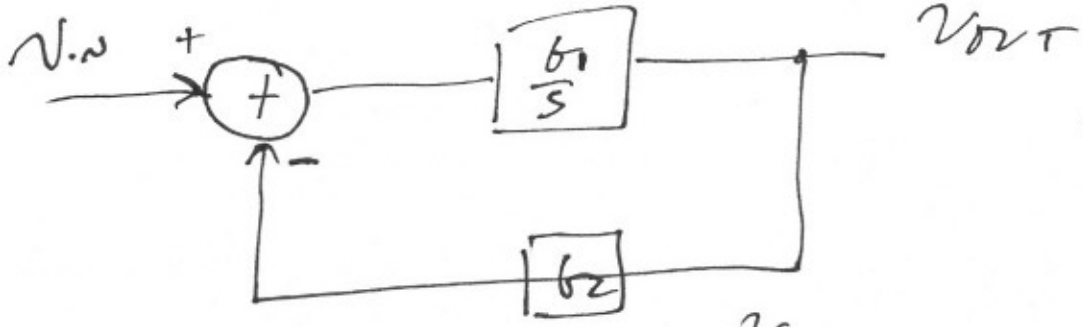
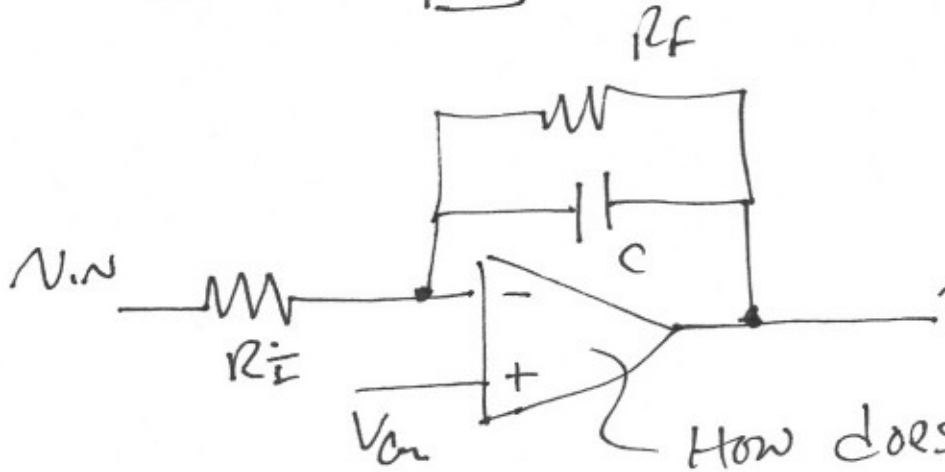
March 12 Lecture 3 !Extra!

BOISE STATE UNIVERSITY

ECE 615 CMOS Mixed-Signal Circuit Design



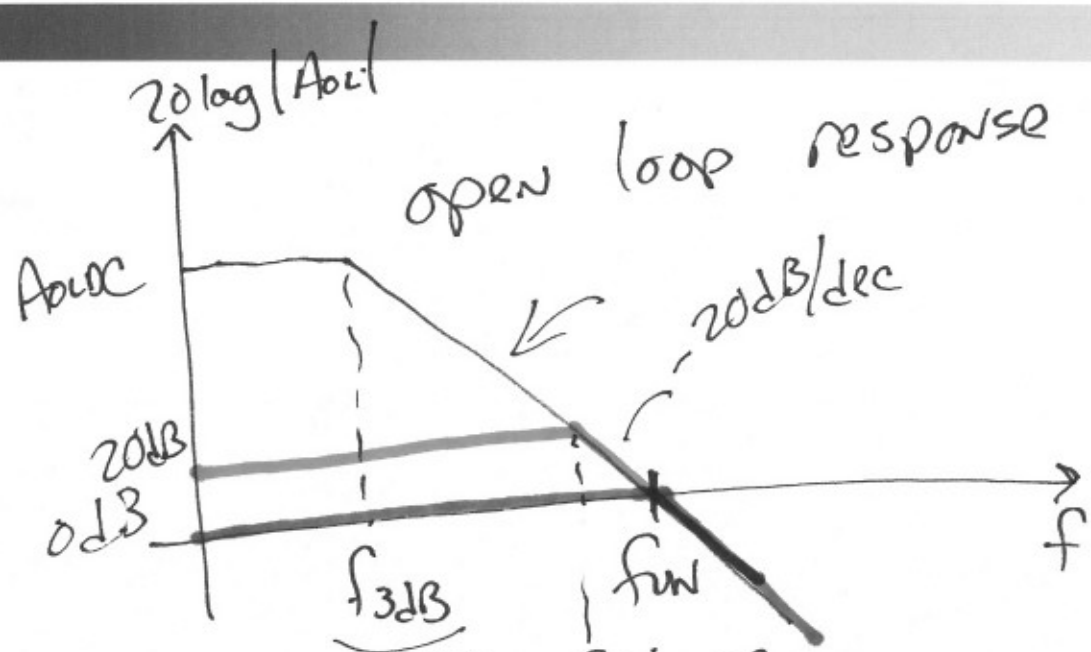
$$\frac{V_{OUT}}{V_{IN}} = \frac{\frac{1}{G_2}}{1 + \frac{s}{G_1 G_2}}$$



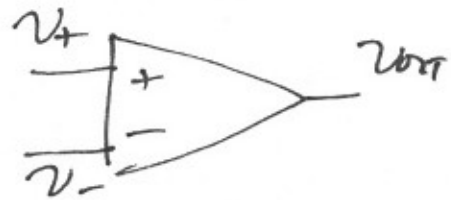
$$G_2 = \frac{R_I}{R_F}$$

$$G_1 = \frac{1}{R_I \cdot C}$$

How does the op-Amp limit performance?



$A_{OL}(s) = \frac{V_{OUT}}{V_+ - V_-}$



$10{,}000 = A_{OLDC}$

100MHz

10KHz

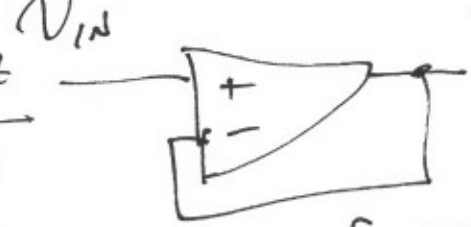
$f_{w}/10 = f_{3dB,10}$

$f_w = A_{OLDC} \cdot f_{3dB}$

$f_w = GAIN \cdot BW$

$f_{3dB} = \frac{100MHz}{10{,}000}$

$= \frac{10^8}{10^4} = 10KHz$



$f_w = 100MHz$

$A_{CL} = 1$

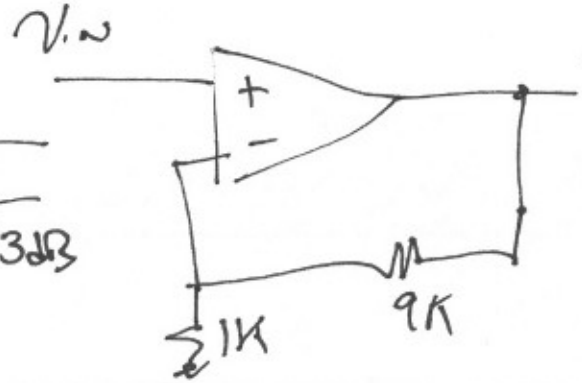
$f_w = 100MHz, f_{3dB,10}$

$= 10MHz$

$\frac{V_{OUT}}{V_{IN}} = 10 \Rightarrow 20dB$

$A_{CL} = 10$

$A_{CL} = \frac{A_{OLDC}}{1 + j\frac{f}{f_{3dB}}}$



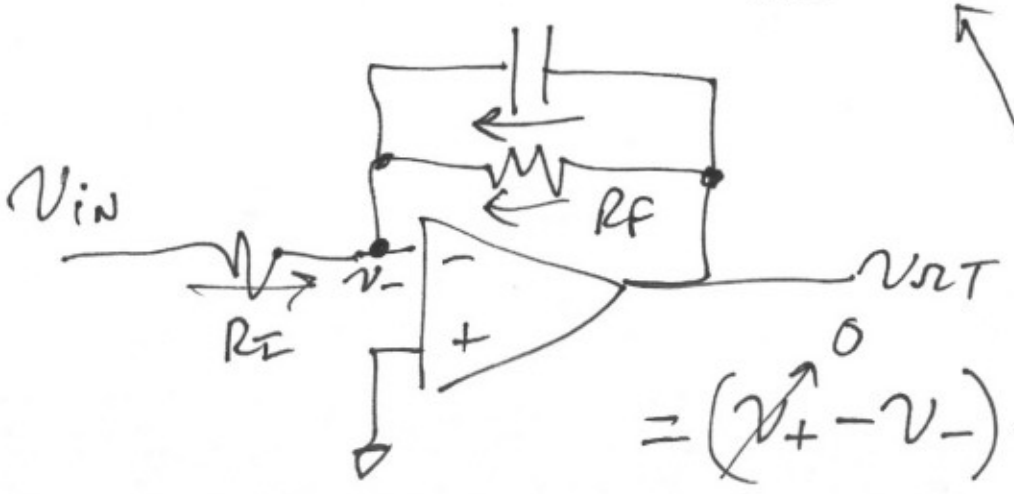
2)

OP-Amp frequency response

$$A_{OL} \simeq \frac{A_{OLDC}}{j \cdot \frac{f}{f_{3dB}}} = \frac{f_{3dB} \cdot A_{OLDC}}{j \cdot f}$$

$$A_{OL} \simeq \frac{f_{UN} \cdot 2\pi}{j \cdot f \cdot 2\pi} = \frac{1}{j \cdot \frac{f}{f_{UN}}} \simeq \frac{V_{OUT}}{V_+ - V_-}$$

$$A_{OL}(f) \simeq \frac{\omega_{UN}}{s}$$



$$\frac{V_{IN} - V_-}{R_I} + \frac{V_{OUT} - V_-}{R_F} + sC(V_{OUT} - V_-) = 0$$

$$= (V_+ - V_-) \cdot A_{OL}(f)$$

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$$V_{OUT} = -A_{OL}(f) \cdot V_-$$

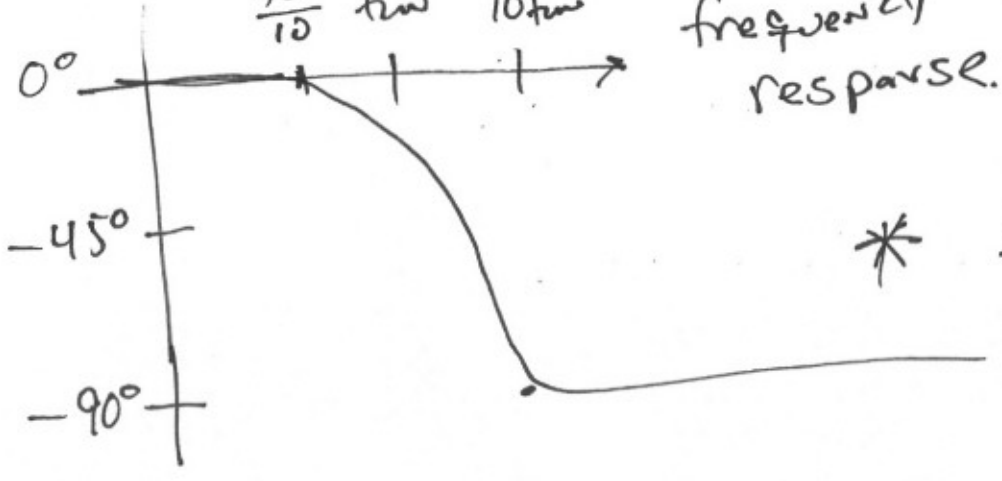
3)

$$\frac{V_{OT}}{V_{in}} = \frac{-\frac{R_F}{R_I}}{1 + SCR_F + \frac{SCR_F}{A_{OL}(f)} + \frac{1}{A_{OL}(f)} \cdot \left(1 + \frac{R_F}{R_I}\right)}$$

$R_F = R_I \quad G_2 = 1$

$$\frac{V_{OT}}{V_{in}} = \frac{1}{1 + S/G_1} \cdot \frac{1}{1 + j\frac{f}{f_{UN}}}$$

Models op Amp frequency response.

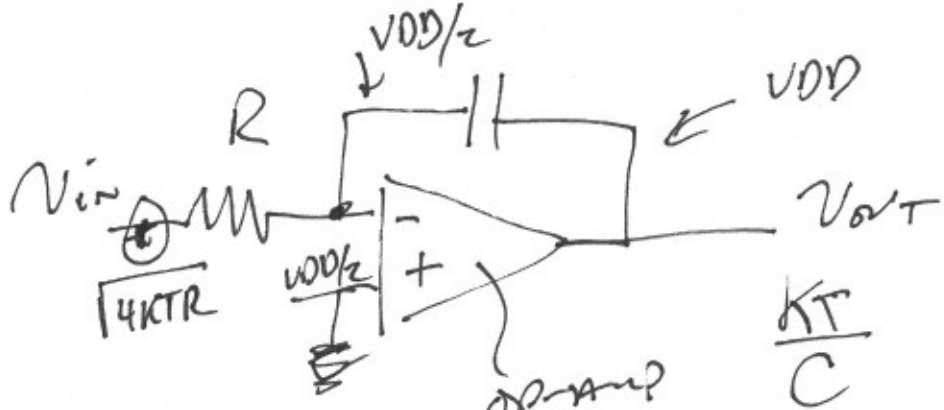


If $A_{OL}(f)$ is Big

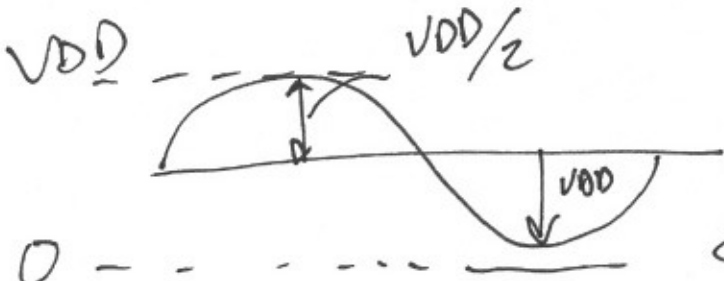
* A_{OL} to be big
* $\frac{R_F}{R_I} \rightarrow 1$ as possible

* $f_{UN} \geq 10 \cdot f_{3dB} = 10 \cdot \frac{G_1}{2\pi}$

4)



$\frac{KT}{C}$ (TABLE 2.1)



$$SNR = 20\log\left[\frac{VDD/2\cdot\sqrt{2}}{\sqrt{KT/C}}\right]$$

$$\frac{1}{2}C\left(\frac{VDD}{2}\right)^2$$

$$= 20\log\left[\frac{VDD^2/8}{KT/C}\right] = \frac{\text{Electrical Energy}}{\text{Thermal Energy}}$$

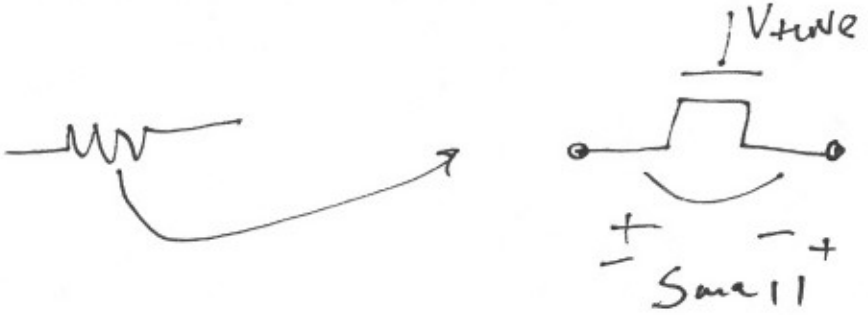
$$KT$$

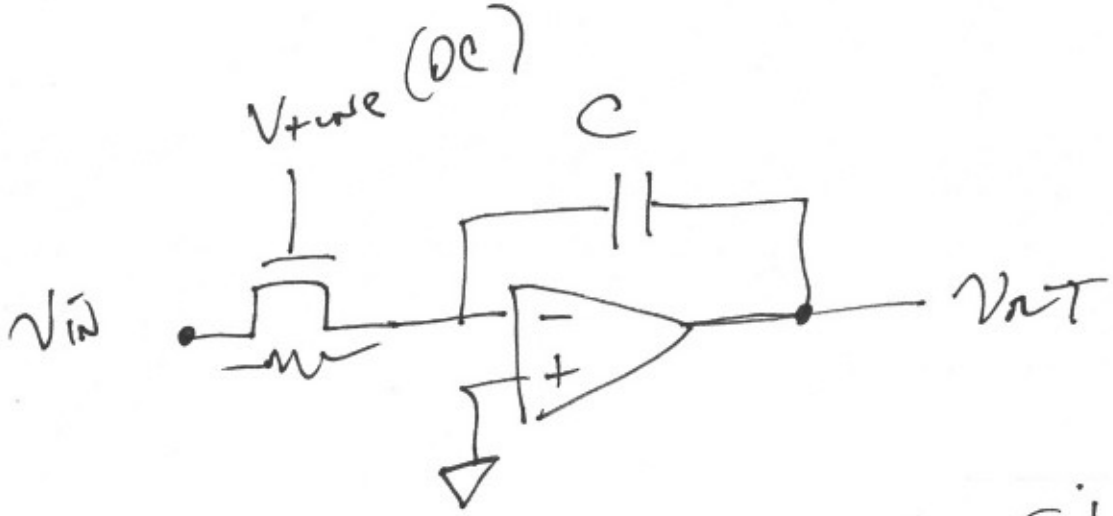
RC-filter

SNR → 90 dB

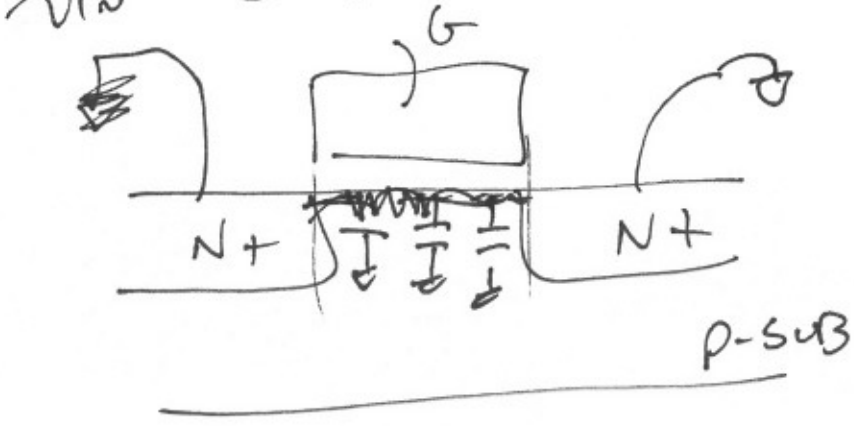
5)

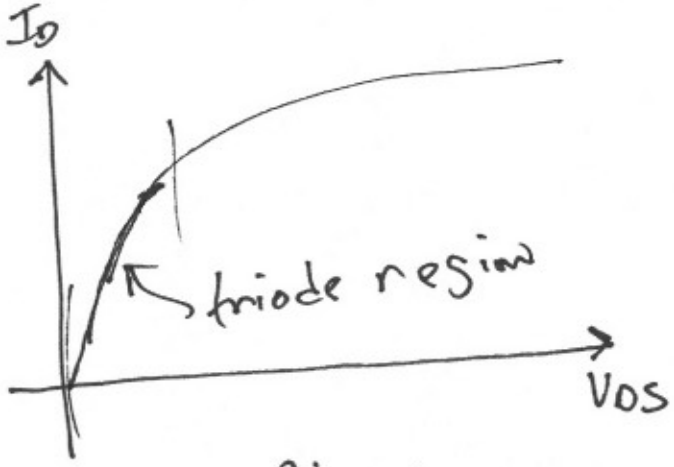
MOSFET-C Integrator

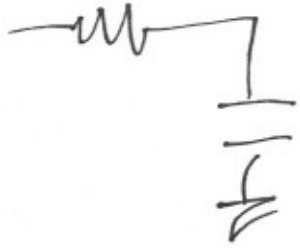


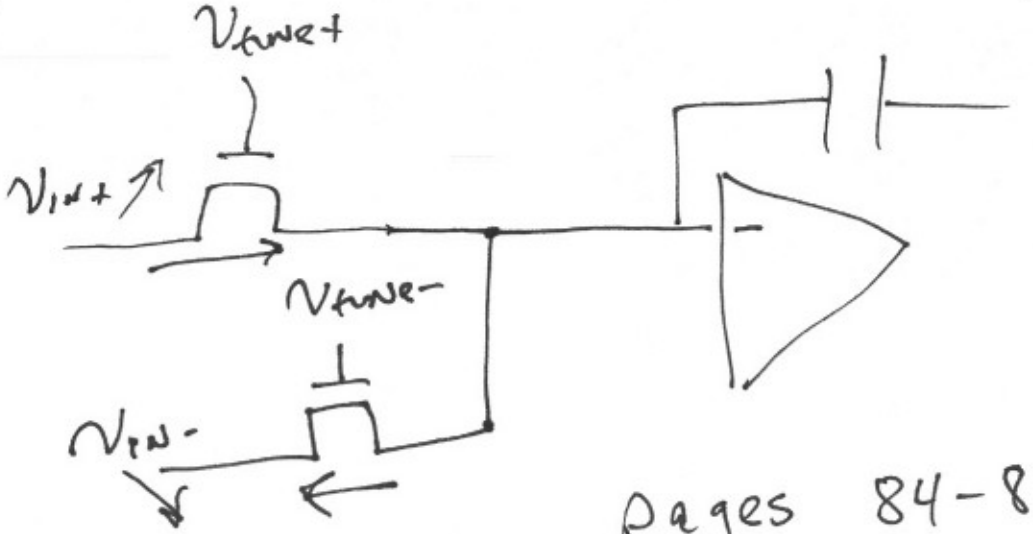


VIN Simple MOSFET-C Filter









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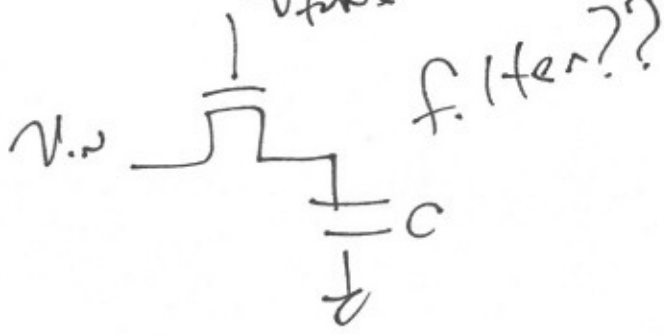
more details

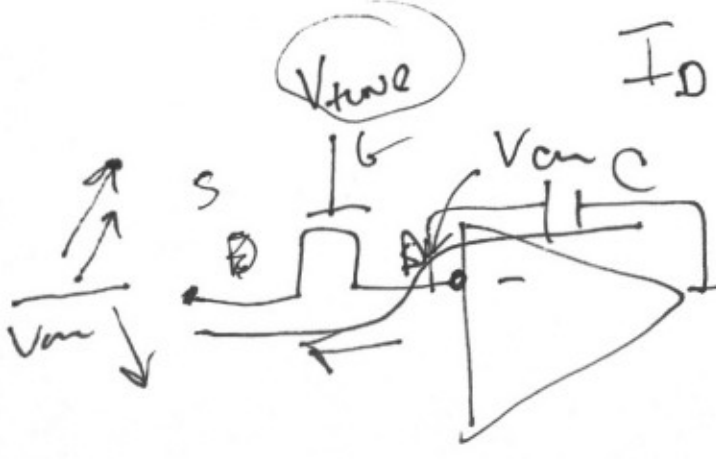


filter??

7)

op-Amp provides isolation

$$I_D = \beta\left((V_{GS}-V_{TH})V_{DS} - \frac{V_{DS}^2}{2}\right)$$



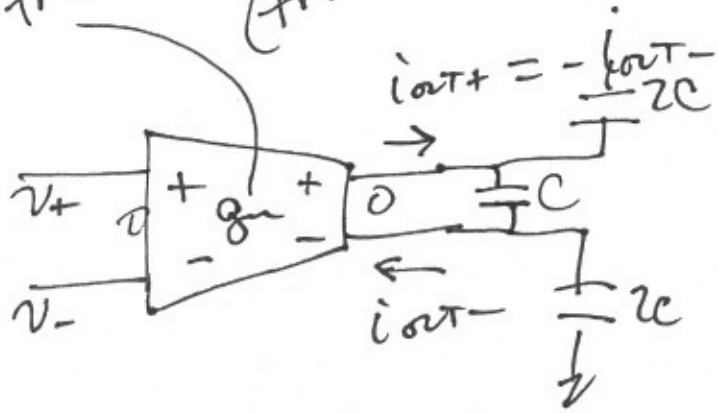
$$\frac{V_{DS}}{I_D} = R_N = \frac{1}{\beta(V_{GS}-V_{TH})}$$

↑ tune

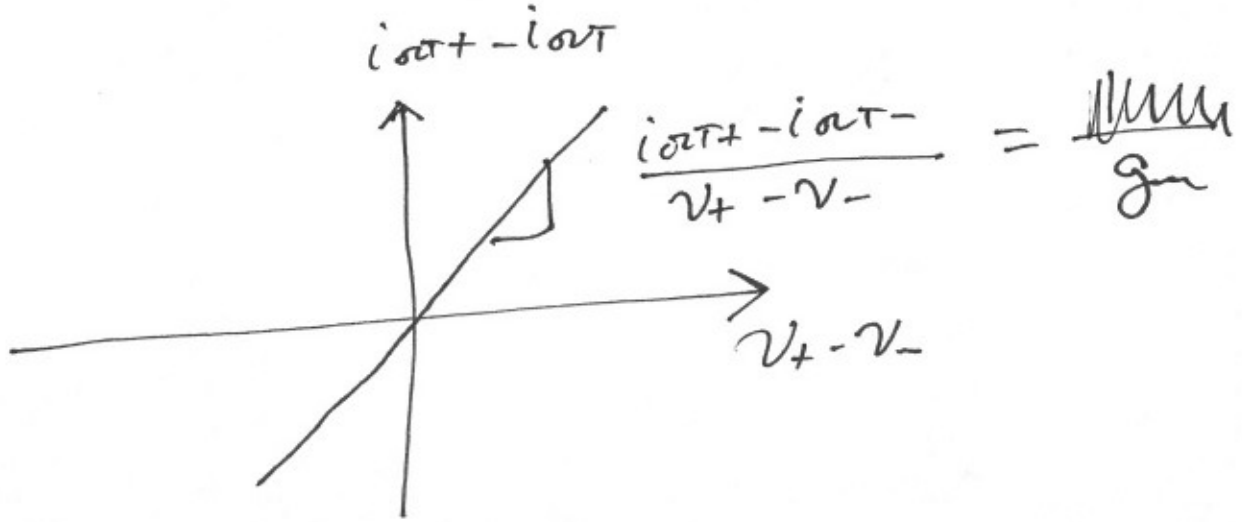
8)

g_m-C (transconductor filters)

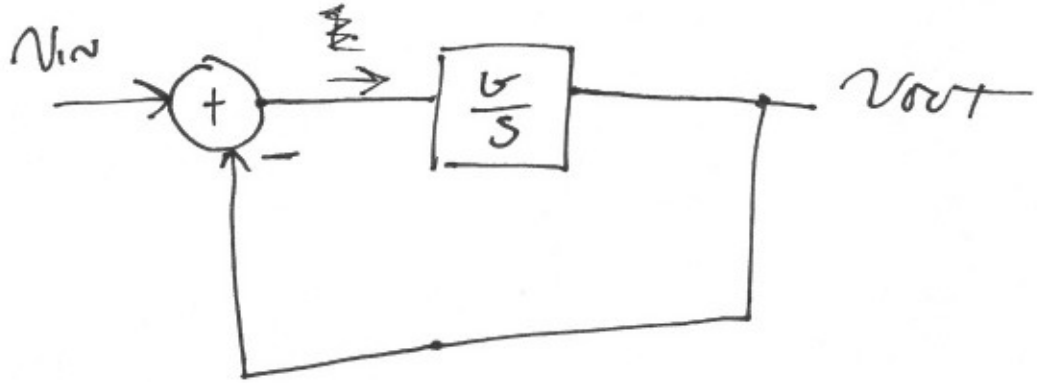
transconductor (transconductance Amp)

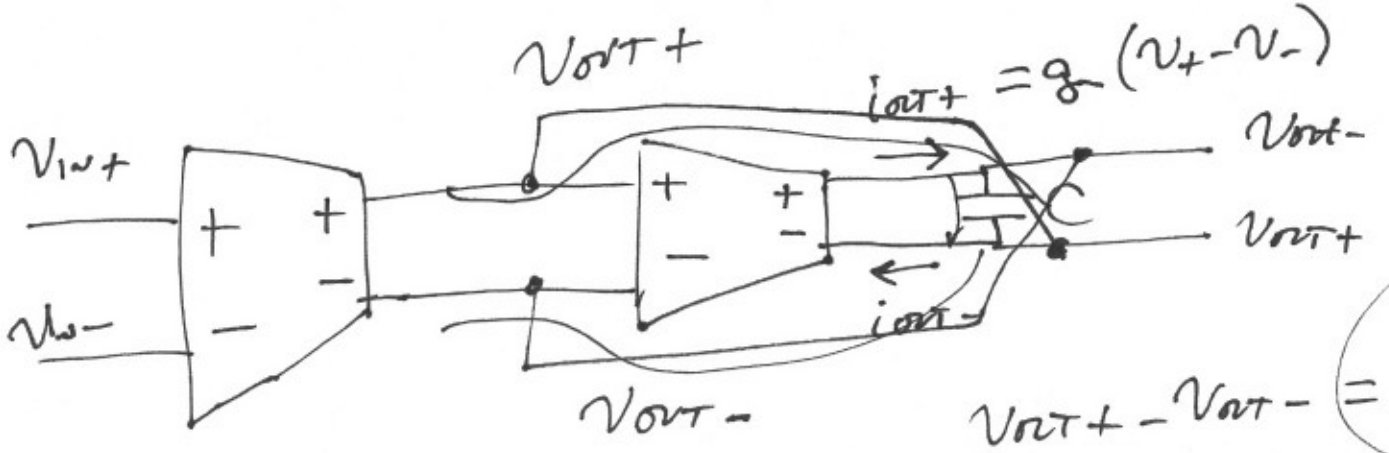


$g_m(v_+ - v_-) = i_{OUT+} - i_{OUT-}$



$\frac{i_{OUT+} - i_{OUT-}}{v_+ - v_-} = g_m$

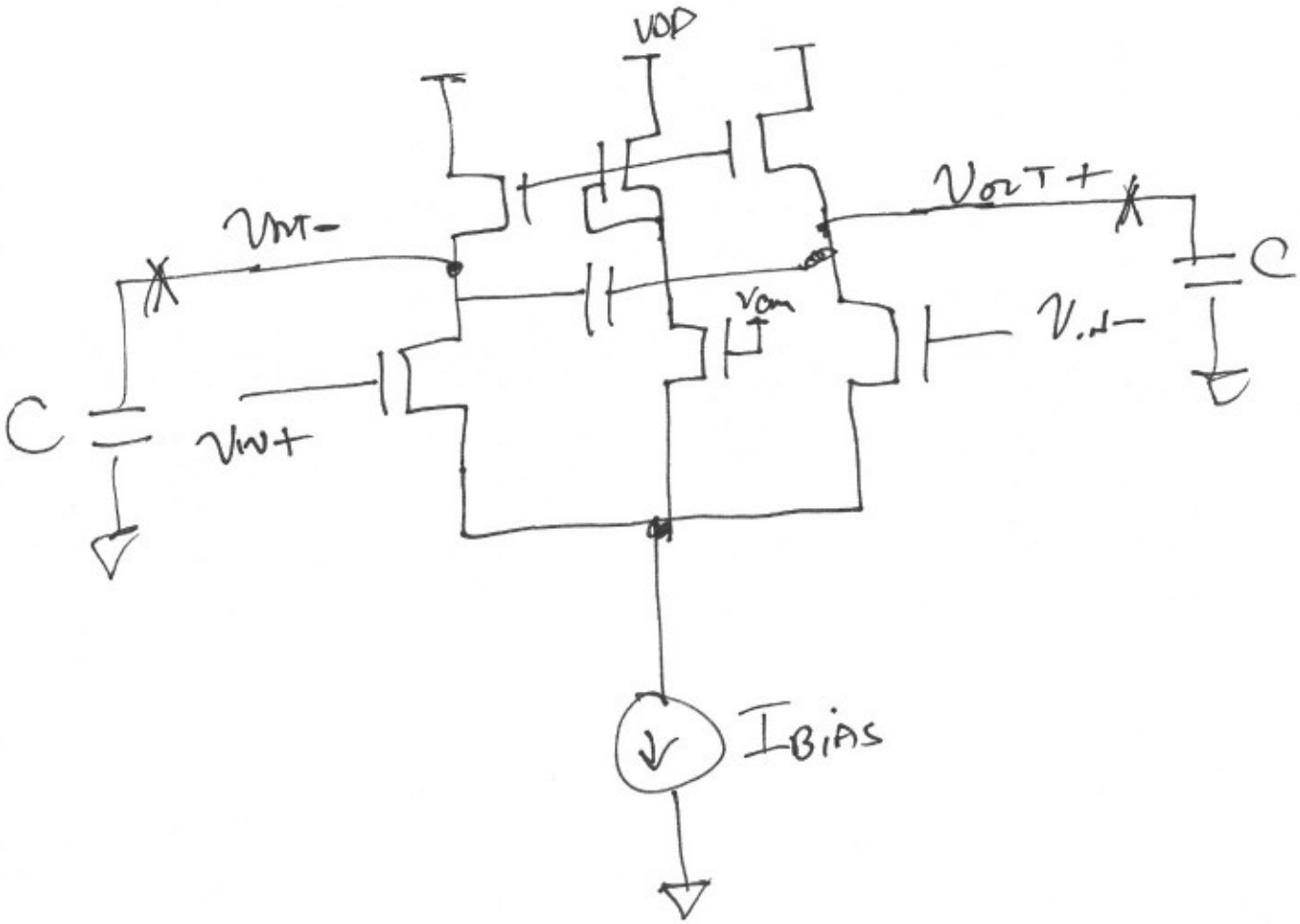




$$V_{OUT+} - V_{OUT-} = \frac{i_{out+}}{j\omega C}$$

$$\frac{V_{OUT+} - V_{OUT-}}{V_{IN+} - V_{IN-}} = \frac{1}{j \cdot \omega \cdot \frac{C}{g_m}} \qquad G = \frac{g_m}{C} = C \cdot \frac{1}{g_m}$$

→ easily adjustable



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