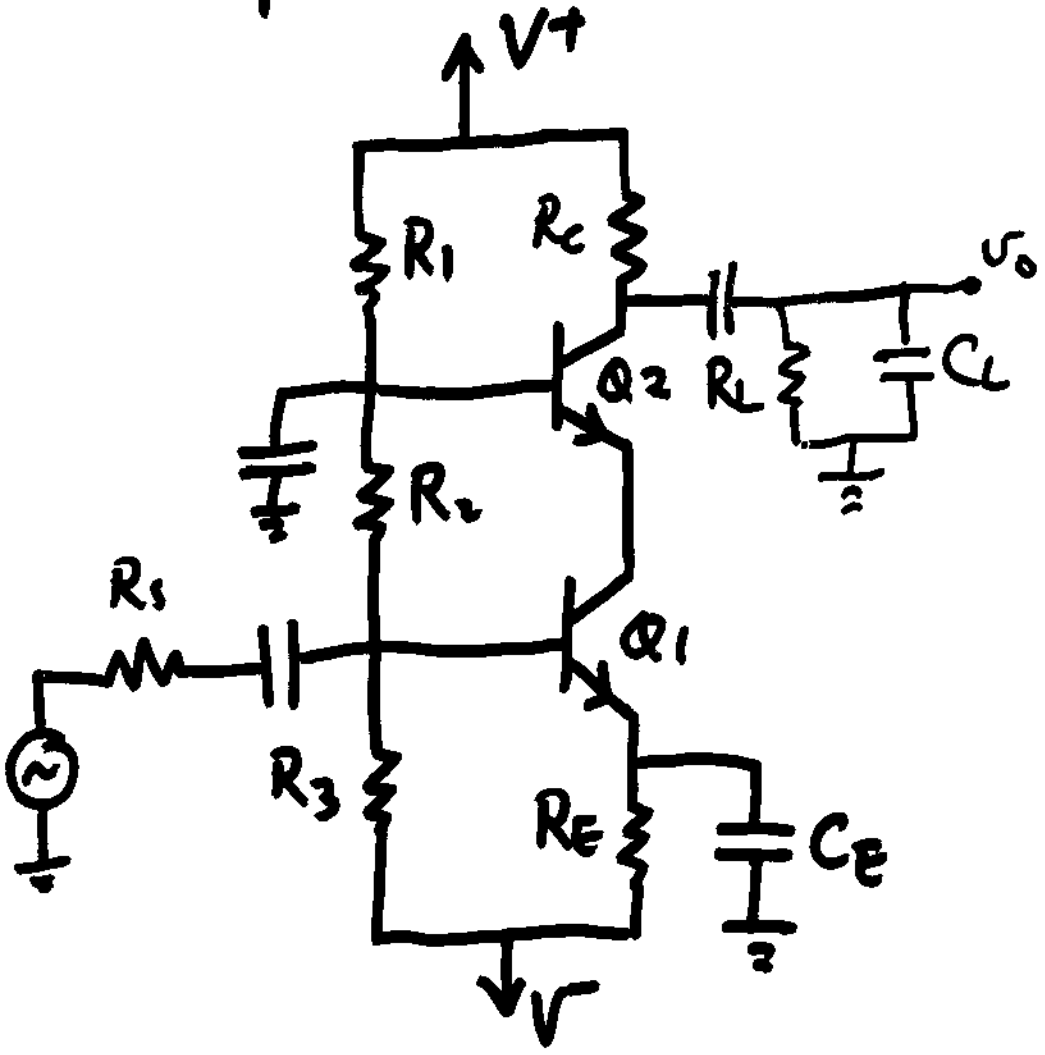
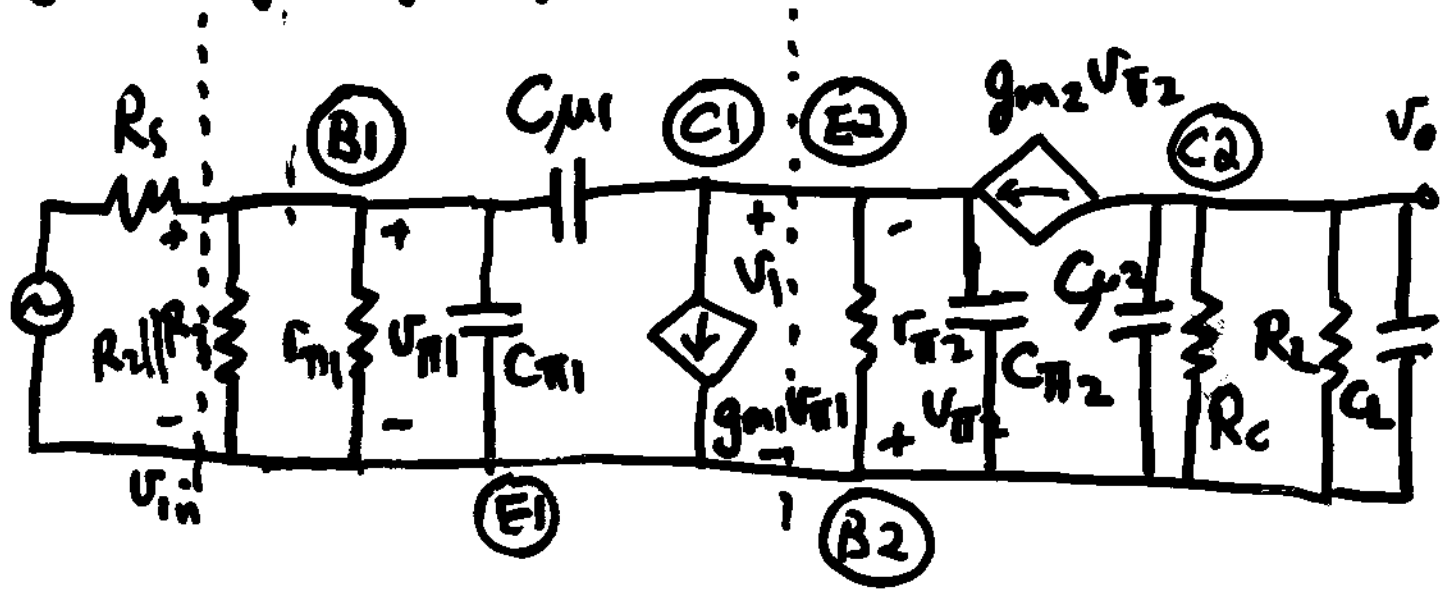
CE-CB Amplifier (Cascode)



High-frequency equiv. ckt



Miller Effect

$$A_{V_1} = \frac{V_1}{V_{in}}$$

$$= -g_{m_1} \frac{r_{\pi 2}}{\beta_2 + 1}$$

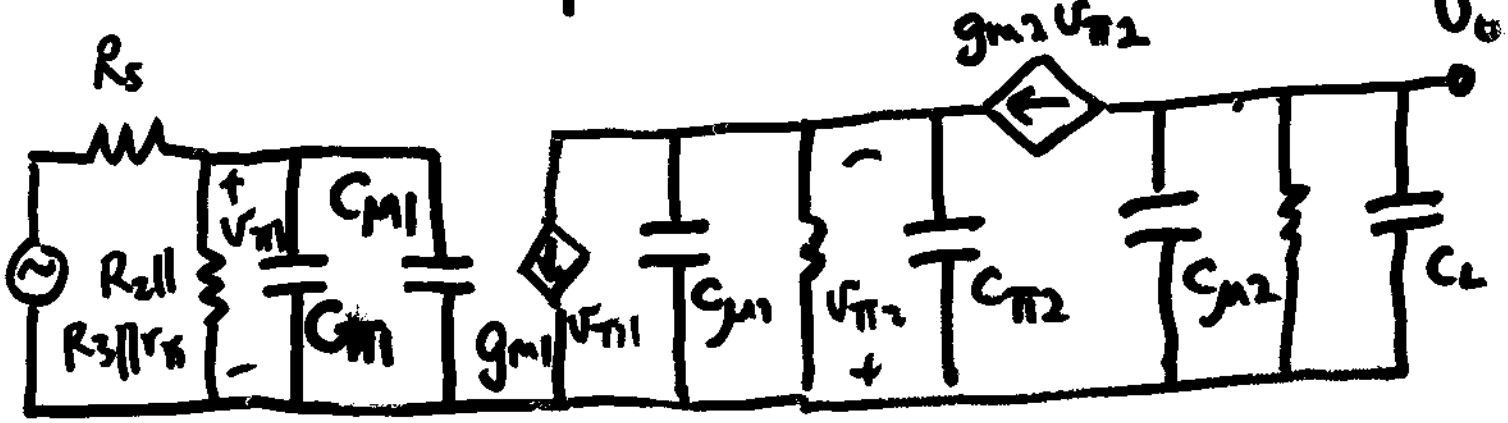
If $\beta_1 = \beta_2$, $I_{C1} \cong I_{C2}$, $I_{B1} \cong I_{B2}$

$$g_{m1} \cong g_{m2}, \; r_{\pi 1} \cong r_{\pi 2}$$

$$A_{V_1} \cong \frac{-\beta}{\beta + 1}$$

insignificant

$$C_{M1} = \left(1 - \left(\frac{-\beta}{\beta+1}\right)\right) C_{\mu 1} \cong 2\, C_{\mu 1}$$



$$R_{\pi 1} = R_S \| R_2 \| R_3 \| r_{\pi_1}$$

$$R_{\mu 1} = (R_S \| R_2 \| R_3 \| r_{\pi 1})\left(1 + g_{m1}\frac{r_{\pi 2}}{\beta+1}\right) + \frac{r_{\pi 2}}{\beta+1}$$

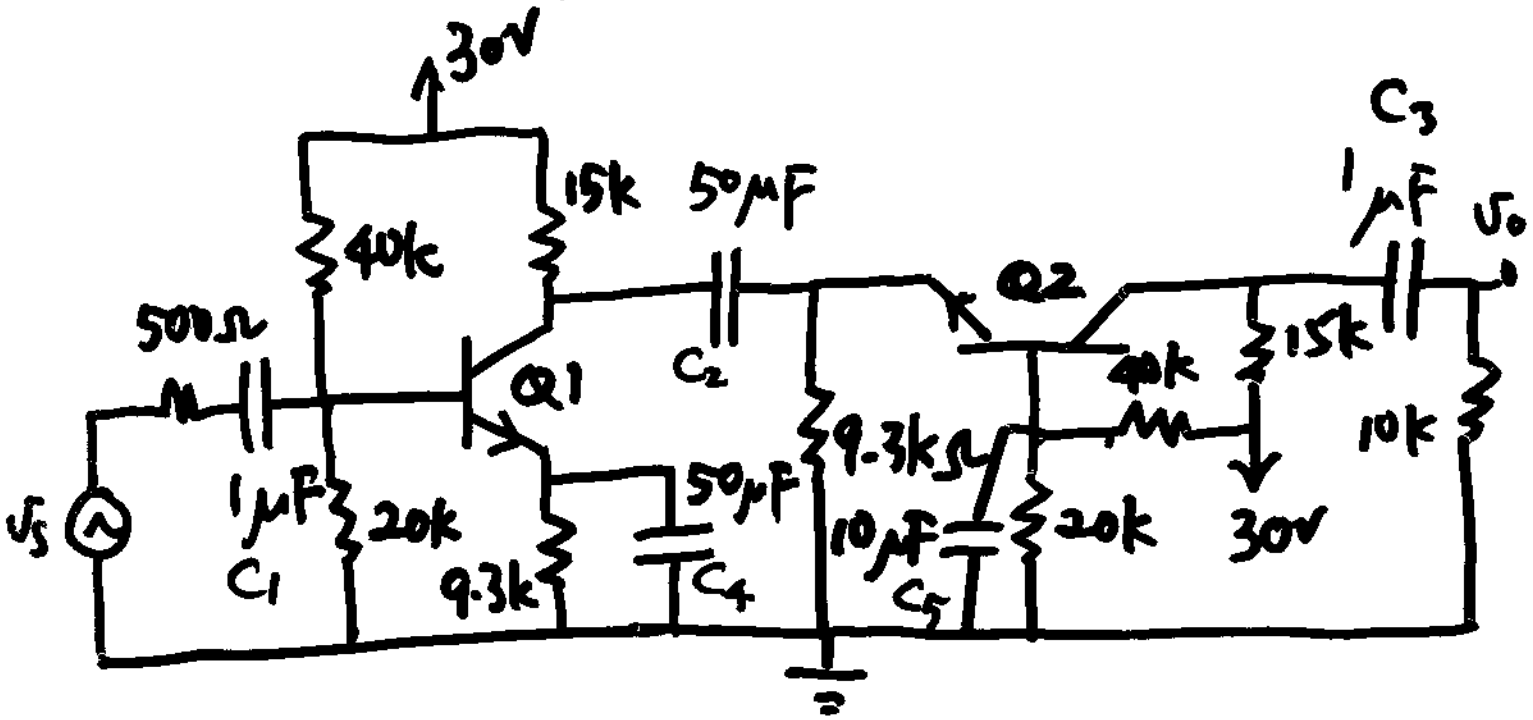
$$R_{\pi 2} = \frac{r_{\pi 2}}{\beta+1}$$

$$R_{\mu 2} = R_C \| R_L$$

$$R_{CL} = R_C \| R_L$$

$$\omega_H \cong \frac{1}{\tau_{\pi 1} + \tau_{\mu 1} + \tau_{\pi 2} + \tau_{\mu 2} + \tau_{CL}}$$

Cascode Example



$\beta = 150$, $V_{BE(ON)} = 0.7\,V$

$f_T = 500\,MHz$ @ $I_C = 2\,mA$

$C_\mu = 0.3\,pF$ @ $V_{CB} = 5V$

Note: The two stages are identical

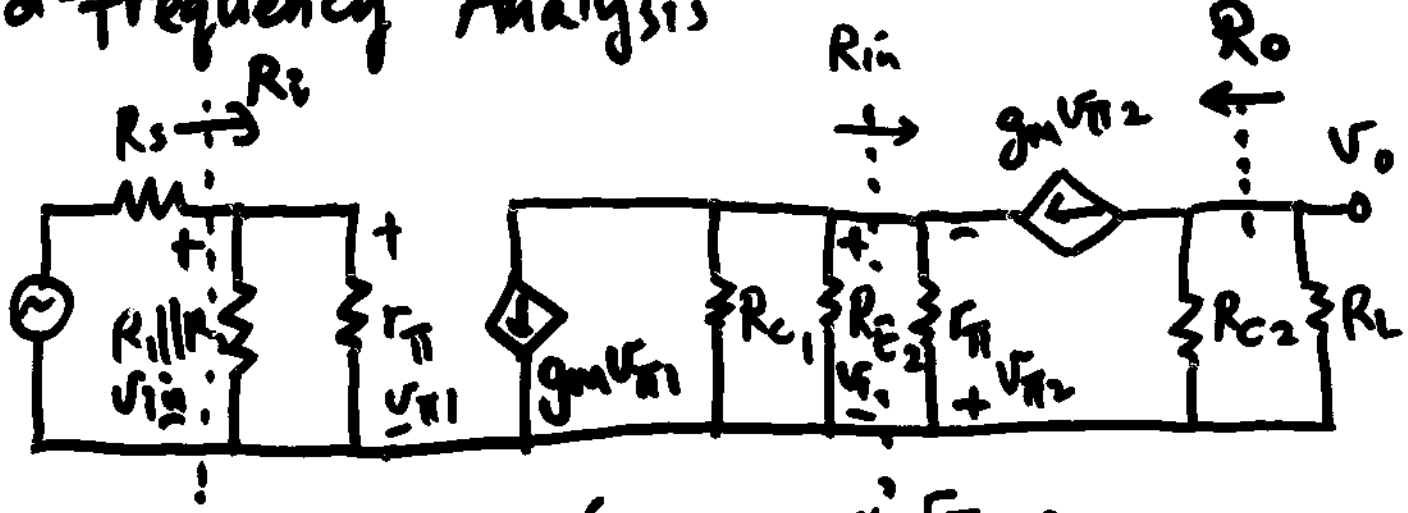
DC analysis: $I_{C1} \cong I_{B1} = 1\,mA$

$V_{CB} = 5V$

AC analysis: $g_m = 38.5\,mA/V$

$r_\pi = \frac{\beta}{g_m} = 3.9\,k\Omega$

Mid-frequency Analysis



$$A_{V_1} = \frac{v_1}{v_{in}} = -g_m \left(R_{c1} \| R_{E2} \| \frac{r_\pi}{\beta+1} \right)$$

$$= -0.99 \text{ V/V}$$

R_{in}

$$A_{V_2} = \frac{v_o}{v_1} = +g_m (R_{c2} \| R_L)$$

$$= +231 \text{ V/V}$$

$$A_V = \frac{v_o}{v_{in}} = -229$$

$$R_i = R_1 \| R_2 \| r_\pi = 3\,k\Omega$$

$$R_o = R_{c2} = 15\,k\Omega$$

Low Frequency:

$$R_{C1,eq} = R_S + R_1 \| R_2 \| r_\pi \qquad O(k\Omega)$$

$$R_{C2,eq} = R_{C1} + R_{E2} \| \frac{r_\pi}{\beta+1} \qquad O(k\Omega)$$

$$R_{C3,eq} = R_{C2} + R_L \qquad O(k\Omega)$$

$$R_{C4,eq} = R_{E1} \| \frac{r_\pi + R_1 \| R_2 \| R_S}{\beta+1} \qquad O(10\Omega)$$

$$R_{C5,eq} = R_1 \| R_2 \| \left[r_\pi + (\beta+1) R_{E2} \| R_{C1} \right] \qquad O(k\Omega)$$

$R_{C4,eq}$ dominates

$$\omega_L \cong \frac{1}{R_{C4,eq} C_4} \cong \frac{1}{30\Omega \times 50\mu F}$$

$$\cong 667 \text{ rad/s}$$

$$= 105 \text{ Hz}$$

High Frequency:

Calculate for C_π first

$f_T = 500\,MHz$ @ $I_c = 2mA$

Assume $f_T \tilde{\propto} I_c \Rightarrow f_T = 250\,MHz$ @ $I_c = 1mA$

$$f_T = \frac{g_m}{2\pi(C_\pi + C_\mu)}$$

$$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu$$

$$= 24.2\,pF$$

$$R_{\pi 1,eq} = (R_S \| R_1 \| R_2 \| r_\pi)$$

$$= 430\Omega$$

$$\tau_{\pi 1} = R_{\pi 1,eq} C_{\pi 1} = 10.4\,ns$$

$$R_{\pi 2,eq} = R_{C1} \| R_{E2} \| \frac{r_\pi}{\beta+1}$$

$$= 36\Omega$$

$$\tau_{\pi 2} = 0.63\,ns$$

$$R_{\mu 1,eq} = (R_S \| R_1 \| R_2 \| r_\pi)(1 + g_m(R_{C1} \| R_{E2} \| \frac{r_\pi}{\beta+1}))$$
$$+ (R_{C1} \| R_{E2} \| \frac{r_\pi}{\beta+1})$$

$$= 886\Omega$$

$$\tau_{\mu 1} = 0.27\,ns \leftarrow \text{does not dominate}$$

$$R_{\mu 2,eq} = R_{C2} \| R_L = 6k.$$

$$\tau_{\mu 2} = 1.8\,ns$$

$$\frac{1}{\Sigma\tau} < \omega_H < \frac{1}{\tau_{\pi 1}}$$

$$12.1\,MHz < f_H < 15.3\,MHz$$