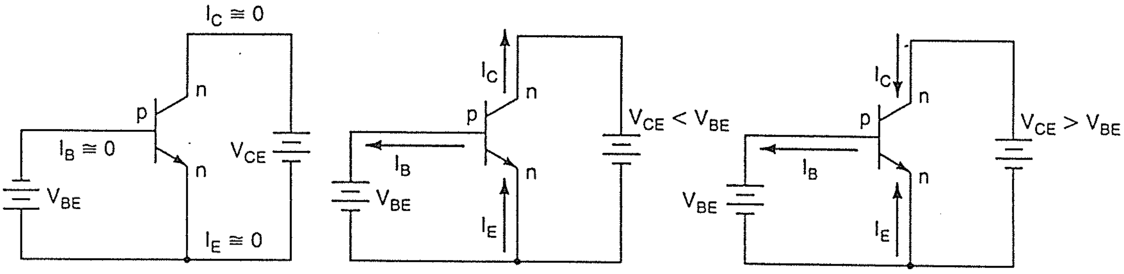
LESSON 3

Summary of selected information

(Sources: Paynter's Introductory Electronic devices & Circuits, 3rd ed. & Floyd Electronic Devices, 3rd ed.)

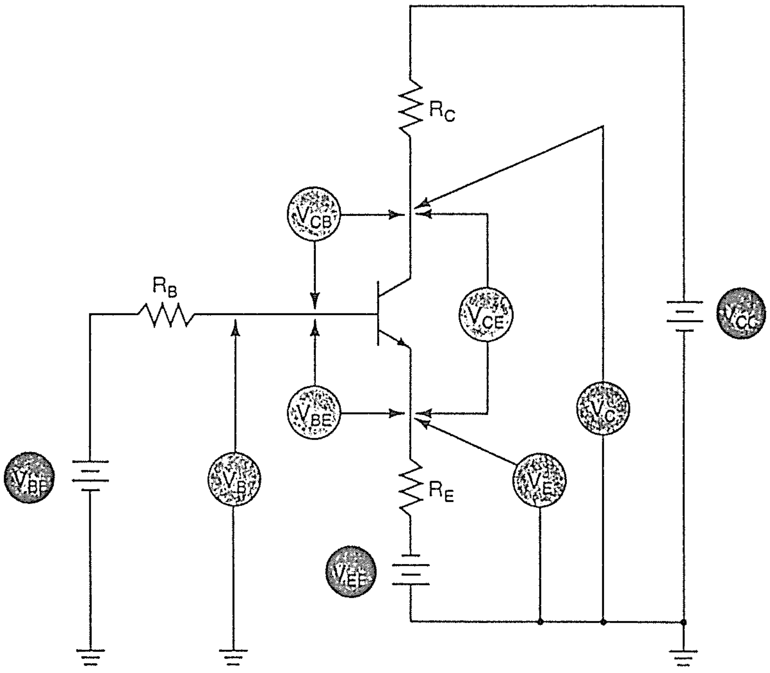
1. The three operating conditions of a transistor.

Operating region:	Cutoff*	Saturation	Active
B–E Junction Biasing:	Reverse	Forward	Forward
C–B Junction Biasing:	Reverse	Forward	Reverse
**Schematic of an npn circuit:			
Collector Current (I_C):	Approximately equal to zero.	Maximum; limited by external components in the collector-emitter circuit.	Determined by the values of β and I_B.

*The characteristics listed are identical to those of *zero bias*.
**For *pnp* circuits, the voltage polarities and current directions are the opposite of those shown.

2. BJT Amplifier DC Voltage Terminology.

BJT amplifier voltages.



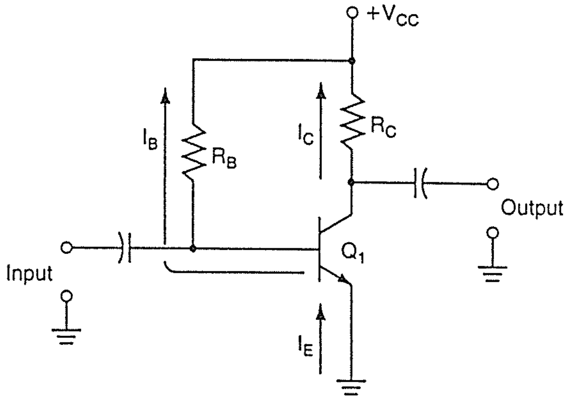
Transistor Voltages

Voltage Abbreviation	*Definition*
V_{CC}	*Collector biasing voltage.* This is a power supply voltage that is directly or indirectly applied to the collector of the transistor.
V_{BB}	*Base biasing voltage.* This is a dc voltage that is used to bias the base of the transistor. It may come directly from a dc voltage supply or may be applied indirectly to the base by a resistive circuit.
V_{EE}	*Emitter biasing voltage.* This, again, is a dc biasing voltage. In many cases, V_{EE} will be nothing more than a *ground* connection.
V_C	This is the dc voltage *measured from the collector terminal of the component to ground.*
V_B	This is the dc voltage *measured from the base terminal to ground.*
V_E	This is the dc voltage *measured from the emitter terminal to ground.*
V_{CE}	This is the dc voltage *measured between the collector and emitter terminals of the transistor.*
V_{BE}	This is the dc voltage *measured between the base and emitter terminals of the transistor.*
V_{CB}	This is the dc voltage *measured between the collector and base terminals of the transistor.*

A Memory Trick: There is a relatively simple way to remember the voltages listed here. When the voltage has a double subscript (such as *CC, BB* or *EE*), it is a supply voltage. When two different subscripts are shown (such as *CE, BE*, or *CB*), the voltage is measured between the two terminals. When only one subscript is shown, the voltage is measured from that terminal to ground.

CHARACTERISTICS OF BIASING CIRCUITS.

A. Base Bias.

Biasing circuit:	Base Bias
Schematic diagram:	
Circuit recognition:	A single base resistor (R_B) between the base terminal and V_{CC}, and no emitter resistor.
Advantages:	Circuit simplicity.
Disadvantages:	Beta dependent output values; subject to severe Q-point shift.
Applications:	Switching circuits only.

BASE BIAS

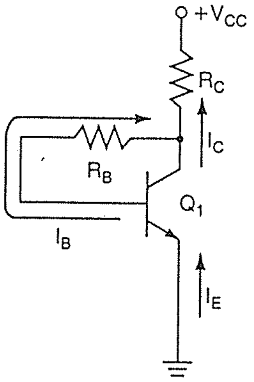
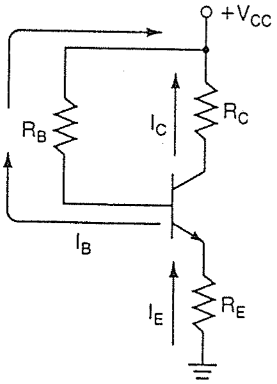
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta_{dc} I_B$$

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

$$V_{CE} = V_{CC} - \beta_{dc} I_B R_C$$

B. Collector Bias.

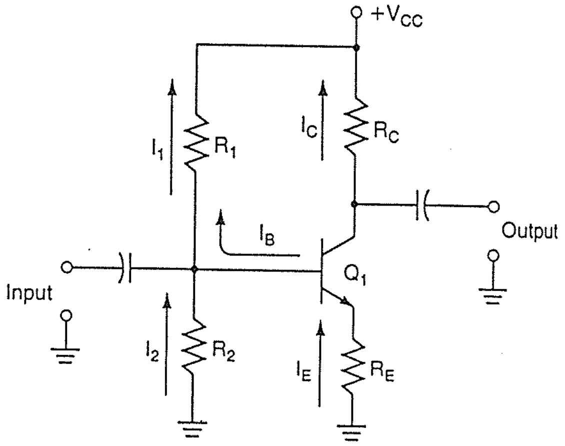
Biasing circuit:	Collector-feedback bias	Emitter-feedback bias
Schematic diagram:		
Circuit recognition:	The base resistor is connected between the base and collector terminals of the transistor.	Identical to base-bias with the exception of an added emitter resistor. Looks like voltage-divider bias with R_2 missing.
Advantages:	A simple circuit that is relatively beta independent.	A simple circuit that is relatively beta independent. Has better ac characteristics than collector-feedback bias.
Disadvantages:	Poor ac characteristics.	More complex circuitry than collector-feedback bias.
Applications:	Linear amplifiers.	Linear amplifiers.

COLLECTOR-FEEDBACK BIAS

$$I_B = \frac{V_C - V_{BE}}{R_B}$$

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

C. Voltage Divider Bias.

Biasing circuit:	Voltage-Divider Bias
Schematic diagram:	
Circuit recognition:	The voltage divider in the base circuit.
Advantages:	The circuit is beta-independent (like emitter-bias), but does not require a dual-polarity power supply.
Disadvantages:	None (as compared to other biasing circuits) in terms of dc operation.
Applications:	Used primarily as linear amplifiers.

VOLTAGE-DIVIDER BIAS (NPN)

$$R_{\mathrm{IN(base)}} = \frac{V_{\mathrm{IN}}}{I_{\mathrm{IN}}}$$

$$R_{\mathrm{IN(base)}} \cong \beta_{\mathrm{dc}} R_E$$

$$V_B = \frac{R_2 \| \beta_{\mathrm{dc}} R_E}{R_1 + (R_2 \| \beta_{\mathrm{dc}} R_E)} V_{CC}$$

$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right) V_{CC},\ \beta_{\mathrm{dc}} R_E >> R_2$$

$$V_E = V_B - V_{BE}$$

$$I_E = \frac{V_E}{R_E}$$

$$V_{CE} \cong V_{CC} - I_E(R_C + R_E)$$

$$I_E \cong \frac{V_{TH} - V_{BE}}{R_E},\ R_E >> R_{TH}/\beta_{\mathrm{dc}}$$

VOLTAGE-DIVIDER BIAS (PNP)

$$V_B = \left(\frac{R_1}{R_1 + R_2}\right) V_{EE},\ \beta_{\mathrm{dc}} R_E >> R_2$$

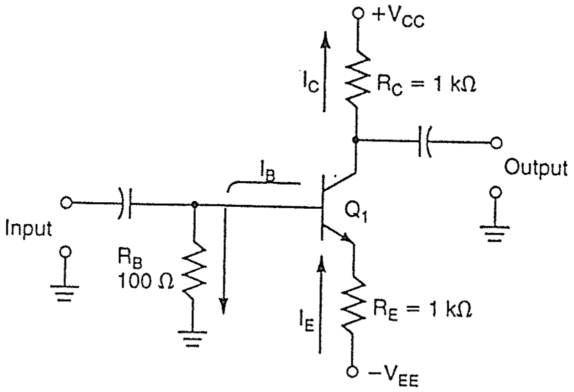
$$V_E = V_B + V_{BE}$$

$$I_E = \frac{V_{EE} - V_E}{R_E}$$

$$V_C = I_C R_C$$

$$V_{EC} = V_E - V_C$$

D. Dual Supply or Emitter Bias.

Biasing circuit:	Emitter Bias
Schematic diagram:	
Circuit recognition:	A *split* (dual-polarity) power supply and the base resistor connected to ground.
Advantages:	Beta independent output values.
Disadvantages:	Requires the use of a dual-polarity power supply.
Applications:	Used primarily as a linear amplifier.

EMITTER BIAS

$$V_B \cong 0$$

$$V_E \cong -V_{BE}$$

$$I_E = \frac{V_E - V_{EE}}{R_E}$$

$$I_C \cong I_E$$

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

$$V_{CE} = V_C - V_E$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E + R_B/\beta_{\text{dc}}}$$

$$I_E \cong \frac{V_{EE} - V_{BE}}{R_E},\ R_E >> R_B/\beta_{\text{dc}}$$

$$I_E \cong \frac{V_{EE}}{R_E},\ V_{EE} >> V_{BE}$$

VOLTAGE-DIVIDER BIASED PNP

As you know, a pnp transistor requires bias polarities opposite to the npn. This can be accomplished with a negative collector supply voltage, as in Figure 5–26(a), or with a positive emitter supply voltage, as in Figure 5–26(b). In a schematic, the pnp is often drawn upside down so that the supply voltage line can be drawn across the top of the schematic and ground at the bottom, as in Figure 5–27. The analysis procedure is basically the same as for an npn circuit, as demonstrated in the following steps with reference to Figure 5–27. Assuming that $\beta_{dc}R_E >> R_2$, the base voltage is

$$V_B = \left(\frac{R_1}{R_1 + R_2}\right)V_{EE} \qquad (5\text{–}22)$$

and

$$V_E = V_B + V_{BE} \qquad (5\text{–}23)$$

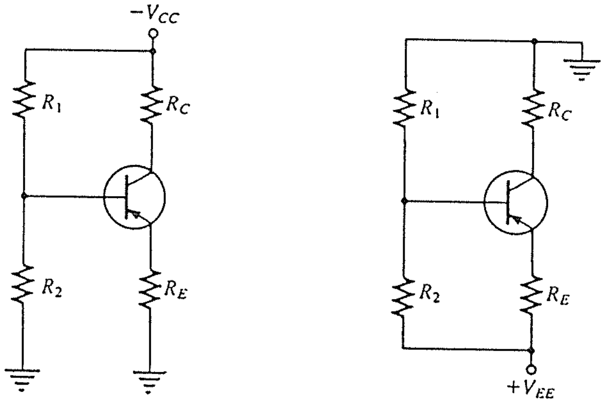
So,

$$I_E = \frac{V_{EE} - V_E}{R_E} \qquad (5\text{–}24)$$

and

$$V_C = I_C R_C \qquad (5\text{–}25)$$

$$V_{EC} = V_E - V_C \qquad (5\text{–}26)$$



(a) Negative supply voltage (b) Positive supply voltage

FIGURE 5–26
Voltage-divider biased pnp transistor.

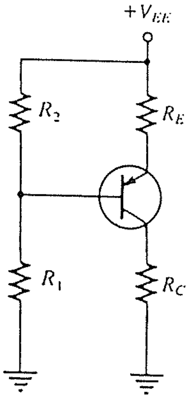


FIGURE 5–27

EXAMPLE

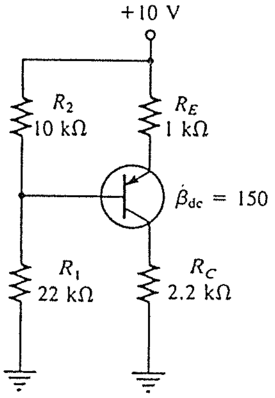
Find I_C and V_{EC} in Figure 5–28.

SOLUTION

Let's check to see if $R_{\text{IN(base)}}$ can be neglected.

$$R_{\text{IN(base)}} = \beta_{\text{dc}}R_E = (150)(1\text{ k}\Omega) = 150\text{ k}\Omega$$

FIGURE 5–28



Since 150 kΩ is more than ten times R_2, the condition $\beta_{\text{dc}}R_E >> R_2$ is met and $R_{\text{IN(bas}}$ can be neglected. First calculate V_B.

$$V_B = \left(\frac{R_1}{R_1 + R_2}\right)V_{EE} = \left(\frac{22\text{ k}\Omega}{32\text{ k}\Omega}\right)10\text{ V} = 6.88\text{ V}$$

Then

$$V_E = 6.88\text{ V} + 0.7\text{ V} = 7.58\text{ V}$$

and

$$I_E = \frac{V_{EE} - V_E}{R_E} = \frac{10\text{ V} - 7.58\text{ V}}{1\text{ k}\Omega} = 2.42\text{ mA}$$

From I_E, we can get I_C and V_{CE} as follows:

$$I_C \cong I_E = 2.42\text{ mA}$$

and

$$V_C = I_C R_C = (2.42\text{ mA})(2.2\text{ k}\Omega) = 5.32\text{ V}$$

Therefore,

$$\begin{aligned} V_{EC} &= V_E - V_C \\ &= 7.58\text{ V} - 5.32\text{ V} \\ &= 2.26\text{ V} \end{aligned}$$