Negative feedback amplifier transfer function :

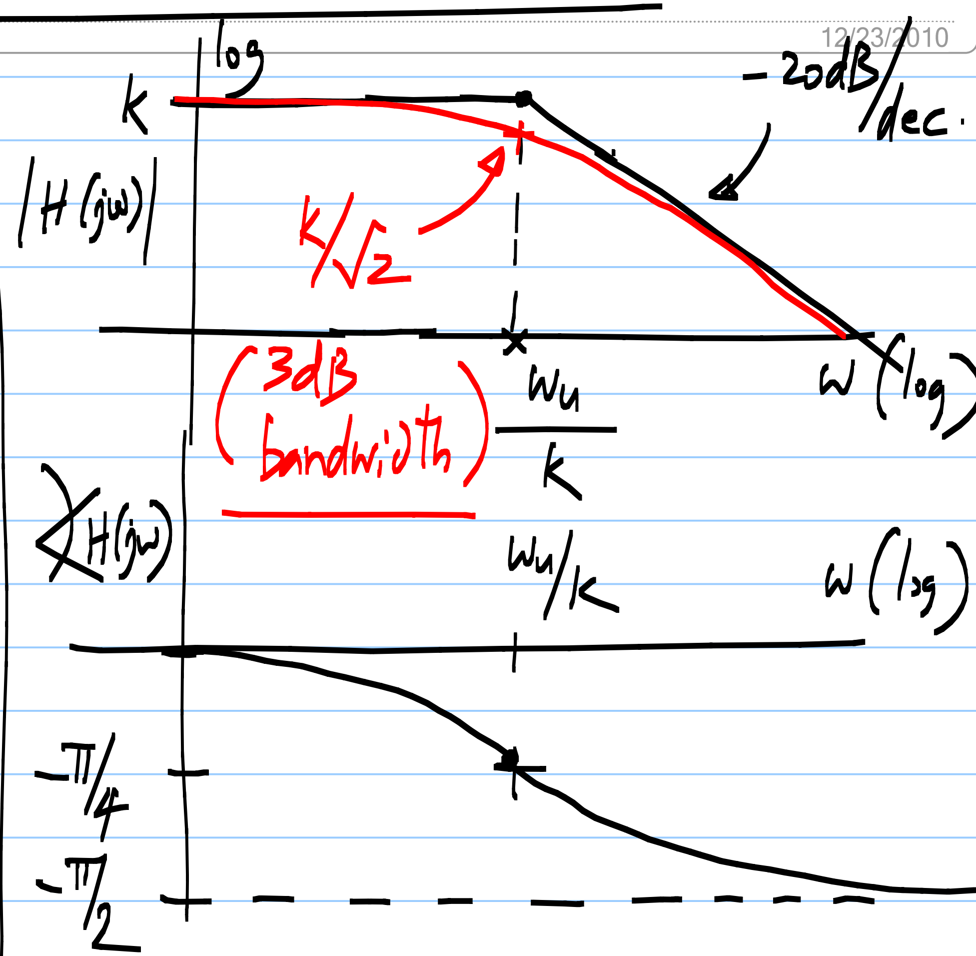
Note Title 12/23/2010

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

$$H(j\omega) = \frac{k}{1 + j\omega\cdot\frac{k}{\omega_u}}$$

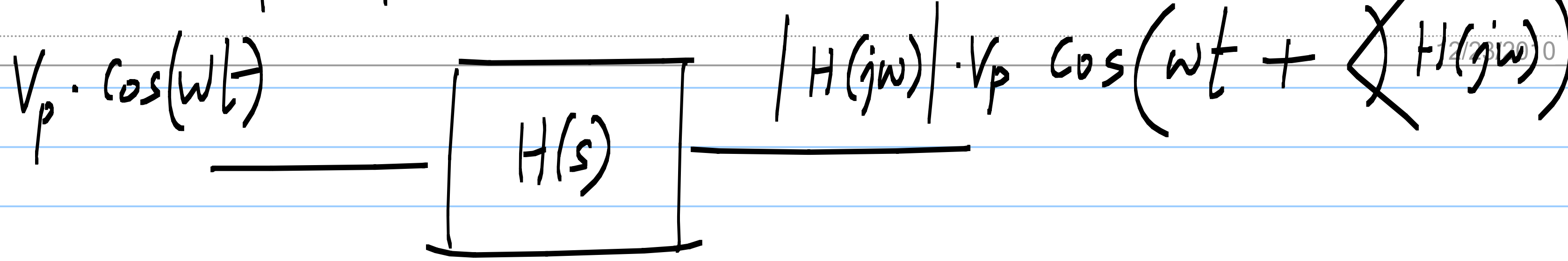
$$\left|H(j\omega)\right| = \frac{k}{\sqrt{1 + \frac{k^2\omega^2}{\omega_u^2}}}$$

$$\angle H(j\omega) = -\tan^{-1}\left(\frac{\omega\cdot k}{\omega_u}\right)$$



Note Title

Transfer function : $H(s)$



Input : $V_p \cos \omega t$

Output : $$\frac{k V_p}{\sqrt{1 + \frac{\omega^2 k^2}{\omega_n^2}}} \cdot \cos\left(\omega t - \tan^{-1}\left(\frac{\omega \cdot k}{\omega_n}\right)\right)$$

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Input : $V_p \cos \omega t$

Output : $\dfrac{kV_p}{\sqrt{1+\dfrac{\omega^2 k^2}{\omega_u^2}}} \cdot \cos\left(\omega t - \tan^{-1}\left(\dfrac{\omega \cdot k}{\underline{\underline{\omega_u}}}\right)\right)$

$\boxed{\omega \ll \dfrac{\omega_u}{k}}$ $\qquad \tan^{-1} x \simeq x$

Output $\simeq$ $kV_p \cdot \cos\left(\omega t - \dfrac{\omega \cdot k}{\omega_u}\right)$

$= \underline{\underline{kV_p}} \cos\left(\omega\left(t - \underbrace{\dfrac{k}{\omega_u}}\right)\right)$

Amplitude $= kV_p$ (Gain $= k$)

delay $\left(\dfrac{k}{\omega_u}\right)$

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Output:
$$\frac{k V_p}{\sqrt{1+\frac{\omega^2 k^2}{\omega_u^2}}} \cos\left(\omega t - \tan^{-1}\left(\frac{\omega \cdot k}{\omega_u}\right)\right)$$

$$\omega \gg \frac{\omega_u}{k} \qquad \frac{k V_p}{\sqrt{k^2\omega^2/\omega_u^2}} = \frac{\omega_u}{\omega} \cdot V_p$$

$$\text{output} \simeq \underline{\frac{\omega_u}{\omega} \cdot V_p \cdot \cos\left(\omega t - \pi/2\right)}$$

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Low frequencies $\left(\omega \ll \frac{\omega_u}{k}\right)$

Output $\simeq$ $kV_p \cos\left(\omega\left(t - \frac{k}{\omega_u}\right)\right)$ — Amplifier working properly

- Ideal gain — independent of ω_u, the parameter of the integrator
- Delay k/ω_u

High frequencies $\left(\omega \gg \frac{\omega_u}{k}\right)$

Output $\simeq$ $\frac{\omega}{\omega_u} \cdot \cos\left(\omega t - \pi/2\right)$ — Amplifier is "not working properly"

$\boxed{\text{Bandwidth = usable range of } \omega}$

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Frequency domain analysis:

- The amplifier is usable for frequencies below $\frac{\omega_u}{K}$ ($\leftarrow$ Bandwidth of the system)
- For higher bandwidth, use an integrator with a higher ω_u

Time domain:

Step response: $V_o(t) = kV_x\left(1 - \exp\left(-\frac{\omega_u t}{k}\right)\right)$

time constant $= k/\omega_u$

Frequency domain:

pole: $-\omega_u/k \longrightarrow$ Bandwidth $= \frac{\omega_u}{k}$

$$\boxed{\text{what is the significance of } \frac{\omega_u}{k}\text{?}}$$

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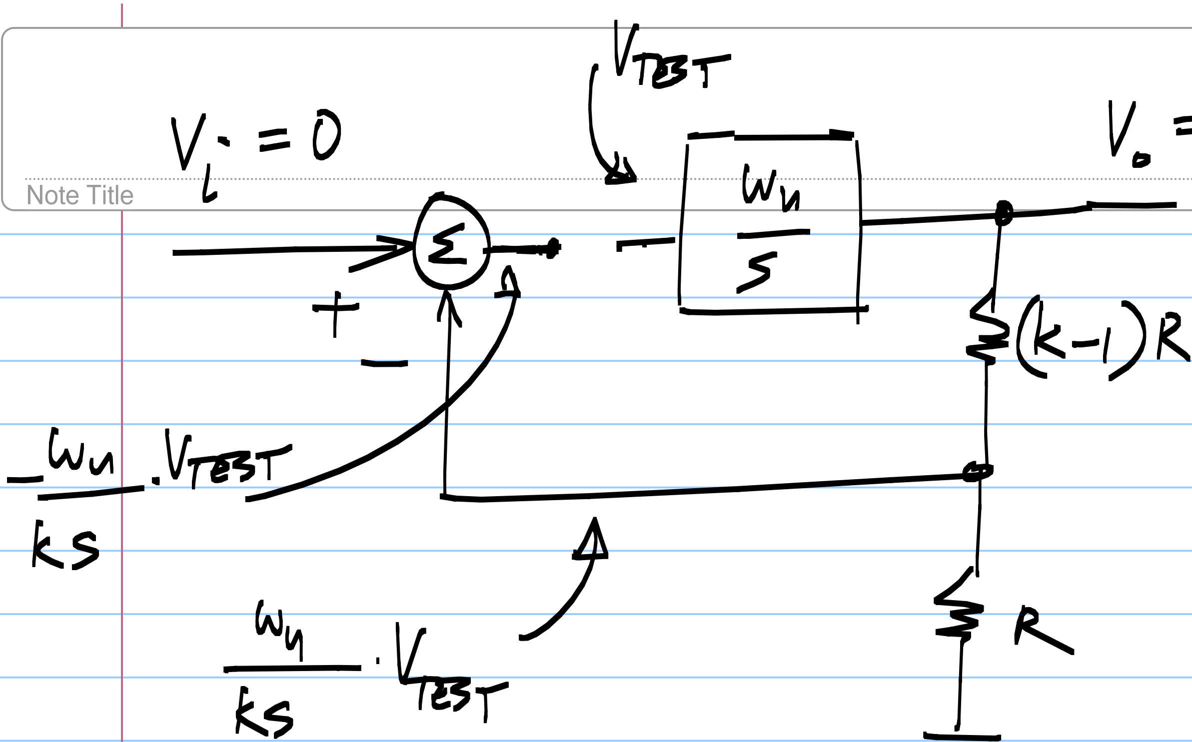

$$V_o = \frac{\omega_u}{s} \cdot V_{TEST}$$

$L(s)$: loop gain

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

$$V_{RETURN} = -\frac{\omega_u}{ks} \cdot V_{TEST}$$

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

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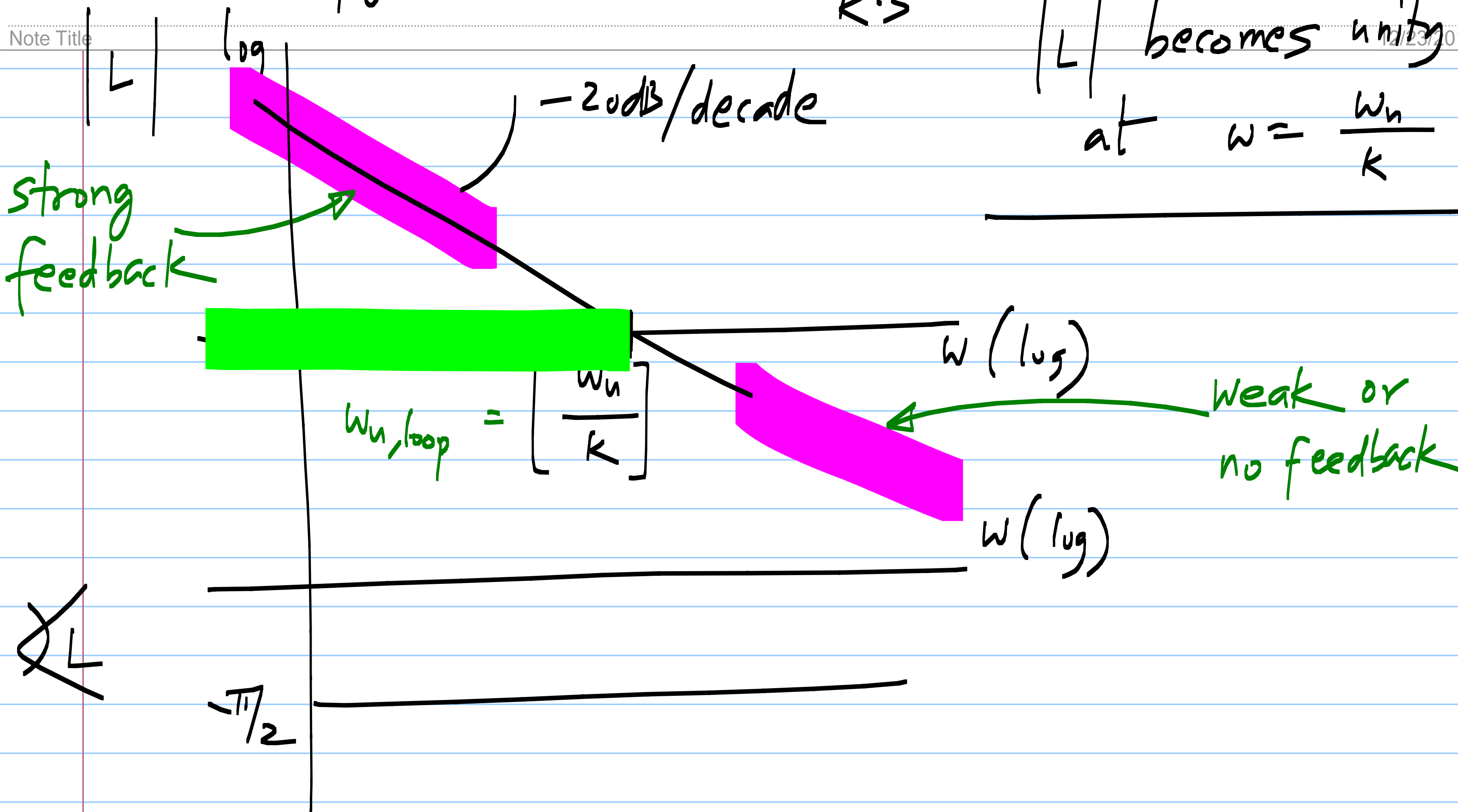
Loopgain $L(s) = \frac{\omega_n}{k \cdot s}$

$|L|$ becomes unity at $\omega = \frac{\omega_n}{k}$



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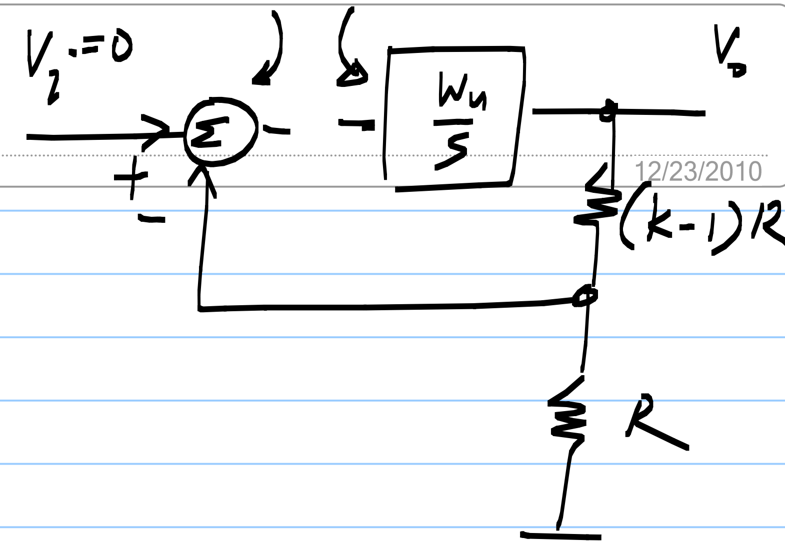
$$\frac{V_{RETURN}}{V_{TEST}} = -L(s)$$



$L(s)$: loop gain

Frequencies where $|L(j\omega)| \gg 1$

- strong feedback
- ideal behavior

unity loop gain frequency : $\omega_{u,loop}$

Frequencies where $|L(j\omega)| \ll 1$

- weak feedback, non-ideal behavior

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The unity loop gain frequency $\omega_{u,loop}$ is the frequency at which $|L(j\omega)| = 1$

- divides regions of ideal & non ideal behavior
- $\omega_{u,loop} \simeq$ bandwidth of the negative feedback system.

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

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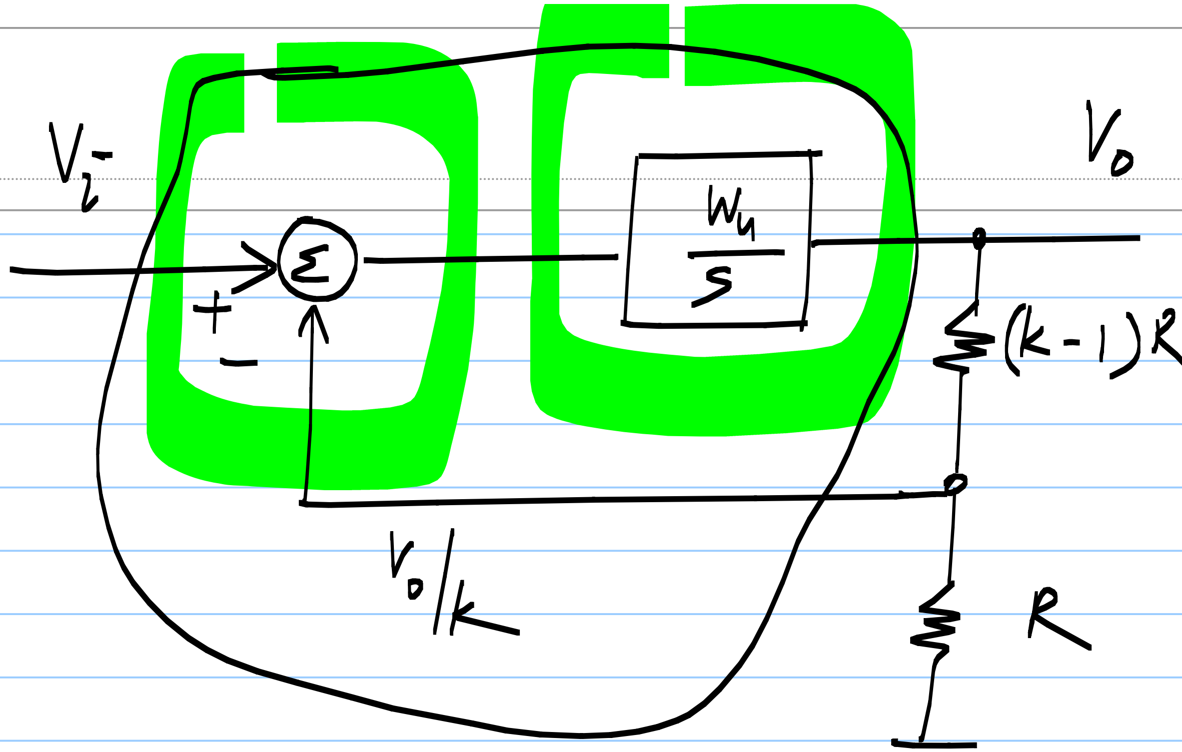

- Difference between input & feedback
- Integrates

Operational amplifier (opamp)

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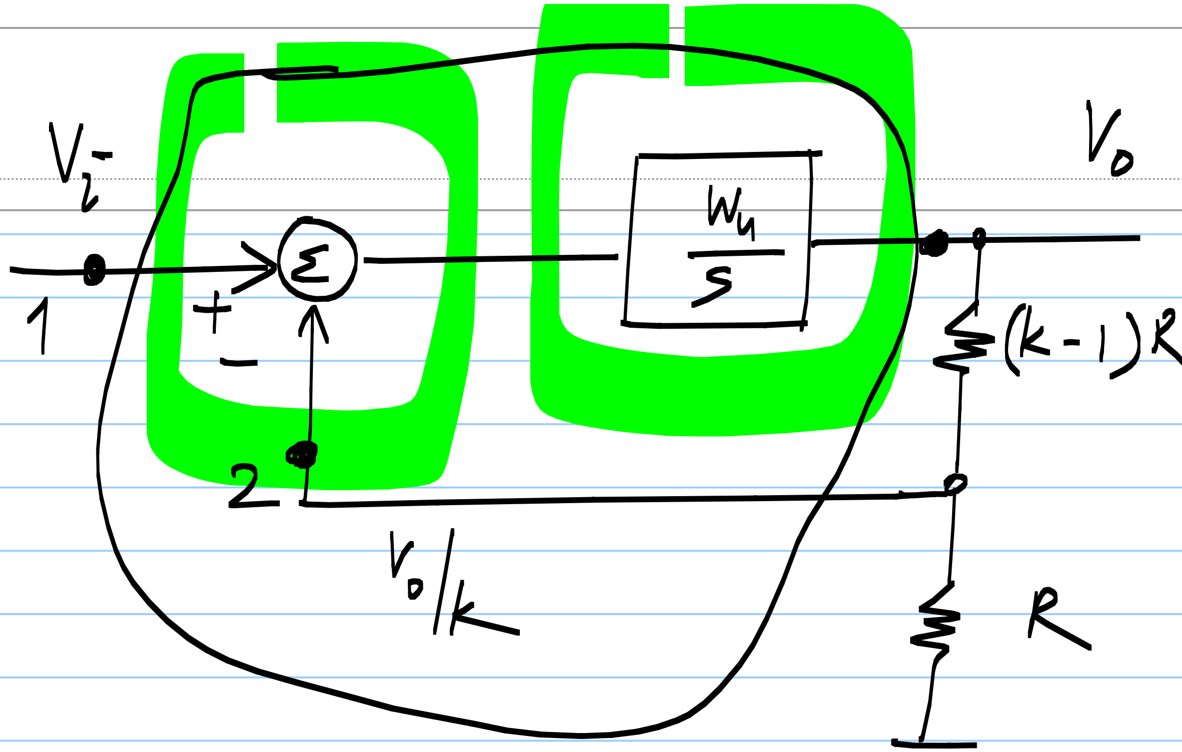
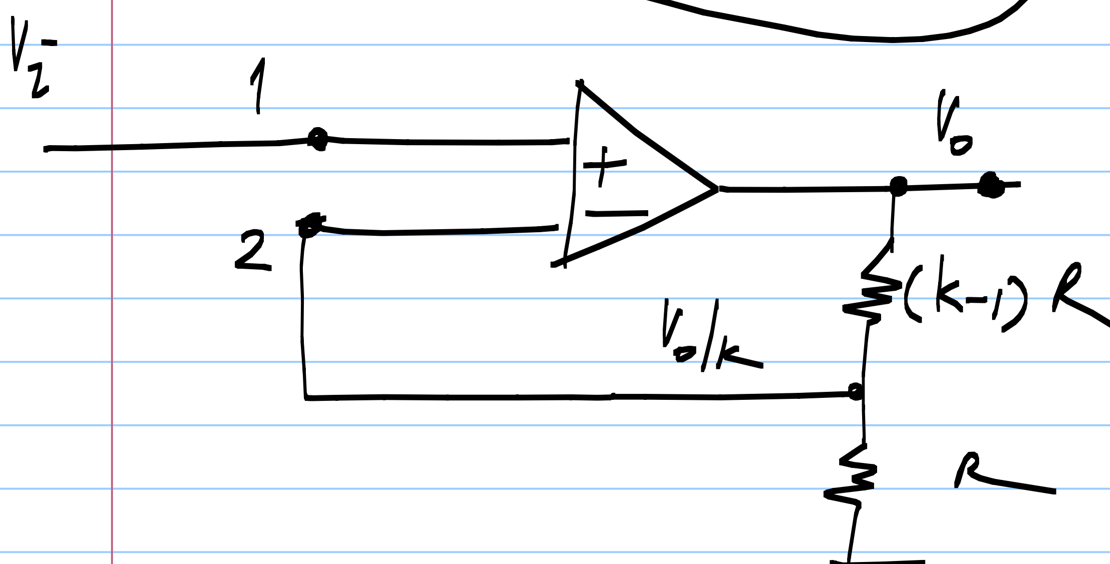
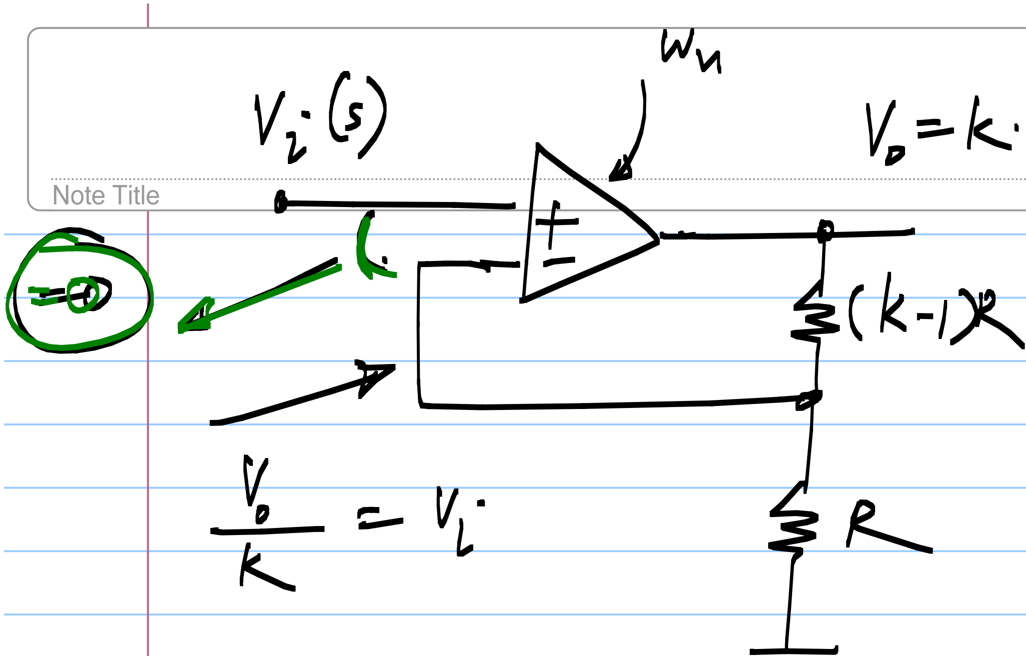




(dc gain > 0)

"Non inverting" amplifier



ω_u : unity gain frequency of the opamp

$$\frac{V_o}{k} = V_i$$

Bandwidth $= \dfrac{\omega_u}{k}$

$\omega_u = \infty$

$\Rightarrow$ Bandwidth $= \infty$

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

Ideal opamp:

$\omega_u \to \infty$