Common-Collector Amplifier Example

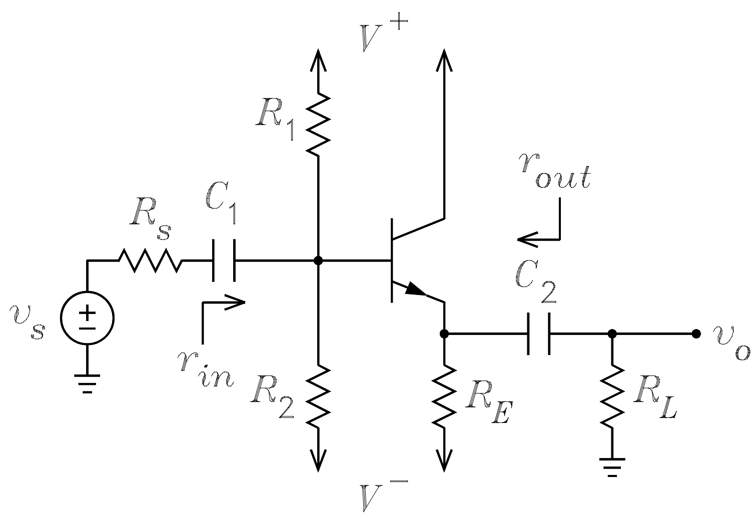
$R_P(x,y) := \frac{x \cdot y}{x+y}$ Function for calculating parallel resistors.

$R_1 := 100000$ $R_2 := 120000$ $R_C := 0$ $R_E := 5600$ $R_S := 5000$ $R_L := 10000$

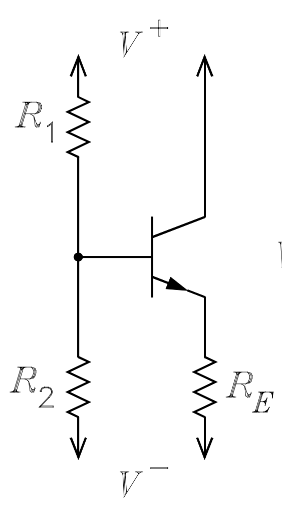
$V_{plus} := 15$ $V_{minus} := -15$ $V_{BE} := 0.65$ $V_T := 0.025$ $\beta := 99$ $\alpha := 0.99$

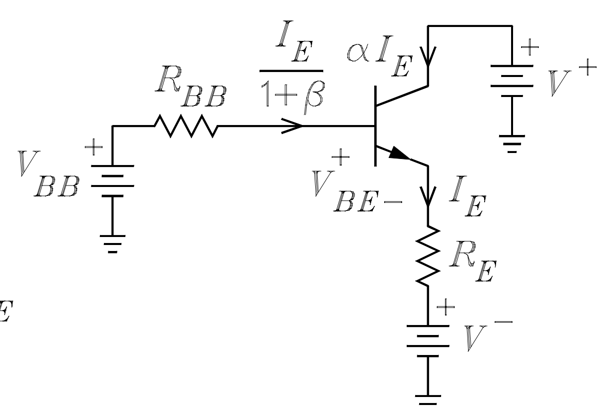
$r_x := 20$ $r_0 := 50000$

$v_s := 1$ With $v_s = 1$, the voltage gain is equal to v_o.



DC Bias Circuits - The second circuit follows from a Thevenin equivalent circuit looking out of the base.





$$V_{BB} := \frac{V_{plus} \cdot R_2 + V_{minus} \cdot R_1}{R_1 + R_2} \qquad V_{BB} = 1.364$$

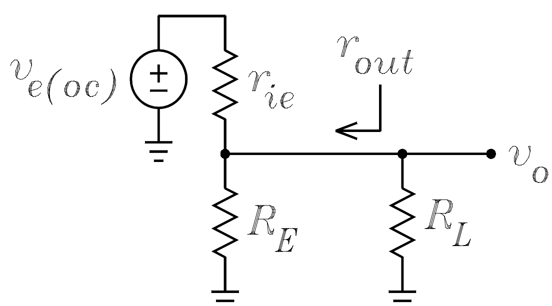
$$R_{BB} := R_P(R_1, R_2) \qquad R_{BB} = 5.455 \cdot 10^4$$

$$I_E := \frac{V_{BB} - V_{minus} - V_{BE}}{\frac{R_{BB}}{1+\beta} + R_E} \qquad I_E = 2.557 \cdot 10^{-3}$$

$$r_e := \frac{V_T}{I_E} \qquad r_e = 9.777$$

AC Solutions

This solution uses the equations involving R_{tc}, even though $R_{tc} = 0$. It is based on the Thevenin emitter circuit which has v_{eoc} in series with r_{ie}.



$$v_{tb} := v_s \cdot \frac{R_P(R_1, R_2)}{R_S + R_P(R_1, R_2)} \qquad v_{tb} = 0.916$$

$$R_{tb} := R_P(R_S, R_P(R_1, R_2)) \qquad R_{tb} = 4.58 \cdot 10^3$$

$$R_{te} := R_P(R_E, R_L) \qquad R_{te} = 3.59 \cdot 10^3$$

$$r'_e := \frac{R_{tb} + r_x}{1+\beta} + r_e \qquad r'_e = 55.779$$

$$R_{tc} := R_C \qquad R_{tc} = 0$$

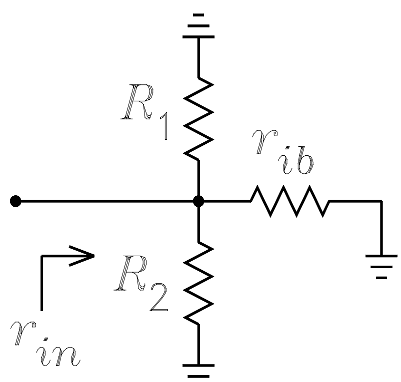
$$v_{eoc} := v_{tb} \cdot \frac{r_0 + \frac{R_{tc}}{1+\beta}}{r'_e + r_0 + \frac{R_{tc}}{1+\beta}} \qquad v_{eoc} = 0.915$$

$$r_{ie} := r'_e \cdot \frac{r_0 + R_{tc}}{r'_e + r_0 + \frac{R_{tc}}{1+\beta}} \qquad r_{ie} = 55.717$$

$$v_o := v_{eoc} \cdot \frac{R_P(R_E, R_L)}{r_{ie} + R_P(R_E, R_L)} \qquad v_o = 0.901$$

$$A_v := v_o \qquad A_v = 0.901$$ This is the voltage gain.

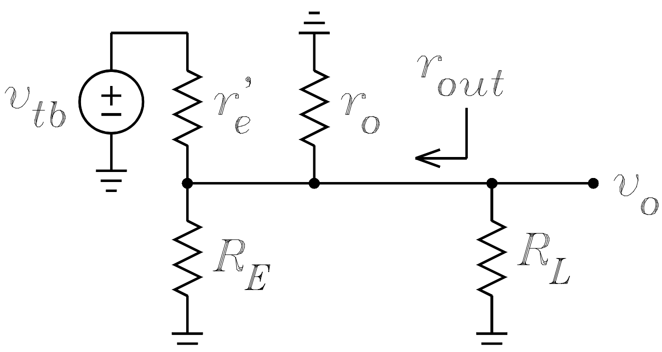
$$r_{out} := R_P(r_{ie}, R_E) \qquad r_{out} = 55.168$$



$$r_{ib} := r_x + (1+\beta) \cdot r_e + R_{te} \cdot \frac{(1+\beta) \cdot r_0 + R_{tc}}{r_0 + R_{te} + R_{tc}} \qquad r_{ib} = 3.359 \cdot 10^5$$

$$r_{in} := R_P(r_{ib}, R_P(R_1, R_2)) \qquad r_{in} = 4.693 \cdot 10^4$$

The following solution is based on the simplified T model. I prefer it when $R_{tc} = 0$. Note that this is an exact solution, where r_0 is considered to be an external resistor. The answers are the same as the ones in the solution above.



$$v_o := v_{tb} \cdot \frac{R_P(R_E, R_P(r_0, R_L))}{r_{ie} + R_P(R_E, R_P(r_0, R_L))} \qquad v_o = 0.901$$

$$A_v := v_o \qquad A_v = 0.901$$ This is the voltage gain.

$$r_{out} := R_P(r_{ie}, R_P(r_0, R_E)) \qquad r_{out} = 55.107$$

$$r_{ib} := r_x + (1+\beta)\cdot(r_e + R_P(R_E, R_P(r_0, R_L))) \qquad r_{ib} = 3.359 \cdot 10^5$$

$$r_{in} := R_P(r_{ib}, R_P(R_1, R_2)) \qquad r_{in} = 4.693 \cdot 10^4$$

Note that the CC amplifier has a voltage gain that is just less than unity, a low output resistance, and a high input resistance.

Approximate Solution 1

Assume r_x = 0 and r_0 = infinity. See the class notes for the derivation of the gain expression.

$g_m := \frac{\alpha \cdot I_E}{V_T}$ $g_m = 0.101$ $r_{ib} := (1+\beta)\cdot(r_e + R_{te})$ $r_{ib} = 3.6 \cdot 10^5$

$$A_v := \frac{R_P(R_1, R_2)}{R_S + R_P(R_1, R_2)} \cdot \frac{r_{ib}}{R_{tb} + r_{ib}} \cdot \frac{\frac{g_m \cdot R_{te}}{\alpha}}{1 + \frac{g_m \cdot R_{te}}{\alpha}} \qquad A_v = 0.902$$

This is very close to the exact solution above.

$r_{in} := R_P(r_{ib}, R_P(R_1, R_2))$ $r_{in} = 4.737 \cdot 10^4$ $r_{out} := R_P(r'_e, R_{te})$ $r_{out} = 54.925$

These are close to the exact solutions above.

Approximate Solution 2

Assume r_x = 0 and r_0 = infinity. See the class notes for the derivation of the gain expression.

$$A_v := \frac{R_P(R_1, R_2)}{R_S + R_P(R_1, R_2)} \cdot \frac{(1+\beta)\cdot R_{te}}{R_{tb} + r_{ib}} \qquad A_v = 0.902$$

This is the same answer as Approximate Solution 1. The answers for r_{in} and r_{out} are the same.

Note that both approximate solutions can be made exact if r_{ib} is added back to r_{ib} and r_0 is combined in parallel with R_{te}. The latter can be done only when R_{tc} = 0.