ing managers to believe that this device will soon become the most important electronic device, primarily because of its integrated-circuit applications. In this chapter, we shall focus our attention on the construction, working and circuit applications of field effect transistors.

19.1 Types of Field Effect Transistors

A bipolar junction transistor (*BJT*) is a current controlled device *i.e.*, output characteristics of the device are controlled by base current and not by base voltage. However, in a field effect transistor (*FET*), the output characteristics are controlled by input voltage (*i.e.*, electric field) and not by input current. This is probably the biggest difference between *BJT* and *FET*. There are two basic types of field effect transistors:

(*i*) Junction field effect transistor (*JFET*)

(*ii*) Metal oxide semiconductor field effect transistor (*MOSFET*)

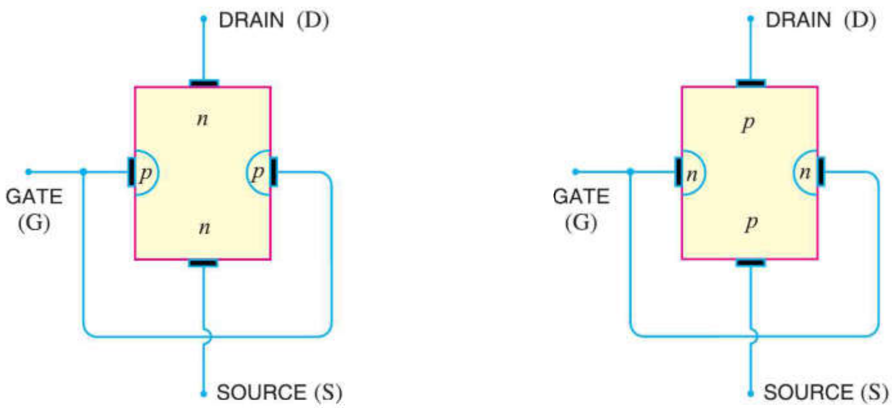
To begin with, we shall study about *JFET* and then improved form of *JFET*, namely; *MOSFET*.

19.2 Junction Field Effect Transistor (JFET)

A **junction field effect transistor** *is a three terminal semiconductor device in which current conduction is by one type of carrier i.e., electrons or holes.*

The *JFET* was developed about the same time as the transistor but it came into general use only in the late 1960s. 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. The *JFET* has high input impedance and low noise level.

Constructional details. A *JFET* consists of a *p*-type or *n*-type silicon bar containing two *pn* junctions at the sides as shown in Fig.19.1. The bar forms the conducting channel for the charge carriers. If the bar is of *n*-type, it is called *n-channel JFET* as shown in Fig. 19.1 (*i*) and if the bar is of *p*-type, it is called a *p-channel JFET* as shown in Fig. 19.1 (*ii*). The two *pn* junctions forming diodes are connected *internally and a common terminal called *gate* is taken out. Other terminals are *source* and *drain* taken out from the bar as shown. Thus a *JFET* has essentially three terminals *viz.*, *gate* (*G*), *source* (*S*) and *drain* (*D*).



n-Channel JFET (*i*)   *p-Channel JFET* (*ii*)

Fig. 19.1

* It would seem from Fig. 19.1 that there are three doped material regions. However, this is not the case. The gate material *surrounds* the channel in the same manner as a belt surrounding your waist.

JFET polarities. Fig. 19.2 (*i*) shows *n*-channel *JFET* polarities whereas Fig. 19.2 (*ii*) shows the *p*-channel *JFET* polarities. Note that in each case, the voltage between the gate and source is such that the gate is reverse biased. This is the normal way of *JFET* connection. The drain and source terminals are interchangeable *i.e.*, either end can be used as source and the other end as drain.

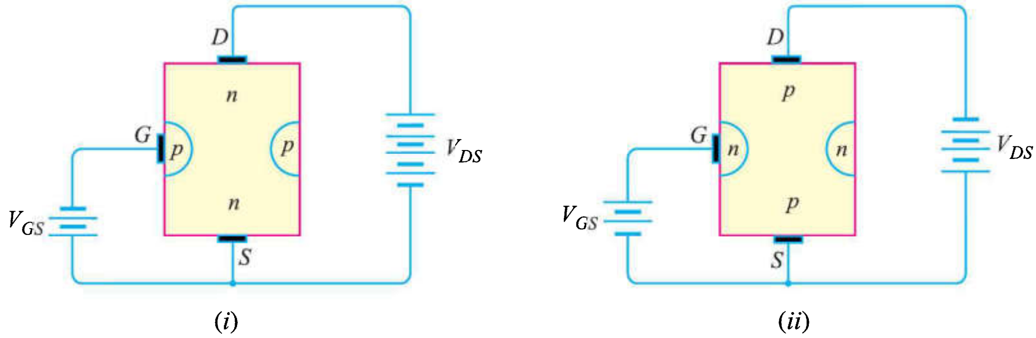


Fig. 19.2

The following points may be noted :

(*i*) The input circuit (*i.e.* gate to source) of a *JFET* is reverse biased. This means that the device has high input impedance.

(*ii*) The drain is so biased w.r.t. source that drain current I_D flows from the source to drain.

(*iii*) In all *JFETs*, source current I_S is equal to the drain current *i.e.* $I_S = I_D$.

19.3 Principle and Working of JFET

Fig. 19.3 shows the circuit of *n*-channel *JFET* with normal polarities. Note that the gate is reverse biased.

Principle. The two *pn* junctions at the sides form two depletion layers. The current conduction by charge carriers (*i.e.* free electrons in this case) is through the channel between the two depletion layers and out of the drain. The width and hence *resistance of this channel can be controlled by changing the input voltage V_{GS}. The greater the reverse voltage V_{GS}, the wider will be the depletion layers and narrower will be the conducting channel. The narrower channel means greater resistance and hence source to drain current decreases. Reverse will happen should V_{GS} decrease. *Thus JFET operates on the principle that width and hence resistance of the conducting channel can be varied by changing the reverse voltage* V_{GS}. In other words, the magnitude of drain current (I_D) can be changed by altering V_{GS}.

Working. The working of *JFET* is as under :

(*i*) When a voltage V_{DS} is applied between drain and source terminals and voltage on the gate is zero [See Fig. 19.3 (*i*)], the two *pn* junctions at the sides of the bar establish depletion layers. The electrons will flow from source to drain through a channel between the depletion layers. The size of these layers determines the width of the channel and hence the current conduction through the bar.

(*ii*) When a reverse voltage V_{GS} is applied between the gate and source [See Fig. 19.3 (*ii*)], the width of the depletion layers is increased. This reduces the width of 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 layers also decreases. This increases the width of the conducting channel and hence source to drain current.

* The resistance of the channel depends upon its area of X-section. The greater the X-sectional area of this channel, the lower will be its resistance and the greater will be the current flow through it.

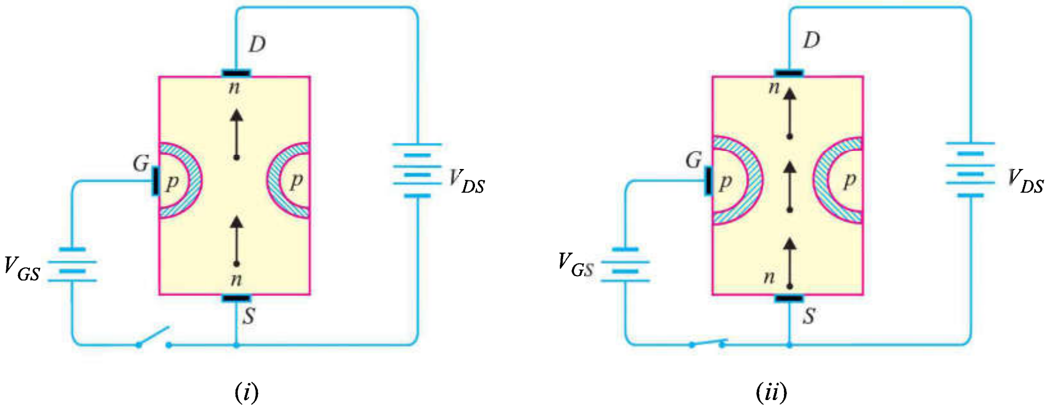
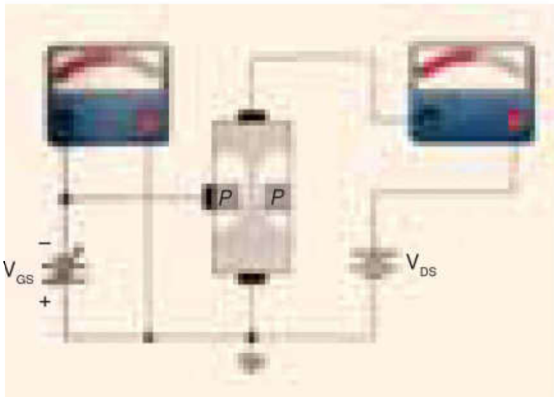


Fig. 19.3

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 *field effect transistor*. It may be noted that a *p*-channel *JFET* operates in the same manner as an *n* -channel *JFET* except that channel current carriers will be the holes instead of electrons and the polarities of V_{GS} and V_{DS} are reversed.

Note. If the reverse voltage V_{GS} on the gate is continuously increased, a state is reached when the two depletion layers touch each other and the channel is cut off. Under such conditions, the channel becomes a non-conductor.



JFET biased for Conduction

19.4 Schematic Symbol of JFET

Fig. 19.4 shows the schematic symbol of *JFET*. The vertical line in the symbol may be thought

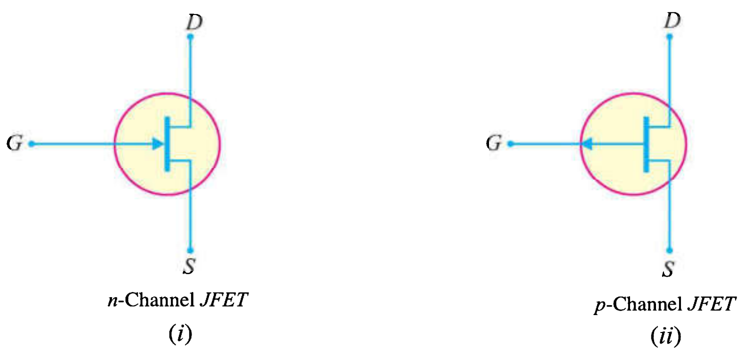
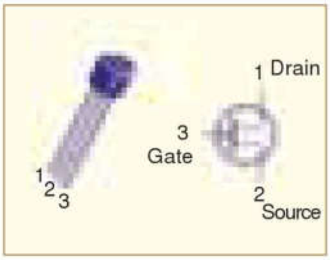


Fig. 19.4

as channel and source (S) and drain (D) connected to this line. If the channel is n-type, the arrow on the gate points towards the channel as shown in Fig. 19.4 (*i*). However, for p-type channel, the arrow on the gate points from channel to gate [See Fig. 19.4 (*ii*)].



19.5 Importance of JFET

A *JFET* acts like a voltage controlled device *i.e.* input voltage (V_{GS}) controls the output current. This is different from ordinary transistor (or bipolar transistor) where input current controls the output current. Thus *JFET* is a semiconductor device acting *like a vacuum tube. The need for *JFET* arose because as modern electronic equipment became increasingly transistorised, it became apparent that there were many functions in which bipolar transistors were unable to replace vacuum tubes. Owing to their extremely high input impedance, *JFET* devices are more like vacuum tubes than are the bipolar transistors and hence are able to take over many vacuum-tube functions. Thus, because of *JFET*, electronic equipment is closer today to being completely solid state.

The *JFET* devices have not only taken over the functions of vacuum tubes but they now also threaten to depose the bipolar transistors as the most widely used semiconductor devices. As an amplifier, the *JFET* has higher input impedance than that of a conventional transistor, generates less noise and has greater resistance to nuclear radiations.

19.6 Difference Between JFET and Bipolar Transistor

The *JFET* differs from an ordinary or bipolar transistor in the following ways :

(*i*) In a *JFET*, there is only one type of carrier, holes in p-type channel and electrons in n-type channel. For this reason, it is also called a *unipolar transistor*. However, in an ordinary transistor, both holes and electrons play part in conduction. Therefore, an ordinary transistor is sometimes called a *bipolar transistor*.

(*ii*) As the input circuit (*i.e.*, gate to source) of a *JFET* is reverse biased, therefore, the device has high input impedance. However, the input circuit of an ordinary transistor is forward biased and hence has low input impedance.

(*iii*) The primary functional difference between the *JFET* and the *BJT* is that no current (actually, a very, very small current) enters the gate of *JFET* (*i.e.* $I_G = 0$A). However, typical *BJT* base current might be a few μA while *JFET* gate current a thousand times smaller [See Fig. 19.5].

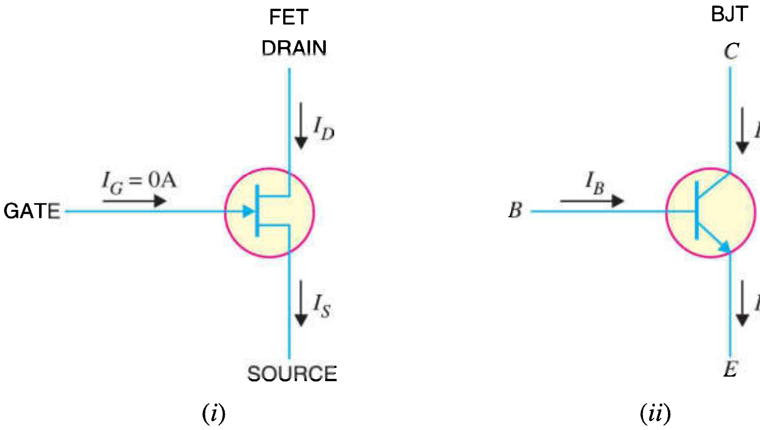


Fig. 19.5

* The gate, source and drain of a *JFET* correspond to grid, cathode and anode of a vacuum tube.