Electronic Devices and Circuit Theory

Boylestad

FET Biasing

Chapter 7

Common FET Biasing Circuits

JFET Biasing Circuits

Fixed-Bias
Self-Bias
Voltage-Divider Bias

D-Type MOSFET Biasing Circuits

Self-Bias
Voltage-Divider Bias

E-Type MOSFET Biasing Circuits

Feedback Configuration
Voltage-Divider Bias

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Basic Current Relationships

For all FETs:

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

$$I_D = I_S$$

For JFETS and D-Type MOSFETs:

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

For E-Type MOSFETs:

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

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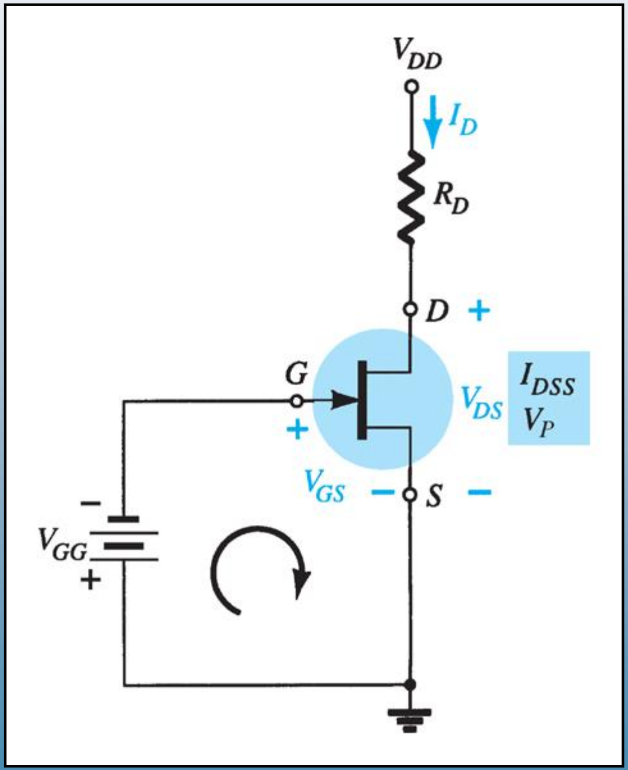
Fixed-Bias Configuration

$$V_{DS} = V_{DD} - I_D R_D$$
$$V_S = 0\ V$$
$$V_D = V_{DS}$$
$$V_G = V_{GS}$$
$$V_{GS} = -V_{GG}$$



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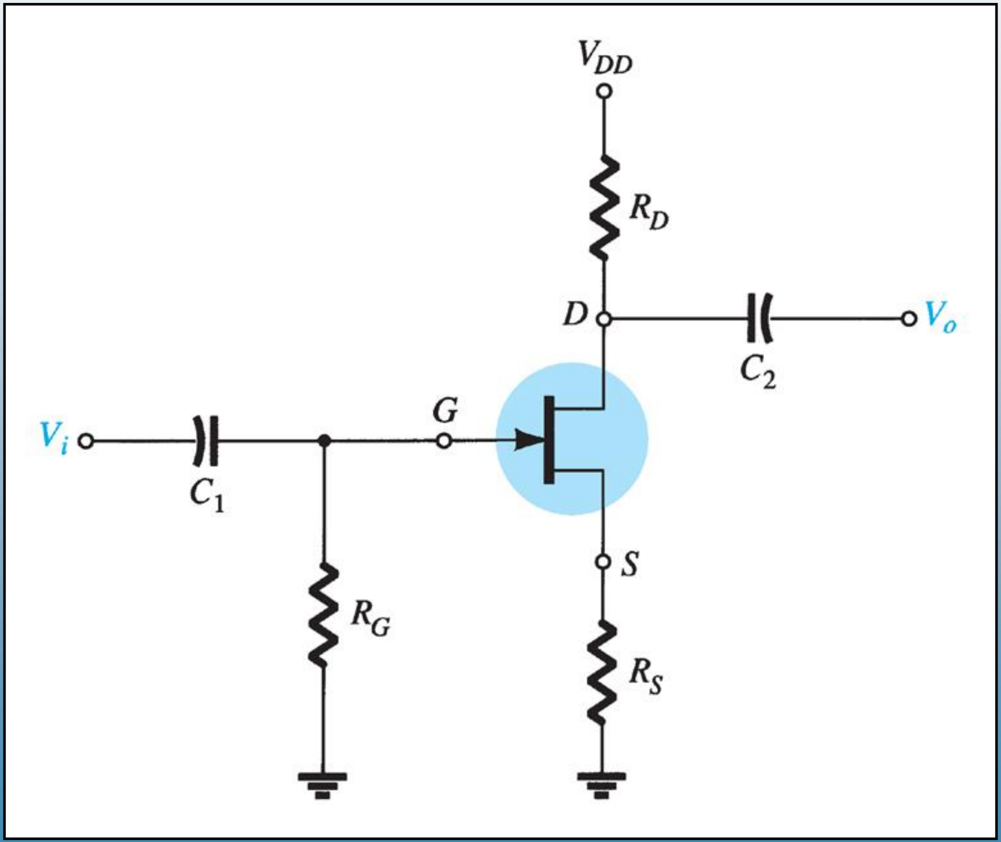
Self-Bias Configuration



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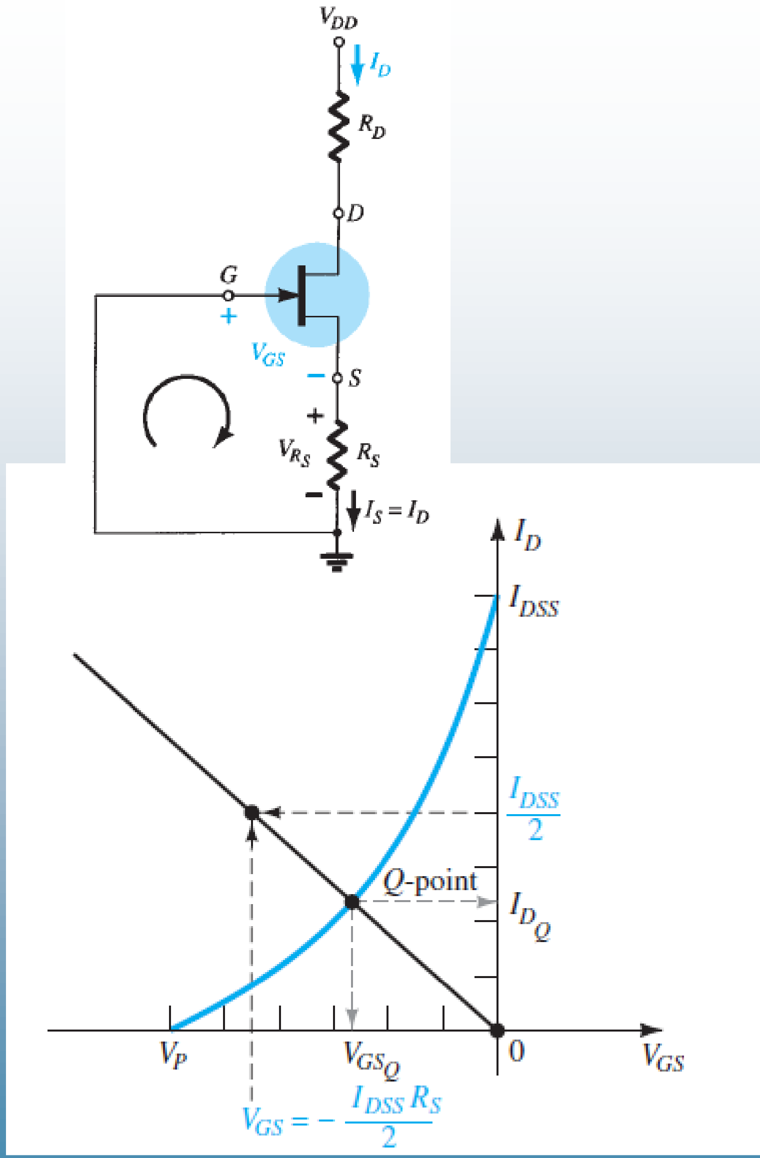
Self-Bias Calculations

$$V_{GS_Q} = -I_{DQ}R_S$$

1. Select a value of $I_D < I_{DSS}$ and use the component value of R_S to calculate V_{GS}. Plot the point identified by I_{DQ} and V_{GSQ} and draw a line from the origin of the axis to this point.
2. Plot the transfer curve using I_{DSS} and V_P ($V_P = |V_{GSoff}|$ on spec sheets) and a few points such as $V_{GS} = V_P / 4$ and $V_{GS} = V_P / 2$ etc.

The Q-point is located where the first line intersects the transfer curve. Using the value of I_D at the Q-point (I_{DQ}):



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

$$V_S = I_D R_S$$

$$V_D = V_{DS} + V_S = V_{DD} - V_{RD}$$

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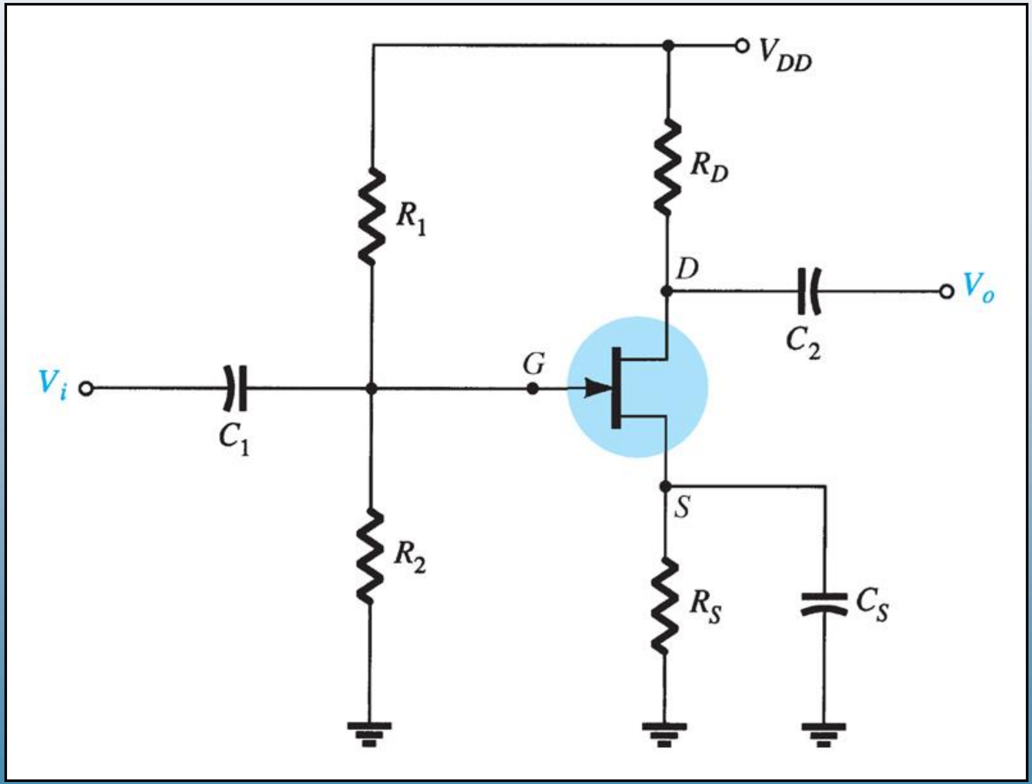
Voltage-Divider Bias

$I_G = 0$ A

I_D responds to changes in V_{GS}.



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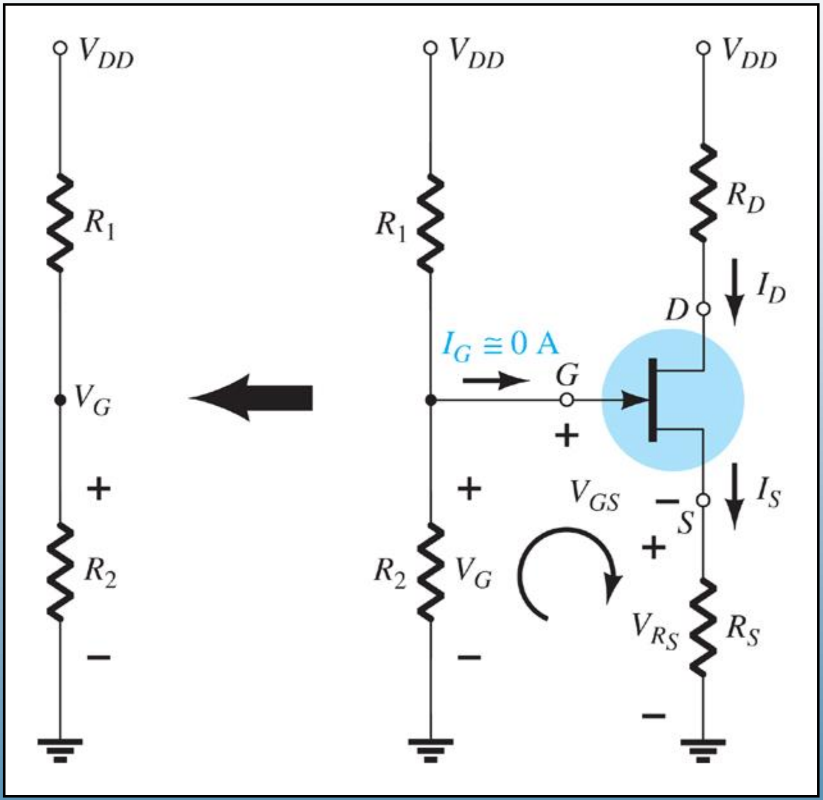
Voltage-Divider Bias Calculations

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.

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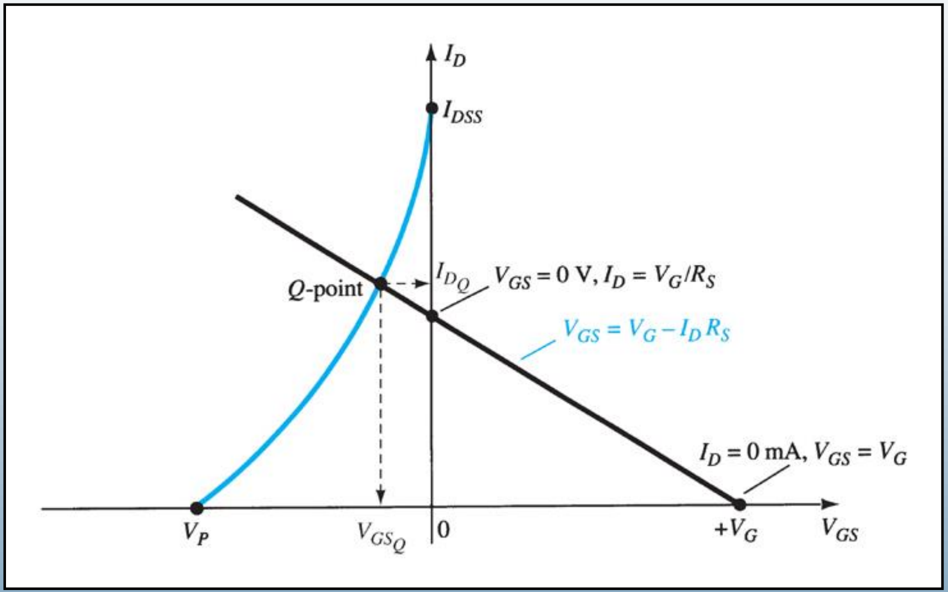
Voltage-Divider Q-Point

Plot the line that is defined by these two points:

$V_{GS} = V_G,\ I_D = 0\ \mathrm{A}$

$V_{GS} = 0\ \mathrm{V},\ I_D = V_G / R_S$

Plot the transfer curve by plotting I_{DSS}, V_P and the calculated values of I_D



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

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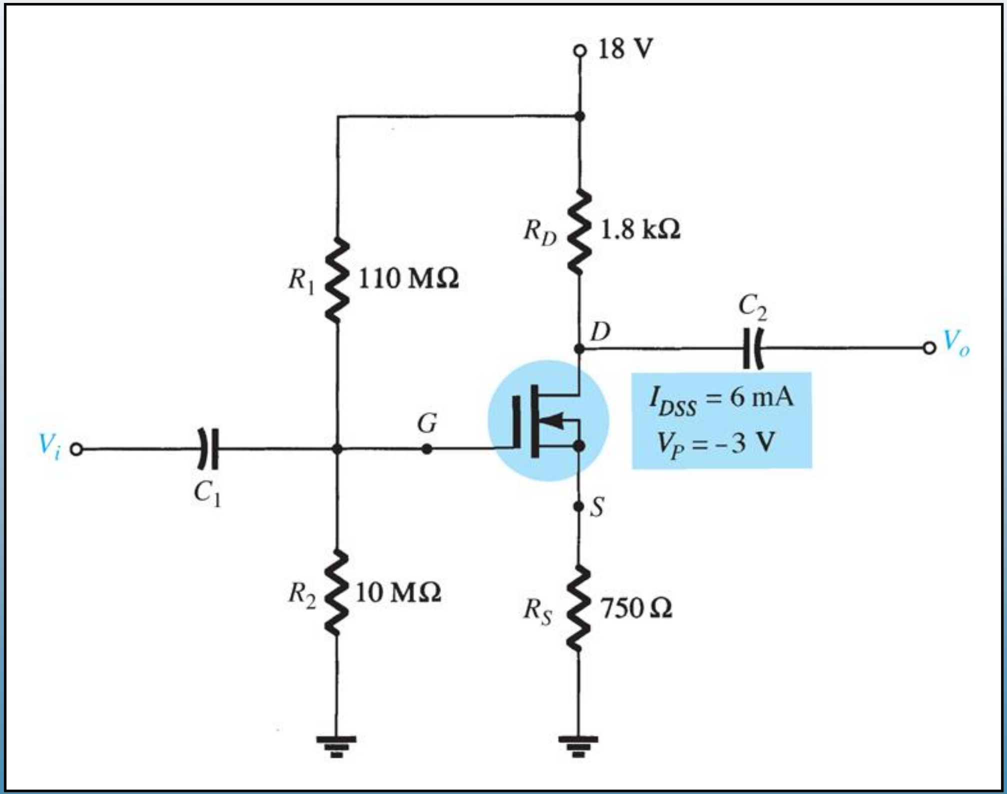
D-Type MOSFET Bias Circuits

Depletion-type MOSFET bias circuits are similar to those used to bias JFETs. The only difference is that D-type MOSFETs can operate with positive values of V_{GS} and with I_D values that exceed I_{DSS}.



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Self-Bias Q-Point (D-MOSFET)

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

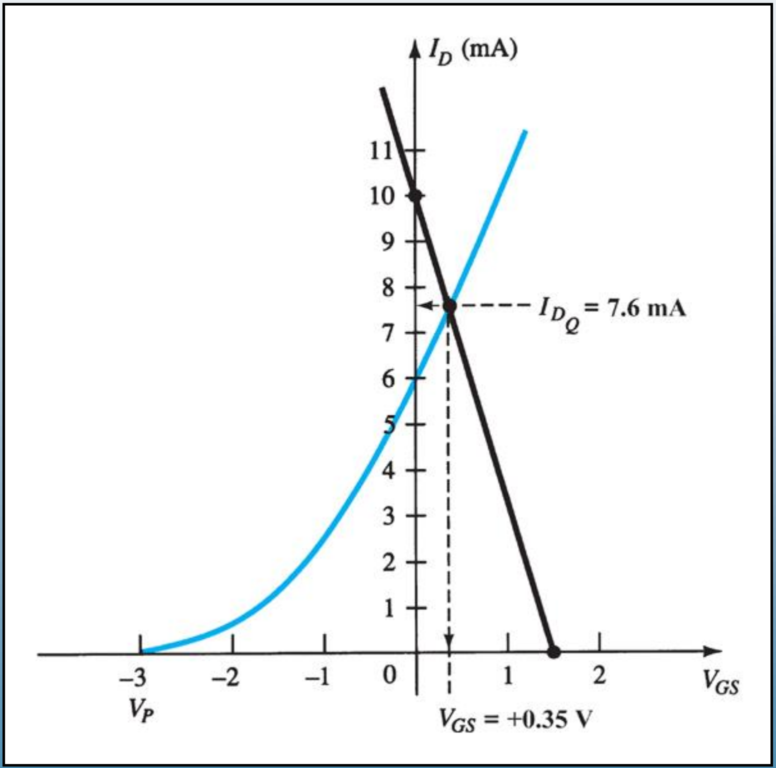
Plot the line that is defined by these two points:

$V_{GS} = V_G$, $I_D = 0$ A

$I_D = V_G / R_S$, $V_{GS} = 0$ V

Plot the transfer curve using I_{DSS}, V_P and calculated values of I_D.

The Q-point is located where the line intersects the transfer curve. Use the value of I_D at the Q-point to solve for the other circuit values.



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

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Voltage-Divider Bias (D-MOSFET)

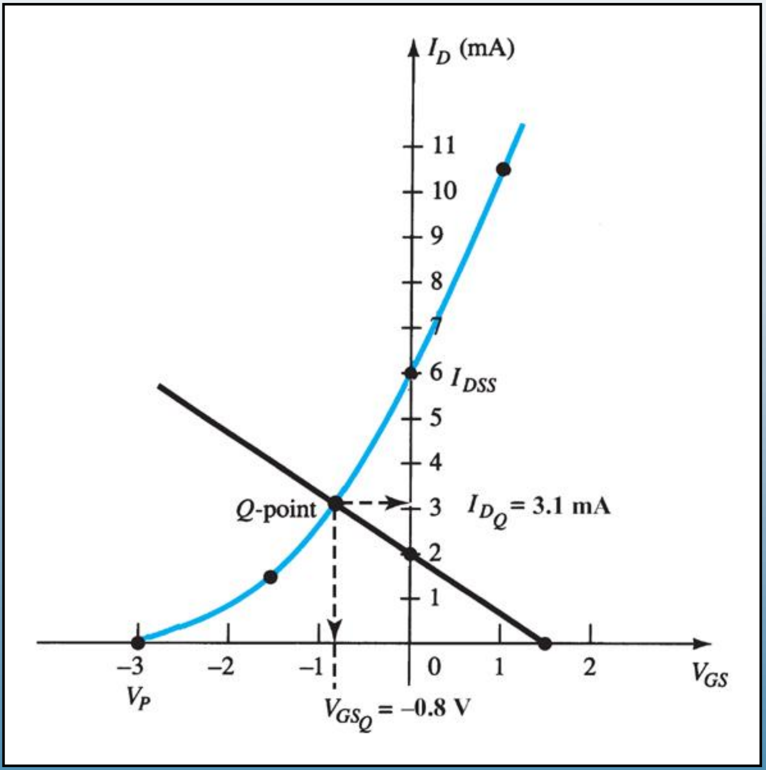
Plot the line that is defined by these two points:

$V_{GS} = V_G$, $I_D = 0$ A

$I_D = V_G/R_S$, $V_{GS} = 0$ V

Plot the transfer curve using I_{DSS}, V_P and calculated values of I_D.

The Q-point is located where the line intersects the transfer curve. Use the value of I_D at the Q-point to solve for the other variables in the circuit.



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

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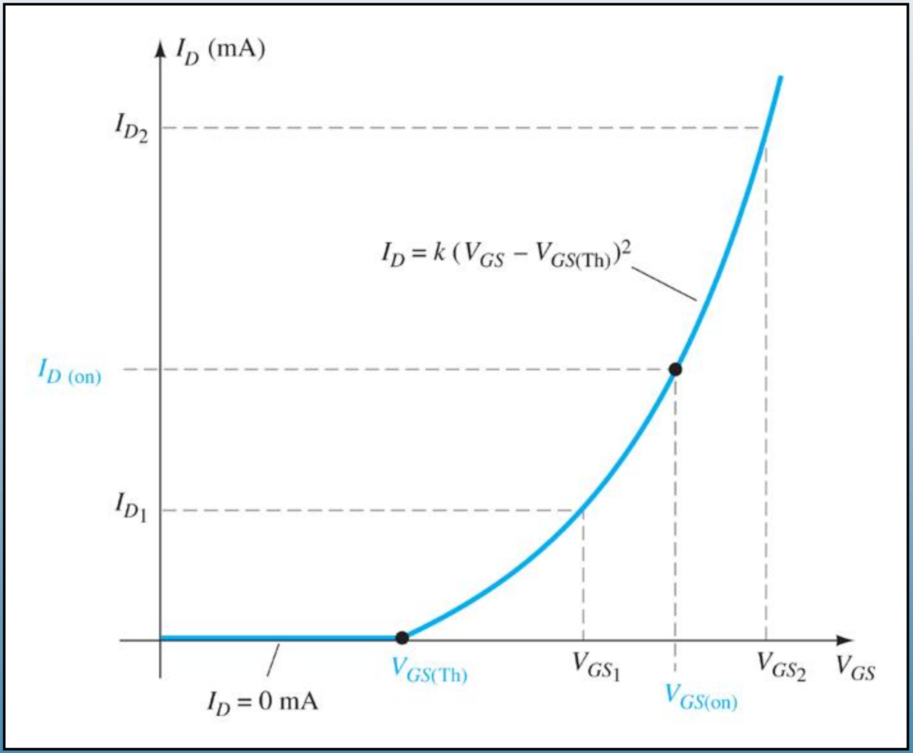
E-Type MOSFET Bias Circuits

The transfer curve for the E-MOSFET is very different from that of a simple JFET or D-MOSFET.



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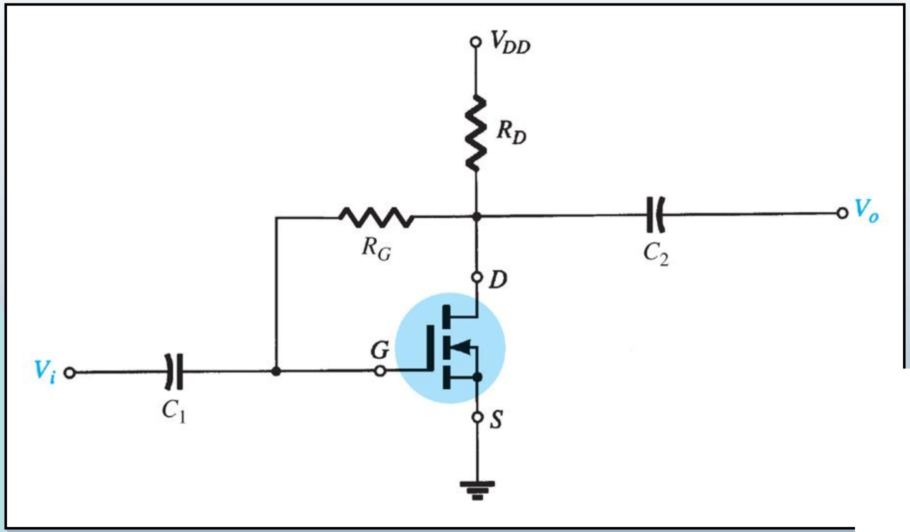
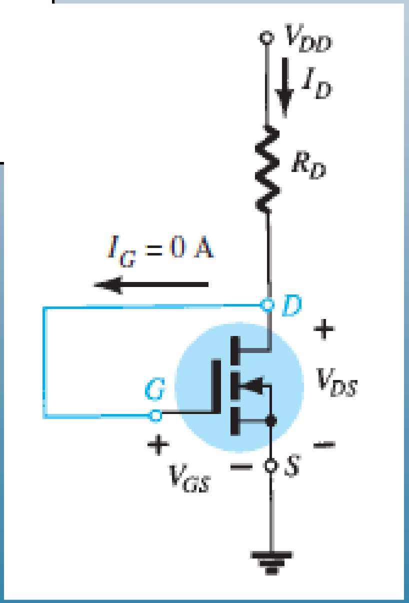
Feedback Bias Circuit (E-MOSFET)

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





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Feedback Bias Q-Point (E-MOSFET)

Plot the line that is defined by these two points:

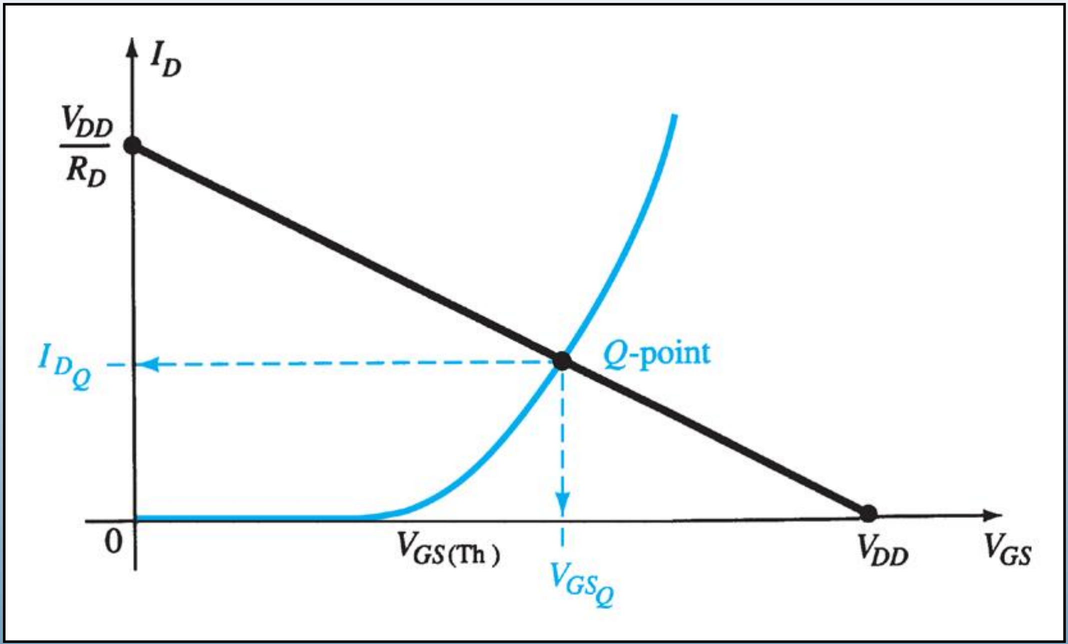
$V_{GS} = V_{DD}$, $I_D = 0$ A

$I_D = V_{DD} / R_D$, $V_{GS} = 0$ V

Using these values from the spec sheet, plot the transfer curve:

V_{GSTh} , $I_D = 0$ A

$V_{GS(on)}$, $I_{D(on)}$



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

Using the value of I_D at the Q-point, solve for the other variables in the circuit

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Voltage-Divider Biasing

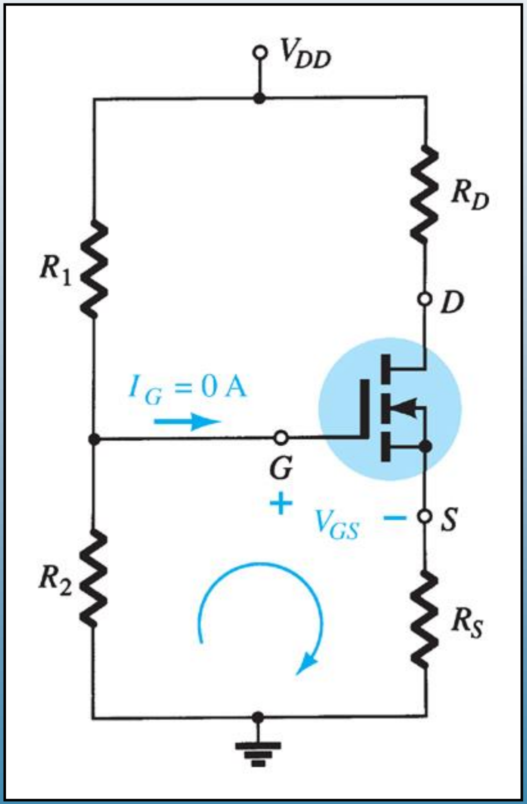
Plot the line and the transfer curve to find the Q-point using these equations:

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

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

$$V_{DS} = V_{DD} - V_{RS} - V_{RD}$$

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



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Voltage-Divider Bias Q-Point (E-MOSFET)

Plot the line using

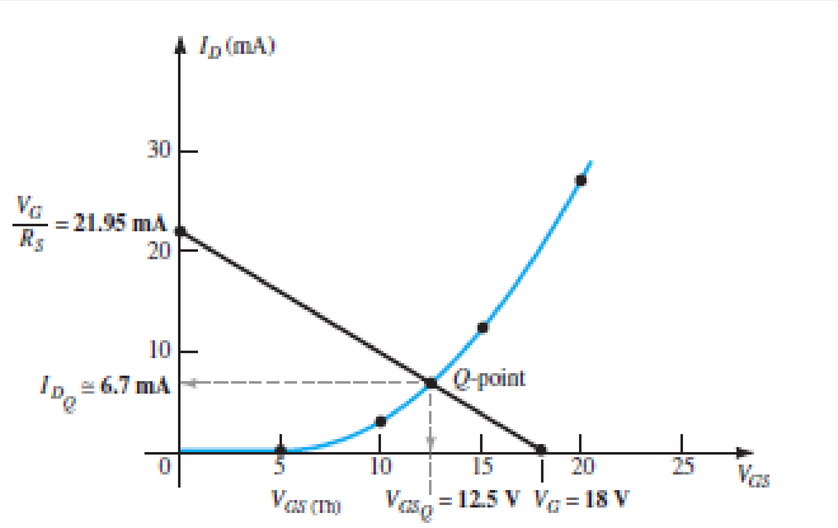
$V_{GS} = V_G$, $I_D = 0$ A

$I_D = V_G / R_S$, $V_{GS} = 0$ V

Using these values from the spec sheet plot the transfer curve:

V_{GSTh}, $I_D = 0$ A

$V_{GS(on)}$, $I_{D(on)}$



The point where the line and the transfer curve intersect is the Q-point.

Using the value of I_D at the Q-point, solve for the other circuit values.

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p-Channel FETs

For *p*-channel FETs the same calculations and graphs are used, except that the voltage polarities and current directions are reversed.

The graphs are mirror images of the *n*-channel graphs.

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Applications

- Voltage-controlled resistor
- JFET voltmeter
- Timer network
- Fiber optic circuitry
- MOSFET relay driver

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