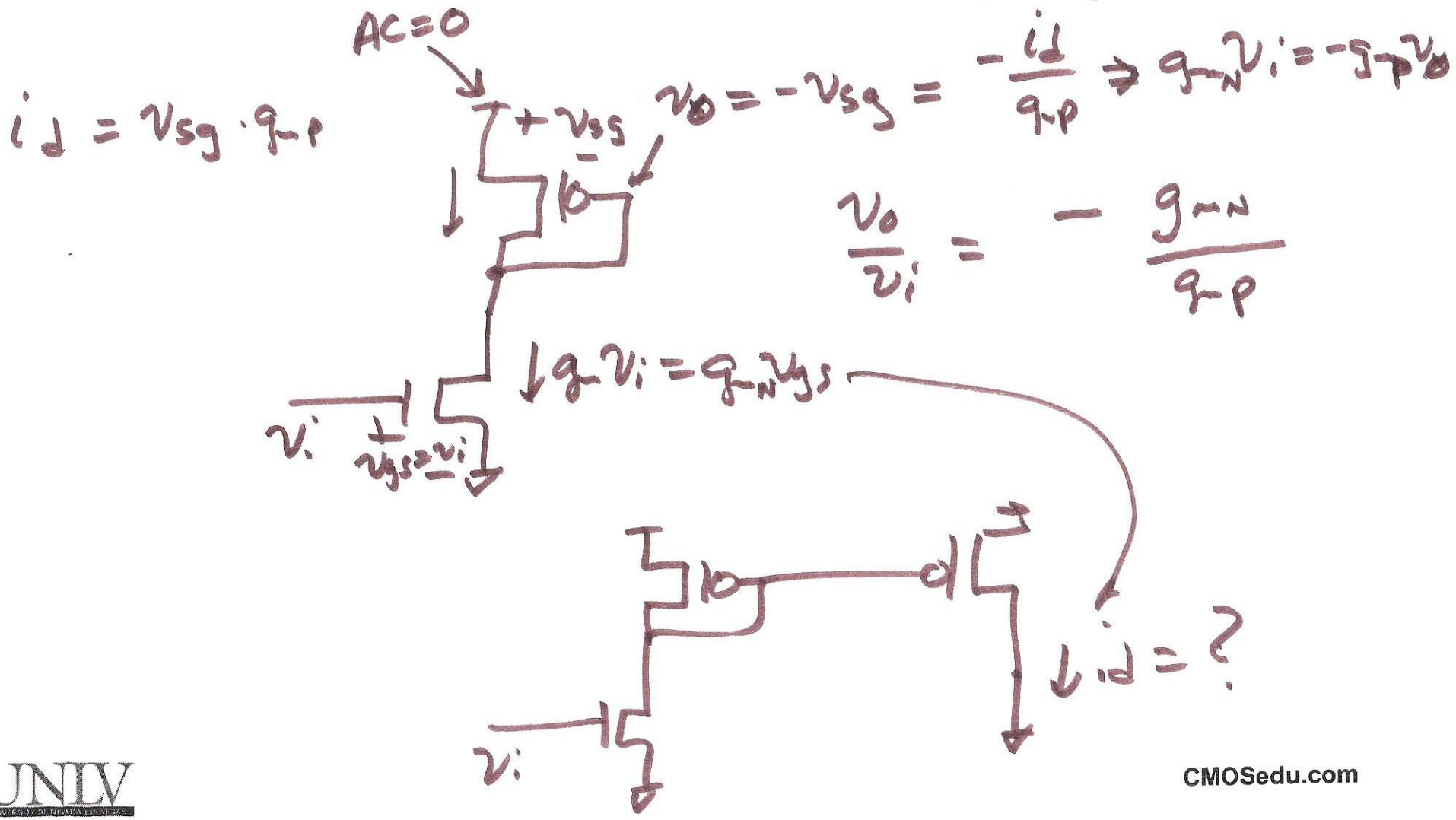
# EE 422 / ECE 622
# Analog IC Design
## Lecture 14, 3/15/13

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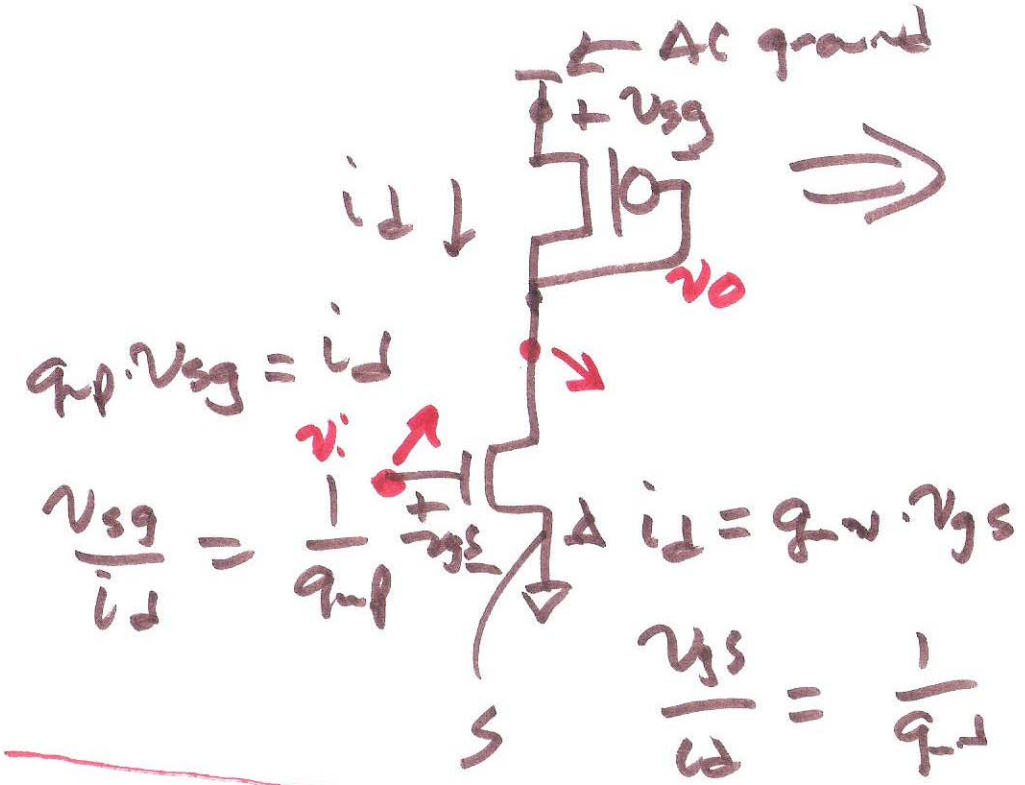
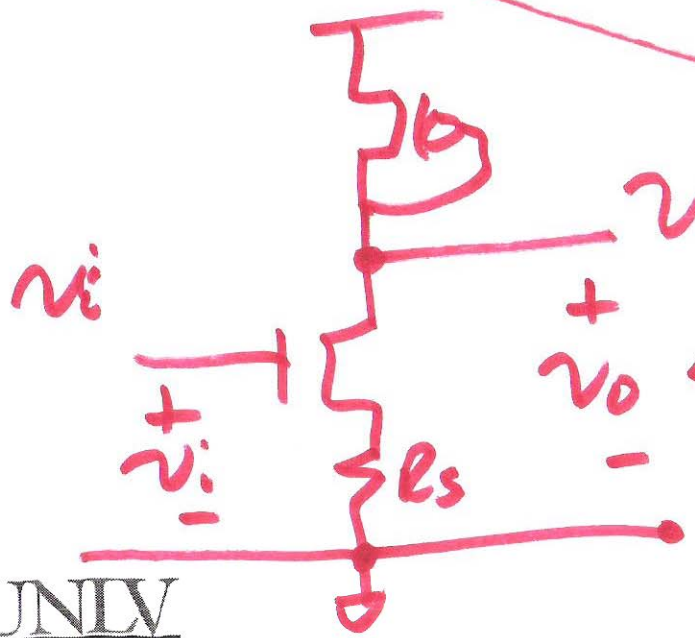



$\Rightarrow$ $\frac{1}{g_{mp}}$ Neg. $r_o$

$$gain = -\frac{1/g_{mp}}{1/g_{mN}}$$

$$= -\frac{g_{mN}}{g_{mp}}$$

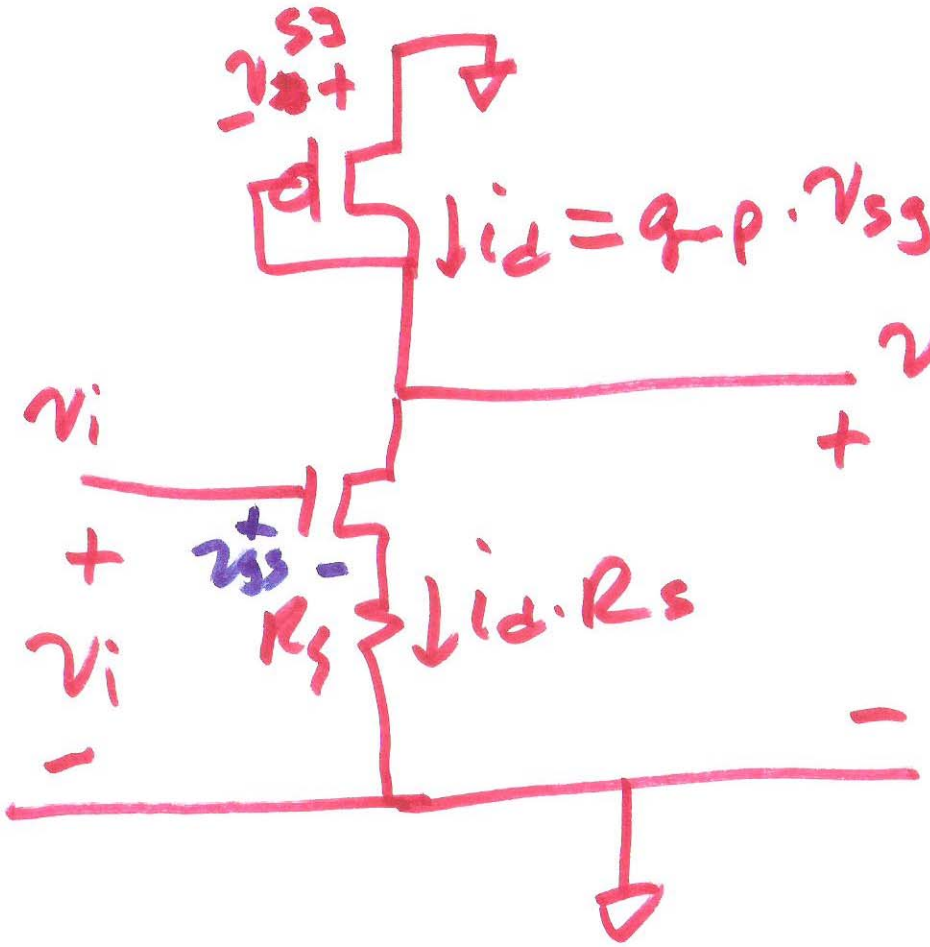
$$= \frac{\text{resistance in drain}}{\text{resistance in source}}$$




$$\frac{v_o}{v_i} = -\frac{1/g_{mp}}{1/g_{mN} + R_S} = -\frac{1}{1 + g_{mN} R_S}$$



2) Common-Source Amplifier




$$v_{gs} = \frac{i_d}{g_m}$$

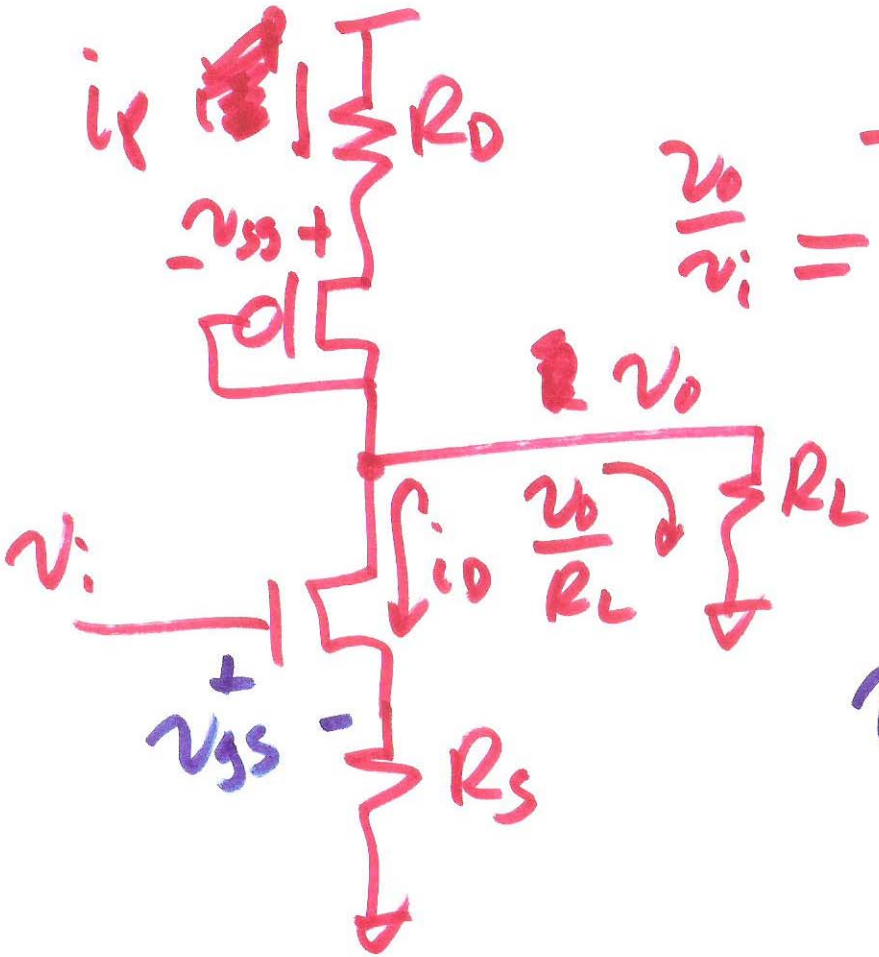
$$v_{out} = -v_{sg} = -\frac{i_d}{g_{mp}}$$

$$v_i = v_{gs} + i_d \cdot R_s$$

$$= \frac{i_d}{g_m} + i_d \cdot R_s$$

$$v_i = i_d \left( \frac{1}{g_m} + R_s \right)$$

$$\frac{v_{out}}{v_i} = \frac{-i_d / g_{mp}}{i_d \left( \frac{1}{g_m} + R_s \right)}$$




$$\frac{v_o}{v_i} = \frac{-\left(R_D + \frac{1}{g_{mp}}\right) \| R_L}{R_s + \frac{1}{g_{mN}}}$$

$$v_i = v_{gs} + i_d \cdot R_s$$

$$= i_d \left(\frac{1}{g_{mN}} + R_s\right)$$

$$i_d = i_p - \frac{v_o}{R_L}$$

$$v_o = -v_{sg} - i_p \cdot R_D$$

$$= -i_p \left(\frac{1}{g_{mp}} + R_D\right)$$

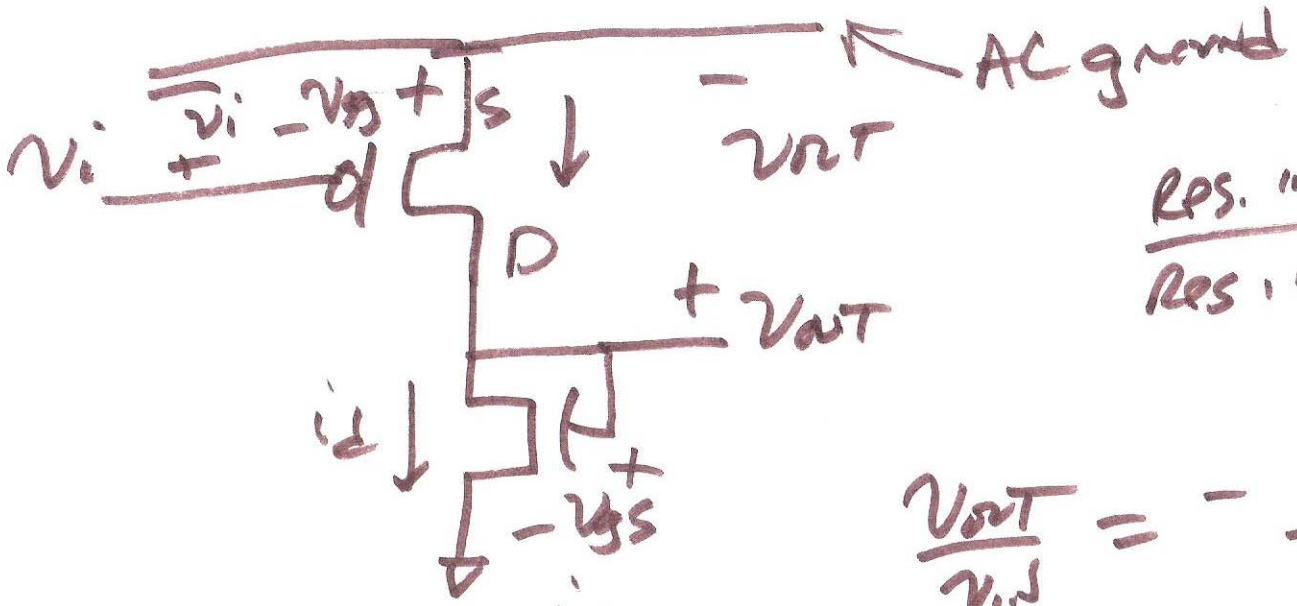
$$i_p = \frac{-v_o}{\frac{1}{g_{mp}} + R_D}$$

$$v_i = i_d \cdot \left(\frac{1}{g_{mN}} + R_S\right)$$

$$i_d = -v_o\left(\frac{1}{R_L} + \frac{1}{\frac{1}{g_{mP}} + R_D}\right)$$

$$v_i = \frac{-v_o\left(\frac{1}{g_{mN}} + R_S\right)}{R_L \| \left(\frac{1}{g_{mP}} + R_D\right)}$$

$$\frac{v_o}{v_i} = \frac{-R_L \| \left(\frac{1}{g_{mP}} + R_D\right)}{\frac{1}{g_{mN}} + R_S}$$




RPS. INDRAN-
RES. IN SOURCE

$$v_{out} = v_{gs} = \frac{i_d}{g_{mN}}$$

$$v_i = -v_{sg} = \frac{-i_d}{g_{mP}}$$

$$\frac{v_{out}}{v_{in}} = -\frac{1/g_N}{1/g_P} = -\frac{g_P}{g_N}$$

$$\frac{v_{out}}{v_i} = \frac{i_d/g_N}{-i_d/g_P} = -\frac{g_P}{g_N}$$



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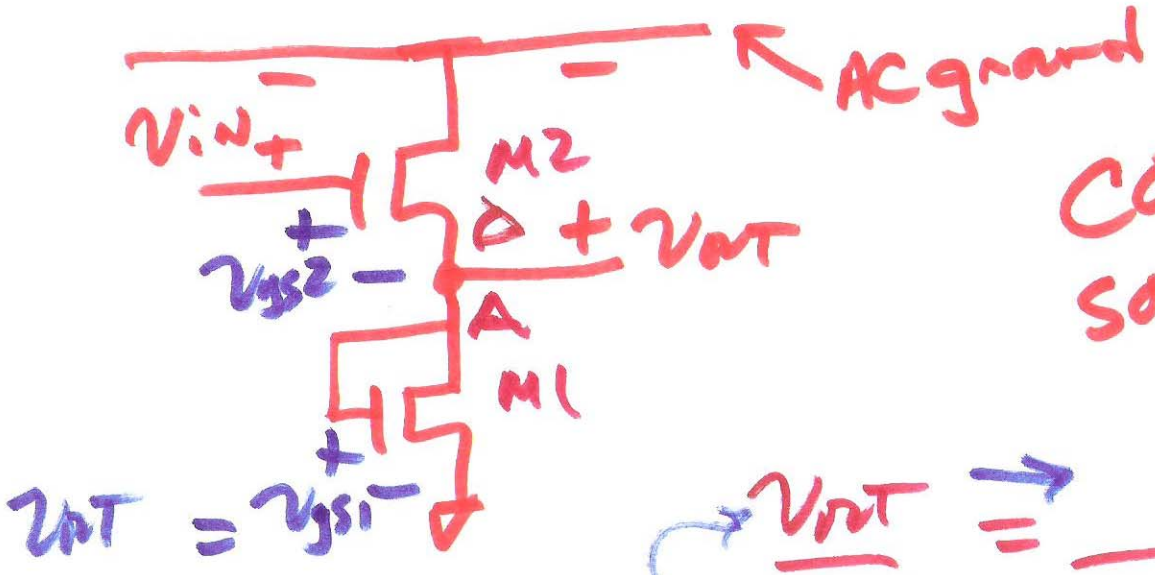
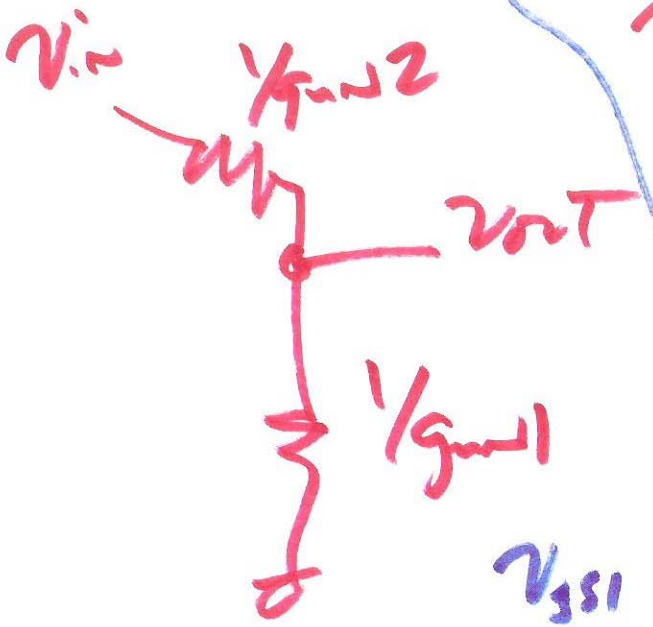



## Common-Drain or source follower

$$\frac{v_{out}}{v_{in}} = \frac{1/g_{mN2} \,||\, 1}{1/g_{mN1} + 1/g_{mN2}}$$

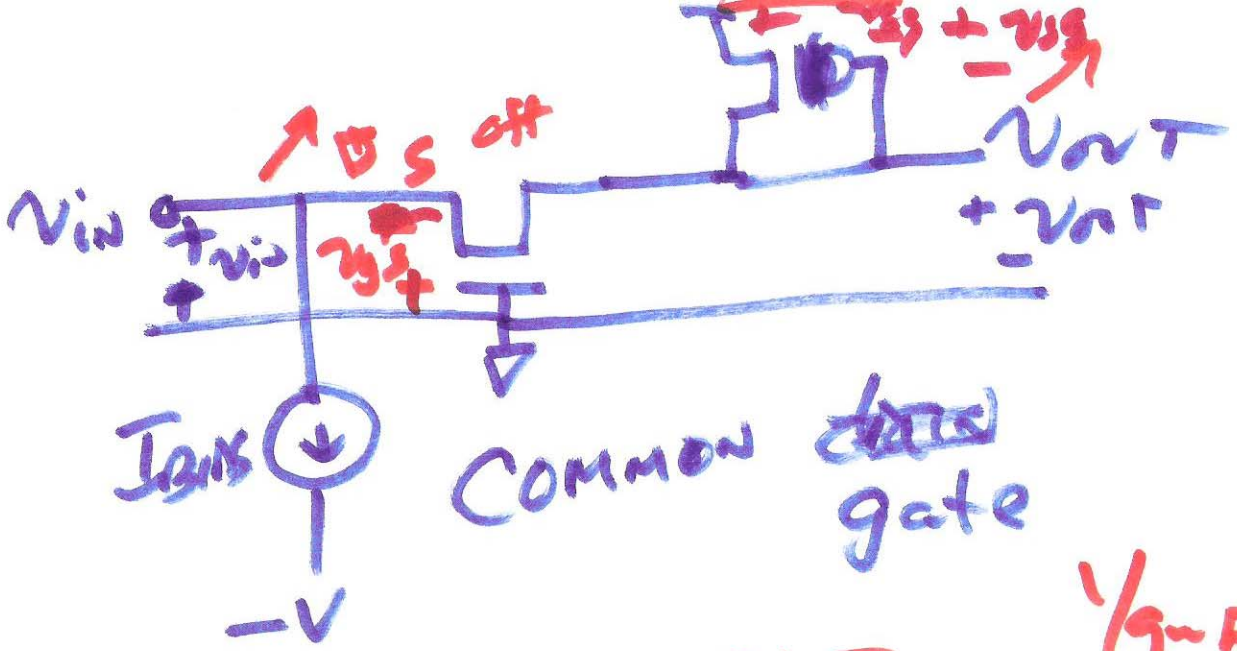



$$v_{in} = v_{gs2} + v_{gs1}$$

$$= \frac{i_d}{g_{mN2}} + \frac{i_d}{g_{mN1}}$$

$$v_{gs1} = v_{out} = \frac{i_d}{g_{mN1}}$$

## Common-Drain

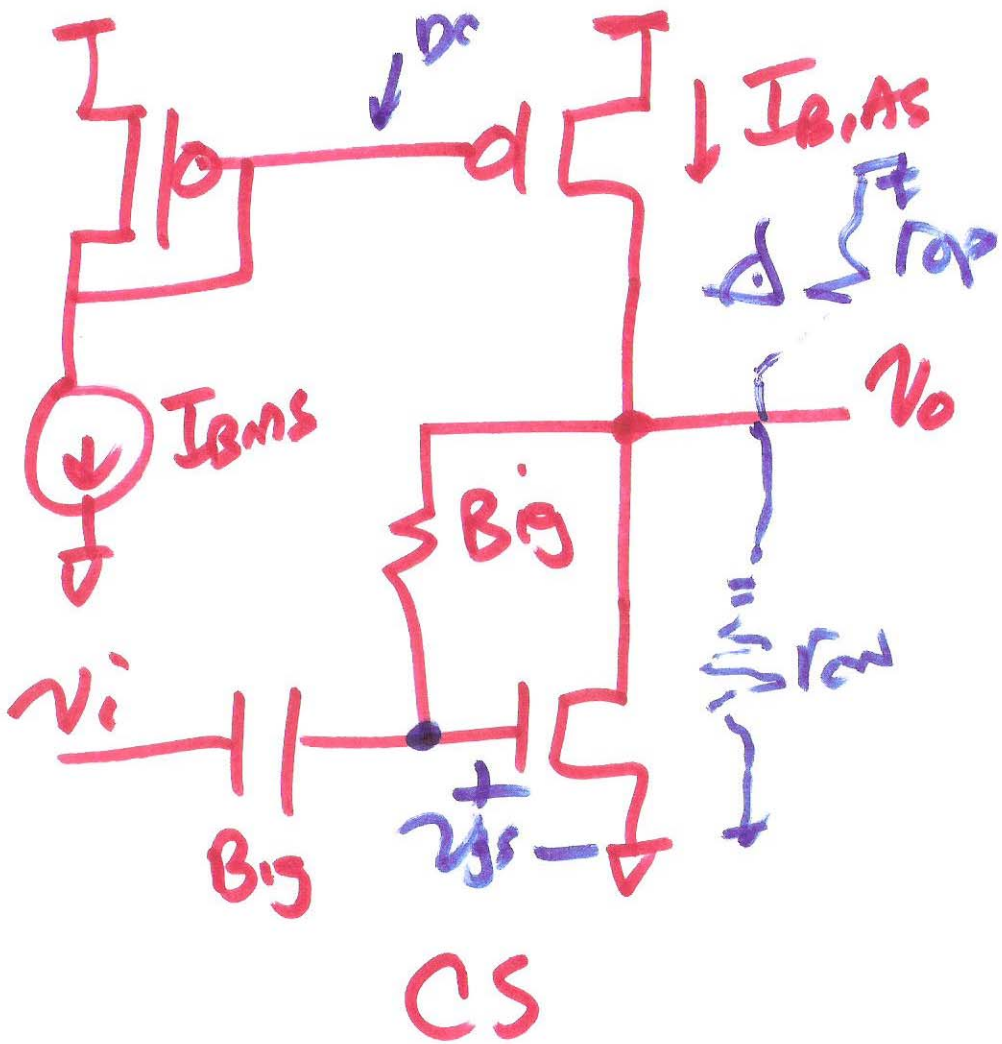



$$\frac{v_{out}}{v_{in}} = \frac{1/g_{mp}}{1/g_{mn}}$$

$$v_{in} = -v_{gs} = \frac{-i_d}{g_{mN}}$$

$$v_{out} = -v_{sg} = \frac{-i_d}{g_{mp}}$$

$$\frac{v_{out}}{v_{in}} = \frac{-i_d/g_{mp}}{-i_d/g_{mN}} = \frac{1/g_{mp}}{1/g_{mN}}$$




$$\frac{V_{out}}{v_{in}} = \frac{-r_{op} \| r_{on}}{1/g_{mn}}$$

$$= -g_{mn}(r_{on} \| r_{op})$$



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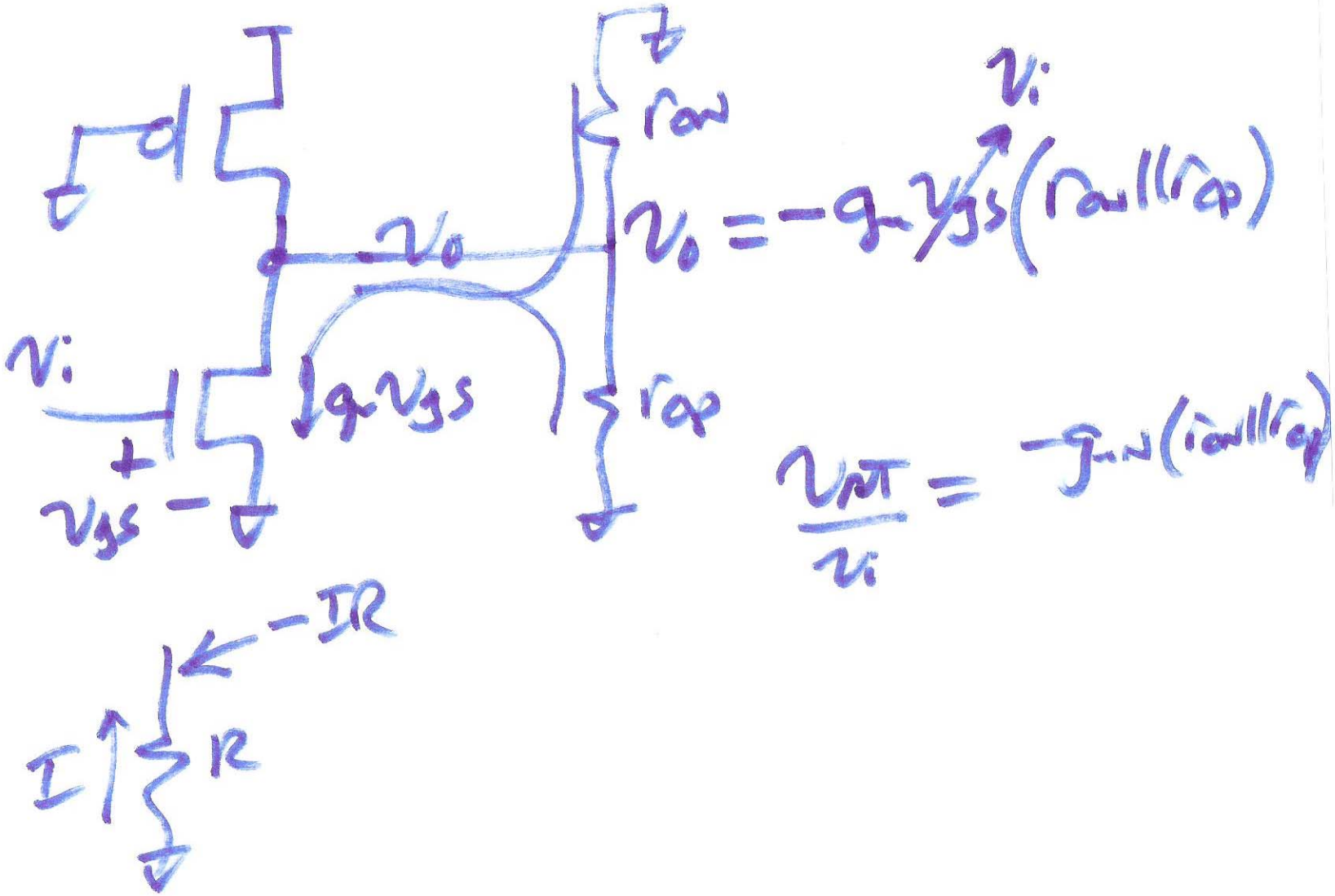
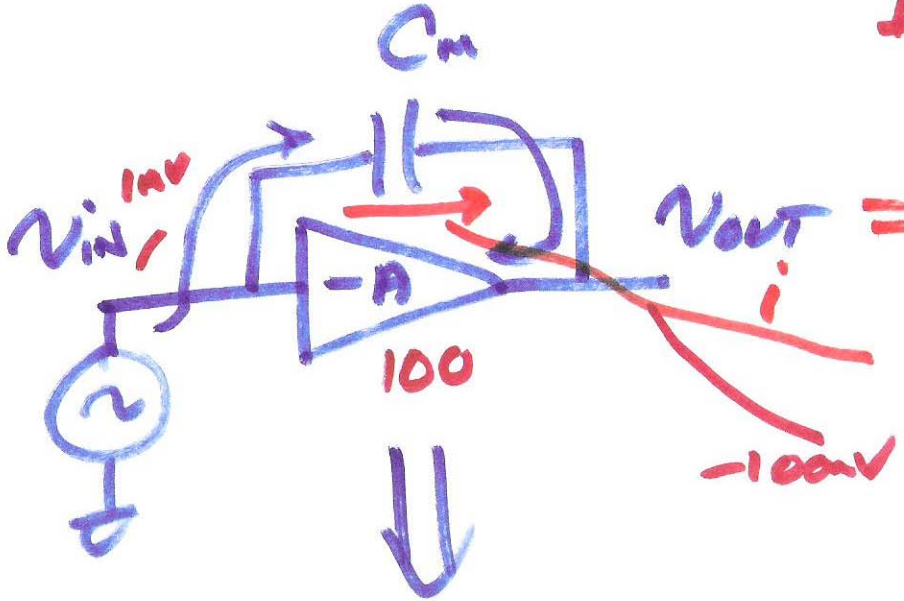

$r_{on}$
$v_i$
$v_o$
$v_o = -g_m v_{gs}(r_{on} \| r_{op})$
$v_i$
$g_m v_{gs}$
$r_{op}$
$+$
$v_{gs}$
$-$
$\frac{v_{out}}{v_i} = -g_m(r_{on} \| r_{op})$
$-IR$
$I$
$R$

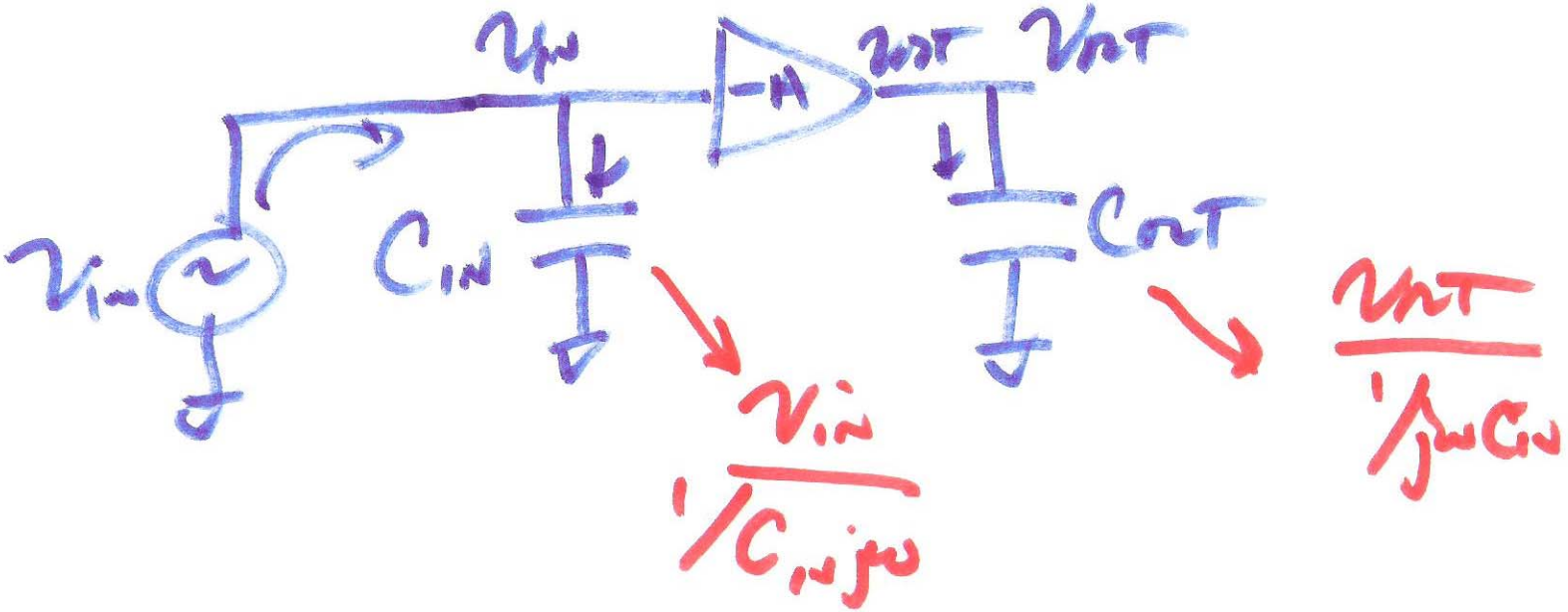
# Miller Effect




$$I = C\frac{dV}{dt}$$

$$V_{OUT} = -A \cdot V_{IN}$$

$$\frac{V_{IN} - V_{OUT}}{1/jwC_M}$$



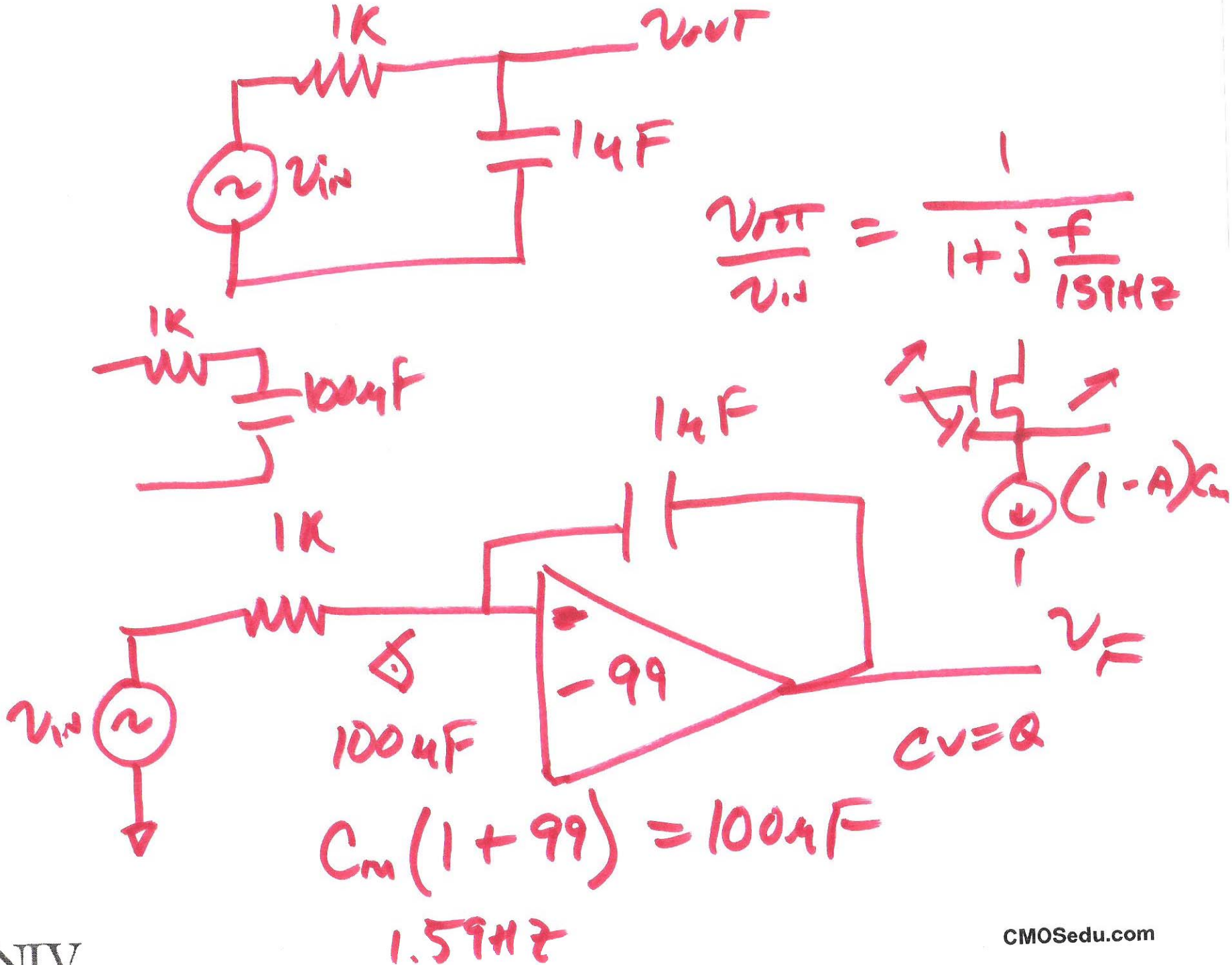
$$V_{IN} \cdot C_{IN} \cdot j\omega = j\omega C_M (V_{IN} - V_{OUT})$$

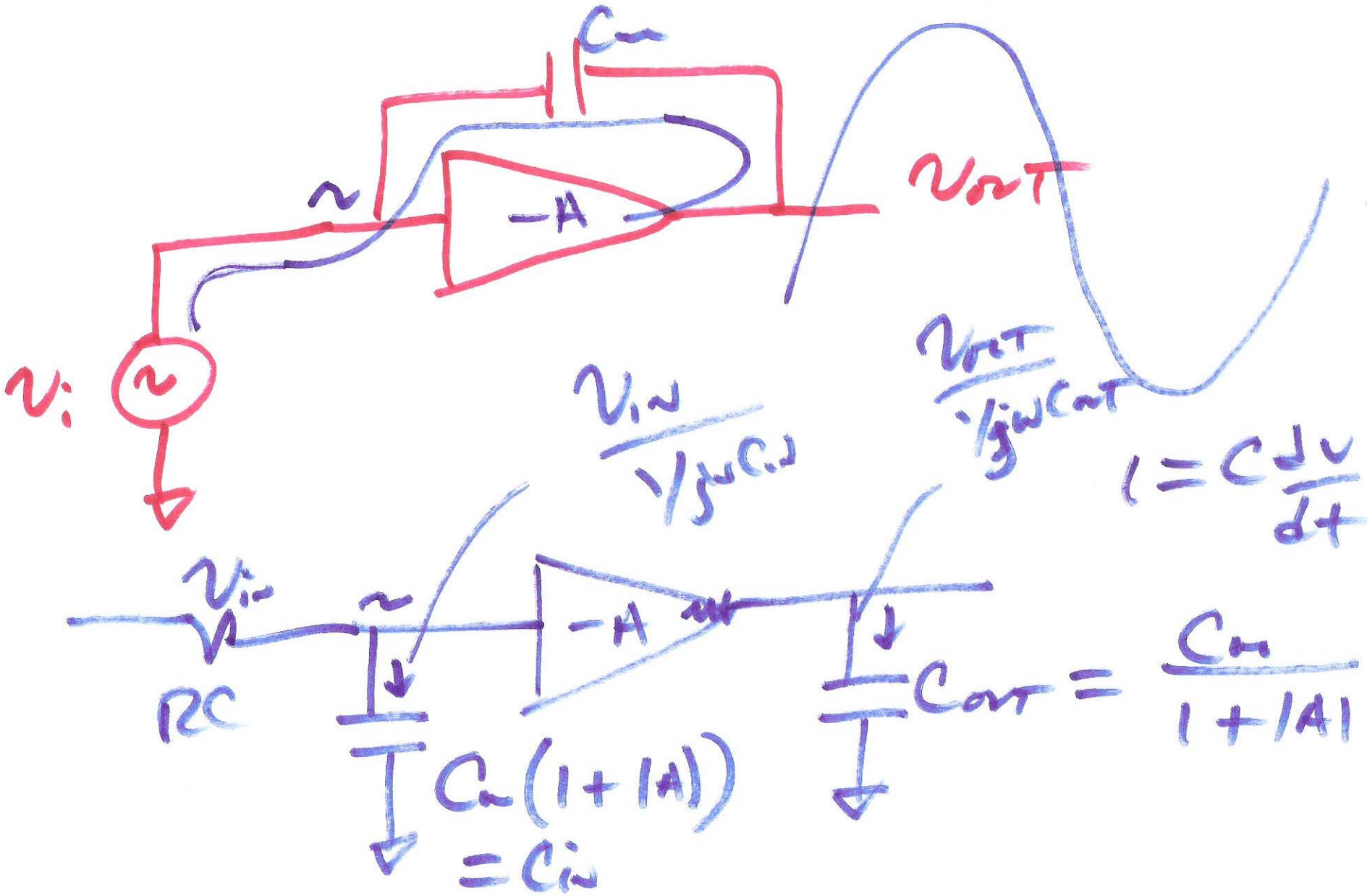
$$V_{IN} C_{IN} = C_M (V_{IN} - (-A \cdot V_{IN}))$$

$$V_{IN} C_{IN} = C_M (|A| + 1) V_{IN}$$

$$C_{IN} = C_M (1 + |A|)$$

$$C_{OUT} = \frac{C_M}{1 + |A|}$$


1K
$v_{OUT}$
1μF
$v_{in}$
$\frac{v_{out}}{v_{in}} = \frac{1}{1+j\frac{f}{159Hz}}$
1K
100μF
1μF
1K
$(1-A)C_m$
$v_F$
-99
$v_{in}$
100μF
$CV=Q$
$C_m(1+99) = 100\mu F$
1.59Hz


$C_m$
$-A$
$V_{OUT}$
$V_i$
$V_{IN}$
$1/j\omega C_{in}$
$V_{OUT}$
$1/j\omega C_{OUT}$
$I = C\frac{dV}{dt}$
$V_i$
$RC$
$-A$
$C_{OUT} = \frac{C_m}{1+|A|}$
$C_m(1+|A|)$
$= C_{in}$