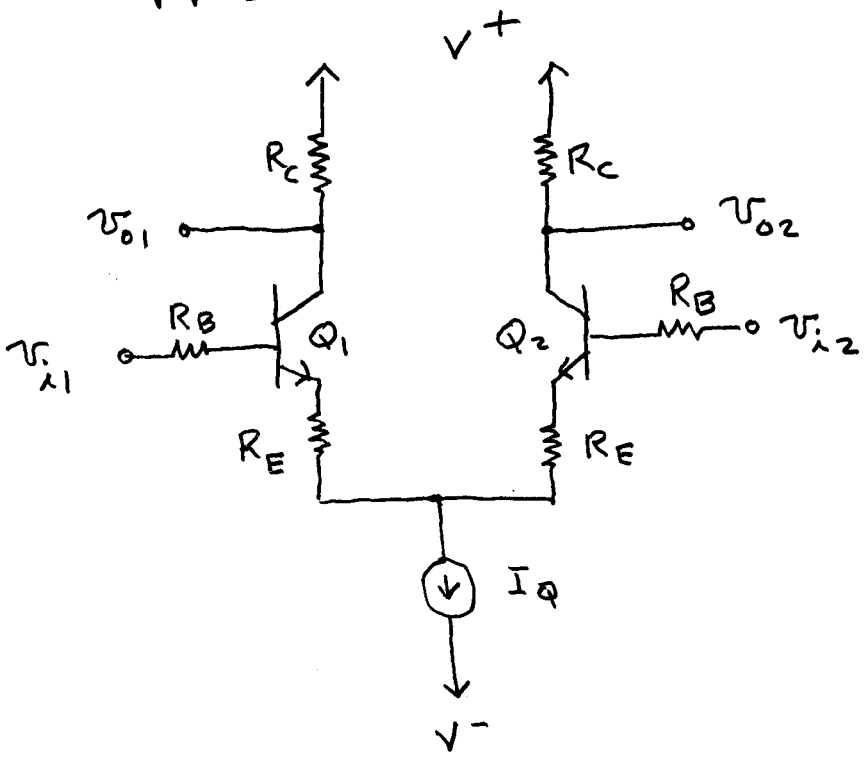
The BJT Diff Amp with Current Source Tail Supply



DC Solution - set $v_{i1} = v_{i2} = 0$

Assume Q_1 and Q_2 are identical.

$$\Rightarrow \quad I_{E1} = I_{E2} = \frac{I_Q}{2}$$

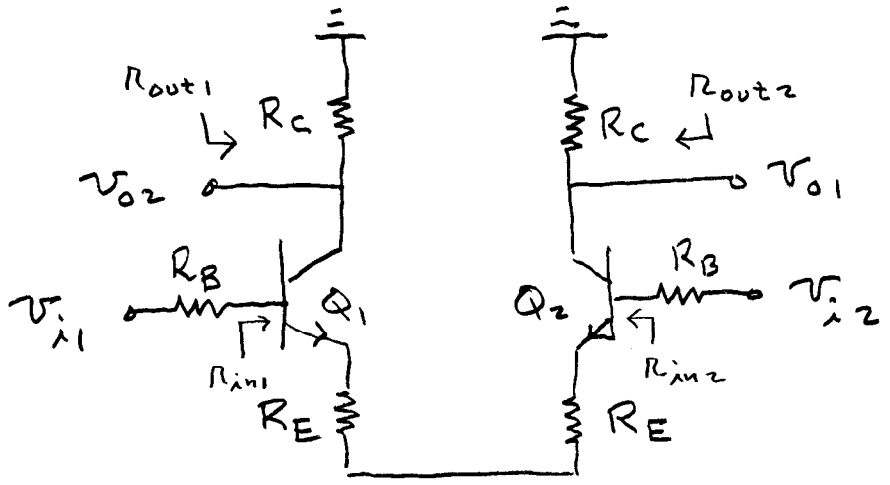
$$V_{CB} = V_C - V_B = \left(V^+ - \alpha \frac{I_Q}{2} R_C\right) - \left(-\frac{I_Q}{2(1+\beta)} R_B\right)$$

$$= V^+ - \frac{I_Q}{2}\left(\alpha R_C - \frac{R_B}{1+\beta}\right)$$

For the active mode $V_{CB} > 0$.

Small-Signal AC Solution

Set $V^+ = V^- = 0$ and $I_Q = 0$.



$$r_{e1} = r_{e2} = r_e = \frac{V_T}{I_E} = \frac{2V_T}{I_Q}$$

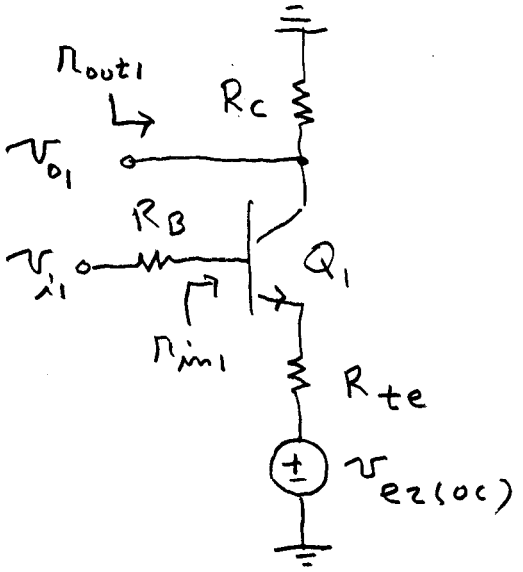
$$r'_{e1} = r'_{e2} = r'_e = \frac{R_B + r_x}{1+\beta} + r_e$$

$$r_{ie1} = r_{ie2} = r_{ie} = r'_e \frac{r_o + R_C}{r'_e + r_o + \frac{R_C}{1+\beta}}$$

$$R_{te1} = R_{te2} = R_{te} = 2R_E + r_{ie}$$

$$v_{e2(oc)} = v_{i2} \frac{r_o + \frac{R_C}{1+\beta}}{r'_e + r_o + \frac{R_C}{1+\beta}}$$

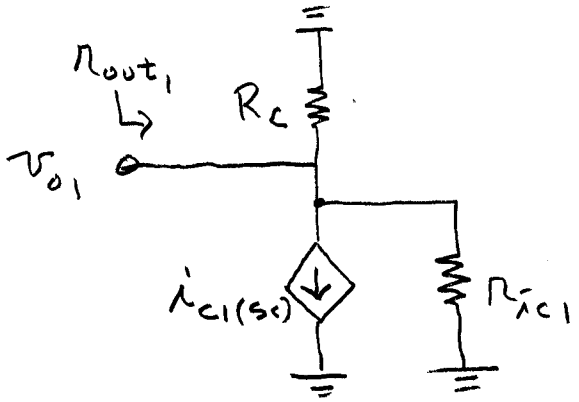
The circuit for v_{o1}, R_{out1}, and R_{in1} is



$$R_{in1} = r_{ib1}$$

$$= R_X + (1+\beta) R_e + R_{te} \frac{(1+\beta) R_o + R_C}{R_{te} + R_o + R_C}$$

Replace Q_1 with its Norton collector circuit



$$R_{ic1} = \frac{R_o + R_e' \| R_{te}}{1 - \frac{\alpha R_{te}}{R_e' + R_{te}}}$$

$$v_{o1} = -i_{c1(sc)} R_{ic1} \| R_{c1}$$

$$i_{c1(sc)} = G_{mb1} v_{i1} - G_{me1} v_{e2(oc)}$$

$$G_{mb1} = G_{mb2} = G_{mb} = \frac{\alpha}{r_e' + R_{te} \| r_o} \cdot \frac{r_o - \frac{R_{te}}{\beta}}{r_o + R_{te}}$$

$$G_{me1} = G_{me2} = G_{me} = \frac{1}{R_{te} + r_e' \| r_o} \cdot \frac{\alpha r_o + r_e'}{r_o + r_e'}$$

$$\Rightarrow v_{o1} = \left[G_{mb1} v_{i1} - G_{me1} v_{e2(oc)} \right] \times \left(- r_{ic}' \| R_c \right)$$

$$= \left[G_{mb1} v_{i1} - G_{me1} v_{i2} \frac{r_o + \frac{R_c}{1+\beta}}{r_e' + r_o + \frac{R_c}{1+\beta}} \right]$$

$$\times \left(- r_{ic} \| R_c \right)$$

$$r_{out1} = r_{ic1} \| R_c$$

For v_{o2}, r_{out2}, and r_{in2}, interchange the subscripts 1 and 2 in the above solutions.