Quadrant II – Transcript and Related Materials

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Unit: 2

Module Name: Basic characteristics of JFET: Principles of operation

Module No: 6

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Notes

The Field Effect Transistor belongs to the family of Solid State Devices and consists of two types: Junction Field Effect Transistor (JFET: depletion type) and Metal Oxide Semiconductor Field Effect Transistor (MOSFET or IGFET). The JFET can be either of the N-channel type or P-channel type depending on the majority current carriers while the MOSFET is of two types: Depletion type and Enhancement type, each of both comprising of the N-channel and P-channel type.

Advantages and Disadvantages of the FET:

Advantages:

The main advantage of the FET is its high input resistance, in the order of 100 M ohms for a JFET and 10^{10} to 10^{15} ohms for a MOSFET. Thus, the FET is a Voltage-controlled device and not a current-controlled device like the conventional transistor. It shows a high degree of isolation between the input and output. The FET is a unipolar device, depending on the majority current flow: either electrons in the N-type or holes in the P-type. In contrast, the conventional transistor is a bipolar device relying on two types of charge carriers: electrons and holes. The FET is less noisy than the bipolar transistor and hence is found in front ends of FM tuners.

Disadvantages:

The main disadvantage of the FET is the relatively low gain-bandwidth product compared with that of the conventional transistor.

Basic construction of the JFET:

A cross-sectional view of an N-channel JFET is as shown in the fig. 1 below together with the supply voltages and circuit symbol(fig.2)

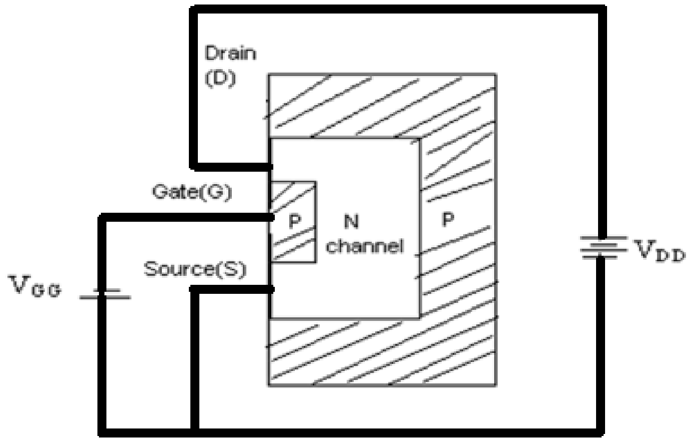

Fig.1 Diagram of JFET with normal bias voltages.

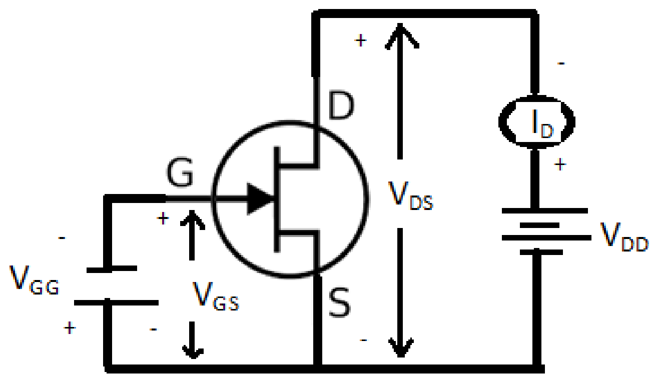

Fig.2 Symbol of the N-channel JFET

The symbol and structure bear a resemblance with that of the uni-junction transistor. However, the FET is operated with the PN junction reverse-biased and hence, the gate draws negligible current. The symbol has an arrow pointing in the direction in which the conventional current would flow if the junction were forward-biased. A P-channel JFET will have an arrow pointing inward.

The device consists of a lightly doped N-type channel diffused into a P-type bulk or substrate. An ohmic contact is made to one end of the channel called the Source, through which the majority carriers (electrons in this case) enter the channel. They then travel the entire length of the channel before reaching the ohmic contact Drain of the channel. A heavily doped P-type concentration called the gate is fused into the channel creating the P-N junction. The gate is the terminal that controls the flow of drain current I_D from Source S to drain D.

Characteristic curves of the JFET:

The application of a voltage V_{DS} from the source to the drain causes electrons to flow through the channel and a current I_D will be determined. The output characteristic of the JFET is a plot of the output current I_D versus the output voltage V_{DS} for a given value of input voltage V_{GS}(reverse-bias voltage) as seen in Fig.3 below.

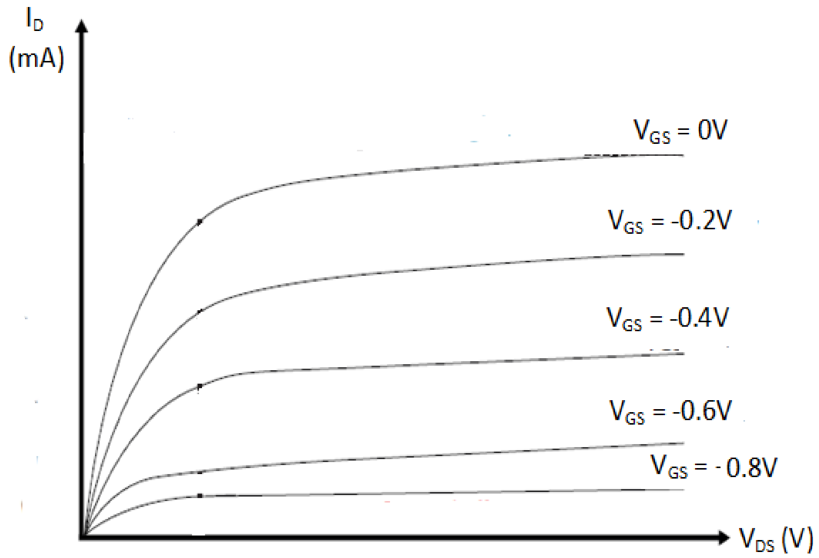

Fig.3 : Typical characteristic curves of an N-channel JFET.

With VGS =0, the P-N junction is forward-biased rather than being reverse-biased. With an increase in VDS, the drain current ID also increases in a nearly linear manner, until at some voltage of VDS, a saturation effect is observed. On the gate now being made negative with respect to the source, the drain to source voltage VDS is once again varied and a curve of a similar shape is observed but shifted down. This indicates that a negative voltage on the gate has reduced the drain current. As the gate to source voltage is made more and more negative, the drain current is further reduced when the drain to source voltage is varied. The fact that when the gate is made more and more negative with respect to source, has an effect on the channel conductivity gives a clear indication of why the device is called a Voltage-controlled device. Voltage corresponds to the reverse-bias voltage controlling the current through the device. However, the control of the drain current is a result of the constriction of narrowing of the channel. To understand this, it is appropriate to examine the effect that the width of the depletion region has on the channel conductivity as seen in Fig. 4.

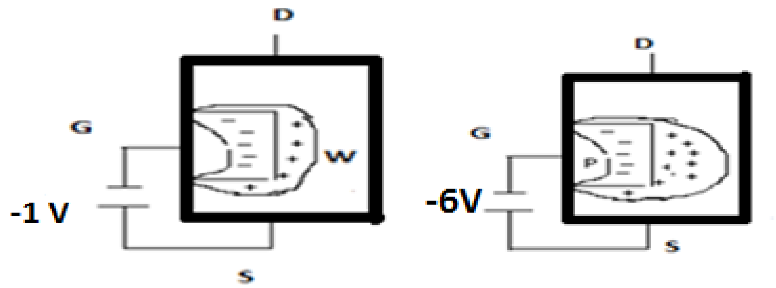

Fig. 4: Effect of reverse-bias on the width of the channel.

We know that the creation of P-N junction gives rise to the setting up of a depletion region of a certain width on either side of the junction. The width of the depletion region is known to decrease in forward-bias and increase in reverse-bias. When V_{GS} = 0V, the width of the depletion region in the channel is at its bare minimum, with the result that a maximum flow of electrons through the channel from the source to drain occurs giving rise to a large current I_D. With a small reverse-bias voltage of -1V, the width of the depletion region extends into the channel, constricting the channel further thereby reducing its width and narrowing down the flow of electrons from the source to the drain thereby, reducing the current and hence shifting the curve further below. With a further increase in reverse-bias voltage to -6V, the depletion region extends further into the channel with the result that the width of the channel reduces further, thereby further reducing the flow of electrons through the channel and lowering the channel conductivity. Finally a value of reverse-bias voltage is reached that pinches off channel conduction all together as the width of the depletion extends so much into the channel that it no longer permits the flow of electrons from the source to the drain. This value of f gate to source voltage is called the Pinch-off voltage VP, as its pinches off channel conduction all together. The mechanism of current control depends on the extent to which the electric field (due to charge in the depletion region) extends into the channel and provides the effect of decreasing the conductivity through the device. Hence, the name as Field Effect Transistor or FET. The effect that the reverse-bias voltage has on the channel conductivity and drain current Id can be correlated from the Transfer characteristic curve which is a plot of the drain current I_D as a function of the reverse-bias voltage V_{GS}.

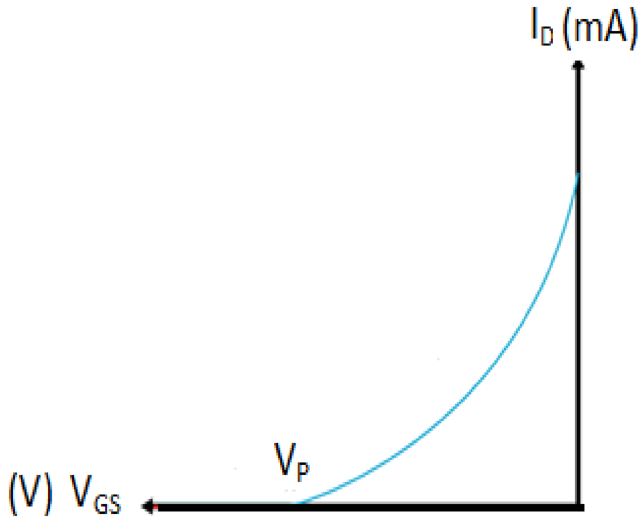

Fig. 5. Transfer characteristic for N-channel JFET.