Transistor Cheat Sheet

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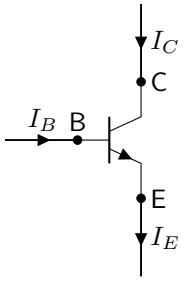
Bipolar transistor (NPN)

General Node Equations

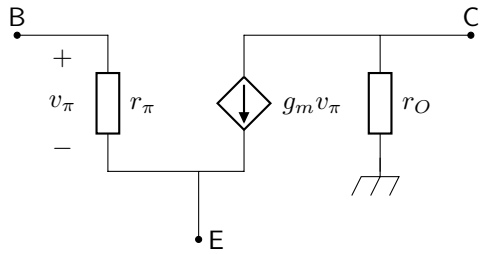


$$V_{CE} = V_{CB} + V_{BE}$$
$$I_E = I_C + I_B$$
$$I_C = \beta I_B$$

$$\beta = \frac{\alpha + 1}{\alpha}$$
$$\alpha = \frac{\beta}{\beta + 1}$$
$$\beta = \beta_F \left(1 + \frac{V_{CB}}{V_T}\right)$$

$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right)$$
$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right) \underbrace{\left[1 + \frac{V_{CE}}{V_A}\right]}_{\text{Early voltage corrective terRm}}$$

Small-signal model



$$r_\pi = \frac{V_T}{I_{B0}} \qquad g_m = \frac{I_{C0}}{V_T} \qquad r_O = \frac{V_A}{I_{C0}}$$

Amplifiers

Common-Emitter (CE)

without degeneration

$$A_V = -g_m R_C$$
$$R_{in} = (R_B \| r_\pi)$$
$$R_{out} = R_C$$

with degeneration

$$A_V = \frac{-g_m R_C}{1 + \left(\frac{1}{r_\pi} + g_m\right) R_E}$$
$$R_{in} = (R_E \| R_{in,B})$$
$$R_{in,B} = r_\pi \left[1 + \left(\frac{1}{r_\pi} + g_m\right) R_E\right]$$
$$R_{out} = R_C$$

Common-Base (CB)

for $V_A = \infty$

$$A_V = g_m R_C$$
$$R_{in} = (r_\pi \| R_C \| \frac{1}{g_m})$$
$$R_{in} \approx \frac{1}{g_m}, \text{ for } I_C >> I_B$$
$$R_{out} = R_C$$

Common-Collector (CC)

for $V_A = \infty$

$$A_V = \frac{-g_m R_C}{1 + \frac{1}{R_E\left(\frac{1}{r_\pi} + g_m\right)}}$$
$$R_{in} = r_\pi + (1 + \beta) R_E$$
$$R_{out} = (R_E \| R_{in,B} \| \frac{1}{g_m})$$