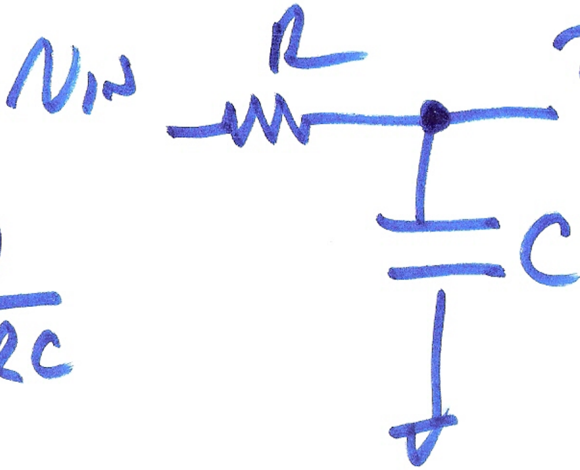
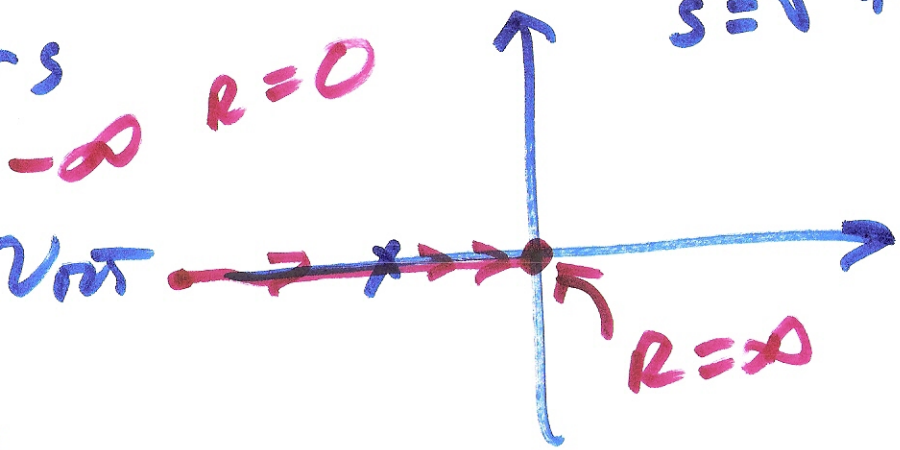
ECE 615 CMOS Mixed-Signal Circuit des.

Sept. 20, 2010

Lecture 8

Analog filters

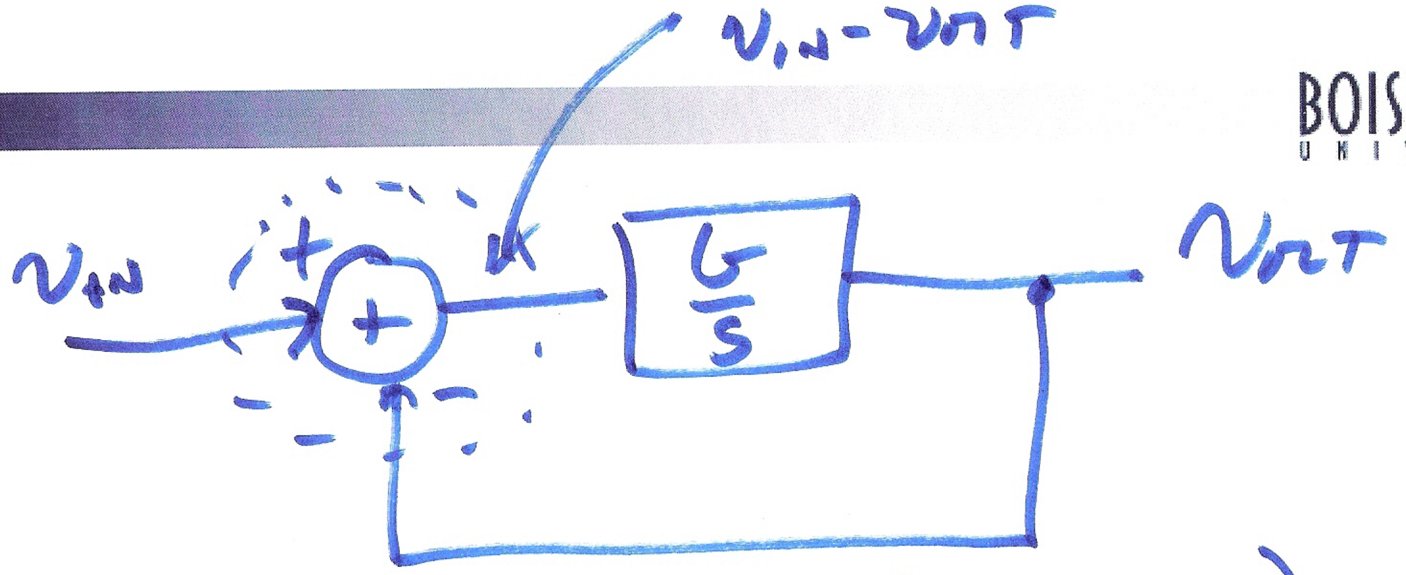




$s_{pole} = -\frac{1}{RC}$

$$\frac{v_{OUT}}{v_{IN}} = \frac{1/j\omega C}{1/j\omega C + R}$$

$$\frac{1}{1+sRC} = \frac{1}{1+j\omega RC} \quad s = -\frac{1}{RC}$$



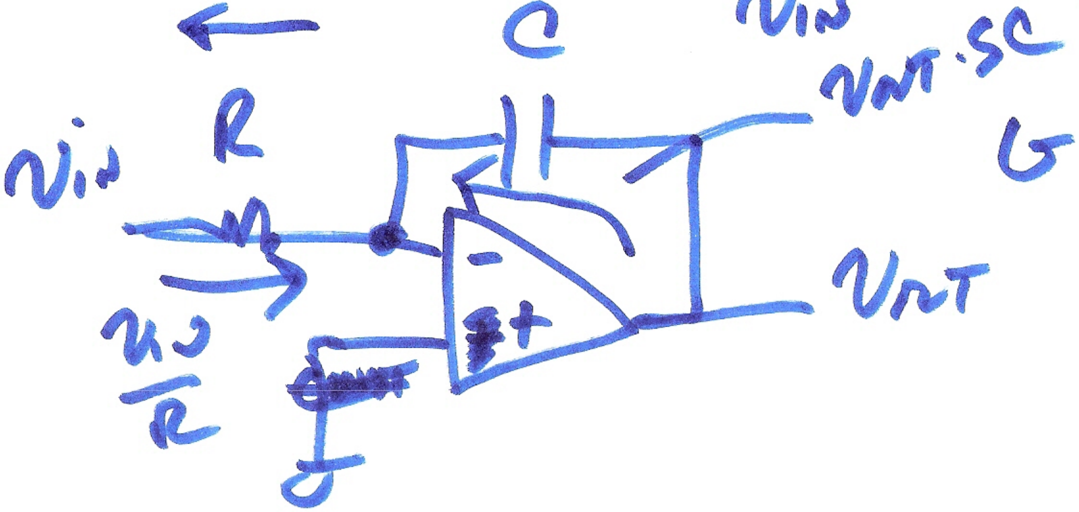
$$v_{OUT} = \frac{G}{s}\left(v_{IN} - v_{OUT}\right)$$

$v_{IN}\left(-1/R\right)$

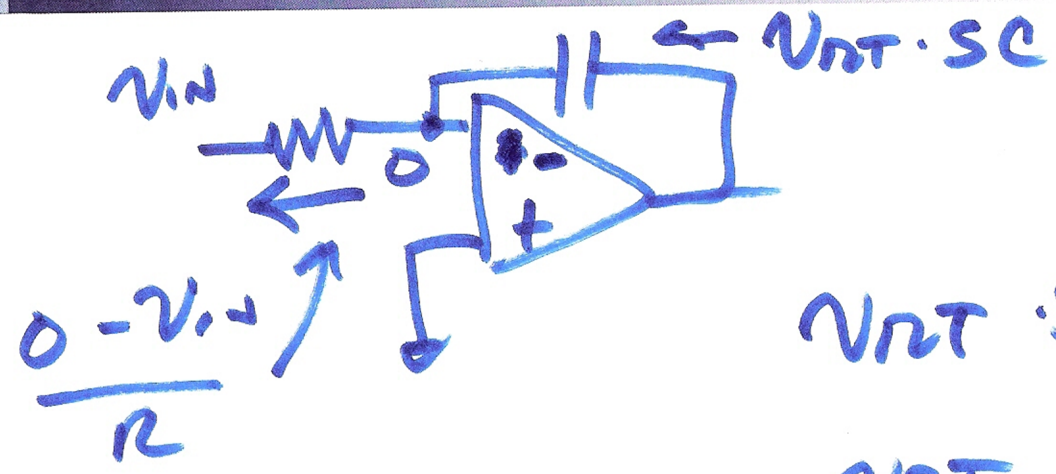
$-v_{IN}/R$

$$\frac{v_{OUT}}{v_{IN}} = \frac{1}{1 + s/G} = \frac{1}{1 + sRC}$$

$$G = \frac{1}{RC}$$

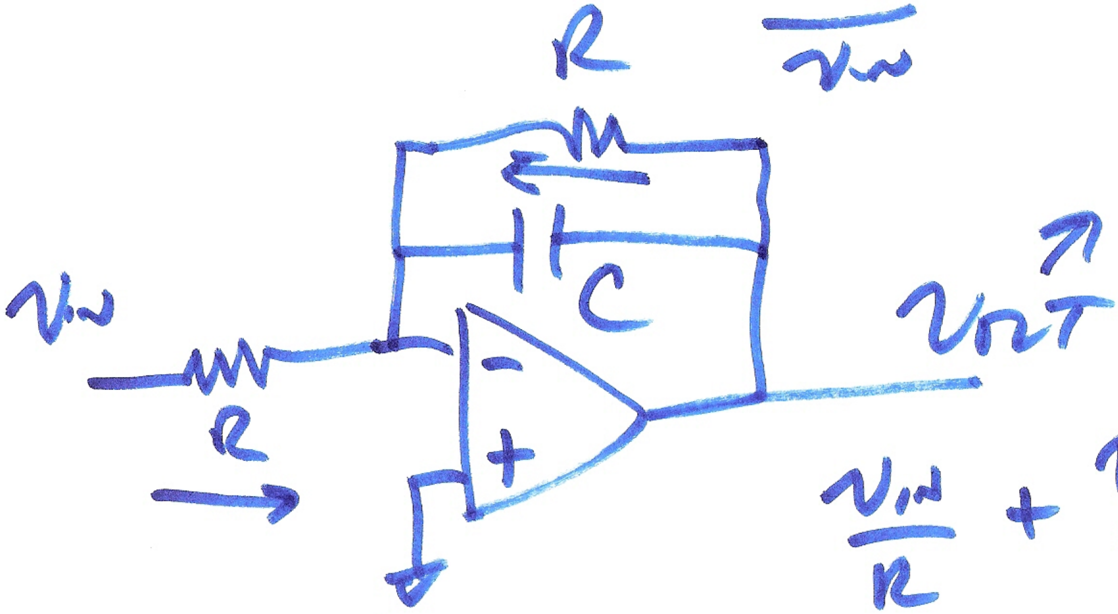


2)



$$V_{OUT} \cdot SC = -\frac{V_{IN}}{R}$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{1}{SRC}$$

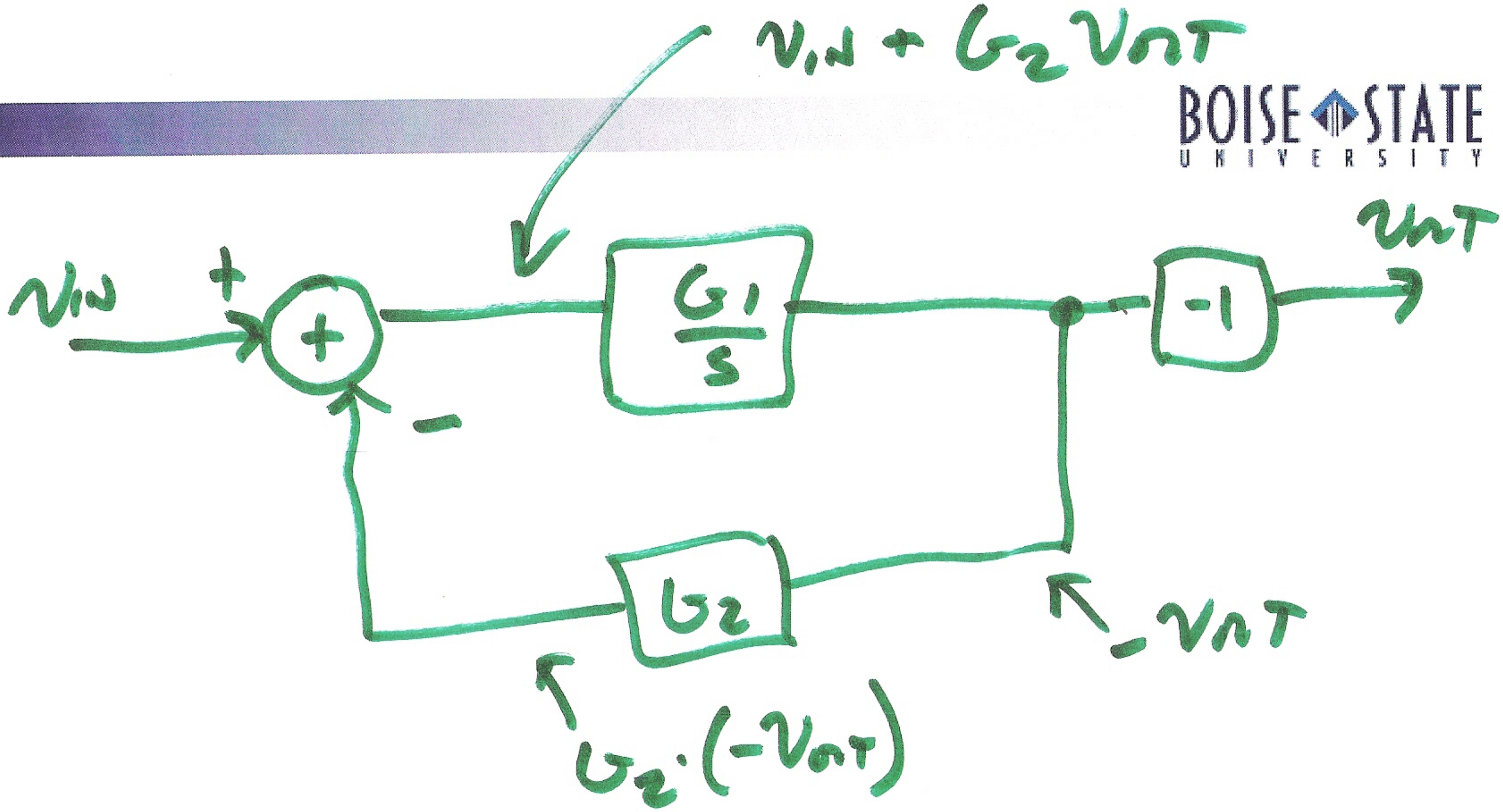


$$\frac{V_{IN}}{R} + \frac{V_{OUT}}{R} + V_{OUT}SC = 0$$

$$-\frac{V_{IN}}{R} = V_{OUT}\left(\frac{1}{R} + SC\right)$$

$$\frac{V_{OUT}}{V_{IN}} = \frac{-1}{1 + SRC}$$

3)

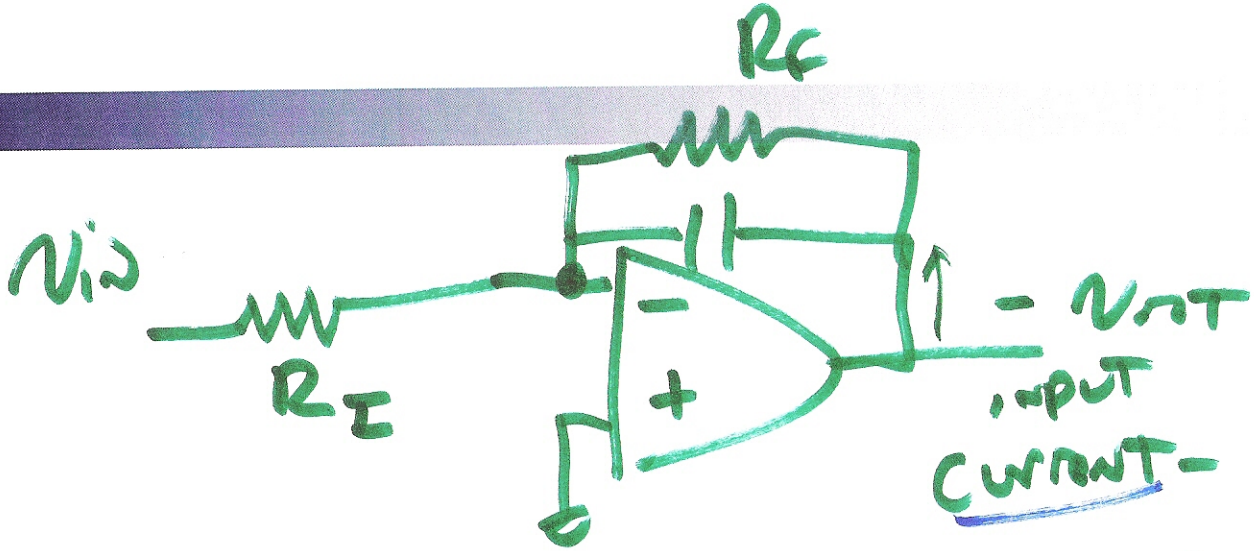


$$-v_{OUT} = \frac{G_1}{s}\left(v_{IN} + G_2 v_{OUT}\right)$$

$$-v_{OUT}\left(1 + \frac{G_1 G_2}{s}\right) = \frac{G_1}{s} v_{IN}$$

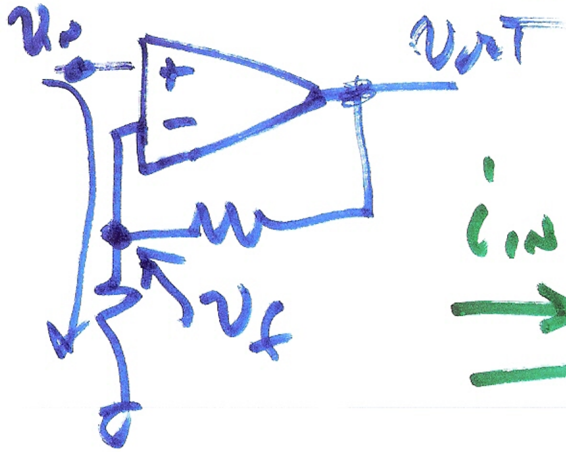
$$\frac{-v_{OUT}}{v_{IN}} = \frac{G_1}{\cancel{G_1G_2\, s}\; G_1 G_2 + s} = \frac{\frac{1}{G_2}}{1 + \frac{s}{G_1 G_2}}$$

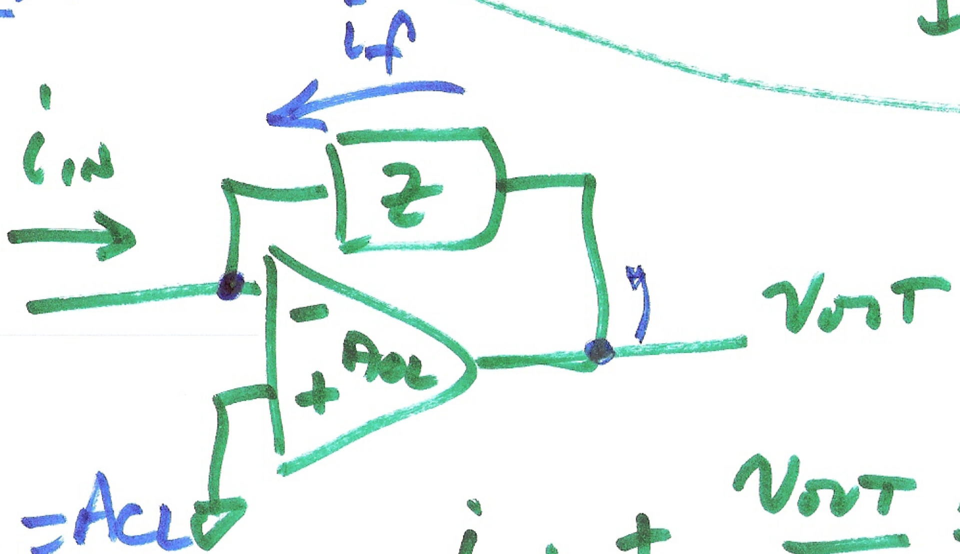
4)



input current – output voltage

$$\frac{V}{I} = \text{transimped.}$$





$$i_f = \beta \cdot V_{out}$$

$$\beta = +\frac{1}{Z}$$

$$\frac{A_{OL}}{A_{OL}\beta + 1} = A_{CL}$$

$$i_{IN} + \frac{V_{out}}{Z} = 0$$

$$\boxed{\frac{V_{out}}{i_{IN}} = -Z}$$

$$\frac{1}{\beta + 1/A_{OL} \to 0} = A_{CL} = \frac{1}{\beta}$$

5)

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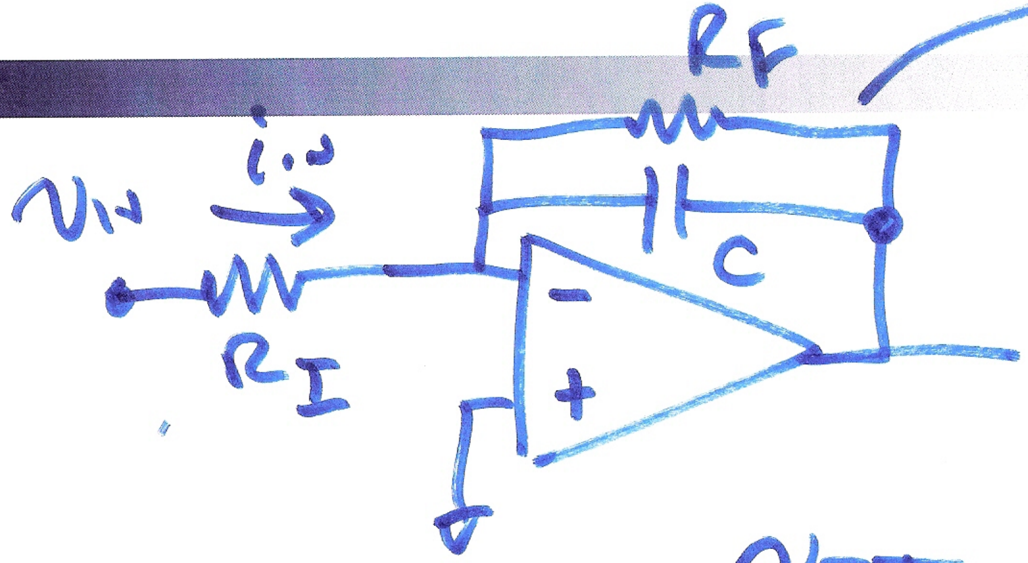


$$\frac{R_F}{1+sR_FC} = Z$$

$$\frac{1}{G_1 G_2} = R_F C$$

$$\left(G_1 \frac{R_I}{R_F}\right)^{-1} = R_F C$$

$$i_{IN} = \frac{v_{in}}{R_I}$$

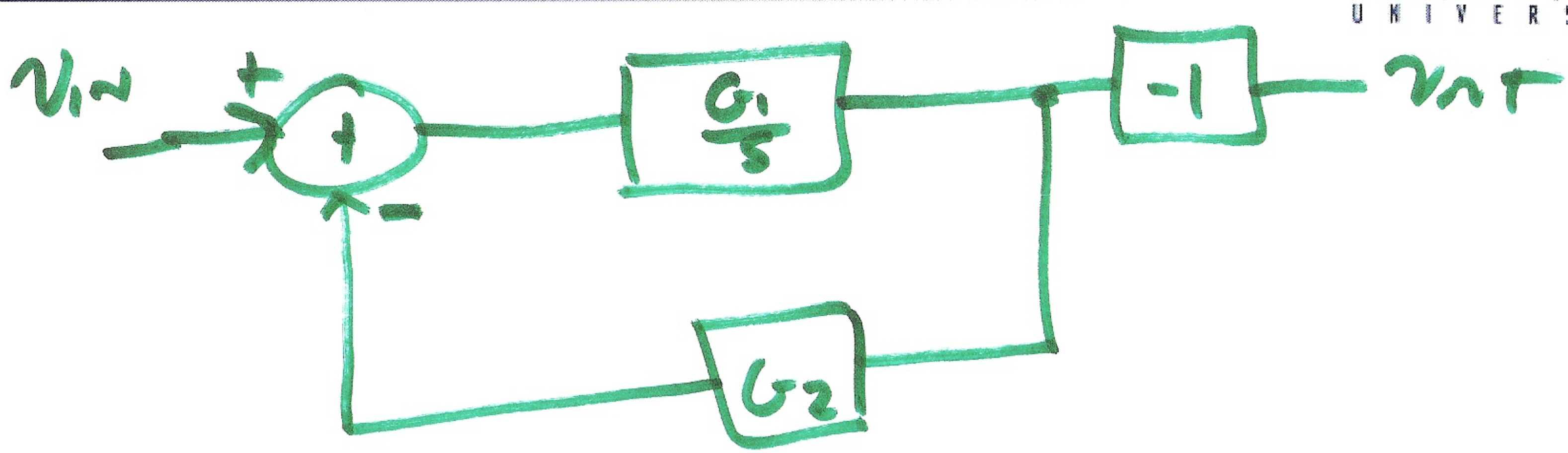
$$\frac{v_{out}}{v_{in}} = \frac{-\frac{R_F}{1+R_F \cdot s \cdot C}}{R_I}$$

$$\frac{v_{out}}{i_{in}} = \frac{-R_F}{1+sR_FC}$$

$$\frac{-\frac{R_F}{R_I}}{1+sR_FC} = \frac{-\frac{1}{G_2}}{1+\frac{s}{G_1 G_2}}$$

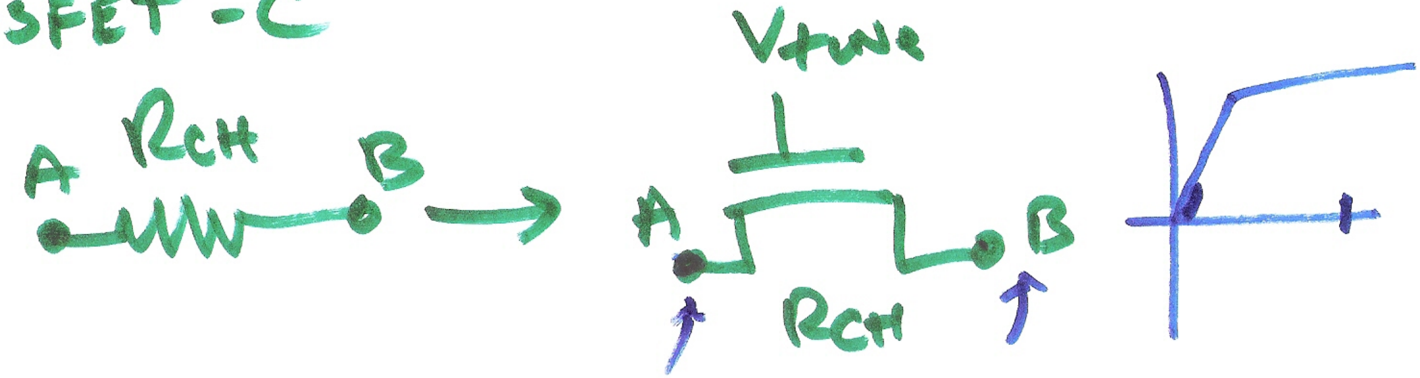
$$\left\{ \begin{array}{l} G_2 = \frac{R_I}{R_F} \\ G_1 = \frac{1}{R_I \cdot C} \end{array} \right.$$

b)



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

MOSFET - C



g_m-C (transconductor) OTA

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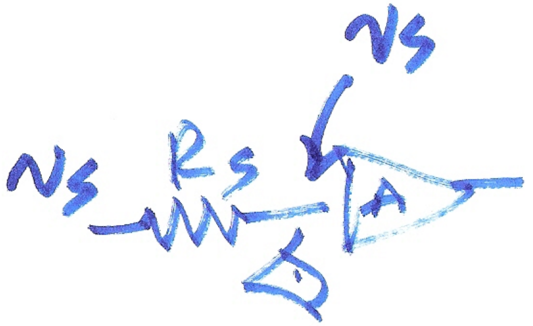
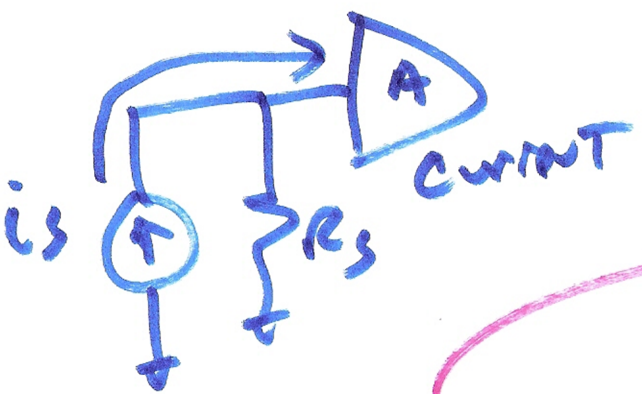
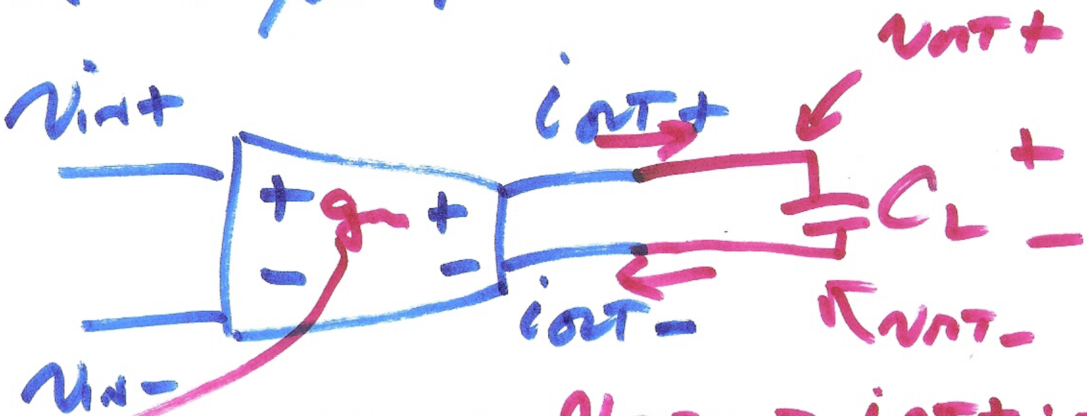
transconductor with only two high-impedance nodes INPUTS/OUTPUTS

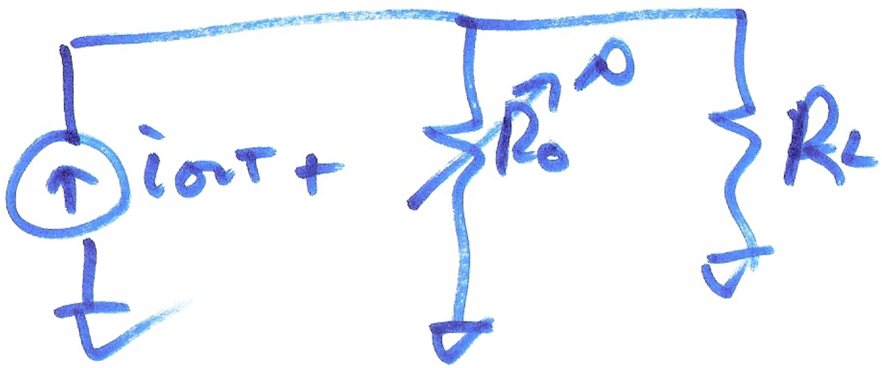






$$v_{OUT+} - v_{OUT-} = i_{OUT+} \cdot \frac{1}{j\omega C_L}$$

$$= i_{OUT} \cdot \frac{1}{j\omega C_L}$$

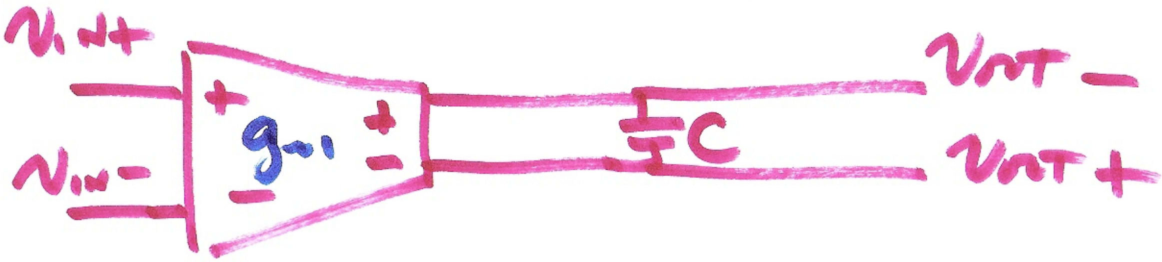


$$g_m(v_{IN+} - v_{IN-}) = (i_{OUT+} - i_{OUT-})$$

$$= \frac{g_m}{2}(v_{IN+} - v_{IN-}) = \pm i_{OUT\pm}$$

8)

Integrator using g_m-C

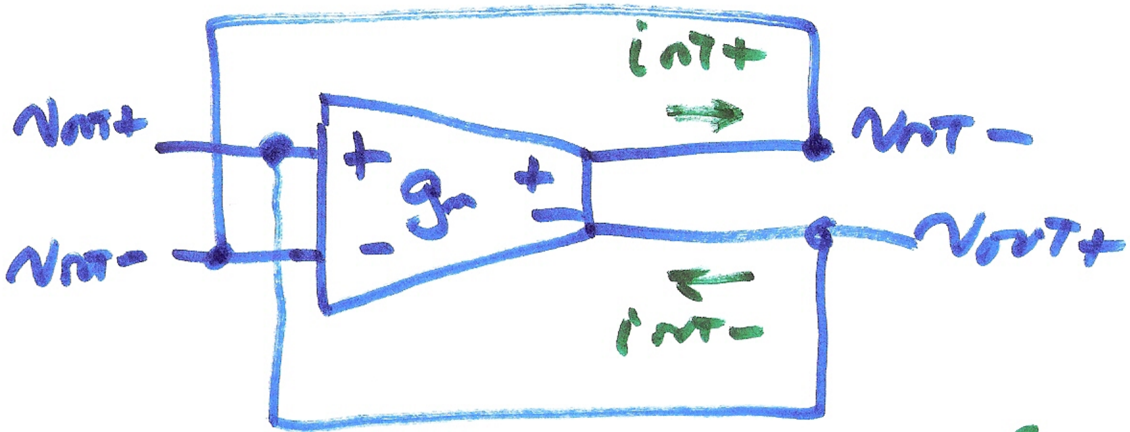


$$v_{OUT+} - v_{OUT-} = i_{OUT\pm} \cdot \frac{1}{j\omega C}$$

$$= \frac{g_m}{2}\left(v_{IN+} - v_{IN-}\right)\frac{1}{j\omega C}$$

$$\frac{v_{OUT+} - v_{OUT-}}{v_{IN+} - v_{IN-}} = \frac{1}{j\omega \cdot \frac{2}{g_m} \cdot C}$$

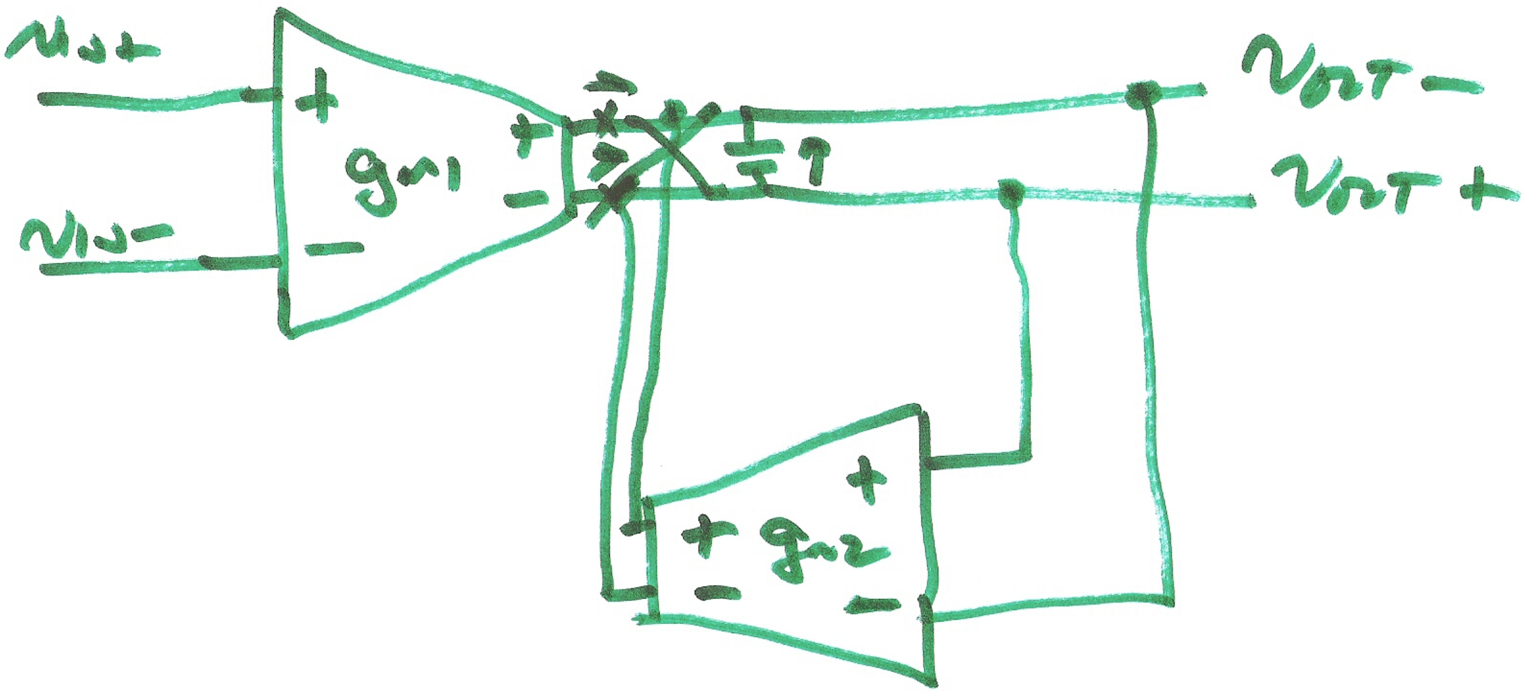
9)



$$g_m\left(v_{out+} - v_{out-}\right) = \left(i_{out+} - i_{out-}\right)$$

$$\frac{v_{out+} - v_{out-}}{i_{out+} - i_{out-}} = \frac{1}{g_m} \quad \text{(Res.!)}$$

Fig. 3.16

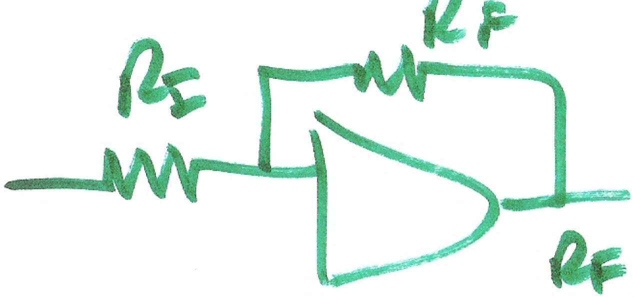


$$\frac{-g_{m1}(v_{in+} - v_{in-}) + g_{m2}(v_{out+} - v_{out-})}{} + (v_{out-} - v_{out-}) \cdot sC = 0$$

$$(v_{out+} - v_{out-}) \cdot (g_{m2} + sC) = g_{m1}(v_{in+} - v_{in-})$$

11)

$$\frac{V_{OUT+}-V_{OUT-}}{V_{IN+}-V_{IN-}} = \frac{g_{m1}}{g_{m2}+sC}$$



$$\frac{R_F}{R_I} \qquad = \frac{\frac{g_{m1}}{g_{m2}}}{1+\frac{sC}{g_{m2}}}$$

$$\frac{1/g_{m2}}{1/g_{m1}}$$

$$= \frac{\frac{1}{G_2}}{1+\frac{s}{G_1 G_2}}$$

$$G_2 = \frac{g_{m2}}{g_{m1}}$$

$$\frac{1}{G_1 G_2} = \frac{C}{g_{m2}} \rightarrow G_1 = \frac{g_{m1}}{g_{m2}} \cdot \frac{g_{m2}}{C} = \frac{g_{m1}}{C}$$

$$\frac{v_{OUT}}{v_1(z) - v_2(z)} = \frac{C_I}{C_F} \cdot \frac{z^{-1/2}}{1 - z^{-1}}$$

$$\frac{1}{s}$$

$$z = e^{j2\pi \frac{f}{f_s}} \approx 1 + j2\pi\frac{f}{f_s}$$

$$f \ll f_s$$

$$\boxed{\frac{z^{-1}}{1-z^{-1}}}$$

$$\frac{C_I}{C_F} \cdot \frac{1}{z-1} \approx \frac{C_I}{C_F} \cdot \frac{-1}{j2\pi\frac{f}{f_s}}$$

$$\frac{v_1 \cdot z^{-1/2} - v_2 z^{-1/2}}{1 - z^{-1}} \quad \frac{C_I}{C_F}$$

$$\frac{G}{s}$$

$$\boxed{G = \frac{C_I}{C_F} \cdot f_s}$$

$$f \ll f_s$$