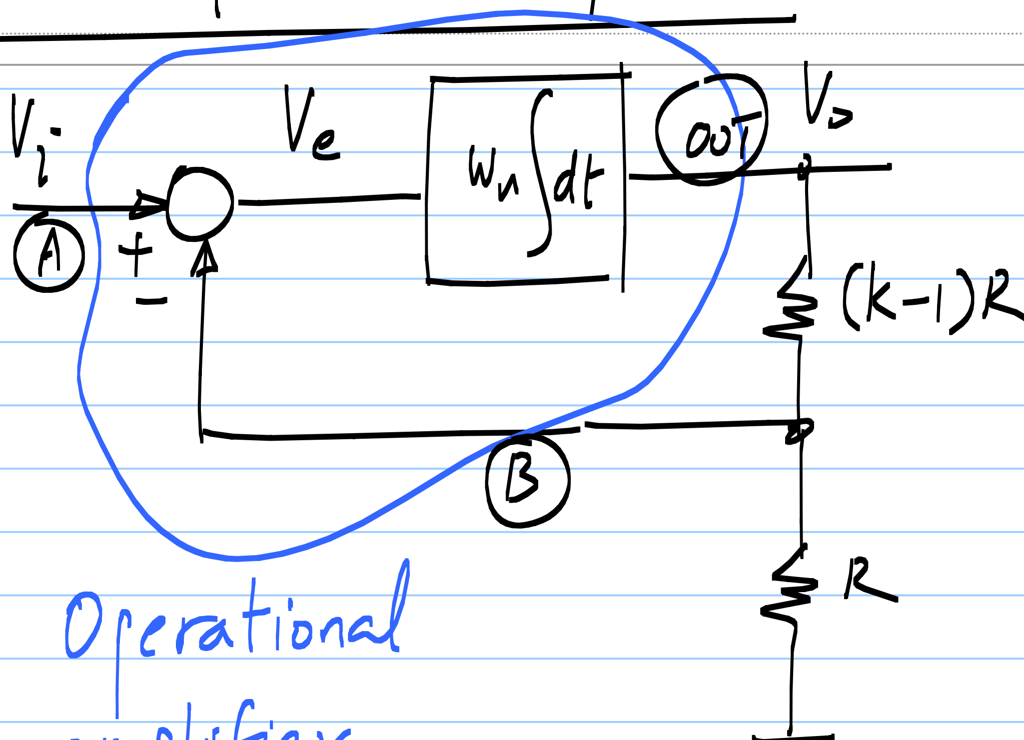
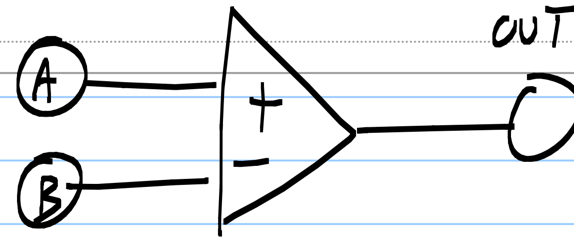
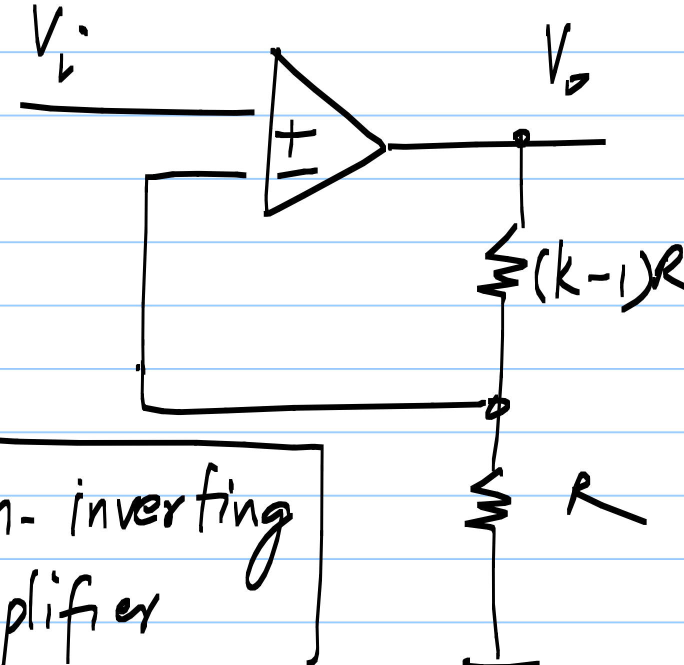
Note Title 1/20/2011

Negative feedback amplifier:



= Operational amplifier (OPAMP)





Non-inverting amplifier

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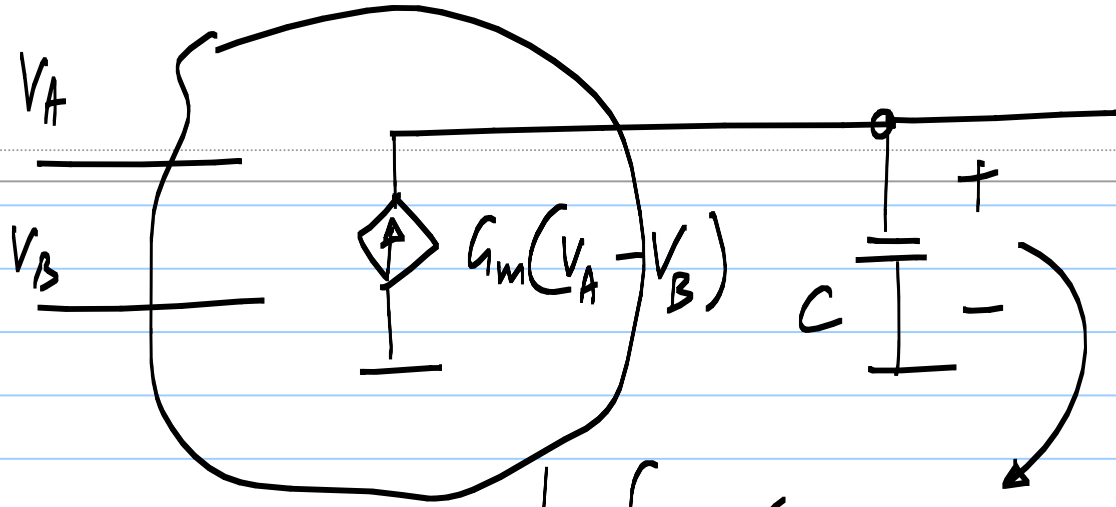
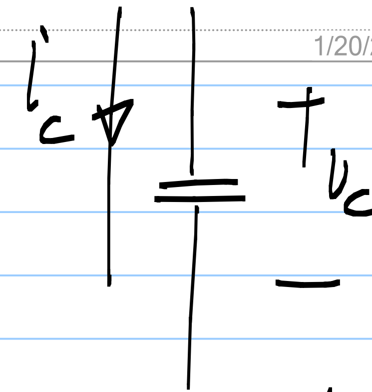
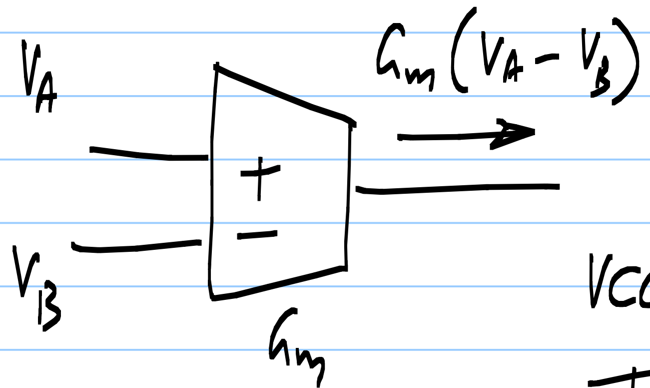


$$\frac{1}{C}\int G_m(V_A - V_B)\cdot dt$$



$$i_c = C\cdot\frac{dv_c}{dt}$$

$$v_c = \frac{1}{C}\cdot\int i_c\, dt$$



VCCS OR

Transconductor

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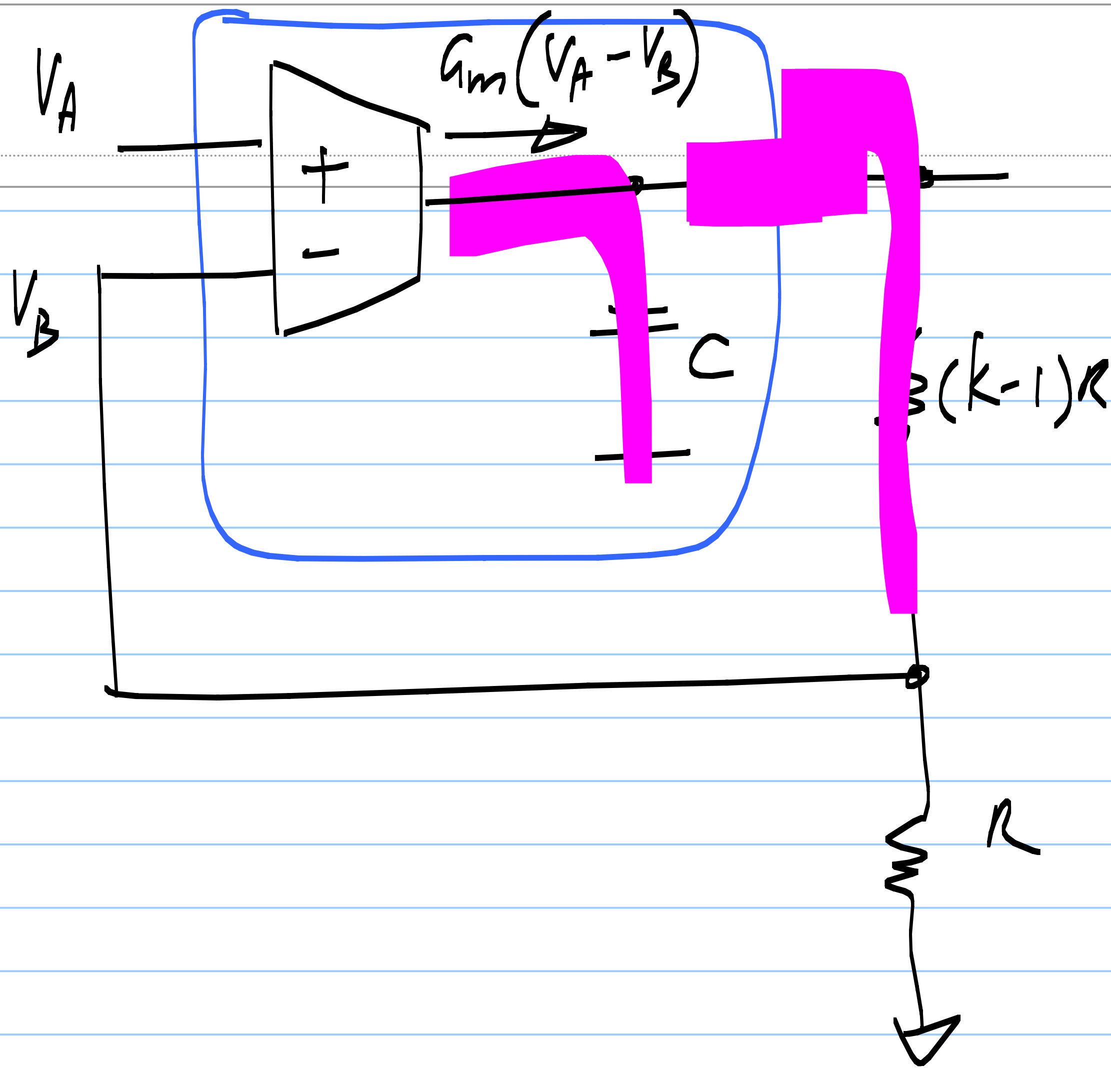
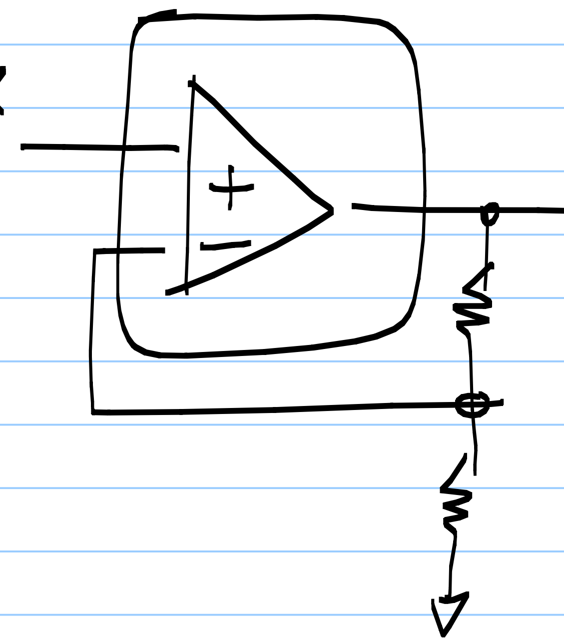
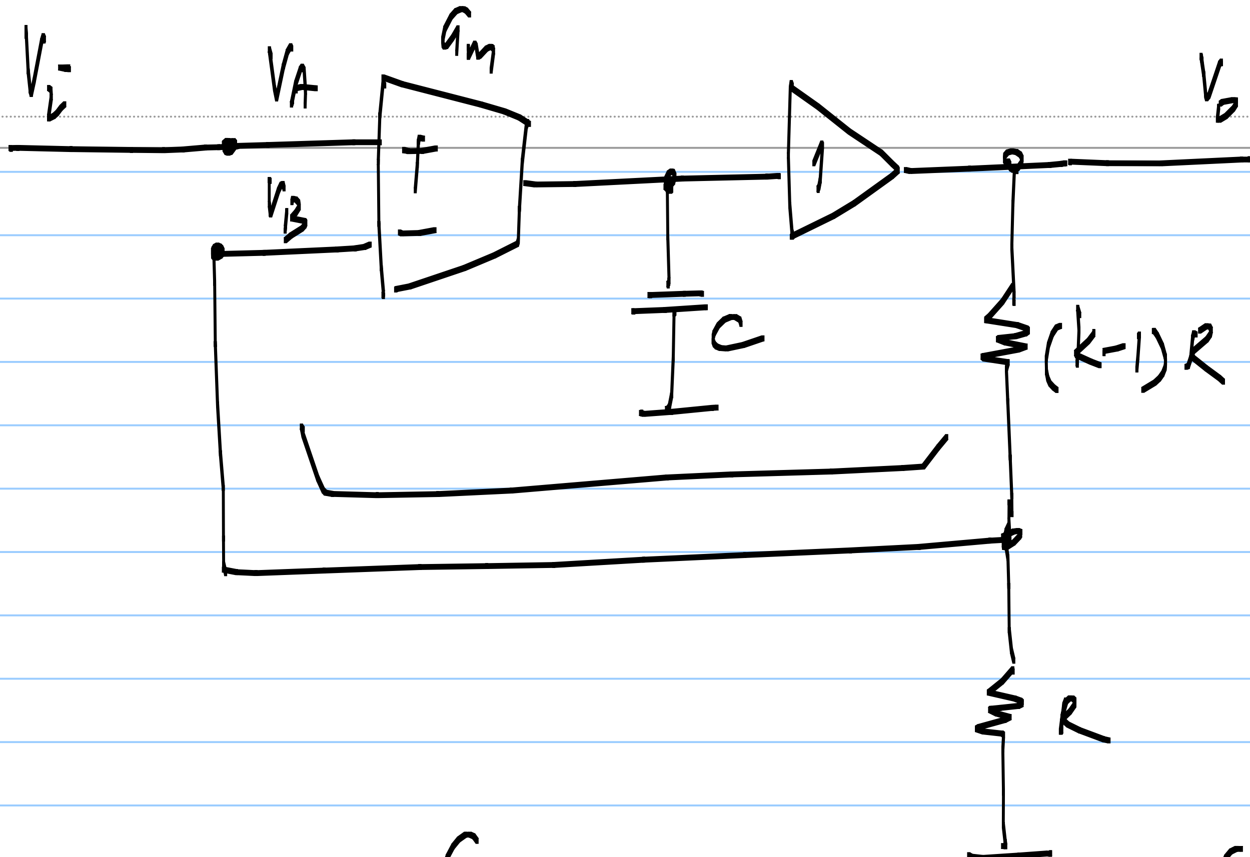


$$V_C = \frac{G_m}{C}\int (V_A - V_B)\,dt$$



Note Title

20/2011



$$\omega_u = \frac{G_m}{C}$$

$$V_o = \frac{G_m}{C}\int (V_A - V_B)\cdot dt \qquad \omega_u \int (V_A - V_B)\cdot dt$$

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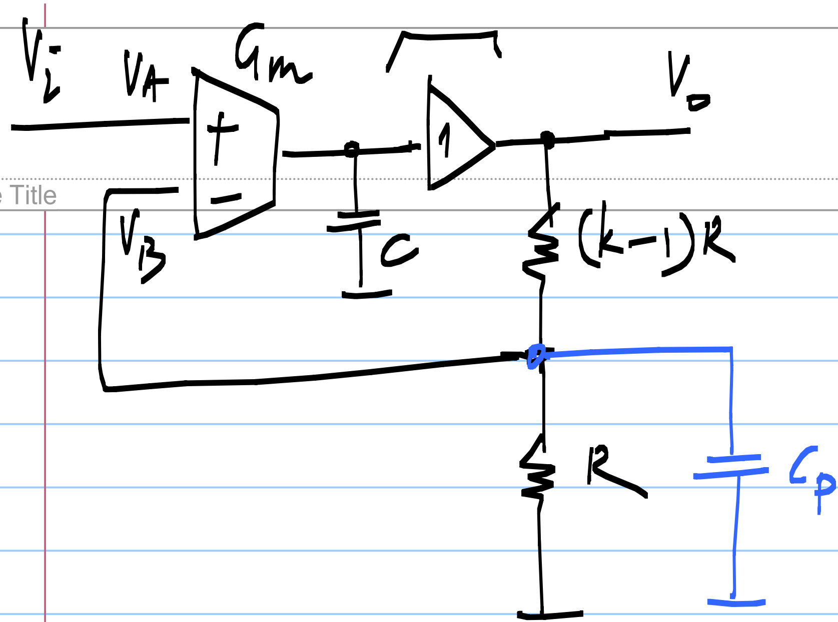

* Voltage buffer

Transfer function (ideal) = 1

In reality $= 1 \cdot \dfrac{(1+s/z_1)\cdots}{(1+s/p_1)\cdots}$

* Voltage divider

pole due to parasitic capacitance C_p

* Transconductor

$$\frac{I_{OUT}}{V_A - V_B} = G_m \cdot \frac{(1+s/z_1)\cdots}{(1+s/p_1)\cdots}$$

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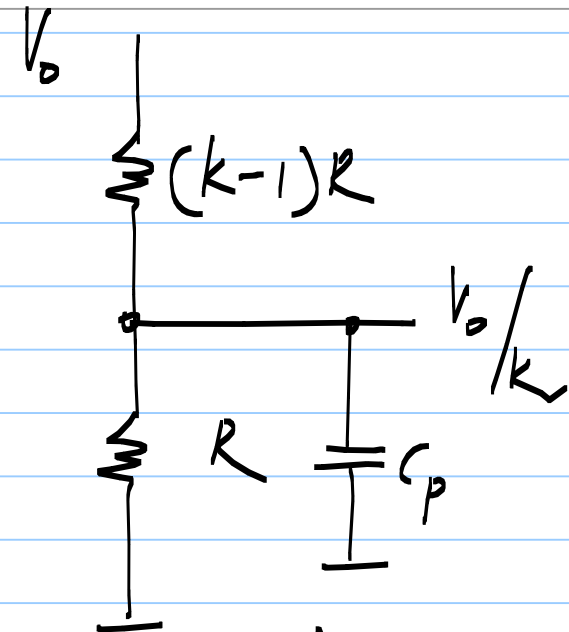
Voltage divider:



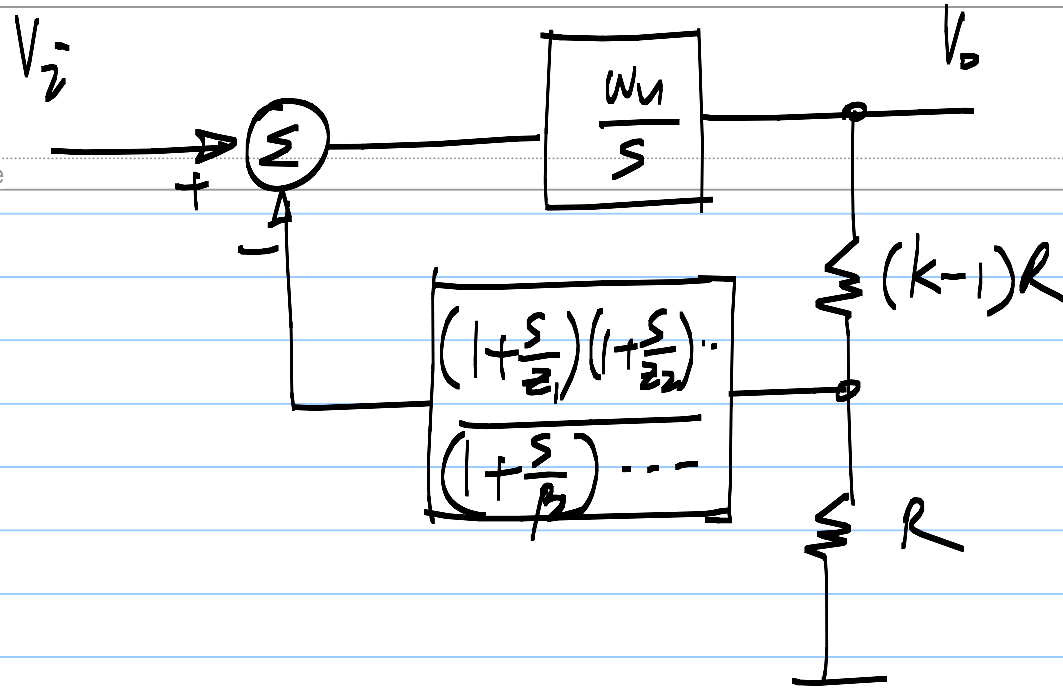
$$V_o \cdot \frac{\dfrac{R}{1+sC_pR}}{\dfrac{R}{1+sC_pR} + (k-1)R} = \frac{1}{k + (k-1)sC_pR}$$

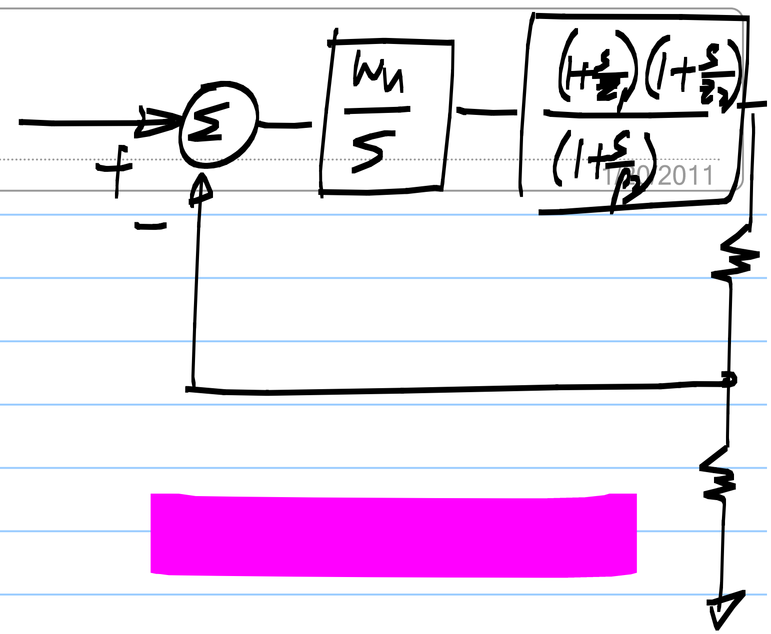
$$= \frac{1}{k} \cdot \frac{1}{1 + \dfrac{k-1}{k} \cdot sC_pR}$$

$$= \frac{1}{k} \cdot \frac{1}{\left(1 + \dfrac{s}{p_2}\right)}$$

$$p_2 = \frac{k}{k-1} \cdot \frac{1}{C_pR}$$

Note Title





* Extra poles & zeros in the system

* Poles & zeros ← Transconductor, Buffer, Voltage divider

* Modeled by poles/zeros in the fb. path/fwd path

Model all the extra poles & zeros in the forward path

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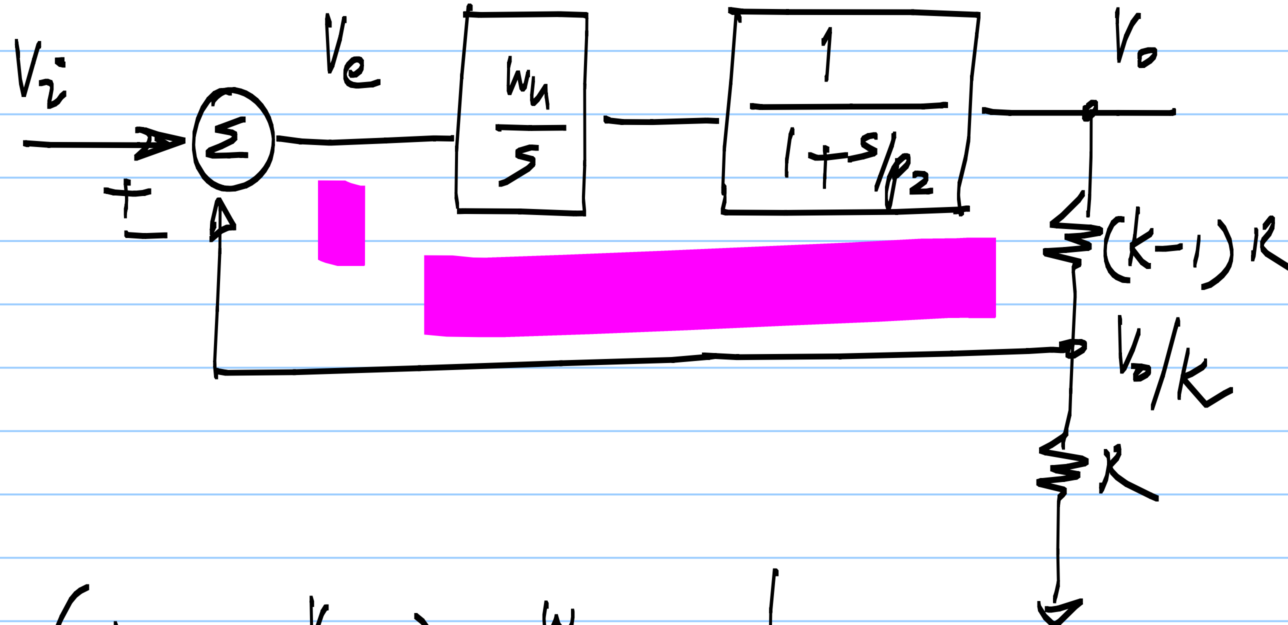

$$\left(V_o - \frac{V_o}{k}\right) \cdot \frac{\omega_u}{s} \cdot \frac{1}{1+s/p_2} = V_o$$

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$$\left(V_i - \frac{V_o}{k}\right)\frac{\omega_u}{s}\frac{1}{1+\frac{s}{p_2}} = V_o$$

$$V_i = V_o \cdot \frac{s}{\omega_u} \cdot \left(1+\frac{s}{p_2}\right) + \frac{V_o}{k}$$

$$\frac{V_o}{V_i} = \frac{1}{\frac{1}{k} + \frac{s}{\omega_u} + \frac{s^2}{\omega_u p_2}}$$

$$= k\frac{1}{1 + \frac{s \cdot k}{\omega_u} + \frac{s^2 \cdot k}{\omega_u \cdot p_2}}$$

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$$\frac{V_o}{V_i} = k \frac{1}{1 + s\cdot\frac{k}{w_u} + s^2\cdot\frac{k}{w_u \cdot p_2}}$$

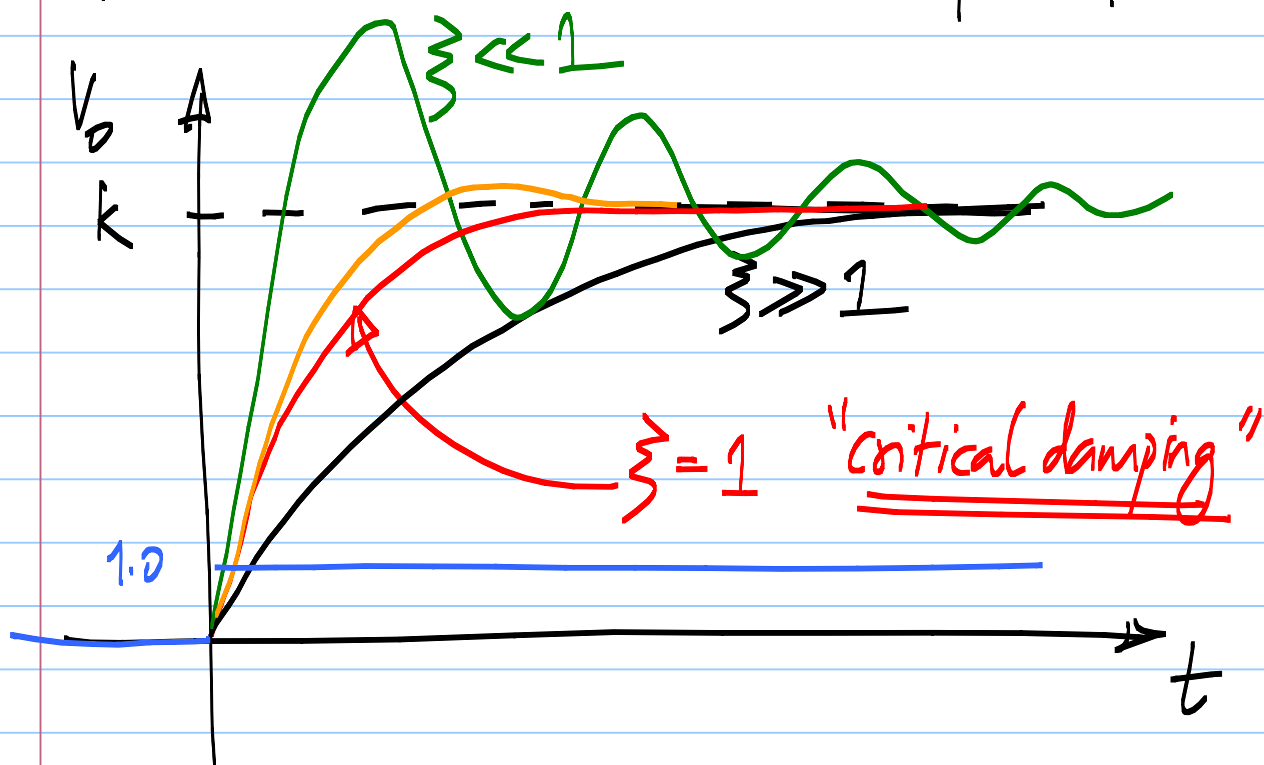
$$= k \cdot \left[\frac{w_u p_2/k}{s^2 + s\cdot p_2 + \frac{w_u p_2}{k}}\right] \qquad \frac{p_2}{2\sqrt{\frac{w_u p_2}{k}}}$$

natural frequency $= w_n = \sqrt{\frac{w_u \cdot p_2}{k}}$

damping factor $= \xi = \frac{1}{2}\frac{\sqrt{p_2}}{\sqrt{w_u/k}}$

Negative feedback amplifier with an extra pole in the fwd path

* Second order transfer fn.



dc gain = k

$$\omega_n = \sqrt{p_2 \cdot \frac{\omega_u}{k}}$$

$$\zeta = \frac{1}{2} \frac{\sqrt{p_2}}{\sqrt{\omega_u / k}}$$

Desired response : critically damped or slightly underdamped

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$$\xi = 1.0 \qquad \xi = \frac{1}{2}\sqrt{\frac{p_2}{\omega_n/k}} = 1.0$$

$$p_2 = 4 \cdot \left(\frac{\omega_n}{k}\right)$$

Underdamped response

if $\xi \ll 1$

$$p_2 \ll 4 \cdot \frac{\omega_n}{k}$$

$$\boxed{\xi = 1 \quad \equiv \quad T_d = \frac{1}{e}\left(\frac{k}{\omega_n}\right) \qquad p_2 = 4\,\frac{\omega_n}{k}}$$

Critical damping

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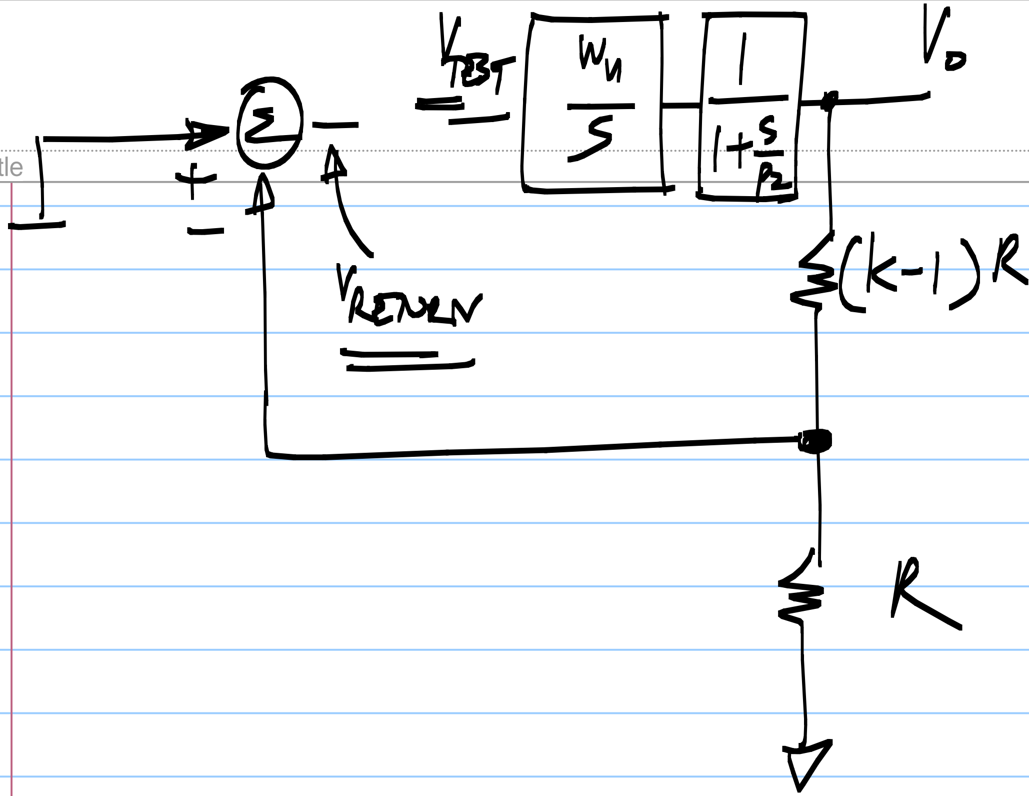

$$L(s) = -\frac{V_{RETURN}}{V_{TEST}}$$

$$= \frac{\omega_u}{s \cdot k}$$

$$L(s) = \frac{\omega_u}{s \cdot k} \frac{1}{1+\frac{s}{p_2}}$$

(w/ extra pole)

① No extra pole:

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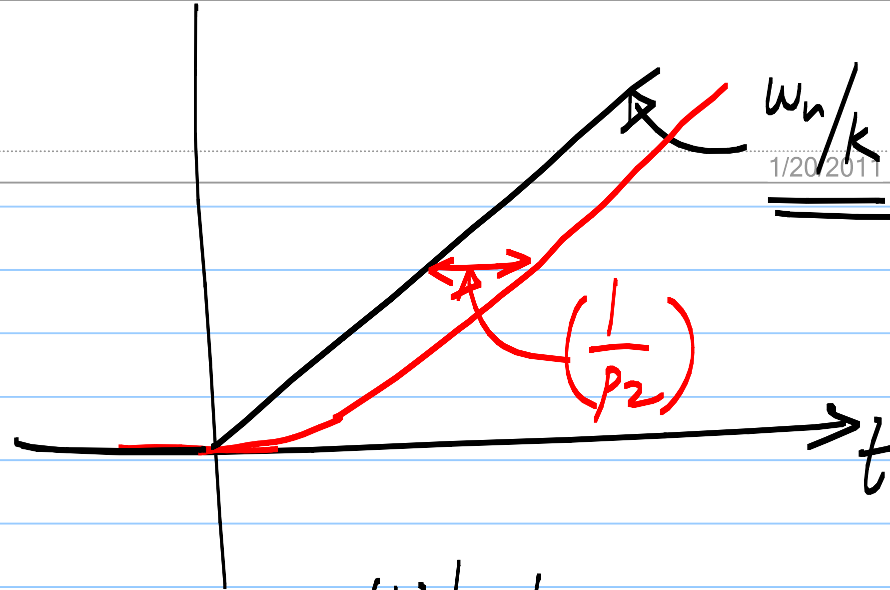
$$\text{Loop gain} = \frac{\omega_u/k}{s}$$



Unit step response of the loop gain

② 1 extra pole

$$\text{Loop gain} = \underbrace{\frac{\omega_u/k}{s} \cdot \frac{1}{1+s/p_2}}$$

Step response is delayed by $\left(\frac{1}{p_2}\right)$

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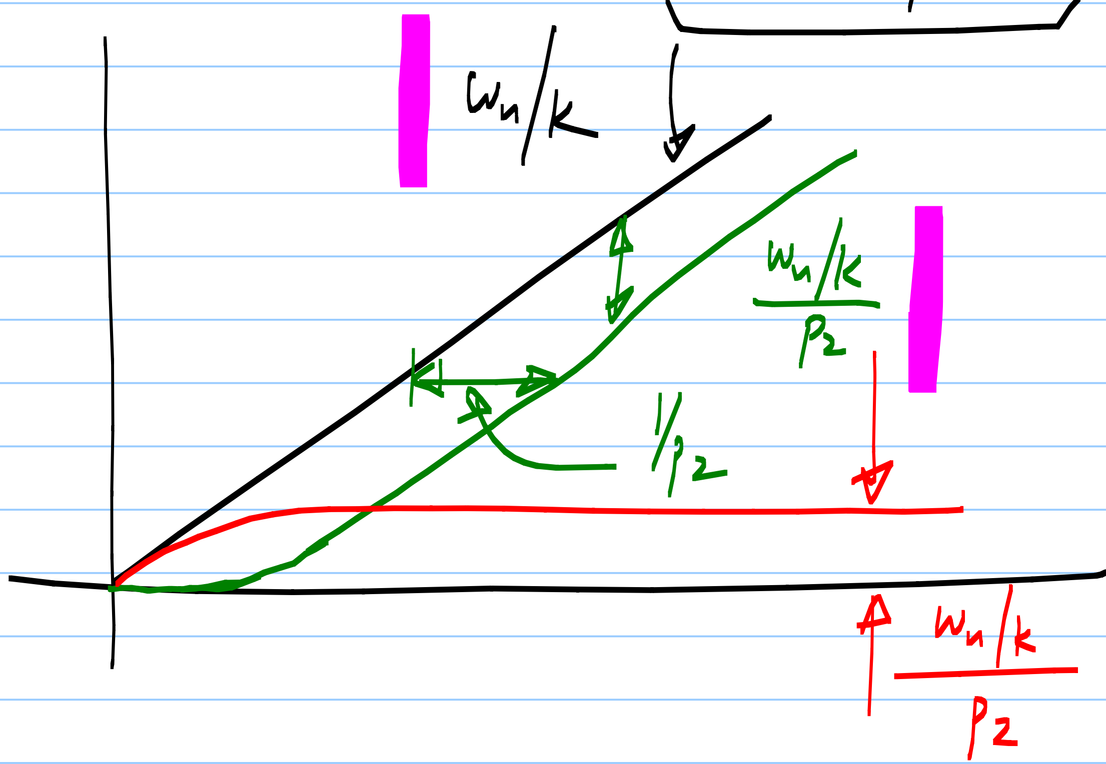
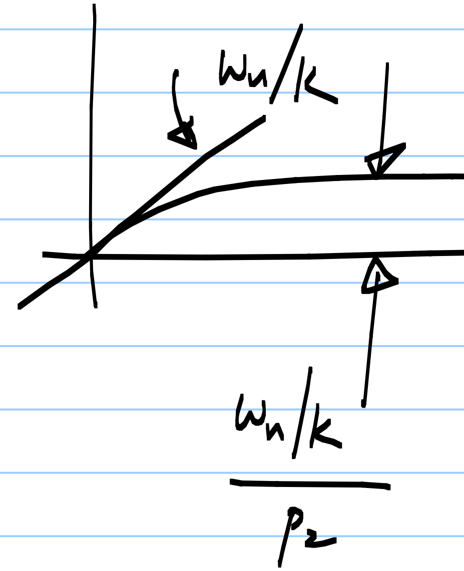
$$L(s) = \frac{\omega_n/K}{s} \cdot \frac{1}{1 + s/p_2}$$

$$= \frac{\omega_n/K}{s} - \underbrace{\frac{\left[(\omega_n/K)/p_2\right]}{1 + s/p_2}}$$

$$\frac{1 - \exp(-p_2 t)}{}$$





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