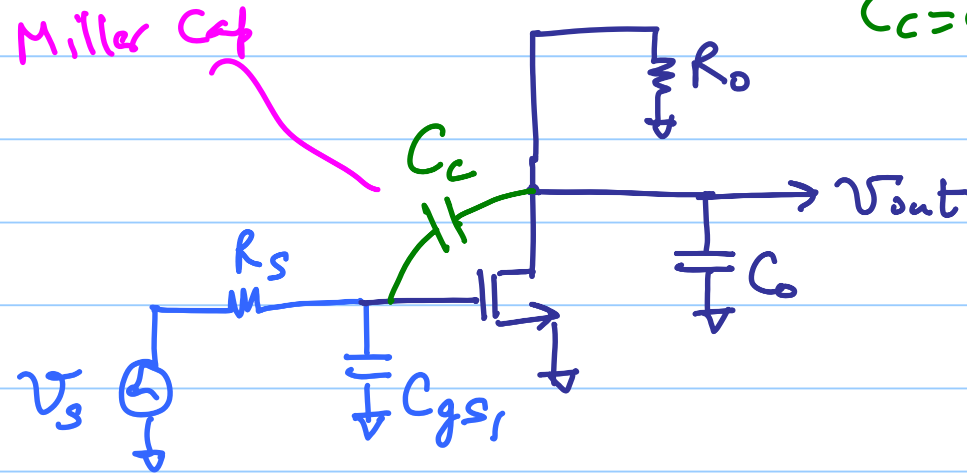
ECE 511- Lecture 17

Note Title 3/17/2015

frequency response of CS stage

Ac

$C_c = C_{gd_1}$



$$\omega_z = \frac{g_{m_1}}{C_c}$$

$$\omega_{p_1} = \frac{1}{R_s[(1+|A_v|)C_c + C_{gs_1}] + R_o(C_c + C_o)}$$

$$\omega_{p_2} = \frac{R_s(1+g_{m_1}R_o)C_c + R_sC_{gs_1} + R_o(C_c + C_o)}{R_sR_o[C_{gs_1}C_c + C_{gs_1}C_o + C_cC_o]}$$

We make an assumption $|\omega_{p1}| \ll |\omega_{p2}|$

Dominant pole

Sweep C_c and study

① $C_c = 0$ & $\boxed{\text{large } C_o}$

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

approximations

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

not good for stability

* Now, increase C_c

when $C_c \gg C_{gs_1}$

adding more C_c to enhance Miller effect

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

$$\omega_{p_2} \simeq \frac{\cancel{R_s}(1+g_{m_1}R_o)\cancel{C_c} + \cancel{R_o(C_c+C_o)}}{\cancel{R_s}R_o\cancel{C_c}[C_o+C_{gs_1}]}$$ ignore

$$\simeq \frac{(\cancel{1+}g_{m_1}R_o)}{R_o(C_o+C_{gs_1})} \simeq \boxed{\frac{g_{m_1}}{C_o+C_{gs_1}}} \propto \frac{g_{m_1}}{C_o}$$

	$C_c = 0$	$C_c \gg C_{gs_1}$
ω_{p_1}	$\simeq \dfrac{1}{R_S C_{gs_1} + R_o C_o}$	$\simeq \dfrac{1}{R_S(1+\lvert A\rvert)C_c + R_o[C_c + C_o]}$
ω_{p_2}	$\simeq \dfrac{1}{R_o C_o}$	$\simeq \dfrac{g_{m_1}}{C_o + C_{gs_1}}$
ω_z	$\dfrac{g_{m_1}}{C_{gd_1}}$	$\dfrac{g_{m_1}}{C_c}$

$\omega_{p_1} \downarrow$

$\stackrel{\Delta}{\simeq} \dfrac{g_{m_1}}{C_o} \stackrel{\Delta}{=} g_{m_1} R_o \left[\dfrac{1}{R_o C_o}\right]$

$\omega_{p_2} \uparrow$

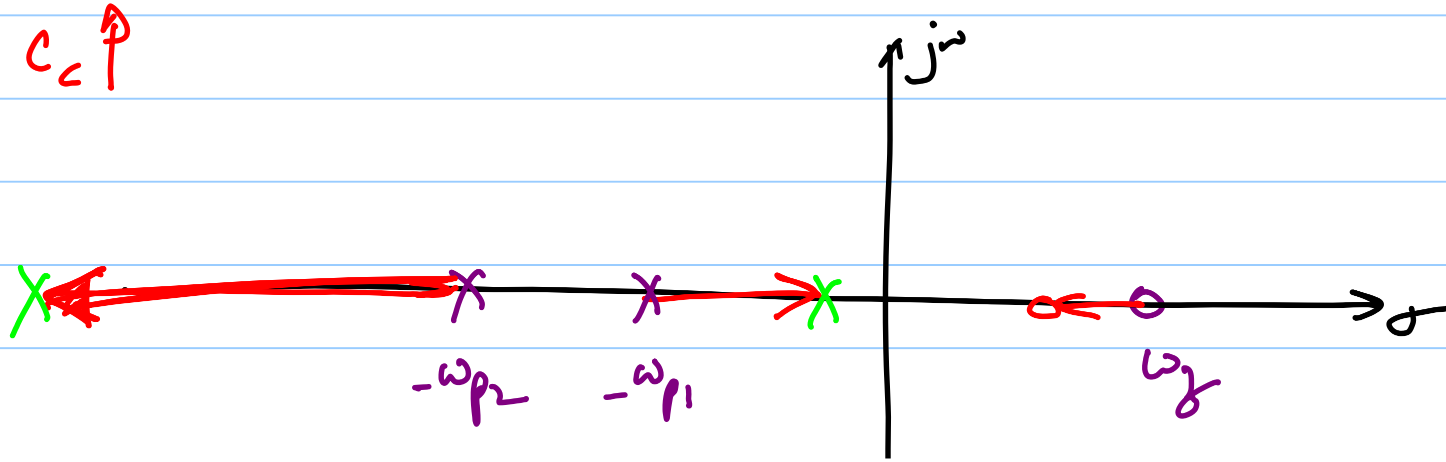
ω_{p_2} is increased by $g_{m_1} R_o$

↳ a large value

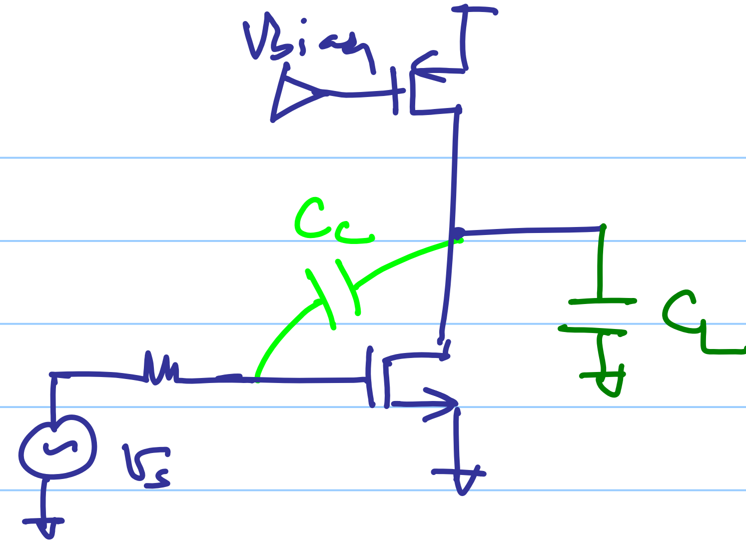
$\omega_z \downarrow$

$C_c \uparrow$

Root locus



Miller Compensation



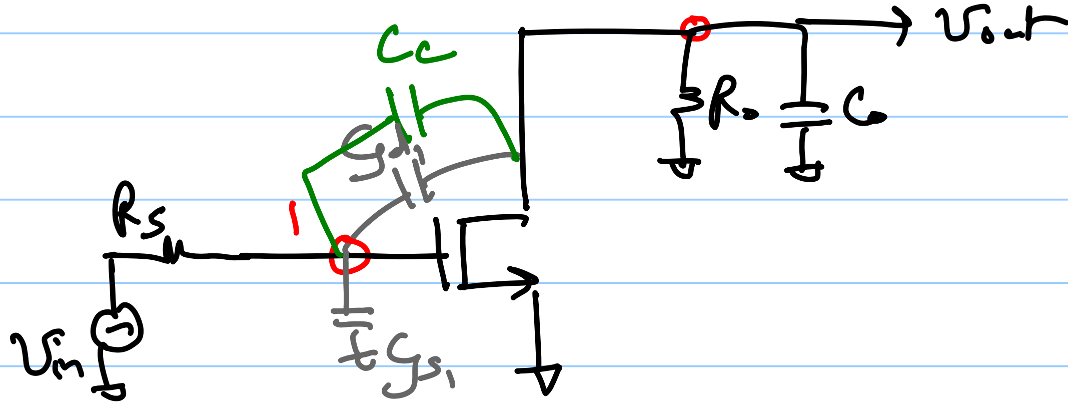
$C_o \simeq C_L$

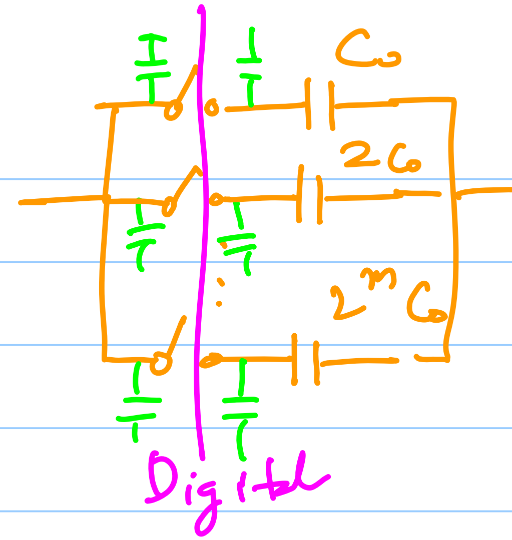
$C_c \uparrow$

$\omega_{p_1} \downarrow$

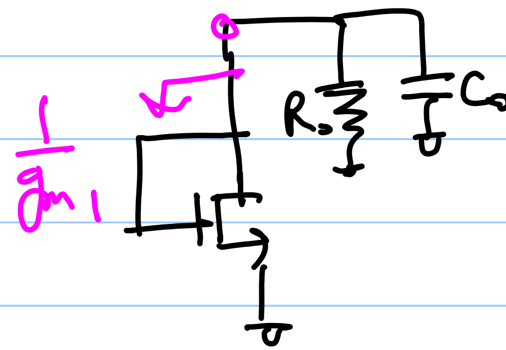
$\omega_{p_2} \uparrow$ by a large factor

↳ "Pole splitting"



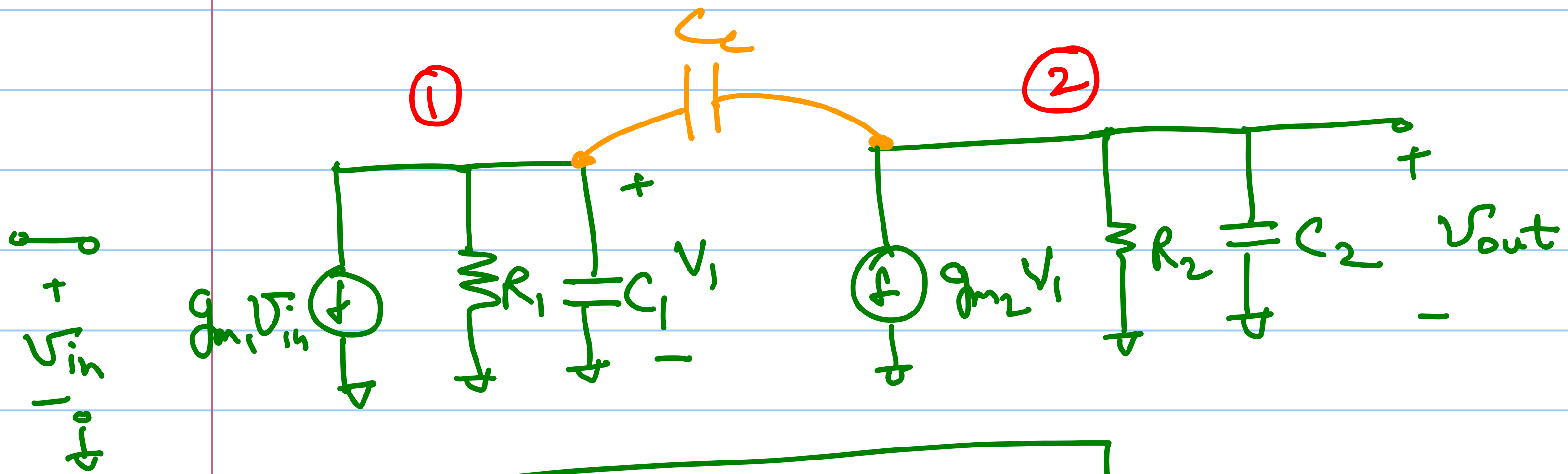


@ high frequencies C_c shorts



$$\omega_2 \simeq \frac{1}{\frac{1}{g_{m1}} C_o} = \frac{g_{m1}}{C_o}$$

Generic Model for "2nd order" amplifier



$$\boxed{A_V = g_{m1}R_1 \cdot g_{m2}R_2}$$

$$\omega_{p1} \simeq \frac{1}{R_2(C_2+C_c)+R_1(C_1+C_c(1+g_{m2}R_2))}$$

$$\boxed{\omega_{p1} \overset{\Delta}{\simeq} \frac{1}{g_{m2}R_2R_1C_c}}$$

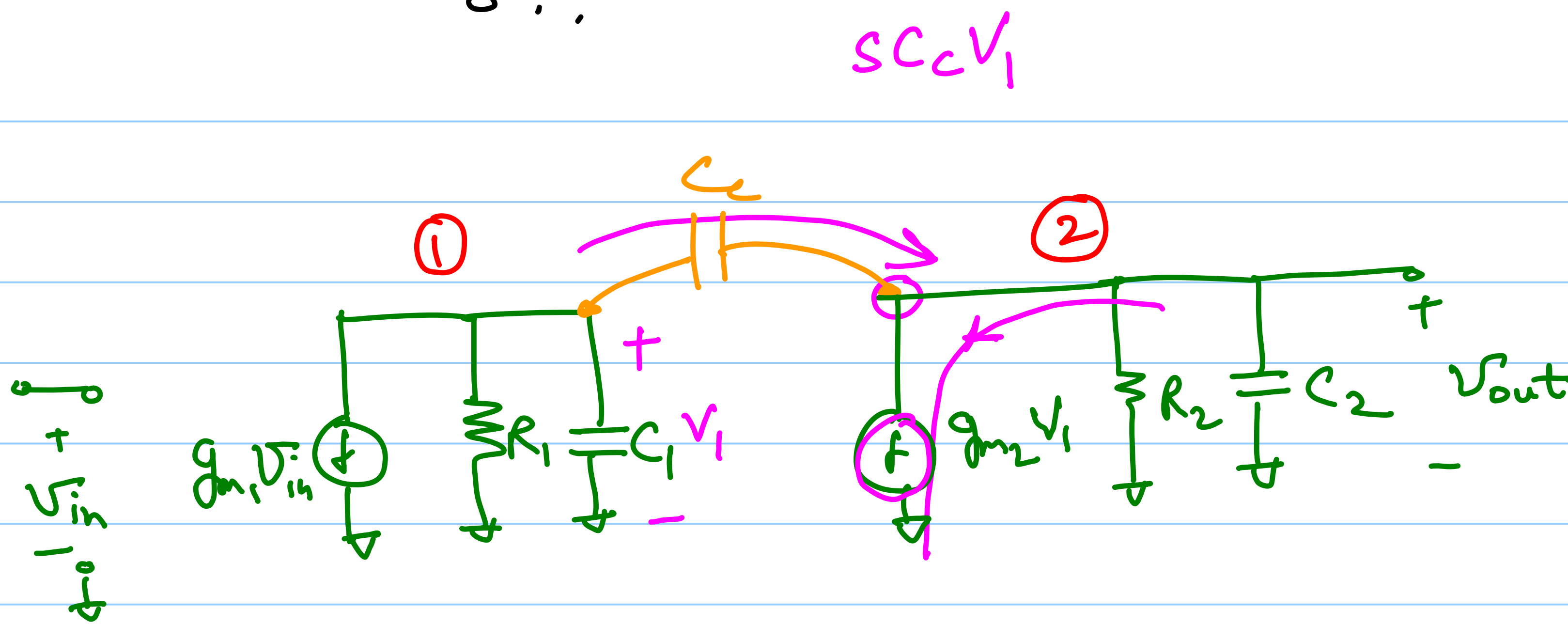
$$\boxed{\omega_{p_2} \simeq \frac{g_{m_2} C_c}{C_c C_1 + C_1 C_2 + C_c C_2}} \overset{\Delta}{\propto} \frac{g_{m_2}}{C_2}$$

for $C_2 \simeq C_c \gg C_1$

$$\boxed{\omega_z = \frac{g_{m_2}}{C_c}}$$

$$\boxed{\omega_{un} \simeq \frac{g_{m_1}}{C_c}}$$

where is ω_z??



$$s_z C_c \cancel{V_1} = g_{m_2}\cancel{V_1}$$

$$s_z = \left|\frac{g_{m_2}}{C_c}\right| = \left|j\omega_z\right|$$

$$\boxed{\omega_z \triangleq \frac{g_{m_2}}{C_c}}$$

$$\frac{V_o}{V_s}(s) = A_v(s) = \frac{A_v\left(1-\frac{s}{\omega_z}\right)}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)}$$

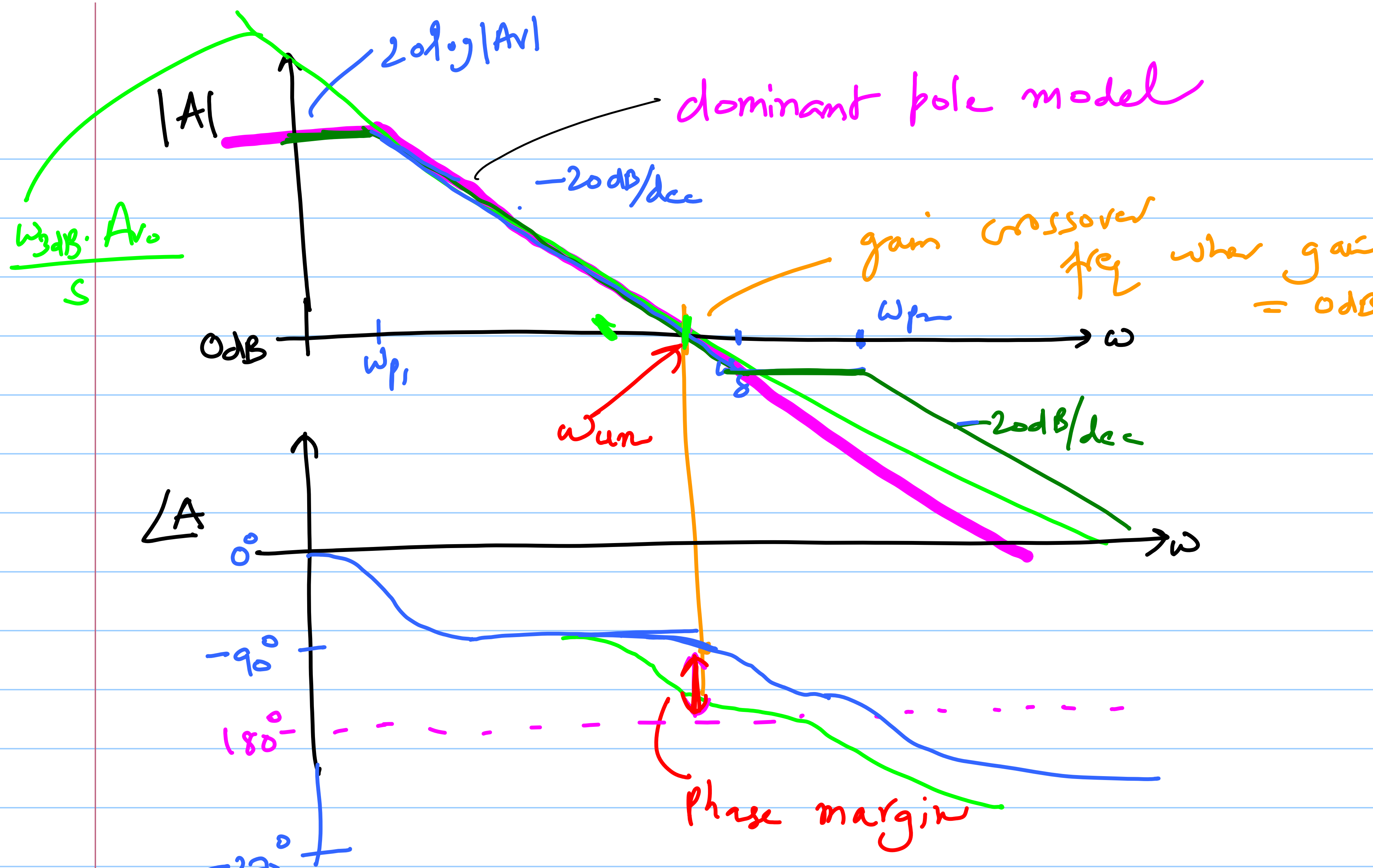
RHP zero

Compensated by C_c $\Rightarrow$ pole splitting

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

dominant pole

$$\angle\frac{V_o}{V_i} = -\underbrace{\tan^{-1}\left(\frac{\omega}{\omega_z}\right)}_{\text{RHP zero}} - \tan^{-1}\left(\frac{\omega}{\omega_{p1}}\right) - \tan^{-1}\left(\frac{\omega}{\omega_{p2}}\right)$$



|A|
20log|Av|
dominant pole model
-20dB/dec
w3dB·Avo / s
gain crossover freq when gain = 0dB
0dB
wp1
wp2
w
wun
-20dB/dec
∠A
0°
-90°
180°
-270°
phase margin

dominant pole model

$$A(s) = \frac{A_{vo}}{\left(1+\frac{s}{\omega_{p_1}}\right)} \triangleq \frac{A_{vo}}{\left(1+\frac{s}{\omega_{3dB}}\right)}$$

3dB BW

$$A(s) = \frac{A_{vo}}{1+\frac{s}{\omega_{3dB}}}$$

at frequencies $\omega \gg \omega_{3dB}$

$$1+\frac{s}{\omega_{3dB}} \simeq \frac{s}{\omega_{3dB}}$$

$$\simeq \frac{A_{vo}}{\frac{s}{\omega_{3dB}}} = \frac{A_{vo}\,\omega_{3dB}}{s}$$

$$= \frac{\omega_{un}}{s} \Rightarrow \omega_{un} = A_{vo} \cdot \omega_{p_1}$$

same

$$\omega_{un} \triangleq A_v \cdot \omega_{p1} = A_v \cdot \omega_{3dB}$$

$$= g_{m1} \cancel{R_1}\, \cancel{g_{m2}}\, \cancel{R_2} \times \frac{1}{\cancel{g_{m2}}\, \cancel{R_2}\, \cancel{R_1}\, C_c}$$

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

unity-gain frequency

$$\omega_{un} = A_{v0} \times \omega_{3dB}$$

$$\omega_{un} = \text{Gain} \times BW$$

"GBW"

gain - Bandwidth Tradeoff