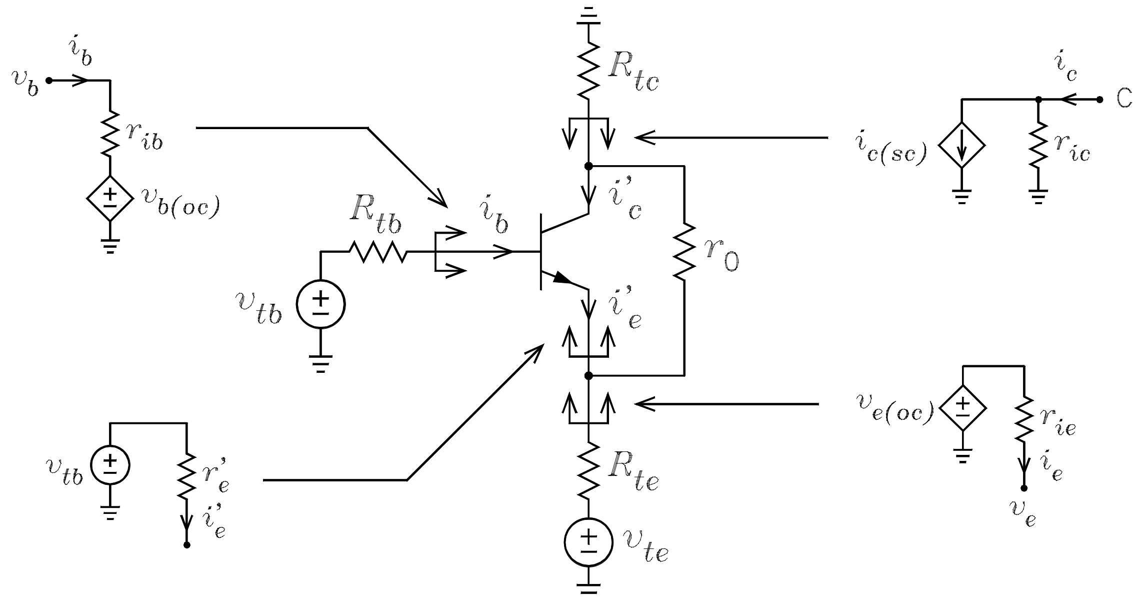
ECE 3050 Analog Electronics - BJT Formula Summary

Equations are for the npn BJT. For the pnp device, reverse the directions of all current labels and reverse the order of subscripts involving node labels, i.e. V_{CE} becomes V_{EC}. When more than one equation is given, either can be used.



$$i_C = I_S e^{v_{BE}/V_T} \qquad I_S = I_{S0}\left(1 + \frac{v_{CE}}{V_A}\right) \qquad i_B = \frac{i_C}{\beta} \qquad i_E = i_C + i_B \qquad \beta = \beta_0\left(1 + \frac{v_{CE}}{V_A}\right)$$

$$g_m = \frac{I_C}{V_T} \qquad r_\pi = \frac{V_T}{I_B} = (1+\beta)\, r_e \qquad r_e = \frac{V_T}{I_E} = \frac{r_\pi}{1+\beta} = \frac{\alpha}{g_m} \qquad r_0 = \frac{V_A + V_{CE}}{I_C} \qquad \alpha = \frac{\beta}{1+\beta}$$

$$\beta = \frac{\alpha}{1-\alpha} \qquad \frac{r_e}{\alpha} = \frac{r_\pi}{\beta} \qquad r'_e = \frac{R_{tb} + r_x + r_\pi}{1+\beta} = \frac{R_{tb} + r_x}{1+\beta} + r_e \qquad i'_c = g_m v_{b'e} = \alpha i'_e = \beta i_b$$

$$i_{c(sc)} = G_{mb} v_{tb} - G_{me} v_{te} \qquad G_{mb} = \frac{\alpha}{r'_e + R_{te} \| r_0} \frac{r_0 - R_{te}/\beta}{r_0 + R_{te}} \qquad G_{me} = \frac{1}{R_{te} + r'_e \| r_0} \frac{\alpha r_0 + r'_e}{r_0 + r'_e}$$

$$r_{ic} = \frac{r_0 + r'_e \| R_{te}}{1 - \alpha R_{te}/\left(r'_e + R_{te}\right)} \overset{R_{tb}=0,\ r_x=0}{=} r_0 \left[1 + g_m \left(r_\pi \| R_{te}\right)\right] + R_{te} \qquad v_{e(oc)} = v_{tb} \frac{r_0 + R_{tc}/(1+\beta)}{r'_e + r_0 + R_{tc}/(1+\beta)}$$

$$r_{ie} = r'_e \frac{r_0 + R_{tc}}{r'_e + r_0 + R_{tc}/(1+\beta)} \qquad v_{b(oc)} = v_{te} \frac{r_0 + R_{tc}}{R_{te} + r_0 + R_{tc}}$$

$$r_{ib} = r_x + (1+\beta)\, r_e + R_{te} \frac{(1+\beta)\, r_0 + R_{tc}}{r_0 + R_{te} + R_{tc}} = r_x + r_\pi + R_{te} \frac{(1+\beta)\, r_0 + R_{tc}}{r_0 + R_{te} + R_{tc}} \overset{r_0 \text{ large}}{=} r_x + r_\pi + (1+\beta)\, R_{te}$$

r_0 Approximations – Assume $r_0 = \infty$ except when calculating r_{ic}

$$i'_e = i_e \qquad i_{c(sc)} = i'_c = \alpha i_e = \beta i_b = G_m \left(v_{tb} - v_{te}\right) \qquad G_m = \frac{\alpha}{r'_e + R_{te}}$$

$$r'_e = \frac{R_{tb} + r_x + r_\pi}{1+\beta} = \frac{R_{tb} + r_x}{1+\beta} + r_e \qquad r_{ic} = \frac{r_0 + r'_e \| R_{te}}{1 - \alpha R_{te}/\left(r'_e + R_{te}\right)} \qquad v_{e(oc)} = v_{tb}$$

$$r_{ie} = r'_e \qquad v_{b(oc)} = v_{te} \qquad r_{ib} = r_x + r_\pi + (1+\beta)\, R_{te} = r_x + (1+\beta)\left(r_e + R_{te}\right)$$