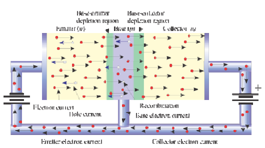
Electronic Devices

Ninth Edition

Floyd

Chapter 5: Transistor Bias Circuits

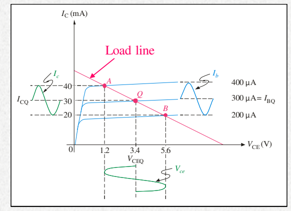


Summary

The DC Operating Point

Bias establishes the operating point (Q-point) of a transistor amplifier; the ac signal moves above and below this point.

For this example, the dc base current is 300 µA. When the input causes the base current to vary between 200 µA and 400 µA, the collector current varies between 20 mA and 40 mA.

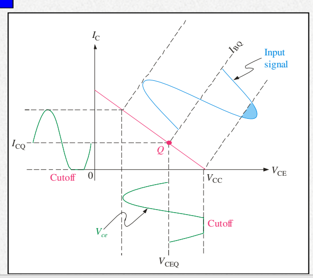


Summary

The DC Operating Point

A signal that swings outside the active region will be clipped.

For example, the bias has established a low Q-point. As a result, the signal is will be clipped because it is too close to cutoff.



Summary

Voltage-Divider Bias

A practical way to establish a Q-point is to form a voltage-divider from V_{CC}.

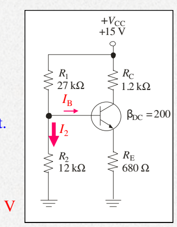
R_1 and R_2 are selected to establish V_B. If the divider is stiff, I_B is small compared to I_2. Then,

$$V_B \approx \left(\frac{R_2}{R_1+R_2}\right)V_{CC}$$

Example: Determine the base voltage for the circuit.

Solution:

$$V_B = \left(\frac{R_2}{R_1+R_2}\right)V_{CC} = \left(\frac{12\text{ k}\Omega}{27\text{ k}\Omega + 12\text{ k}\Omega}\right)(+15\text{ V}) = 4.62\text{ V}$$



Summary

Voltage-Divider Bias

Follow-up:

What is the emitter voltage, V_E, and current, I_E?

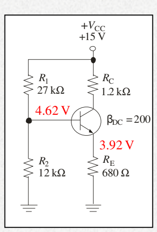
Solution:

V_E is one diode drop less than V_B:

$V_E = 4.62\text{ V} - 0.7\text{ V} = 3.92\text{ V}$

Applying Ohm's law:

$$I_E = \frac{V_E}{R_E} = \frac{3.92\text{ V}}{680\ \Omega} = 5.76\text{ mA}$$



Summary

Voltage-Divider Bias

The unloaded voltage divider approximation for V_B gives reasonable results. A more exact solution is to Thevenize the input circuit.

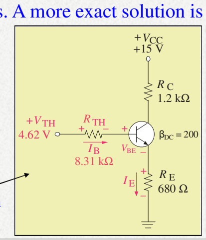
$V_{TH} = V_{B(\text{no load})}$

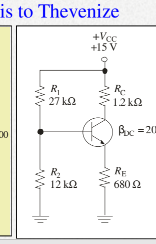
$= 4.62\text{ V}$

$R_{TH} = R_1 \| R_2 =$

$= 8.31\text{ k}\Omega$

The Thevenin input circuit can be drawn





Summary

Voltage-Divider Bias

Now write KVL around the base emitter circuit and solve for I_E.

$$V_{TH} = I_B R_{TH} + V_{BE} + I_E R_E$$

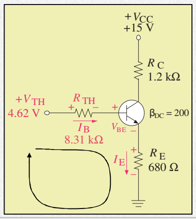
$$I_E = \frac{V_{TH} - V_{BE}}{R_E + R_{TH}/\beta_{DC}}$$

Substituting and solving,

$$I_E = \frac{4.62\ \text{V} - 0.7\ \text{V}}{680\ \Omega + 8.31\ \text{k}\Omega/200} = 5.43\ \text{mA}$$

and $V_E = I_E R_E = (5.43\ \text{mA})(0.68\ \text{k}\Omega)$

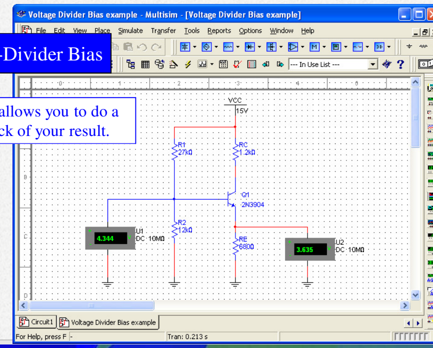
$= 3.69\ \text{V}$



Summary

Voltage-Divider Bias

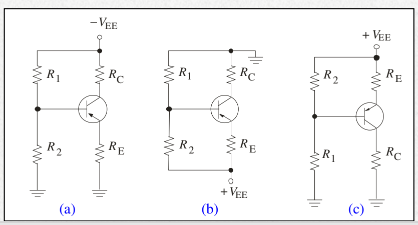
Multisim allows you to do a quick check of your result.



Summary

Voltage-Divider Bias

A *pnp* transistor can be biased from either a positive or negative supply. Notice that (b) and (c) are the same circuit; both with a positive supply.



Summary

Voltage-Divider Bias

Example: Determine I_E for the *pnp* circuit. Assume a stiff voltage divider (no loading effect).

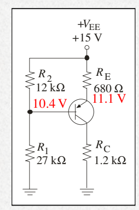
Solution:

$$V_B = \left(\frac{R_1}{R_1 + R_2}\right) V_{EE}$$

$$= \left(\frac{27\ \text{k}\Omega}{27\ \text{k}\Omega + 12\ \text{k}\Omega}\right)(+15.0\ \text{V}) = 10.4\ \text{V}$$

$$V_E = V_B + V_{BE} = 10.4\ \text{V} + 0.7\ \text{V} = 11.1\ \text{V}$$

$$I_E = \frac{V_{EE} - V_E}{R_E} = \frac{15.0\ \text{V} - 11.1\ \text{V}}{680\ \Omega} = 5.74\ \text{mA}$$



Summary

Emitter Bias

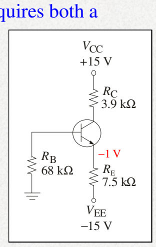
Emitter bias has excellent stability but requires both a positive and a negative source.

For troubleshooting analysis, assume that V_E for an *npn* transistor is about −1 V.

Example: Assuming that V_E is −1 V, what is I_E?

Solution:

$$I_E = \frac{-V_{EE} - 1\ \text{V}}{R_E} = \frac{-15\ \text{V} - (-1\ \text{V})}{7.5\ \text{k}\Omega} = -1.87\ \text{mA}$$



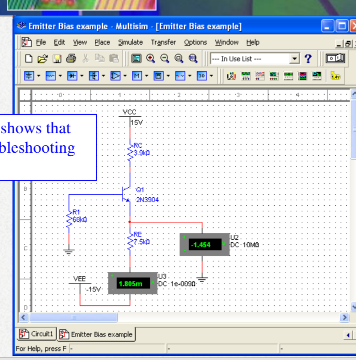
Summary

Emitter Bias

A check with Multisim shows that the assumption for troubleshooting purposes is reasonable.

For detailed analysis work, you can include the effect of β_{DC}. In this case,

$$I_E = \frac{-V_{EE} - 1\ \text{V}}{R_E + R_B/\beta_{DC}}$$



Summary

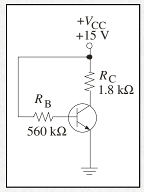
Base Bias

Base bias is used in switching circuits because of its simplicity, but not widely used in linear applications because the *Q*-point is β dependent.

Base current is derived from the collector supply through a large base resistor.

Example:

What is I_B?



Solution:

$$I_B = \frac{V_{CC} - 0.7\text{ V}}{R_B} = \frac{15\text{ V} - 0.7\text{ V}}{560\text{ k}\Omega} = 25.5\ \mu\text{A}$$

Summary

Base Bias

Follow up:

Compare V_{CE} for the case where β = 100 and β = 200.

Solution:

For β = 100: $I_C = \beta I_B = (100)(25.5\ \mu\text{A}) = 2.55\text{ mA}$

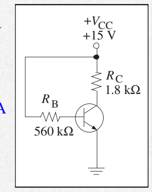
$V_{CE} = V_{CC} - I_C R_C$

$= 15\text{ V} - (2.55\text{ mA})(1.8\text{ k}\Omega) = 10.4\text{ V}$

For β = 300: $I_C = \beta I_B = (300)(25.5\ \mu\text{A}) = 7.65\text{ mA}$

$V_{CE} = V_{CC} - I_C R_C$

$= 15\text{ V} - (7.65\text{ mA})(1.8\text{ k}\Omega) = 1.23\text{ V}$



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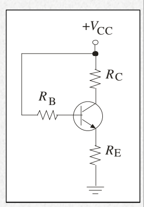
Summary

Emitter-Feedback Bias

An emitter resistor changes base bias into emitter-feedback bias, which is more predictable. The emitter resistor is a form of **negative feedback**.

The equation for emitter current is found by writing KVL around the base circuit. The result is:

$$I_E = \frac{V_{CC} - V_{BE}}{R_E + R_B/\beta_{DC}}$$



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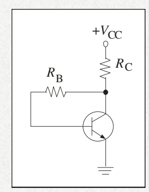
Summary

Collector-Feedback Bias

Collector feedback bias uses another form of **negative feedback** to increase stability. Instead of returning the base resistor to V_{CC}, it is returned to the collector.

The equation for collector current is found by writing KVL around the base circuit. The result is

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + R_B/\beta_{DC}}$$



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Summary

Collector-Feedback Bias

Example:

Compare I_C for the case when β = 100 with the case when β = 300.

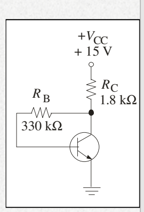
Solution:

When β = 100,

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + R_B/\beta_{DC}} = \frac{15\text{ V} - 0.7\text{ V}}{1.8\text{ k}\Omega + 330\text{ k}\Omega/100} = 2.80\text{ mA}$$

When β = 300,

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + R_B/\beta_{DC}} = \frac{15\text{ V} - 0.7\text{ V}}{1.8\text{ k}\Omega + 330\text{ k}\Omega/300} = 4.93\text{ mA}$$



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Key Terms

***Q*-point** The dc operating (bias) point of an amplifier specified by voltage and current values.

DC load line A straight line plot of I_C and V_{CE} for a transistor circuit.

Linear region The region of operation along the load line between saturation and cutoff.

Stiff voltage divider A voltage divider for which loading effects can be ignored.

Feedback The process of returning a portion of a circuit's output back to the input in such a way as to oppose or aid a change in the output.

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Quiz

1. A signal that swings outside the active area will be

a. clamped

b. clipped

c. unstable

d. all of the above

Quiz

2. A stiff voltage divider is one in which

a. there is no load current

b. divider current is small compared to load current

c. the load is connected directly to the source voltage

d. loading effects can be ignored

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Quiz

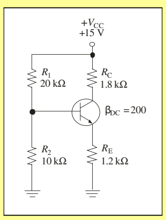
3. Assuming a stiff voltage-divider for the circuit shown, the emitter voltage is

a. 4.3 V

b. 5.7 V

c. 6.8 V

d. 9.3 V



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Quiz

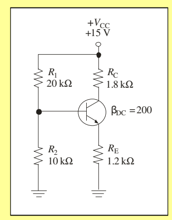
4. For the circuit shown, the dc load line will intersect the *y*-axis at

a. 5.0 mA

b. 10.0 mA

c. 15.0 mA

d. none of the above



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Quiz

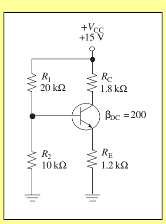
5. If you Thevenize the input voltage divider, the Thevenin resistance is

a. 5.0 kΩ

b. 6.67 kΩ

c. 10 kΩ

d. 30 kΩ



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Quiz

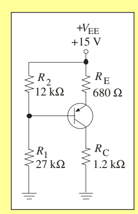
6. For the circuit shown, the emitter voltage is

a. less than the base voltage

b. less than the collector voltage

c. both of the above

d. none of the above



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Quiz

7. Emitter bias

a. is not good for linear circuits

b. uses a voltage-divider on the input

c. requires dual power supplies

d. all of the above

Quiz

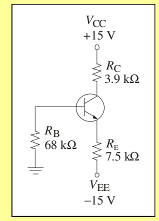
8. With the emitter bias shown, a reasonable assumption for troubleshooting work is that the

a. base voltage = +1 V

b. emitter voltage = +5 V

c. emitter voltage = −1 V

d. collector voltage = V_{CC}



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Quiz

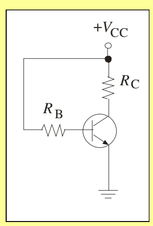
9. The circuit shown is an example of

a. base bias

b. collector-feedback bias

c. emitter bias

d. voltage-divider bias



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Quiz

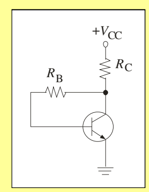
10. The circuit shown is an example of

a. base bias

b. collector-feedback bias

c. emitter bias

d. voltage-divider bias



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Quiz

Answers:

1. b	6. d
2. d	7. c
3. a	8. c
4. a	9. a
5. b	10. b

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