EGG 720
Advanced Analog IC Design

March 15, 2016

Lecture 16

Voltage Amp is a series-shunt amp

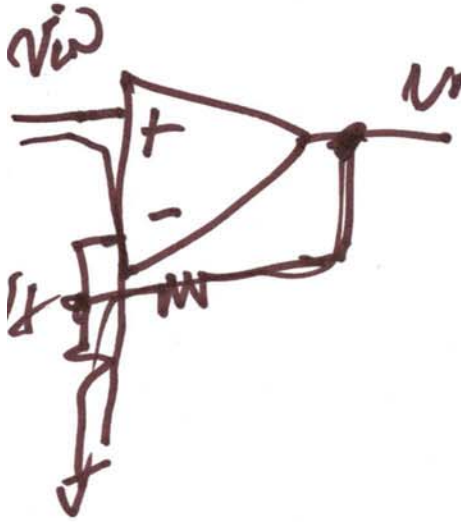
INPUT MIXING
SHUNT, i_{IN}
SHUNT, i_{IN}
SERIES, V_{IN}
SERIES, V_{IN}

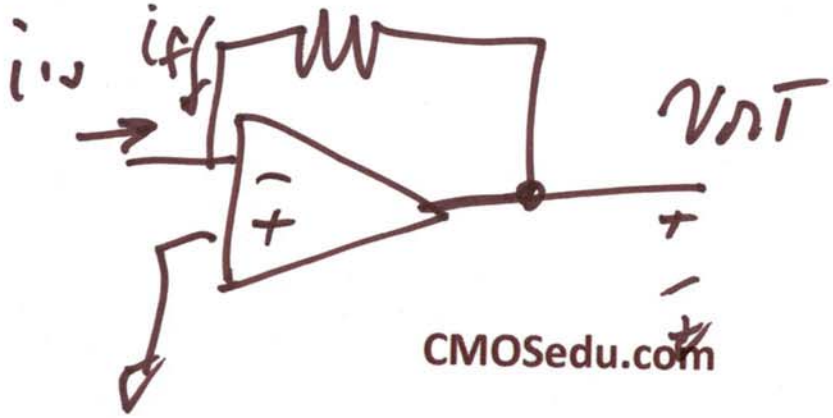
OUTPUT MIXING
SHUNT, V_{OUT}
SERIES, i_{OUT}
SHUNT, V_{OUT}
SERIES, i_{OUT}

TIA, $R = \frac{V}{I}$

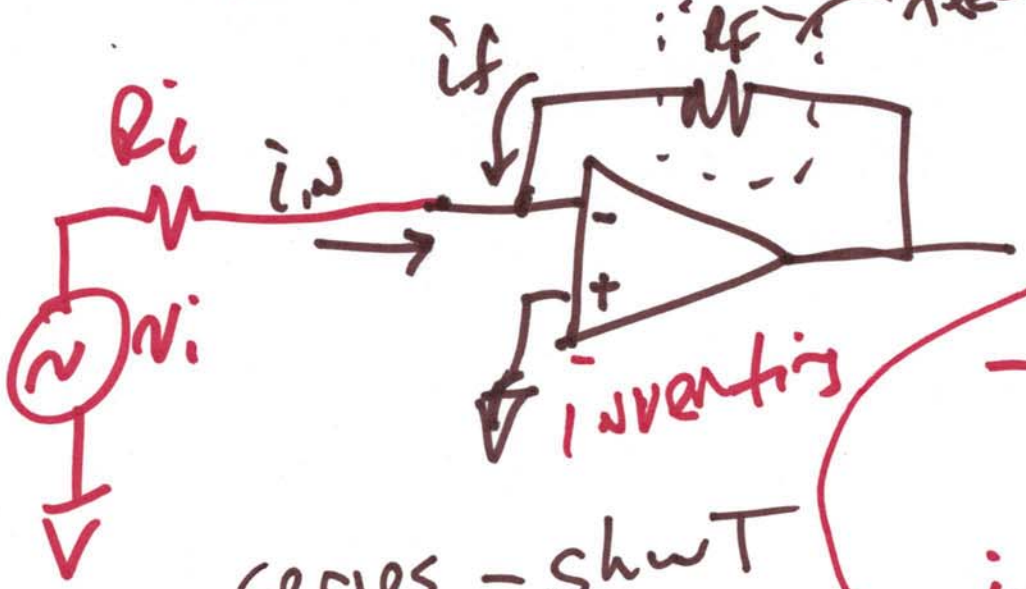
SHUNT-SHUNT

$\frac{V}{V}$





Shunt - Shunt



$-R_f$ = ideal TIA gain

$\frac{V_{out}}{i_{in}}$ = transresistance

$V_{out} = i_f \cdot R_f$

$-\frac{R_f}{R_i} = \frac{V_{out}}{V_{in}}$

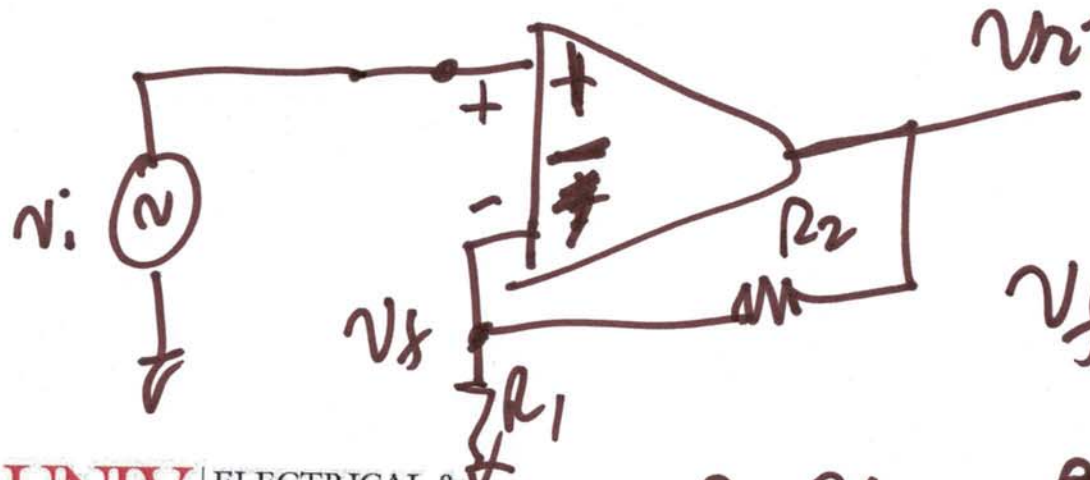
$i_f = \frac{V_{out}}{R_f} = \beta \cdot V_{out}$

$i_{in} = \frac{V_{in}}{R_i}$

$\frac{V_{out}}{V_{in}} = -R_f$

feedback factor

Series - Shunt



$\frac{\beta}{\frac{R_1}{R_1+R_2} \cdot V_{out}}$

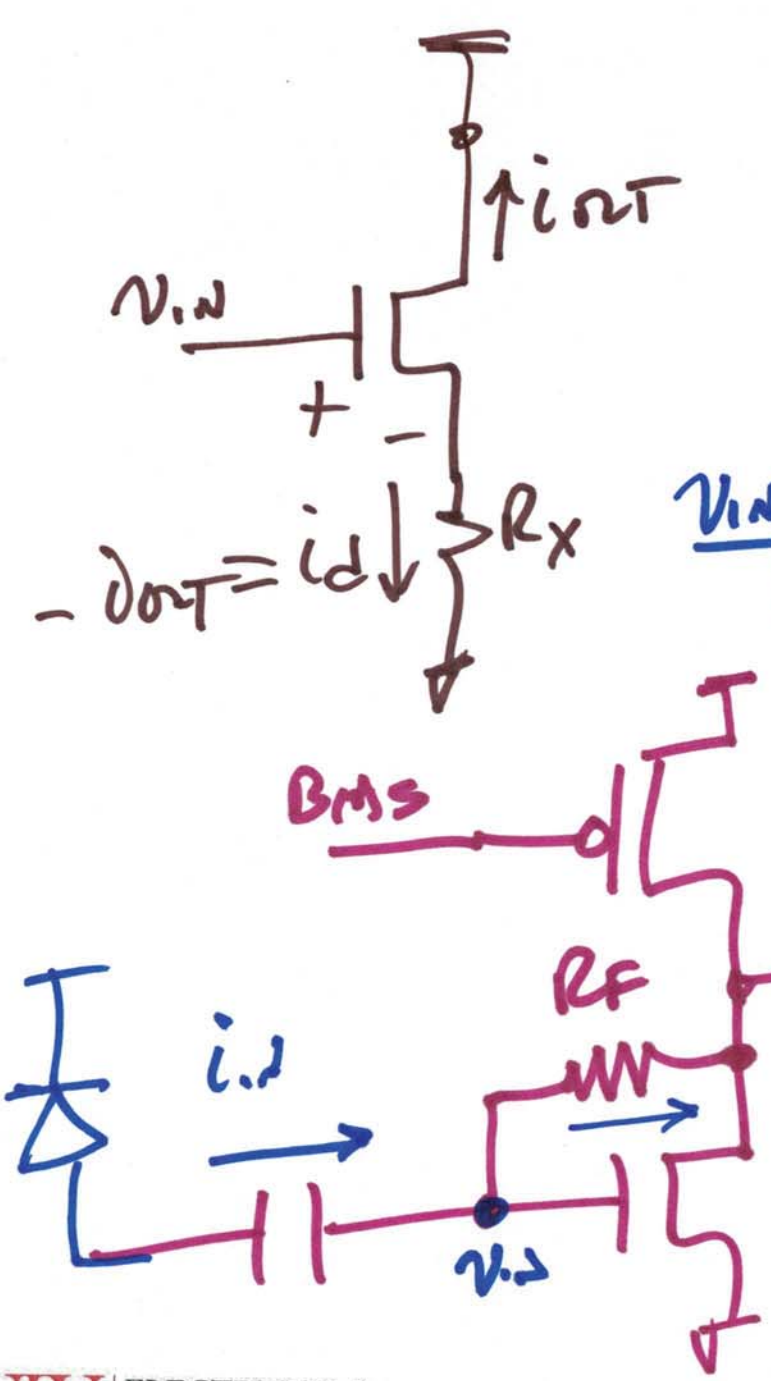
$V_f = \frac{R_1}{R_1+R_2} \cdot V_{out}$

$\frac{1}{\text{ideal closed loop gain}}$

$\frac{1}{\beta} = \frac{R_1+R_2}{R_1}$

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

2)



series − series i_{OUT} / V_{IN} f.b. Amp

transconductance Amp

$\frac{V_{IN} - V_{OUT}}{R_F} = i_{IN}$

$V_{IN} = V_{gs}$

$\frac{i_{OUT}}{V_{IN}} = R_X + \frac{1}{g_m}$

$i_d = g_m V_{in} \tilde{=} R_X$

If $R_X >> \frac{1}{g_m}$

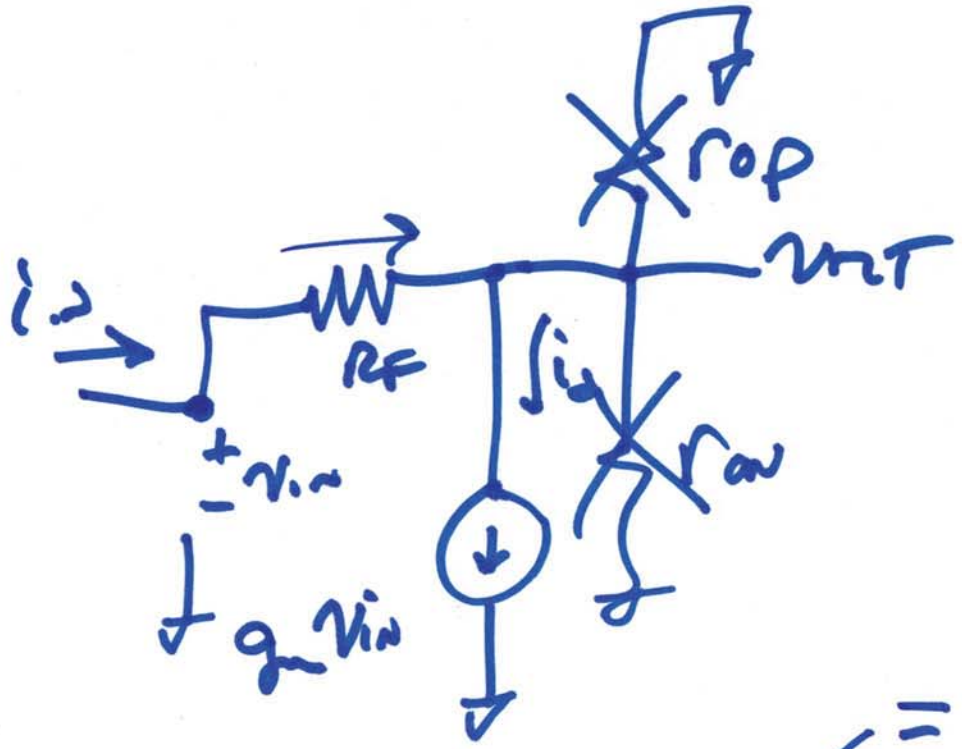
R_F i_{IN}

short short

V_{OUT}

i_{IN}

TIA



$$g_{ain} = \frac{v_{oT}}{v_{in}}$$

$$\frac{v_{in} - v_{oT}}{R_f} = i_{in}$$

$$= i_d = g_m v_{in}$$

$$\frac{i_{in}}{g_m} - v_{oT} = i_{in} \cdot R_f$$

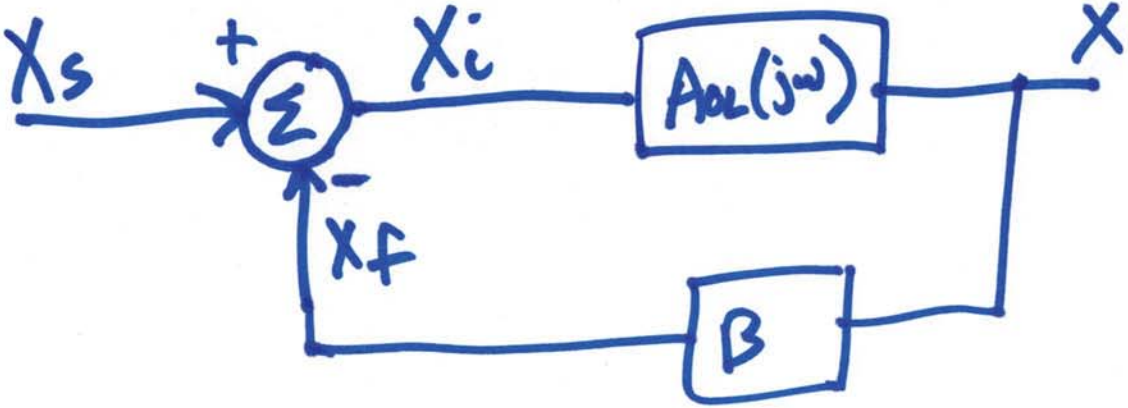
$R_f \ll r_{op} \| r_{ON}$

$$-v_{oT} = i_{in}\left(R_f + \frac{1}{g_m}\right) \rightarrow i_{in} \approx g_m v_{in}$$

$$\frac{v_{oT}}{v_{in}} = -\left(R_f + \frac{1}{g_m}\right) \qquad v_{in} = \frac{i_{in}}{g_m}$$

if g_m = big $\frac{v_{oT}}{v_{in}} \approx -R_f$

4)



$X_o = A_{OL}(j\omega)\cdot(X_s - X_f)$

β = feedback factor

$X_i = \beta(X_s - X_f)$

$X_o = A_{OL}(j\omega)\cdot(X_s - X_f)$

$X_o = A_{OL}\cdot X_s - X_f \cdot A_{OL}\cdot\beta$

$X_f = \beta\cdot X_o$

$X_o(1 + A_{OL}\beta) = A_{OL}\cdot X_s$,

$$\frac{X_o}{X_s} = \frac{A_{OL}}{1+\beta A_{OL}}$$

$$\frac{P_o}{1+\beta A_{OL}}$$

$A_{OL} \to \infty \quad \frac{X_o}{X_s} = \frac{1}{\beta}$

$A_{CL} = 10$, $\beta = 0.1 = 10^{-1}$

series - shunt

$$A_{CL} = \frac{2 \cdot 10^3}{1 + 2 \cdot 10^3 \cdot 10^{-1}} = \frac{A_{OL}}{1 + \beta A_{OL}}$$

$$= \frac{1}{0.001 + 0.1} = \frac{1}{0.101}$$

$0.000\,5$ $\quad\quad$ $\frac{1}{0.100\,5}$

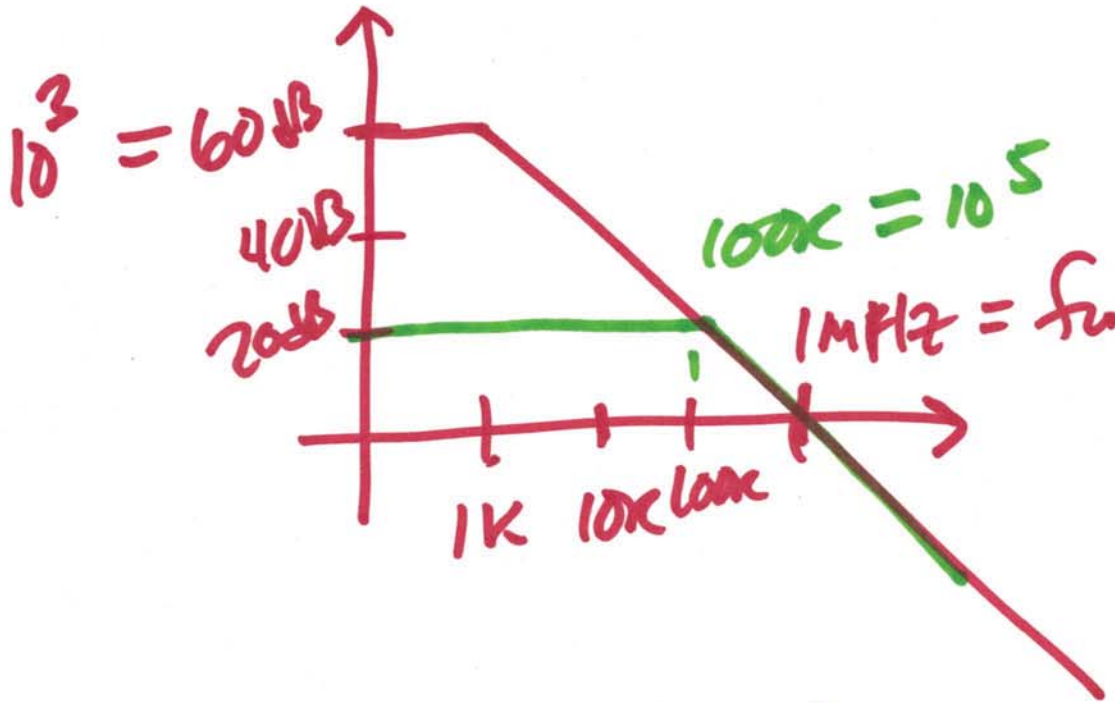
A_{OL} GAin desensitivity

Bandwidth extension

$$A_{OL}(f) = \frac{A_{OLDC}}{1 + j\frac{f}{f_{3dB}}}$$

$A_{OLDC} \to 10^3$

$f_{3dB} \to 1\,KHz$



$\beta = 0.1$

$$A_{CL} = \frac{\frac{10^3}{1 + jf/10^6}}{1 + 0.1 \cdot \frac{10^3}{1 + j\frac{f}{10^6}}}$$

$$A_{CL} = \frac{1}{j\frac{f}{10^6} + 0.1}$$

$$= \frac{10}{1 + j\frac{f}{10^7}}$$

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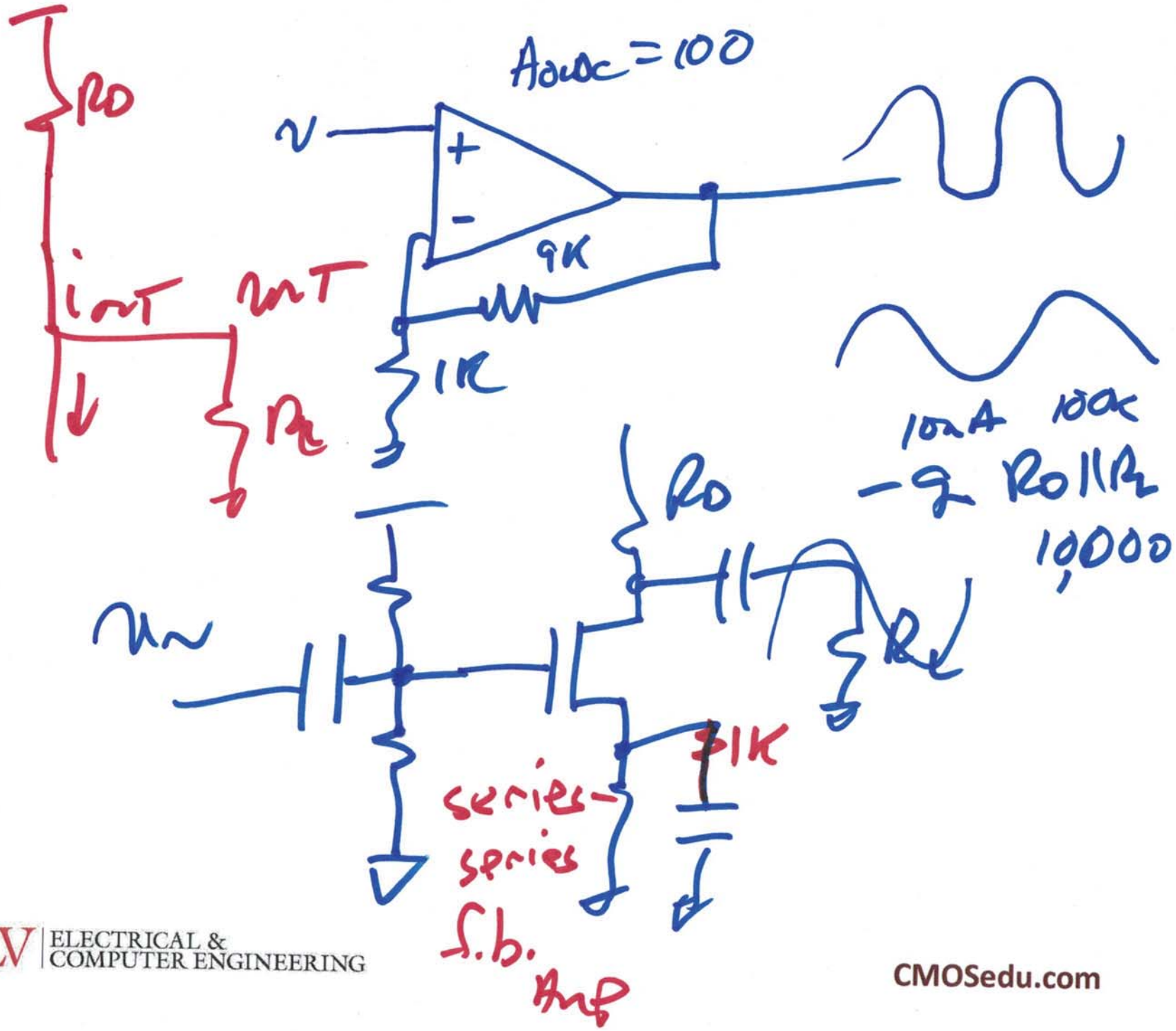
7)



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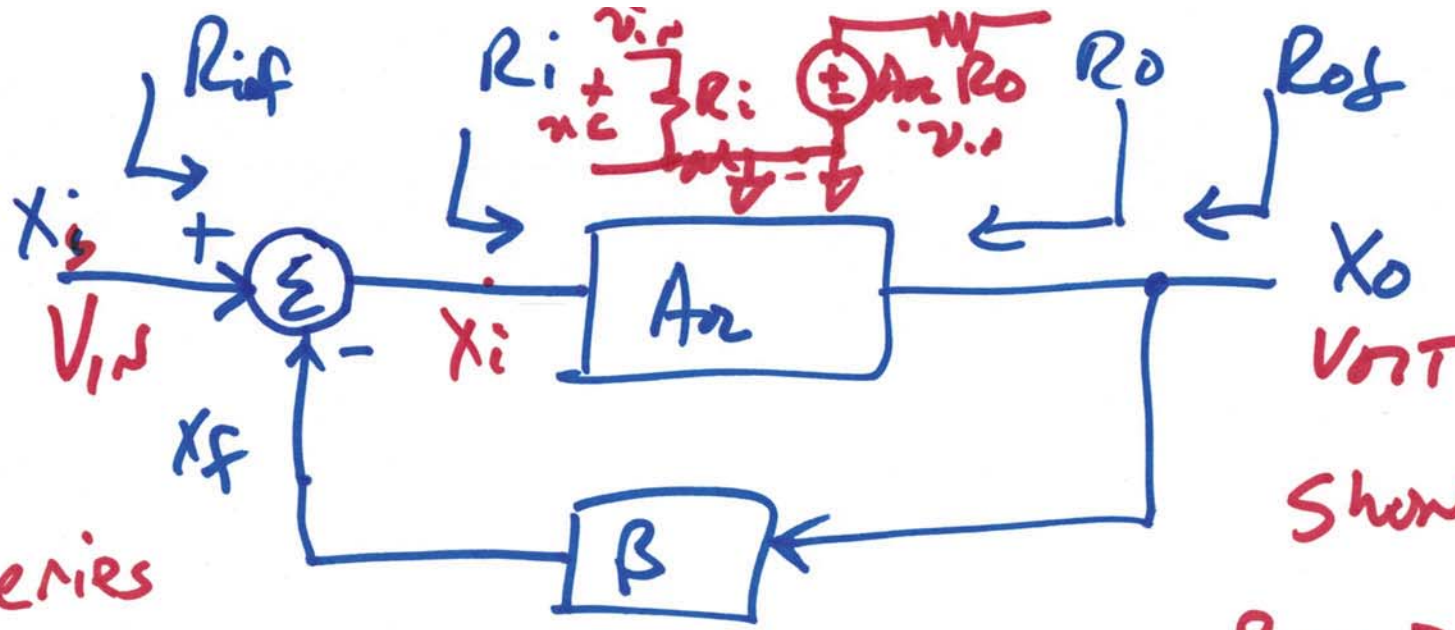
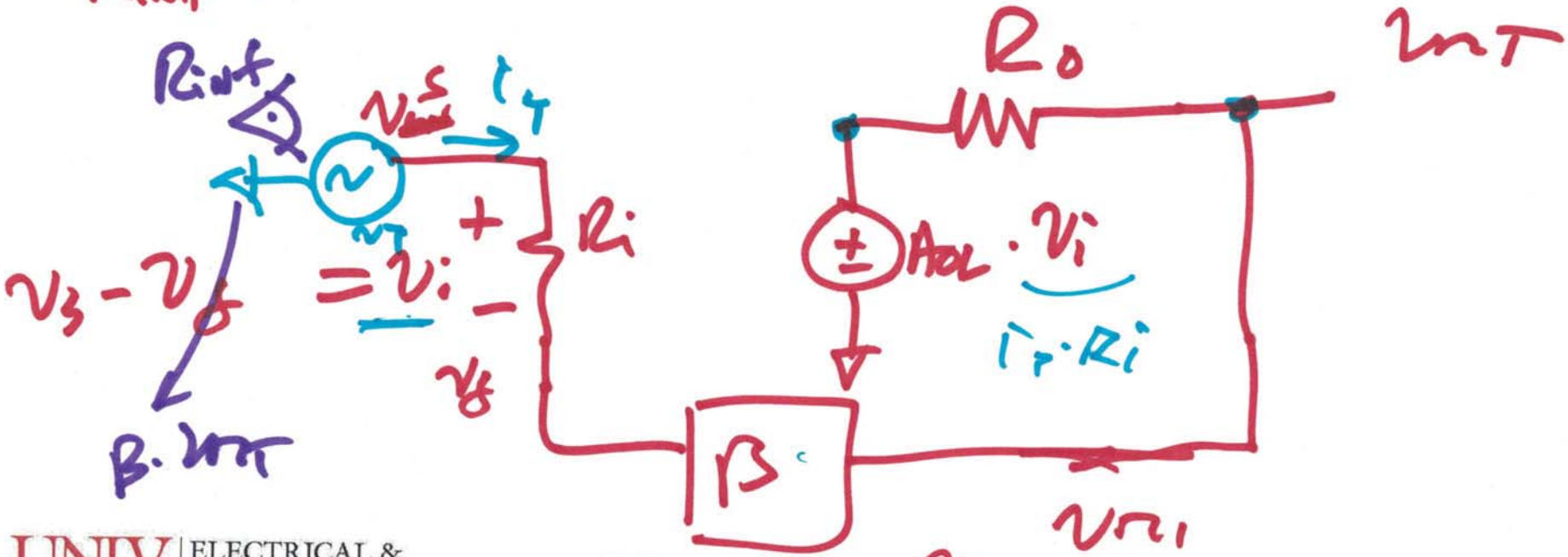
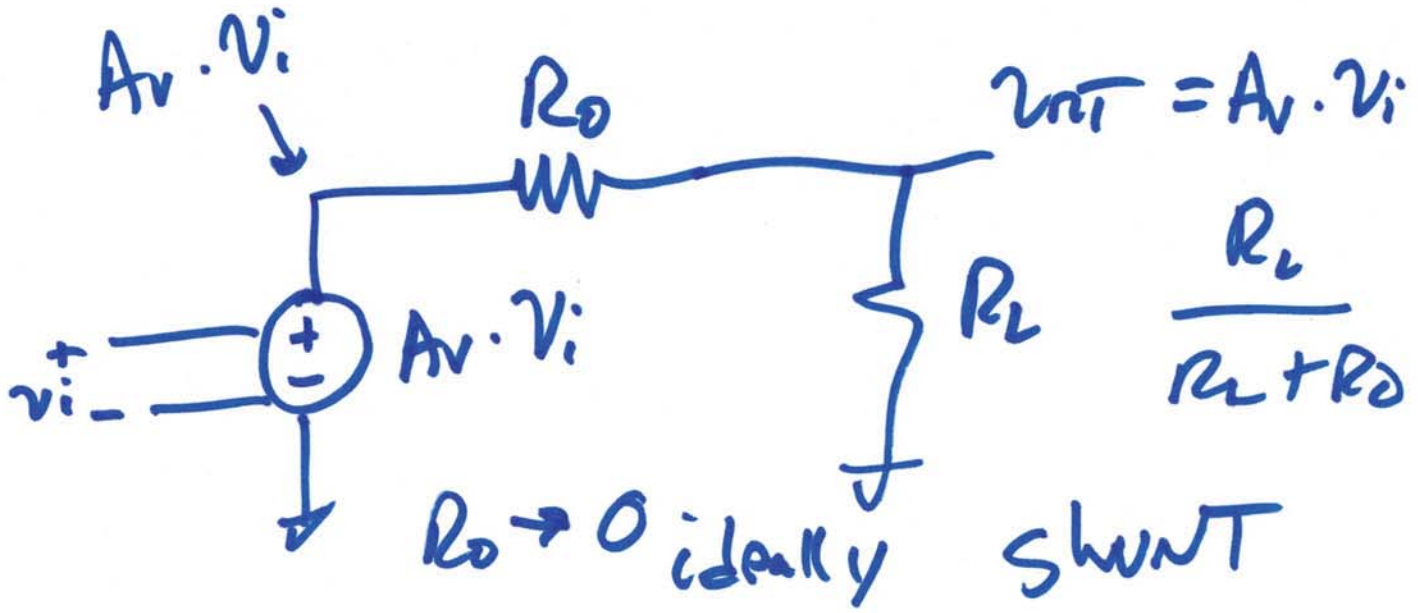
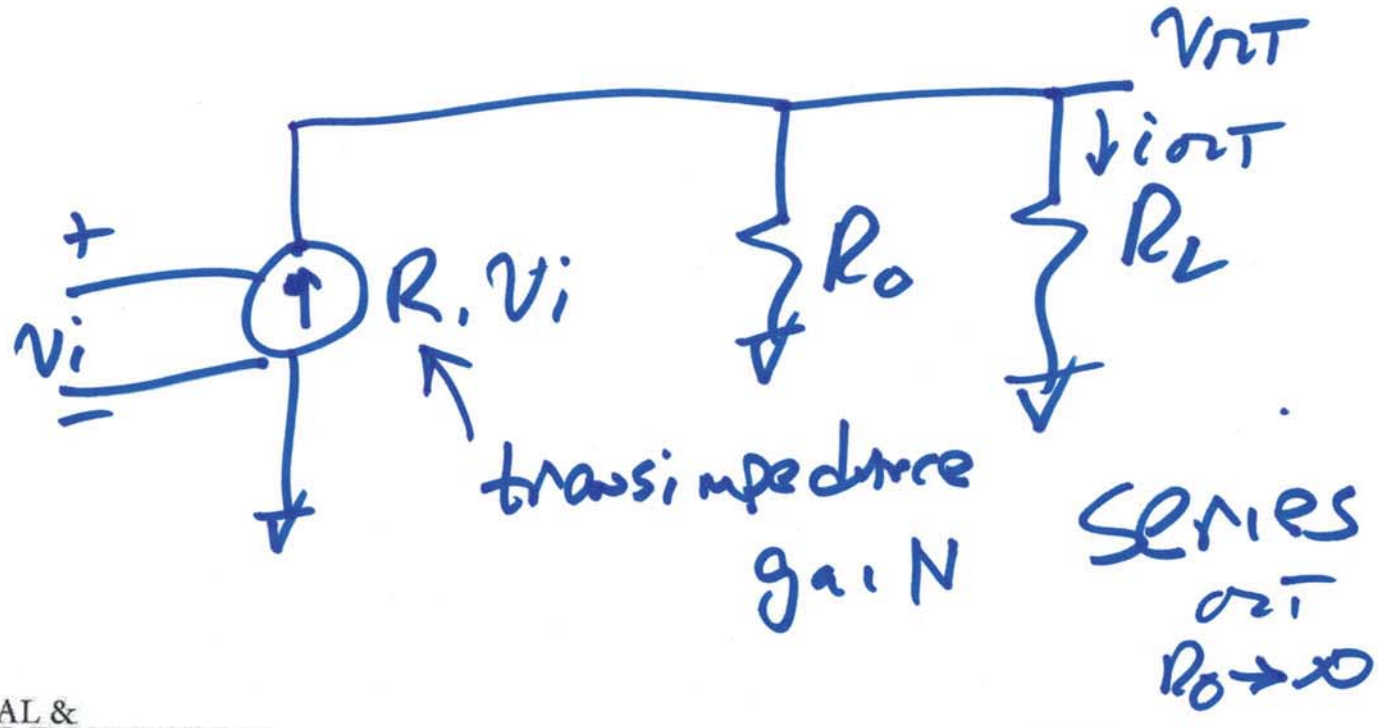
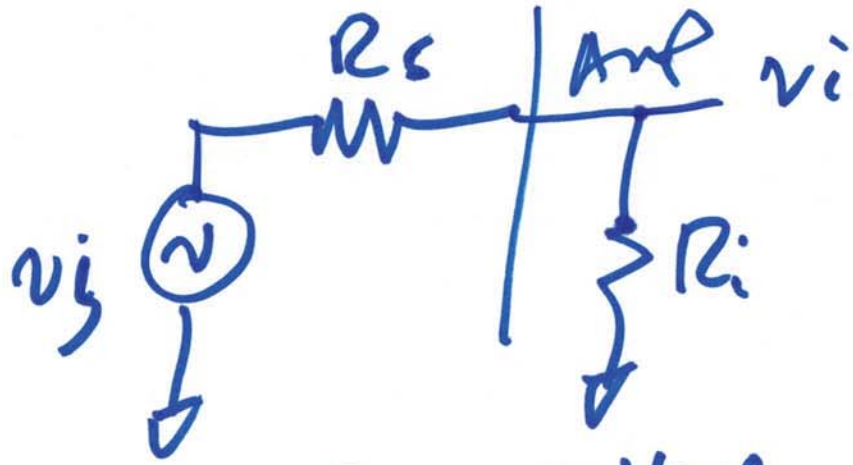
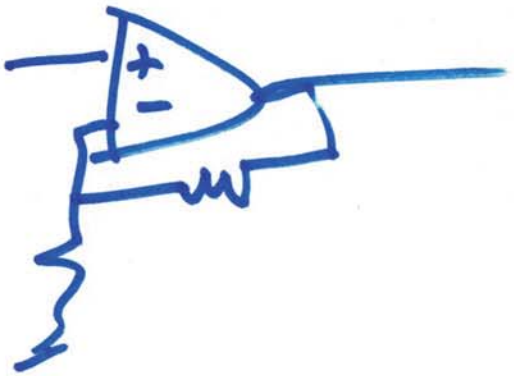

Rif
Ri
Ro
Rof
Xs
VIN
Xi
Xf
Aol
Xo
VOUT
B
series
SHUNT
Rof → 0
Rinf → ∞


Rinf
Ri
Ro
Aol · Vi
Ir · Ri
B
B. VOUT
VOUT
Vi
Rf
Rc
Vi = Ri/(Ri+Rf) · VOUT


$A_V \cdot V_i$
R_O
$V_{OUT} = A_V \cdot V_i \cdot \frac{R_L}{R_L + R_O}$
R_L
$A_V \cdot V_i$
V_i
$R_O \to 0$ ideally
SHUNT


V_{OUT}
i_{OUT}
R_L
R_O
$R_i \cdot V_i$
V_i
transimpedance gain
SERIES
OUT
$R_O \to \infty$

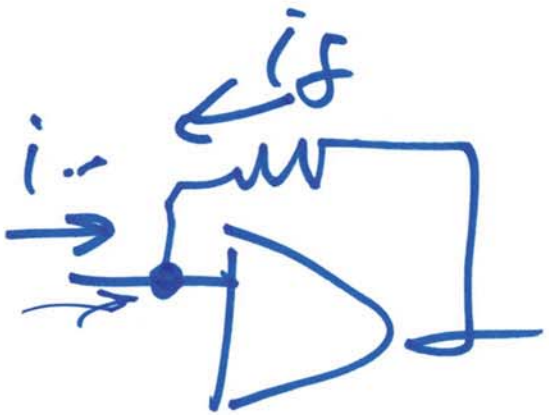


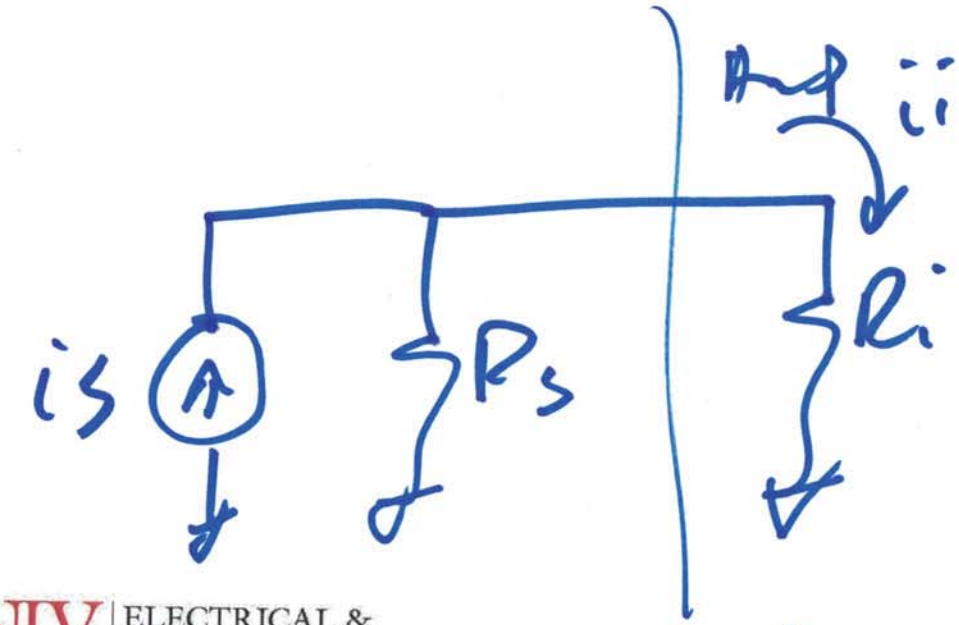


INPUT is a voltage

Series - INPUT mixing

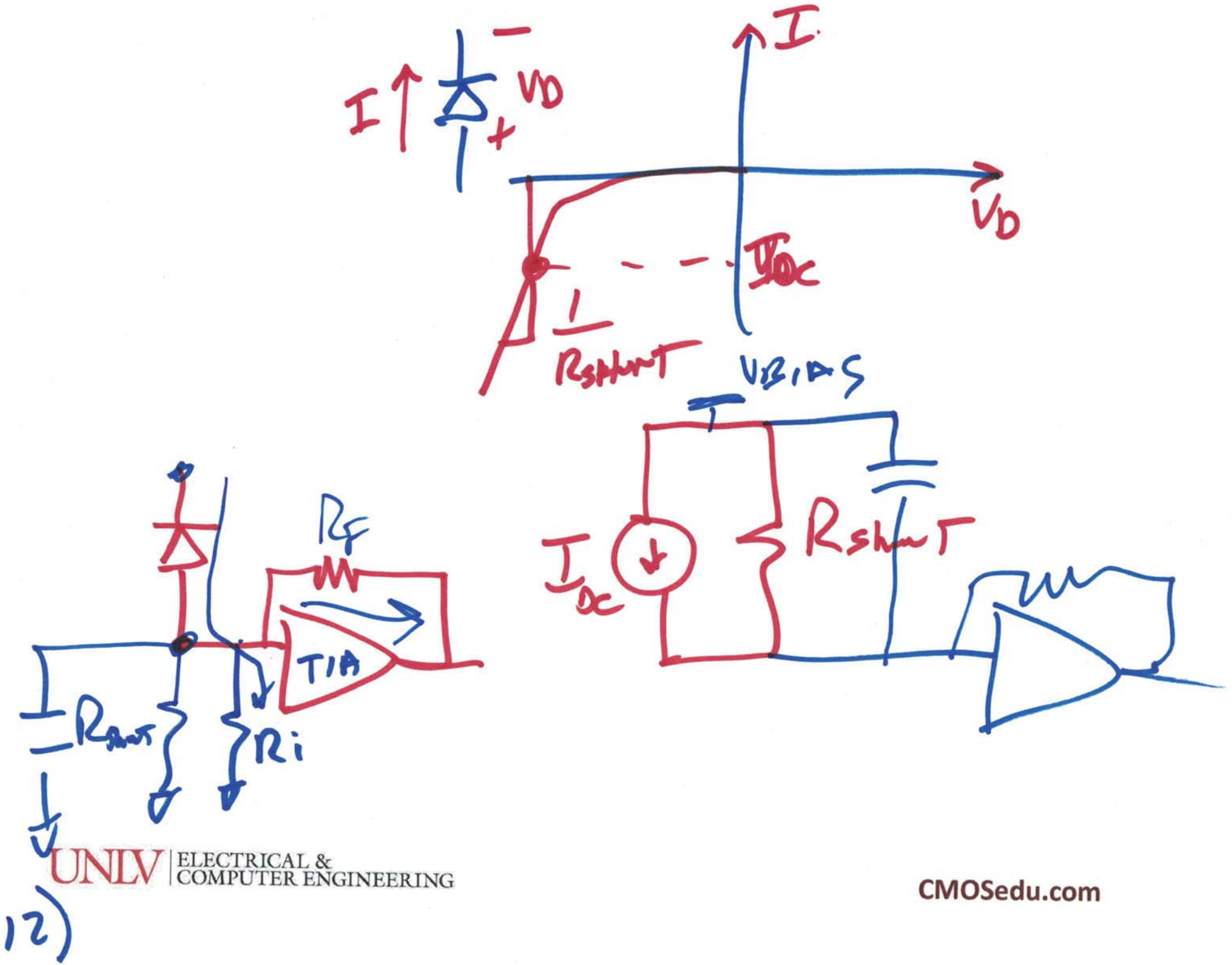
$R_i \to \infty$





$R_i \to 0$

Shunt, current input


I
VD
I
VD
IDC
1/RSHUNT
VBIAS
RF
TIA
RSHUNT
Ri
IDC
RSHUNT

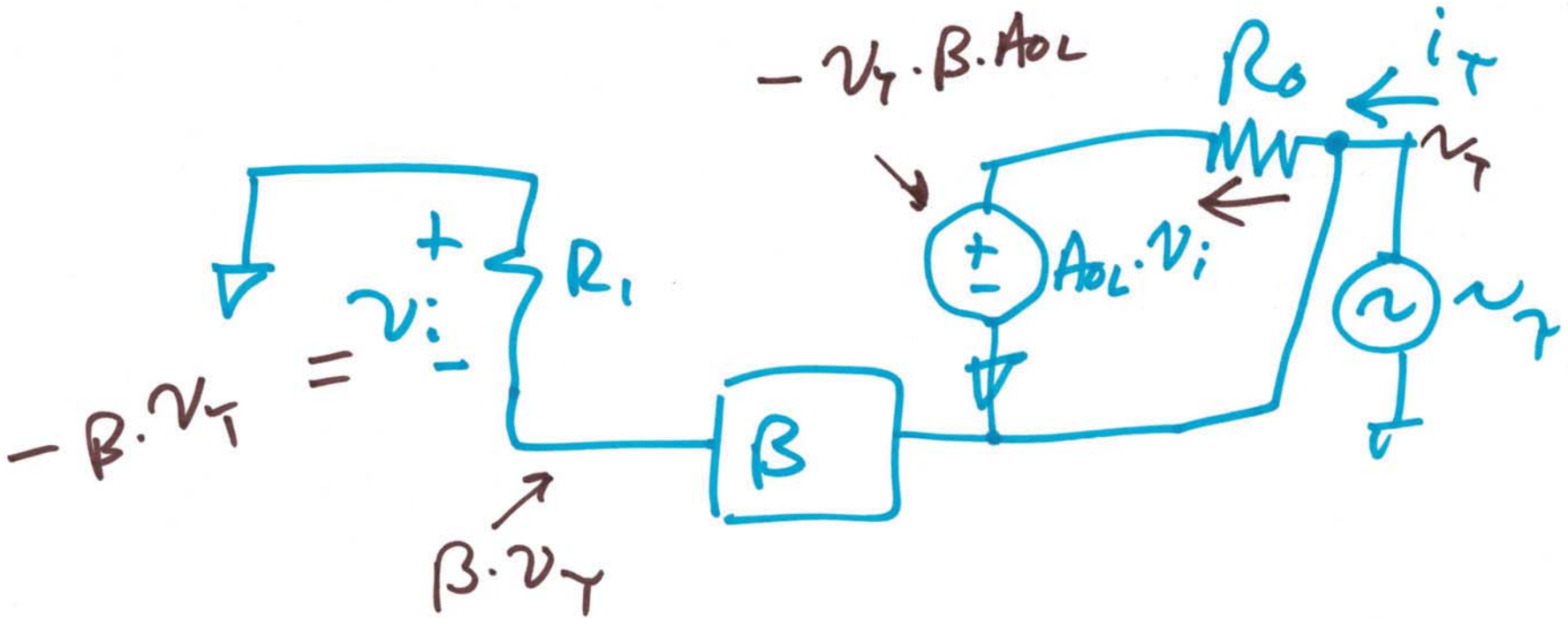
$$i_T = \frac{v_T - \beta v_{out}}{R_i}$$

$$v_{out} = \underbrace{i_T \cdot R_i}_{v_i} \cdot A_{OL}$$

$$i_T \cdot R_i = v_T - \beta R_i A_{OL} \cdot i_T$$

$$\frac{v_T}{i_T} = R_i \left(1 + \underbrace{\beta A_{OL}}_{\text{Loop gain}}\right)$$

1K, $\frac{1}{10}$, 10^3



$$\frac{v_T - (-v_T \beta \cdot A_{OL})}{R_o} = i_T$$

$$\frac{v_T}{i_T} = \frac{R_o}{1 + \beta A_{OL}}$$