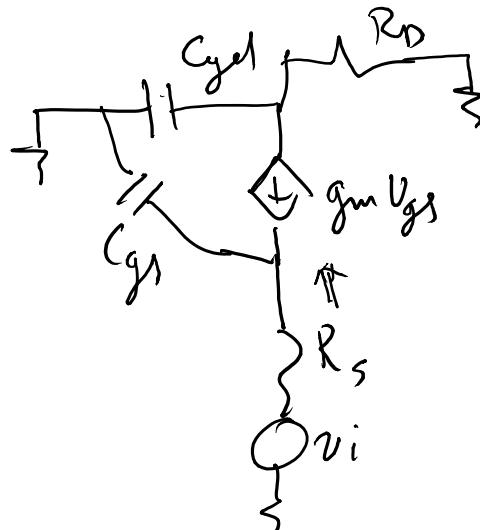


Freq. Analysis Tools: Miller approx, ZCTC, SCTC

CS  $\rightarrow$  CG:



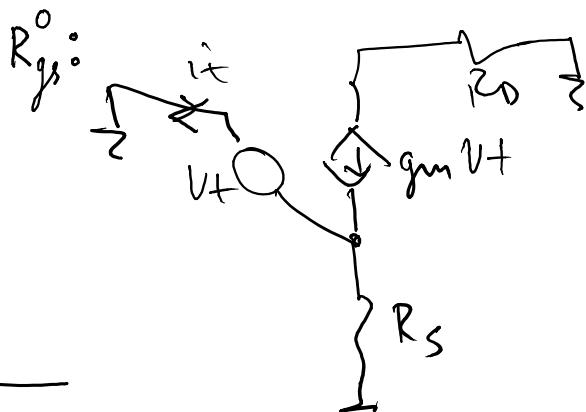
$$\frac{V_o}{V_i} = \frac{\frac{1}{g_m + sC_{gs}}}{R_s + \frac{1}{g_m + sC_{gs}}} \cdot g_m \cdot \left( R_D \parallel \frac{1}{sC_{gd}} \right) \frac{R_D}{1 + s(C_{gd}R_D)}$$

$$= g_m R_D \cdot \frac{1}{R_s(g_m + sC_{gs}) + 1} \cdot \frac{1}{1 + s(C_{gd}R_D)}$$

$$= \frac{g_m R_D}{1 + g_m R_s} \cdot \frac{1 + R_s g_m + sC_{gs} R_s}{1 + \frac{sC_{gs} R_s}{1 + g_m R_s}} \cdot \frac{1}{1 + s(C_{gd}R_D)}$$

$$A_o = \frac{1}{1 - \frac{\Sigma}{r_1}} \cdot \frac{1}{1 - \frac{\Sigma}{r_2}}$$

GCTC (ZCTC) :



$$p_1 = - \frac{1}{C_{gd} \cdot R_{gd} + C_{gs} \cdot R_{gds}^o}$$

$$R_{gds}^o = R_s \parallel \frac{1}{gm}$$

$$= - \frac{1}{C_{gd} R_0 + (R_{gds} \cdot R_s \parallel \frac{1}{gm})}$$

$$R_{gd}^o = R_0$$

p2: SCTC

$$p_2 = - \left( \frac{1}{C_{gd} \cdot R_{gd}} + \frac{1}{C_{gs} \cdot R_{gds}^s} \right)$$

$$R_{gd}^s = R_0$$

$$R_{gds}^s = R_s \parallel \frac{1}{gm}$$

$$p_2 = - \left( \frac{1}{C_{gd} R_0} + \frac{1}{C_{gs} (R_s \parallel \frac{1}{gm})} \right)$$

$\underbrace{\qquad\qquad\qquad}_{\omega T}$

$$p_1^{cs} = \frac{1}{C_{gd} \left( gm R_s R_0 \right)}$$

Tinber

$$p_1 \approx - \frac{1}{C_{gd} R_0}$$

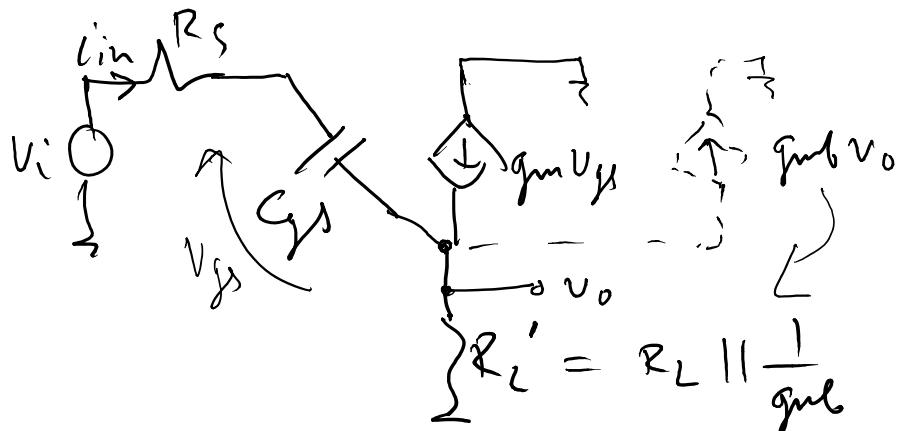
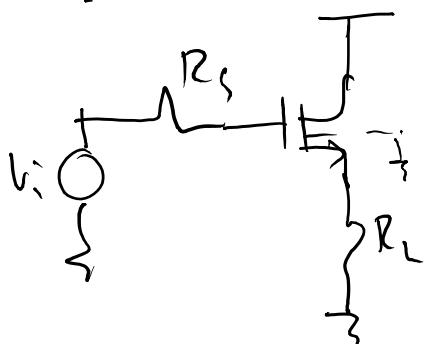
$\downarrow$

dominant

dominant

$$p_2 = - \frac{gm}{C_{gs}} \approx - \omega_T$$

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CD :

$$V_o = R_L' (i_{in} + g_m \cdot \frac{i_{in}}{sC_{gs}}) = R_L' (1 + \frac{g_m}{sC_{gs}}) i_{in}$$

$$V_o = R_L' \left( 1 + \frac{g_m}{sC_{gs}} \right) \cdot \frac{V_i - V_o}{R_s + \frac{1}{sC_{gs}}}$$

$$V_o \left( 1 + R_L' \frac{s(C_{gs} + g_m)}{sC_{gs}R_s + 1} \right) = R_L' \cdot \frac{s(C_{gs} + g_m)}{sC_{gs}R_s + 1} \cdot V_i$$

$$\frac{V_o}{V_i} = R_L' \cdot \frac{(g_m + sC_{gs})}{1 + sC_{gs}R_s + sC_{gs}R_L' + g_m R_L'} =$$

$$= \frac{g_m R_L'}{1 + g_m R_L'} \cdot \frac{1 + s \frac{C_{gs}}{g_m}}{1 + s C_{gs} \frac{R_s + R_L'}{1 + g_m R_L'}}$$

$Z_1 = - \frac{g_m}{C_{gs}}$

$$\Rightarrow P_1 = - \frac{1 + g_m R_L'}{C_{gs} (R_s + R_L')}$$

$$= A_o \cdot \frac{1 - \frac{s}{Z_1}}{1 - \frac{s}{\infty}}$$

$$1 - \frac{s}{r^1}$$

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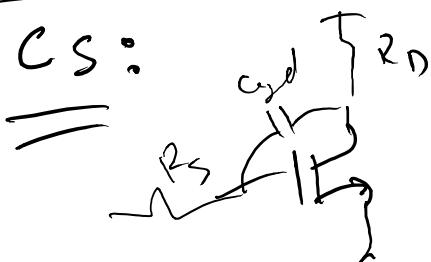
$$z_1 = - \frac{g_m}{C_{gs}}$$

If assume  $g_m R_2' \gg 1$   
 &  $R_s \ll R_2'$

$$r_1 = - \frac{1 + g_m R_2'}{C_{gs} (R_s + R_2')} \approx - \frac{g_m}{C_{gs}} \approx z_1$$

If  $G_S \gg G_D \dots z_1, r_1 \approx -\omega_T$

---



$$\Rightarrow z \approx \frac{g_m}{G_D}$$

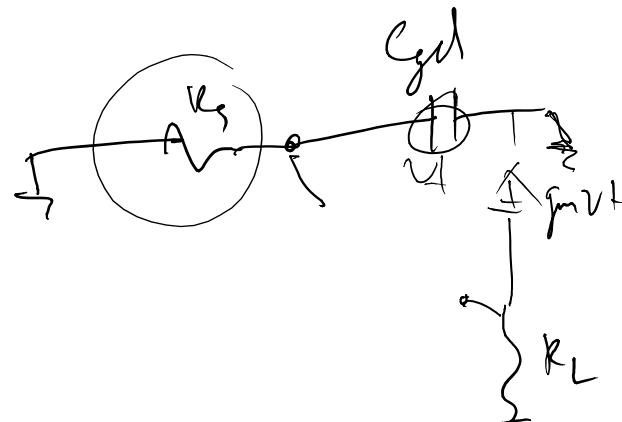
very small  
 but play a role  
 in stability  
 analysis

$2CTC$ : dominant pole in CD

$$R_L' (-it + g_m v_t) + v_t = R_s \cdot it$$

$$(1 + g_m R_L') v_t = (R_s + R_L') it$$

$$R_{gs}^0 = \frac{R_s + R_L'}{1 + g_m R_L'}$$



$$R_{gd}^0 = R_s$$

$$p = - \frac{1}{C_{gs} R_{gs}^0 + C_{gd} R_{gd}^0} = - \frac{1}{\left( C_{gs} \frac{R_s + R_L}{1 + g_m R_L} \right) + C_{gd} \cdot R_s} \quad \text{negligible.}$$

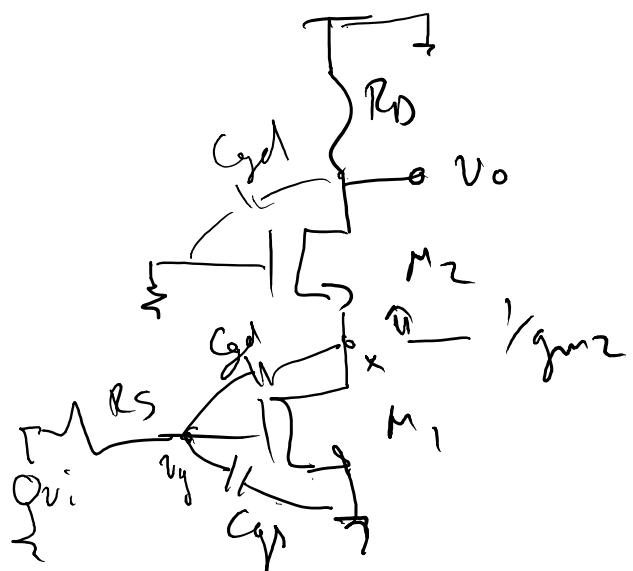
For CC:

$$Z_1 = - \frac{g_m + \frac{1}{r_n}}{C_n} \approx - \frac{g_m}{C_n} \approx \omega_T$$

$$p_1 = - \frac{1}{C_n \left( r_n \parallel \frac{R_s + R_L}{1 + g_m R_L} \right)} \quad \leftarrow \text{close to } \omega_T$$

Multi-stage amplifier examples:

Cascade amplifier:



$$\frac{v_o}{v_i} = -g_{m1} \cdot R_D$$

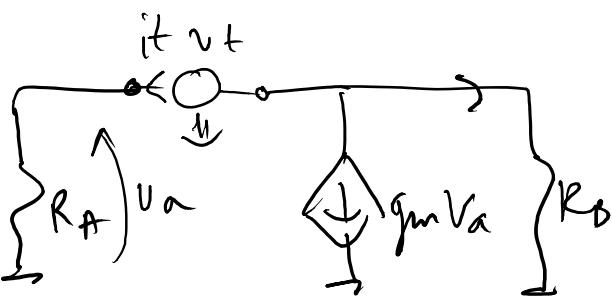
$$= -g_{m1} \cdot \frac{1}{g_{m2}} \cdot g_{m2} \cdot R_D$$

$$\left( \frac{v_x}{v_g} \right) = -\frac{g_{m1}}{g_{m2}} \approx -1$$

Miller multiplier

ZVTC:

$$p_1 = \frac{1}{(g_{s1}R_s + G_{d11} \cdot \left( R_s + \frac{1}{g_{m2}} + \frac{g_{m1}}{g_{m2}} \cdot R_s \right)) + C_{gs2} \cdot \frac{1}{g_{m2}} + G_{d2} R_D}$$



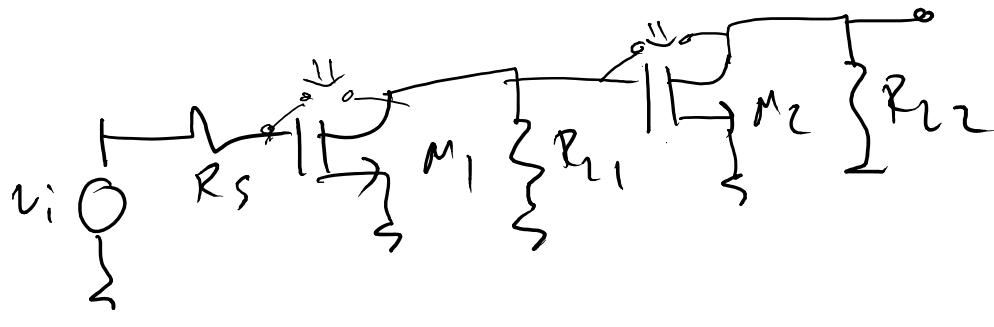
$$v_a = R_s \cdot it$$

$$R_A \cdot it - vt = -R_B \left( g_m R_A it + \frac{vt}{it} \right)$$

Compare to CS:

$$p_1 = -\frac{1}{R_s C_{gs} + G_{d1} (R_s + R_D + g_m R_s R_D)}$$

$$R_A + R_B + g_m R_A R_B = \frac{vt}{it}$$



$R_{gs}^o$  - easy

$$R_{gs1} = R_s$$

$R_{gd}^o$  - trickier

$$R_{gd1} = R_s + R_{L1} + g_{m1} R_s R_{L1}$$

$$R_{gd2} = R_{L1} + R_{L2} + g_{m2} R_{L1} R_{L2}$$

