FIELD EFFECT TRANSISTOR (FET)

PREPARED BY-

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SHORTHAND METHOD

If we specify V_{GS} to be one-half the pinch-off value V_P,

$$
\begin{aligned}
I_D &= I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \\
&= I_{DSS}\left(\frac{1 - V_P/2}{V_P}\right)^2 = I_{DSS}\left(1 - \frac{1}{2}\right)^2 = I_{DSS}(0.5)^2 \\
&= I_{DSS}(0.25)
\end{aligned}
$$

and

$$\boxed{I_D = \frac{I_{DSS}}{4}\bigg|_{V_{GS}=V_P/2}}$$

If we choose $I_D = I_{DSS}/2$

$$
\begin{aligned}
V_{GS} &= V_P\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right) \\
&= V_P\left(1 - \sqrt{\frac{I_{DSS}/2}{I_{DSS}}}\right) = V_P(1 - \sqrt{0.5}) = V_P(0.293)
\end{aligned}
$$

and

$$\boxed{V_{GS} \cong 0.3V_P|_{I_D=I_{DSS}/2}}$$

V_{GS} Versus I_D Using Shockley's Equation

V_{GS}	I_D
0	I_{DSS}
$0.3V_P$	$I_{DSS}/2$
$0.5V_P$	$I_{DSS}/4$
V_P	0 mA

SHORTHAND METHOD

EXAMPLE 6.1 Sketch the transfer curve defined by $I_{DSS} = 12\text{ mA}$ and $V_P = -6\text{ V}$.

Solution: Two plot points are defined by

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

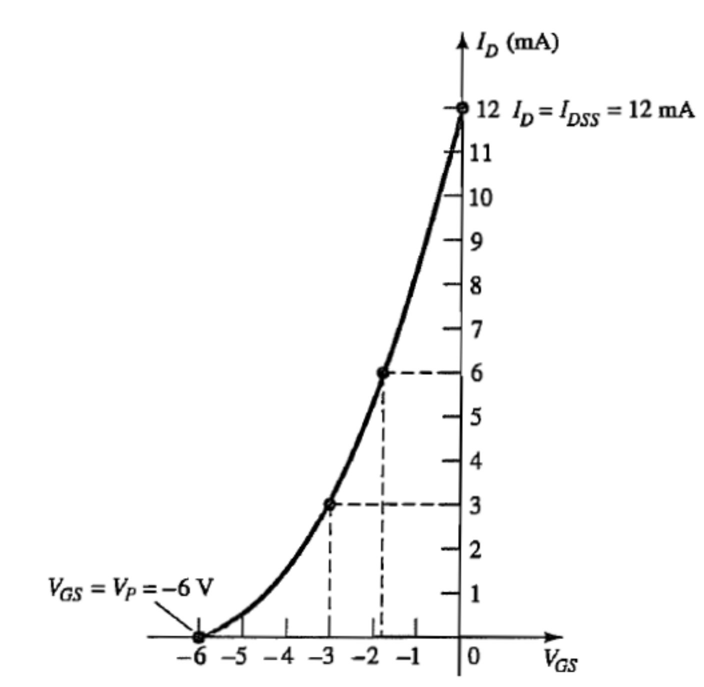
and

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

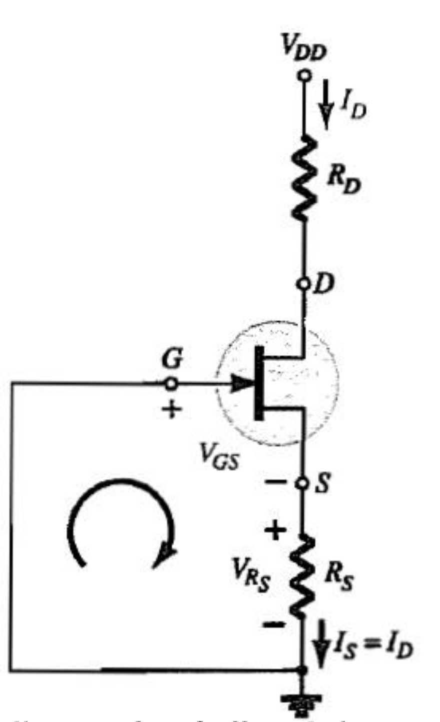
At $V_{GS} = V_P/2 = -6\text{ V}/2 = \mathbf{-3\text{ V}}$ the drain current is determined by $I_D = I_{DSS}/4 = 12\text{ mA}/4 = \mathbf{3\text{ mA}}$. At $I_D = I_{DSS}/2 = 12\text{ mA}/2 = \mathbf{6\text{ mA}}$ the gate-to-source voltage is determined by $V_{GS} \cong 0.3V_P = 0.3(-6\text{ V}) = \mathbf{-1.8\text{ V}}$. All four plot points are well defined on Fig. 6.18 with the complete transfer curve.

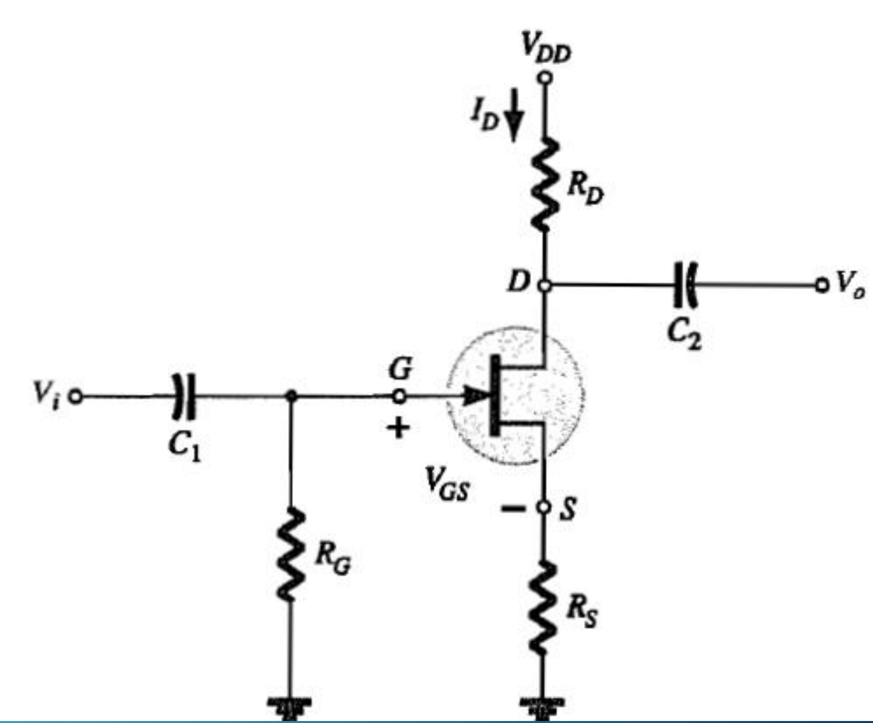
V_{GS} Versus I_D Using Shockley's Equation

V_{GS}	I_D
0	I_{DSS}
$0.3V_P$	$I_{DSS}/2$
$0.5V_P$	$I_{DSS}/4$
V_P	0 mA



FET BIASING (SELF BIAS CONFIGURATION)





For the dc analysis, the capacitors can again be replaced by "open circuits" and the resistor R_G replaced by a short-circuit equivalent since $I_G = 0$ A. The result is the network of Fig. 7.9 for the important dc analysis.

The current through R_S is the source current I_S, but $I_S = I_D$ and

$$V_{R_S} = I_D R_S$$

For the indicated closed loop of Fig. 7.9, we find that

$$-V_{GS} - V_{R_S} = 0$$

and

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

or

$$\boxed{V_{GS} = -I_D R_S} \qquad (7.10)$$

FET BIASING (SELF BIAS CONFIGURATION)

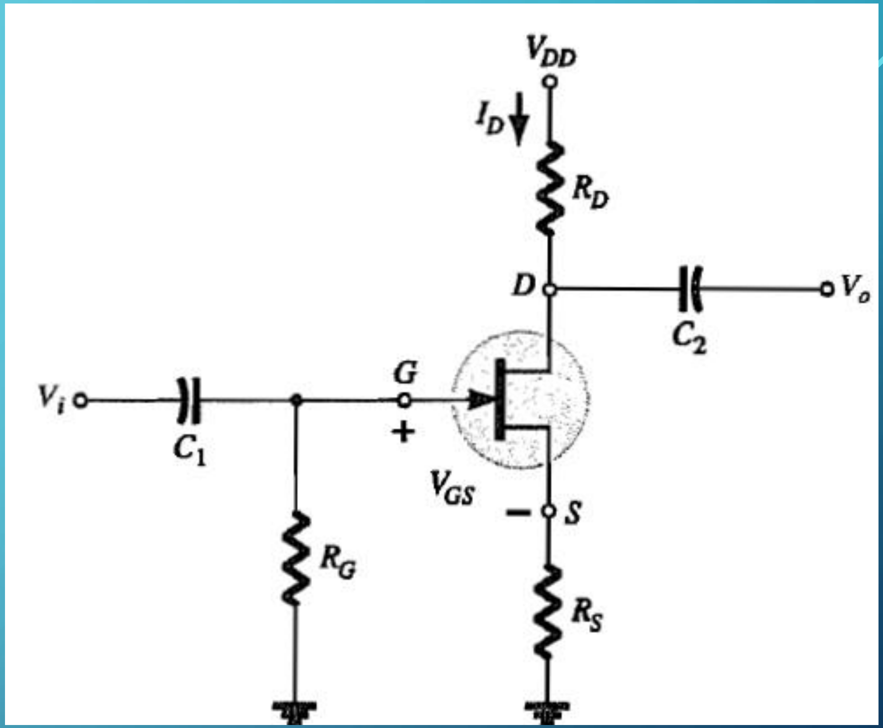
$$I_D = I_S$$

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

$$\boxed{V_S = I_D R_S}$$

$$\boxed{V_G = 0\,\text{V}}$$

$$\boxed{V_D = V_{DS} + V_S = V_{DD} - V_{R_D}}$$



FET BIASING (SELF BIAS CONFIGURATION)

a. The gate-to-source voltage is determined by

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

Choosing $I_D = 4$ mA, we obtain

$$V_{GS} = -(4\text{ mA})(1\text{ k}\Omega) = -4\text{ V}$$

The result is the plot of Fig. 7.13 as defined by the network.

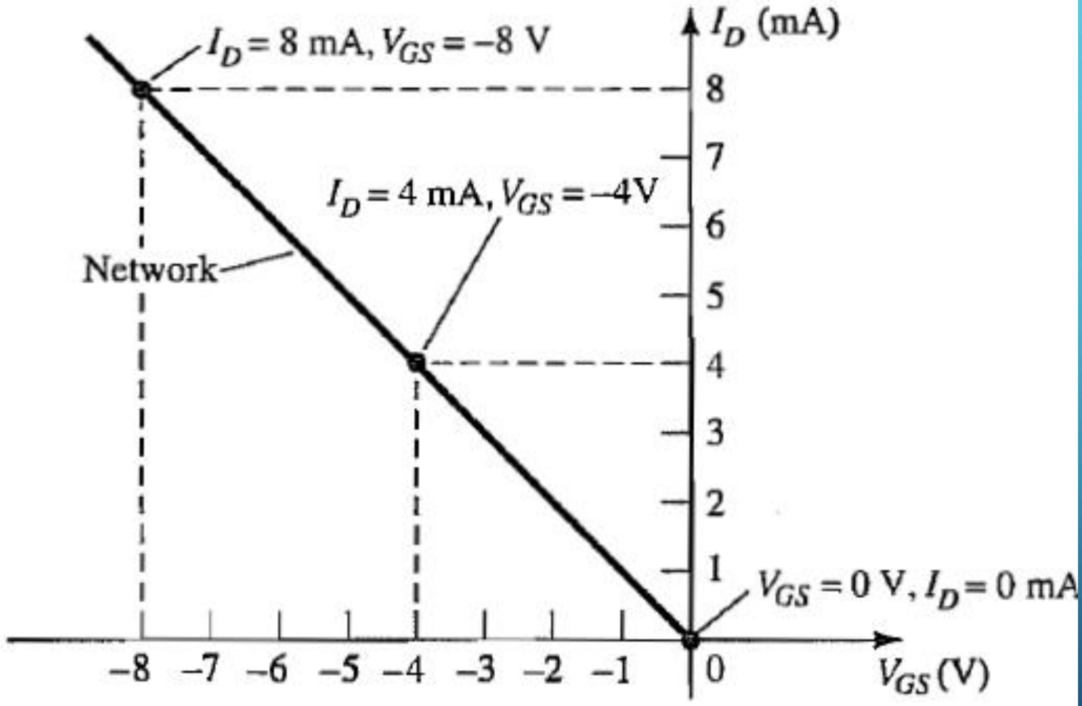


FIG. 7.13

EXAMPLE 7.2 Determine the following for the network of Fig. 7.12:

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

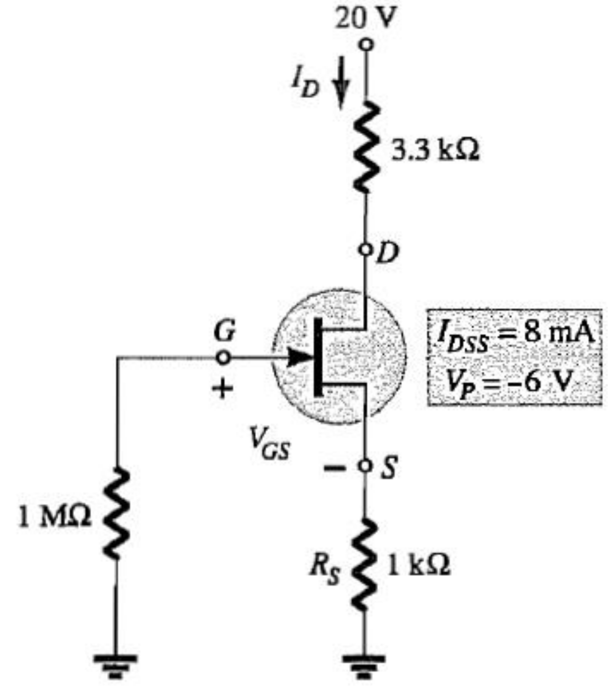


FIG. 7.12

FET BIASING (SELF BIAS CONFIGURATION)

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

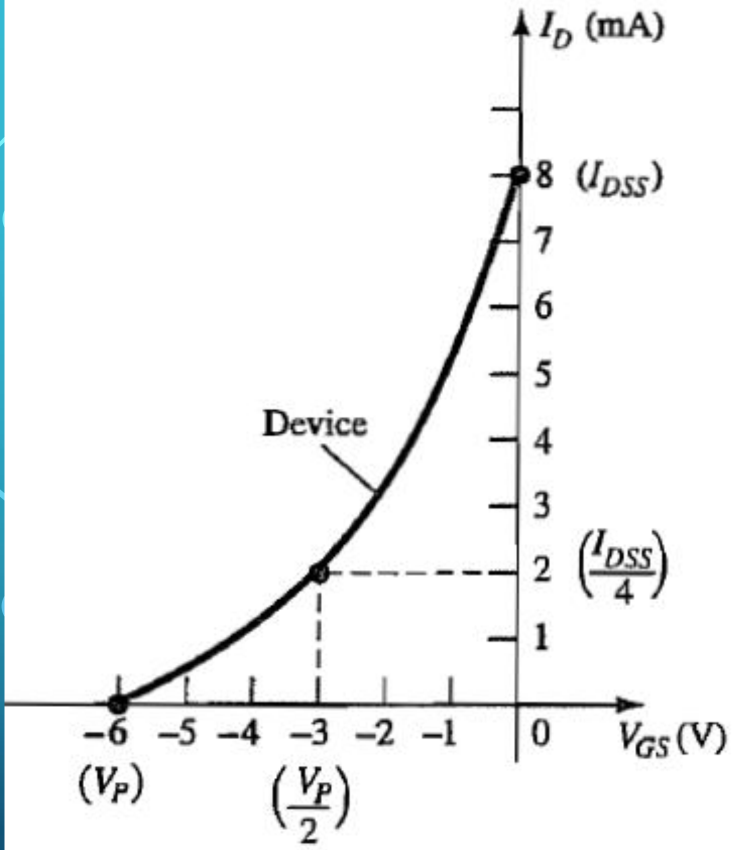


FIG. 7.14
Sketching the device characteristics for the JFET of Fig. 7.12.

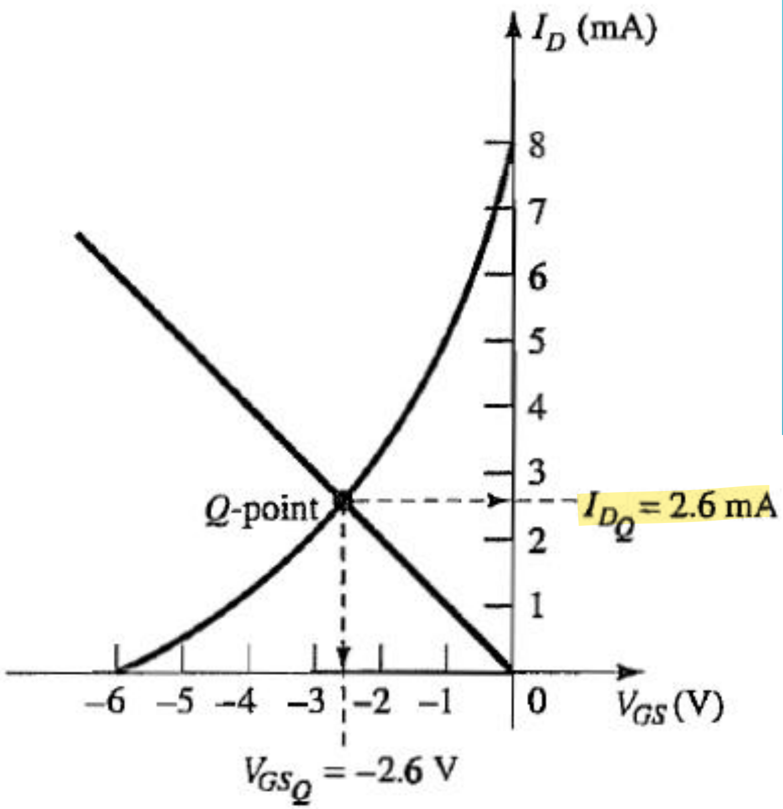


FIG. 7.15
Determining the Q-point for the network of Fig. 7.12.

EXAMPLE 7.2 Determine the following for the network of Fig. 7.12:

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

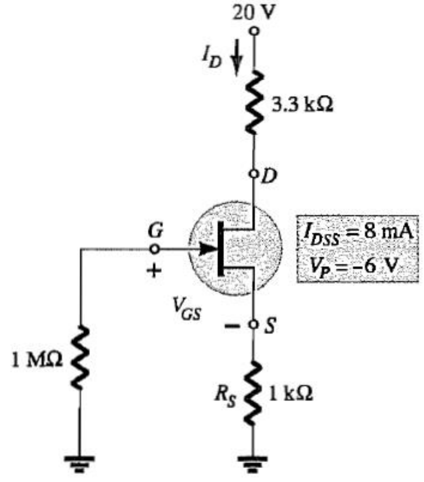


FIG. 7.12

b. At the quiescent point

$$I_{D_Q} = 2.6\text{ mA}$$

c. Eq. (7.11): $V_{DS} = V_{DD} - I_D(R_S + R_D)$
$= 20\text{ V} - (2.6\text{ mA})(1\text{ k}\Omega + 3.3\text{ k}\Omega)$
$= 20\text{ V} - 11.18\text{ V}$
$= \mathbf{8.82\text{ V}}$

d. Eq. (7.12): $V_S = I_D R_S$
$= (2.6\text{ mA})(1\text{ k}\Omega)$
$= \mathbf{2.6\text{ V}}$

e. Eq. (7.13): $V_G = \mathbf{0\text{ V}}$

f. Eq. (7.14): $V_D = V_{DS} + V_S = 8.82\text{ V} + 2.6\text{ V} = \mathbf{11.42\text{ V}}$
or $V_D = V_{DD} - I_D R_D = 20\text{ V} - (2.6\text{ mA})(3.3\text{ k}\Omega) = \mathbf{11.42\text{ V}}$

FET BIASING (FIXED BIAS CONFIGURATION)

$$I_G \cong 0\,\text{A}$$
$$V_{R_G} = I_G R_G = (0\,\text{A})R_G = 0\,\text{V}$$

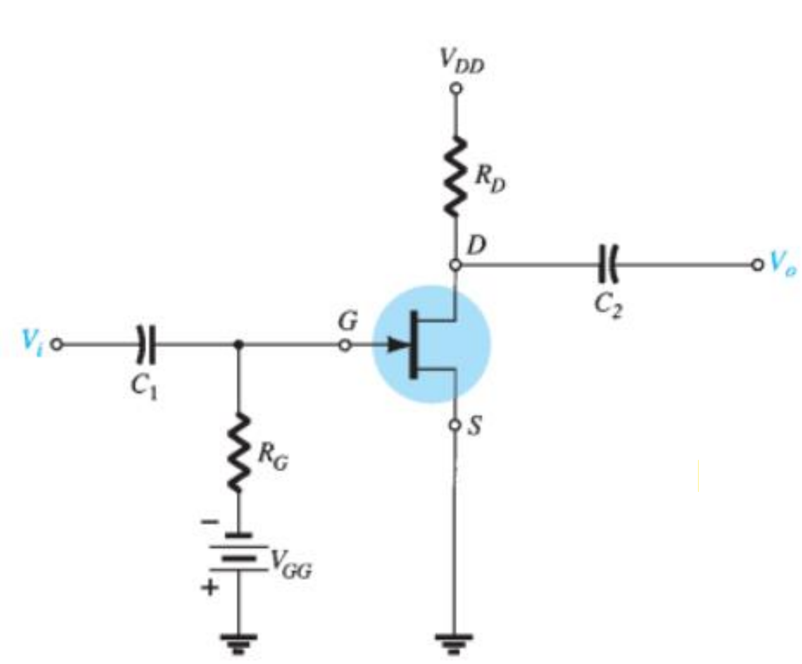
$$-V_{GG} - V_{GS} = 0$$
$$\boxed{V_{GS} = -V_{GG}}$$

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

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

$$\boxed{V_S = 0\,\text{V}}$$

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



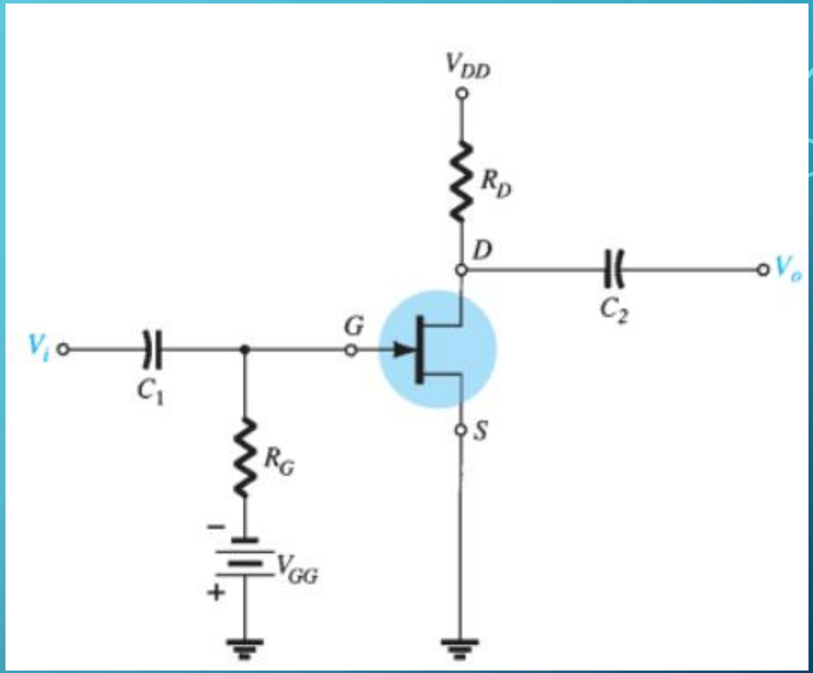
FET BIASING (FIXED BIAS CONFIGURATION)

$$V_{DS} = V_D - V_S$$
$$V_D = V_{DS} + V_S = V_{DS} + 0\,\text{V}$$

$$\boxed{V_D = V_{DS}}$$

$$V_{GS} = V_G - V_S$$
$$V_G = V_{GS} + V_S = V_{GS} + 0\,\text{V}$$

$$\boxed{V_G = V_{GS}}$$



FET BIASING (FIXED BIAS CONFIGURATION)

EXAMPLE 7.1 Determine the following for the network of Fig. 7.6:

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

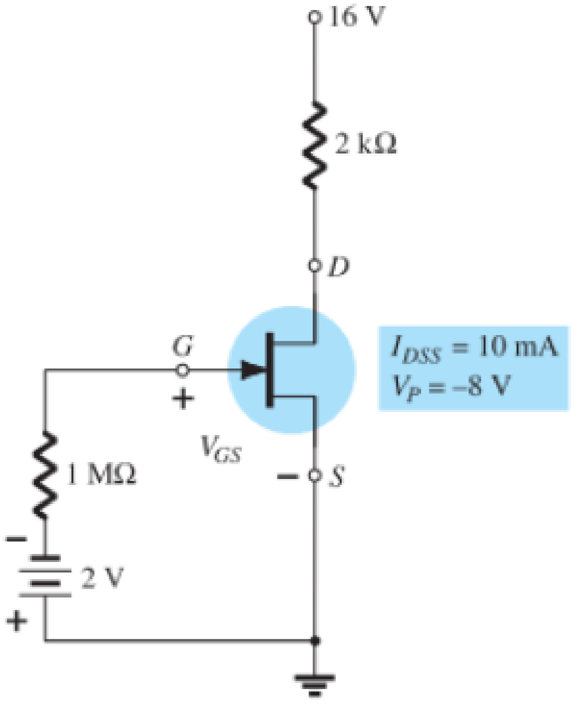


FIG. 7.6
Example 7.1.

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

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

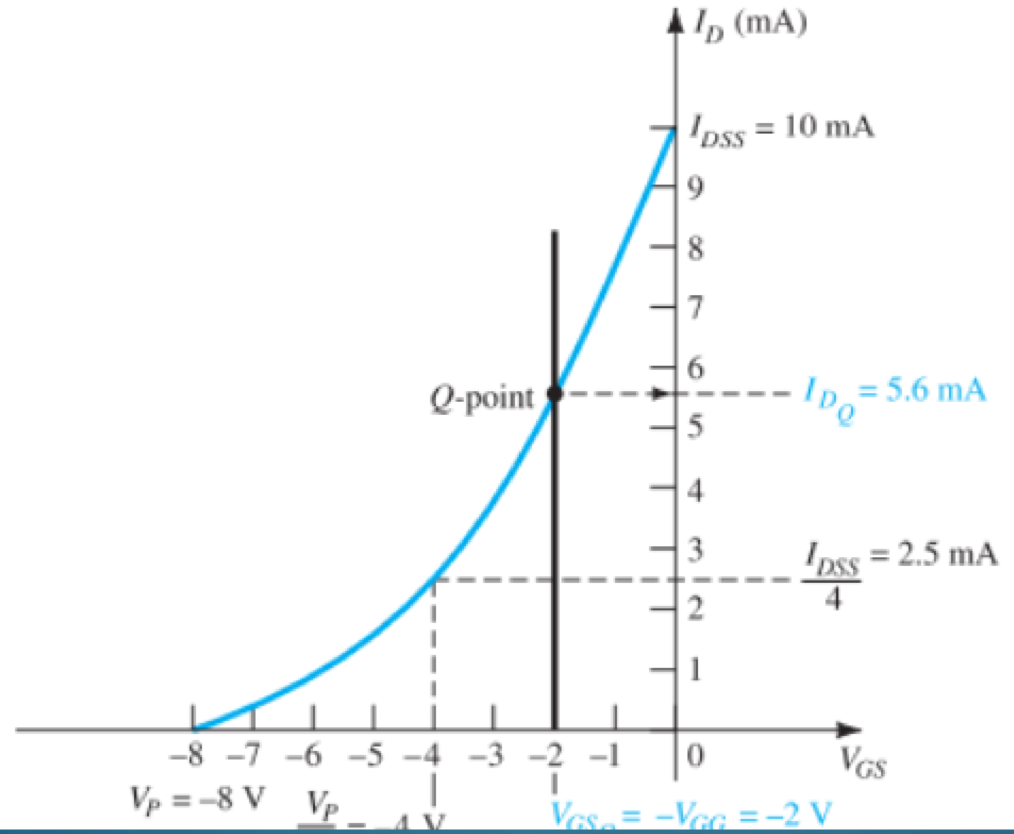
d. $V_D = V_{DS} = \mathbf{4.75\ V}$

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

f. $V_S = \mathbf{0\ V}$

FET BIASING (FIXED BIAS CONFIGURATION)

Graphical Approach The resulting Shockley curve and the vertical line at $V_{GS} = -2$ V are provided in Fig. 7.7. It is certainly difficult to read beyond the second place without



significantly increasing the size of the figure, but a solution of 5.6 mA from the graph of Fig. 7.7 is quite acceptable.

FET BIASING (FIXED BIAS CONFIGURATION)

a. Therefore,

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

b. $I_{D_Q} = \mathbf{5.6\ mA}$

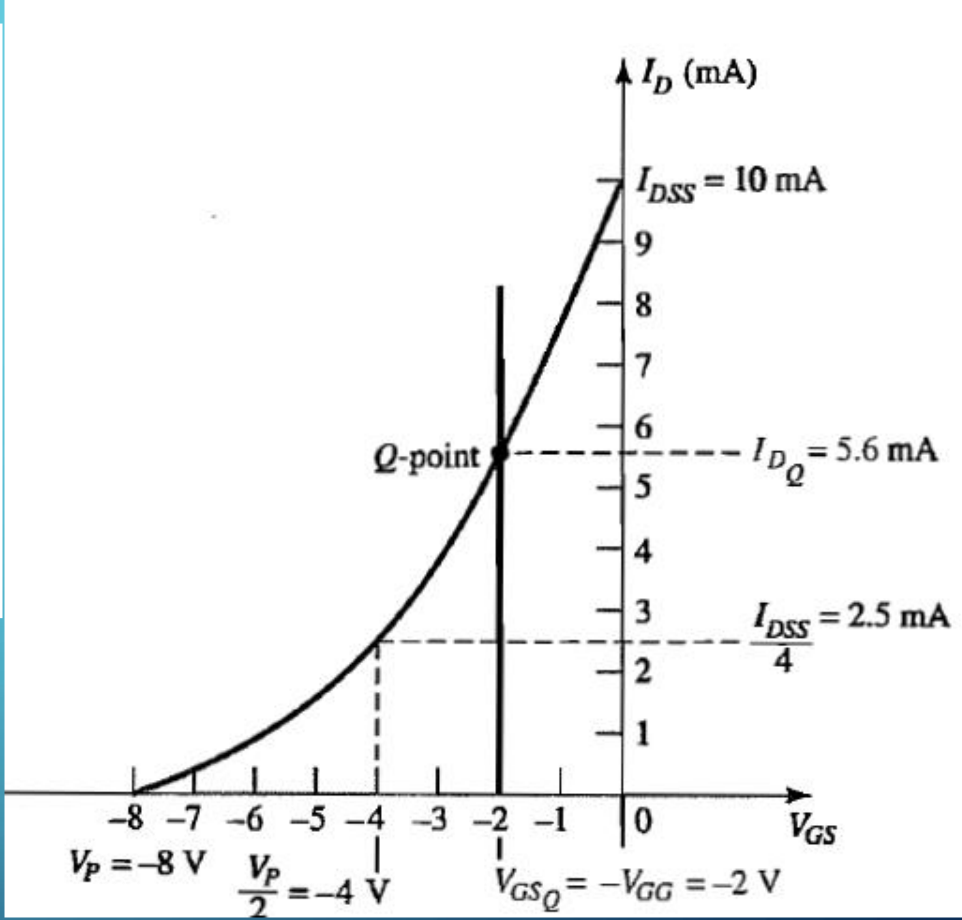
c. $V_{DS} = V_{DD} - I_D R_D = 16\ \text{V} - (5.6\ \text{mA})(2\ \text{k}\Omega)$
$= 16\ \text{V} - 11.2\ \text{V} = \mathbf{4.8\ V}$

d. $V_D = V_{DS} = \mathbf{4.8\ V}$

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

f. $V_S = \mathbf{0\ V}$

The results clearly confirm the fact that the mathematical and graphical approaches generate solutions that are quite close.



FET BIASING (VOLTAGE DIVIDER BIAS CONFIGURATION)

$I_G \cong 0\ \text{A}$

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

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

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

$$V_{GS} = V_G - I_D R_S$$
$$= V_G - (0\ \text{mA}) R_S$$

$$\boxed{V_{GS} = V_G \big|_{I_D = 0\ \text{mA}}}$$

$$V_{GS} = V_G - I_D R_S$$
$$0\ \text{V} = V_G - I_D R_S$$

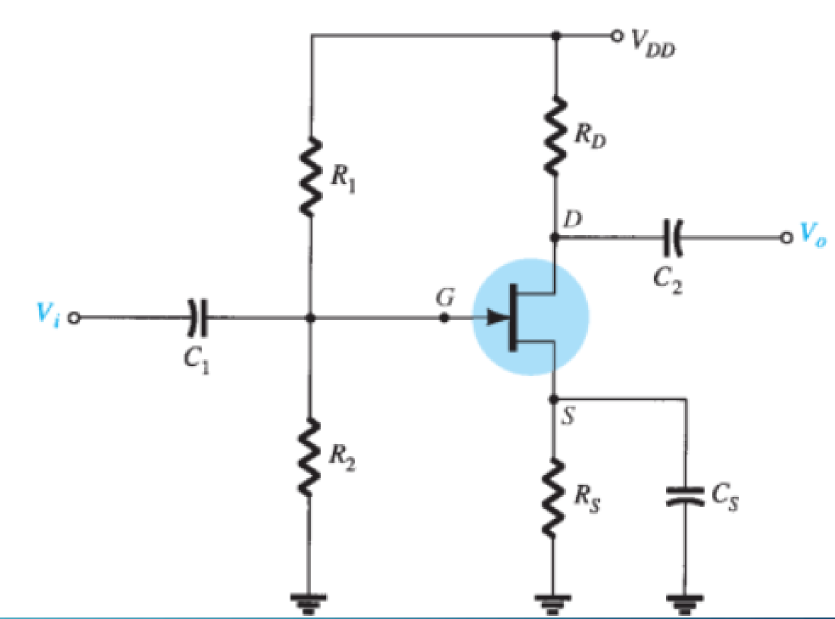
$$\boxed{I_D = \frac{V_G}{R_S}\bigg|_{V_{GS} = 0\ \text{V}}}$$

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

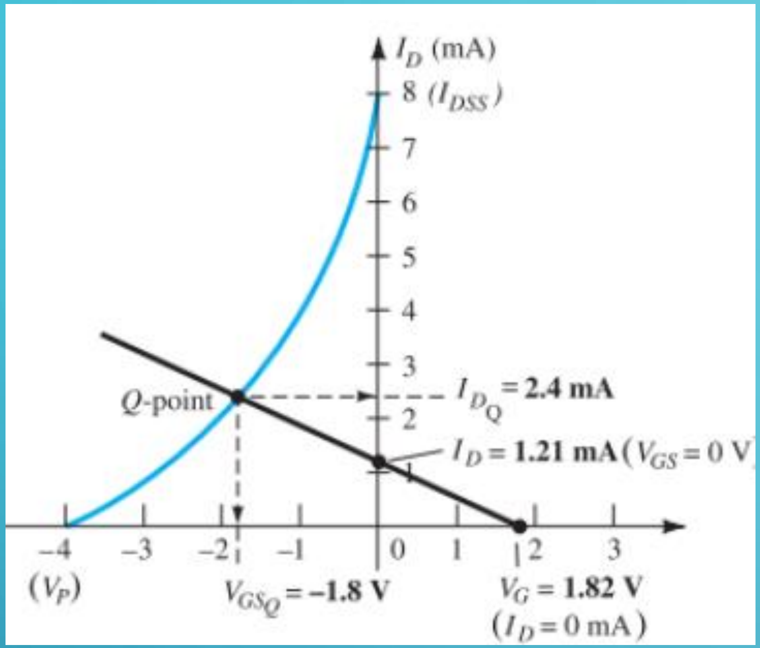
$$\boxed{V_D = V_{DD} - I_D R_D}$$

$$\boxed{V_S = I_D R_S}$$

$$\boxed{I_{R_1} = I_{R_2} = \frac{V_{DD}}{R_1 + R_2}}$$



FET BIASING (VOLTAGE DIVIDER BIAS CONFIGURATION)



EXAMPLE 7.4 Determine the following for the network of Fig. 7.21:

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

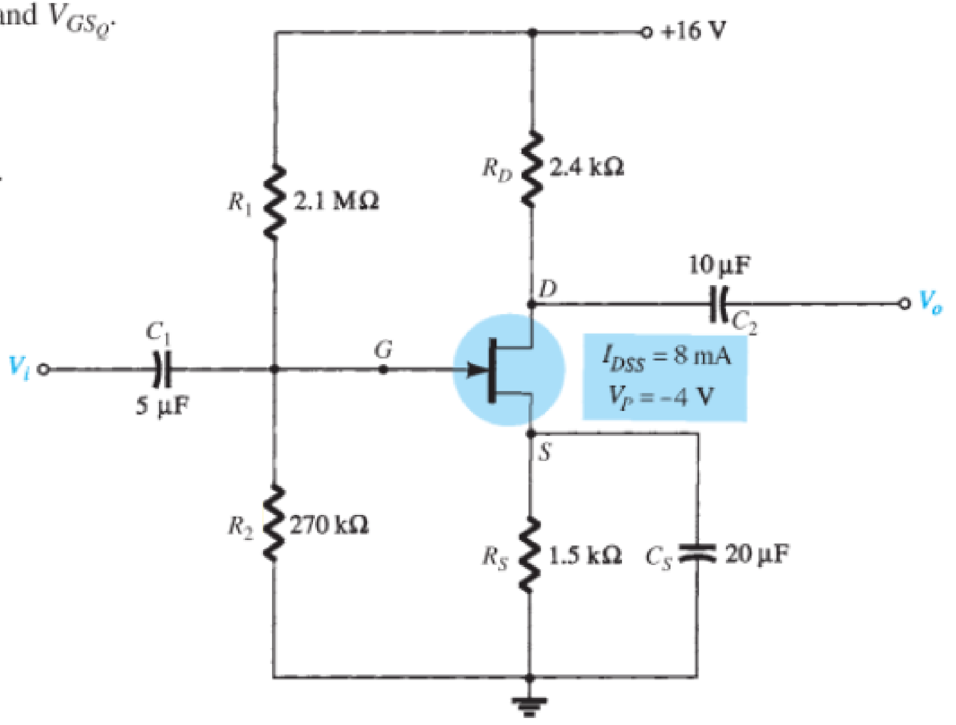


FIG. 7.21
Example 7.4.

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. 7.22. 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

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

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

FET BIASING (VOLTAGE DIVIDER BIAS CONFIGURATION)

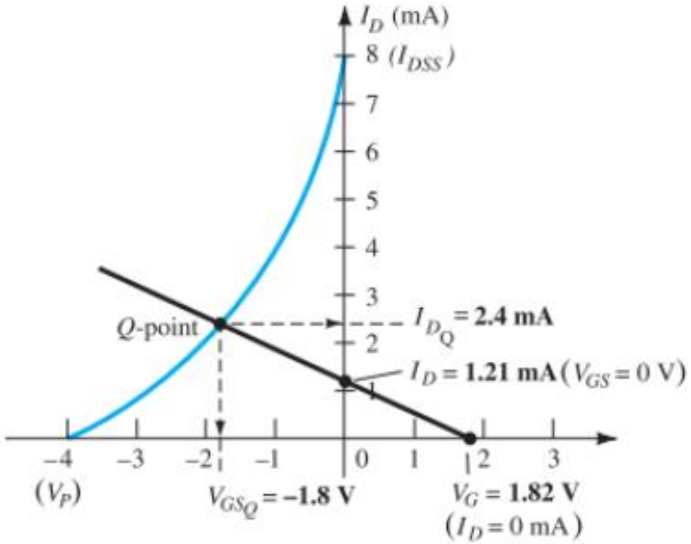


FIG. 7.22
Determining the Q-point for the network of Fig. 7.21.

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. 7.22 with quiescent values of

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

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

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

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

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

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

EXAMPLE 7.4 Determine the following for the network of Fig. 7.21:

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

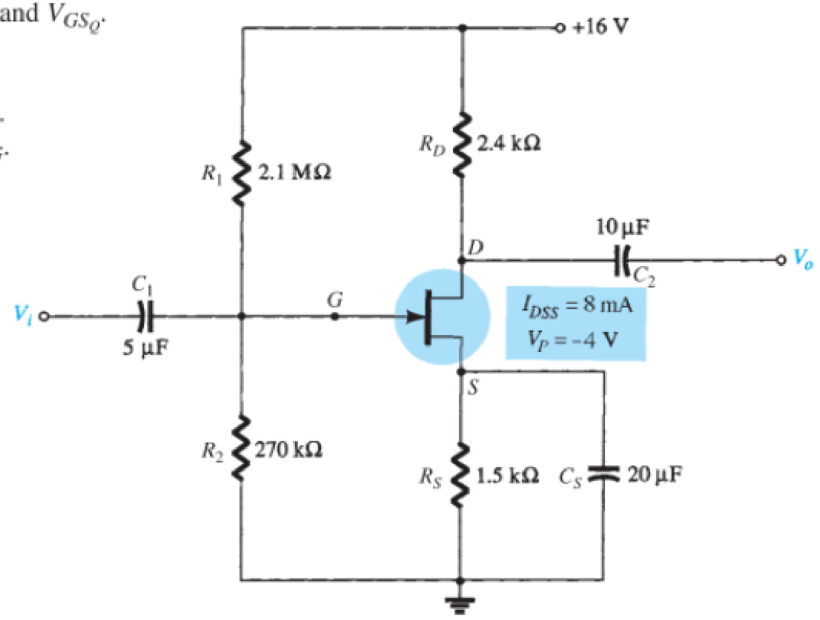


FIG. 7.21
Example 7.4.

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

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

Thank You!