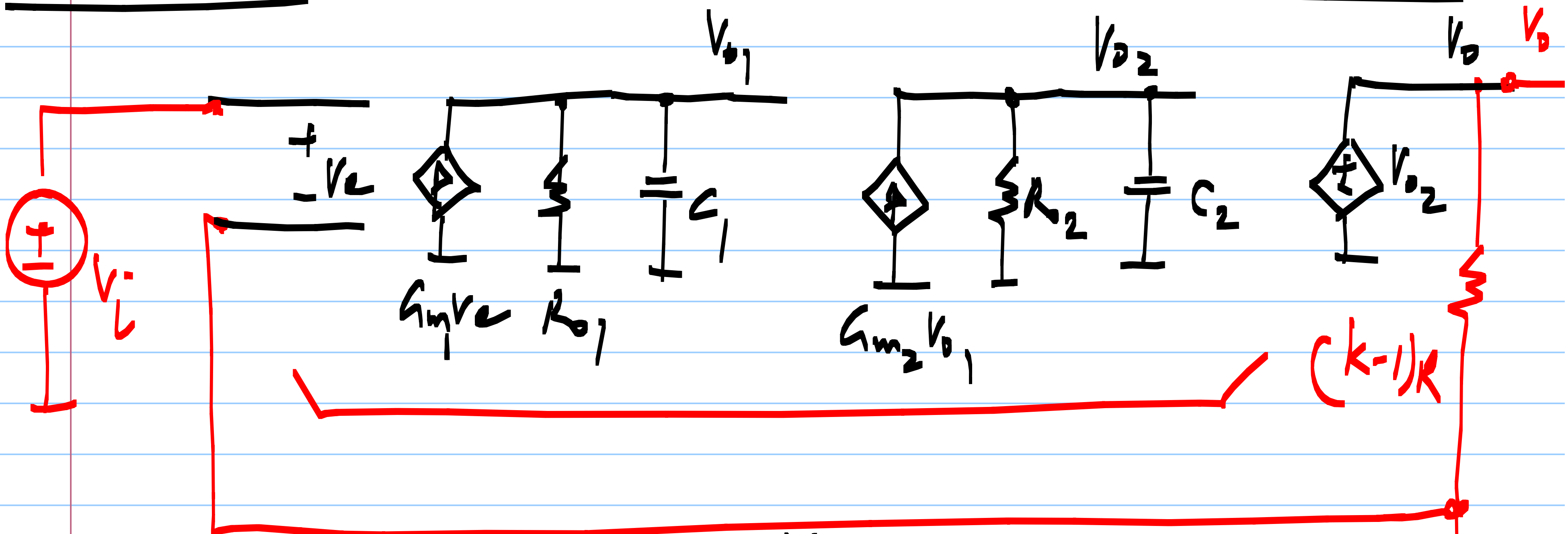
EE 2019 15/2/2018



$$\frac{V_o}{V_e} = \frac{\text{[illegible]}}{(1 + sC_1 R_{o1})(1 + sC_2 R_{o2})} = \underbrace{\left[\frac{A_o}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}\right]}_{}$$

$A(s)$ ·

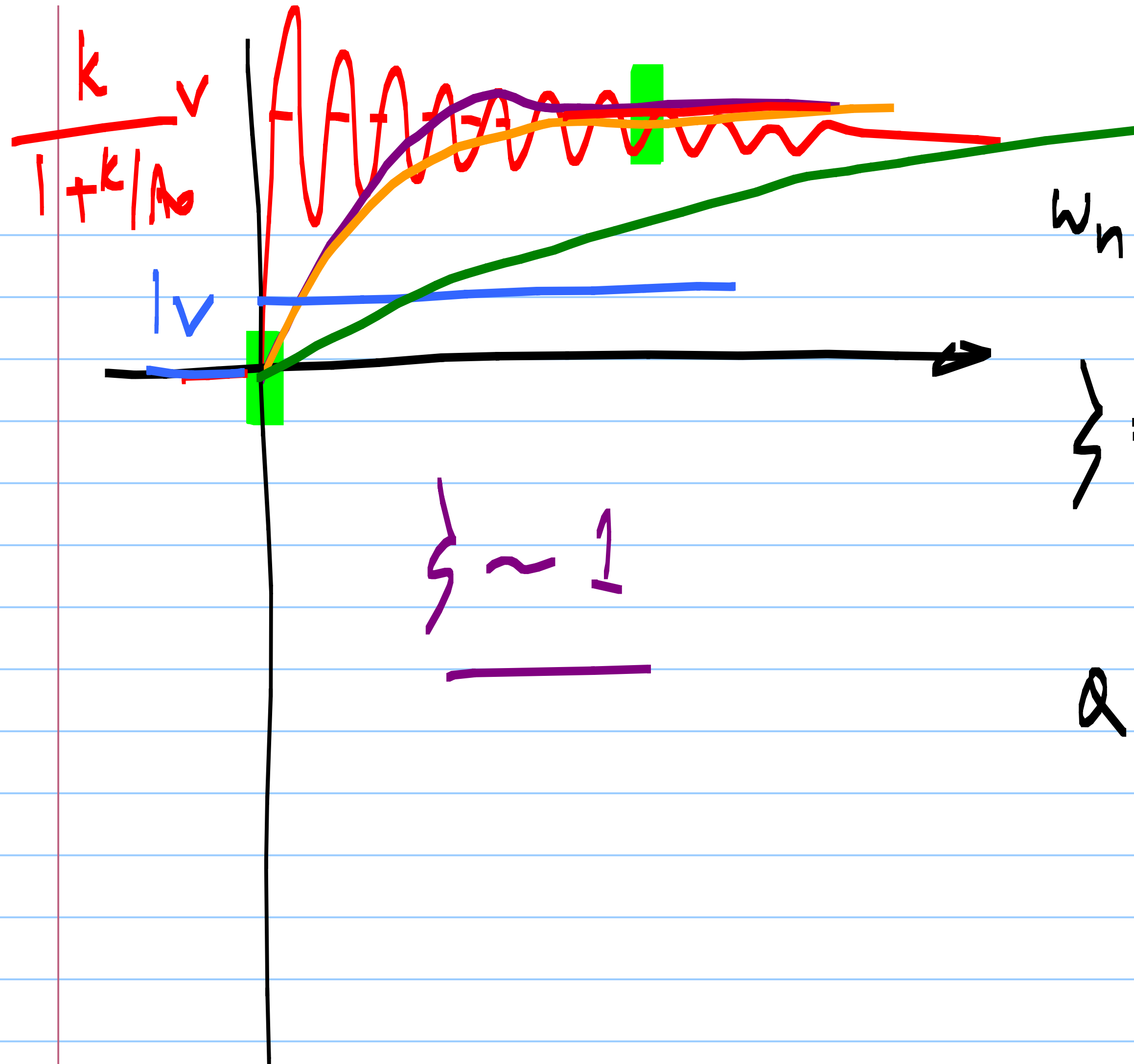
$$\frac{s^2 + 2\zeta\omega_n s + \omega_n^2}{k} \qquad \frac{s^2 + \frac{\omega_n s}{Q} + \omega_n^2}{}$$

$$\frac{V_o}{V_i} = \frac{k}{1 + \frac{k}{A(s)}} = \frac{k}{1 + \frac{k}{A_o}\left(1 + \frac{s}{p_1}\right)\left(1 + \frac{s}{p_2}\right)}$$

$$= \frac{k}{\underbrace{\left(1 + \frac{k}{A_o}\right) + s\left(\frac{1}{p_1} + \frac{1}{p_2}\right)\frac{k}{A_o} + s^2 \cdot \frac{1}{p_1 p_2}\cdot\frac{k}{A_o}}}$$

Second order polynomial with all coeff. > 0

$\Rightarrow$ roots in LHP



$\zeta \sim 1$

$$\omega_n = \sqrt{\left(\frac{A_0}{k}+1\right)\cdot(p_1 p_2)}$$

$$\zeta = \frac{1}{2}\left(\sqrt{\frac{p_1}{p_2}}+\sqrt{\frac{p_2}{p_1}}\right)\cdot\boxed{\sqrt{\frac{k}{A_0+k}}}$$

$$Q = \frac{1}{2\zeta} = \sqrt{\frac{A_0+k}{k}}\;\frac{1}{\sqrt{\frac{p_1}{p_2}}+\sqrt{\frac{p_2}{p_1}}}$$

$$\zeta = \frac{1}{2}\left[\sqrt{\frac{p_1}{p_2}} + \sqrt{\frac{p_2}{p_1}}\right] \cdot \underbrace{\sqrt{\frac{k}{A_0 + k}}}_{\text{very small because } \frac{A_0}{k} \gg 1}$$

Assume $p_1 < p_2$;

has to be made very large

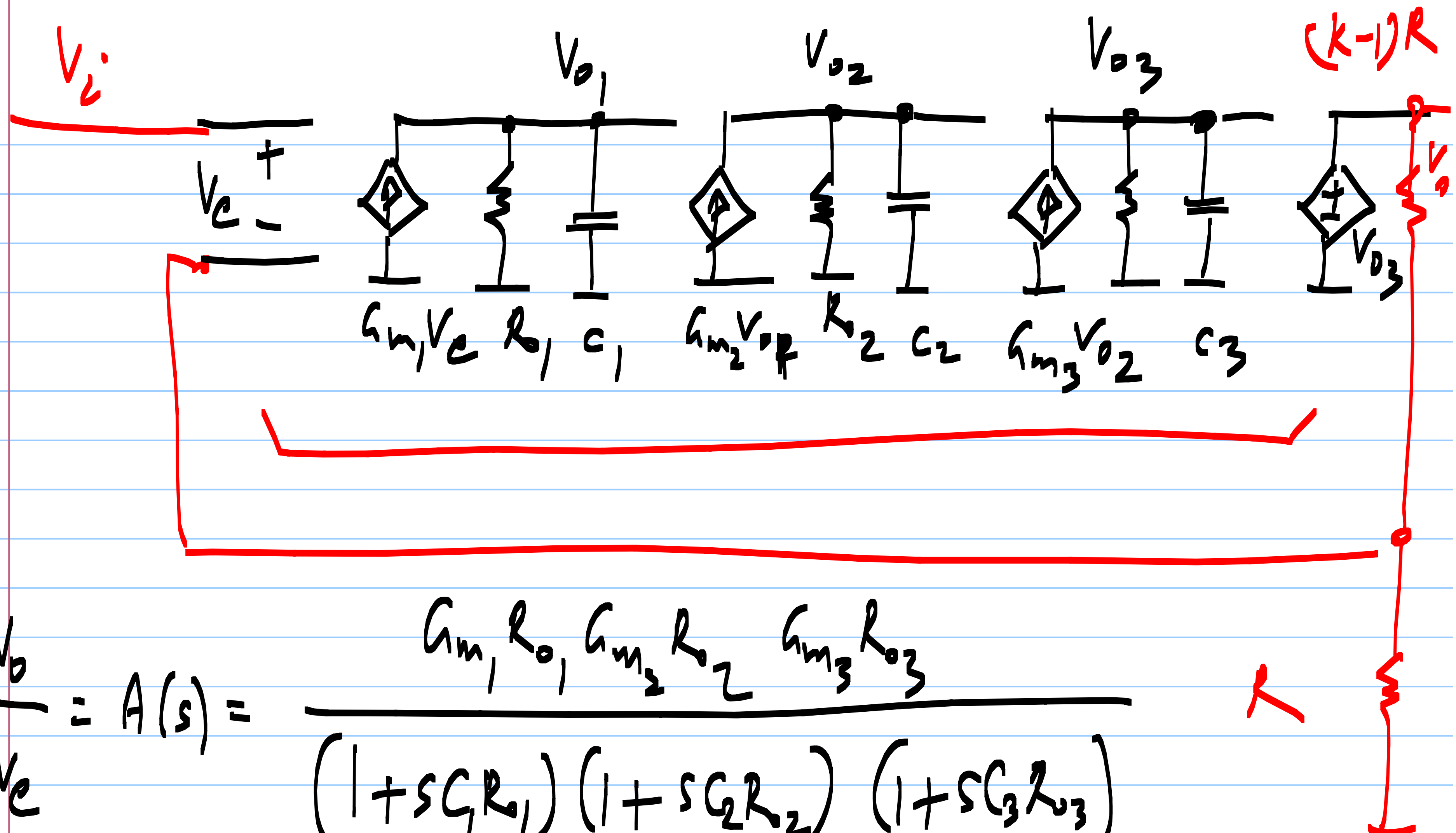
so that ζ comes close to 1

$$\zeta = 1, \quad \frac{p_2}{p_1} = 4\left(\frac{A_0}{k} + 1\right)$$

$$4\,(1000 + 1)$$

2nd order opamp

* Unconditionally stable
* For well-behaved response, poles should be widely sep.



$$\frac{V_o}{V_e} = A(s) = \frac{G_{m_1} R_{o_1} G_{m_2} R_{o_2} G_{m_3} R_{o_3}}{(1+sC_1R_{o_1})(1+sC_2R_{o_2})(1+sC_3R_{o_3})}$$

$$A(s) = \frac{A_0}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)\left(1+\frac{s}{p_3}\right)}$$

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

$$\frac{A_0}{\left(1+\frac{s}{p_1}\right)^3}$$

$$= \frac{k}{\underbrace{1 + \frac{k}{A_0}\left(1+\frac{s}{p_1}\right)^3}}$$

$$1 + \frac{k}{A_0}\left(1+\frac{s}{p_1}\right)^3 = 0$$

$$\left(1+\frac{s}{p_1}\right) = \underbrace{\sqrt[3]{-1}}\ \sqrt[3]{\frac{A_0}{k}}$$

$\frac{A_0}{k} < 8$ LHP

$\frac{A_0}{k} = 8$ Imag. axis

$$1+\frac{k}{A_0}\left(1+\frac{j\omega}{p_1}\right)^3=0 \quad \begin{cases} \text{Re} & \dfrac{A_0}{k}=8 \\ \text{Im} & \omega=\sqrt{3}\cdot p_1 \end{cases}$$

For $\frac{A_0}{k}=8$, there is a pair of poles on the $j\omega$ axis

for $\frac{A_0}{k}>8$, there is a pair of poles in the RHP