



# Lecture (07) Bipolar Junction Transistor (3)

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By:

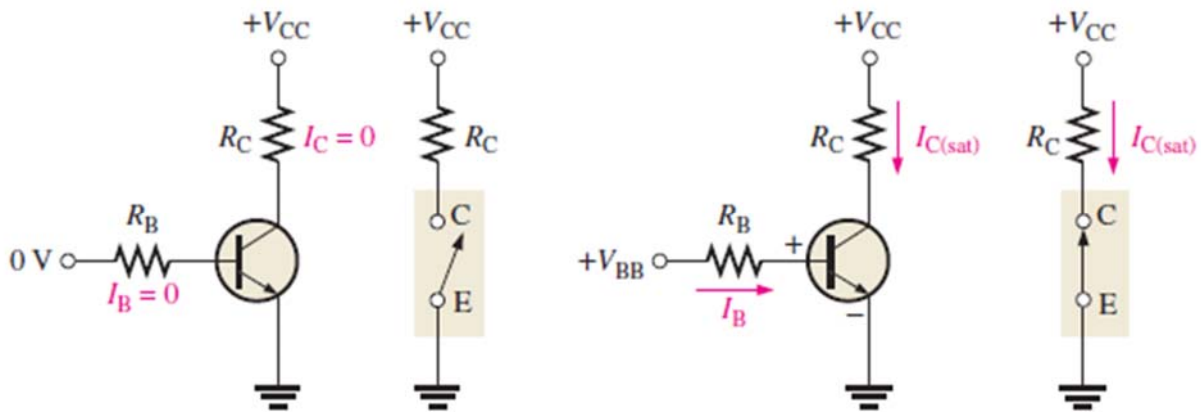
**Dr. Ahmed ElShafee**

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## THE BJT AS A SWITCH

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- The second major application area is switching applications. When used as an electronic switch, a BJT is normally operated alternately in cutoff and saturation.
- Many digital circuits use the BJT as a switch.



the transistor is in the saturation region because the base-emitter junction and the base-collector junction are forward-biased and the base current is made large enough to cause the collector current to reach its saturation value. A small voltage drop across the transistor of up to a few tenths of a volt normally occurs, which is the saturation voltage,  $V_{CE(sat)}$ .

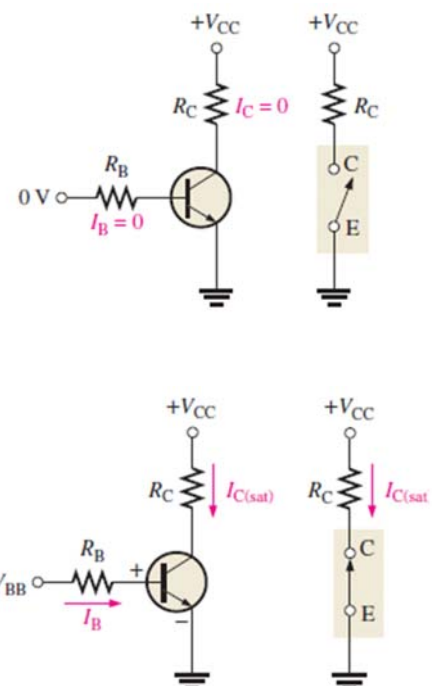
- **Conditions in Cutoff**

$$V_{CE(\text{cutoff})} = V_{CC}$$

- **Conditions in Saturation**

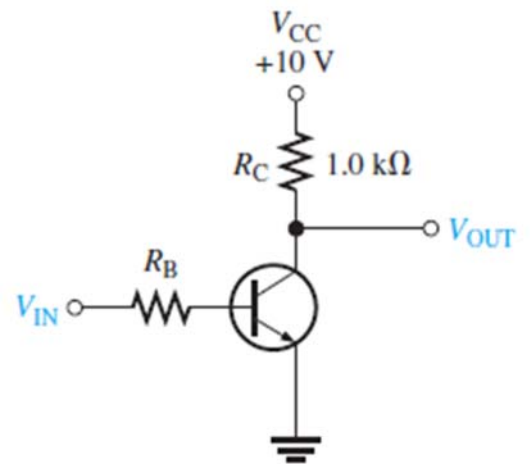
$$I_{C(\text{sat})} = \frac{V_{CC} - V_{CE(\text{sat})}}{R_C}$$

$$I_{B(\text{min})} = \frac{I_{C(\text{sat})}}{\beta_{DC}}$$



# Example 06

- (a) For the transistor circuit in Figure 4–24, what is  $V_{CE}$  when  $V_{IN} = 0$  V?
- (b) What minimum value of  $I_B$  is required to saturate this transistor if  $\beta_{DC}$  is 200? Neglect  $V_{CE(sat)}$ .
- (c) Calculate the maximum value of  $R_B$  when  $V_{IN} = 5$  V.



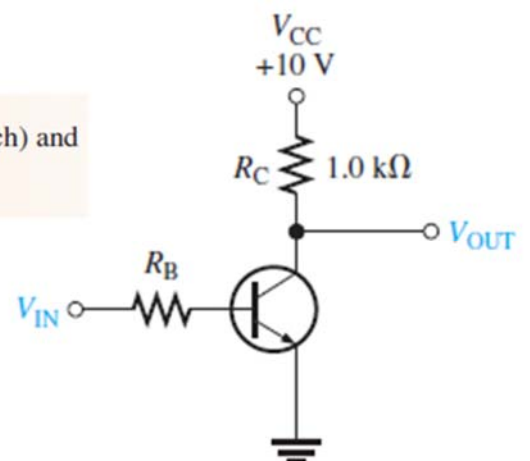
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# Example 06

- (a) For the transistor circuit in Figure 4–24, what is  $V_{CE}$  when  $V_{IN} = 0$  V?
- (b) What minimum value of  $I_B$  is required to saturate this transistor if  $\beta_{DC}$  is 200? Neglect  $V_{CE(sat)}$ .
- (c) Calculate the maximum value of  $R_B$  when  $V_{IN} = 5$  V.

(a) When  $V_{IN} = 0$  V, the transistor is in cutoff (acts like an open switch) and

$$V_{CE} = V_{CC} = 10 \text{ V}$$



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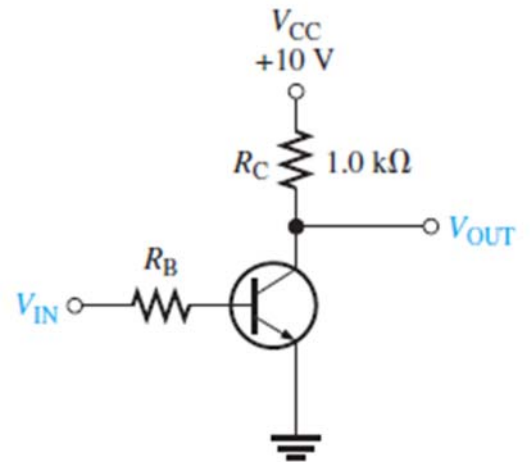
# Example 06

- (a) For the transistor circuit in Figure 4–24, what is  $V_{CE}$  when  $V_{IN} = 0$  V?
- (b) What minimum value of  $I_B$  is required to saturate this transistor if  $\beta_{DC}$  is 200? Neglect  $V_{CE(sat)}$ .
- (c) Calculate the maximum value of  $R_B$  when  $V_{IN} = 5$  V.

(b) Since  $V_{CE(sat)}$  is neglected (assumed to be 0 V),

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{10 \text{ V}}{1.0 \text{ k}\Omega} = 10 \text{ mA}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{10 \text{ mA}}{200} = 50 \mu\text{A}$$



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# Example 06

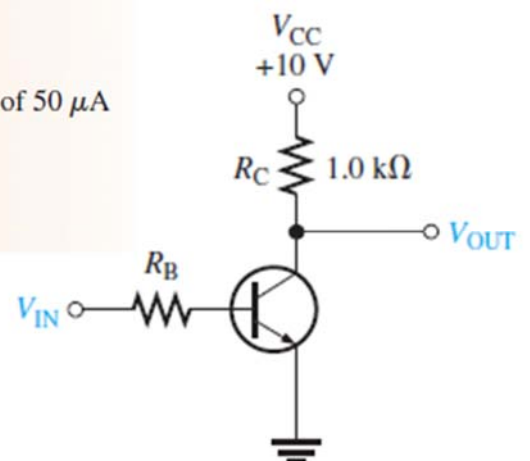
- (a) For the transistor circuit in Figure 4–24, what is  $V_{CE}$  when  $V_{IN} = 0$  V?
- (b) What minimum value of  $I_B$  is required to saturate this transistor if  $\beta_{DC}$  is 200? Neglect  $V_{CE(sat)}$ .
- (c) Calculate the maximum value of  $R_B$  when  $V_{IN} = 5$  V.

(c) When the transistor is on,  $V_{BE} \cong 0.7$  V. The voltage across  $R_B$  is

$$V_{R_B} = V_{IN} - V_{BE} \cong 5 \text{ V} - 0.7 \text{ V} = 4.3 \text{ V}$$

Calculate the maximum value of  $R_B$  needed to allow a minimum  $I_B$  of  $50 \mu\text{A}$  using Ohm's law as follows:

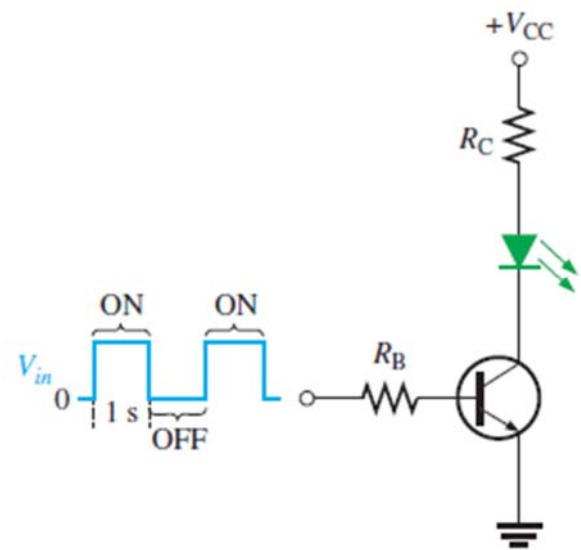
$$R_{B(max)} = \frac{V_{R_B}}{I_{B(min)}} = \frac{4.3 \text{ V}}{50 \mu\text{A}} = 86 \text{ k}\Omega$$



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# A Simple Application of a Transistor Switch

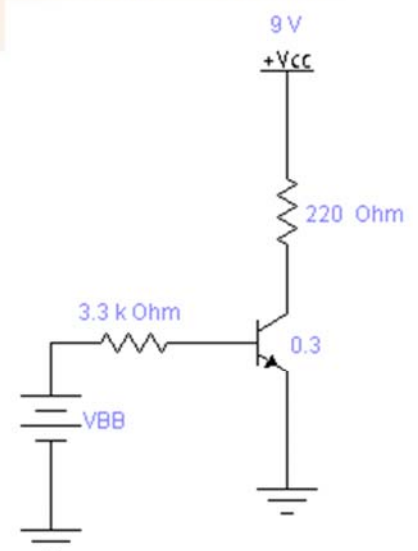


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## Example 07

The LED in Figure 4–25 requires 30 mA to emit a sufficient level of light. Therefore, the collector current should be approximately 30 mA. For the following circuit values, determine the amplitude of the square wave input voltage necessary to make sure that the transistor saturates. Use double the minimum value of base current as a safety margin to ensure saturation.  $V_{CC} = 9\text{ V}$ ,  $V_{CE(\text{sat})} = 0.3\text{ V}$ ,  $R_C = 220\ \Omega$ ,  $R_B = 3.3\text{ k}\Omega$ ,  $\beta_{DC} = 50$ , and  $V_{LED} = 1.6\text{ V}$ .



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# Example 07

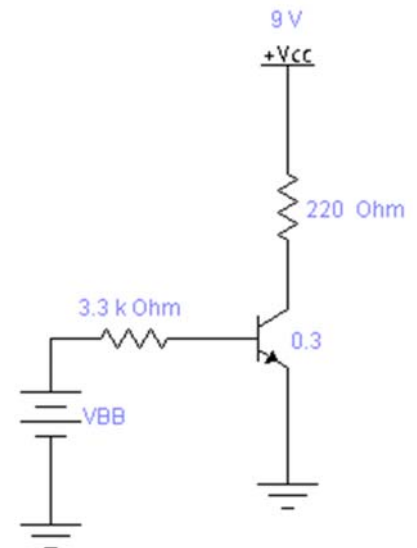
margin to ensure saturation.  $V_{CC} = 9\text{ V}$ ,  $V_{CE(\text{sat})} = 0.3\text{ V}$ ,  $R_C = 220\ \Omega$ ,  $R_B = 3.3\text{ k}\Omega$ ,  $\beta_{DC} = 50$ , and  $V_{LED} = 1.6\text{ V}$ .

$$I_{Csat} = \frac{V_{CC} - V_{CE}}{R_C} = \frac{9 - 0.3}{220} = 32.3\text{ mA}$$

$$I_{Bmin} = \frac{I_{Csat}}{\beta} = \frac{32.3}{50} = 6.46\ \mu\text{A}$$

$$I_B = 2 I_{Bmin} = 1.29\text{ mA}$$

$$V_{BB} = I_B R_B + V_{BE} = (3.3 \times 1.29) + 0.7 \\ = 4.96\text{ V}$$



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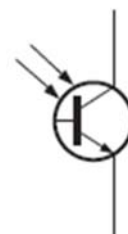
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## Photo transistor

- In a **phototransistor** the base current is produced when light strikes the photosensitive semiconductor base region.
- The collector-base *pn* junction is exposed to incident light through a lens opening in the transistor package.
- When light strikes the collector-base *pn* junction, a base current,  $I_\lambda$ , is produced that is directly proportional to the light intensity

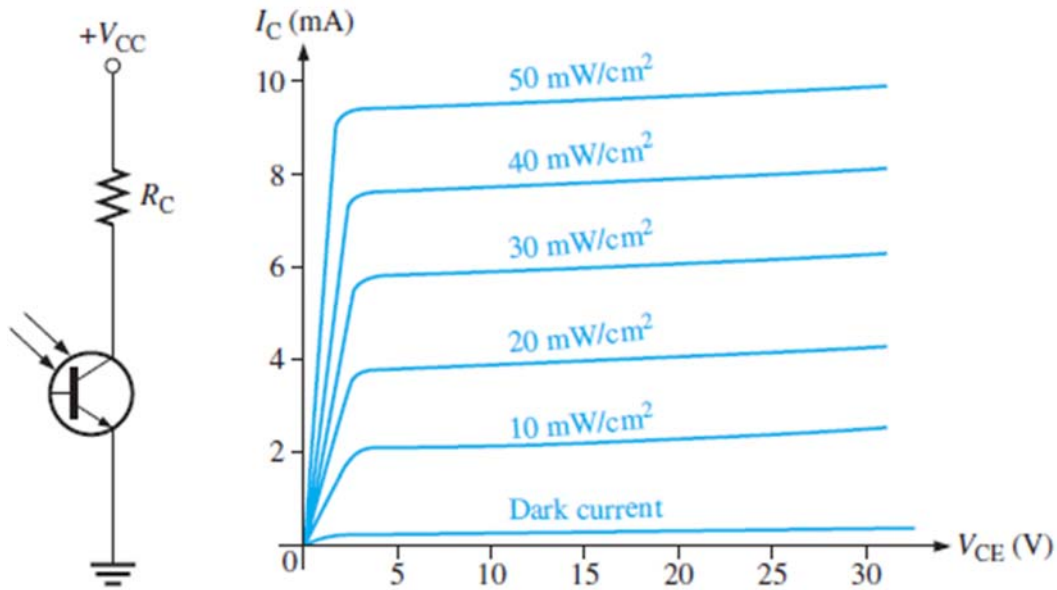
$$I_C = \beta_{DC} I_\lambda$$

- A phototransistor can be either a two-lead or a three-lead device

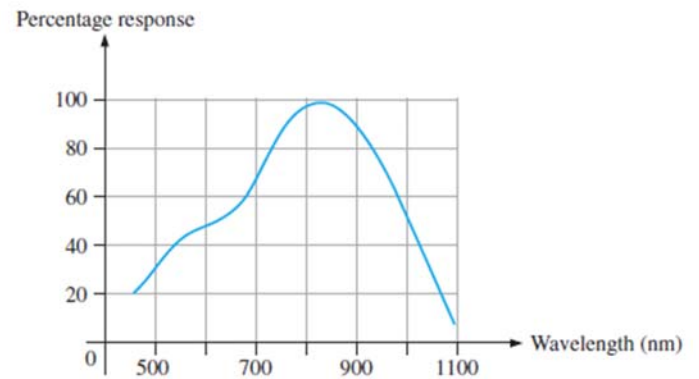


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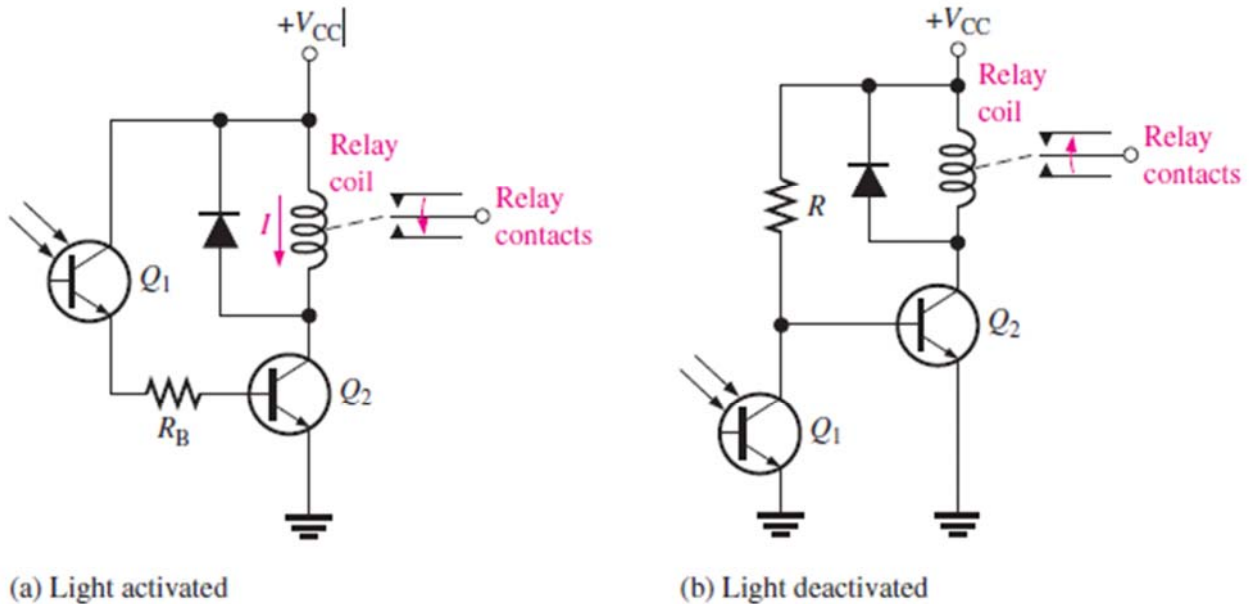
- Phototransistors are not sensitive to all light but only to light within a certain range of wavelengths.
- They are most sensitive to particular wavelengths in the red and infrared part of the spectrum, as shown by the peak of the infrared spectral response curve in Figure



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- **Applications**

- Relay circuits driven by a phototransistor.

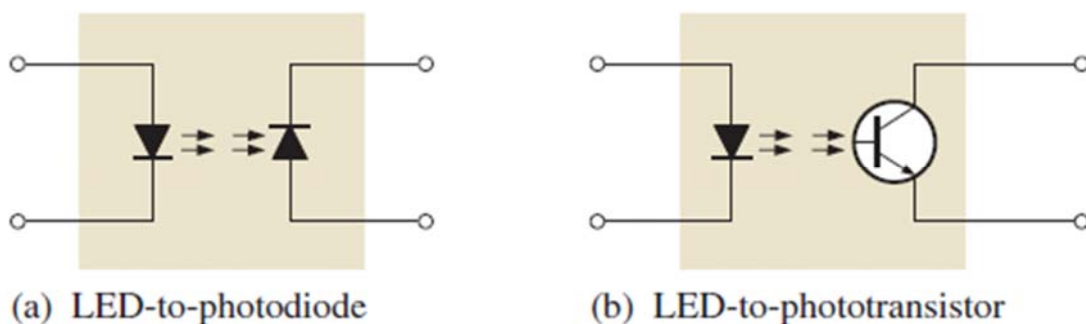


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- **Optocouplers**

- An **optocoupler** uses an LED optically coupled to a photodiode or a phototransistor in a single package.
- Two basic types are LED-to-photodiode and LED-to-phototransistor, as shown in Figure



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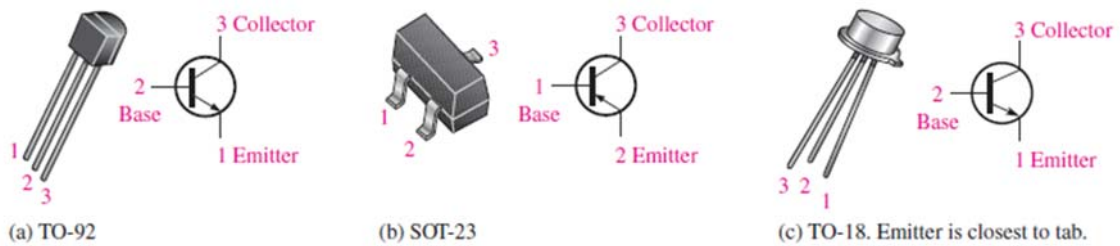


# Transistor Categories

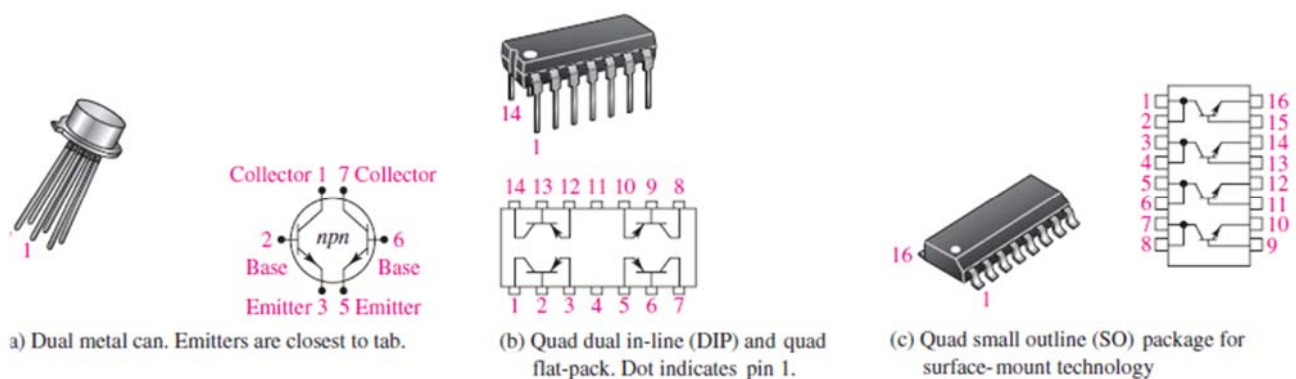
Manufacturers generally classify bipolar junction transistors into three broad categories

**1. General-Purpose/Small-Signal Transistors** General-purpose/small-signal transistors are generally used for low- or medium-power amplifiers or switching circuits.

The packages are either plastic or metal cases.



dual in-line (DIP) and the small-outline (SO)

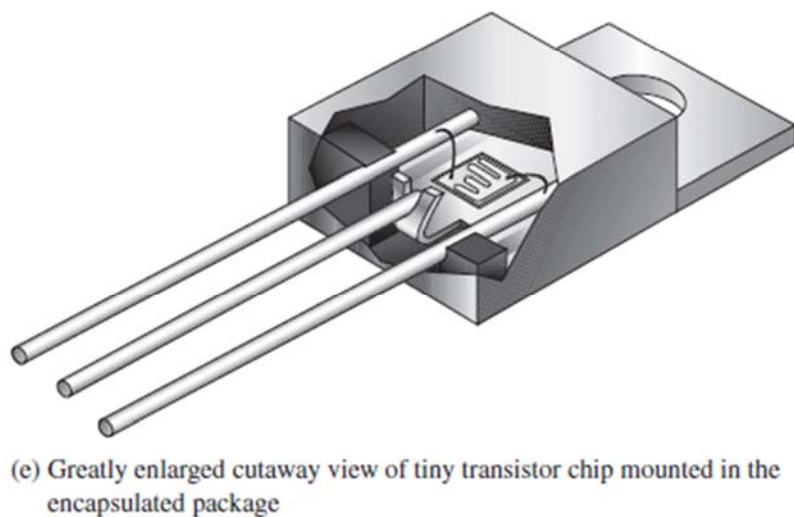
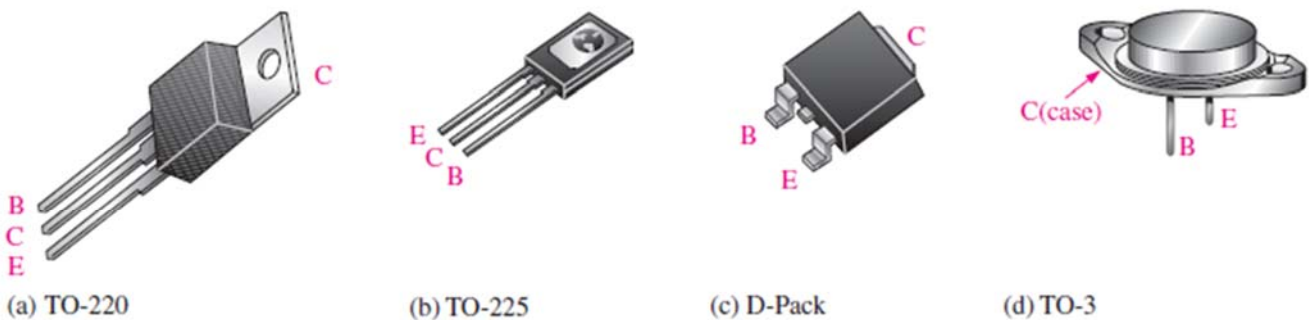


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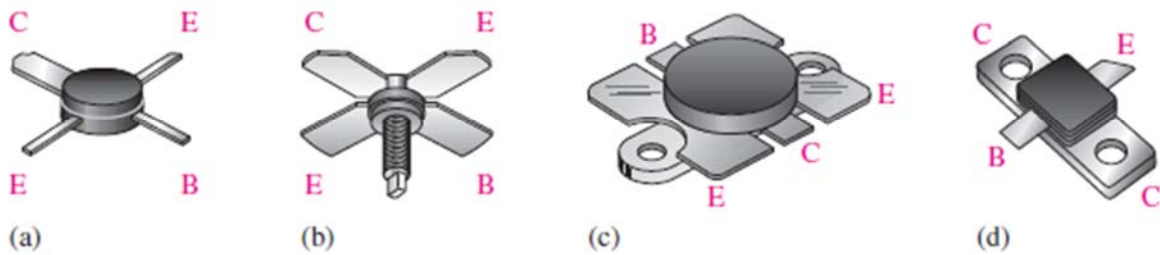
**2. Power Transistors** Power transistors are used to handle large currents (typically more than 1 A) and/or large voltages.

For example, the final audio stage in a stereo system uses a power transistor amplifier to drive the speakers.

- The metal tab or the metal case is common to the collector and is thermally connected to a heat sink for heat dissipation



**3. RF Transistors** RF transistors are designed to operate at extremely high frequencies and are commonly used for various purposes in communications systems and other high frequency applications.



# Troubleshooting

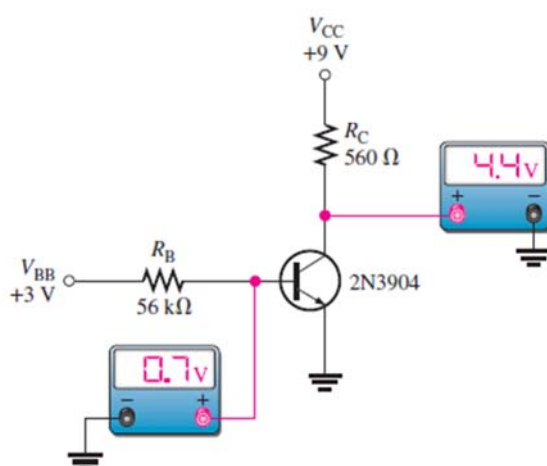
## Troubleshooting a Biased Transistor

$$V_B = V_{BE} = 0.7 \text{ V}$$

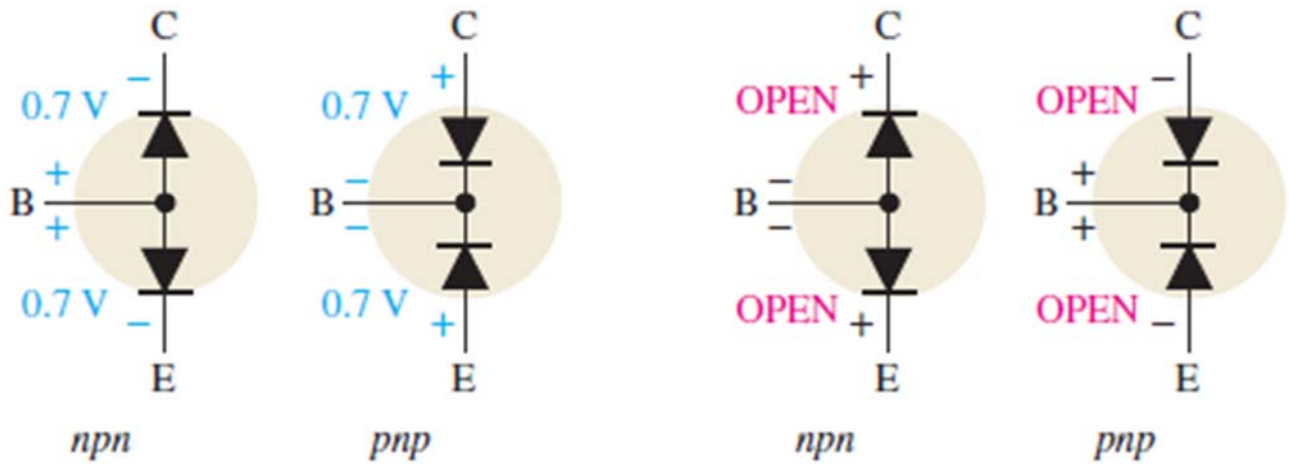
$$I_B = \frac{V_{BB} - 0.7 \text{ V}}{R_B} = \frac{3 \text{ V} - 0.7 \text{ V}}{56 \text{ k}\Omega} = \frac{2.3 \text{ V}}{56 \text{ k}\Omega} = 41.1 \mu\text{A}$$

$$I_C = \beta_{DC} I_B = 200(41.1 \mu\text{A}) = 8.2 \text{ mA}$$

$$V_C = 9 \text{ V} - I_C R_C = 9 \text{ V} - (8.2 \text{ mA})(560 \Omega) = 4.4 \text{ V}$$



## out circuit test

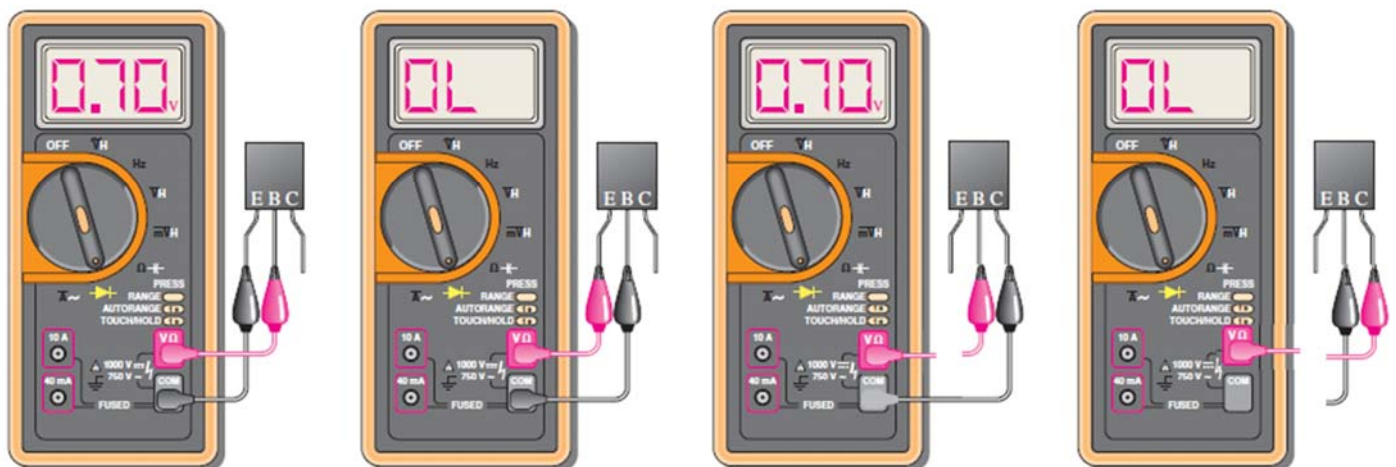


(a) Both junctions should typically read 0.7 V when forward-biased.

(b) Both junctions should ideally read OPEN when reverse-biased

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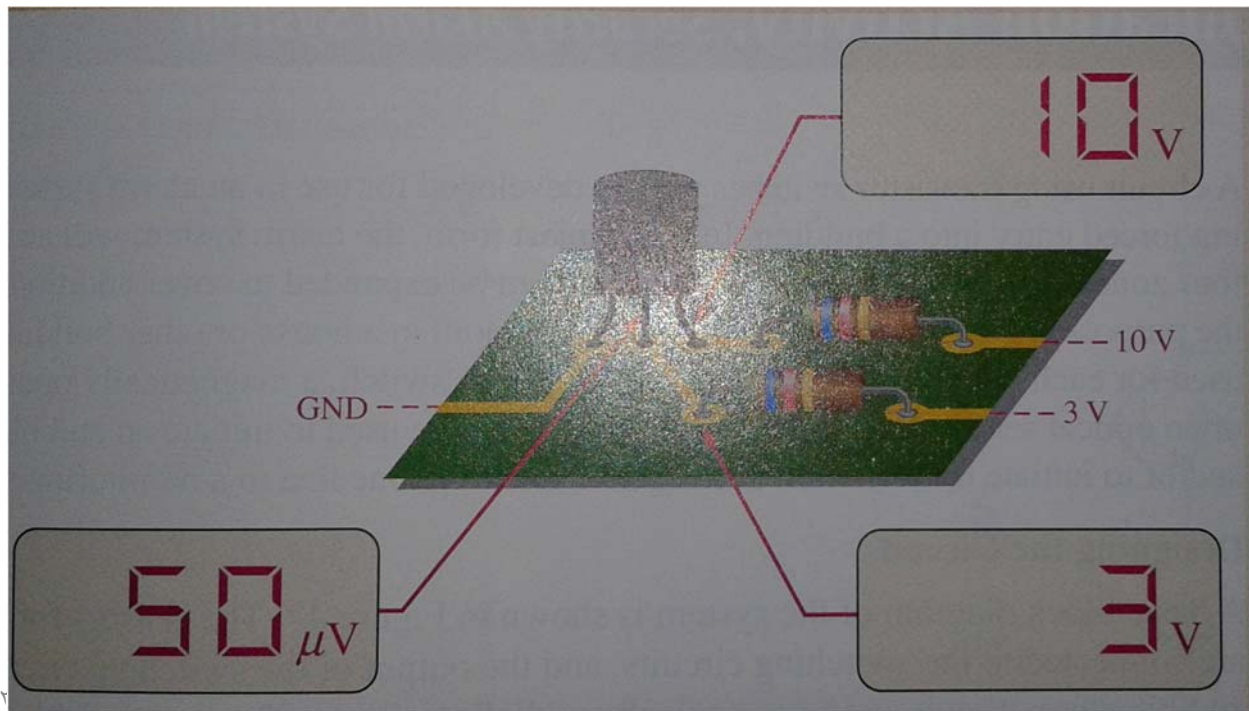
(a) Forward-bias test of the BE junction

(b) Reverse-bias test of the BE junction

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In circuit test



Thanks,..

See you next week (ISA),...