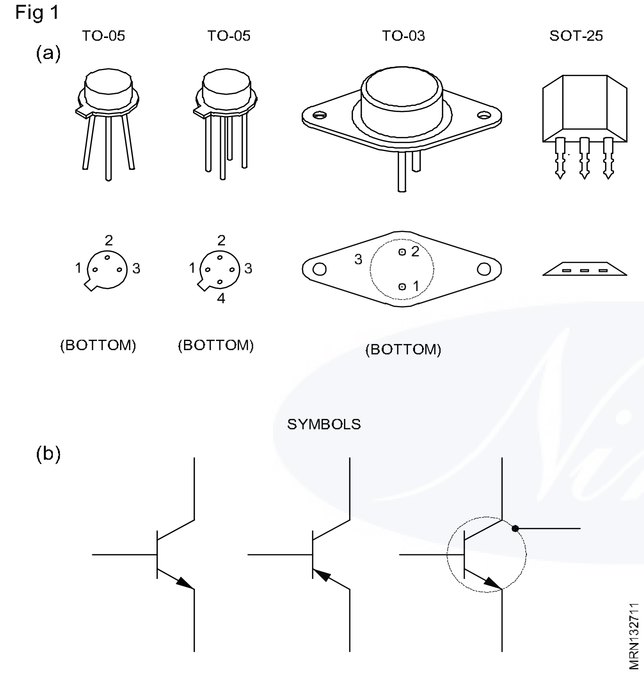
Transistors and classification, identification and checking transistor

Objectives : At the end of this lesson you shall be able to
- **state the two main uses of transistors**
- **list the advantages and classifications of transistors**
- **state the use of a transistor data book**
- **check the transistor with multimeter/ohmmeter.**

Introduction to transistors

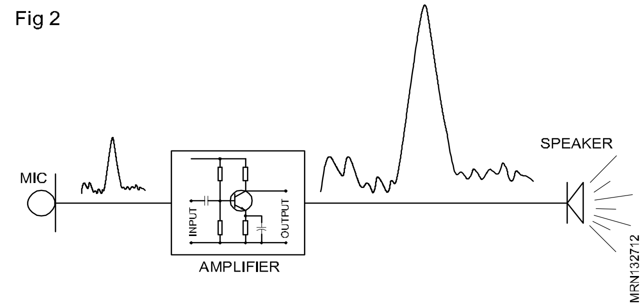
Transistors are the semiconductor devices having three or four leads/terminals. Fig 1a shows some typical transistors. Fig 1b shows the symbols used for different types of transistors.

Fig 1



Transistors are mainly used for enlarging or amplifying small electric/electronic signals as shown in Fig 2. The circuit which uses transistors for amplifying is known as a transistor amplifier.

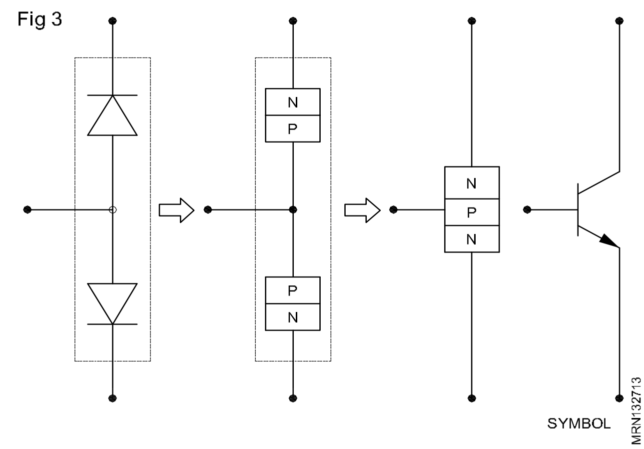
Fig 2



One other important application of transistors is it use as a solid state switch. A solid state switch is nothing but a switch which does not involve any physical ON/OFF contacts for switching.

Transistors can be thought of as two PN junction diodes connected back to back as shown in Fig 3.

Fig 3



Compared with the present day transistors the vacuum tubes were big in size , consumed more power, generated lot of unwanted heat and were fragile. Hence vacuum tubes became absolute as soon as transistors came to market.

Transistors were invented by Walter H. Brazil and John Barlow of Bell Telephone Laboratories on 23rd Dec. 1947. Compared to vacuum tubes (also known as valves), transistors have several advantages. Some important advantages are listed below;

- Very small in size
- Light in weight
- Minimum or no power loss in the form of heat
- Low operating voltage
- Rugged in construction.

To satisfy the requirements of different applications, several types of transistors in different types of packaging are available. As in diodes, depending upon the characteristics, transistors are given a type number such as BC 107, 2N 6004 etc., The characteristics data corresponding to these type numbers are given in Transistor data books.

Classification of transistors

1 Based on the semiconductor used.

- Germanium transistors
- Silicon transistors

Like in diodes, transistors can be made, using any one of the above two important semiconductors. However, most of the transistors are made using silicon. This is because, silicon transistors work better over a wide temperature range (higher thermal stability) compared to germanium transistors.

Transistor data books give information about the semiconductor used in any particular transistor.

2 **Based on the way the P and N junctions are organized as shown in Fig 4.**

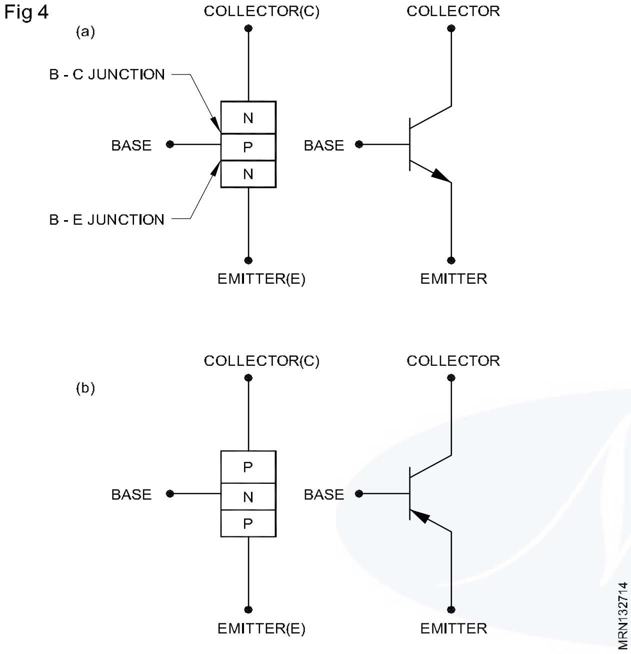
- NPN transistors
- PNP transistors

Both NPN and PNP transistors are equally useful in electronic circuits. However, NPN transistors are preferred for the reason that NPN has higher switching speed compared to PNP.

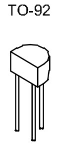
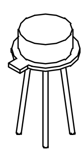
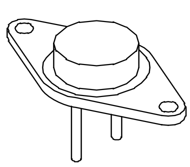
NOTE: Details of switching speed is discussed in further lessons.

Whether a transistor is PNP or NPN can be found with the help of transistor data book.

Fig 4



3 **Based on the power handling capacity of transistors as shown in Table below (Fig 5).**

Low power transistors (less than 2 watts)	**Medium power transistors** (2 to 10 watts)	**High power transistors** (more than 10 watts)
Fig 5 TO-92 	TO-05 	TO-03 

Low power transistors, also known as small signal amplifiers, are generally used at the first stage of amplification in which the strength of the signal to be amplified is low. For example, to amplify signals from a microphone, tape head, transducers etc.,

Medium power and high power transistors, also known as large signal amplifiers are used for achieving medium to high power amplification. For example, signals to be given to loudspeakers etc. High power transistors are usually mounted on metal chassis or on a physically large piece of metal known as heat sink. The function of heat sink is to, take away the heat from the transistor and pass it to air.

Transistor data books give information about the power handling capacity of different transistor.

4 **Based on the frequency of application**

- Low freq. transistors (Audio frequency or A/F transistors)
- High freq. transistor (Radio frequency or R/F transistors)

Amplification required for signals of low or audio range of frequencies in Tape recorders, PA systems etc., make use of A/F transistors. Amplifications required for signals of high and very high frequencies as, in radio receivers, television receivers etc., use R/F transistors.

Testing transistors using ohmmeter

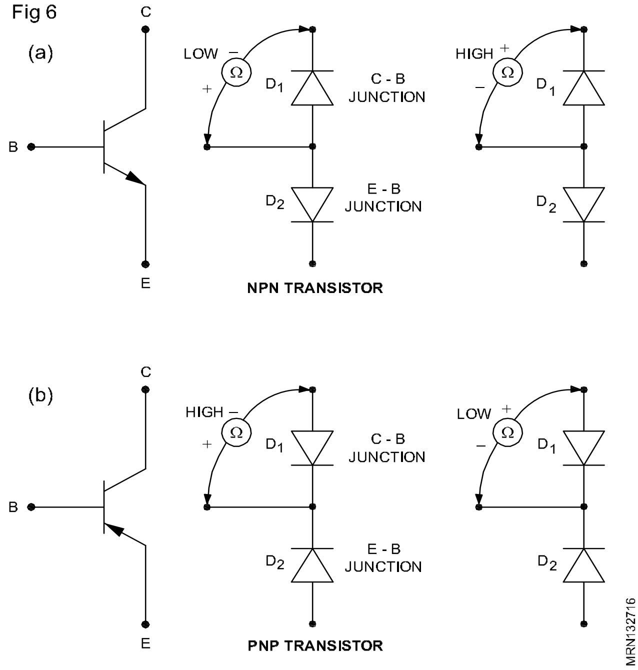
1 **Junction test**

Since a transistor can be regarded as two diodes connected back-to-back, a transistor's general working condition (quick-test) can be assessed by checking these two diodes as shown in Fig 6a and 6b.

Fig 6a shows a NPN transistor and Fig 6b shows a PNP transistor. The imaginary diodes 1 and 2 can be tested as testing any diode. When a diode is tested, if the ohmmeter shows high resistance in one direction and low resistance in another direction, then the diode corresponding to that diode junction can be regarded as GOOD. One important point to note in a transistor is that, both the diodes of the transistor should be GOOD to declare the transistor as GOOD.

While testing, a transistor using ohmmeter, it is suggested to use the middle ohmmeter range (Rx100) because, ohmmeters in low range can produce excessive current and ohmmeters in high range can produce excessive voltage which may be sufficient to damage small signal transistors.

Fig 6



Half wave and full wave rectifiers

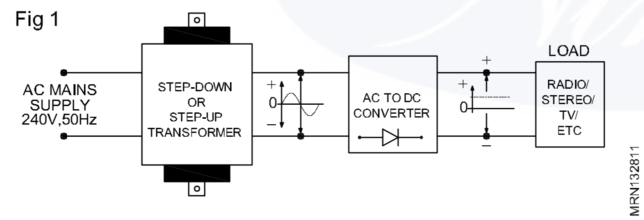
Objectives : At the end of this lesson you shall be able to
- **state the meaning of the term rectification**
- **describe the working of a half-wave and two diode full-wave rectifier**
- **state the output of a half-wave rectifier in terms of rms value of input AC, peak value of input AC**
- **state the output DC level and the current rating of diode in a two-diode fullwave rectifier**
- **state the ripple frequency in a half-wave rectifier and a full-wave rectifiers**
- **state the value of PIV in half-wave and full-wave rectifiers**
- **list the limitations of half-wave and a two diode full-wave rectifiers.**

Rectification

Almost all electronic circuits need DC voltage for their working. This DC voltage can be obtained by dry cells and batteries. Use of a dry cell is practicable only in portable electronic circuits such as transistor radio, tape recorders etc. But in circuits requiring large voltages and currents, like high power audio amplifiers, television sets etc. batteries will not only be very expensive but also be voluminous.

An alternative method of obtaining DC voltage is by converting the AC mains supply of 240V, 50Hz into DC voltage. This technique is not only convenient but also takes very small space compared to battery packs. This process of converting AC to DC is known as rectification. Fig 1 shows the principle of converting AC to DC of required voltage level.

Fig 1



The transformer will step-down or step-up the mains AC to the required level. The stepped-up or stepped-down AC from the output of the transformer is then converted to DC using diodes making use of their unique unidirectional property.

Half way rectifier

The simplest form of AC to DC converter is by using one diode. such an AC to DC converter is known as half-wave rectifier as shown in Fig 2.

At the secondary of the transformer, across terminals P & Q, when seen on a CRO, the electric signal is a sinusoidal wave with its peak value of V_P and a frequency determined by the rate at which the alternations (+ve to –ve) are taking place. In Fig 2, the frequency is 50Hz as this voltage is taken from 50Hz AC mains supply.

If the voltage across P and Q is measured using an AC voltmeter, the voltmeter shows the rms (root mean square) value, V_{rms} of the sinusoidal wave which will be less than the peak value. The relationship between V_{Peak} and V_{rms} is given by,

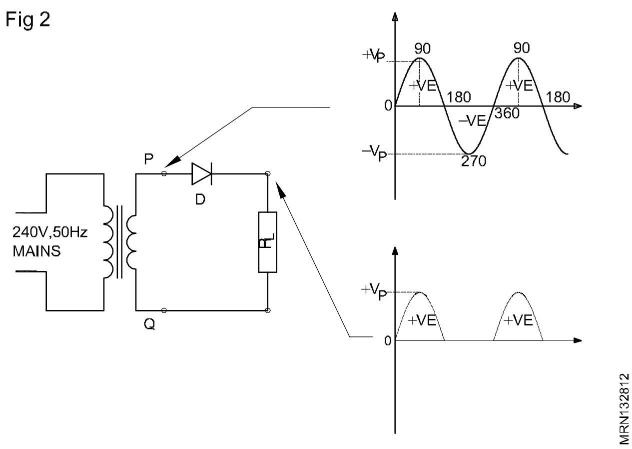
$$V_{rms} = 0.707\ V_{peak}$$

conversely,

$$V_{peak} = \frac{V_{rms}}{0.707} = \sqrt{2}\ V_{rms}$$

When this sinusoidal signal is applied across the diode D as shown in Fig 2, the diode conducts (behaves as a closed switch) only during the +ve half cycle of the input sinusoidal voltage and does not conduct (behaves as a open switch) during the -ve half of the input sinusoidal voltage. This process repeats again and again thus producing a pulsating +ve wave-form at the output across the load, R_L as shown in Fig 2.

Fig 2



Bridge rectifiers

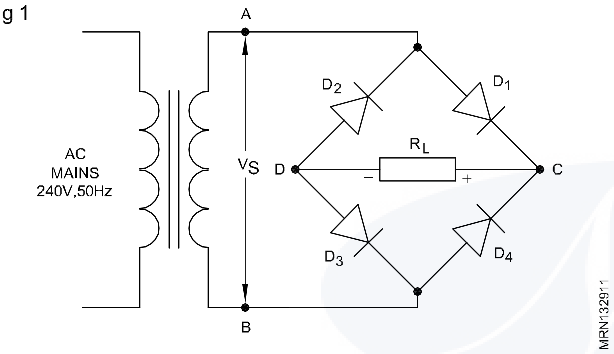
Objectives : At the end of this lesson you shall be able to
- **describe the working of a bridge rectifier**
- **state the output DC level in a bridge rectifier**
- **state the ripple frequency in a bridge rectifier.**

The bridge rectifier

The disadvantages of a full wave rectifier using two diodes and centre-tap transformer can be overcome by a modified fullwave rectifier as shown in Fig 1. In Fig 1, since the diodes are connected in the form of a bridge, this rectifier circuit is commonly known as a *Bridge rectifier.*

As can be seen in Fig 1, the bridge rectifier does not need a centre-tapped transformer. Also, all the secondary voltage is used for rectification at any given time.

Fig 1

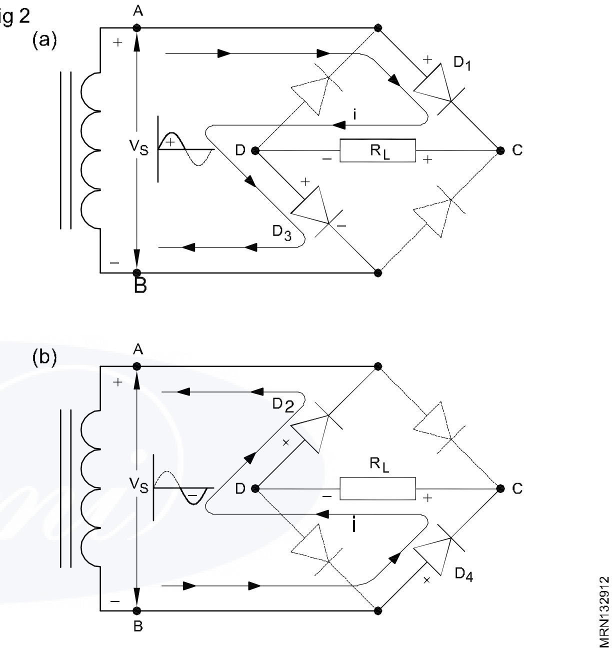


The operation of a bridge rectifier can be summarized in the following steps;

- When end A of the transformer secondary is +ve, as shown in Fig 2a, diodes D_1 and D_3 are forward biased whereas, D_2 and D_4 are reverse biased, and, hence, D_2 and D_4 do not come in the circuit.
- Current flows from the transformer(end A) D_1 R_L D_3 back to the transformer(end B). From the direction of the current flow point C is the positive terminal of the DC output across R_L.
- During the other half cycle of the input (–ve half cycle), end B of the transformer becomes +ve as shown in Fig 2b. Diodes D_4 and D_2 are forward biased, whereas D_1 and D_3 are reverse biased.
- Current flows from the transformer (end B) D_4 R_L D_2 back to the transformer(end A). From the direction of the current flow, point C is again the +ve terminal of the DC output across R_L.

Note that, current I is in the same direction through R_L during both +ve and –ve half cycles of the input AC. The result is, a +ve rectified DC voltage appears at the end of R_L connected to the cathodes of D_1 and D_4.

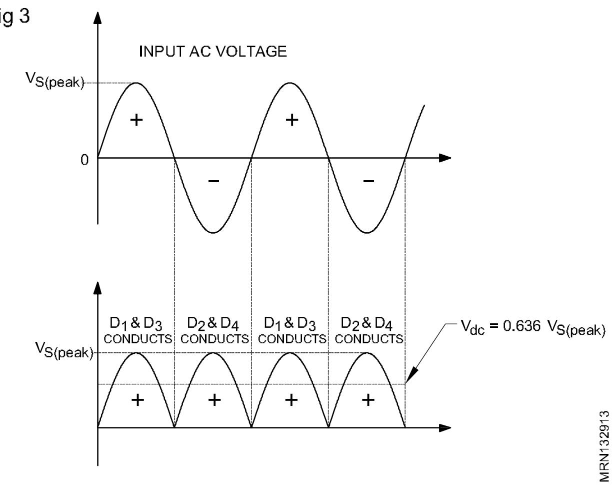
Fig 2



Output DC level in a bridge rectifier

Fig 3 shows the input AC and the output pulsating DC wave-form of a bridge rectifier.

Fig 3



Series voltage regulators

Objectives : On the end of this lesson you shall be able to
- **state the disadvantages of a zener regulator**
- **state the working of a simple series regulator**
- **design a simple series regulator for a required dc output voltage**
- **write the blocks of a series regulator with voltage feedback and explain their functions**
- **design a series regulator for a given input-output specification**
- **state the modification necessary to make the output of a voltage regulator variable**
- **state the characteristics of a darlington pair connection**
- **state the method of increasing the load current capacity of series regulator.**

Disadvantages of a zener regulator

1 When the load current requirement is higher, say of the order of a few amperes, the zener regulator requires a very high wattage zener diode capable of handling high current.

2 In a zener regulator, the load resistor sees an output impedance of approximately the zener impedance, R_Z which ranges from a few ohms to a few tens of ohms (typically 5Ω to 25Ω). This is a considerably high output impedance because the output impedance of a ideal power supply should be zero ohms.

These two disadvantages of zener regulators are overcome in a simple series regulator shown in Fig 1a.

The simple series regulator shown in Fig 1a, redrawn in Fig 1b is nothing but a zener regulator followed by an emitter follower. A circuit like this can hold the load voltage almost constant, thus working as a voltage regulator.

The advantages of this circuit are listed below;

1 Less load on the zener diode.

In this circuit Fig 1a or 1b the base current is very much smaller than the emitter current or the load current, a very small wattage zener diode itself is sufficient.

For instance for a load of say 1 amp, if the β_{dc} of the transistor is 100, then the zener diode need to handle only, 20mA for a typical $I_{z(min)}$ of 5 to 10mA.

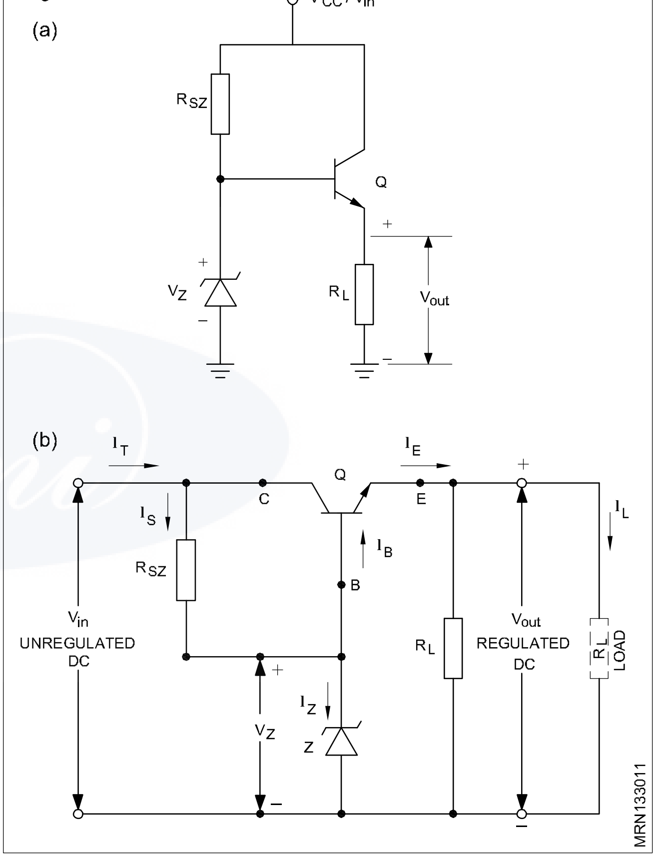
2 Lower output impedance

This circuit also offers a lower output impedance of 0.07W which is close to the ideal output impedance of zero required for a power supply. For further information, refer IMP of Electronic Mechanic Ist year.

Working of a simple series regulator

In Fig 1b, the current through R_{SZ} should be atleast equal to zener breakdown current, plus, base current for the transistor Q.

Fig 1



The voltage across the zener, V_Z drives the base of the emitter follower. Therefore, the dc output voltage is bootstrapped to within one V_{BE} drop of the zener voltage. The regulated dc output voltage will be,

$$V_{out} = V_Z - V_{BE} \quad ....[1]$$

The collector - emitter voltage across the transistor will be the difference in the voltage between the input and output.

$$V_{CE} = V_{in} - V_{out}$$

Using voltage regulator using zener diode

Objectives : At the end of this lesson you shall be able to
- **state the need of regulators in power supplies**
- **state the formula to calculate the % load regulation factor**
- **list the main similarities and differences between rectifier diodes and zener diodes**
- **name the main application of zener diodes**
- **state the meaning of ICs**
- **explain the fixed voltage regulators.**

Voltage regulators

Recall that, the DC output voltage level of power supplies such as, full-wave and bridge rectifiers, tend to decrease or increase,

– when the load current increases or decreases

– when the AC input voltage level decreases or increases.

Such variations in the output DC voltage level of power supply is not acceptable for most of the electronic circuits. Hence, it is required to regulate the DC output of power supplies so as to keep the DC output level constant, inspite of variations in the DC load current or the AC input voltage. Circuits or components used to keep the DC output voltage of a power supply constant are called voltage regulators.

Regulation factor

The ability of a power supply to maintain a constant DC output voltage for variations in the load current is referred to as load regulation. Load regulation of a power supply is generally given as a percentage.

Load regulation factor % = x 100

where,

V_{NL} = DC output at no load or open circuit

and V_{FL} = DC output at rated full load.

It should be noted that lower the percentage of load regulation factor, better is the voltage regulation.

Example: The DC output of a power supply is 12 volts at no-load and 11 volts at full load.

% Load regulation = x 100 = 8.33%

In practice the load regulation of a good power supply should be less than 0.1 %.

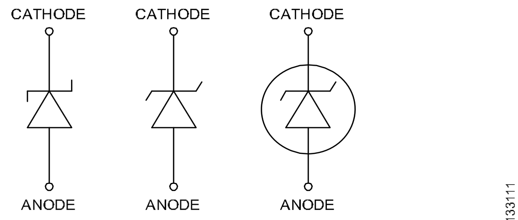
Regulating the DC output voltage for variations in the input AC level is termed as line regulation. This is discussed in further units.

The zener diode

In a power supply one of the simplest ways of regulating the DC output voltage (keeping the output voltage constant) is by using a zener diode. With zener in reverse breakdown condition, the voltage across the zener diode remains constant for a wide range of input and load variations.

Because of this property, zener diodes are also known as voltage regulators or voltage reference diodes. Fig 1 shows the symbol used for zener diodes.

Fig 1



ZENER DIODE SCHEMATIC SYMBOLS

The difference between a rectifier diode and a zener diode are listed below;

– Compared to normal rectifier diodes, zener diodes are heavily doped.

– Unlike ordinary diodes which do not work in the breakdown region, zener diodes work only in the breakdown region.

– General rectifier diodes are used in forward-biased condition, whereas zeners are always used in reverse-biased condition.

– The reverse breakdown voltage of zener diodes is very much less (3 to 18V) compared to rectifier diodes (minimum 50V).

The similarities of a zener diode with those of general purpose rectifier diodes are listed below;

– Zener diodes are also PN junction diodes, which are also generally made of silicon.

– Zener diodes also have two terminals (anode and cathode).

– In physical appearance, the zener diodes and ordinary diodes look alike.

– Like rectifier diodes, zener diodes are also available with glass, plastic and metal casing.

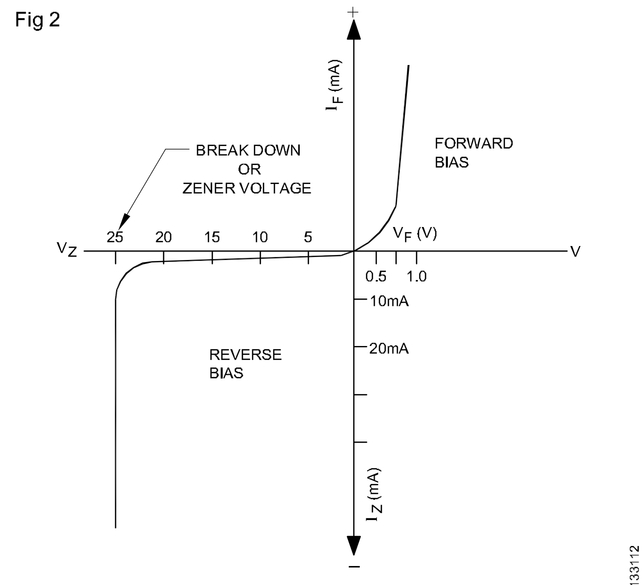
– The anode and cathode marking technique on the body is same for both zener and rectifier diodes.

– The zener can be tested with an ohmmeter in the same way as in rectifier diodes.

– Zener requires approximately the same voltage for it to be forward-biased into conduction as that of an ordinary diode.

Fig 2 shows the conduction characteristics of a typical zener diode. Because of the nature and heavy doping in a zener, its characteristics are different compared to a rectifier diode.

Fig 2



ZENER DIODE CONDUCTION CHARACTERISTICS

Note that, the zener diode acts as a rectifier diode when forward biased. It also behaves as a rectifier diode when reverse-biased, till the voltage across it reaches the breakdown voltage. As can be seen from Fig 2, even the reverse or leakage current remains almost negligible and constant despite the increase in the reverse-biased voltage till the break down voltage, also called zener voltage is reached. But, Once the zener breakdown voltage is reached, the diode current begins to increase rapidly and the zener suddenly begins to conduct. In the case of a normal rectifier diode, once the break down voltage is reached the diode gets punctured and starts conducting heavily whereas, in a zener diode, the diode does not get punctured even though it conducts current in the reverse biased condition.

The cause for this reverse conduction is referred to as the avalanche effect. The avalanche effect cause, the electrons to be knocked loose from their bonds in the crystal structure. As more electrons are loosened, they in turn knock others and current builds quickly. This action causes the voltage drop across the zener to remain constant regardless of the zener current. As shown in Fig 2, once the zener voltage is reached, very small voltage changes create much greater current changes. It is this characteristic, which makes the zener useful as a constant voltage source or as a voltage regulator.

Unlike in a rectifier diode, the reverse current through the zener is not destructive. If the current is kept within the specified limits depending upon the wattage rating of the zener, using a suitable series resistance, no harm is done to the zener diode.

Because the zener diode is designed to operate as a breakdown device, the zener can be brought out of condition easily. A zener is brought out of its zener conduction by lowering the reverse-biased voltage below the zener voltage or by reversing the polarity of the applied voltage.

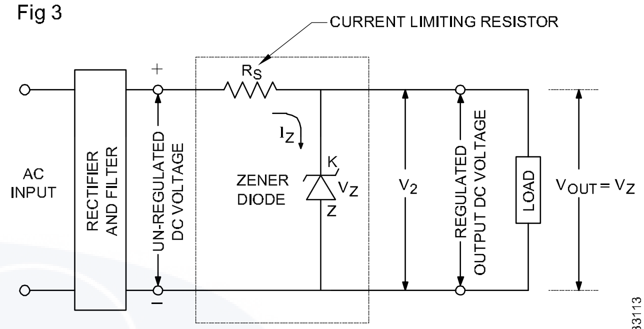
Application of zener diodes

The most popular use of zener diodes is as voltage regulators in DC power supplies. Fig 3 illustrates a simple zener regulated power supply.

In the circuit at Fig 3, the zener diode is in parallel with the output or load of the power supply. It is very important to note that the zener is connected in the reverse-biased condition. Such a parallel circuit connection is often called a shunt. When used in this way, the zener is said to be a shunt regulator.

In Fig 3, the zener begins to conduct in the reverse-biased condition as the voltage across it reaches the zener voltage V_Z. The voltage across the zener remains constant immaterial of the input DC voltage. Since the load is in parallel with the zener, the voltage across the load V_{OUT} will be same as the voltage across the zener V_z ($V_{OUT} = V_Z$).

Fig 3



ZENER SHUNT REGULATOR

If the input DC voltage to the zener increases, as can be seen from its characteristics in Fig 2, the current I_Z through the zener increases but the voltage across the zener remains the same due to avalanche effect. Because the zener voltage, V_Z does not change, the output voltage V_{OUT}, does not change and so the voltage across the load is constant. Thus, the output is said to be regulated.

Introduction

Electronic circuits invariably consist of a number of discrete components connected to each other in a specific way. For instance, the series regulator circuit discussed in earlier lessons, consists of transistors, zener diodes, resistors and so on, connected in a defined way for it to function as a regulator. If all these components instead of building on a board, if they are built on a single wafer of a semiconductor crystal, then, the physical size of the circuit becomes very very small. Although small, this will do the same job as that of the circuit wired using discrete components. Such miniaturised electronic circuits produced within and upon a single crystal, usually silicon, are known as **integrated circuits** or **IC**s. Integrated circuits (ICs) can consists of thousands of active components like transistor, diodes and passive components like resistors and capacitors in some specific order such that they function in a defined way say as voltage regulators or amplifiers or oscillators and so on.

Classification of integrated circuits

Integrated circuits may be classified in several ways. However the most popular classifications is as follows:

1 Based on its type of circuitry

a Analog ICs - Example: amplifier ICs, voltage regulator ICs etc.

b Digital ICs - Example: Digital gates, flip-flops, adders etc.

2 Based on the number of transistors built into IC

a Small scale integration (SSI) - consists of 1 to 10 transistors.

b Medium scale integration (MSI) - consists of 10 to 100 transistors.

c Large scale integration (LSI) - 100 to 1000 transistors.

d Very large scale integration (VLSI) - 1000 and above.

3 Based on the type of transistors used

a Bipolar - carries both electron and hole current.

b Metal oxide semiconductor (MOS) - electron or hole current.

c Complementary metal oxide semiconductor (CMOS) - electron or hole current.

NOTE: The terms MOS and CMOS are another type of transistors which will be discussed in further lessons. Further details on different classifications of ICs will be discussed at appropriate lessons.

Integrated circuit (IC) voltage regulators

The series voltage regulators discussed in earlier lessons are available in the form of integrated circuits (ICs). They are known as voltage regulator ICs.

There are two types of voltage regulator ICs. They are,

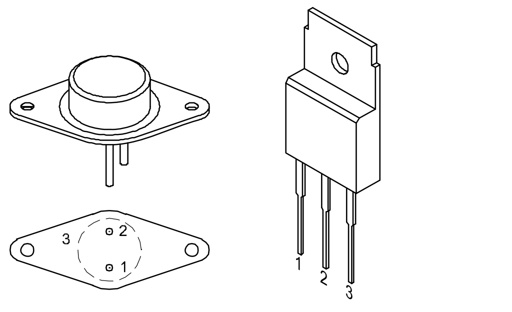
1 Fixed output voltage regulator ICs

2 Adjustable output voltage regulator ICs.

Fixed output voltage regulator ICs

The latest generation of fixed output voltage regulator ICs have only three pins as shown in Fig 1. They are designed to provide either positive or negative regulated DC output voltage.

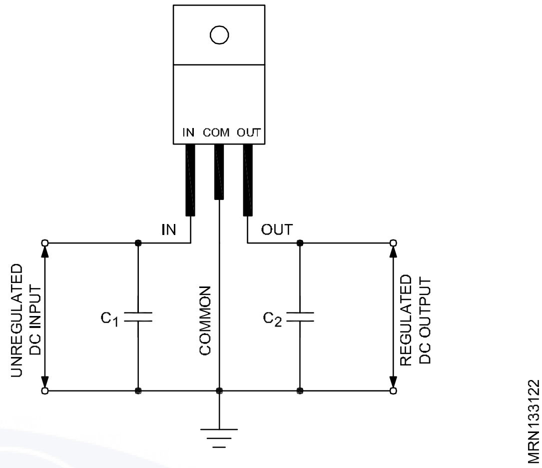
Fig 1



These ICs consists of all those components and even more in the small packages shown in Fig 1. These ICs, when used as voltage regulators, do not need extra components other than two small value capacitors as shown in Fig 2.

The reason behind using capacitor C_1 is, when the voltage regulator IC is more than a few inches from the filter capacitors of the unregulated power supply, the lead inductance may produce oscillations within the IC. Capacitor C_1 prevents setting up of such oscillations. Typical value of bypass capacitor C_1 range from 0.220µF to 1µF. It is important to note that C_1 should be connected as close to the IC as possible.

Fig 2



The capacitor C_2 is used to improve the transient response of the regulated output voltage. C_2 bypasses these transients produced during the ON/OFF time. Typical values of C_2 range from 0.1µF to 10 µF.

Fixed voltage three terminal regulators are available from different IC manufacturers for different output voltages (such as 5V, 9V, 12V, 24V) with maximum load current rating ranging from 100mA to more than three amps.

The most popular three terminal IC regulators are,

1 LMXXX-X series

Example: LM320-5, LM320-24 etc.

2 78XX and 79XX series

Example: 7805, 7809, 7812, 7905, 7909, 7912

Identify specifications and testing of SCR

Objectives At the end of this lesson you shall be able to
- **explain the role of SCR in the field of industrial electronics**
- **explain the construction and working principle of SCR**
- **explain the method of checking SCRs using JIG.**

Introduction to Industrial electronics

Industrial electronics is concerned primarily with electronics as applied to industries such as industrial equipments, controls and processes. An important application of electronics in industries is in controlling of machinery.

In communication electronics, domestic & entertainment electronics, generally, the electronic devices operate with currents in the order of microampers to milliampers. For industrial applications, most frequently, devices are required to handle currents in the range of ampers to several thousands of ampers. This, therefore calls for high power electronic devices. One such high power electronic device frequently used in industrial electronic application is the SCR. SCRs can be used to run, dc motors from an ac power source, control power tool speed,also to control motor speeds of small appliances like, mixers and food blenders, illumination control, temperature control and so on.

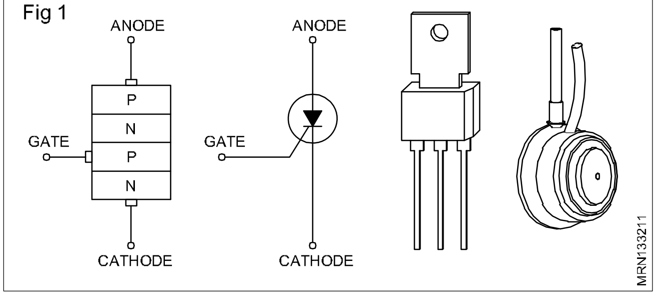
Silicon Controlled Rectifier(SCR)

Before Silicon controlled rectifiers were invented(1956), a glass tube device called Thyratron was used for high power applications. Silicon Controlled Rectifier (SCR) is the first device of the thyristor family. The term thyristor is coined from the expression Thyratron-transistor. SCR is a semiconductor device. SCR does the function of controlled rectification. Unlike a rectifier diode, SCR has an additional terminal called the gate which controls the rectification(gated silicon rectifier).

The basic principle application of SCRs is to control the amount of power delivered to a load(motor, lamp, etc.,).

A rectifier diode will have one PN junction. SCRs on the other hand will have two PN junctions (P-N-P-N layers). Fig 1 shows the electrical symbol, basic construction and a typical SCR packages.

Fig 1



Basic operation of SCR

When a gate current is applied to the gate terminal, forward current conduction commences in the SCR(latched into conduction). When the gate current is removed, the forward current through the SCR **does not cut-off**. This means, once the SCR is latched into conduction, the gate loses control over the conduction. The current through the SCR can be turned off only by reducing the current through it(load current) below a critical value called the **Holding current**.

QUICK Check of SCRs

Quick check on SCRs can be carried out using a ohmmeter/ multimeter. Since SCRs are made of PNPN junction, resistance between junctions can be measured to conclude good working condition of the SCR. A good SCR shows following resistances between its terminal leads;

CHECK - 1

Between Anode - Cathode	- Infinite resistance
[Irrespective of polarity]	
Between Gate - Cathode	
(i) Forward biased	- Very low resistance (30 to 500 ohms)
(ii) Reverse biased	- High resistance
Between Gate - Anode	- Infinite resistance
[Irrespective of polarity]	

CHECK - 2

- Set multimeter to low resistance range.
- Connect positive lead of multimeter to the anode and the negative lead to the cathode. Meter should show infinite resistance.
- Now, for moment, short anode and gate of SCR by a piece of wire. The meter should show low resistance and will continue to show low resistance even after the short between anode and gate is been removed.

It is difficult to check leaky SCRs using only a ohmmeter/multimeter.

Checking SCRs using a SCR checking JIG

A simple "SCR checking jig" is shown in Fig 2. In Fig 2, the SCR shown in dotted lines is the SCR to be checked. This could be any SCR that you want to check.

In Fig 2, the stepped down to 12 AC is rectified by diode D_1 and filtered by capacitor C_1 when switch S_2 is at position A. The rectified and filtered DC is applied to the anode of SCR through lamp L_1 via a limiting resistor R_4. Resistor R_2, R_3 in series with a push button switch S_3 form a potential divider across dc. Voltage across R_3 is applied to the gate of SCR. This voltage is sufficient to turn on the SCR. Another push button Switch S_4 is connected directly across the Anode and Cathode of the SCR to be checked.

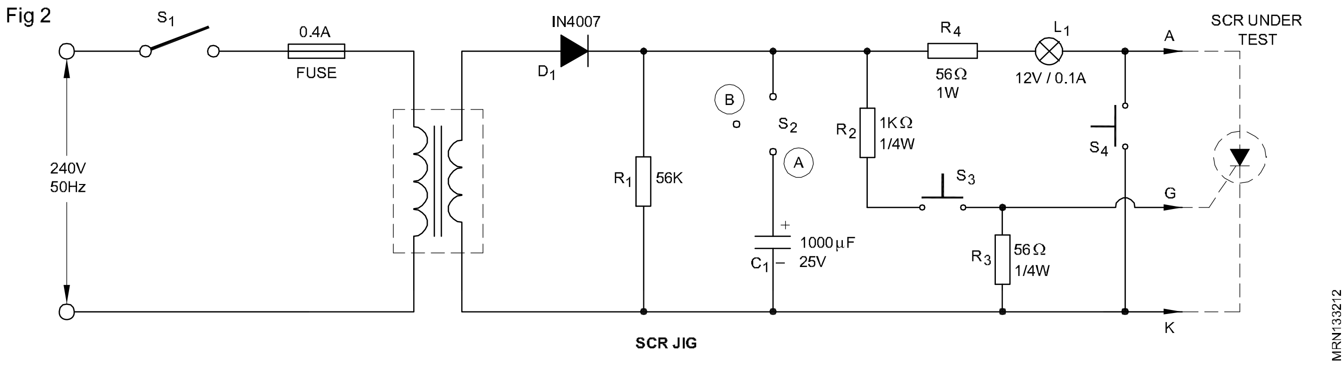
When a good SCR is placed in the test jig(in place of the SCR shown dotted) the circuit should function as given below;

1 When mains supply is on, and S_2 is at DC position, the lamp will start glowing as soon as the switch S_3 is pressed. Even on releasing S_3, the lamp should keep on glowing. Under this condittion, if swithch S_4 is pressed once and released the SCR stops conducting and hence the lamp stops glowing.

2 If switch S_2 is put to AC position, lamp should glow only as long as switch S_3 is pressed.

The Instructor has to discuss the reasons for 1 & 2 above as an interactive discussion. Instructor also discuss the outcome of above steps, when a open or a shorted SCR is checked.

Fig 2



Application of UJT as time delay

Objectives: At the end of this lesson you shall be able to
- **list the use of UJT in electric circuit**
- **state the method of varying oscillator frequency**
- **explain the method of triggering SCR through UJT band relaxation oscillator.**

Application of UJTs: UJTs are employed in a wide variety of circuits involving electronic switching and voltage or current sensing applications. These include

– triggers for thyristors

– as oscillators

– as pulse and sawtooth generators

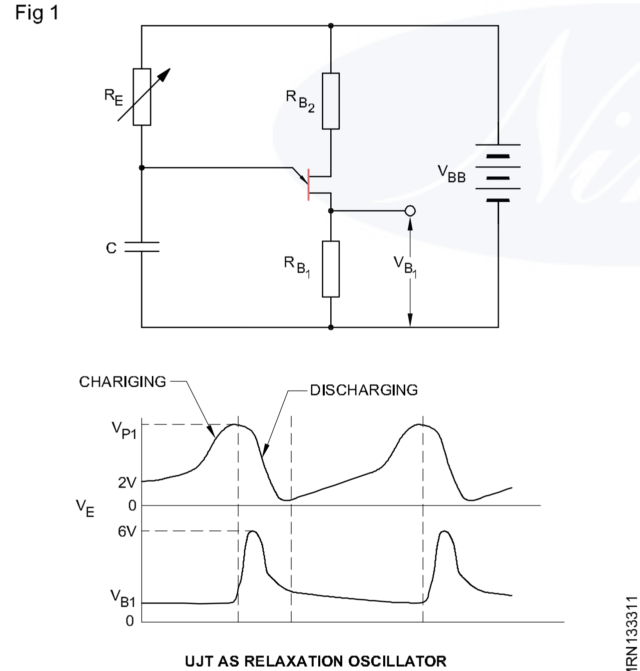
– timing circuits

– regulated power supplies

– bistable circuits and so on.

Let us analyse the waveform generated across the capacitor and R_1 with respect to the relaxation oscillator shown in Fig 1.

Fig 1



UJT AS RELAXATION OSCILLATOR

The negative - resistance portion of the UJT characteristic is used in the circuit shown in Fig 1 to develop a relaxation oscillator.

The wave form developed across the capacitor is shown in Fig 1 as V_E, whereas the waveform produced across the resistor R_{B1} is shown as a pulse V_{B1}.

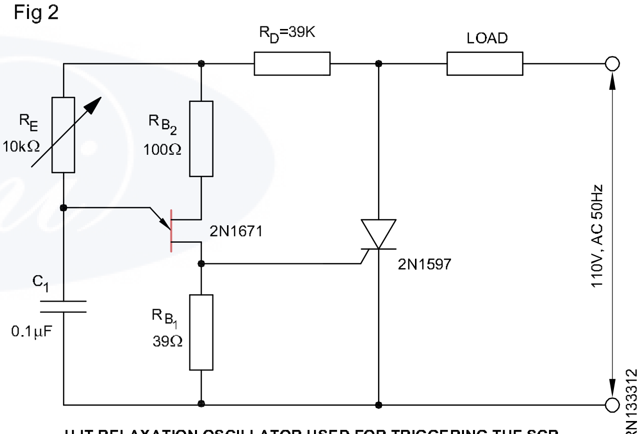
The frequency of oscillation

$$f = \frac{1}{R_E C}$$

Where R_E is the value of variable resistor in ohms and C is the value of the capacitor in farad.

By varying the value of R_E, the frequency of the oscillator can be varied. Although such an oscillator using a DC supply voltage could be used to trigger a SCR, there would be trouble in synchronizing the pulses with the cycles of alternating current. Fig 2 shows a stable triggering circuit for an SCR in which the firing angle can be varied from 0° to 180°.

Fig 2



UJT RELAXATION OSCILLATOR USED FOR TRIGGERING THE SCR

The low output impedance of the UJT (39ohms) is ideal for driving the SCR, which has a relatively low input impedance from gate to cathode.

Resistor R_D is used as a dropping resistor to restrict the peak voltage across the UJT to within its specifications.

By varying the variable resistor R_E the oscillator frequency can be varied thereby the frequency of trigger pulses which are used to trigger the SCR. Time used for delay in switching the SCR could be measured through a slip watch from the time of switching on.

Photodiodes and phototransistors

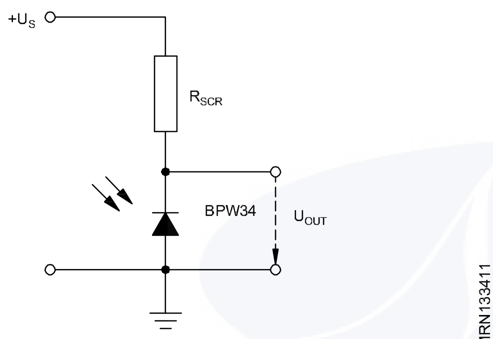
Objectives: At the end of this lesson you shall be able to
- **explain working of photodiode**
- **explain the advantages of PIN photodiode**
- **list a few application of photodiodes**
- **explain working of photodiode**
- **explain the working of a light controlled switch using photo transistor**
- **state the working principles of operational amplifier.**

Photo diodes

P-N Photo diodes

Photodiodes are produced by silicon techniques. Photodiodes are operated in the reverse direction. A supply voltage and a series resistor are therefore required to operate photodiodes. The basic circuit for the operation of photodiodes is shown in Fig.1

Fig 1



When no light is incident on the photodiode, a reverse current flows through the p-n junction, as it does in any normal semiconductor diode, but in photodiodes it is usually referred to as the "dark current" I_{Ro}.

When light strikes the p-n junction, crystal bonds are broken as a result of the supply of energy. Mobile charge-carrier pairs are produced, which immediately migrate as a result of the electric field present. The holes travel towards the p-layer and the electrons towards the n-layer. As a result of illumination, an additional photocurrent I'_{photo} occurs, which increases linearly with the illuminance. This photocurrent is superimposed as a reverse current on the relatively small dark current, so that for the total photocurrent occurring with illumination, the following applies:

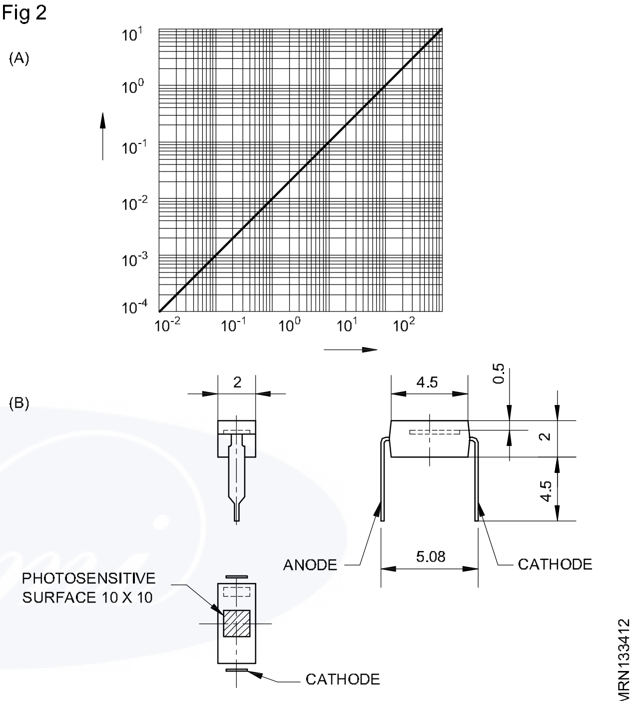
$I_{photo} = I_{Ro} + I'_{photo}$

Since I_{Ro} is far smaller than I'_{photo} then:

$I_{photo} = I'_{photo}$

The rise in I_{photo} is almost linear. Photodiodes are therefore particularly suitable for the accurate measurement of illuminance. Physical appearance and dimensions of a typical photodiode BPW 32 is shown in Fig 2.

Fig 2



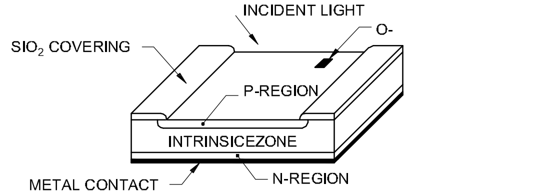
PIN Photo diodes

PIN photodiodes were developed to overcome the drawbacks of p-n photodiodes. The letters PIN indicate the zone sequence as given below;

P-layer/Intrinsic-layer/N-layer

A typical internal construction of a PIN photodiode is shown in Fig 3.

Fig 3



TECHNOLOGICAL CONSTRUCTION OF PIN PHOTODIODES

The advantages of PIN photodiodes are;

– high sensitivity in the infrared range

– short switching times,

because of which, they are extensively used in remote control using modulated infrared light.

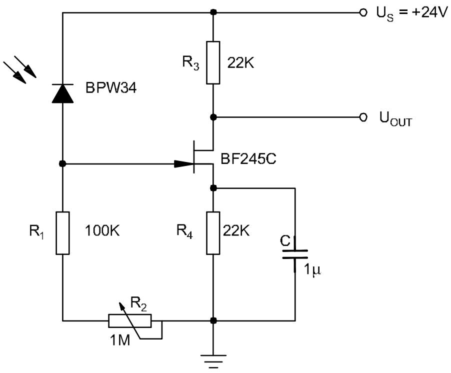
In operation they are similar to p-n photo diodes as shown in Fig 1.

Typical application of Photodiodes

Because of the very small photocurrent, photodiodes are generally used with an amplifier as shown in Fig 4. Amplifier stages with FET(Field Effect Transistor) are usually used with photodiodes because of the high input resistance of FET.

> **Note: Field Effect Transistors well known as FET is another type of transistor. Details of FET is discussed in lessons to follow.**

Fig 4



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Circuit diagram of a simple Light controlled amplifier is shown in Fig 5. This circuit uses a single FET for amplifying the output of the photodiode connected in series with a resistor.

The working point of the FET can be adjusted with trimmer R_2. As the illumination on the photo diode increases, the negative gate is reduced and therefore V_{out} reduces. The same value of R_3 and R_4 are chosen to ensure linear relationship between I_{photo} and V_{out} over a wide range. Thus this photoamplifer works satisfactorily not only for very slow changes in illumination but also with alternating light.

Illumination Photometer using photodiode and Opamp

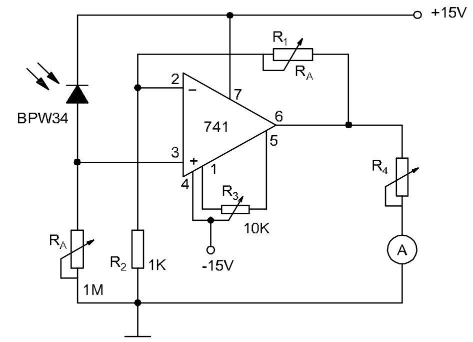
An illumination Photometer with an op-amp as an amplifier is shown in Fig 5. The output of the photo sensor follows the illuminance linearly, which may be in the range between 0.05 lx and 5000 lx, with a sensitivity of 5µA/lx. The sensor has the type designation TFA 1001W and is intended for use in video cameras and optical instruments.

Photo Transistor

Both in the construction and in their mode of operation, phototransistor's can be thought of as a combination of a photodiode and a normal bipolar transistor. The simplified equivalent circuit diagram of a phototransistor is shown in Fig 6.

Without illumination, only a very small dark current I_{Ro} flows through the photodiode. This dark current, at the same time is the base current of the transistor. The following is then obtained for the dark current I_{Co} of the transistor,

Fig 5



ILLUMINATION PHOTOMETER WITH OP-AMP

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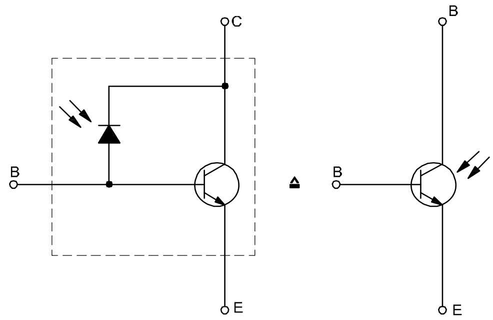
Fig 6



SIMPLIFIED EQUIVALENT CIRCUIT DIAGRAM OF A PHOTOTRANSISTOR

MRN133416

$I_{Co} = B \times (I_{CBo} + I_{Ro})$,

Where,

I_{CBo}, is the reverse current of the collector/base diode and B is the current gain of the transistor.

When the photodiode is illuminated, a photocurrent I_{photo} flows, which is amplified by the current gain B and is superimposed on the dark current.

Therefore, the collector current of the phototransistor is,

$I_C = I_{Co} + B \times I_{photo}$

Since the dark current I_{Co} is much less than $B \times I_{photo}$, I_{Co} can generally be neglected, so in practice,

I_C approximately = $B \times I_{photo}$

Advantage of Phototransistors over Photodiodes

Advantages of phototransistors over photodiodes are,

– their considerably greater sensitivity and

– the illuminance-dependent collector current IC, which is increased by a factor B.

Operational Amplifier

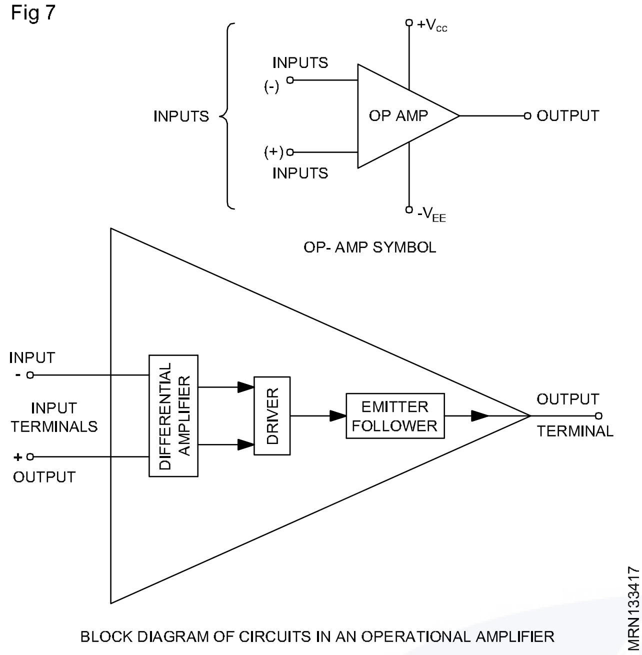
Basic linear integrated circuit-'Operational Amplifiers' (OP Amps)

An operational amplifier, often referred as op-Amp, is a high gain, direct coupled differential amplifier, designed to amplify both DC and AC signals.

The term operational is used with these amplifiers because, in early days these amplifiers were used in analog computers to perform mathematical operations such as addition, multiplication etc., Symbol used to represent an Op-Amp and the functional blocks inside it are shown in Fig 7.

As can be seen from Fig 7, operational amplifiers will have two inputs and one output. The reason for having two input points is that Op Amps have a special type of amplifier configuration known as Differential amplifier as its first stage.

Fig 7



A typical differential amplifier stage is shown in Fig 8. A differential amplifier stage consists of two transistors with an input to each transistor. The output is taken between the collectors of the transistors as shown in Fig 8. The most important point to note is, both the transistors have identical characteristics, load resistors, input resistors and a single emitter resistor. Dual power supply(+ve,-ve and Gnd) is required for differential amplifiers (single supply can also be used with a few extra components). If a dual supply is used and if the amplifier is properly balanced (symmetrical values), the output voltage across the collectors will be equal to the difference of the two input voltages. Hence, this amplifier is called differential amplifier.

Modes of operation of differential amplifiers

Any operational amplifier can be operated in two modes. They are,

- Common-mode operation
- Differential-mode operation.

Fig 8