

Electronic Circuits

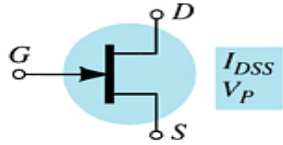
Elektronik Devreler

Dr. Gökhan Bilgin

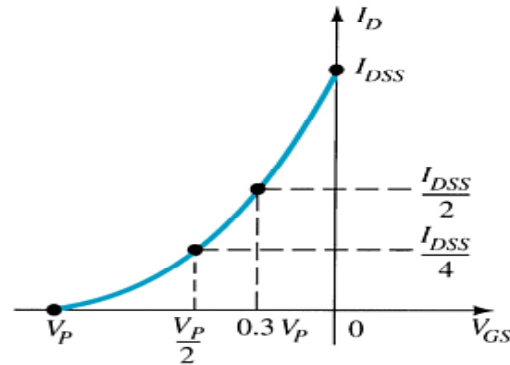
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Electronic Circuits Questions

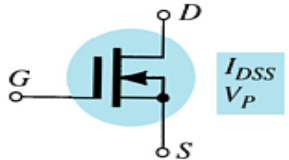
$$I_G = 0 \text{ A}, I_D = I_S$$



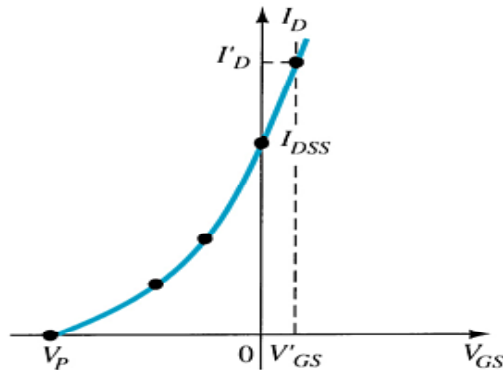
$$I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$$



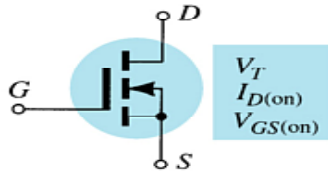
$$I_G = 0 \text{ A}, I_D = I_S$$



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

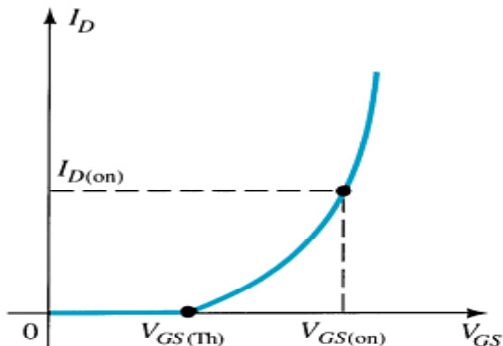


$$I_G = 0 \text{ A}, I_D = I_S$$



$$I_D = k (V_{GS} - V_{GS(Th)})^2$$

$$k = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(Th)})^2}$$



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

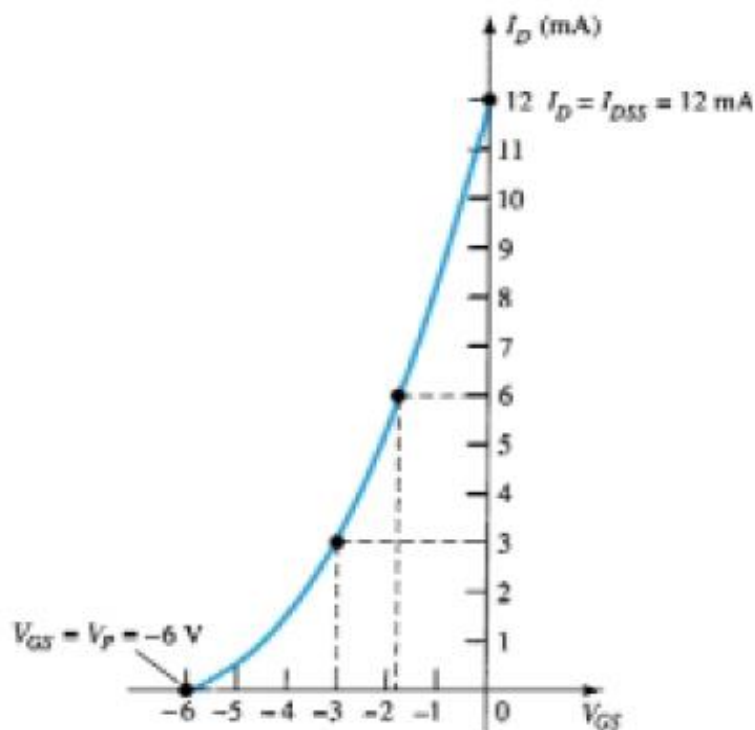
Solution

Two plot points are defined by

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

and $I_D = 0 \text{ mA} \quad \text{and} \quad V_{GS} = V_P$

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



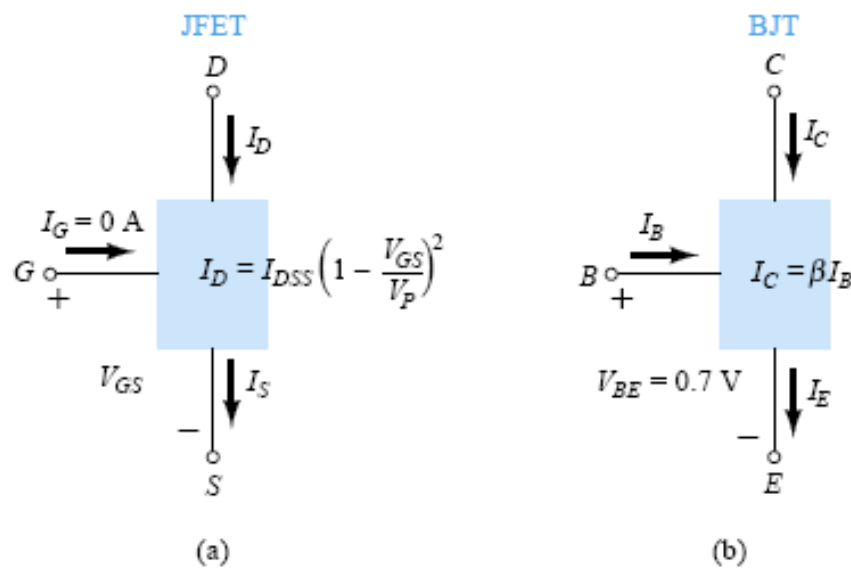


Figure 5.22 (a) JFET versus (b) BJT.

<i>JFET</i>		<i>BJT</i>
$I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P} \right)^2$	\Leftrightarrow	$I_C = \beta I_B$
$I_D = I_S$	\Leftrightarrow	$I_C \cong I_E$
$I_G \cong 0 \text{ A}$	\Leftrightarrow	$V_{BE} \cong 0.7 \text{ V}$

(5.10)

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

Solution

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

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

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

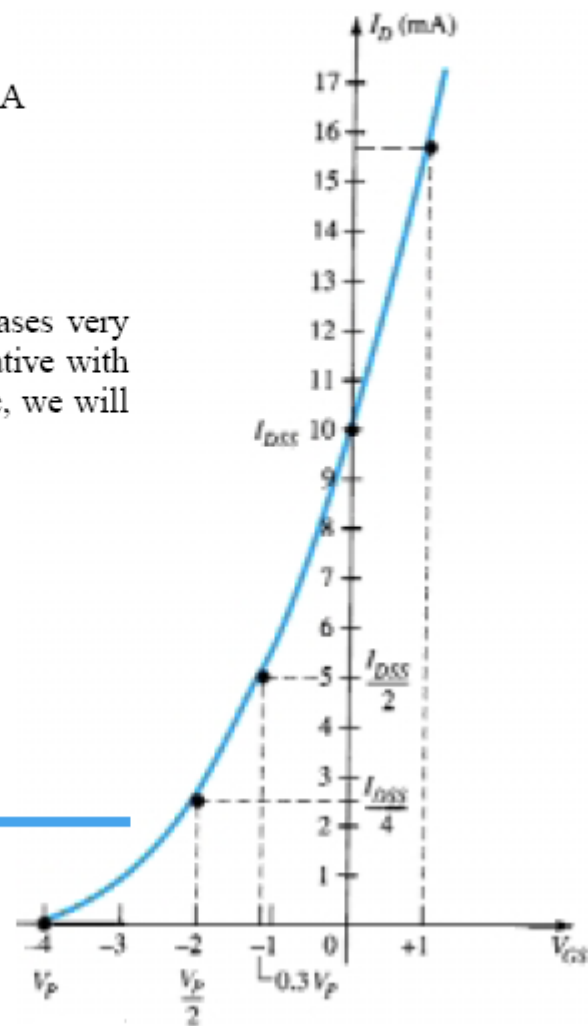
$$\text{and at } I_D = \frac{I_{DSS}}{2}, \quad V_{GS} = 0.3V_P = 0.3(-4 \text{ V}) = -1.2 \text{ V}$$

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 $+1 \text{ V}$ as follows:

$$\begin{aligned} I_D &= I_{DSS} \left(1 - \frac{V_{GS}}{V_P} \right)^2 \\ &= 10 \text{ mA} \left(1 - \frac{+1 \text{ V}}{-4 \text{ V}} \right)^2 = 10 \text{ mA} (1 + 0.25)^2 = 10 \text{ mA} (1.5625) \\ &\cong 15.63 \text{ mA} \end{aligned}$$

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 $V_{GS(Th)} = 3$ V, determine:

- (a) The resulting value of k for the MOSFET.
- (b) The transfer characteristics.

Solution

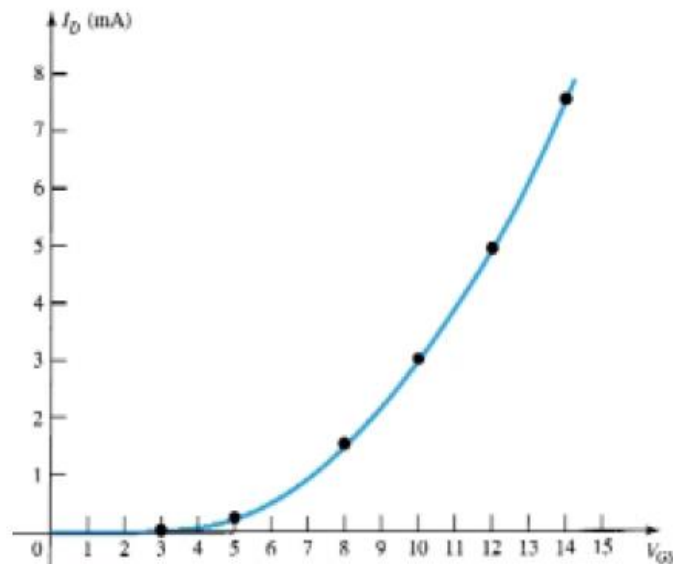
(a) Eq. (5.14):
$$k = \frac{I_{D(on)}}{(V_{GS(on)} - V_{GS(Th)})^2}$$
$$= \frac{3 \text{ mA}}{(10 \text{ V} - 3 \text{ V})^2} = \frac{3 \text{ mA}}{(7 \text{ V})^2} = \frac{3 \times 10^{-3}}{49} \text{ A/V}^2$$
$$= 0.061 \times 10^{-3} \text{ A/V}^2$$

(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,

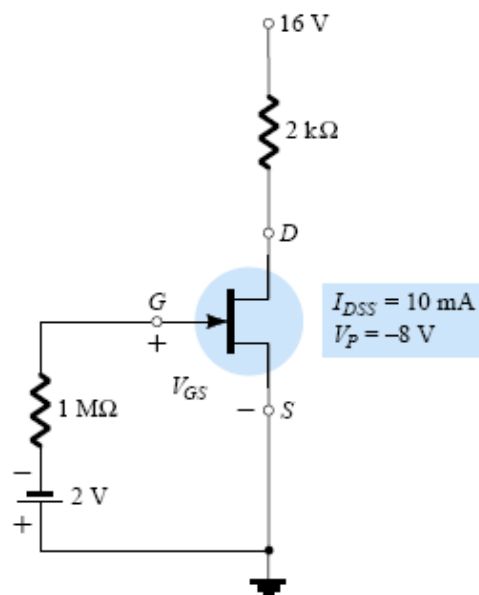
$$I_D = 0.061 \times 10^{-3}(5 \text{ V} - 3 \text{ V})^2 = 0.061 \times 10^{-3}(2)^2$$
$$= 0.061 \times 10^{-3}(4) = 0.244 \text{ mA}$$

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_{GSQ} .
- (b) I_{DQ} .
- (c) V_{DS} .
- (d) V_D .
- (e) V_G .
- (f) V_S .



Solution

Mathematical Approach:

$$(a) \ V_{GSQ} = -V_{GG} = -2 \text{ V}$$

$$\begin{aligned} (b) \ I_{DQ} &= I_{DSS} \left(1 - \frac{V_{GS}}{V_P} \right)^2 = 10 \text{ mA} \left(1 - \frac{-2 \text{ V}}{-8 \text{ V}} \right)^2 \\ &= 10 \text{ mA} (1 - 0.25)^2 = 10 \text{ mA} (0.75)^2 = 10 \text{ mA} (0.5625) \\ &= \mathbf{5.625 \text{ mA}} \end{aligned}$$

$$\begin{aligned} (c) \ V_{DS} &= V_{DD} - I_D R_D = 16 \text{ V} - (5.625 \text{ mA})(2 \text{ k}\Omega) \\ &= 16 \text{ V} - 11.25 \text{ V} = \mathbf{4.75 \text{ V}} \end{aligned}$$

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

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

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

Determine the following for the network of Fig. 6.24.

- (a) I_{DQ} and V_{GSQ} .
- (b) V_D .
- (c) V_S .
- (d) V_{DS} .
- (e) V_{DG} .

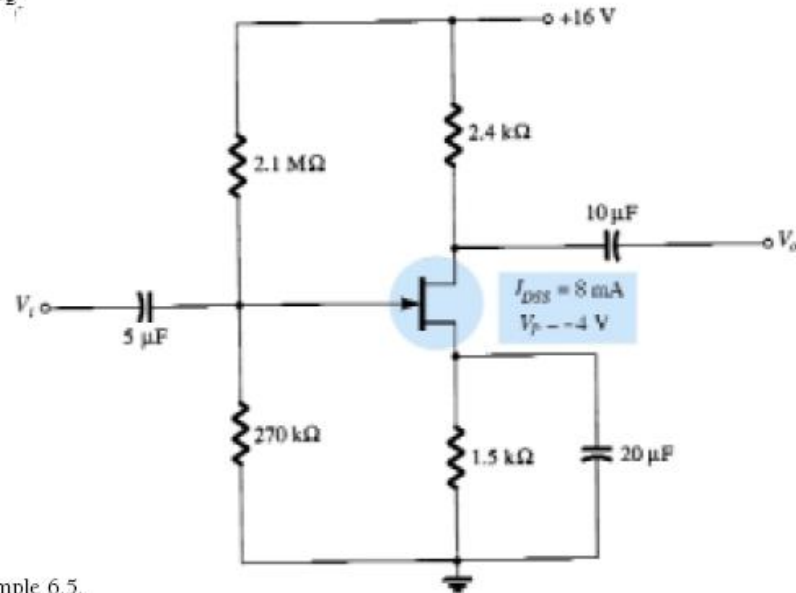


Figure 6.24 Example 6.5.

- (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

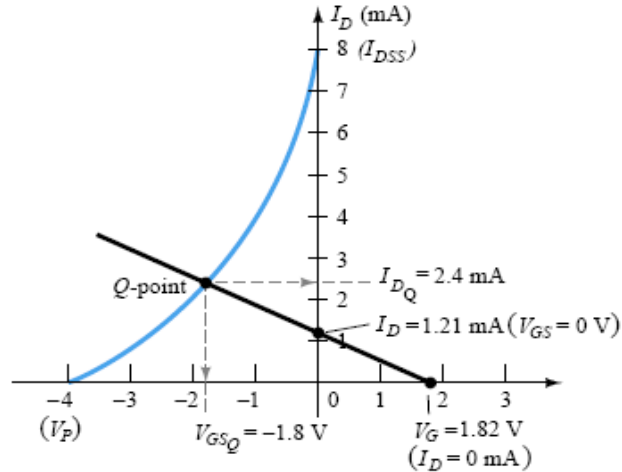
$$\begin{aligned} V_G &= \frac{R_2 V_{DD}}{R_1 + R_2} \\ &= \frac{(270 \text{ k}\Omega)(16 \text{ V})}{2.1 \text{ M}\Omega + 0.27 \text{ M}\Omega} \\ &= 1.82 \text{ V} \end{aligned}$$

and

$$\begin{aligned} V_{GS} &= V_G - I_D R_S \\ &= 1.82 \text{ V} - I_D(1.5 \text{ k}\Omega) \end{aligned}$$

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

$$I_{DQ} = 2.4 \text{ mA}$$

and

$$V_{GSQ} = -1.8 \text{ V}$$

$$\begin{aligned} \text{(b) } V_D &= V_{DD} - I_D R_D \\ &= 16 \text{ V} - (2.4 \text{ mA})(2.4 \text{ k}\Omega) \\ &= \mathbf{10.24 \text{ V}} \end{aligned}$$

$$\begin{aligned} \text{(c) } V_S &= I_D R_S = (2.4 \text{ mA})(1.5 \text{ k}\Omega) \\ &= \mathbf{3.6 \text{ V}} \end{aligned}$$

$$\begin{aligned} \text{(d) } V_{DS} &= V_{DD} - I_D(R_D + R_S) \\ &= 16 \text{ V} - (2.4 \text{ mA})(2.4 \text{ k}\Omega + 1.5 \text{ k}\Omega) \\ &= \mathbf{6.64 \text{ V}} \end{aligned}$$

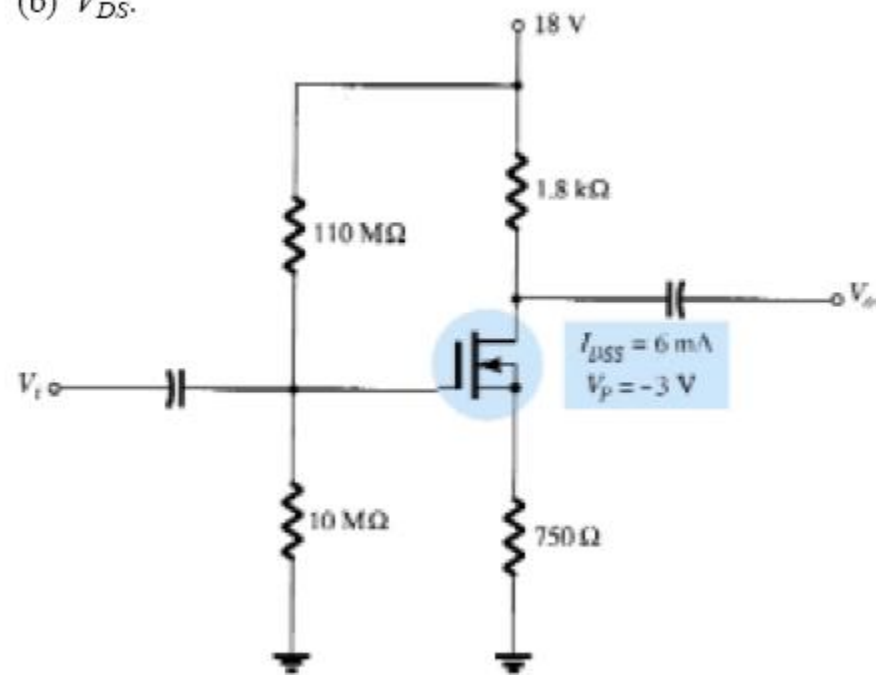
$$\begin{aligned} \text{or } V_{DS} &= V_D - V_S = 10.24 \text{ V} - 3.6 \text{ V} \\ &= \mathbf{6.64 \text{ V}} \end{aligned}$$

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

$$\begin{aligned} V_{DG} &= V_D - V_G \\ &= 10.24 \text{ V} - 1.82 \text{ V} \\ &= \mathbf{8.42 \text{ V}} \end{aligned}$$

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

$$\begin{aligned} I_D &= I_{DSS} \left(1 - \frac{V_{GS}}{V_P} \right)^2 \\ &= 6 \text{ mA} \left(1 - \frac{+1 \text{ V}}{-3 \text{ V}} \right)^2 = 6 \text{ mA} \left(1 + \frac{1}{3} \right)^2 = 6 \text{ mA}(1.778) \\ &= 10.67 \text{ mA} \end{aligned}$$

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

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

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

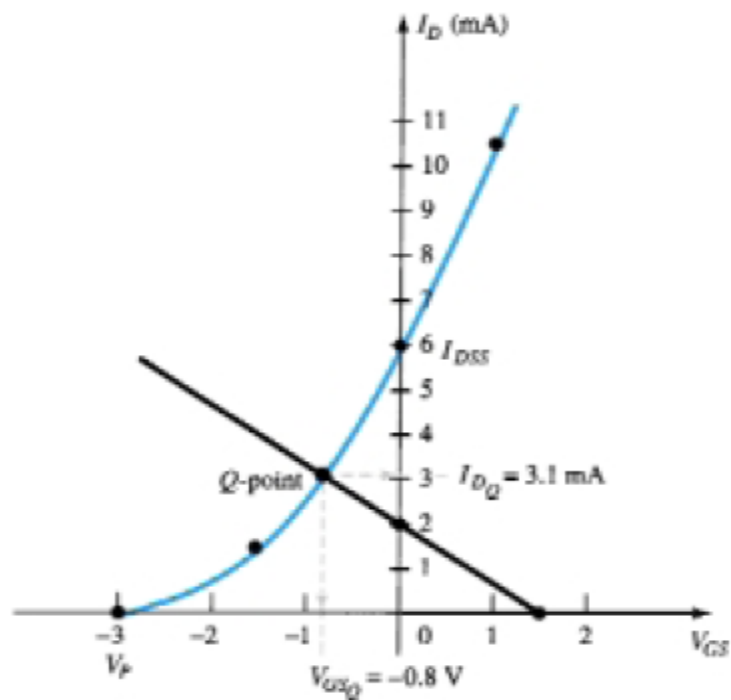


Figure 6.30 Determining the Q -point for the network of Fig. 6.29.

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:

$$I_{DQ} = 3.1 \text{ mA}$$

$$V_{GSQ} = -0.8 \text{ V}$$

$$\begin{aligned} \text{(b) Eq. (6.19): } V_{DS} &= V_{DD} - I_D(R_D + R_S) \\ &= 18 \text{ V} - (3.1 \text{ mA})(1.8 \text{ k}\Omega + 750 \Omega) \\ &\cong 10.1 \text{ V} \end{aligned}$$

Determine the following for the network of Fig. 6.32.

- (a) I_{DQ} and V_{GSQ} .
 (b) V_D .

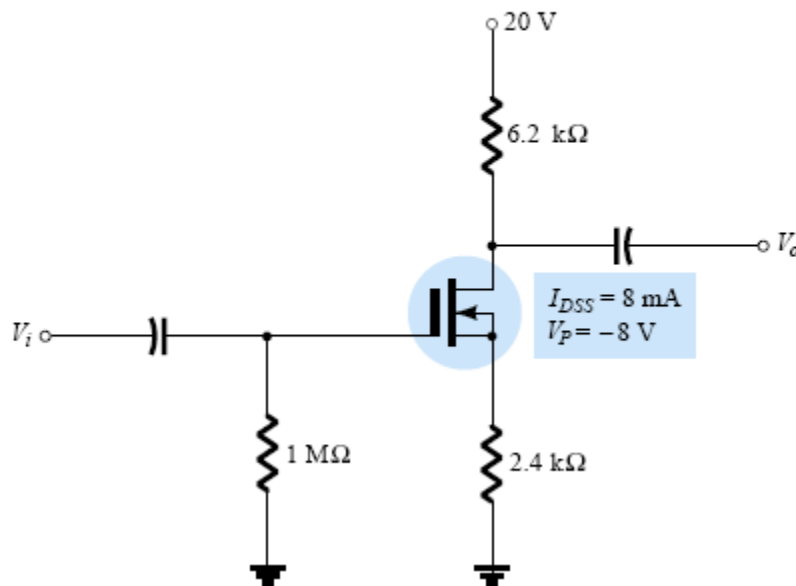


Figure 6.32 Example 6.9.

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 $V_{GS} < 0\text{ V}$ 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 $V_{GS} = 0 \text{ V}$, $I_D = 0 \text{ mA}$. Choosing $V_{GS} = -6 \text{ V}$ gives

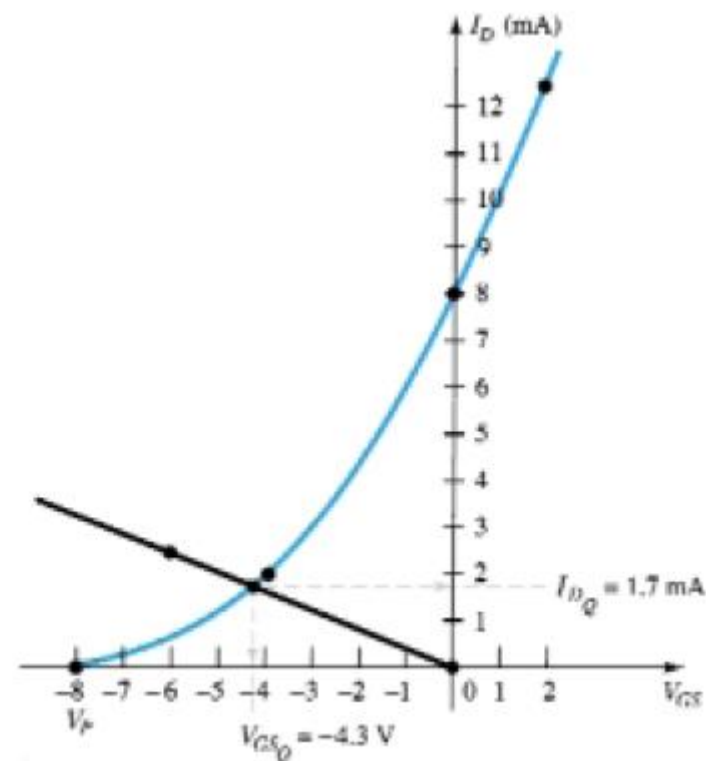
$$I_D = -\frac{V_{GS}}{R_S} = -\frac{-6 \text{ V}}{2.4 \text{ k}\Omega} = 2.5 \text{ mA}$$

The resulting Q -point:

$$I_{DQ} = 1.7 \text{ mA}$$

$$V_{GSQ} = -4.3 \text{ V}$$

(b) $V_D = V_{DD} - I_D R_D$
 $= 20 \text{ V} - (1.7 \text{ mA})(6.2 \text{ k}\Omega)$
 $= 9.46 \text{ V}$



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,

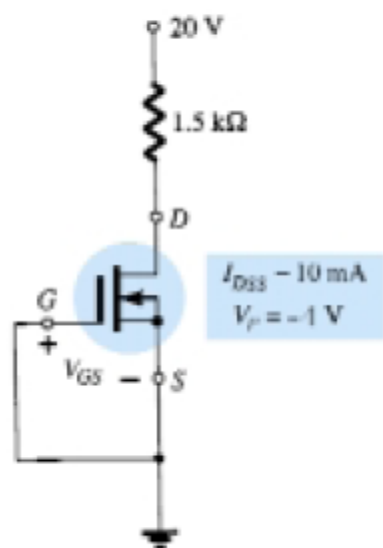
$$V_{GSQ} = 0 \text{ V}$$

and

$$I_{DQ} = 10 \text{ mA}$$

There is therefore no need to draw the transfer curve and

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



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

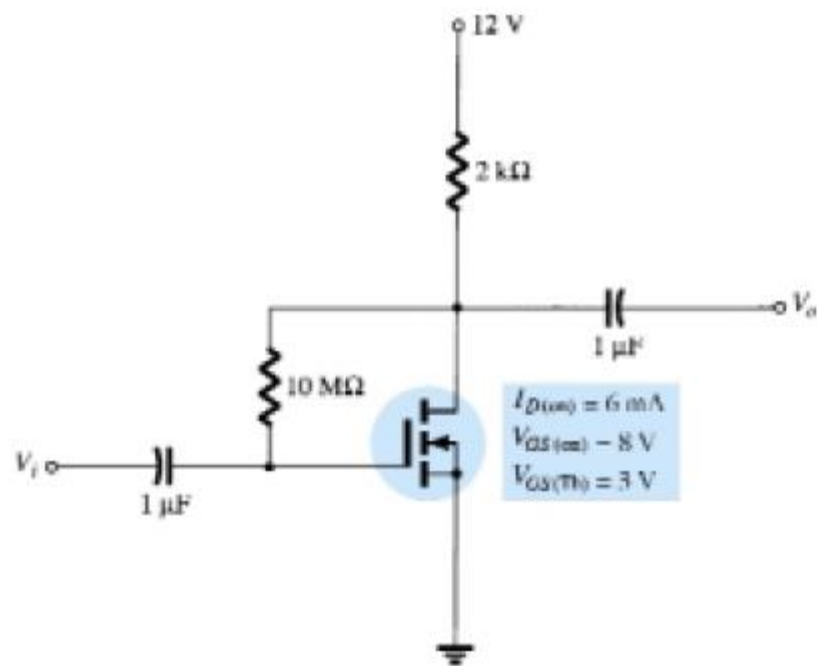


Figure 6.39 Example 6.11.

Solution

Plotting the Transfer Curve:

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

$$\begin{aligned}\text{Eq. (6.26): } k &= \frac{I_{D(\text{on})}}{(V_{GS(\text{on})} - V_{GS(\text{Th})})^2} \\ &= \frac{6 \text{ mA}}{(8 \text{ V} - 3 \text{ V})^2} = \frac{6 \times 10^{-3}}{25} \text{ A/V}^2 \\ &= 0.24 \times 10^{-3} \text{ A/V}^2\end{aligned}$$

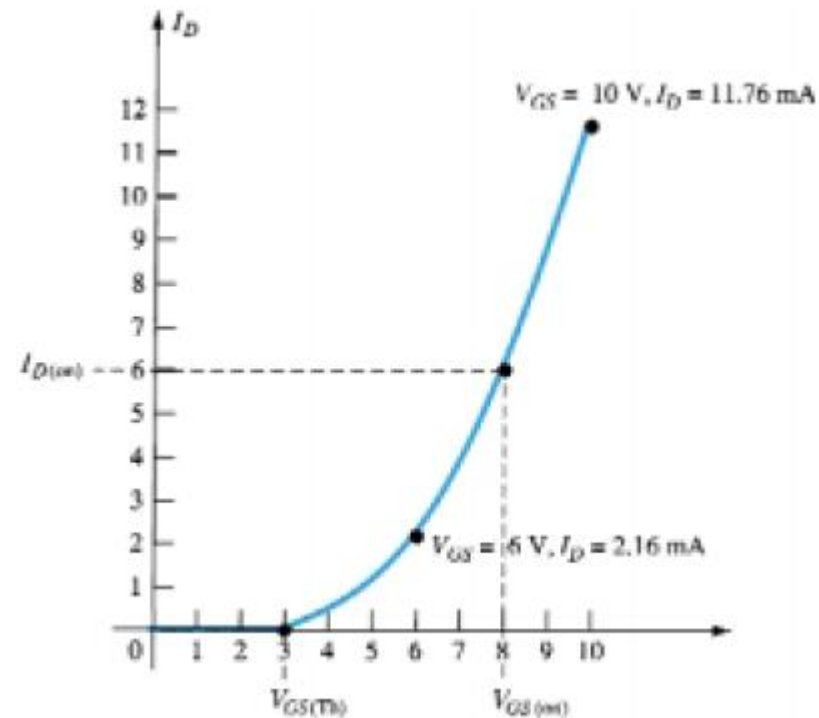
For $V_{GS} = 6 \text{ V}$ (between 3 and 8 V):

$$\begin{aligned}I_D &= 0.24 \times 10^{-3}(6 \text{ V} - 3 \text{ V})^2 = 0.24 \times 10^{-3}(9) \\ &= 2.16 \text{ mA}\end{aligned}$$

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

$$\begin{aligned}I_D &= 0.24 \times 10^{-3}(10 \text{ V} - 3 \text{ V})^2 = 0.24 \times 10^{-3}(49) \\ &= 11.76 \text{ mA}\end{aligned}$$

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:

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

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

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

The resulting bias line appears in Fig. 6.41.

At the operating point:

$$I_{DQ} = 2.75 \text{ mA}$$

and

$$V_{GSQ} = 6.4 \text{ V}$$

with

$$V_{DSQ} = V_{GSQ} = 6.4 \text{ V}$$

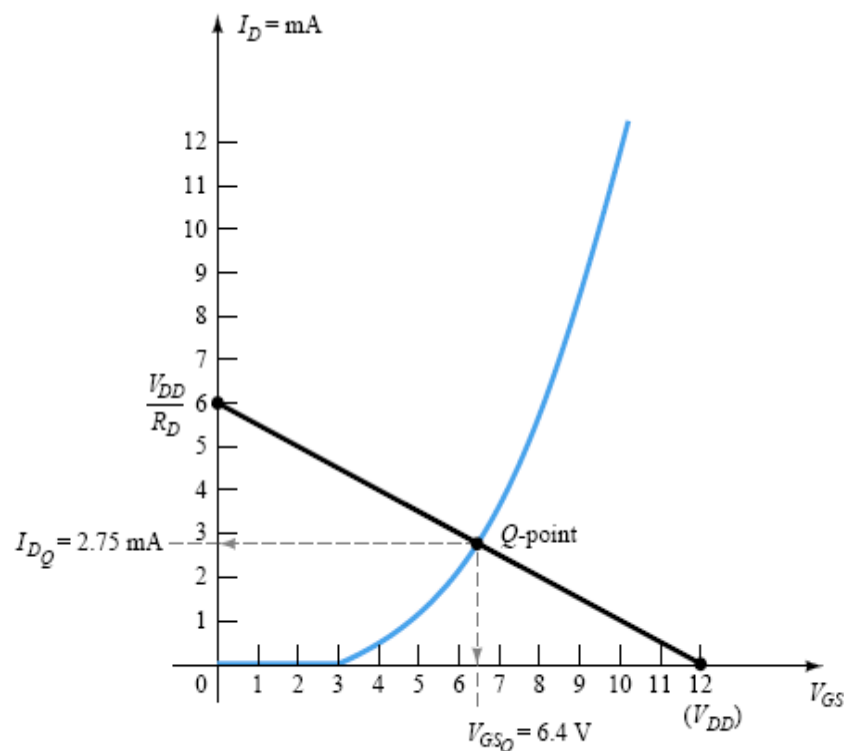


Figure 6.41 Determining the Q -point for the network of Fig. 6.39.

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

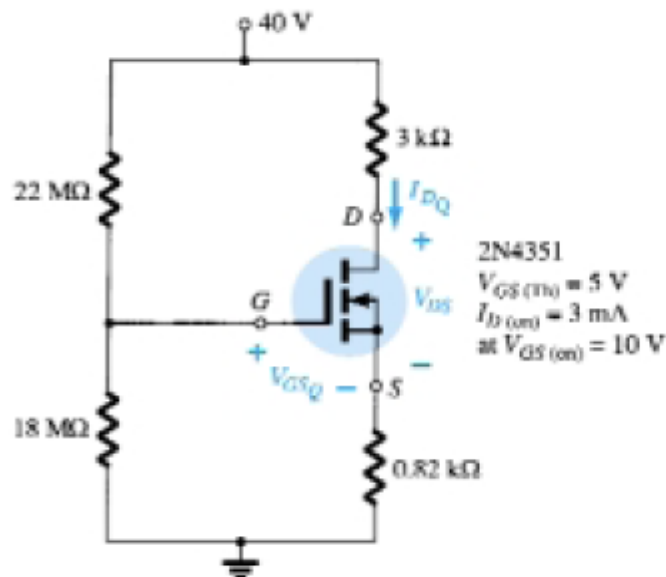


Figure 6.43 Example 6.12.

Solution

Network:

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

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

When $I_D = 0 \text{ mA}$,

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

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

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

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

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

as appearing on Fig. 6.44.

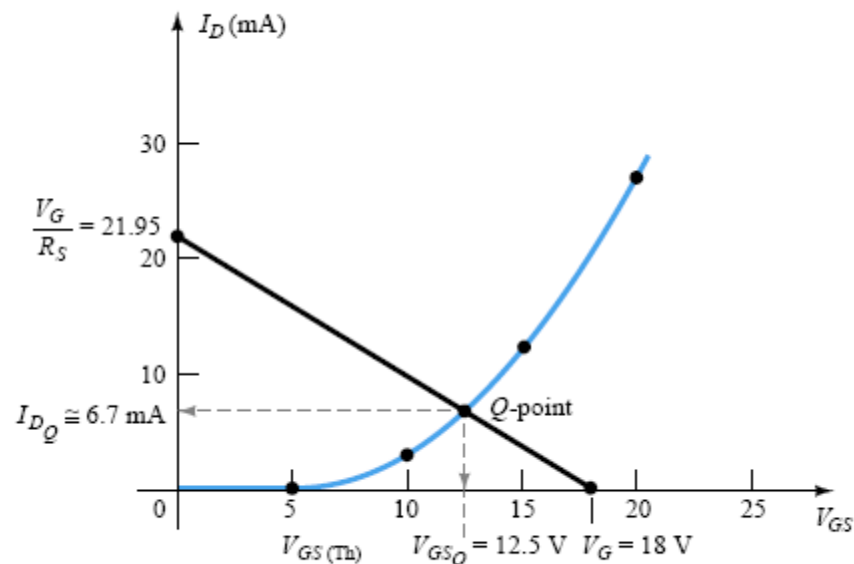


Figure 6.44 Determining the Q -point for the network of Example 6.12.

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

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

and

$$\begin{aligned} I_D &= k(V_{GS} - V_{GS(\text{Th})})^2 \\ &= 0.12 \times 10^{-3}(V_{GS} - 5)^2 \end{aligned}$$

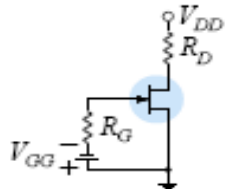
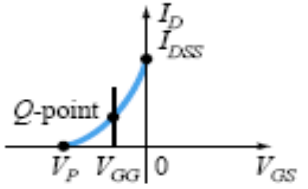
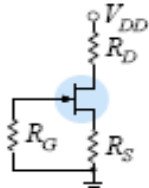
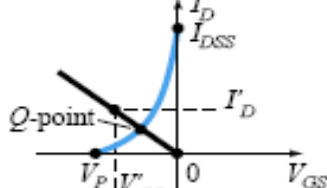
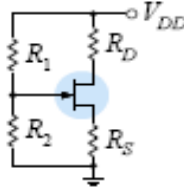
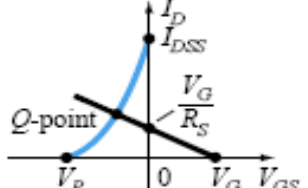
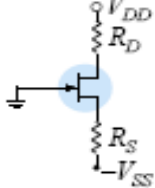
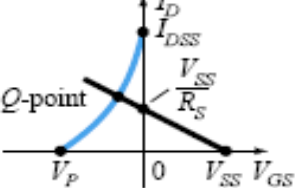
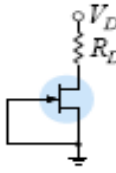

which is plotted on the same graph (Fig. 6.44). From Fig. 6.44,

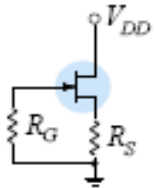
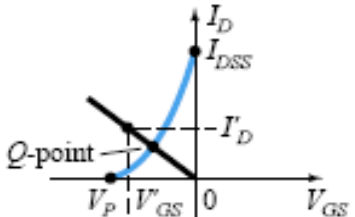
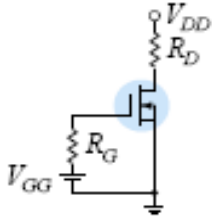
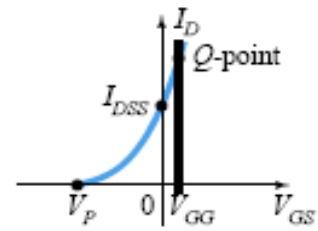
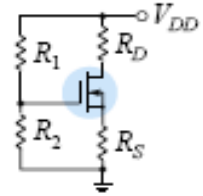
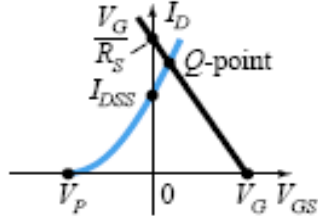
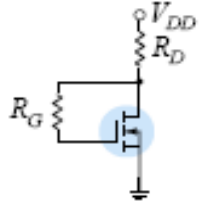
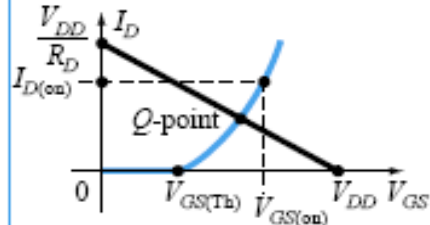
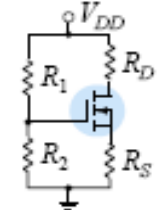
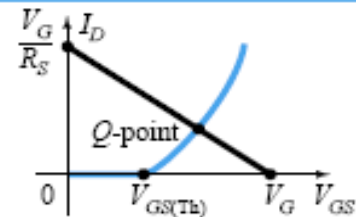
$$I_{DQ} \cong 6.7 \text{ mA}$$

$$V_{GSQ} = 12.5 \text{ V}$$

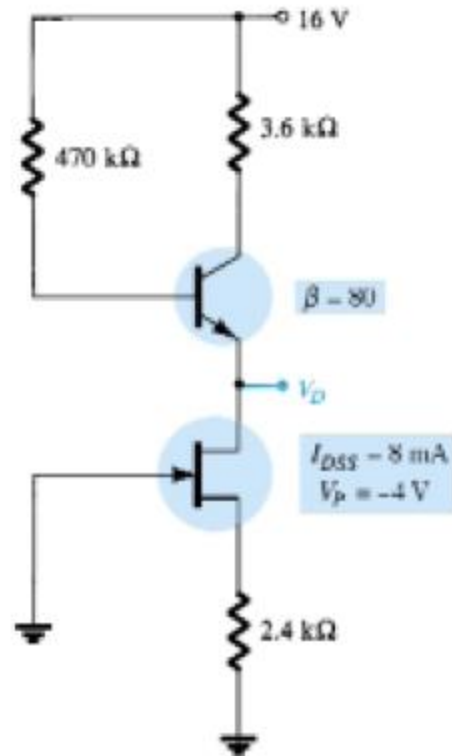
$$\begin{aligned} \text{Eq. (6.33): } V_{DS} &= V_{DD} - I_D(R_S + R_D) \\ &= 40 \text{ V} - (6.7 \text{ mA})(0.82 \text{ k}\Omega + 3.0 \text{ k}\Omega) \\ &= 40 \text{ V} - 25.6 \text{ V} \\ &= 14.4 \text{ V} \end{aligned}$$

TABLE 6.1 FET Bias Configurations

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

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

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

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

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

For the transistor,

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

and

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

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

and

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

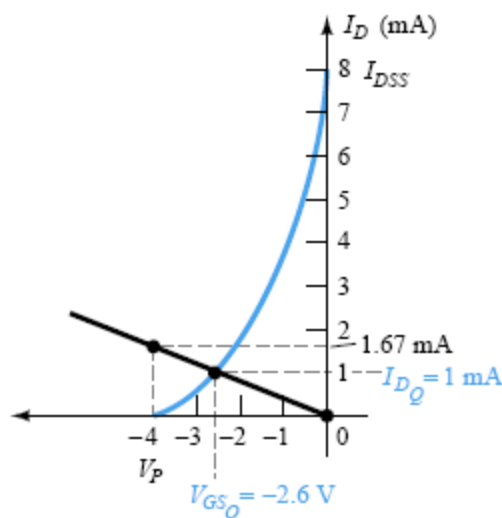


Figure 6.48 Determining the Q -point for the network of Fig. 6.47.

EXAMPLE 6.16

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

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

$$\begin{aligned} I_D &= \frac{V_{DD} - V_D}{R_D} \\ &= \frac{16\text{ V} - 12\text{ V}}{1.8\text{ k}\Omega} = 2.22\text{ mA} \end{aligned}$$

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

$$\begin{aligned} V_{GS} &= V_G - I_D R_S \\ -2\text{ V} &= 5.44\text{ V} - (2.22\text{ mA})R_S \\ -7.44\text{ V} &= -(2.22\text{ mA})R_S \end{aligned}$$

and

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

The nearest standard commercial value is $3.3\text{ k}\Omega$.

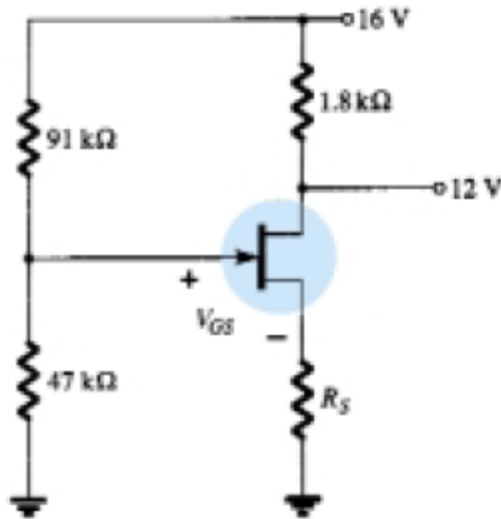


Figure 6.52 Example 6.16.

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

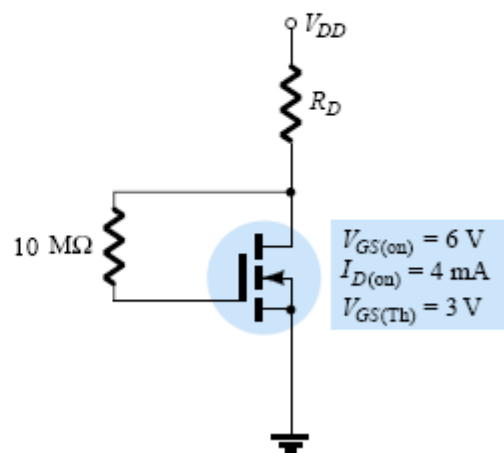


Figure 6.53 Example 6.17.

Solution

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

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

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

so that $V_{DD} = 12 \text{ V}$

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

which is a standard commercial value.

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

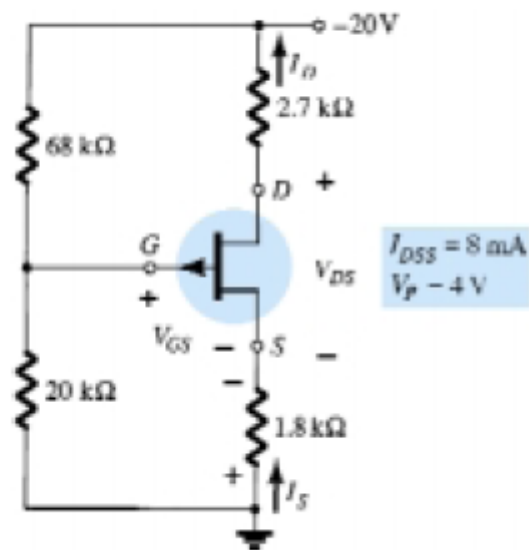


Figure 6.56 Example 6.18.

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 $I_D = 0 \text{ mA}$ yields

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

as appearing in Fig. 6.57.

Choosing $V_{GS} = 0 \text{ V}$, 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:

$$I_{DQ} = 3.4 \text{ mA}$$

$$V_{GSQ} = 1.4 \text{ V}$$

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

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

and

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

