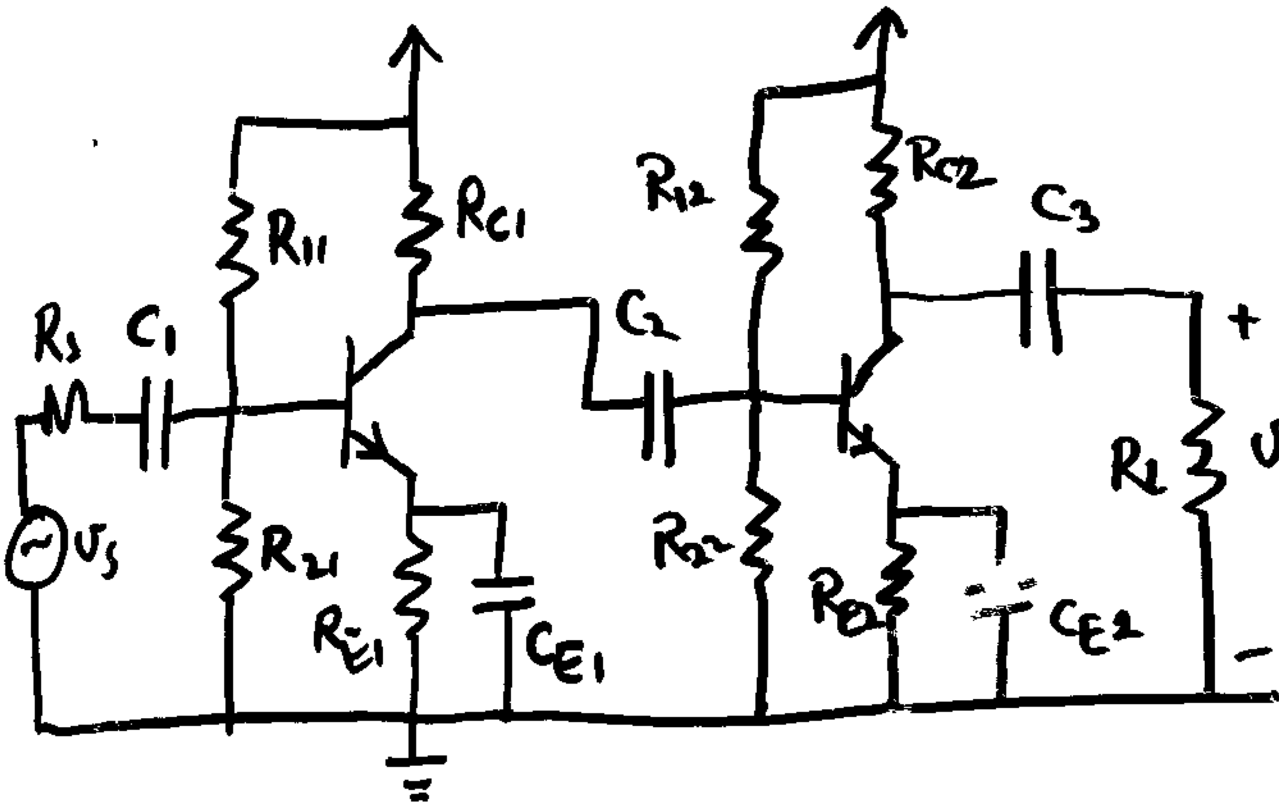
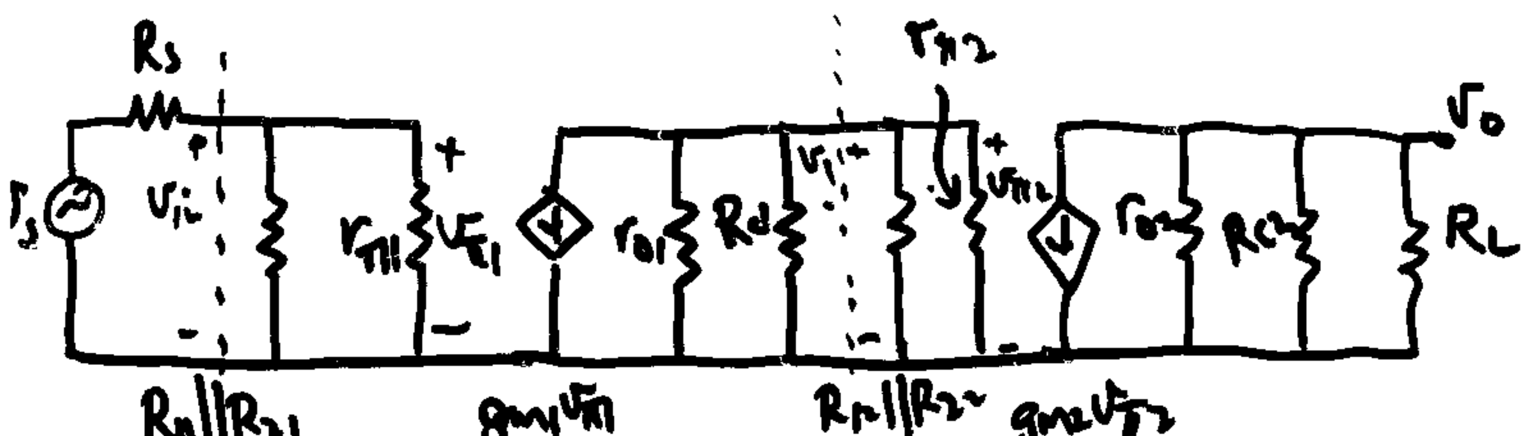
CE-CE Amplifier



Midband Model

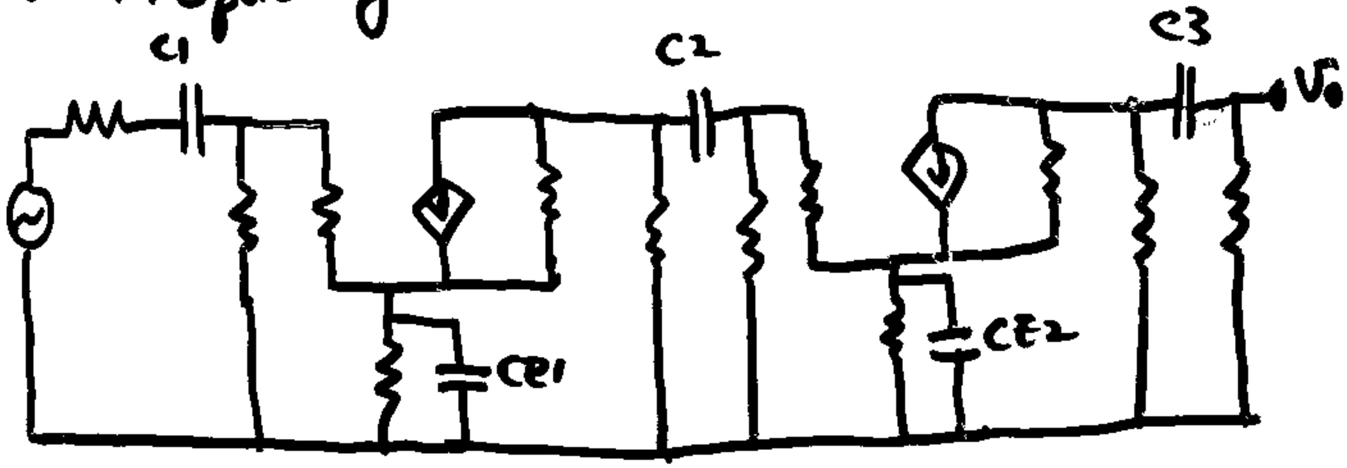


$$A_{v_1} = \frac{v_1}{v_{in}} = -g_{m1}\left(r_{o1} \| R_{C1} \| R_{12} \| R_{22} \| r_{\pi 2}\right)$$

$$A_{v_2} = \frac{v_o}{v_1} = -g_{m2}\left(r_{o2} \| R_{C2} \| R_L\right)$$

$$A_{v_s} = \frac{v_o}{v_s} = \frac{R_{11} \| R_{21} \| r_{\pi 1}}{R_{11} \| R_{21} \| r_{\pi 1} + R_s} A_{v_1} \cdot A_{v_2}$$

Low Frequency Model



$$R_{C1,eq} = R_S + R_{11} \| R_{21} \| r_{\pi 1}$$

$$R_{C2,eq} = R_{C1} \| r_{o1} + R_{12} \| R_{22} \| r_{\pi 2}$$

$$R_{C3,eq} = R_L + r_{o2} \| R_{C2}$$

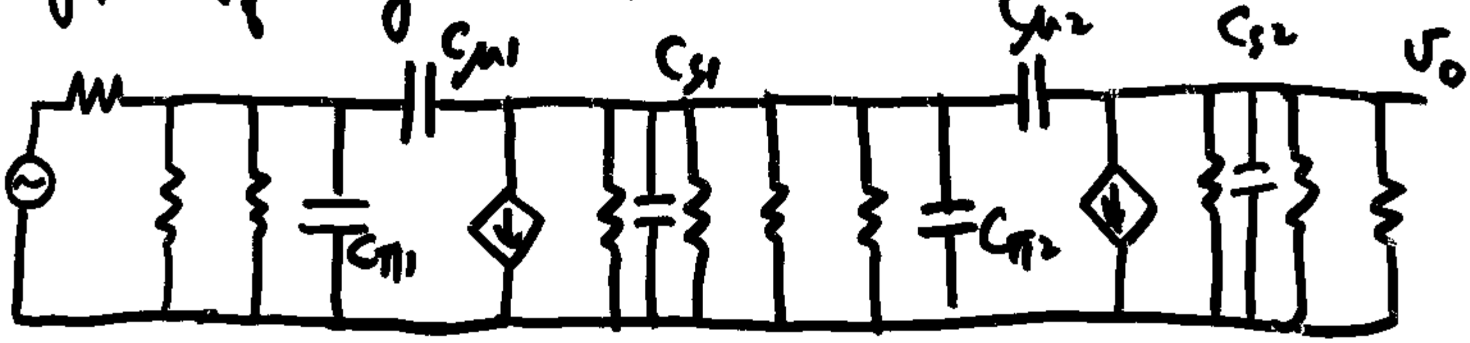
$$R_{CE1,eq} = R_{E1} \| \frac{r_{\pi 1} + R_S \| R_{11} \| R_{21}}{\beta_1 + 1}$$

$$R_{CE2,eq} = R_{E2} \| \frac{r_{\pi 2} + R_{C1} \| R_{12} \| R_{22}}{\beta_2 + 1}$$

(Assume $r_{o1} = \infty$, $r_{o2} = \infty$)

→ The other corner defined by $R_{E1} C_{E1}$ & $R_{E2} C_{E2}$

High Frequency Model



$$R_{\pi 1,eq} = R_S \| R_{11} \| R_{21} \| r_{\pi 1}$$

$$R_{\pi 2,eq} = r_{o1} \| R_{C1} \| R_{12} \| R_{22} \| r_{\pi 2}$$

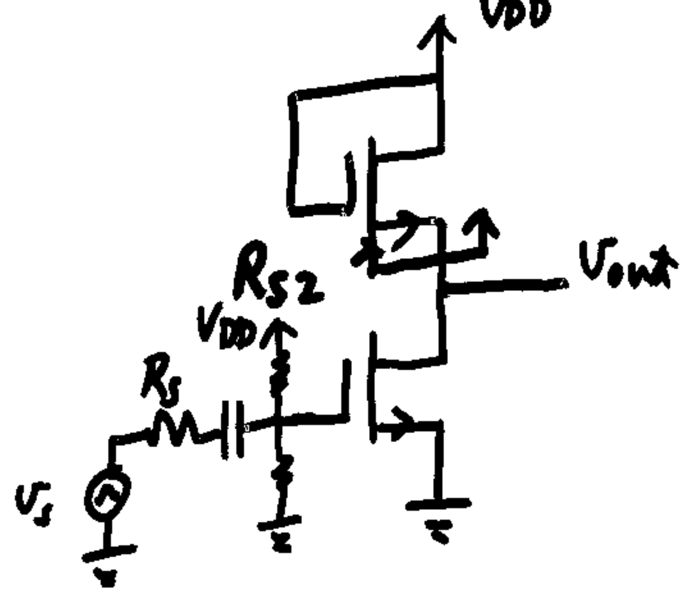
$$R_{CS1,eq} = R_{\pi 2,eq}$$

$$R_{CS2,eq} = R_{C2} \| R_L \| r_{o2}$$

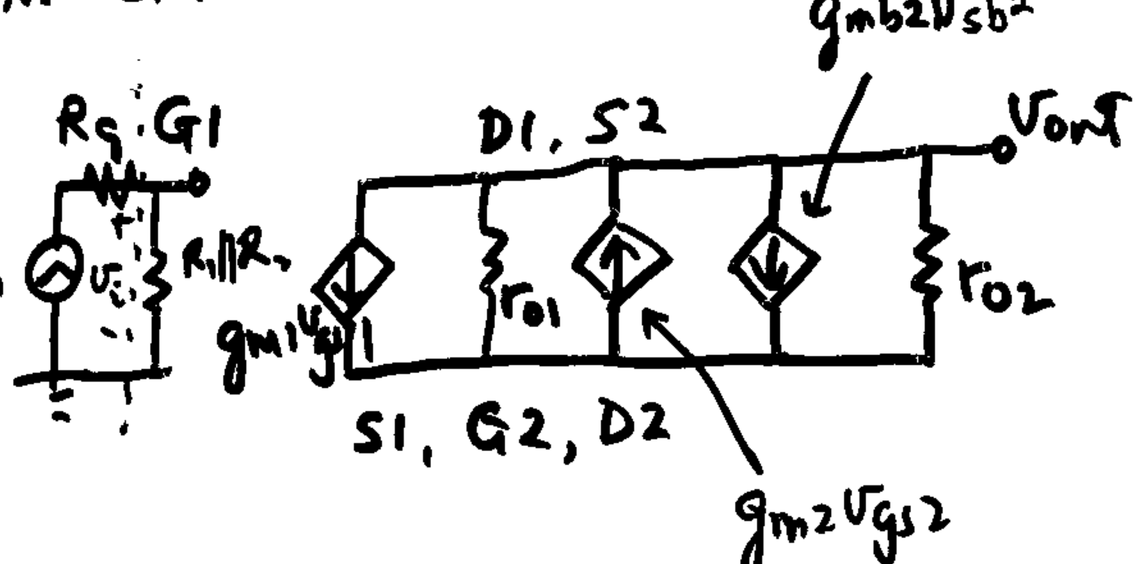
$$R_{\mu 1,eq} = R_{\pi 1,eq} \times (1 - Av_1) + R_{CS1,eq}$$

$$R_{\mu 2,eq} = R_{\pi 2,eq} \times (1 - Av_2) + R_{CS2,eq}$$

Active loads



Equiv. ckt



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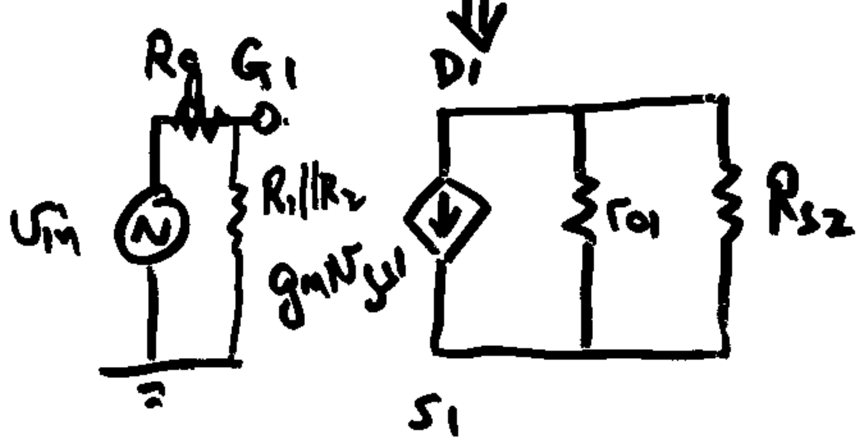


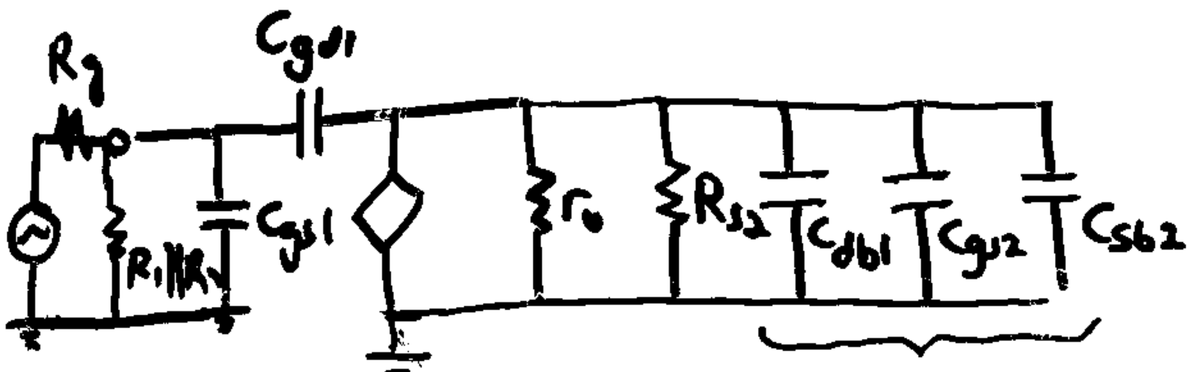
$$R_{S2} = \frac{1}{g_{m2}+g_{mb2}+\frac{1}{r_{o2}}}$$

$$\frac{v_o}{v_i} = A_{MB} = -g_{m1}(r_{o1} \| R_{S2})$$

$$= \frac{-g_{m1}}{g_{m2} + g_{mb2} + \frac{1}{r_{o1}} + \frac{1}{r_{o2}}}$$

$$\simeq -\frac{g_{m1}}{g_{m2}}$$

High Frequency Model



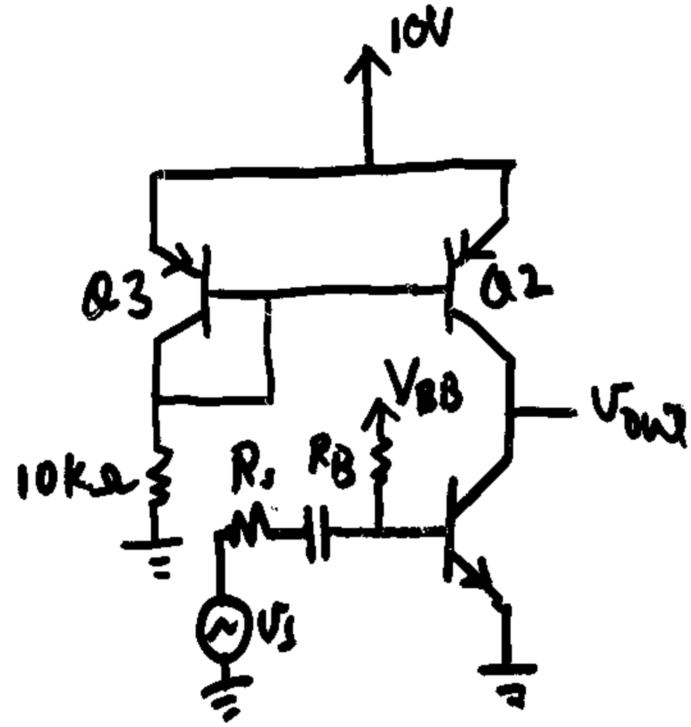
$$\equiv C_{out} = C_{db1} + C_{gs2} + C_{sb2}$$

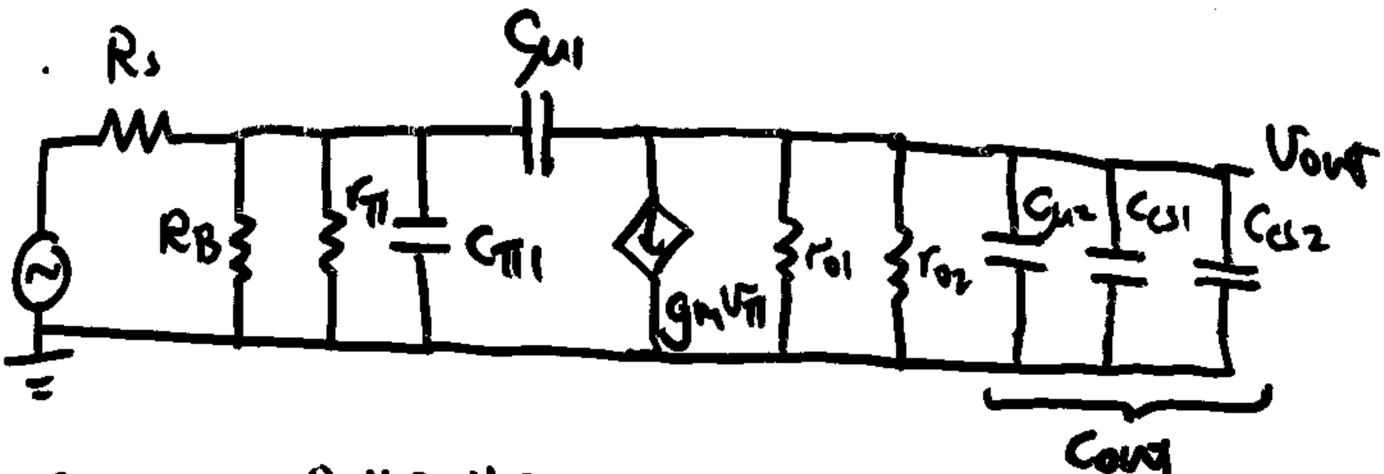
$$R_{gs1,eq} = R_g \| R_1 \| R_2$$

$$R_{gd1,eq} = R_{gs1,eq}(1 - A_{MB}) + r_o \| R_{S2}$$

$$R_{out,eq} = r_o \| R_{S2}$$

Current Mirror Load

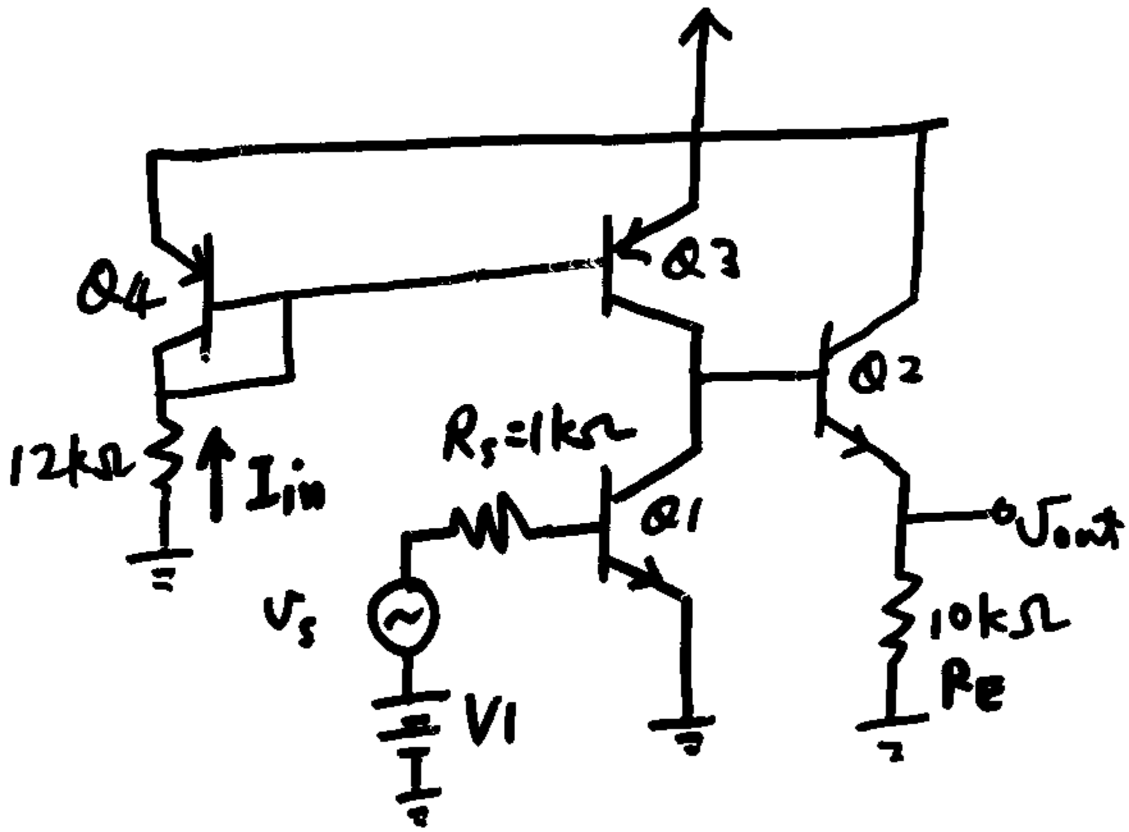




$$R_{\pi 1,eq} = R_s \| R_B \| r_\pi$$

$$R_{\mu 1,eq} = R_{\pi 1,eq}\left(1 - g_m(r_{o1}\|r_{o2})\right) + r_{o1}\|r_{o2}$$

$$R_{out,eq} = r_{o1}\|r_{o2}$$



$\beta = 80$

$|V_{BE(ON)}| = 0.7V$

$|V_A| = 62V$

$C_\mu = 2pF$

$C_\pi = 20pF$

$C_{cs} = 2pF$

$V_{out,DC} = 4V$

DC solution

$$I_{C3} \approx I_{C2} \approx \frac{\beta}{\beta+2} I_{in}$$

$$= \frac{80}{80+2} \frac{8-0.7}{12\,k\Omega} = 0.59\,mA$$

$r_{\pi 1} = 3.57\,k\Omega$

$g_{m1} = 22.7\,mA/V$

$$r_{o1} = r_{o3} = \frac{V_A}{I_C} = 105\,k\Omega$$

$V_{OUT,DC} = 4V$

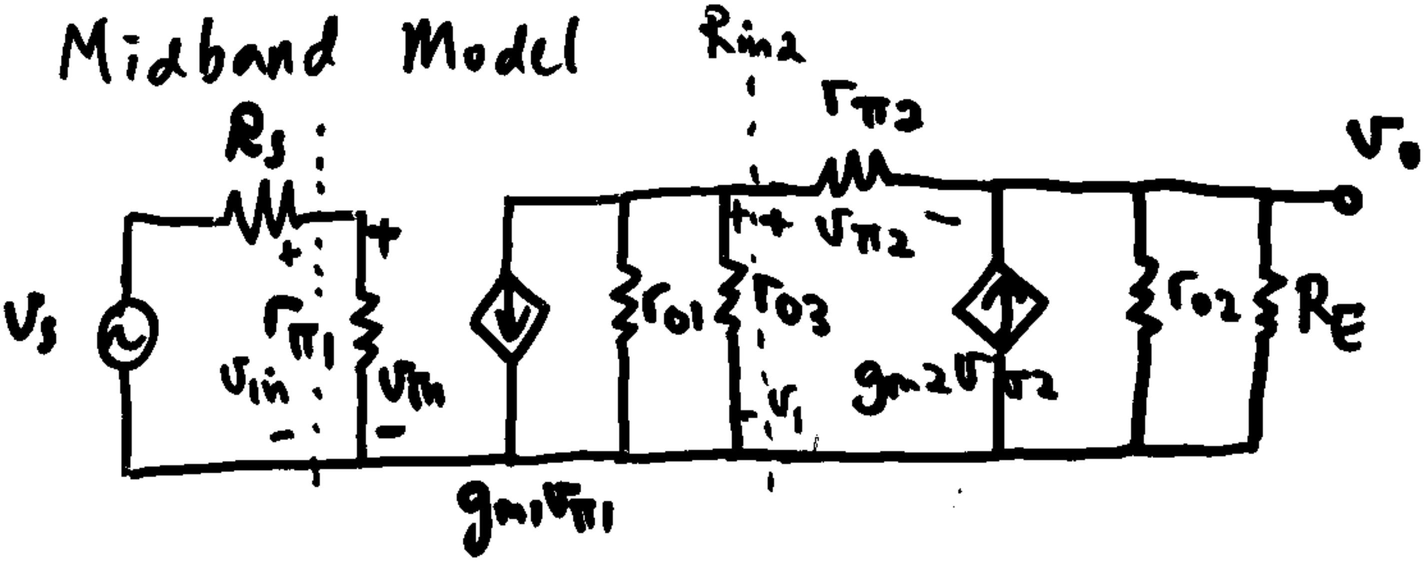
$I_{E2} = 0.4\,mA$

$r_{\pi 2} = 802\,\Omega$

$g_{m2} = 15.2\,mA/V$

$r_{o2} = 157\,k\Omega$

Midband Model



$$R_{in2} = r_\pi + (r_{o2} \| R_E)(\beta + 1)$$

$$\cong 810\,k\Omega$$

$$v_1 = -g_{m1} v_{\pi 1} (r_{o1} \| r_{o3} \| R_{in2})$$

$$A_{v1} = \frac{v_1}{v_{in}} = -g_{m1}(r_{o1} \| r_{o3} \| R_{in2})$$

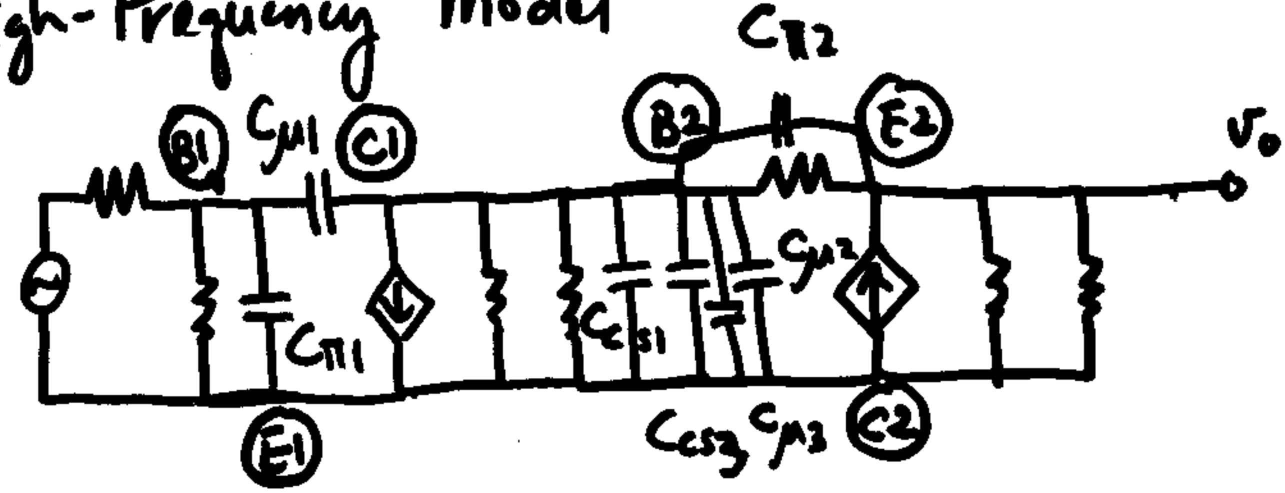
$$v_o = \frac{r_{o2} \| R_E}{r_{o2} \| R_E + \frac{r_{\pi 2}}{\beta + 1}} v_1$$

$$A_{v2} = \frac{v_o}{v_1} = \frac{r_{o2} \| R_E}{r_{o2} \| R_E + \frac{r_{\pi 2}}{\beta + 1}}$$

$$A_{vs} = \frac{v_o}{v_s} = \frac{r_{\pi 1}}{R_s + r_{\pi 1}} \cdot A_{v1} \cdot A_{v2}$$

$$= -858\ V/V$$

High-Frequency Model



$$C_{in} = C_{\pi 1} + (1 - A_{v_1}) C_{\mu 1}$$

$$= 20 + 1106 \times 2 = 2232\,pF$$

$$R_{in,eq} = R_s \| r_{\pi 1} = 781\,\Omega$$

$$\tau_{in} = 1.74\,\mu s$$

$$C_{out} = C_{cs1} + C_{cs3} + C_{\mu 1} + C_{\mu 2} + C_{\mu 3} = 10\,pF$$

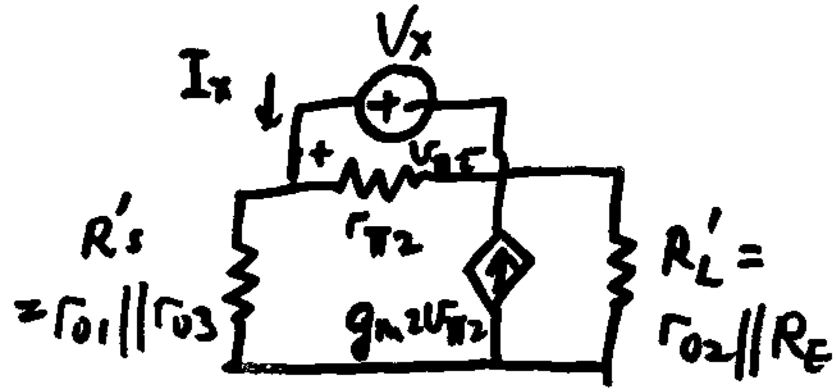
$$R_{out,eq} = r_{o1} \| r_{o3} \| R_{in2} = 49.3\,k\Omega$$

$$\tau_{out} = 0.49\,\mu s$$

$$\tau_H = \tau_{in} + \tau_{out} + \tau_{\pi 2}$$

$$f_H = \frac{1}{2\pi \tau_H} = 71\,kHz$$

$$C_{\pi 2} = 20\,pF$$

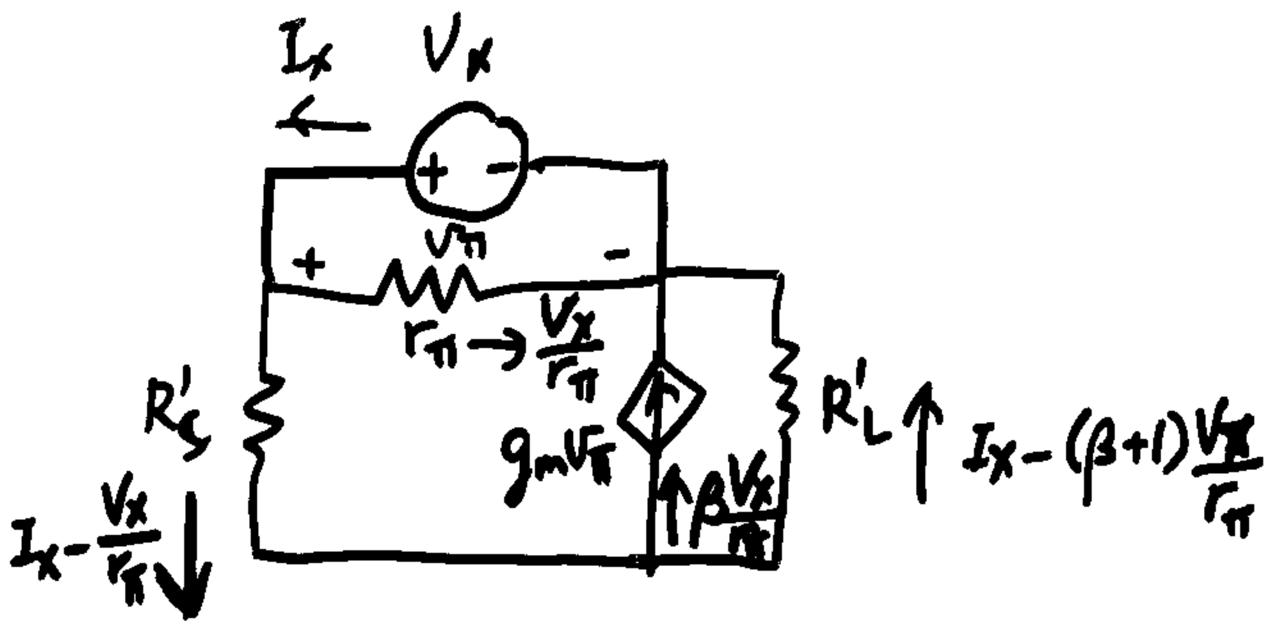


$$R_{\pi 2,eq} = r_{\pi 2} \left\| \frac{R'_s + R'_L}{1 + g_{m2} R'_L} \right.$$

$$= 802 \left\| \frac{52.5\,k\Omega + 9.4\,k\Omega}{1 + 15.2 \times 9.4\,k\Omega} \right.$$

$$= 280\,\Omega$$

$$\tau_{\pi 2} = 5\,ps$$



$$V_x = \left(I_x - \frac{V_x}{r_\pi}\right)R_s' + \left(I_x - (\beta+1)\frac{V_x}{r_\pi}\right)R_L'$$

$$V_x + \frac{V_x}{r_\pi}R_s' + (\beta+1)\frac{V_x}{r_\pi}R_L' = (R_s' + R_L')I_x$$

$$\frac{I_x}{V_x} = \frac{1}{R_s' + R_L'} + \frac{1}{r_\pi} + \frac{g_m R_L'}{R_s' + R_L'}$$

$$= \frac{1}{r_\pi} + \frac{1 + g_m R_L'}{R_s' + R_L'}$$

$$\frac{V_x}{I_x} = r_\pi \,\Big\|\, \frac{R_s' + R_L'}{1 + g_m R_L'} = R_{\pi,eq}$$