Junction Field effect transistor: Basic structure, types, working of n channel JFET, output and transfer characteristics.

Reference: Donald A Neamen, "Microelectronics circuit analysis and design",4th Edition

N-Channel JFET

The current in a JFET is through a semiconductor region known as the channel, with ohmic contacts at each end. The basic transistor action is the modulation of the channel conductance by an electric field perpendicular to the channel. Since the modulating electric field is induced in the space-charge region of a reverse-biased pn junction, the field is a function of the gate voltage. Modulation of the channel conductance by the gate voltage modulates the channel current.

3.6.1 pn JFET and MESFET Operation

pn JFET

A simplified cross section of a symmetrical pn JFET is shown in Figure 3.54. In the n-region channel between the two p-regions, majority carrier electrons flow from the source to the drain terminal; thus, the JFET is called a majority-carrier device. The two gate terminals shown in Figure 3.54 are connected to form a single gate.

In a p-channel JFET, the p- and n-regions are reversed from those of the n-channel device, and holes flow in the channel from the source to the drain. The current direction and voltage polarities in the p-channel JFET are reversed from

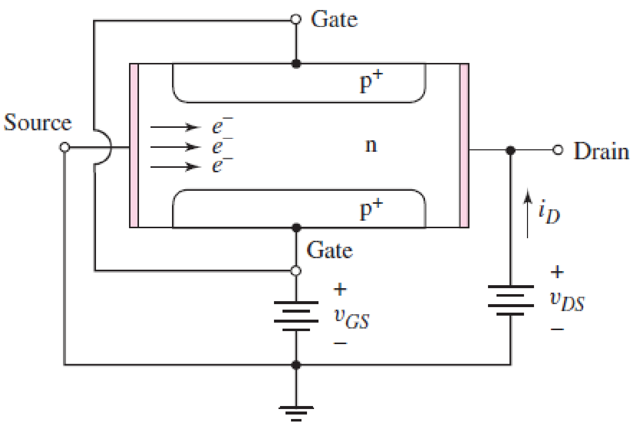

Figure 3.54 Cross section of a symmetrical n-channel pn junction field-effect transistor

those in the n-channel device. Also, the p-channel JFET is generally a lower-frequency device than the n-channel JFET, because hole mobility is lower than electron mobility.

Junction Field effect transistor: Basic structure, types, working of n channel JFET, output and transfer characteristics.

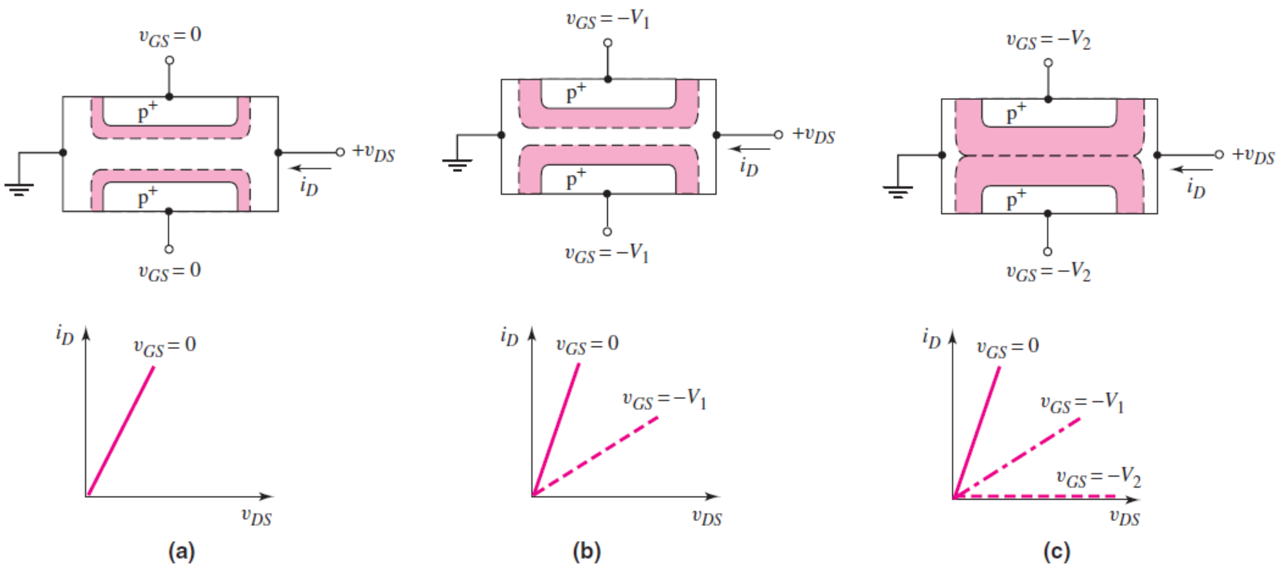

Figure 3.55 Gate-to-channel space-charge regions and current–voltage characteristics for small drain-to-source voltages and for: (a) zero gate voltage, (b) small reverse-biased gate voltage, and (c) a gate voltage that achieves pinchoff

Figure 3.55(a) shows an n-channel JFET with zero volts applied to the gate. If the source is at ground potential, and if a small positive drain voltage is applied, a drain current i_D is produced between the source and drain terminals. Since the n-channel acts essentially as a resistance, the i_D versus v_{DS} characteristic for small v_{DS} values is approximately linear, as shown in the figure.

If a voltage is applied to the gate of a pn JFET, the channel conductance changes. If a negative gate voltage is applied to the n-channel pn JFET in Figure 3.55, the gate-to-channel pn junction becomes reverse biased. The space-charge region widens, the channel region narrows, the resistance of the n-channel increases, and the slope of the i_D versus v_{DS} curve, for small v_{DS}, decreases. These effects are shown in Figure 3.55(b). If a larger negative gate voltage is applied, the condition shown in Figure 3.55(c) can be achieved. The reverse-biased gate-to-channel space-charge region completely fills the channel region. This condition is known as **pinchoff.** Since the depletion region isolates the source and drain terminals, the drain current at pinchoff is essentially zero. The i_D versus v_{DS} curves are shown in Figure 3.55(c). The current in the channel is controlled by the gate voltage. The control of the current in one part of the device by a voltage in another part of the device is the basic transistor action. The pn JFET is a "normally on," or depletion mode, device; that is, a voltage must be applied to the gate terminal to turn the device off.

Junction Field effect transistor: Basic structure, types, working of n channel JFET, output and transfer characteristics.

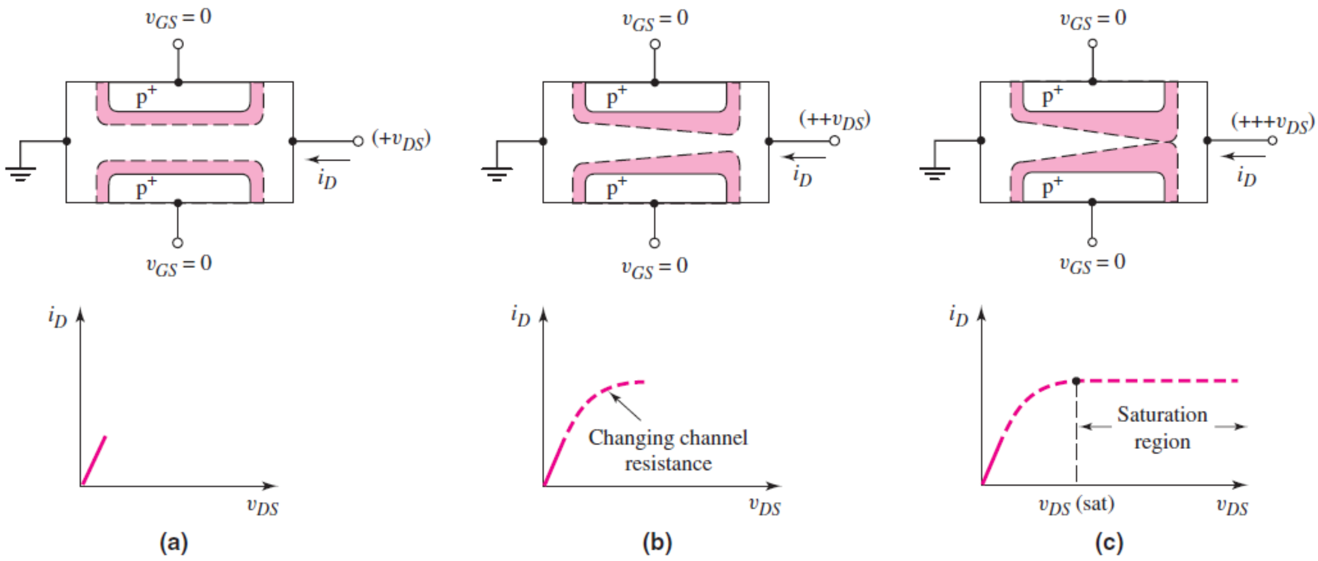

Figure 3.56 Gate-to-channel space-charge regions and current–voltage characteristics for zero gate voltage and for: (a) a small drain voltage, (b) a larger drain voltage, and (c) a drain voltage that achieves pinchoff at the drain terminal

Consider the situation in which the gate voltage is zero, $v_{GS} = 0$, and the drain voltage changes, as shown in Figure 3.56(a). As the drain voltage increases (positive), the gate-to-channel pn junction becomes reverse biased near the drain terminal, and the space-charge region widens, extending farther into the channel. The channel acts essentially as a resistor, and the effective channel resistance increases as the space-charge region widens; therefore, the slope of the i_D versus v_{DS} characteristic

decreases, as shown in Figure 3.56(b). The effective channel resistance now varies along the channel length, and, since the channel current must be constant, the voltage drop through the channel becomes dependent on position.

If the drain voltage increases further, the condition shown in Figure 3.56(c) can result. The channel is pinched off at the drain terminal. Any further increase in drain voltage will not increase the drain current. The i_D–v_{DS} characteristic for this condition is also shown in the figure. The drain voltage at pinchoff is $v_{DS}(\text{sat})$. Therefore, for $v_{DS} > v_{DS}(\text{sat})$, the transistor is biased in the saturation region, and the drain current for this ideal case is independent of v_{DS}.