EE210: Microelectronics-I

Lecture-20 :CE Amplifier-8

Upper Cutoff Frequency

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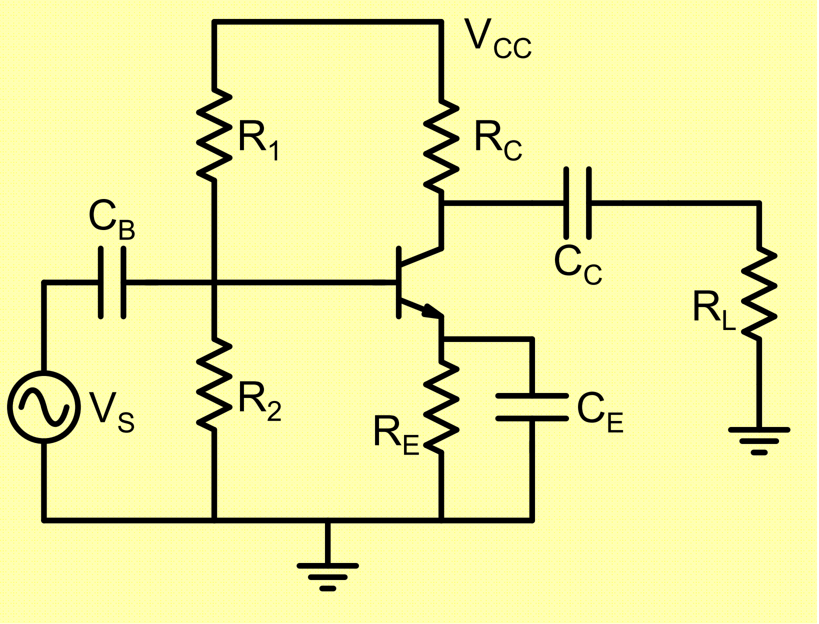
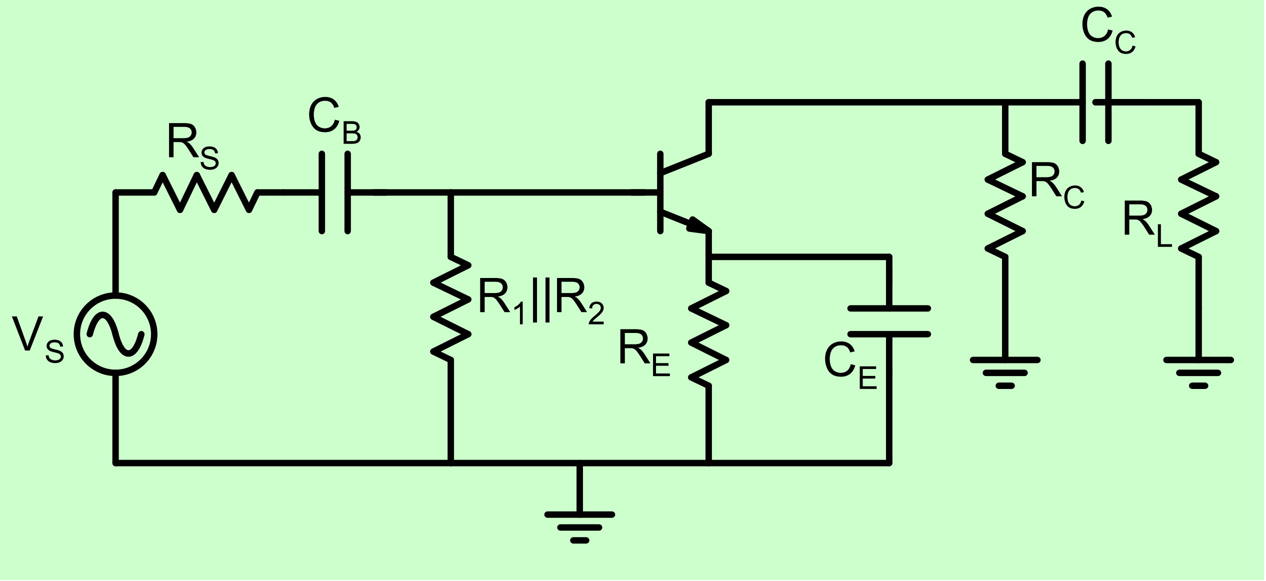
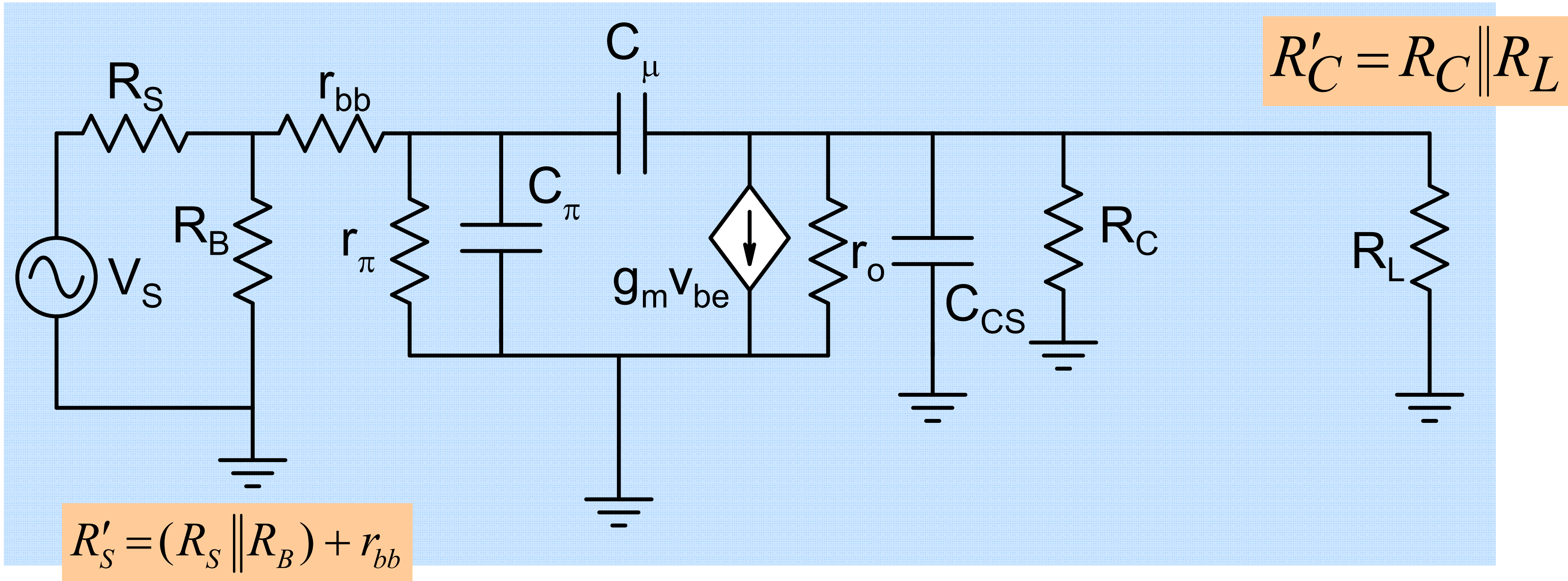
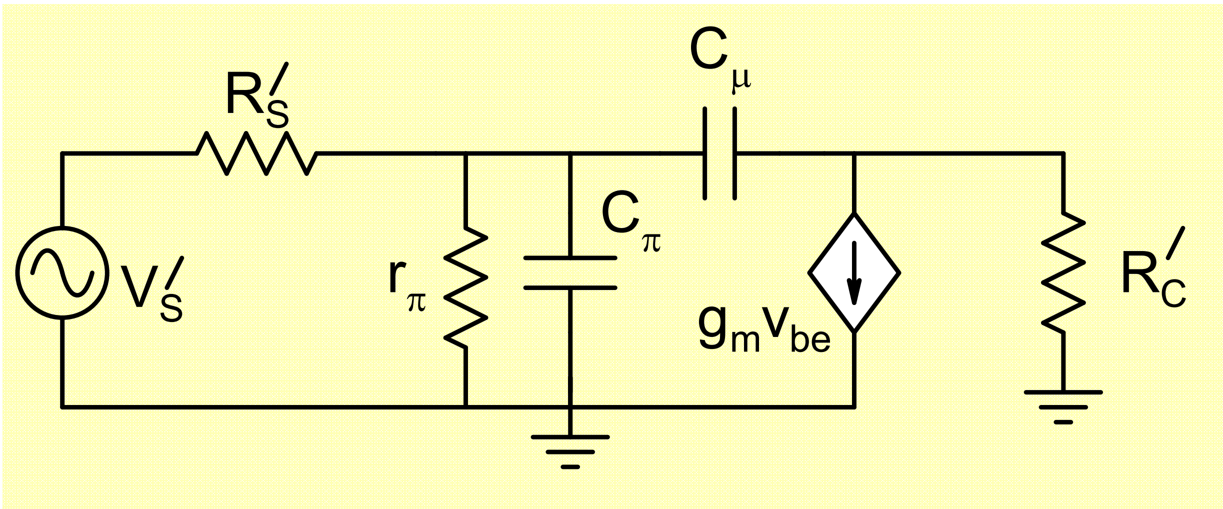
CE Amplifier



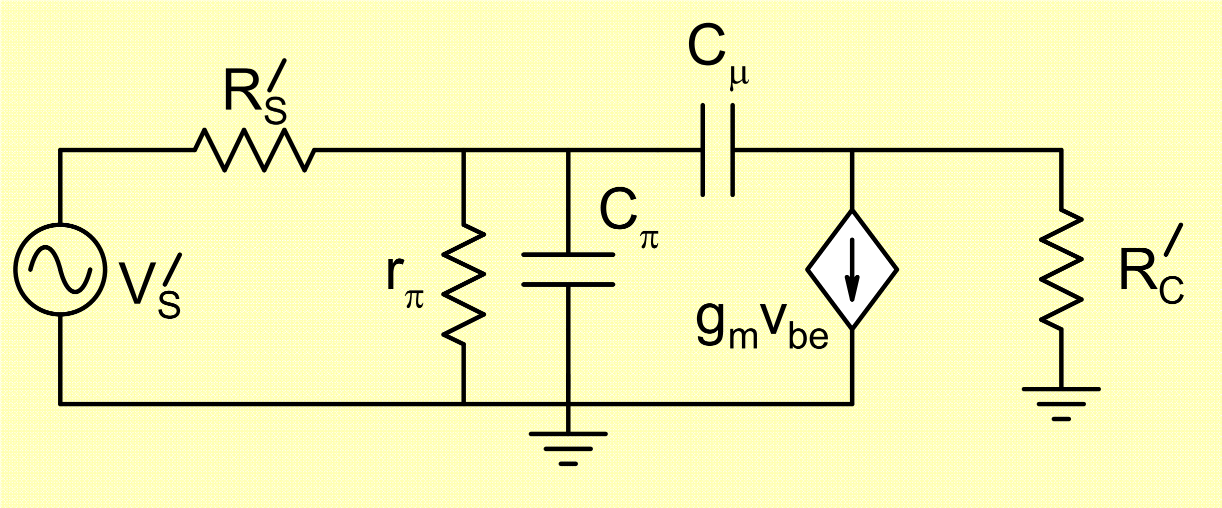


High Frequency equivalent circuit





Transfer Function



$$H(s) = \frac{-g_m R_c' + R_c' C_\mu s}{(R_S'/r_\pi + 1) + (((R_S'/r_\pi)R_c' + g_m R_c' R_s' + R_S' + R_c')C_\mu + R_S' C_\pi)s + C_\pi C_\mu R_c' R_S' s^2}$$

$$D(s) = (1 + \frac{s}{p_1})(1 + \frac{s}{p_2}) = 1 + s(\frac{1}{p_1} + \frac{1}{p_2}) + \frac{s^2}{p_1 p_2}$$

Assuming a dominant pole p_1

$$D(s) \cong 1 + \frac{s}{p_1} + \frac{s^2}{p_1 p_2}$$

$$H(s) = \frac{-g_m R'_c + R'_c C_\mu s}{(R'_S / r_\pi + 1) + (((R'_S / r_\pi) R'_c + g_m R'_c R'_s + R'_S + R'_c) C_\mu + R'_S C_\pi) s + C_\pi C_\mu R'_c R'_S s^2}$$

$$D(s) \cong 1 + \frac{s}{p_1} + \frac{s^2}{p_1 p_2}$$

$$p_1 = \frac{1}{(R'_S \| r_\pi)\{C_\pi + C_\mu (1 + g_m R'_C)\} + R'_C C_\mu}$$

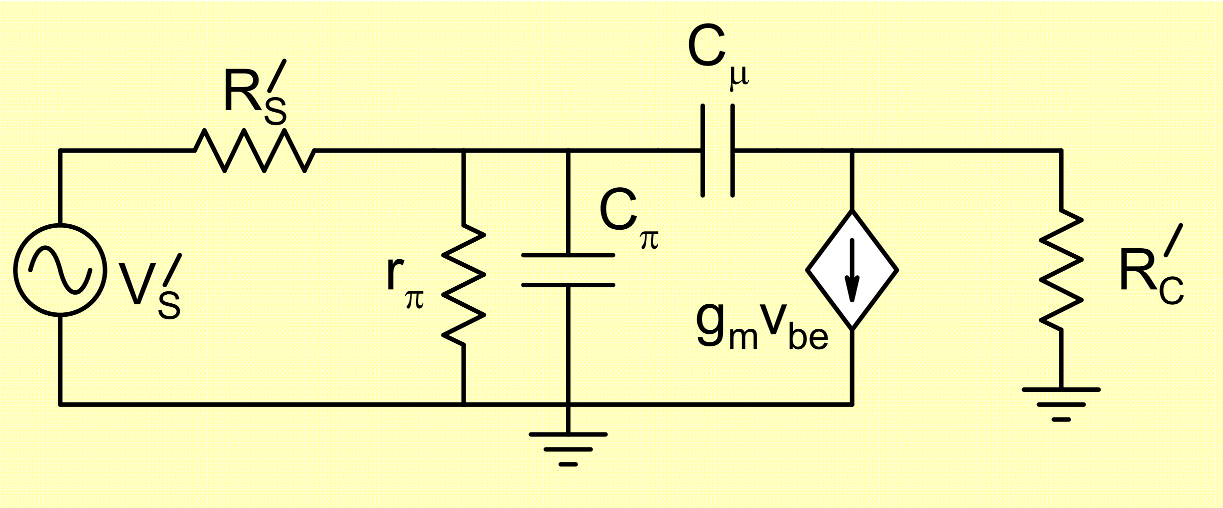
$$p_2 = \frac{1}{p_1 C_\pi C_\mu R'_c R'_S}$$

$$\text{Right half zero:} \quad z = \frac{g_m}{C_\mu}$$

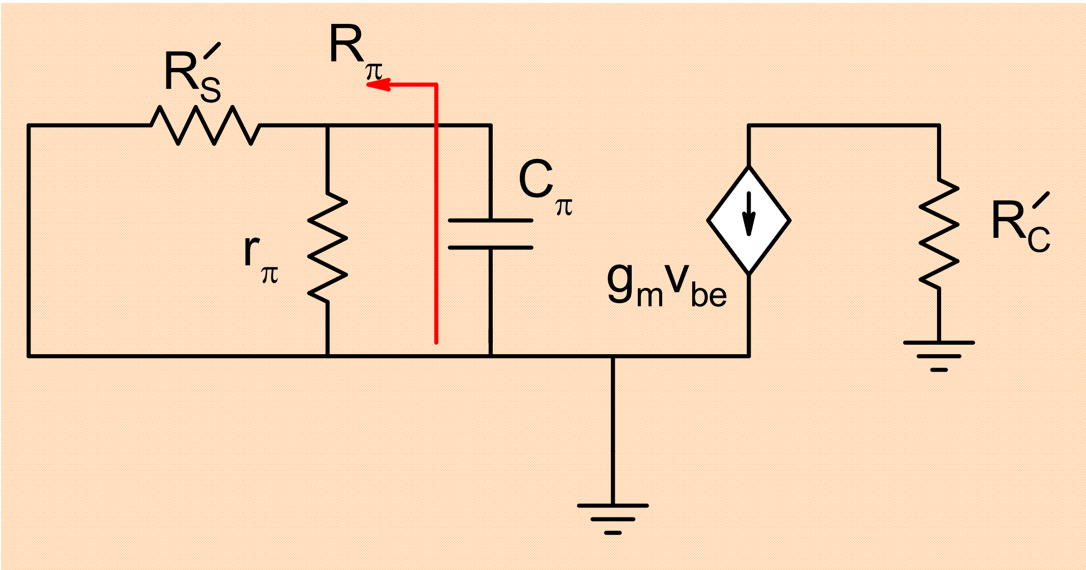
Under dominant pole approximation:

$$\omega_H \cong \frac{1}{(R'_S \| r_\pi)\{C_\pi + C_\mu (1 + g_m R'_C)\} + R'_C C_\mu}$$

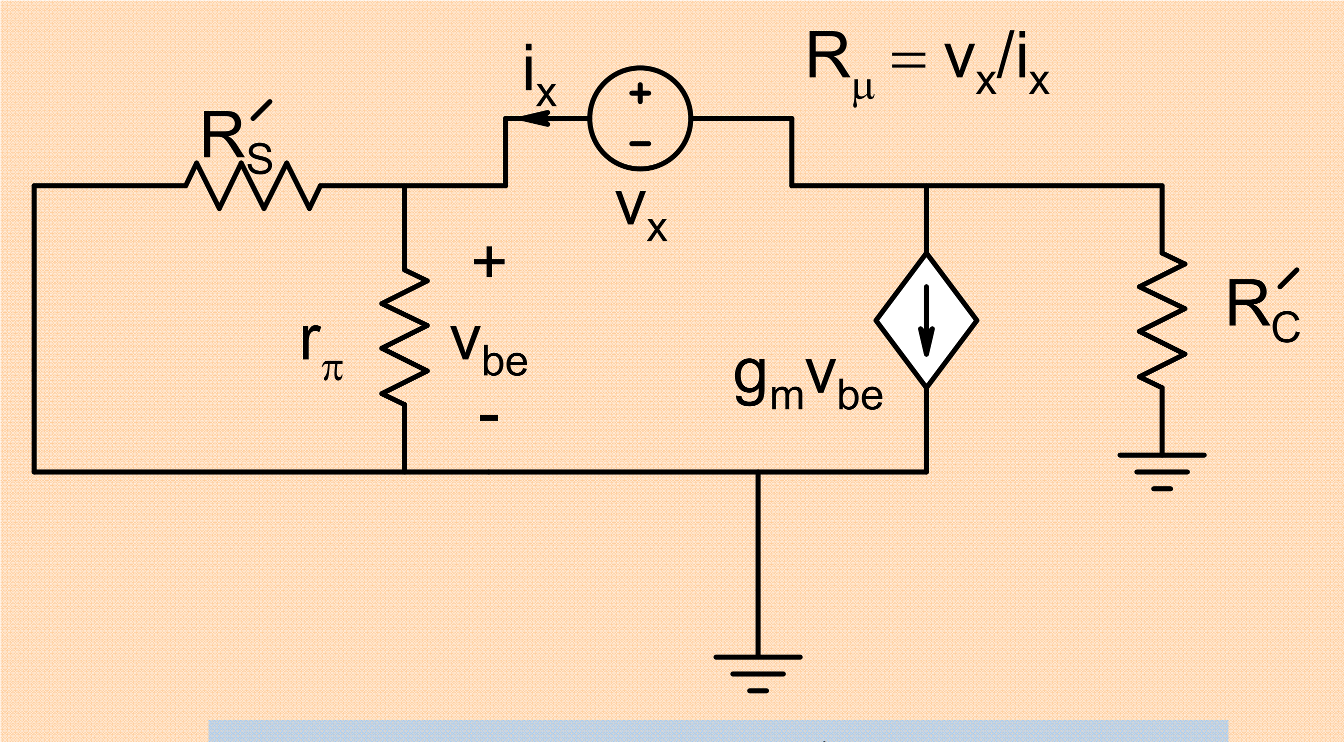
Method-2: Open circuit time constant



$$\omega_H \cong \frac{1}{R_\pi C_\pi + R_\mu C_\mu}$$



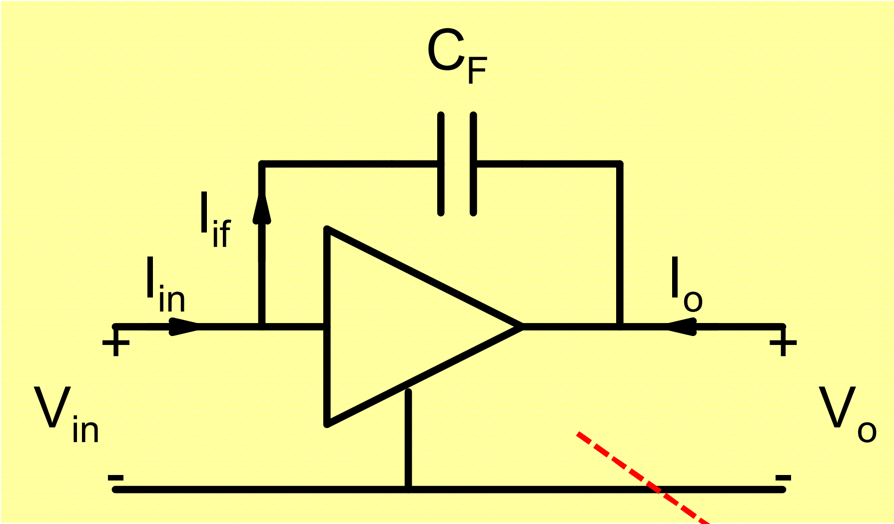
$$R_\pi = r_\pi \| R'_S$$

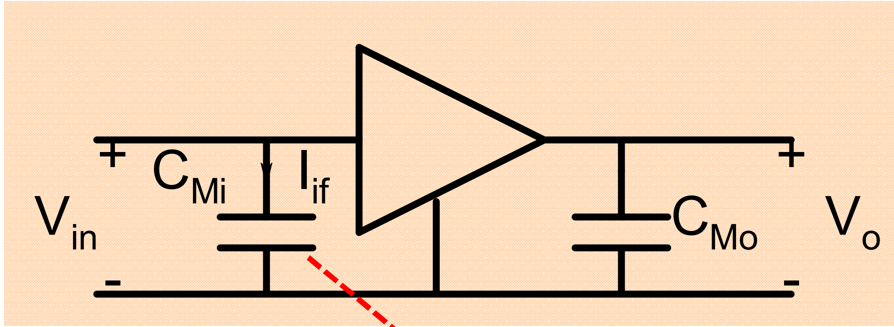


$$R_\mu = \frac{1}{(R_S' \| r_\pi)(1 + g_m R_C') + R_C'}$$

$$\omega_H \cong \frac{1}{(R_S' \| r_\pi)\{C_\pi + C_\mu(1 + g_m R_C')\} + R_C' C_\mu}$$

Method -3 : Miller's Theorem





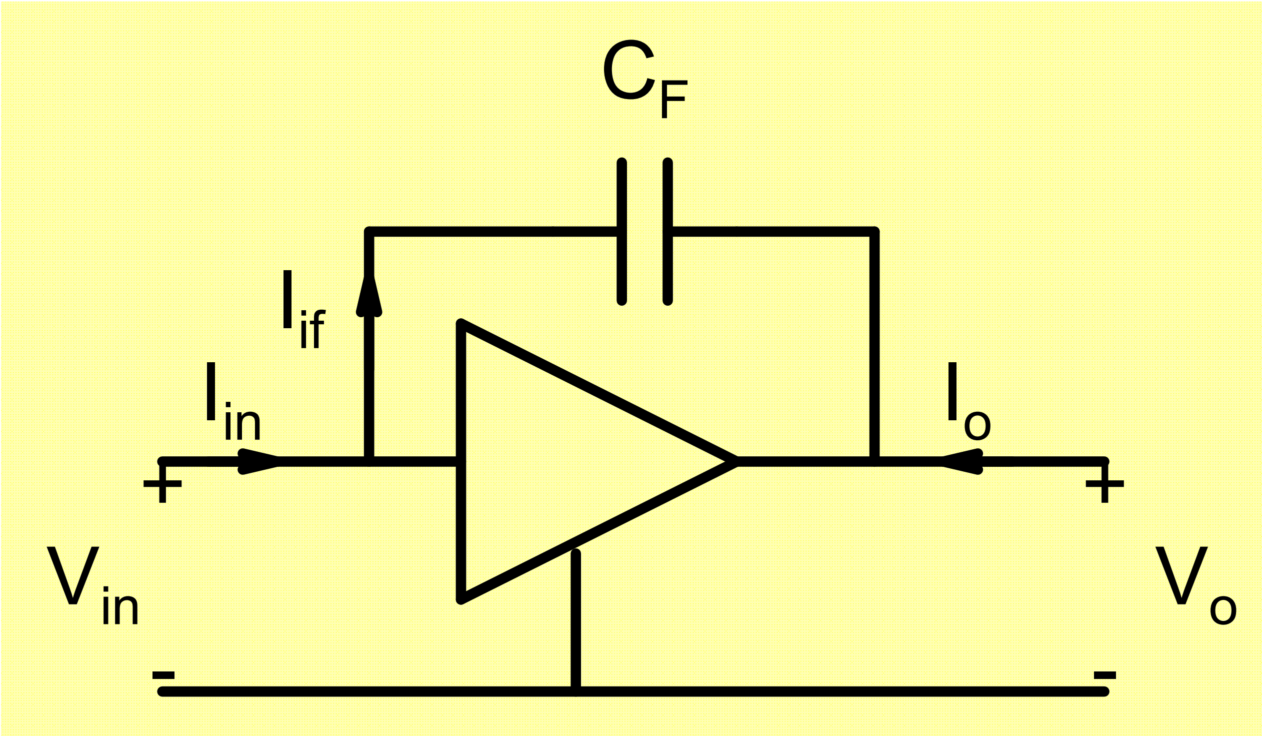
$$I_{if} = \frac{V_{in} - V_o}{1/j\omega C_F}$$

$$I_{if} = V_{in} \times (1 - A_V) \times j\omega C_F$$

$$I_{if} = j\omega C_{Mi} \times V_{in}$$

$$C_{Mi} = C_F \times (1 - A_V)$$

Miller's Theorem



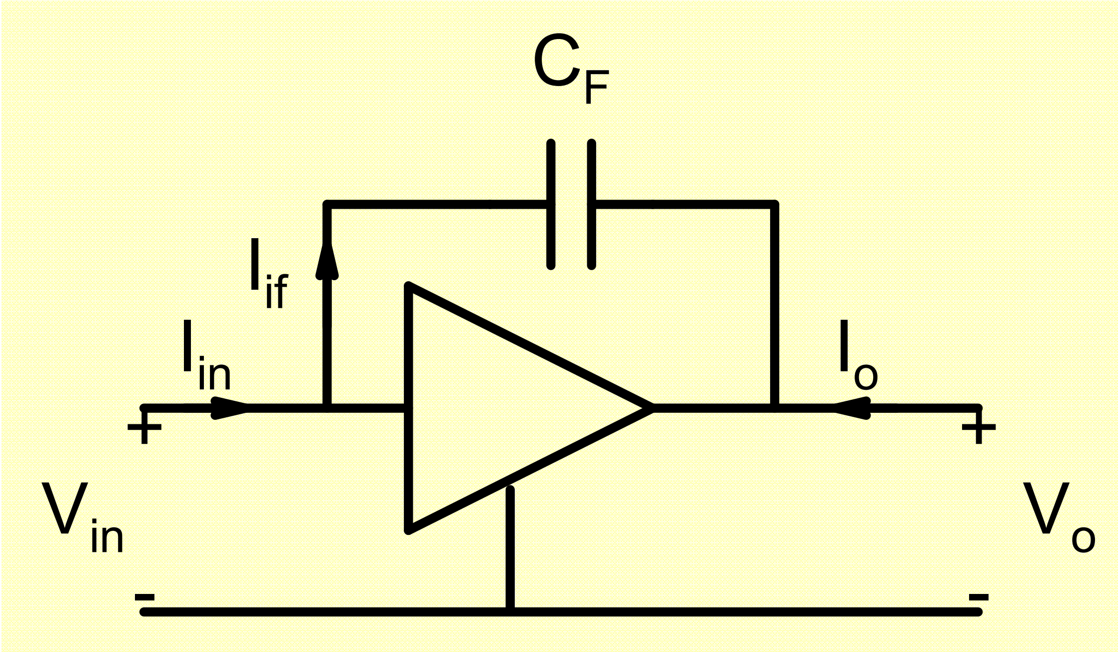
$$I_{of} = \frac{V_o - V_{in}}{1/j\omega C_F}$$

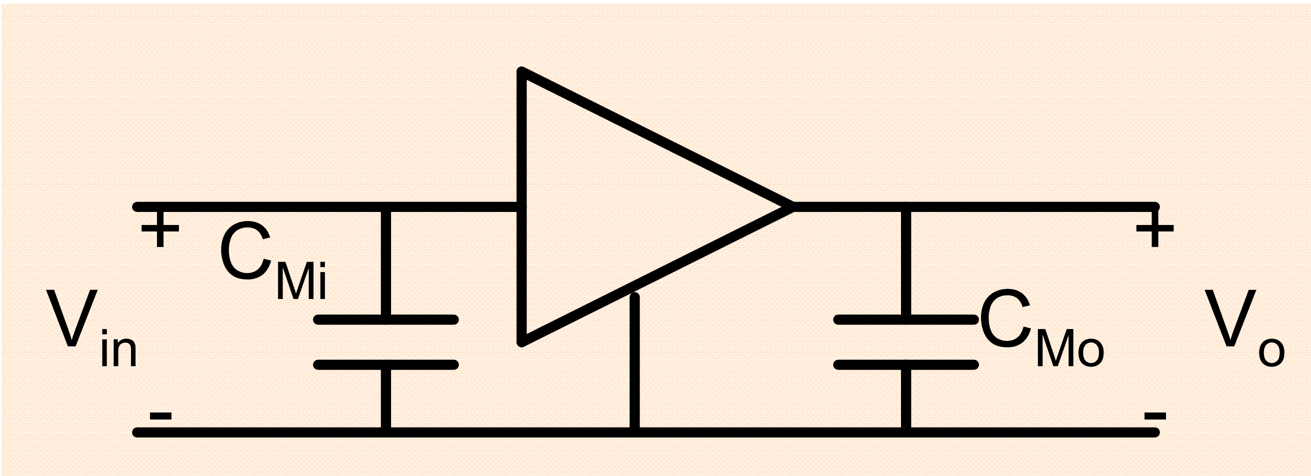
$$I_{of} = V_o \times (1 - \frac{1}{A_V}) \times j\omega C_F$$

$$I_{of} = j\omega C_{Mo} \times V_o$$

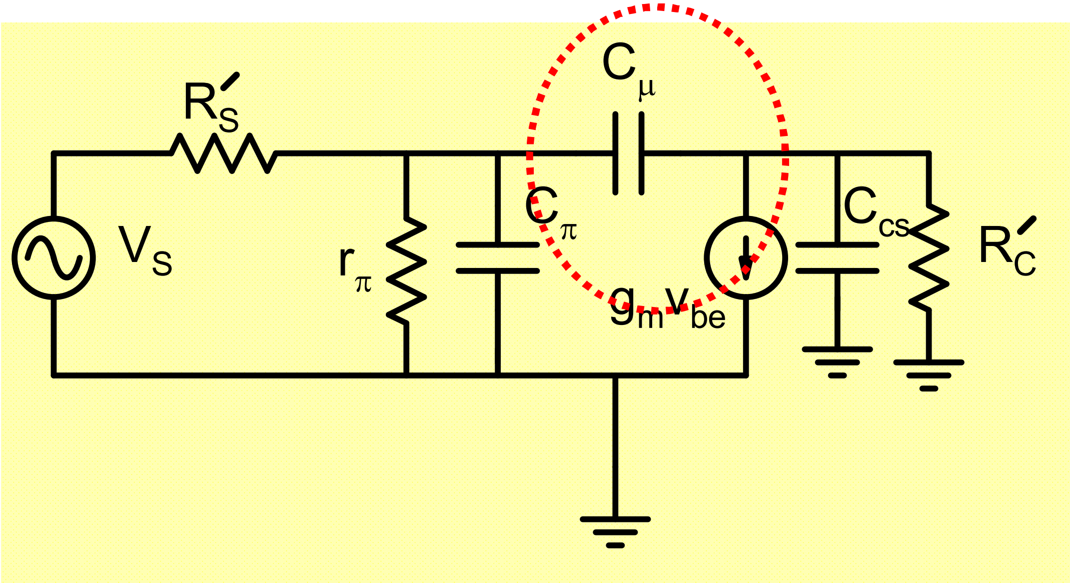
$$C_{Mo} = C_F \times (1 - \frac{1}{A_V})$$

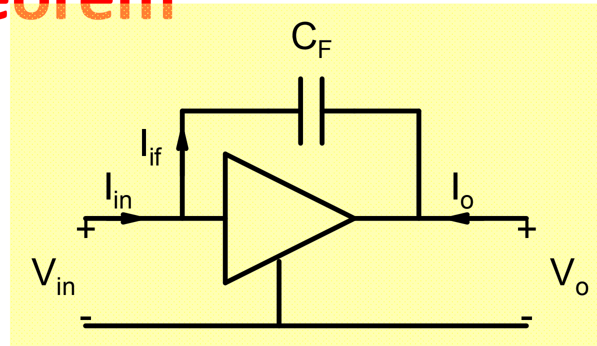
Equivalent Circuit

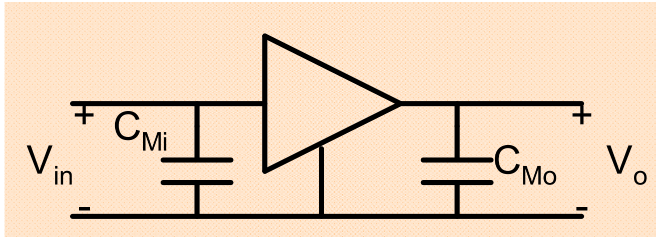


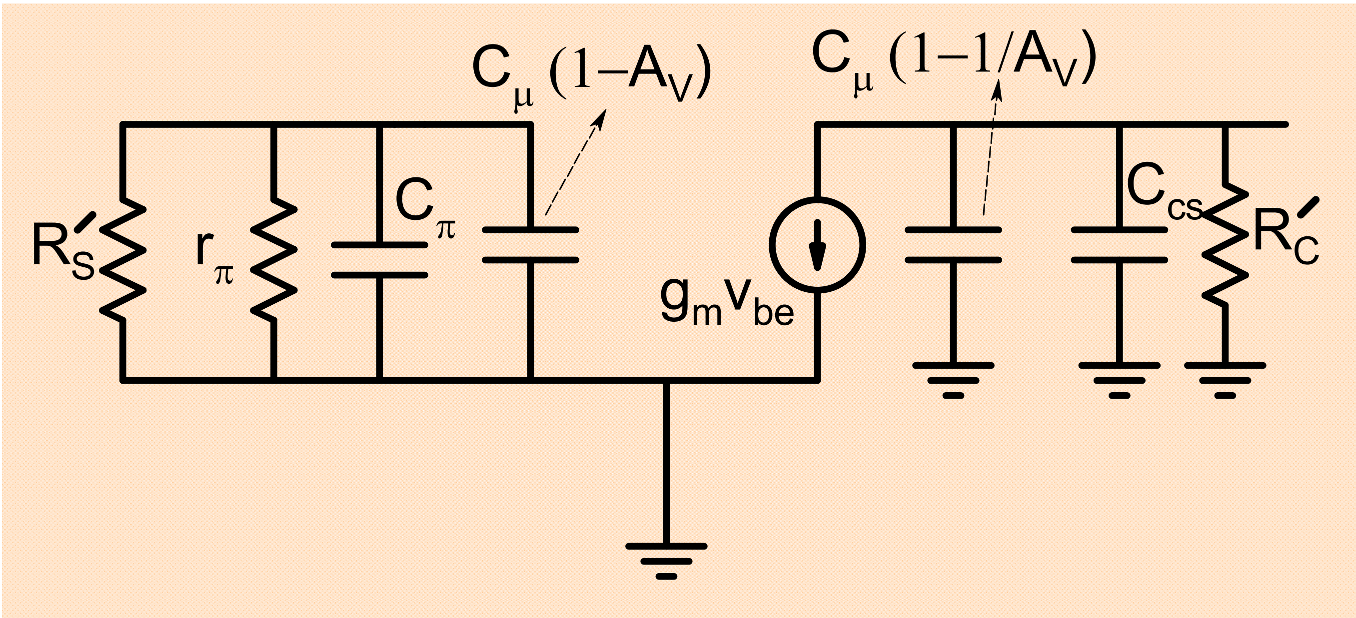


Upper Cutoff Frequency Using Miller's Theorem





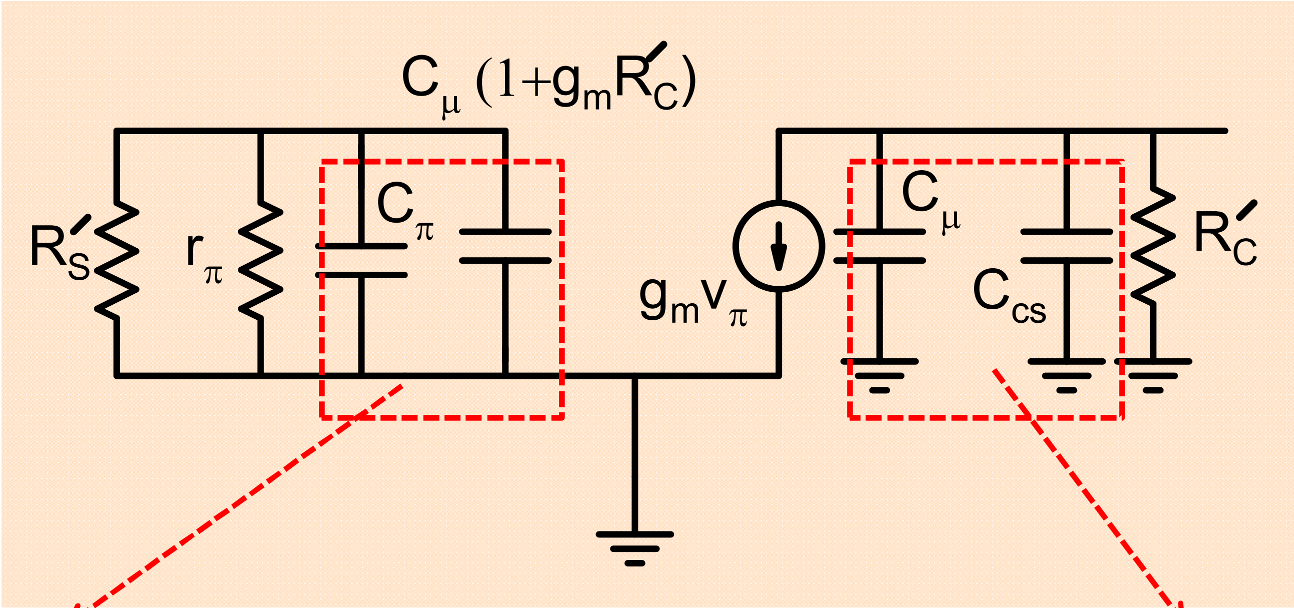




Problem: A_V depends on frequency

Approximate Gain by its Mid- frequency value

$$A_V = -g_m R_C \| R_L$$



$$C_{in} = C_\pi + C_\mu (1 + g_m R'_C)$$

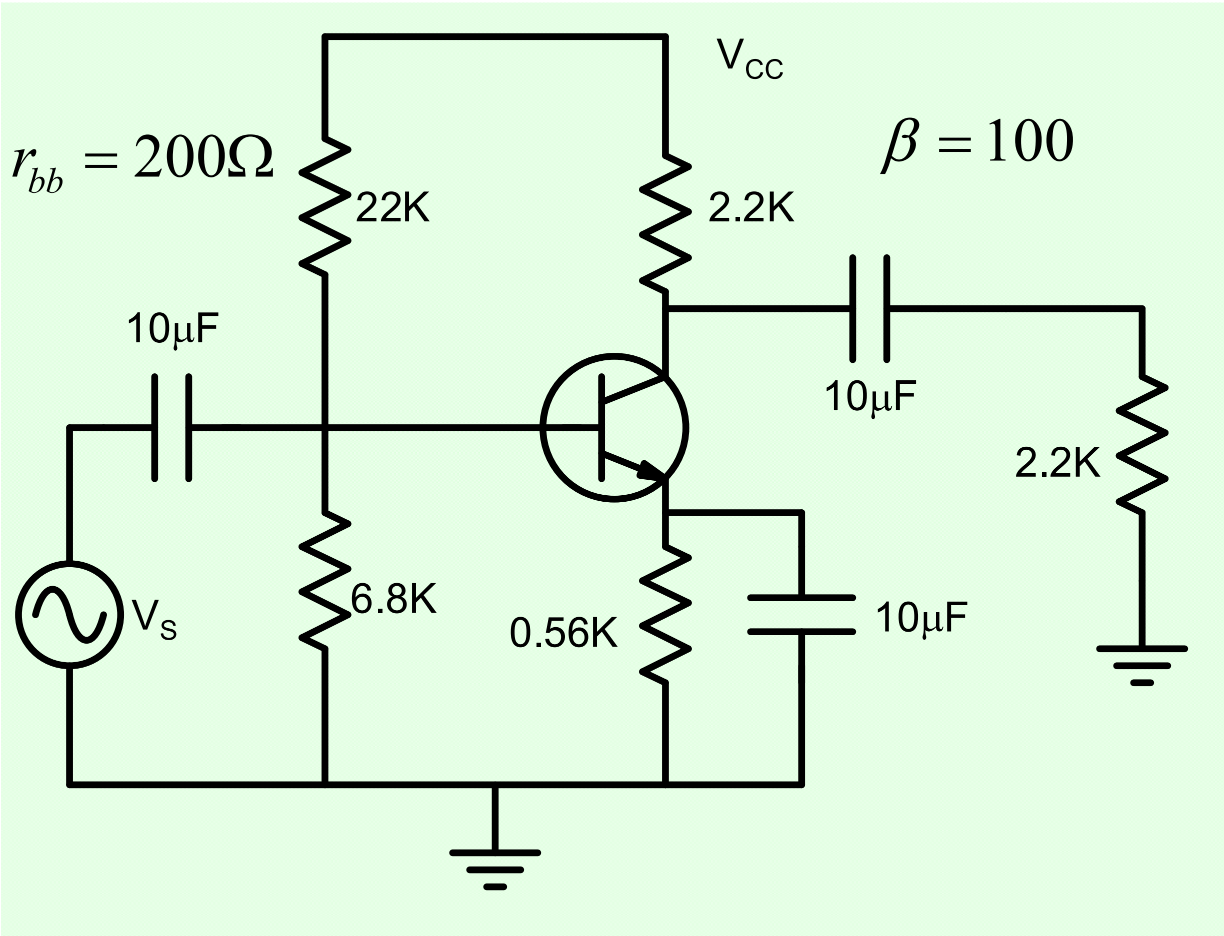
$$C_{out} = C_{cs} + C_\mu$$

$$R_{eqin} = R'_S \| r_\pi$$

$$R_{eqout} = R'_C$$

$$\omega_H \cong \frac{1}{(R'_S \| r_\pi)\{C_\pi + C_\mu (1 + g_m R'_C)\} + R'_C (C_\mu + C_{CS})}$$

Example



$$R_B = R_1 \| R_2 = 5.2k$$

$$I_C = 3.47mA$$

$$V_{CEQ} = 2.41V$$

$$V_E = 1.95V$$

$g_m = .13$ [illegible] $; r_\pi = 0.75k;$

$r_o = 28.8k\Omega$

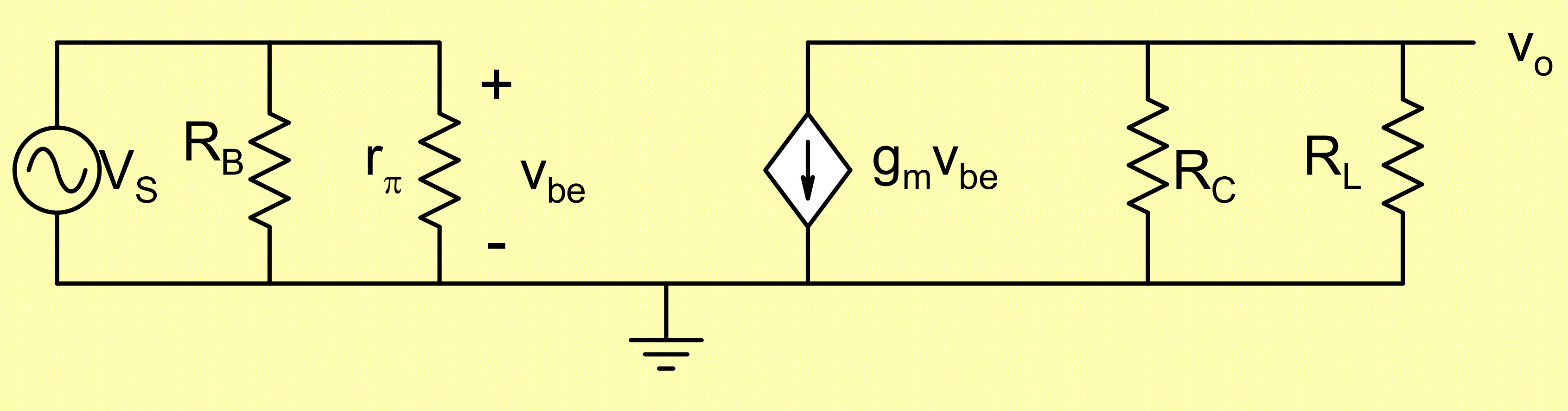
$$A_{vo} = 232; A_V = 116$$

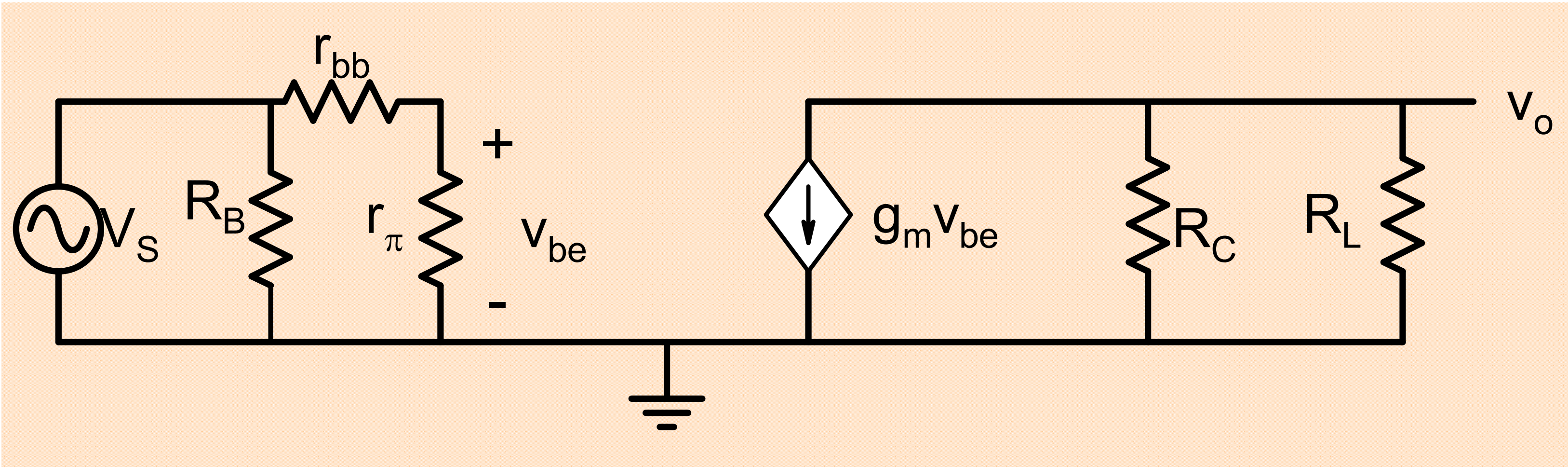
$$\frac{A_v \times R_{in}}{R_O} = 42.3 \quad < \beta$$

$$R_{in} = 0.8k\Omega$$

$$R_o = 2.2k\Omega$$

Effect of internal base resistance





$$v_o = -g_m v_{be} \times R_C \| R_L$$

$$v_o = -\frac{r_\pi}{r_{bb} + r_\pi} g_m v_{be} \times R_C \| R_L$$

Maximum Voltage Swing

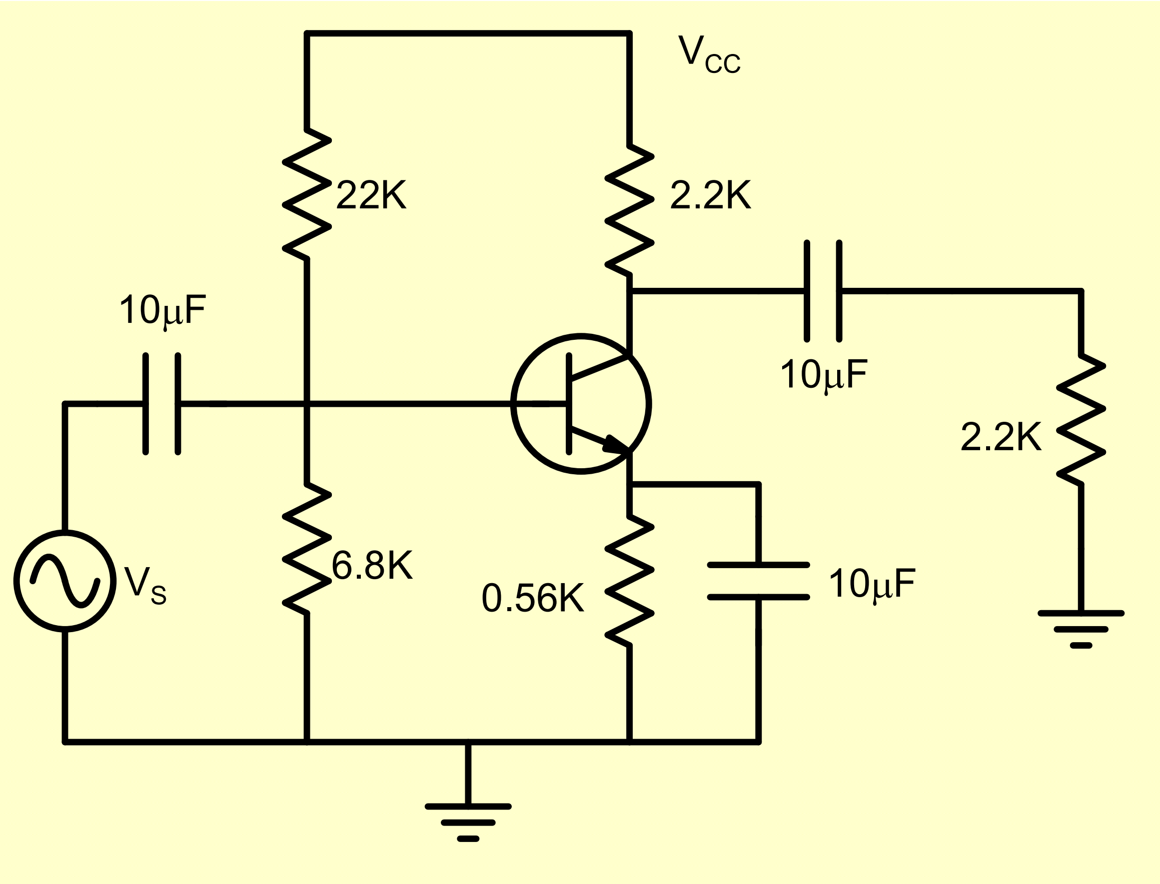
$$V_{om} = Min.\left\{(V_{CEQ} - V_{CEsat.}), \frac{H_{D2}}{25} \times I_{CQ} R_C \| R_L \right\}$$

For $\mathrm{HD}_2 = 10\%$: $\frac{H_{D2}}{25} \times I_{CQ} R_C \| R_L = 1.53V$

$$V_{CEQ} - V_{CEsat.} = 2.2V$$

$$V_{om} = 1.53V$$

Lower Cutoff Frequency



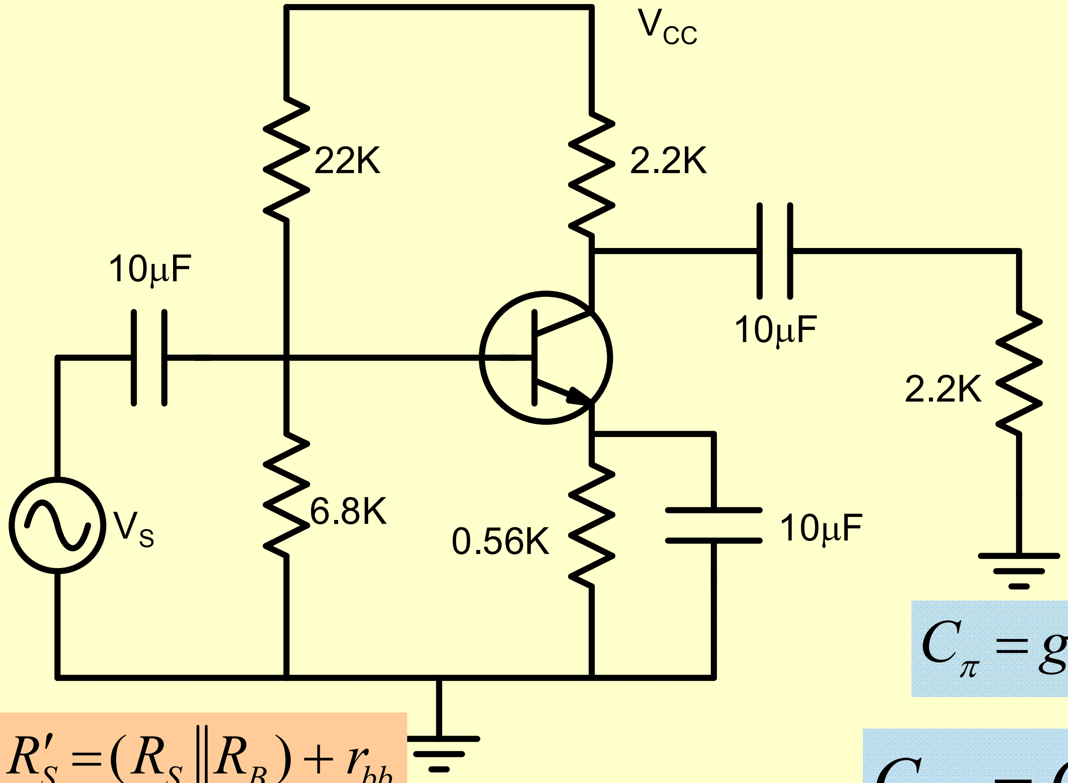
$$f_B = 19.85Hz$$

$$f_C = 3.6Hz$$

$$f_E = 1.7KHz$$

$$f_L \cong 1.7KHz$$

Upper Cutoff Frequency



$$R'_S = (R_S \| R_B) + r_{bb}$$

$$C_{je} = \frac{1pf}{\left(1 - \frac{V_{BE}}{0.85}\right)^{1/3}} = 2.38pF$$

$$C_{jc} = \frac{0.5pf}{\left(1 - \frac{V_{BC}}{0.55}\right)^{1/3}} = 0.29pF$$

$$C_{js} = \frac{3pf}{\left(1 - \frac{V_{CS}}{0.45}\right)^{1/3}} = 1.2pF$$

$$C_\pi = g_m \tau_F + C_{je} = 0.136nF \ ; \ C_\mu = 0.3pF$$

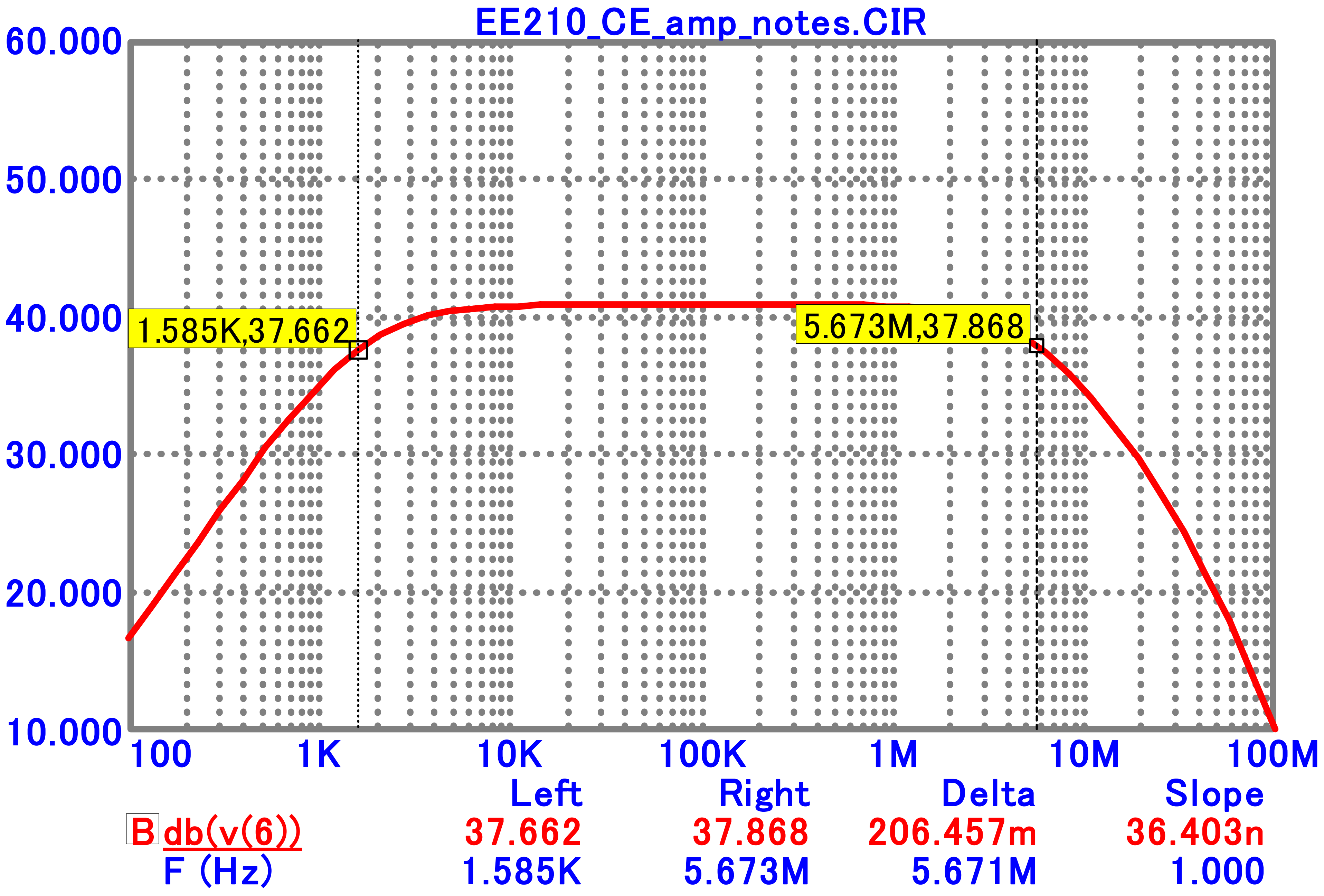
$$C_{in} = C_\pi + C_\mu g_m (R_C \| R_L) = 0.18nF$$

$$f_H \cong \frac{1}{2\pi[(R'_S \| r_\pi)\{C_\pi + C_\mu(1 + g_m R'_C)\} + R'_C(C_\mu + C_{CS})]} = 5.3MHz$$

28ns

0.3ns

Simulation Results



Impact of variation of current gain

$$\beta = 100$$
$$I_{CQ} = 3.47mA; V_{CEQ} = 2.4V$$
$$A_V = 116$$
$$R_{in} = 0.8K$$
$$R_O = 2.2K$$
$$v_{om} = 1.53V\ @\ HD_2 = 10\%$$
$$f_L = 1.7kHz$$
$$f_H = 5.3MHz$$

$$\beta = 200$$
$$I_{CQ} = 3.6mA; V_{CEQ} = 1.97V$$
$$A_V = 135$$
$$R_{in} = 1.24K$$
$$R_O = 2.2K$$
$$v_{om} = 1.6V\ @\ HD_2 = 10\%$$
$$f_L = 2kHz$$
$$f_H = 4.5MHz$$

$$S = \frac{\Delta I_{CQ} / I_{CQ}}{\Delta\beta / \beta} = \frac{1}{1 + \frac{\beta R_E}{R_B}} = 0.085$$