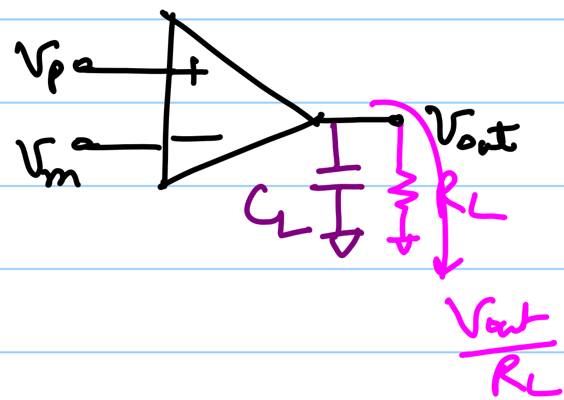
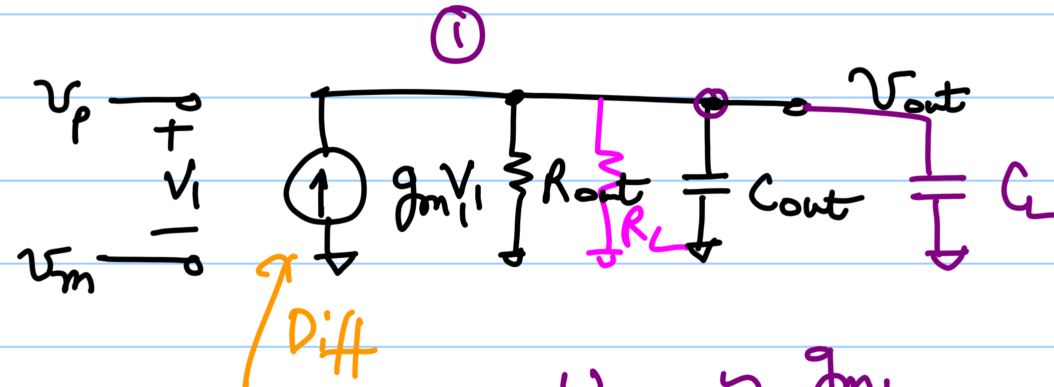
ECE 511 - Lecture 24

Note Title 4/24/2014

Single Stage Diff Amplifier



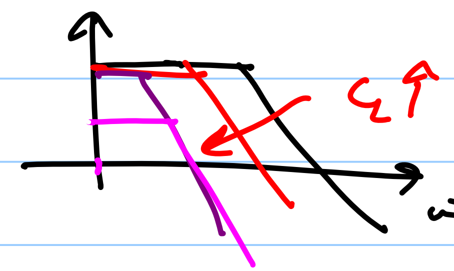


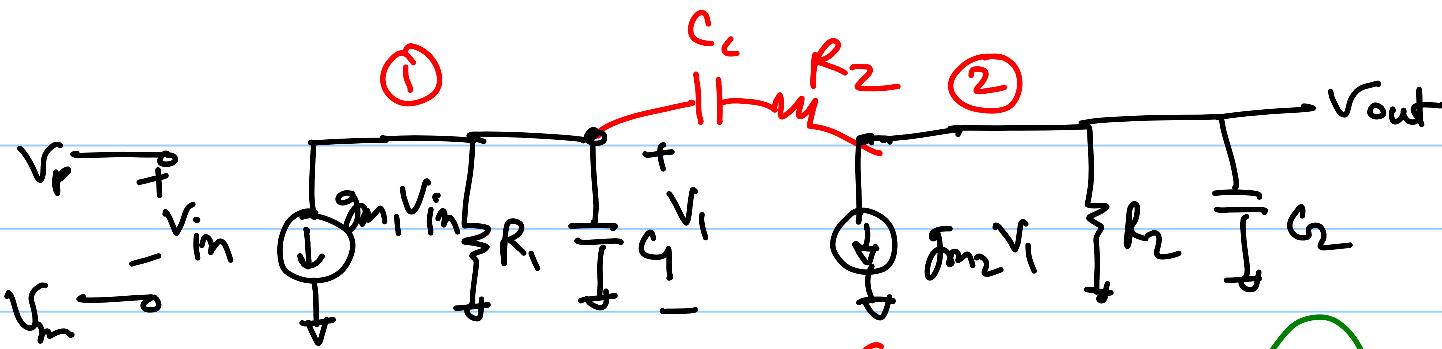
$\omega_{un} \simeq \frac{g_{m1}}{C_L}$

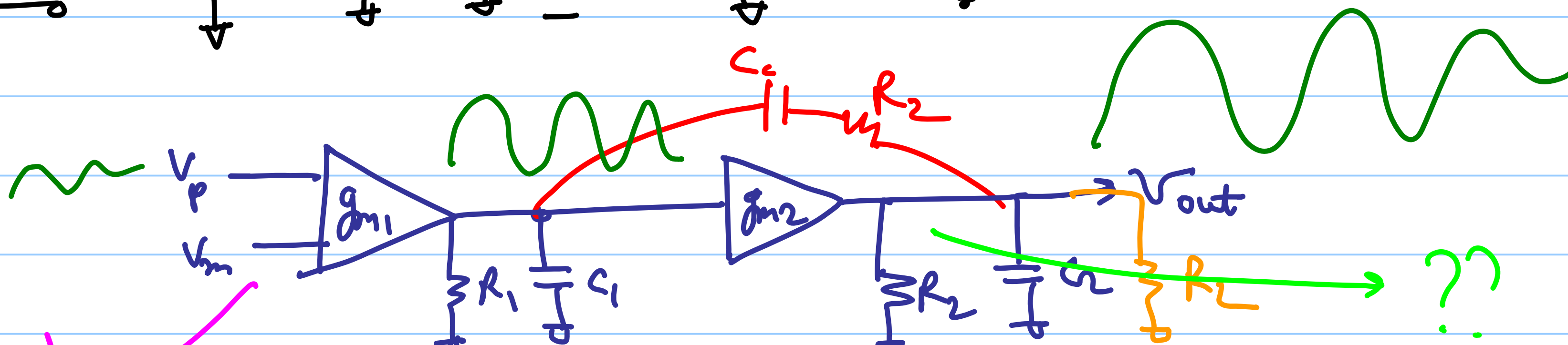
$A_v = g_{m1} \cancel{R_{out}}$

$g_{m1} (R_{out} || R_L)$

Slewing







CMLoad Diffamp

Telescopic

Folded Cascode

⋮

$g_{m1}R_1$

High-Stage

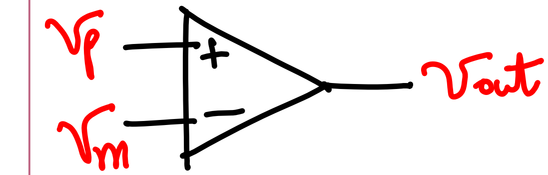
$\underbrace{g_{m2}(R_2||R_L)}$

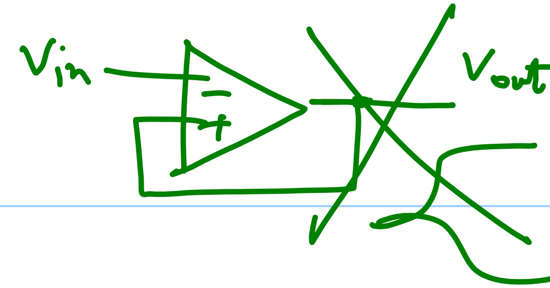
High swing

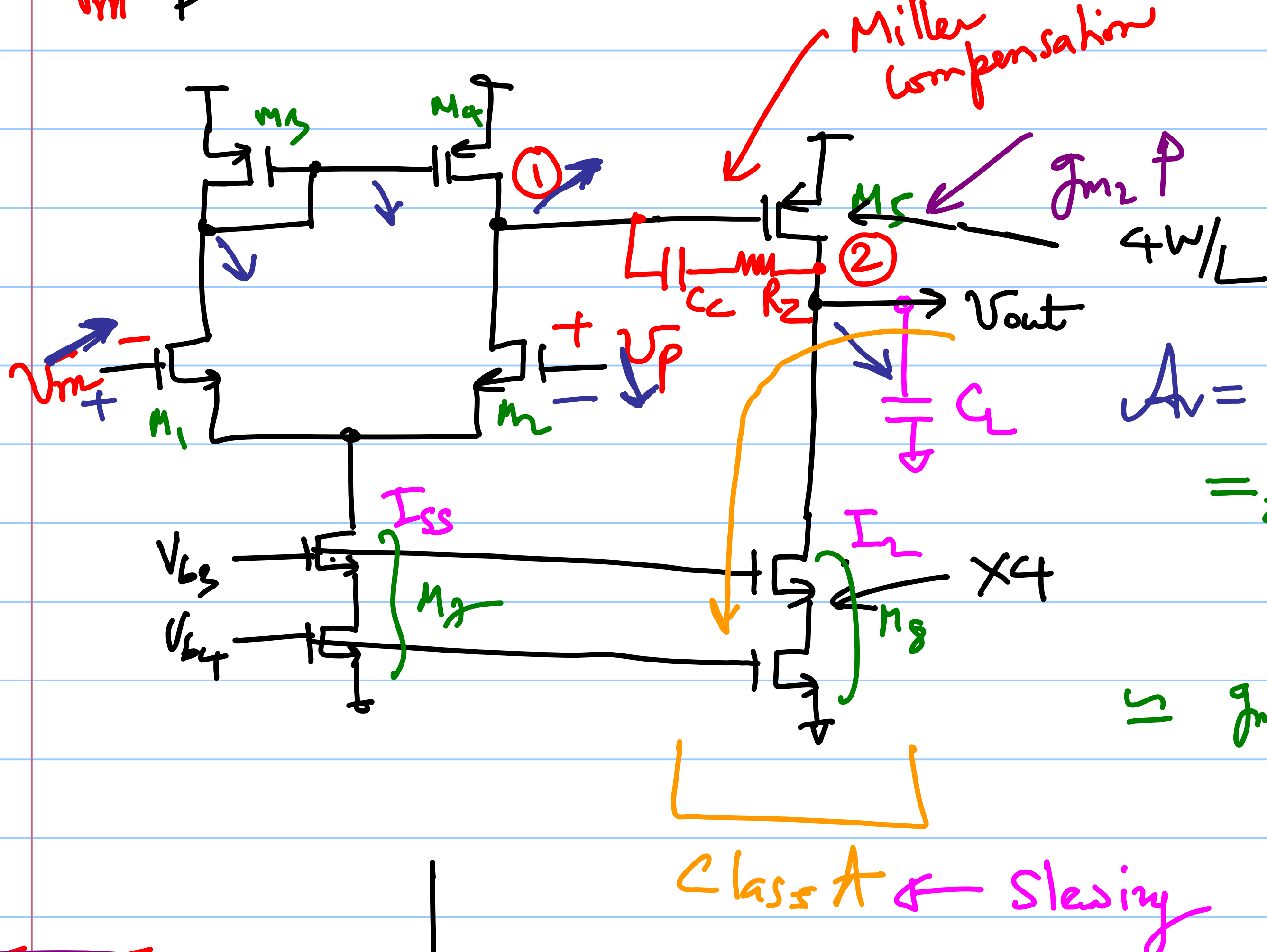
large load drive capacity

isolate gain from swing/drive requirements

* Diffamp has a limited o/p swing



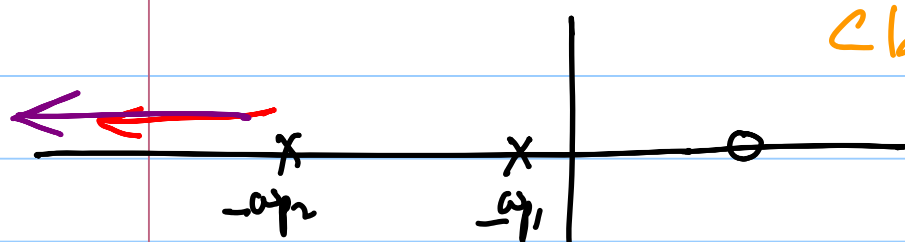




$$A_v = A_{v_1} \cdot A_{v_2}$$

$$= g_{m_{1,2}} (r_{o_2} \| r_{o_4}) \times g_{m_5} \cdot (r_{o_5} \| g_{m_8} r_{o_8}^2)$$

$$\simeq g_{m_{1,2}} (r_{o_2} \| r_{o_4}) \times g_{m_5} r_{o_5}$$



Second stage have higher
Mx (W/L) for g_{m_2} ↑

$$\downarrow \omega_{um} = \frac{g_{m1}}{C_{c}}$$

$$\omega_{p2}\uparrow \sim f\left(\frac{g_{m2}}{C_L}\uparrow\right)$$

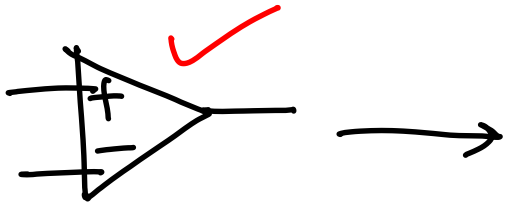
$C_c \uparrow$

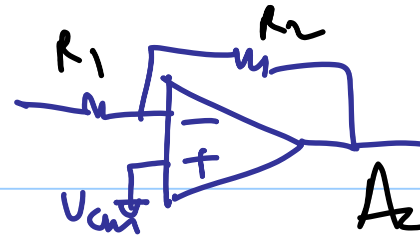
V_{ov}

$$\boxed{f_T \propto \frac{V_{ov}}{L}}$$

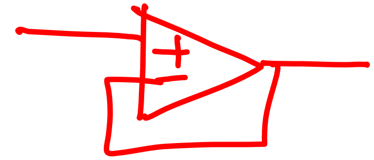
$\left\{ \begin{array}{l} g_{m1} \\ C_c \\ g_{m2} \end{array} \right.$

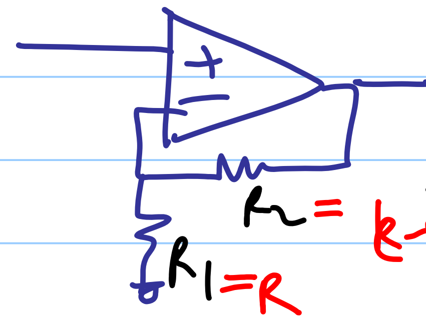
$$\boxed{V_{ov} = 2\text{–}5\% \text{ of } V_{DD}}$$





$A_{v} = -\frac{R_2}{R_1}$



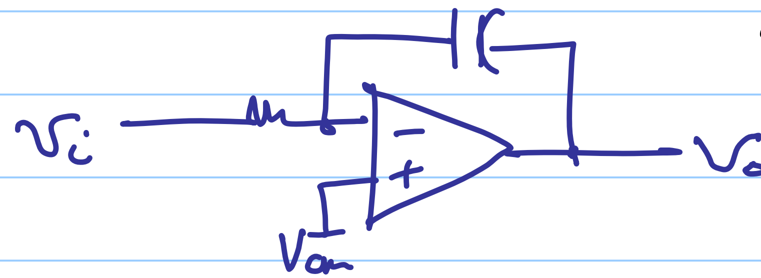


$R_2 = (k-1)R$

$R_1 = R$

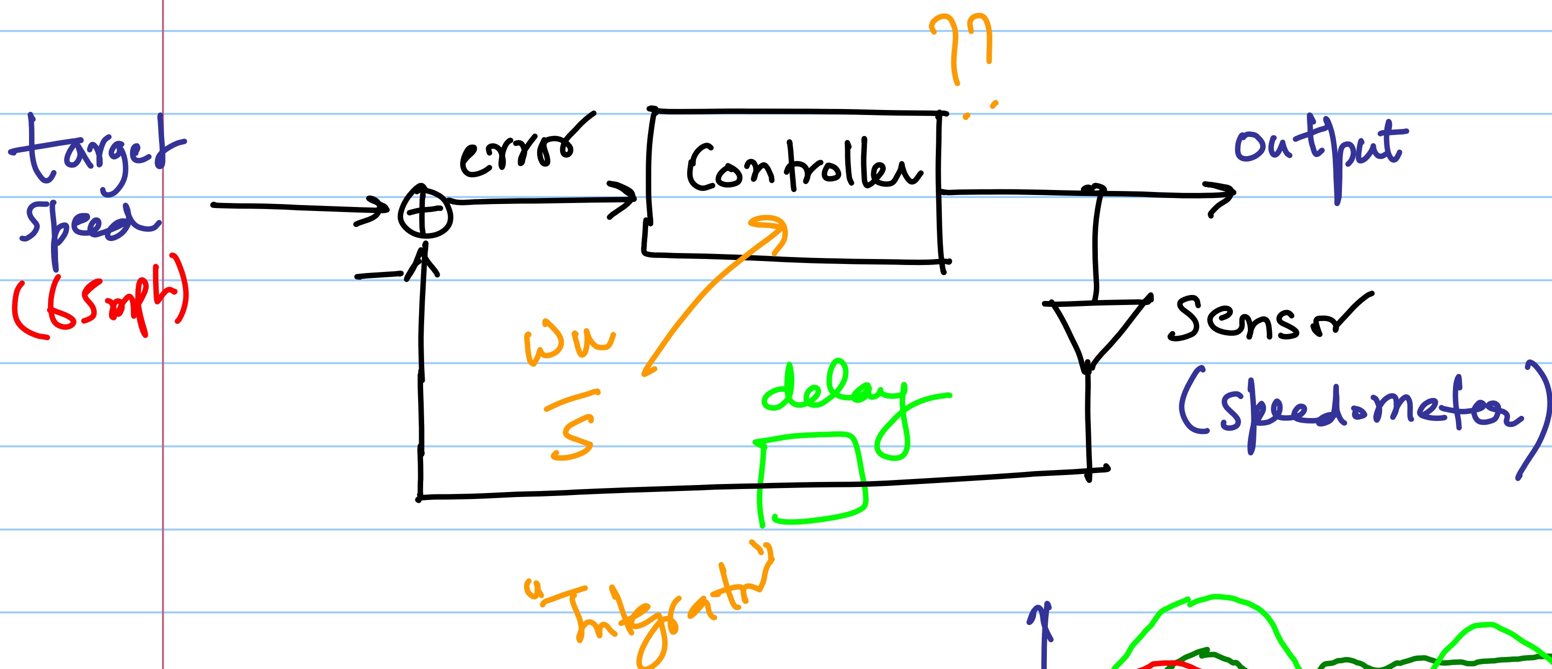
$A_{v} = 1 + \frac{R_2}{R_1} = k$

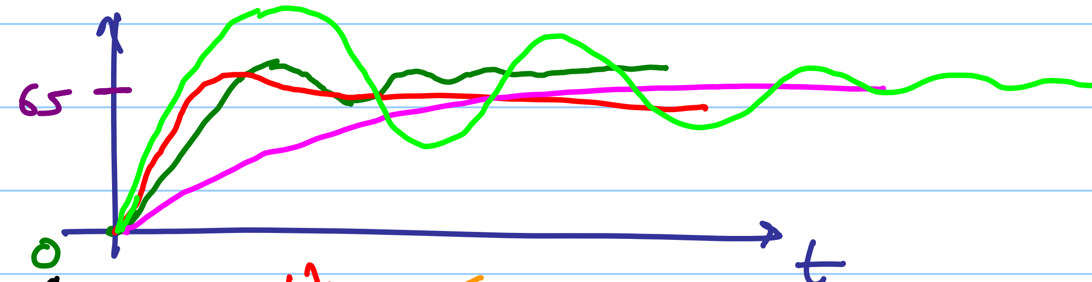
Integrator

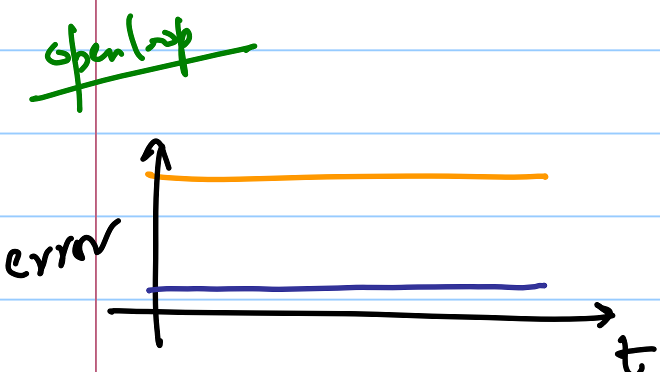


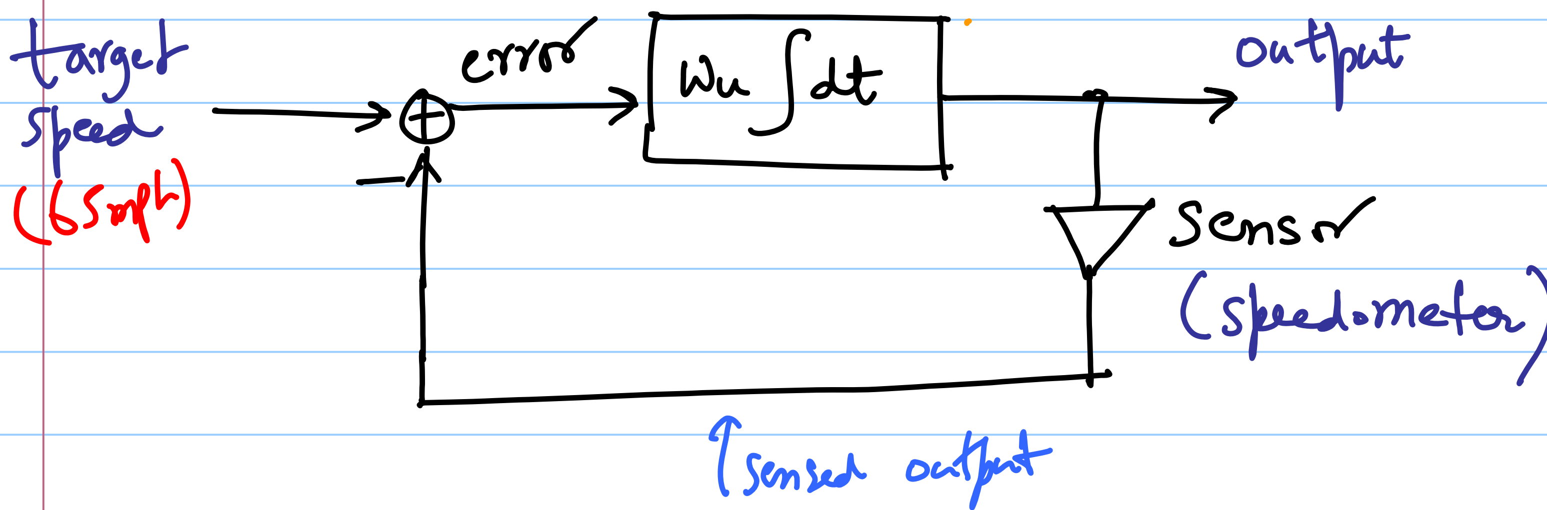
"Negative feedback Loops"

Controller: change the o/p until error goes to zero

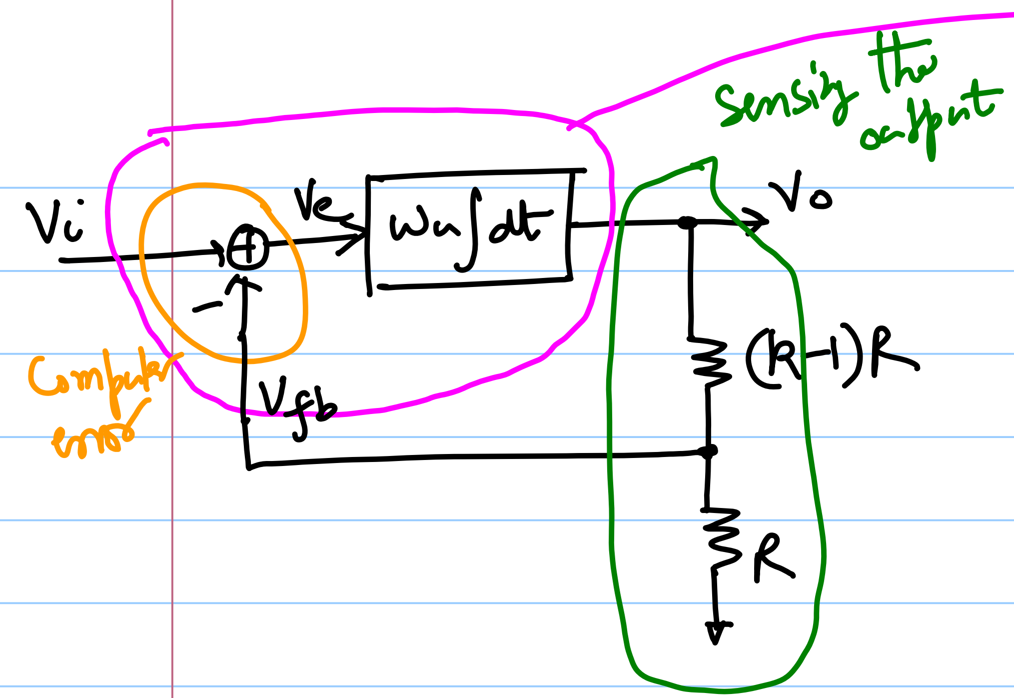


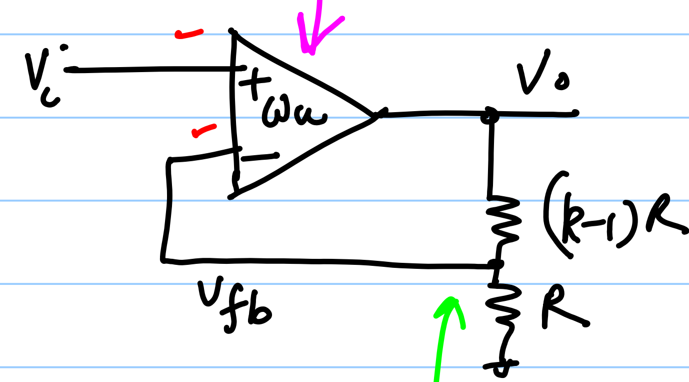






target speed
(65mph)
error
Wu ∫dt
output
Sensor
(speedometer)
sensed output





$$V_{fb} = \frac{V_o}{k}$$

$$V_e = V_i - \frac{V_o}{k} \to 0$$

$$\Rightarrow \quad V_o \to kV_i$$

We require $\quad V_o = kV_i$

In steady-state $\quad$ error $\to 0$

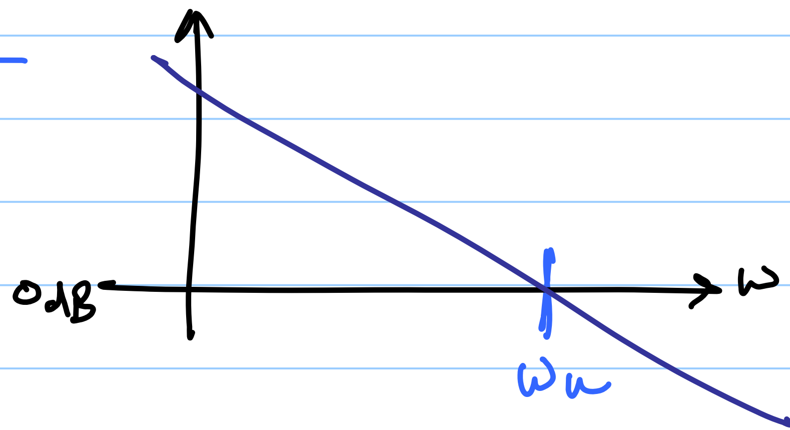
$$\Rightarrow \quad V_o \to kV_i$$

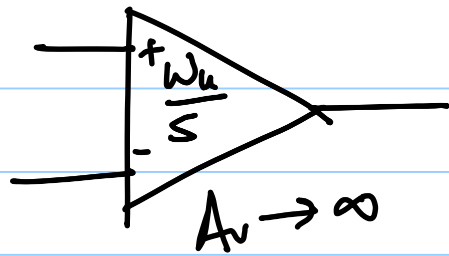
precise gain set by resistive ratio

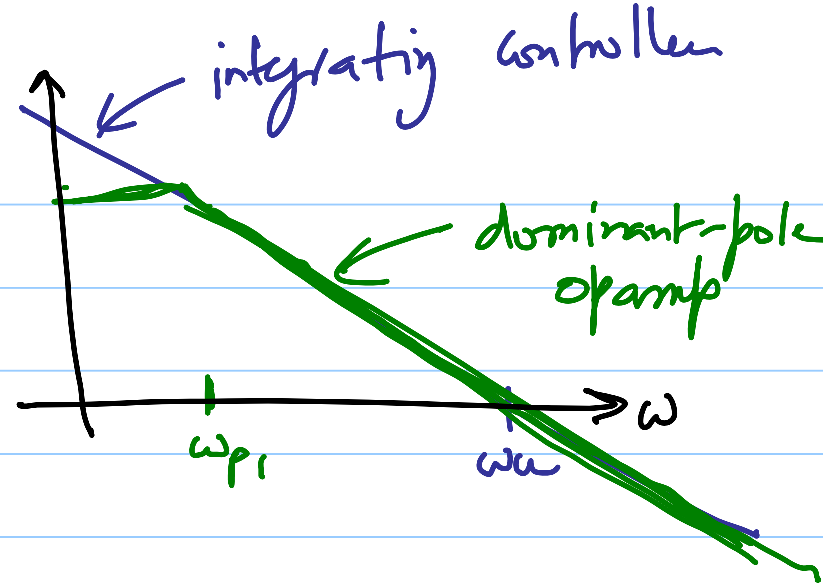
$\omega_u \rightarrow$ is the slope of the open-loop output for a unit step input

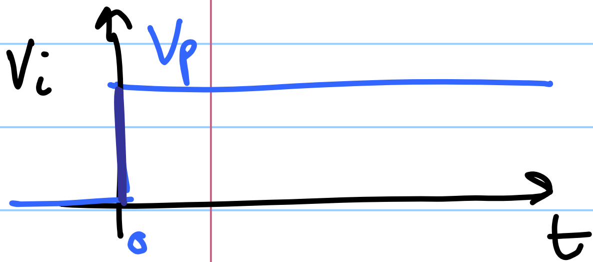
$\hookrightarrow$ also the unity gain frequency of the opamp. (controller)

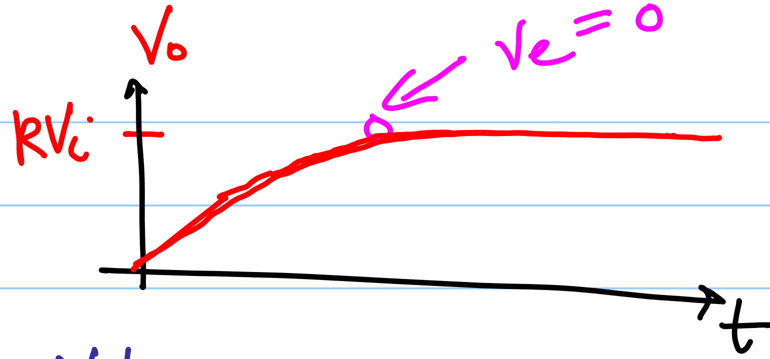
$\boxed{\int \omega_u \, dt} \rightarrow \boxed{\dfrac{\omega_u}{s}}$

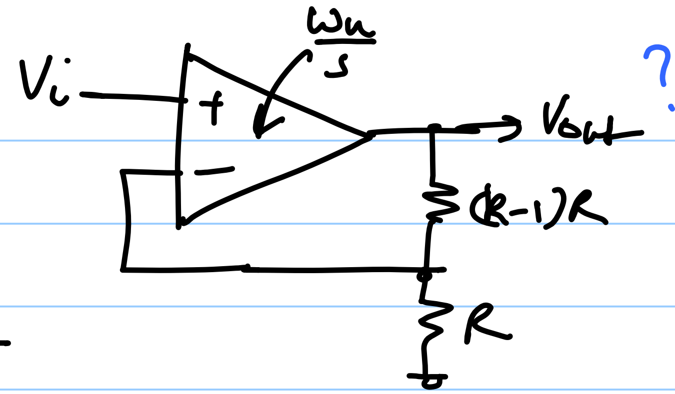



+
−
ωu/s
Av → ∞


integrating controller
dominant-pole opamp
ω
ωp1
ωu







Assume $V_o(t=0) = 0$

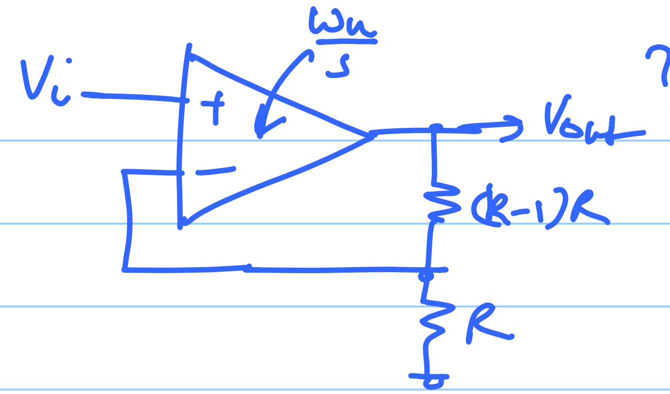
at $t=0$, $V_e = V_p$ $\Rightarrow$ output start ramping at a rate $\omega_u V_p$

$\Rightarrow$ feedback signal $V_{fb} = \dfrac{\omega_u V_p}{k}$

as $V_{fb} \uparrow$ $\Rightarrow$ $V_e \downarrow$

$\Rightarrow$ rate of increase in $V_o \downarrow$

$$V_o(s) = \frac{\omega_u}{s}\left[\overbrace{V_i(s) - \frac{V_o(s)}{k}}^{V_e(s)}\right]$$



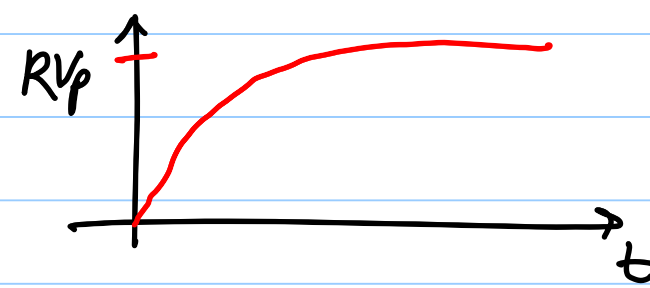
$$\frac{V_o}{V_i}(s) = \frac{k}{1 + \frac{ks}{\omega_u}}$$

for $\quad V_i(s) = \frac{V_p}{s}$

$$\Rightarrow \quad V_o(s) = \frac{kV_p}{s\left(1 + \frac{ks}{\omega_u}\right)} \longrightarrow$$

partial fraction & apply inverse Laplace Transform

$$V_{out}(t) = kV_p\left[1 - e^{-\left(\frac{\omega_u t}{k}\right)}\right]$$



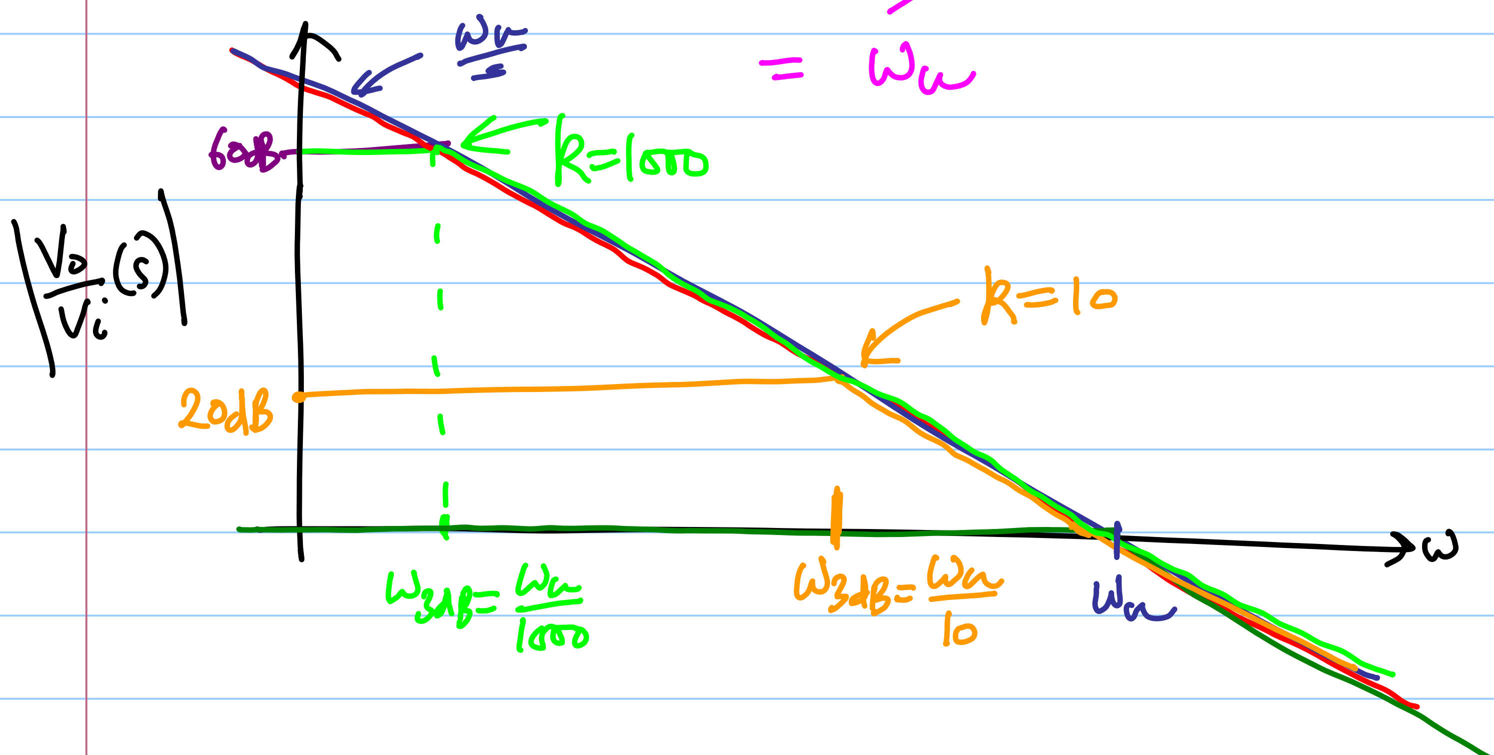
closed loop gain $\longrightarrow k$

closed-loop bandwidth $\longrightarrow \omega_u/k$

$$\frac{V_o}{V_i}(s) = \frac{k}{1+\frac{sk}{\omega_u}} = \frac{A_{CL}}{1+s/\omega_{3dB}}$$

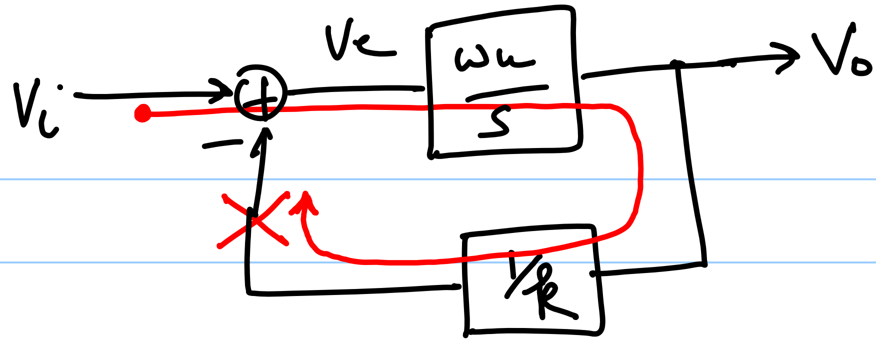
$$\omega_{3dB} = \frac{\omega_u}{k}$$

$$A_{CL} \times \omega_{3dB} = \cancel{k} \times \frac{\omega_u}{\cancel{k}} = \omega_u$$



$k=1$

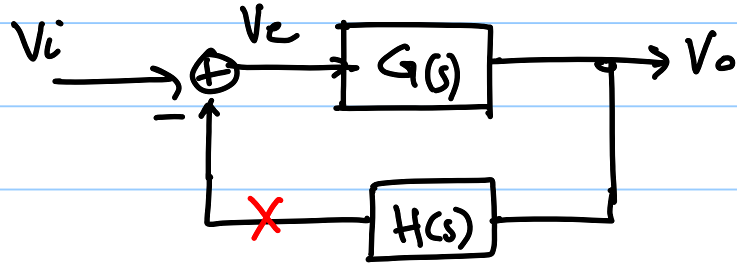
Microelectronics by Razavi



ω_u = unity gain frequency of the integrator controller

Loop-response $\quad L(s) = \dfrac{\omega_u}{k \cdot s}$ $\Leftarrow$ Loop-gain $\Rightarrow$ implies open-loop behavior

$$\omega_{u,loop} = \frac{\omega_u}{k} \leftarrow \text{unity gain loop frequency}$$



$$L(s) = G(s) \cdot H(s)$$

Closed-loop response

$$\frac{V_o}{V_i}(s) = \frac{G(s)}{1 + G \cdot H(s)}$$

$$\frac{V_o}{V_i}(s) = \frac{G}{1+GH} = \frac{1}{H(s)} \cdot \frac{1}{1+\frac{1}{G(s)\cdot H(s)}}$$

$$\simeq \begin{cases} \frac{1}{H(s)} & |GH| \gg 1 \leftarrow |L| \gg 1 \\ G(s) & |GH| \ll 1 \end{cases}$$

for large $|L| \gg 1$ (loop gain)

closed-loop gain $\simeq \frac{1}{|H|}$