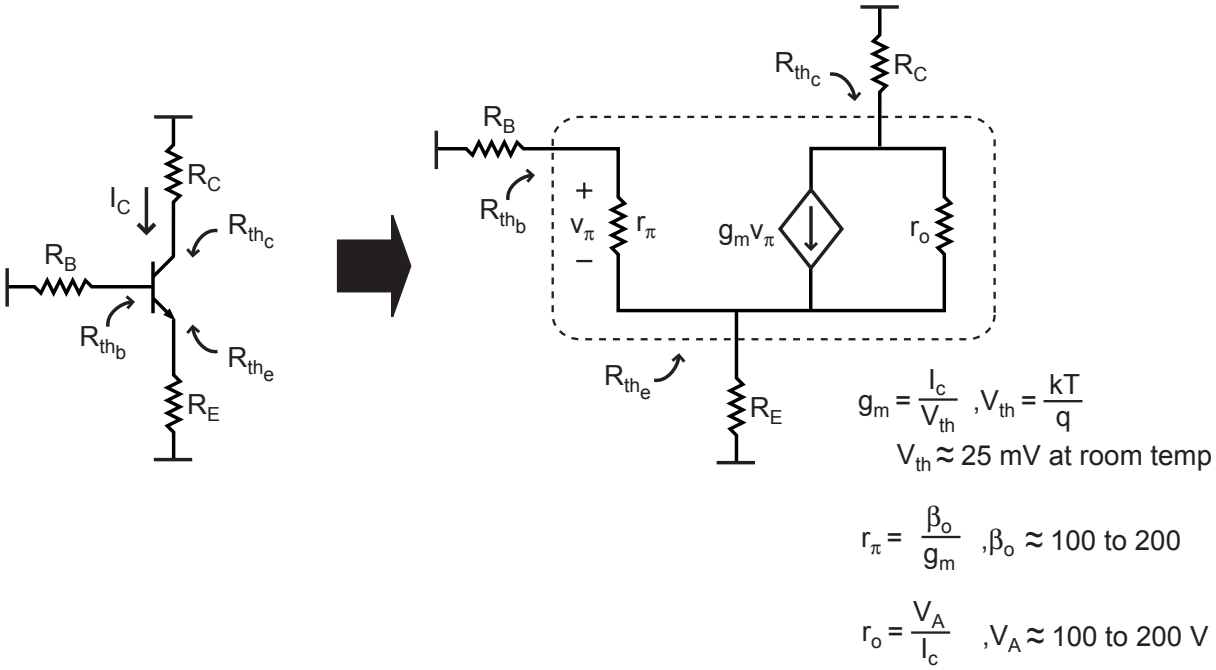
Small Signal Models of the Bipolar Transistor

6.301 — Spring 2002

Massachusetts Institute of Technology

Michael Perrott

General Thevenin Resistance View



Thevenin resistance at collector:

$$R_{th_c} = \frac{(1 + g_m r_o) R_E (r_\pi + R_B/(1 + g_m r_o))}{R_E + r_\pi + R_B} + r_o$$

$$R_{th_c} \approx (1 + g_m (r_\pi || R_E)) r_o \quad \text{for } R_B \ll r_\pi, R_E$$

Thevenin resistance at base:

$$R_{th_b} = r_\pi + (\beta_o + 1) R_E \left(\frac{r_o + R_C/(\beta_o + 1)}{r_o + R_C + R_E} \right)$$

$$R_{th_b} \approx r_\pi + (\beta_o + 1) R_E \quad \text{for } R_C \ll r_o, R_E \ll r_o$$

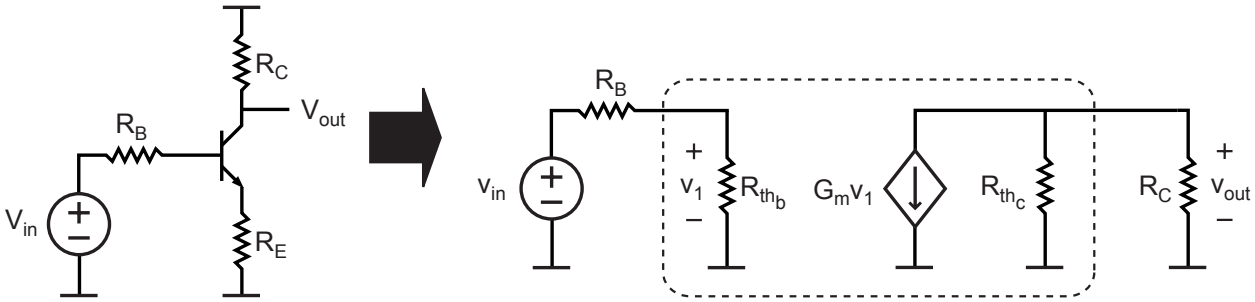
Thevenin resistance at emitter:

$$R_{th_e} = \frac{r_\pi + R_B}{1 + \beta_o} || \frac{r_o}{1 + R_C/(r_\pi + R_B)}$$

$$R_{th_e} \approx \frac{1}{g_m} + \frac{R_B}{1 + \beta_o} \quad \text{for } \frac{r_o}{1 + R_C/(r_\pi + R_B)} \gg \frac{1}{g_m} + \frac{R_B}{1 + \beta_o}$$

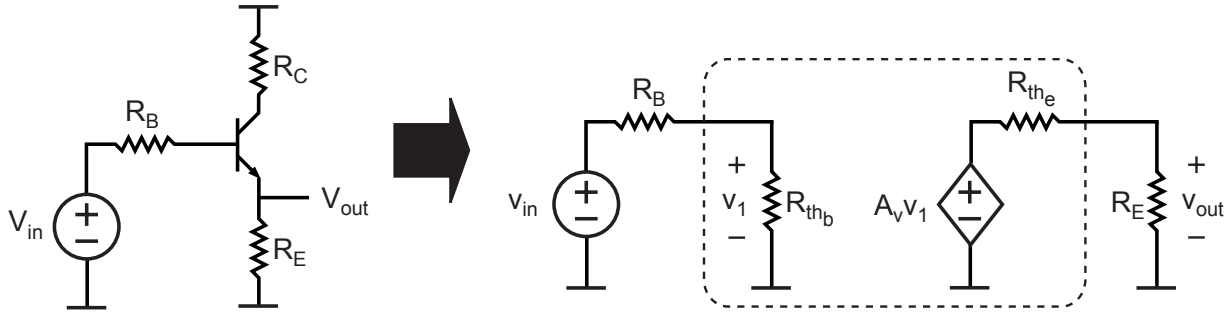
Amplifier Configurations

Common Emitter (with degeneration):



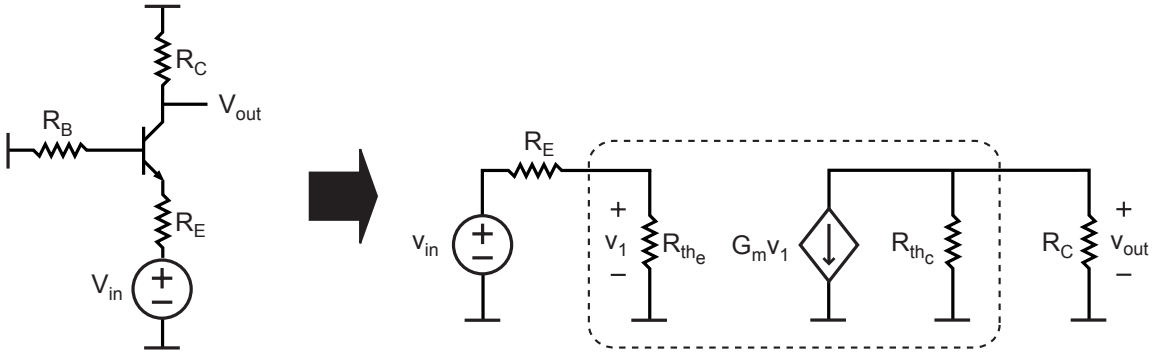
$$G_m = g_m\left(\frac{1 - R_E/(\beta_o r_o)}{1 + g_m R_E(1 + 1/\beta_o + 1/(g_m r_o))}\right) \approx \frac{g_m}{1 + g_m R_E} \quad \text{for } R_E \ll r_o,\ g_m r_o \gg 1$$

Emitter Follower:



$$A_v = \frac{1}{1 + (1 + R_C)/(r_\pi + \beta_o r_o)} \approx 1$$

Common Base:



$$G_m = -\left(g_m\left(\frac{r_\pi}{R_B + r_\pi}\right) + \frac{1}{r_o}\right) \approx -g_m \quad \text{for } R_B \ll r_\pi,\ r_o \gg 1/g_m$$