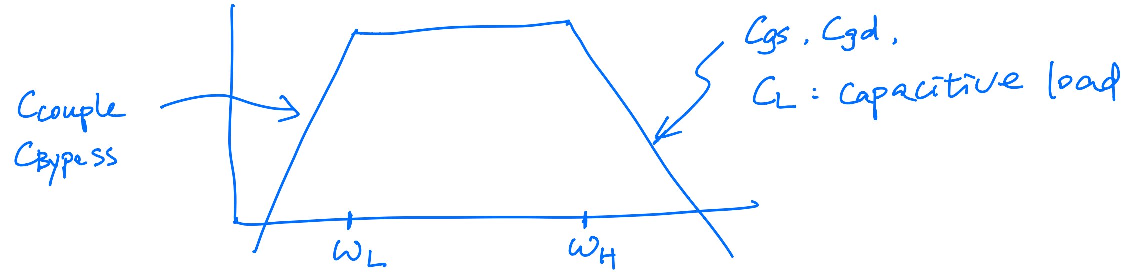
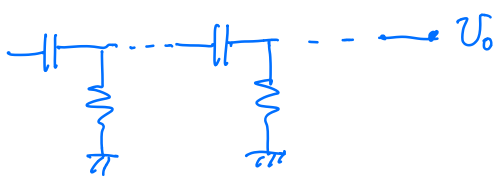
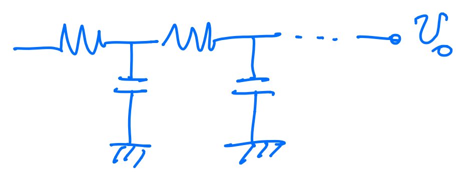
Summary of Frequency Response

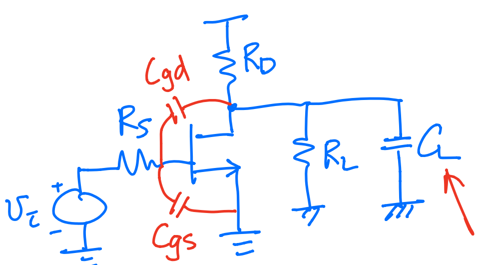


SCTC → ω_L	OCTC → ω_H
↳ AC. equivalent	↳ AC. eq ckt
All other C's short-circuited	All other C's open
Find R_i seen by C_i	Find R_i seen by C_i
$\omega_L = \sum_i \frac{1}{R_i C_i} = \sum_i \frac{1}{\tau_i}$	$\omega_H = \frac{1}{\sum_i R_i C_i} = \frac{1}{\sum_i \tau_i}$





Apply OCTC to CS amplifier:



$R'_{out} = R_D // R_L // r_o$

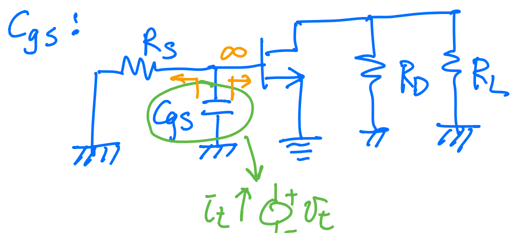
Miller Approx

$$\frac{1}{\omega_L} = R_S\left[C_{gs} + (1 + g_m R'_{out}) C_{gd}\right]$$

Exact Solution

$$\frac{1}{\omega_L} = R_S\left[C_{gs} + (1 + g_m R'_{out}) \cdot C_{gd}\right] + R'_{out}(C_{gd} + C_L)$$

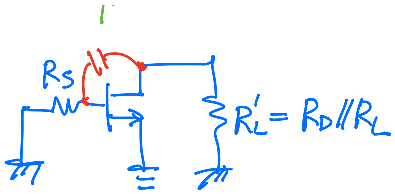
C_{gs}:

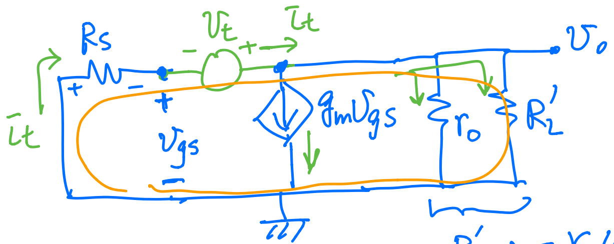


$C_1 = C_{gs}$.
$R_1 = R_S$

$\tau_1 = R_S + C_{gs}$

C_{gd}





$$R'_{out} = r_o // R'_L = r_o // R_L // R_D$$

$$V_{gs} = -I_t \cdot R_s$$

KCL at Drain $\quad I_t = g_m V_{gs} + \dfrac{V_o}{R'_{out}}$

KLV $\quad V_o = V_{gs} + V_t$

$$I_t = g_m V_{gs} + \frac{V_{gs} + V_t}{R'_{out}}$$

$$= \left(g_m + \frac{1}{R'_{out}}\right) \cdot \underbrace{V_{gs}}_{-I_t R_s} + \frac{1}{R'_{out}} \cdot V_t$$

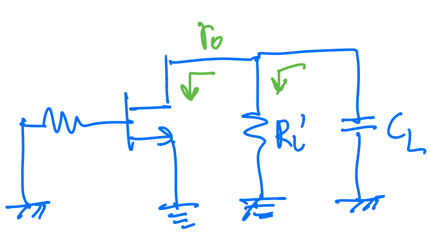
$$I_t \left(1 + R_s g_m + \frac{R_s}{R'_{out}}\right) = \frac{V_t}{R'_{out}}$$

$$R_{gd} = \frac{V_t}{I_t} = R'_{out} + g_m R_s R'_{out} + R_s$$

$$\tau_2 = R_{gd} \cdot C_{gd} = C_{gd} \left(R'_{out} + \underbrace{g_m R_s R'_{out}} + R_s\right)$$

$$\approx C_{gd} \cdot \left(g_m R_s R'_{out}\right)$$

C_L :



$$R_3 = R'_L // r_o = R'_{out}$$

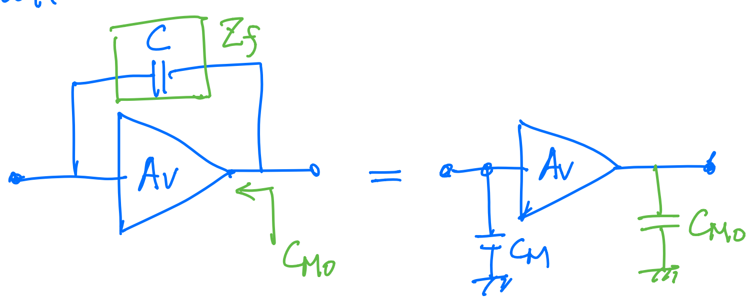
$$\tau_3 = R_3 \cdot C_L = R'_{out} C_L$$

OCTC $\frac{1}{\omega_H} = \sum_i R_i C_i = R_S \cdot C_{gs} + C_{gd}\,(R_{out}' + g_m R_S R_{out}' + R_S) + R_{out}' \cdot C_L$

$= R_S \cdot [C_{gs} + C_{gd}(1 + g_m R_{out}')] + R_{out}' (C_{gd} + C_L)$

Exact: $\frac{1}{\omega_H} = R_S [C_{gs} + C_{gd}(1 + g_m R_{out}')] + R_{out}' (C_{gd} + C_L)$

Miller Approx: $\frac{1}{\omega_H} = R_S [C_{gs} + C_{gd}(1 + g_m R_{out}')]$



$C_M = (1 - A_V)\,C$

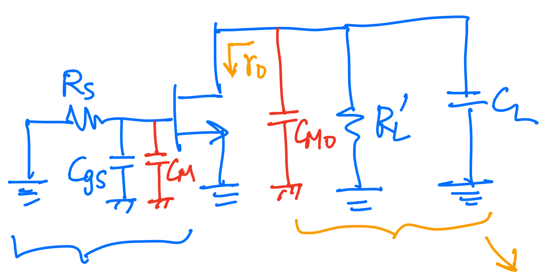
$Z_{MO} = \frac{v_o}{i_o} = \frac{v_o}{\frac{v_o - v_i}{Z_f}}$

$= \frac{Z_f}{1 - \frac{v_i}{v_o}} = \frac{Z_f}{1 - \frac{1}{A_V}}$

$Z_{MO} = \frac{1}{j\omega C_{MO}} = \frac{1}{j\omega C} \cdot \frac{1}{1 - \frac{1}{A_V}}$

$\Rightarrow C_{MO} = C\left(1 - \frac{1}{A_V}\right)$

Refined Miller Approx.

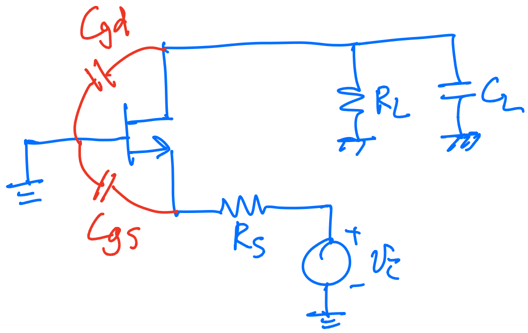


$C_{MO} = \left(1 + \frac{1}{g_m R_{out}'}\right) \cdot C_{gd}$

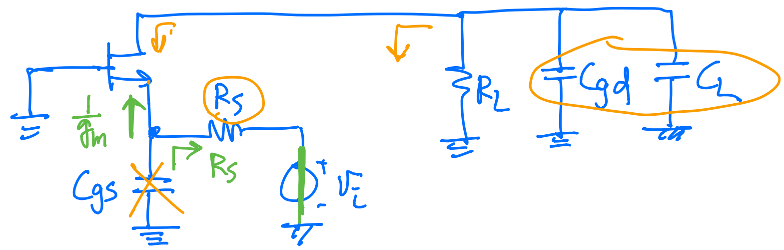
$\approx C_{gd}$

$\frac{1}{\omega_H} \approx R_S [C_{gs} + C_{gd}(1 + g_m R_{out}')] + \underbrace{(R_L' /\!/ r_o)}_{R_{out}'} \cdot (C_L + C_{gd})$

Apply OCTC to CG amplifier.



$R_o' = r_o + (1 + g_m r_o) \cdot R_S$



$\tau_1 = C_{gs} \cdot \left(\frac{1}{g_m} /\!/ R_S\right) \approx C_{gs} \cdot \frac{1}{g_m}$

$\tau_2 = (C_{gd} + C_L) \cdot (R_L /\!/ R_o') \simeq (C_{gd} + C_L) \cdot R_L$

$$\omega_H = \frac{1}{\sum_i R_i C_i} = \frac{1}{\tau_1 + \tau_2} = \frac{1}{C_{gs} \cdot \frac{1}{g_m} + (C_{gd} + C_L) \cdot R_L} \rightarrow \text{large}$$

small small

Broadband Amplifiler ,