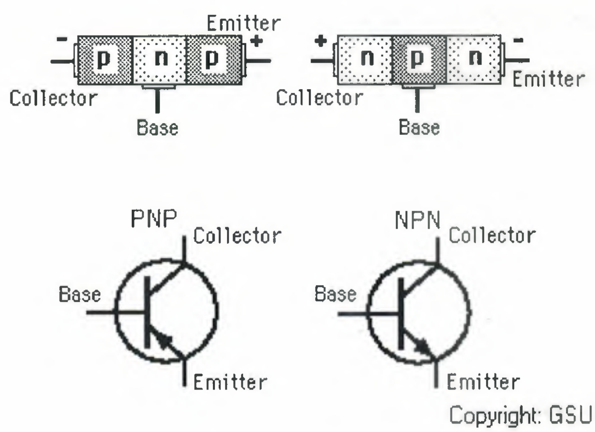


Figure1.4.1 Junction sysbole of transistor

The layers of an NPN transistor must have the proper voltage connected across them. The voltage of the base must be more positive than that of the emitter. The voltage of the collector, in turn, must be more positive than that of the base. The voltages are supplied by a battery or some other source of direct current. The emitter supplies electrons. The base pulls these electrons from the emitter because it has a more positive voltage than does the emitter. This movement of electrons creates a flow of electricity through the transistor.

The current passes from the emitter to the collector through the base. Changes in the voltage connected to the base modify the flow of the current by changing the number of electrons in the base. In this way, small changes in the base voltage can cause large changes in the current flowing out of the collector. Manufacturers also make PNP junction transistors. In these devices, the emitter and collector are both a p-type semiconductor material and the base is n-type. A PNP junction transistor works on the same principle as an NPN transistor. But it differs in one respect.

The main flow of current in a PNP transistor is controlled by altering the number of holes rather than the number of electrons in the base. Also, this type of transistor works properly only if the negative and positive connections to it are the reverse of those of the NPN transistor.

1.4.2 NPN

NPN is one of the two types of bipolar transistors, in which the letters "N" and "P" refer to the majority charge carriers inside the different regions of the transistor. Most bipolar transistors used today are NPN, because electron mobility is higher than hole mobility in semiconductors, allowing greater currents and faster operation.NPN transistors consist of a layer of P-doped semiconductor (the "base") between two N-doped layers. A small current entering the base in common-emitter mode is amplified in the collector output. In other terms, an NPN transistor is "on" when its base is pulled high relative to the emitter.The arrow in the NPN transistor symbol is on the emitter leg and points in the direction of the conventional current flow when the device is in forward active mode.One mnemonic device for identifying the symbol for the NPN transistor is "not pointing in"

1.4.3 PNP

The other type of BJT is the PNP with the letters "P" and "N" referring to the majority charge carriers inside the different regions of the transistor.PNP transistors consist of a layer of N-doped semiconductor between two layers of P-doped material. A small current leaving the base in common-emitter mode is amplified in the collector output. In other terms, a PNP transistor is "on" when its base is pulled low relative to the emitter.The arrow in the PNP transistor symbol is on the emitter leg and points in the direction of the conventional current flow when the device is in forward active mode.One mnemonic device for identifying the symbol for the PNP transistor is "points in proudly".

1.4.4 BJT Configuration

A.There are plenty of texts written about transistor theory, so this page describes a brief look at three popular bipolar junction transistor (BJT) configurations. In each case, one terminal is common to both the input and output signal. All the circuits are shown here are without bias circuits and power supplies for clarity.

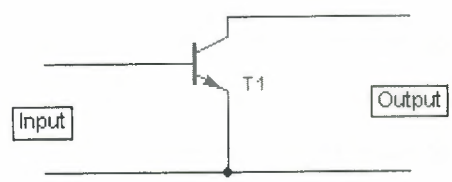


Figure1.4.2 Common Emitter Configuration

In the common emitter configuration in figure 1.4.2 , the emitter terminal is common to both the input and output signal. The arrangement is the same for a PNP transistor, except that the power supplies (not shown) will have the opposite polarity. Used in this way the transistor has the advantages of a medium input impedance, medium output impedance, high voltage gain and high current gain.

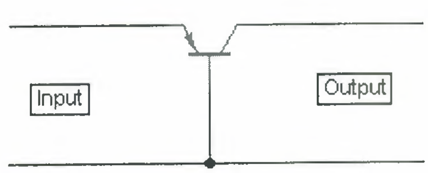


Figure1.4.3 Common Base Configuration

When the base is used as the common terminal, the transistor will have a low input impedance, high output impedance, unity (or less) current gain and high voltage gain in figure 1.4.3. This configuration also realises the best high frequency performance, and finds dominant use in RF amplifiers and high frequency circuits in figure .

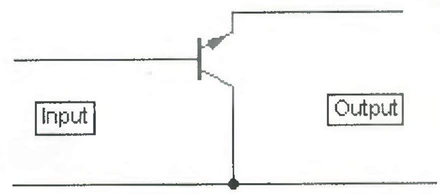


Figure1.4.4 Common Collector Configuration

This last configuration is also commonly known as the emitter follower in figure 1.4.4. This is because the input signal is applied to the base and passes out at the emitter with little loss. Stage properties are high input impedance, a very low output impedance, a unity (slightly less) voltage gain and high current gain. The circuit is also used extensively as a "buffer" converting impedances or for feeding or driving long cables or low impedance loads. In both the the common base and emitter follower configurations, the input and output signals are in phase, but with the common emitter configuration only, the input and output signals are phase inverted, a positive input resulting in a negative output and vice versa. This is also known as phase displacement

1.4.5 Connecting

Transistors have three leads which must be connected the correct way round. Please take care with this because a wrongly connected transistor may be damaged instantly when you switch on..If you are lucky the orientation of the transistor will be clear from the PCB or stripboard layout diagram, otherwise you will need to refer to a supplier's catalogue to identify the leads. The drawings on the right show the leads for some of the most common case styles.

Please note that transistor lead diagrams show the view from below with the leads towards you in figure 1.4.5.

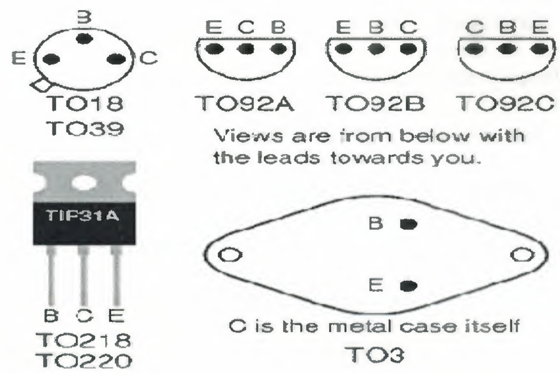


Figure1.4.5 transistor pin connection types

This is the opposite of IC (chip) pin diagrams which show the view from above.

1.4.6 Testing a Transistor with a Multimeter

Set a digital multimeter to diode test and an analogue multimeter to a low resistance range such as × 10, as described above for testing a diode Test each pair of leads both ways (six tests in total).The base-emitter (BE) junction should behave like a diode and conduct one way only.The base-collector (BC) junction should behave like a diode and conduct one way only.

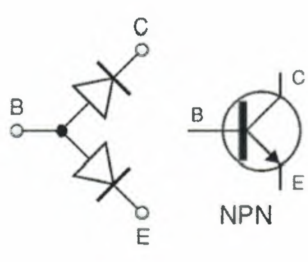


Figure1.4.6 Testing an NPN transistor

The collector-emitter (CE) should not conduct either way.The diagram shows how the junctions behave in an NPN transisto in figure 1.4.6. The diodes are reversed in a PNP transistor but the same test procedure can be used

1.4.7 Transistor codes

There are three main series of transistor codes used in the UK:

Codes beginning with B (or A), for example BC108, BC478 The first letter B is for silicon, A is for germanium (rarely used now). The second letter indicates the type; for example C means low power audio frequency; D means high power audio frequency; F means low power high frequency. The rest of the code identifies the particular transistor. There is no obvious logic to the numbering system. Sometimes a letter is added to the end (eg BC108C) to identify a special version of the main type, for example a higher current gain or a different case style. If a project specifies a higher gain version (BC108C) it must be used, but if the general code is given (BC108) any transistor with that code is suitable.

Codes beginning with TIP, for example TIP31A TIP refers to the manufacturer: Texas Instruments Power transistor. The letter at the end identifies versions with different voltage ratings.

Codes beginning with 2N, for example 2N3053.The initial '2N' identifies the part as a transistor and the rest of the code identifies the particular transistor. There is no obvious logic to the numbering system.

1.5 FIELD EFFECT TRANSISTOR

1.5.1 Junction Field Effect Transistor

A JFET is an interesting device from a Compound Semiconductor perspective for a number of reasons in figure 1.5.1, Wide bandgap materials will allow greater breakdown voltages and possibly faster switching speeds, narrow bandgap materials may significantly reduce noise for low-noise applications.

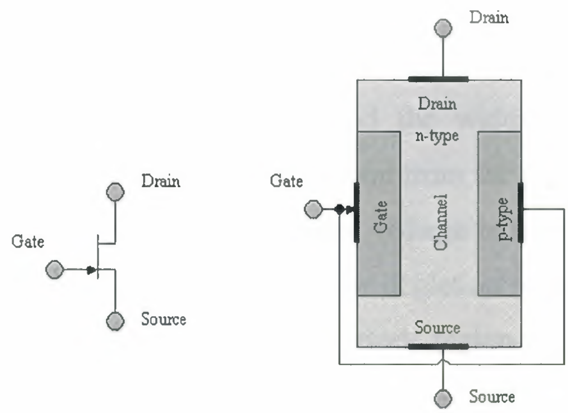


Figure 1.5.1 A simplified n-channel JFET

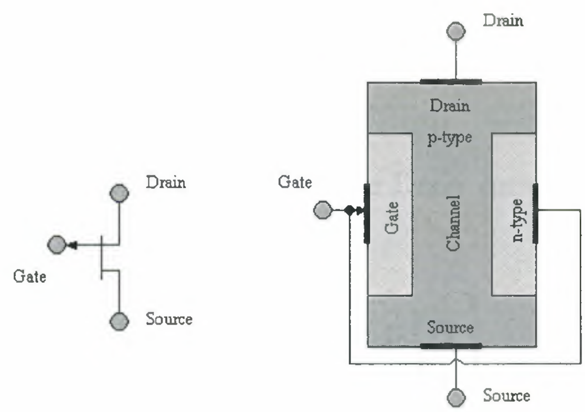


Figure 1.5.2 A simplified p-channel JFET

In the n-channel JFET the device is generally operated with the gate to channel pn junction in a reverse bias, the level of the reverse bias determines the thickness of the depletion region in the channel to control the Drain to Source resistance in figure 1.5.1 P-channel JFET is doped so that it contains an abundance of positive charge carriers in figure 1.5.2

1.5.2 J-Fet Basics

The JFET is a class of Unipolar semiconductor device which comes in two basic varieties, see the figures 1 & 2 below. While there is a small amount of current carried (leakage current) across the reverse biased gate to channel junction, the interesting current is carried in the channel by a single type of charge carrier. The device in general has three modes of operation;

1.5.2.1 Triode

The Drain to Source voltage is small and the width of the channel (as determined by the width of the depletion region from the pn junction within the channel) is constant, as the Drain to Source voltage is increased the Drain to gate reverse voltage is also increased and the depletion region begins to pinch off on the drain side of the channel, in the triode region the i-v characteristics may be characterized by:

$$i_D = I_{DSS}\left[2\left(1-\frac{v_{GS}}{V_P}\right)\frac{v_{DS}}{-V_P}-\left(\frac{v_{DS}}{V_P}\right)^2\right]\left(1+\frac{v_{DS}}{V_A}\right)$$

Equation 1.5.1

1.5.2.2 Pinch-Off

Once the channel has begun to pinch-off, the Drain current remains relatively constant and may be described by:

$$i_D = I_{DSS}\left(1-\frac{v_{GS}}{V_P}\right)^2\left(1+\frac{v_{DS}}{V_A}\right)$$

Equation 1.5.2

1.5.2.3 Breakdown

At some positive Drain to Source voltage the device will have breakdown, at which point the current will increase very rapidly (unless limited by the external circuit). This breakdown voltage is decreased by the bias applied to the gate.

Another important property of a JFET is it's transconductance, this is generally considered a small signal characteristic and is determined by the Saturation

Current, the Pinch-Off voltage, and the DC bias applied by (not lower case variables are small signal, uppercase are bias):

$$g_m = \frac{i_d}{v_{gs}} = \frac{2I_{DSS}}{|V_P|}\left(1 - \frac{V_{GS}}{V_P}\right)$$

Equation 1.5.3

A high transconductance is desirable in a JFET.So, how do these device parameters relate to the characteristics of the material (ie. why do I want Compound Semiconductors instead of Silicon). To answer this we will relate the above parameters to the device dimensions and material characteristics.As can be seen the materials parameters of conductivity a

Pinch-Of Voltage;

$$V_P = -\frac{qa^2 N_d}{2\varepsilon}$$

Equation 1.5.4

Saturation Current;

$$I_{DSS} = -\frac{G_0 V_P}{3} \quad \text{where} \quad G_0 = \frac{2aZ}{\rho L} \quad \text{so that} \quad I_{DSS} = \frac{qa^3 Z}{3L\varepsilon}\frac{N_d}{\rho}$$

Equation 1.5.5

q - charge of an electron

a - half width of the channel

L - channel length

N_d - the concentrations of donors

ε - the material's emissivity

ρ - the resistivity of the channel

As can be seen, the materials parameters of conductivity and emissivity together help to determine the device performance. Additionally, the frequency response of the device is determined by the capacitance characteristics of the

Gate to channel junction. The above treatment is for an n-channel JFET; similar results would be expected for the p-channel device.

1.5.3 Advantages of JFET

FET has high input resistance (approx. in order of 100-M ohms for a JFET and 1010 to 1015 ohms for the MOSFET). Thus, the FET is a voltage-controlled device, like a tube, and not current-controlled, like a conventional transistor It shows a high degree of isolation between input and output.All field-effect transistors are **unipolar** rather than **bipolar** devices. That is, the main current through them is comprised either of electrons through an N-type semiconductor or holes through a P-type semiconductor while conventional transistor is a bipolar device relying upon two types of charge carrier, electrons and holes.The FET is less noisy than a bipolar transistor.FET has relatively low gain-bandwidth product compared to conventional transistors.

1.5.4 Uses

The most commonly used FET is the MOSFET. The CMOS (complementary-symmetry metal oxide semiconductor) process technology is the basis for modern digital integrated circuits. This process technology uses an arrangement where the (usually "enhancement-mode") p-channel MOSFET and n-channel MOSFET are connected in series such that when one is on, the other is off. The fragile insulating layer of the MOSFET between the gate and channel makes it vulnerable to electrostatic damage during handling. This is not usually a problem after the device has been installed.

In FETs electrons can flow in either direction through the channel when operated in the linear mode, and the naming convention of drain terminal and source terminal is somewhat arbitrary, as the devices are typically (but not always) built symmetrically from source to drain. This makes FETs suitable for switching analog signals between paths (multiplexing). With this concept, one can construct a solid-state mixing board, for example.

1.6 TRANSFORMERS

1.6.1 General Information About Transformers

A transformer is an energy transfer device. It has an input side (primary) and an output side (secondary). Electrical energy applied to the primary is converted to a magnetic field which in turn, induces a current in the secondary which carries energy to the load connected to the secondary. The energy applied to the primary must be in the form of a changing voltage which creates a constantly changing current in the primary, since only a changing magnetic field will produce a current in the secondary.

A transformer consists of at least two sets of windings wound on a single magnetic core. There are two main purposes for using transformers. The first is to convert the energy on the primary side to a different voltage level on the secondary side. This is accomplished by using differing turns counts on primary and secondary windings. The voltage ratio is the same as the turns ratio. The second purpose is to isolate the energy source from the destination, either for personal safety, or to allow a voltage offset between the source and load.Transformers are generally divided into two main types. Power transformers are used to convert voltages and provide operating power for electrical devices, while signal transformers are used to transfer some type of useful information from one form or location to another.

1.6.2 Basic Operation of Transformers

In its most basic form a transformer consists of:

- A primary coil or winding.
- A secondary coil or winding.
- A core that supports the coils or windings.

Refer to the transformer circuit in figure 1.6.1 as you read the following explanation: The primary winding is connected to a 60 hertz ac voltage source. The magnetic field (flux) builds up (expands) and collapses (contracts) about the primary winding.

The expanding and contracting magnetic field around the primary winding cuts the secondary winding and induces an alternating voltage into the winding.

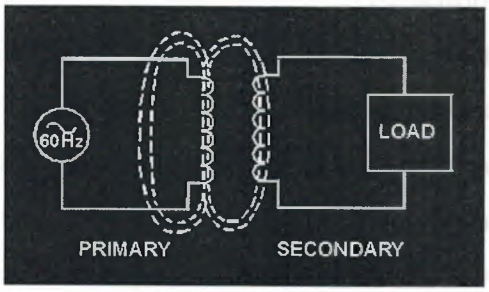


Figure 1.6.1. - Basic transformer action

This voltage causes alternating current to flow through the load. The voltage may be stepped up or down depending on the design of the primary and secondary windings.

1.6.3. The Components of Transformers

Two coils of wire (called windings) are wound on some type of core material. In some cases the coils of wire are wound on a cylindrical or rectangular cardboard form. In effect, the core material is air and the transformer is called an AIR-CORE Trnasformer .

Transformers used at low frequencies, such as 60 hertz and 400 hertz, require a core of low-reluctance magnetic material, usually iron. This type of transformer is called an IRON-CORE transformer. Most power transformers are of the iron-core type. The principle parts of a transformer and their functions are:

- The core, which provides a path for the magnetic lines of flux.
- The Primary winding, which receives energy from the ac source.
- The secondary winding, which receives energy from the primary winding and delivers it to the load.
- The enclosure, which protects the above components from dirt, moisture, and mechanical damage.

1.6.4 Core Characteristics

The composition of a transformer core depends on such factors as voltage, current, and frequency. Size limitations and construction costs are also factors to be considered. Commonly used core materials are air, soft iron, and steel. Each of these materials is suitable for particular applications and unsuitable for others. Generally, air-core transformers are used when the voltage source has a high frequency (above 20 kHz). Iron-core transformers are usually used when the source frequency is low (below 20 kHz). A soft-iron-core transformer is very useful where the transformer must be physically small, yet efficient. The iron-core transformer provides better power transfer than does the air-core transformer. A transformer whose core is constructed of laminated sheets of steel dissipates heat readily; thus it provides for the efficient transfer of power. The majority of transformers you will encounter in Navy equipment contain laminated-steel cores.

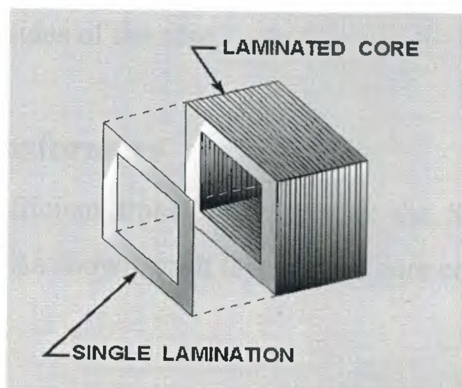


Figure 1.6.2. - Hollow-core construction

These steel laminations (see figure 1.6.2) are insulated with a nonconducting material, such as varnish, and then formed into a core. It takes about 50 such laminations to make a core an inch thick. The purpose of the laminations is to reduce certain losses which will be discussed later in this chapter. An important point to remember is that the most efficient transformer core is one that offers the best path for the most lines of flux with the least loss in magnetic and electrical energy. .

1.6.5 Hollow-Core Transformers

There are two main shapes of cores used in laminated-steel-core transformers. One is the HOLLOW-CORE, so named because the core is shaped with a hollow square through the center.

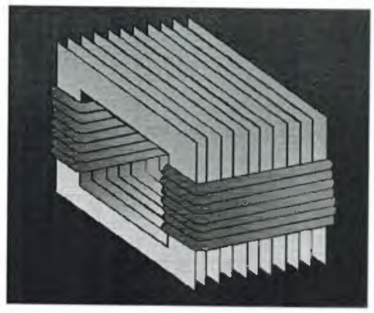


Figure 1.6.3 - Windings wrapped around laminations

Figure 1.6.3 illustrates this shape of core. Notice that the core is made up of many laminations of steel. Figure 5-3 illustrates how the transformer windings are wrapped around both sides of the core.

1.6.6 Shell-Core Transformers

The most popular and efficient transformer core is the SHELL CORE, as illustrated in figure 1.6.4. As shown, each layer of the core consists of E- and I-shaped sections of metal.

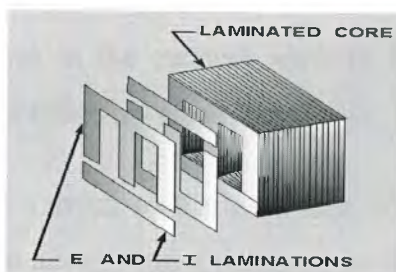


Figure 1.6.4. - Shell-type core construction

These sections are butted together to form the laminations. The laminations are insulated from each other and then pressed together to form the core.

1.6.7 Transformer Windings

As stated above, the transformer consists of two coils called Windings which are wrapped around a core. The transformer operates when a source of ac voltage is connected to one of the windings and a load device is connected to the other. The winding that is connected to the source is called the Primary winding. The winding that is connected to the load is called the Secondary winding . (Note: In this chapter the terms "primary winding" and "primary" are used interchangeably; the term: "secondary winding" and "secondary" are also used interchangeably.)

Shows an exploded view of a shell-type transformer in figure 1.6.5. The primary is wound in layers directly on a rectangular cardboard form.

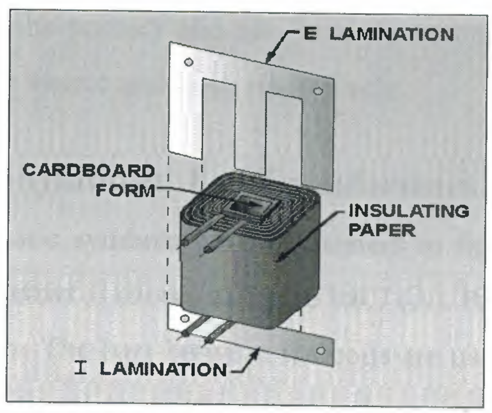


Figure 1.6.5 - Exploded view of shell-type transformer construction.

In the transformer shown in the cutaway view in figure 1.6.6, the primary consists of many turns of relatively small wire.

The wire is coated with varnish so that each turn of the winding is insulated from every other turn. In a transformer designed for high-voltage applications, sheets of insulating material, such as paper, are placed between the layers of windings to provide additional insulation.

When the primary winding is completely wound, it is wrapped in insulating paper or cloth. The secondary winding is then wound on top of the primary winding. After the secondary winding is complete, it too is covered with insulating paper.

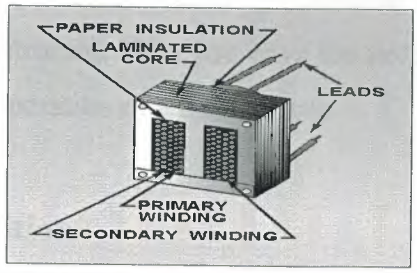


Figure 1.6.6. - Cutaway view of shell-type core with windings.

Next, the E and I sections of the iron core are inserted into and around the windings as shown.The leads from the windings are normally brought out through a hole in the enclosure of the transformer. Sometimes, terminals may be provided on the enclosure for connections to the windings. The figure shows four leads, two from the primary and two from the secondary. These leads are to be connected to the source and load, respectively.

1.6.8 Schematic Symboles For Transformers

Shows typical schematic symbols for transformers in figure 5.7. The symbol for an air-core transformer is shown in figure 1.6.7 (A). Parts (B) and (C) show iron-core transformers. The bars between the coils are used to indicate an iron core. Frequently, additional connections are made to the transformer windings at points other than the ends of the windings.

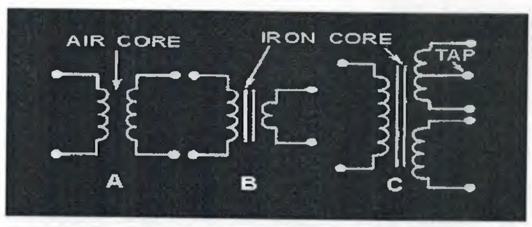


Figure 1.6.7. - Schematic symbols for various types of transformers

These additional connections are called TAPS. When a tap is connected to the center of the winding, it is called a CENTER TAP. Figure 5-7(C) shows the schematic representation of a center-tapped iron-core transformer.

1.6.9 How a transformer work

Up to this point the chapter has presented the basics of the transformer including transformer action, the transformer's physical characteristics, and how the transformer is constructed. Now you have the necessary knowledge to proceed into the theory of operation of a transformer.

1.6.10 No-Load Condition

You have learned that a transformer is capable of supplying voltages which are usually higher or lower than the source voltage. This is accomplished through mutual induction, which takes place when the changing magnetic field produced by the primary voltage cuts the secondary winding.A no-load condition is said to exist when a voltage is applied to the primary, but no load is connected to the secondary, as illustrated by figure 1.6.8. Because of the open switch, there is no current flowing in the secondary winding. With the switch open and an ac voltage applied to the primary, there is, however, a very small amount of current called EXCITING CURRENT flowing in the primary. Essentially, what the exciting current does is "excite" the coil of the primary to create a magnetic field. The amount of exciting current is determined by three factors: (1) the amount of voltage applied (E_a), (2) the resistance (R) of the primary coil's wire and core losses, and (3) the X_L which is dependent on the frequency of the exciting current. These last two factors are controlled by transformer design.

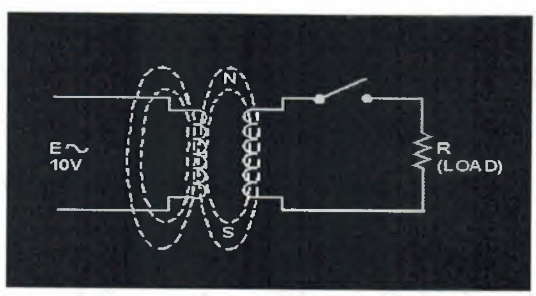


Figure 1.6.8. - Transformer under no-load conditions.

This very small amount of exciting current serves two functions:

- Most of the exciting energy is used to maintain the magnetic field of the primary.
- A small amount of energy is used to overcome the resistance of the wire and core losses which are dissipated in the form of heat (power loss).

Exciting current will flow in the primary winding at all times to maintain this magnetic field, but no transfer of energy will take place as long as the secondary circuit is open.

1.6.11 Producing a Counter EMF

When an alternating current flows through a primary winding, a magnetic field is established around the winding. As the lines of flux expand outward, relative motion is present, and a counter emf is induced in the winding. This is the same counter emf that you learned about in the chapter on inductors. Flux leaves the primary at the north pole and enters the primary at the south pole. The counter emf induced in the primary has a polarity that opposes the applied voltage, thus opposing the flow of current in the primary. It is the counter emf that limits exciting current to a very low value.

1.6.12 Inducing a Voltage In The Secondary

To visualize how a voltage is induced into the secondary winding of a transformer, again refer to figure 5-8. As the exciting current flows through the primary, magnetic lines of force are generated. During the time current is increasing in the primary, magnetic lines of force expand outward from the primary and cut the secondary. As you remember, a voltage is induced into a coil when magnetic lines cut across it. Therefore, the voltage across the primary causes a voltage to be induced across the secondary.

1.6.12 Primary And Secondary Phase Relationship

The secondary voltage of a simple transformer may be either in phase or out of phase with the primary voltage. This depends on the direction in which the windings are wound and the arrangement of the connections to the external circuit (load). Simply, this means that the two voltages may rise and fall together or one may rise while the other is falling.

Transformers in which the secondary voltage is in phase with the primary are referred to as LIKE-WOUND transformers, while those in which the voltages are 180 degrees out of phase are called UNLIKE-WOUND transformers. Dots are used to indicate points on a transformer schematic symbol that have the same instantaneous polarity (points that are in phase). The use of phase-indicating dots is illustrated in figure 1.6.9. In part (A) of the figure, both the primary and secondary windings are wound from top to bottom in a clockwise direction, as viewed from above the windings. When constructed in this manner, the top lead of the primary and the top lead of the secondary have the SAME polarity. This is indicated by the dots on the transformer symbol. A lack of phasing dots indicates a reversal of polarity.

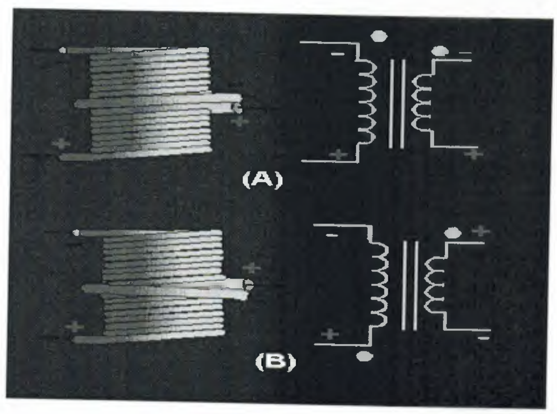


Figure 1.6.9 - Instantaneous polarity depends on direction of winding.

Part (B) of the figure illustrates a transformer in which the primary and secondary are wound in opposite directions. As viewed from above the windings, the primary is wound in a clockwise direction from top to bottom, while the secondary is wound in a counterclockwise direction. Notice that the top leads of the primary and secondary have OPPOSITE polarities. This is indicated by the dots being placed on opposite ends of the transformer symbol. Thus, the polarity of the voltage at the terminals of the secondary of a transformer depends on the direction in which the secondary is wound with respect to the primary.

1.6.13 Coefficient Of Coupling

The coefficient of coupling of a transformer is dependent on the portion of the total flux lines that cuts both primary and secondary windings. Ideally, all the flux lines generated by the primary should cut the secondary, and all the lines of the flux generated by the secondary should cut the primary.

The coefficient of coupling would then be one (unity), and maximum energy would be transferred from the primary to the secondary. Practical power transformers use high-permeability silicon steel cores and close spacing between the windings to provide a high coefficient of coupling. Lines of flux generated by one winding which do not link with the other winding are called LEAKAGE FLUX. Since leakage flux generated by the primary does not cut the secondary, it cannot induce a voltage into the secondary.

The voltage induced into the secondary is therefore less than it would be if the leakage flux did not exist. Since the effect of leakage flux is to lower the voltage induced into the secondary, the effect can be duplicated by assuming an inductor to be connected in series with the primary. This series Leakage Inductance is assumed to drop part of the applied voltage, leaving less voltage across the primary.

1.6.14 Turn And Voltage Ratios

The total voltage induced into the secondary winding of a transformer is determined mainly by the RATIO of the number of turns in the primary to the number of turns in the secondary, and by the amount of voltage applied to the primary. Refer to figure 1.6.10. Part (A) of the figure shows a transformer whose primary consists of ten turns of wire and whose secondary consists of a single turn of wire. You know that as lines of flux generated by the primary expand and collapse, they cut both the ten turns of the primary and the single turn of the secondary. Since the length of the wire in the secondary is approximately the same as the length of the wire in each turn in the primary, EMF induced to the Sesondary will be the same as the EMF the induced in to each turn in the primary.

This means that if the voltage applied to the primary winding is 10 volts, the counter emf in the primary is almost 10 volts. Thus, each turn in the primary will have an induced counter emf of approximately one-tenth of the total applied voltage, or one volt.

Since the same flux lines cut the turns in both the secondary and the primary, each turn will have an emf of one volt induced into it. The transformer in part (A) of figure 1.6.10 has only one turn in the secondary, thus, the emf across the secondary is one volt.

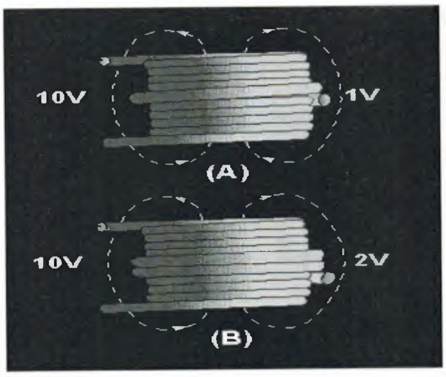


Figure 1.6.10. - Transformer turns and voltage ratios.

has a ten-turn primary and a two-turn secondary. Since the flux induces one volt per turn, the total voltage across the secondary is two volts. Notice that the volts per turn are the same for both primary and secondary windings. Since the counter emf in the primary is equal (or almost) to the applied voltage, a proportion may be set up to express the value of the voltage induced in terms of the voltage applied to the primary and the number of turns in each winding. This proportion also shows the relationship between the number of turns in each winding and the voltage across each winding. This proportion is expressed by the equation:

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

Where:

N_P = number of turns in the primary

E_P = voltage applied to the primary

E_S = voltage induced in the secondary

N_S = number of turns in the secondary

Equation1.6.1

Notice the equation shows that the ratio of secondary voltage to primary voltage is equal to the ratio of secondary turns to primary turns. The equation can be written as:

$$E_P N_S = E_S N_P$$

Equation 1.6.2

The following formulas are derived from the above equation:

Transposing for E_S: $$E_S = \frac{E_S N_P}{N_P}$$

Transposing for E_P: $$E_P = \frac{E_S N_P}{N_S}$$

Equation 1.6.3

If any three of the quantities in the above formulas are known, the fourth quantity can be calculated. Example. A transformer has 200 turns in the primary, 50 turns in the secondary, and 120 volts applied to the primary (E_p).

1.6.15 Effect Of Load

When a load device is connected across the secondary winding of a transformer, current flows through the secondary and the load. The magnetic field produced by the current in the secondary interacts with the magnetic field produced by the current in the primary. This interaction results from the mutual inductance between the primary and secondary windings.

1.6.16 Transformer Losses

Practical power transformers, although highly efficient, are not perfect devices. Small power transformers used in electrical equipment have an 80 to 90 percent efficiency range, while large, commercial powerline transformers may have efficiencies exceeding 98 percent.The total power loss in a transformer is a combination of three types of losses. One loss is due to the dc resistance in the primary and secondary windings. This loss is called COPPER loss or I^2R loss. The two other losses are due to Eddy currents and to Hysteresis in the core of the transformer. Copper loss, eddy-current loss, and hysteresis loss result in undesirable conversion of electrical energy into heat energy.

1.6.16.1 Copper Loss

Whenever current flows in a conductor, power is dissipated in the resistance of the conductor in the form of heat. The amount of power dissipated by the conductor is directly proportional to the resistance of the wire, and to the square of the current through it. The greater the value of either resistance or current, the greater is the power dissipated. The primary and secondary windings of a transformer are usually made of low-resistance copper wire.

The resistance of a given winding is a function of the diameter of the wire and its length. Copper loss can be minimized by using the proper diameter wire. Large diameter wire is required for high-current windings, whereas small diameter wire can be used for low-current windings.

1.6.16.2 Eddy-Current Loss

The core of a transformer is usually constructed of some type of ferromagnetic material because it is a good conductor of magnetic lines of flux. Whenever the primary of an iron-core transformer is energized by an alternating-current source, a fluctuating magnetic field is produced. This magnetic field cuts the conducting core material and induces a voltage into it. The induced voltage causes random currents to flow through the core which dissipates power in the form of heat. These undesirable currents are called Eddy current. To minimize the loss resulting from eddy currents, transformer cores are Laminated. Since the thin, insulated laminations do not provide an easy path for current, eddy-current losses are greatly reduced.

1.6.16.3 Hysteresis Loss

When a magnetic field is passed through a core, the core material becomes magnetized. To become magnetized, the domains within the core must align themselves with the external field. If the direction of the field is reversed, the domains must turn so that their poles are aligned with the new direction of the external field. Power transformers normally operate from either 60 Hz, or 400 Hz alternating current. Each tiny domain must realign itself twice during each cycle, or a total of 120 times a second when 60 Hz alternating current is used. The energy used to turn each domain is dissipated as heat within the iron core. This loss, called Hysteresis loss, can be thought of as resulting from molecular friction. Hysteresis loss can be held to a small value by proper choice of core materials.

1.6.17 Transformer Efficiency

To compute the efficiency of a transformer, the input power to and the output power from the transformer must be known. The input power is equal to the product of the voltage applied to the primary and the current in the primary. The output power is equal to the product of the voltage across the secondary and the current in the secondary. The difference between the input power and the output power represents a power loss. You can calculate the percentage of efficiency of a transformer by using the standard efficiency formula shown below:

$$\text{Efficiency (in \%)} = \frac{P_{out}}{P_{in}} \times 100$$

Where:

P_{out} = total output power delivered to the load

P_{in} = total input power

Equation 1.6.4

1.6.18 Types And Applications Of Transformers

The transformer has many useful applications in an electrical circuit. A brief discussion of some of these applications will help you recognize the importance of the transformer in electricity and electronics.

1.6.19 Power Transformers

Power transformers are used to supply voltages to the various circuits in electrical equipment. These transformers have two or more windings wound on a laminated iron core. The number of windings and the turns per winding depend upon the voltages that the transformer is to supply. Their coefficient of coupling is 0.95 or more.

You can usually distinguish between the high-voltage and low-voltage windings in a power transformer by measuring the resistance. The low-voltage winding usually carries the higher current and therefore has the larger diameter wire. This means that its resistance is less than the resistance of the high-voltage winding, which normally carries less current and therefore may be constructed of smaller diameter wire.

So far you have learned about transformers that have but one secondary winding. The typical power transformer has several secondary windings, each providing a different voltage. The schematic symbol for a typical power-supply transformer is shown in figure 1.6.11. For any given voltage across the primary, the voltage across each of the secondary windings is determined by the number of turns in each secondary.

A winding may be center-tapped like the secondary 350 volt winding shown in the figure. To center tap a winding means to connect a wire to the center of the coil, so that between this center tap and either terminal of the winding there appears one-half of the voltage developed across the entire winding.

Most power transformers have colored leads so that it is easy to distinguish between the various windings to which they are connected.

Carefully examine the figure which also illustrates the color code for a typical power transformer. Usually, red is used to indicate the high-voltage leads, but it is possible for a manufacturer to use some other color(s).

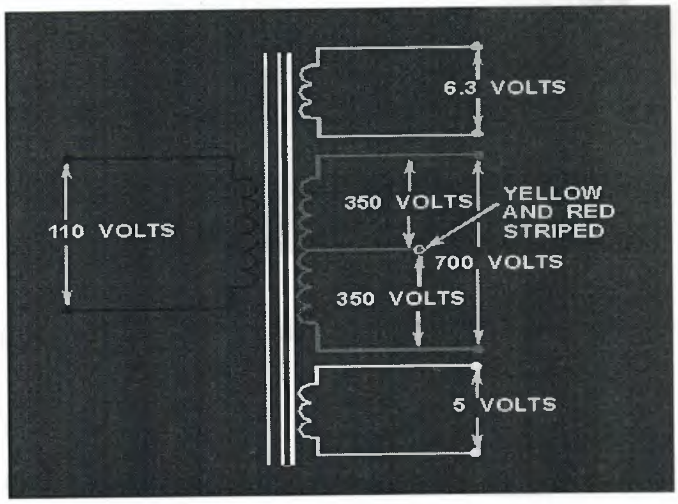


Figure 1.6.11 - Schematic diagram of a typical power transformer.

There are many types of power transformers. They range in size from the huge transformers weighing several tons-used in power substations of commercial power companies-to very small ones weighing as little as a few ounces-used in electronic equipment.

1.6.20 Autotaransformers

It is not necessary in a transformer for the primary and secondary to be separate and distinct windings. Figure 1.6.12 is a schematic diagram of what is known as an Autotransformer.

Note that a single coil of wire is "tapped" to produce what is electrically a primary and secondary winding. The voltage across the secondary winding has the same relationship to the voltage across the primary that it would have if they were two distinct windings.

The movable tap in the secondary is used to select a value of output voltage, either higher or lower than E_p, within the range of the transformer.

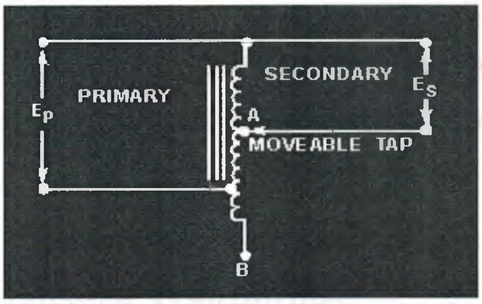


Figure 1.6.12 - Schematic diagram of an autotransformer.

That is, when the tap is at point A, Es is less than Ep; when the tap is at point B, Es is greater than E p.

1.6.21 Audio-Frequency Transformers

Audio-frequency (af) transformers are used in af circuits as coupling devices. Audio-frequency transformers are designed to operate at frequencies in the audio frequency spectrum (generally considered to be 15 Hz to 20kHz).

They consist of a primary and a secondary winding wound on a laminated iron or steel core. Because these transformers are subjected to higher frequencies than are power transformers, special grades of steel such as silicon steel or special alloys of iron that have a very low hysteresis loss must be used for core material.

These transformers usually have a greater number of turns in the secondary than in the primary; common step-up ratios being 1 to 2 or 1 to 4. With audio transformers the impedance of the primary and secondary windings is as important as the ratio of turns, since the transformer selected should have its impedance match the circuits to which it is connected.

1.6.22 Radio -Frequency Transformer

Radio-frequency (rf) transformers are used to couple circuits to which frequencies above 20,000 Hz are applied. The windings are wound on a tube of nonmagnetic material, have a special powdered-iron core, or contain only air as the core material. In standard broadcast radio receivers, they operate in a frequency range of from 530 kHz to 1550 kHz. In a short-wave receiver, rf transformers are subjected to frequencies up to about 20 MHz - in radar, up to and even above 200 MHz.

1.6.23 Impedance-Matching Transformer

For maximum or optimum transfer of power between two circuits, it is necessary for the impedance of one circuit to be matched to that of the other circuit. One common impedance-matching device is the transformer.

To obtain proper matching, you must use a transformer having the correct turns ratio. The number of turns on the primary and secondary windings and the impedance of the transformer have the following mathematical relationship

$$\frac{N_P}{N_S} = \sqrt{\frac{Z_P}{Z_S}}$$

Equation 1.6.5

Because of this ability to match impedances, the impedance-matching transformer is widely used in electronic equipment.

1.7 OP-AMP

1.7.1 Operational Amplfier

Let's define what that component is and look at the parameters of this amazing device. An operational amplifier IC is a solid-state integrated circuit that uses external feedback to control its functions. It is one of the most versatile devices in all of electronics. The term 'op-amp' was originally used to describe a chain of high performance dc amplifiers that was used as a basis for the analog type computers of long ago. The very high gain op-amp IC's our days uses external feedback networks to control responses. The op-amp without any external devices is called 'open-loop' mode, refering actually to the so-called 'ideal' operational amplifier with infinite open-loop gain, input resistance, bandwidth and a zero output resistance.However, in practice no op-amp can meet these ideal characteristics. And as you will see, a little later on, there is no such thing as an ideal op-amp.Since the LM741/NE741/μA741 Op-Amps are the most popular one, this tutorial is direct associated with this particular type. Nowadays the 741 is a frequency compensated device.

1.7.2 Absolute Maximum Parameters:

Maximum means that the op-amp can safely tolerate the maximum ratings as given in the data section of such op-amp without the possibility of destroying it.There ia rating table in figure 1.7.1

Max Ratings	Fig. 2
Supply voltage	±18Volts
Internal Power Dissipation	500mW
Differential Input Voltage	±30Volt
Input voltage	±15Volt
Voltage Offset Null/V-	±0.5Volt
Operating Temperature Range	0°to +70°C
Storage Temperature Range	-65°to +150°C
Lead Temperature, Solder, 60sec.	300°C
Output Short Circuit	Indefinite

Figure1.7.1 LM741 rating table

The μA741 is a high perfor operational amplifier with high open loop gain, internal compensation, high common mode range and exceptional temperature stability. The μA741 is short-circuit protected and allows f nulling of the offset voltage. The μA741 is Manufactured by Fairchild Semiconductor.Supply Voltage (+/-Vs): The maximum voltage (positive and negative) that can be safely used to feed the op-amp.): The maximum power the op-amp is able to dissipate, by specified ambient temperature (500mW @ 80° C).Dissipation (Pd) is the maximum voltage that can be applied across the + and - inputs.Differential Input Voltage (Vid): The maximum input voltage that can be simultaneously applied between both input and ground also referred to as the Input Voltage (Vicmcommon-mode voltage. In general, the maximum voltage is equal to the supply voltage.): This is the ambient temperature range for which the op-amp will operate within the manufacutre's Operating Temperature (Taspecifications. Note that the military grade version(μA741)has a wider temperature range than the commercial, or hobbyist, grade version (μA741C).Output Short-Circuit Duration: This is the amount of time that an op-amp's ouput can be short-circuited to either supply voltage.

1.7.3 Input Parameters

1. Input Offset Voltage (VoiThis is the voltage that must be applied to one of the input pins to give a zero output voltage. Remember, for an ideal op-amp, output offset voltage is zero!)
2. Input Bias Current (IbThis is the average of the currents flowing into both inputs. Ideally, the two input bias currents are equal.)
3. Input Offset Current (IosThis is the difference of the two input bias currents when the output voltage is zero.)
4. Input Voltage Range (VcmThe range of the common-mode input voltage (i.e. the voltage common to both inputs and ground)
5. Input Resistance (ZiThe resistance 'looking-in' at either input with the remaining input grounded.)

1.7.4 Output Parameters

1. Output Resistance (ZoiThe resistance seen 'looking into' the op-amp's output.)

2. Output Short-Circuit Current (IoscThis is the maximum output current that the op-amp can deliver to a load. max)

3. Output Voltage Swing (VoDepending on what the load resistance is, this is the maximum 'peak' output voltage that the op-amp can supply without saturation or clipping).

1.7.5 Dynamic Parameters

1. Open-Loop Voltage Gain: (AolThe output to input voltage ratio of the op-amp without external feedback).

2. Large-Signal Voltage Gain: This is the ratio of the maximum voltage swing to the charge in the input voltage required to drive the ouput from zero to a specified voltage (e.g. 10 volts).

3. Slew Rate (SR) The time rate of change of the ouput voltage with the op-amp circuit having a voltage gain of unity (1.0).

1.7.6 Other Parameters:

1. Supply Current This is the current that the op-amp will draw from the power supply.

2. Common-Mode Rejection Ratio (CMRR) :A measure of the ability of the op-amp' to reject signals that are simultaneously present at both inputs. It is the ratio of the common-mode input voltage to the generated output voltage, usually expressed in decibels (dB).

3. Channel Seperation: Whenever there is more than one op-amp in a single package, like the 747 op-amp, a certain amount of "crosstalk" will be present. That is, a signal applied to the input of one section of a dual op-amp will produce a finite output signal in the remaining section, even though there is no input signal applied to the unused section.

1.7.7 Open-Loop Gain & Frequency

Unlike the ideal op-amp (Fig. 5-1), the op-amp that is used in more realistic circuits today, does not have infinite gain and bandwidth. Look at Open-loop gain in Fig. 4 above, it is graphed for a type 741 op-amp as a function of frequency. At very low frequencies, the open-loop gain of an op-amp is constant, but starts to taper off at about 6Hz or so at a rate of -6dB/octave or -20dB/decade (an octave is a doubling in frequency, and a decade is a ten-fold increase in frequency). This decrease continues until the gain is unity, or 0 dB. The frequency at which the gain is unity is called the unity gain frequency or fT.Maybe the first factor in the consideration of a specific op-amp is its "gain-bandwidth product" or GBP. For the response curve of Fig. 1.7.2, the product of the open-loop gain and frequency is a constant at any point on the curve, so that: GBP = ABWol

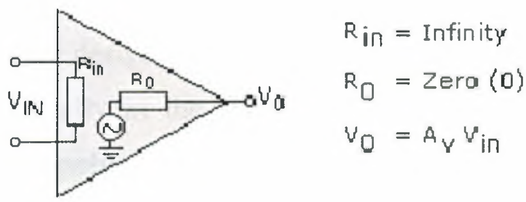


Figure 1.7.2 Ideal amplifier

Graphically, the bandwidth is the point at which the closed-loop gain curve intersects the open-loop curve, as shown in Fig. 1.7.2 for a family of closed-loop gains. For a more practical design situation, the actual design of an op-amp circuit should be approximately 1/10 to 1/20 of the open-loop gain at a given frequency. This ensures that the op-amp will function properly without distortion. As an example, using the response in Fig. 4, the closed-loop gain at 10Khz should be about 5 to 10, since the open-loop gain is 100 (40dB).One additional parameter is worth mentioning, the Transient Response, or rise time is the time that it takes for the output signal to go from 10% to 90% of its final value when a step-function pulse is used as an input signal, and is specified under close-loop condistions. From electronic circuit theory, the rise time is related to the bandwidth of the op-amp by the relation: BW = 0.35 /rise time

1.7.8 Open-Loop Gain

Lets have a look how the 'ideal' amplifier would look like in Fig. 5-1. The search for an ideal amplifier is, of course, a futile exercise. The characteristics of the operational amplifier are good enough, however, to allow us to treat it as ideal. Below are some amplifier properties that make this so. (Please realize that these ratings are next to impossible to achieve).

1. Gain--infinite
2. Input impedance--infinite
3. Output impedance--zero
4. Bandwidth--infinite
5. Voltage out--zero (when voltages into each other are equal)
6. Current entering the amp at either terminal--extremely small

1.7.9 Power Supply

In general op-amps are designed to be powered from a dual or bipolar voltage supply which is typically in the range of +5V to +15Vdc with respect to ground, and another supply voltage of -5V to -15Vdc with respect to ground, as shown in Fig. 7. Although in certain cases an op-amp, like the LM3900 and called a 'Norton Op-Amp', may be powered from a single supply voltage.

1.7.10 Definition of LM 741- pin function

Pin 1 (Offset Null): Since the op-amp is the differential type, input offset voltage must be controlled so as to minimize offset. Offset voltage is nulled by application of a voltage of opposite polarity to the ofset. An offset null-adjustment potentiometer may be used to compensate for offset voltage.

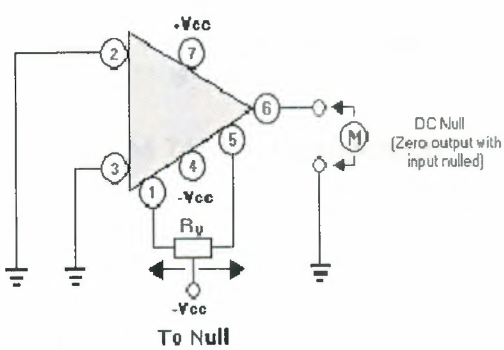


Figure1.7.3 Offset Null

The null-offset potentiometer also compensates for irregularities in the operational amplifier manufacturing process which may cause an offset.

Consequently, the null potentiometer is recommended forcritical applications. See 'Offset Null Adjustment' for method.

Pin 2 (Inverted Input): All input signals at this pin will be inverted at output pin 6. Pins 2 and 3 are very important (obviously) to get the correct input signals or the op amp can not do its work.

Pin 3 (Non-Inverted Input): All input signals at this pin will be processed normally without invertion. The rest is the same as pin 2.

Pin 4 (-V): The V- pin (also referred to as Vss) is the negative supply voltage terminal. Supply-voltage operating range for the 741 is -4.5 volts (minimum) to -18 volts (max), and it is specified for operation between -5 and -15 Vdc. The device will operate essentially the same over this range of voltages without change in timing period. Sensitivity of time interval to supply voltage change is low, typically 0.1% per volt. (Note: Do not confuse the -V with ground).

Pin 5 (Offset Null): See pin 1, and Fig.1.7.3

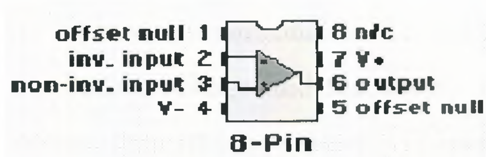


Figure1.7.4 LM 741 Pin Configuraion

Pin 6 (Output): Output signal's polarity will be the oposite of the input's when this signal is applied to the op-amp's inverting input. For example, a sine-wave at the inverting input will output a square-wave in the case of an inverting comparator circuit.

Pin 7 (posV): The V+ pin (also referred to as Vcc) is the positive supply voltage terminal of the 741 Op-Amp IC. Supply-voltage operating range for the 741 is +4.5 volts (minimum) to +18 volts (maximum), and it is specified for operation between +5 and +15 Vdc.

Pin 8 (N/C): The 'N/C' stands for 'Not Connected'. There is no other explanation. There is nothing connected to this pin, it is just there to make it a standard 8-pin package.

1.7.11 Distortion in op-amps

Very often operational amplifiers are used for audio filters. It is important the evaluation of the distortion introduced by the Distortion Multiplication Factor (Kd) described by Oscar Bonello. The behavior of this type of operational amplifiers is important to get low distortion amplifiers and audio consoles for sound recording and reproduction.

1.7.12 Power considerations

Limited output current The output current must obviously be finite. In practice, most op-amps are designed to limit the output current so as not to exceed a specified level — around 25 mA for a type 741 IC op-amp — thus protecting the op-amp and associated circuitry from damage.

Limited dissipated power An opamp is a linear amplifier. It therefore dissipates some power as heat, proportional to the output current, and to the difference between the output voltage and the supply voltage. If the opamp dissipates too much power, then its temperature will increase above some safe limit. The opamp may enter thermal shutdown, or it may be destroyed.

1.7.13 Use in electronics system design

The use of op-amps as circuit blocks is much easier and clearer than specifying all their individual circuit elements (transistors, resistors, etc.), whether the amplifiers used are integrated or discrete. In the first approximation op-amps can be used as if they were ideal differential gain blocks; at a later stage limits can be placed on the acceptable range of parameters for each op-amp.

Circuit design follows the same lines for all electronic circuits. A specification is drawn up governing what the circuit is required to do, with allowable limits. For example, the gain may be required to be 100 times, with a tolerance of 5% but drift of less than 1% in a specified temperature range; the input impedance not less than 1 megohm; etc.A basic circuit is designed, often with the help of circuit modeling (on a computer). Specific commercially available op-amps and other components are then chosen that meet the design criteria within the specified tolerances at acceptable cost. If not all criteria can be met, the specification may need to be modified.A prototype is then built and tested; changes to meet or improve the specification, alter functionality, or reduce the cost, may be made.

1.7.14 Other applications

- audio- and video-frequency pre-amplifiers and buffers
- voltage comparators
- differential amplifiers
- differentiators and integrators
- filters
- precision rectifiers
- precision peak detectors
- voltage and current regulators
- analog calculators
- analog-to-digital converters
- digital-to-analog converter
- voltage clamps

oscillators and waveform generators

2.POWER SUPPLY

2.1 Basic Power Supply

The basic power supply in Figure 2.1 shows the block diagram of the basic power supply. Most power supplies are made up of four basic sections: a Transformer, a Rectifier, a Filter, and a Rgulator.

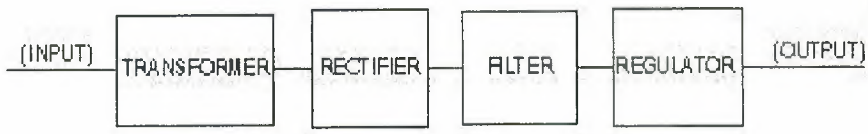


Figure 2-1.—Block diagram of a basic power supply

As you can see, the first section is the Transformer. The transformer serves two primary purposes:

(1) to step up or step down the input line voltage to the desired level and
(2) to couple this voltage to the rectifier section.

The Rectifier section converts the ac signal to a pulsating dc voltage. However, you will see later in this chapter that the pulsating dc voltage is not desirable. For this reason, a Filter section is used to convert the pulsating dc voltage to filtered dc voltage. The final section, the Regulator, does just what the name implies. It maintains the output of the power supply at a constant level in spite of large changes in load current or in input line voltage. Depending upon the design of the equipment, the output of the regulator will maintain a constant dc voltage within certain limits. Now that you know what each section does, let's trace a signal through the power supply and see what changes are made to the input signal. In figure 2.2, the input signal of 120 volts ac is applied to the primary of the transformer, which has a turns ratio of 1:3. We can calculate the output by multiplying the input voltage by the ratio of turns in the secondary winding to turns in the primary winding. Therefore, the output voltage of our example is: 120 volts ac × 3, or 360 volts ac. Depending on the type of rectifier used (full-wave or half-wave), the output from the rectifier will be a portion of the input. Figure 2.2 shows the ripple waveform associated with a full-wave rectifier.

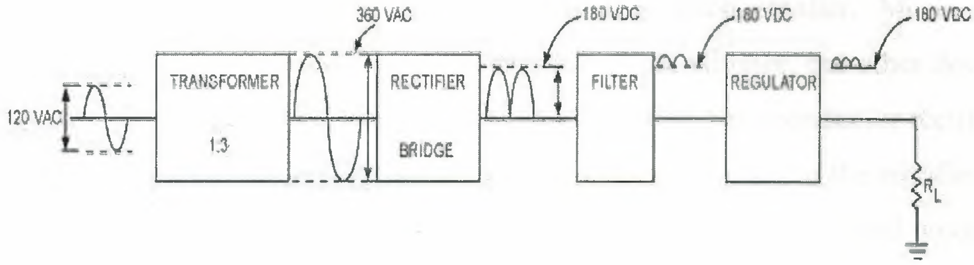


Figure2.2 The block diagram of ripple wave form

The filter section contains a network of resistors, capacitors, or inductors that controls the rise and fall time of the varying signal so that the signal remains at a more constant dc level. You will see this more clearly in the discussion of the actual filter circuits. You can see that the output of the filter is at a 180-volt dc level with an ac RIPPLE voltage riding on it. (Ripple voltage is a small ac voltage riding at some dc voltage level. Normally, ripple voltage is an unwanted ac voltage created by the filter section of a power supply.) This signal now goes to the regulator where it will be maintained at approximately 180 volts dc to the load.Block diagram of a power supply in figure 2.2

2.2 Rectifier

A nonlinear circuit component that allows more current to flow in one direction than in the other. An ideal rectifier is one that allows current to flow in one (forward) direction unimpeded but allows no current to flow in the other (reverse) direction. Thus, ideal rectification might be thought of as a switching action, with the switch closed for current in one direction and open for current in the other direction. Rectifiers are used primarily for the conversion of alternating current (ac) to direct current (dc). See also Electronic power supply. A variety of rectifier elements are in use. The vacuum-tube rectifier can efficiently provide moderate power. Its resistance to current flow in the reverse direction is essentially infinite because the tube does not conduct when its plate is negative with respect to its cathode. In the forward direction, its resistance is small and almost constant. Gas tubes, used primarily for higher power requirements, also have a high resistance in the reverse direction. The semiconductor rectifier has the advantage of not requiring a filament or heater supply. This type of rectifier has approximately constant forward and reverse resistances, with the forward resistance being much smaller. Mechanical rectifiers can also be used. The most common is the vibrator, but other devices are also used. See also Gas tube; Mechanical rectifier; Semiconductor rectifier. If the average current is subtracted from the current flowing in the rectifier, an alternating current results. This ripple current flowing through a load produces a ripple voltage which is often undesirable. Filter and regulator circuits are used to reduce it to as low a value as is required. See also Electric filter;

2.3 Voltage regulator

A half-wave rectifier circuit is shown in Fig.ure 2.3 The rectifier, a diode, is practically ideal. The ac input is applied to the primary of the transformer; secondary voltage e supplies the rectifier and load resistor RL. The rectifying action of the diode is shown in Fig. 2.3, in which the current i of the rectifier is plotted against the voltage ed across the diode. The applied sinusoidal voltage from the transformer secondary is shown under the voltage axis; the resulting current i flowing through the diode is shown at the right to be half-sine loops.

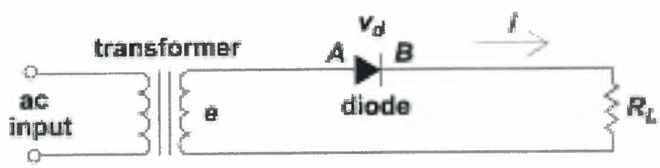
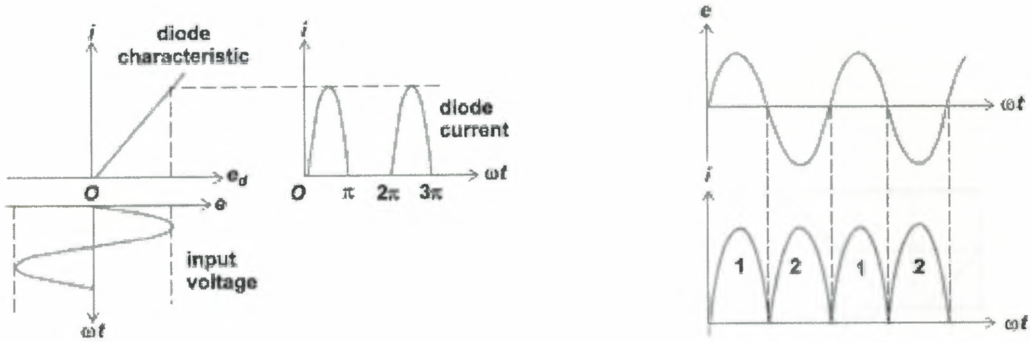


Figure2.3 Half wave rectifier

Half-wave diode rectifier. Vd = voltage across diode. Ideal diode allows current i to flow only in forward direction from A to B. Rectifying action of half-wave diode rectifier. t = time; ω = angular frequency of input voltage. A full-wave rectifier circuit uses two separate diodes. The resulting current wave shape is shown in Fig. 2.4-a and b. A more continuous flow of direct current is produced because the first diode conducts for the positive half-cycle and the second diode conducts for the negative half-cycle.



a-Applied voltage and output current **b**-Input and Output wave form

Figure2.4 Wave form of Full wave rstifier

When high dc power is required by an electronic circuit, a polyphase rectifier circuit may be used. It is also desirable when expensive filters must be used. This is particularly true of power supplies for the final radio-frequency and audiofrequency stages of large radio and television transmitters.Applied voltage and output current of full-wave rectifier.

2.4 Rectifier Systems

Component of an electric circuit used to change alternating current to direct current. Rectifiers are made in various forms, all operating on the principle that current passes through them freely in one direction but only slightly or not at all in the opposite direction. One early type of rectifier was the diode electron tube. Semiconductor rectifiers are essentially diodes made large enough to safely dissipate the heat caused by current flow. For heavy currents, they are often equipped with cooling fins or heat sinks. Rectifiers are commonly used in power supplies for electronics. The other uses a synchronized vibrating reed to change single-phase alternating current into pulsating direct current. Both have been largely superseded by solid-state devices.

A rectifier is an electrical device that converts alternating current to direct current, a process known as rectification. Rectifiers are used as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components. A circuit which performs the opposite function (converting DC to AC) is known as an inverter.You can see the output wave form of full wave rectifier system in 2.5

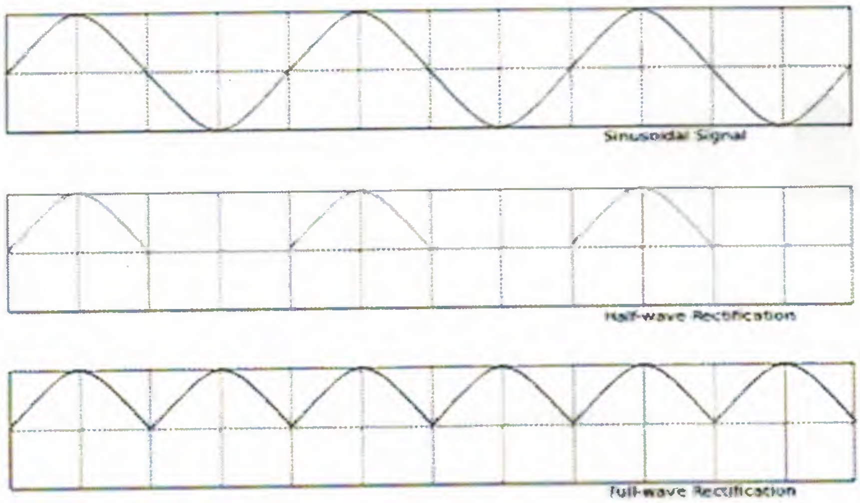


Figure2.5 AC, half-wave and full wave rectified signals

When only one diode is used to rectify AC (by blocking the negative or positive portion of the waveform), the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting AC to DC than is possible with only one diode. Before the development of silicon semiconductor rectifiers, vacuum tube diodes and copper oxide or selenium rectifier stacks were used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulfide) to serve as a point-contact rectifier or "crystal detector". In gas heating systems flame rectification can be used to detect a flame. Two metal electrodes in the outer layer of the flame provide a current path and rectification of an applied alternating voltage, but only while the flame is present.

2.5 Half-Wave Rectification

A half wave rectifier is a special case of a clipper. In half wave rectification, either the positive or negative half of the AC wave is passed easily, while the other half is blocked, depending on the polarity of the rectifier.You can see the circuit and output wave of half rectifier in figure 2.6

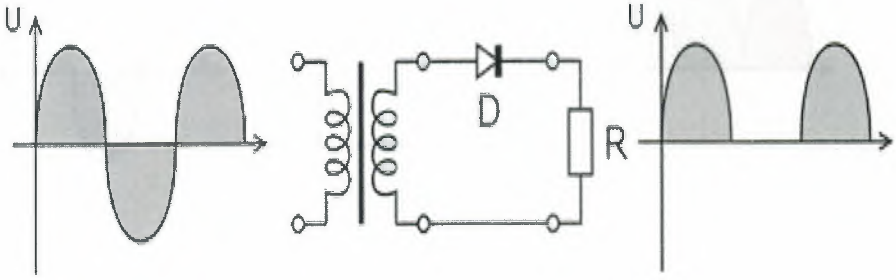


Figure2.6 Half wave rectification

Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half-wave rectification can be achieved with a single diode in a one phase supply.

2.6 Full-Wave Rectification

Full-wave rectification converts both polarities of the input waveform to DC(direct current), and is more efficient. However, in a circuit with a non-center tapped transformer, four diodes are required instead of the one needed for half-wave rectification.

This is due to each output polarity requiring two rectifiers each, for example, one for when AC terminal 'X' is positive and one for when AC terminal 'Y' is positive.The other DC output requires exactly the same, resulting in four individual junctions (See semiconductors, diode). Four rectifiers arranged this way are called a diode bridge or bridge rectifier:

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output by reversing the negative (or positive) portions of the alternating current waveform. The positive (or negative) portions thus combine with the reversed negative (or positive) portions to produce an entirely positive (or negative) voltage/current waveform.

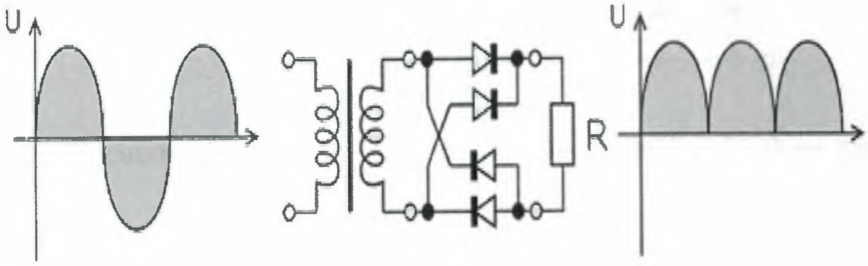


Figure 2.7 Full wave rectification(anodes-to-anode or cathode-to-cathode)

For single-phase AC, if the transformer is center-tapped, then two diodes back-to-back (i.e. anodes-to-anode or cathode-to-cathode) form a full-wave rectifier.

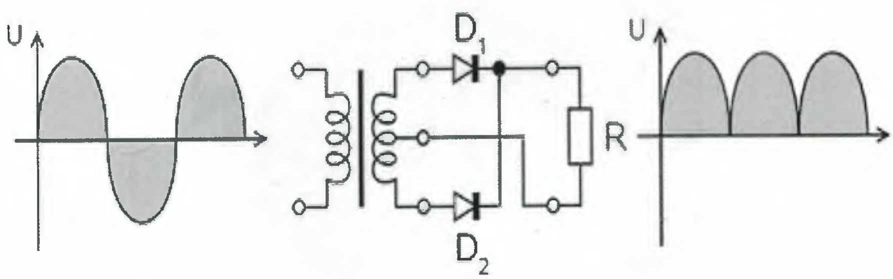
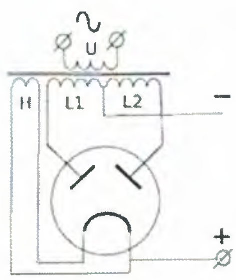


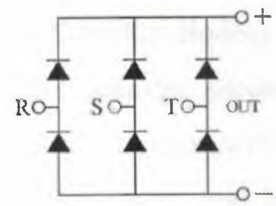
Figure2.8 Full-wave rectifier, with vacuum tube having two anodes.

There are two types of full wave rectifcation circuts and output wave form in figure 2.7and 2.8

2.7 Three-Phase Bridge Rectifier

For three-phase AC, six diodes are used. Typically there are three pairs of diodes, each pair, though, is not the same kind of double diode that would be used for a full wave single-phase rectifier. Instead the pairs are in series (anode to cathode). A very common vacuum tube rectifier configuration contained one cathode and twin anodes inside a single envelope in figure 2.9-a





a-Vacuum tube rectifier **b**-diode rectifier for three phase

Figure2.9 Three phase rectifiers

in this way, the two diodes required only one vacuum tube. The 5U4 and 5Y3 were popular examples of this configuration.Typically, commercially available double diodes have four terminals so the user can configure them as single-phase split supply use, for half a bridge, or for three-phase use in figure 2.9-b.

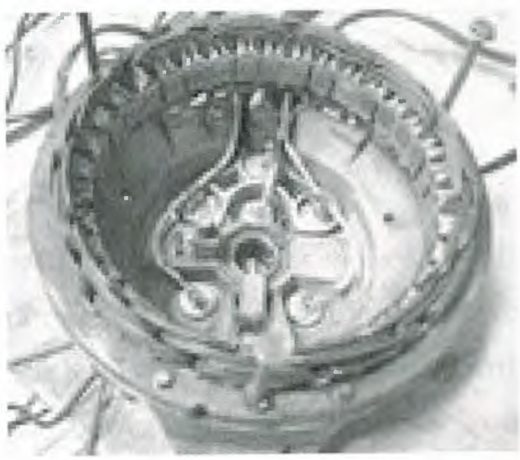


Figure2.10 Disassembled automobile alternator

Disassembled automobile alternator, showing the six diodes that comprise a full-wave three-phase bridge rectifier in figure 2.10. Most devices that generate alternating current (such devices are called alternators) generate three-phase AC. For example, an automobile alternator has six diodes inside it to function as a full-wave rectifier for battery charging applications.

2.8 Peak Loss

An aspect of most rectification is a loss from peak input voltage to the peak output voltage, caused by the threshold voltage of the diodes (around 0.7 V for ordinary silicon p-n-junction diodes and 0.1 V for Schottky diodes). Half-wave rectification and full-wave rectification using two separate secondaries will have a peak voltage loss of one diode drop. Bridge rectification will have a loss of two diode drops. This may represent significant power loss in very low voltage supplies. In addition, the diodes will not conduct below this voltage, so the circuit is only passing current through for a portion of each half-cycle, causing short segments of zero voltage to appear between each "hump".

2.9 Rectifier Output Smoothing

While half- and full-wave rectification suffice to deliver a form of DC output, neither produces constant-voltage DC. In order to produce steady DC from a rectified AC supply, a smoothing circuit, sometimes called a **filter**[1], is required. In its simplest form this can be what is known as a **reservoir capacitor**, Filter capacitor or smoothing capacitor, placed at the DC output of the rectifier. There will still remain an amount of AC **ripple** voltage where the voltage is not completely smoothed.

Sizing of the capacitor represents a tradeoff. For a given load, a larger capacitor will reduce ripple but will cost more and will create higher peak currents in the transformer secondary and in the supply feeding it. In extreme cases where many rectifiers are loaded onto a power distribution circuit, it may prove difficult for the power distribution authority to maintain a correctly shaped sinusoidal voltage curve.

For a given tolerable ripple the required capacitor size is proportional to the load current and inversely proportional to the supply frequency and the number of output peaks of the rectifier per input cycle. The load current and the supply frequency are generally outside the control of the designer of the rectifier system but the number of peaks per input cycle can be affected by the choice of rectifier design.

A half-wave rectifier will only give one peak per cycle and for this and other reasons is only used in very small power supplies. A full wave rectifier achieves two peaks per cycle and this is the best that can be done with single-phase input. For three-phase inputs a three-phase bridge will give six peaks per cycle and even higher numbers of peaks can be achieved by using transformer networks placed before the rectifier to convert to a higher phase order.

To further reduce this ripple, a capacitor-input filter can be used. This complements the reservoir capacitor with a choke and a second filter capacitor, so that a steadier DC output can be obtained across the terminals of the filter capacitor. The choke presents a high impedance to the ripple current.

If the DC load is very demanding of a smooth supply voltage, a voltage regulator will be used either instead of or in addition to the capacitor-input filter, both to remove the last of the ripple and to deal with variations in supply and load characteristics.

2.10 Voltage-Doubling Rectifiers

The simple half wave rectifier can be built in two versions with the diode pointing in opposite directions, one version connects the negative terminal of the output direct to the AC supply and the other connects the positive terminal of the output direct to the AC supply.By combining both of these with separate output smoothing it is possible to get an output voltage of nearly double the peak AC input voltage. This also provides a tap in the middle which allows use of such a circuit as a split rail supply.

A variant of this is to use two capacitors in series for the output smoothing on a bridge rectifier then place a switch between the midpoint of those capacitors and one of the AC input terminals. With the switch open this circuit will act like a normal bridge rectifier with it closed it will act like a voltage doubling rectifier. In other words this makes it easy to derive a voltage of roughly 320V (+/- around 15%) DC from any mains supply in the world, this can then be fed into a relatively simple switched mode power supply.

2.11 High-Power Rectification

Vacuum tubes, metal oxide rectifier stacks and semiconductor diodes are useful in the range of milliamperes to several thousand amperes of current in a single device.Some interesting electromechanical solutions have been devised and were used before the advent of electron devices. For example, to convert AC current into DC current in electric locomotives, a synchronous rectifier may be used. It consists of a synchronous motor driving a set of heavy-duty electrical contacts. The motor spins in time with the AC frequency and periodically reverses the connections to the load just when the sinusoidal current goes through a zero-crossing. The contacts do not have to *switch* a large current, but they need to be able to *carry* a large current to supply the locomotive's DC traction motors. In the past, the vibrators used in battery-to-high-voltage-DC power supplies often contained a second set of contacts that performed synchronous mechanical rectification of the stepped-up voltage.

Another type of rectifier used in high-voltage direct current power transmission systems and industrial processing between about 1909 to 1975 is a mercury arc rectifier or mercury arc valve. The device is enclosed in a bulbous glass vessel or large metal tub. One electrode, the cathode, is submerged in a pool of liquid mercury at the bottom of the vessel and one or more high purity graphite electrodes, called anodes, are suspended above the pool. There may be several auxiliary electrodes to aid in starting and maintaining the arc. When an electric arc is established between the cathode pool and suspended anodes, a stream of electrons flows from the cathode to the anodes through the ionized mercury, but not the other way. These devices can be used at power levels of hundreds of kilowatts, and may be built to handle one to six phases of AC current. Mercury arc rectifiers have largely been replaced by silicon semiconductor rectifiers from the mid 1970s onward. The most powerful mercury arc rectifiers ever built were installed in the Manitoba Hydro Nelson River Bipole HVDC project, with a combined rating of more than one million kilowatts and 450,000 volts.

The General Electric Tungar rectifier was an argon gas-filled electron tube device with a tungsten filament cathode and a carbon button anode. It was useful for battery chargers and similar applications from the 1920's until low-cost solid state rectifers supplanted it. These were made up to a few hundred volts and a few amperes rating, and in some sizes strongly resembled an incandescent lamp with an additional electrode.

Another type of rectifier, a motor-generator set or the similar rotary converter, is not a rectifier in the strict sense. Here, an AC motor is mechanically coupled to a DC generator. The DC generator produces a multiphase alternating current in its windings, but a commutator is used to convert the alternating currents into a direct current output; or a homopolar generator directly produces direct current without need for a commutator. Such devices are useful for producing thousands of amperes of direct current at tens to hundreds of volts.

2.12 AC voltage stabilizers

A voltage stabilizer is a type of household mains regulator which uses a continuously variable autotransformer to maintain an AC output that is as close to the standard or normal mains voltage as possible, under conditions of fluctuation. It uses a servomechanism (or negative feedback) to control the position of the tap (or wiper) of the autotransformer, usually with a motor. An increase in the mains voltage causes the output to increase, which in turn causes the tap (or wiper) to move in the direction that reduces the output towards the nominal voltage.

An alternative method is the use of a type of saturating transformer called a ferroresonant transformer or constant-voltage transformer. These transformers use a tank circuit composed of a high-voltage resonant winding and a capacitor to produce a nearly constant average output with a varying input. The ferroresonant approach is attractive due to its lack of active components, relying on the square loop saturation characteristics of the tank circuit to absorb variations in average input voltage. Older designs of ferroresonant transformers had an output with high harmonic content, leading to a distorted output waveform. Modern devices are used to construct a perfect sinewave. The ferroresonant action is a flux limiter rather than a voltage regulator, but with a fixed supply frequency it can maintain an almost constant average output voltage even as the input voltage varies widely.

The ferro resonant transformers, which are also know as Constant Voltage Transformers (CVTs) or ferros are also a good surge suppressors, and it provides high isolation and an inherent shortcircuit protections.
It can operate with an input voltage range as wide as ±40% or more of the nominal voltage. Output power factor remains in the range of 0.96 or higher from half to full load. Because it regenerates an output voltage waveform, output distortion, which is typically less than 4%, is independent of any input voltage distortion, including notching. Efficiency at full load is typically in the range of 89% to 93%. However, at low loads, efficiency can drop below 60% and no load losses can be as high as 20%.

The current-limiting capability also becomes a handicap when a CVT is used in an application with moderate to high inrush current like motors, transformers or magnets. In this case, the CVT has to be sized to accommodate the peak current, thus forcing it to run at low loads and poor efficiency.Minimum maintenance is required beyond annual replacement of failed capacitors. Redundant capacitors built into the units allow several capacitors to fail between inspections without any noticeable effect to the device's performance.

Output voltage varies about 1.2% for every 1% change in supply frequency. For example, a 2-Hz change in generator frequency, which is very large, results in an output voltage change of only 4%, which has little effect for most loads. It accepts 100% single-phase switch-mode power supply loading without any requirement for derating, including all neutral components. Input current distortion remains less than 8% THD even when supplying nonlinear loads with more than 100% current THD. One of the draw back of CVT(constant voltage transformer) is its higher size and high audible humming sound.

2.13 DC voltage stabilizers

Many simple DC power supplies regulate the voltage using a shunt regulator such as a zener diode, avalanche breakdown diode, or voltage regulator tube. Each of these devices begins conducting at a specified voltage and will conduct as much current as required to hold its terminal voltage to that specified voltage. The power supply is designed to only supply a maximum amount of current that is within the safe operating capability of the shunt regulating device (commonly, by using a series resistor). In shunt regulators, the voltage reference is also the regulating device. If the stabilizer must provide more power, the shunt regulator output is only used to provide the standard voltage reference for the electronic device, known as the voltage stabilizer. The voltage stabilizer is the electronic device, able to deliver much larger currents on demand.

2.14 Active regulators

Because they (essentially) dump the excess current not needed by the load, shunt regulators are inefficient and only used for low-power loads. When more power must be supplied, more sophisticated circuits are used. In general, these can be divided into several classes:

- Linear regulators
- Switching regulators
- SCR regulators
- Comparing linear vs. switching regulators

2.14.1 Linear regulators

Linear regulators are based on devices that operate in their linear region (in contrast, a switching regulator is based on a device forced to act as an on/off switch). In the past, one or more vacuum tubes were commonly used as the variable resistance. Modern designs use one or more transistors instead. Linear designs have the advantage of very "clean" output with little noise introduced into their DC output, but are less efficient and unable to step-up or invert the input voltage like switched supplies.

Entire linear regulators are available as integrated circuits. These chips come in either fixed or adjustable voltage types.

2.14.2 Switching regulators

Switching regulators rapidly switch a series device on and off. The duty cycle of the switch sets how much charge is transferred to the load. This is controlled by a similar feedback mechanism as in a linear regulator. Because the series element is either fully conducting, or switched off, it dissipates almost no power; this is what gives the switching design its efficiency. Switching regulators are also able to generate output voltages which are higher than the input, or of opposite polarity — something not possible with a linear design.

Like linear regulators, nearly-complete switching regulators are also available as integrated circuits. Unlike linear regulators, these usually require one external component: an inductor that acts as the energy storage element. (Large-valued inductors tend to be physically large relative to almost all other kinds of componentry, so they are rarely fabricated within integrated circuits and IC regulators — with some exceptions.[1])

2.14.3 Comparing linear vs. switching regulators

The two types of regulators have different advantages. Linear regulators are best when low output noise is required . Linear regulators are best when a fast response to input and output disturbances is required. At low levels of power, linear regulators are cheaper. Switching regulators are best when power efficiency is critical (such as in portable computers).Switching regulators are required when the only power supply is a DC voltage, and a higher output voltage is required. At high levels of power (above a few watts), switching regulators are cheaper.

2.14.4 SCR regulators

Regulators powered from AC power circuits can use silicon controlled rectifiers (SCRs) as the series device. Whenever the output voltage is below the desired value, the SCR is triggered, allowing electricity to flow into the load until the AC mains voltage passes through zero (ending the half cycle). SCR regulators have the advantages of being both very efficient and very simple, but because they can not terminate an on-going half cycle of conduction, they are not capable of very accurate voltage regulation in response to rapidly-changing loads.

2.15 Applications

A rectifier diode (silicon controlled rectifier in figure 2.11) and associated mounting hardware. The heavy threaded stud helps remove heat.

Figure2.11 Rectifier Diode

The primary application of rectifiers is to derive usable DC power from an AC supply. Virtually all electronics requires a DC supply but mains power is AC so rectifiers find uses inside the power supplies of virtually all electronic equipment.Converting DC voltage from one level to another is much more complicated. One method of such DC-to-DC conversion is to first convert to AC (using a device called an inverter), then use a transformer to change the voltage, and finally rectify it back to DC. Rectifiers also find a use in detection of amplitude modulated radio signals. The signal may or may not be amplified before detection but if unamplified a very low voltage drop diode must be used. When using a rectifier for demodulation the capacitor and load resistance must be carefully matched. Too low a capacitance will result in the high frequency carrier passing to the output and too high will result in the capacitor just charging and staying charged. Rectifiers are also used to supply polarised voltage for welding.

3.PCB METHODE

3.1 How Does Makes PCB

Before the schematics is converted into the PCB, the following steps have to be made:

- Creating a component and track layout for the PCB, based on the schematics, component sizes and other factors.
- Transferring the layout scheme onto PCB material. Track's places are protected by the paint.
- Chemical removal of all copper, which does not belong to tracks and contact pads.
- Drilling the holes.
- Soldering components into fresh PCB

Result of the first step is so called layout scheme, which represents the layout of components onto the PCB. This step is one of the most complicated, but it determines, how good the board will be. The next step gives the 'painted' board, where future track and pads are drawn with the water- and acid-resistive paint. After the third and fourth step, you will have the board, which is ready to insert components and solder them into.

3.3 Creating Layout Scheme

Drew the complete schematics, which include all the components which are to be placed onto the board. To simplify the viewing, avoid using 'grounding' symbols, draw all wires. Also for convenience ground network should be at the bottom of schematics, and the power line - at the top

Then sizes of particular components should be determined according to what you have. Typically, there are a lot of similar components (resistor, capacitors, low-power-transistors etc.), and a small number of unique, usually big ones (transformers, high-power transistors and diodes etc.). The bigger is the ratio between smallest and largest component, the difficult is layout creation.

After all of the above the creation process itself starts. First of all, it should be decided, whether you need double- or single- sided PCB. Most analog circuits can be made using one-sided PCBs, but for digital boards double-sided PCB is usually required.There is a layout scheme as example

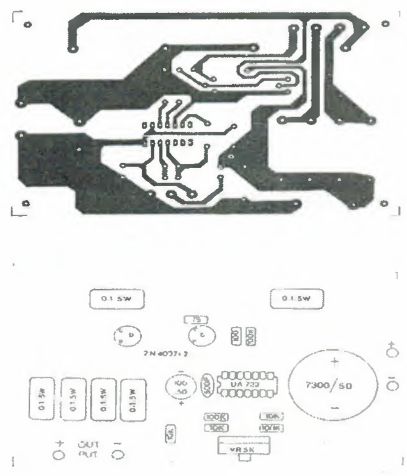


Figure 3.1 Layout scheme

There are many words said and written about the strategy and rules of placing components and routing, but i would like to outline the following topics, which help to make analog PCBs with reasonable quality using minimal amount of time and efforts.

- Try to keep ground track near the bottom of PCB (looking from track side), keep the power track at the top
- Try to make layout similar to the schematics, do not try to make complicated 'rearrangements' without strong necessity.
- It is better to create the layout in order, how the signal passes the stages: In an amplifier, for example, first stage should be processed first.
- At the beginning, set the approximate width of the board and then try to fill it, moving from right to the left.
- Do not forget to make the pads for external connections. If some net has more than one external connection, make the pad for each one.

- If the board has some large components, think about their placement first.
- In RF boards, follow the necessity of proximity of somencomponents, as well as the largest possible distance between others (this is derived from schematics)
- If the schematics is not straightforward and has many feedbacks and other difficulties, do not process these wires last - you probably will not have place for it.
- There is nothing bad, if your final board will have some insulated wires at the component side, which serve instead of unroutable tracks.
- In double-sided PCB, try to minimize the number of tracks on the component side - they are more difficult to solder. Also, try to avoid using of excessive number of vias.
- Do not make track's layout to dense - minimal width should be at least 0.7-1 mm. Thin tracks are very difficult to paint, and sometimes they are removed with the rest of copper during chemical dissolving.

For digital boards, another technique is used: according to the proximity in the principal circuit you place ICs in the regular grid-order, making several rows and columns. The nearest interconnections should be kept in mind - for example, if you have a counter and decoder connected to each other by 4-bit bus, chips should be placed to provide this connection by the easiest way. After rather simple placing, you route the board using double-side technique.

Layout scheme drawing is performed on gridded paper by a erasable pencil. If you feel, that the routing goes by wrong way, you may erase the wrong part and start again. Holes are presented as points, and tracks - as lines. The scheme may not reflect the actual shape of tracks, it must represent just a order of connectivity. On double-sided PCB, three color pencils are to be used - two for each side and the last for vias. After you are done, you can determine physical sizes of PCB (DO NOT try to save material on 'cutting edges' - 3-5 mm from each side of PCB should be left blank) and cut your material to this size.

3.4 Transferring layout to the PCB

After you have a layout scheme, the process of PCB production becomes quite straightforward. Transferring layout means only transferring of holes positions, because the tracks you will paint, looking on the free space and according to your art taste. Holes positions can be transferred easily: you take something like a hard needle, turn the paper with layout over the cut PCB material, aligning physical board margins with the scheme. Then you puncture the paper in places of holes with some force (a small hummer may be used). The result is, that positions of holes are transferred onto board as needle traces, which help with subsequent drilling.

If it is double-sided PCB, you have to drill the holes first, otherwise you can wait with it. Then, board should cleaned mechanically and chemically (acetone, alcohol etc.) to provide clean and fat-free surface (otherwise, paint will not have a good adhesion to the foil).

After it, you take your favorite paint and your favorite drawing instrument and draw pads and tracks Then you can connect all the pads according to the layout scheme by the tracks. After everything is done, board have to be checked in order to eliminate unnecessary paint leaks. Also, it is the good practice to compare the board with original schematics, because it is the last time you may introduce some corrections. After the paint is dry, you may go to the next step.

3.5 Chemical Removal of Unused Copper Foil

Classical and widely used method for dissolving of unprotected (by the paint) copper foil is using of ferric chloride (FeCl3) solution. The reaction goes fast, allowing to complete the whole process in less than one hour. But ferric chloride is rather expensive and sometimes hard to get, so my favorite method is using another solution. I use mixture of copper sulfate pentahydrate (CuSO4x5H2O) with ordinary salt (NaCl). When dissolved in minimal amount of water, this mixture forms a deep-green solution, which is capable to dissolve metallic copper.

Copper sulfate can be bought in an agriculture store for a quite reasonable price, because it is widely used for some purposes in plant growing (at least here, in Russia).Unfortunately, the process goes not so fast, and typically 8-20 hours is required to process a PCB at room temperature. At 60-80 C, reaction goes much faster, but i still prefer to set it up over the night and do not worry about overheating and problem caused by it. At the end, reaction may slow down, and some heating with probably addition of reagents will not interfere.

After all unprotected copper is removed, you take the board off, wash it rigorously to remove chemicals, remove the paint with appropriate solvent, clean the copper surface again. If holes have not been drilled before, now it's right time to do it.

After all procedures described, your PCB is ready to be filled by components. All equipment i describe on my pages is made using such PCB's. The total procedure (except chemical treatment) for typical PCB can be made in several hours, and after the night your board is ready to solder!

4.ABOUT PROJECT

4.1 About Layout of Project Circuit

A relatively simple step. I just use my cleaning block and rub it over the entire board until it is shinning a nice copper colour (as illustrated). If you want to clean the board further, a good cleaning agent will help. Above shows in figure 4.1, a copper board that has been sitting away for quite some time left, the image on the right shows the same board after a quick bit of cleaning with the cleaning block (also shown).You can see all of the picture as big size in appendix B

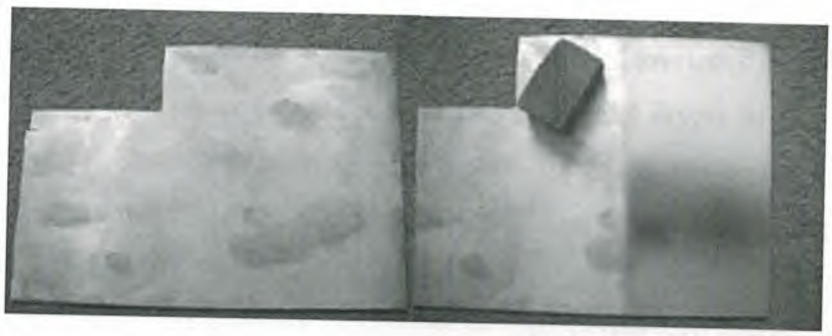


Figure 4.1. Copper plate cleaning

I have found the drawing of layout from content of project as ready. I didn't need to design a new layout scheme I prepare my circuit with the resistive pen.

Figure 4.2. Pcb making methode

Firstly I got the copy of circuit layout from printer. I combined the layout paper with copper plate .

I used the sticky tape .You can see the Figure 4.2 . You can see all of pciture as big size in appendix B.In this case, you will need to reserve it for drawing the track layout on the back of the board..

With this reversed image, its simply a case of drawing this image onto the back of the board with the etch resistant pen. Make sure that as you are drawing the image that you avoid leaning on the board with your wrists and fingers as this will cause the copper to quickly oxidise which will cause problems when itcomes to etching. Keep shaking the pen as you use it too to get the best ink solution when you draw on the board. With my particular pen, ink is not released until you press hard on the tip, where ink flows out when this happens. When performing this, do it on an area of low track density on on a separate piece of paper (do make sure this is several layers as the ink will soak through). Once you have all you tracks drawn on the board, check to make sure that the ink does not bridge two tracks in any way and that you layout is satisfactory. To correct small mistakes. Larger mistakes will need to be corrected by use of thinners or something similar that will remove the pen. Leave to dry for about an hour after you have finished.

Figure 4.3. Etching

Now you are about to etch the board, if you have not done so before, prepare the etchant as mentioned earlier or if it is already made and you are reusing etchant from before, give it a quick shake or stir (naturally the container it is in must be tight) and transfer it into a container that you will use to etch the board in.

You can see the etching time in figure 4.3 and you can see tall of the figures as big size in appendix B After etching, the etchant can be reused quite a few times, you will notice it will start at a very orange/brown colour and then turn to a blue/green colour as the ferrite chloride is replaced by copper chloride. You will also notice that some iron will start to lay at the bottom of the solution after time too, an understanding of simple chemistry tells you why. That is the copper is more reactive then the iron (ferrite) and the chlorine reacts with the more reactive metal, that being copper. Like any chemical reaction, you can speed up the process by applying more heat and stirring, hence your etching will go faster

After the etching process is complete (this may take over 30 minutes), all copper that was not protected by the etch resistant ink should have been removed. If this is the case, you can now remove the board (with rubber gloves on) and begin the cleaning process.

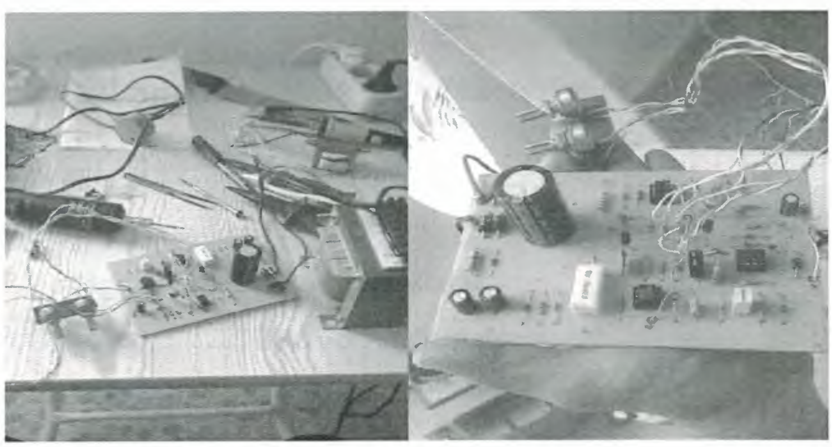


Figure 4.4. montage of components view

There will still be copper etchant left on the board when you remove this, do your best of remove as much as possible with tissues/kitchen roll then use fast flowing water to remove the rest. You can use some thinners to remove the pen from the board and lots of water and this is quick and easy. Once the board is clean, dry it and examine it. If there are any small defeats, excess copper can be removed by using a sharp knife to break any wanted contacts. If you find there is not contact where there should be, then you can try to use solder or small wire to bridge the gap.

Finally I checked my soldering and board construction and I checked whether all my components are in the right way.There are my circuit montage pictures in figure 4 .4 You can see all of the picture as big size in Appendix B

4.2 General Description

This is a high quality power supply with a continuously variable stabilised output adjustable at any value between 0 and 30VDC. The circuit also incorporates an electronic output current limiter that effectively controls the output current from a few milliamperes (2 mA) to the maximum output of three amperes that the circuit can deliver. This feature makes this power supply indispensable in the experimenters laboratory as it is possible to limit the current to the typical maximum that a circuit under test may require, and power it up then, without any fear that it may be damaged if something goes wrong. There is also a visual indication that the current limiter is in operation so that you can see at a glance that your circuit is exceeding or not its preset limits.

4.3 Technical Specifications – Characteristics

- Input Voltage: .... 24 VAC
- Input Current: .... 3 A (max)
- Output Voltage: .... 0-30 V adjustable
- Output Current: .... 2 mA-3 A adjustable
- Output Voltage Ripple: .... 0.01 % maximum

4.4 Features

- Reduced dimensions, easy construction, simple operation.
- Output voltage easily adjustable.
- Output current limiting with visual indication.
- Complete protection of the supplied device against over loads and malfunction.

4.5 How it Works

There are circuit scheme of power supply in figure 4.5. To start with, there is a step-down mains transformer with a secondary winding rated at 24 V/3 A, which is connected across the input points of the circuit at pins 1 & 2. (the quality of the supplies output will be directly proportional to the quality of the transformer). The AC voltage of the transformers secondary winding is rectified by the bridge formed by the four diodes D1-D4. The DC voltage taken across the output of the bridge is smoothed by the filter formed by the reservoir capacitor C1 and the resistor R1. The circuit incorporates some unique features which make it quite different from other power supplies of its class. Instead of using a variable feedback arrangement to control the output voltage, our circuit uses a constant gain amplifier to provide the reference voltage necessary for its stable operation. The reference voltage is generated at the output of U1.

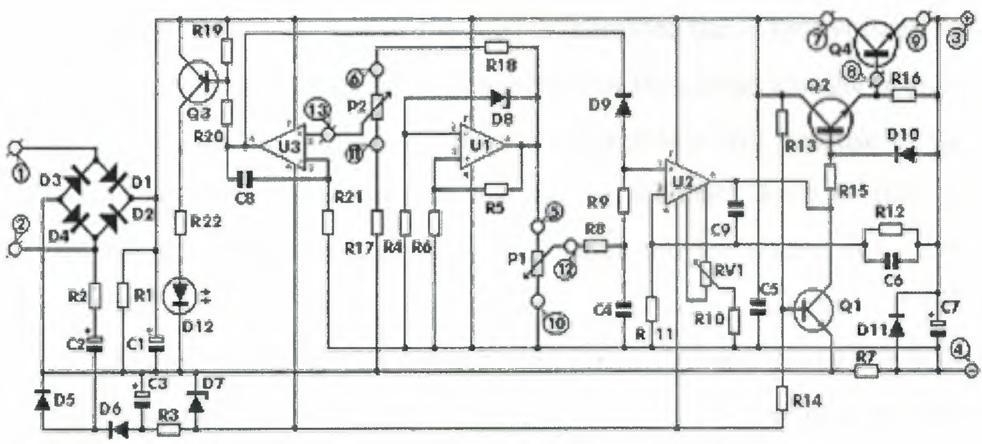


Figure4.5 Schematic diagrammof power supply

The circuit operates as follows: The diode D8 is a 5.6 V zener, which here operates at its zero temperature coefficient current. The voltage in the output of U1 gradually increases till the diode D8 is turned on. When this happens the circuit stabilises and the Zener reference voltage (5.6 V) appears across the resistor R5. The current which flows through the non inverting input of the op-amp is negligible, therefore the same current flows through R5 and R6, and as the two resistors have the same value the voltage across the two of them in series will be exactly twice the voltage across each one. Thus the voltage present at the output of the op-amp (pin 6 of U1) is 11.2 V, twice the zeners reference voltage. The integrated circuit U2 has a constant amplification factor of approximately 3 X, according to the formula A=(R11+R12)/R11, and raises the 11.2 V reference voltage to approximately 33 V. The trimmer RV1 and the resistor R10 are used for the adjustment of the output voltages limits so that it can be reduced to 0 V, despite any value tolerances of the other components in the circuit. Another very important feature of the circuit, is the possibility to preset the maximum output current which can be drawn from the p.s.u., effectively converting it from a constant voltage source to a constant current one. To make this possible the circuit detects the voltage drop across a resistor (R7) which is connected in series with the load. The IC responsible for this function of the circuit is U3. The inverting input of U3 is biased at 0 V via R21. At the same time the non inverting input of the same IC can be adjusted to any voltage by means of P2.

Let us assume that for a given output of several volts, P2 is set so that the input of the IC is kept at 1 V. If the load is increased the output voltage will be kept constant by the voltage amplifier section of the circuit and the presence of R7 in series with the output will have a negligible effect because of its low value and because of its location outside the feedback loop of the voltage control circuit. While the load is kept constant and the output voltage is not changed the circuit is stable. If the load is increased so that the voltage drop across R7 is greater than 1 V, IC3 is forced into action and the circuit is shifted into the constant current mode. The output of U3 is coupled to the non inverting input of U2 by D9. U2 is responsible for the voltage control and as U3 is coupled to its input the latter can effectively override its function. What happens is that the voltage across R7 is monitored and is not allowed to increase above the preset value (1 V in our example) by reducing the output voltage of the circuit.

This is in effect a means of maintaining the output current constant and is so accurate that it is possible to preset the current limit to as low as 2 mA. The capacitor C8 is there to increase the stability of the circuit. Q3 is used to drive the LED whenever the current limiter is activated in order to provide a visual indication of the limiters operation. In order to make it possible for U2 to control the output voltage down to 0 V, it is necessary to provide a negative supply rail and this is done by means of the circuit around C2 & C3. The same negative supply is also used for U3. As U1 is working under fixed conditions it can be run from the unregulated positive supply rail and the earth.

The negative supply rail is produced by a simple voltage pump circuit which is stabilised by means of R3 and D7. In order to avoid uncontrolled situations at shut-down there is a protection circuit built around Q1. As soon as the negative supply rail collapses Q1 removes all drive to the output stage. This in effect brings the output voltage to zero as soon as the AC is removed protecting the circuit and the appliances connected to its output. During normal operation Q1 is kept off by means of R14 but when the negative supply rail collapses the transistor is turned on and brings the output of U2 low. The IC has internal protection and can not be damaged because of this effective short circuiting of its output. It is a great advantage in experimental work to be able to kill the output of a power supply without having to wait for the capacitors to discharge and there is also an added protection because the output of many stabilised power supplies tends to rise instantaneously at switch off with disastrous results.

4.6 Construction

First of all let us consider a few basics in building electronic circuits on a printed circuit board. The board is made of a thin insulating material clad with a thin layer of conductive copper that is shaped in such a way as to form the necessary conductors between the various components of the circuit. The use of a properly designed printed circuit board is very desirable as it speeds construction up considerably and reduces the possibility of making errors. To protect the board during storage from oxidation and assure it gets to you in perfect condition the copper is tinned during manufacturing and covered with a special varnish that protects it from getting oxidised and also makes soldering easier.

Soldering the components to the board is the only way to build your circuit and from the way you do it depends greatly your success or failure. This work is not very difficult and if you stick to a few rules you should have no problems. The soldering iron that you use must be light and its power should not exceed the 25 Watts. The tip should be fine and must be kept clean at all times. For this purpose come very handy specially made sponges that are kept wet and from time to time you can wipe the hot tip on them to remove all the residues that tend to accumulate on it.

DO NOT file or sandpaper a dirty or worn out tip. If the tip cannot be cleaned, replace it. There are many different types of solder in the market and you should choose a good quality one that contains the necessary flux in its core, to assure a perfect joint every time.

DO NOT use soldering flux apart from that which is already included in your solder. Too much flux can cause many problems and is one of the main causes of circuit malfunction. If nevertheless you have to use extra flux, as it is the case when you have to tin copper wires, clean it very thoroughly after you finish your work.

4.7 In order to solder a component correctly

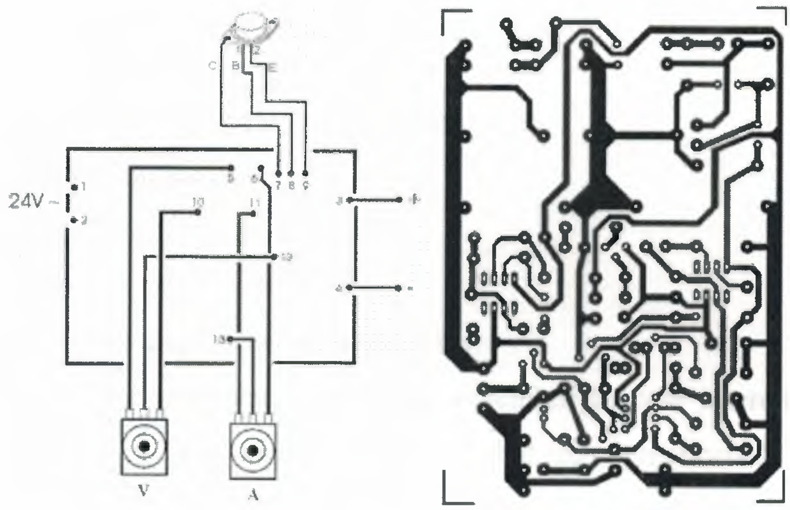
Clean the component leads with a small piece of emery paper.
Bend them at the correct distance from the components body and insert he component in its place on the board.

- You may find sometimes a component with heavier gauge leads than usual, that are too thick to enter in the holes of the p.c. board. In this case use a mini drill to enlarge the holes slightly. Do not make the holes too large as this is going to make soldering difficult afterwards.
- Take the hot iron and place its tip on the component lead while holding the end of the solder wire at the point where the lead emerges from the board. The iron tip must touch the lead slightly above the p.c. board.

- When the solder starts to melt and flow wait till it covers evenly the area around the hole and the flux boils and gets out from underneath the solder.
- The whole operation should not take more than 5 seconds. Remove the iron and allow the solder to cool naturally without blowing on it or moving the component. If everything was done properly the surface of the joint must have a bright metallic finish and its edges should be smoothly ended on the component lead and the board track. If the solder looks dull, cracked, or has the shape of a blob then you have made a dry joint and you should remove the solder (with a pump, or a solder wick) and redo it. Take care not to overheat the tracks as it is very easy to lift them from the board and break them.
- When you are soldering a sensitive component it is good practice to hold the lead from the component side of the board with a pair of long-nose pliers to divert any heat that could possibly damage the component.
- Make sure that you do not use more solder than it is necessary as you are running the risk of short-circuiting adjacent tracks on the board, especially if they are very close together.
- When you finish your work, cut off the excess of the component leads and clean the board thoroughly with a suitable solvent to remove all flux residues that may still remain on it.

4.8 PCB – Connections

As it is recommended start working by identifying the components and separating them in groups. Place first of all the sockets for the ICs and the pins for the external connections and solder them in their places. Continue with the resistors. Remember to mound R7 at a certain distance from the printed circuit board as it tends to become quite hot, especially when the circuit is supplying heavy currents, and this could possibly damage the board. It is also advisable to mount R1 at a certain distance from the surface of the PCB as well. Continue with the capacitors observing the polarity of the electrolytic and finally solder in place the diodes and the transistors taking care not to overheat them and being at the same time very careful to align them correctly. Mount the power transistor on the heatsink. To do this follow the diagram and remember to use the mica insulator between the transistor body and the heatsink and the special fibber washers to insulate the screws from the heatsink. Remember to place the soldering tag on one of the screws from the side of the transistor body, this is going to be used as the collector lead of the transistor. Use a little amount of Heat Transfer Compound between the transistor and the heatsink to ensure the maximum transfer of heat between them, and tighten the screws as far as they will go. Attach a piece of insulated wire to each lead taking care to make very good joints as the current that flows in this part of the circuit is quite heavy, especially between the emitter and the collector of the transistor.



a-Pin connection on teh PCB b-pcb Layout

Figure 4.6 PCB

It is convenient to know where you are going to place every thing inside the case that is going to accommodate your power supply in figure 4.6 , in order to calculate the length of the wires to use between the PCB and the potentiometers, the power transistor and for the input and output connections to the circuit.(It does not really matter if the wires are longer but it makes a much neater project if the wires are trimmed at exactly the length necessary).Connect the potentiometers, the LED and the power transistor and attach two pairs of leads for the input and output connections. Make sure that you follow the circuit diagram very care fully for these connections as there are 15 external connections to the circuit in total and if you make a mistake it may be very difficult to find it afterwards. It is a good idea to use cables of different colours in order to make trouble shooting easier.

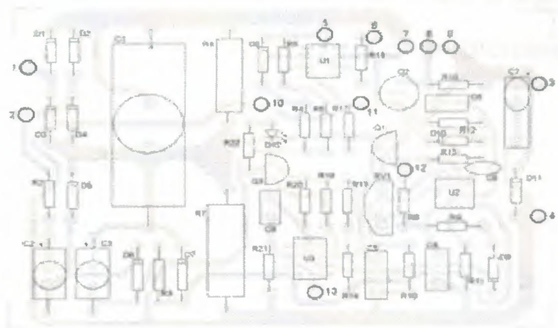


Figure 4.7 PCB upper side view

- 1 & 2 AC input, the secondary of the transformer.
- 3 (+) & 4 (-) DC output.
- 5, 10 & 12 to P1.
- 6, 11 & 13 to P2.
- 7 (E), 8 (B), 9 (E) to the power transistor Q4.
- The LED should also be placed on the front panel of the case where it is always visible but the pins where it is connected at are not numbered.

When all the external connections have been finished make a very careful inspection of the board and clean it to remove soldering flux residues. Make sure that there are no bridges that may short circuit adjacent tracks and if everything seems to be all right connect the input of the circuit with the secondary of a suitable mains transformer. Connect a voltmeter across the output of the circuit and the primary of the transformer to the mains.

The voltmeter should measure a voltage between 0 and 30 VDC depending on the setting of P1, and should follow any changes of this setting to indicate that the variable voltage control is working properly. Turning P2 counter-clockwise should turn the LED on, indicating that the current limiter is in operation.You can learn information about component specification in Appendix B

4.9 Adjustments

If you want the output of your supply to be adjustable between 0 and 30 V you should adjust RV1 to make sure that when P1 is at its minimum setting the output of the supply is exactly 0 V. As it is not possible to measure very small values with a conventional panel meter it is better to use a digital meter for this adjustment, and to set it at a very low scale to increase its sensitivity.

4.10 If it does not work

Check your work for possible dry joints, bridges across adjacent tracks or soldering flux residues that usually cause problems. Check again all the external connections to and from the circuit to see if there is a mistake there. See that there are no components missing or inserted in the wrong places...

4.11 Component List

R1 = 2,2 KOhm 1W	C1 = 3300 uF/50V electrolytic
R2 = 82 Ohm 1/4W	C2, C3 = 47uF/50V electrolytic
R3 = 220 Ohm 1/4W	C4 = 100nF polyester
R4 = 4,7 KOhm 1/4W	C5 = 200nF polyester
R5, R6, R13, R20, R21 = 10 KOhm 1/4W	C6 = 100pF ceramic
R7 = 0,47 Ohm 5W	C7 = 10uF/50V electrolytic
R8, R11 = 27 KOhm 1/4W	C8 = 330pF ceramic
R9, R19 = 2,2 KOhm 1/4W	C9 = 100pF ceramic
R10 = 270 KOhm 1/4W	D5, D6 = 1N4148
R12, R18 = 56KOhm 1/4W	D7, D8 = 5,6V Zener
R14 = 1,5 KOhm 1/4W	D9, D10 = 1N4148
R15, R16 = 1 KOhm 1/4W	D11 = 1N4001 diode 1A
R17 = 33 Ohm 1/4W	Q1 = BC548, NPN transistor or BC547
R22 = 3,9 KOhm 1/4W	Q2 = 2N2219 NPN transistor
RV1 = 100K trimmer	Q3 = BC557, PNP transistor or BC327
P1, P2 = 10KOhm linear pontesiometer	Q4 = 2N3055 NPN power transistor
D1, D2, D3, D4 = 1N5402,3,4 diode 2A - RAX GI837U	U1, U2, U3 = LM741, operational amplifier
	D12 = LED diode

Table 4.1 Component list

4.12 Component Price List

Component	Price is for 1 piece	Number of pieces
Resistor	0.25$	22 pieces = 5.5$
Capacitor(Electrolitic)	1.5$	4 pieces = 4$
Capacitor (polyester)	1$	2 piece = 2$
Capacitor((Ceramic)	0.5$	3 pieces = 1.5$
Transistor (2N3055).	4$	1 piece = 4$
Diode(1N5402,3,4 diode 2A)	2$	4 pieces = 8$
Diode (1N4148)	0.5$	4 pieces = 2$
Diode (5.6V zener)	0.5$	2 pieces = 1$
Diode (1N4001)	0.75	1 piece = 0.75$
Transistor(code of BC)	2$	2 pieces = 4$
Transistor (2N3055)	3$	1 piece = 3$
Chip (IC741)	3.5$	2 pieces = 7$
Voltage Tranformer	40$	1 piece = 40$
Linear pontesiometer	1.75$	2 pieces = 3.5$
LED	0.25$	1 piece = 0.25$
PCB card	6$	1 piece = 6$
Acid compound	5$	100 grams = 5$
Board maker pen	7$	1 piece = 7$

Total cost =104.5 $

Table4.2 Component Price List

CONCLUSION

While the importance of power supply and electronic system designing are continuously being reduced by their digital and analogue counterparts, they remain an important study, if no reason than they provide a gateway to the power supply. The design of power supply requires priority information about using electronic components and statistic of the data to be processes.

The power supply is optimum only when the suitable electronic material selection and technique and theoretical information on which the design of power supply .When this information is not known completely, However, it may not be possible to design the power supply or else the design may no longer be optimum. Electronic circuits make with PCB (printed circuit board) method as generally. PCB (printed circuit board) design provide the high efficiently and it provide the designing as correctly

In these days, Power Supply is in every device. It has a vital importance in devices. The aim of the project is to provide a small laboratory size power supply to use during laboratory exercises. Also to improve my knowledge on electronic component, we leaned how they can be use and how create a bigger component by combining all electronic components.

We learned that it has advantage to design the electronic components with PCB (printed circuit board) methods. Such as circuit works more efficiently and looks more compact. Also it is easier to find the fault during a fault occurs .In this project you can see also find information about which parts includes of basic power supply

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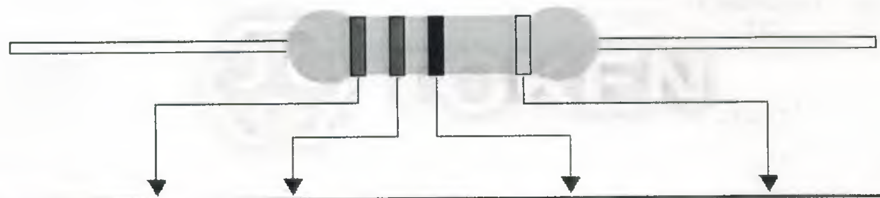
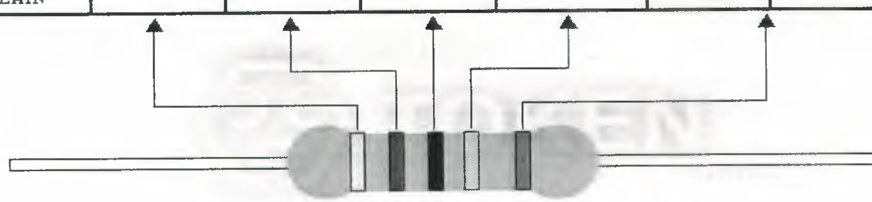
APPENDIX-A

APPENDIX-A Resistor colouor code table

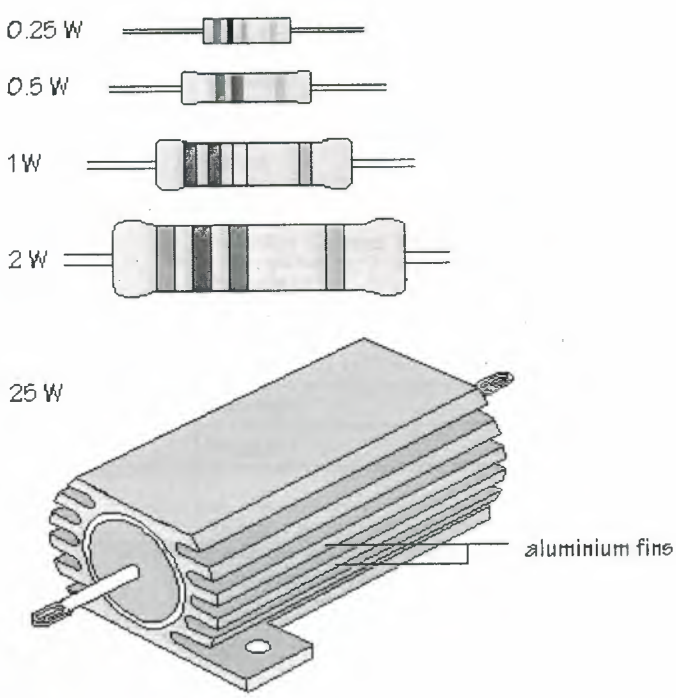
TOKEN RESISTOR COLOR CODE



COLOR	1ST BAND	2ND BAND	3TH BAND	MULTIPLIER	TOLERANCE	
BLACK	0	0	0	1		
BROWN	1	1	1	10	± 1%	F
RED	2	2	2	100	± 2%	G
ORANGE	3	3	3	1K		
YELLOW	4	4	4	10K		
GREEN	5	5	5	100K	± 0.5%	D
BLUE	6	6	6	1M	± 0.25%	C
VIOLET	7	7	7	10M	± 0.10%	B
GREY	8	8	8		± 0.05%	A
WHITE	9	9	9			
GOLD				0.1	± 5%	J
SILVER				0.01	± 10%	K
PLAIN					± 20%	M



APPENDIX-A Types of resistor size



APPEMDIX-A Capacitor colour code table

Capacitor Colour Code Table

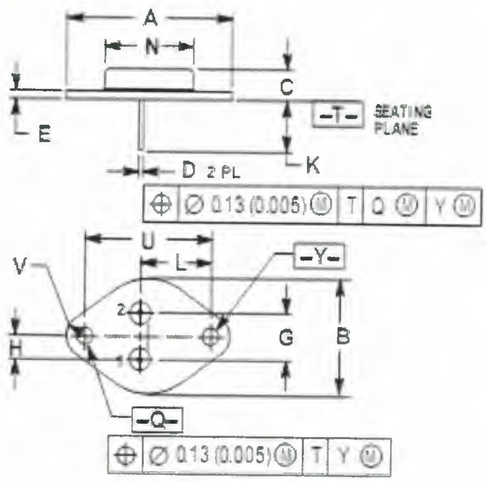
Colour	Digit A	Digit B	Multiplier D	Tolerance T > 10pf	Tolerance T < 10pf	Temperature Coefficient TC	Working voltage V
Black	0	0	x1	± 20%	± 2.0pF		
Brown	1	1	x10	± 1%	± 0.1pF	$-33x10^{-6}$	
Red	2	2	x100	± 2%	± 0.25pF	$-75x10^{-6}$	250v
Orange	3	3	x1000	± 3%		$-150x10^{-6}$	
Yellow	4	4	x10k	+100%,-0%		$-220x10^{-6}$	400v
Green	5	5	x100k	± 5%	± 0.5pF	$-330x10^{-6}$	100v
Blue	6	6	x1m			$-470x10^{-6}$	630v
Violet	7	7				$-750x10^{-6}$	
Grey	8	8	x0.01	+80%,-20%			
White	9	9	x0.1	± 10%			

APPENDIX-A Dielectric constant table

Dielectric Constants	
Kind of Dielectric	Approx K Value
Air (at atmospheric Pressure)	1.0
Bakelite	5.0
Cambric	4.0
Fiber	5.0
Glass	8.0
Mica	6.0
Paraffin Coated Paper	3.5
Porcelain	6.0
Pyrex	4.5
Quartz	5.0
Rubber	3.0
Wood	5.0
These values are approximate since true values depend on grade of material used, moisture content, temperature, and frequency characteristics.	

APPENDIX-B

APPENDIX-B 2N3005 Transistor datasheet



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. ALL RULES AND NOTES ASSOCIATED WITH REFERENCED TO-204AA OUTLINE SHALL APPLY.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.550 REF		39.37 REF	
B	—	1.050	—	26.67
C	0.250	0.335	6.35	8.51
D	0.038	0.043	0.97	1.09
E	0.055	0.070	1.40	1.77
G	0.430 BSC		10.92 BSC	
H	0.215 BSC		5.46 BSC	
K	0.440	0.480	11.18	12.19
L	0.665 BSC		16.89 BSC	
N	—	0.830	—	21.08
Q	0.151	0.165	3.84	4.19
U	1.187 BSC		30.15 BSC	
V	0.131	0.188	3.33	4.77

STYLE 1:
PIN 1. BASE
2. EMITTER
CASE: COLLECTOR

Complementary Silicon Power Transistors

. . . designed for general–purpose switching and amplifier applications

- DC Current Gain — h_{FE} = 20–70 @ I_C = 4 Adc
- Collector–Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 1.1 Vdc (Max) @ I_C = 4 Adc
- Excellent Safe Operating Area

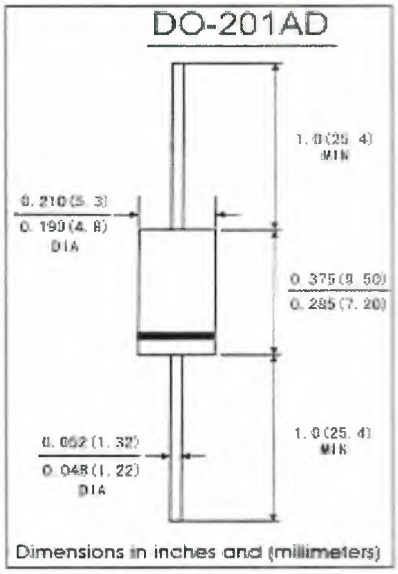
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	V_{CEO}	60	Vdc
Collector–Emitter Voltage	V_{CER}	70	Vdc
Collector–Base Voltage	V_{CB}	100	Vdc
Emitter–Base Voltage	V_{EB}	7	Vdc
Collector Current — Continuous	I_C	15	Adc
Base Current	I_B	7	Adc
Total Power Dissipation @ T_C = 25°C Derate above 25°C	P_D	115 0.657	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1.52	°C/W

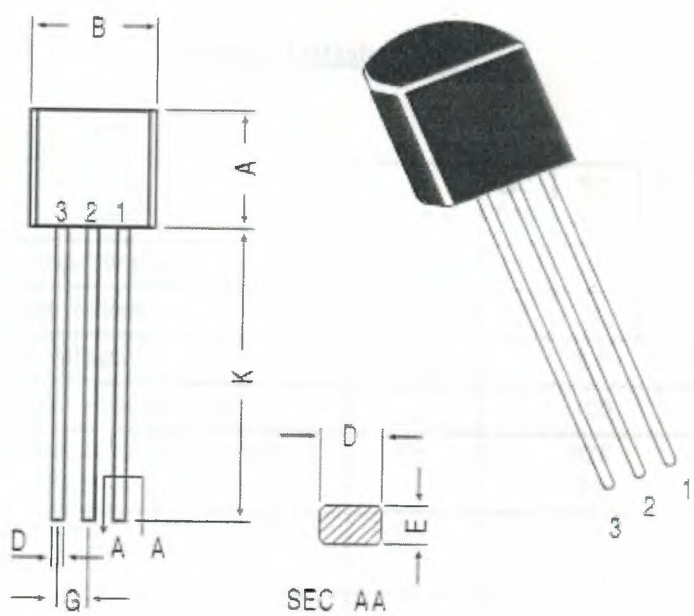
APPENDIX-B Datasheet of 1N5402 diode



		Symbols	1N 5400	1N 5401	1N 5402	1N 5403	1N 5404	1N 5405	1N 5406	1N 5407	1N 5408	Units
Maximum repetitive peak reverse voltage		V_{RRM}	50	100	200	300	400	500	600	800	1000	Volts
Maximum RMS voltage		V_{RMS}	35	70	140	210	280	350	420	560	700	Volts
Maximum DC blocking voltage		V_{DC}	50	100	200	300	400	500	600	800	1000	Volts
Maximum average forward rectified current 0.375"(9.5mm)lead length at T_A=70℃		$I_{(AV)}$					3.0					Amps
Peak forward surge current 8.3ms sing-wave superimposed on rated load (JEDEC method) T_A=70℃		I_{FSM}					200.0					Amps
Maximum instantaneous forward voltage at 1.5 A		V_F					1.1					Volts
Maximum reverse current at rated DC blocking voltage	TA=25℃	I_R					10.0					μA
	TA=100℃						300.0					
Typical thermal resistance(Note 2)		$R_{\theta JA}$					20.0					℃/W
Typical junction Capacitance(Note 1)		C_J					35.0					pF
Maximum DC Blocking Voltage temperature		T_A					+150.0					℃
Operating and storage temperature range		T_J T_{STG}					-50 to +175					℃

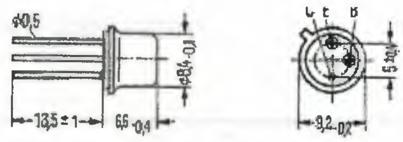
APPENDIX-B BC557 Datasheet

DYNAMIC CHARACTERISTICS					
Transistors Frequency	ft	IC=10mA, VCE=5V f=100MHz		typ150	MHz
Collector out-put Capacitance	Ccbo	VCB=10V, f=1MHz		<6.0	pF
Emitter Input Capacitance	Cib	VEB=0.5V, f=1MHz		typ9.0	pF
Noise Figure	NF	IC=0.2mA, VCE=5V Rs=2kohm, f=1kHZ B=200Hz		<10	dB
		ALL f=1KHz			
Small Signal Current Gain	hfe	IC=2mA, VCE=5V	A	typ220	
			B	typ330	
			C	typ600	
Input Impedance	hie	IC=2mA, VCE=5V	A	1.6-4.5	khoms
			B	3.2-8.5	
			C	6.0-15	
Voltage Feedback Ratio	hre	IC=2mA, VCE=5V	A	typ1.5	X'10-4
			B	typ2.0	
			C	typ3.0	
Out put Adimttance	hoe	IC=2mA, VCE=5V	A	<30	umhos
			B	<60	
			C	<110	



APPENDIX-B 2N2219 Transistor Datasheet

Type	Ordering code
2 N 2218	Q62702-F109
2 N 2219	Q62702-F133
2 N 2218 A	Q62702-S29
2 N 2219 A	Q62702-F59



Approx. weight 1.5 g   Dimensions in mm

Maximum ratings		2 N 2218 2 N 2219	2 N 2218 A 2 N 2219 A	
Collector-base voltage	V_{CBO}	60	75	V
Collector-emitter voltage	V_{CEO}	30	40	V
Emitter-base voltage	V_{EBO}	5	6	V
Collector current	I_C	0.8	0.8	A
Junction temperature	T_j	175	175	°C
Storage temperature range	T_{stg}	–65 to +200		°C
Total power dissipation ($T_{amb} \leq 25$ °C)	P_{tot}	0.8	0.8	W
Total power dissipation ($T_{case} \leq 25$ °C)	P_{tot}	3	3	W
Thermal resistance				
Junction to ambient air	R_{thJA}	≤ 188	≤ 188	K/W
Junction to case	R_{thJC}	≤ 50	≤ 50	K/W

APPENDIX-B BC 548 Transistor Datasheet

MAXIMUM RATINGS

Rating	Symbol	BC 546	BC 547	BC 548	Unit
Collector–Emitter Voltage	V_{CEO}	65	45	30	Vdc
Collector–Base Voltage	V_{CBO}	80	50	30	Vdc
Emitter–Base Voltage	V_{EBO}	6.0			Vdc
Collector Current — Continuous	I_C	100			mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0			mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12			Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–55 to +150			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

APPENDIX-B 1N401 Diode Datasheet

General Purpose Rectifiers (Glass Passivated)

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current. .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics

T_A = 25°C unless otherwise noted

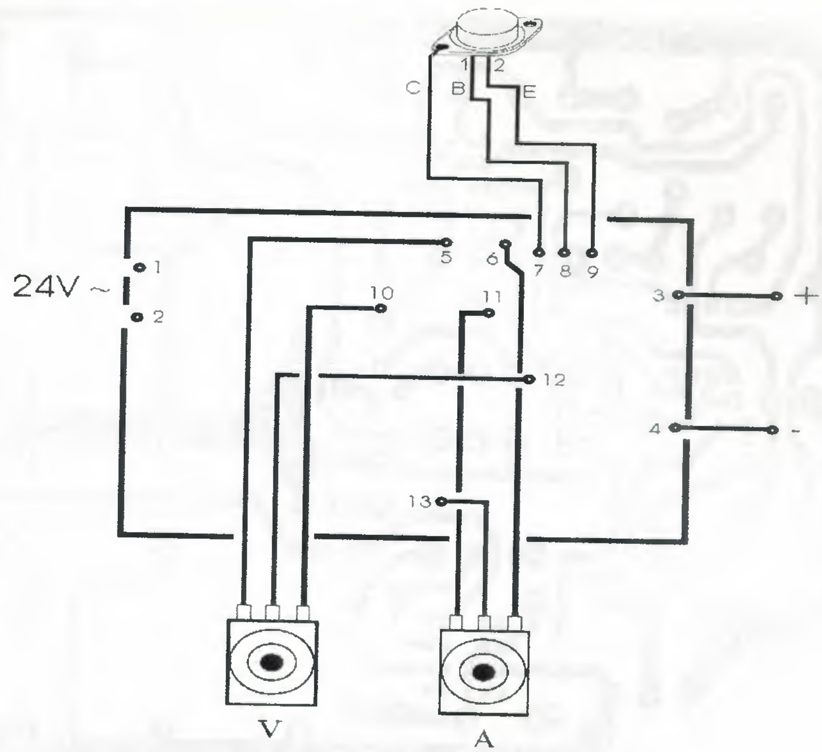
Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

APPENDIX-B 1N4148 Diode Datasheet

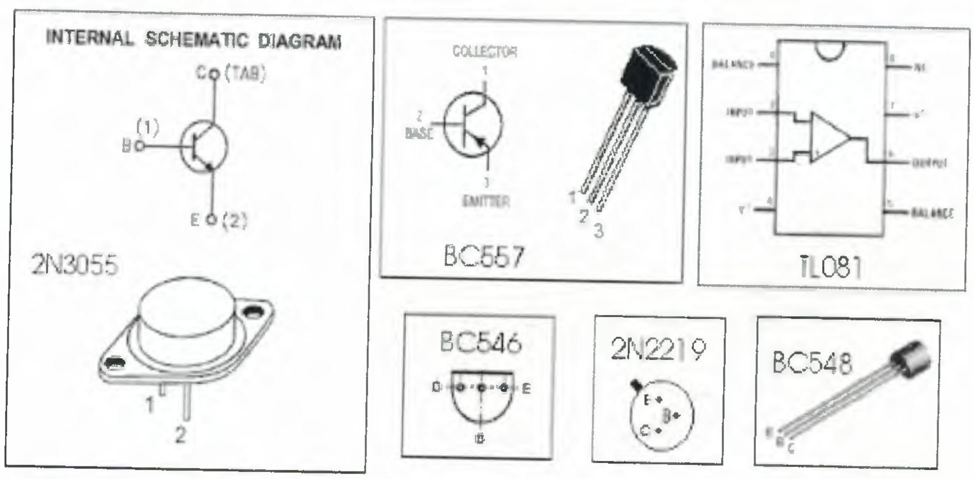
Absolute maximum ratings (Ta = 25°C)

Type	V_{RM} (V)	V_R (V)	I_{FM} (mA)	I_O (mA)	I_F (mA)	I_{FSM} 1 µs (A)	P (mW)	Tj (°C)	Topr (°C)	Tstg (°C)
1N4148	100	75	450	150	200	2	500	200	−65~+200	−65~+200
1N4150	50	50	600	200	250	4	500	200	−65~+200	−65~+200
1N4448 (1N914B)	100	75	450	150	200	2	500	200	−65~+200	−65~+200

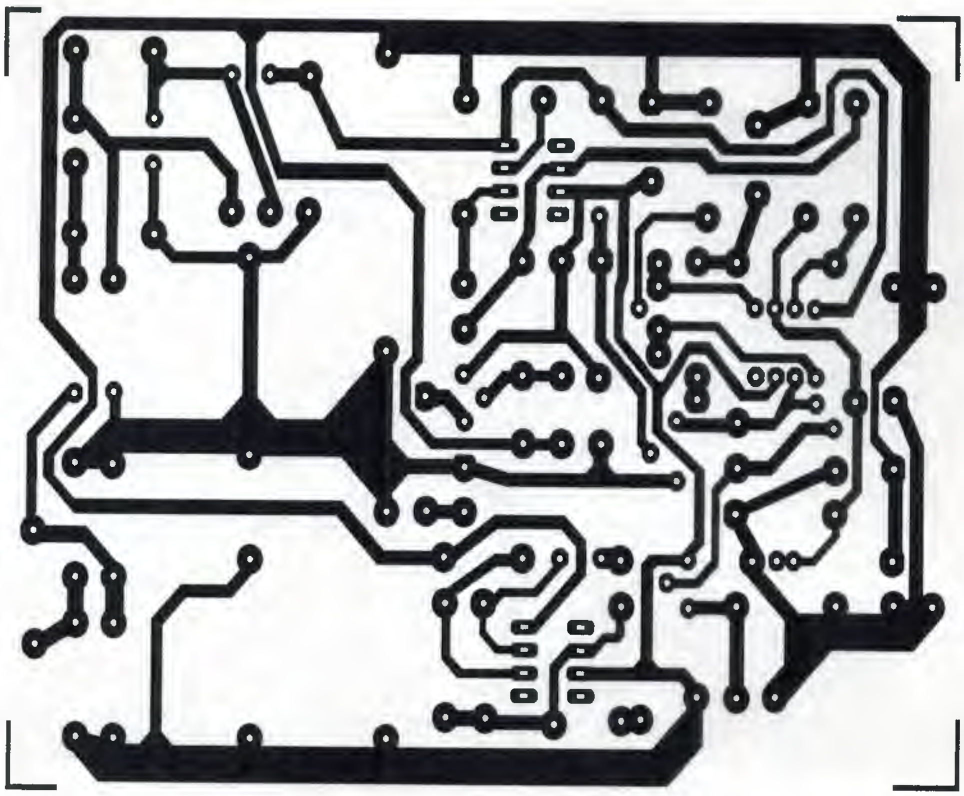
APPENDIX-B Pin connection of circuit



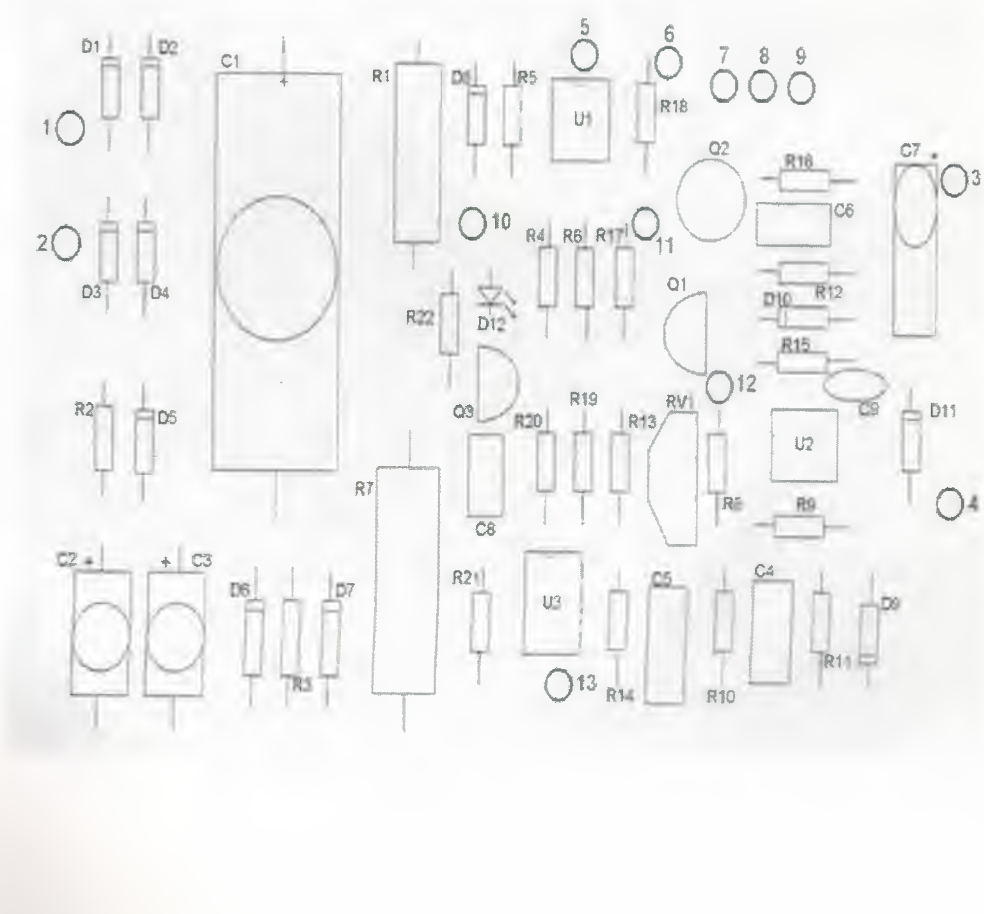
APPENDIX-B Pin configuration of some circuit in the project



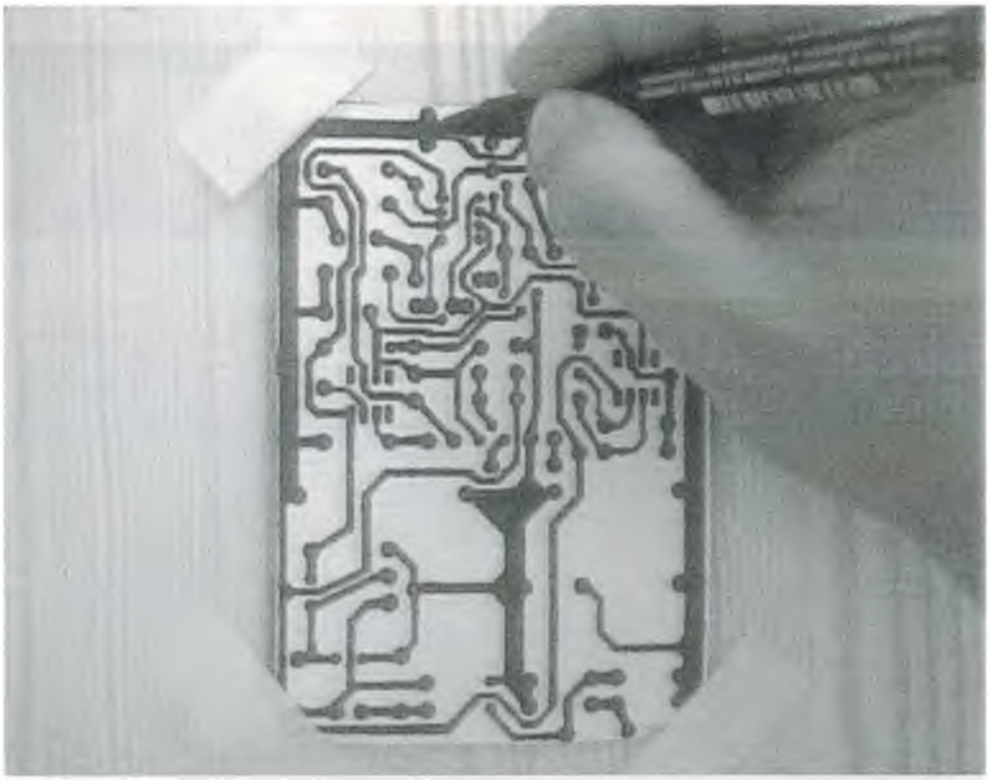
APPENDIX-B Printed circuit board scheme



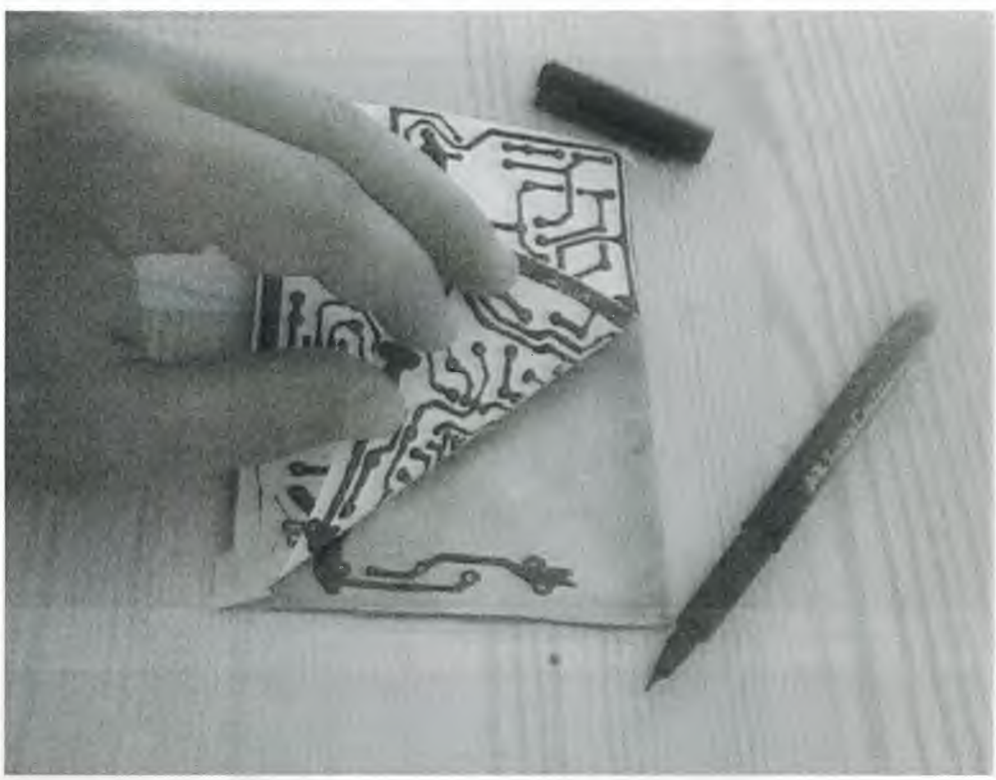
APPENDIX-B Layout scheme of circuit



APPENDIX-B Drawing to copper plate with resistive pen

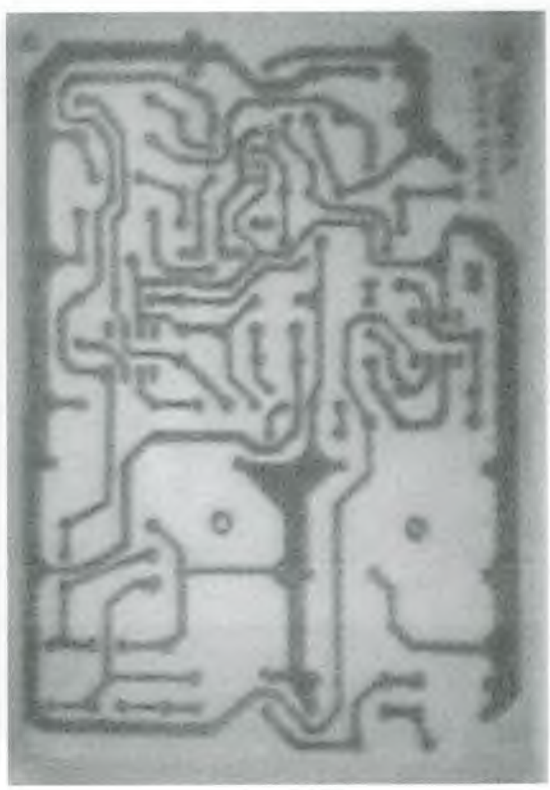


APPENDIX-B Scheme tansport to copper plate by resistive pen method

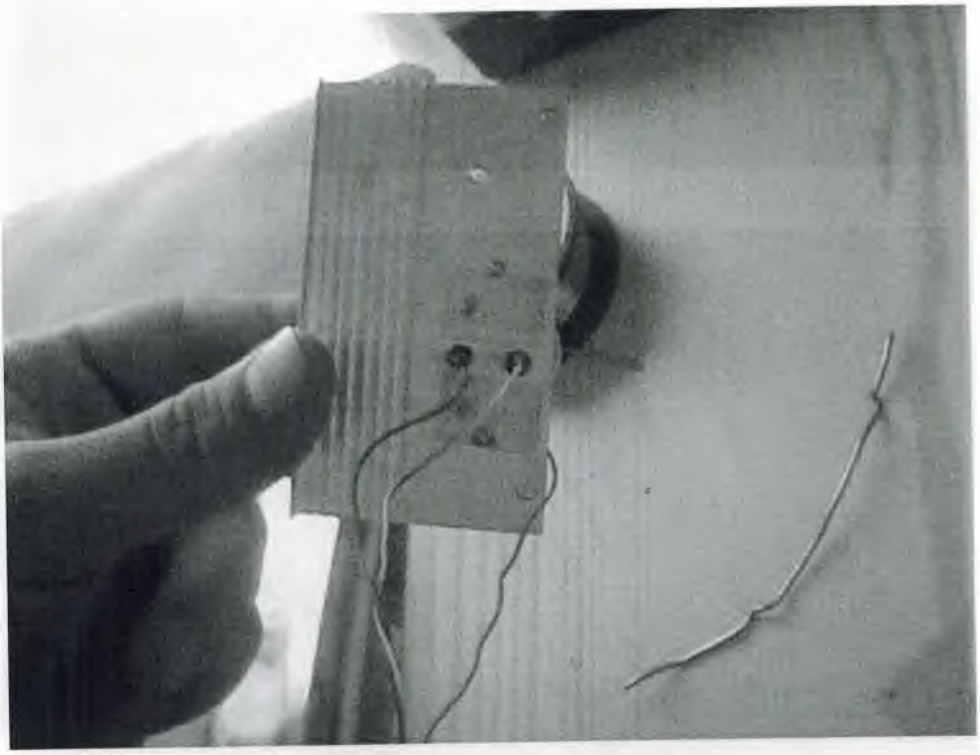


APPENDIX-B Copper plate in the etch time

APPENDIX-B After etch



APPENDIX-B Montage of transistor



APPENDIX-B Soldered circuit