VOLUME-16 Part B and C

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VI. Electronics

VI.1.3. Field effect devices

INTRODUCTION

In the type of transistor, both holes and electrons play part in the conduction process. For this reason, it is sometimes called a bipolar transistor. The ordinary or bipolar transistor has two principle disadvantages. First, it has a low input impedance because of forward biased emitter junction. Secondly, it has considerable noise level. Although low input impedance problem may be improved by careful design and use of more than one transistor, yet it is difficult to achieve input impedance more than a few megaohms. The field effect transistor (FET) has, by virtue of its construction and biasing, large input impedance which may be more than 100 megaohms. The FET is generally much less noisy than the ordinary or bipolar transistor. The rapidly expanding FET market has led many semiconductor marketing 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 being with, we shall study about JFET and then improved from 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 JEFT 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 JFET has high input impedance and low noise level.

Constructional details. A JFET consists of p-type or n-type silicon bar containing two pn junction at the sides as shown in Fig. 19.1. The bar forms the conducting channel for the charge carrier. If the bar is of n-type, it is called n-channel JFET as shown in Fig. 19.1 (ii). The two pn junctions forming codes 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 JEFT has essentially three terminals viz., gate (G) source (S) and drain (D).

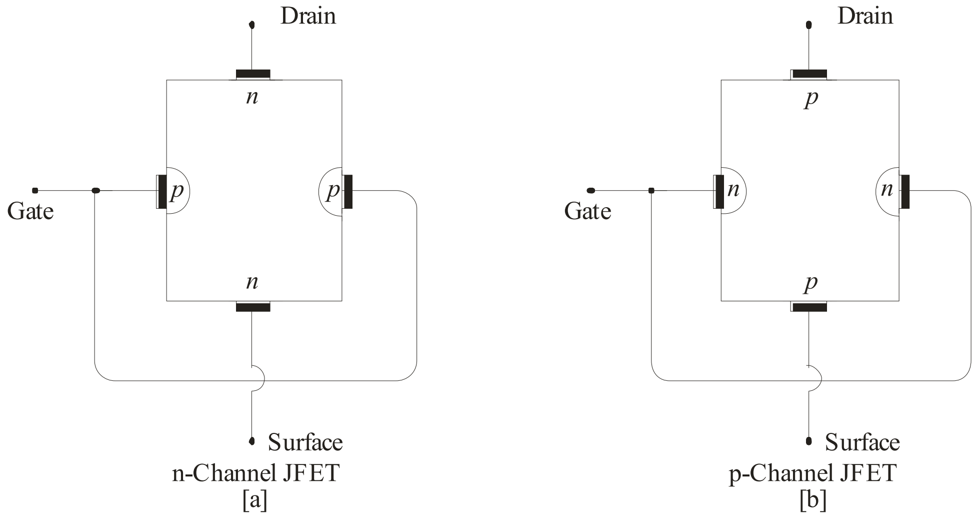


Figure 19.1

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.

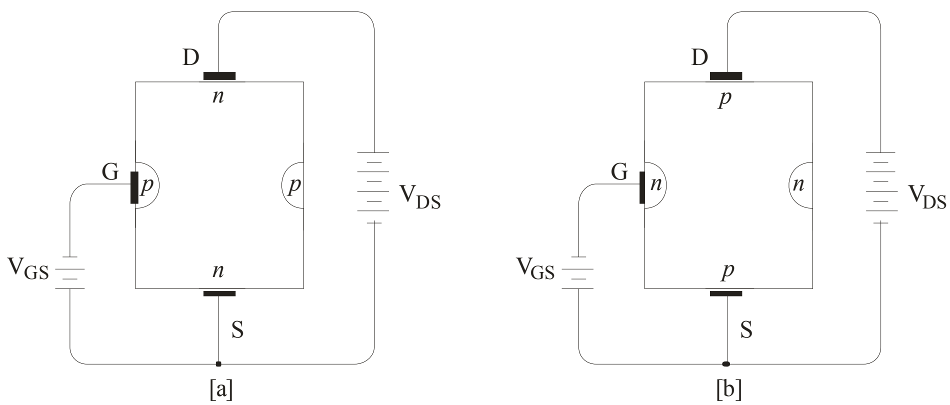


Figure.19.2

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 cource 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 carries (i.e. free electrons in this case) is through the channel between the two depletion layers and out of the drain. The width and the hence *resistance of this channel can be controlled by changing the input voltage V_{GS}. [Note: The resistance of the channel depends upon its area of X-section. The greater the X-sectional area of the channel, the lower will be its resistance and the greater will be the current flow through it.].The greater the reverse V_{GS}, the wider will be 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_{CS}, decrease. Thus JFET operates on the principle that the width and hence resistance of the conducting channel can be carried 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 p is zero [See Fig. 19.3 (i)], the *pn* junctions at the sides of the 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 increase the width of the conducting channel and hence source to drain current.

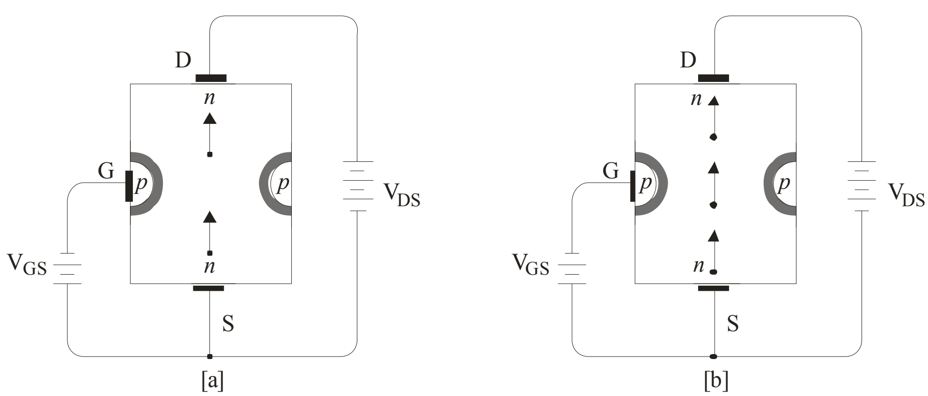
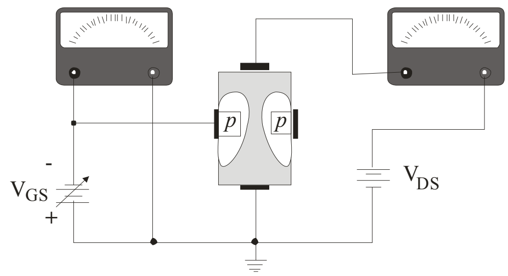


Figure.19.3

It is clear from the above discussion not current from source to drain can be controlled by the application of potential (photo electric field) on the gate. For this reason, the device is called field effect.



JFET biased for Conduction

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

Notes. It the reverse voltage V_{GS} continuously increased, a state is when the two depletion layers touch other and the channel is cut off. Under such conditions, the channel becomes a non-conductor.

19.4 Schematic Symbol of JFET

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

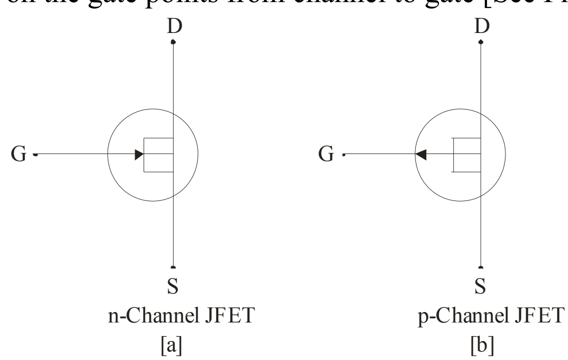


Figure.19.4

19.5 Importance of JFET

A JFET acts like a voltage controlled device i.e. input voltage (V_{GS}) controls the input current. This is different from ordinary transistor (or bipolar transistor) where input currant controls the output current. Thus JFET is semiconductor device acting like a vacuum tube [Note: The gate, source and drain of a JFET correspond to grid, cathode and anode of a vacuum tube]. The need for JFET arouse because as modern electronic equipment became increasingly transistorized, it became apparent the 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.

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