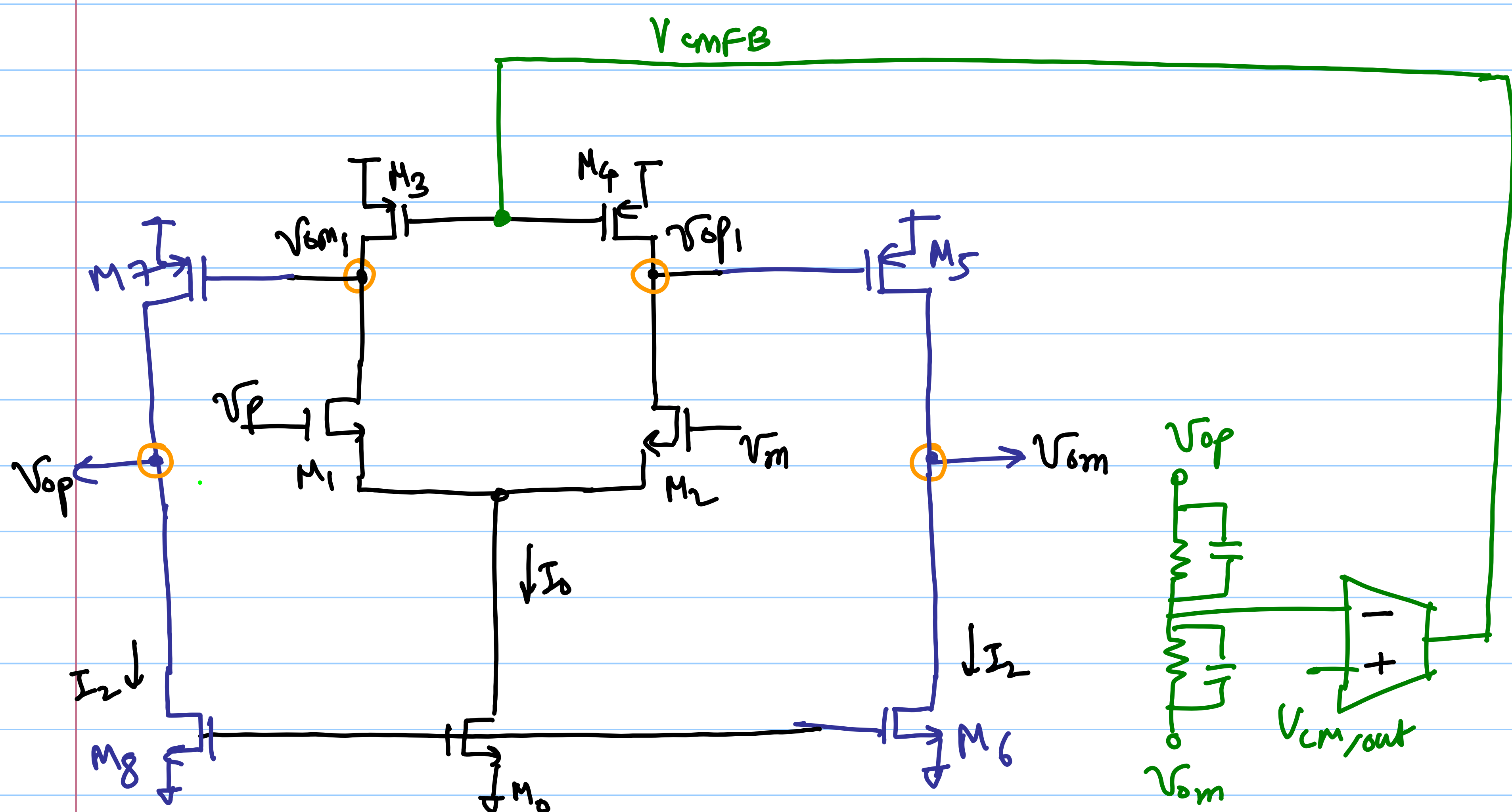
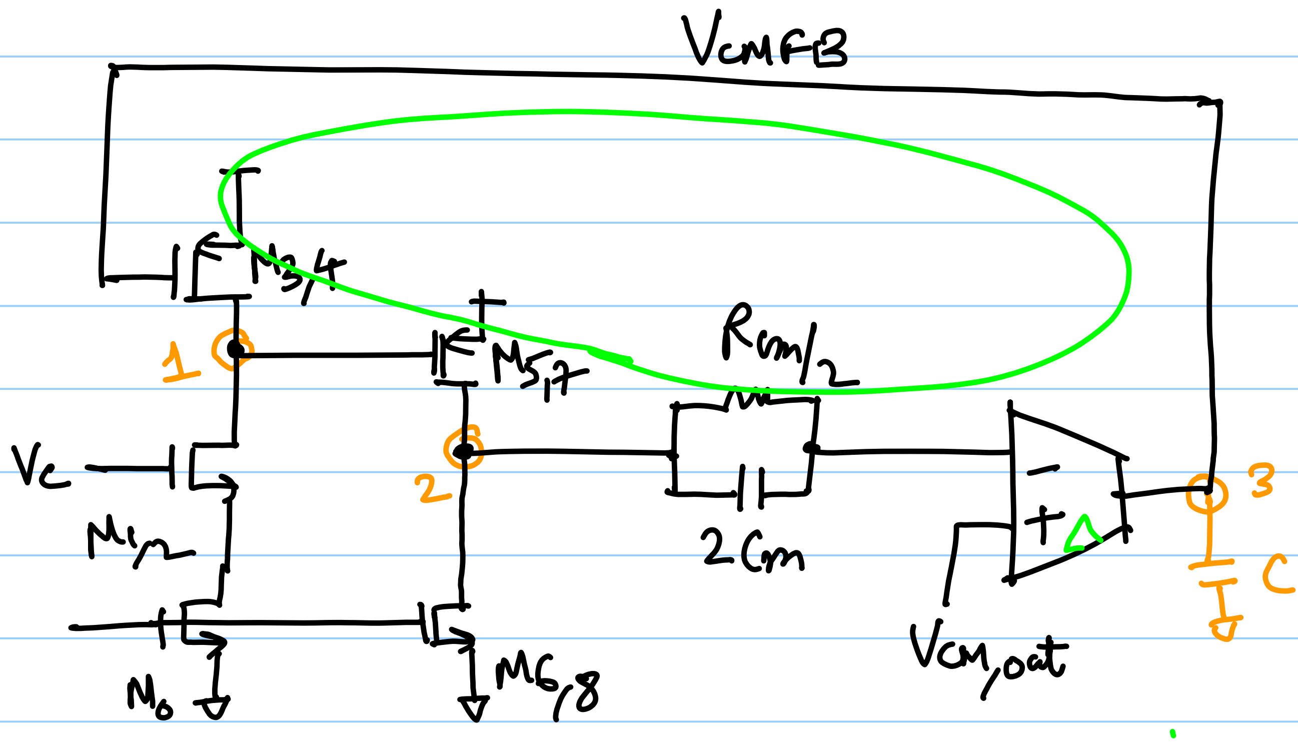
ECE 614 – Lecture 5

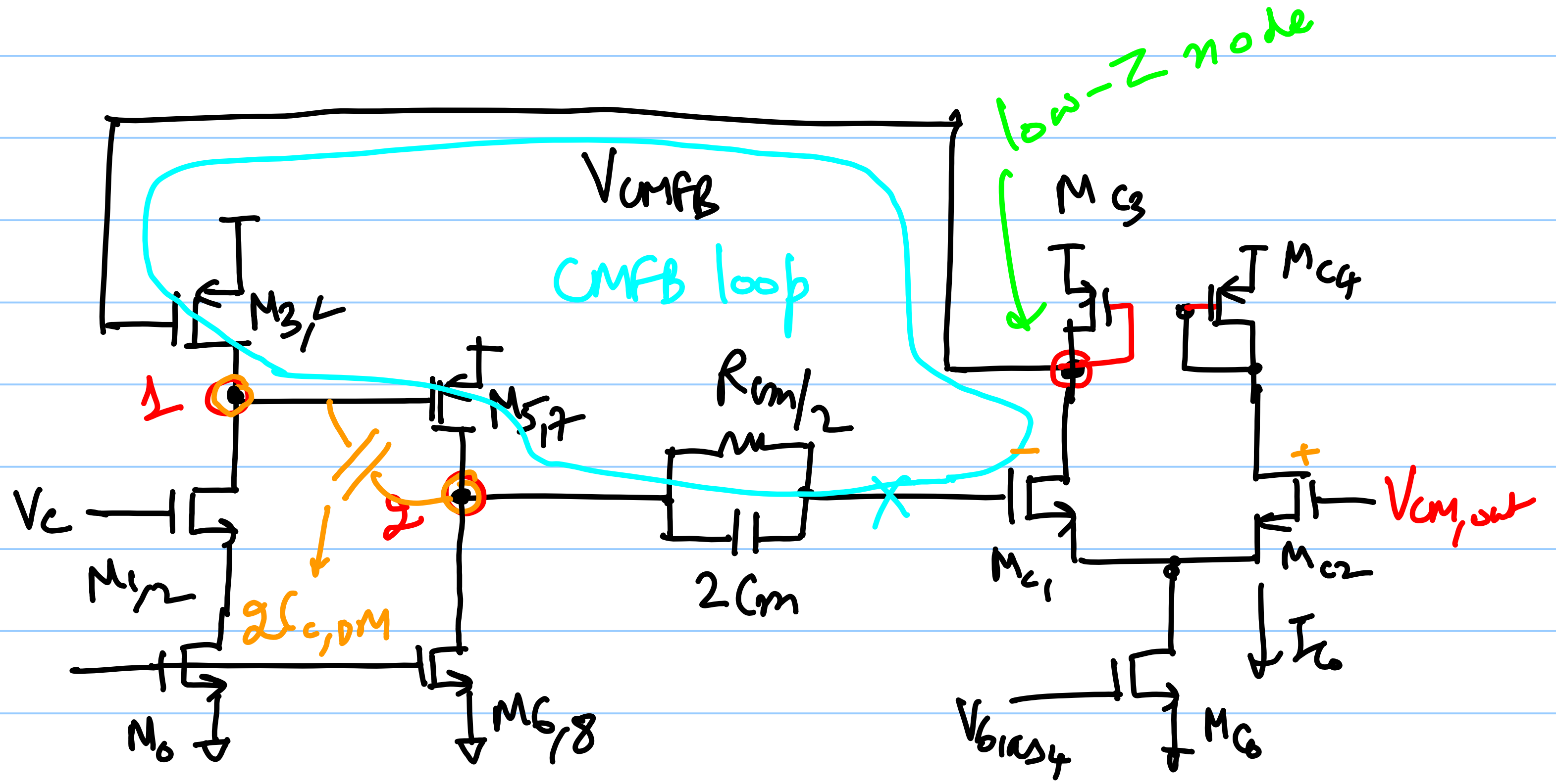
Note Title 9/9/2014





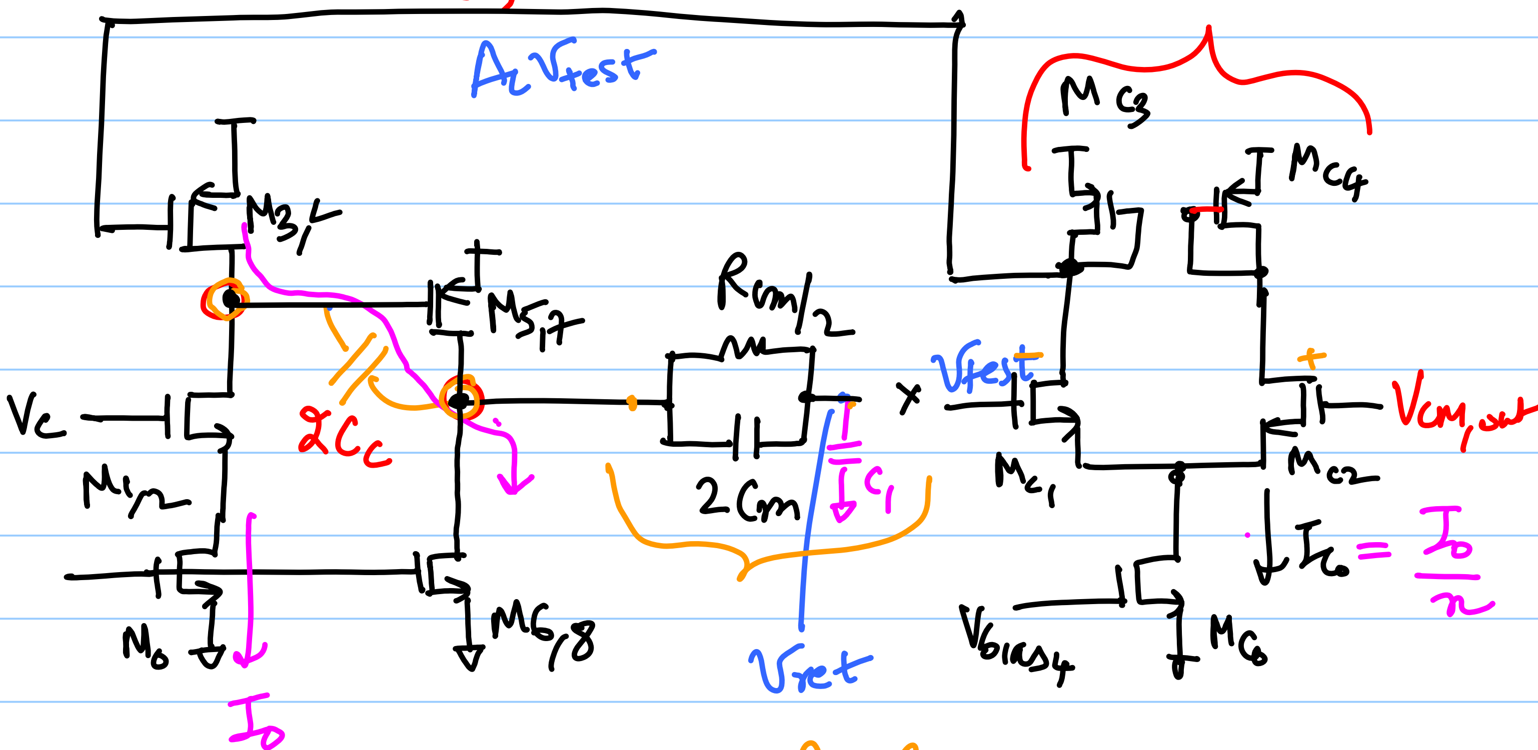
VCMFB
M3,4
M5,7
Rcm/2
1
2
3
Vc
M1,2
2Cm
M0
M6,8
Vcm,out
C

$$G_c = \frac{1}{2}\left(\frac{g_{mc_1}}{g_{mc_3}}\right)$$



* Using the differential path C_c for compensating the CM-path itself.

Find open loop response $L(s)$ gain ⇒ A_z



$$\frac{1+sR_{cm}C_{cm}}{1+sR_{cm}\left(C_{cm}+\frac{C_1}{2}\right)} \simeq 1$$

$i = V_{test} \cdot A_z \cdot g_{m34}$ ⇐ this current flows through $2C_c$

$$V_{return} \simeq \frac{A_2\, g_{m3,4}}{s\, 2C_c} \cdot V_{test}$$

$$L_{CM}(s) \simeq \frac{A_2\, g_{m3,4}}{2sC_c}$$

CM equivalent

$$g_{m3,4} = 2g_{m3}$$

$$\omega_{u,CM} = \frac{A_2\, g_{m3,4}}{2C_c} = \underbrace{\frac{1}{2}\frac{g_{mC_1}}{g_{mC_3}}}_{A_2} \times \frac{g_{m3,4}}{2C_c}$$

$$\frac{\omega_3}{\omega_{C_3}} = n$$

$$= \frac{1}{2}\frac{g_{mC_1}}{g_{mC_3}} \times \frac{g_{m3}}{C_c}$$

$$= \frac{1}{2}\frac{g_{mC_1}}{C_c}\left(\frac{g_{m3}}{g_{mC_3}}\right) = \frac{1}{2}\frac{g_{mC_1}}{C_c} \times n$$

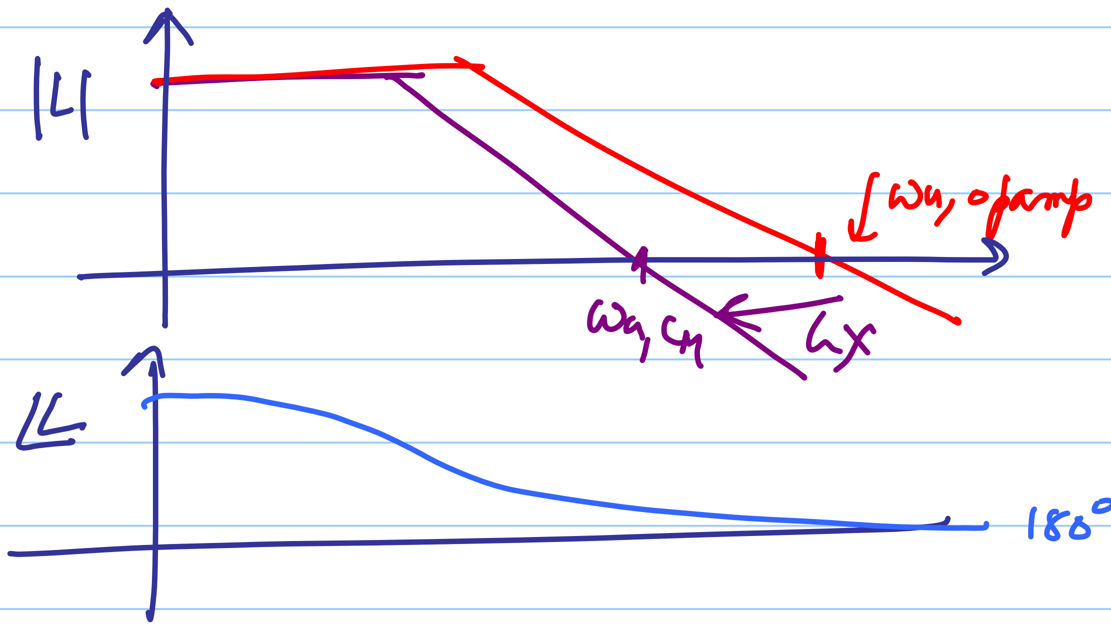
$$= \frac{1}{2}\frac{g_{m1}}{C_c}$$

$$\omega_{u,opamp} = \frac{g_{m1}}{C_c}$$

$$\omega_{u,cm} \le \frac{1}{2} \cdot \frac{g_{m1}}{C_c}$$

To ensure CMFB loop stability

$$\omega_{u,cm} \le \omega_{u,opamp}$$

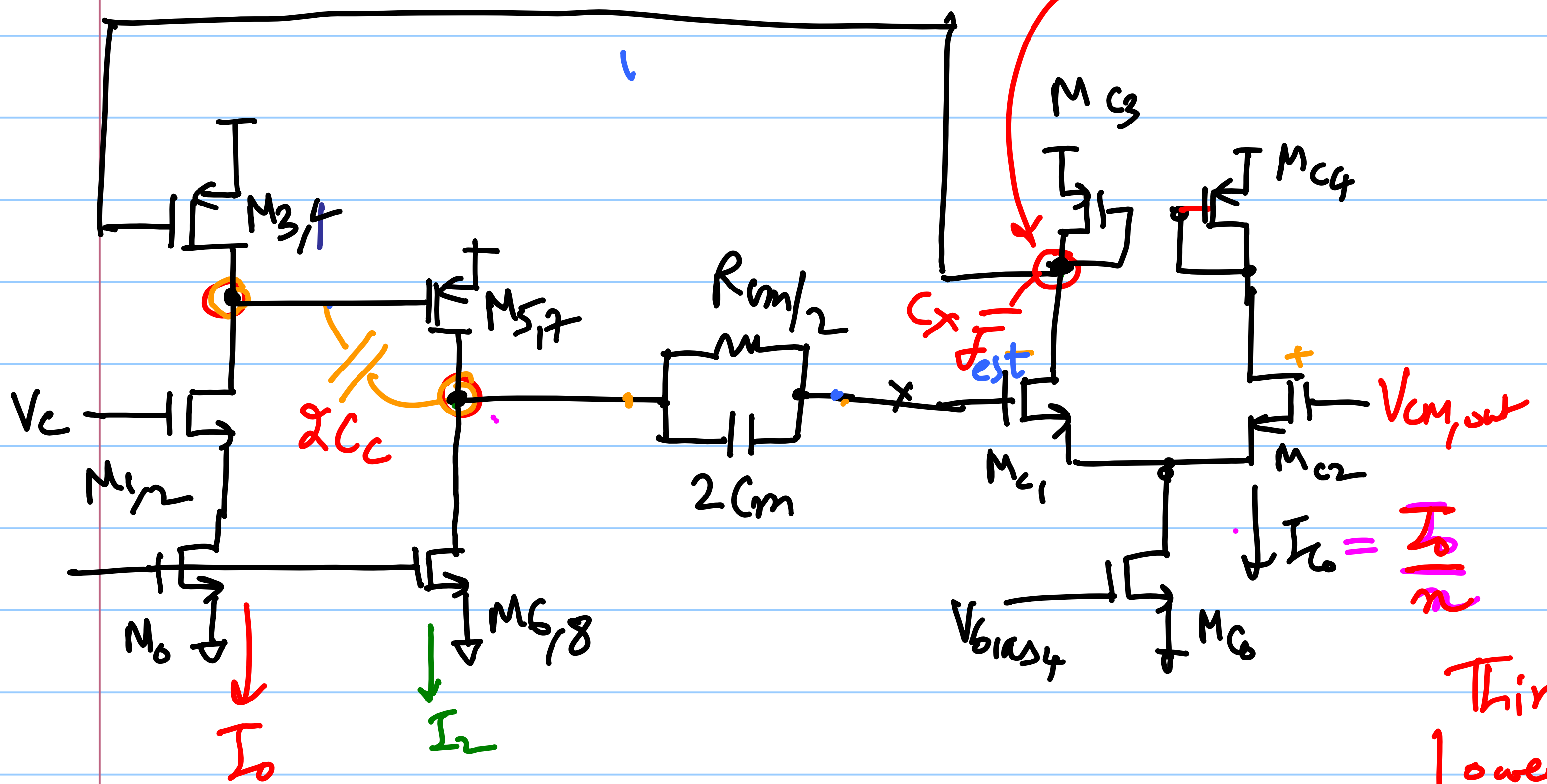


$$f_3 \simeq \frac{g_{mc1,3}}{C_x}$$

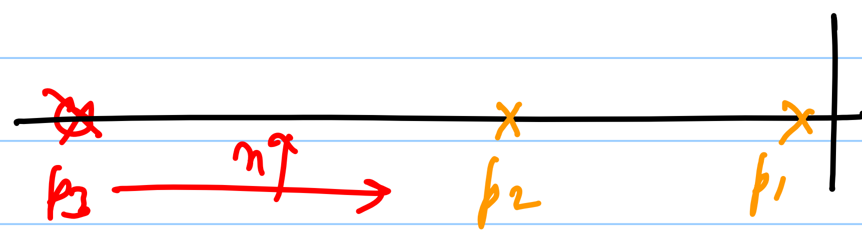
$$\uparrow n = \frac{g_{m1,3}}{g_{mc1,3}}$$

$n \uparrow$

$g_{mc1,3} \downarrow$

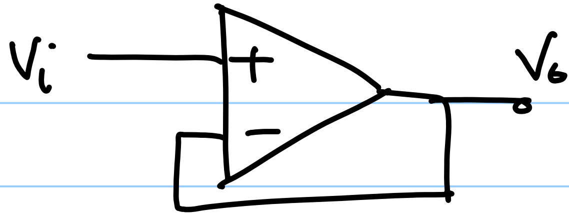


Third pole appears at lower frequency as $n \uparrow$

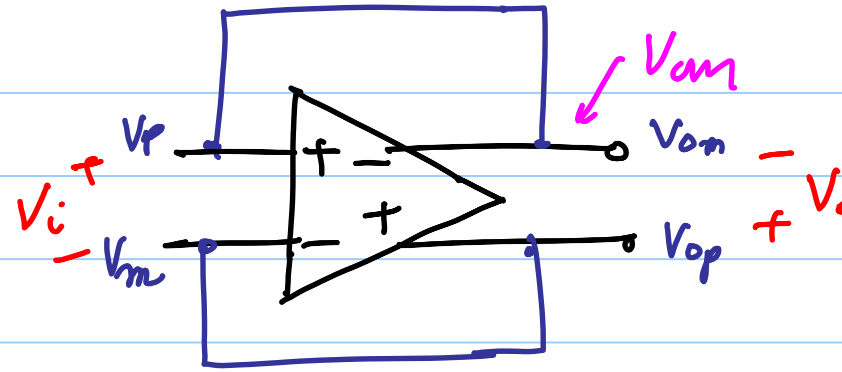


$$\frac{W_{3,4}}{I_o} = \frac{W_{5,7}}{I_2} = \frac{W_{3,4c}}{I_{oc}}$$

Use same current density to avoid systemic offset.



$\beta \leq 1$



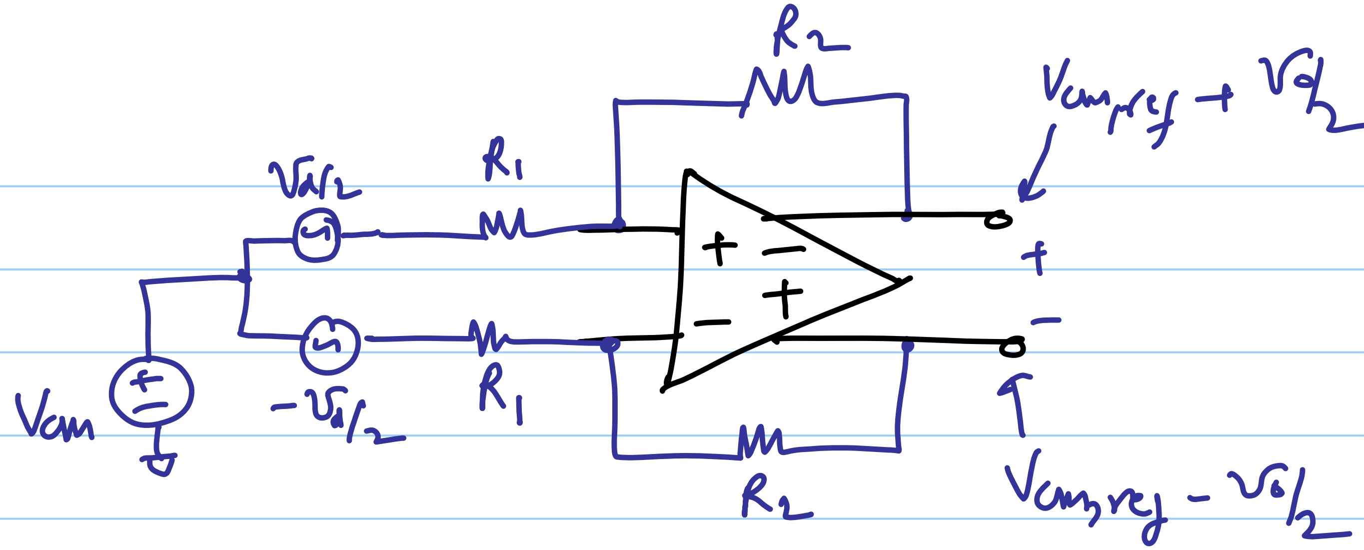
$$(v_{op} - v_{om}) = A\,(v_p - v_m)$$

$\forall \quad v_{op} = v_{om}$

$v_p = v_m$

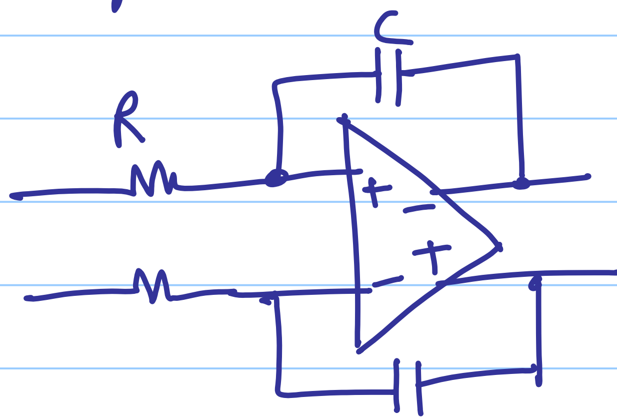
No unity gain configuration in FD opamp

$\Rightarrow$ just shorts output and inputs

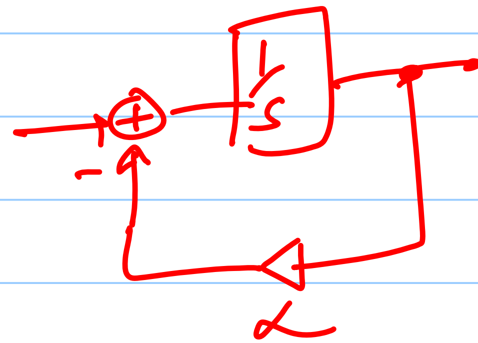


Active-RC filter

Integrator

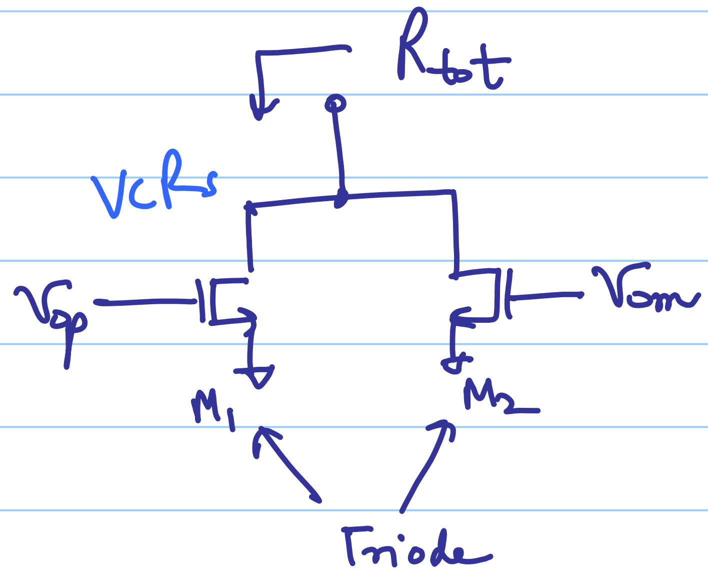


$$\beta \Rightarrow \frac{R_1}{R_1+R_2}$$



LPF

CMFB using Triode Devices



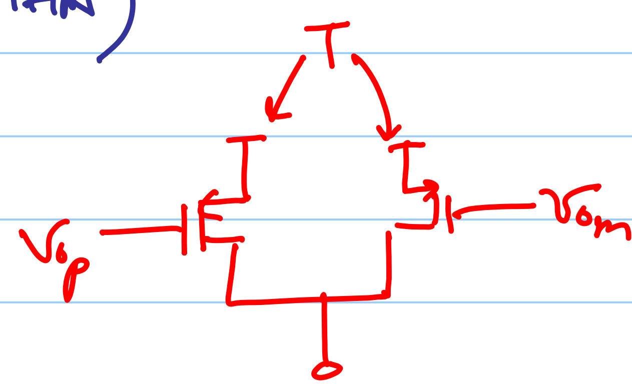
$$R_{tot} = R_{on_1} \| R_{on_2}$$

$$= \frac{1}{KP_n \frac{W}{L}(V_{op} - V_{THN})} \Big\| \frac{1}{KP_n \frac{W}{L}(V_{om} - V_{THN})}$$

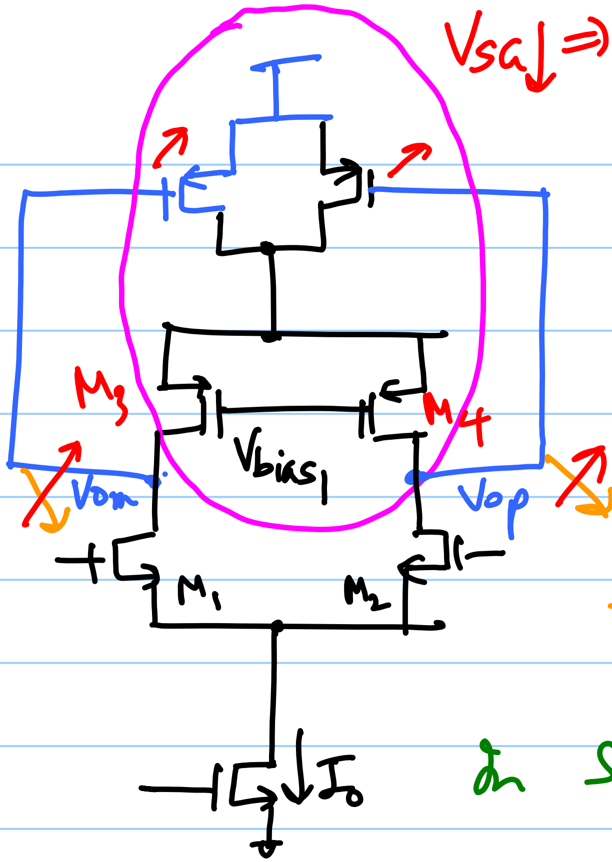
$$\simeq \frac{1}{\underbrace{KP_n \frac{W}{L}}_{\beta_n}(V_{op} + V_{om} - 2V_{THN})}$$

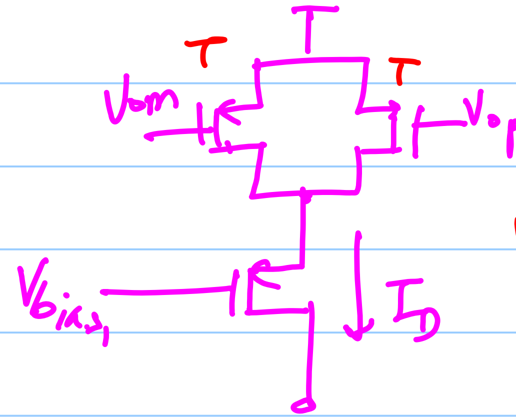
$$G_{tot} = \frac{1}{R_{tot}} = 2\beta_n \left(\underbrace{\frac{V_{op}+V_{om}}{2}}_{V_{CM,\,det}} - V_{THN} \right)$$

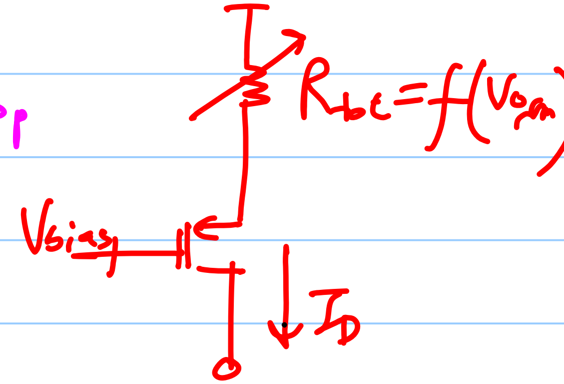
$$g_{tot} = f(v_{o,cm})$$



$V_{SG}\downarrow \Rightarrow R\uparrow \Rightarrow I_D\downarrow$







Source degenerated current source

$I_D < I_0$

in steady-state

$I_D = I_0$

$$I_D \simeq \frac{V_{bias_1} - V_{SG}}{R_{tot}}$$

(+) Not consuming additional current

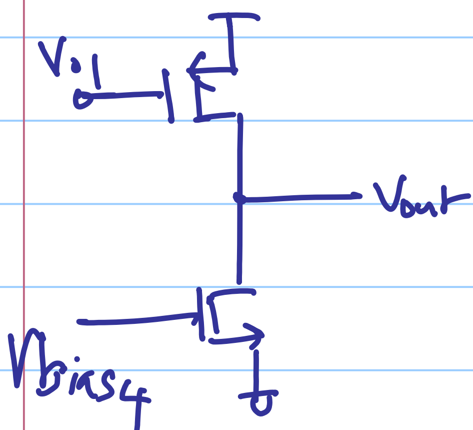
(−) the output CM-level depends on the device parameters

$$V_{o,cm} = \left(\frac{V_{op}+V_{om}}{2}\right) = \frac{I_D}{k'_p\left(\frac{W}{L}\right)_{3,4}} \cdot \frac{1}{\left(V_{DD}-V_{bias_1}-V_{SG_{3,4}}\right)} + V_{THP}$$

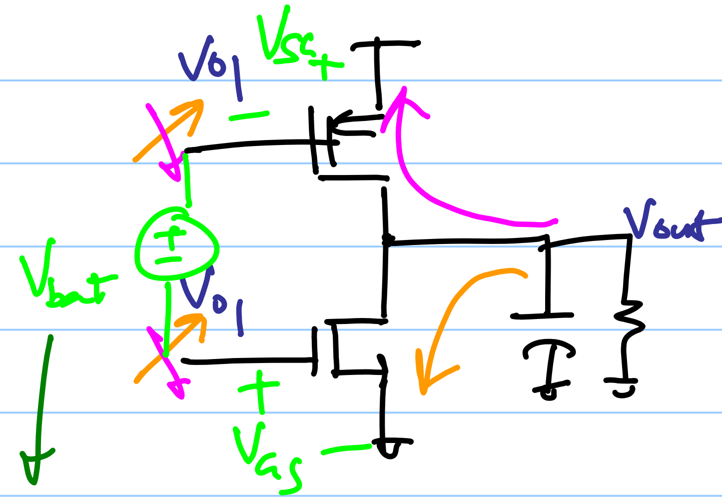
See Razavi Section 9.6 for details.

Class AB Design:

push-pull stage

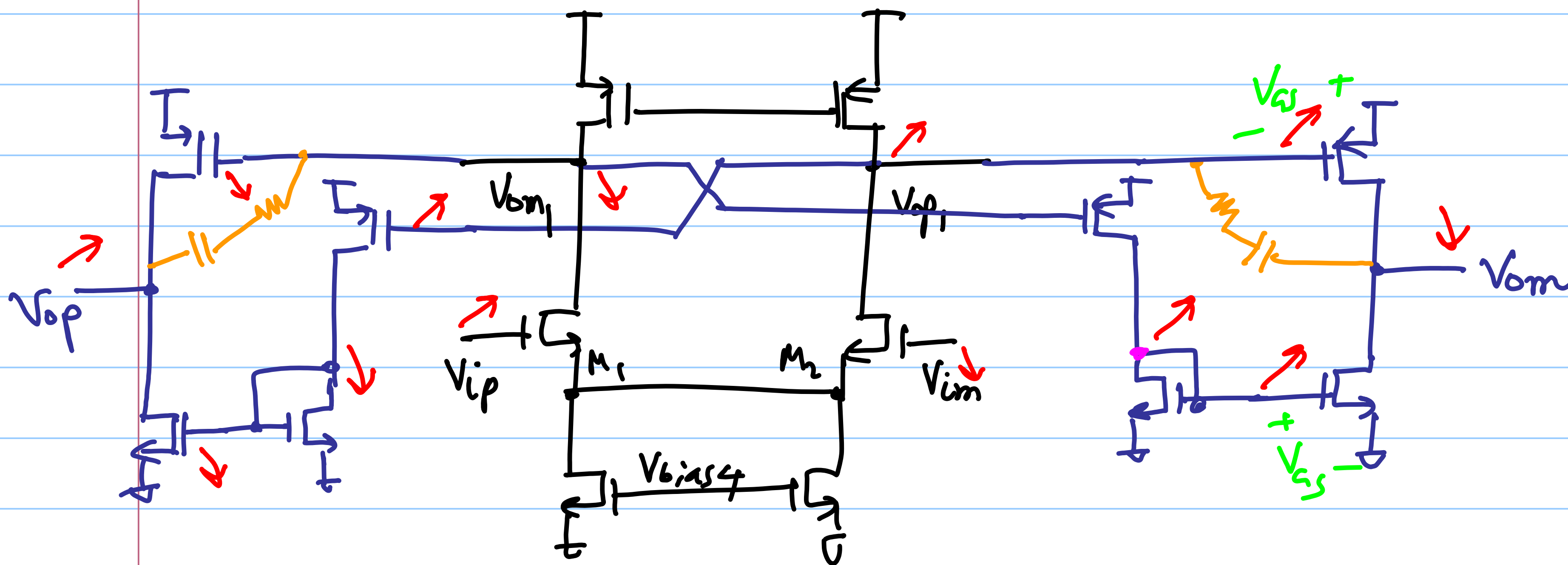


Class A



Class AB

$$V_{bat} = V_{DD} - V_{SG} - V_{GS}$$



Vop
Vom1
Vop1
Vip
Vim
M1
M2
Vbias4
VGS
Vom