Lesson 2: Transistors and Applications
Introduction

- A **transistor** is a semiconductor device that controls current between two terminals based on the current or voltage at a third terminal.
- It is used for amplification or switching of electrical signals.
- The basic structure of the bipolar junction transistor, BJT, determines its operating characteristics.
- DC bias is important to the operation of transistors in terms of setting up proper currents and voltages in a transistor circuit.
- Two important parameters are $\alpha_{DC}$ and $\beta_{DC}$
Bipolar junction transistors (BJTs)

The BJT is a transistor with three regions and two $pn$ junctions. The regions are named the **emitter**, the **base**, and the **collector** and each is connected to a lead.

There are two types of BJTs – *nnp* and *ppn*.

Separating the regions are two junctions.
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Bipolar junction transistors (BJTs)

**FIGURE 17–2** Transistor symbols.

(a) *npn*  

(b) *pnp*
BJT biasing

For normal operation, the base-emitter junction is forward-biased and the base collector junction is reverse-biased.

For the *ppp* transistor, this condition requires that the base is more positive than the emitter and the collector is more positive than the base.
FIGURE 17–4 Transistor currents.
BJT currents

A small base current ($I_B$) is able to control a larger collector current ($I_C$). Some important current relationships for a BJT are:

\[ I_E = I_C + I_B \]

\[ I_C = \alpha_{DC} I_E \]

Where $\alpha_{DC}$ (dc alpha) = $I_C / I_E$

\[ I_C = \beta_{DC} I_B \]

Where $\beta_{DC}$ (dc beta) = $I_C / I_B$
Voltage-divider bias

Because the base current is small, the approximation

\[ V_B = \left( \frac{R_2}{R_1 + R_2} \right) V_{CC} \]

is useful for calculating the base voltage.

After calculating \( V_B \), you can find \( V_E \) by subtracting 0.7 V for \( V_{BE} \).

\[ V_E = V_B - V_{BE} \]

Next, calculate \( I_E \) by applying Ohm’s law to \( R_E \):

\[ I_E = \frac{V_E}{R_E} \]

Then apply the approximation \( I_C \approx I_E \)

Finally, you can find the collector voltage from

\[ V_C = V_{CC} - I_C R_C \quad V_{CE} = V_C - V_E \]
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Voltage-divider bias

Example 1: Calculate $V_B$, $V_E$, and $V_C$ for the circuit.

Solution:

$$V_B = \left( \frac{R_2}{R_1 + R_2} \right) V_{cc} = \left( \frac{6.8 \text{k} \Omega}{27 \text{k} \Omega + 6.8 \text{k} \Omega} \right) 15 \text{ V} = 3.02 \text{ V}$$

$$V_E = V_B - 0.7 \text{ V} = 2.32 \text{ V}$$

$$I_E = \frac{V_E}{R_E} = \frac{2.32 \text{ V}}{1.0 \text{k} \Omega} = 2.32 \text{ mA}$$

$$I_C \approx I_E = 2.32 \text{ mA}$$

$$V_C = V_{cc} - I_C R_C = 15 \text{ V} - (2.32 \text{ mA})(2.2 \text{ k} \Omega) = 9.90 \text{ V}$$
Determine $V_B$, $V_E$, $V_C$, $V_{CE}$, $I_B$, $I_E$, and $I_C$ in the given Figure. The 2N3904 is a general-purpose transistor with a typical $\beta_{DC} = 200$. 

![Diagram](image-url)
Collector characteristic curves

The collector characteristic curves are a family of curves that show how collector current varies with the collector-emitter voltage for a given $I_B$.

The curves are divided into three regions:

- The **saturation region** occurs when the base-emitter and the base-collector junctions are both forward biased.

- The **breakdown region** is after the saturation region. It is characterized by a rapid increase in collector current. Operation in this region may destroy the transistor.

- The **active region** is after the saturation region. This is the region for operation of class-A operation.
Collector characteristic curves
Example 3: Draw the family of collector characteristics curves for the circuit in the given figure for $I_B = 5 \, \mu A$ to $25 \, \mu A$ in $5 \, \mu A$ increments. Assume $\beta_{DC} = 100$. 

Collector characteristic curves
Draw the family of collector characteristics curves for the circuit in the given figure for $I_B = 5 \, \mu A$ to $25 \, \mu A$ in $5 \, \mu A$ increments. Assume $\beta_{DC} = 100$

**Solution:**

\[
\begin{array}{|c|c|}
\hline
I_B & I_C \\
\hline
5 \, \mu A & 0.5 \, mA \\
10 \, \mu A & 1.0 \, mA \\
15 \, \mu A & 1.5 \, mA \\
20 \, \mu A & 2.0 \, mA \\
25 \, \mu A & 2.5 \, mA \\
\hline
\end{array}
\]

\[
I_C = \beta_{DC}I_B
\]

\[
I_C = 100 \times 5 \, \mu A = 0.5 \, mA
\]
Load lines

A load line is an $IV$ curve that represents the response of a circuit that is external to a specified load. For example, the load line for the Thevenin circuit can be found by calculating the two end points: the current with a shorted load, and the output voltage with no load.

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

$I_{NL} = 0 \text{ mA}$

$V_{NL} = 12 \text{ V}$
Load lines

The $IV$ response for any load will intersect the load line and enables you to read the load current and load voltage directly from the graph.

Example: Read the load current and load voltage from the graph if a 3.0 kΩ resistor is the load.

$$V_L = 7.2 \text{ V} \quad I_L = 2.4 \text{ mA}$$
Load lines

The load line concept can be extended to a transistor circuit. For example, if the transistor is connected as a load, the transistor characteristic curve and the base current establish the Q-point.
Load lines

Load lines can illustrate the operating conditions for a transistor circuit. Assume the $IV$ curves are as shown:

If you add a transistor load to the last circuit, the base current will establish the $Q$-point. Assume the base current is represented by the blue line.

For this base current, the $Q$-point is:

The load voltage ($V_{CE}$) and current ($I_C$) can be read from the graph.
For the transistor, assume the base current is established at 10 μA by the bias circuit. Show the Q-point and read the value of $V_{CE}$ and $I_C$.

The Q-point is the intersection of the load line with the 10 μA base current.

$V_{CE} = 7.0 \text{ V}; \ I_C = 2.4 \text{ mA}$
Signal (ac) operation

- When a signal is applied to a transistor circuit, the output can have a larger amplitude because the small base current controls a larger collector current.

- This increase is called amplification.

- The ratio of the ac collector current \( I_c \) to the ac base current \( I_b \) is designated by \( \beta_{ac} \) (the ac beta) of \( h_{fe} \):

\[
\beta_{ac} = \frac{I_c}{I_b}
\]

**FIGURE 17–13** An amplifier with voltage-divider bias with capacitively coupled input signal. \( V_{in} \) and \( V_{out} \) are with respect to ground.
Signal (ac) operation

When a signal is applied to a transistor circuit, the output can have a larger amplitude because the small base current controls a larger collector current.

Example:

For the load line and characteristic curves from the last example (Q-point shown) assume $I_B$ varies between 5.0 $\mu$A and 15 $\mu$A due to the input signal. What is the change in the collector current?

Solution:

The operation along the load line is shown in red. Reading the collector current, $I_C$ varies from 1.2 mA to 3.8 mA.
In a common-emitter amplifier, the input signal is applied to the base and the output is taken from the collector. The signal is larger but inverted at the output.
CE amplifier

The bypass capacitor increases voltage gain. It shorts the signal around the emitter resistor, $R_E$, in order to increase the voltage gain. To understand why let us consider the amplifier without the bypass capacitor as explained the preceding equations.
Formulas

Lowercase italic subscript indicate signal (ac) voltages and signal (alternating currents)

\[ A_v \text{ (Voltage gain)} = \frac{V_{out}}{V_{in}} \]

\[ V_{out} = I_c R_C \]

The signal voltage at the base is approximately equal to
\[ V_b \equiv V_{in} \equiv I_e (r_e + R_E) \]
where \( r_e \) is the internal emitter resistance of the transistor.
Formulas without the bypass capacitor

\[ A_v \text{ now can be expressed as} \]
\[ A_v = \frac{V_{out}}{V_{in}} = \frac{I_c R_C}{I_e (r_e + R_E)} \]

Since \( I_c \equiv I_e \), the currents cancel and the gain is the ratio of the resistance.

\[ A_v = \frac{R_C}{(r_e + R_E)} \]

If \( R_E \) is much greater than \( r_e \), then

\[ A_v \equiv \frac{R_C}{R_E} \]
If the bypass capacitor is connected across $R_E$, it effectively shorts the signal to ground leaving only $r_e$ in the emitter. Thus the voltage gain of the CE amplifier with the bypass capacitor shorting $R_E$ is:

$$A_v = \frac{R_C}{r_e}$$

The transistor parameter $r_e$ is important because it determines the voltage gain of a CE amplifier in conjunction with $R_C$. A formula for estimating $r_e$ is given without derivation in the following equation:

$$r_e \equiv \frac{25\text{mV}}{I_E}$$
Voltage gain of a CE amplifier

Example: Calculate the voltage gain of the CE amplifier. The dc conditions were calculated earlier; $I_E$ was found to be $2.32 \text{ mA}$.

Solution: 

$$r_e = \frac{25 \text{ mV}}{I_E} = \frac{25 \text{ mV}}{2.32 \text{ mA}} = 10.8 \ \Omega$$

$$A_v = \frac{V_{out}}{V_{in}} \approx \frac{R_C}{r_e}$$

$$= \frac{2.2 \text{ k}\Omega}{10.8 \ \Omega} = 204$$

Sometimes the gain will be shown with a negative sign to indicate phase inversion.
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Phase Inversion

The output voltage at the collector is 180 degrees out of phase with the input voltage at the base. Therefore, the CE amplifier is characterized by a phase inversion between the input and output. The inversion is sometimes indicated by a negative voltage gain.

**AC Input Resistance**

\[ R_{in} = \frac{V_b}{I_b} \]

\[ V_b = I_e r_e \]

\[ I_e = \beta_{ac} I_b \]

\[ R_{in} \equiv \beta_{ac} \frac{I_b r_e}{I_b} \]

The \( I_b \) terms cancel, leaving

\[ R_{in} \equiv \beta_{ac} r_e \]

**Total Input Resistance of a CE amplifier:**

\[ R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in} \]

\[ R_{in(tot)} = R_1 \parallel R_2 \parallel \beta_{ac} r_e \]

\( R_C \) has no effect because of the reverse-biased, base-collector junction.
**Current Gain:**

The signal current gain of a CE amplifier is

\[ A_i = \frac{I_c}{I_s} \]

Where \( I_s \) is the source current and is calculated by \( \frac{V_{in}}{R_{in(tot)}} \).

**Power Gain:**

The power gain of a CE amplifier is the product of the voltage gain and the current gain.

\[ A_p \equiv A_v A_i \]
Decibel (dB) Measurement

The decibel (dB) is a logarithmic measurement of the ratio of one voltage to another or one power to another, which can be used to express the input-to-output relationship.

VOLTAGE RATIO: $\text{dB} = 20 \log \left( \frac{V_{\text{out}}}{V_{\text{in}}} \right)$

POWER RATIO: $\text{dB} = 10 \log \left( \frac{P_{\text{out}}}{P_{\text{in}}} \right)$
The input resistance of a CE amplifier is an ac resistance that includes the bias resistors and the resistance of the emitter circuit as seen by the base. Because $I_B << I_E$, the emitter resistance appears to be much larger when viewed from the base circuit. The factor is $(\beta_{ac}+1)$, which is approximately equal to $\beta_{ac}$. Using this approximation, $R_{in(tot)} = R_1 || R_2 || \beta_{ac} r_e$. 

\[
R_{in(tot)} = R_1 || R_2 || \beta_{ac} r_e
\]

Where $R_1 = 27 \, \text{k}\Omega$, $R_2 = 6.8 \, \text{k}\Omega$, $R_C = 2.2 \, \text{k}\Omega$, $R_E = 1.0 \, \text{k}\Omega$, $C_1 = 2.2 \, \mu\text{F}$, $C_2 = 1.0 \, \mu\text{F}$, and $C_3 = 100 \, \mu\text{F}$. The power supply is $V_{CC} = +15 \, \text{V}$. The transistor used is 2N3904.
Input resistance of a CE amplifier

FIGURE 17–20 Total input resistance.
**Input resistance of a CE amplifier**

**Example:** Calculate the input resistance of the CE amplifier. The transistor is a 2N3904 with an average $\beta_{ac}$ of 200. The value of $r_e$ was found previously to be 10.8 $\Omega$. Thus, $\beta_{ac}r_e = 2.16$ k$\Omega$.

**Solution:**

\[
R_{in(tot)} = R_1 || R_2 || \beta_{ac} r_e
\]

= 27 k$\Omega$ || 6.8 k$\Omega$ || 2.16 k$\Omega$

= 1.55 k$\Omega$

Notice that the input resistance of this configuration is dependent on the value of $\beta_{ac}$, which can vary.
CE amplifier

**Example:** Determine the voltage gain, current gain, and power gain for the CE amplifier given. $\beta_{\text{DC}} = \beta_{\text{ac}} = 100$. Also, express the voltage and power gains in decibels.

**Solution:**

[Image of the CE amplifier diagram with labels and values: $V_{\text{CC}} = +30 \text{ V}$, $R_1 = 100 \text{ k}\Omega$, $R_C = 4.7 \text{ k}\Omega$, $C_2 = 1 \mu\text{F}$, $\beta_{\text{DC}} = \beta_{\text{ac}} = 100$, $V_{\text{in}} = 10 \text{ mV rms}$, $R_2 = 10 \text{ k}\Omega$, $R_E = 1.0 \text{ k}\Omega$, $C_3 = 10 \mu\text{F}$]
CC amplifier (emitter-follower)

In a common-collector amplifier, the input signal is applied to the base and the output is taken from the emitter. There is no voltage gain, but there is power gain.

The output voltage is nearly the same as the input; there is no phase reversal as in the CE amplifier.

The input resistance is larger than in the equivalent CE amplifier because the emitter resistor is not bypassed.
The voltage gain of a CC amplifier is approximately 1, but the current gain is always greater than 1.

**Voltage Gain**

\[ A_v (\text{Voltage Gain}) \]

\[ A_v = \frac{V_{out}}{V_{in}} \]

\[ V_{out} = I_e R_E \]

\[ V_{in} = I_e (r_e + R_E) \]

\[ A_v = \frac{I_e R_E}{I_e (r_e + R_E)} \]

The gain expression simplifies to:

\[ A_v = \frac{R_E}{r_e + R_E} \]

It is important to notice here that the gain is always less than 1. Because \( r_e \) is normally much less than the \( R_E \), then a good approximation is \( A_v = 1 \).
**AC Input Resistance**

The emitter-follower is characterized by a high input resistance, which makes it a very useful circuit. Because of the very high input resistance, the emitter follower can be used as a buffer to minimize loading effects when one circuit is driving another.

\[ R_{in} = \frac{V_b}{I_b} \]

\[ V_b = I_e (r_e + R_E) \]

\[ I_e \equiv \beta_{ac} I_b \]

\[ R_{in} \equiv \beta_{ac} \frac{I_b (r_e + R_E)}{I_b} \]

The \( I_b \) terms cancel, leaving

\[ R_{in} \equiv \beta_{ac} (r_e + R_E) \]

If \( R_E \) is at least ten times larger than \( r_e \), then the input resistance at the base is:

\[ R_{in} \equiv \beta_{ac} R_E \]

Total Input Resistance of a CC amplifier:

\[ R_{in(tot)} = R_1 \parallel R_2 \parallel R_{in} \]
Current Gain:

The signal current gain for the emitter-follower is

\[ A_i = \frac{I_e}{I_s} \]

Where \( I_s \) is the signal current and is calculated by \( \frac{V_{in}}{R_{in(tot)}} \)

Since \( I_e = \frac{V_{out}}{R_E} \) and \( I_s = \frac{V_{in}}{R_{in(tot)}} \) then \( A_i \) can also be expressed as assuming \( \frac{V_{out}}{V_{in}} = 1 \):

\[ A_i = \left( \frac{V_{out}}{R_E} \right) / \left( \frac{V_{in}}{R_{in(tot)}} \right) = R_{in(tot)} / R_E \]

Power Gain:

The power gain of is the product of the voltage gain and the current gain. For the emitter-follower, the power gain is approximately equal to the current gain because the voltage gain is approximately equal to 1.

\[ A_p = A_i \]
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**CC amplifier**

**Example:** Calculate \( r_e \) and \( R_{in(tot)} \) for the CC amplifier. Use \( \beta = 200 \).

**Solution:**

\[
V_B = \left( \frac{R_2}{R_1 + R_2} \right) V_{CC} = \left( \frac{27 \, \text{k}\Omega}{22 \, \text{k}\Omega + 27 \, \text{k}\Omega} \right) 15 \, \text{V} = 8.26 \, \text{V}
\]

\[
V_E = V_B - 0.7 \, \text{V} = 7.76 \, \text{V}
\]

\[
I_E = \frac{V_E}{R_E} = \frac{7.76 \, \text{V}}{1.0 \, \text{k}\Omega} = 7.76 \, \text{mA}
\]

\[
r_e = \frac{25 \, \text{mV}}{I_E} = \frac{25 \, \text{mV}}{7.76 \, \text{mA}} = 3.2 \, \Omega
\]

\[
R_{in(tot)} = R_1 \| R_2 \| \beta_{ac} (r_e + R_E)
\]

\[
= 22 \, \text{k}\Omega \| 27 \, \text{k}\Omega \| 200 \, (1.0 \, \text{k}\Omega) = 9.15 \, \text{k}\Omega
\]

Because \( r_e \) is small compared to \( R_E \), it has almost no affect on \( R_{in(tot)} \).
Determine the input resistance of the emitter-follower in the given figure. Also find the voltage gain, current gain and power gain.
The BJT as a switch

BJTs are used in switching applications when it is necessary to provide current drive to a load.

In switching applications, the transistor is either in cutoff or in saturation.

In cutoff, the input voltage is too small to forward-bias the transistor. The output (collector) voltage will be equal to $V_{CC}$.

When $I_{IN}$ is sufficient to saturate the transistor, the transistor acts like a closed switch. The output is near 0 V.
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The BJT as a switch

(a) Cutoff — open switch

(b) Saturation — closed switch

FIGURE 17–30 Ideal switching action of a transistor.
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The BJT as a switch

**FIGURE 17–30** Ideal switching action of a transistor.

(a) Cutoff — open switch  
(b) Saturation — closed switch

*Conditions in Cutoff* A transistor is in cutoff when the base-emitter junction is not forward biased.

\[ V_{CE(cutoff)} \approx V_{CC} \]

*Conditions in Saturation* When the base-emitter junction is forward-biased and there is enough base current to produce a maximum collector current, the transistor is saturated.

The minimum value of base current to produce saturation is:

\[ I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} \]

\[ V_{BE} = 0.7V \quad V_{RB} = V_{IN} - 0.7V \]

\[ R_{B(max)} = \frac{V_{RB}}{I_{B(min)}} \]
(a) For the transistor switching circuit in the given figure, what is \( V_{CE} \) when \( V_{IN} = 0 \) V?

(b) What minimum value of \( I_B \) will saturate this transistor if the \( \beta_{DC} \) is 200?

(c) Calculate the maximum value of \( R_B \) when \( V_{IN} = 5 \) V.
The field-effect transistor (FET) is a voltage controlled device where gate voltage controls drain current. There are two types of FETs – the JFET and the MOSFET.

JFETs have a conductive channel with a source and drain connection on the ends. Channel current is controlled by the gate voltage.

The gate is always operated with reverse bias on the $pn$ junction formed between the gate and the channel. As the reverse bias is increased, the channel current decreases.
FIGURE 17–33 Effects of $V_{GG}$ on channel width and drain current ($V_{GG} = V_{GS}$).

(a) JFET biased for conduction

(b) Greater $V_{GG}$ narrows the channel (between white areas) which increases the resistance of the channel and decreases $I_D$.

(c) Less $V_{GG}$ widens the channel which decreases the resistance of the channel and increases $I_D$. 
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The FET

FIGURE 17–34 JFET schematic symbols.

(a) $n$ channel  (b) $p$ channel
The MOSFET (Metal Oxide Semiconductor FET) differs from the JFET in that it has an insulated gate instead of a \( pn \) junction between the gate and channel. Like JFETs, MOSFETs have a conductive channel with the source and drain connections on it.

Channel current is controlled by the gate voltage. The required gate voltage depends on the type of MOSFET.
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The FET: MOSFET

FIGURE 17–35 Representation of the basic structure of D-MOSFETs.

(a) n channel

(b) p channel
In addition to the channel designation, MOSFETs are subdivided into two types – depletion mode (D-mode) or enhancement mode (E-mode).

The **D-MOSFET** has a physical channel which can be enhanced or depleted with bias. For this reason, the D-MOSFET can be operated with either negative bias (D-mode) or positive bias (E-mode).

**FIGURE 17–36** Operation of *n*-channel D-MOSFET.
The FET: MOSFET

FIGURE 17–37 D-MOSFET schematic symbols.

(a) $n$ channel

(b) $p$ channel
The E-mode MOSFET has no physical channel. It can only be operated with positive bias (E-mode). Positive bias induces a channel and enables conduction as shown here with a $p$-channel device.

**FIGURE 17–38** E-MOSFET construction and operation.
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The FET: MOSFET

(a) n channel

(b) p channel

FIGURE 17–39 E-MOSFET schematic symbols.
JFETs are depletion mode devices – they must be operated such that the gate-source junction is reverse biased.

The simplest way to bias a JFET is to use a small resistor in series with the source and a high value resistor from the gate to ground. The voltage drop across the source resistor essentially reverse biases the gate-source junction.

Because of the reverse-biased junction, there is almost no current in $R_G$. Thus, $V_G = 0$ V.
JFET biasing

For the $n$-channel JFET, the gate-to-source voltage is $V_{GS} = V_G - V_S = 0V - I_D R_S$

$V_{GS} = -I_D R_S$

For the $p$-channel JFET, the gate-to-source voltage is $V_{GS} = +I_D R_S$

The drain voltage with respect to ground is $V_D = V_{DD} - I_D R_D$

Since $V_S = I_D R_S$, the drain-to-source voltage is $V_{DS} = V_{DD} - I_D (R_D + R_S)$

**FIGURE 17–40** Self-biased JFETs ($I_S = I_D$ in all FETs).
JFET biasing

Example:
Find $V_{DS}$ and $V_{GS}$ in the JFET circuit below, given that $I_D = 5\text{mA}$

Solution:
D-MOSFET biasing

D-MOSFETs can be operated in either depletion mode or in enhancement-mode. For this reason, they can be biased with various bias circuits.

The simplest bias method for a D-MOSFET is called zero bias. In this method, the source is connected directly to ground and the gate is connected to ground through a high value resistor.

Only $n$-channel D-MOSFETs are available, so this is the only type shown.

$n$-channel D-MOSFET with zero bias
D-MOSFET biasing

Recall that depletion/enhancement MOSFETs can be operated with either positive or negative values of $V_{GS}$.

A simple bias method, called zero bias, is to set $V_{GS} = 0$ V so that an ac signal at the gate varies the gate-to-source voltage above and below this bias point.

Since $V_{GS} = 0$ V, $I_D = I_{DSS}$ as indicated. $I_{DSS}$ is defined as the drain current when $V_{GS} = 0$ V.

The drain-to-source voltage is expressed as $V_{DS} = V_{DD} - I_{DSS}R_D$.
D-MOSFET biasing

Example:
Determine the drain-to-source voltage in the circuit of the given figure. The MOSFET data sheet give $V_{GS(\text{off})} = -8$ V and $I_{DSS} = 12$ mA

Solution:
E-MOSFET biasing

E-MOSFETs can use bias circuits similar to BJTs but larger value resistors are normally selected because of the very high input resistance.

The bias voltage is normally set to make the gate more positive than the source by an amount exceeding $V_{GS(th)}$. 

Drain-feedback bias

Voltage-divider bias
Recall that enhancement-only MOSFETs must have a $V_{GS}$ greater than the threshold value $V_{GS(th)}$.

In either bias arrangement, the purpose is to make the gate voltage more positive than the source by an amount exceeding $V_{GS(th)}$.

In the drain-feedback circuit, there is negligible gate current and, therefore, no voltage drop across $R_G$. As a result, $V_{GS} = V_{DS}$.

Equation for the voltage-divider bias is given by

$$V_{GS} = \left( \frac{R_2}{R_1 + R_2} \right) V_{DD}$$

$$V_{DS} = V_{DD} - I_D R_D$$
E-MOSFET biasing

Example:
Determine the amount of drain current in the given figure. The MOSFET has a $V_{GS(th)}$ of 3 V.
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Selected Key Terms

**Bipolar junction transistor (BJT)**
A transistor with three doped semiconductor regions separated by two *pn* junctions.

**Class A amplifier**
An amplifier that conducts for the entire input cycle and produces an output signal that is a replica of the input signal in terms of its waveshape.

**Saturation**
The state of a transistor in which the output current is maximum and further increases of the input variable have no effect on the output.
**Lesson 2**

Selected Key Terms

- **Cutoff**: The non-conducting state of a transistor.

- **Q-point**: The dc operating (bias) point of an amplifier.

- **Amplification**: The process of producing a larger voltage, current or power using a smaller input signal as a pattern.

- **Common-emitter (CE)**: A BJT amplifier configuration in which the emitter is the common terminal.

- **Class B amplifier**: An amplifier that conducts for half the input cycle.
Junction field-effect transistor (JFET) A type of FET that operates with a reverse-biased junction to control current in a channel.

MOSFET Metal-oxide semiconductor field-effect transistor.

Depletion mode The condition in a FET when the channel is depleted of majority carriers.

Enhancement mode The condition in a FET when the channel has an abundance of majority carriers.
1. The Thevenin circuit shown has a load line that crosses the \( y \)-axis at

   a. +10 V.
   b. +5 V.
   c. 2 mA.
   d. the origin.
1. The Thevenin circuit shown has a load line that crosses the y-axis at

   a. +10 V.

   b. +5 V.

   c. 2 mA.

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2. In a common-emitter amplifier, the output ac signal will normally

   a. have greater voltage than the input.
   b. have greater power than the input.
   c. be inverted.
   d. all of the above.
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Quiz

2. In a common-emitter amplifier, the output ac signal will normally
   a. have greater voltage than the input.
   b. have greater power than the input.
   c. be inverted.
   d. all of the above.
3. In a common-collector amplifier, the output ac signal will normally
   a. have greater voltage than the input.
   b. have greater power than the input.
   c. be inverted.
   d. have all of the above.
Lesson 2

Quiz

3. In a common-collector amplifier, the output ac signal will normally
   a. have greater voltage than the input.
   b. have greater power than the input.
   c. be inverted.
   d. have all of the above.
Quiz

4. The type of amplifier shown is a

a. common-collector.

b. common-emitter.

c. common-drain.

d. none of the above.

![Diagram of a transistor amplifier](image-url)
4. The type of amplifier shown is a
   a. common-collector.
   b. common-emitter.
   c. common-drain.
   d. none of the above.
5. A major advantage of FET amplifiers over BJT amplifiers is that generally they have
   a. higher gain.
   b. greater linearity.
   c. higher input resistance.
   d. all of the above.
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   a. higher gain.

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6. A type of field effect transistor that can operate in either depletion or enhancement mode is an

a. D-MOSFET.

b. E-MOSFET.

c. JFET.

d. none of the above.
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a. D-MOSFET.

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d. none of the above.
8. A transistor circuit shown is a

a. D-MOSFET with voltage-divider bias.
b. E-MOSFET with voltage-divider bias.
c. D-MOSFET with self-bias.
d. E-MOSFET with self bias.
8. A transistor circuit shown is a
   
a. D-MOSFET with voltage-divider bias.
   
b. E-MOSFET with voltage-divider bias.
   
c. D-MOSFET with self-bias.
   
d. E-MOSFET with self bias.
10. If you were troubleshooting the circuit shown here, you would expect the gate voltage to be

a. more positive than the drain voltage.

b. more positive than the source voltage.

c. equal to zero volts.

d. equal to $+V_{DD}$
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