# ECE 511 — Lecture 15

Note Title 3/14/2013

$\omega_{p_1} << \omega_{p_2}$

$$\omega_{p_1} = \frac{1}{R_s[1+g_{m_1}R_o]C_{gd_1} + R_s C_{gs_1} + R_o(C_{gd_1}+C_o)}$$

coeff$^n$ of $s^2 \Rightarrow \frac{1}{\omega_{p_1}\omega_{p_2}}$

$$\Rightarrow \quad \omega_{p_2} = \frac{1}{\omega_{p_1}} \times \frac{1}{R_s R_o \xi}$$ coeff of $s^2$ in $D(s)$

$$= \frac{1}{\omega_{p_1}} \times \frac{1}{R_s R_o[C_{gs_1}C_{gd_1} + C_{gs_1}C_o + C_{gd_1}C_o]}$$

$$= \frac{\cancel{R_s(1+g_m R_o)C_{gd_1}} + R_s C_{gs_1} + \cancel{R_o(C_{gd_1}+C_o)}}{R_s R_o[C_{gs_1}C_{gd_1} + C_{gs_1}C_o + C_{gd_1}C_o]}$$

$$* \quad C_{gs1} \gg (1+g_m R_o)\, C_{gd1} + \frac{R_o}{R_S}\left(C_{gd1} + C_o\right)$$

$$\boxed{\omega_{p2} \simeq \frac{1}{R_o\,(C_{gd1} + C_o)}}$$

same as $\omega_{out}$

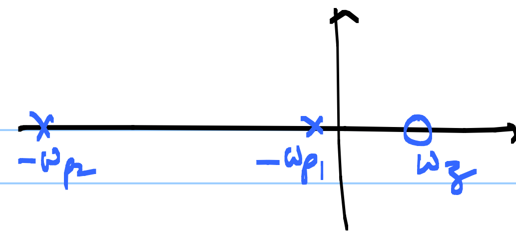
only valid when $C_{gs1}$ dominates the response

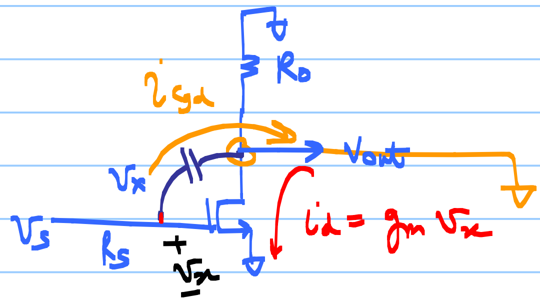
$$\frac{V_{out}}{V_{in}}(s) = \frac{A_v\,\left(1 - s/\omega_z\right)}{\left(1 + \frac{s}{\omega_{p1}}\right)\left(1 + \frac{s}{\omega_{p2}}\right)}$$

RHP zero

## zero:

$$\omega_z = \frac{g_{m1}}{C_{gd1}} \longrightarrow \text{RHP}$$



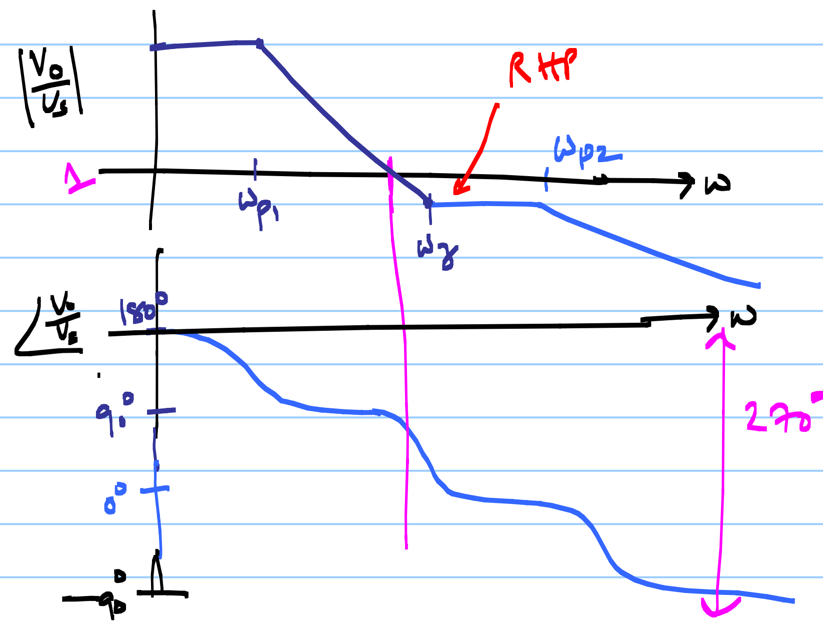

@ high frequencies, the feedforward path current adds to the main path in the opposite phase.

$@\ \omega = \omega_z \Rightarrow$

$$i_{C_{gd1}} + i_d = 0$$

$$V_x s C_{gd1} - g_m V_x = 0$$

$$\boxed{s_z = \frac{g_m}{C_{gd1}}}$$




$$\angle = 180^\circ - \tan^{-1}\left(\frac{\omega}{\omega_{p_1}}\right) - \tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_{p_2}}\right)$$

"RHP zero degrades phase"

$$\omega_z = +\frac{g_{m1}}{C_c} \quad @\ \text{RHP}$$

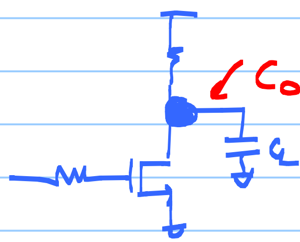
$C_{gd1} \longrightarrow C_c$

$A_v = -g_m R_o$

$$\omega_{p1} = \frac{1}{R_s\left[(1+|A_v|)C_c + C_{gs1}\right] + R_o(C_c + C_o)}$$

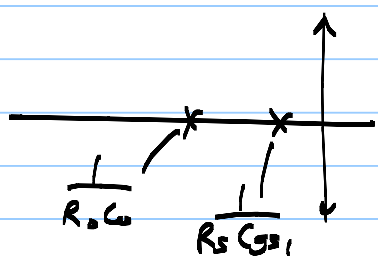
$$\omega_{p2} = \frac{R_s(1+|A_v|)C_c + R_s C_{gs1} + R_o(C_c + C_o)}{R_s R_o\left[C_{gs1} C_c + C_{gs1} C_o + C_c C_o\right]}$$

$+ \quad C_c = 0 \quad \& \quad \text{large } \underline{\underline{C_o}} < C_{gs1}$




$$\omega_{p1} \simeq \frac{1}{R_s C_{gs1} + R_o C_o}$$

$$\omega_{p2} \simeq \frac{\cancel{R_s C_{gs1}} + R_o \cancel{C_o}}{\cancel{R_s} R_o \ \cancel{C_{gs1}} C_o} \simeq \frac{1}{R_o C_o}$$



* Increase $C_c$ :

Consider when $C_c >> C_{gs_1}$

$$\omega_{p_1} \simeq \frac{1}{R_s(1+|A_v|)C_c + R_o(C_c+C_o)}$$

$$\omega_{p_2} \simeq \frac{R_s(\overbrace{1+|A_v|}) C_c + \cancel{R_o(C_c+C_o)}}{R_s R_o \; C_c [C_o + C_{gs_1}]}$$

$|A_v| >> 1$

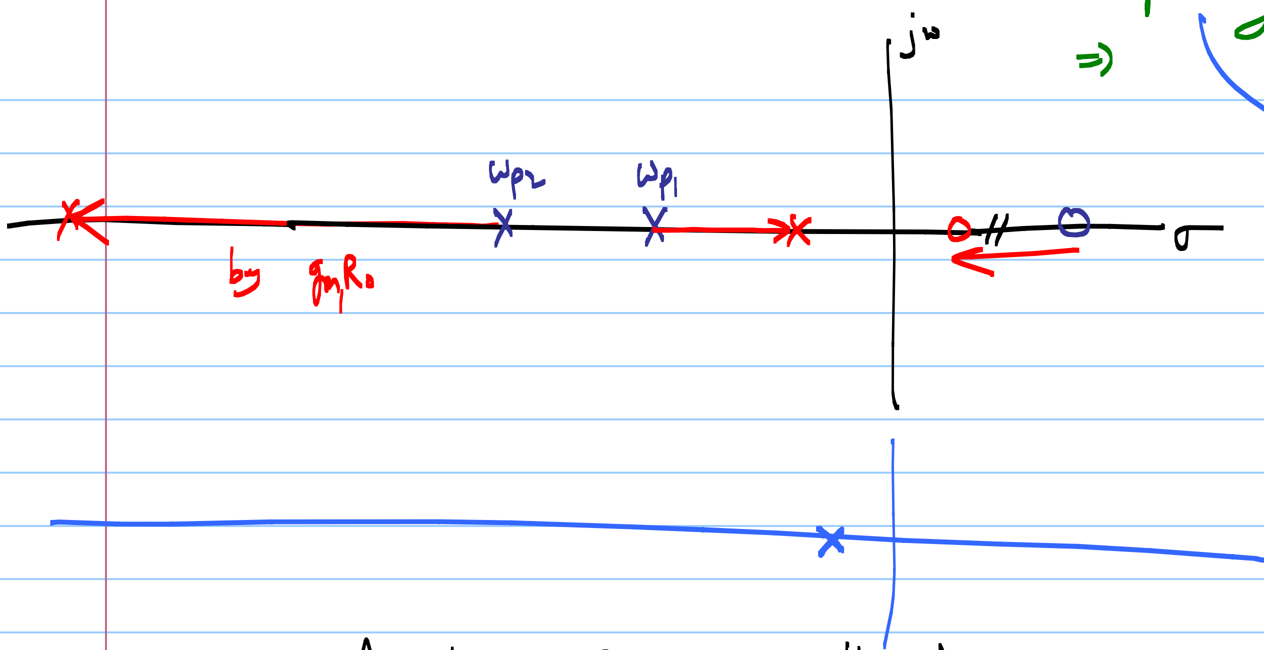
$$\simeq \frac{\cancel{R_s}(1+\overbrace{g_{m_1}R_o}) \cancel{C_c}}{\cancel{R_s} R_o(C_o + C_{gs_1}) \cancel{C_c}}$$

$$\simeq \frac{g_{m_1} \cancel{R_o}}{\cancel{R_o}(C_o + C_{gs_1})} \simeq \boxed{\frac{g_{m_1}}{C_o + C_{gs_1}}}$$

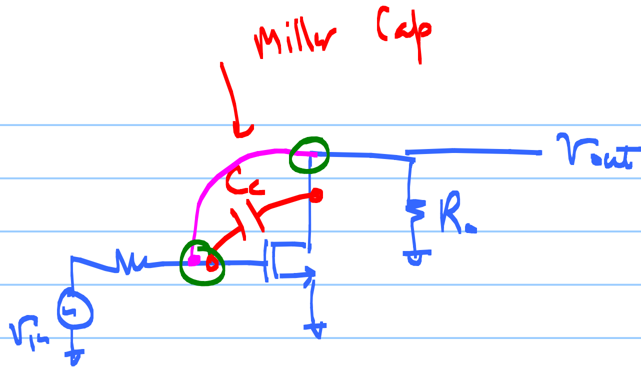
| | $C_c = 0$ | Typical case $C_c >> C_{gs_1}$ & $C_c \simeq C_o$ |
|---|---|---|
| $\omega_{p_1}$ | $\simeq \frac{1}{R_s C_{gs_1} + R_o C_o}$ | $= \frac{1}{R_s(1+\lvert A \rvert)C_c + R_o[C_c + C_o]}$ <br> $\omega_{p_1}$ is smaller |
| $\omega_{p_2}$ | $\simeq \frac{1}{R_o C_o}$ | $\simeq \frac{g_{m_1}}{C_o + C_{gs_1}} \simeq \frac{g_{m_1}}{C_o} = g_{m_1} R_o \left(\frac{1}{R_o C_o}\right)$ <br> $\omega_{p_2}$ is increased by $(g_{m_1} R_o) \Rightarrow$ a large value |
| $\omega_z$ | $\frac{g_m}{C_{gd_1}}$ | $\frac{g_{m_1}}{C_c}$ $\downarrow$ |

$C_c \uparrow$

"Pole splitting" $\Rightarrow$ Miller Compensation



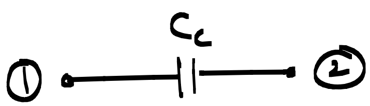

A Large $C_c$ splits the poles into a
dominant pole $\omega_{p1}$
non-dominant pole $\omega_{p2}$



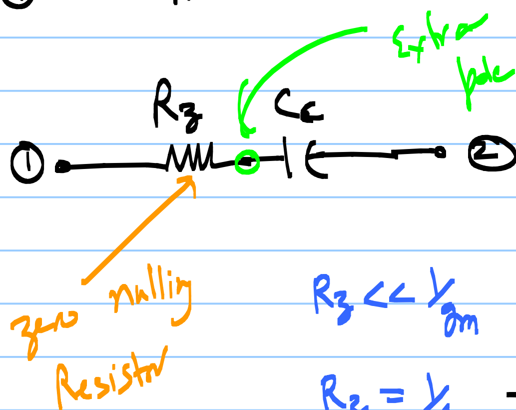

$$\omega_{p_2} \approx \frac{g_{m1}}{C_o}$$

$$(\omega_{p_1}, \omega_{p_2}) \quad ① \quad ②$$

Miller Cap




$$\omega_z = \frac{g_{m1}}{C_c} \quad @\ RHP$$

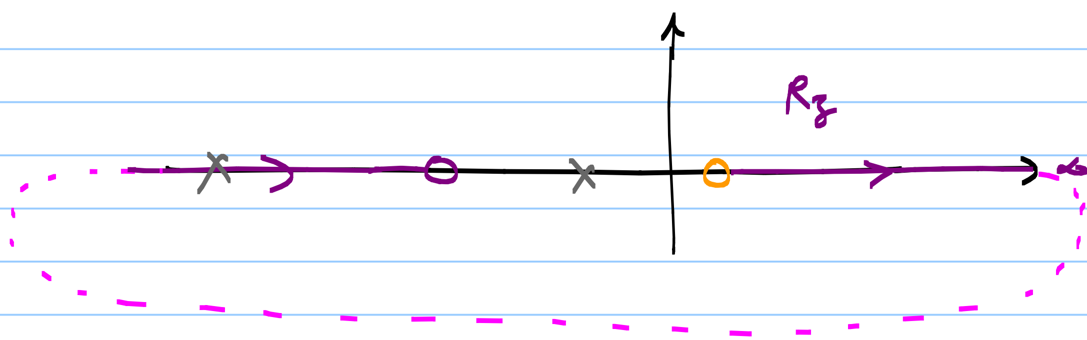


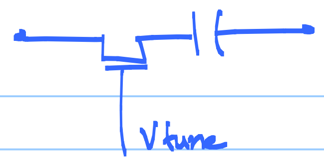

$$\omega_z' = \frac{1}{C_c\left(\frac{1}{g_{m1}} - R_z\right)}$$

$R_z << 1/g_m \rightarrow$ RHP

$R_z = 1/g_m \rightarrow \infty$

$R_z > 1/g_m \rightarrow$ LHP




Vtune

"Generic 2 node Amplifier Model"