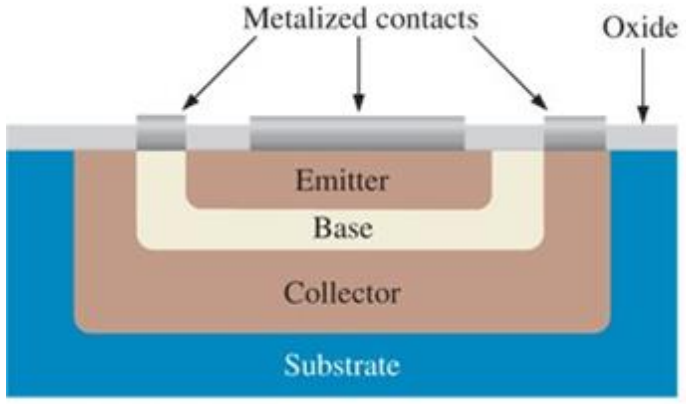
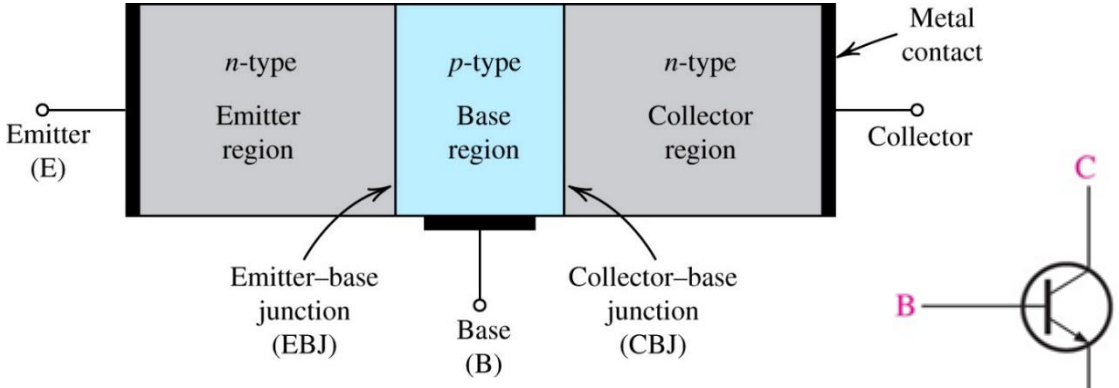
Last Lecture → BJTs

9/16/2019

- **Two external voltage sources are required for biasing**
- **Three operation modes:**
  1) **Cut-Off** — *used for switching (digital)*
  2) **Saturation**
  3) **Active** — *used for amplification (analog)*

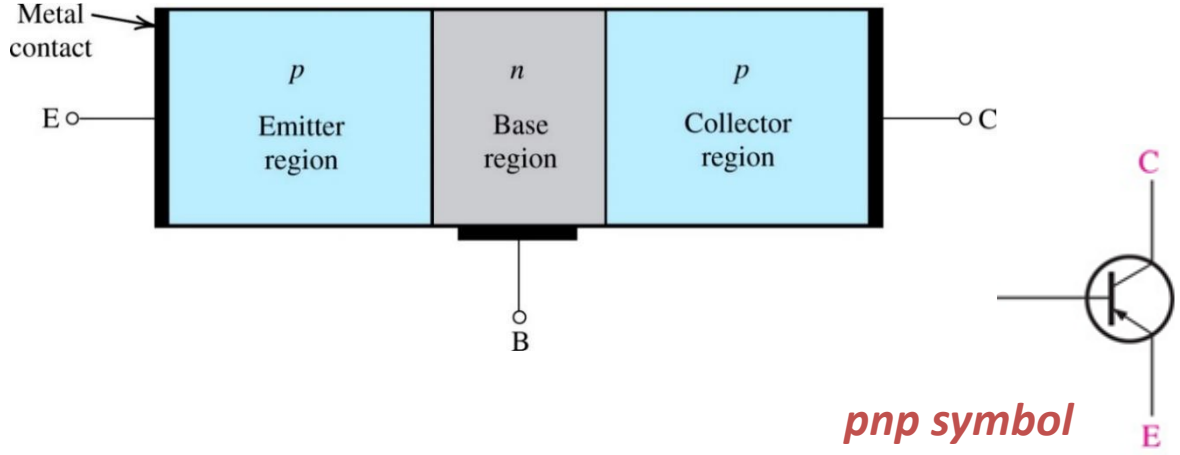


- **Simplified structure of the *npn* transistor**



npn symbol

- **Simplified structure of the *npn* transistor**

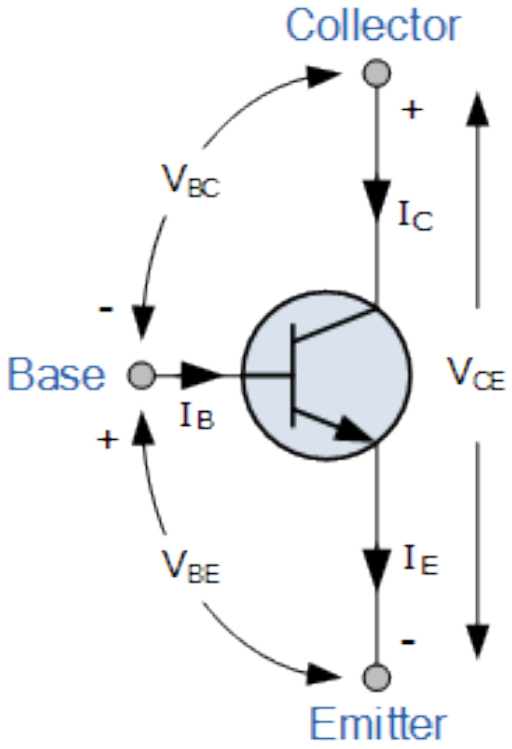


pnp symbol

Last Lecture → BJTs

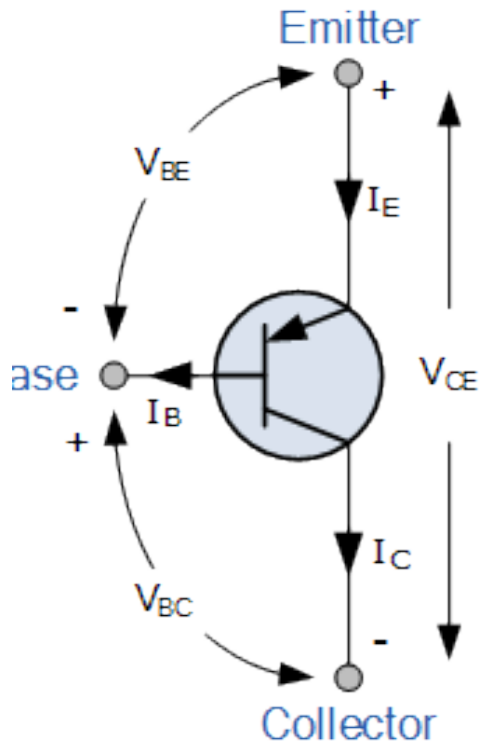
- ***npn***

  Voltages are measured with respect to the emitter (lowest potential)



- ***pnp***

  Voltages are measured with respect to the emitter (highest potential)

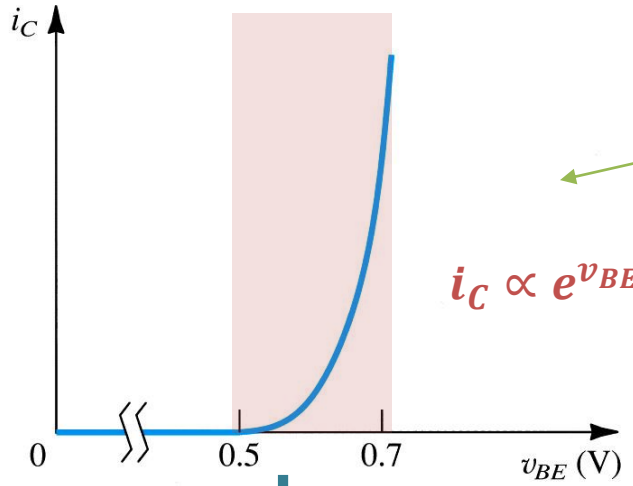


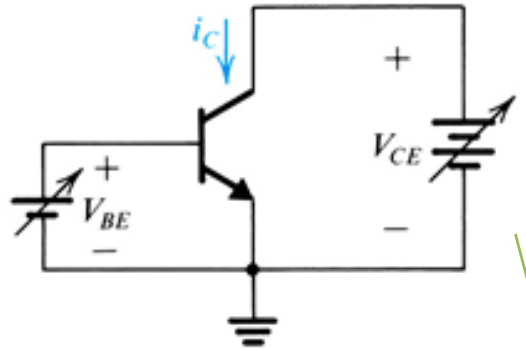
- **I_B – base current**
- **I_E – emitter current**
- **I_C – collector current**

Last Lecture → Active Model

9/16/2019

- $i_C = f(v_{BE})$

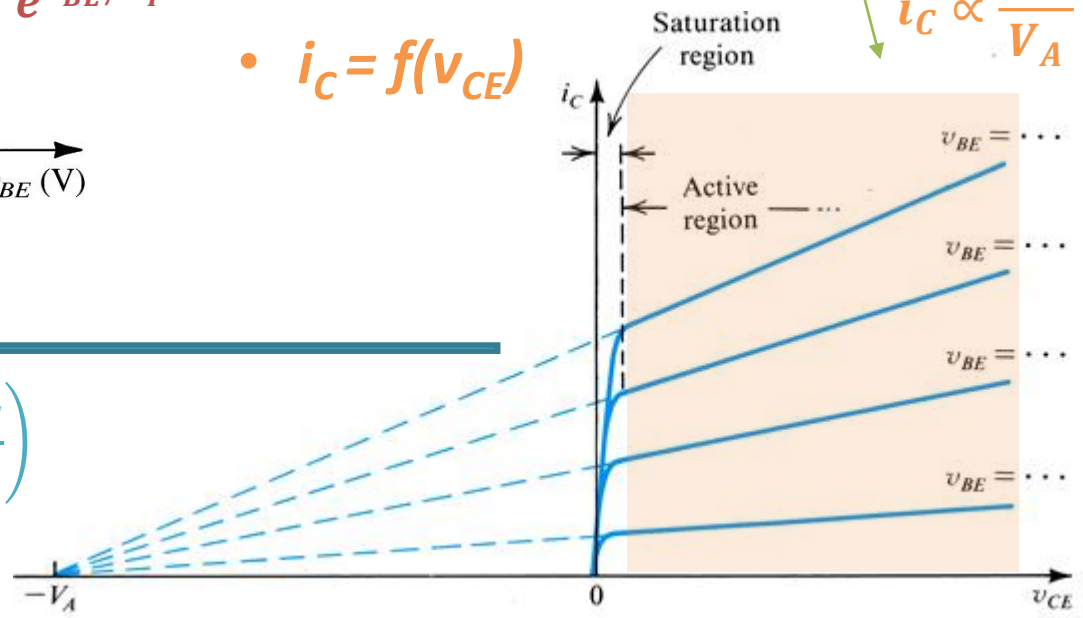




$i_C \propto e^{v_{BE}/V_T}$

$i_C \propto \frac{v_{CE}}{V_A}$

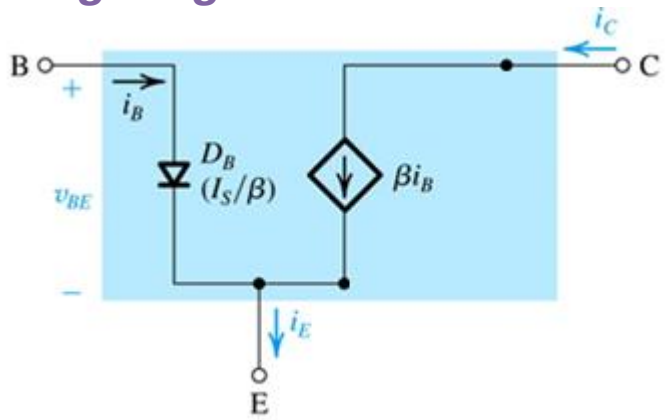
- $i_C = f(v_{CE})$



Collector Current

$$i_C = I_S e^{v_{BE}/V_T}\left(1 + \frac{v_{CE}}{V_A}\right) \approx I_S e^{v_{BE}/V_T}$$

Large Signal Model



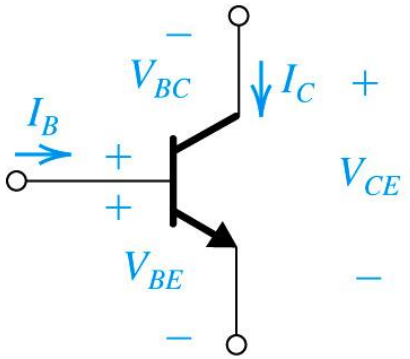
Base / Emitter Currents

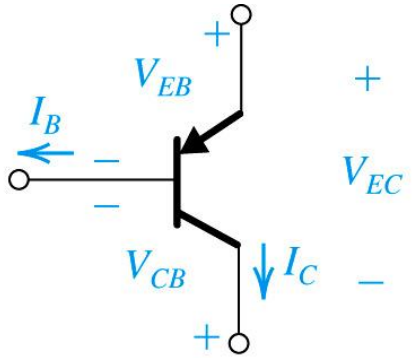
$$i_B = \frac{i_C}{\beta}$$

$$i_E = i_B + i_C = \frac{\beta + 1}{\beta} i_C = \frac{i_C}{\alpha}$$

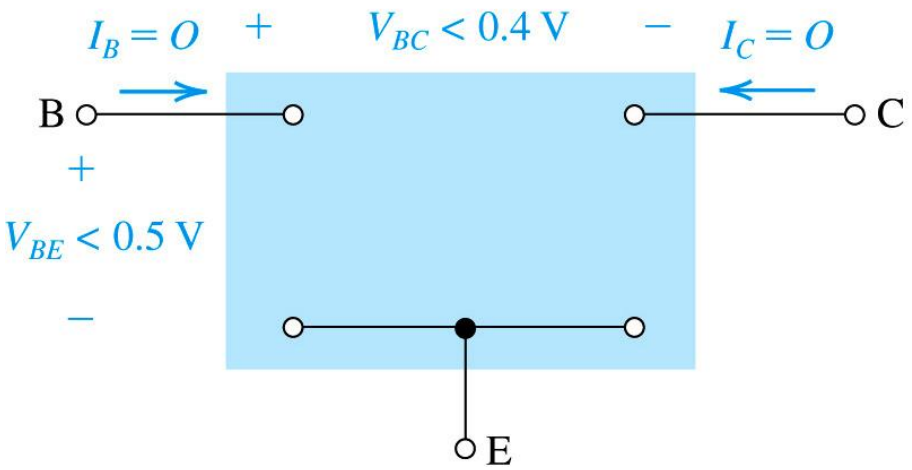
BJTs: Conditions & Models

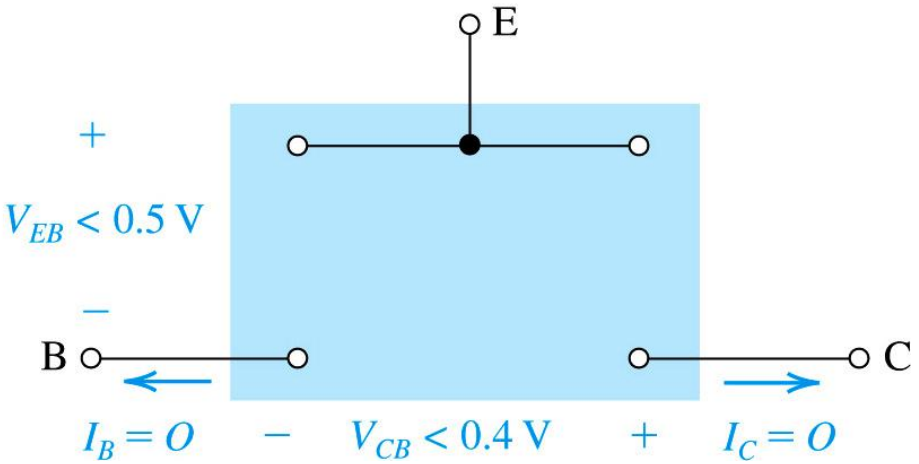
9/16/2019





- ***Cut-OFF***

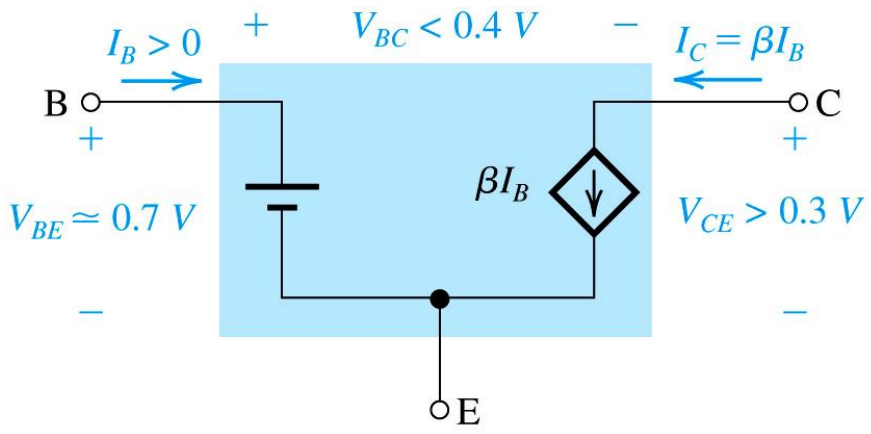


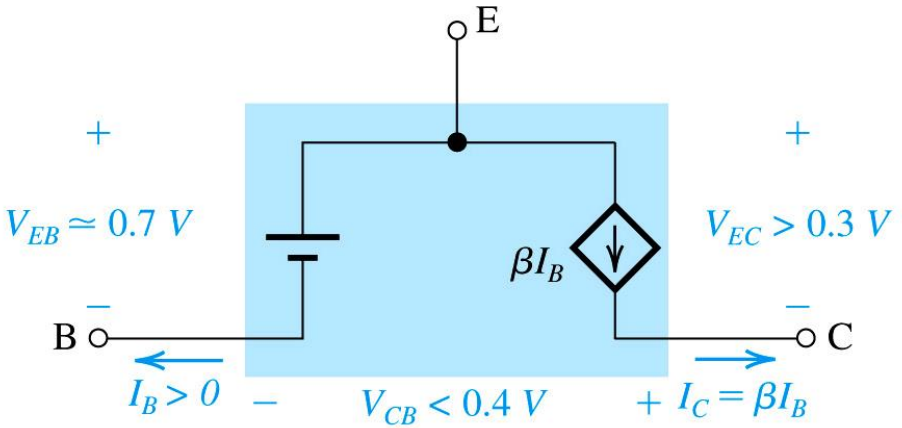


BJTs: Conditions & Models

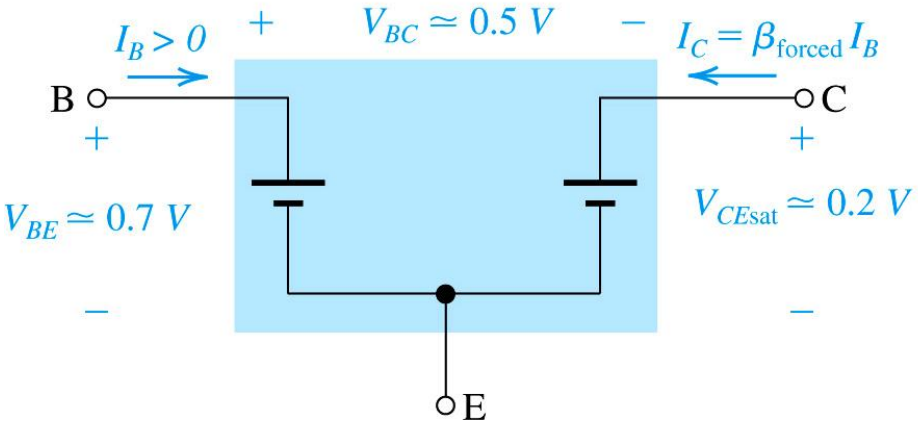
9/16/2019

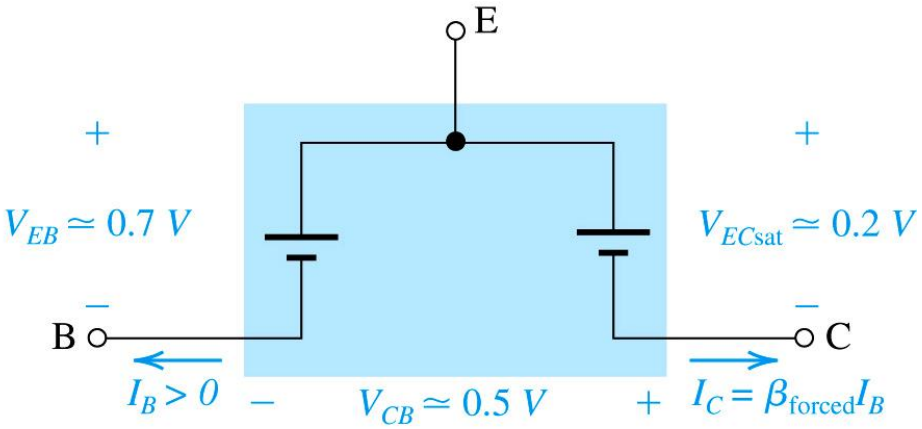
- ***Active***





- ***Saturation***





BJTs: Large Signal Analysis

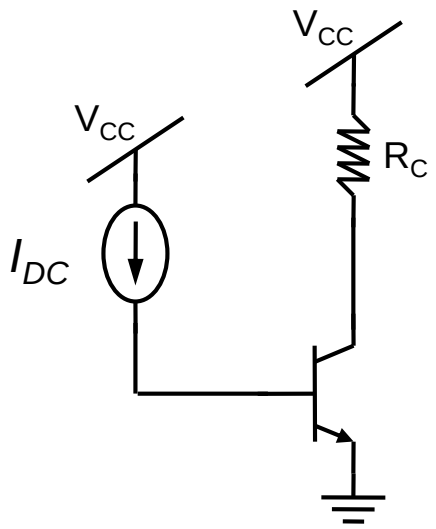
1) When applicable, simplify the circuit
2) Determine if BE/EB junction is forward (transistor = "on")
   - If reverse, transistor → cut off
   - If forward, transistor → active / saturation

     ∴ Make an educated guess of the region of operation
3) Substitute the appropriate model and or assumptions
4) Solve for the transistor operating point (I_C & V_{CE})
5) Verify proper operation @ the assumed region
   - If cut off → $V_{BE} < 0.5V$
   - If active → $V_{BE} >= 0.5V$, $V_{CE} >= 0.3V$
   - If saturation → $V_{BE} >= 0.5V$, $I_C / I_B < \beta$

Example 6.1

9/16/2019

An npn transistor having $I_s = 10^{-15}$A, $\beta = 100$, and $V_A = \infty$ is connected as follows: the emitter is grounded, the base is fed with a constant-current source supplying a dc current of 10μA, and the collector is connected to a 5-V dc supply via a resistance R_C of 3kΩ. Assuming that the transistor is operating in the active mode, find V_{BE} and V_{CE}. Use these values to verify active-mode operation. Replace the current source with a resistance connected from the base to the 5-V dc supply. What resistance value is needed to result in the same operating conditions?



Example 6.3

For the given circuit (R_B=10kΩ, R_C=1kΩ, V_{cc}=10V) assuming V_{BE} remains constant at 0.7V and transistor β is specified to be 50, it is required to determine the value of the voltage V_{BB} that results in the transistor operating

a) **in the active mode with V_{CE}=5V**
b) **at the edge of saturation (V_{CEsat} = 0.3V)**
c) **deep in saturation (V_{CEsat} = 0.2V) with β_{forced}=10.**