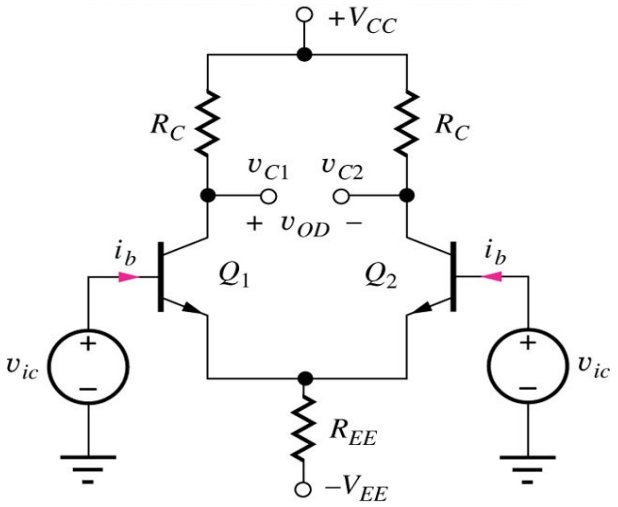
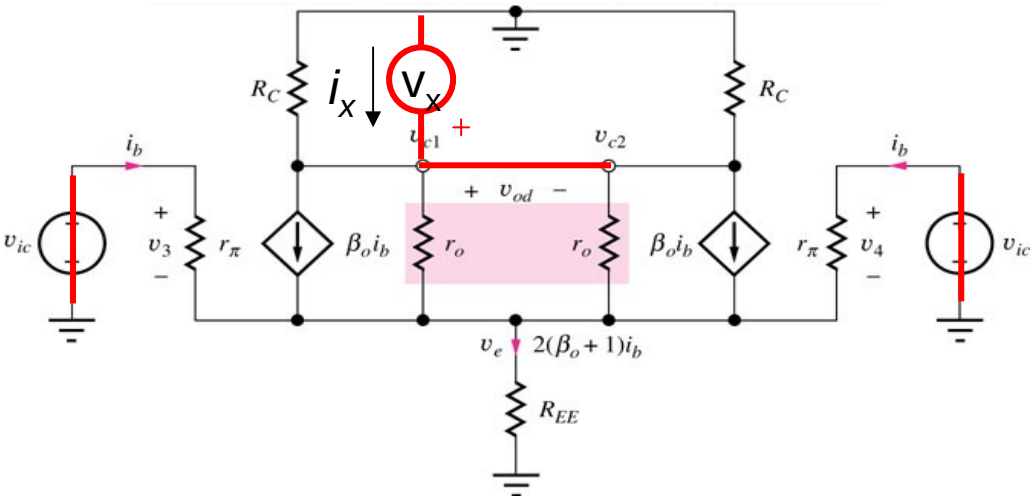
# Output Resistance – for CM output




To find CM $R_{out}$, tie $v_{C1}$ and $v_{C2}$ together and apply a test voltage between $v_{C1}$ and ground.

KCL at emitter: $\dfrac{-v_e}{r_\pi}(1+\beta)2 + 2\dfrac{v_x - v_e}{r_o} = \dfrac{v_e}{R_{EE}}$

$$v_e 2\left[\frac{1+\beta}{r_\pi} + \frac{1}{r_o} + \frac{1}{2R_{EE}}\right] = 2\frac{v_x}{r_o}$$

$$v_e = v_x \frac{1}{r_o}\left[\frac{\beta}{r_\pi} + \frac{1}{2R_{EE}}\right]^{-1} \quad \text{for } \frac{1+\beta}{r_\pi} >> \frac{1}{r_o} \quad (1)$$

and $\beta >> 1$

KCL at collector:

$$i_x = 2\left(\beta\frac{-v_e}{r_\pi} + \frac{v_x - v_e}{r_o}\right) + 2\frac{v_x}{R_C}$$

$$= -2v_e\left(\frac{\beta}{r_\pi} + \frac{1}{r_o}\right) + 2\left(\frac{1}{R_C} + \frac{1}{r_o}\right)v_x$$

$$\cong -2v_e\frac{\beta}{r_\pi} + 2\left(\frac{1}{R_C} + \frac{1}{r_o}\right)v_x \quad (2)$$

# Output Resistance – for CM output

Put (2) into (1), we obtain:

$$R_{out} \equiv \frac{v_x}{i_x} = \frac{1}{2}\left[\frac{1}{r_o}\frac{1}{1+2\beta\frac{R_{EE}}{r_\pi}}+\frac{1}{R_C}\right]^{-1}$$

$$\approx \frac{1}{2}R_C$$