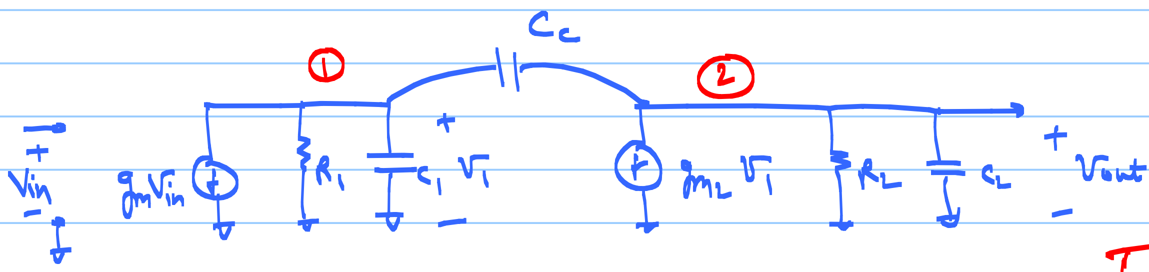
ECE 511 – Lecture 16

Note Title 3/19/2013



$$\boxed{\omega_{un} \simeq \frac{g_{m1}}{C_c}}$$

$$A_v = g_{m1} R_1 \, g_{m2} R_L$$

$$\omega_{p1} = \frac{1}{R_L(C_2 + C_c) + R_1\left(C_1 + C_c(1 + \underbrace{g_{m2} R_L}_{})\right)}$$

$$\simeq \frac{1}{g_m R_L R_1 C_c}$$

$$\omega_{p2} \simeq \frac{g_{m2} C_c}{C_c C_1 + C_1 C_2 + C_c C_2} \quad \alpha \ \frac{g_{m2}}{C_2} \ \text{for} \ C_c \simeq C_2 \gg C_1$$

$$\omega_z = \frac{g_{m2}}{C_c} \quad @ \text{ RHP}$$

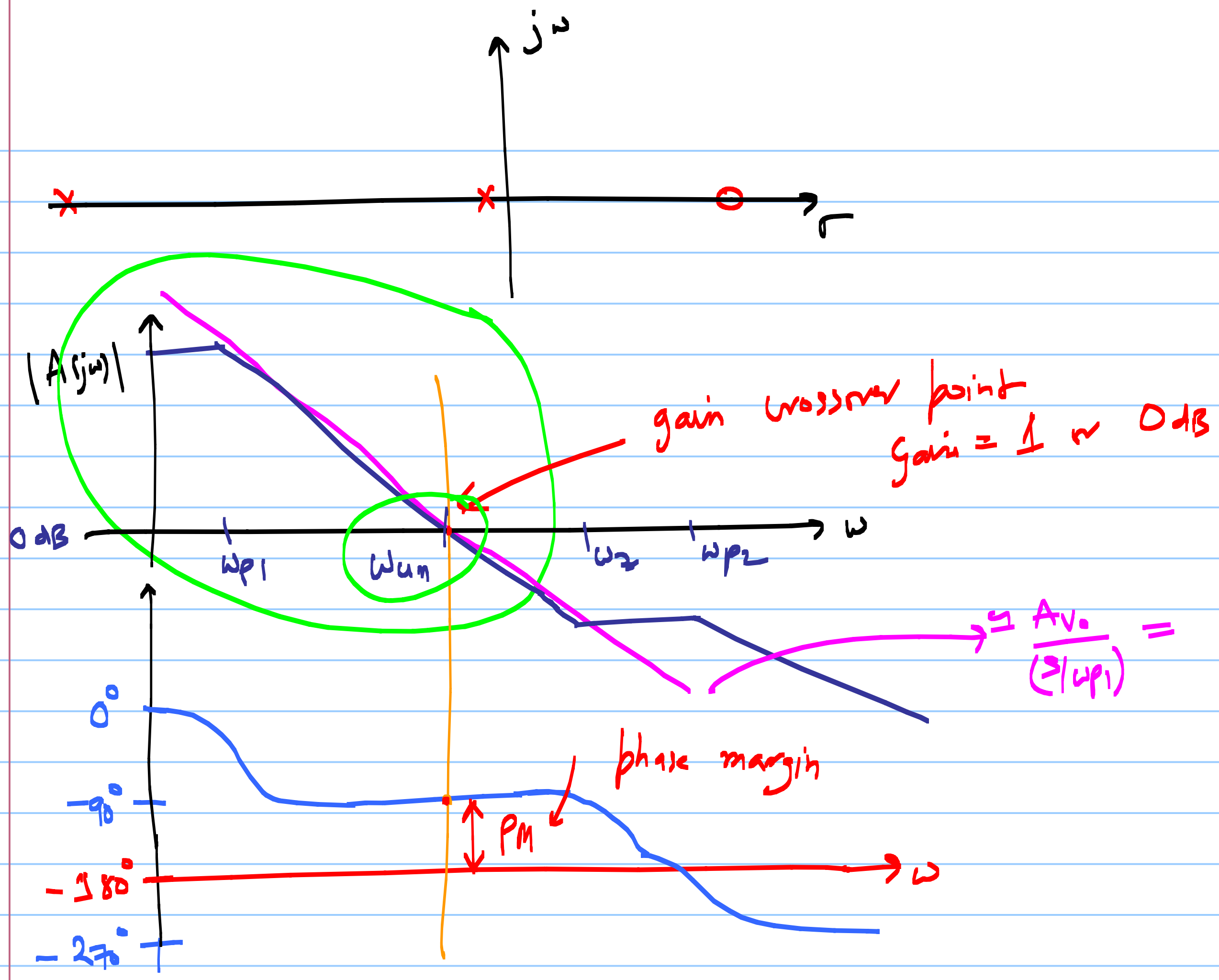
$$A_v(s) = \frac{A_{v_0}\left(1 - s/\omega_z\right)}{\left(1 + s/\omega_{p_1}\right)\left(1 + s/\omega_{p_2}\right)}$$

if $\omega_{p_1} \ll \omega_{p_2} \Rightarrow \omega_{p_1} \Rightarrow$ dominant pole

ω_z is also far out

$$A_v(s) \simeq \frac{A_{v_0}}{\left(1 + s/\omega_{p_1}\right)}$$

$$\omega_{3dB} = \frac{1}{g_{m2} R_2 R_1 C_c}$$



$$\simeq \frac{A_{v_0}}{(s/\omega_{p1})} = \frac{A_{v_0}\omega_{p1}}{s}$$

Deriving ω_{un}

$$A_v(s) = \frac{A_{v0}}{1 + s/\omega_{p1}}$$

$$|A_v(j\omega)| = \frac{|A_{v0}|}{\left(1 + \frac{\omega^2}{\omega_p^2}\right)^{1/2}}$$

for $\frac{\omega}{\omega_p} \gg 1$

$$1 + \left(\frac{\omega}{\omega_p}\right)^2 \simeq \left(\frac{\omega}{\omega_p}\right)^2$$

$$\simeq \frac{A_{v0}\,\omega_{p1}}{s} = \frac{\omega_{un}}{s}$$

because @ $s = \omega_{un}$, $\left|\frac{\omega_{un}}{s}\right| = 1$

$$\Rightarrow \omega_{un} = A_{v0} \cdot \omega_{p1} = g_{m1} \cancel{R_1}\, \cancel{g_{m2}} \cancel{R_2} \cdot \frac{1}{\cancel{g_{m2}} \cancel{R_2} \cancel{R_1} C_c} = \frac{g_{m1}}{C_c}$$

$$\boxed{\omega_{um} = \frac{g_{m_1}}{C_c}}$$

$\Rightarrow$ what is ω_{um} ?

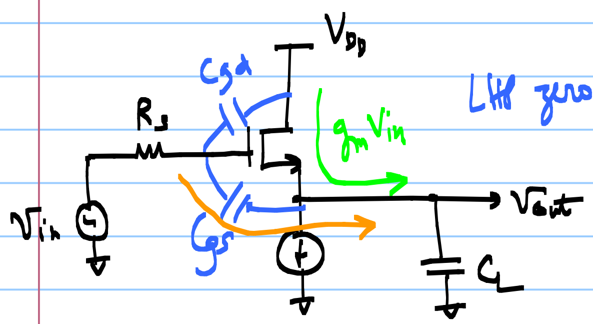
$$\omega_{um} = A_{v_0} \times \omega_{p_1}$$

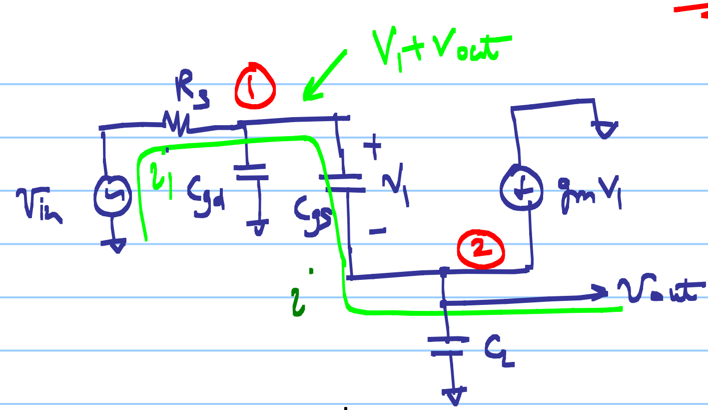
$$= A_{v_0} \cdot \omega_{3dB} = \text{Gain-Bandwidth product}$$

"Ex. 21.6 to 21.10 for pole splitting"

Source Follower Frequency Response

$\gamma = \lambda = 0$





KCL @ node 2

$$V_1 C_{gs} s + g_m V_1 = V_{out} \cdot sC_L$$

$$\Rightarrow V_1 = \frac{sC_L}{g_m + sC_{gs}} \cdot V_{out}$$

KCL @ node 1

$$\frac{V_1}{1/sC_{gs}} + \frac{(V_1 + V_{out})}{1/sC_{gd}} - i_1 = 0$$

$$i_1 = sC_{gs}V_1 + (V_1 + V_{out})sC_{gd}$$

* KVL beginning from V_{in}

plug-in V_1

$$V_{in} = R_s\left[V_1 sC_{gs} + (V_1 + V_{out})C_{gd}s\right] + V_1 + V_{out}$$

$$\frac{V_{out}}{V_{in}}(s) = \frac{(g_m + C_{gs} s)}{R_s\left[C_{gs}C_L + C_{gs}C_{gd} + C_{gd}C_L\right]s^2 + \left[g_m R_s C_{gd} + C_L + C_{gs}\right]s + g_m}$$

LHP zero $\Rightarrow$ $\omega_z = \frac{g_m}{C_{gs}}$ | $s_z = -\frac{g_m}{C_{gs}}$

Assuming $|\omega_{p1}| \ll |\omega_{p2}|$

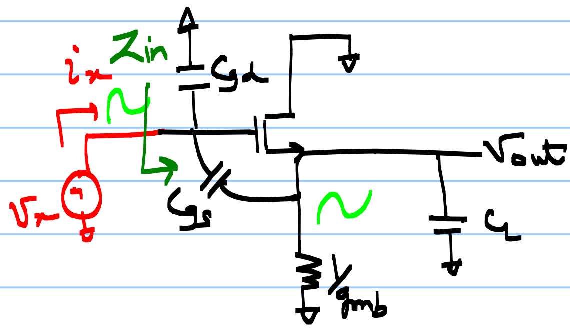
$$\omega_{p1} \simeq \frac{g_m}{g_m R_s C_{gd} + C_L + C_{gs}}$$

$$= \frac{1}{R_s C_{gd} + \frac{C_L + C_{gs}}{g_m}}$$

if $R_s C_{gd}$ is small

$$\boxed{\omega_{p1} \simeq \frac{g_m}{C_L + C_{gs}}}$$

Input impedance of SF



@ low frequencies $g_{mb} >> |sC_L|$

$$Z_{in} \simeq \frac{1}{sC_{gs}}\left(1+\frac{g_m}{g_{mb}}\right) + \frac{1}{g_{mb}}$$

$$= \frac{1}{s\,\frac{C_{gs}}{\left(1+\frac{g_m}{g_{mb}}\right)}} + \frac{1}{g_{mb}}$$

* input cap is a fraction of C_{gs}

@ higher frequencies

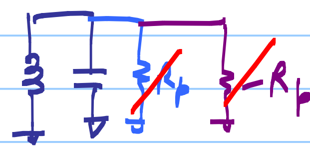
$$g_{mb} \ll |sC_L|$$

$$Z_{in_1} \simeq \frac{1}{sC_{gs}} + \frac{1}{sC_L} + \frac{g_m}{C_{gs} C_L s^2}$$

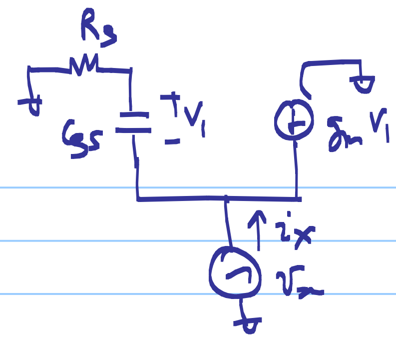
$$Z_{in_1}(j\omega) = \underbrace{\frac{1}{j\omega}\left[\frac{1}{C_{gs}} + \frac{1}{C_L}\right]}_{\text{Capacitance}} - \underbrace{\frac{g_m}{C_{gs} C_L \omega^2}}_{\text{negative resistance}}$$

$$Re(Z_{in}) = -\frac{g_m}{C_{gs} C_L \omega^2} \leftarrow \text{useful in oscillators}$$

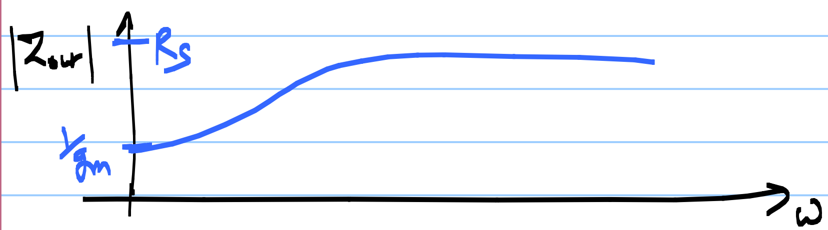
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

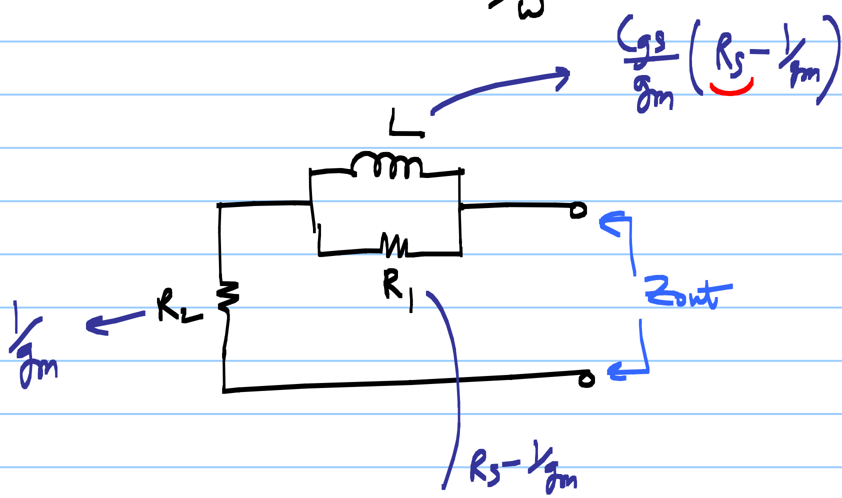


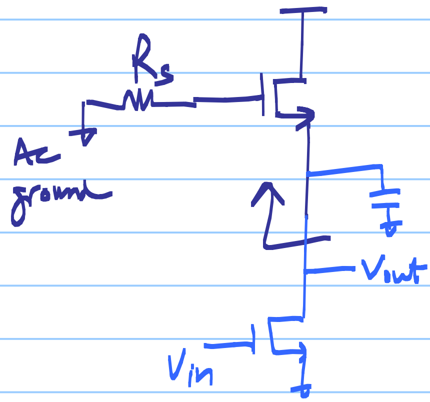
output impedance

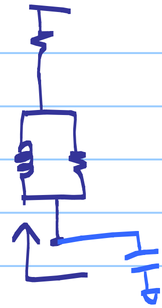


$$Z_{out} = \frac{R_S C_{gs} s + 1}{g_m + s C_{gs}}$$



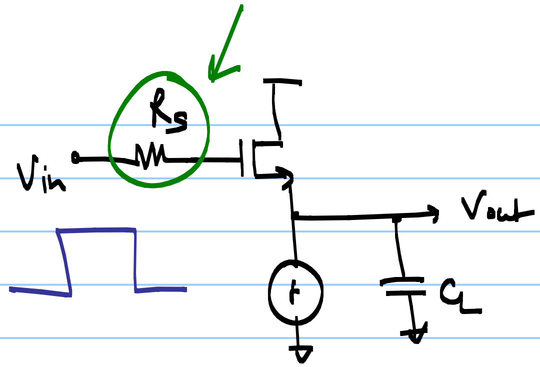




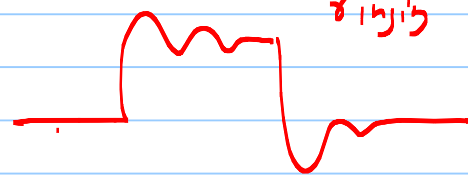


inductive load

(active inductor load)



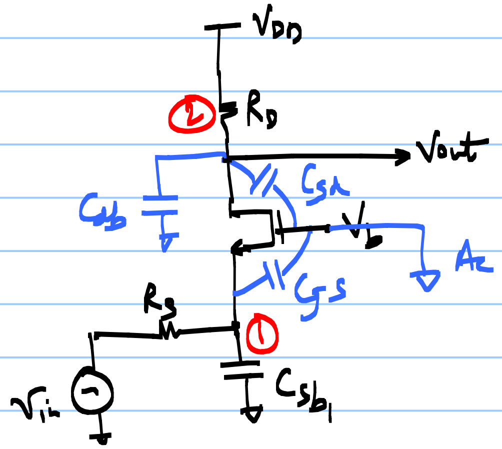
ringing in the output



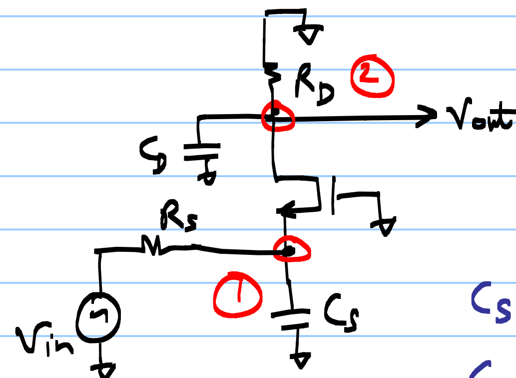
* If the SF is driven by a large R_S

↳ substantial inductive peaking

Common Gate Frequency Response



redraw $\Longrightarrow$



$\underline{\underline{\lambda = 0}}$

$C_S = C_{gs} + C_{sb}$

$C_D = C_{gd_1} + C_{db}$

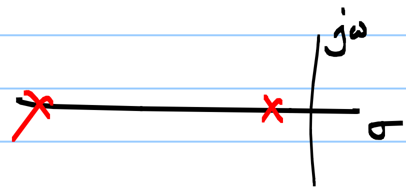
@ node-1

$$\omega_{p_1} = \frac{1}{\left(R_S \| \frac{1}{g_m + g_{mb}}\right) C_S}$$

@ node-2

$$\omega_{p_2} = \frac{1}{R_D C_D}$$

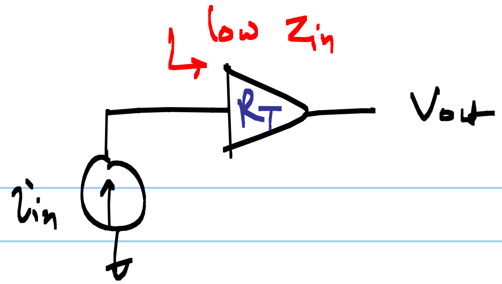
$$\frac{V_{out}}{V_{in}}(s) = \frac{(g_m+g_{mb})R_D}{1+(g_m+g_{mb})R_S} \cdot \frac{1}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)}$$



* No miller cap ⇒ potentially wideband response

↳ low-impedance input → Current Buffer.

⇒ Transimpedance amplifier


low Z_{in}
R_T
V_{out}
i_{in}