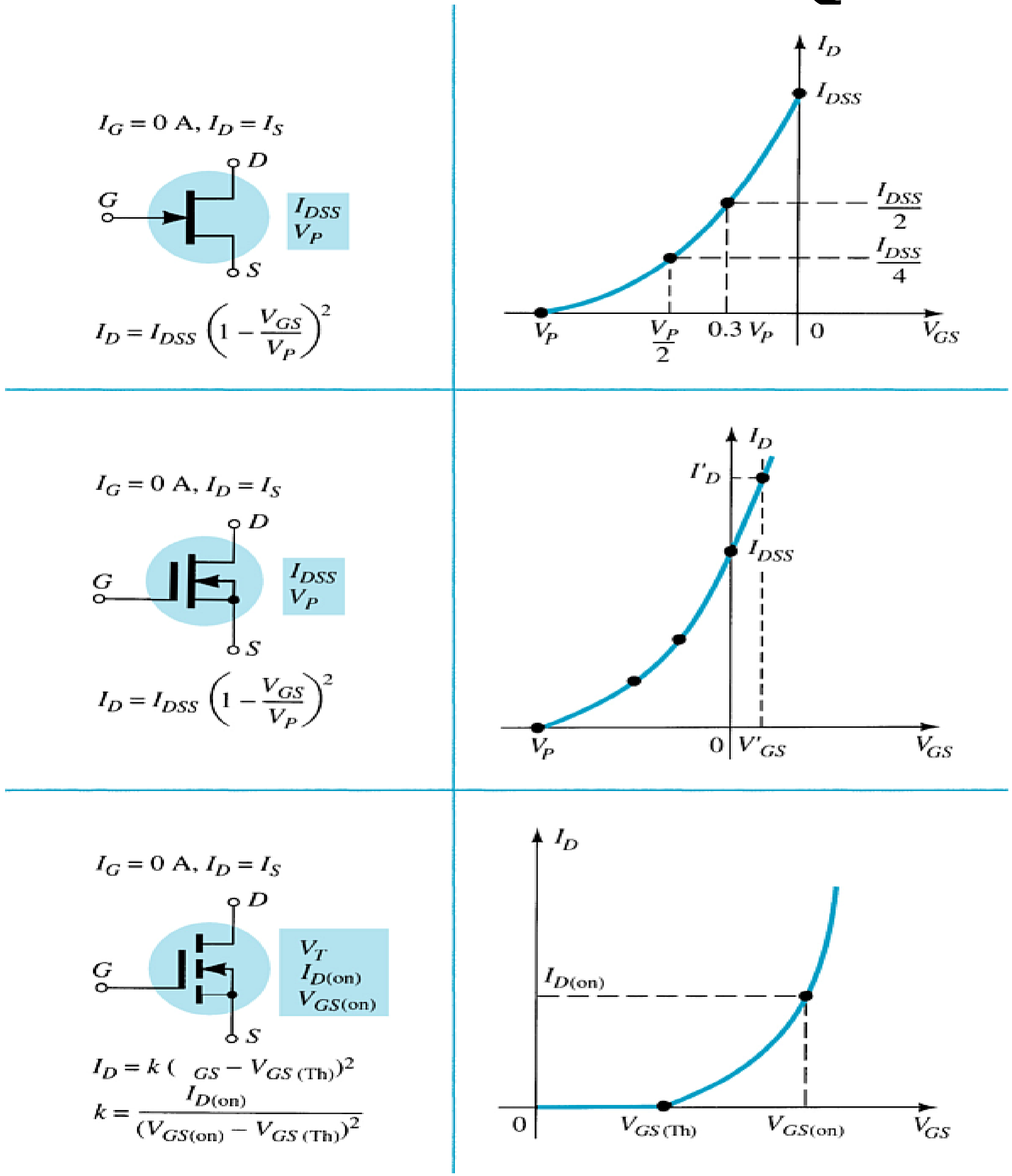
Electronic Circuits
Elektronik Devreler

Dr. Gökhan Bilgin

Electronic Circuits Questions



Sketch the transfer curve defined by $I_{DSS} = 12$ mA and $V_P = -6$ V.

Solution

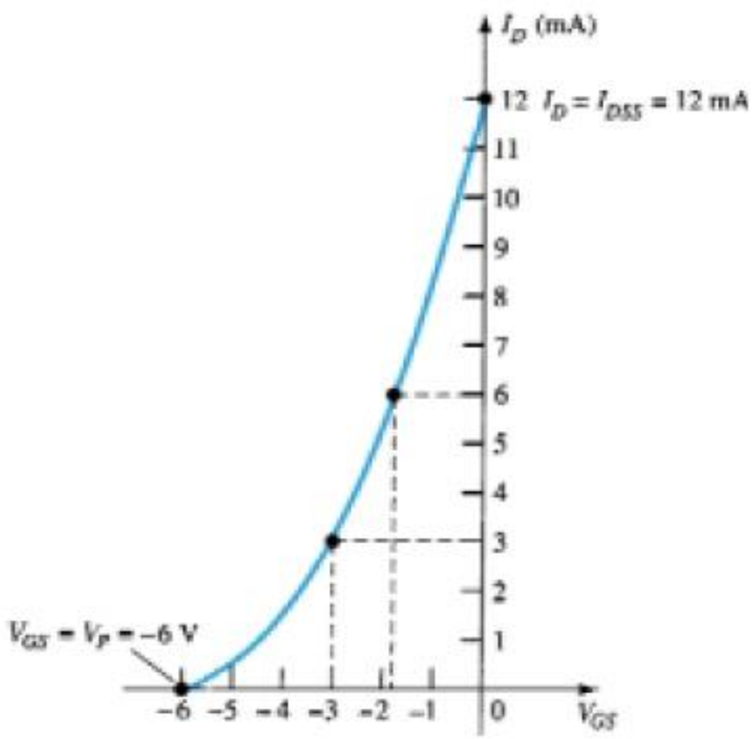
Two plot points are defined by

$$I_{DSS} = \mathbf{12\ mA} \qquad \text{and} \qquad V_{GS} = \mathbf{0\ V}$$

and

$$I_D = \mathbf{0\ mA} \qquad \text{and} \qquad V_{GS} = \boldsymbol{V_P}$$

At $V_{GS} = V_P/2 = -6\text{ V}/2 = \mathbf{-3\ V}$ the drain current will be determined by $I_D = I_{DSS}/4 = 12\text{ mA}/4 = \mathbf{3\ mA.}$ At $I_D = I_{DSS}/2 = 12\text{ mA}/2 = \mathbf{6\ mA}$ the gate-to-source voltage is determined by $V_{GS} \cong 0.3V_P = 0.3(-6\text{ V}) = \mathbf{-1.8\ V.}$ All four plot points are well defined on Fig. 5.16 with the complete transfer curve.



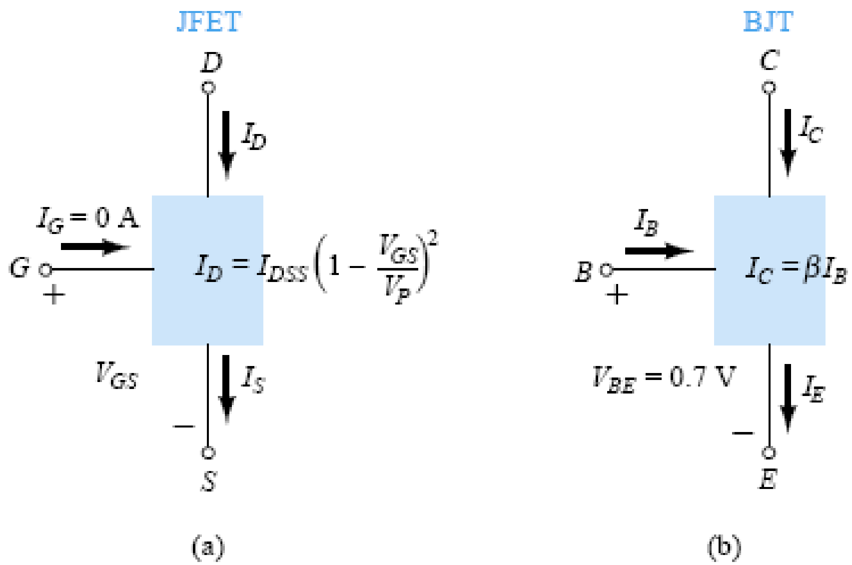


Figure 5.22 (a) JFET versus (b) BJT.

$$\begin{array}{lcc} \textbf{JFET} & & \textbf{BJT} \\ I_D = I_{DSS}\left(1 - \dfrac{V_{GS}}{V_P}\right)^2 & \Leftrightarrow & I_C = \beta I_B \\ I_D = I_S & \Leftrightarrow & I_C \cong I_E \\ I_G \cong 0\text{ A} & \Leftrightarrow & V_{BE} \cong 0.7\text{ V} \end{array} \tag{5.10}$$

Sketch the transfer characteristics for an n-channel depletion-type MOSFET with $I_{DSS} = 10$ mA and $V_P = -4$ V.

Solution

$$\text{At } V_{GS} = 0 \text{ V}, \qquad I_D = I_{DSS} = 10 \text{ mA}$$

$$V_{GS} = V_P = -4 \text{ V}, \qquad I_D = 0 \text{ mA}$$

$$V_{GS} = \frac{V_P}{2} = \frac{-4 \text{ V}}{2} = -2 \text{ V}, \qquad I_D = \frac{I_{DSS}}{4} = \frac{10 \text{ mA}}{4} = 2.5 \text{ mA}$$

$$\text{and at } I_D = \frac{I_{DSS}}{2}, \qquad V_{GS} = 0.3V_P = 0.3(-4 \text{ V}) = -1.2 \text{ V}$$

all of which appear in Fig. 5.27.

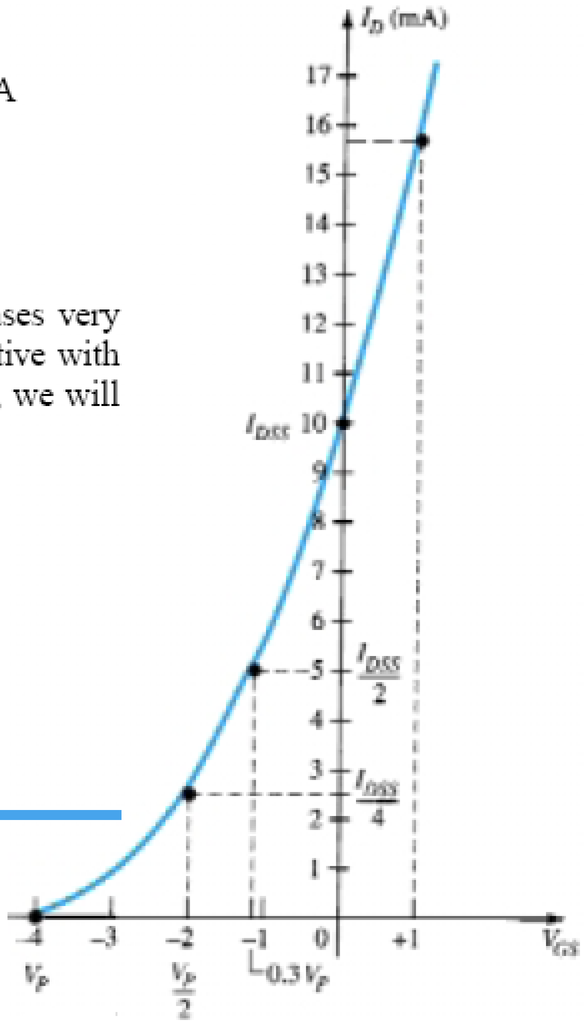
Before plotting the positive region of V_{GS}, keep in mind that I_D increases very rapidly with increasing positive values of V_{GS}. In other words, be conservative with the choice of values to be substituted into Shockley's equation. In this case, we will try +1 V as follows:

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

$$= 10 \text{ mA}\left(1 - \frac{+1 \text{ V}}{-4 \text{ V}}\right)^2 = 10 \text{ mA}(1 + 0.25)^2 = 10 \text{ mA}(1.5625)$$

$$\cong 15.63 \text{ mA}$$

which is sufficiently high to finish the plot.



Using the data provided on the specification sheet of Fig. 5.39 and an average threshold voltage of $V_{GS(\text{Th})} = 3$ V, determine:

(a) The resulting value of k for the MOSFET.

(b) The transfer characteristics.

Solution

(a) Eq. (5.14): $$k = \frac{I_{D(\text{on})}}{(V_{GS(\text{on})} - V_{GS(\text{Th})})^2}$$

$$= \frac{3\text{ mA}}{(10\text{ V} - 3\text{ V})^2} = \frac{3\text{ mA}}{(7\text{ V})^2} = \frac{3 \times 10^{-3}}{49}\text{ A/V}^2$$

$$= \mathbf{0.061 \times 10^{-3}\ A/V^2}$$

(b) Eq. (5.13): $$I_D = k(V_{GS} - V_T)^2$$

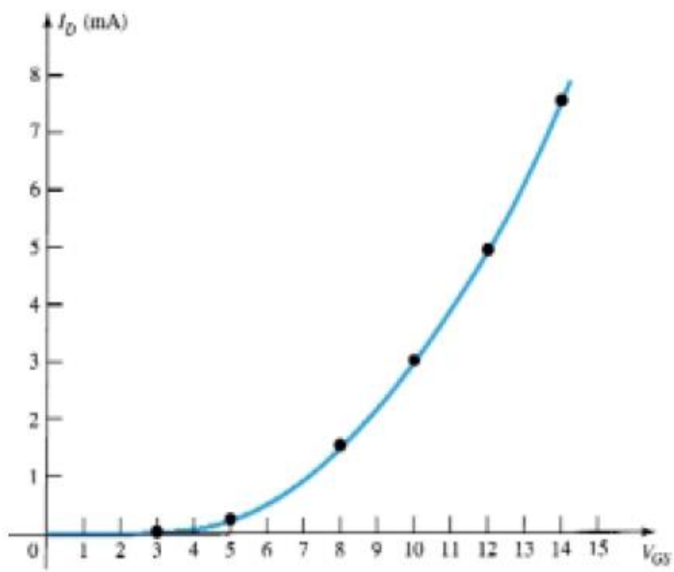
$$= 0.061 \times 10^{-3}(V_{GS} - 3\text{ V})^2$$

For $V_{GS} = 5$ V,

$$I_D = 0.061 \times 10^{-3}(5\text{ V} - 3\text{ V})^2 = 0.061 \times 10^{-3}(2)^2$$

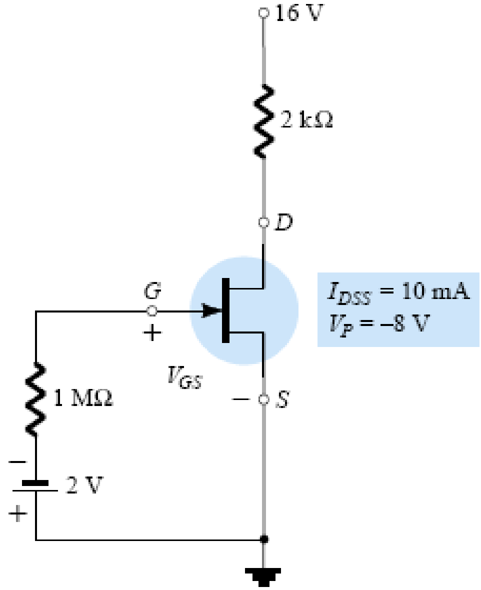
$$= 0.061 \times 10^{-3}(4) = 0.244\text{ mA}$$

For $V_{GS} = 8$, 10, 12, and 14 V, I_D will be 1.525, 3 (as defined), 4.94, and 7.38 mA, respectively. The transfer characteristics are sketched in Fig. 5.40.



Determine the following for the network of Fig. 6.6.

(a) V_{GS_Q}.
(b) I_{D_Q}.
(c) V_{DS}.
(d) V_D.
(e) V_G.
(f) V_S.



Solution

Mathematical Approach:

(a) $V_{GS_Q} = -V_{GG} = \mathbf{-2\ V}$

(b) $I_{D_Q} = I_{DSS}\left(1 - \dfrac{V_{GS}}{V_P}\right)^2 = 10\text{ mA}\left(1 - \dfrac{-2\text{ V}}{-8\text{ V}}\right)^2$

$$= 10\text{ mA}(1 - 0.25)^2 = 10\text{ mA}(0.75)^2 = 10\text{ mA}(0.5625)$$

$$= \mathbf{5.625\ mA}$$

(c) $V_{DS} = V_{DD} - I_D R_D = 16\text{ V} - (5.625\text{ mA})(2\text{ k}\Omega)$

$$= 16\text{ V} - 11.25\text{ V} = \mathbf{4.75\ V}$$

(d) $V_D = V_{DS} = \mathbf{4.75\ V}$

(e) $V_G = V_{GS} = \mathbf{-2\ V}$

(f) $V_S = \mathbf{0\ V}$

Determine the following for the network of Fig. 6.24.

(a) I_{D_Q} and V_{GS_Q}.
(b) V_D.
(c) V_S.
(d) V_{DS}.
(e) V_{DG}.

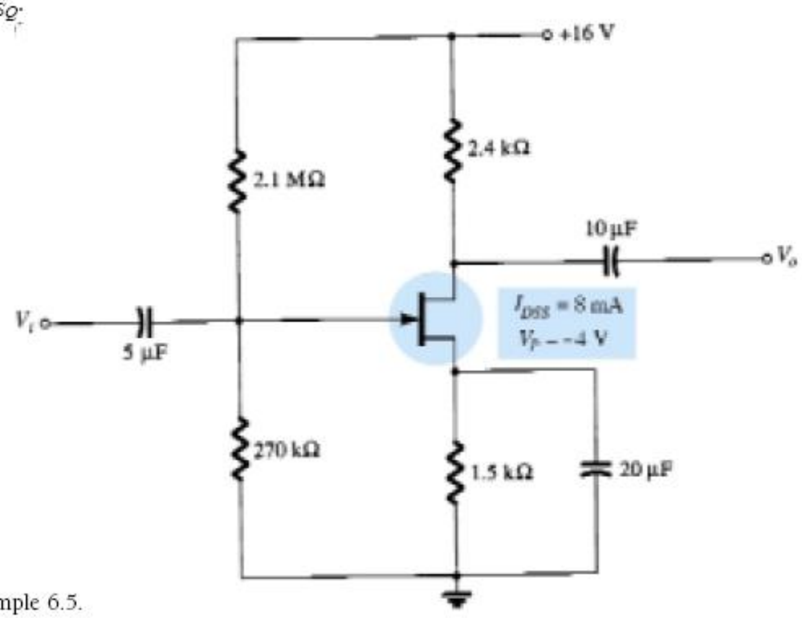


Figure 6.24 Example 6.5.

(a) For the transfer characteristics, if $I_D = I_{DSS}/4 = 8\text{ mA}/4 = 2\text{ mA}$, then $V_{GS} = V_P/2 = -4\text{ V}/2 = -2\text{ V}$. The resulting curve representing Shockley's equation appears in Fig. 6.25. The network equation is defined by

$$V_G = \frac{R_2 V_{DD}}{R_1 + R_2}$$

$$= \frac{(270\text{ k}\Omega)(16\text{ V})}{2.1\text{ M}\Omega + 0.27\text{ M}\Omega}$$

$$= 1.82\text{ V}$$

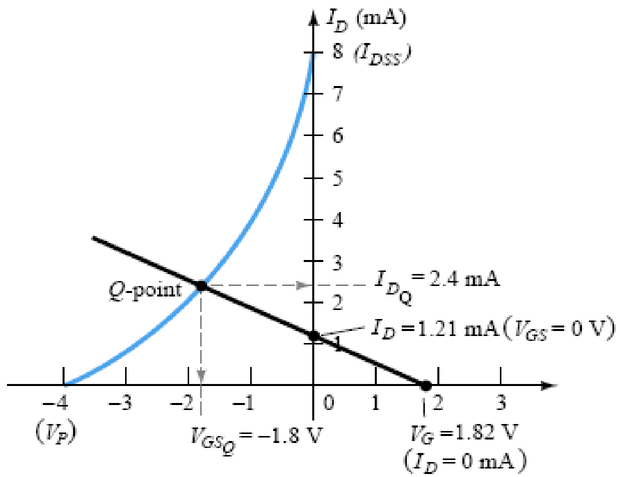
and

$$V_{GS} = V_G - I_D R_S$$

$$= 1.82\text{ V} - I_D(1.5\text{ k}\Omega)$$

When $I_D = 0$ mA:

$$V_{GS} = +1.82 \text{ V}$$



When $V_{GS} = 0$ V:

$$I_D = \frac{1.82 \text{ V}}{1.5 \text{ k}\Omega} = 1.21 \text{ mA}$$

The resulting bias line appears on Fig. 6.25 with quiescent values of

$$I_{D_Q} = \mathbf{2.4 \text{ mA}}$$

and

$$V_{GS_Q} = \mathbf{-1.8 \text{ V}}$$

(b) $V_D = V_{DD} - I_D R_D$

$= 16 \text{ V} - (2.4 \text{ mA})(2.4 \text{ k}\Omega)$

$= \mathbf{10.24 \text{ V}}$

(c) $V_S = I_D R_S = (2.4 \text{ mA})(1.5 \text{ k}\Omega)$

$= \mathbf{3.6 \text{ V}}$

(d) $V_{DS} = V_{DD} - I_D(R_D + R_S)$

$= 16 \text{ V} - (2.4 \text{ mA})(2.4 \text{ k}\Omega + 1.5 \text{ k}\Omega)$

$= \mathbf{6.64 \text{ V}}$

or $V_{DS} = V_D - V_S = 10.24 \text{ V} - 3.6 \text{ V}$

$= \mathbf{6.64 \text{ V}}$

(e) Although seldom requested, the voltage V_{DG} can easily be determined using

$$V_{DG} = V_D - V_G$$

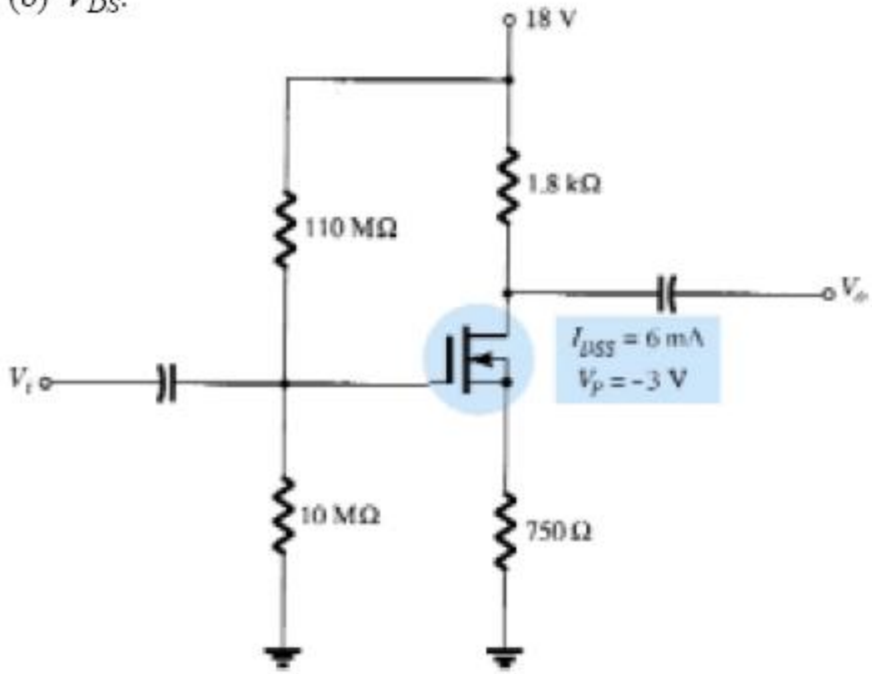
$$= 10.24 \text{ V} - 1.82 \text{ V}$$

$$= \mathbf{8.42 \text{ V}}$$

For the n-channel depletion-type MOSFET of Fig. 6.29, determine:

(a) I_{DQ} and V_{GSQ}.

(b) V_{DS}.



Solution

(a) For the transfer characteristics, a plot point is defined by $I_D = I_{DSS}/4 = 6\text{ mA}/4 = 1.5\text{ mA}$ and $V_{GS} = V_P/2 = -3\text{ V}/2 = -1.5\text{ V}$. Considering the level of V_P and the fact that Shockley's equation defines a curve that rises more rapidly as V_{GS} becomes more positive, a plot point will be defined at $V_{GS} = +1\text{ V}$. Substituting into Shockley's equation yields

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

$$= 6\text{ mA}\left(1 - \frac{+1\text{ V}}{-3\text{ V}}\right)^2 = 6\text{ mA}\left(1 + \frac{1}{3}\right)^2 = 6\text{ mA}(1.778)$$

$$= 10.67\text{ mA}$$

The resulting transfer curve appears in Fig. 6.30. Proceeding as described for JFETs, we have:

$$\text{Eq. (6.15):}\quad V_G = \frac{10\text{ M}\Omega(18\text{ V})}{10\text{ M}\Omega + 110\text{ M}\Omega} = 1.5\text{ V}$$

$$\text{Eq. (6.16):}\quad V_{GS} = V_G - I_D R_S = 1.5\text{ V} - I_D(750\ \Omega)$$

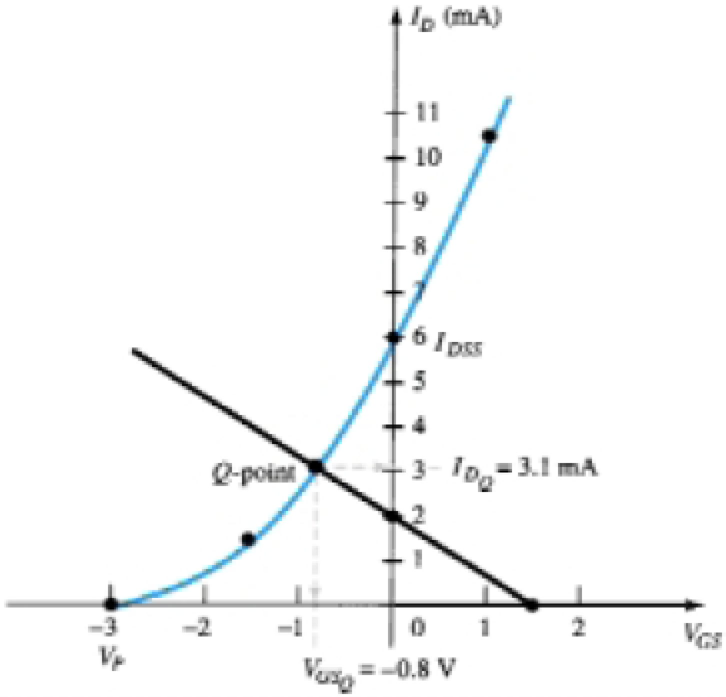


Figure 6.30 Determining the *Q*-point for the network of Fig. 6.29.

Setting $I_D = 0$ mA results in

$$V_{GS} = V_G = 1.5 \text{ V}$$

Setting $V_{GS} = 0$ V yields

$$I_D = \frac{V_G}{R_S} = \frac{1.5 \text{ V}}{750\ \Omega} = 2 \text{ mA}$$

The plot points and resulting bias line appear in Fig. 6.30. The resulting operating point:

$$I_{D_Q} = \mathbf{3.1\ mA}$$

$$V_{GS_Q} = \mathbf{-0.8\ V}$$

(b) Eq. (6.19): $V_{DS} = V_{DD} - I_D(R_D + R_S)$

$$= 18 \text{ V} - (3.1 \text{ mA})(1.8 \text{ k}\Omega + 750\ \Omega)$$

$$\cong \mathbf{10.1\ V}$$

Determine the following for the network of Fig. 6.32.

(a) I_{D_Q} and V_{GS_Q}.
(b) V_D.

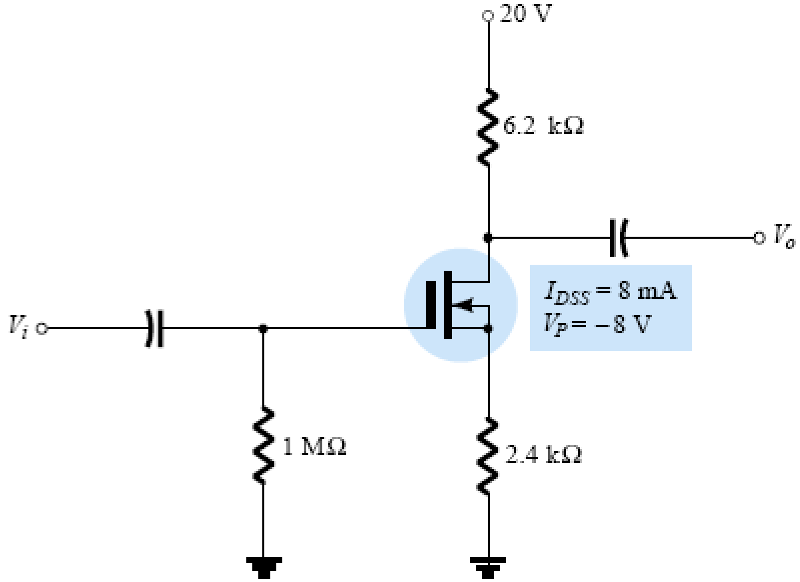


Figure 6.32 Example 6.9.

Solution

(a) The self-bias configuration results in

$$V_{GS} = -I_D R_S$$

as obtained for the JFET configuration, establishing the fact that V_{GS} must be less than zero volts. There is therefore no requirement to plot the transfer curve for positive values of V_{GS}, although it was done on this occasion to complete the transfer characteristics. A plot point for the transfer characteristics for $V_{GS} < 0$ V is

$$I_D = \frac{I_{DSS}}{4} = \frac{8\text{ mA}}{4} = 2\text{ mA}$$

and
$$V_{GS} = \frac{V_P}{2} = \frac{-8\text{ V}}{2} = -4\text{ V}$$

and $$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 8\text{ mA}\left(1 - \frac{+2\text{ V}}{-8\text{ V}}\right)^2$$

$$= 12.5\text{ mA}$$

The resulting transfer curve appears in Fig. 6.33. For the network bias line, at $V_{GS} =$ 0 V, $I_D = 0$ mA. Choosing $V_{GS} = -6$ V gives

$$I_D = -\frac{V_{GS}}{R_S} = -\frac{-6\text{ V}}{2.4\text{ k}\Omega} = 2.5\text{ mA}$$

The resulting Q-point:

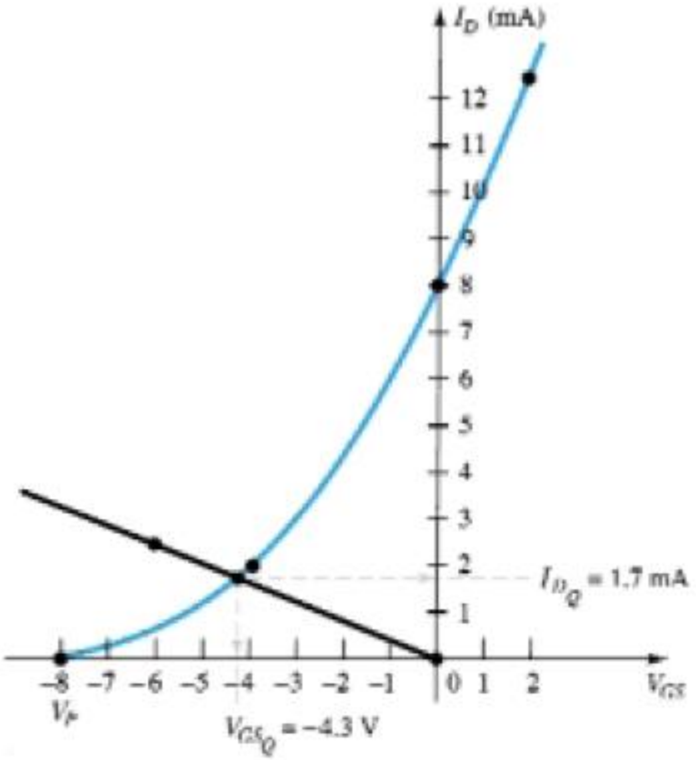
$$I_{D_Q} = \mathbf{1.7\ mA}$$

$$V_{GS_Q} = \mathbf{-4.3\ V}$$

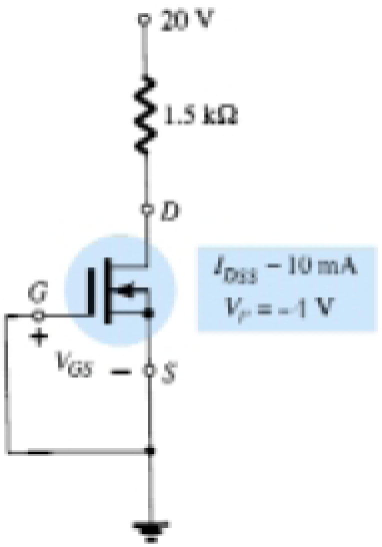
(b) $V_D = V_{DD} - I_D R_D$

$= 20\text{ V} - (1.7\text{ mA})(6.2\text{ k}\Omega)$

$= \mathbf{9.46\ V}$



EXAMPLE 6.10 Determine V_{DS} for the network of Fig. 6.34.



Solution

The direct connection between the gate and source terminals requires that

$$V_{GS} = 0 \text{ V}$$

Since V_{GS} is fixed at 0 V, the drain current must be I_{DSS} (by definition). In other words,

$$V_{GS_Q} = \mathbf{0\ V}$$

and

$$I_{D_Q} = \mathbf{10\ mA}$$

There is therefore no need to draw the transfer curve and

$$\begin{aligned} V_D &= V_{DD} - I_D R_D = 20 \text{ V} - (10 \text{ mA})(1.5 \text{ k}\Omega) \\ &= 20 \text{ V} - 15 \text{ V} \\ &= \mathbf{5\ V} \end{aligned}$$

Determine I_{DQ} and V_{DSQ} for the enhancement-type MOSFET of Fig. 6.39.

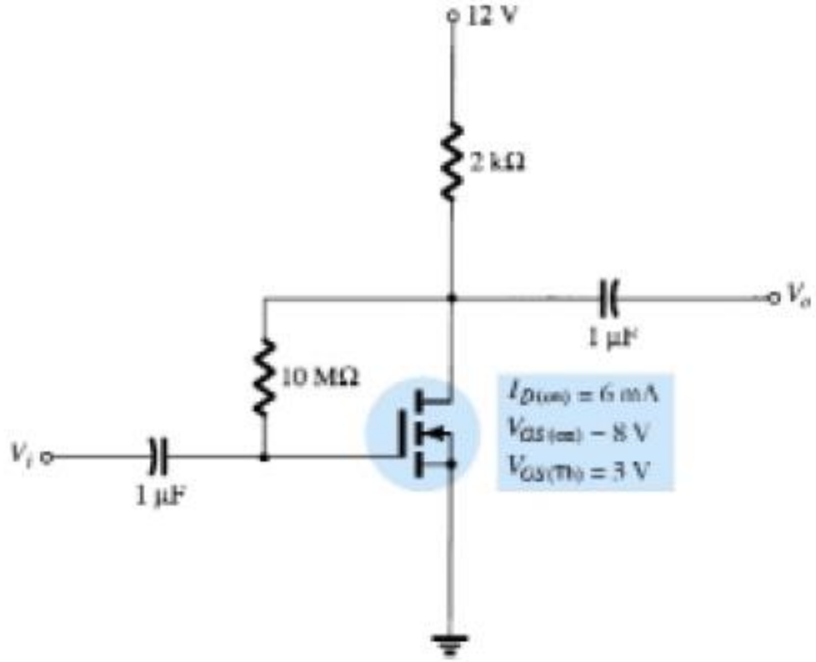


Figure 6.39 Example 6.11.

Solution

Plotting the Transfer Curve:

Two points are defined immediately as shown in Fig. 6.40. Solving for k:

$$\text{Eq. (6.26):}\quad k = \frac{I_{D(\text{on})}}{(V_{GS(\text{on})} - V_{GS(\text{Th})})^2}$$

$$= \frac{6\text{ mA}}{(8\text{ V} - 3\text{ V})^2} = \frac{6 \times 10^{-3}}{25}\text{A/v}^2$$

$$= \mathbf{0.24 \times 10^{-3}\ A/V^2}$$

For $V_{GS} = 6$ V (between 3 and 8 V):

$$I_D = 0.24 \times 10^{-3}(6\text{ V} - 3\text{ V})^2 = 0.24 \times 10^{-3}(9)$$

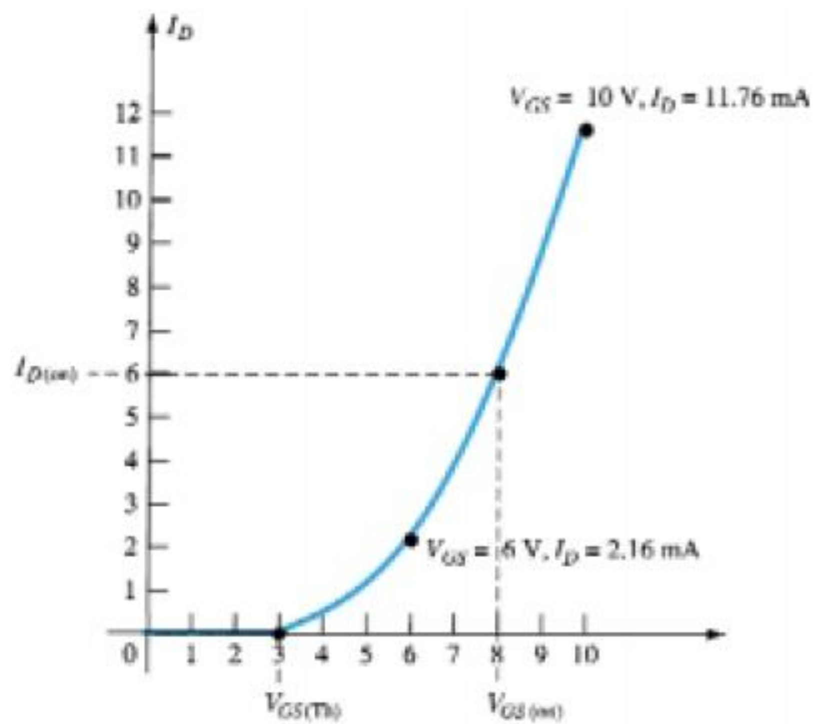
$$= 2.16\text{ mA}$$

as shown on Fig. 6.40. For $V_{GS} = 10$ V (slightly greater than $V_{GS(\text{Th})}$):

$$I_D = 0.24 \times 10^{-3}(10\text{ V} - 3\text{ V})^2 = 0.24 \times 10^{-3}(49)$$

$$= 11.76\text{ mA}$$

as also appearing on Fig. 6.40. The four points are sufficient to plot the full curve for the range of interest as shown in Fig. 6.40.



For the Network Bias Line:

$$V_{GS} = V_{DD} - I_D R_D$$
$$= 12\text{ V} - I_D(2\text{ k}\Omega)$$

Eq. (6.29): $V_{GS} = V_{DD} = 12\text{ V}\big|_{I_D = 0\text{ mA}}$

Eq. (6.30): $I_D = \dfrac{V_{DD}}{R_D} = \dfrac{12\text{ V}}{2\text{ k}\Omega} = 6\text{ mA}\Big|_{V_{GS} = 0\text{ V}}$

The resulting bias line appears in Fig. 6.41.

At the operating point:

$$I_{D_Q} = \mathbf{2.75\ mA}$$

and $V_{GS_Q} = 6.4\text{ V}$

with $V_{DS_Q} = V_{GS_Q} = \mathbf{6.4\ V}$

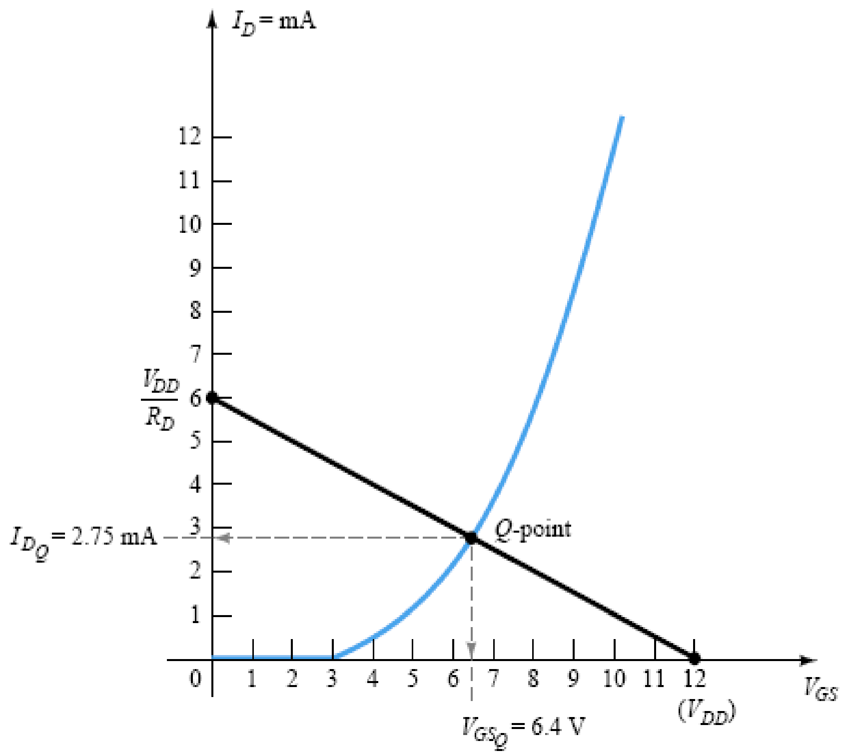


Figure 6.41 Determining the Q-point for the network of Fig. 6.39.

Determine I_{DQ}, V_{GSQ}, and V_{DS} for the network of Fig. 6.43.

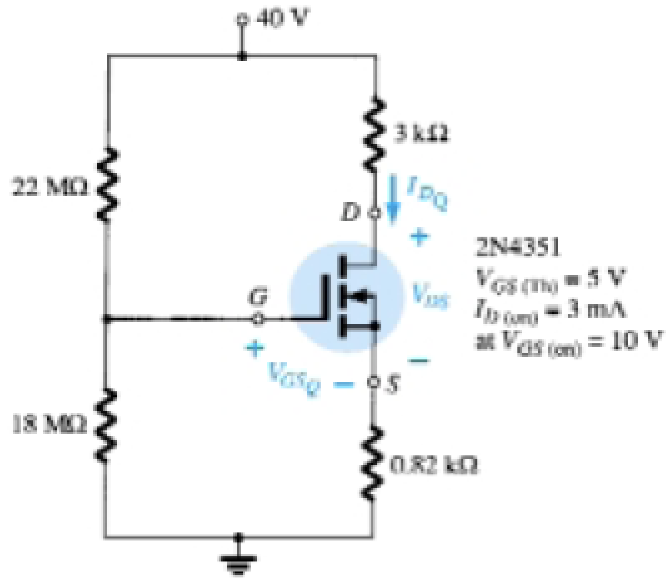


Figure 6.43 Example 6.12.

Solution

Network:

$$\text{Eq. (6.31):} \quad V_G = \frac{R_2 V_{DD}}{R_1 + R_2} = \frac{(18\ \text{M}\Omega)(40\ \text{V})}{22\ \text{M}\Omega + 18\ \text{M}\Omega} = 18\ \text{V}$$

$$\text{Eq. (6.32):} \quad V_{GS} = V_G - I_D R_S = 18\ \text{V} - I_D(0.82\ \text{k}\Omega)$$

When $I_D = 0$ mA,

$$V_{GS} = 18\ \text{V} - (0\ \text{mA})(0.82\ \text{k}\Omega) = 18\ \text{V}$$

as appearing on Fig. 6.44. When $V_{GS} = 0$ V,

$$V_{GS} = 18\ \text{V} - I_D(0.82\ \text{k}\Omega)$$

$$0 = 18\ \text{V} - I_D(0.82\ \text{k}\Omega)$$

$$I_D = \frac{18\ \text{V}}{0.82\ \text{k}\Omega} = 21.95\ \text{mA}$$

as appearing on Fig. 6.44.

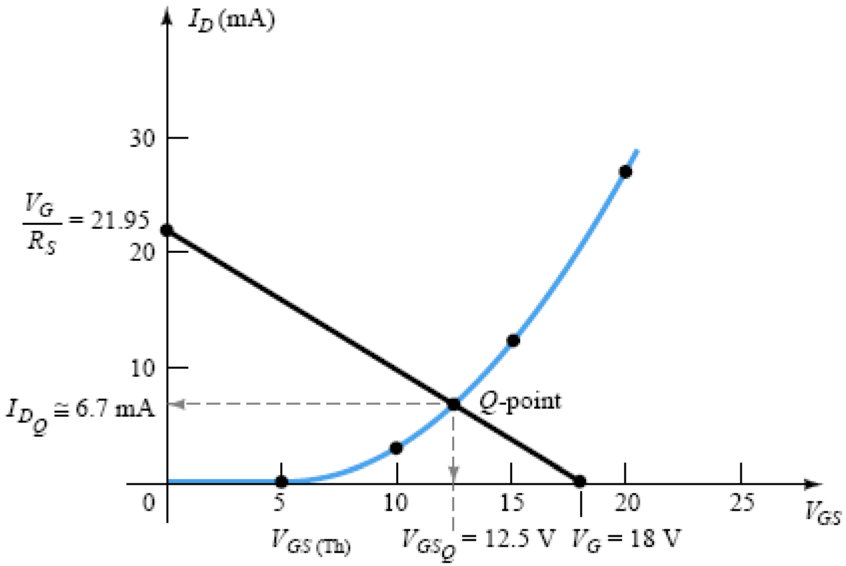


Figure 6.44 Determining the Q-point for the network of Example 6.12.

$$V_{GS(\mathrm{Th})} = 5\text{ V}, \qquad I_{D(\mathrm{on})} = 3\text{ mA with } V_{GS(\mathrm{on})} = 10\text{ V}$$

Eq. (6.26):
$$k = \frac{I_{D(\mathrm{on})}}{(V_{GS(\mathrm{on})} - V_{GS(\mathrm{Th})})^2}$$
$$= \frac{3\text{ mA}}{(10\text{ V} - 5\text{ V})^2} = 0.12 \times 10^{-3}\text{ A/V}^2$$

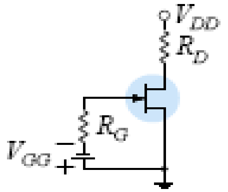
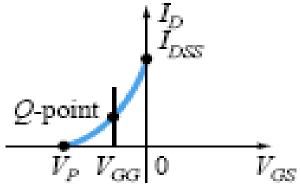
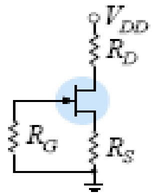
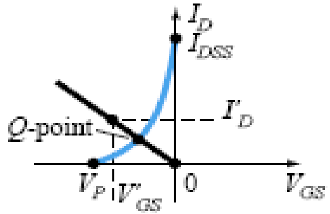
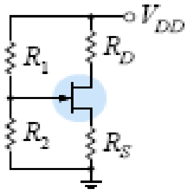
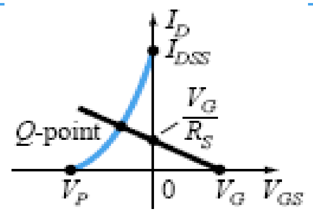
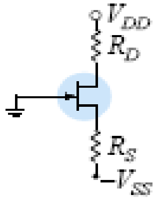
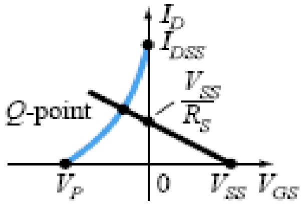
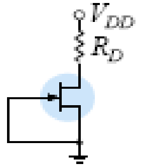
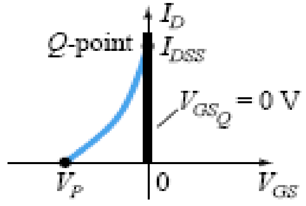
and
$$I_D = k(V_{GS} - V_{GS(\mathrm{Th})})^2$$
$$= 0.12 \times 10^{-3}(V_{GS} - 5)^2$$

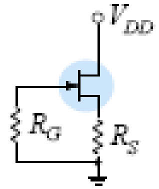
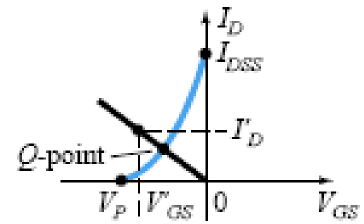
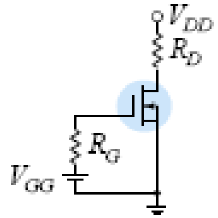
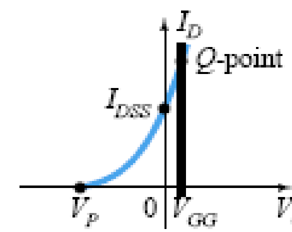
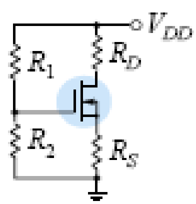
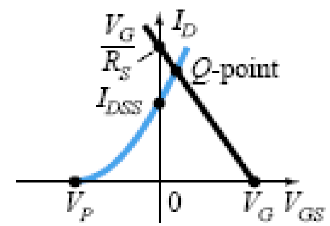
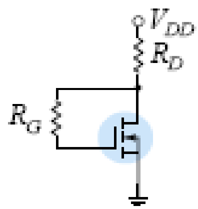
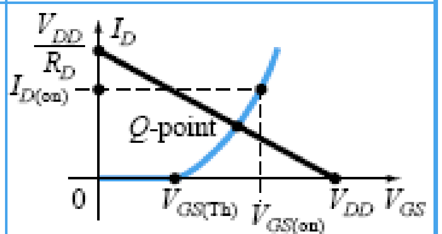
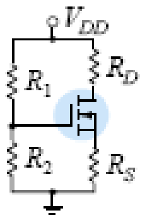
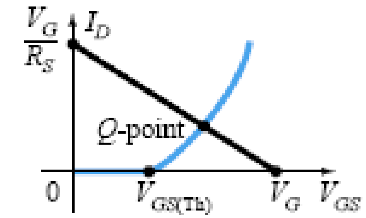
which is plotted on the same graph (Fig. 6.44). From Fig. 6.44,

$$I_{D_Q} \cong \mathbf{6.7\ mA}$$
$$V_{GS_Q} = \mathbf{12.5\ V}$$

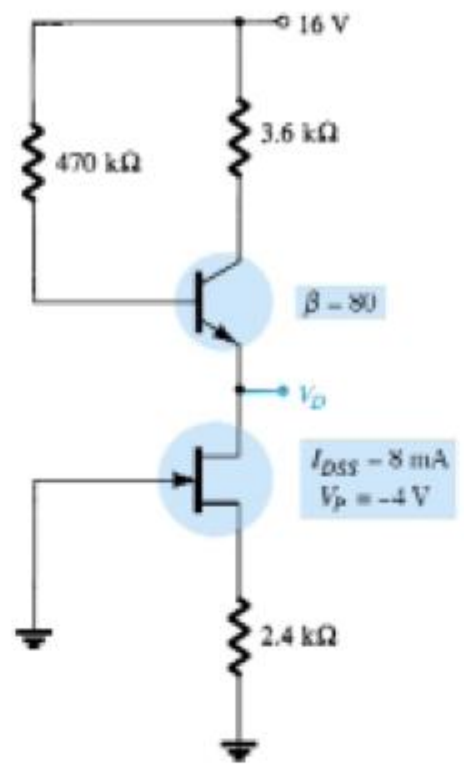
Eq. (6.33):
$$V_{DS} = V_{DD} - I_D(R_S + R_D)$$
$$= 40\text{ V} - (6.7\text{ mA})(0.82\text{ k}\Omega + 3.0\text{ k}\Omega)$$
$$= 40\text{ V} - 25.6\text{ V}$$
$$= \mathbf{14.4\ V}$$

TABLE 6.1 FET Bias Configurations

Type	*Configuration*	*Pertinent Equations*	*Graphical Solution*
JFET Fixed-bias		$V_{GS_Q} = -V_{GG}$ $V_{DS} = V_{DD} - I_D R_S$	
JFET Self-bias		$V_{GS} = -I_D R_S$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$	
JFET Voltage-divider bias		$V_G = \dfrac{R_2 V_{DD}}{R_1 + R_2}$ $V_{GS} = V_G - I_D R_S$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$	
JFET Common-gate		$V_{GS} = V_{SS} - I_D R_S$ $V_{DS} = V_{DD} + V_{SS} - I_D(R_D + R_S)$	
JFET ($V_{GS_Q} = 0$ V)		$V_{GS_Q} = 0$ V $I_{D_Q} = I_{DSS}$	

JFET ($R_D = 0\ \Omega$)		$V_{GS} = -I_D R_S$ $V_D = V_{DD}$ $V_S = I_D R_S$ $V_{DS} = V_{DD} - I_S R_S$	
Depletion-type MOSFET Fixed-bias		$V_{GS_Q} = +V_{GG}$ $V_{DS} = V_{DD} - I_D R_S$	
Depletion-type MOSFET Voltage-divider bias		$V_G = \dfrac{R_2 V_{DD}}{R_1 + R_2}$ $V_{GS} = V_G - I_S R_S$ $V_{DS} = V_{DD} - I_D(R_D + R_S)$	
Enhancement type MOSFET Feedback configuration		$V_{GS} = V_{DS}$ $V_{GS} = V_{DD} - I_D R_D$	
Enhancement- type MOSFET Voltage-divider bias		$V_G = \dfrac{R_2 V_{DD}}{R_1 + R_2}$ $V_{GS} = V_G - I_D R_S$	

Determine V_D for the network of Fig. 6.47.



Solution

In this case, there is no obvious path to determine a voltage or current level for the transistor configuration. However, turning to the self-biased JFET, an equation for V_{GS} can be derived and the resulting quiescent point determined using graphical techniques. That is,

$$V_{GS} = -I_D R_S = -I_D(2.4\ \text{k}\Omega)$$

resulting in the self-bias line appearing in Fig. 6.48 that establishes a quiescent point at

$$V_{GS_Q} = -2.6\ \text{V}$$

$$I_{D_Q} = 1\ \text{mA}$$

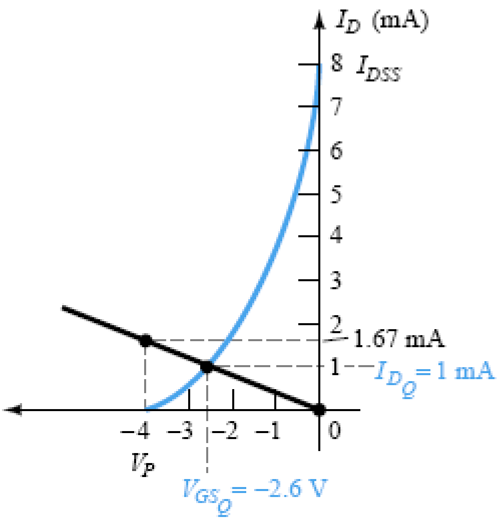


Figure 6.48 Determining the Q-point for the network of Fig. 6.47.

For the transistor,

$$I_E \cong I_C = I_D = 1\ \text{mA}$$

and

$$I_B = \frac{I_C}{\beta} = \frac{1\ \text{mA}}{80} = 12.5\ \mu\text{A}$$

$$\begin{aligned} V_B &= 16\ \text{V} - I_B(470\ \text{k}\Omega) \\ &= 16\ \text{V} - (12.5\ \mu\text{A})(470\ \text{k}\Omega) = 16\ \text{V} - 5.875\ \text{V} \\ &= 10.125\ \text{V} \end{aligned}$$

and

$$\begin{aligned} V_E = V_D &= V_B - V_{BE} \\ &= 10.125\ \text{V} - 0.7\ \text{V} \\ &= \mathbf{9.425\ V} \end{aligned}$$

EXAMPLE 6.16

For the voltage-divider bias configuration of Fig. 6.52, if $V_D = 12$ V and $V_{GS_Q} = -2$ V, determine the value of R_S.

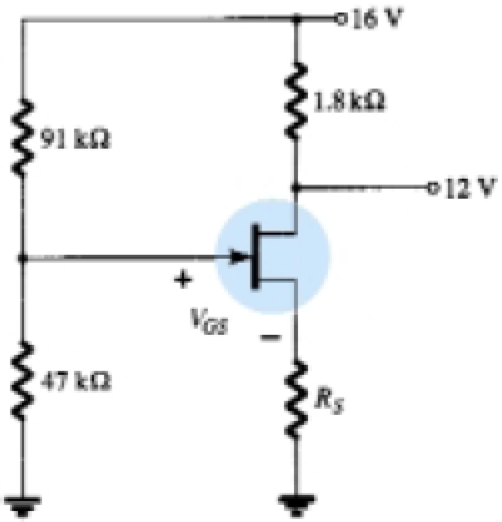


Figure 6.52 Example 6.16.

Solution

The level of V_G is determined as follows:

$$V_G = \frac{47\text{ k}\Omega(16\text{ V})}{47\text{ k}\Omega + 91\text{ k}\Omega} = 5.44\text{ V}$$

with

$$I_D = \frac{V_{DD} - V_D}{R_D}$$

$$= \frac{16\text{ V} - 12\text{ V}}{1.8\text{ k}\Omega} = 2.22\text{ mA}$$

The equation for V_{GS} is then written and the known values substituted:

$$V_{GS} = V_G - I_D R_S$$

$$-2\text{ V} = 5.44\text{ V} - (2.22\text{ mA})R_S$$

$$-7.44\text{ V} = -(2.22\text{ mA})R_S$$

and

$$R_S = \frac{7.44\text{ V}}{2.22\text{ mA}} = \mathbf{3.35\ k\Omega}$$

The nearest standard commercial value is 3.3 kΩ.

The levels of V_{DS} and I_D are specified as $V_{DS} = \frac{1}{2}V_{DD}$ and $I_D = I_{D(\text{on})}$ for the network of Fig. 6.53. Determine the level of V_{DD} and R_D.

EXAMPLE 6.17

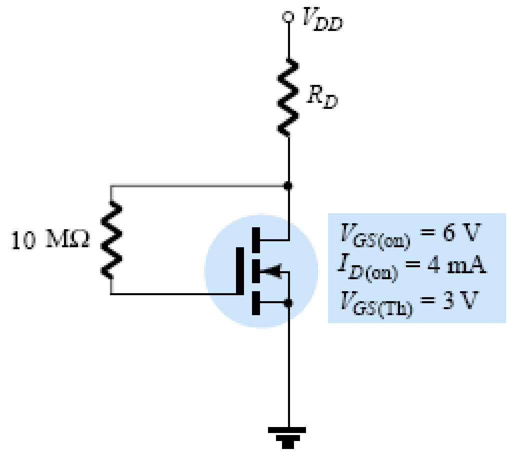


Figure 6.53 Example 6.17.

Solution

Given $I_D = I_{D(\text{on})} = 4$ mA and $V_{GS} = V_{GS(\text{on})} = 6$ V, for this configuration,

$$V_{DS} = V_{GS} = \tfrac{1}{2}V_{DD}$$

and

$$6\text{ V} = \tfrac{1}{2}V_{DD}$$

so that

$$V_{DD} = \mathbf{12\ V}$$

Applying Eq. (6.34) yields

$$R_D = \frac{V_{R_D}}{I_D} = \frac{V_{DD} - V_{DS}}{I_{D(\text{on})}} = \frac{V_{DD} - \frac{1}{2}V_{DD}}{I_{D(\text{on})}} = \frac{\frac{1}{2}V_{DD}}{I_{D(\text{on})}}$$

and

$$R_D = \frac{6\text{ V}}{4\text{ mA}} = \mathbf{1.5\ k\Omega}$$

which is a standard commercial value.

Determine I_{DQ}, V_{GSQ}, and V_{DS} for the *p*-channel JFET of Fig. 6.56.

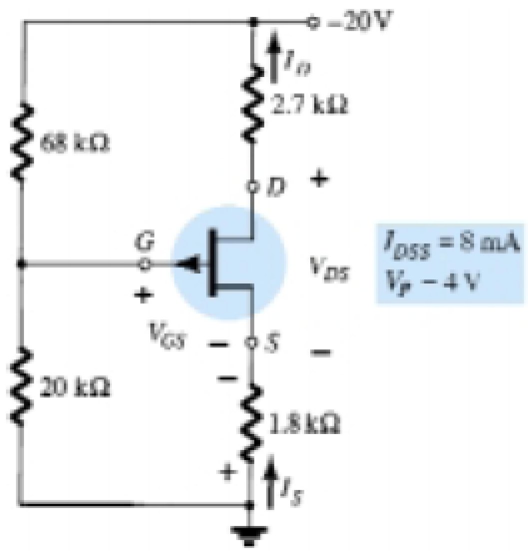


Figure 6.56 Example 6.18.

Solution

$$V_G = \frac{20\ \text{k}\Omega(-20\ \text{V})}{20\ \text{k}\Omega + 68\ \text{k}\Omega} = -4.55\ \text{V}$$

Applying Kirchhoff's voltage law gives

$$V_G - V_{GS} + I_D R_S = 0$$

and
$$V_{GS} = V_G + I_D R_S$$

Choosing $I_D = 0$ mA yields

$$V_{GS} = V_G = -4.55\ \text{V}$$

as appearing in Fig. 6.57.
Choosing $V_{GS} = 0$ V, we obtain

$$I_D = -\frac{V_G}{R_S} = -\frac{-4.55\ \text{V}}{1.8\ \text{k}\Omega} = 2.53\ \text{mA}$$

as also appearing in Fig. 6.57.
The resulting quiescent point from Fig. 6.57:

$$I_{D_Q} = \mathbf{3.4\ mA}$$

$$V_{GS_Q} = \mathbf{1.4\ V}$$

For V_{DS}, Kirchhoff's voltage law will result in

$$-I_D R_S + V_{DS} - I_D R_D + V_{DD} = 0$$

and
$$\begin{aligned} V_{DS} &= -V_{DD} + I_D(R_D + R_S) \\ &= -20\ \text{V} + (3.4\ \text{mA})(2.7\ \text{k}\Omega + 1.8\ \text{k}\Omega) \\ &= -20\ \text{V} + 15.3\ \text{V} \\ &= \mathbf{-4.7\ V} \end{aligned}$$