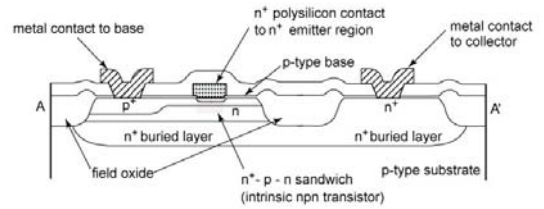


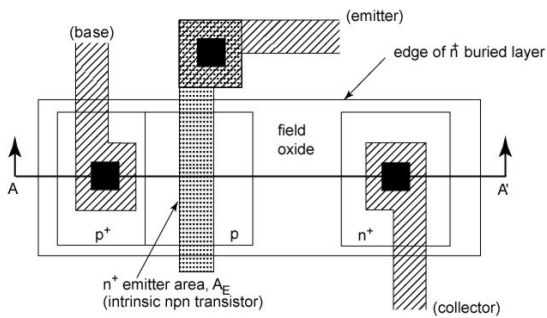
Lecture 28

- Last time:
 - DC and small-signal model of the forward-biased diode
- Today :
 - the npn bipolar junction transistor (BJT): large-signal characteristics

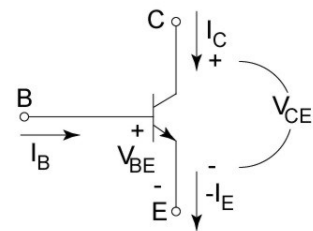
npn Bipolar Transistor Structure



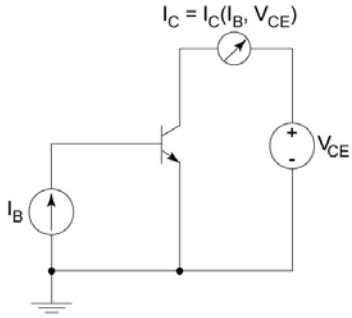
npn Bipolar Transistor Layout



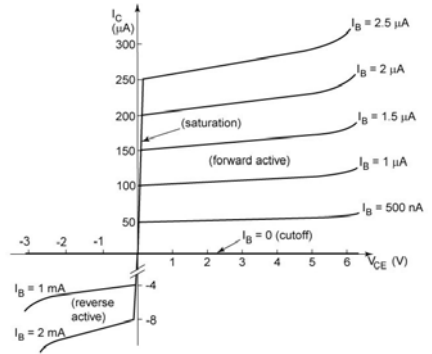
BJT Symbol



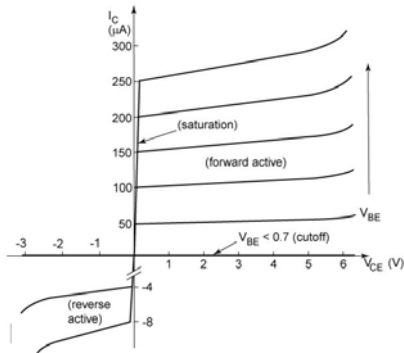
Measuring the BJT's Collector Characteristics



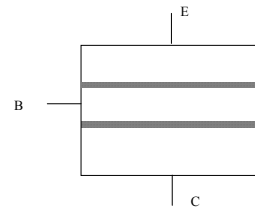
Collector Characteristics



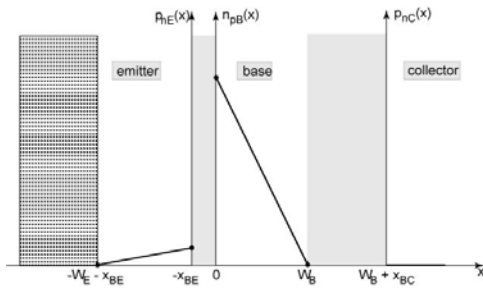
Base-Emitter Voltage Control



“Transistor Action”



Diffusion Currents



BJT Currents

Collector current is nearly identical to the (magnitude) of the emitter current ... define

$$I_C = -\alpha_F I_E$$

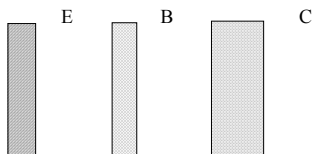
Kirchhoff:

$$-I_E = I_C + I_B$$

DC Current Gain:

Origin of α_F

Base-emitter junction: some reverse injection of holes into the emitter \rightarrow base current isn't zero



Typical α_F

Collector Current

Diffusion of electrons across base results in

$$J_n^{diff} = qD_n \frac{dn_p}{dx} =$$

$$I_C = I_S e^{V_{BE}/V_{th}}$$

Base Current

Diffusion of holes across emitter results in

$$J_p^{diff} = -qD_p \frac{dp_{nE}}{dx} =$$

$$I_B =$$

Current Gain β_F

$$\beta_F = \frac{I_C}{I_B} = \frac{\left(\frac{qD_n n_{pBo} A_E}{W_B} \right)}{\left(\frac{qD_p p_{nEo} A_E}{W_E} \right)} =$$

Parameter sensitivities:

Ebers-Moll Equations

Exp. 6: measure E-M parameters

Derivation: write emitter and collector currents in terms of internal currents at two junctions

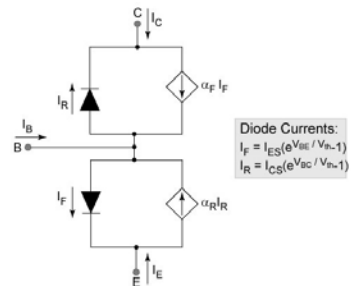
$$I_E = -I_{ES} \left(e^{V_{BE}/V_{th}} - 1 \right) + \alpha_R I_{CS} \left(e^{V_{BC}/V_{th}} - 1 \right)$$

$$I_C = \alpha_F I_{ES} \left(e^{V_{BE}/V_{th}} - 1 \right) - I_{CS} \left(e^{V_{BC}/V_{th}} - 1 \right)$$

$$\alpha_F I_{ES} = \alpha_R I_{CS}$$

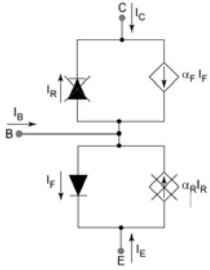
Ebers-Moll Equivalent Circuit

Building blocks: diodes and I -controlled I sources



Forward-Active Model

B-C junction is not forward-biased $\rightarrow I_R$ is very small



Simplified Ebers-Moll (Cont.)

Forward-Active Case

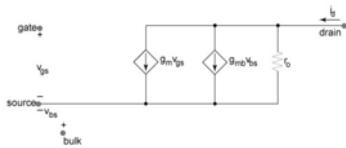
Saturation: both diodes are forward-biased \rightarrow batteries

Small-Signal Model

Analogy from MOSFET s.s. model:

$$i_D = f(v_{GS}, v_{DS}, v_{BS})$$

$$i_C = f(v_{BE}, v_{CE})$$



Transconductance g_m

