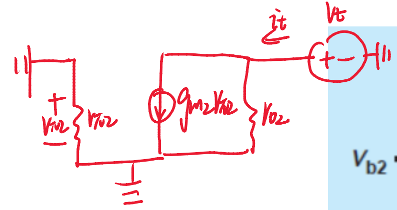
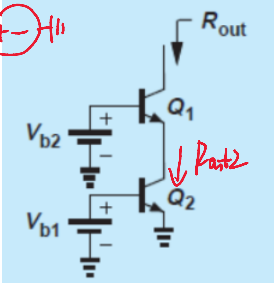
Extra Exercise 1

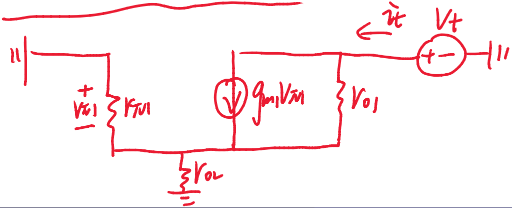
Determine the output resistance of the circuit below. With Early Effect.





$v_{\pi 2} = 0$

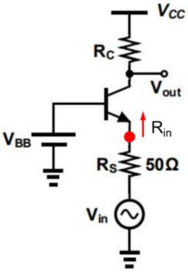
$\Rightarrow i_t = \frac{V_t}{r_{o2}} \Rightarrow R_{out2} = r_{o2}$



$R_{out} = r_{o1}\left[1 + g_{m1}\left(r_{o2} \| r_{\pi 1}\right)\right]$

Extra Exercise 2

(23FA Mid/9) The figure below shows a BJT amplifier. Assume $V_{BE} = 0.7$ V, $V_T = 25$ mV, β is very large (to be infinity). No Early effect. [15 points]

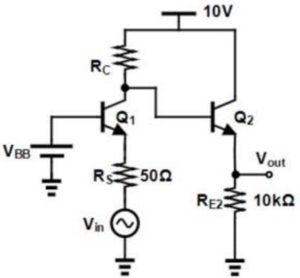


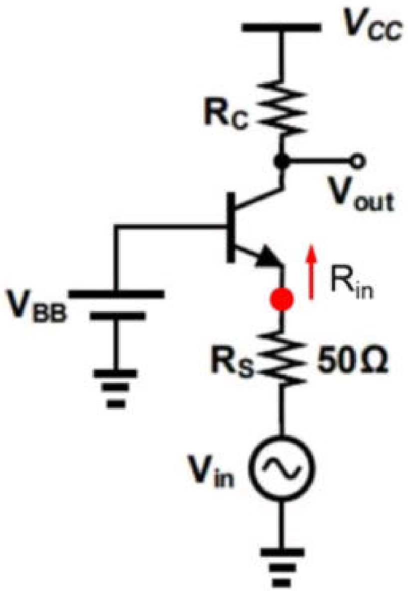
(a) Draw the small signal model and derive the gain for the amplifier. [5 points]

Extra Exercise 2

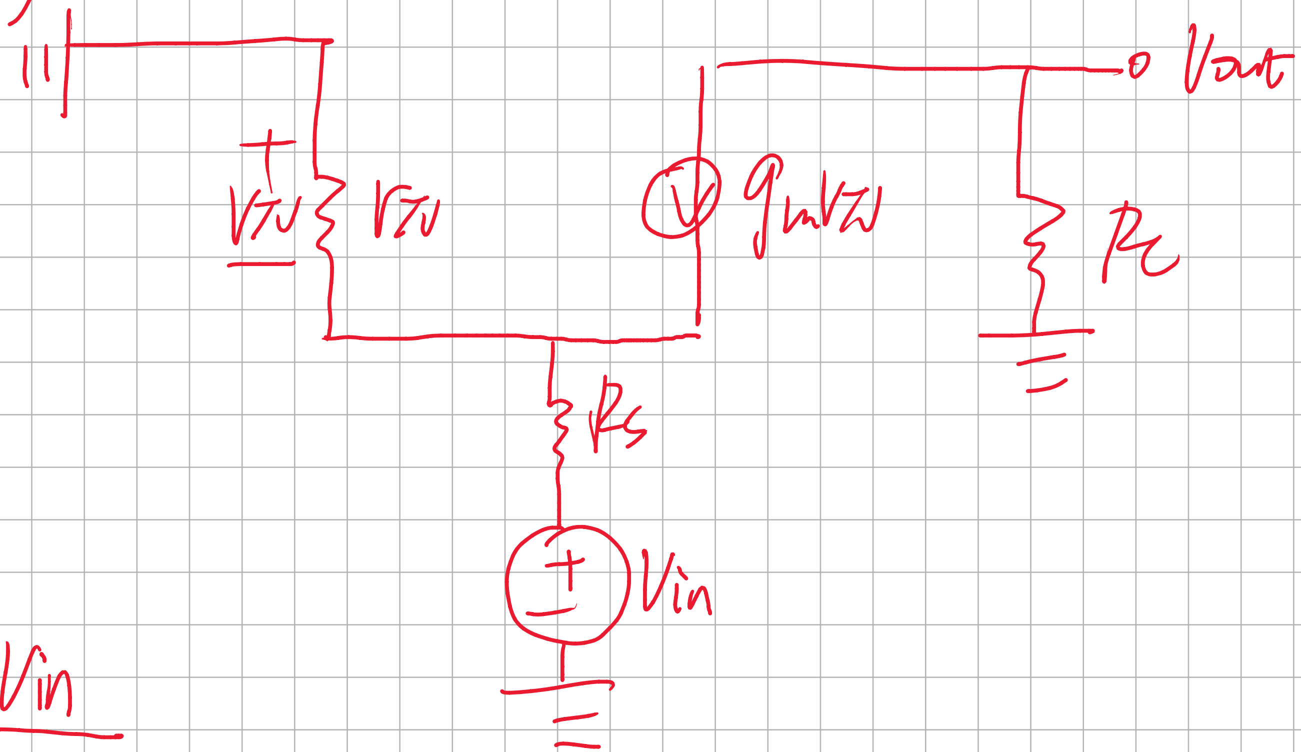
(b) Find values of V_{BB} and R_C to have a gain of 20 and a matched resistance of 100 Ω at the input, i.e. $R_{in} = 100\ \Omega$ from the point above R_S. [5 points]

(c) By cascading another BJT circuit to the circuit in part b as shown below, find the total parametric gain of the amplifier. [5 points]





(a)



$$\frac{V_\pi}{r_\pi} + g_m V_\pi = \frac{-V_\pi - V_{in}}{R_S}$$

$$V_\pi\left(\frac{1}{r_\pi} + g_m + \frac{1}{R_S}\right) = -\frac{1}{R_S} V_{in}$$

$$\Rightarrow V_\pi = -\frac{1}{R_S\left(\frac{1}{r_\pi} + g_m + \frac{1}{R_S}\right)} V_{in}$$

$$g_m V_\pi + \frac{V_{out}}{R_C} = 0$$

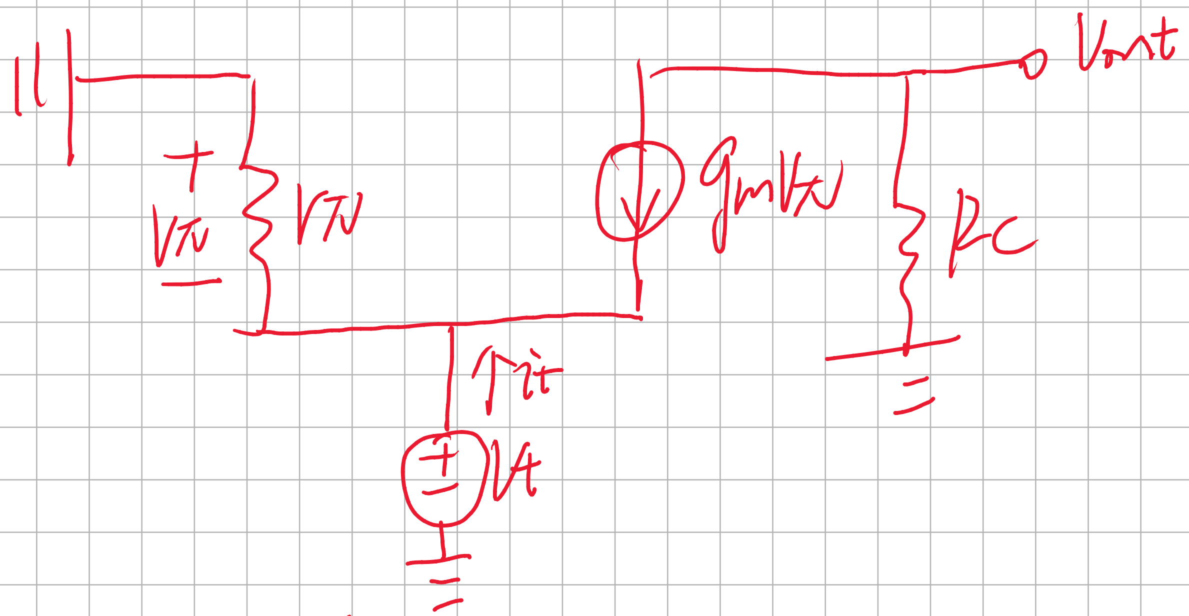
$$\Rightarrow V_{out} = -g_m R_C V_\pi = \frac{g_m R_C}{\frac{R_S}{r_\pi} + R_S g_m + 1} V_{in}$$

$\because \beta \to \infty$

$\therefore r_\pi = \frac{\beta}{g_m} \to \infty$

$\therefore \frac{V_{out}}{V_{in}} = \frac{g_m R_C}{g_m R_S + 1}$

(b) ① R_{in}



$$V_\pi = -V_t$$

$$i_t = -\frac{V_\pi}{r_\pi} - g_m V_\pi$$

$$= V_t\left(\frac{1}{r_\pi} + g_m\right)$$

$$\Rightarrow R_{in} = \frac{V_t}{i_t} = \frac{1}{\frac{1}{r_\pi} + g_m} = \frac{1}{g_m} = 100\Omega$$

$$\Rightarrow g_m = 0.01\,\Omega^{-1}$$

② A_v

$$A_v = \frac{g_m R_C}{g_m R_S + 1} = 20$$

$$\Rightarrow \frac{0.01\,R_C}{0.01 \times 50 + 1} = 20$$

$$\Rightarrow R_C = 3 \times 10^3\,\Omega$$

③ V_{BB}

$$V_{BB} = V_{BE} + V_E \qquad g_m = \frac{I_C}{V_T}$$

$$\Rightarrow I_C = 2.5 \times 10^{-4} A$$

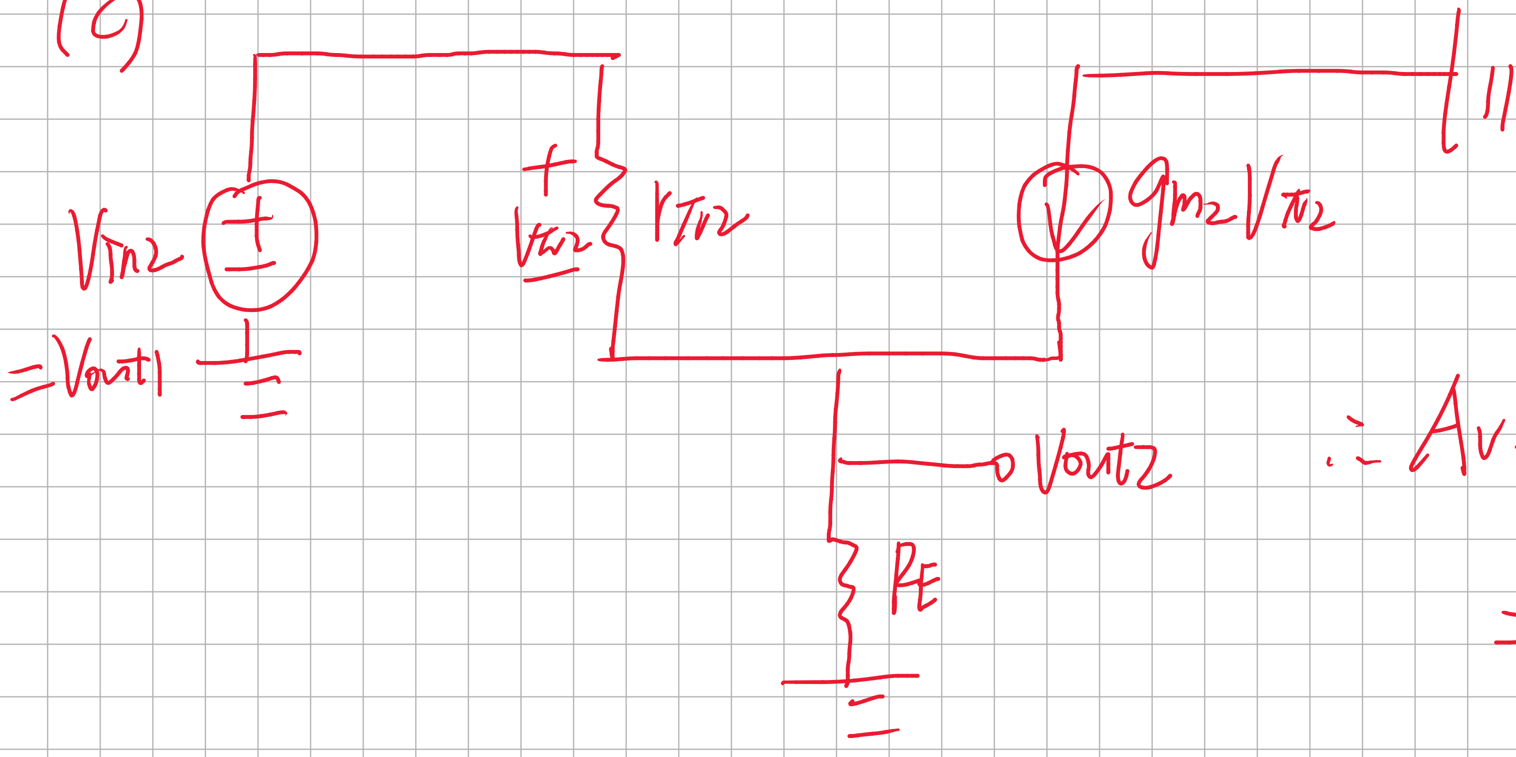
$$I_E \quad \beta \to \infty \Rightarrow I_B = 0$$

$$g_m \longrightarrow I_C \Rightarrow I_E = I_C = 2.5 \times 10^{-4} A$$

$$V_E = R_S I_E = 1.25 \times 10^{-2} V$$

$$V_{BB} = V_{BE} + V_E = 0.7125 V$$

(c)



$$\therefore A_v = \frac{g_{m2}R_{E2}}{1+g_{m2}R_{E2}} \cdot \frac{g_{m1}R_C}{g_{m1}R_S+1}$$

$$= \frac{R_C}{R_S+\frac{1}{g_m}} \cdot \frac{R_{E2}}{R_{E2}+\frac{1}{g_{m2}}}$$

$\beta \to \infty$, $r_{\pi 2} \to \infty$, $\frac{V_{\pi 2}}{r_{\pi 2}} \to 0$

$$V_{out2} = R_E\, g_{m2} V_{\pi 2} = R_E\, g_{m2}(V_{in2} - V_{out2})$$

$$\Rightarrow \frac{V_{out2}}{V_{in2}} = \frac{g_{m2}R_{E2}}{1+g_{m2}R_{E2}}$$