BIPOLAR JUNCTION TRANSISTOR

Introduction:

Power transistors like BJT are controlled devices. In other words, their turn-on & turn-off characteristics are under control. These are turned on when a current signal is given to the base, or control terminal. The transistor remains in the on-state as long as control signal is present. When this control s/g is removed, a power transistor is turned off.

Power transistors are of three types

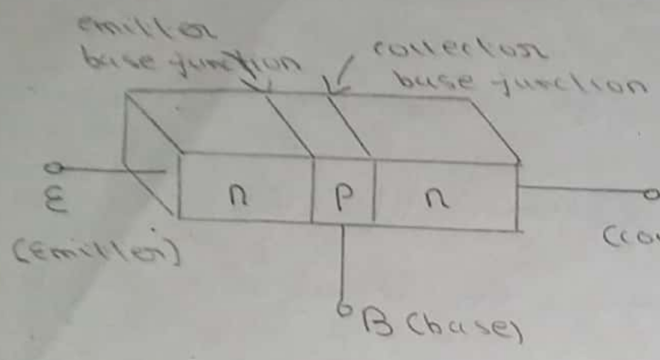
i) BJT (Bipolar Junction Transistor)

ii) MOSFET (Metal oxide Semiconductor field effect transistor)

(iii) IGBT (Insulated Gate Bipolar transistor)

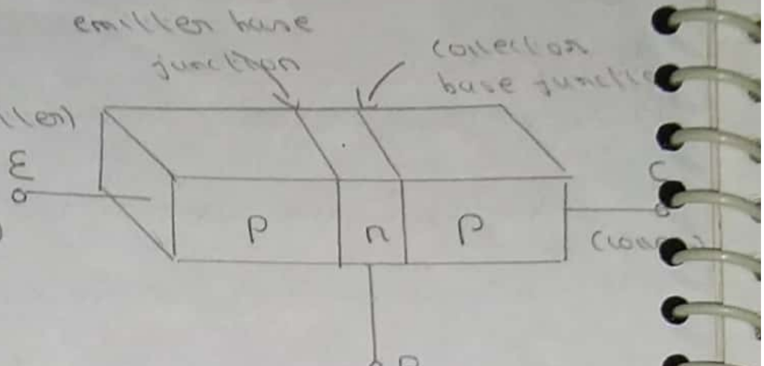
Construction :

A BJT is a three layer two junction npn or pnp semiconductor device. The term 'bipolar' denotes that the current flow in the device is due to the movement of both holes & electrons.



npn transistor

fig (i)



B

(base)

Pnp transistor

fig (ii)

A BJT has three terminals named emitter, collector and base. An emitter is indicated by an arrowhead indicating the direction of emitter current.

BJT can be either a pnp transistor or a npn transistor depending upon the configuration of p & n semiconductor devices.

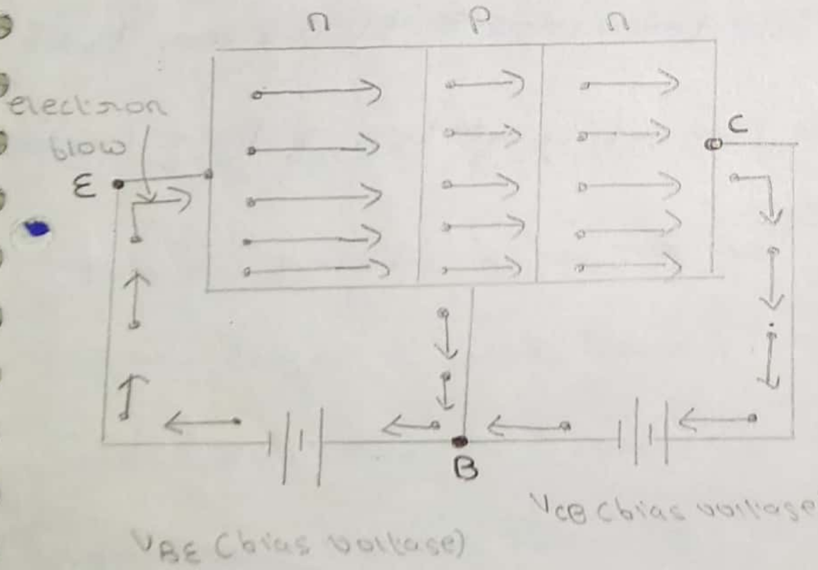
<u>npn transistor:</u> A npn transistor is composed of two n-type semiconductors separated by a thin section of p-type as shown in fig (i).

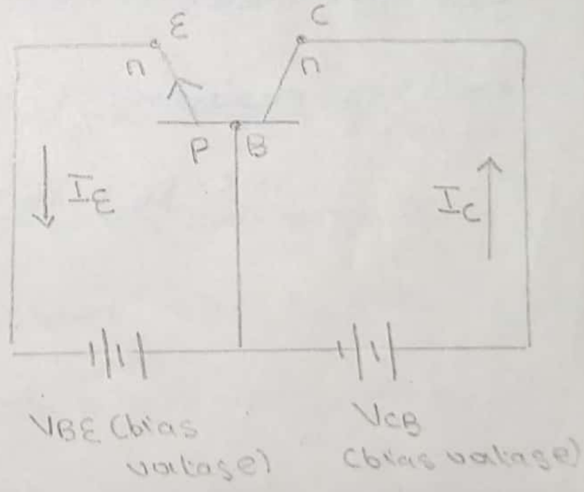
<u>pnp transistor:</u> A pnp transistor is formed by two p-sections separated by a thin section of n-type as shown in fig (ii)

Principle of operation of npn transistor:

The basic principle of transistor operation is that a small current in the base region can control a much larger current through the transistor., i.e., from the emitter to the collector.

For a transistor to work, it has to be biased by applying external voltage supply voltage with proper polarity. For operation in the active region, a transistor's emitter base junction must be forward biased while the collector base region reverse biased as shown in the fig.





operation of npn transistor & Biasing of npn transistor

The forward bias causes the electrons in the n-type emitter to flow towards the base. This constitutes the emitter current I_E. As these electrons flow through the p-type base, they tend to combine with ~~base~~ holes. As the base is lightly doped and very thin, therefore only a few electrons (less than 5%) combine with holes to constitute base current I_B. ~~The remainder (more than~~ 95%) ~~combine with holes to constitute base current I_B~~ The remainder (more than 95%) cross over into the collector region to constitute collector current I_C. In this way, almost the entire emitter current flows in the collector circuit. It is clear that emitter current is the sum of collector & base current

i.e. $I_E = I_B + I_C$.

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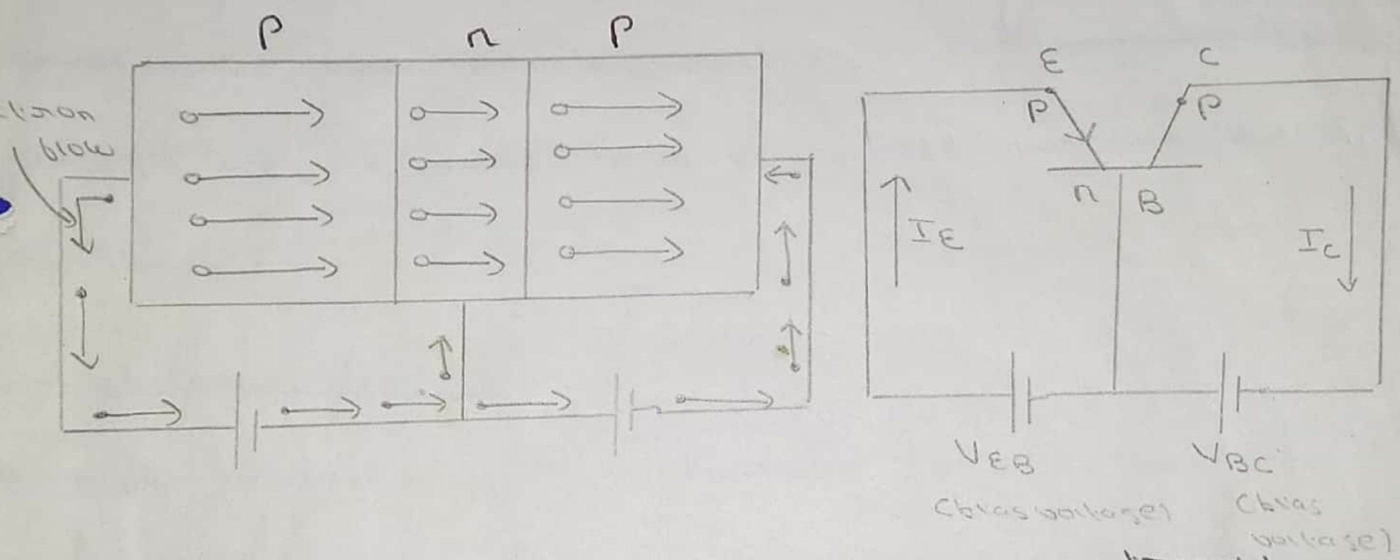
Principle of operation of pnp transistor:

Fig shows the basic connection of pnp transistor. The forward bias causes the holes in the p-type emitter to flow towards the base. This constitutes the emitter current I_E.



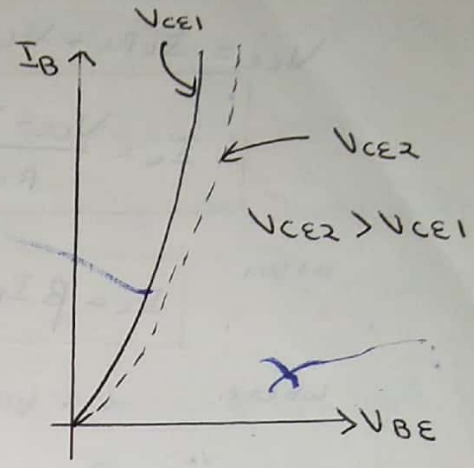
operation & basic connection of pnp transistor

As these holes cross into the n-type base, they tend to combine with the electrons. As the base is lightly doped & very thin, therefore, only a few holes (less than 5%) combine with electrons. The remainder (more than 95%) cross into the collector region to constitute collector current I_C. In this way almost the entire emitter current flows in the collector circuit.

It may be noted that current conduction within pnp transistor is by holes. However, in the external connecting wires, the current conduction is still by electrons.

Input characteristics:

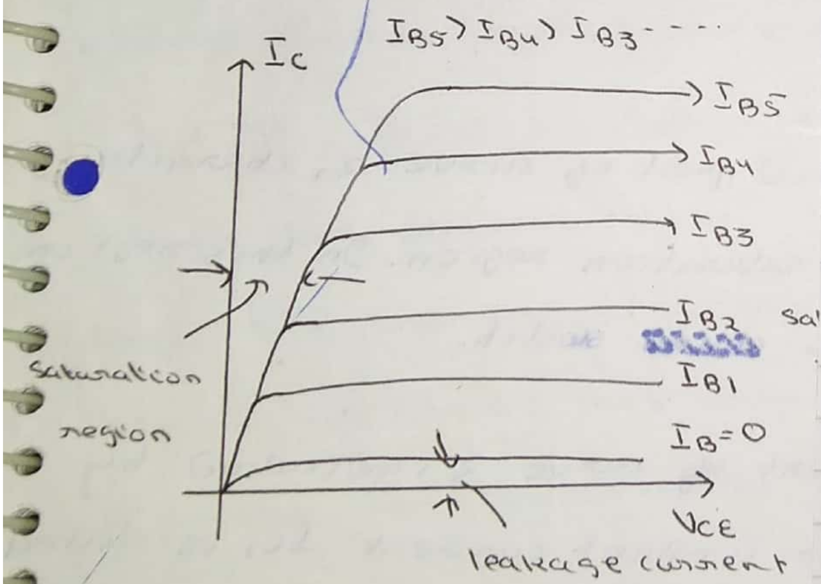
A graph between the base current I_B and base-emitter voltage V_{BE} gives i/p characteristics.



As the base-emitter junction of a transistor is like a diode, I_B versus V_{BE} graph resembles a diode ~~graph~~ curve. When collector-emitter voltage V_{CE2} is more than V_{CE1}, base current decreases as shown

Output characteristics:

A graph between collector current I_C and collector emitter voltage V_{CE} gives the output characteristics.



Output characteristics

(a)

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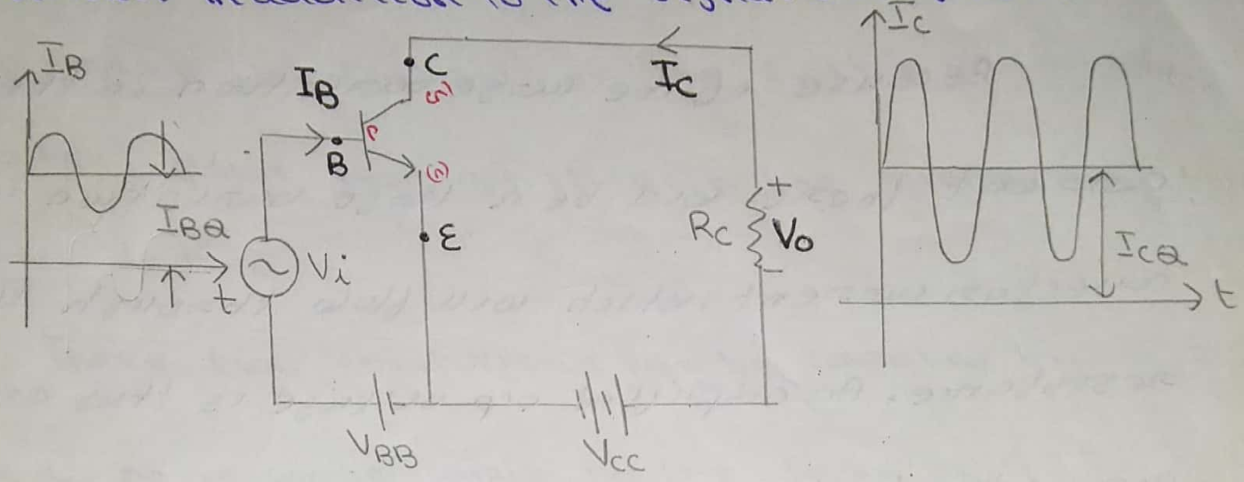
BJT as a CE Amplifier

Fig shows the common emitter npn amplifier circuit. Note that the battery V_{BB} is connected in the input circuit in addition to the signal voltage (V_i).



This dc voltage (V_{BB}) is known as bias voltage and its magnitude is such that it always keeps the emitter-base junction forward biased regardless of the polarity of the signal source (V_i).

Operation: During the positive half cycle of the signal, the forward bias across the emitter-base junction is increased. Therefore, more electrons flow from the emitter to the collector via the base. This causes an increase in collector current. The increased collector current produces a greater voltage drop across the collector load resistance R_c

However, during the negative half-cycle of the signal, the forward bias across the emitter base junction is decreased. Therefore, collector current decreases. This results in the decreased o/p voltage (in the opp direction).

Because of the large variation in the base current there will be a large variation in the collector current, which will flow through the load resistance. An amplified o/p voltage is thus available across the load.

BJT as a switch:

A BJT can be used as an amplifier as well as as a switch.

A switch either closes a circuit or opens a circuit.

There are two states for a switch i.e., either there is no current flow (cut-off) or the switch is closed, i.e., current flows through it with the minimum of resistance offered.

These two conditions can be created by applying a pulse wave input to the base of BJT.

In the case of amplifier we had applied a bias voltage plus an ac signal that had to be amplified to the base circuit. In the case of switching operation, a pulse voltage of appropriate level has to be applied as shown in fig (a) & fig (b).

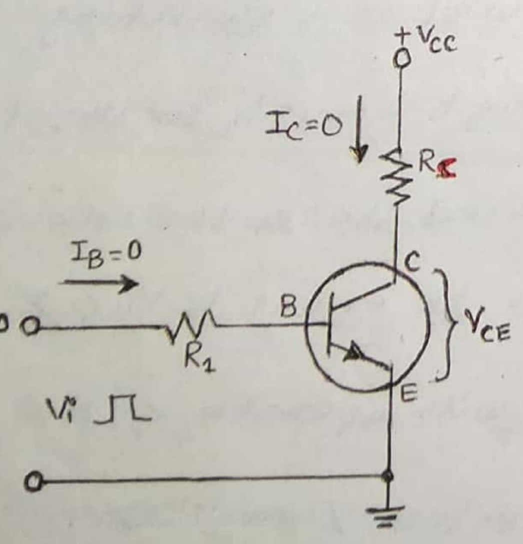


Fig (a)

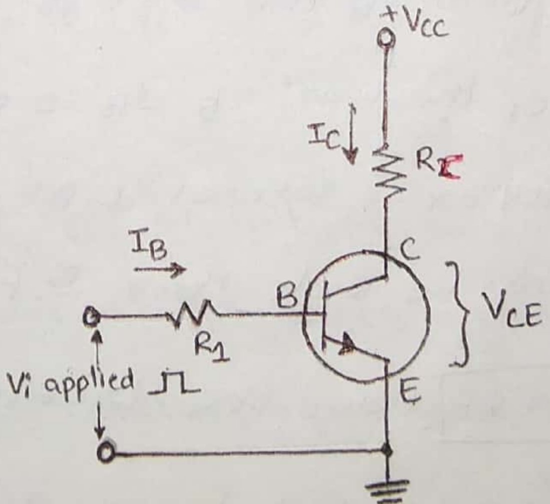


Fig (b)

-> The base voltage level is either at zero level or at an appropriate positive level. When the i/p voltage V_i is at zero level, the base current is zero and there is no collective current, i.e. $I_C = 0$ as shown in fig. (a).

In this condition, the BJT is cut-off and works like an open switch.

From fig (a),

V_{CE} = Supply voltage - voltage drop across R_C

or $V_{CE} = V_{CC} - I_C R_C$

$\because I_C = 0 \quad \boxed{\therefore V_{CE} = V_{CC}}$

i.e. switch in off state

-> When V_i is at positive level, base current I_B will flow. If the BJT is to be used as a switching device, the level of I_B is made high enough so that the transistor is saturated. At saturated state, the level of I_C will be such that $I_C R_C$ will be equal to V_{CC} & $\boxed{V_{CE} = 0.}$ Now, the transistor will operate as a closed switch between the collector & emitter.

Junction Field Effect Transistor (JFET)

- FET
  - JFET
    - N-channel
    - P-channel
  - MOSFET
    - Depletion type
      - n-channel
      - P-channel
    - Enhancement type
      - n-channel
      - P-channel

A JFET is a three terminal semiconductor device in which current conduction is by one type of carrier i.e., electrons or holes.

In a JFET, the current conduction is either by electrons or holes and is controlled by means of an electric field between the gate electrode and the conducting channel of the device. In JFET, conduction path is along the depletion layer and not across as in BJT.

Construction:

A JFET ~~is a~~ consists of a p-type or n-type silicon bar containing two pn junctions at the sides as shown in the fig. The bar forms the conducting channel for the charge carriers.

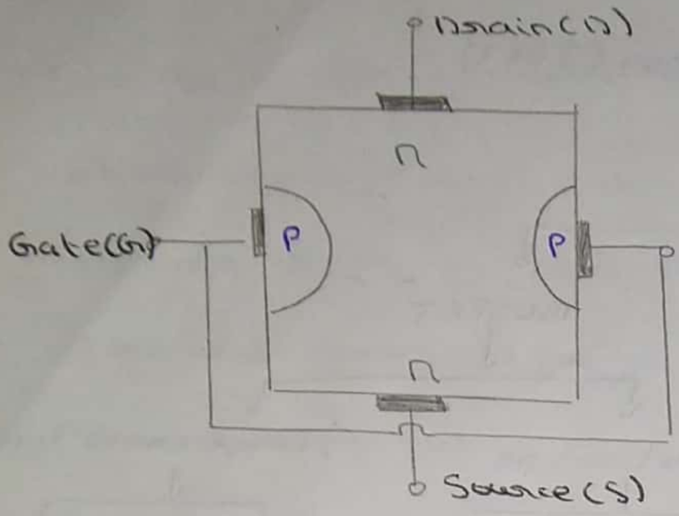


fig (a): n-channel JFET

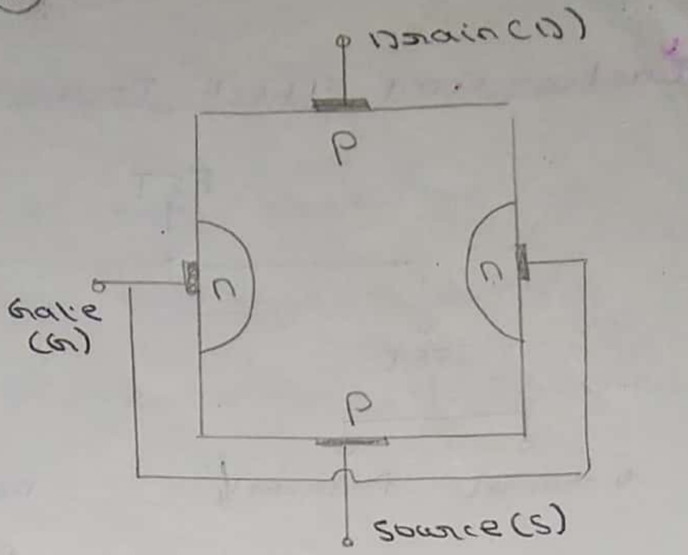
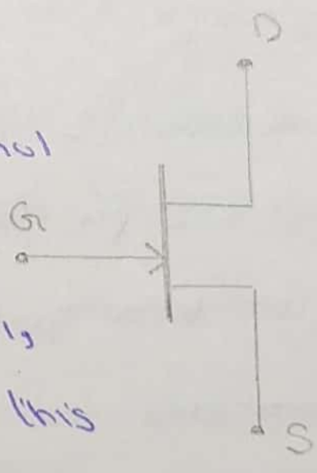


fig (b): p-channel JFET

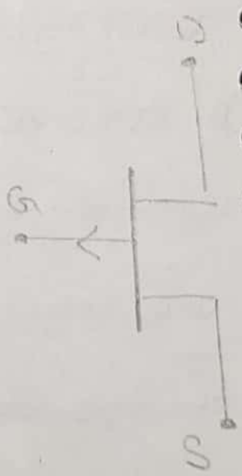
If the bar is of n-type, it is called n-channel JFET as shown in fig (a) and if the bar is of p-type, it is called p-channel JFET, as shown in fig (b). The two pn junctions forming diodes are connected internally and a common terminal called gate is taken out. Other terminals are source & drain taken out from the bar as shown in fig. Thus a JFET has essentially three terminals, drain, source & gate

Circuit symbol of JFET

The fig shows the schematic symbol of JFET. The vertical line in the symbol may be thought as a channel, and source & drain connected to this channel.



n-chanel JFET



p-channel JFET

Principle of operation

Let us consider an N-channel JFET as shown in fig.

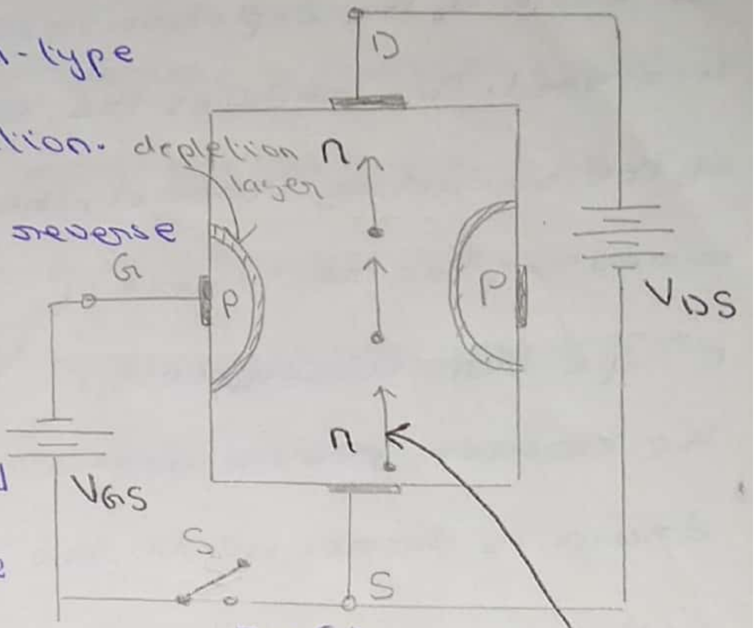


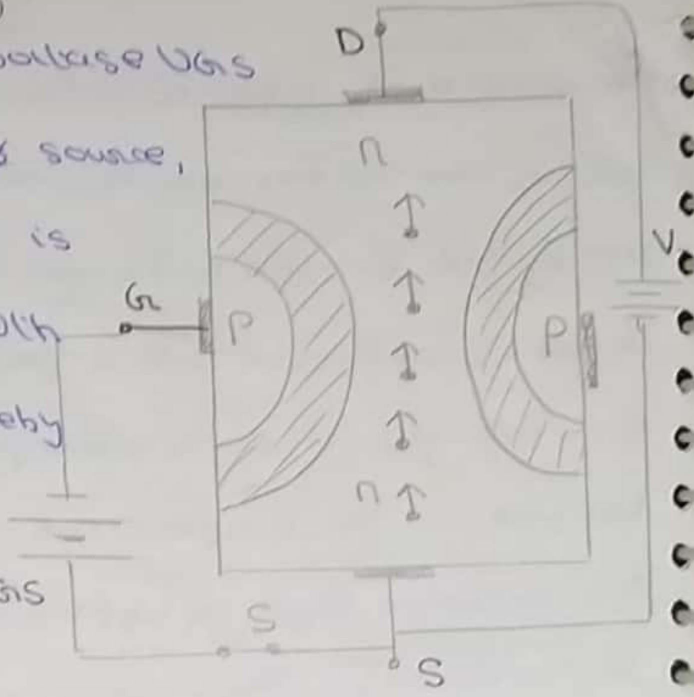
Fig (a)

electron conducti

Here, the P-type gate and N-type channel constitute a PN junction. This PN junction is always reverse biased in JFET operation. The reverse bias is applied by a voltage V_{GS} connected between the gate & source terminal. It can be noted that the positive terminal of the voltage V_{GS} is connected to source(S) and negative terminal to gate (G).

Now, when a voltage V_{DS} is applied between drain & source terminals and voltage on the gate is zero(switch S open)↑, the two pn junctions at the sides of the bar establish depletion layers. The electrons will flow from source to drain through the channel between the depletion layers. The size of this layers determines the width of the channel and hence the current conduction through the bar.

as shown in Fig (a)



Now, when the reverse voltage V_{GS} is applied between the gate & source, the width of the depletion layer is increased. This reduces the width of the conducting channel, thereby increasing the resistance of n type bar. Consequently, the current from source to drain is decreased. On the other hand, if the reverse voltage on the gate is decreased, the width of the depletion layer also ~~increases~~ decreases. This increases the width of the conducting channel and hence source to drain current.

It is clear from the above discussion that current from source to drain can be controlled by the application of potential (i.e. electric field) on the gate. For this reason, the device is called junction field effect transistor.

Difference between JFET & BJT

JFET differs from BJT in the following ways

i) In a JFET, there is only one type of carrier, holes in the p-type channel & electrons in the n-type channel. For this reason, it is called a unipolar transistor. However BJT is a bipolar transistor as both holes & electrons take part in current conduction

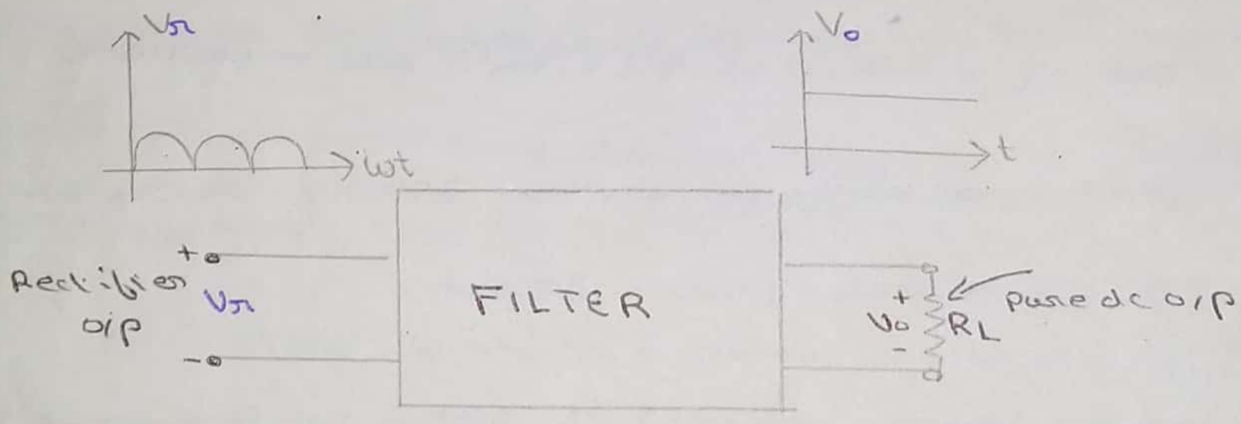
ii) The i/p circuit of JFET has high impedance whereas the i/p circuit of BJT has low impedance

(iii) JFET is a voltage driven device whereas BJT is a current driven device

iv) Noise level in JFET is small as compared to BJT b/oz of junctions in BJT.

Introduction to passive filters

Generally, a rectifier is required to produce pure d.c. supply for using at various places in the electronic circuits. However, the output of a rectifier has pulsating character i.e., it contains a.c. and d.c. components. The a.c. component is undesirable and must be kept away from the load. To do so, a filter circuit is used which removes (or filters out) the ac component and allows only the d.c. component to reach the load.



Filter circuit

A filter is a device which removes the a.c. component of rectifier output but allows the d.c component to reach the load.