Lecture 20

- Last time:
  - the npn bipolar junction transistor (BJT)
- Today :
  - Large-signal model under forward bias
  - Ebers-Moll model

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

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

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

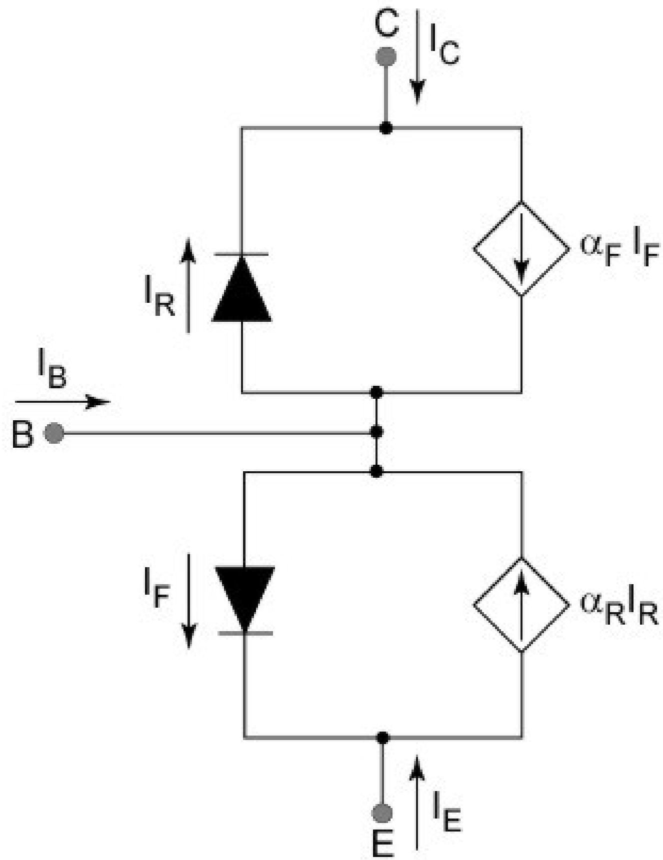
$$I_E = -I_{ES}\left(e^{V_{BE}/V_{th}} - 1\right) + \alpha_R I_{CS}\left(e^{V_{BC}/V_{th}} - 1\right)$$

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

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

Ebers-Moll Equivalent Circuit

Building blocks: diodes and *I*-controlled *I* sources



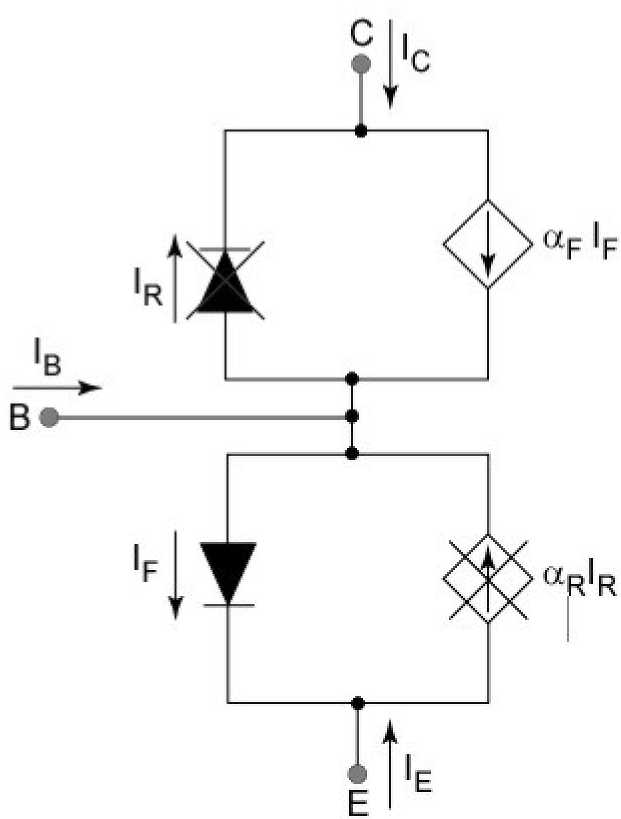
Diode Currents:

$I_F = I_{ES}(e^{V_{BE}/V_{th}}-1)$

$I_R = I_{CS}(e^{V_{BC}/V_{th}}-1)$

Forward-Active Model

B-C junction is not forward-biased → I_R is very small



Simplified Ebers-Moll (Cont.)

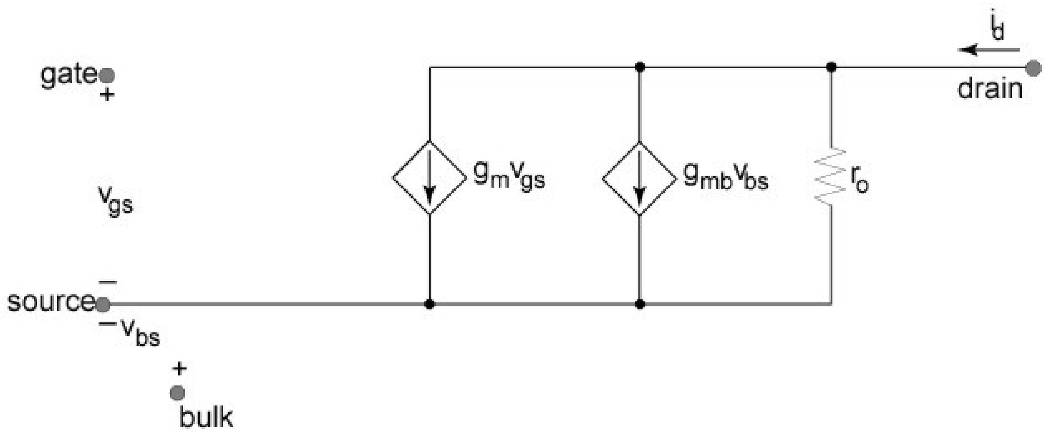
Forward-Active Case

Saturation: both diodes are forward-biases → batteries

Small-Signal Model

Analogy from MOSFET s.s. model:

$$i_D = f(v_{GS}, v_{DS}, v_{BS}) \qquad i_C = f(v_{BE}, v_{CE})$$



Transconductance g_m