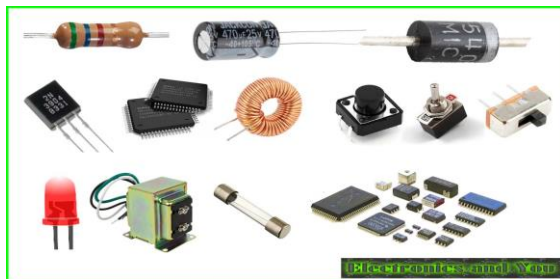


# Biomedical Equipment Servicing

## Level – II

**Based on September, 2021, Curriculum, Version II**



**Module Title:** Test Electrical & Electronic Components

**Module Code:** HLT BES2 M04 0921

**Nominal duration:** 120 hours

**Prepared By:** Ministry of Labor and Skills

**August 2022**

**Addis Ababa, Ethiopia**

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## Acronyms

AC	alternating current
BJT	bipolar junction transistor
CRT	cathode ray tube
DC	direct current
JFET	junction field effect transistor
LCD	liquid crystal display
MOSFET	metal oxide semiconductor field effect transistor
PSU	power supply unit

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## Introduction to Electrical & Electronic Components

Electronic components are the basic building blocks of an electronic circuit or electronic system or electronic device. They control the flow of electrons in an electronic system or electronic circuit. Electronic components are very small. Hence, it is easy to carry them from one place to another place. The cost of electronic components is also low. Electronic components consist of two or more terminals.

When a group of electronic components is connected together in an electronic board such as printed circuit board (PCB), a useful electronic circuit is formed. Each electronic component in a circuit performs a particular task.

Electrical/electronic components are categorized in two groups. These are: Passive and Active components. Passive electronic components include Resistors, Capacitors, Inductors, and Transformers. Active components include Diode, Transistor, IC, Vacuum tube.

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### Module units

- Preparing workstation and requirement
- Electrical/electronic components
- Testing Electrical/electronic components

### Learning objectives of the Module

At the end of this session, the students will able to:

- Plan and prepare workstation and requirement
- Demonstrate Working principle and technology of electrical/electronic components
- Test Electrical/electronic components

### Module Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks
5. Perform Operation Sheets
6. Do the “LAP test”

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## Unit one: Preparing workstation and requirement

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Materials Identification
- Selection of tools and test instruments
- OHS guidelines

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify Materials according to specifications
- Select appropriate tools and test instrument
- Ensure occupational health and safety (OHS) guidelines and procedures

## 1.1 Materials Identification

Electrical Materials or Electrical Supplies are essential parts or elements used in a construction project to connect your home, office or building to an electrical power source. Electrical parts can vary from a small house circuit to as big as a large industrial plant.

### 1.1.1 Specification

Exact statement of the particular needs to be satisfied, or essential characteristics that a customer requires (in a good, material, method, process, service, system, or work) and which a vendor must deliver. Specifications are written usually in a manner that enables both parties (and/or an independent certifier) to measure the degree of conformance. They are, however, not the same as control limits (which allow fluctuations within a range), and conformance to them does not necessarily mean quality (which is a predictable degree of dependability and uniformity).

Specifications are divided generally into two main categories:

1. **Performance specifications:** conform to known customer requirements such as keeping a room's temperature within a specified range.
2. **Technical specifications:** express the level of performance of the individual units, and are subdivided into (a) individual unit specifications which state boundaries (parameters) of the unit's performance consisting of a nominal (desired or mandated) value and tolerance (allowable departure from the nominal value, (b) acceptable quality level which states limits that are to be satisfied by most of the units, but a certain percentage of the units is allowed to exceed those limits, and (c) distribution specifications which define an acceptable statistical distribution (in terms of mean deviation and standard Deviation) for each unit, and are used by a producer to monitor its production processes.

### 1.1.2. Importance of specification




When completing a job for someone else you should always try and follow every specification so you can get future work from them. You may have to make sure that you follow every specification when you are trying to set up a new factory.

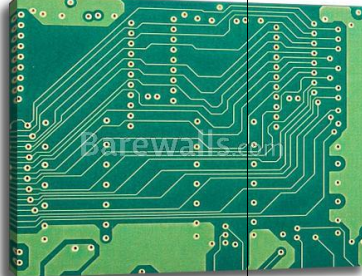


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It is not only sufficient to plan the required materials, tools and equipments for the lesson, it needs to check and identify which of them are: defect free (normal), to be maintaining easily and not to be maintained. In addition to the above consumable components, it is intended that the following consumable materials, tools and testing instruments which are going to be used in this UC are listed in the table below. The details list of these materials, tools and instruments (with their specification, quantities, items to trainee's ratio) are present in Annex "Resource Requirement" in the corresponding curriculum. Hence, based on both these information, the trainer can prepare consumable materials, tools and equipment request detail plan before the practical training time

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Table 1.1. Some materials with their specification and tasks

Materials	Specification	Tasks	Picture /image of materials
Soldering lead	We provide soldering wire of grade 63/37sn/pb,62/38,60/40 ,50/50 and 40/60 0.8mm, 1mm	-used to attach a wire to the pin of a component on the rear of PCB	
Flux	Rosin used as flux for soldering A flux pen used for electronics rework Multicore solder containing flux Wire freshly coated with solder, still immersed in molten rosin Flux	-is a chemical cleaning agent, flowing agent, or purifying agent. Fluxes may have more than one function at a time.	
Cables	<b>3x2.5mm<sup>2</sup></b> <b>3x4mm<sup>2</sup></b>	-an assembly one or more wires which may be insulated, used for transmission electrical power or signal.	



Printed circuit board (PCB)	<p>PCB materials</p> <p>Conductive ink</p> <p>Laminate materials:</p> <p>BT-Epoxy</p> <p>Composite epoxy material , CEM-1,5</p> <p>Cyanate Ester</p> <p>FR-2</p> <p>FR-4 , the most common PCB material</p> <p>Polyimide</p> <p>PTFE ,</p> <p>Polytetrafluoroethylene (Teflon)</p>	<p>A printed circuit board ( PCB ) mechanically supports and electrically connects electronic components or electrical components using conductive tracks, pads and other features Etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate.</p> <p>Components are generally soldered onto the PCB to both electrically connect and mechanically fasten them to it.</p>	 <p>bwc2035289 Barewalls</p>
Electrical/Electronic parts and components (resistor, diode, transistor, capacitor etc.)	<b>1kohm, 10w</b>		
Wires	1mm <sup>2</sup> , 1.5mm <sup>2</sup> , and 2.5mm <sup>2</sup>	-Used for transmission of electricity or electrical signals	



AC/DC power supply	<p>Total Max Power: 250 W</p> <p>Total Max Current: 20.8 A</p> <p>Input Voltage: 90 V to 264 V</p> <p>Output Voltage: 12 V to 52.8 V</p> <p>Outputs: Single</p> <p>Size (L x W x H): 4.000" x 2.000" x 1.290"</p> <p>Warranty: 3 years</p> <p>Operating Temperature: -20 to 70 °C</p>	<p>A power supply is an electrical device that supplies electric power to an electrical load . The primary function of a power supply is to convert electric current from a source to the correct voltage , current, and frequency to power the load. As a result, power supplies are sometimes referred to as electric power converters</p>	
Data book	ECG book	<p>-is a document that summarizes the performance and other characteristics of a product, machine, component (e.g., an electronic component ), material, a subsystem (e.g., a power supply ) or software in sufficient detail that allows a buyer to understand what the product and a design engineer to understand the role of the component in the overall system.</p>	





Soldering iron	<p>Specifications</p> <p>Max Temp 460°C</p> <p>Min Temp Room Temperature</p> <p>Temperature Control? No</p> <p>Voltage 230V</p> <p>Watts 20-50W</p> <p>Colour Hot Rod Red</p> <p>Bit type out-of-box Chisel 50W Rated</p> <p>Plug Round Indian Type</p>	<p>-It supplies heat to melt solder so that it can flow into the joint between two workpieces.</p> <p>A soldering iron is composed of a heated metal tip and an insulated handle. Heating is often achieved electrically, by passing an electric current (supplied through an electrical cord or battery cables) through a resistive heating element .</p>	
Soldering Sucker	<p>Length 19cm</p> <p>Diameter 2cm</p>	<p>Solders can be removed using a vacuum plunger (on the right) and a soldering iron .</p> <p>In electronics, desoldering is the removal of solder and components from a circuit board for troubleshooting , repair, replacement, and salvage.</p>	

## 1.2 Selection of tools and test instruments

The following table shows tools and instruments which are appropriate to perform the electrical/electronic tasks given under this topic.

**Table 1.2:** tools and instruments

Tools	Test instrument & other equipments	Consumable materials
Different Pliers	Multimeter	Wire, Cable
Screw Drivers	Megger	Solder lead, Flux
Wrenches	Frequency meter	PCB
Pipe cutter	Inductance meter	
Steel rule	Oscilloscope	
	Power supply	
	Soldering gun	
	Digital IC Tester	

### 1.2.1 Electronic Testing Equipment

The testing equipment used to detect faults in the operation of electronic devices by creating stimulus signals and capture responses from electronic devices under test is known as electronic test equipment. If any faults are detected, then identified faults can be traced and rectified using electronic testing equipment. Most often all electrical and electronic circuits are tested and troubleshoot to detect faults or abnormal functioning if any.

Therefore, testing equipment is necessary to find and analyze the circuit conditions, for checking electronic test equipment and maintenance in various industries. Many industries utilize different types of electronic test equipment ranging from the very simple and inexpensive to complex and sophisticated ones.

#### Voltmeter

A basic electronics device or instrument used to measure voltage or electrical potential difference between two points in electrical circuits is known as voltmeter. There are two types of voltmeters: analog and digital. An analog voltmeter moves a pointer across a scale in proportional to the voltage of the electrical circuit. A digital voltmeter measures an unknown input voltage by converting the voltage to a digital value by using a converter and then displays the voltage in numeric form.





Figure 1.1 voltmeter

## Ohmmeter

An electrical instrument that measures electrical resistance is known as an ohmmeter. The instrument used to measure small value of resistance are micro-ohmmeters. Similarly meg-ohmmeters is used to make large resistance measurements. Resistance values are measured in ohms ( $\Omega$ ). Originally, ohmmeter is designed with a small battery to apply a voltage to a resistance.



Figure 1.2 ohmmeter

The smaller currents can be measured by using milliammeters or micro ammeters, units of measuring the smaller current are in the milliampere or micro-ampere range. There are different types of ammeters such as moving-coil, moving magnet and moving-iron, etc.

## Multimeter

A multimeter is an electronic instrument used to measure the three basic electrical characteristics: voltage, current and resistance. It has multiple functions and acts like ohmmeter, voltmeter and ammeter and also used for household wiring, electric motors, testing batteries and power supplies. The multimeter is a handheld device with a needle over a numeric LCD digital display for indication purpose. It is also used to test continuity between two points in an electrical circuit. There are three types of multimeters made available in the market such as: digital multimeter, analog multimeter and fluke multimeter.



Figure 1.3 multimeter

## Signal Generator

A signal generator is also named as pitch generator, function generator or frequency generator is an electronic device used for generating electronic signals either in the analog or digital domains (repeating or non-repeating signals). Signal generators are used in testing, designing and repairing electro acoustic or electronic devices.



Figure 1.4 Signal Generator

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### Pulse Generator

A pulse generator is either an electronic circuit or a piece of electronic test equipment used to generate electrical pulses in different shapes: mostly used for tests at analog or electrical level. Pulse generators are used to control the width, frequency, delay based on the low and high voltage levels of the pulses and with respect to an internal and external triggering. There are three types of pulse generators namely optical pulse generator, bench pulse generators and microwave pulsers.



Figure 1.5 Pulse Generator

### Digital Pattern Generator

A digital generator is an electronic testing equipment or software used to generate digital electronics stimuli. Digital electronics stimuli are a specific type of electrical waveform varying between two conventional voltages corresponding to two logic gates (either 1 or 0, low or high). The function of the digital pattern generator is to stimulate the inputs of a electronic device. For that purpose, the voltage levels are generated by a digital pattern generator are compared to I/O standards of digital electronics: TTL, LVTTTL and LVDS. It is also known as a logic source because it is a source of synchronous digital stimulus.



Figure 1.6 Digital Pattern Generator

It generates a signal for testing digital electronics at logic level. This generator also produces a single shot or repetitive signals in which some sort of triggering source takes place ( internally or externally)

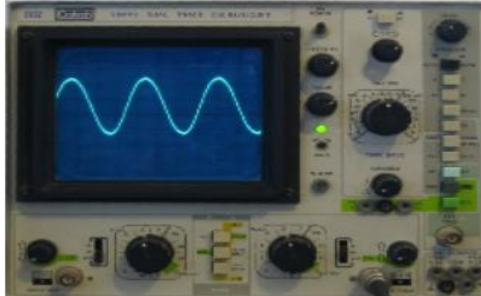
### **Oscilloscope**

The oscilloscope is an electronic test instrument that constantly observes varying voltage signals as a two dimensional plot of one or more signals as a function of time. The other names for oscilloscope are oscillography, cathode ray oscilloscope or digital storage oscilloscope. It is also used for converting non electrical signals such as vibration or sound into voltages and then displays the result.

### **Cathode Ray Oscilloscope**

Oscilloscopes are used to observe the change of an electrical signal based on time such that voltage and time describe a shape of the signals and graphed continuously compared with a calibrated scale. The obtained waveforms can be considered for following properties such as frequency, amplitude, time interval, rise time and others. Modern digital instruments may calculate these properties directly and displays them.

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*Cathode Ray Oscilloscope*

Figure 1.7 Oscilloscope

### Frequency counter

Digital frequency counter is an electrical test equipment used for measuring the frequency of repetitive signals and elapsed time between events. Digital frequency counters are also used to measure the radio frequency where it is important to measure the precise frequency of a particular signal.



Figure 1.8 Frequency Counter

There is a slight difference between the timers and frequency counters in the electronic industry. It is often possible to use both timers and frequency counters to perform the both functions: to measure the time and frequency. Frequency counters are mostly used as general purpose laboratory test equipment to measure higher frequencies.

## Advanced or Less Commonly used Testing Equipment

### LCR Meter

LCR Meter name itself indicates that it is used to measure the inductance, capacitance and resistance of electronics components. The inductance, capacitance and resistance are denoted by the letters L, C, and R so it is named as LCR Meter. A variety of meters are made available in the market, but simple versions of LCR meters indicates impedance only for converting the values to capacitance or inductance.

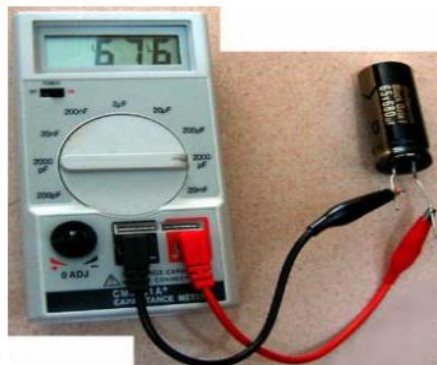


Figure 1.9 LCR Meter

More designs are available and used to measure the capacitance or inductance, and also the equivalent series resistance of capacitors and the Q factor of inductive components. These conditions make the LCR meters valuable for measuring the quality and overall performance of the component

## 1.3 OHS guidelines

The purpose of an OHS program is to prevent injuries and occupational diseases and to deal effectively with any accidents or incidents that occur.

### Safe work practices

Safe work practices and procedures are necessary to ensure that the workplace in the work shop is as safe as possible for yourself, your friends, resources (materials tools and equipments). Safe work practices are designed to ensure that OHS regulations are obeyed in the workplace. Safe

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work practices are ways of doing your work safely. The main safe work practices you have to know are:-

- a. Use correct manual handling method
- b. Use personal protective equipment's as required
- c. Use tools and measuring instrument in correct handling and Applying method
- d. Use safe posture and movement
- e. Avoid getting tired by taking rest and rotating tasks
- f. Use hazardous/dangerous equipments safely such as sharp knife, hot surfaces, electrical appliances
- g. Handle hazardous substances safely
- h. Pay attention to safety signs
- i. Identify and remove or control hazards from your own work area

#### **Hazard control responsibilities(OHS rules)**

- Identify potential hazards through regular inspections and either eliminate or control the hazards with Out delay.
- Remedy any workplace conditions that are hazardous to worker health or safety.
- Develop written safe work procedures.
- Encourage workers to express concerns and suggest improvements on health and safety issues,for example
- through safety talks, meetings,or consultation with worker representatives

**Directions: Answer all the questions listed below.**

**Test 1. Write true or false for the following statements**

1. Safe work practices and procedures are necessary to ensure that the workplace in the work shop is as safe as possible for yourself, your friends, and resources.
2. One of an example of Safe work practices is to use correct manual handling method.
3. Safe work practices are not designed to ensure that OHS regulations are obeyed in the workplace.
4. Safe work practices are ways of doing your work safely.
5. Potential hazards can be identified through regular inspection.

**Test 2. Match column "A" with column "B"**

A	B
1. LCR meter	A. observes varying voltage signals
2. Ohm meter	B .frequency of repetitive signals
3. Frequency counter	C .capacitance or inductance
4. Oscilloscope	D. resistance
5. Voltmeter	E. voltage

**Test 3: Short answer**

1. Write main safe work practices?
2. List and explain testing equipments?



## Unit Two: Electrical/electronic components

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Electrical/electronic components
- Component coding

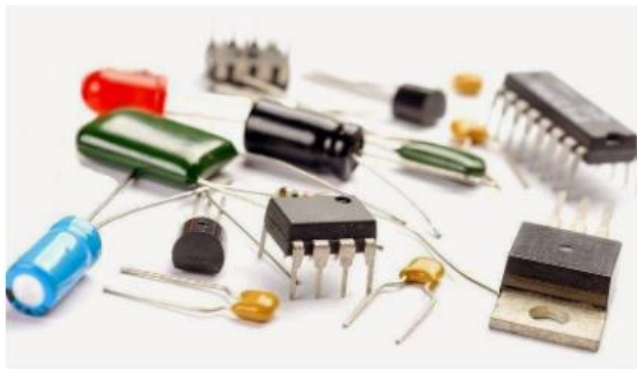
This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify Electrical/electronic components
- Identify types of component coding
- Demonstrate working principles of electrical/electronic component

## 2.1 Electrical/electronic components

Numerous basic electronic components are used for building electronic circuits. Without these components, circuit designs are never complete or didn't function well. These components include resistors, diodes, capacitors, integrated circuits, and so on. Some of these components consist of two or more terminals that are soldered to circuit boards. Some may be packaged types like integrated circuits in which different semiconductor devices are integrated.

Electronic components are basic discrete devices in any electronic system to use in electronics otherwise different associated fields. These components are basic elements that are used to design electrical and electronic circuits. These components have a minimum of two terminals which are used to connect to the circuit. The classification of electronic components can be done based on applications like active, passive, and electromechanical



*Major Electronic Components*

Figure 2.1 major electrical components

In designing an electronic circuit following are taken into consideration:

- Basic electronic components: capacitors, resistors, diodes, transistors, etc.
- Power sources: Signal generators and DC power supplies.
- Measurement and analysis instruments:
- Cathode Ray Oscilloscope (CRO), multimeters, etc.

Electrical/electronic components are categorized in two groups. These are: **Passive** and **Active** components

### Passive Components

The electronic component, which consumes energy in the form of voltage from the source, but does not produce or supply energy is called passive electronic component.

- ✓ Passive components cannot control the flow of electrons or electric current through a circuit, but they limit the flow of electrons or electric current.
- ✓ Passive components cannot amplify or increase the power of an electrical signal.
- ✓ Passive components temporarily store the electrical energy in the form of static electric field or magnetic field.
- ✓ Passive components do not depend on the external source of energy or voltage to perform a specific operation.

Passive Components: **Resistors, Capacitors, Inductors, and Transformers**

### Active components

The electronic component, which consumes energy in the form of voltage or current and produces or supplies energy in the form of electric current or voltage is called active component.

- I. An active component not only controls the flow of electrons or electric current, but also amplifies or increases the power of electronic signal.
- II. Active components depend on the external source of energy or voltage to perform a specific operation.
- III. When the active components consume enough voltage, they start operating.

Active components:-those generate (transform) energy. Such as Vacuum tube, Diode, Transistor, IC

### Electromechanical Components

These components use an electrical signal to make some mechanical changes like rotating a motor. Generally, these components use electrical current to form a magnetic field so that physical movement can be caused. Different types of switches and relays are applicable in these

kinds of components. The devices, which have the process of electrical as well as mechanical, are electromechanical devices. An electromechanical component is operated manually to generate electrical output through the mechanical movement.

### Display Devices

LCD: A liquid crystal display (LCD) is a flat display technology, which is mostly used in applications like computer monitors, cell phone displays, calculators, etc. This technology uses two polarized filters and electrodes to selectively disable or enable the light to pass from reflective backing to the eyes of the viewer.

The display like 16X2 LCD is the most frequently used module in electrical as well as electronic circuits. This kind of display includes 2 rows and 16 columns so it is known as an alphanumeric display. This kind of display is used to show the highest of 32 characters. Please refer to this link to know more about 16 X 2 LCD



Figure 2.3 LCD

### CRT

Cathode ray tube display technology is mostly used in televisions and computer screens that work on the movement of an electron beam back and forth on the back of the screen. This tube is an elongated vacuum tube in which the flattened surface has external components as an electron gun, electron beam, and a phosphorescent screen.



FIGURE 2.4 CRT

## Power Sources

The different power sources used in the circuits are DC power supply and batteries.

### DC Power Supply

In electronic circuits, the DC power supply is very essential which is used as one kind of power source. The major electronic components work with DC power supply because it is a consistent power source. Different power supplies used in the circuit to provide the supply are AC to DC, SMPS, linear regulators, etc. A wall adapter is used as an alternate to the DC power supply in some projects which require 5V otherwise 12V.



Figure 2.5 DC power supply

### Batteries

The battery is one kind of electrical energy storage device. This device is used to change the energy from chemical to electrical to supply the power to various electronic devices like mobile phones, flashlights, laptops, etc.

These consist of one or more cells and each cell contains an anode, cathode, and electrolyte. Batteries are available in various sizes which are also divided into primary as well as secondary. Primary types are used until they discharge the power & throw away them afterward whereas secondary batteries can also be used even after they discharged. The batteries used in the circuits are 1.5V AA type otherwise 9V PP3 type.



Figure 2.6 Batteries

### 2.1.1 Resistors

These are passive components mainly used for controlling flow of electric current and providing desired amount of voltage in a circuit.

#### Concept Structure:

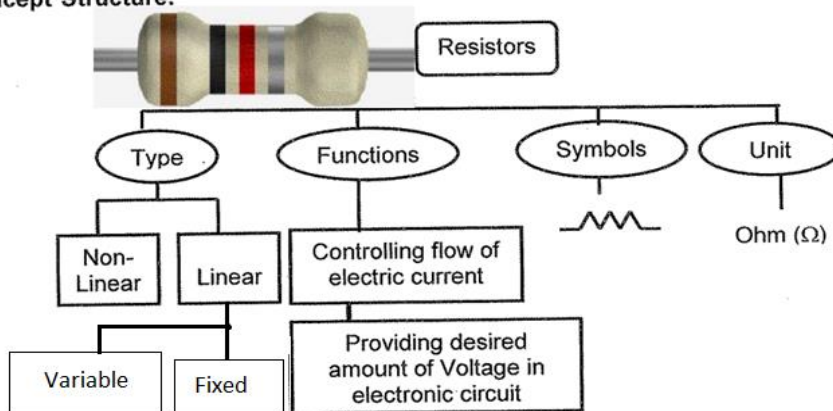


Figure: Resistor types

- Restricting the flow of electrons or electric current to a certain level is called **resistance** and
- The device or component used to restrict the electric current is called **resistor**.
- Mica, Glass, Rubber, Wood etc. are the examples of resistive materials. The unit of resistance is OHM ( $\Omega$ ) where  $1 \Omega = 1 \text{ V} / 1 \text{ A}$ . which is derived from the basic electrical Ohm's law =  $V = IR$ .

- Resistance of a resistor depends on their length ( $l$ ), resistivity ( $\rho$ ) and its cross sectional area ( $a$ ) which is also known as laws of resistance ...  $R = \rho (l/a)$ .

#### How Resistors works?

- ✓ It works by converting electrical energy into heat, which is dissipated into the air.
- ✓ A resistor is a dissipative element. It converts electrical energy into heat energy
- ✓ The resistor has two terminals and works in both directions.
- ✓ It has no polarization.
- ✓ The primary characteristic of a resistor is its resistance ( $\Omega$ ) and the power rating ( $W$ ).

#### Resistors Power Rating

- ✓ When an electrical current passes through a resistor, electrical energy is lost by the resistor in the form of heat and the greater this current flow the hotter the resistor will get. This is known as the **Resistor Power Rating**
- ✓ Power rating depends on the resistor's construction
- ✓ Larger physical size indicates a higher power rating.
- ✓ Higher-wattage resistors can operate at higher temperatures.
- ✓ Wire-wound resistors are physically larger and have higher power ratings than carbon resistors
- ✓ A higher power rating resistor can dissipate more energy than a lower power rating resistor.
- ✓ When a resistor's power rating is exceeded, it can burn open or drift way out of tolerance

#### Types of Resistors

Resistors are available in different size, Shapes and materials. We will discuss all possible resistor types one by one in detail with pro and cons and application/uses. There are two basic types of resistors.

1. Linear Resistors
2. Non Linear Resistors

#### 1. Linear Resistors:

- ✓ Those resistors, which values change with the applied voltage and temperature, are called linear resistors.

- ✓ In other words, a resistor, which current value is directly proportional to the applied voltage is known as linear resistors.

Generally, there are two types of resistors which have linear properties.

- I. Fixed Resistors
- II. Variable Resistors

#### A. Fixed Resistors

As the name tells everything, fixed resistor is a resistor which has a specific value and we can't change the value of fixed resistors.

**Types of Fixed resistors: According to type of material**

- Carbon composition
- Carbon film
- Metal film
- Wire wound
- Surface mounted devices
- Fusible resistor

#### Carbon Composition Resistors

- Made of carbon or graphite mixed with a powdered insulating material.
- Metal caps with tinned copper wire (called axial leads) are joined to the ends of the carbon resistance element.
- Carbon composite resistors are very cheap to make and are therefore commonly used in electrical circuits.
- They are available in 1 ohm to 25 mega ohms and in power rating from ¼ watt to up to 5 Watts.

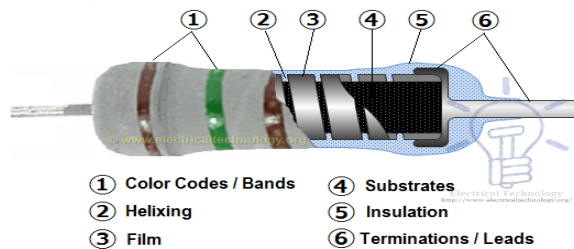




Figure:carbon composition resistor

### Carbon film Resistor

- Compared to carbon composition resistors, carbon-film resistors have tighter tolerances, are less sensitive to temperature changes and aging, and generate less noise.



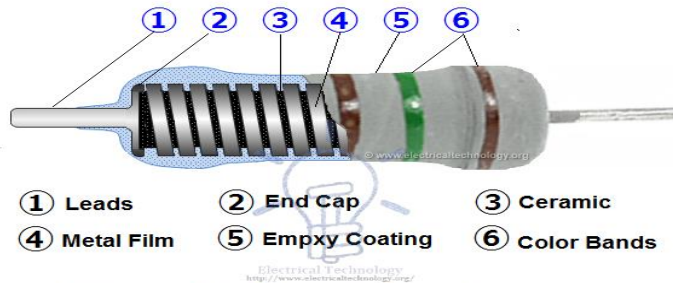
### Carbon Film Resistors

Figure: Carbon film resistor

### Metal Film Resistors

- Metal film resistors have very tight tolerances, are less sensitive to temperature changes and aging, and generate less noise.
- These resistors are superior to carbon resistors because their ohmic value does not change with age and they have improved tolerance

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## Metal Film Resistors

Figure: Metal film resistor

### Wire-wound resistors

- Wire-wound resistors are fixed resistors that are made by winding a piece of resistive wire around a ceramic core.
- These are used when a high power rating is required.
- Special resistance wire is wrapped around an insulating core, typically porcelain, cement, or pressed paper.
- These resistors are typically used for high-current applications with low resistance and appreciable power.
- They are available in the range of 2 watts up to 1 00 watt power rating or more.
- The ohmic value of these types of resistors is 1 ohm up to 200k ohms or more and can be operated safely up to 350°C.

#### • Wire wound resistor coding

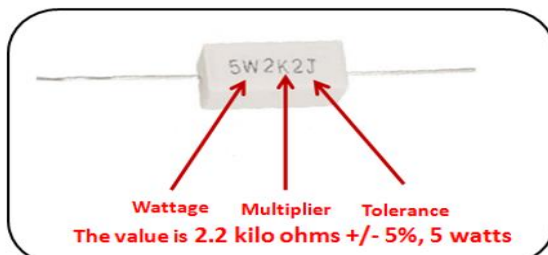


Figure: wirewound resistor

## Wirewound Resistor

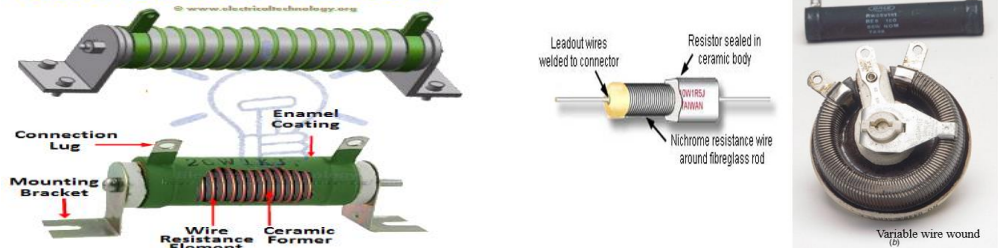


Figure: wire wound resistors

### Surface-Mount Resistors

- Surface-Mount Resistors (also called chip resistors)
- These resistors are:
  - ✓ Temperature-stable and rugged
  - ✓ Their end electrodes are soldered directly to a circuit board.
  - ✓ Much smaller than conventional resistors with axial leads.
  - ✓ Power dissipation rating is usually 1/8 to 1/4 W.



Figure: SMD resistors

### Fusible Resistors

- These kinds of resistors are same like a wire wound resistor.
- When a circuit power rating increased than the specified value, then this resistor is fused, i.e. it breaks or open the circuit. That's why it is called Fusible resistors.
- Fusible restores perform double jobs means they limit the current as well as it can be used as a fuse.
- They used widely in TV Sets, Amplifiers, and other expensive electronic circuits. Generally, the ohmic value of fusible resistors is less than 10 Ohms.

## B. Variable Resistors

As the name indicates, those resistors which values can be changed through a dial, knob, and screw or manually by a proper method. In these types of resistors, there is a sliding arm, which is connected to the shaft and the value of resistance can be changed by rotating the arm. They are used in the radio receiver for volume control and tone control resistance. Following are the further types of Variable Resistors

1. Potentiometers
2. Rheostats
3. Trimmers

### Potentiometers

Potentiometer is a three terminal device which is used for controlling the level of voltage in the circuit. The resistance between two external terminals is constant while the third terminal is connected with moving contact (Wiper) which is variable. The value of resistance can be changed by rotating the wiper which is connected to the control shaft. This way, Potentiometers can be used as a voltage divider and these resistors are called variable composition resistors. They are available up to 10 Mega Ohms.

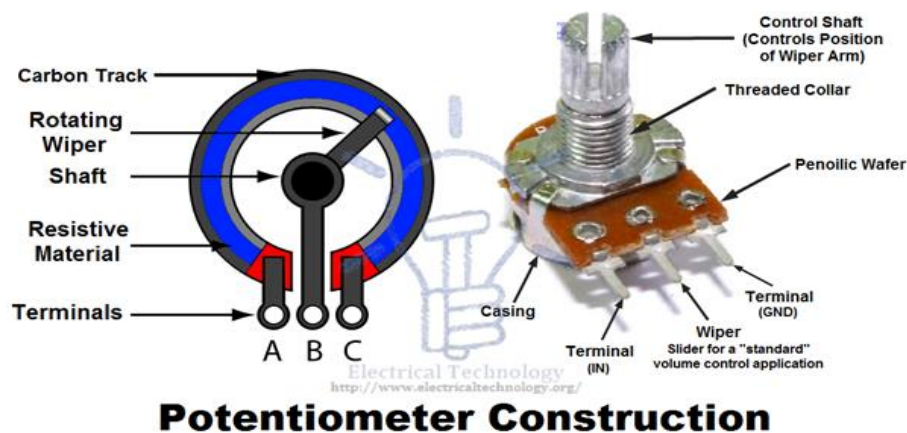


Figure 2.7 potentiometer

### Rheostats

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Rheostats are a two or three terminal device which is used for the current limiting purpose by hand or manual operation. Rheostats are also known as tapped resistors or variable wire wound resistors. While the most used Rheostats according to power rating is between 5 to 50 Watts.

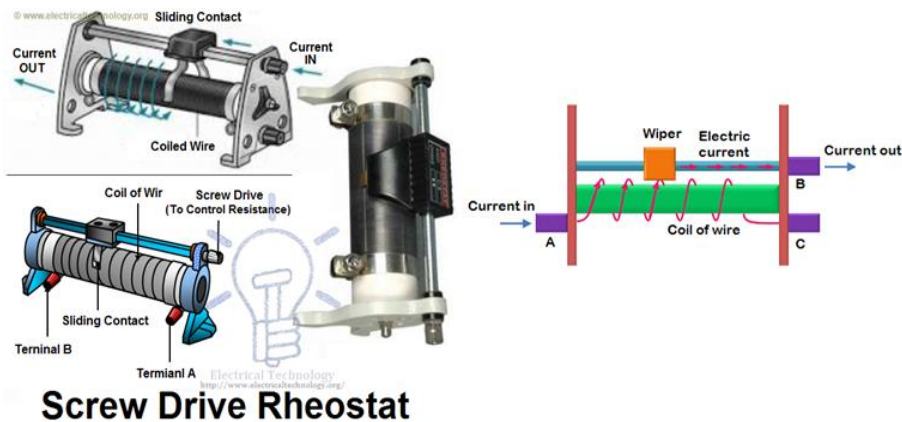


Figure 2.8 Rheostat

#### What is the main Difference between Potentiometer and Rheostats?

Basically, there is no difference between Potentiometer and Rheostat. Both are variable resistors. The main difference is the use and circuit operation, i.e. for which purpose we use that variable resistor? For example, if we connect a circuit between resistor element terminals (where one terminal is a general end of the resistor element while the other one is sliding contact or wiper) as a variable resistor for controlling the circuit current, then it is Rheostats. In the other hand, if we do the same as mentioned above for controlling the level of voltage, then this variable resistor would be called a potentiometer. That's it.

#### Trimmers

There is an additional screw with Potentiometer or variable resistors for better efficiency and operation and they are known as Trimmers. The value of resistance can be changed by changing the position of screw to rotate by a small screwdriver. They are made from carbon composition, carbon film, cermet and wire materials and available in the range of 50 Ohms up to 5 mega ohms. The power rating of Trimmers potentiometers are from 1 /3 to ¾ Watts.

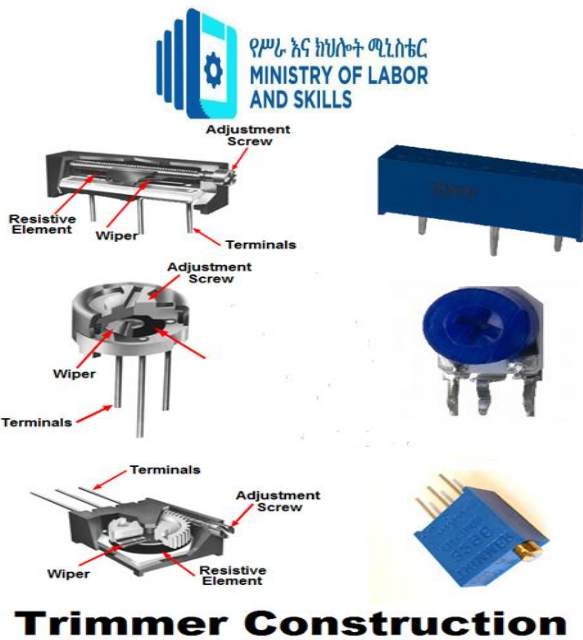


Figure 2.9 Trimmer

## 2. Non Linear Resistors

- Dependent on physical quantity

1. Thermistors
2. Varistors (VDR)
3. Photo Resistor or Photo Conductive Cell or LDR

### Thermistors

Thermistors is a two terminal device which is very sensitive to temperature. Thermistors are made from the cobalt, Nickel, Strontium and the metal oxides of Manganese.

**NTC resistors (Negative Temperature Co-efficient):** their resistance lowers with temperature rise.

**PTC resistors (Positive Temperature Co-efficient):** Their resistance increases with the temperature rise.

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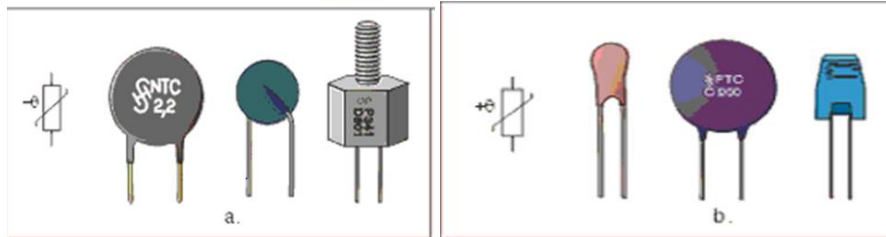


Figure: thermistors

## Varistors (VDR)

Varistors are voltage dependent Resistors (VDR) which is used to eliminate the high voltage transients. In other words, a special type of variable resistors used to protect circuits from destructive voltage spikes is called varistors.

When voltage increases (due to lighting or line faults) across a connected sensitive device or system, then it reduces the level of voltage to a secure level i.e. it changes the level of voltages.



Types of Varistor

Figure: varistor

## Photo Resistor or LDR

In other words, those resistors, which resistance values changes with the falling light on their surface is called Photo Resistor or Photo Conductive Cell or LDR (Light Dependent Resistor). The material which is used to make these kinds of resistors is called photo conductors, e.g. cadmium sulfide, lead sulfide etc. Their resistance lowers with the increase in light and vice versa.

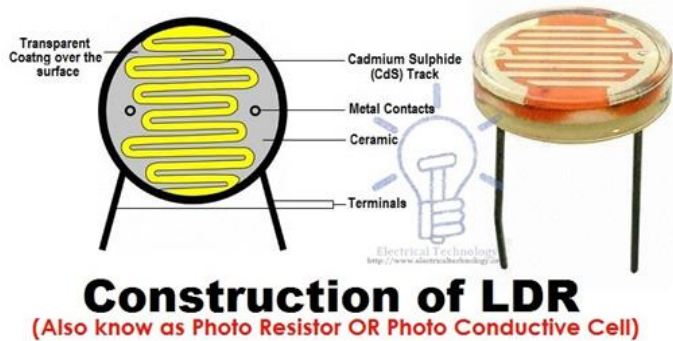


Figure: LDR

#### Application of LDR

- These types of resistors are used in burglar alarm, Door Openers, Flame detectors, Smoke detectors, light meters, light activated relay control circuits, industrial, and commercial automatic street light control and photographic devices and equipments.

#### Humistor

The name humistor is derived from the combination of words: humidity and resistor. Humistors are very sensitive to the humidity. The resistance of the humistor changes with the slight change in the humidity of the surrounding air. Humistors are also known as resistive humidity sensors or Humidity sensitive resistors.

#### Force sensitive resistors

The name itself suggests that, the force sensitive resistors are very sensitive to the applied force. When we apply force to the force sensitive resistor, its resistance changes rapidly. Force sensitive resistors are also known as force sensors, pressure sensor, force-sensing resistors, or FSR.

#### Uses / Application of Resistors

Practically, both types of resistors (Fixed and Variable) are generally used for the following purposes. Resistors are used:

- ✓ For Current control and limiting
- ✓ To change electrical energy in the form of heat energy

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- ✓ As a shunt in Ampere meters
- ✓ As a multiplier in a Voltmeter
- ✓ To control temperature
- ✓ To control voltage or Drop
- ✓ For protection purposes, e.g. Fusible Resistors
- ✓ In laboratories
- ✓ In home electrical appliances like heater, iron, immersion rod etc.
- ✓ Widely used in the electronics industries

### Resistor color code

Resistance value is marked on the resistor body. A majority of resistors have color bars to indicate their resistance magnitude. There are usually 4 to 6 bands of color on a resistor. Most resistors have 4 bands.

- ✓ The first two bands provide the numbers for the resistance
- ✓ the third band provides the number of zeros.
- ✓ The fourth band indicates the tolerance

Generally, code refers to a representation of information in another form by using symbols, signals, and letters for the purposes of secrecy. Here, the signals or symbols act as codes. The resistance and the tolerance of the resistor are printed on the body of the resistor with a color code. The power rating is determined by the physical size of the resistor.

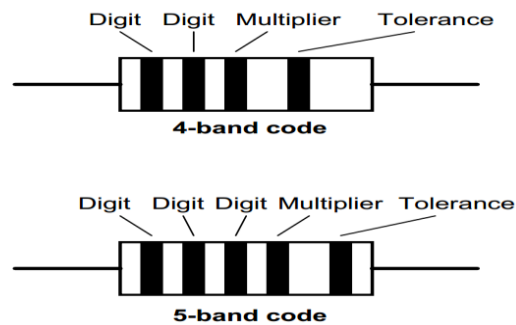


Figure: resistor color bands

$$\text{Resistor value} = AB \times 10^C \pm \text{tol} \% (\Omega)$$

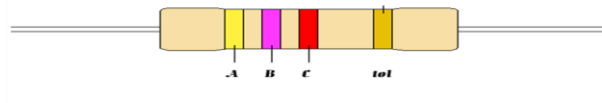


Figure: resistor color bands representation


- Four band resistor colour code
  - 1st band provides the first digit of the code
  - 2nd band provides the second digit of the code
  - 3rd band is the multiplier
  - 4th band indicates the tolerance value
- 
- A diagram of a resistor with four color bands. The bands are labeled 1, 2, 3, and 4. The bands are colored brown, green, red, and yellow respectively.

Figure: resistor color code calculation

Table 2.1: Resistor color coding

COLOR	DIGIT	MULTIPLIER	TOLERANCE
Silver		x 0.01Ω	±10%
Gold		x 0.1Ω	±5%
Black	0	x 1Ω	
Brown	1	x 10Ω	±1%
Red	2	x 100Ω	±2%
Orange	3	x 1 kΩ	
Yellow	4	x 10 kΩ	
Green	5	x 100 kΩ	±0.5%
Blue	6	x 1 MΩ	±0.25%
Violet	7	x 10 MΩ	±0.1%
Grey	8	x 100 MΩ	
White	9	x 1 GΩ	

### Example

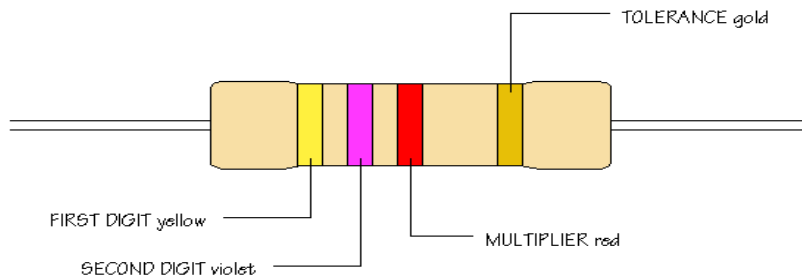


Figure: color code example

The first band is yellow, so the first digit is 4

The second band is violet, so the second digit is 7

The third band is red, so the multiplier is  $10^2$

The fourth value is gold, so the tolerance is 5%

Resistor value is  $47 \times 10^2 \pm 5\% \Omega$

- In formulas the letter R is used for the resistor and the unit is  $\Omega$  (Ohm). To keep large numbers small and handy the units are used in conjunction with the SI prefixes.  
1000  $\Omega$  is 1 k $\Omega$  and 1000 k $\Omega$  is 1 M $\Omega$
- In circuit diagrams very often the dot is replaced by the R or  $\Omega$ .
  - 47K = 47 K $\Omega$
  - 1K5 = 1.5 K $\Omega$
  - 1M0 = 1.0 M $\Omega$
  - 2R2 = 2.2  $\Omega$
  - 0 $\Omega$ 22 = 0.22  $\Omega$

**What is TCR?** The rate at which the resistance of the resistor changes with change in temperature is called TCR (Temperature Co-efficient of Resistance).

### Resistors in series and parallel connection

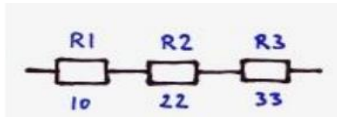
There are two different ways to connect resistors: Serial and parallel connection. In addition to that a combination of this two principles is possible, the serial-parallel connection.

#### Resistor in Series

- Two or more resistors can put together like a chain.

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- The values of the single resistors simply have to be added to get the value of the whole combination
- In series connection the total resistance is always higher than the highest value of a single resistor.



$$R_{\text{total}} = R_1 + R_2 + R_3 + \dots$$

Figure: resistors in series

- Example: The total value of this resistor combination is:  $10 \Omega + 22 \Omega + 33 \Omega = 65 \Omega$
- Series connected resistors have a common Current flowing through them.

$$I = I_1 = I_2 = I_3 \dots \text{etc.}$$

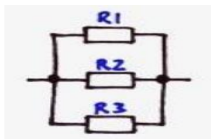
- Total circuit voltage is equal to the sum of all the individual voltage drops.

$$V = V_1 + V_2 + V_3 \dots \text{etc.}$$

- The total resistance of a series connected circuit will always be greater than the highest value resistor.

### Resistors in parallel

- In parallel connection the total resistance is always lower than the lowest value of a single resistor.



$$R_{\text{total}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots}$$

Figure: resistors in series

- Example: The total value of this resistor combination is:

$$\frac{1}{\frac{1}{10} + \frac{1}{22} + \frac{1}{33}} = \frac{1}{0.1 + 0.045 + 0.03} = \frac{1}{0.175} = \underline{5.71 \Omega}$$

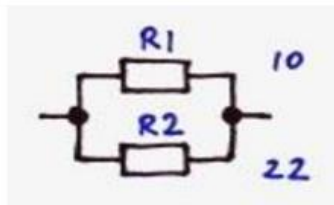
- Parallel resistors have a common Voltage across them.

$$V = V_1 = V_2 = V_3 \dots \text{etc.}$$

- Total circuit current flow is equal to the sum of all the individual branch currents added together.

$$I = I_1 + I_2 + I_3 \dots \text{etc.}$$

- The total resistance of a parallel circuit will always be less than the value of the smallest resistor
- If only two resistors are put in parallel a more simple formula can be used then, the total resistance is the product of the two resistors, divided by the sum of the two resistors.



$$R_{\text{total}} = \frac{R_1 \times R_2}{R_1 + R_2}$$

Figure: Two resistors in parallel

- A series-parallel connection is nothing else than a combination of a serial and a parallel connection.
- The calculation has to be done step by step with using the above mentioned formulas.

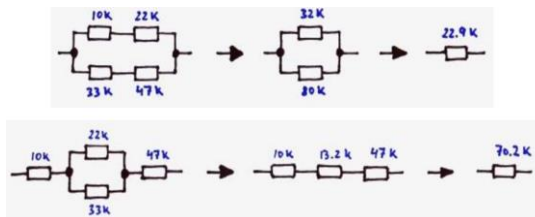


Figure: resistors in series-parallel

### 2.1.2 Capacitors

These are passive electronic components which have ability to charge or store electric energy. It is made up of two parallel conducting plates separated by some dielectric materials. The capacitor is a two terminal electrical device used to store electrical energy in the form of electric field between the two plates. It is also known as a condenser and the SI

unit of its capacitance measure is Farad “F”, where Farad is a large unit of capacitance, so they are using microfarads ( $\mu\text{F}$ ) or nanofarads (nF) nowadays.

### Concept Structure:

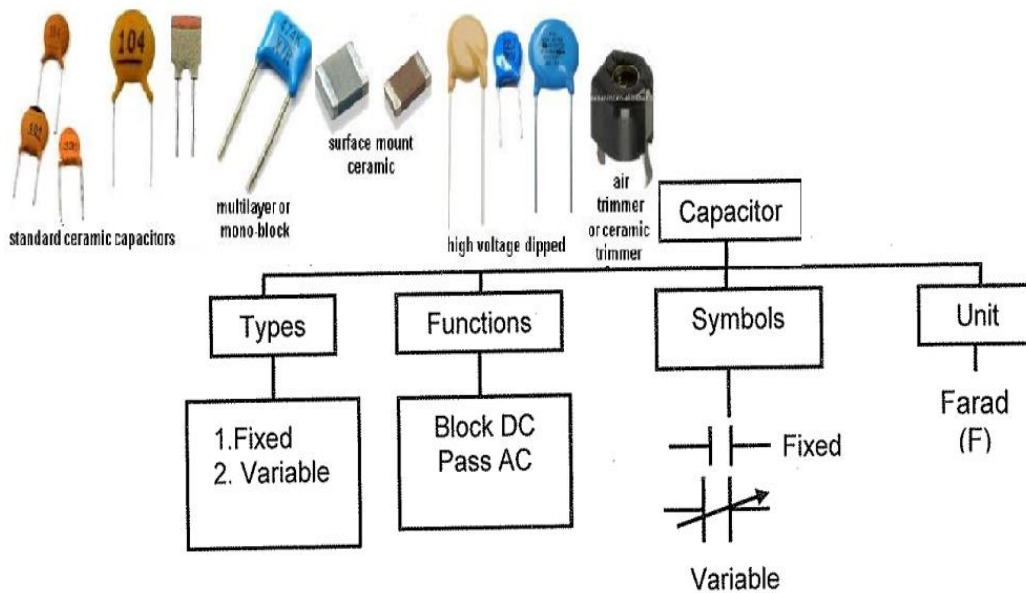


Figure: capacitor classification

### How Capacitor Works?

- Whenever voltage is applied across its terminals, (Also known as charging of a capacitor) current start to flow and continue to travel until the voltage across both the negative and positive (Anode and Cathode) plates become equal to the voltage of the source (Applied Voltage).
- These two plates are separated by a dielectric material (such as mica, paper, glass, etc. which are insulators), which is used to increase the capacitance of the capacitor.
- When we connect a charged capacitor across a small load, it starts to supply the voltage (Stored energy) to that load until the capacitor fully discharges.

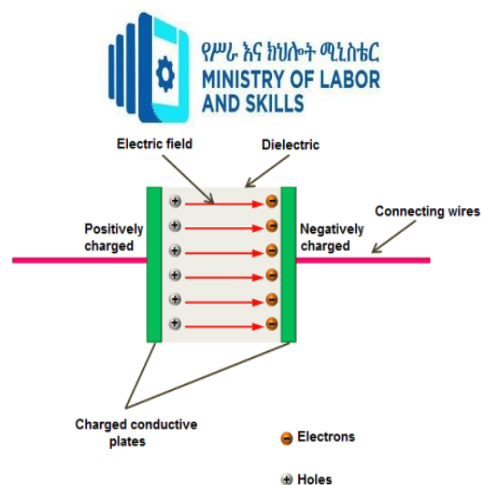


Figure: Capacitor construction

Capacitor comes in different shapes and their value is measured in farad (F). Capacitors are used in both AC and DC systems (We will discuss it below).

### Capacitance (C)

- Capacitance is the amount of electric charge moved in the condenser (Capacitor), when one volt power source is attached across its terminal. Mathematically,

Capacitance Equation:  $C = Q/V$

Where,  $C$  = Capacitance in Farads (F)

$Q$  = Electrical Charge in Coulombs

$V$  = Voltage in Volts

- Capacitance is measure in farads (F). Practically farad is a large unit. The smaller units are microfarads, Nano-farads and pico-farads.
  - ✓ 1 microfarad =  $1/1,000,000$  farad
  - ✓ 1 nanofarad =  $1/1,000,000,000$  farad
  - ✓ 1 picofarad =  $1/1,000,000,000,000$  farad
  - ✓ So,  $0.01\mu F = 10nF = 10,000pF$
- Microfarad can be written as MFD, MF or  $\mu F$  or simply M. Nano-farad is written as NF. Pico-farad is written as P.F Capacitors.

### Capacitor behavior

- ✓ Current through capacitor proportional to rate of change in voltage across it:

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$$i = \frac{\Delta Q}{\Delta t} = C \frac{\Delta V}{\Delta t}$$

- ✓ Capacitors act to resist changes in voltage
- ✓ Capacitor current can change (very) quickly
- ✓ Capacitors store energy:

$$E_{\text{stored}} = \frac{1}{2} CV^2 \Leftrightarrow E_{\text{stored}} = \frac{1}{2} \frac{Q^2}{C}$$

### Types of capacitors

#### Ceramic Capacitors

The plate material in a ceramic capacitor is a silver compound that is fixed or deposited upon the surface of a dielectric. The dielectric is a ceramic form made of tantanium dioxide or a silicate compound. The overall capacitor assembly is coated with plastic material. Ceramic capacitor have a high dielectric constant that provides them with high working voltage ratings. That capacitance of these capacitors varies from 1 pF to 0.1 uF. They have a wider applications like filtering, coupling and decoupling, resonant circuit parameter and others

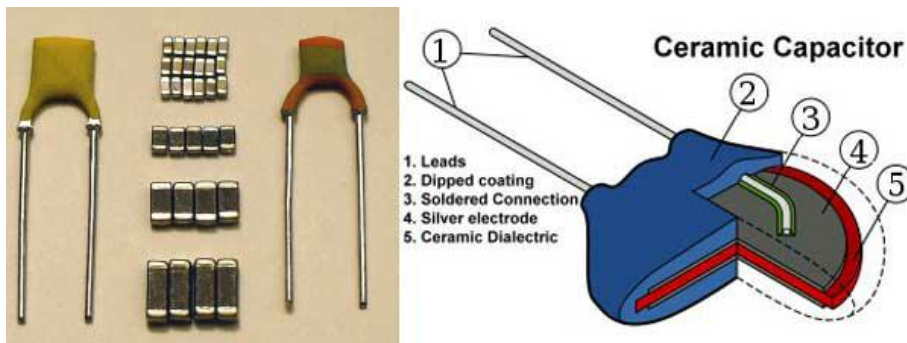


Figure: ceramic capacitor

#### Paper Capacitor

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- Its plates are made of aluminum or tin foil with a dielectric of paper that is impregnated (saturated) with an oil or wax compound.
- Such capacitors are non-polarized devices.
- Their capacitance range from 0.001 to 1  $\mu\text{F}$  and their temperature coefficient is comparatively higher than those of the other types.

### Plastic Film Capacitor

- These capacitors are manufactured from plastic films usually of the oriented crystalline type.
- The plastics used are thermoplastic films that have been extruded, stretched and heat treated.
- Moisture has a little effect on the plastic films dielectric properties.
- This fact makes the packaging of plastic film capacitors easier compared with other types.
- There are 3 general classes of plastic film capacitors – polystyrene, polyester, and polycarbonates.



### Mica Capacitor

Several strips of metal foil, either aluminum, tin or copper, are sandwiched between thin sheets of mica which serve as the dielectric materials. Alternate strips of foil are connected to form the plate. These capacitors are found in the range of 1 pF to 0.01  $\mu\text{F}$  in capacitance. Its useful applications are in high frequency circuit



Figure: mica capacitor

## Electrolytic Capacitor

These are capacitors whose dielectric layers are formed by an electrolytic method. The most common electrolytic capacitors are the aluminum electrolytic capacitors and tantalum electrolytic capacitors.

### Aluminum Electrolytic Capacitors

Consist of etched foils (the anode and cathode foils) and paper separators rolled into a tabular form. During the assembly process, thin coating of aluminum oxide is deposited upon the surface of the anode foil and this coating becomes the dielectric material of the capacitor. The thickness of the oxide determines the working voltage rate of the capacitor which generally does not exceed 500volts.

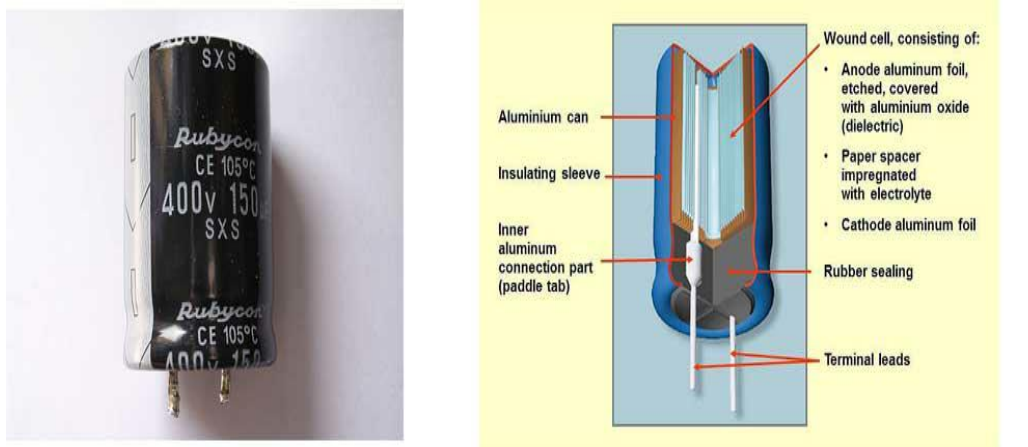


Figure 2.10 Electrolyte capacitor

### Tantalum Electrolytic Capacitors

Use tantalum metal foils and acid electrolytes. The oxide coating deposited upon the surface of their foils has greater dielectric constant than that of aluminum oxide. These capacitors are more rugged and have high temperature coefficient. However, their working voltage ratings are much lower compared with the first. Take note that both types of electrolytic are polarized devices that must be operated under Direct Current (DC) voltage condition.

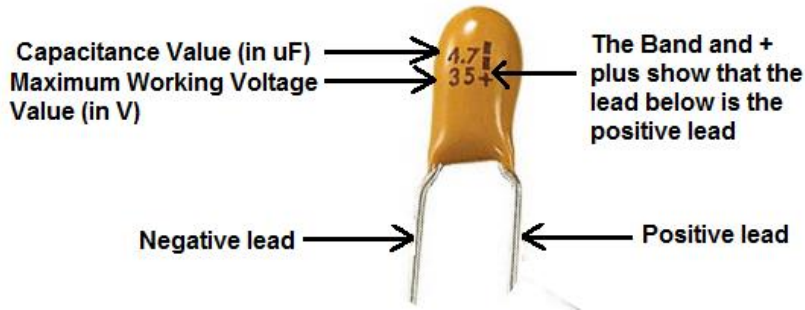


Figure: Tantalum capacitor

### Variable Capacitor

- This capacitor are also known as air dielectric variable (or tuning) capacitor.
- It consists of stationary plates (stator) and a set of a position that allows them to mesh with each other without touching.
- By rotating the shaft of this capacitor, the surface area directly opposite the stator plates varies, causing the capacitance to vary

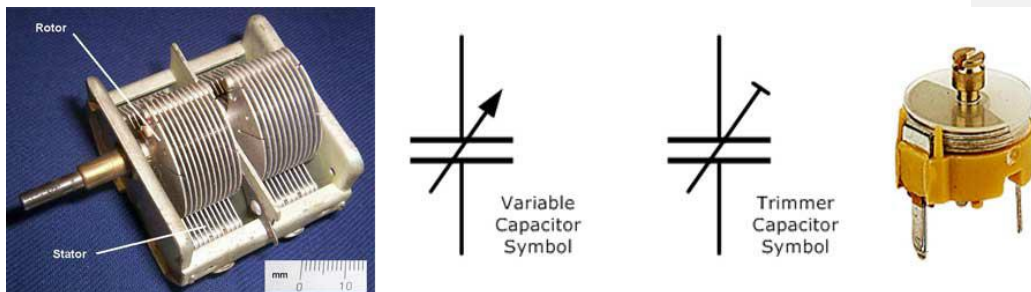


Figure: Variable capacitors

### Super capacitors

Super capacitor is an electronic device that store large amount of electric charge. These capacitors are also known as ultracapacitors or electric double layer capacitors.

### Types of supercapacitors

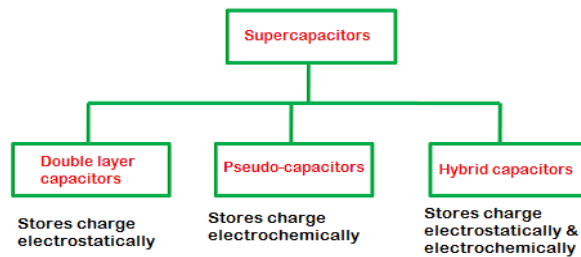


Figure: Types of supercapacitors

### Advantages of super capacitors

- Stores large amount of charge compared to the conventional capacitors (High capacitance).
- Delivers energy or charge very quickly (high power density)
- Long lifetime
- Low cost
- Supercapacitors do not explode like batteries even if it is overcharged.

### Applications of supercapacitors

- Flash light applications
- Solar power applications
- Supercapacitors are used in electronic devices such as laptop computers, portable media players, hand held devices, and photovoltaic systems to stabilize the power supply.
- Supercapacitors are used as temporary energy storage devices for energy harvesting systems.
- Supercapacitors are used in defibrillators (an instrument that controls irregular heart beat by supplying electric current to the chest wall).
- The difference among conventional capacitor, battery and super capacitors is shown in the table below

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Table 2.2 difference among conventional capacitor, battery and super capacitors

Functions	Battery	Conventional capacitor	Supercapacitor
Charge storage	large	small	large
Charge delivery	slow	quick	quick
Surface area of plates	-----	small	large
Dielectric thickness	-----	thick	Very thin

## Polar and Non-Polar Capacitor

### Non Polar Capacitor

- The Non Polar capacitors can be used in both AC and DC systems.
- They can be connected to the power supply in any direction and their capacitance does not effect by the reversal of polarity.

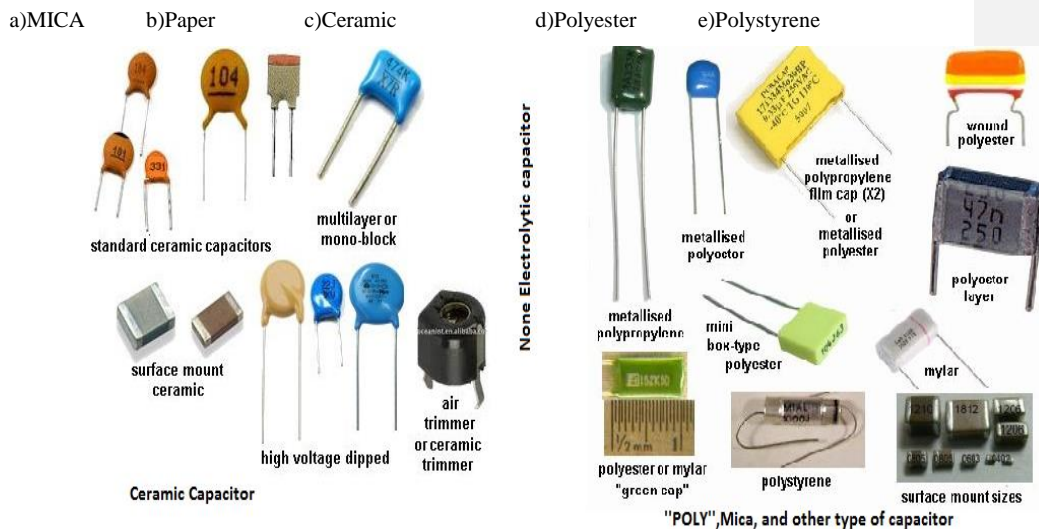




Figure 2.11 different types of capacitors

### Polar Capacitor

- This type of capacitor is sensitive about their polarity and can be only used in DC systems and networks.
- Polar Capacitors don't work in the AC system, because of the reversal of polarity after each half cycle in AC supply.

Example: Electrolytic capacitor and Tantalum

### Applications of Capacitors in AC Circuits and System:

- The capacitor has lots of applications in AC systems and we will discuss few uses of capacitor in AC networks below.

#### Transformer less power supply:

- Capacitors are used in transformer less power supplies.
- In such circuits, the capacitor is connected in series with the load because we know that the capacitor and inductor in pure form does not consume power. They just take power in one cycle and deliver it back in the other cycle to the load.
- In this case, it is used to reduce the voltage with less power wastage.

#### Split phase induction motors:

- The capacitors are also used in induction motor to split a single phase supply into a two phase supply to produce a revolving magnetic field in the rotor to catch that field.
- This type of capacitor is mostly used in household water pumps, Fans, air conditioner and many devices which need at least two phases to work.

#### Power Factor Correction and Improvement:

- In a three phase power systems, capacitor bank is used to supply reactive power to the load and hence improve the power factor of the system.
- Capacitor bank is installed after a precise calculation.
- Basically, it delivers the reactive power which was previously traveled from the power system, hence it reduces the losses and improves the efficiency of the system.

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## Applications of Capacitors in DC Circuits and system:

### Power conditioning:

- In DC systems, capacitor is used as a filter (mostly).
- Its most common use is converting AC to DC power supply in rectification (such as bridge rectifier).
- DC Polar capacitor is used. Its value is calculated precisely and depends on the system voltage and the demand load current.

### Decoupling Capacitor:

- Decoupling capacitor is used, where we have to decouple the two electronics circuits.
- In other words, the noise generated by one circuit is grounded by decoupling capacitor and it does not affect the performance of other circuit.

### Coupling Capacitor:

- As we know that Capacitor blocks DC and allows AC to flow through it. So it is used to separate AC and DC signals (also used in the filter circuits for the same purpose).
- Coupling Capacitor is also used in filters (ripple remover circuits like RC filters) to separate AC and DC signal.

### How to discharge a capacitor

- Do not use a screwdriver to short between the terminals as this will damage the capacitor internally and the screw driver.
- Use a 1k 3watt or 5watt resistor or 100watt bulb on jumper leads and keep them connected for a few seconds to fully discharge the electron.
- Test it with a voltmeter to make sure all the energy has been removed.

### How to read capacitor numeric code

The non-polarized capacitor of nominal value of less than 1000pF is usually plain marked. For instant, for a 220pF capacitor, it will be marked 220 only. For capacitance values of 1000pF or more, a three digit code issued. The first two digits represent the two significant digits and the

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third digit represents the decimal multiplier. For instance, 102 represents a capacitance of  $10 \times 10^2 = 1000 \text{ pF}$  and 104 represents a capacitance of  $10 \times 10^4 = 100000 \text{ pF} = 0.1 \mu\text{F}$ . Basically it has the same calculation method as resistor.

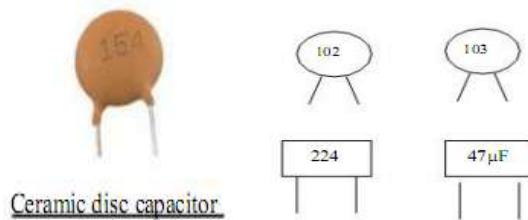


Figure: Ceramic disc capacitor

Example 1: What is the capacitance value of these capacitors marked?

- 22  $\Rightarrow$  22 picofarad
- 330  $\Rightarrow$  330 picofarad
- 471  $\Rightarrow 47 \times 10 = 470$  picofarad
- 562  $\Rightarrow 56 \times 10^2 = 5600$  picofarad or 5.6 nanofarad
- 103  $\Rightarrow 10 \times 10^3 = 10000$  picofarad or 10 nanofarad
- 224  $\Rightarrow$  microfarad  $22 \times 10 = 220000$  picofarad or 220 nanofarad or .22
- 335  $\Rightarrow 33 \times 10 = 3300000$  picofarad or 3300 nanofarad or 3.3 microfarad

Electrolytic capacitors have their capacitance, voltage rating, and polarity printed on the case as shown in Figure below

**Value of color coded capacitor** can be determined in similar way as that of color coded resistor except the voltage rating of capacitor can be indicated in the color code technique



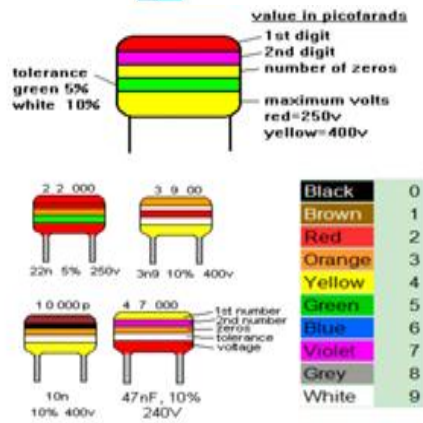


Figure: Capacitor color code

Table 2.3 Capacitor circuit symbols and their functions

Capacitors circuit symbols and their functions		
Component	Circuit Symbol	Function of Component
<a href="#">Capacitor</a>		A capacitor stores electric charge. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
<a href="#">Capacitor, polarised</a>		A capacitor stores electric charge. This type must be connected the correct way round. A capacitor is used with a resistor in a timing circuit. It can also be used as a filter, to block DC signals but pass AC signals.
<a href="#">Variable Capacitor</a>		A variable capacitor is used in a radio tuner.
<a href="#">Trimmer Capacitor</a>		This type of variable capacitor (a trimmer) is operated with a small screwdriver or similar tool. It is designed to be set when the circuit is made and then left without further adjustment.

#### Parallel and Series combination of Capacitors

Capacitors can be connected in **parallel** and/or **series** for a number of reasons. If you do not have the exact value, two or more connected in parallel or series can produce the value you need. Capacitors connected in series will produce one with a higher voltage rating. Capacitors connected in parallel will produce a larger-value capacitance.

■  $V = V_1 + V_2 + V_3$

$$\frac{1}{C_{\text{tot}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_{\text{tot}} = \frac{C_1 \cdot C_2}{C_1 + C_2}$$

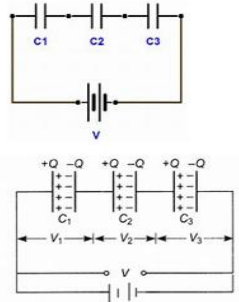


Figure: series connection of capacitor

$V = V_1 = V_2$

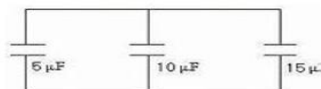
$C = C_1 + C_2$

parallel combination

series combination

PARALLEL		$C_p = C_1 + C_2$
SERIES		$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$

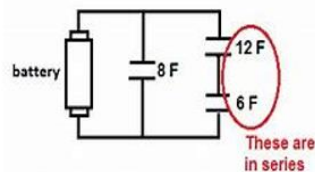
example



Capacitor Connected In Parallel

$$C_T = 5 + 10 + 15 \text{ microfarad} \\ = 30 \text{ microfarad}$$

Figure: Parallel connection of capacitor



$$C_{\text{total}} = C_1 + C_{\text{eq}} \\ = 8F + 4F \\ C_{\text{total}} = 12F$$

$$\frac{1}{C_{\text{eq}}} = \frac{1}{12F} + \frac{1}{6F} = \frac{3}{12F}$$

$$C_{\text{eq}} = \frac{12F}{3} = 4F$$

Figure: Capacitors in series and parallel

### 2.1.3 Inductors

Are passive components used to minimize AC current while permitting (passing) DC current. An inductor, or induction coil, stores electrical energy in a magnetic field. Inductors are used in many electronics and they play an especially important role in PSUs. An inductor is simply a coil of wire wrapped around a core (composed of iron, ferrite or simply air). Depending on their usage they have several names: coils, chokes, solenoids, etc.

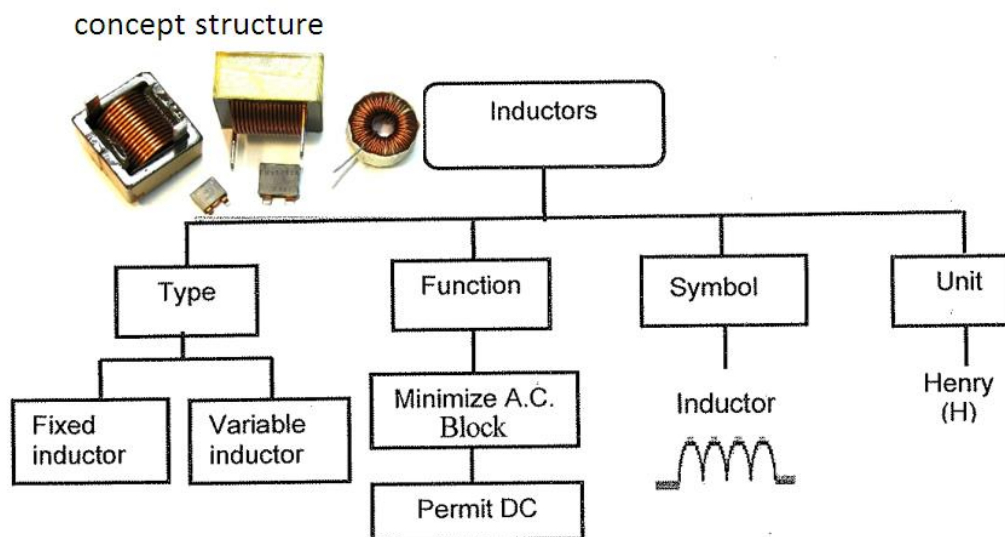


Figure: Types of Inductors

#### How do inductors work?

- The whole concept is very simple: when a current passes through an inductor, a magnetic field is created around the wire. Every change in current affects the magnetic field, which in turn induces voltage across the inductor.
- That voltage creates a current flow opposite of the initial current. This property is known as **inductance (L)** and it's measured in henries, which is a quite large unit of measure usually documented in millihenries (mH) or microhenries (μH).

Here are some interesting facts about inductors:

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- ✓ They store electrical energy in magnetic fields.
- ✓ They act as an open circuit at first when DC (direct current) is applied to them, but after a while they freely allow it to pass.
- ✓ They oppose current changes.

### Types of Cores

- The core material of an inductor plays a large role in the performance of an inductor. The core material directly impacts the inductance of the inductor and will impact the maximum operating frequency, and current capacity of the inductor.
- The types of inductor cores include:
  - ✓ **Air Core** - Higher frequency operation due to no core losses but a lower inductance
  - ✓ **Iron Core** - Low resistance with high inductance. Core losses, eddy currents, magnetic saturation and hysteresis limit the operating frequency and current
  - ✓ **Ferrite Core** - Non-conductive ceramic material for higher frequency operation. Magnetic saturation limits the current capacity
  - ✓ **Toroidal Core** - A core shaped like a donut that reduces radiated EMI and provides high inductance
  - ✓ **Laminated Core** - High inductance with lower hysteresis and eddy current losses

The counter emf is directly proportional to the rate of change of current through the coil ( $V=L[\Delta i/\Delta t]$ ). The proportionality constant is the inductance  $L$ , which has the unit of henrys (H). In an ac circuit, as shown in, the inductor offers reactance to alternating current. The inductive reactance  $X_L$  has the units of ohms and is given by

$$X_L = \omega L = 2\pi fL$$

Total inductance

$$L = L_1 + L_2 + L_3 \text{ -----}$$

Inductances in parallel :

$$1/L = 1/L_1 + 1/L_2 + 1/L_3$$

**Inductor behavior-** Voltage across inductor is proportional to the rate of change of current through it:

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$$V = L \frac{\Delta I}{\Delta t}$$

- ✓ Inductors act to resist changes in current
- ✓ Inductor voltage can change quickly
- ✓ Inductors store energy:

$$E_{\text{stored}} = \frac{1}{2}LI^2$$

### 2.1.4 Transformer

An AC device used to change high voltage and low current AC into low voltage and high current AC and vice-versa without changing the frequency. The device that changes AC voltage. It can not change (direct current) DC voltage. Transformer is label as “T” in the circuit board. Transformer basically consists of two inductors one of these inductors is a meant for supplying alternative current from external source(is called primary winding), the other coil in which the primary winding induce voltage( is known as secondary winding). In brief

- ✓ Transfers electric power from one circuit to another
- ✓ It does so without a *change of frequency*
- ✓ It accomplishes this by the principle of *Electromagnetic induction*
- ✓ Where the two electric circuits are in mutual inductive influence of each other
- ✓ *Input and output are AC*

#### Electromagnetic Induction

- When a conductor is moved through a magnetic field, a voltage is induced across the conductor
- This principle is known as electromagnetic induction
  - The faster the relative motion, the greater the induced voltage.
- Electromagnetic Induction is the process of generating an *electric current* by varying the *magnetic field* that passes through a circuit.
- Electromagnetic induction establish an important link between electricity and magnetism.

A transformer consists of 3 basic components

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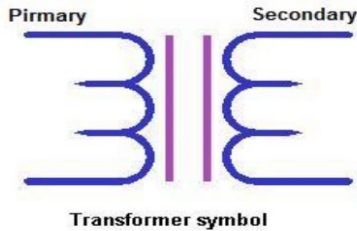


Figure: Transformer symbol

#### Primary Coil or Primary Winding :

- It is an electrical wire wrapped around the core on the input side.
- The winding, which receives electrical energy

#### Secondary Coil or Secondary Winding:

- It is an electrical wire wrapped around the core on the output side.
- The winding, which delivers electrical energy

**Core:** A ferromagnetic material that can conduct a magnetic field through it. Example: Iron  
Windings are made of copper. The windings are *stationary* and the magnetic flux is *changing*.

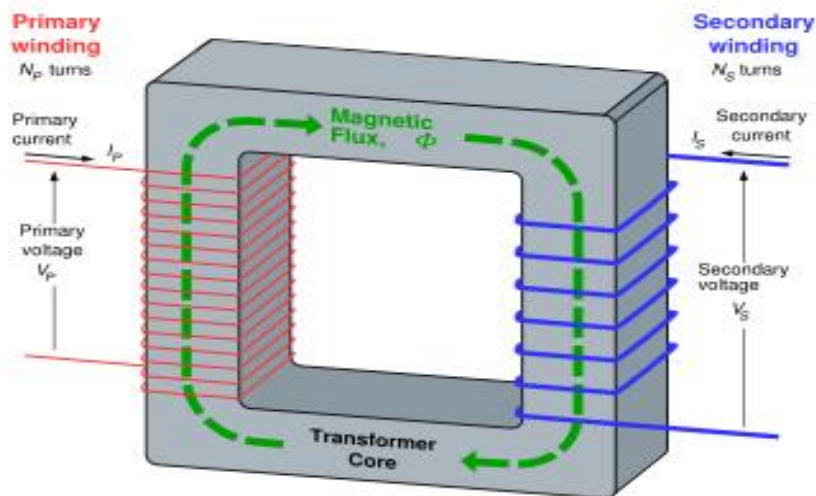


Figure 2.12 Transformer Structure

## Types of Transformer

According to the transformer construction, they are classified into two types.

- a) Core type transformer
- b) Shell type transformer

### a) Core type transformer

In the core type transformers, *the windings surround the core*.



Figure: Core type transformer

### b) Shell type transformer

- In shell type transformers, *the core surrounds the windings*.



Figure: Shell type transformer

Generally there are two types of transformer based on their uses in **power supply**

- a) Linear type power transformer
- b) Switching mode power transformer

a) **Linear transformer** divided in to three:

- 1) **Step up transformer**

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- Increase the output voltage
- Example: 240v ac input with a 480v ac output (high voltage)

## 2. Step down transformer

- Decrease the output voltage
- Example: 240v ac input with a 12v ac output (low voltage)

## 3. Isolation transformer

- Produce the same amount of voltage as the input voltage

Example: 240v ac input with 240v ac output

### Comparison between step up and step down transformer

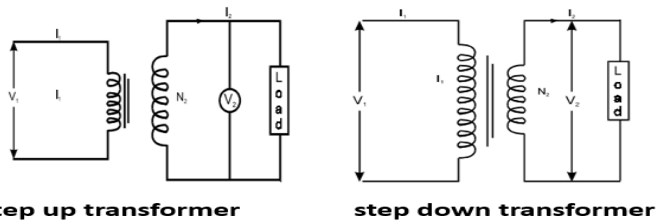


Figure: step-up and step-down transformer

Table: Comparison between step-up and step-down transformer

Step up transformer	Step down transformer
Secondary voltage more than primary voltage ( $V_2 > V_1$ )	Secondary voltage less than primary voltage ( $V_2 < V_1$ )
$N_2 > N_1$ N2 number of secondary turn N1 number of primary turn	$N_2 < N_1$ N2 number of secondary turn N1 number of primary turn
$I_2 < I_1$ I2 current in secondary winding I1 current in primary winding	$I_2 > I_1$ I2 current in secondary winding I1 current in primary winding
Transformer ratio $K = V_2/V_1$ is more than one	Transformer ratio is less than one
Power transformer at a Power Generating Station is an example of this type	Distribution transformer is an example of this type

Commented [WU1]: Fig title and number?

## Tapped Transformers



The center tap (CT) transformer is equivalent to two secondary windings with half the voltage across each.

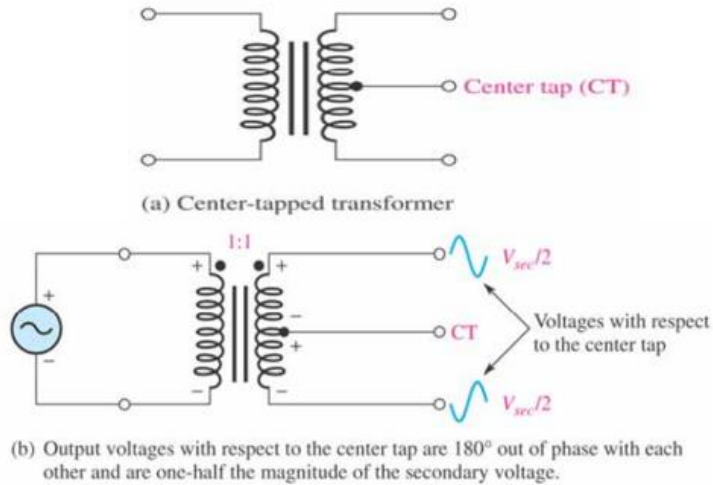


Figure: Center tap transformer

### b) Switching mode power transformer (SMPT)

used in switch mode power supplies in electronic equipment such as computer monitor, TV, DVD and so on.

- ✓ SMPT converts ac wave to some other value, lower or higher
- ✓ Have input(primary winding) and out put(secondary winding)
- ✓ SMPT rarely break down
- ✓ If it break down causes power section components to blow or totally blow up
- ✓ If SMPT is failed , normally it was the primary winding shorted.
- ✓ The secondary winding are very robust and seldom have problem

Other types of transformer based on their applications

**Power transformer(PT)**-main transformer

**Audio frequency transformer(AFT)**-operated at audio frequency of 20Hz to 20 KHz

**Radio frequency transformer(RFT)**-operated at a very high frequency of 300kHz to 3MHz

**Intermediate frequency transformer (IFT)**—lie between audio and radio frequency range and fixed.

**Auto transformer (AT)**—the same coil is used to provide turns the primary as well as the secondary

### Auto transformer

An autotransformer has **only one tapped** winding, which is both the primary and the secondary. Since only one winding is needed the autotransformer is cheaper than a normal transformer. The disadvantages of the autotransformer is that:

- ✓ There is a direct metallic connection between the input and the output, whereas *the coupling in a double-wound transformer* is magnetic only, giving electrical isolation of the two windings.
- ✓ In the event of an open-circuit fault in the common part of the winding, the input voltage.
- ✓ An autotransformer uses only one coil for the primary and secondary.
- ✓ It uses taps on the coil to produce the different ratios and voltages.

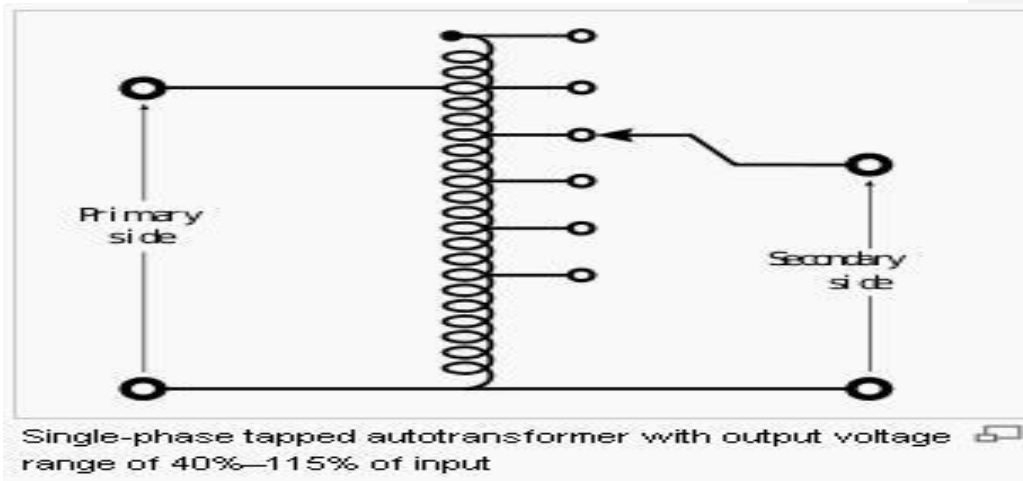


Figure: Autotransformer

### Isolation transformer (IT)

In isolation transformer, the primary and secondary are physically isolated (no electrical connection). when the number of the primary winding ( $N_1$ ) is equal to the number of the secondary winding ( $N_2$ ) that is  $N_1 = N_2$ . While isolating the powered device from the power source, usually *for safety* reason. It has 1 to 1 turn ratio (1:1)

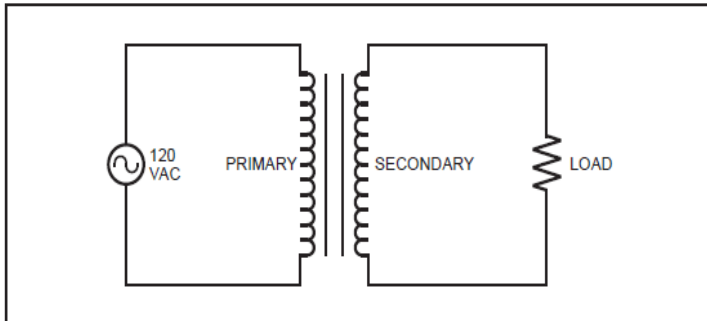


Figure: Isolation transformer

#### Advantages of Isolation Transformer

- ✓ Voltage **spikes** that might occur on the primary are greatly reduced or eliminated in the secondary
- ✓ If the primary is shorted somehow, any load connected to the secondary is not damaged
- ✓ Example: In TV monitors to protect the picture tube from voltage spikes in main power lines

#### 2.1.5 Diodes

Diodes are active components used to pass current in only one direction while it blocks in the reverse direction

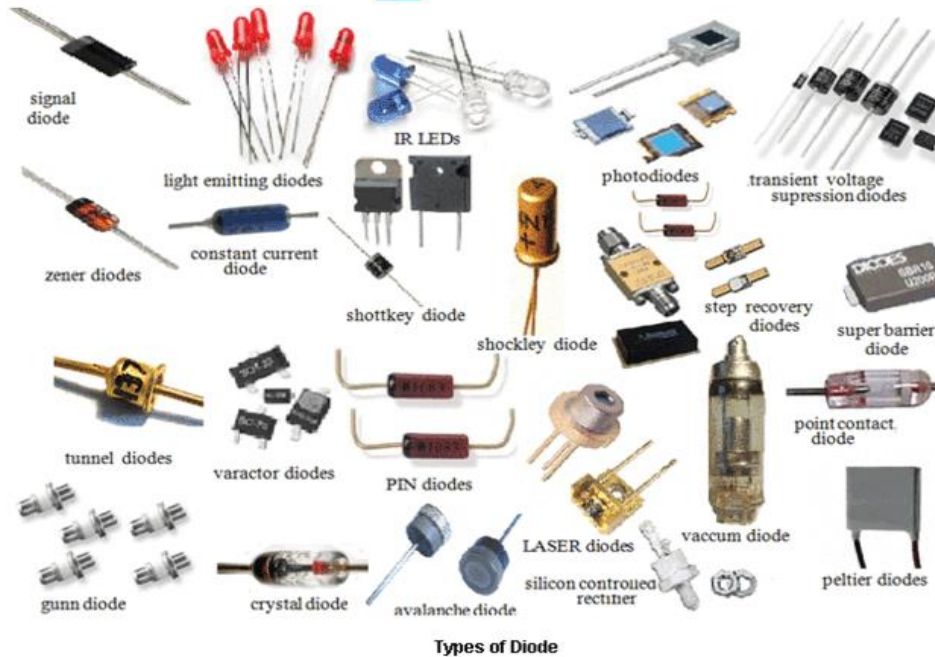


Figure 2.13 different types of diodes

A Diode (D) lets current flow through in only one direction. (Hence the arrow in the symbol). One leg of the diode is marked, usually with a fat black or white line. The marked leg is the 'cathode', where current can flow out of, but not into. (ie. the - end) The other leg (where the current can flow into the diode, the + end) is called the 'anode'

**Diodes:** General purpose diode, Rectifier diode, Zener diode, LED, photo diode

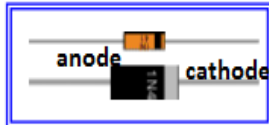
Diode is unidirectional PN-junction electronics device used in many applications. Such as:

- ✓ Converting AC power from the 60Hz line into DC power for radios, televisions, telephone answering machines, computers, and many other electronic devices.
- ✓ Converting radio frequency signals into audible signals in radios.
- ✓ Used as rectifier in DC Power Supplies.
- ✓ In Demodulation or Detector Circuits.
- ✓ In clamping networks used as DC Restorers
- ✓ In clipping circuits used for waveform generation.

- ✓ As switches in digital logic circuit

## PN Junction Diodes

Example:



Circuit symbol:

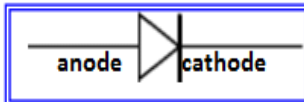


Figure: PN junction diode

A p-n junction is a boundary or interface between two types of semiconductor material, P-type and n-type, inside a single crystal of semiconductor. P-n junctions are elementary "building blocks" of most semiconductor electronic devices such as diodes, transistors, solar cells, LEDs, and integrated circuits. After joining p-type and n-type semiconductors, electrons from the n region near the p-n interface tend to diffuse into the p region. The regions nearby the p-n interfaces lose their neutrality and become charged, forming the space charge region or depletion layer

### Function

Diodes allow electricity to flow in only one direction. The arrow of the circuit symbol shows the direction in which the current can flow.

### Forward Voltage Drop

When a forward voltage is applied to diode, a small voltage experiences 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).

### 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  $\mu\text{A}$  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

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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. In addition there are other types of diodes as such : LEDs, Zener diodes ,Tunnel diode,PINdiode,Photo diode and Varicap diode etc.

### 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.

**Biasing of Diode:** the process of applying an external voltage is called as “biasing”.

There are two ways in which we can bias a pn junction diode.

- 1) Forward bias
- 2) Reverse bias

**Forward Bias** – The voltage potential is connected positive, (+ve) to the P-type material and negative, (-ve) to the N-type material across the diode which has the effect of **Decreasing** the PN junction diodes’s width. **Reverse Bias** – The voltage potential is connected negative, (-ve) to the P-type material and positive, (+ve) to the N-type material across the diode which has the effect of **Increasing** the PN junction diode’s width.

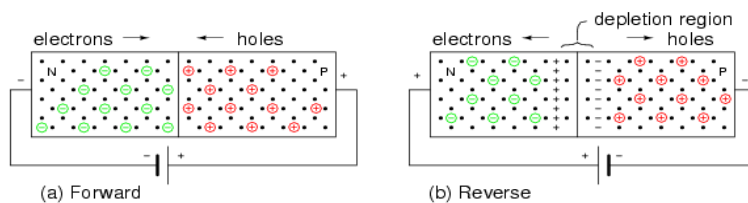


Figure: Forward & Reverse bias & V-I characteristics of PN junction Diode

### Forward Biased PN Junction Diode

When a diode is connected in a **Forward Bias** condition, a negative voltage is applied to the n-type material and a positive voltage is applied to the p-type material. If this external voltage becomes greater than the value of the potential barrier, approx. 0.7 volts for silicon and 0.3 volts for germanium, the potential barriers opposition will be overcome and current will start to flow.

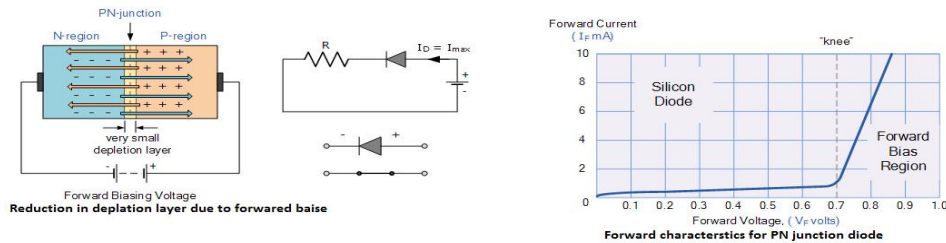


Figure: Forward Biased PN Junction Diode

### Reverse Biased PN Junction Diode

When a diode is connected in a **Reverse Bias** condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material. The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode. Thus

- ✓ The depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator.
- ✓ The result is that a high potential barrier is created thus preventing current from flowing through the semiconductor material.
- ✓ High resistances value to the PN junction and practically zero current flows through the junction diode with an increase in bias voltage. However, a very small **leakage current** does flow through the junction which can be measured in microamperes, ( $\mu A$ ).

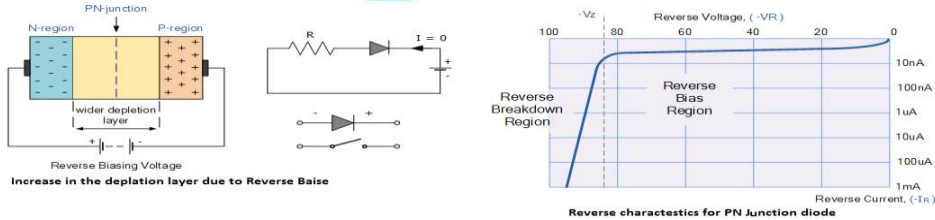


Figure: Reverse Biased PN Junction Diode

### Junction Diode Summary

The PN junction region of a **Junction Diode** has the following important characteristics:

- ✓ Semiconductors contain two types of mobile charge carriers, **Holes** and **Electrons**.
- ✓ The holes are positively charged while the electrons negatively charged.
- ✓ A semiconductor may be doped with donor impurities such as Antimony (N-type doping), so that it contains mobile charges which are primarily electrons.
- ✓ A semiconductor may be doped with acceptor impurities such as Boron (P-type doping), so that it contains mobile charges which are mainly holes.
- ✓ The junction region itself has no charge carriers and is known as the depletion region.
- ✓ The junction (depletion) region has a physical thickness that varies with the applied voltage.
- ✓ When a diode is **Zero Biased** no external energy source is applied and a natural **Potential Barrier** is developed across a depletion layer which is approximately 0.5 to 0.7v for silicon diodes and approximately 0.3 of a volt for germanium diodes.
- ✓ When a junction diode is **Forward Biased** the thickness of the depletion region reduces and the diode acts like a short circuit allowing full current to flow.
- ✓ When a junction diode is **Reverse Biased** the thickness of the depletion region increases and the diode acts like an open circuit.



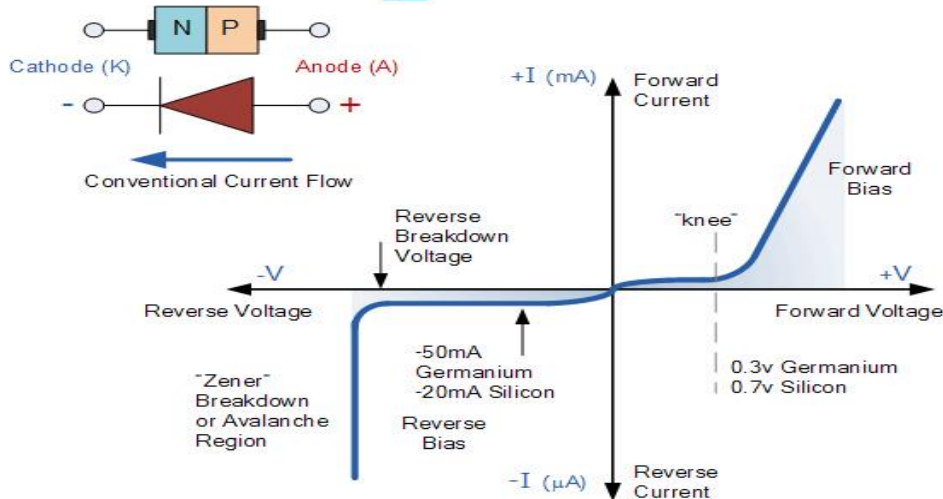


Figure: Voltage-current characteristics of silicon and germanium diodes and its symbol

#### Rectifier diode:- Convert AC to DC

The conversion of bidirectional alternating current (a.c.) into unidirectional direct current (d.c.) is called rectification. Electronic devices can convert a.c. power into d.c. power with very high efficiency.

**Half wave rectifier:** In this type the rectifier conducts current only during the +ve half cycles of the a.c. supply. In this type, the rectifier utilizes both half cycles of a.c. input voltage to produce the d.c. output.

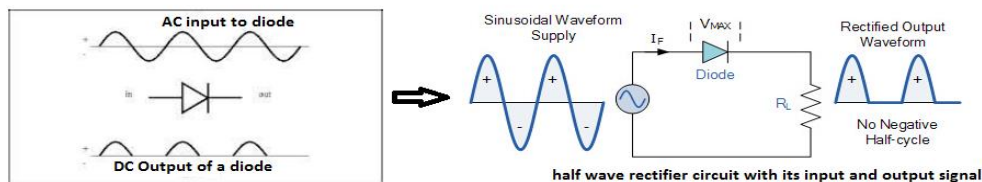


Figure: Half wave rectifier

Here –ve half cycles are suppressed i.e. during –ve half cycle no current passes through the diode hence no voltage appears across the load.

Max. Rectifier Efficiency= Max. d.c.output power/ a.c. input power =40.6%

### Full Wave Rectifier:

#### a) Full Wave Rectifier(Centre Tapped Type)

During the positive half cycle of the supply(look at the following Figure .a), diodeD1 conducts , while diodeD2 is reverse biased and the current flows through the load as shown .Similarly ,during the negative half cycle of the supply, diodeD2 conducts , while diodeD1 is reverse biased and the current flows through the load as shown .

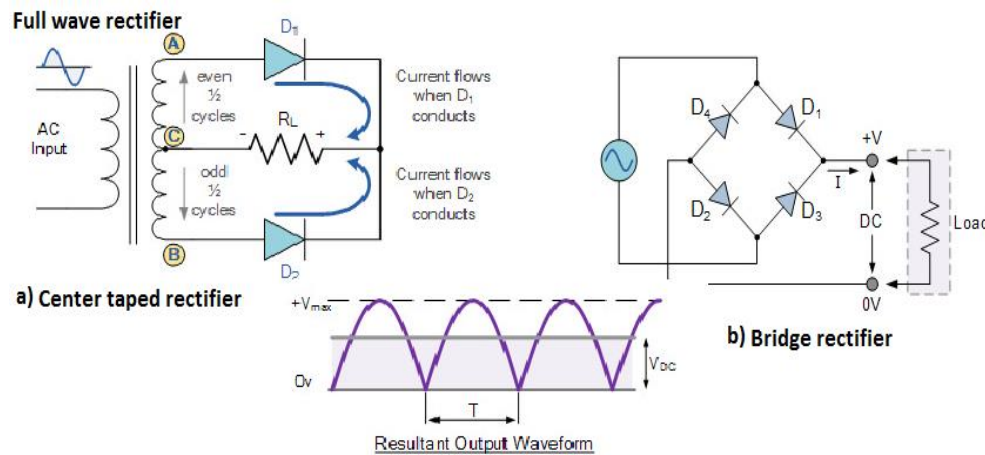


Figure: Full wave rectifier

#### b) Bridge Full wave rectifier:

During the positive half cycle of the supply(look at Figure. b above), diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown above.

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch “OFF” as they are now reverse biased. The current flowing through the load is the same direction as before.

**Notice:** the detail discussion about rectifier is presented in UC “AC/DC Power supply”

### Zener diodes

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Zener diodes or as they may sometimes be called, reference diodes operate like an ordinary diode in the forward bias direction. They have the normal turn on voltage of 0.6 volts for a silicon diode. However in the reverse direction their operation is rather different. Zener diodes are used to maintain a fixed voltage. They are designed to 'breakdown' in a reliable and nondestructive 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.

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. Some of 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.

**The VI characteristic of the Zener** to voltage reference diode is the key to its operation. In the forward direction, the diode performs like any other, but it is in the reverse direction where its specific performance parameters can be utilized.

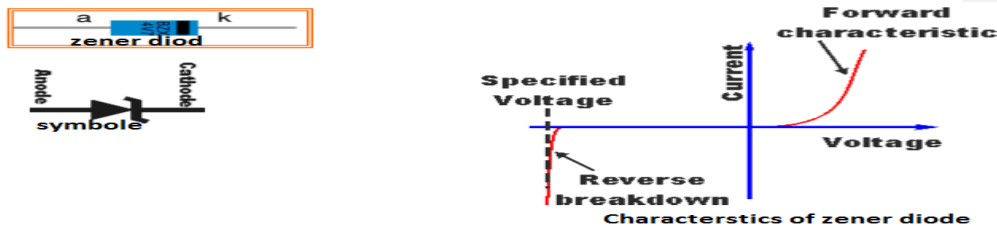


Figure: VI characteristic of the Zener

### Application of Zener

Used in Voltage Stabilizer, Clipper Circuit, Reference voltage limiter circuits

### Simple Zener diode circuit for voltage regulator

When used in a regulator circuit, the Zener diode must have the current entering it limited. If a perfect voltage source was placed across it, then it would draw excessive current once the

Break down voltage had been reached. To overcome this Zener diode must be driven by a current source. This will limit the current to the chosen value. The value of the series resistor is simple to calculate. It is simply the voltage across the resistor, divided by the current required. The level of Zener current can be chosen to suit the circuit and the Zener diode used.

### Light emitting diode (LED)

A Light-Emitting Diode (LED) lets current flow through in only one direction, and emits light when current is flowing. LED's sometimes have the cathode (the -) marked with a flattened edge, and usually have the anode (the +) leg being longer than the cathode leg.

A light emitting diode (LED) is known to be one of the best optoelectronic devices. The device is capable of emitting a fairly narrow bandwidth of visible or invisible light when its internal diode junction attains a forward electric current or voltage. The visible lights that an LED emits are usually *orange, red, yellow, or green*. The invisible light includes the infrared light.

### LED as an Indicator

The circuit shown below is one of the main applications of LED. The circuit is designed by wiring it in inverse parallel with a normal diode, to prevent the device from being reverse biased. The value of the series resistance should be half, relative to that of a DC circuit.



Figure: LED Circuit

### Advantages of LED

- ✓ Very low voltage and current are enough to drive the LED.
- ✓ Voltage range – 1 to 2 volts.
- ✓ Current – 5 to 20 milli amperes.
- ✓ Total power output will be less than 150 milli watts.

- ✓ The response time is very less – only about 10 nanoseconds.
- ✓ The device does not need any heating and warm up time.
- ✓ Miniature in size and hence lightweight.
- ✓ Have a rugged construction and hence can withstand shock and vibrations.
- ✓ An LED has a life span of more than 20 years.

### Disadvantages

- ✓ A slight excess in voltage or current can damage the device.
- ✓ The device is known to have a much wider bandwidth compared to the laser.
- ✓ The temperature depends on the radiant output power and wavelength.

### Photodiodes

A **photodiode** is a semiconductor device that converts light into current. The current is generated when photons are absorbed in the photodiode. A small amount of current is also produced when no light is present.

A *photodiode* is a diode optimized to produce an electron current flow in response to irradiation by ultraviolet, visible, or infrared light. Silicon is most often used to fabricate photodiodes; though, germanium and gallium arsenide can be used.

In photo diode construction shown in the Figure bellow, shallow P-type diffusion into an N-type wafer produces a PN junction near the surface of the wafer.

The P-type layer needs to be thin to pass as much light as possible. A heavy N+ diffusion on the back of the wafer makes contact with metallization. The top metallization may be a fine grid of metallic fingers on the top of the wafer for large cells. In small photodiodes, the top contact might be a sole bond wire contacting the bare P-type silicon top.

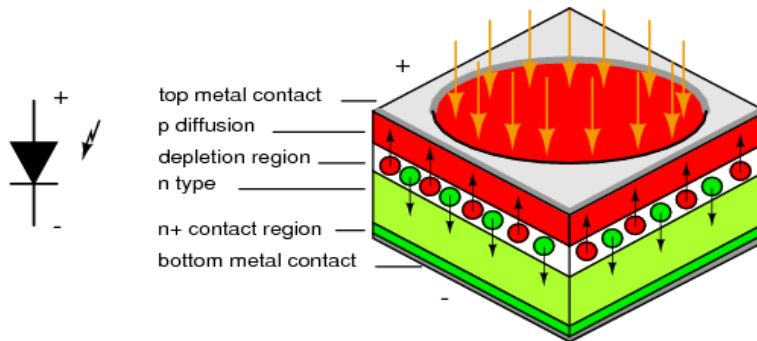


Figure 2.14 Photodiode: Schematic symbol and cross section

#### Applications:

Photodiodes are used in consumer electronics devices such as compact disc players, smoke detectors, and the receivers for infrared remote control devices used to control equipment from televisions to air conditioners.

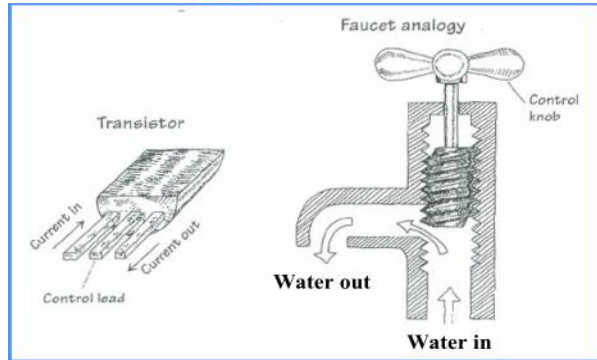
Photodiodes may contain optical filters, built-in lenses, and may have large or small surface areas. Photodiodes usually have a slower response time as its surface area increases. The common, traditional solar cell used to generate electric solar power is a large area photodiode.

#### 2.1.6 Transistors

Transistors are three lead, solid-state, active non-linear semiconductor devices that facilitate signal amplification and act as switching (controlling) device.

"Switching" (digital electronics) or "amplification" (analogue electronics).

Transistor is analogous to a faucet. Turning faucet's control knob alters the flow rate of water coming out from the faucet. A small voltage/current applied at transistor's control lead controls a larger current flow through its other two leads.



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Figure: faucet analogy

#### Concept Structure:

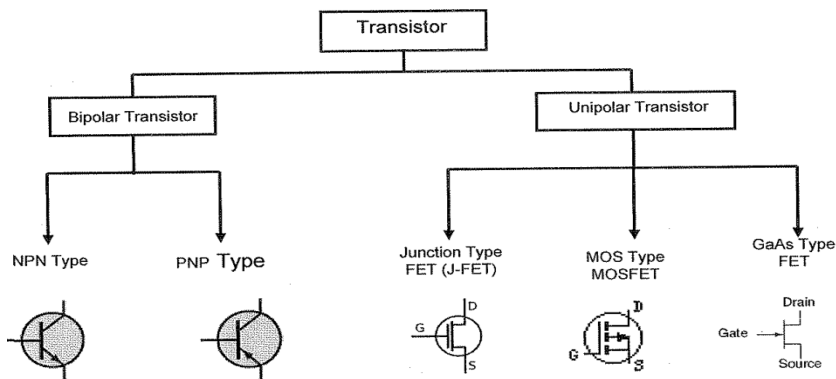


Figure: Transistor types

There are two main classes of transistors: bipolar-junction transistors (BJT) and field-effect transistors (FET).

#### Bipolar Junction Transistors (BJT)

If we join together two individual signal diodes back-to-back, this will give us two PN-junctions connected together in series that share a common P or N terminal. The fusion of these two diodes produces a three layer, two junction, three terminal device forming the basis of a **Bipolar junction Transistor**, or **BJT** for short.

The **Bipolar Transistor** basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are known and labeled as the Emitter (E), the Base (B) and the Collector (C) respectively.

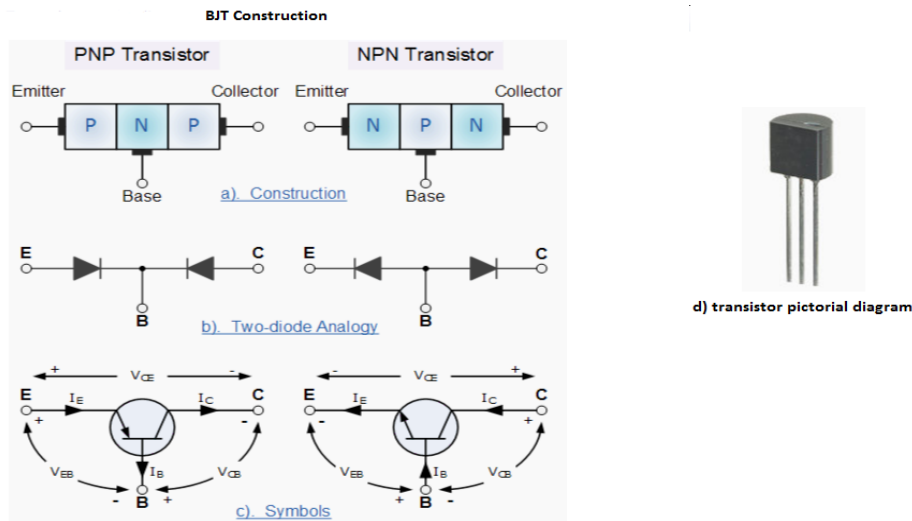


Figure: BJT construction

The construction and circuit symbols for both the NPN and PNP bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive P-type region to the negative N-type region for both transistor types, exactly the same as for the standard diode symbol.

Bipolar Transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current-controlled switch. The principle of operation of the two transistors types NPN and PNP, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

Then bipolar transistors have the ability to operate within three different regions:

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1. Active Region - the transistor operates as an amplifier and  $I_c = \beta I_b$
2. Saturation - the transistor is "fully-ON" operating as a switch and  $I_c = I(\text{saturation})$
3. Cut-off - the transistor is "fully-OFF" operating as a switch and  $I_c = 0$

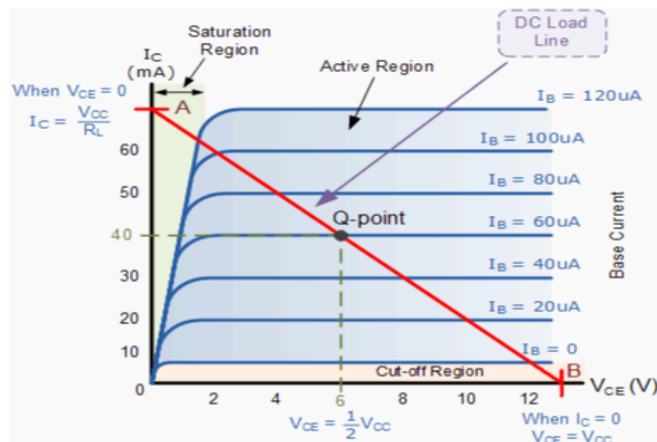
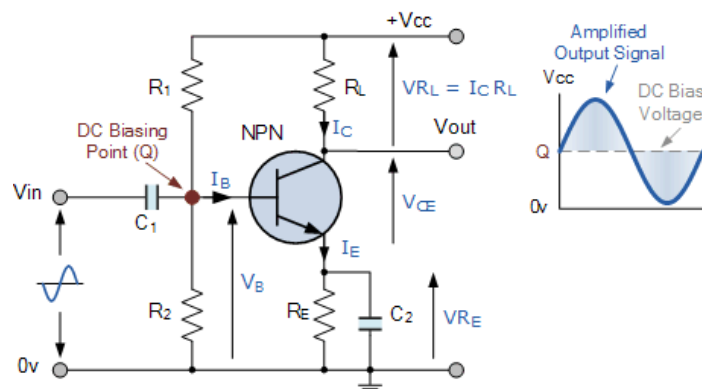


Figure: Output characteristic curves for a typical BJT

## Active region

Single Stage Common Emitter Amplifier Circuit



$I_e = I_c + I_b$ , the ratio of  $I_c/I_e$  is called Alpha, given the Greek symbol of  $\alpha$ . Note: that the value of Alpha will always be less than unity. Since the electrical relationship between these three

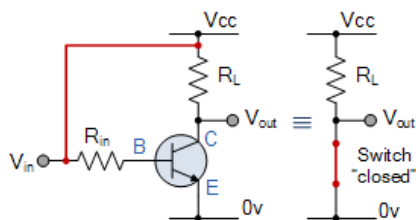
currents,  $I_b$ ,  $I_c$  and  $I_e$  is determined by the physical construction of the transistor itself, any small change in the base current ( $I_b$ ), will result in a much larger change in the collector current ( $I_c$ ). Then, small changes in current flowing in the base will thus control the current in the emitter collector circuit. Typically, Beta has a value between 20 and 200 for most general purpose transistors. So if a transistor has a Beta value of say 100, then one electron will flow from the base terminal for every 100 electrons flowing between the emitter-collector terminal. By combining the expressions for both Alpha,  $\alpha$  and Beta,  $\beta$  the mathematical relationship between these parameters and therefore the current gain of the transistor can be given as:

$$\text{Alpha, } (\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta, } (\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha \cdot I_E = \beta \cdot I_B$$

$$\text{as: } \alpha = \frac{\beta}{\beta + 1} \quad \beta = \frac{\alpha}{1 - \alpha}$$

## Saturation Region



- The input and Base are connected to  $V_{CC}$
- Base-Emitter voltage  $V_{BE} > 0.7V$
- Base-Emitter junction is forward biased
- Base-Collector junction is forward biased
- Transistor is "fully-ON" (saturation region)
- Max Collector current flows ( $I_C = V_{CC}/R_L$ )
- $V_{CE} = 0$  (ideal saturation)
- $V_{OUT} = V_{CE} = "0"$
- Transistor operates as a "closed switch"

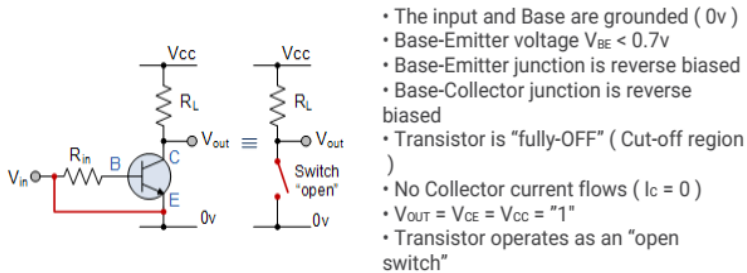
Then we can define the "saturation region" or "ON mode" when using a bipolar transistor as a switch as being, both junctions forward biased,  $V_B > 0.7V$  and  $I_C = \text{Maximum}$ . For a PNP transistor, the Emitter potential must be positive with respect to the Base.

## Cut-off Region

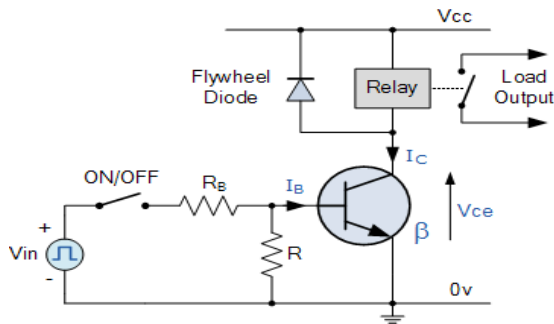
Here the operating conditions of the transistor are zero input base current ( $I_B$ ), zero output collector current ( $I_C$ ) and maximum collector voltage ( $V_{CE}$ ) which results in a large depletion

layer and no current flowing through the device. Therefore the transistor is switched “Fully-OFF”.

### Cut-off Characteristics



An example of an NPN Transistor as a switch being used to operate a relay is given below. With inductive loads such as relays or solenoids a flywheel diode is placed across the load to dissipate the back EMF generated by the inductive load when the transistor switches “OFF” and so protect the transistor from damage. If the load is of a very high current or voltage nature, such as motors, heaters etc, then the load current can be controlled via a suitable relay as shown.



## Junction Field Effect Transistor (JFET)

Junction field effect transistors like BJTs are three lead semiconductor devices. JFETs are used as:

- ✓ electrically controlled switches
- ✓ current amplifiers, and
- ✓ voltage-controlled resistors

Unlike BJTs, JFETs do not require a bias current and are controlled by using only a voltage. JFETs are normally on when  $V_G - V_S = 0$ . When  $V_G - V_S > 0$ , then JFETs become resistive to current flow through the drain-source pair “JFETs are depletion devices.”

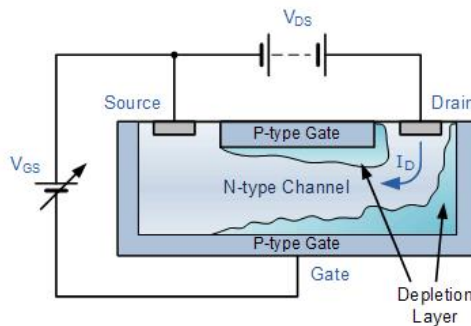
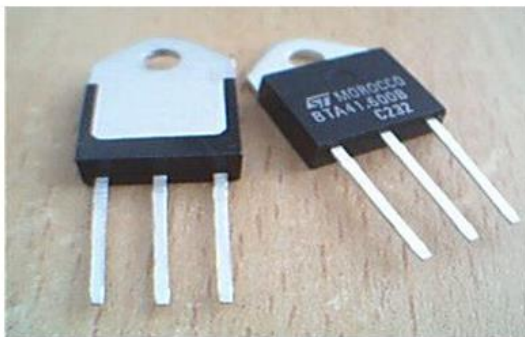


Figure: Junction field effect transistors

## Output characteristic V-I curves of a typical junction FET

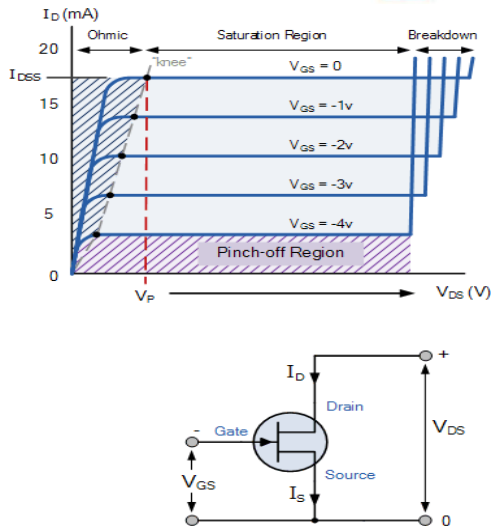


Figure: Output characteristic V-I curves of a typical junction FET

**Ohmic Region** – When  $V_{GS} = 0$  the depletion layer of the channel is very small and the JFET acts like a voltage controlled resistor.

**Cut-off Region** – This is also known as the pinch-off region where the Gate voltage,  $V_{GS}$  is sufficient to cause the JFET to act as an open circuit as the channel resistance is at maximum.

**Saturation or Active Region** – The JFET becomes a good conductor and is controlled by the Gate-Source voltage, ( $V_{GS}$ ) while the Drain-Source voltage, ( $V_{DS}$ ) has little or no effect.

**Breakdown Region** – The voltage between the Drain and the Source, ( $V_{DS}$ ) is high enough to cause the JFET's resistive channel to break down and pass uncontrolled maximum current. The characteristics curves for a P-channel junction field effect transistor are the same as those above, except that the Drain current  $I_D$  decreases with an increasing positive Gate-Source voltage,  $V_{GS}$ .

### JFET Types

Two types of JFETs:

In n-channel JFET, a -ve voltage applied @ its gate (with  $V_G < V_S$ ) reduces current flow from drain to source. It operates with  $V_D > V_S$ .

In p-channel JFET, a +ve voltage applied @ its gate (with  $V_G > V_S$ ) reduces current flow from source to drain. It operates with  $V_S > V_D$ .

JFETs have very high input impedance and draw little or no input current. If there is any circuit/component connected to the gate of a JFET, no current is drawn away from or sunk into this circuit.

### MOSFET-Metal oxide semiconductor FET

A metal oxide insulator is placed at the gate to obtain a high input impedance @ the gate. Gate input impedance approx.  $10^{14} \Omega$ . Use of insulator as described above yields a low gate-to-channel capacitance. If too much static electricity builds up on the gate, then the MOSFET may be damaged.

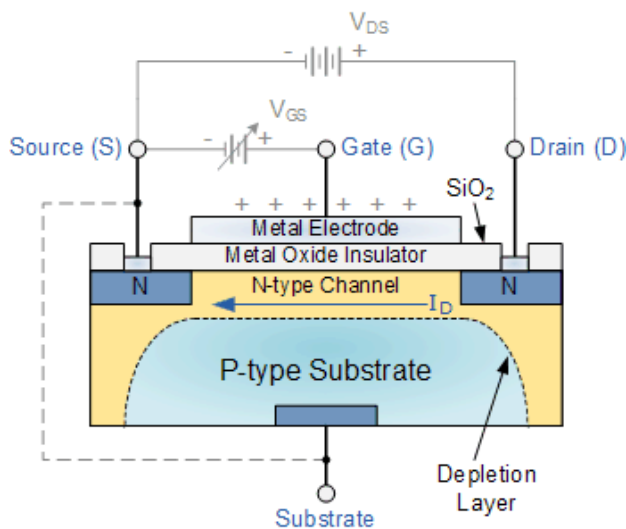


Figure: MOSFET structure

### MOSFET Types

#### Enhancement type:

Normally off, thus no current flows through drain-source channel when  $V_G = V_S$ .

When a voltage applied @ the gate causes  $V_G \neq V_S$  the drain-source channel reduces resistance to current flow.

Normally on, thus maximum current flows through drain-source channel when  $V_G = V_S$ .

– When a voltage applied @ the gate causes  $V_G \neq V_S$  the drain-source channel increases resistance to current flow

**Depletion type:**

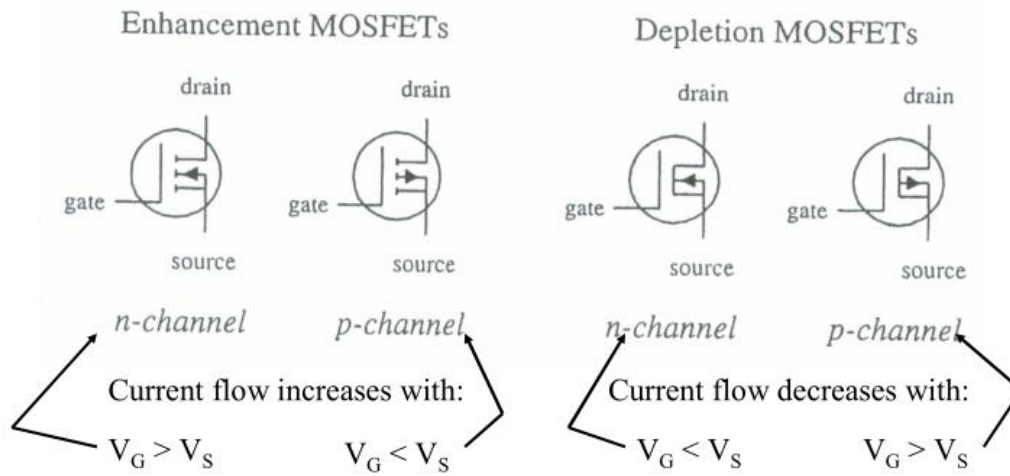


Figure: MOSFET symbols

Table 2.4 MOSFET conducting modes

MOSFET type	$V_{GS} = +ve$	$V_{GS} = 0$	$V_{GS} = -ve$
N-Channel Depletion	ON	ON	OFF
N-Channel Enhancement	ON	OFF	OFF
P-Channel Depletion	OFF	ON	ON
P-Channel Enhancement	OFF	OFF	ON

### 2.1.7 Integrated circuits

An integrated circuit (IC), sometimes called a *chip* or microchip, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. An IC can function as an amplifier, oscillator, timer, counter, computer memory, or microprocessor. A particular IC is categorized as either linear analog or digital, depending on its intended application. The cost of Integrated circuit is low compared to the discrete components because in integrated circuit all the components are fabricated on a single chip

It can function as a microprocessor, amplifier, and counter. The invention of ICs had changed the world of electronics. Integrated circuits (“ICs”) means all the circuits are packaged a single chip, consisting of mainly passive, active components and their interconnections

Table: types of ICS based on number of transistors

IC's are classified depending upon the number of transistors integrated on same chip

Complexity	Number of Transistors
Small Scale integration (SSI)	Fewer than 12
Medium-scale integration (MSI)	12 to 99
Large Scale integration (LSI)	100 to 9999
Very large scale integration (VLSI)	10,000 to 99,999
Ultra scale—scale integration (ULSI)	100,000 or more

### Types of ICs

ICs are mainly classified into three classes Analog ICs, Digital ICs and Hybrid (Mixed ICs) generally Analog ICs have supply voltage more than 5volt and Digital ICs have a supply voltage of 5 volt.

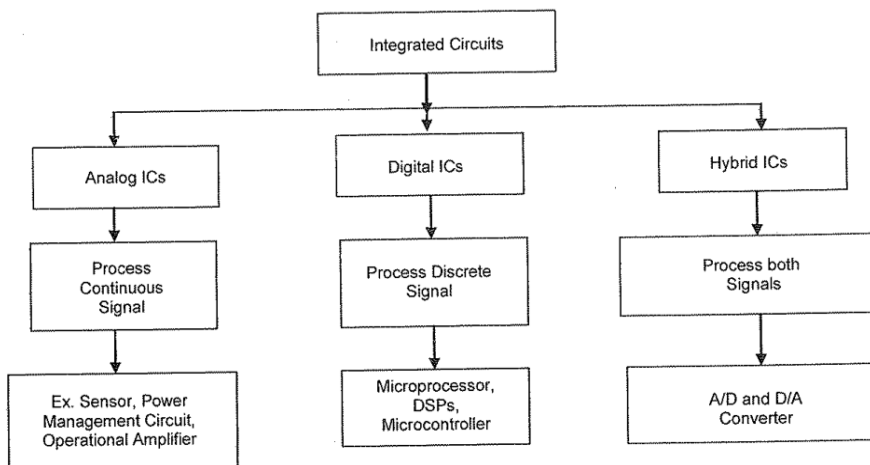


Figure: IC types



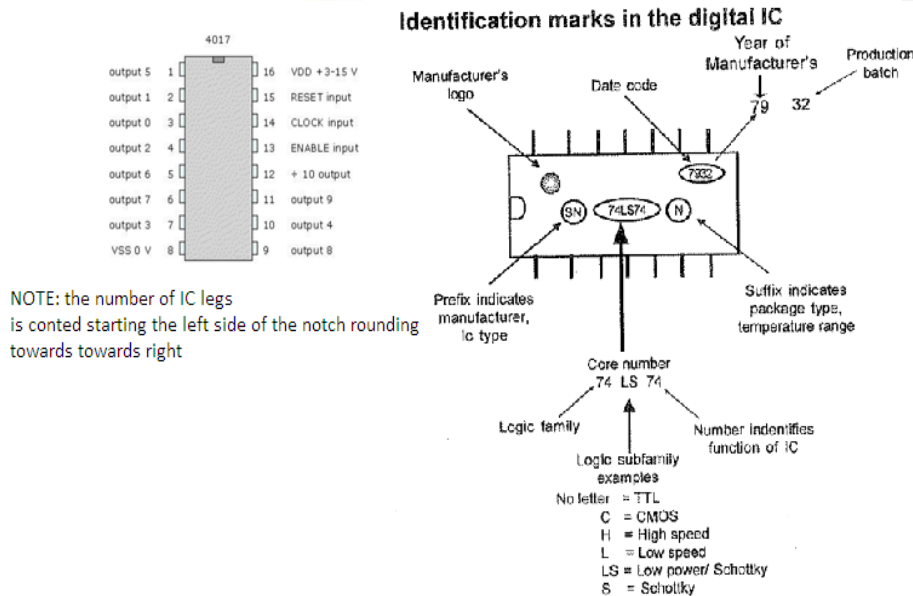


Figure: Identification marks on ICs

### 2.1.8 Thyristor

The name Thyristor comes from two similar device names 'Thyratron' and 'Transistor'. Thyristors are useful due to their ability to handle large current in power applications and fast switching. The most common thyristor is the SCR which stands for "Silicon Controlled Rectifier". Thyristors are a class of semiconductor devices characterized by 4-layers of alternating p and n material. Four-layer devices act as either open or closed switches; for this reason, they are most frequently used in control applications.

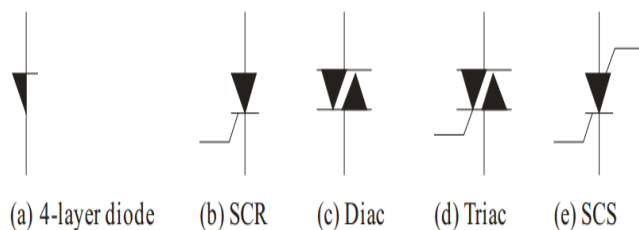


Figure 2.15: Some Thyristors and their symbols

#### 4-layer diode (or Shockley diode)

The 4-layer diode (or Shockley diode) is a type of thyristor that acts something like an ordinary diode but conducts in the forward direction only after a certain anode to cathode voltage called the forward-break over voltage is reached. The 4-layer diode has two leads, labeled the anode (A) and the cathode (K). The symbol reminds you that it acts like a diode. It does not conduct when it is reverse-biased.

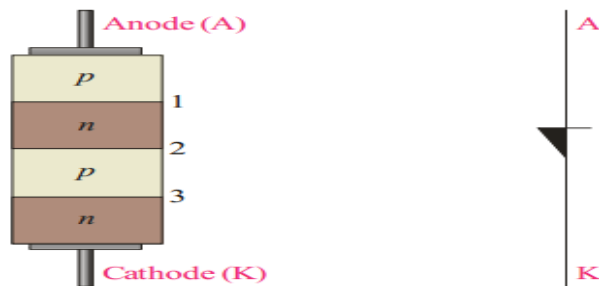


Figure: basic construction of a 4-layer diode and its schematic symbol

The concept of 4-layer devices is usually shown as an equivalent circuit of a *pnp* and an *nnp* transistor. Ideally, these devices would not conduct, but when forward biased, if there is sufficient leakage current in the upper pnp device, it can act as base current to the lower npn device causing it to conduct and bringing both transistors into saturation.

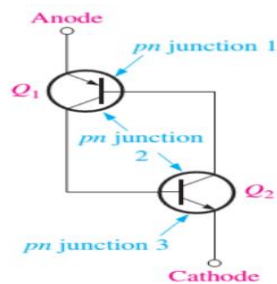


Figure: An equivalent circuit of a pnp and an npn transistor

#### Silicon-Controlled Rectifier (SCR)

The SCR had its roots in the 4-layer diode. By adding a gate connection, the SCR could be triggered into conduction. The SCR is the most widely used thyristor. It can switch very large currents on and off. The SCR can be turned on by exceeding the forward Break over voltage or

by gate current. The gate current controls the amount of forward break over voltage required for turning it on. Three important SCR specifications are:

**Forward-break over voltage:** This is the voltage at which the SCR enters the forward-conduction region.

**Holding current:** This is the value of anode current below which the SCR switches from the forward conduction region to the forward-blocking region.

**Gate trigger current:** This is the value of gate current necessary to switch the SCR from the forward-blocking region to the forward-conduction region under specified conditions

### DIAC

The diac is a thyristor that acts like two back to back 4-layer diodes. It can conduct current in either direction. Because it is bidirectional, the terminals are equivalent and labeled  $A_1$  and  $A_2$ .

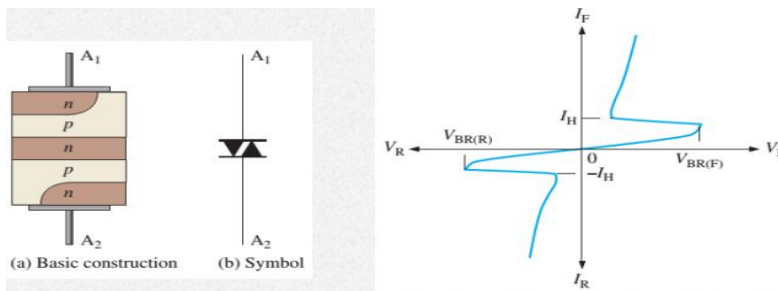


Figure: DIAC Basic construction and symbol

### TRIAC

Basically, a triac can be thought as two SCRs connected in parallel and in opposite directions with a common gate terminal. Unlike the SCR, the triac can conduct current in either direction when it is triggered on, depending on the polarity of the voltage across its  $A_1$  and  $A_2$  terminals.

#### Triac Applications

Like the SCR, triacs are also used to control average power to a load by the method of phase control. The triac can be triggered such that the ac power is supplied to the load for a controlled portion of each half-cycle. During +ve half-cycle, the triac is off for a certain interval, called the delay angle, and then it is on for the remaining portion, called the conduction angle. Similar action occurs on the negative half-cycle.

### The Silicon-Controlled Switch (SCS)

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The SCS is similar in construction to the SCR. The SCS, however, has two gate terminals, the cathode gate and the anode gate. The SCS can be turned on and off using either gate terminal.

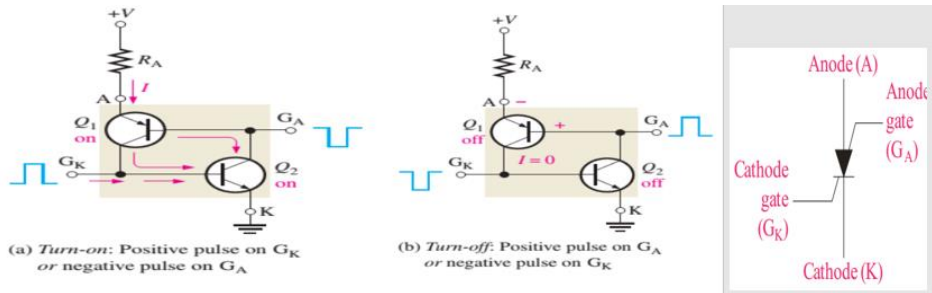


Figure: SCS Symbol, npn and pnp equivalent circuit

The SCS can also be turned on by applying a positive pulse on the cathode gate or a negative pulse on the anode gate. To turn the SCS off, a negative pulse is applied to the cathode gate or a positive pulse is applied to the anode gate. The SCS and SCR are used in similar applications. The SCS has the advantage of faster turn-off with pulses on either gate terminal.

## 2.2 Component coding

The following are most common electronic component coding types

- Color coding
- Structural coding
- Number coding
- Letter coding

### 2.2.1 Color coding

In electronic color code is used to indicate the values or ratings of electronic components, usually for resistors, but also for capacitors, inductors, diodes and others. A separate code, the 25-pair color code, is used to identify wires in some telecommunications cables. Different codes are used for wire leads on devices such as transformers or in building wiring.

#### Resistors Color band system

To distinguish left from right there is a gap between the C and D bands:

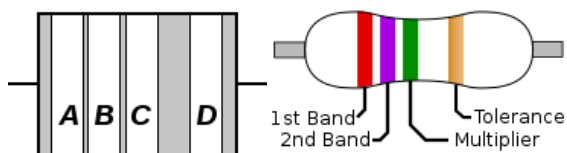


Figure: Color code

1. The first significant Figure of component value (left side)
2. The second significant Figure (some precision resistors have a third significant Figure, and thus five bands).
3. The decimal multiplier (number of trailing zeroes, or power of 10 multiplier)
4. If present, indicates tolerance of value in percent (no band means 20%)

In the above example, a resistor with bands of red, violet, green, and gold has first digit 2 (red; see table below), second digit 7 (violet), followed by 5 (green) zeroes: 2700000 ohms. Gold signifies that the tolerance is  $\pm 5\%$ .

### Capacitors color codes

Capacitors may be marked with 4 or more colored bands or dots. The colors encode the first and second most significant digits of the value in picofarads, and the third color the decimal multiplier. Additional bands have meanings which may vary from one type to another. Low-tolerance capacitors may begin with the first 3 (rather than 2) digits of the value. It is usually, but not always, possible to work out what scheme is used by the particular colors used. Cylindrical capacitors marked with bands may look like resistors.

Table 2.5 capacitor color codes

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Color	Significant digits	Multiplier	Tolerance [%]	Characteristic	DC working voltage [V]	Operating temperature [°C]	EIA/vibration [Hz]
Black	0	1	—	—	—	−55 to +70	10 to 55
Brown	1	10	±1	B	100	—	—
Red	2	100	±2	C	—	−55 to +85	—
Orange	3	1 000	—	D	300	—	—
Yellow	4	10 000	—	E	—	−55 to +125	10 to 2000
Green	5	100 000	±0.5	F	500	—	—
Blue	6	1 000 000	—	—	—	−55 to +150	—
Violet	7	10 000 000	—	—	—	—	—
Grey	8	—	—	—	—	—	—
White	9	—	—	—	—	—	EIA
Gold	—	—	±5 <sup>[nb 4]</sup>	—	1000	—	—
Silver	—	—	±10	—	—	—	—

### 2.2.2 Structural coding

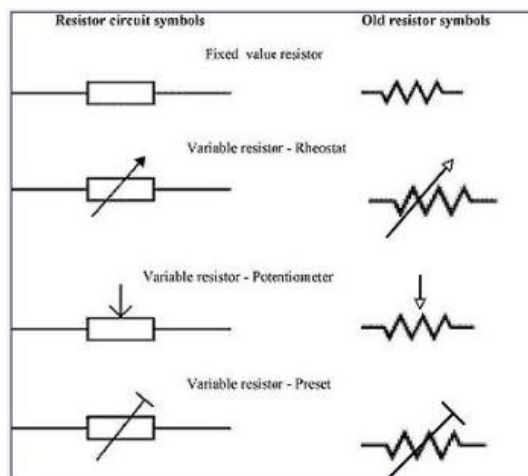


Figure: Resistor Symbols

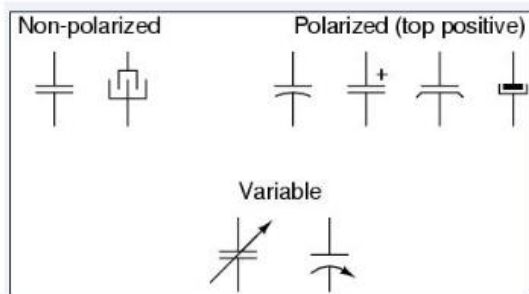


Figure: Capacitor symbols

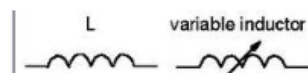


Figure: Inductor symbols

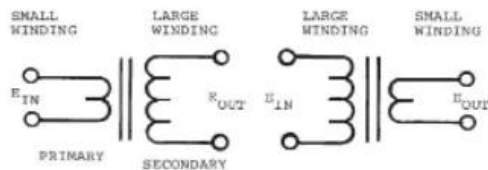


Figure: Transformer symbols

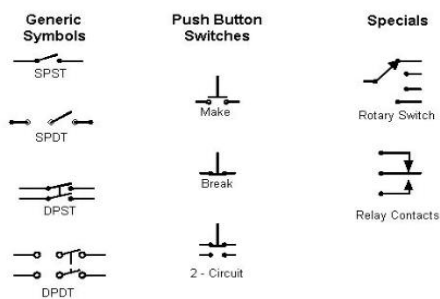


Figure: Switches

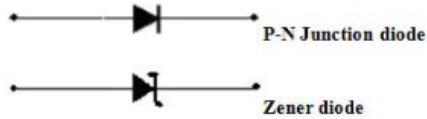
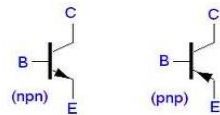


Figure: Diodes symbols

#### BJT types



#### FET types

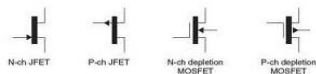


Figure: Transistors symbols

### 2.2.3 Letter and Number coding

There are many thousands of different types of diode, bipolar transistor and FET. These semiconductor devices have different characteristics according to the way they are designed and made.

As a result it is essential that the different semiconductor devices are given different part numbers to distinguish them from each other.



BC547 transistor - BC in the part number indicates it is a silicon audio frequency low power transistor

Figure 2.5: BC547 transistor

#### Pro-Electron or EECA Numbering Coding System

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The Pro-Electron numbering scheme to provide a standardised scheme for semiconductor numbering - in particular diodes, transistors and field effect transistors was set up in 1966 at a meeting in Brussels, Belgium.

The scheme for the numbering of semiconductor diodes, bipolar transistors and FETs was based around the format of the system developed by Mullard and Philips for thermionic valve or vacuum tube numbering that had existed since the early 1930s. In this the first letter designated the heater voltage and current, the second and subsequent letters the individual functions within the glass envelope and the remaining numbers indicated the valve based and the serial number for the type.

The Pro-Electron scheme took this and used letters that were seldom used for the heater descriptions to designate the semiconductor type and then used the second letter to define the function. Similarities existed between the valve / tube designations and those used for the semiconductor devices. For example, "A" was used for a diode, etc.

The scheme was widely used and in 1983 its management was taken over by the European Electronic Component Manufacturers Association, EECA.

#### First letter

- A = Germanium
- B = Silicon
- C = Gallium Arsenide
- R = Compound materials

#### Second letter

- A = Diode - low power or signal
- B = Diode - variable capacitance
- C = Transistor - audio frequency, low power
- D = Transistor - audio frequency, power
- E = Tunnel diode

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- F = Transistor - high frequency, low power
- G = Miscellaneous devices
- H = Diode - sensitive to magnetism
- L = Transistor - high frequency, power
- N = Photocoupler
- P = Light detector
- Q = Light emitter
- R = Switching device, low power, e.g. thyristor, diac, unijunction
- S = Transistor - switching low power
- T = Switching device, low power, e.g. thyristor, triac
- U = Transistor - switching, power
- W = Surface acoustic wave device
- X = Diode multiplier
- Y = Diode rectifying
- Z = Diode - voltage reference

### Subsequent characters

The characters following the first two letters form the serial number of the device. Those intended for domestic use have three numbers, but those intended for commercial or industrial use have letter followed by two numbers, i.e. A10 - Z99.

### Suffix

On some occasions there may be a suffix letter that is added:

- A = low gain
- B = medium gain
- C = high gain

- No suffix = gain unclassified

This is useful to both manufacturers and users because when transistors are manufactured, there is a large spread in the levels of gain. They can then be sorted into groups and marked according to their gain.

Using the numbering scheme it can be seen that a transistor with the part number BC107 is a silicon low power audio transistor and a BBY10 is silicon variable capacitance diode for industrial or commercial use. A BC109C for example is a silicon low power audio transistor with a high gain

### JEDEC Numbering or Coding System

JEDEC, Joint Electron Device Engineering Council is an independent industry semiconductor engineering trade organisation and standardisation body. It provides many functions, one of which is the standardisation of semiconductor, and in this case, diode, bipolar transistor and field effect transistor part numbering.

The earliest origins of JEDEC can be traced back to 1924 when the Radio Manufacturers Association was established - many years later this became the Electronic Industries Association, EIA. In 1944, the Radio Manufacturers Association and the National Electronic Manufacturers Association established a body called the Joint Electron Tube Engineering Council, JETEC. This was set up with the aim of assigning and coordinating type numbers of electron tubes, (thermionic valves).

Initial numbering of the semiconductor devices followed the broad outlines of the tube of valve numbering scheme that had been developed: "1" stood for "No filament / heater" and the "N" stood for "crystal rectifier".

The first digit for semiconductor device numbering was repurposed from indicating no filament to the number of PN junctions in the semiconductor device, and the numbering system was described in EIA/JEDEC EIA-370.

First Number =

- 1 = Diode

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- 2 = Bipolar transistor or single gate field effect transistor
- 3 = Dual gate field effect transistor

The number equates to the number of junctions, although this has to be interpreted a little for MOSFETs.

Second Letter = N

- Subsequent numerals = Serial number

Thus a device with the numbering code 1N4148 is a diode and a 2N706 is a bipolar transistor.

Sometimes extra letters are added to the part number and these often refer to the manufacturer. M means the manufacturer is Motorola, while TI means Texas Instruments, although an A added to the part number often means a revision of the specification, e.g. 2N2222A transistors are widely available and these are an updated version of the 2N2222. Interpreting these numbers sometimes requires a little background knowledge.

### JIS semiconductor device numbering scheme

The Japanese Industrial Standards, JIS part numbering scheme for semiconductor devices is standardised under JIS-C-7012.

This scheme uses a type number that comprises of a number followed by two characters and then this is followed by a serial number.

#### First Number

The first number indicates the number of junctions in the semiconductor device.

- 1 = Diode
- 2 = Bipolar transistor or single gate field effect transistor
- 3 = Dual gate field effect transistor

#### Letters in positions 2 & 3

- SA = PNP high frequency bipolar transistor
- SB = PNP audio frequency bipolar transistor

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- SC = NPN high frequency bipolar transistor
- SD = NPN audio frequency bipolar transistor
- SE = Diodes
- SF = Thyristor (SCR)
- SG = Gunn devices
- SH = UJT (Unijunction transistor)
- SJ = P-channel JFET / MOSFET
- SK = N-channel JFET / MOSFET
- SM = Triac
- SQ = LED
- SR = Rectifier
- SS = Signal diode
- ST = Avalanche diode
- SV = Varactor diode / varicap diode
- SZ = Zener diode / voltage reference diode

### Serial number

The serial number follows the first digit and the two semiconductor device type letters. The numbers run between 10 and 9999.

### Suffix

Following the serial number a suffix can be used to indicate the device has been type approved, i.e. there is a guarantee that it has been manufactured under the right conditions to produce the required semiconductor device.

### Manufacturer numbers

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Despite the fact that there are industry organisations in place to generate device numbers, some manufacturers wanted to produce devices that were unique to them. In some areas it would provide a device with a unique selling point that other manufacturers could not copy.

These semiconductor devices numbers are unique to the manufacturer and as a result they can be used to identify the source.

Some common examples are given below:

- MJ = Motorola power, metal case
- MJE = Motorola power, plastic case
- MPS = Motorola low power, plastic case
- MRF = Motorola RF transistor
- TIP = Texas Instruments power transistor (plastic case)
- TIPL = TI planar power transistor
- TIS = TI small signal transistor (plastic case)
- ZT = Ferranti
- ZTX = Ferranti

<b>Self-Check -2</b>	<b>Written Test</b>
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**Directions:** Answer all the questions listed below.

**Test 1. Write true or false for the following statements**

1. Basic electrical/electronic components have a minimum of two terminals
2. Active Electronic Components are those that do not have gain or directionality
3. Passive Electronic Components are those that have gain or directionality.
4. Function capacitor is to store electrical charge in an electrical field
5. Transistors is A semiconductor device capable of amplification

**Test 2. Multiple Choice**

1. ----- is an electronic component that is used in circuits to either amplify or switch electrical signals or power, allowing it to be used in a wide array of electronic devices  
A. Transistor      C. Diode  
B. Resistor      D. IC
2. ----- is a device used in the power transmission of electric energy  
A. Transistor      C. Diode  
B. Resistor      D. transformer
3. Which of the following: is Passive components that use in piezoelectric. Effect.  
A. resonator      C. IC  
B. Resistor      D. transformer
4. A semiconductor device capable of amplification  
A. Resonator      C. transistor  
B. Resistor      D. transformer
5. ----- consists of a stator, a rotor, and a frame  
A. Tuning capacitor      C. resistor  
B. variable capacitor      D. zenor diode

**Test 3. Write short answer**

1. What is the difference between active and passive components?
2. Write different types of resistors and their properties?

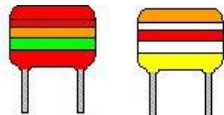
**Commented [WU3]:** 3 options. Good work!

3. What is the function of diode, transistors and capacitors?
4. How to identify step-up and step-down transformer?
5. Calculates the value of the following components

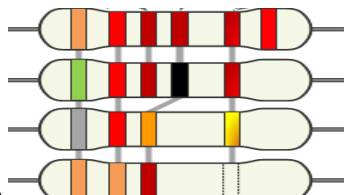
A.



B .



C.





## Operation Sheet - 1

**Operation Title:** Reading resistor color codes

**Instructions:** Select different color band resistors and read the color codes

**Purpose:** To check resistance value of a resistor

**Required tools and equipment:** Multimeter, 4 band resistor, 5 band resistor, 6-band resistor etc.

**Precautions:**

- ✓ Use PPE
- ✓ Care should be taken in deciding the first edge.
- ✓ Tolerance can also be taken into consideration while measuring resistance as per colour code.

**Procedures:**

- 1) Identify the color type on each band
- 2) The resistance of the given resistor is measured according to the colour code system including tolerance.
- 3) Verify with the value measured by digital multi-meter by keeping its band switch in proper resistance range.

**Quality criteria**

Understanding resistor color codes

### Unit Three: Testing Electrical/electronic components

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Safety procedures
- Test electrical/electronic components
- Components data, function and value

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Observe Safety procedures
- Test electrical /electronic component
- Interpret datasheet

### 3.1 Safety procedures

When working with or testing any electronic equipment, it's always important to be cautious. Whatever type of equipment you're handling, whether simple or complex, it's important to take the right safety precautions.

#### General Safety

Before working on any electronics, consider following these basic safety precautions to help reduce any hazards.

- ✓ Remove any electronic equipment you're testing or working on from the power source.
- ✓ Never assume the power circuit is off. Test and test again with a voltmeter to confirm.
- ✓ Remove fuses and replace them only after the power to the circuit is disconnected.
- ✓ Don't connect power to a circuit until you're done working on it and rechecked the work.
- ✓ Always ensure that all electronics equipment is properly grounded
- ✓ If it's damaged, replace it. For instance, replace cables instead of repairing with insulating tape.
- ✓ Always use the right electronics repair and maintenance tools.
- ✓ Always return covers after removing them to reduce the risk of electric shock.
- ✓ Make sure your circuit is not overloaded.
- ✓ Always have safety equipment like a fire extinguisher, a basic first aid kit and a mobile phone nearby.

#### Personal Safety

It's important to ensure that you're safe when working on electronic circuits. Here are some personal safety precautions to keep in mind:

- ✓ Always keep your work area dry.
- ✓ Always work in a well-ventilated area.
- ✓ Don't wear flapping or loose clothing when working.
- ✓ Don't work with metallic jewelry on your hands like watches, rings and bracelets.
- ✓ Don't use bare hands to remove hot parts.
- ✓ Always wear non-conductive shoes.
- ✓ Always wear insulator gloves in your hands when carrying out repairs.
- ✓ When removing high-voltage charges on capacitors, always use a shorting stick.
- ✓ Don't hold the test prods when measuring voltage over 300V.
- ✓ Always remove power to a circuit before connecting alligator clips.
- ✓ Always wear safety goggles.



- ✓ Be careful when handling large capacitors as they can still hold high voltage even after you've disconnected the circuit from power.

### High Voltage Safety

One mistake that electronics experts make when doing repairs or maintenance work is assuming routine safety procedures after getting all too familiar with their work. It's important to know that most electronic equipment use high-voltage that is dangerous and can be fatal. Always follow these safety precautions when working on or near high-voltage circuits.

- ✓ Don't work on electronic equipment or make repairs with high voltage on
- ✓ Don't take chances doing what you're not sure about.
- ✓ Consider using an isolation transformer when working on AC powered electronic circuits or equipment.
- ✓ Never tamper with interlocks.
- ✓ Don't ground yourself: Make it a practice to use only one hand when connecting equipment to an electronic circuit.

### Electrical safety checklist

- Use a meter that meets accepted safety standards for the environment in which it will be used.
- Use a meter with fused current inputs and be sure to check the fuses before making current measurements.
- Inspect test leads for physical damage before making a measurement.
- Use the meter to check continuity of the test leads.
- Use test leads that have shrouded connectors and finger guards.
- Use meters with recessed input jacks.
- Select the proper function and range for your measurement.
- Be certain the meter is in good operating condition.
- Follow all equipment safety procedures.
- Always disconnect the "hot" (red) test lead first.
- Don't work alone.
- Use a meter that has overload protection on the ohms function.
- When measuring current without a current clamp, turn the power off before connecting into the circuit.
- Be aware of high-current and high-voltage situations and use the appropriate equipment, such as high-voltage probes and high-current clamps.

### 3.1.1 Personal protective equipment

#### Goggles

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Goggles are the primary protectors intended to shield the eyes against liquid or chemical splash, irritating mists, vapors, and fumes. They form a protective seal around the eyes, and prevent objects or liquids from entering under or around the goggles. This is especially important when working with or around liquids that may splash, spray, or mist.

Eye protection includes

- ✓ Laser (Class 3 or 4) Optical density based on beam parameters
- ✓ UV (Marked "ANSI Z87 U and scale number")
- ✓ Welding (Marked "ANSI Z87 W shade number")
- ✓ Impact/Machine Shop (Marked "ANSI Z87+")



Figure: Eye protector

### Glove

Gloves prevent contamination of healthcare professionals' hands and help reduce the spread of pathogens only if: They are used properly; and Hand hygiene is performed before and after wear. It's important to know that gloves do not provide complete protection from hand contamination. That's why hand hygiene is so important before and after glove use!

Make sure you know the "Do's and Don'ts" for wearing gloves in the healthcare environment.

The World Health Organization recommends that you clean your hands and put gloves on:

- ✓ Before a sterile procedure
- ✓ When you think you'll come in contact with blood or another bodily fluid
- ✓ When you're going to care for a patient during contact precautions
- ✓ Take gloves off and clean your hands:
- ✓ As soon as gloves are damaged or punctured
- ✓ When your contact with blood or bodily fluid has ended
- ✓ When your contact with a single patient and his/her surroundings has ended
- ✓ When there is a need for hand hygiene

Remember: NEVER wear the same pair of gloves for the care of more than one patient!



Figure: Gloves

### 3.2 Testing Electrical/electronic components

Electrical testing can be used to identify suspect parts and aid in counterfeit mitigation. It can also be used to determine that parts moving through the supply chain have been handled or stored correctly. However, not all components need to be fully powered up to be examined. For these parts, low power methods are used.

#### Low Power Electrical Testing

In standard electrical testing, power is applied to an electronic component to test the viability of the electrical connections. Low power electrical testing is similar to standard electrical testing as it checks to make sure the component is giving the correct signature or measurement. However, it requires very little power to be added to an electronic component. In fact, a lot of low power electrical tests require no power at all. No power testing, commonly referred to as power-off testing, is performed if there is any concern over a part getting damaged by applied power. Power-off tests allow for components to be safely examined and are often used in troubleshooting.

Low power testing tricks the part into thinking it's being properly powered up in order to get the signature reading or other measurement. This is done by applying a current limited sine-wave voltage to an un-powered circuit or electronic component. These measurements are then compared to a standard, which can be found in the test equipment's manual for the component. Electronic-Component-Testing-Signature-Example If the reading does not match the standard, it could indicate that there's a problem with the pins, electrical connection to the die, or that there is damage caused by electrostatic discharge (ESD). Low power and power-off tests, such as curve tracing and analog signature analysis, can also help identify suspect parts.

#### What Electronic Components can be tested?

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Low power electrical testing can be performed on a wide variety of electronic components including: Batteries, Capacitors, Chokes, Crystals, Diodes, Fuses, Inductors, Op amps, Relays, Resistor, Switches, Thyristors, Transistors

#### Methods

- Resistance test
- Continuity test
- Short/open test
- Color code/Value reading
- Components pin identification

#### 3.2.1 Testing a transistor with a multimeter

Remove the transistor from the circuit for accurate test results.

##### Step 1: (Base to Emitter)

Hook the positive lead from the multimeter to the to the BASE (B) of the transistor. Hook the negative meter lead to the EMITTER (E) of the transistor. For an good NPN transistor, the meter should show a voltage drop between 0.45V and 0.9V. If you are testing PNP transistor, you should see “OL” (Over Limit).

##### Step 2: (Base to Collector)

Keep the positive lead on the BASE (B) and place the negative lead to the COLLECTOR (C). For an good NPN transistor, the meter should show a voltage drop between 0.45V and 0.9V. If you are testing PNP transistor, you should see "OL" (Over Limit).

##### Step 3: (Emitter to Base)

Hook the positive lead from the multimeter to the to the EMITTER (E) of the transistor. Hook the negative meter lead to the BASE (B) of the transistor.

For an good NPN transistor, you should see “OL” (Over Limit).If you are testing PNP transistor, the meter should show a voltage drop between 0.45V and 0.9V.

##### Step 4: (Collector to Base)

Hook the positive lead from the multimeter to the to the COLLECTOR (C) of the transistor. Hook the negative meter lead to the BASE (B) of the transistor.

For an good NPN transistor, you should see “OL” (Over Limit).If you are testing PNP transistor, the meter should show a voltage drop between 0.45V and 0.9V.

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#### Step 5: (Collector to Emitter)

Hook the positive meter lead to the COLLECTOR (C) and the negative meter lead to the EMITTER (E) – A good NPN or PNP transistor will read "OL"/Over Limit on the meter. Swap the leads (Positive to Emitter and Negative to Collector) – Once again, a good NPN or PNP transistor should read "OL".

If your bipolar transistor measures contrary to these steps, consider it to be bad.

You may also be able to use the voltage drop to determine which lead is the emitter on an unmarked transistor, as the emitter-base junction typically has a slightly higher voltage drop than the collector-base junction.

Remember: This test only verifies that the transistor is not shorted or open, it does not guarantee that the transistor is operating within its designed parameters. It should only be used to help decide if you need "replace" or "move on to the next component". This test works on bipolar transistors only – you need to use a different method for testing FETs.

### 3.2.2 Testing Diodes with a Digital Multimeter

Digital multimeters can test diodes using one of two methods:

1. Diode Test mode: almost always the best approach.
2. Resistance mode: typically used only if a multimeter is not equipped with a Diode Test mode.

**Note:** In some cases it may be necessary to remove one end of the diode from the circuit in order to test the diode.

Things to know about the Resistance mode when testing diodes:

- Does not always indicate whether a diode is good or bad.
- Should not be taken when a diode is connected in a circuit since it can produce a false reading.
- CAN be used to verify a diode is bad in a specific application after a Diode Test indicates a diode is bad.

A diode is best tested by measuring the voltage drop across the diode when it is forward-biased.

A forward-biased diode acts as a closed switch, permitting current to flow.

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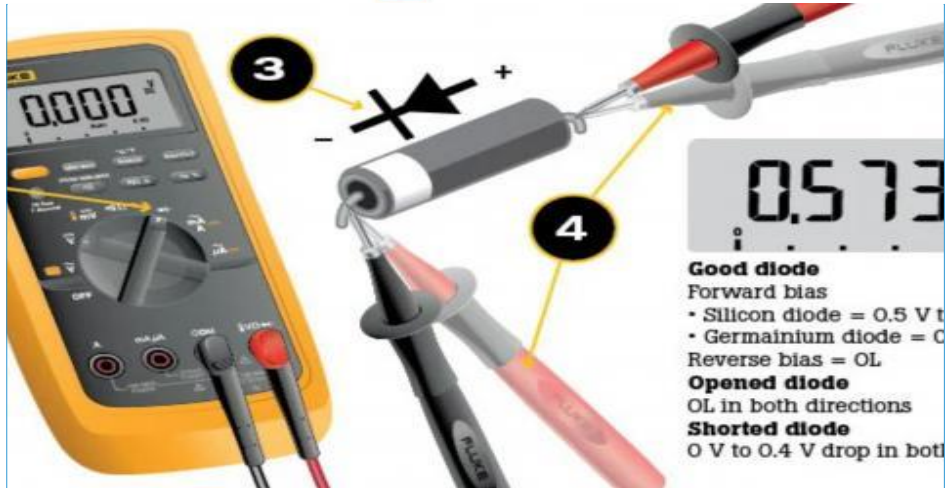


Figure 3.1: Diode testig

A multimeter's Diode Test mode produces a small voltage between test leads. The multimeter then displays the voltage drop when the test leads are connected across a diode when forward-biased. The Diode Test procedure is conducted as follows:

1. Make certain a) all power to the circuit is OFF and b) no voltage exists at the diode. Voltage may be present in the circuit due to charged capacitors. If so, the capacitors need to be discharged. Set the multimeter to measure ac or dc voltage as required.
2. Turn the dial (rotary switch) to Diode Test mode. It may share a space on the dial with another function.
3. Connect the test leads to the diode. Record the measurement displayed.
4. Reverse the test leads. Record the measurement displayed.

#### Diode test analysis

- A good forward-based diode displays a voltage drop ranging from 0.5 to 0.8 volts for the most commonly used silicon diodes. Some germanium diodes have a voltage drop ranging from 0.2 to 0.3 V.
- The multimeter displays OL when a good diode is reverse-biased. The OL reading indicates the diode is functioning as an open switch.

- A bad (opened) diode does not allow current to flow in either direction. A multimeter will display OL in both directions when the diode is opened.
- A shorted diode has the same voltage drop reading (approximately 0.4 V) in both directions.

A multimeter set to the Resistance mode ( $\Omega$ ) can be used as an additional diode test or, as mentioned previously, if a multimeter does not include the Diode Test mode.

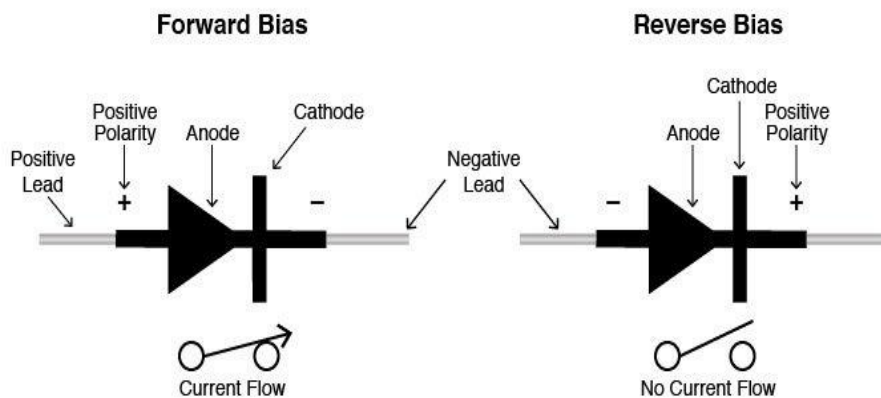


Figure: forward and reverse biased diode testing

A diode is forward-biased when the positive (red) test lead is on the anode and the negative (black) test lead is on the cathode.

- The forward-biased resistance of a good diode should range from 1000  $\Omega$  to 10 M $\Omega$ .
- The resistance measurement is high when the diode is forward-biased because current from the multimeter flows through the diode, causing the high-resistance measurement required for testing.

A diode is reverse-biased when the positive (red) test lead is on the cathode and the negative (black) test lead is on the anode.

Commented [WU5]: Fig title and number?

- The reverse-biased resistance of a good diode displays OL on a multimeter. The diode is bad if readings are the same in both directions.



Figure 3.2: Resistance mode diode testing

The resistance mode procedure is conducted as follows:

1. Make certain a) all power to the circuit is OFF and b) no voltage exists at the diode. Voltage may be present in the circuit due to charged capacitors. If so, the capacitors need to be discharged. Set the multimeter to measure ac or dc voltage as required.
2. Turn the dial to Resistance mode ( $\Omega$ ). It may share a space on the dial with another function.
3. Connect the test leads to the diode after it has been removed from the circuit. Record the measurement displayed.
4. Reverse the test leads. Record the measurement displayed.
5. For best results when using the Resistance mode to test diodes, compare the readings taken with a known good diode.

### 3.2.3 Testing a Resistor

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To check to see whether a resistor is good or not, we need to only perform one test and this is to check the resistor's resistance value, using the ohmmeter of a multimeter.

### **Test a Resistor with an Ohmmeter**

Testing a Resistor with an ohmmeter is the best, easiest and most effective way to tell whether a resistor is good or not.

To set up for the check, we take the ohmmeter and place its probes across the leads of the resistor. The orientation doesn't matter, because resistance isn't polarized.

Resistor resistance test with an ohmmeter of a multimeter

The resistance that the ohmmeter reads should be close to the rated resistance of the resistor. For example, the following resistor above is a  $1K\Omega$  resistor with a tolerance rating of 5%. Therefore, the resistance of the resistor can vary between  $950\Omega$  and  $1050\Omega$ .

If the ohmmeter is reading in the value and tolerance range of the resistor, the resistor is good.

If the ohmmeter is reading (especially drastically) outside of this range, the resistor is defective and should be replaced.

### **How to Test whether a Resistor is Open**

If a resistor is reading a very high resistance, above its rated value, it is open. It is defective and, thus, should be replaced.

### **How To Test whether a Resistor is Shorted**

If a resistor is reading a very low resistance, near  $0\Omega$ , it's shorted internally. It is defective and, thus, should be replaced.

A resistance test is the only test that is needed to determine whether a resistor is good. If you want to examine more advanced features of a resistor, then additional tests may be necessary, but for all basic purposes, this test is sufficient for checking resistor

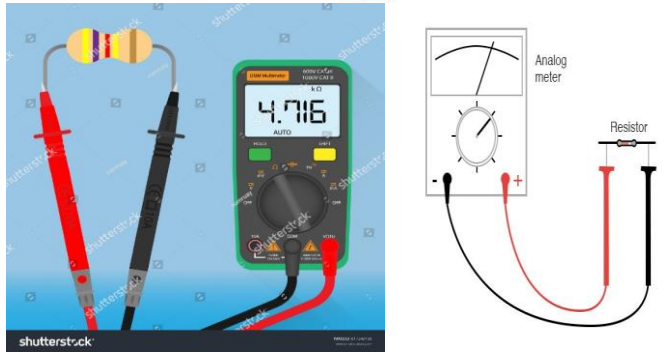


Figure 3.3: Resistor testing

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### 3.2.4 Testing capacitor

A multimeter determines capacitance by charging a capacitor with a known current, measuring the resulting voltage, then calculating the capacitance.

**Warning:** A good capacitor stores an electrical charge and may remain energized after power is removed. Before touching it or taking a measurement, a) turn all power OFF, b) use your multimeter to confirm that power is OFF and c) carefully discharge the capacitor by connecting a resistor across the leads (as noted in the next paragraph). Be sure to wear appropriate personal protective equipment.



Figure 3.4: Capacitor testing

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**To safely discharge a capacitor:** After power is removed, connect a 20,000  $\Omega$ , 5-watt resistor across the capacitor terminals for five seconds. Use your multimeter to confirm the capacitor is fully discharged.

1. Use your digital multimeter (DMM) to ensure all power to the circuit is OFF. If the capacitor is used in an ac circuit, set the multimeter to measure ac voltage. If is used in a dc circuit, set the DMM to measure dc voltage.
2. Visually inspect the capacitor. If leaks, cracks, bulges or other signs of deterioration are evident, replace the capacitor.
3. Turn the dial to the Capacitance Measurement mode. The symbol often shares a spot on the dial with another function. In addition to the dial adjustment, a function button usually needs to be pressed to activate a measurement. Consult your multimeter's user manual for instructions..
4. 4. For a correct measurement, the capacitor will need to be removed from the circuit. Discharge the capacitor as described in the warning above.

**Note:** Some multimeters offer a Relative (REL) mode. When measuring low capacitance values, the Relative mode can be used to remove the capacitance of the test leads. To place a multimeter in Relative mode for capacitance, leave the test leads open and press the REL button. This removes the residual capacitance value of the test leads.

5. Connect the test leads to the capacitor terminals. Keep test leads connected for a few seconds to allow the multimeter to automatically select the proper range.
6. Read the measurement displayed. If the capacitance value is within the measurement range, the multimeter will display the capacitor's value. It will display OL if a) the capacitance value is higher than the measurement range or b) the capacitor is faulty.

### Capacitance measurement overview

Troubleshooting single-phase motors is one of the most practical uses of a digital multimeter's Capacitance Function.

A capacitor-start, single-phase motor that fails to start is a symptom of a faulty capacitor. Such motors will continue to run once operating, making troubleshooting tricky. Failure of the hard-start capacitor for HVAC compressors is a good example of this problem. The compressor motor may start, but soon overheat resulting in a breaker trip.

Single-phase motors with such problems and noisy single-phase motors with capacitors require a multimeter to verify properly functioning capacitors. Almost all motor capacitors will have the microfarad value marked on the capacitor.

Three-phase power factor correction capacitors are typically fuse protected. Should one or more of these capacitors fail, system inefficiencies will result, utility bills will most likely increase and inadvertent equipment trips of may occur. Should a capacitor fuse blow, the suspected faulty capacitor microfarad value must be measured and verified it falls within the range marked on the capacitor.

Some additional factors involving capacitance are worth knowing:

- Capacitors have a limited life and are often the cause of a malfunction.
- Faulty capacitors may have a short circuit, an open circuit or may physically deteriorate to the point of failure.
- When a capacitor short circuits, a fuse may blow or other components may be damaged.
- When a capacitor opens or deteriorates, the circuit or circuit components may not operate.
- Deterioration can also change the capacitance value of a capacitor, which can cause problems.

### 3.3 Electrical components data, function and value

#### 3.3.1 Manufacturer's Data Sheets

Datasheets are instruction manuals for electronic components. They (hopefully) explain exactly what a component does and how to use it. Unfortunately these documents are usually written by engineers for other engineers, and as such they can often be difficult to read, especially for newcomers. Nevertheless, datasheets are still the best place to find the details you need to design a circuit or get one working.

A datasheet's contents will vary widely depending on the type of part, but they will usually have most of the following sections:

The first page is usually a summary of the part's function and features. This is where you can quickly find a description of the part's functionality, the basic specifications (numbers that describe what a part needs and can do), and sometimes a functional block diagram that shows the

internal functions of the part. This page will often give you a good first impression as to whether potential part will work for your project or not:

- Documentation published by electronic component manufacturers that designers use when constructing circuits.

#### Data Sheet Information

- General Description
- Device Features
- Typical Applications
- Equivalent Circuits of IC's
- Device Connection diagrams (pinouts)
- Maximum Ratings and Electrical Characteristics
- Timing Diagrams for digital circuits
- Design formulas
- Typical Application Circuits

Typical Data Sheet Information Example

**LM555 Timer IC Manufactured by National Semiconductor (and others)**

**LM555 Timer**  
**General Description**  
The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.

**Features**

- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output
- Available in 8-pin MSOP package

**Applications**

- Precision timing
- Pulse generator
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

**Summary of key features**

**Explains the device function**

**Typical applications**

Commented [WU9]: Fig title and number?

Figure 3.5: Typical Data Sheet information Example

Connection Diagram

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Relates the IC input and output leads from schematic to pins on package. Shows package orientation.

(Where is pin 1?)

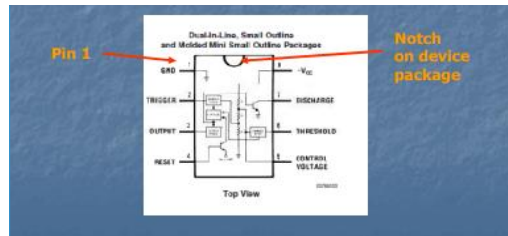


Figure: connection diagram

Commented [WU10]: Fig title and number?

<b>Self-check 3</b>	<b>Written test</b>
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**Direction: answer the following question**

**Test 1: True or False**

1. A good capacitor stores an electrical charge and not energized after power is removed
2. A good forward-biased diode displays a voltage drop ranging from 0.5 to 0.8 volts
3. Electrical testing can be used to identify suspect parts and aid in counterfeit mitigation
4. Power-off tests allow components to be safely examined and are often used in troubleshooting.
5. The first safety step when working with electronic components is removing any electronic equipment you're testing or working on from the power source

**Test 2: Choice**

1. Which one is personal safety precautions to consider when working with electronics circuit?
 

A. Always keep your work area dry.
C. Always wear non-conductive shoes.
2. Which one of the following indicates defective resistor?
 

A. Very high resistance, above its rated value
C. it's shorted internally

B. Low resistance, near  $0\Omega$ 
D. all

**Test 3: Short Answer**

1. Explain Data Sheet and Data Sheet information?
2. Write the procedures to test a diode.

**Note: Satisfactory rating – 10 points**

**Unsatisfactory - below 5 points**

Score = \_\_\_\_\_

Rating: \_\_\_\_\_

Name: \_\_\_\_\_

Date: \_\_\_\_\_

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## Operation Sheet - 2

**Operation Title:** Testing Capacitors

**Instructions:** Select different types of capacitors and test using digital multimeter

**Purpose:** To check the functionality of capacitors, capacitance value

**Required tools and equipment:** Multimeter, Capacitor, DC power supply, soldering iron, soldering lead, side cutter, etc.

**Precautions:**

- ✓ Make sure the capacitor is discharged
- ✓ Do not charge by higher current or higher voltage than specified
- ✓ Do not reverse placement of (+) and (-)
- ✓ Do not solder directly to the capacitor
- ✓ Do not heat, disassemble, nor dispose of in fire
- ✓ Do not discharge by force

**Procedures:**

- 1) Use your digital multimeter (DMM) to ensure all power to the circuit is OFF. If the capacitor is used in an ac circuit, set the multimeter to measure ac voltage. If is used in a dc circuit, set the DMM to measure dc voltage.
- 2) Visually inspect the capacitor. If leaks, cracks, bulges or other signs of deterioration are evident, replace the capacitor.
- 3) Turn the dial to the Capacitance Measurement mode. The symbol often shares a spot on the dial with another function. In addition to the dial adjustment, a function button usually needs to be pressed to activate a measurement. Consult your multimeter's user manual for instructions.
- 4) For a correct measurement, the capacitor will need to be removed from the circuit. Discharge the capacitor as described in the warning above.

Note: Some multimeters offer a Relative (REL) mode. When measuring low capacitance values, the Relative mode can be used to remove the capacitance of the test leads. To place a multimeter in Relative mode for capacitance, leave the test leads open and press the REL button. This removes the residual capacitance value of the test leads.

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- 5) Connect the test leads to the capacitor terminals. Keep test leads connected for a few seconds to allow the multimeter to automatically select the proper range.
- 6) Read the measurement displayed. If the capacitance value is within the measurement range, the multimeter will display the capacitor's value. It will display OL if a) the capacitance value is higher than the measurement range or b) the capacitor is faulty

#### Quality criteria

Safety

Testing method

Multimeter operation

LAP Test	Practical Demonstration
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Name: \_\_\_\_\_

Date: \_\_\_\_\_

Time started: \_\_\_\_\_

Time finished: \_\_\_\_\_

**Instruction I:** Given necessary templates, tools and materials you are required to perform the following tasks within 2 hours.

**Task 1:** Reading resistor color codes

**Task 2** Testing Capacitors



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