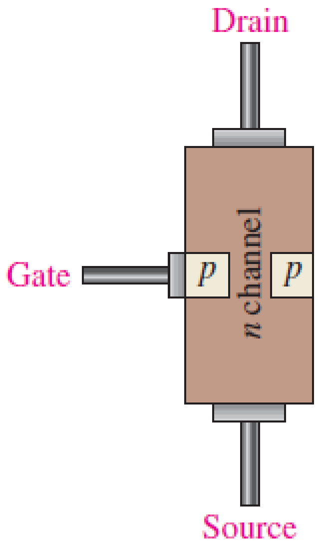
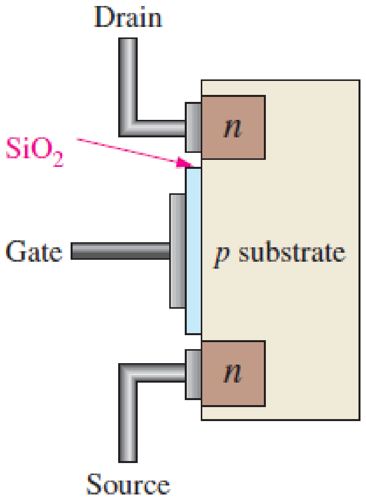
Chapter 8

Field-Effect Transistors (FETs)



n-channel JFET



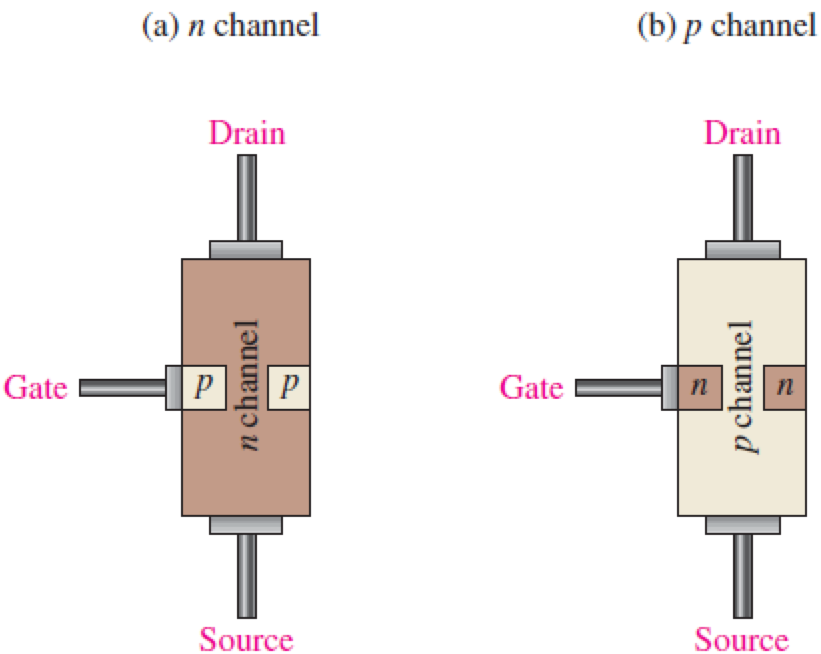
n-channel E-MOSFET

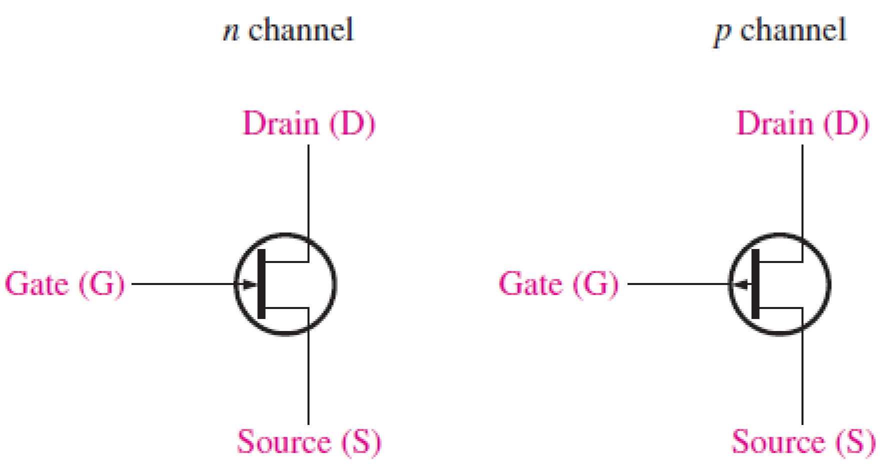
Comparison between BJT and FET

Bipolar Junction Transistor (BJT)	Field Effect Transistor (FET)
Bipolar: use both electron and hole current	**Unipolar**: operated with one type of carrier
Current-controlled device: base current controls the amount of collector current	**Voltage-controlled device:** voltage between two of the terminals (gate and source) controls the current through the device
	Advantage: very high input resistance **Applications**: low-voltage switching(faster) **Two main types of FETs:** • Junction field-effect transistor (**JFET**) • Metal oxide semiconductor field-effect transistor (**MOSFET**).

Junction Field Effect Transistor (JFET)

Basic Structure **Symbols**





- The JFET is a type of FET that operates with a reverse-biased pn junction to control current in a channel.
- Depending on their structure, JFETs fall into either of two categories, n channel or p channel.

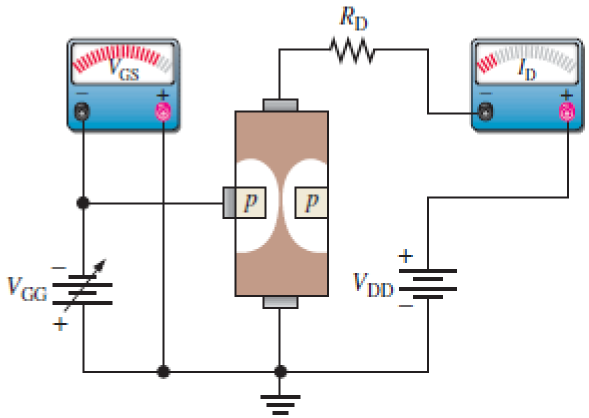
Basic Operation of JFET

n-channel JFET Operation

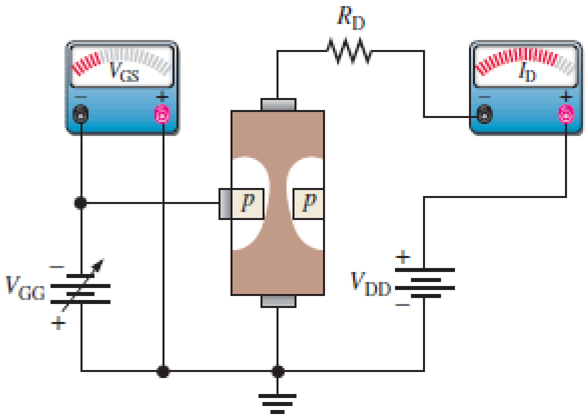
- V_{DD} provides a drain-to-source voltage and supplies current from drain to source.

- V_{GG} sets the reverse-bias voltage between the gate and the source, as shown.

- Reverse biasing of the gate-source junction produces a depletion region which increases channel resistance by restricting the channel width ➔ **Controlling I_D**.



Greater V_{GG} narrows the channel (between the white areas) which increases the resistance of the channel and decreases I_D.



Less V_{GG} widens the channel (between the white areas) which decreases the resistance of the channel and increases I_D.

JFET Characteristics and Parameters

When $V_{GS} = 0$

- The JFET operates as a voltage-controlled, **constant-current** device.

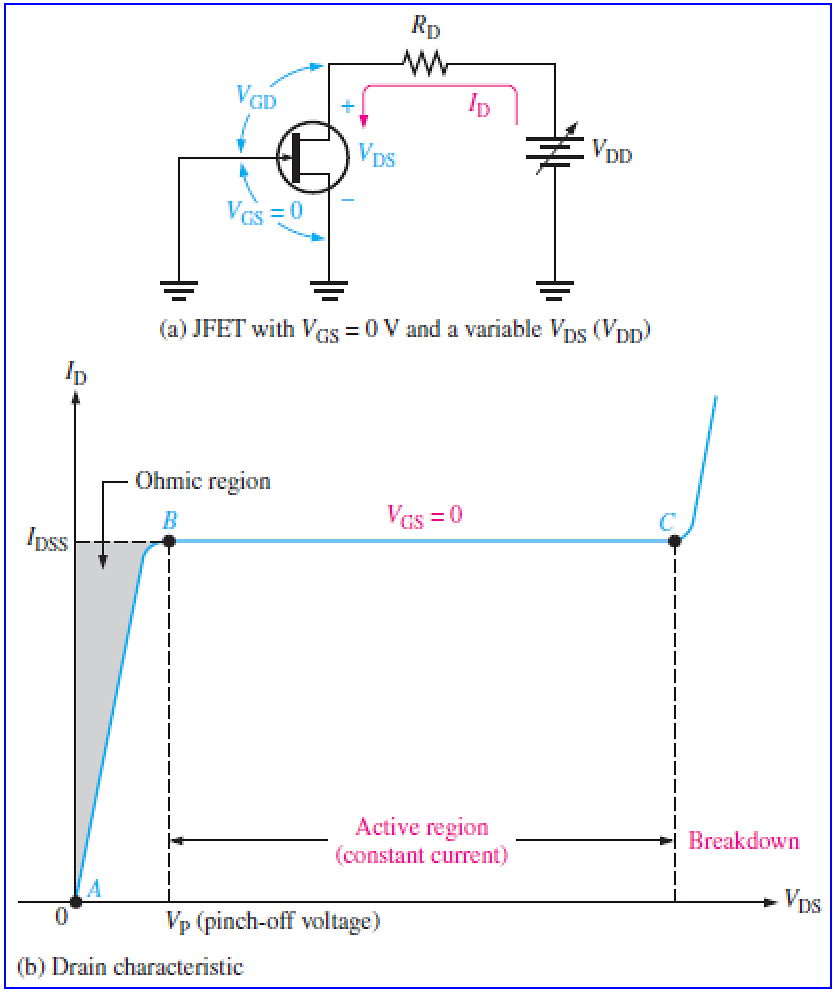
- The JFET must be operated between V_{GS}= 0 V and $V_{GS(off)}$. For this range of gate-to-source voltages, I_D will vary from a maximum of I_{DSS} to a minimum of almost zero.

- **Pinch-Off Voltage, Vp:** For V_{GS} 0 V, the value of V_{DS} at which I_D becomes essentially constant (point *B*)

- As V_{DS} increase above the Vp, I_D becomes constant.

- $\mathbf{I_{DSS}}$ (Drain to Source current with gate Shorted): is the maximum drain current and it is always specified for the condition, V_{GS} = 0 V.

Drain Characteristic Curve for V_{GS} =0



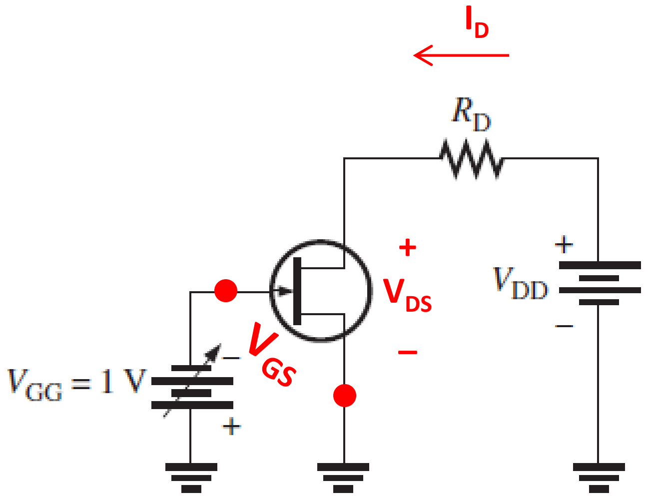
JFET Characteristics and Parameters

When V_{GS} Controls I_D

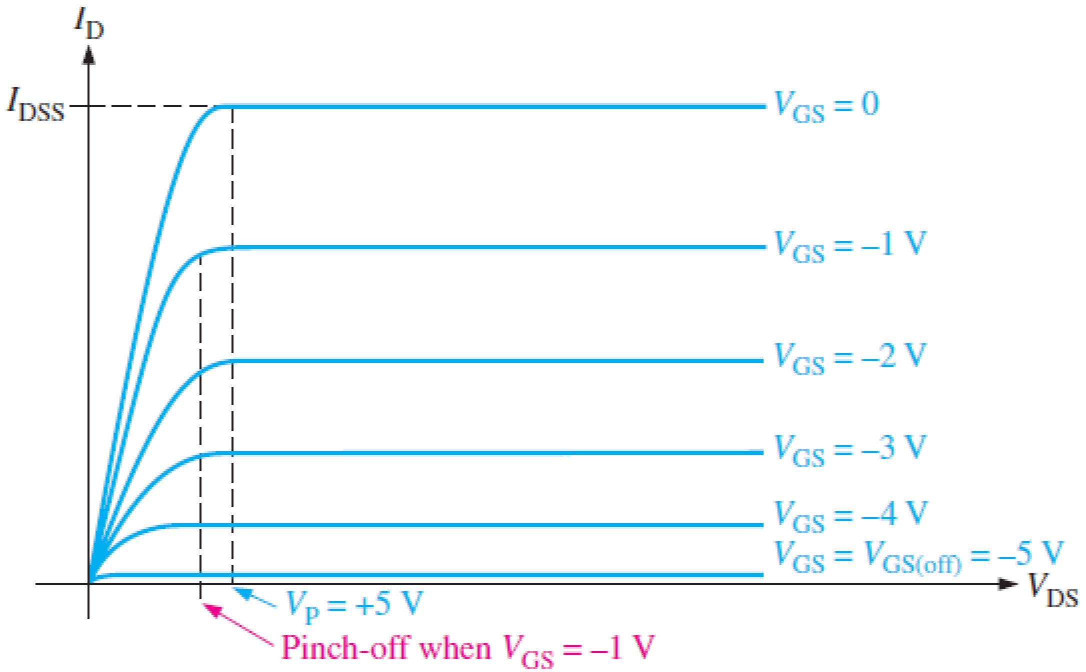
- As V_{GS} is set to increasingly more negative values by adjusting V_{GG}, a family of drain characteristic curves is produced.

- Notice that I_D decreases as the magnitude of V_{GS} is increased to larger negative values because of the narrowing of the channel.

- **Cutoff Voltage, $V_{GS\,(off)}$:** The value of V_{GS} that makes I_D = zero.



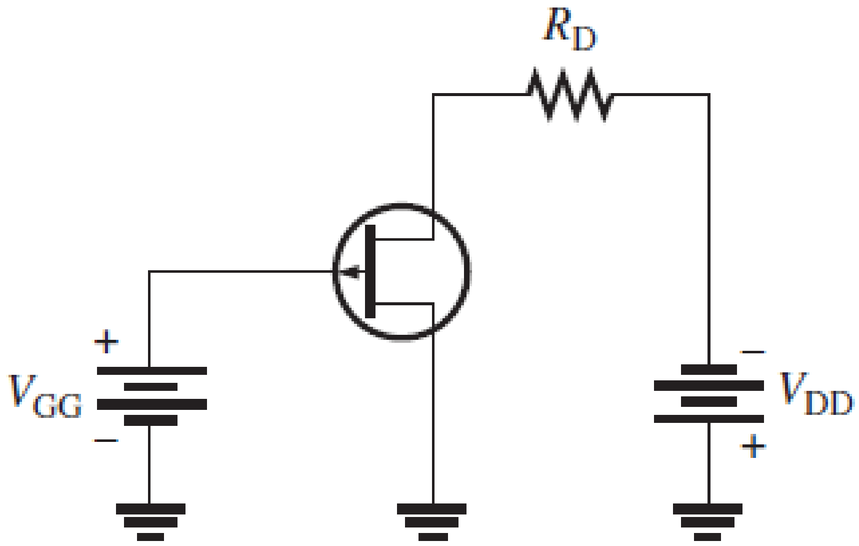
(a) JFET biased at $V_{GS} = -1$ V



(b) Family of drain characteristic curves

P-channel JFET Operation

The basic operation of a *p*-channel JFET is the same as for an *n*-channel device except that a *p*-channel JFET requires a **negative V_{DD}** and a **positive V_{GS}**, as illustrated below.

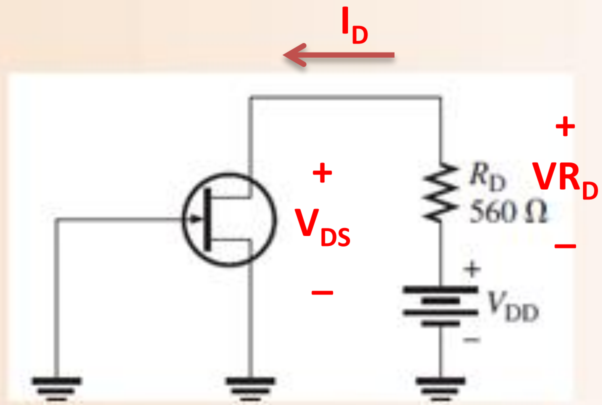


A biased *p*-channel JFET.

EXAMPLE 8–1

For the JFET in Figure 8–11, $V_{GS(off)} = -4\text{ V}$ and $I_{DSS} = 12\text{ mA}$. Determine the *minimum* value of V_{DD} required to put the device in the constant-current region of operation when $V_{GS} = 0\text{ V}$.

▶ FIGURE 8–11



Since $V_{GS(off)} = -4\text{ V}$, $V_P = 4\text{ V}$. The minimum value of V_{DS} for the JFET to be in its constant-current region is

$$V_{DS} = V_P = 4\text{ V}$$

In the constant-current region with $V_{GS} = 0\text{ V}$,

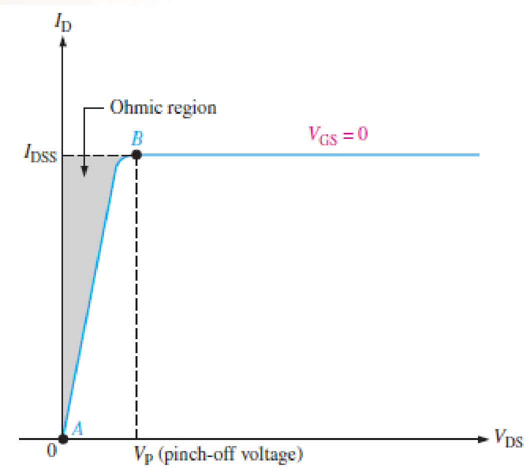
$$I_D = I_{DSS} = 12\text{ mA}$$

The drop across the drain resistor is

$$V_{R_D} = I_D R_D = (12\text{ mA})(560\ \Omega) = 6.72\text{ V}$$

Apply Kirchhoff's law around the drain circuit.

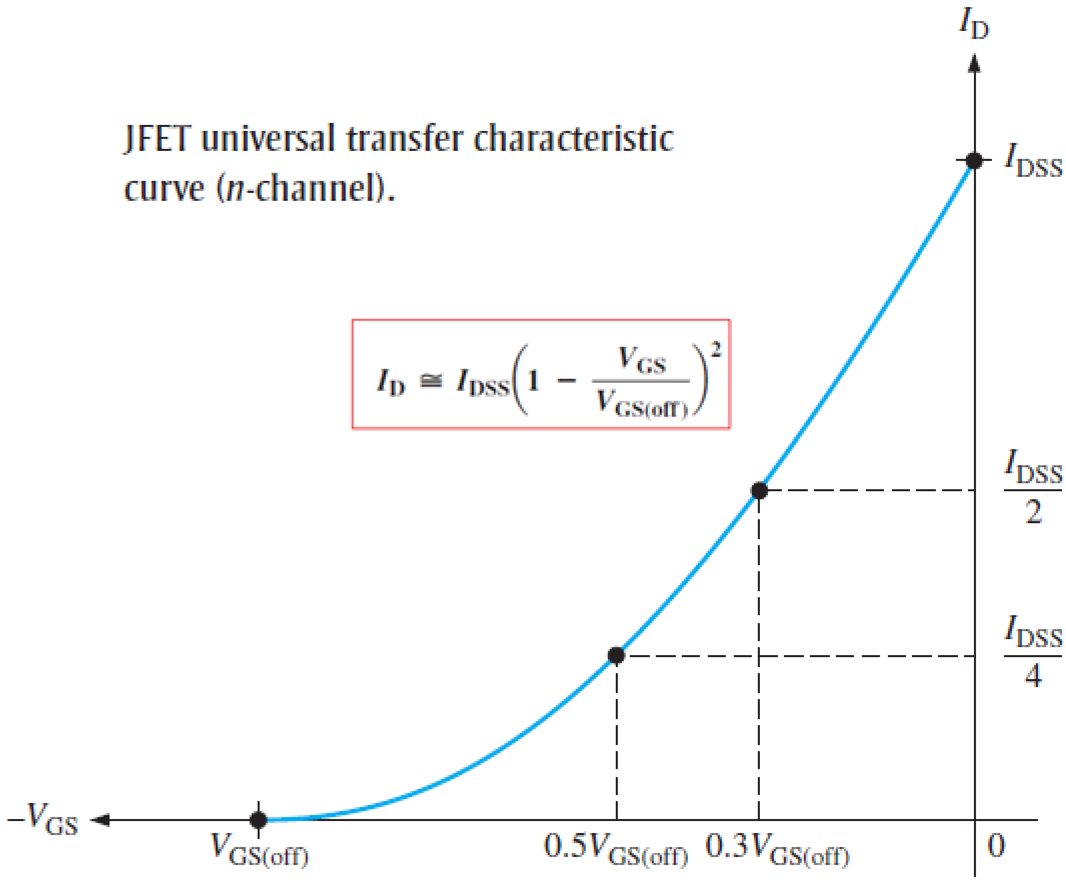
$$V_{DD} = V_{DS} + V_{R_D} = 4\text{ V} + 6.72\text{ V} = \mathbf{10.7\text{ V}}$$



This is the value of V_{DD} to make $V_{DS} = V_P$ and put the device in the constant-current region.

JFET Universal Transfer Characteristic

- Figure shows a general transfer characteristic curve that illustrates graphically the relationship between V_{GS} and I_D.
- For an *n*-channel JFET, $V_{GS(off)}$ is negative, and for a *p*-channel JFET, $V_{GS(off)}$ is positive.



JFET Universal Transfer Characteristic

- The transfer characteristic curve can also be developed from the drain characteristic curves by plotting values of I_D for the values of V_{GS} taken from the family of drain curves at pinch-off. Each point on the transfer characteristic curve corresponds to specific values of V_{GS} and I_D on the drain curves.

The transfer characteristic curve

$$I_D \cong I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

The drain characteristic curves