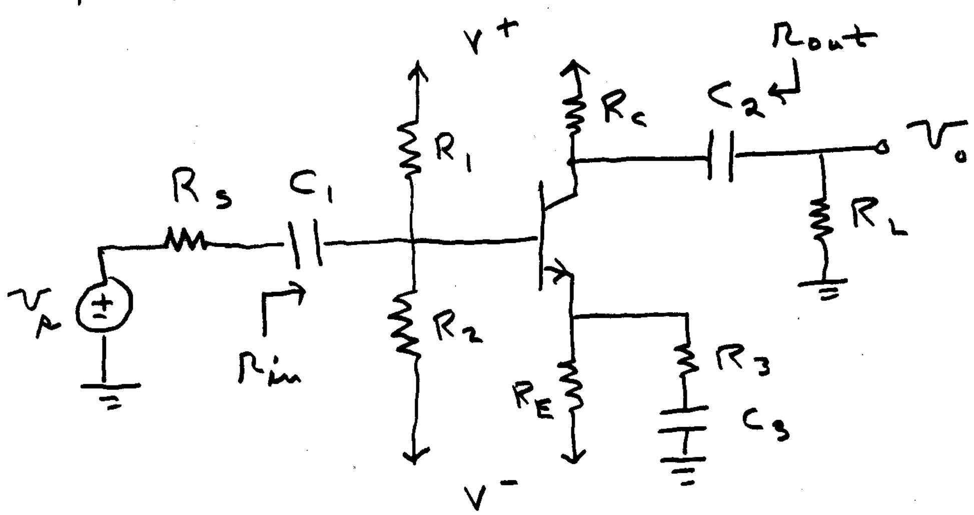
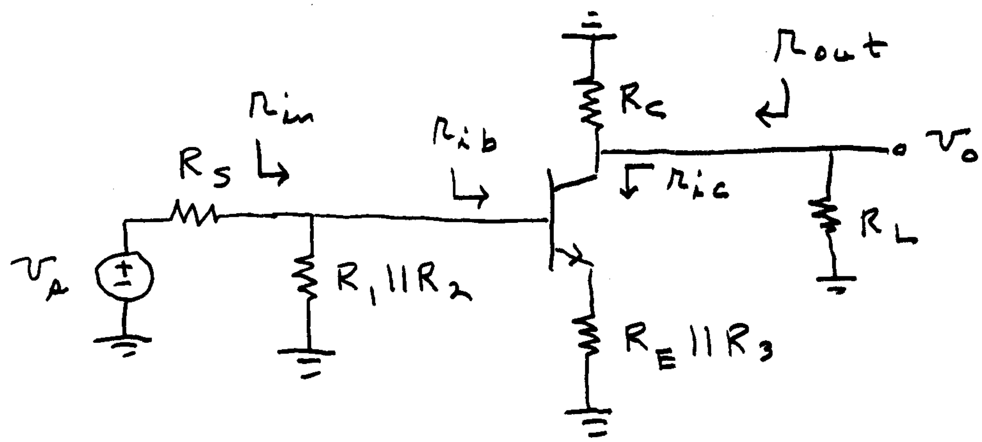
The Common Emitter (CE) Amplifier

For the CE amplifier, the signal is applied to the base and the output is taken from the collector. A typical capacitively coupled CE amplifier is shown.



The dc bias currents and voltages are solved for assuming the capacitors are open circuits. For the ac small-signal solution, set $V^+ = V^- = 0$ and assume the capacitors are ac short circuits. The circuit reduces to



The input and output resistances are given by

$$r_{in} = R_1 \| R_2 \| r_{ib}$$
$$r_{out} = R_c \| r_{ic}$$

where

$$r_{ib} = r_x + r_\pi + R_{te} \frac{(1+\beta) r_0 + R_{tc}}{r_0 + R_{te} + R_{tc}}$$

$$R_{te} = R_E \| R_3 \qquad R_{tc} = R_c \| R_L$$

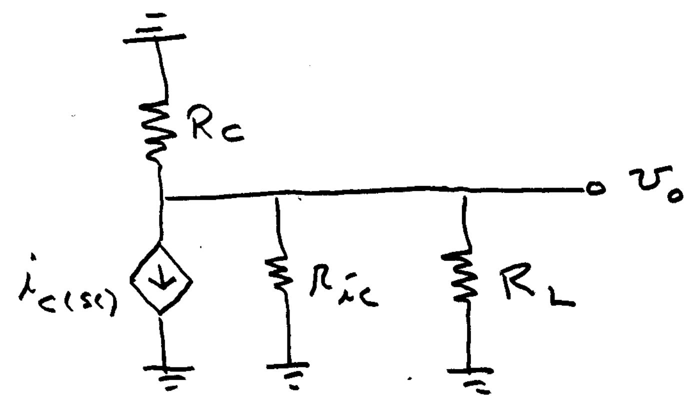
$$r_{ic} = \frac{r_0 + r_e' \| R_{te}}{1 - \dfrac{\alpha R_{te}}{r_e' + R_{te}}}$$

$$r_e' = \frac{R_{tb} + r_x}{1+\beta} + r_e \qquad R_{tb} = R_S \| R_1 \| R_2$$

Looking out of the base, the Thévenin equivalent circuit has the values

$$v_{tb} = v_s \frac{R_1 \| R_2}{R_s + R_1 \| R_2} \qquad R_{tb} = R_s \| R_1 \| R_2$$

To solve for v_o, we replace the BJT with the Norton collector circuit.



$i_{c(sc)}$ is given by

$$i_{c(sc)} = G_{mb} v_{tb}$$

where

$$G_{mb} = \frac{\alpha}{r_e' + R_{te} \| r_0} \frac{r_0 - R_{te}/\beta}{r_0 + R_{te}}$$

The output voltage is given by

$$v_o = -i_{c(sc)}\, r_{ic} \| R_c \| R_L$$

$$= -G_{mb}\, v_{tb}\, r_{ic} \| R_c \| R_L$$

$$= -G_{mb}\, v_s \frac{R_1 \| R_2}{R_S + R_1 \| R_2}\, r_{ic} \| R_c \| R_L$$

Thus the voltage gain is given by

$$A_v = \frac{v_o}{v_s}$$

$$= -\frac{R_1 \| R_2}{R_S + R_1 \| R_2}\, G_{mb}\, r_{ic} \| R_c \| R_L$$

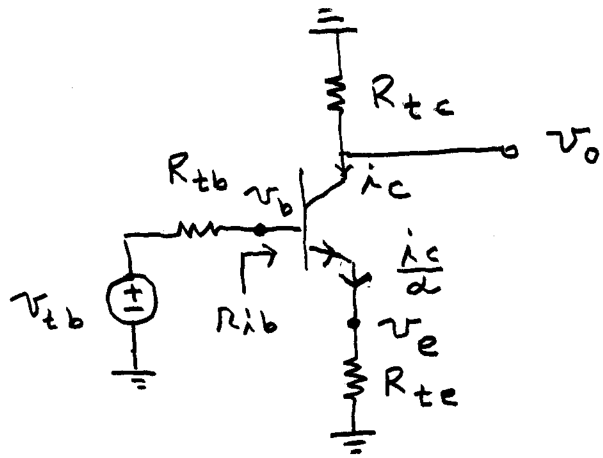
The above solution is exact. Often, an approximate solution is made for rough calculations. Assume that $r_x = 0$ and $r_o = \infty$ for the approximations. In this case

$$r_{ib} = (1+\beta)(r_e + R_{te})$$

$$= r_\pi + (1+\beta) R_{te}$$

$$i_c = \alpha i_e = g_m v_{be} = g_m (v_b - v_e)$$

The signal equivalent circuit is



$$v_b = v_{tb} \frac{r_{ib}}{R_{tb} + r_{ib}} \qquad v_e = \frac{i_c}{\alpha} R_{te}$$

$$i_c = g_m (v_b - v_e) = g_m \left(v_b - \frac{i_c}{\alpha} R_{te}\right)$$

$$\Rightarrow \quad i_c = \frac{g_m v_b}{1 + \frac{g_m R_{te}}{\alpha}}$$

$$v_o = -i_c R_{tc} = -\frac{g_m v_b}{1 + \frac{g_m R_{te}}{\alpha}} R_{tc}$$

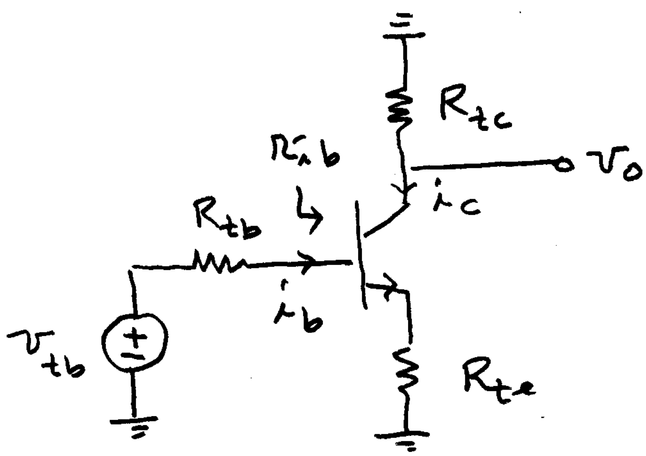
$$= -v_{tb} \frac{r_{ib}}{R_{tb} + r_{ib}} \frac{g_m R_{tc}}{1 + \frac{g_m R_{te}}{\alpha}}$$

$$= -v_s \frac{R_1 \| R_2}{R_s + R_1 \| R_2} \frac{r_{ib}}{R_{tb} + r_{ib}} \frac{g_m R_{tc}}{1 + \frac{g_m R_{tc}}{\alpha}}$$

$$\Rightarrow \quad A_v = \frac{v_o}{v_s}$$

$$= -\frac{R_1 \| R_2}{R_s + R_1 \| R_2} \frac{r_{ib}}{R_{tb} + r_{ib}} \frac{g_m R_{tc}}{1 + \frac{g_m R_{tc}}{\alpha}}$$

An Alternate Approximate Solution



If $r_x = 0$ and $r_o = \infty$, r_{ib} is given by

$$r_{ib} = (1+\beta)(r_e + R_{te}) = r_\pi + (1+\beta) R_{te}$$

$$i_b = \frac{v_{tb}}{R_{tb} + r_{ib}}$$

$$i_c = \beta \, i_b$$

$$v_o = -i_c R_{tc} = -v_{tb} \frac{\beta R_{tc}}{R_{tb} + r_{ib}}$$

$$= -v_s \frac{R_1 \| R_2}{R_s + R_1 \| R_2} \frac{\beta R_{tc}}{R_{tb} + r_{ib}}$$

$$\Rightarrow A_v = \frac{v_o}{v_s} = - \frac{R_1 \| R_2}{R_s + R_1 \| R_2} \frac{\beta R_{tc}}{R_{tb} + r_{ib}}$$