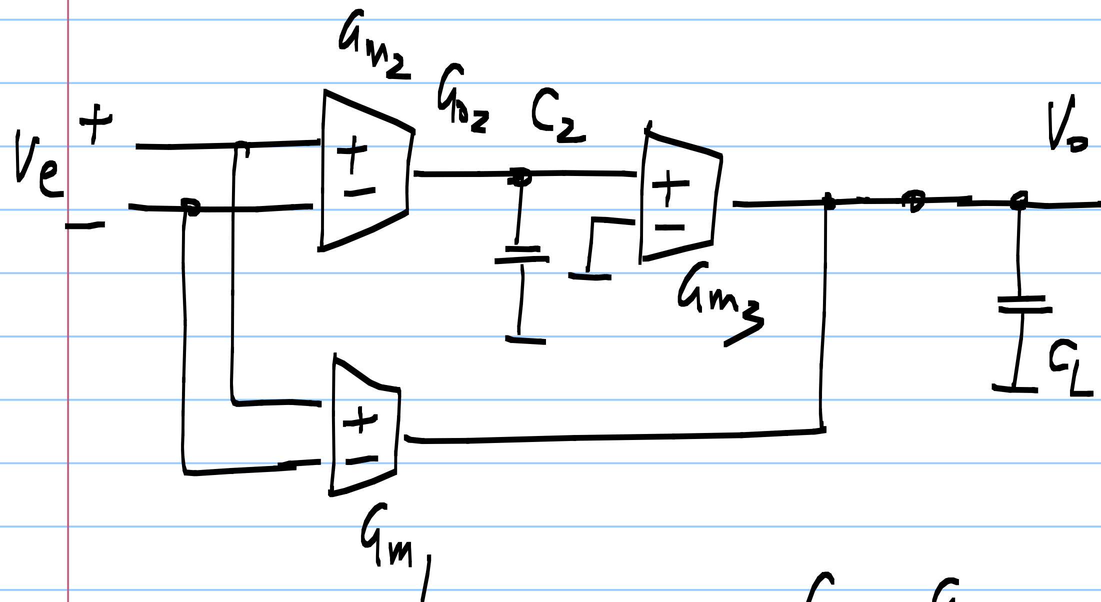
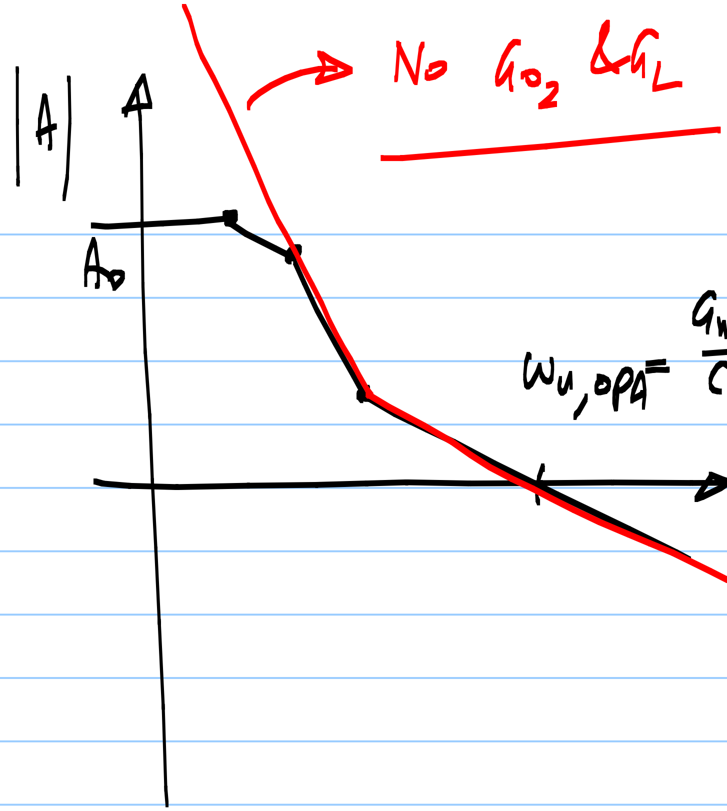
Lecture 18:

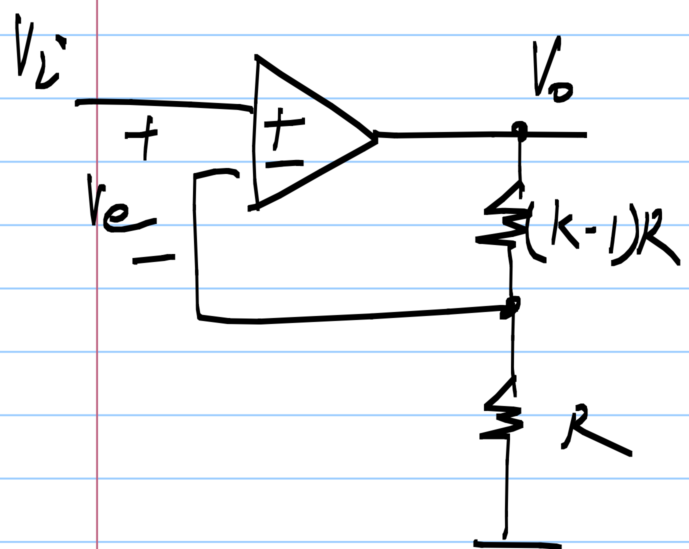
Two stage feedforward opamp:





$$\frac{V_o}{V_e} = \frac{G_{m1} + \frac{G_{m2} \cdot G_{m3}}{sC_2}}{sC_L} = \frac{G_{m1}}{sC_L}\left(1 + \frac{G_{m2} G_{m3}}{G_{m1} \cdot sC_2}\right)$$

$$A(s) = \frac{V_o}{V_e} = \frac{\omega_u}{s}\left(1 + \frac{z_1}{s}\right) = \frac{\omega_u}{s} \cdot \frac{z_1}{s}\left(1 + \frac{s}{z_1}\right)$$



$$\frac{V_o}{V_i} = \frac{k}{1 + \frac{k}{A}}$$

$$= \frac{k}{1 + k\frac{s^2}{\omega_u \cdot z_1} \Big/ \left(1 + \frac{s}{z_1}\right)}$$

$$= k \cdot \frac{1 + s/z_1}{1 + \frac{s}{z_1} + k \cdot \frac{s^2}{\omega_u \, z_1}}$$

$$\frac{\omega_u}{k} = \omega_{u,\text{loop}}$$

$$\frac{V_o}{V_e} = k \frac{\left(1 + s/z_1\right)}{\underbrace{1 + \frac{s}{z_1} + \frac{s^2}{\omega_{u,loop} \cdot z_1}}_{1 + 2\xi \frac{s}{\omega_n} + \frac{s^2}{\omega_n^2}}}$$

$$\omega_n = \sqrt{\omega_{u,loop} \cdot z_1}$$

$$\xi = \frac{1/z_1}{2/\sqrt{\omega_{u,loop} \cdot z_1}} = \frac{1}{2}\sqrt{\frac{\omega_{u,loop}}{z_1}}$$

Damping factor $\xi = \frac{1}{2}\sqrt{\frac{\omega_{u,loop}}{z_1}}$

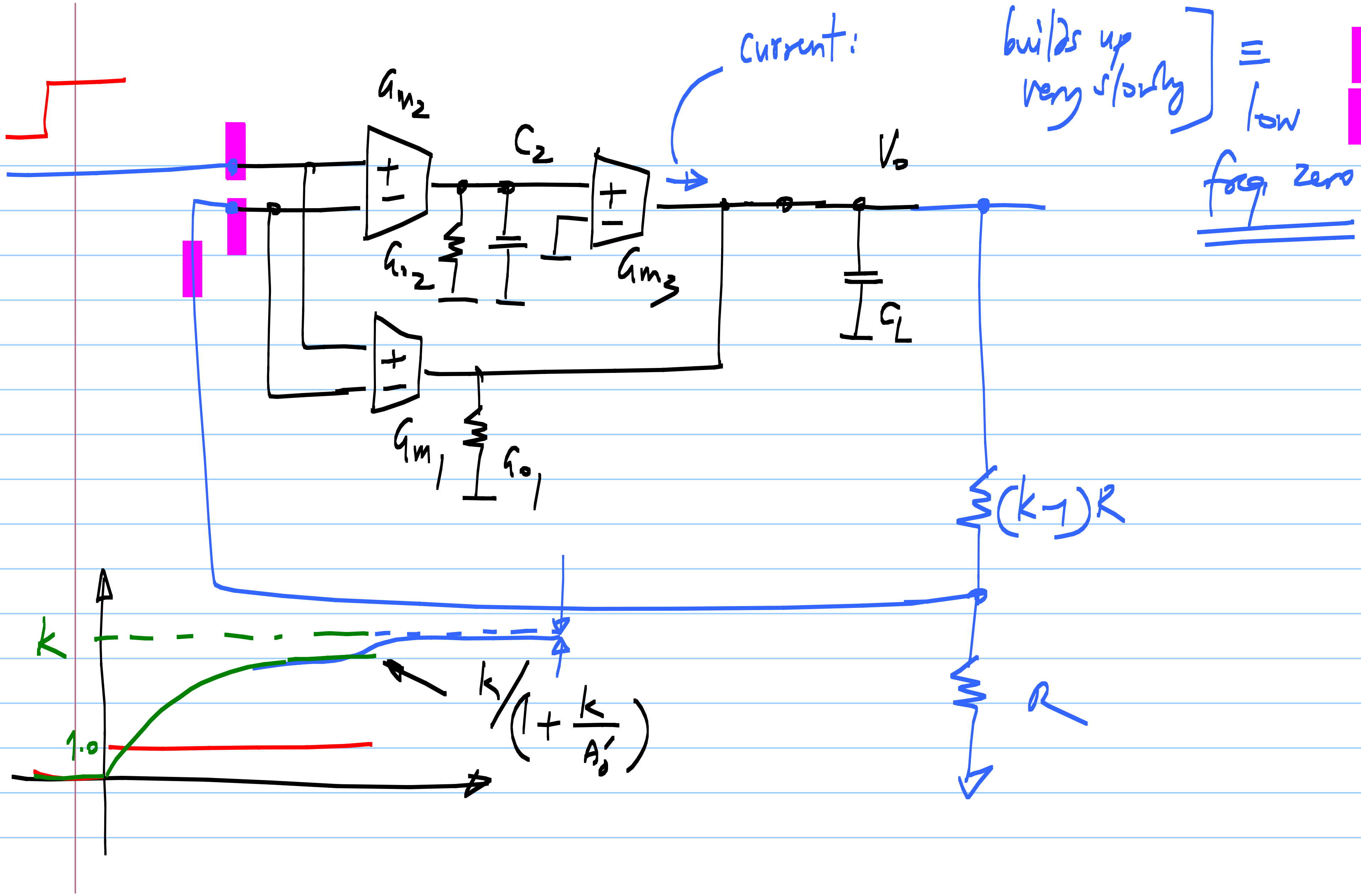
Critical damping $\xi = 1$, $\boxed{z_1 = \omega_{u,loop}/4}$

$$z_1 = \frac{G_{m_2} \; G_{m_3}}{G_{m_1} \cdot C_2} \quad ; \quad \omega_u = \frac{G_{m_1}}{C_L} \; ;$$

$$\omega_{u,loop} = \frac{G_{m_1}}{k \cdot C_L}$$

Exercise: Evaluate the step response corresponding to

$$\frac{V_o}{V_i} = k \cdot \frac{1 + s/z_1}{1 + \frac{s}{z_1} + \frac{s^2}{\omega_{u,loop} \cdot z_1}} \quad ; \quad \boxed{\omega_{u,loop} = \frac{\omega_u}{k}}$$


Gm2
C2
Go2
Gm3
Current:
builds up very slowly
= low freq zero
Vo
CL
Gm1
Go1
(k-1)R
R
k
1.0
k/(1 + k/A0')

Exercise:

$$\frac{V_o}{V_i} = k \cdot \frac{1 + s/z_1}{1 + \frac{s}{z_1} + \frac{s^2}{\omega_{u,loop} \cdot z_1}}$$

$\xi = 1$

$z_1 = \frac{\omega_{u,loop}}{4}$

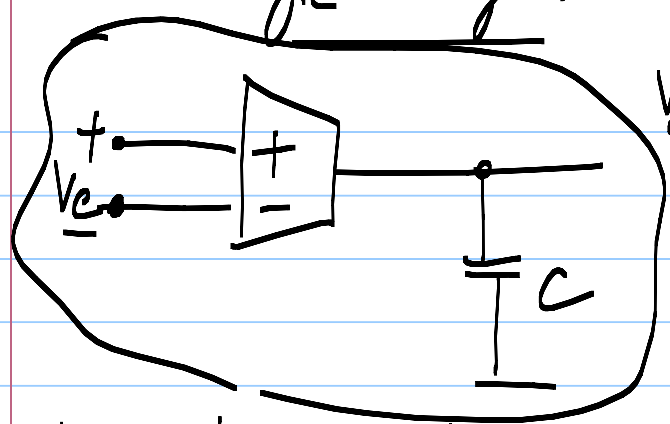
$\left|\frac{V_o}{V_i}\right|$ vs. freq. } different values of z_1

$p_2 = 4 \cdot \omega_{u,loop}$

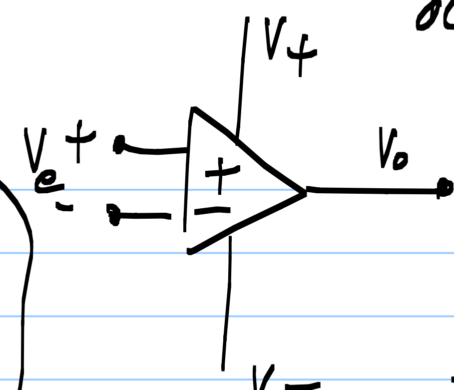
$$\frac{V_o}{V_i} = k \frac{1}{1 + \frac{s}{\omega_{u,loop}} + \frac{s^2}{\omega_{u,loop} \cdot p_2}}$$

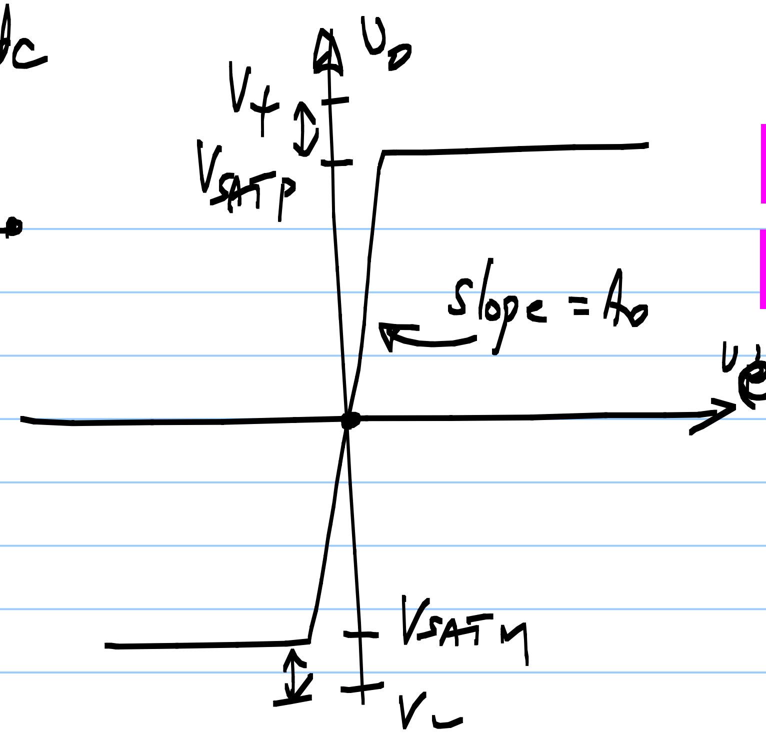
} different values of p_2

Single stage:

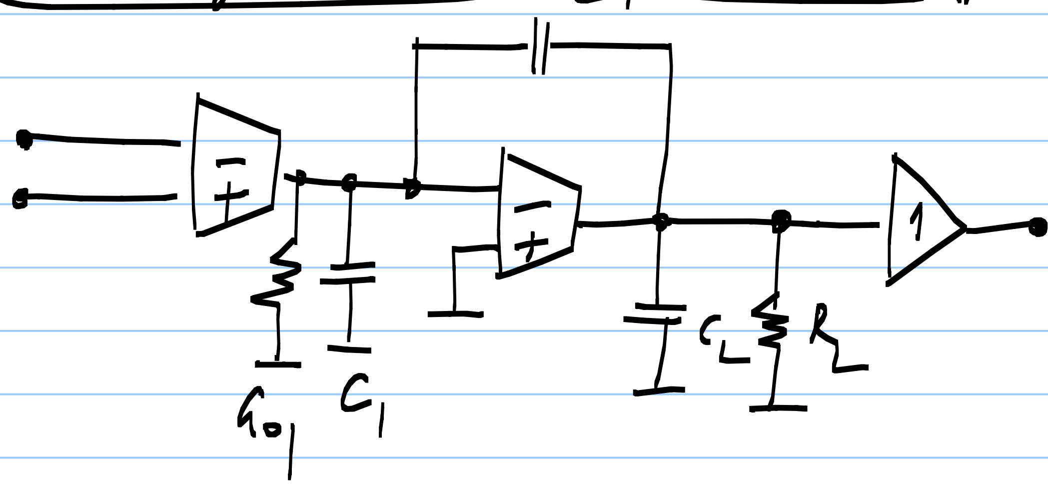


dc



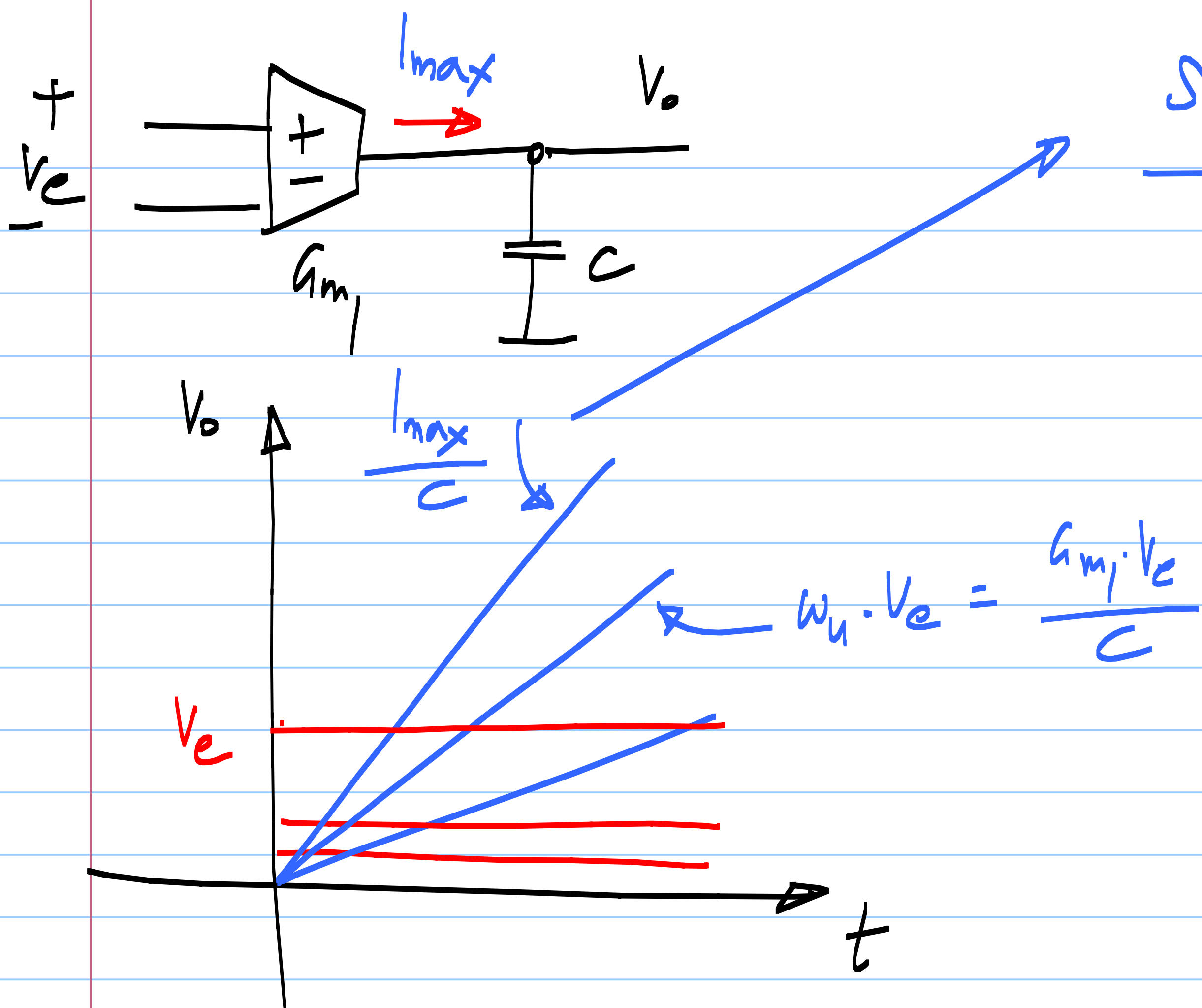


Two stage miller compensated opamp



$$V_{SATP} = V_+ ;$$

$$V_{SATM} = V_- ;$$

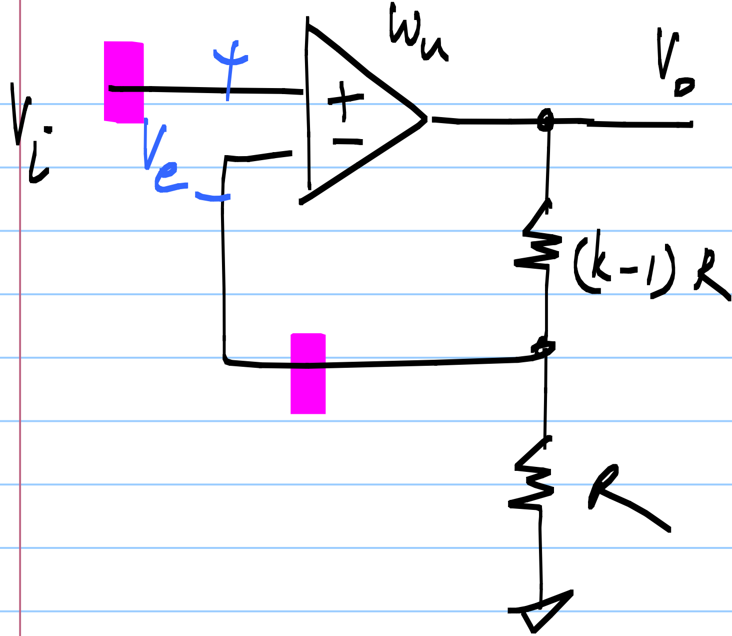


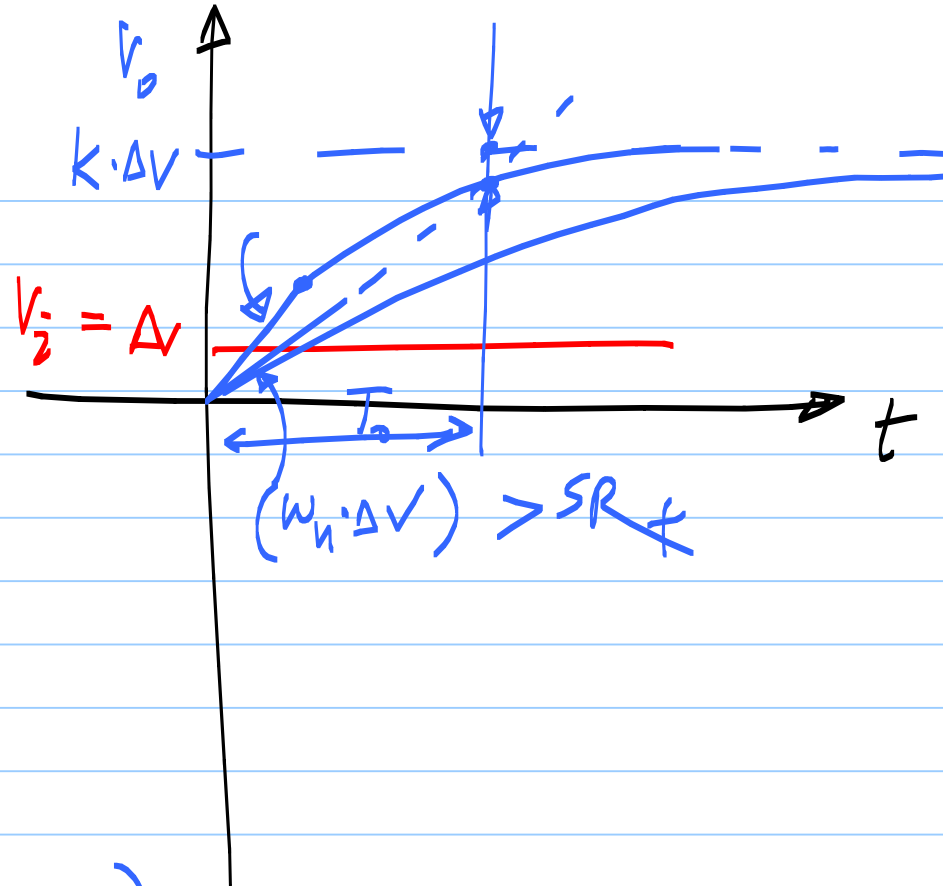
Slew rate limitation:

$$\frac{I_{max}}{C}$$

SR_+, SR_-

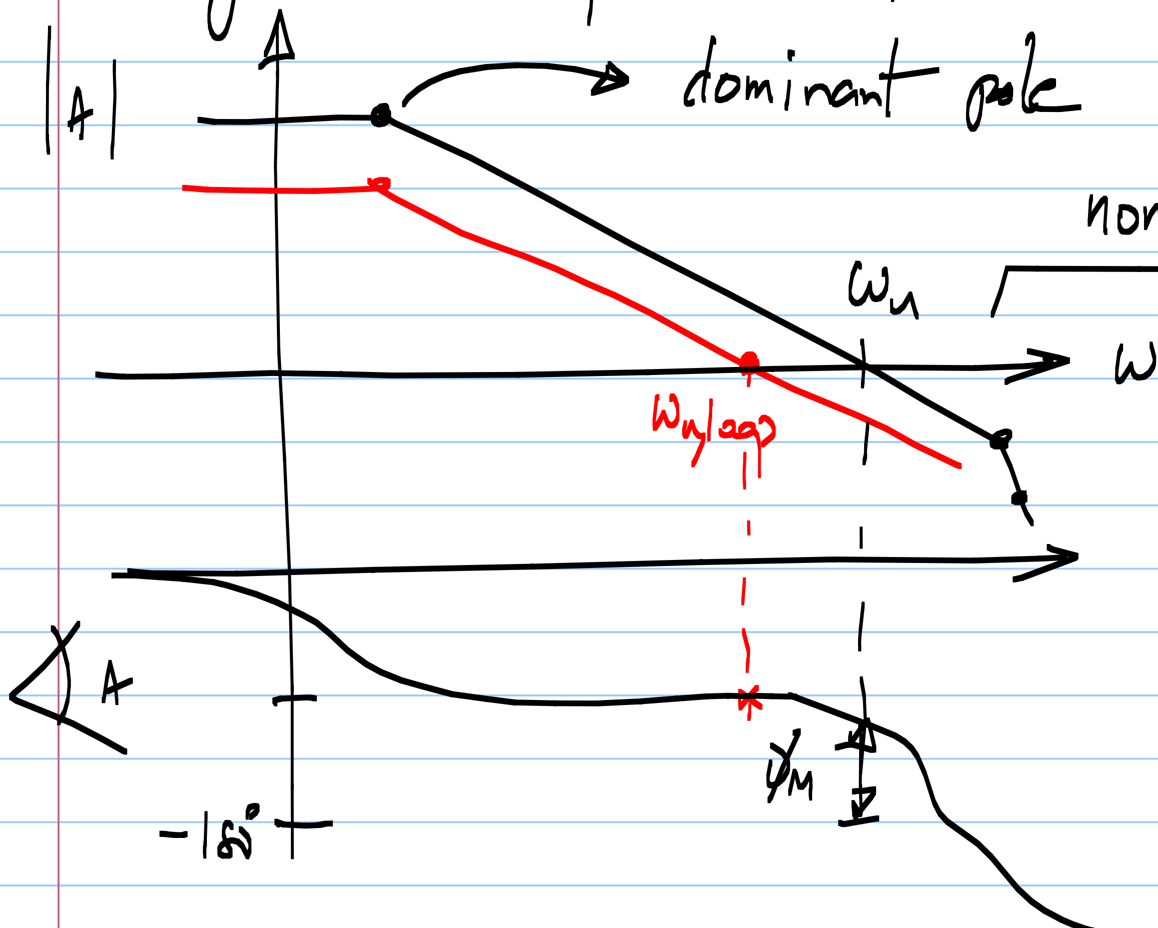
Max. rate of change of V_o





$$V_o = \omega_u \int \left(V_e + V_{off} + v_n\right) dt$$

Magnitude response & phase response of the opamp

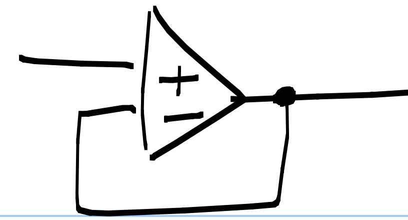


Op amp data sheet:

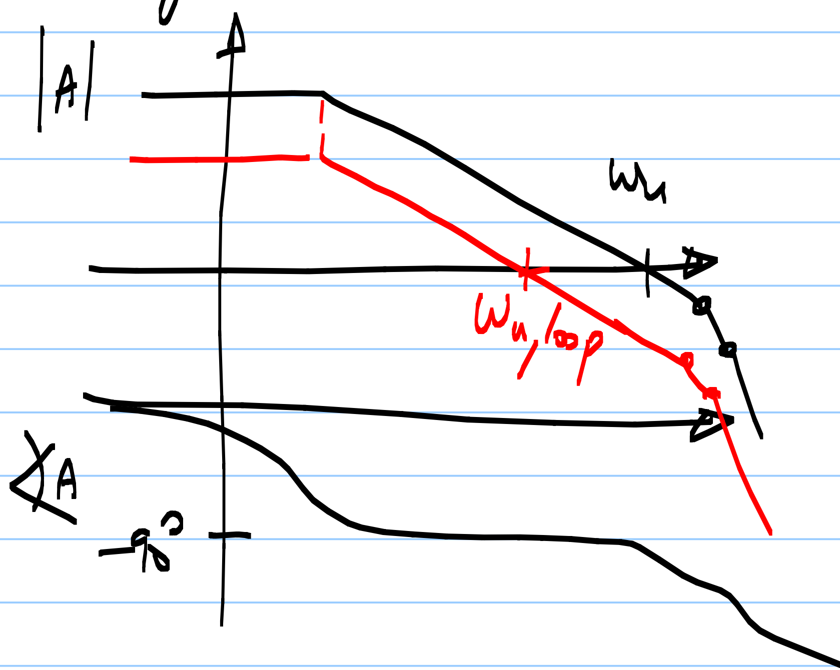
* dc gain; dc v_o vs. v_e; saturation voltages (V_+, V_-)
* ac magnitude response $\{|A(j\omega)|, \angle A(j\omega)\}$
* slew rate
* offset & noise voltages
* Maximum supply voltage; Maximum load current

Dominant pole (compensated) opamps

Unity gain compensated:



* If the opamp is connected in unity negative feedback, it will be stable.



* For any gain $k > 1$ stability is guaranteed.

Opamps not unity gain compensated: Eg. OPA657

(Compensated for $k > 10$)