Lecture 21

- Last time:
  - Large-signal model under forward bias
  - Ebers-Moll model, start small signal model
- Today :
  - Small-signal model of the npn bipolar transistor

Transconductance (cont.)

- Forward-active large-signal current:

$$i_C = I_S e^{v_{BE}/V_{th}} (1 + v_{CE}/V_A)$$

- Differentiating and evaluating at $Q = (V_{BE,} V_{CE})$

Comparison with MOSFET g_m

- Bipolar transistor:

- MOSFET:

- Typical bias point: drain/coll. current = 100 μA;
  Select $(W/L) = 8/1$, $\mu_n C_{ox} = 100\ \mu A/V^2$

What about the Base Current?

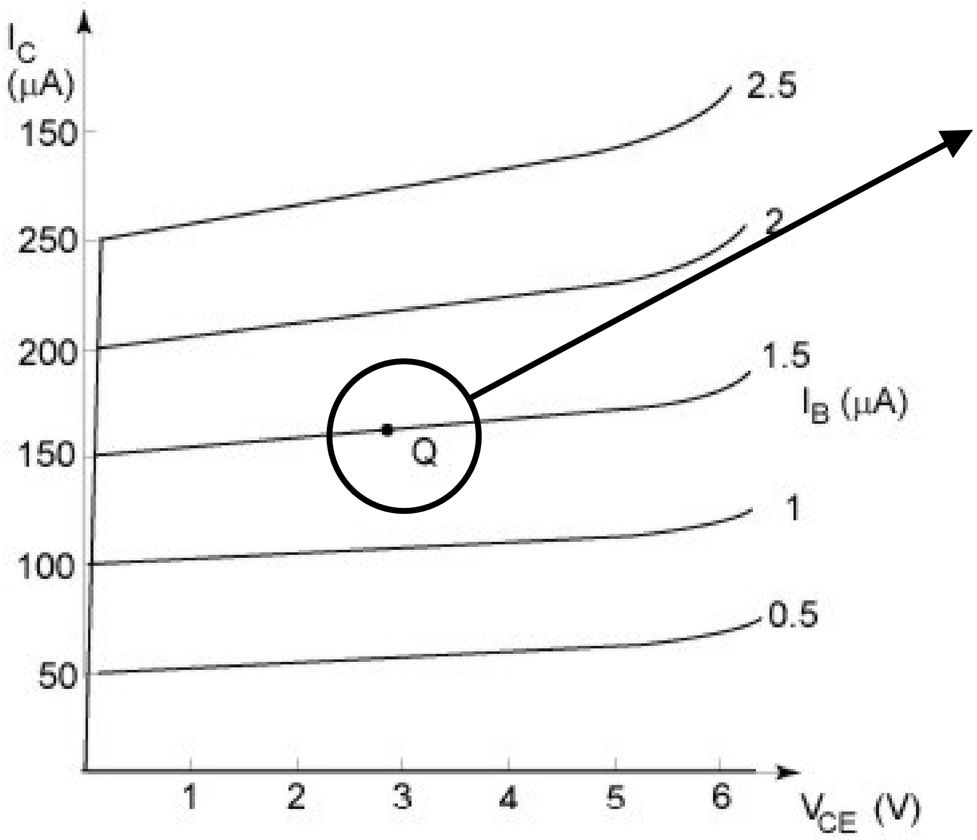
Unlike MOSFET, there is a DC current into the base terminal of a bipolar transistor:

$$I_B = I_C / \beta_F = (I_S / \beta_F) e^{V_{BE} / V_{th}} (1 + V_{CE} / V_{th})$$

To find the change in base current due to change in base-emitter voltage:

$$\left.\frac{\partial i_B}{\partial v_{BE}}\right|_Q = \underbrace{\left.\frac{\partial i_B}{\partial i_C}\right|_Q}\ \underbrace{\left.\frac{\partial i_C}{\partial v_{BE}}\right|_Q} =$$

Small-Signal Current Gain β_o



Input Resistance r_π

$$(r_\pi)^{-1} = \left.\frac{\partial i_B}{\partial v_{BE}}\right|_Q$$

In practice, the DC current gain β_F and the small-signal current gain β_o are both highly variable (+/- 25%)

Typical bias point: DC collector current = 100 μA

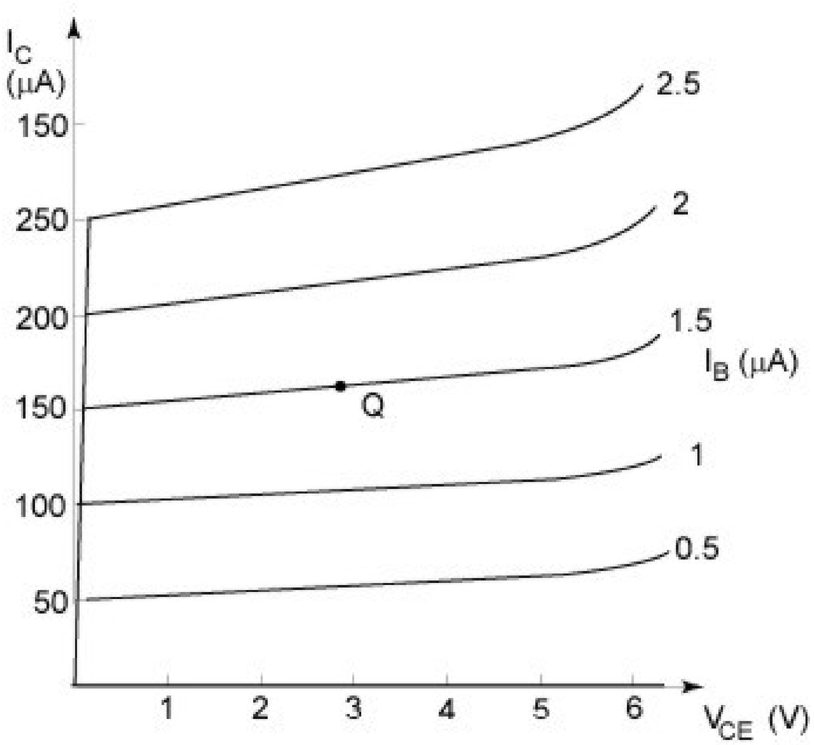
Output Resistance r_o

Why does current increase slightly with increasing v_{CE}?

Model: math is a mess, so introduce the Early voltage

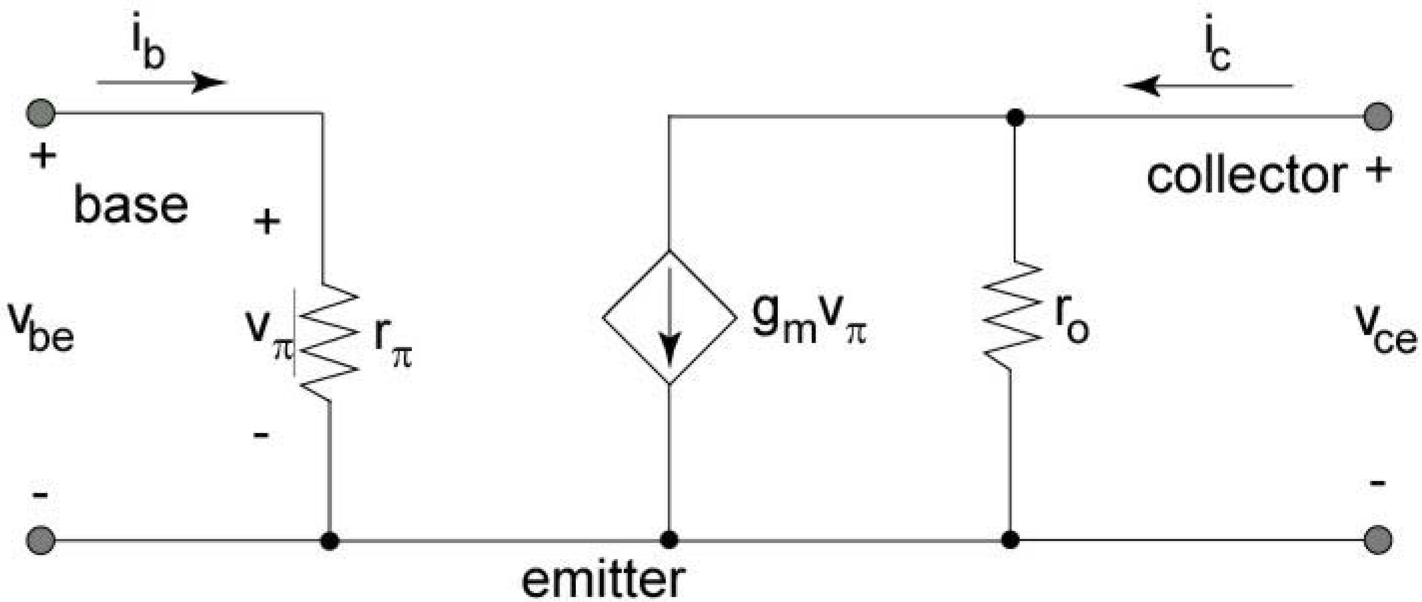
$$i_C = I_S e^{v_{BE}/V_{th}} (1 + v_{CE}/V_A)$$

Graphical Interpretation of r_o



Typical value:

BJT Small-Signal Model



BJT Capacitances

Base-charging capacitance C_b: due to minority carrier charge storage (mostly electrons in the base)

$$C_b = g_m \tau_F$$

Base-emitter depletion capacitance: $C_{jE} = 1.4\ C_{jEo}$

Total B-E capacitance: $C_\pi = C_{jE} + C_b$

Complete Small-Signal Model