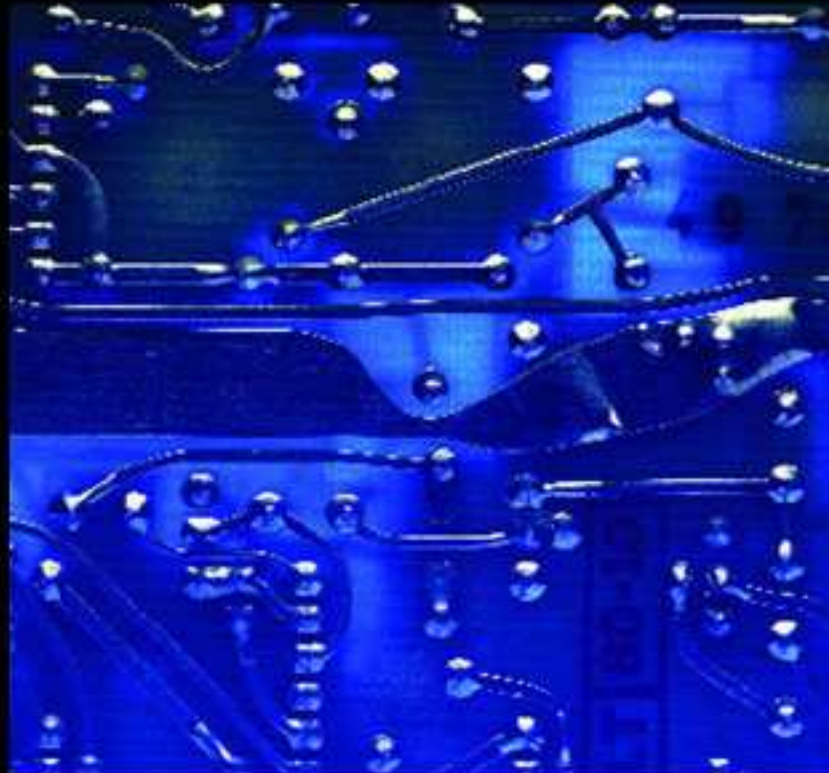


# ELECTRONIC DEVICES AND CIRCUIT THEORY

TENTH EDITION

BOYLESTAD



PEARSON

## Chapter 7: FET Biasing

# 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

# Basic Current Relationships

**For all FETs:**

$$I_G \cong 0A$$

$$I_D = I_S$$

**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

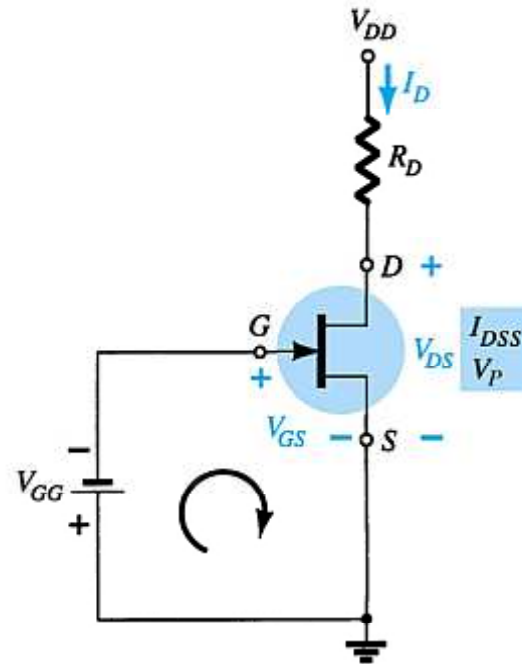
$$V_{DS} = V_{DD} - I_D R_D$$

$$V_S = 0V$$

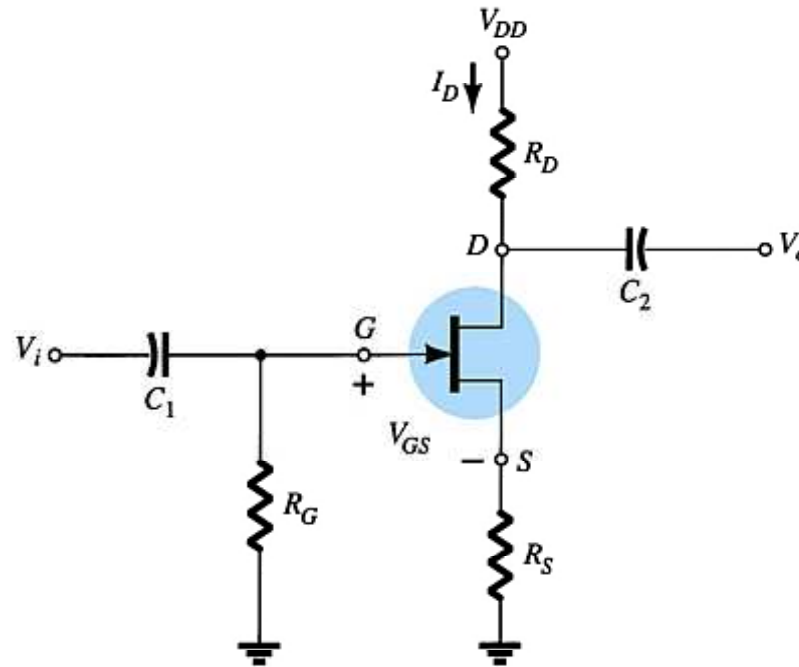
$$V_C = V_{DS}$$

$$V = V_{GS}$$

$$V_{GS} = -V_{GG}$$



# Self-Bias Configuration



# Self-Bias Calculations

For the indicated loop,  $V_{GS} = -I_D R_S$

To solve this equation:

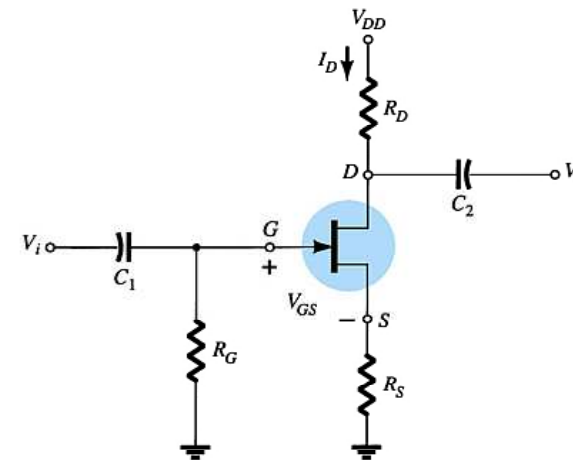
- Select an  $I_D < I_{DSS}$  and use the component value of  $R_S$  to calculate  $V_{GS}$
- Plot the point identified by  $I_D$  and  $V_{GS}$ . Draw a line from the origin of the axis to this point.
- Plot the transfer curve using  $I_{DSS}$  and  $V_P$  ( $V_P = V_{GSoff}$  in specification sheets) and a few points such as  $I_D = I_{DSS} / 4$  and  $I_D = I_{DSS} / 2$  etc.

The Q-point is located where the first line intersects the transfer curve. Use the value of  $I_D$  at the Q-point ( $I_{DQ}$ ) to solve for the other voltages:

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

$$V_S = I_D R_S$$

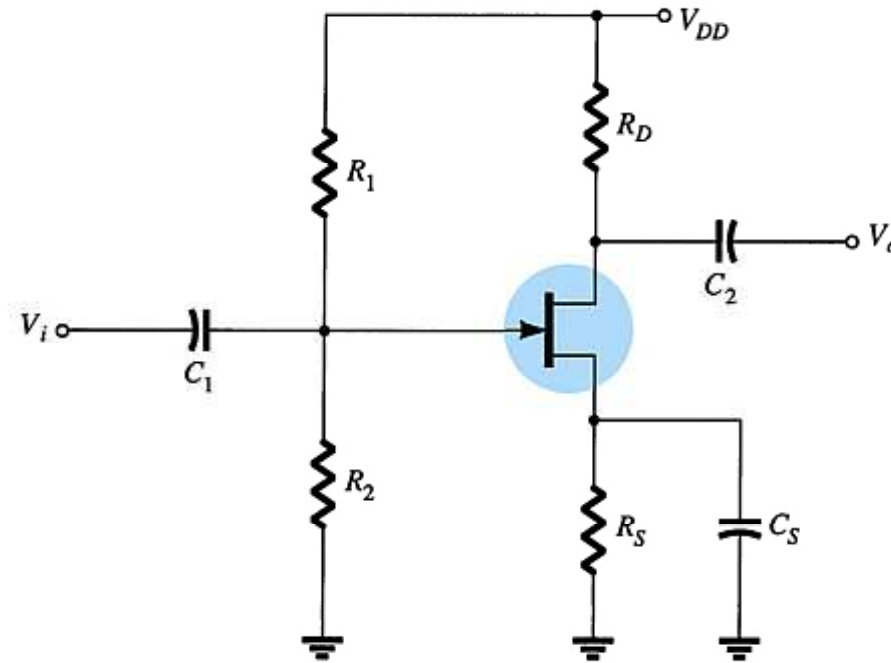
$$V_D = V_{DS} + V_S = V_{DD} - V_{RD}$$



# Voltage-Divider Bias

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

$I_D$  responds to changes in  $V_{GS}$ .



# Voltage-Divider Bias Calculations

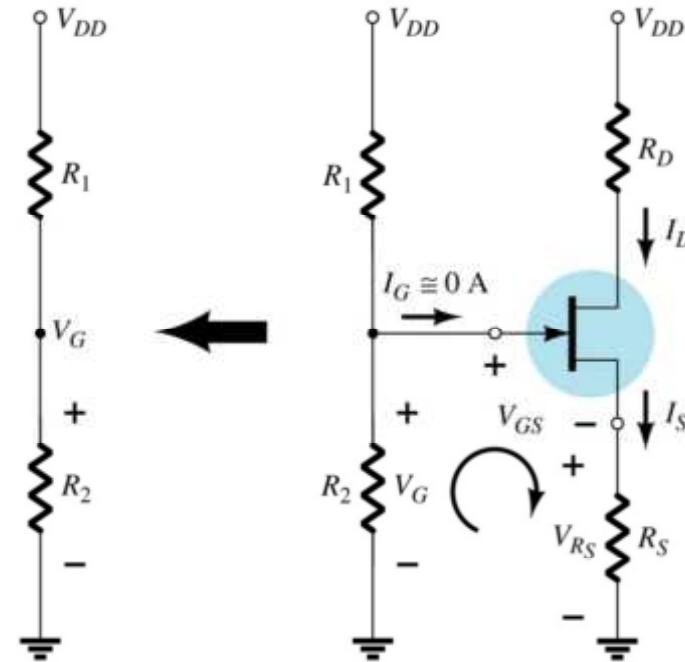
$V_G$  is equal to the voltage across divider resistor  $R_2$ :

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

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.





# Voltage-Divider Q-point

## Step 1

Plot the line by plotting two points:

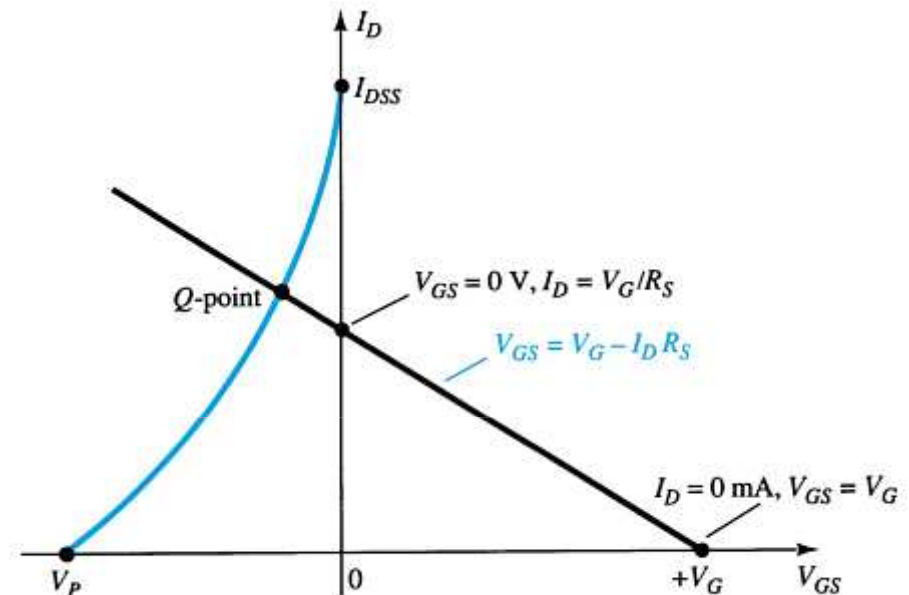
- $V_{GS} = V_G$ ,  $I_D = 0$  A
- $V_{GS} = 0$  V,  $I_D = V_G / R_S$

## 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



# Voltage-Divider Bias Calculations

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

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

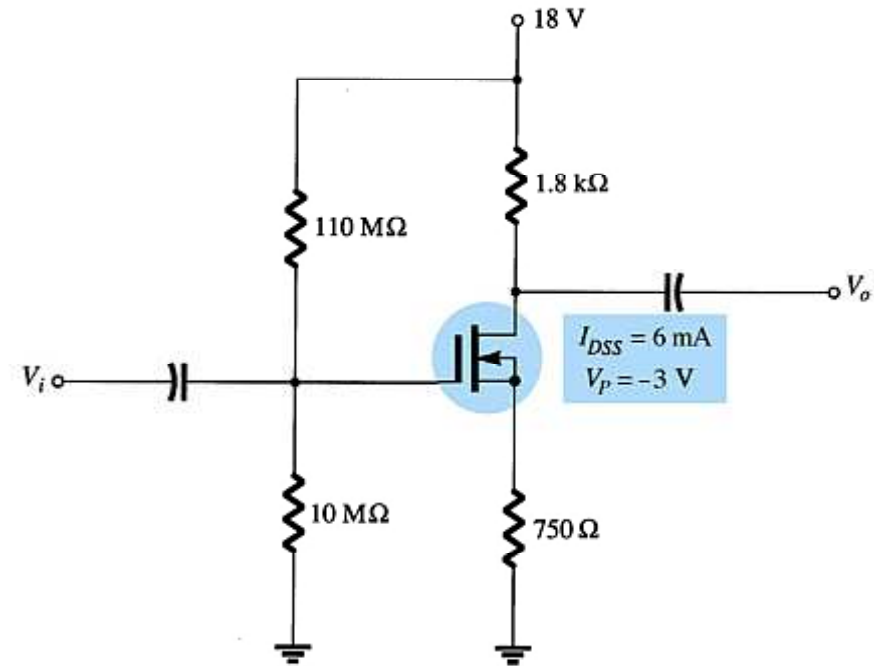
$$V_D = V_{DD} - I_D R_D$$

$$V_S = I_D R_S$$

$$I_{R1} = I_{R2} = \frac{V_{DD}}{R_1 + R_2}$$

# D-Type MOSFET Bias Circuits

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  $I_{DSS}$ .



# Self-Bias

## Step 1

Plot line for

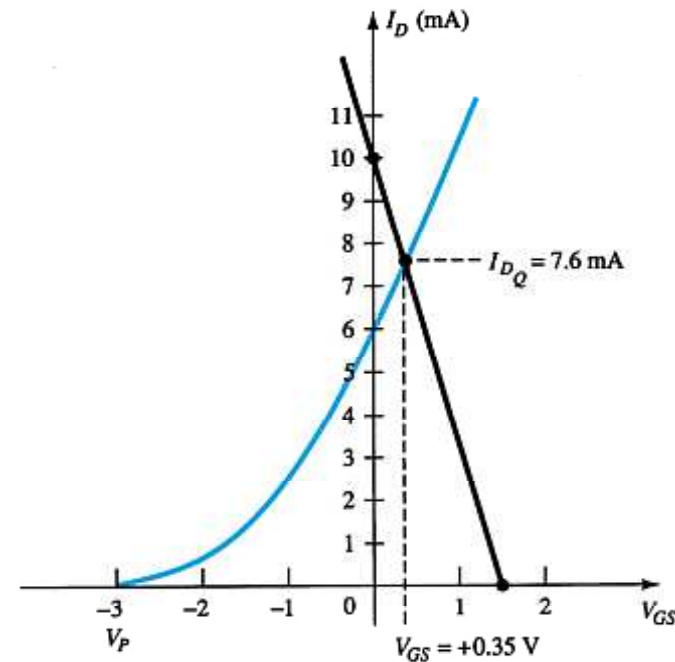
- $V_{GS} = V_G, I_D = 0 \text{ A}$
- $I_D = V_G/R_S, V_{GS} = 0 \text{ V}$

## 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. 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 self-bias circuits.**

# Voltage-Divider Bias

## Step 1

Plot the line for

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

## Step 2

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

## Step 3

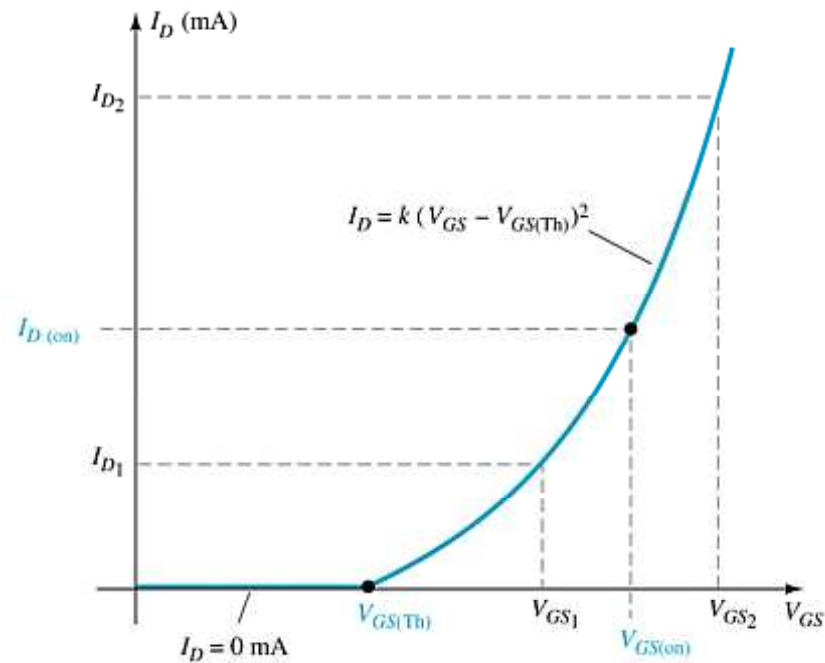
The Q-point is located where the line intersects the transfer curve. Use the  $I_D$  at the Q-point to solve for the other variables in the voltage-divider bias circuit.



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

# E-Type MOSFET Bias Circuits

The transfer characteristic for the e-type MOSFET is very different from that of a simple JFET or the d-type MOSFET.



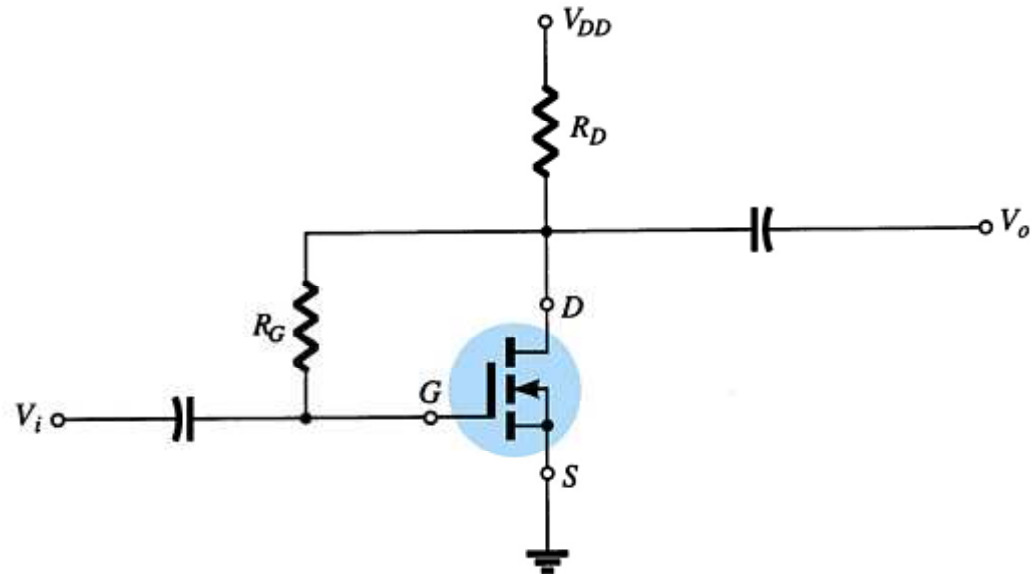
# Feedback Bias Circuit

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

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

$$V_{DS} = V_{GS}$$

$$V_{GS} = V_{DD} - I_D R_D$$



# 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

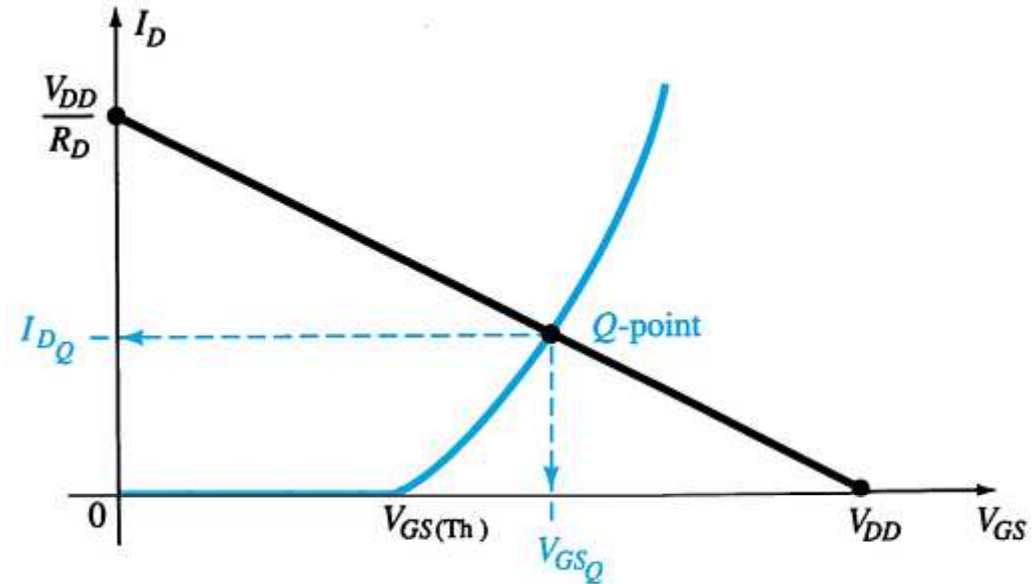
- $V_{GS(Th)}$ ,  $I_D = 0$  A
- $V_{GS(on)}$ ,  $I_{D(on)}$

## 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





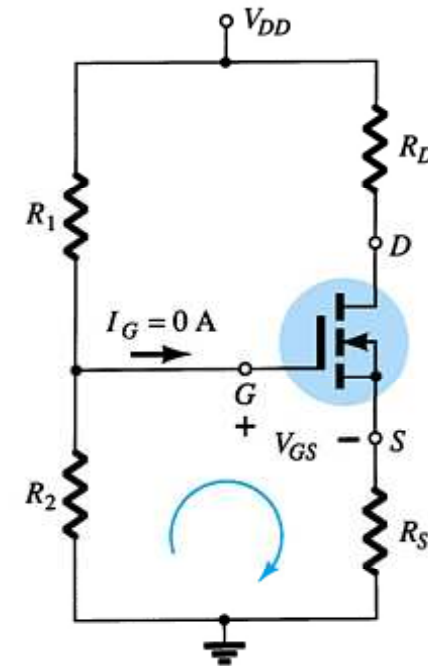
# Voltage-Divider Biasing

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

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

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

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



# Voltage-Divider Bias Q-Point

## Step 1

Plot the line using

- $V_{GS} = V_G = (R_2 V_{DD}) / (R_1 + R_2)$ ,  $I_D = 0 \text{ A}$
- $I_D = V_G / R_S$ ,  $V_{GS} = 0 \text{ V}$

## Step 2

Using values from the specification sheet, plot the transfer curve with

- $V_{GSTh}$ ,  $I_D = 0 \text{ A}$
- $V_{GS(on)}$ ,  $I_{D(on)}$

## Step 3

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

## Step 4

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

# $p$ -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.

# Applications

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