Chapter 7: FET Biasing

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Basic Current Relationships

For all FETs:

\[ I_G \approx 0A \]
\[ I_D = I_S \]

For JFETS and D-Type MOSFETs:

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

For E-Type MOSFETs:

\[ I_D = k(V_{GS} - V_T)^2 \]
Fixed-Bias Configuration

\[ I_G \approx 0A \]
\[ V_{DS} = V_{DD} - I_D R_D \]
\[ V_S = 0, \ V_D = V_{DS}, \ V_{GS} = -V_{GG} \]
\[ I_D = I_{DSS} \left( 1 - \frac{V_{GS}}{V_p} \right)^2 \]

Network for dc analysis.
Fixed-Bias Configuration – Graphical Solution

\[ I_D = I_{DSS} \left( 1 - \frac{V_{GS}}{V_p} \right)^2 \]

Plotting Shockley’s equation.

Finding the solution for the fixed-bias configuration.
Example 7.1

Find $V_{GSQ}$, $I_{DQ}$, $V_{DS}$, $V_D$, $V_G$, $V_S$. 

![Circuit Diagram]

$I_{DSS} = 10$ mA
$V_P = -8$ V
Example 7.1 - graphical solution

- Q-point
- $I_{DS} = 10 \text{ mA}$
- $I_{DQ} = 5.6 \text{ mA}$
- $\frac{I_{DS}}{4} = 2.5 \text{ mA}$

For $V_P = -8 \text{ V}$:
- $\frac{V_P}{2} = -4 \text{ V}$

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

$V_G = 16 \text{ V}$
$V_S = 2 \text{ V}$
$V_{GS} = -2 \text{ V}$
$R = 2 \text{ k}\Omega$
Self-Bias Configuration

DC analysis of the self-bias configuration.
**Self-Bias Configuration**

\[ V_{GS} = -I_D R_S \]

\[ I_D = I_{DSS} \left( 1 - \frac{V_{GS}}{V_p} \right)^2 \]

\[ I_D = I_{DSS} \left( 1 + \frac{I_D R_S}{V_p} \right)^2 \]

By squaring and rearranging, \( I_D \) has the form:

\[ I_D^2 + k_1 I_D + k_2 = 0 \]  [Solve for \( I_D \)]

DC analysis of the self-bias configuration.
Self-Bias Configuration – graphical solution

• Sketch the transfer curve.
• Draw the line:
  \[ V_{GS} = -I_D R_S \]
• The Q-point is located where the line intersects the transfer curve.
• Use the value of \( I_D \) at the Q-point (\( I_{DQ} \)) to solve for the other voltages:

\[
\begin{align*}
V_{DS} &= V_{DD} - I_D (R_S + R_D) \\
V_S &= I_D R_S \\
V_D &= V_{DS} + V_S
\end{align*}
\]
Example 7.2

Find $V_{GSQ}$, $I_{DQ}$, $V_{DS}$, $V_D$, $V_G$, $V_S$.

Solution

Draw the line: $V_{GS} = -I_D R_S$
Example 7.2 - solution

Sketching the device characteristics for the JFET

Determining the $Q$-point for the network.
Voltage-Divider Bias

\[ I_G = 0 \text{ A} \]
\[ I_{R1} = I_{R2} \]

Redrawn network for dc analysis.
Voltage-Divider Bias

$V_G$ is equal to the voltage across divider resistor $R_2$:

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

Using Kirchhoff’s Law:

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

The Q point is established by plotting a line that intersects the transfer curve.
**Voltage-Divider Bias**

**Step 1**  
Plot the line by plotting two points:  
• $V_{GS} = V_G$, $I_D = 0$ A  
• $V_{GS} = 0$ V, $I_D = V_G / R_S$

**Step 2**  
Plot the transfer curve by plotting $I_{DSS}$, $V_P$ and the calculated values of $I_D$.

**Step 3**  
The Q-point is located where the line intersects the transfer curve.

$V_{GS} = V_G - I_D R_S$
Voltage-Divider Bias

\[ V_{GS} = V_G - I_D R_S \]

Effect of \( R_S \) on the resulting \( Q \)-point.
Voltage-Divider Bias

Using the value of $I_D$ at the Q-point, solve for the other variables in the voltage-divider bias circuit:

\[
V_{DS} = V_{DD} - I_D (R_D + R_S) \\
V_D = V_{DD} - I_D R_D \\
V_S = I_D R_S \\
I_{R1} = I_{R2} = \frac{V_{DD}}{R_1 + R_2}
\]
Example 7.5  
Find $V_{GSQ}$, $I_{DQ}$, $V_{DS}$, $V_D$, $V_G$, $V_S$.

![Diagram of a resistor network with annotations](image)

- $Q$-point: $I_D = 2.4$ mA, $V_{GSQ} = -1.8$ V
- $V_D = 1.82$ V, $I_D = 0$ mA
- $I_{DSS} = 8$ mA, $V_D = -4$ V

$V_{GSQ}$, $I_{DQ}$, $V_{DS}$, $V_D$, $V_G$, $V_S$.
Depletion-type MOSFET bias circuits are similar to those used to bias JFETs. The only difference is that depletion-type MOSFETs can operate with positive values of $V_{GS}$ and with $I_D$ values that exceed $I_{DSS}$. 
Example 7.7 Find \( V_{GSQ}, I_{DQ}, V_{DS} \)

**Step 1**
Plot the line for
- \( V_{GS} = V_G, I_D = 0 \) A
- \( I_D = V_G/R_S, V_{GS} = 0 \) V

**Step 2**
Plot the transfer curve using \( I_{DSS}, V_P \) and calculated values of \( I_D \).

**Step 3**
The Q-point is located where the line intersects the transfer curve is. Use the \( I_D \) at the Q-point to solve for the other variables in the voltage-divider bias circuit.

These are the same steps used to analyze JFET voltage-divider bias circuits.

\[
V_G = \frac{R_2 V_{DD}}{R_1 + R_2}
\]

\[
V_{GS} = V_G - I_D R_S
\]
Example 7.7 - Solution

For $V_{GS} = +1V$

$$I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_p}\right)^2 = 6mA \left(1 - \frac{1}{-3}\right)^2 = 10.67mA$$

$$V_G = \frac{10M \cdot (18V)}{10M + 110M} = 1.5V \rightarrow V_{GS} = 1.5V - I_D(750)$$

$$V_G = \frac{R_2 V_{DD}}{R_1 + R_2} \quad V_{GS} = V_G - I_D R_S$$
Example 7.9  Find $V_{GSQ}$, $I_{DQ}$, $V_D$

To plot line $V_{GS} = -I_D R_S$:

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

For $V_{GS} = -6$, $I_D = -(-6) / 2.4k = 2.5mA$

To plot transfer curve for $V_{GS} = +2V$:

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

$= 8mA \left( 1 - \frac{-2}{-8} \right)^2 = 12.5mA$
The transfer characteristic for the e-type MOSFET is very different from that of a simple JFET or the d-type MOSFET.

\[ I_D = k \left( V_{GS} - V_{GS(Th)} \right)^2 \]
Feedback Bias Circuit

\[ I_G = 0 \text{ A} \]
\[ V_{RG} = 0 \text{ V} \]
\[ V_{DS} = V_{GS} \]
\[ V_{GS} = V_{DD} - I_D R_D \]

DC equivalent of the network
**Feedback Bias Q-Point**

**Step 1**
Plot the line using
- \( V_{GS} = V_{DD}, \ I_D = 0 \ A \)
- \( I_D = V_{DD} / R_D, \ V_{GS} = 0 \ V \)

**Step 2**
Using values from the specification sheet, plot the transfer curve with
- \( V_{GSTh}, \ I_D = 0 \ A \)
- \( V_{GS(on)}, \ I_{D(on)} \)

**Step 3**
The Q-point is located where the line and the transfer curve intersect

**Step 4**
Using the value of \( I_D \) at the Q-point, solve for the other variables in the bias circuit.

\[
V_{GS} = V_{DD} - I_D R_D
\]
Example 7.11  

Find $V_{GSQ}$, $I_{DQ}$

Plot Transfer Curve:

$$I_D = k \left( V_{GS} - V_{GS(Th)} \right)^2 = 0.24 \times 10^{-3} \left( V_{GS} - 3 \right)^2$$

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

$k = \frac{6mA}{(8 - 3)^2} = 0.24 \times 10^{-3}$
Example 7.11 - solution

Plot the line: $V_{GS} = V_{DD} - I_D R_D$

$V_{GS} = 12 - I_D(2k)$
Voltage-Divider Biasing

Plot the line and the transfer curve to find the Q-point. Use these equations:

\[ V_G = \frac{R_2 V_{DD}}{R_1 + R_2} \]

\[ V_{GS} = V_G - I_D R_S \]

\[ V_{DS} = V_{DD} - I_D (R_S + R_D) \]
**Example 7.12**

Find $V_{GSQ}$, $I_{DQ}$

\[
k = \frac{I_{D(on)}}{\left(V_{GS(on)} - V_{GS(Th)}\right)^2}
\]

\[
k = \frac{3mA}{(10 - 5)^2} = 0.12 \times 10^{-3}
\]

\[
I_D = k \left(V_{GS} - V_{GS(Th)}\right)^2
\]

\[
I_D = 0.12 \times 10^{-3} \left(V_{GS} - 5\right)^2
\]

\[
V_G = \frac{18M \times (40V)}{22M + 18M} = 18V
\]

\[
V_{GS} = V_G - I_D R_S
\]

\[
V_{GS} = 18V - I_D (0.82k)
\]
Example 7.12 - Solution

\[ I_D = 0.12 \times 10^{-3} (V_{GS} - 5)^2 \]

\[ V_{GS} = 18V - I_D (0.82k) \]