2.2 CONFIGURATION OF TRANSISTOR CIRCUIT

A transistor is a three terminal device. But require _4‘terminals for connecting it in a circuits. (i.e.) 2 terminals for input, 2 terminals for output.

Hence one of the terminal is made common to the input and output circuits.Common terminal is grounded.

TYPES OF CONFIGURATIONS

Three types of configuration is available

1) Common base(CB) configuration
2) Common emitter (CE) configuration
3) Common collector (CC) configuration

COMMON BASE (CB) CONFIGURATION

In common base configuration circuit is shown in figure. Here base is grounded and itis used as the common terminal for both input and output.

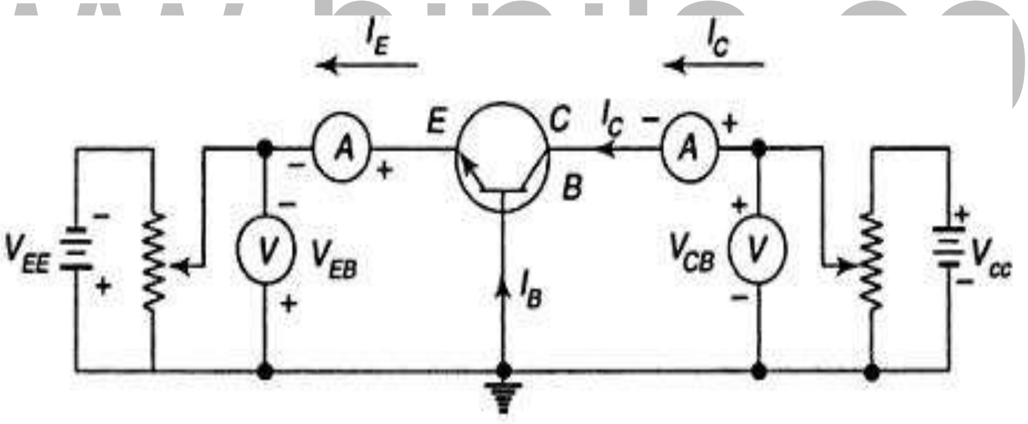


Figure 2.2.1 Circuit to determine CB static characteristics

[Source: “Electronic devices and circuits” by “Balbir Kumar, Shail.B.Jain, and Page: 310]

It is also called as grounded base configuration. Emitter is used as an input terminal whereas collector is the output terminal.

Input characteristics:

It is defined as the characteristic curve drawn between input voltages to input currentwhereas output voltage is constant.

To determine input characteristics, the collector base voltage VCB is kept constant at zero and emitter current IE is increased from zero by increasing VEB.This is repeated for higher fixed values of VCB.

A curve is drawn between emitter current and emitter base voltage at constant collector base voltage is shown in figure 2.2.1.When VCB is zero EB junctions is forward biased. So it behaves

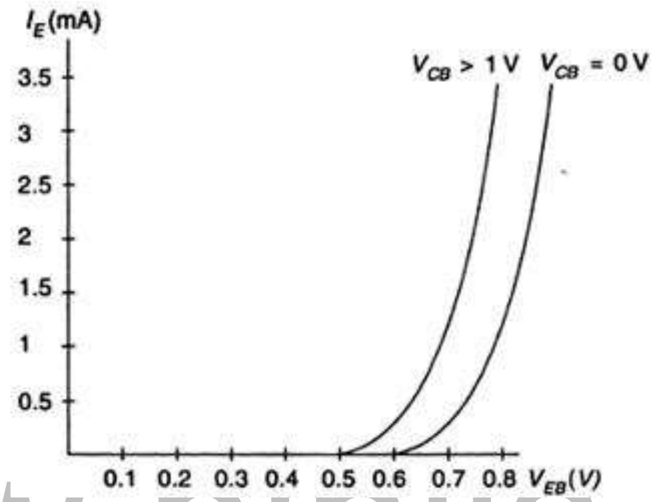


Figure 2.2.2 CB input characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 311]

Output Characteristics

It is defined as the characteristic curve drawn between output voltages to output current whereas input current is constant. To determine output characteristics, the emitter current IE is kept constant at zero and collector current Ic is increased from zero by increasing VCB.This is repeated for higher fixed values of IE.

From the characteristic it is seen that for a constant value of IE, Ic is independent of VCB and the curves are parallel to the axis of VCB.As the emitter base junction is forward biased the majority carriers that is electrons from the emitter region are injected into the base region.

In CB configuration a variation of the base-collector voltage results in a variation of the quasi- neutral width in the base. The gradient of the minority-carrier density in the base therefore changes, yielding an increased collector current as the collector-base current isincreased. This effect is referred to as the early effect.

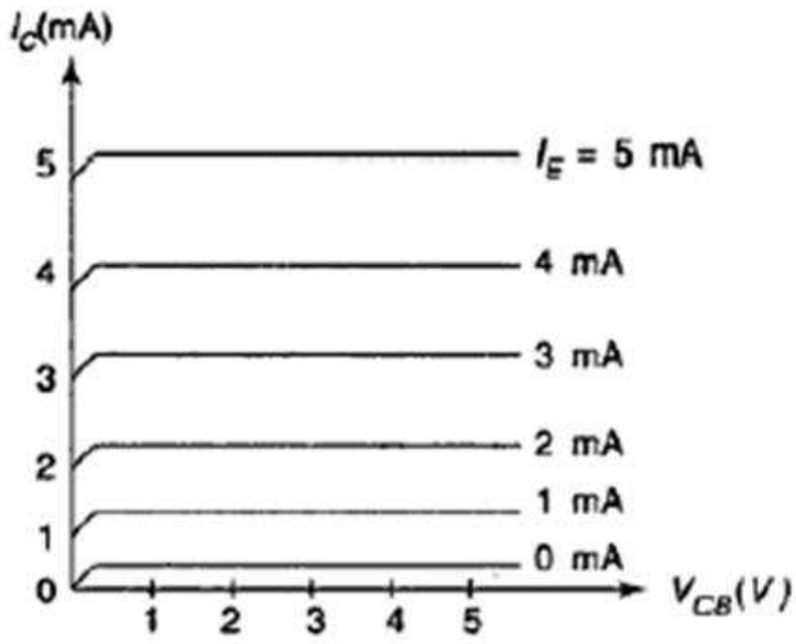


Figure 2.2.3 CB output characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 311]

COMMOM EMITTER CONFIGURATION

In common emitter configuration circuit is shown in figure. Here emitter is grounded and it is used as the common terminal for both input and output. It is also called as grounded emitter configuration. Base is used as a input terminal whereas collector is the output terminal.

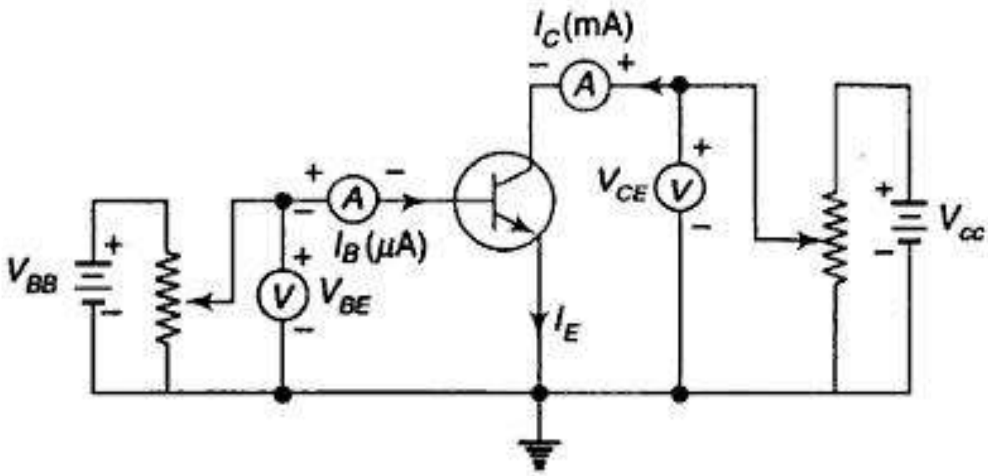


Figure 2.2.4 Circuit to determine CE static characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 312]

Input Characteristics

It is defined as the characteristic curve drawn between input voltages to input current whereas output voltage is constant.

To determine input characteristics, the collector base voltage VCB is kept constant at zero and base current IB is increased from zero by increasing VBE.This is repeated for higher fixed values of VCE. A curve is drawn between base current and base emitter voltage at constant collector base voltage is shown in figure2.14. Here the base width decreases. So curve moves right asVCE increases.

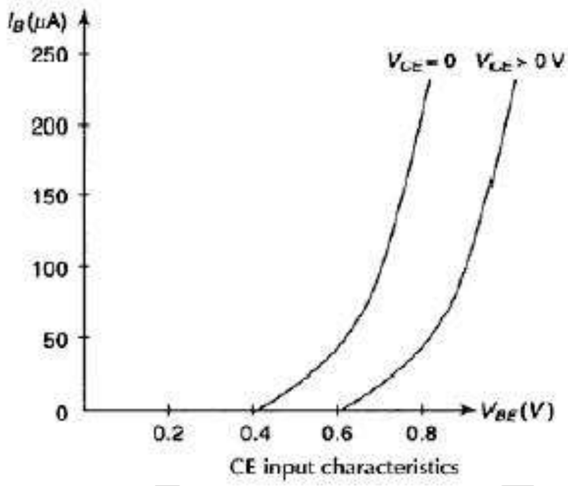


Figure 2.2.5 CE input characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 312

Output Characteristics

It is defined as the characteristic curve drawn between output voltages to output current whereas input current is constant.

To determine output characteristics, the base current IB is kept constant at zero and collector current Ic is increased from zero by increasing VCE.This is repeated for higher fixed values of IB.

From the characteristic it is seen that for a constant value of IB, Ic is independent of VCBand the curves are parallel to the axis of VCE.

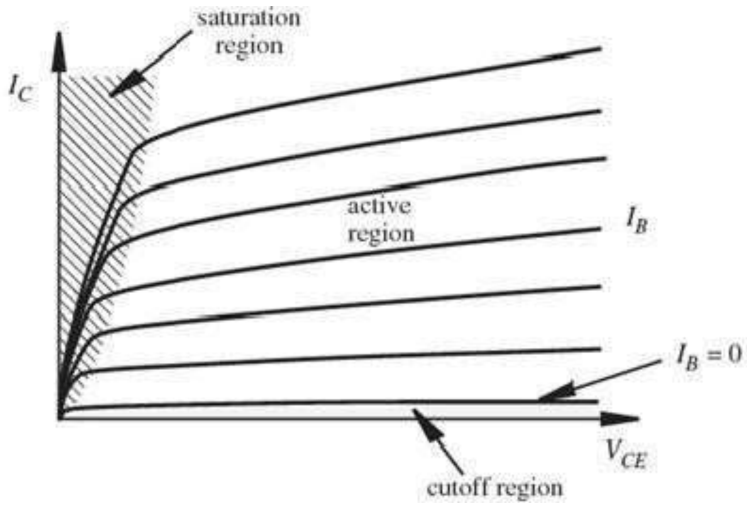


Figure 2.2.6 CE output Characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 312]

The output characteristic has 3 basic regions:

- Active region –defined by the biasing arrangements.
- Cutoff region – region where the collector current is 0A
- Saturation region- region of the characteristics to the left of VCB = 0V.

Active region	Saturation region	Cut-off region
IE increased, IC increased. BE junction forward bias and CB junction reverse bias. Refer to the graph, IC≈ IE IC not depends on VCB Suitable region for the transistor working as amplifier.	BE and CB junction is forward bias Small changes in VCB will cause big different to IC The allocation for this region is to the left of VCB=0V.	Region below the line of IE=0 A BE and CB is reverse biase No current flow at collector, only leakage current.

Table: Common Emitter Region

COMMON COLLECTOR CONFIGURATION

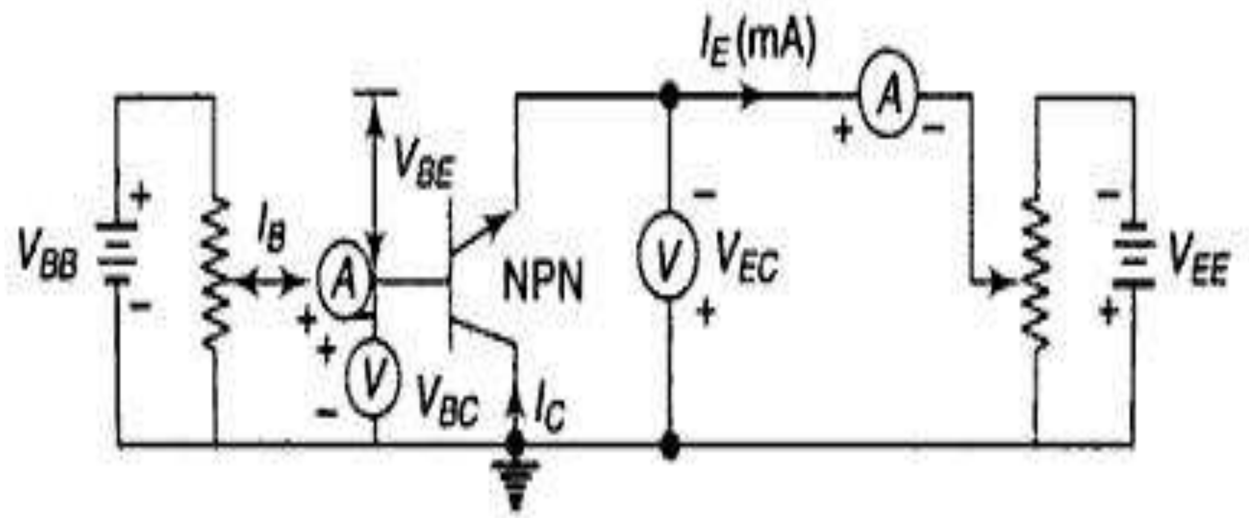


Figure 2.2.7 Circuits to determine CC static characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 313]

Input Characteristics

It is defined as the characteristic curve drawn between input voltages to inputcurrent whereas output voltage is constant.

To determine input characteristics, the emitter base voltage V_{EB} is kept constant at zero and base current I_B is increased from zero by increasing V_{BC}.This is repeated for higher fixed values of V_{CE}.A curve is drawn between base current and base emitter voltage at constant collector base voltage is shown in figure2.2.7

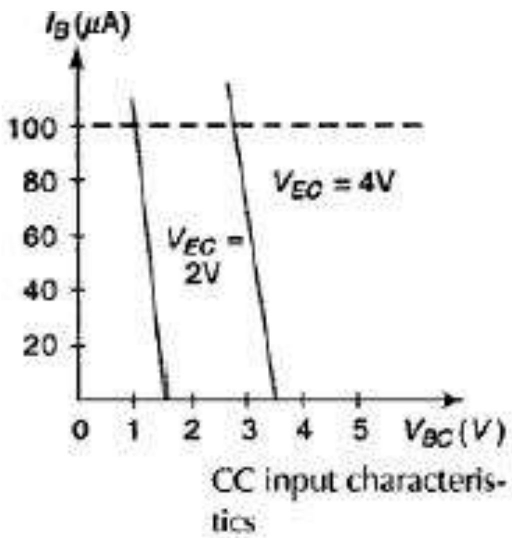


Figure 2.2.8 CC input characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 313]

Output Characteristics

It is defined as the characteristic curve drawn between output voltages to output current whereas input current is constant.

To determine output characteristics, the base current IB is kept constant at zero and emitter current IE is increased from zero by increasing VEC. This is repeated for higher fixed values of IB.

From the characteristic it is seen that for a constant value of IB, IE is independent of VEBand the curves are parallel to the axis of VEC.

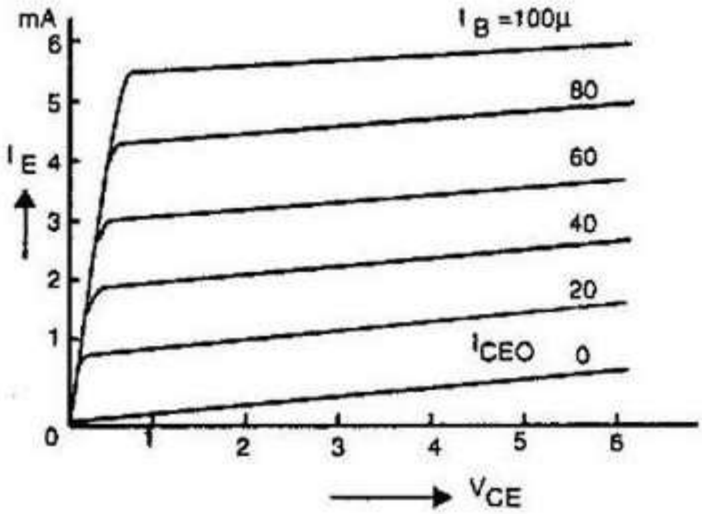


Figure 2.2.9 Common Collector output characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 313]

A comparison of CB, CE and CC Configurations

Property	*CB*	*CE*	*CC*
Input resistance	Low (about 100 Ω)	Moderate (about 750 Ω)	High (about 750 kΩ)
Output resistance	High (about 450 kΩ)	Moderate (about 45 kΩ)	Low (about 25 Ω)
Current gain	1	High	High
Voltage gain	About 150	About 500	Less than 1
Phase shift between input & output voltages	0 or 360°	180°	0 or 360°
Applications	for high frequency circuits	for audio frequency circuits	for impedance matching

2.7 DIAC (DIODE A.C. SWITCH)

The DIAC is a full-wave or bi-directional semiconductor switch that can be turned on in both forward and reverse polarities. The DIAC gains its name from the contraction of the words Diode Alternating Current.

The DIAC is widely used to assist even triggering of a TRIAC when used in AC switches.

DIACs are mainly used in dimmer applications and also in starter circuits for florescent lamps.

A diac is two terminal, three layer bi directional device which can be switched from its off state for either polarity of applied voltage.

Circuit symbol

The DIAC circuit symbol is generated from the two triangles held between two lines as shown below. In some way this demonstrates the structure of the device which can be considered also as two junctions

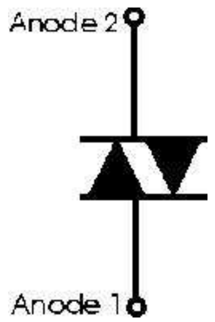


Figure 2.7.1 Circuit symbol

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 120]

The two terminals of the device are normally designated either Anode 1 and Anode 2 or Main Terminals 1 and 2, i.e. MT1 and MT2.

Construction

The DIAC can be constructed in either npn or pnp form. The two leads are connected to p regions of silicon separated by an n- region. The structure of DIAC is similar to that of a transistor differences are

- ✓ There is no terminal attached to the base layer
- ✓ The three regions are nearly identical in size. The doping concentrations are identical togive the device symmetrical properties.

The DIAC can e fabricated as either a two layer or a five layer structure. In the three layer structure the switching occurs when the junction that is reverse biased experiences reverse breakdown. The three layer version of the device is the more common and can have a break-over voltage of around 30 V. Operation is almost symmetrical owing to the symmetry of the device.

A five layer DIAC structure is also available. This does not act in quite the same manner, although it produces an I-V curve that is very similar to the three layer version. It can be considered as two break-over diodes connected back to back.

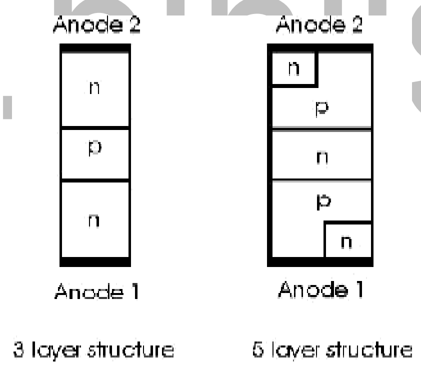


Figure 2.7.2 The structure of a DIAC

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 121]

For most applications a three layer version of the DIAC is used. It provides sufficient improvement in switching characteristics. For some applications the five layer device may be used.

Operation

When a positive or negative voltage is applied across the terminals of Diac only a small leakage current Ibo will flow through the device as the applied voltage is increased , the leakage current will continue to flow until the voltage reaches break over voltage Vbo at this point avalanche breakdown of the reverse biased junction occurs and the device exhibits negative resistance i.e. current through the device increases with the decreasing values of applied voltagethe voltage across the device then drops to break back voltage Vw.

V- I characteristics of a DIAC

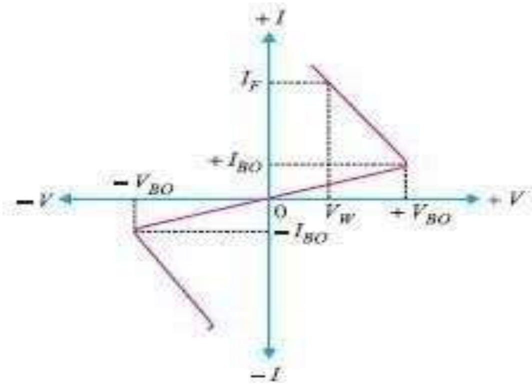


Figure 2.7.3 The V- I characteristics of a DIAC

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 121]

For applied positive voltage less than + Vbo and Negative voltage less than -Vbo , a small leakage current flows through the device. Under such conditions the diac blocks flow of current and behaves as an open circuit. The voltage +Vbo and -Vbo are the breakdown voltages and usually have range of 30 to 50 volts.

When the positive or negative applied voltage is equal to or greater than the breakdown voltage Diac begins to conduct and voltage drop across it becomes a few volts conduction then continues until the device current drops below its holding current break over voltage and holding current values are identical for the forward and reverse regions of operation.

Applications

Diacs are used for triggering of Triacs in adjustable phase control of a c mains power. Applications are light dimming heat control universal motor speed control. Typically the DIAC is placed in series with the gate of a TRIAC. DIACs are often used in conjunction with TRIACs because these devices do not fire symmetrically as a result of slight differences between the two halves of the device. This results in harmonics being generated, and the less symmetrical the device fires, the greater the level of harmonics produced. It is generally undesirable to have high levels of harmonics in a power system.

2.3 Field Effect Transistor:

The field effect transistor is a semiconductor device, which depends for its operation on thecontrol of current by an electric field. There are two of field effect transistors:

- JFET (Junction Field Effect Transistor)
- MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

Several advantages over conventional transistor.

- In a conventional transistor, the operation depends upon the flow of majority and minority carriers. That is why it is called bipolar transistor. In FET the operation depends upon the flow of majority carriers only. It is called unipolar device.
- The input to conventional transistor amplifier involves a forward biased PN junction with its inherently low dynamic impedance. The input to FET involves a reverse biased PN junction hencethe high input impedance of the order of M-ohm.
- It is less noisy than a bipolar transistor.
- It exhibits no offset voltage at zero drain current.
- It has thermal stability.
- It is relatively immune to radiation

The main disadvantage is its relatively small gain bandwidth product in comparison withconventional transistor.

Operation of FET:

Consider a sample bar of N-type semiconductor. This is called N-channel and it is electrically equivalent to a resistance as shown in fig. 2.3.1.

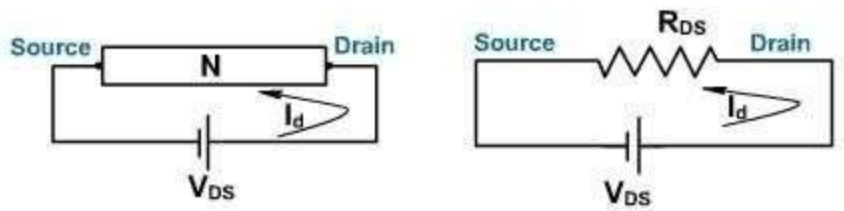


Figure: 2.3.1 FET in N-type semiconductor

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 210]

Ohmic contacts are then added on each side of the channel to bring the external connection. Thus if a voltage is applied across the bar, the current flows through the channel.

The terminal from where the majority carriers (electrons) enter the channel is called source designated by S. The terminal through which majority carriers leaves the channel is called drain and designated by D. For an N-channel device, electrons are the majority carriers. Hence the circuit behaves like a dc voltage V_{DS} applied across a resistance R_{DS}. The resulting current is the drain current I_D. If V_{DS} increases, I_D Increases proportionally.

Now on both sides of the n-type bar heavily doped regions of p-type impurity have been formedby any method for creating p n junction. These impurity regions are called gates (gate1 and gate2) as shown in fig. 2.3.2

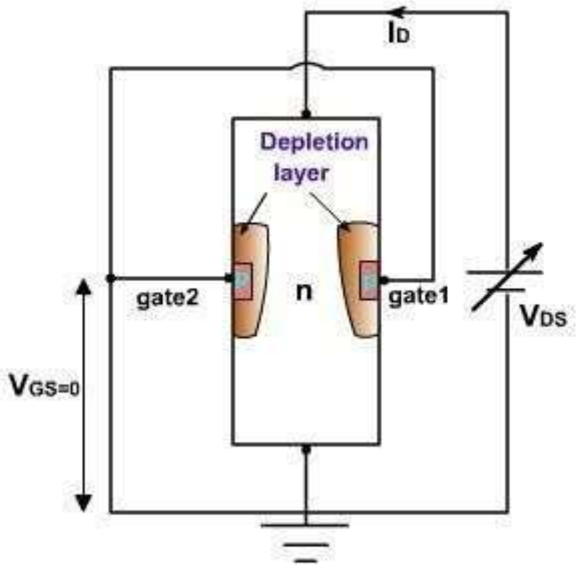


Figure: 2.3.2 N-channel device

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 210]

Both the gates are internally connected and they are grounded yielding zero gate source voltage (V_{GS} =0). The word gate is used because the potential applied between gate and source controlsthe channel width and hence the current.

As with all PN junctions, a depletion region is formed on the two sides of the reverse biased PN junction. The current carriers have diffused across the junction, leaving only uncovered positive ions on the n side and negative ions on the p side. The depletion region width increases with the magnitude of reverse bias. The conductivity of this channel is normally zero because of the unavailability of current carriers.

The potential at any point along the channel depends on the distance of that point from the drain, points close to the drain are at a higher positive potential, relative to ground, then points close to the source. Both depletion regions are therefore subject to greater reverse voltage near the drain. Therefore the depletion region width increases as we move towards drain. The flow of electrons from source to drain is now restricted to the narrow channel between the no conducting depletionregions. The width of this channel determines the resistance between drain and source.

Consider now the behavior of drain current I_D vs drain source voltage V_{DS}. The gate source voltage is zero therefore $V_{GS}= 0$. Suppose that V_{DS} is gradually linearly increased linearly from 0V. I_D also increases.

Since the channel behaves as a semiconductor resistance, therefore it follows ohm's law. The regionis called ohmic region, with increasing current, the ohmic voltage drop between the source and the channel region reverse biased the junction, the conducting portion of the channel begins to constrict and I_D begins to level off until a specific value of V_{DS} is reached, called the **pinch of voltage V_P**.

At this point further increase in V_{DS} do not produce corresponding increase in I_D. Instead, as V_{DS} increases, both depletion regions extend further into the channel, resulting in a no more cross section, and hence a higher channel resistance. Thus even though, there is more voltage, the resistance is also greater and the current remains relatively constant. This is Called pinch off or saturation region. The current in this region is maximum current that FET can produce and designated by I_{DSS}. (Drain to source current with gate shorted)

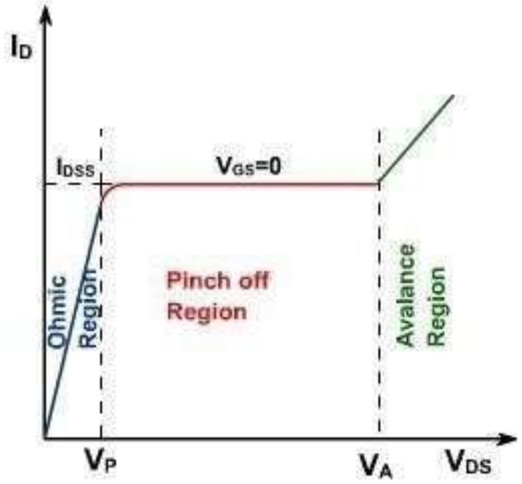


Figure: 2.3.3 P N junction occurs and ID rises

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 211]

As with all p n junctions, when the reverse voltage exceeds a certain level, avalanche breakdown of p n junction occurs and ID rises very rapidly as shown in fig. 2.3.3.

Consider now an N-channel JFET with a reverse gate source voltage as shown in **fig. 2.3.4.**

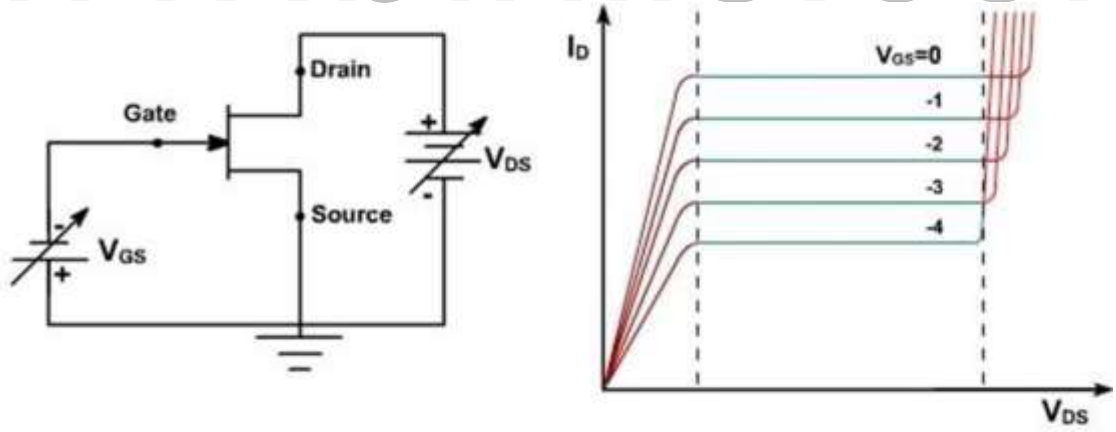


Figure: 2.3.4 JFET with a reverse gate source voltage

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 211]

The additional reverse bias, pinch off will occur for smaller values of | VDS |, and the maximum drain current will be smaller. A family of curves for different values of VGS (negative) is shown in **fig. 2.3.5**. Suppose that VGS= 0 and that due of VDS at a specific point along the channel is +5V with respect to ground.

Therefore reverse voltage across either p-n junction is now 5V. If VGS is decreased from 0 to –1V the net reverse bias near the point is 5 - (-1) = 6V. Thus for any fixed value of VDS, the channel width decreases as VGS is made more negative. Thus ID value changes correspondingly. When the gate voltage is negative enough, the depletion layers touch each other and the conducting channel pinches off (disappears). In this case the drain current is cut off. The gate voltage that produces cut off is symbolized VGS (off). It is same as pinch off voltage.

Since the gate source junction is a reverse biased silicon diode, only a very small reverse current flows through it. Ideally gate current is zero. As a result, all the free electrons from the source go to the drain i.e. ID = IS. Because the gate draws almost negligible reverse current the input resistance is very high 10's or 100's of M ohm. Therefore where high input impedance is required, JFET is preferred over BJT. The disadvantage is less control over output current i.e. FET takes larger changes in input voltage to produce changes in output current. For this reason, JFET has less voltage gain than a bipolar amplifier.

2.4 MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

- Like JFET, it has a source, Drain and Gate.
- It is also called IGFET (Insulated Gate FET) because gate terminal is insulated from channel. Therefore it has extremely high input resistance.

Types of MOSFET

- Depletion mode MOSFET
  N-channel
  P-channel
- Enhancement mode MOSFET
  N-channel
  P-channel

The enhancement-type MOSFET is usually referred to as an E-MOSFET, and the depletion type, a D-MOSFET. The drain current in a MOSFET is controlled by the gate-source voltage VGS.

Depletion mode-MOSFET [D-MOSFET]

In depletion mode of operation the bias voltage on the gate reduce the number of charge carriers in the channel and therefore reduce the drain current ID.It operates in both depletion mode and enhancement mode.

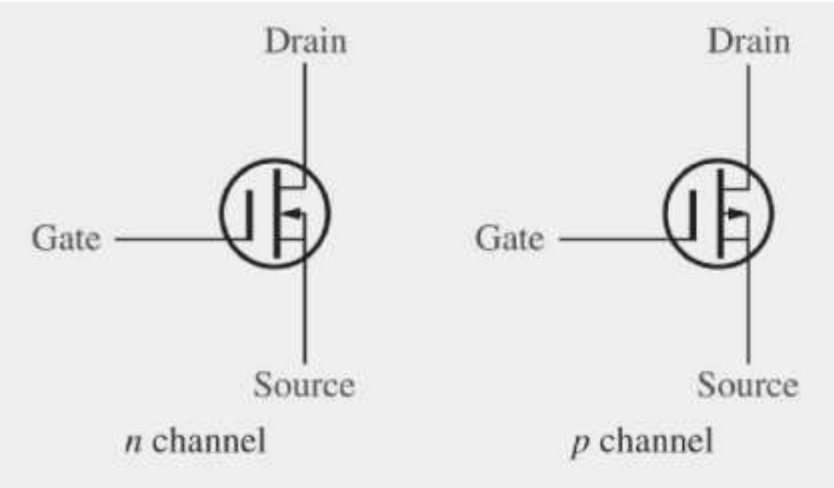


Figure 2.4.1 D-MOSFET symbol for n-channel and p-channel

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 90]

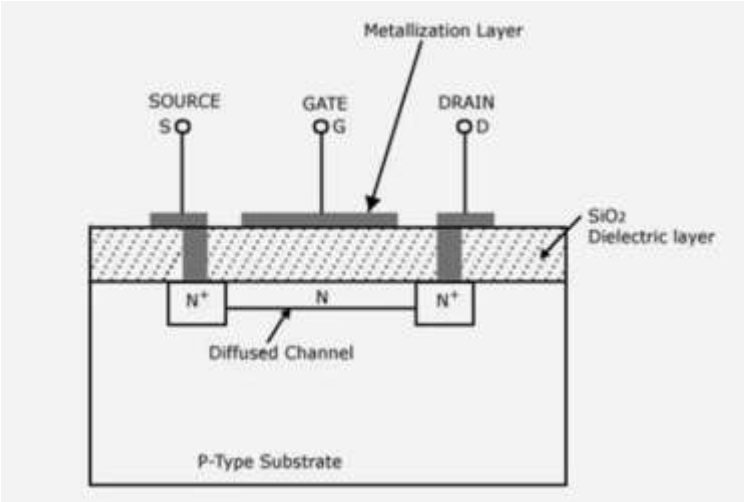


Figure 2.4.2 D-MOSFET n-channel and p-channel

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 90]

- It consists of lightlydiffused. Doped p-type substrate in which two highly doped n-regions are
- The source and drain terminals are connected through metallic contacts to n-doped regions linked by an n-channel. The gate is also connected to a metal contact surface but remains insulated from the n-channel by a very thin silicon dioxide (SiO_2) layer. SiO_2 is a particular type of insulator referred to as a dielectric that sets up opposing (as revealedby the prefix di-) electric fields within the dielectric when exposed to an externally applied field.
- Then the thin layer of metal aluminum is formed over the Sio_2 layer. This metal overs the entire channel region and it forms the gate (G).

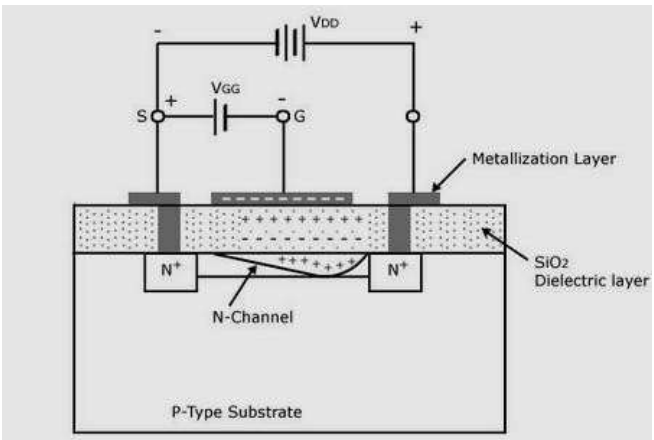


Figure 2.4.3 n-channel D-MOSFET under applied bias

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 91]

Case (i) "when and is increased from zero"

Here N-base (Drain) is connected to positive supply. It act as a reverse bias. Due to this,depletion region gets increases.

Free electron from n-channel are attracted towards positive potential of drain terminal.

This establishes current through channel flows from drain to source and denoted as I_{DSS}.

Pinch of voltage

The pinch off voltage is the voltage at which the junction is depleted of charge carriers.

Case (ii) "when and is increased from zero"

- The negative charge on gate repels conduction electrons from the channel and attract holesfrom the p-type substrate.
- Due to this electron-hole recombination occurs and reduce the number of free electrons inthe channel available for conduction, reducing Drain current (I_D).
- When negative voltage of is increased the pinch of voltage decreased. When is further increased the channel is fully depleted and no current flows through it.
- The negative voltage depletion MOSFET.

Characteristics curve

- Drain characteristics
- Transfer characteristics

D-MOSFET's are biased to operate in two modes:

Depletion or Enhancement mode.

ENHANCEMENT- MODE MOSFET [E-MOSFET]

- In this mode bias on the gate increases the number of charge carriers in the channel and increases the drain current (I_D).

- It operates only in the enhancement mode and has no depletion mode of operation. It has no physical channel

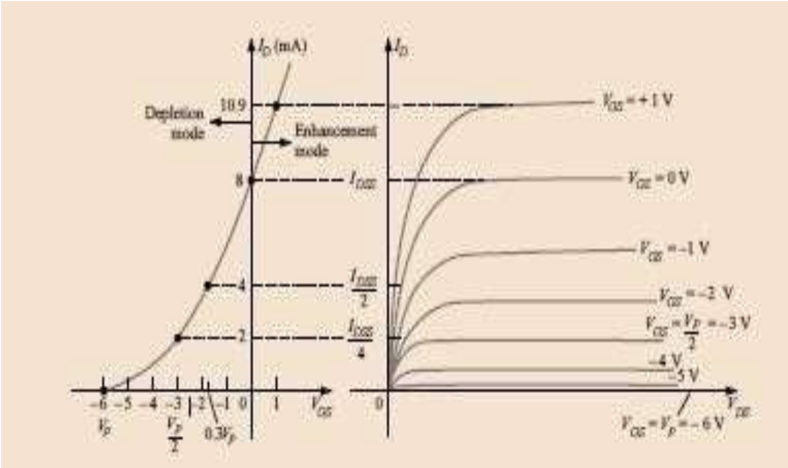


Figure 2.4.4 Drain and transfer characteristics

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 91]

Symbol of E-MOSFET

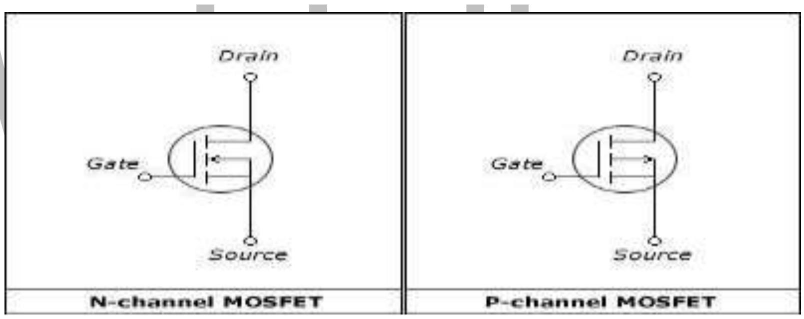


Figure 2.4.5 symbol of n-channel and p-channel E-MOSFET

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 98]

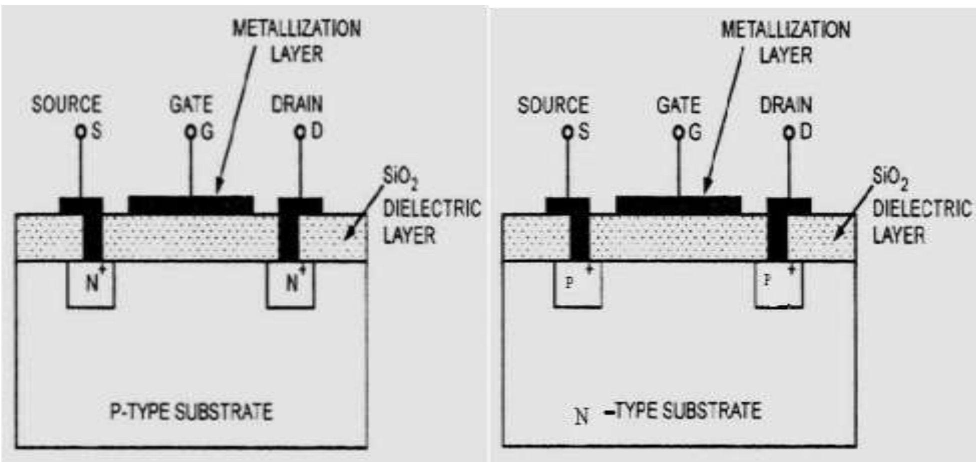


Figure 2.4.6 Construction of n-channel and p-channel E-MOSFET

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 98]

In the basic construction of the n-channel enhancement-type MOSFET, a slab of p-type material is formed from a silicon base and is again referred to as the substrate. As with the depletion-type MOSFET, the substrate is sometimes internally connected to the source terminal, while in other cases a fourth lead is made available for external control of its potential level.

The SiO_2 layer is still present to isolate the gate metallic platform from the region between the drain and source, but now it is simply separated from a . Section of the p-type material.

In summary, therefore, the construction of an enhancement-type MOSFET is quite similar to that of the depletion-type MOSFET, except for the absence of a channel between the drain and source terminals.

Operation

- If V_{GS} is set at 0 V and a voltage applied between the drain and source of the device,the absence of an n-channel (with its generous number of free carriers) will result in a current of effectively zero amperes—quite different from the depletion- type MOSFET and JFET where I_D -I_{DSS}.
- It is not sufficient to saturation level as occurred for the JFET and depletion-typeMOSFET.
- The conductivity of the channel is enhanced by the positive bias voltage on the gate, the device is known as enhancement MOSFET. E-MOSFET's are normally called as –OFF – MOSFET

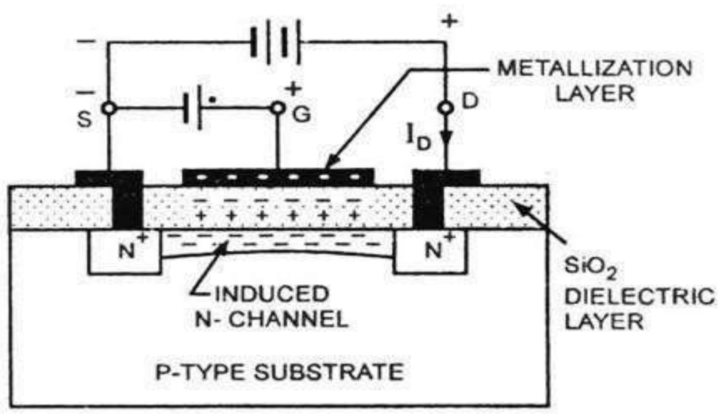
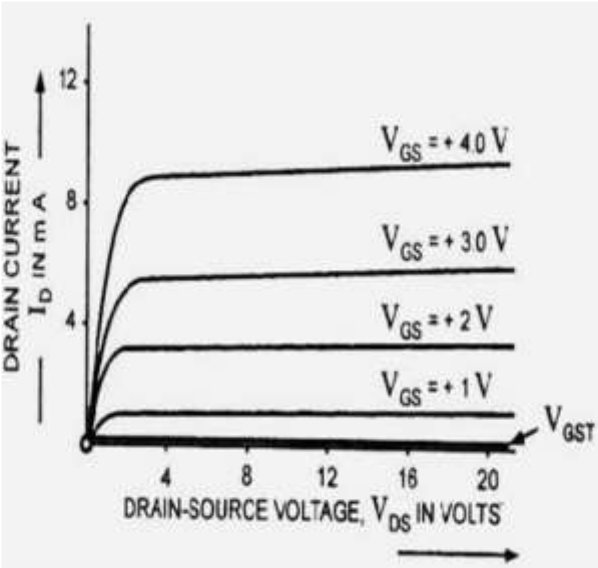


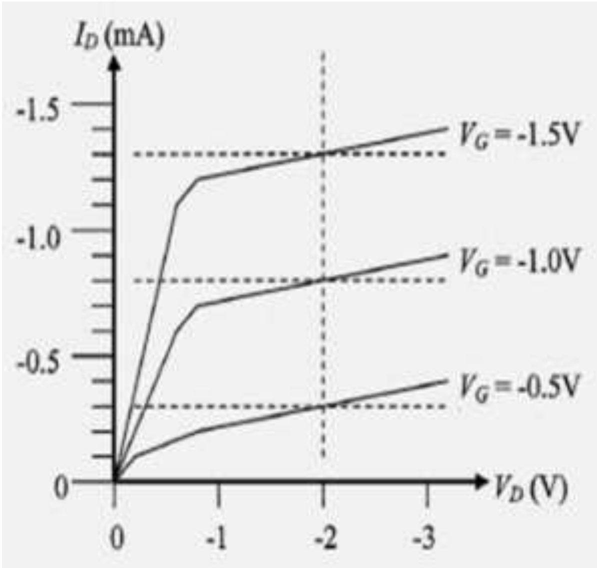
Figure 2.4.7 N-channel E-MOSFET under applied bias

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 99]

Characteristics of E-MOSFET

Drain characteristics curve





a) N-channel b) P-channel

Figure 2.4.8 Drain characteristics curve a) n-channel b) p-channel

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 101]

2.6 SILICON CONTROLLED RECTIFIER (SCR)

The SCR stand for Silicon Control Rectifier, it is used in industries because it can handle high values of current and voltage.

Three terminals

- Anode - P-layer
- Cathode - N-layer (opposite end)
- Gate - P-layer near the cathode

Three junctions - four layers

Connect power such that the anode is positive with respect to the cathode - no current will flow

A silicon controlled rectifier is a semiconductor device that acts as a true electronic switch. It can change alternating current and at the same time can control the amount of power fed to the load. SCR combines the features of a rectifier and a transistor.

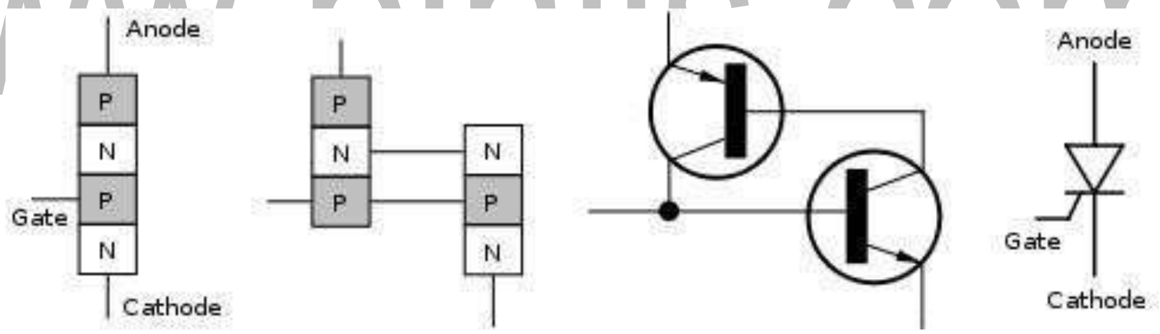


Figure 2.6.1 Basic Structure, equivalent transistor model and symbol of SCR

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 110]

When a p n junction is added to a junction transistor the resulting three p n junction device is called a SCR. ordinary rectifier (p n) and a junction transistor (n p n) combined in one unit to form p n p n device.

Three terminals are taken: one from the outer p- type material called anode a second from the outer n- type material called cathode K and the third from the base of transistor called Gate. GSCR is a solid state equivalent of thyratron. The gate anode and cathode of SCR correspond to the grid plate and cathode of thyratron SCR is called thyristor.

Working Principle

Load is connected in series with anode the anode is always kept at positive potential w.r.t cathode.

SCR Operation / Working

The Silicon Control Rectifier SCR start conduction when it is forward biased. For this purpose the cathode is kept at negative and anode at positive. When positive clock pulse is appliedat the gate the SCR turns ON.

When forward bias voltage is applied to the Silicon Control Rectifier SCR, the junction J1and J3 become forward bias while the junction J2 become reverse bias.

When we apply a clock pulse at the gate terminal, the junction J2 become forward bias and the Silicon Control Rectifier SCR start conduction. The Silicon Control Rectifier SCR turn ON and OFF very quickly, At the OFF state the Silicon Control Rectifier SCR provide infinity resistance and in ON state, it offers very low resistance, which is in the range of 0.01O to 1O.

SCR Firing & Triggering

The Silicon Control Rectifier SCR is normally operated below the forward break over voltage (VBO). To turn ON the Silicon Control Rectifier SCR we apply clock pulse at the gate terminal which called triggering of Silicon Control Rectifier, but when the Silicon Control Rectifier SCR turned ON, now if we remove the triggering voltage, the Silicon Control Rectifier SCR will remain in ON state. This voltage is called Firing voltage

Break over Voltage

It is the minimum forward voltage gate being open at which SCR starts conducting heavily i.e turned on.

Peak Reverse Voltage (PRV)

It is the maximum reverse voltage applied to an SCR without conducting in the reverse direction

Holding Current

It is the maximum anode current gate being open at which SCR is turned off from on conditions.

V-I Characteristics of SCR

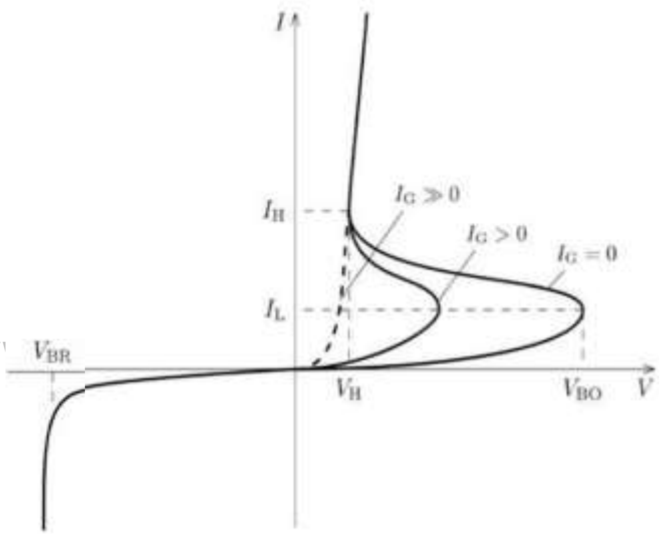


Figure 2.6.2 V-I Characteristics of SCR

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 110]

Forward Characteristics

When anode is +vew.r.t cathode the curve between V &I is called Forward characteristics. OABC is the forward characteristics of the SCR at Ig =0. if the suppliedvoltage is increased from zero point A is reached .SCR starts conducting voltage across SCR suddenly drops (dotted curve AB) most of supply voltage appears across RL

Reverse Characteristics

When anode is –ve w.r.t cathode the curve b/w V&I is known as reverse characteristics reverse voltage come across SCR when it is operated with ac supply reverse voltage is increased anode current remains small avalanche breakdown occurs and SCR starts conducting heavily is known as reverse breakdown voltage.

Application

- ✓ SCR as a switch
- ✓ SCR Half and Full wave rectifier
- ✓ SCR as a static contactor
- ✓ SCR for power control
- ✓ SCR for speed control of d.c. shunt motor
- ✓ Over light detector

2.8 TRIAC

The TRIAC is a three terminal semiconductor device for controlling current. It gains its name from the term diode for Alternating Current.

It is effectively a development of the SCR or thyristor, but unlike the thyristor which is only able to conduct in one direction, the TRIAC is a bidirectional device.

TRIAC symbol

The circuit symbol recognizes the way in which the TRIAC operates. Seen from the outside it may be viewed as two back to back thyristors and this is what the circuit symbol indicates.

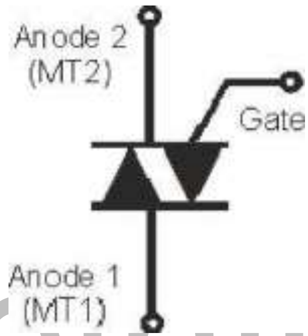


Figure 2.8.1 TRIAC symbol for circuit diagrams

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 115]

On the TRIAC symbol there are three terminals. These are the Gate and two other terminals are often referred to as an "Anode" or "Main Terminal". As the TRIAC has two of these they are labelled either Anode 1 and Anode 2 or Main Terminal, MT1 and MT2.

TRIAC basics

The TRIAC is a component that is effectively based on the thyristor. It provides AC switching for electrical systems. Like the thyristor, the TRIACs are used in many electrical switching applications. They find particular use for circuits in light dimmers, etc., where they enable both halves of the AC cycle to be used.

This makes them more efficient in terms of the usage of the power available. While it is possible to use two thyristors back to back, this is not always cost effective for low cost and relatively low power applications. It is possible to view the operation of a TRIAC in terms of two thyristors placed back to back

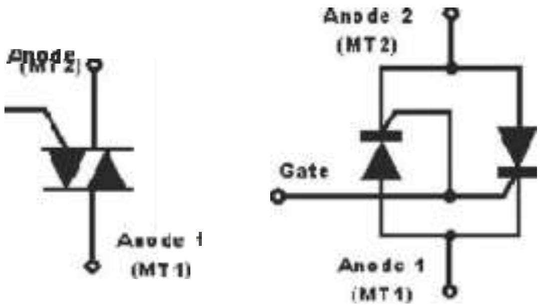


Figure 2.8.2 TRIAC

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 115]

One of the drawbacks of the TRIAC is that it does not switch symmetrically. It will often have an offset, switching at different gate voltages for each half of the cycle. This creates additional harmonics which is not good for EMC performance and also provides an imbalance inthe system

In order to improve the switching of the current waveform and ensure it is more symmetrical is to use a device external to the TRIAC to time the triggering pulse. A DIAC placedin series with the gate is the normal method of achieving this.

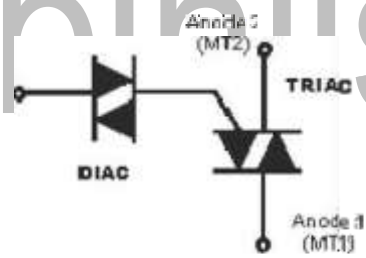


Figure 2.8.3 DIAC and TRIAC connected together

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 116]

With switch S open, there will be no gate current and the triac is cut off. Even with no current the triac can be turned on provided the supply voltage becomes equal to the break over voltage.

When switch S is closed, the gate current starts flowing in the gate circuit. Break over voltage of triac can be varied by making proper current flow. Triac starts to conduct wheather MT2 is positive or negative w.r.t MT1.

Characteristics

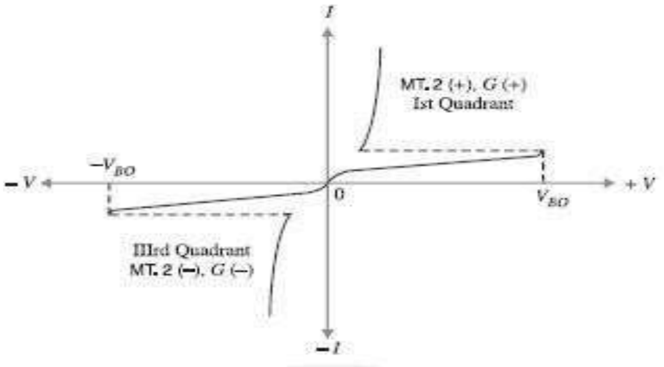


Figure 2.8.4 The V-I Characteristics curve for TRIAC

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 116]

The V-I curve for triac in the Ist and IIIrd quadrants are essentially identical to SCR in the Ist quadrant. The triac can be operated with either positive or negative gate control voltage but in normal operation usually the gate voltage is positive in quadrant I and negative in quadrant III. The supply voltage at which the triac is ON depends upon gate current. The greater gate current and smaller supply voltage at which triac is turned on. This permits to use triac to control a,c. power in a load from zero to full power in a smooth and continuous manner with no loss in the controlling device.

Advantages

- Can switch both halves of an AC waveform
- Single component can be used for full AC switching

Disadvantages

- A TRIAC does not fire symmetrically on both sides of the waveform
- Switching gives rise to high level of harmonics due to non-symmetrical switching
- More susceptible to EMI problems as a result of the non-symmetrical switching
- Care must be taken to ensure the TRIAC turns off fully when used with inductive loads.

Applications

- ✓ Domestic light dimmers
- ✓ Electric fan speed controls
- ✓ Small motor controls
- ✓ Control of small AC powered domestic appliances

2.1 TRANSISTORS

The transistor is the main building block ―element of electronics. It is a semiconductor device and it comes in two general types: the Bipolar Junction Transistor (BJT) and the FieldEffect Transistor (FET).

It is named as transistor which is an acronym of two terms: ‗transfer-of-resistor. It means that the internal resistance of transistor transfers from one value to another values depending on the biasing voltage applied to the transistor. Thus it is called Transfer resistor: i.e. TRANSISTOR.

A bipolar transistor (BJT) is a three terminal semiconductor device in which the operation depends on the interaction of both majority and minority carriers and hence the name bipolar. The voltage between two terminals controls the current through the third terminal. So it is called current controlled device. This is the basic principle of the BJT

It can be used as amplifier and logic switches. BJT consists of three terminals:

- Collector: C
- Base: B
- Emitter: E

➢ **TYPES**

There are two types of bipolar transistors

- NPN transistor
- PNP transistor.

TRANSISTOR CONSTRUCTION

PNP Transistor: In PNP transistor a thin layer of N-type silicon is sandwiched between two layers of P-type silicon. NPN Transistor: In NPN transistor a thin layer of P-type silicon is sandwiched between two layers of N-type silicon. The two types of BJT are represented in figure2.1.1

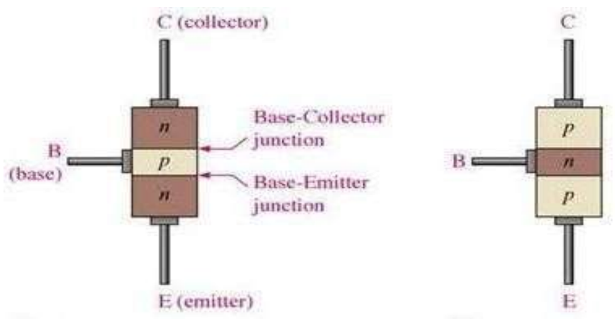


Figure 2.1.1 Transistors: NPN, PNP

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 210]

The symbolic representation of the two types of the BJT is shown in figure 2.1.2

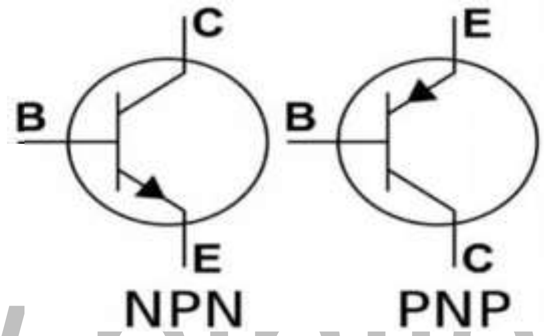


Figure 2.1.2 circuit symbol: NPN transistor, PNP transistor

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 210]

Junctions:

- There are two junctions in this transistor – junction J-1 and junction J-2
- The junction betweenor C-B junction. Collector layer and base layer is called as collector-base junction
- The junction between base layer and emitter layer is called as base-emitter junction or B-E junction. The two junctions have almost same potential barrier voltage of 0.6V to 0.7V, just like in a diode.

Equivalent diode representation:

The transistor formed by back to back connection of two diodes

The states of the two p n junctions can be altered by the external circuitry connected to thetransistor. This is called biasing the transistor. Usually the emitter- base junction is forward biased and collector –base junction is reverse biased. Due to

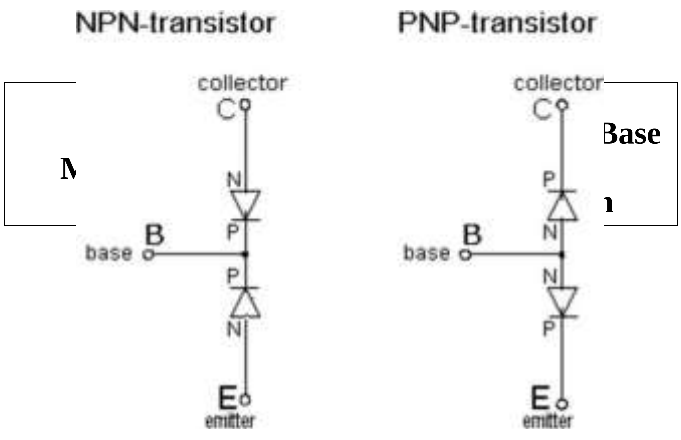


Figure: 2.1.3 NPN-PNP Transistor

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 211]

Forward bias on the emitter- base junction an emitter current flows through the base into the collector. Though, the collector –base junction is reverse biased, almost the entire emitter current flows through the collector circuit.

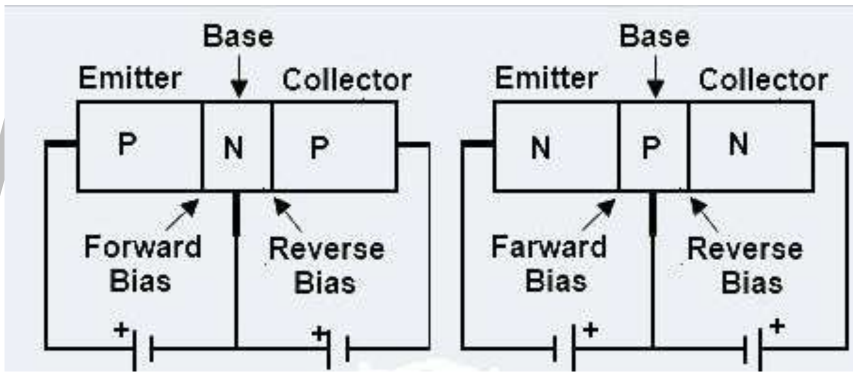


Figure 2.1.4 Transistor biasing: PNP transistor, NPN transistor

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 211]

A single p n junction has two different types of bias:

- Forward bias
- Reverse bias

There are two junctions in bipolar junction transistor. Each junction can be forward or reversebiased independently. Thus there are four modes of operations:

Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward
Reverse active	Reverse	Forward

Table 2.1 Modes of operation of transistor

Forward Active

In this mode of operation, emitter-base junction is forward biased and collector base junction is reverse biased. Transistor behaves as a source. With controlled source characteristics the BJT can be used as an amplifier and in analog circuits.

Cut off

When both junctions are reverse biased it is called cut off mode. In this situation there is nearlyzero current and transistor behaves as an open switch.

Saturation

In saturation mode both junctions are forward biased large collector current flows with a small voltage across collector base junction. Transistor behaves as a closed switch.

Reverse Active

It is opposite to forward active mode because in this emitter base junction is reverse biased and collector base junction is forward biased. It is called inverted mode. It is no suitable for amplification. However the reverse active mode has application in digital circuits and certainanalog switching circuits.

TRANSISTOR CURRENTS

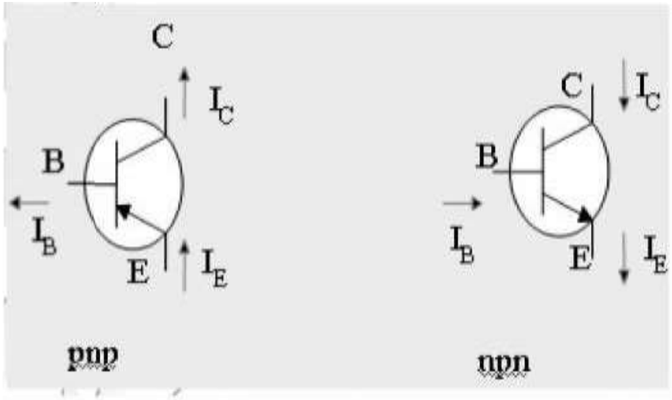


Figure 2.1.5 Transistor current flow directions

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 215]

- The arrow is always drawn on the emitter The arrow always point toward the n-type
- The arrow indicates the direction of the emitter current:
  - PNP: E-> B
  - NPN: B-> E

I_C = the collector current, I_B = the base current, I_E = the emitter current

OPERATION OF AN NPN TRANSISTOR

Emitter base junction is forward biased and collector base junction is reverse biased. Due to emitter base junction is forward biased lot of electrons from emitter entering the base region.

Base is lightly doped with P-type impurity. So the number of holes in the base region is very small.

Due to this, electron- hole recombination is less (i.e,) few electrons (<5%) combine with holesto constitute base current (I_B)

The remaining electrons (>95%) crossover into collector region, to constitute collector current(I_C).

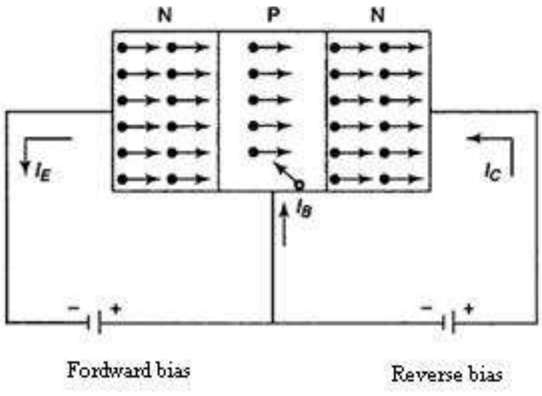


Figure: 2.1.6 Current in NPN transistor

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 216]

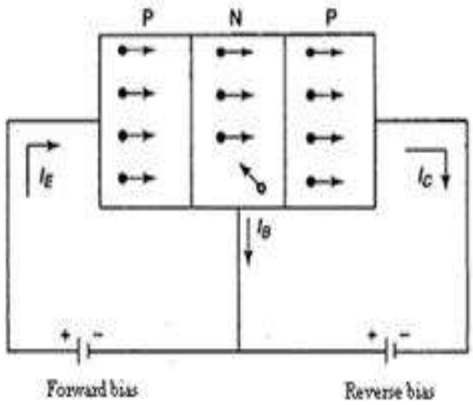


Figure: 2.1.7 Current in PNPtransistor

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 216]

Emitter base junction is forward biased and collector base junction is reverse biased. Due to emitter base junction is forward biased lot of holes from emitter entering the base region and electrons from base to emitter region.

Base is lightly doped with N-type impurity. So the number of electrons in the base regionis very small.

Due to this, electron- hole recombination is less (i.e,) few holes (<5%) combine with electronsto constitute base current (IB)

2.5 UNI JUNCTION TRANSISTOR (UJT)

Unijunction transistor (abbreviated as UJT), also called the double-base diode is a 2-layer, 3-terminal solid-state (silicon) switching device. The device has-a unique characteristic that when it is triggered, its emitter current increases re generatively (due to negative resistance characteristic) until it is restricted by emitter power supply. Since the device has one p n junction and three leads p n junction and three leads

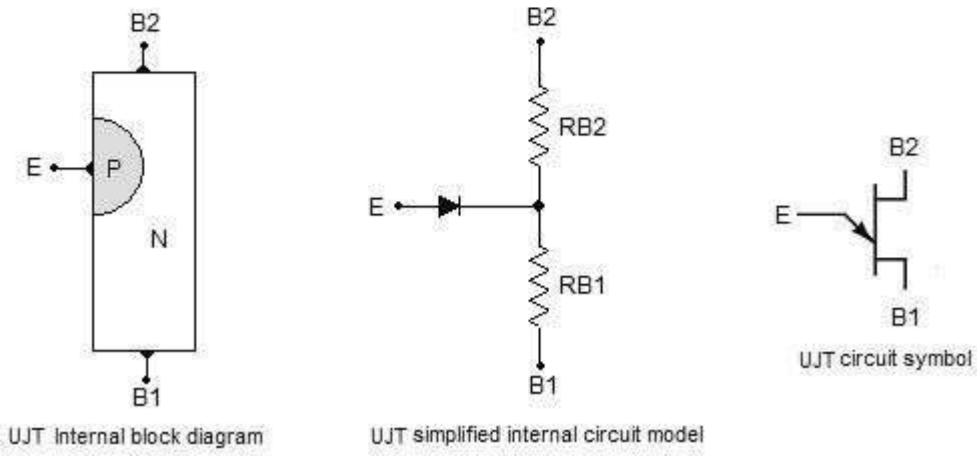


Figure 2.5.1 UJT structure, Equivalent circuit and Symbol

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 105]

Construction of a UJT

The basic structure of a unijunction transistor is shown in figure. It essentially consists of a lightly-doped N-type silicon bar with a small piece of heavily doped P-type material alloyed to its one side to produce single P-N junction. The single P-N junction accounts for the terminology unijunction. The silicon bar, at its ends, has two ohmic contacts designated as base-1 (B1) and base-2 (B2), as shown and the P-type region is termed the emitter (E). The emitter junction is usually located closer to base-2 (B2) than base-1 (B1) so that the device is not symmetrical, because symmetrical unit does not provide optimum electrical characteristics for most of the applications.

The symbol for unijunction transistor is shown in figure. The emitter leg is drawn at anangle to the vertical line representing the N-type material slab and the arrowhead points in the direction of conventional current when the device is forward-biased, active or in the conducting state. The basic arrangement for the UJT is shown in figure. A complementary UJT is formed by diffusing an N-type emitter terminal on a P-type base. Except for the polarities of voltage and current, the characteristics of a complementary UJT are exactly the same as those of a conventional UJT.

- The device has only one junction, so it is called the unijunction device.
- The device, because of one P-N junction, is quite similar to a diode but it differs from an ordinary diode as it has three terminals.
- The structure of a UJT is quite similar to that of an N-channel JFET. The main difference is that P-type (gate) material surrounds the N-type (channel) material in case of JFET and the gate surface of the JFET is much larger than emitter junction of UJT.
- In a unijunction transistor the emitter is heavily doped while the N-region is lightly doped, so the resistance between the base terminals is relatively high, typically 4 to 10 kilo Ohm when the emitter is open.
- The N-type silicon bar has a high resistance and the resistance between emitter and base-1is larger than that between emitter and base-2. It is because emitter is closer to base-2 than base-1.
- UJT is operated with emitter junction forward- biased while the JFET is normally operated with the gate junction reverse-biased.
- UJT does not have ability to amplify but it has the ability to control a large ac power with a small signal. It exhibits a negative resistance characteristic and so it can be employed as an oscillator.

Operation of a UJT

Imagine that the emitter supply voltage is turned down to zero. Then the intrinsic stand-off voltage reverse-biases the emitter diode, as mentioned above. If V_B is the barrier voltage of the emitter diode, then the total reverse bias voltage is $V_A + V_B = \eta V_{BB} + V_B$. For silicon $V_B = 0.7$ V. Now let the emitter supply voltage VE be slowly increased. When VE becomes equal to η VBB, IEo will be reduced to zero. With equal voltage levels on each side of the diode, neither reverse nor forward current will flow

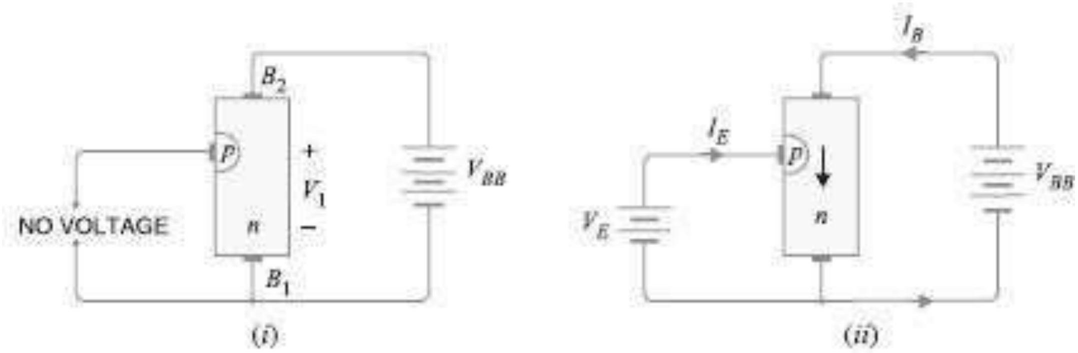


Figure 2.5.2 operation UJT under (i) VE=0 (ii) applied VE

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 105]

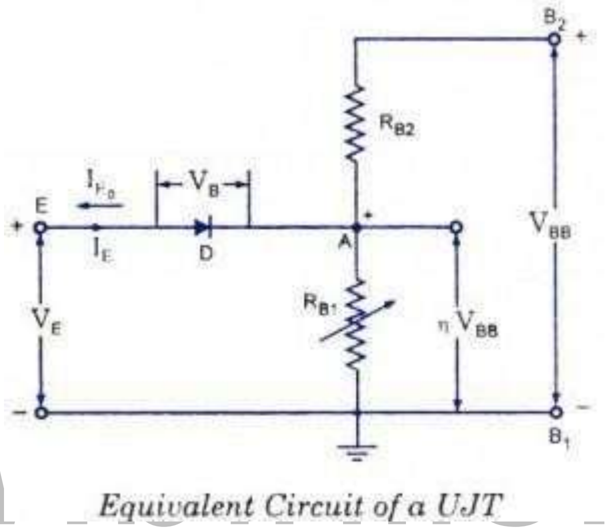


Figure 2.5.3 Equivalent circuit of UJT

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 106]

When emitter supply voltage is further increased, the diode becomes forward-biased as soon as it exceeds the total reverse bias voltage (η V_{BB} + V_B). This value of emitter voltage $V_E$is called the peak-point voltage and is denoted by V_P. When V_E = V_P, emitter current I_E starts to flow through R_{B1} to ground, that is B_1. This is the minimum current that is required to trigger the UJT. This is called the peak-point emitter current and denoted by I_P. Ip is inversely proportional to the inter base voltage, V_{BB}.

Now when the emitter diode starts conducting, charge carriers are injected into the RB region of the bar. Since the resistance of a semiconductor material depends upon doping, the resistance of region RB decreases rapidly due to additional charge carriers (holes). With this decrease in resistance, the voltage drop across RB also decrease, because the emitter diode to be more heavily forward biased. This, in turn, results in larger forward current, and consequently more charge carriers are injected causing still further reduction in the resistance of the RB region. Thus the emitter current goes on increasing until it is limited by the emitter power supply. Since VA decreases with the increase in emitter current, the UJT is said to have negative resistance characteristic. It is seen that the base-2 (B2) is used only for applying external voltage VBB across it. Terminals E and B1 are the active terminals. UJT is usually triggered into conduction by applying a suitable positive pulse to the emitter. It can be turned off by applying a negative trigger pulse.

UJT Characteristics

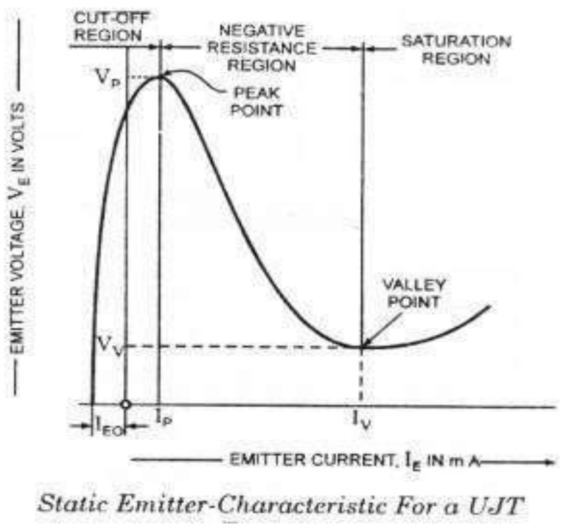


Figure 2.5.4 Static Emitter Characteristic for a UJT

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 106]

The static emitter characteristic (a curve showing the relation between emitter voltage V_E and emitter current I_E) of a UJT at a given inter base voltage V_{BB} is shown in figure. From figure it is noted that for emitter potentials to the left of peak point, emitter current I_E never exceeds I_{Eo}. The current I_{Eo} corresponds very closely to the reverse leakage current I_{Co} of the conventional BJT. This region, as shown in the figure, is called the cut-off region. Once conduction is established at $V_E = V_P$ the emitter potential V_E starts decreasing with the increase in emitter current I_E. This Corresponds exactly with the decrease in resistance R_B for increasing current I_E. This device, therefore, has a negative resistance region which is stable enough to be used with a great deal of reliability in the areas of applications listed earlier. Eventually, the valley point reaches, and any further increase in emitter current I_E places the device in the saturation region, as shown in the figure 2.5.4.

Three other important parameters for the UJT are I_P, V_V and I_V and are defined below:
Peak-Point Emitter Current Ip: It is the emitter current at the peak point. It represents the minimum current that is required to trigger the device (UJT). It is inversely proportional to the inter base voltage V_{BB}.

Valley Point Voltage V: The valley point voltage is the emitter voltage at the valley point. The valley voltage increases with the increase in inter base voltage V_{BB}.
Valley Point Current I_V: The valley point current is the emitter current at the valley point. It increases with the increase in inter-base voltage V_{BB}.

Special Features of UJT.

The special features of a UJT are:

1. A stable triggering voltage (V_P) — a fixed fraction of applied interbase voltage V_{BB}.
2. A very low value of triggering current.
3. A high pulse current capability.
4. A negative resistance characteristic.
5. Low cost.

Applications of UJT.

- ✓ Relaxation oscillators.
- ✓ Switching Thyristors like SCR, TRIAC etc.
- ✓ Magnetic flux sensors.
- ✓ Voltage or current limiting circuit.
- ✓ Bistable oscillators.
- ✓ Voltage or current regulators.
- ✓ Phase control circuits.