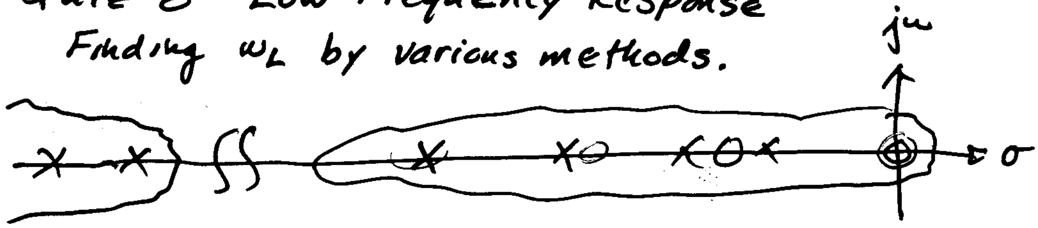
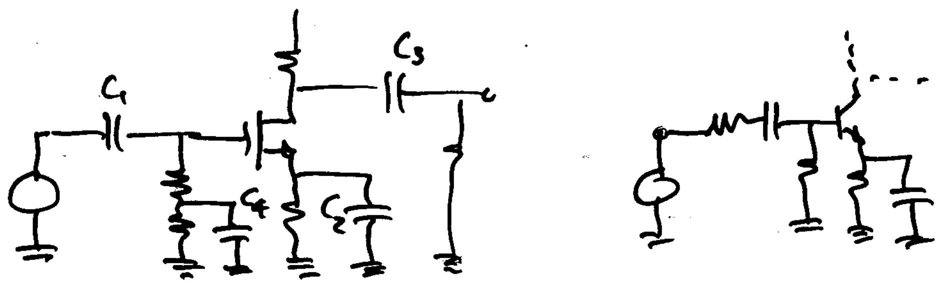
Quiz #8 – Low Frequency Response
Finding ω_L by various methods.



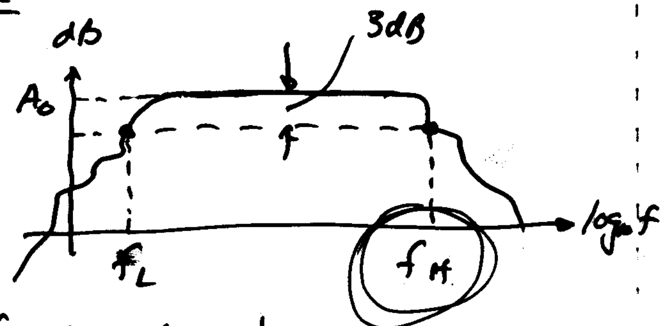
Example of a MOSFET with dependent caps.



High Frequency Response

$$\frac{V_{out}(s)}{V_{in}(s)} = A_{mbg}\, F_L(s)\, F_H(s)$$

Bandwidth $= f_H - f_L$



Methods of Finding $\omega_H, f_H, \omega_{3dB}(upper)$

1.) Given roots $\left(\frac{1}{s+p_i}\right)$

a.) Bode plot

b.) Dominant pole

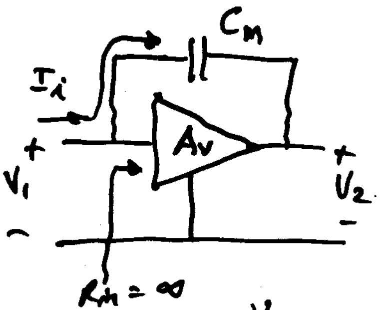
$$\omega_H \simeq \omega_p(\text{dominant}) \text{ if } \omega_p(\text{dominant}) \leq \frac{\omega_p(\text{next})}{4}$$

c.) $$\omega_H \simeq \frac{1}{\sqrt{\sum_n \frac{1}{\omega_{pn}^2} - 2\sum_n \frac{1}{\omega_{zn}^2}}} \simeq \frac{1}{\sqrt{\frac{1}{\omega_{p1}^2} + \frac{1}{\omega_{p2}^2} + \cdots}}$$

d.) Exact solution (quadratic)

2.) Roots are unknown

a.) Miller effect

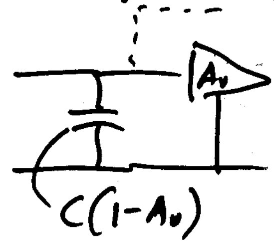


$Z_1 = ? \rightarrow V_1$

$$Z_1 = \frac{V_1}{I_1} = \frac{V_1}{\frac{V_1 - V_2}{1/sC}} \qquad \frac{V_2}{V_1} = A_v$$

$$Z_1 = \frac{1}{sC}\left(\frac{1}{1 - \frac{V_2}{V_1}}\right) = \frac{1}{sC[1 - A_v]}$$

$\therefore$



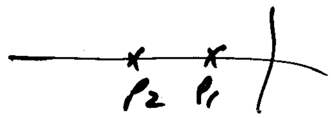
$A_v = -K$

$C_{eq} = sC\underline{(1+K)}$

b.) Approximate algebraic approach (p. 1311)

$$s^2 + as + b = (s+p_1)(s+p_2) = s^2 + s(p_1+p_2) + p_1 p_2$$

Key is to assume that $p_1 \ll p_2$



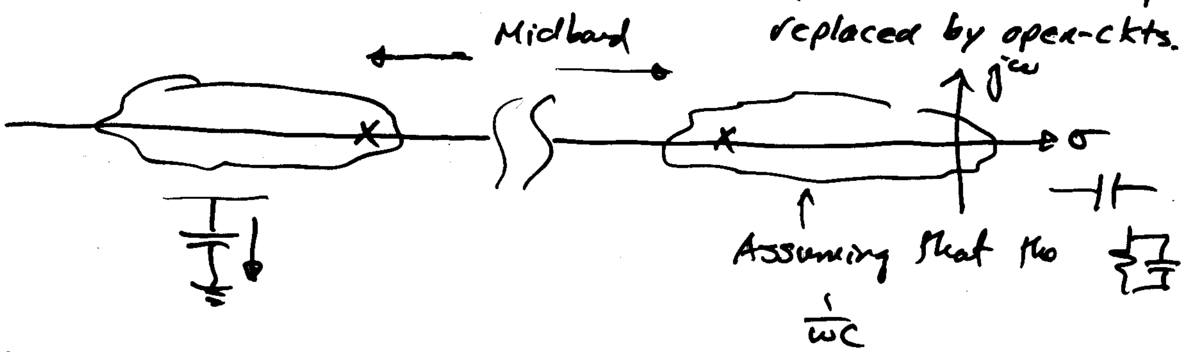
$$s^2 + as + b \approx s^2 + sp_2 + p_1 p_2$$

$p_2 = a$ and $p_1 p_2 = b \rightarrow p_1 = \frac{b}{a}$

c.) Open-circuit Time Constant

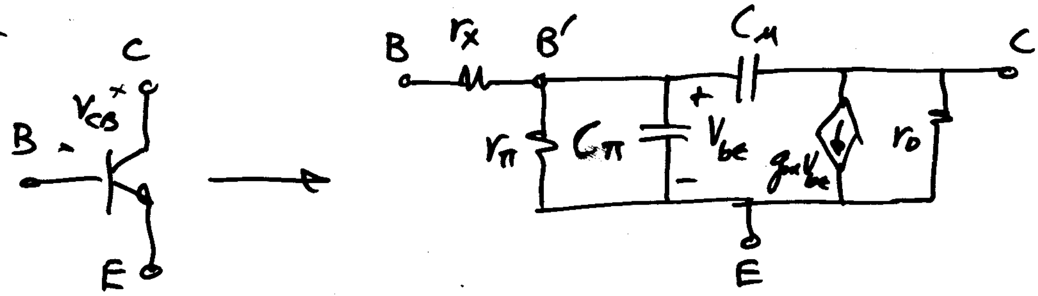
$$\omega_H \approx \frac{1}{\sum_{i=1}^{m} R_{ioc} C_i}$$

where R_{ioc} is the resistance seen from C_i with all other caps replaced by open-ckts.



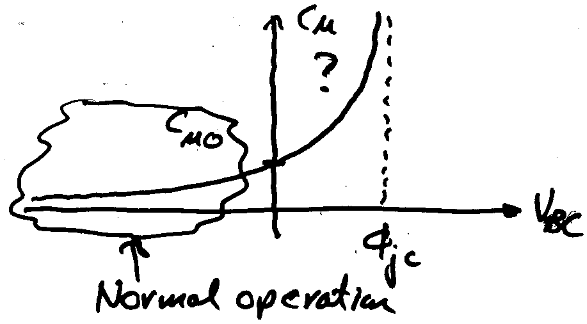
High Frequency, Small-Signal Models

BJT



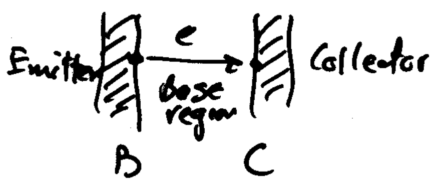
C_μ = the reverse-bias capacitance of the BC junction

$$C_\mu = \frac{C_{\mu 0}}{\sqrt{1 + \frac{V_{CB}}{\phi_{jc}}}}$$

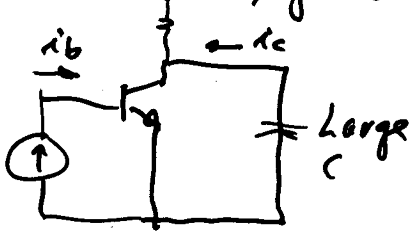


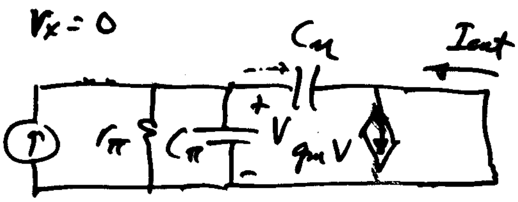
$C_\pi = g_m \tau_F$

τ_F = forward time constant



ω_T (unity gain bandwidth)





$I_{out} \simeq g_m V$

$$V = I_{in} \frac{1}{g_\pi + sC_\pi + sC_\mu} \rightarrow \frac{I_{out}}{I_{in}} = \frac{g_m}{g_\pi + s(C_\pi + C_\mu)} = \frac{g_m r_\pi}{1 + s \cdot (C_\pi + C_\mu) r_\pi}$$

$\therefore \frac{I_{out}(s)}{I_{in}(s)} = \frac{\beta}{s r_\pi (C_\pi + C_\mu) + 1}$ At high frequencies, $\frac{I_{out}}{I_{in}} \approx \frac{\beta}{s r_\pi (C_\pi + C_\mu)}$

ω_T is the frequency where $\left| \frac{I_{out}(j\omega)}{I_{in}(j\omega)} \right| = 1$

$\therefore \omega_T = ?$ $1 = \frac{\beta}{\omega_T r_\pi (C_\pi + C_\mu)} \rightarrow \omega_T = \frac{\beta / r_\pi}{C_\pi + C_\mu}$

$$\boxed{\omega_T = \frac{g_m}{C_\pi + C_\mu}}$$

How do you find C_π?

1.) Given $\tau_F \rightarrow C_\pi = g_m \tau_F$

2.) Given ω_T and $C_\mu \rightarrow C_\pi = \frac{g_m}{\omega_T} - C_\mu$

r_x: r_x is a small resistance in series with the base of about 100Ω to 500Ω. It varies with I_C and is called "the base spreading resistance".

MOSFET