Cascode Amplifier Example - Fall 2000

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

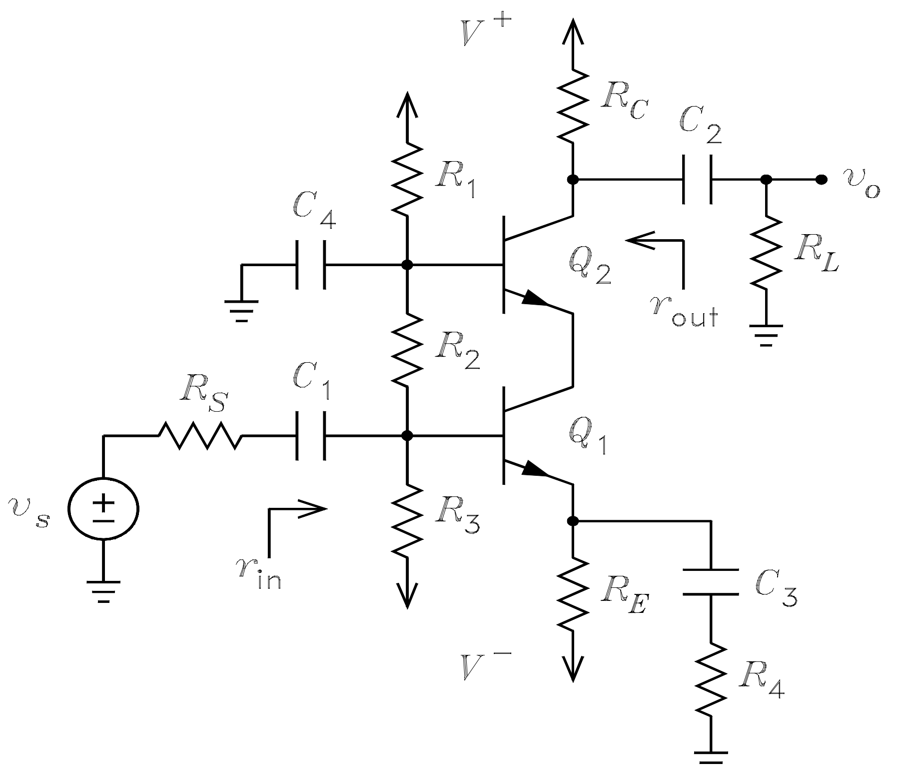
$R_1 := 390000$ $R_2 := 200000$ $R_3 := 56000$ $R_4 := 100$

$R_C := 20000$ $R_E := 4300$ $R_S := 1000$ $R_L := 10000$

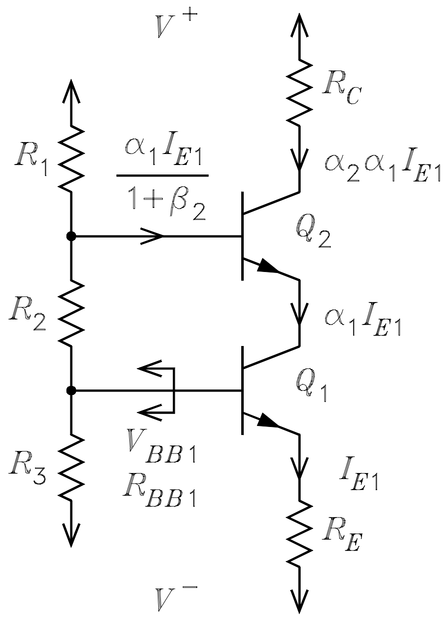
$V_p := 65$ $V_m := 0$ $V_{BE} := 0.65$ $V_T := 0.025$ $\beta := 199$ $\alpha := 0.995$

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

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



DC Bias Solution



$$V_{BB1} := \frac{V_p \cdot R_3 + V_m \cdot (R_1 + R_2)}{R_1 + R_2 + R_3} - \frac{\alpha \cdot I_{E1}}{1+\beta} \cdot \frac{R_1}{R_1 + R_2 + R_3} \cdot R_3$$

$$R_{BB1} := R_p(R_1 + R_2, R_3)$$

$$V_{BB1} - V_m := \frac{I_{E1}}{1+\beta} R_{BB1} + V_{BE} + I_{E1} \cdot R_E$$

Solve these to obtain.

$$I_{E1} := \frac{\dfrac{V_p \cdot R_3 + V_m \cdot (R_1 + R_2)}{R_1 + R_2 + R_3} - V_m - V_{BE}}{\dfrac{R_{BB1}}{1+\beta} + R_E + \dfrac{\alpha}{1+\beta} \cdot \dfrac{R_1 \cdot R_3}{R_1 + R_2 + R_3}} \qquad I_{E1} = 1.0552 \cdot 10^{-3}$$

$$r_{e1} := \frac{V_T}{I_{E1}} \qquad r_{e1} = 23.6922$$

$I_{E2} := \alpha \cdot I_{E1}$ $\quad$ $I_{E2} = 1.0499 \cdot 10^{-3}$

$r_{e2} := \dfrac{V_T}{I_{E2}}$ $\quad$ $r_{e2} = 23.8113$

Checks for active mode.

$V_{B1} := V_{BE} + I_{E1} \cdot R_E + V_m$ $\quad$ $V_{B1} = 5.1874$

$$V_{B2} := \frac{V_p \cdot (R_2 + R_3) + V_m \cdot R_1}{R_1 + R_2 + R_3} - \frac{I_{E2}}{1+\beta} \cdot R_P(R_1, R_2 + R_3) \qquad V_{B2} = 24.9472$$

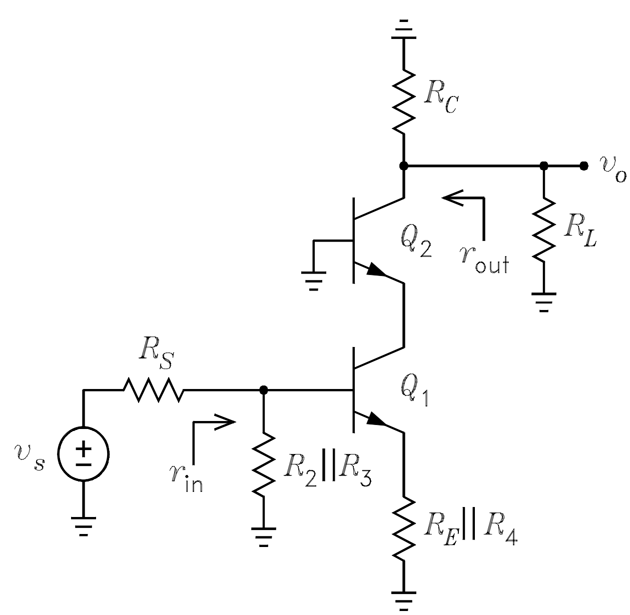
$V_{C1} := V_{B2} - V_{BE}$ $\quad$ $V_{C1} = 24.2972$

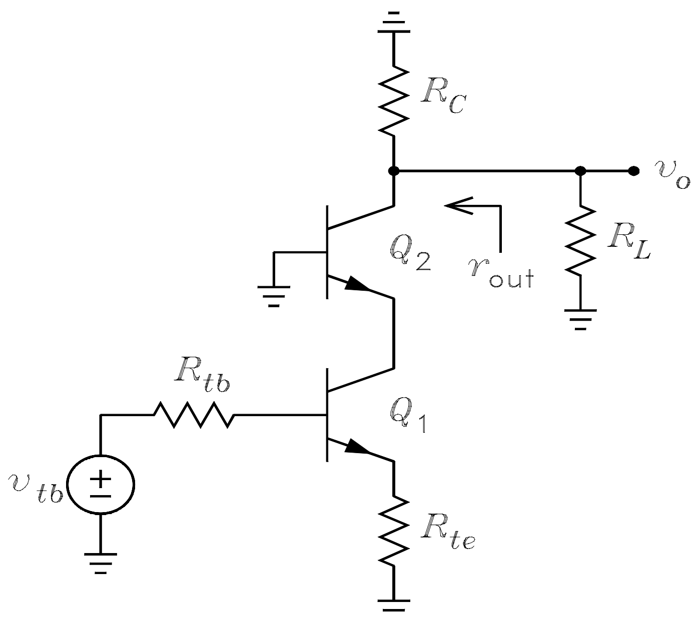
$V_{CB1} := V_{C1} - V_{B1}$ $\quad$ $V_{CB1} = 19.1098$ $\quad$ Active mode.

$V_{C2} := V_p - \alpha \cdot I_{E2} \cdot R_C$ $\quad$ $V_{C2} = 44.1065$

$V_{CB2} := V_{C2} - V_{B2}$ $\quad$ $V_{CB2} = 19.1594$ $\quad$ Active mode.

AC Solution





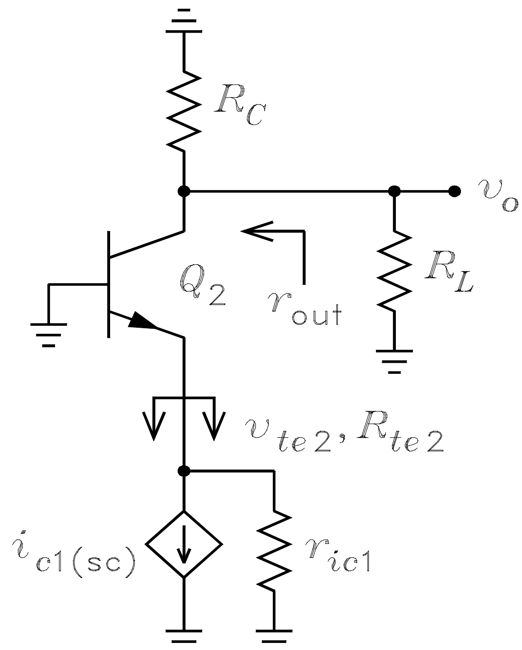
$$v_{tb1} := v_s \cdot \frac{R_P(R_2, R_3)}{R_S + R_P(R_2, R_3)} \qquad v_{tb1} = 0.9777$$

$$R_{tb1} := R_P(R_S, R_P(R_2, R_3)) \qquad R_{tb1} = 977.6536$$

$$R_{te1} := R_P(R_E, R_4) \qquad R_{te1} = 97.7273$$

$$r_{ie1} := \frac{R_{tb1} + r_x}{1 + \beta} + r_{e1} \qquad r_{ie1} = 28.6805$$

$$r_{ie2} := \frac{r_x}{1 + \beta} + r_{e2} \qquad r_{ie2} = 23.9113$$

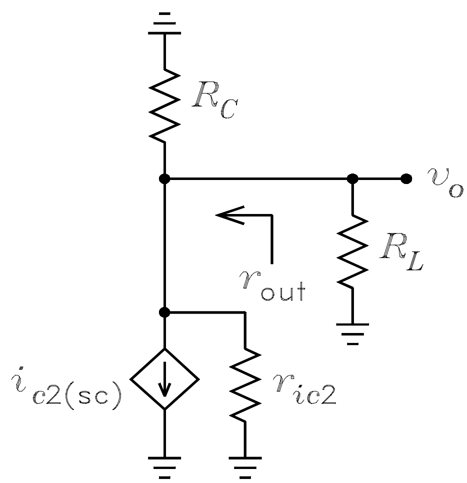


$$r_{ic1} := \frac{r_0 + R_P\left(r_{ie1}, R_{te1}\right)}{1 - \frac{\alpha \cdot R_{te1}}{r_{ie1} + R_{te1}}} \qquad r_{ic1} = 2.1678 \cdot 10^{5}$$

$$i_{c1sc} := \frac{v_{tb1}}{r_{ie1} + R_P\left(R_{te1}, r_0\right)} \cdot \left(\alpha - \frac{R_{te1}}{R_{te1} + r_0}\right) \qquad i_{c1sc} = 7.692 \cdot 10^{-3}$$

$$v_{te2} := -i_{c1sc} \cdot r_{ic1} \qquad v_{te2} = -1.6674 \cdot 10^{3}$$

$$R_{te2} := r_{ic1} \qquad R_{te2} = 2.1678 \cdot 10^{5}$$



$R_{tc2} := R_P(R_C, R_L)$ $\quad$ $R_{tc2} = 6.6667 \cdot 10^3$

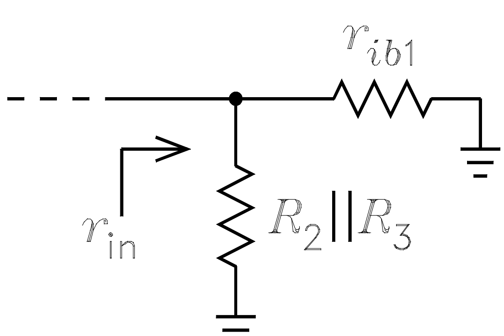
$$i_{c2sc} := \frac{-v_{te2}}{R_{te2} + R_P(r_{ie2}, r_0)} \cdot \frac{\alpha \cdot r_0 + R_{tc2}}{r_0 + R_{tc2}} \qquad i_{c2sc} = 7.6572 \cdot 10^{-3}$$

$$r_{ic2} := \frac{r_0 + R_P(r_{ie2}, R_{te2})}{1 - \dfrac{\alpha \cdot R_{te2}}{r_{ie2} + R_{te2}}} \qquad r_{ic2} = 9.7899 \cdot 10^6$$

$v_o := -i_{c2sc} \cdot R_P(r_{ic2}, R_{tc2})$ $\quad$ $v_o = -51.0132$

$A_v := v_o$ $\quad$ $A_v = -51.0132$ This is the voltage gain.

$r_{out} := R_P(R_C, r_{ic2})$ $\quad$ $r_{out} = 1.9959 \cdot 10^4$



$$r_{ieo2} := r_{ie2} \cdot \frac{r_0 + R_{tc2}}{r_{ie2} + r_0 + \frac{R_{tc2}}{1+\beta}} \qquad r_{ieo2} = 27.0685$$

$$R_{tc1} := r_{ieo2} \qquad R_{tc1} = 27.0685$$

$$r_{ib1} := r_x + (1+\beta) \cdot \left(r_{e1} + R_P\left(R_{te1}, r_0 + R_{tc1}\right)\right) - \frac{\beta \cdot R_{te1} \cdot R_{tc1}}{R_{tc1} + r_0 + R_{te1}}$$

$$r_{ib1} = 2.4255 \cdot 10^4$$

$$r_{in} := R_P\left(r_{ib1}, R_P\left(R_1 + R_2, R_3\right)\right) \qquad r_{in} = 1.6453 \cdot 10^4$$

The following solution is based on the r_0 approximations for Q2 .

$$i_{c2sc} := \alpha \cdot i_{c1sc} \cdot \frac{r_{ic1}}{r_{ie2} + r_{ic1}} \qquad i_{c2sc} = 7.6527 \cdot 10^{-3}$$

The $\frac{r_{ic1}}{r_{ie2} + r_{ic1}}$ is a current divider.

$$v_o := -i_{c2sc} \cdot R_P\left(R_{tc2}, r_{ic2}\right) \qquad v_o = -50.983$$

$$A_v := v_o \qquad A_v = -50.983$$

This is the voltage gain.

$$r_{out} := R_P\left(r_{ic2}, R_C\right) \qquad r_{out} = 1.9959 \cdot 10^4$$

$$r_{ib1} := r_x + (1+\beta) \cdot \left(r_{e1} + R_{te1}\right) \qquad r_{ib1} = 2.4304 \cdot 10^4$$

$$r_{in} := R_P\left(r_{ib1}, R_P\left(R_3, R_2\right)\right) \qquad r_{in} = 1.5624 \cdot 10^4$$