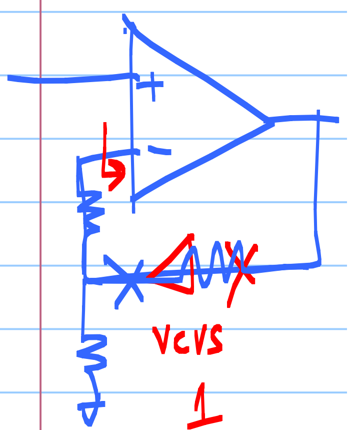
ECE 511 - Lecture 22

Note Title 4/23/2012

Stability Analysis



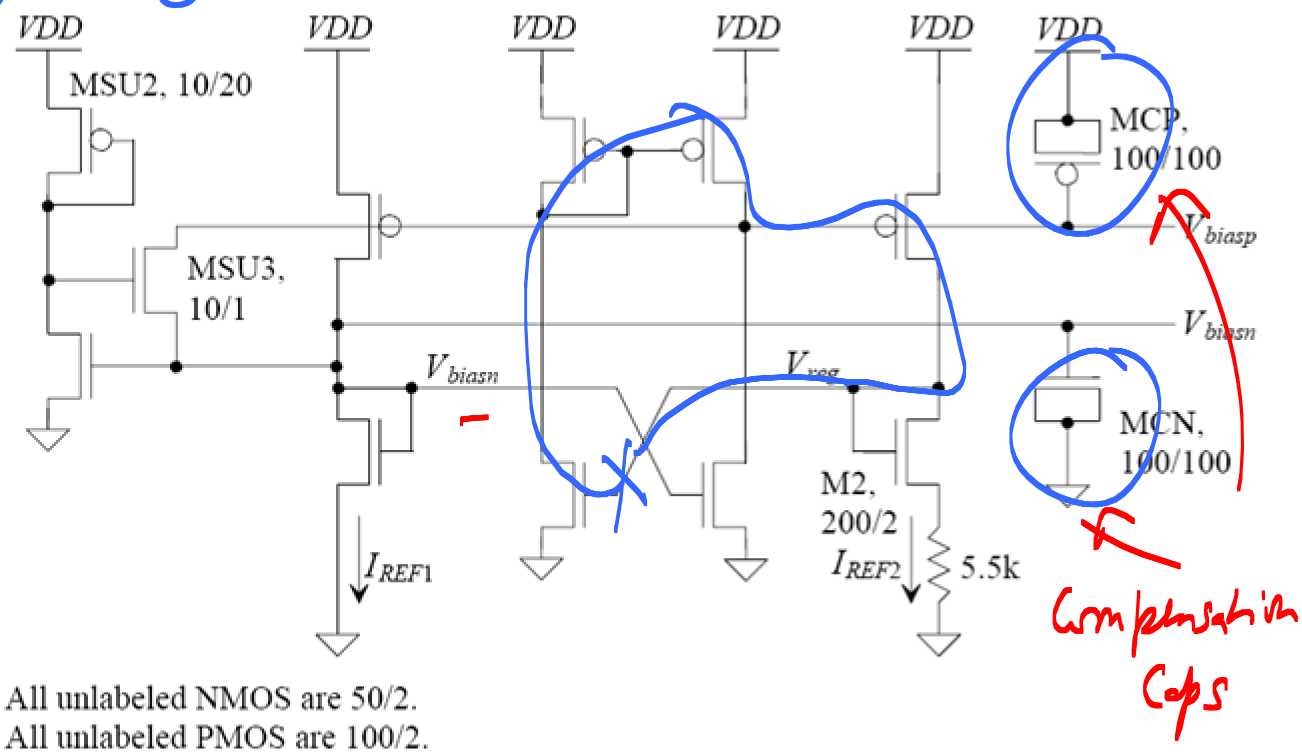


Figure 20.22 Improved current reference for short-channel devices. See also Sec. 23.1.3 for more information.

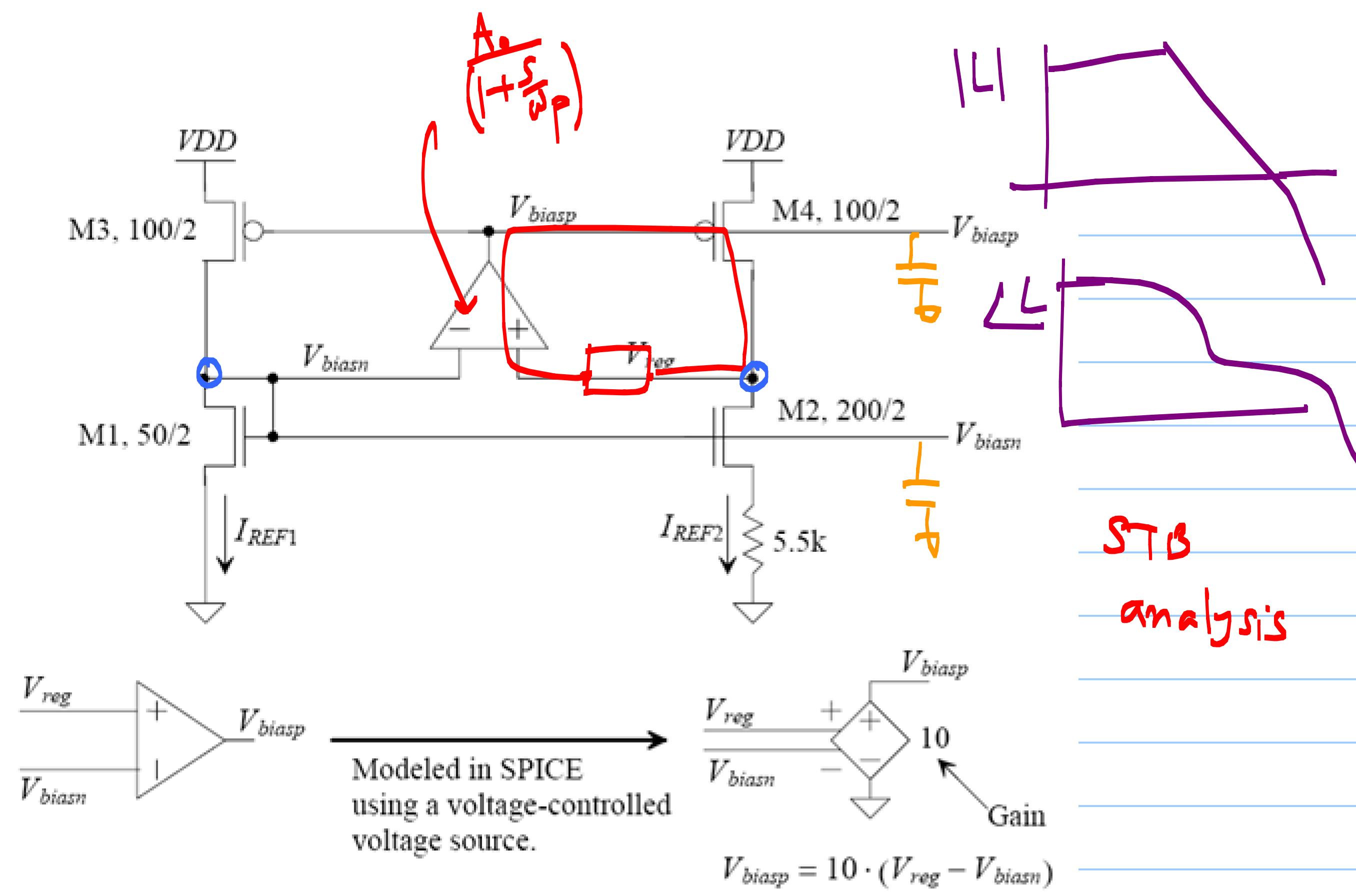
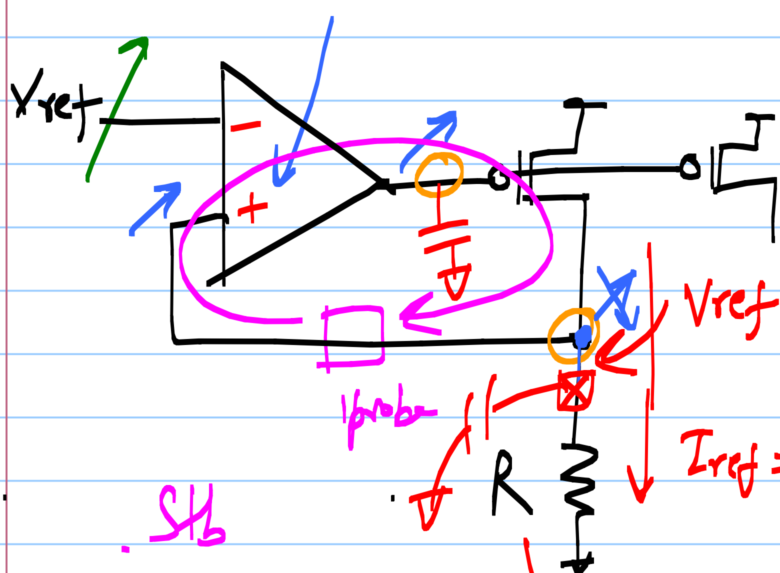
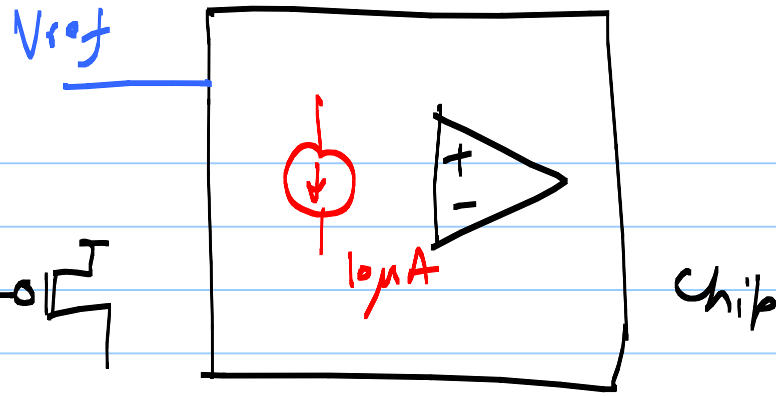


Figure 20.19 Increasing the output resistance of short-channel MOSFETs using feedback. The result, for the Beta-multiplier circuit, is better power supply sensitivity.

Bias Reference

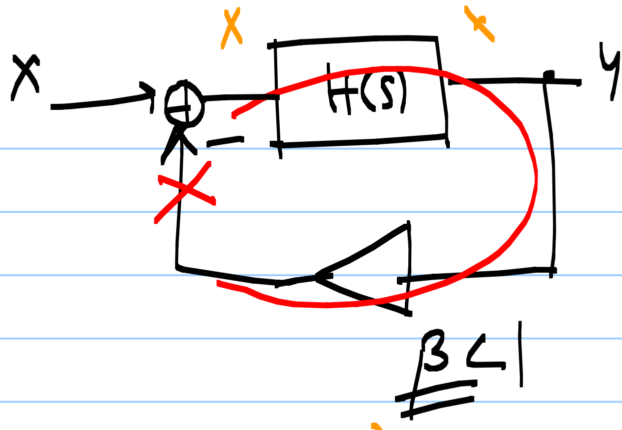


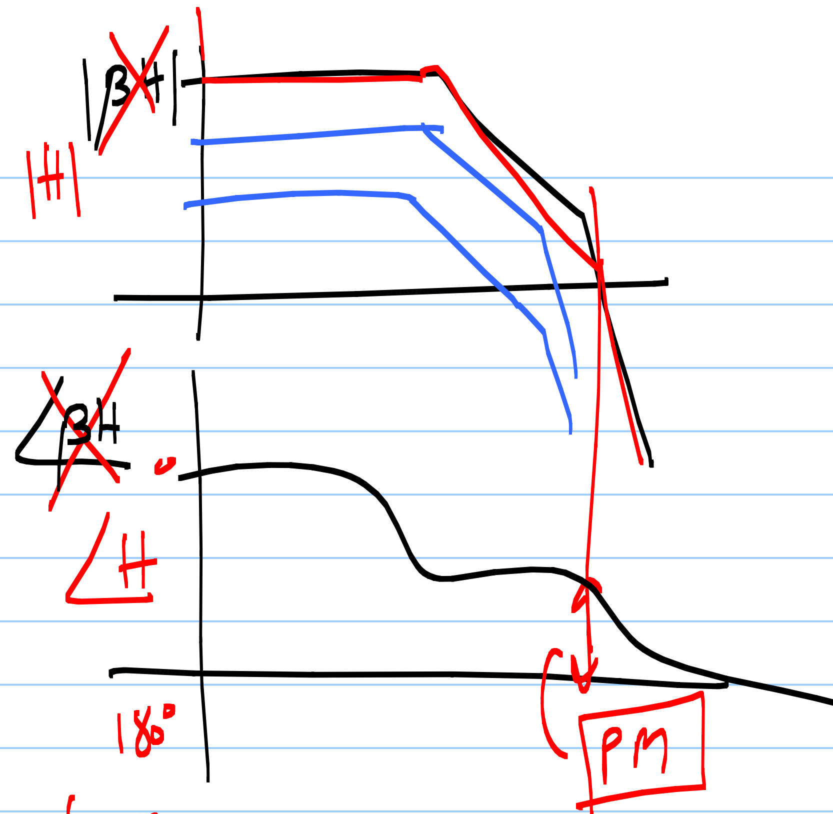


$$I_{ref} = \frac{V_{ref}}{R}$$

Stb

on chip ±20%



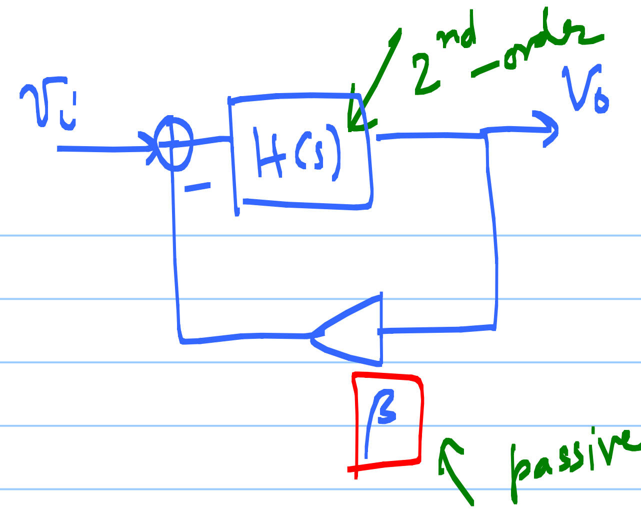


If β is not passive

Consider $\beta(s)H(s)$

open loop response

Ideal closed loop gain $= \frac{1}{\beta} \leftarrow k$



closed-loop TF

$$\frac{V_o}{V_i}(s) = \frac{k}{\left(\frac{s}{\omega_0}\right)^2 + \left(\frac{s}{\omega_0 Q}\right) + 1}$$

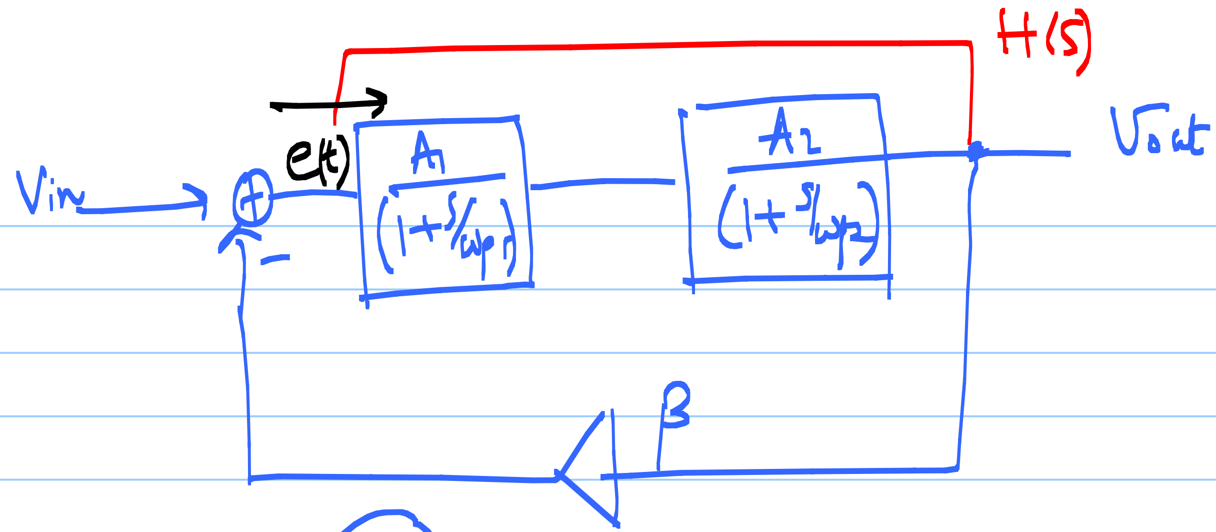
$$= \boxed{\frac{k}{\left(\frac{s}{\omega_0}\right)^2 + 2\zeta\left(\frac{s}{\omega_0}\right) + 1}} \rightarrow ①$$

damping factor

$$\zeta = \frac{1}{2Q}$$

quality factor of the poles

Standard 2nd order TF



$$\boxed{k = \frac{1}{\beta}}$$

$$A_0 = A_1 A_2$$

$$\frac{V_o}{V_i}(s) = \frac{k}{\left(1+\cancel{\frac{k}{A_0}}\right)^{1} + s\left(\frac{1}{\omega_{p1}} + \frac{1}{\omega_{p2}}\right)\frac{k}{A_0} + \frac{s^2}{\omega_{p1}\omega_{p2}}\cdot\frac{k}{A_0}}$$

$$\frac{k}{A_0} = \frac{1}{\beta A_0}$$

2

$$\omega_0 = \sqrt{\omega_{p1}\omega_{p2}} \cdot \sqrt{\frac{A_0}{k}}$$

$$\boxed{\zeta = \frac{1}{2}\sqrt{\frac{k}{A_0}}\left(\sqrt{\frac{\omega_{p2}}{\omega_{p1}}} + \sqrt{\frac{\omega_{p1}}{\omega_{p2}}}\right)}$$

* $\frac{A_0}{k}$ is large $\Rightarrow$ $A_0\beta \gg 1$ $\Rightarrow$ lower steady-state error

better gain precision ($1/\beta$)

$\zeta \leftarrow$ small

$\rightarrow$ lot of ringing

* $\frac{\omega_{p2}}{\omega_{p1}}$ is large $\Rightarrow$ $\zeta \uparrow$ $\Rightarrow$ poles well separated

↳ less ringing

* How much $\zeta = ?$

for $\dfrac{\omega_{p2}}{\omega_{p1}} \simeq \dfrac{A_0}{k}$

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

$$x = \sqrt{\frac{k}{A_0}}$$

$$= \frac{1}{2}\, x \left(x + \frac{1}{x}\right)$$

$$\boxed{x + \frac{1}{x} \leq 2x}$$

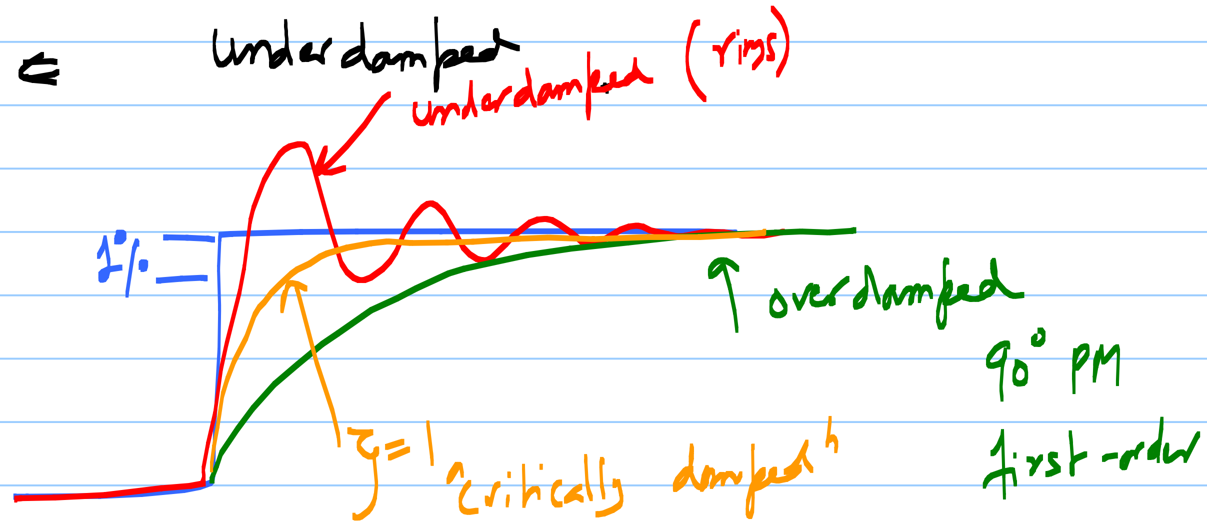
$$\leq 1$$

underdamped
or critically damped

$\zeta = 1 \Leftarrow$ critically damped

$\zeta > 1 \Leftarrow$ overdamped

$\zeta < 1 \Leftarrow$ underdamped



* $\xi = \frac{1}{\sqrt{2}} = 0.7$ → fastest settling for a 2-pole system

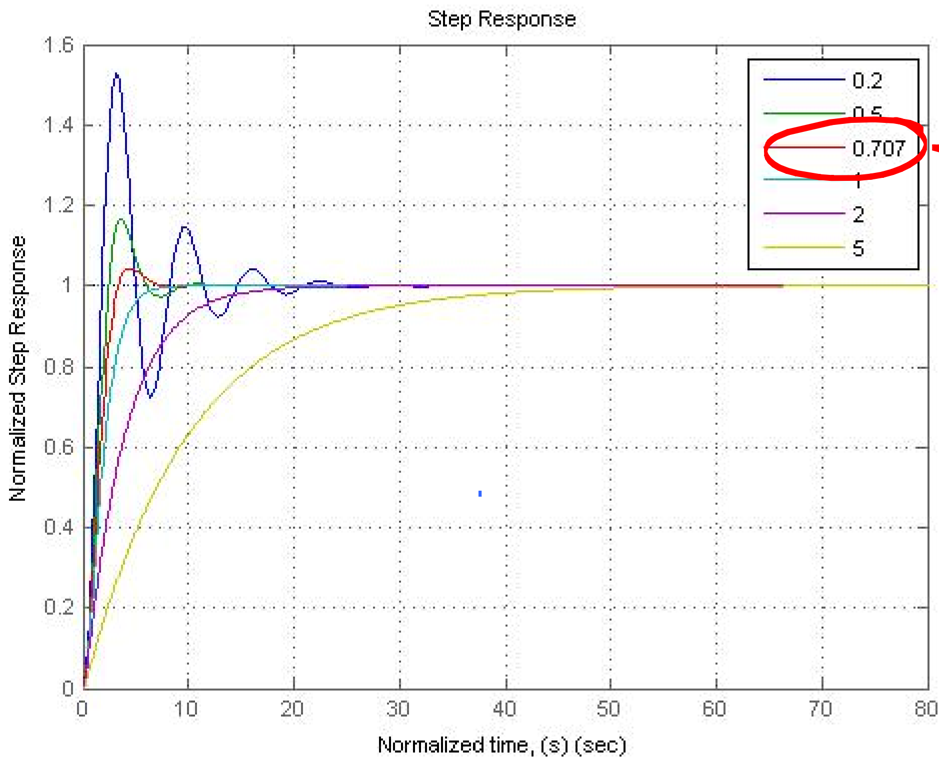
$$\frac{\omega_{p2}}{\omega_{p1}} = \frac{2A_o}{k}$$

$$\Rightarrow \omega_{p2} = 2\omega_{um}$$

$$PM = \phi_M = 90^\circ - \tan^{-1}\left(\frac{\omega_u}{\omega_{p2}}\right) = \boxed{63.5^\circ}$$

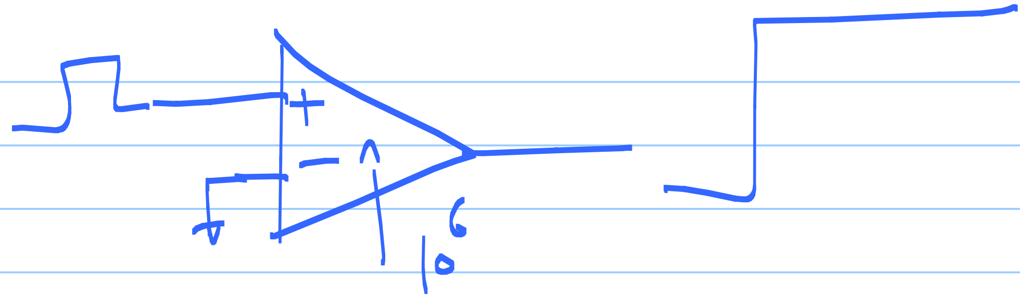
* $\phi_M = 60^\circ$

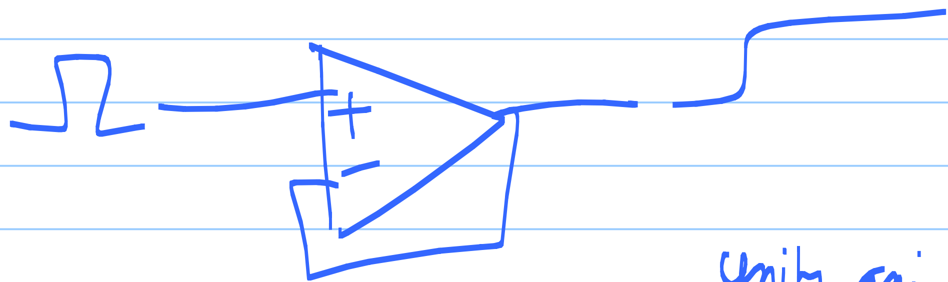
$$\Rightarrow \xi = 0.66$$



Step Response
Normalized Step Response
Normalized time, (s) (sec)
0.2
0.5
0.707
1
2
5

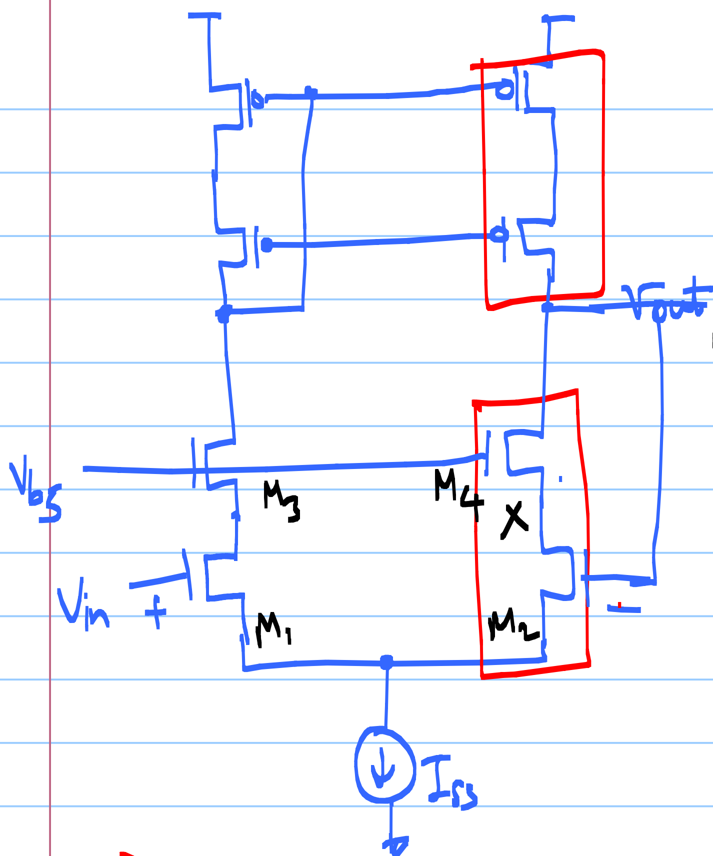
PM = 63.5°

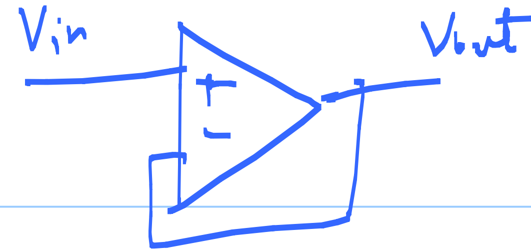




$\beta = 1$

unity gain amp





Both M_2 & M_4 should be in Sat

M_2: $V_{out} \leq V_X + V_{THN} \longrightarrow ①$

M_4: $V_{out} \geq V_{b5} - V_{THN} \longrightarrow ②$

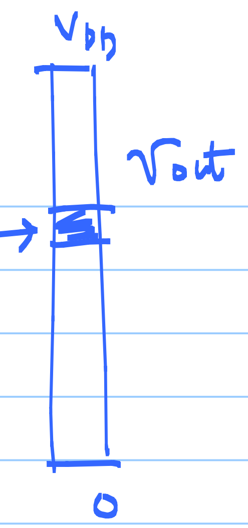
$V_X = V_{b5} - V_{GS4}$

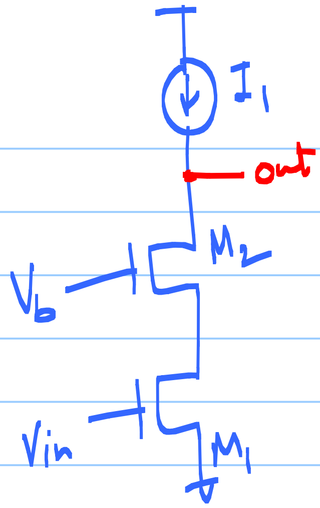
①&② $\Rightarrow$

$$\underbrace{V_{b5} - V_{THN}}_{V_{min}} \leq V_{out} \leq \underbrace{V_{b5} - V_{GS4} + V_{THN}}_{V_{max}}$$

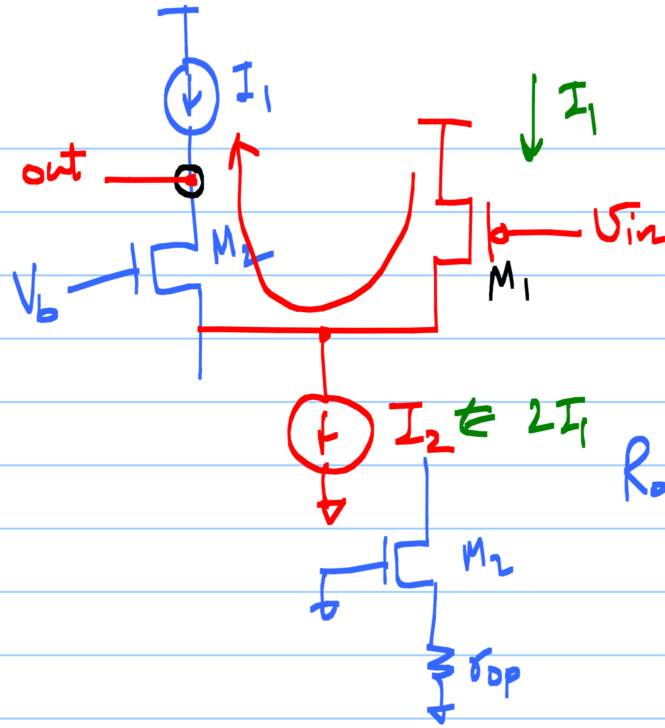
$$V_{max} - V_{min} = 2V_{THN} - V_{GS4}$$

$$\simeq V_{THN} - V_{OV4}$$





Cascod



$g_m R_{out}$

g_{m1}

$R_{out} = \boxed{g_{m2} r_{o2} r_{op}}$