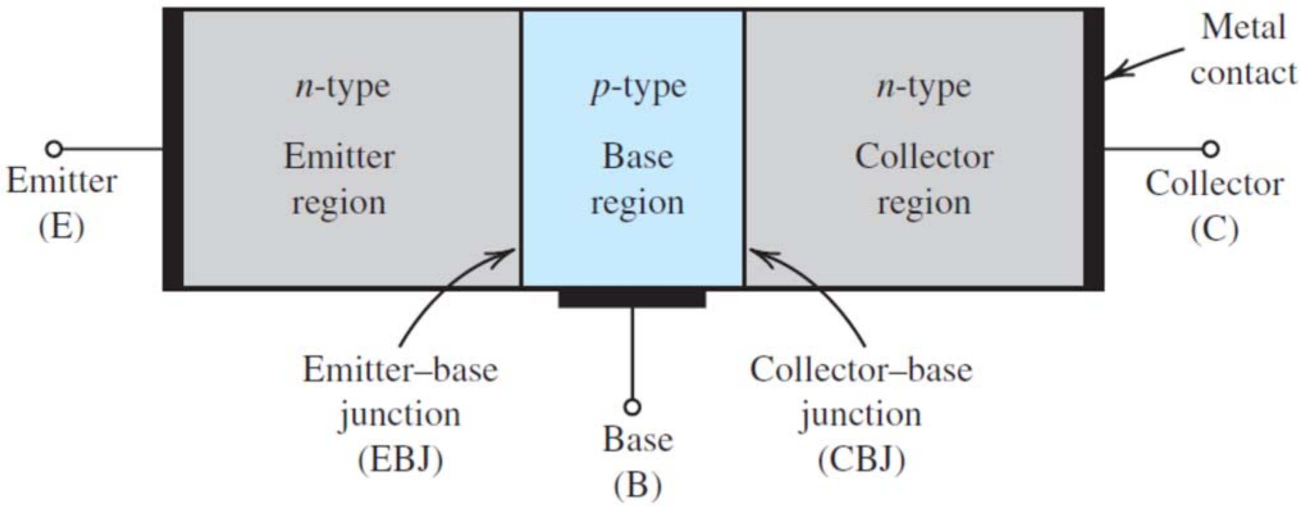
Chapter-6: Bipolar Junction Transistors (BJTs)



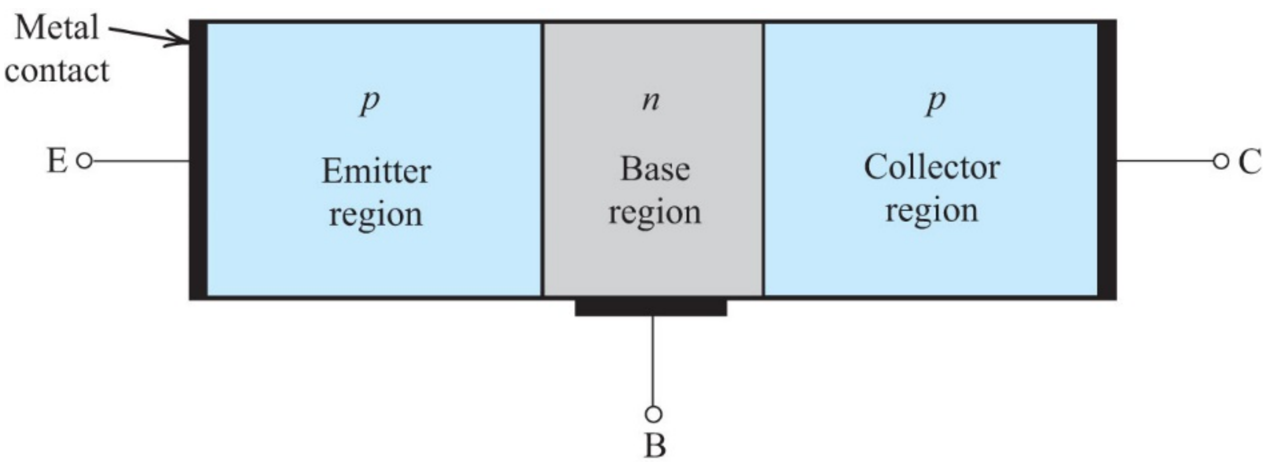
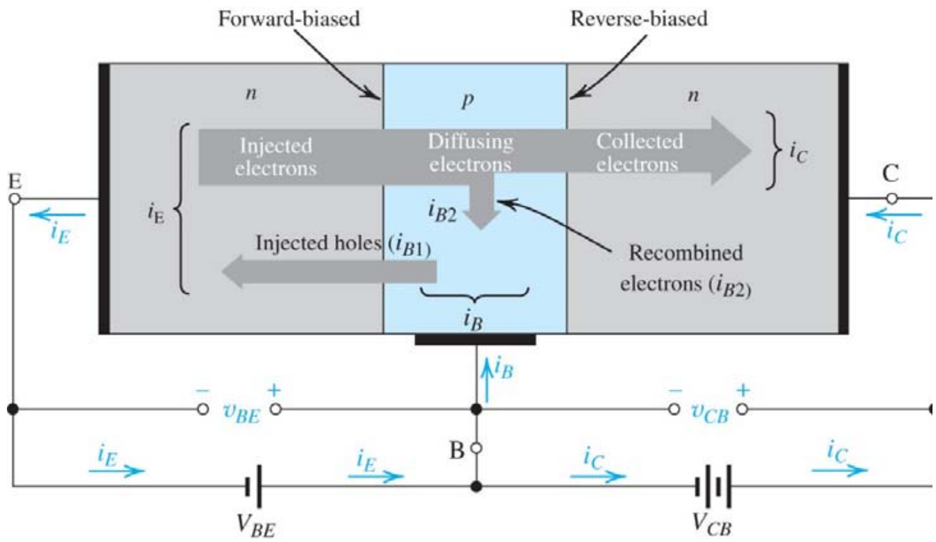


Table 6.1 BJT Modes of Operation

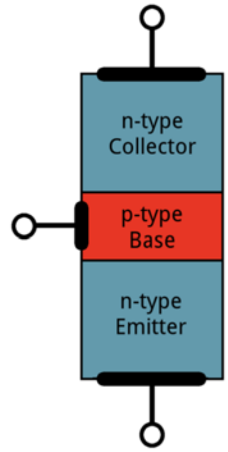
Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

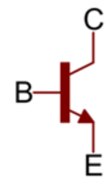
Operation of the npn Transistor in the Active Mode:

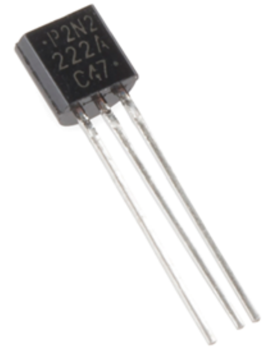


- Two external voltage sources (shown as batteries) are used to establish the required bias conditions for active-mode operation.
- The voltage V_{BE} causes the *p*-type base to be higher in potential than the *n*-type emitter, thus forward biasing the emitter–base junction.
- The collector–base voltage V_{CB} causes the *n*-type collector to be at a higher potential than the *p*-type base, thus reverse biasing the collector–base junction.
- The forward bias on the emitter–base junction will cause current to flow across this junction.
  - Current will consist of two components:
    a) Electrons injected from the emitter into the base, and
    b) Holes injected from the base into the emitter.

The Emitter Current:
Since the current that enters a transistor must leave it, one can conclude that the in "npn" emitter current i_E is equal to the sum of the collector current i_C and the base current i_B; that is, $i_E = i_C + i_B$



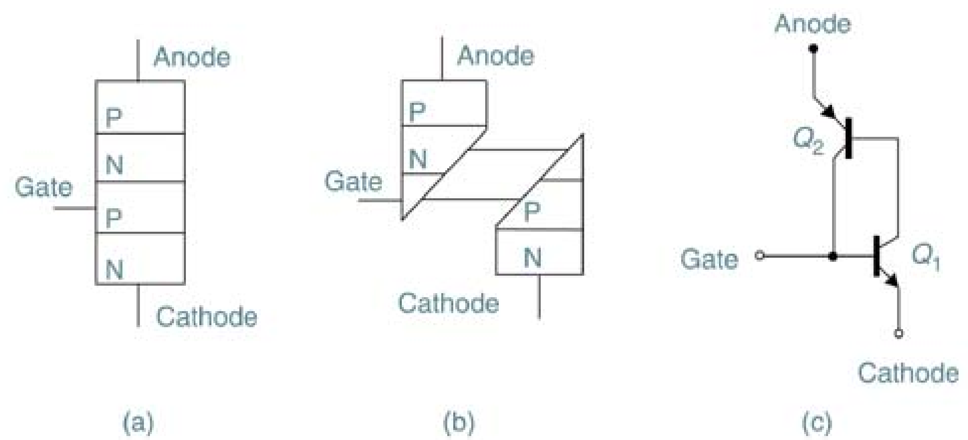


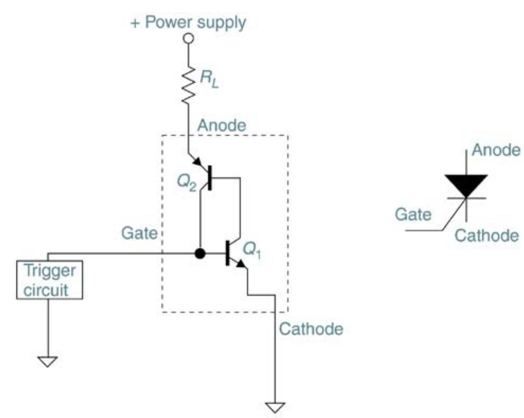


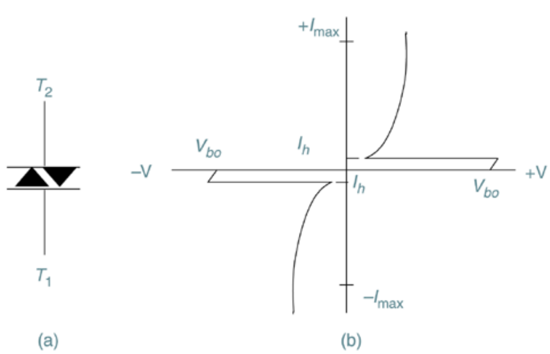
Thyristors:

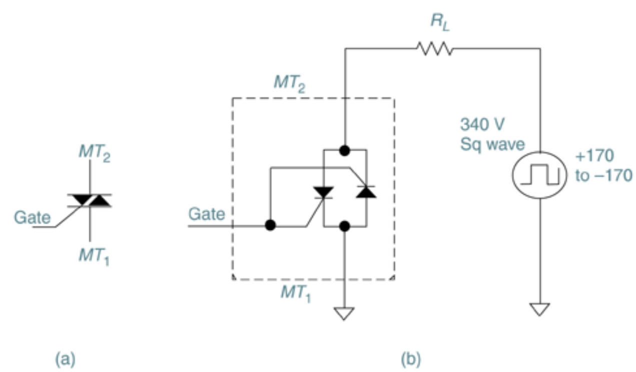
- Are 4-layer silicon semiconductors.
- Use low input power to control large load currents.
- Are very common in industrial power & motor control.
- Are inherently nonlinear devices.
- Have two states: ON and OFF.

Silicon Controlled Rectifiers



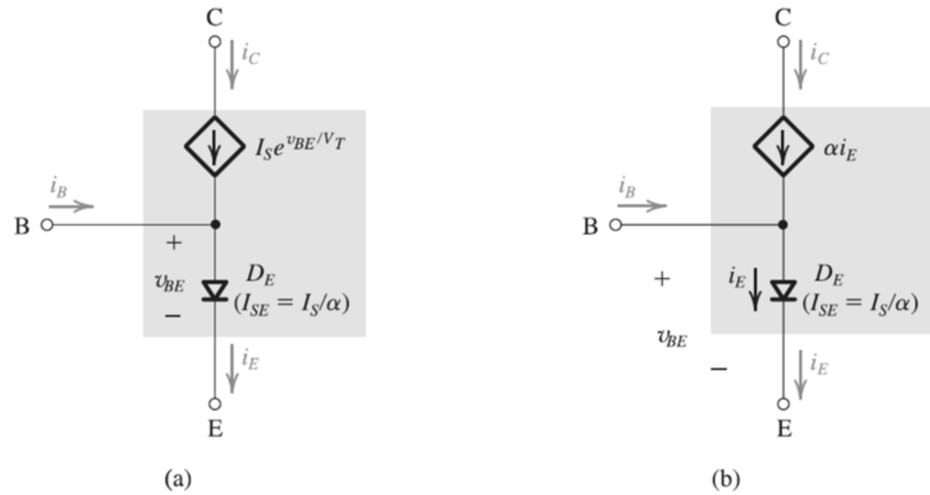




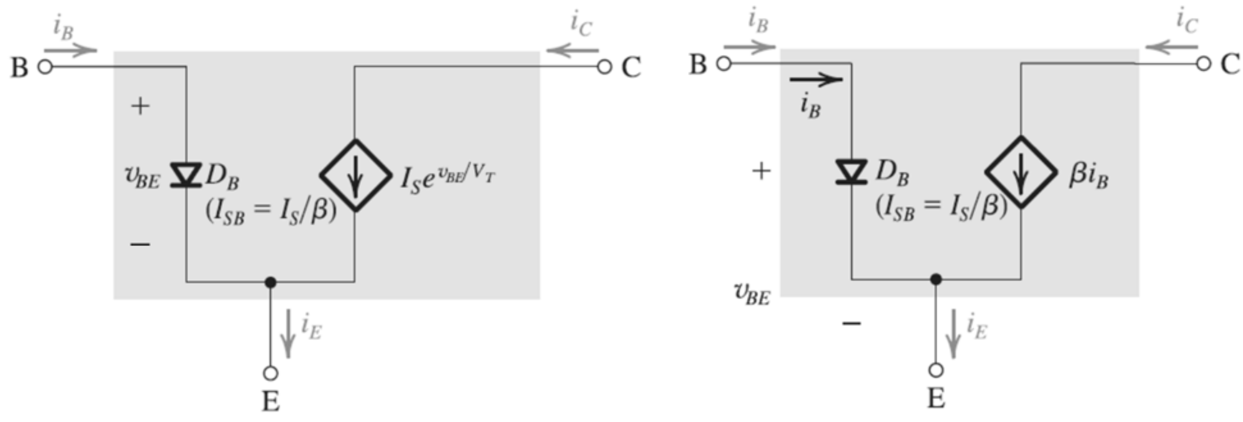


Quadrant 1 operation occurs when the gate and MT2 are positive with respect to MT1
Quadrant 2 operation occurs when the gate is negative and MT2 is positive with respect to MT1
Quadrant 3 operation occurs when the gate and MT2 are negative with respect to MT1
Quadrant 4 operation occurs when the gate is positive and MT2 is negative with respect to MT1.

Equivalent-Circuit Models:
T-Model:



Pi- Model:



(c) (d)

- The model above is essentially a voltage-controlled current source. However, here diode *DB* conducts the base current and thus its current scale factor is $\frac{I_S}{\beta}$, resulting in the *relationship*: $i_B = \left(\frac{I_S}{\beta}\right) e^{\frac{v_{BE}}{v_T}}$

- By simply expressing the collector current as βi_B we obtain the current-controlled current-source model shown in figure on right.

- From this latter model we observe that if the transistor is used as a two-port network with the input port between B and E and the output port between C and E (i.e., with E as the common terminal), then the current gain observed is equal to β. Thus β is called the common-emitter current gain.

6.1 Consider an *npn* transistor with $v_{BE} = 0.7$ V at $i_C = 1$ mA. Find v_{BE} at $i_C = 0.1$ mA and 10 mA.

Solution:

6.3 Measurement of an *npn* BJT in a particular circuit shows the base current to be 14.46 μA, the emitter current to be 1.460 mA, and the base–emitter voltage to be 0.7 V. For these conditions, calculate α, β, and I_S.

Solution:

Example:

A transistor has a β=100 and exhibits a $V_{BE} = 0.7\ V$ at an $i_C\ of\ 1mA$. Design a circuit such that the collector current is 2mA and a +5V appears at the collector.

Solution: