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MCIROPROCESSOR LABORATORY SEVENTH COURSE
ON
BASIC VLSI DESIGN TECHNIQUES

29 October - 23 November 2001

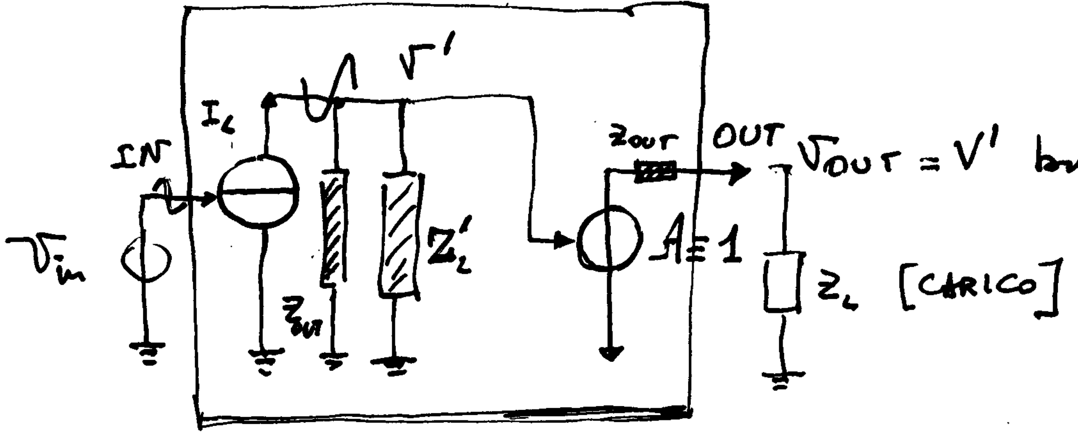
ADDENDUM TO LECTURE NOTES

by

Sandro CENTRO
Dipartimento di Fisica "G. Galilei"
Universita' degli Studi di Padova
Via F. Marzolo 8
35131 Padova
ITALY

INTRODUCTION

ANY AMPLIFER COULD BE THOUGH AS A:



$V_{OUT} = V'$ but with $\underline{\underline{Z_{OUT} = 0}}$!

VOLTAGE CONTROLLED CURRENT GENERATOR, THAT CAN BE FOLLOWED BY VOLTAGE CONTROLLED VOLTAGE GENERATOR, NORMALLY WITH GAIN "1"

$$\boxed{\frac{I_L}{V_{in}} = g_m}$$

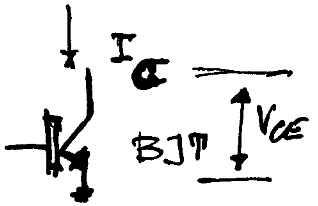
TRANSCONDUCTANCE [mho, siemens]

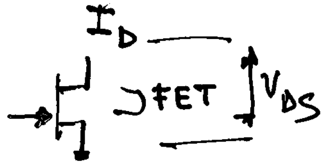
$$V' = I_L * Z = V_{OUT}$$

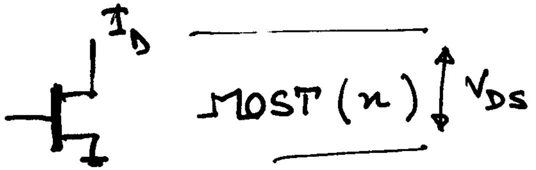
$$\boxed{\frac{V_{OUT}}{V_{in}} = g_m Z'_L}$$

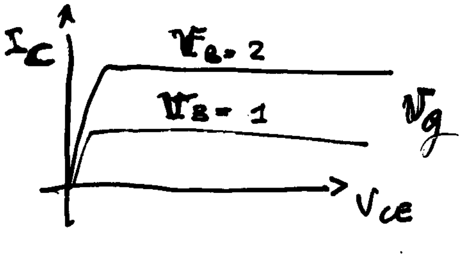
$[Z_{OUT} = \infty]$

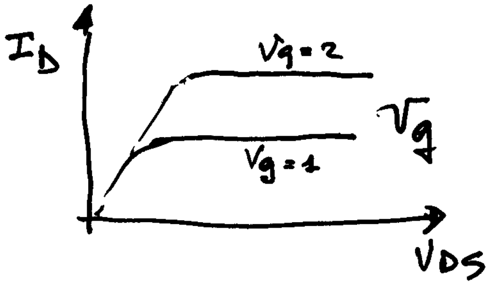
BASIC ENGINES TO MAKE AMPLIFIERS:

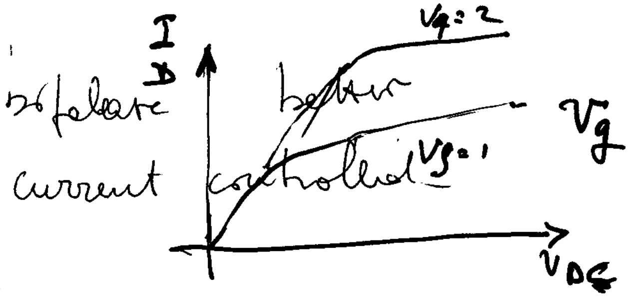












$$\frac{I_c}{V_g} = g_T = \frac{1}{r_e}$$

$$\frac{I_D}{V_g} = g_m$$

$$\frac{I_D}{V_g} = g_m$$

$1.38 \cdot 10^{-23} JK^{-1}$

$$r_e = \frac{KT}{q}\,\frac{1}{I_c} = \frac{25\,mV}{I_c[mA]}$$

$1.6 \cdot 10^{-19} C$

$$= 5 \div 250\ \Omega$$

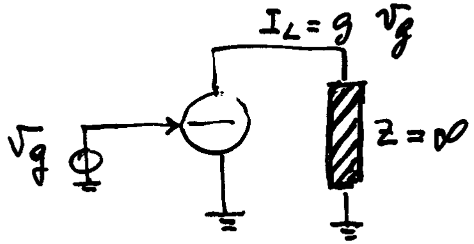
$$\underline{g_T = 4 \div 200\ mS}$$

$$\underline{g_m = .5 \div 20\ mS}$$

$$\underline{g_m = .05 \div 2\ mS}$$

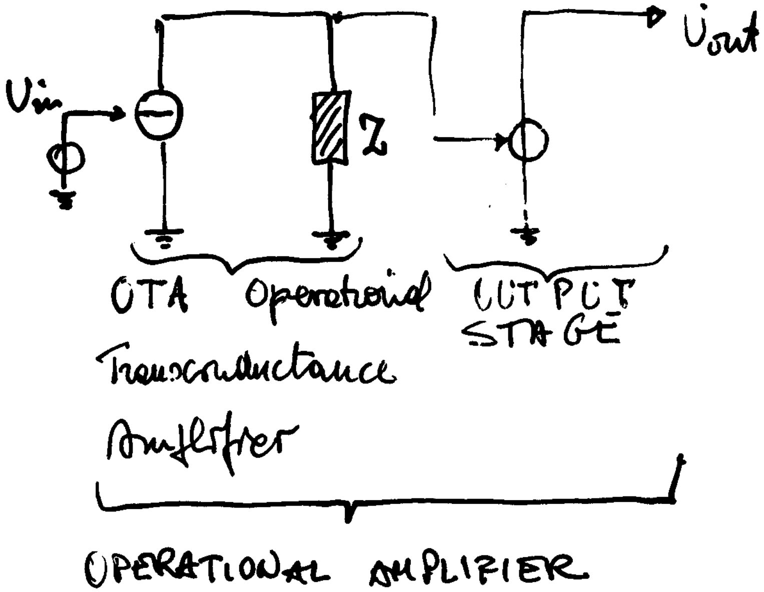
1 (ma Zin piccola) $\;$ 1/10 ma Zin grande) $\;$ 1/100 (ma Zin ∞)

WHICH IS THE LIMIT FOR THE AMPLIFICAZION OF A SINGLE ENGINE ??



THEN $Z_{MAX} = Z_{OUT}$ OF THE ELEMENT.

			A_{LIMIT}
BIPOLAR	$Z_{OUT} \rightarrow$	$10^5 \div 10^6\ \Omega$	$400 \div 200'000$
J-FET	$Z_{OUT} \rightarrow$	$10^5 \div 10^6\ \Omega$	$50 \div 20'000$
C MOS	$Z_{OUT} \rightarrow$	$10^4 \div 10^5\ \Omega$	$.5 \div 200$



THERE ARE ALSO

$A_i = \frac{i_{out}}{i_{in}}$ OCA → OP. Current Amp.

$A_r = \frac{V_{out}}{i_{in}}$ CMA → Current Mode Amp.

$A_V = V_{out} / V_{in}$ BW $= f_T$ NB @ f_T $A_V = 1$

$GBW = A_V f_L = K$ (constant) $= f_T \cdot 1$

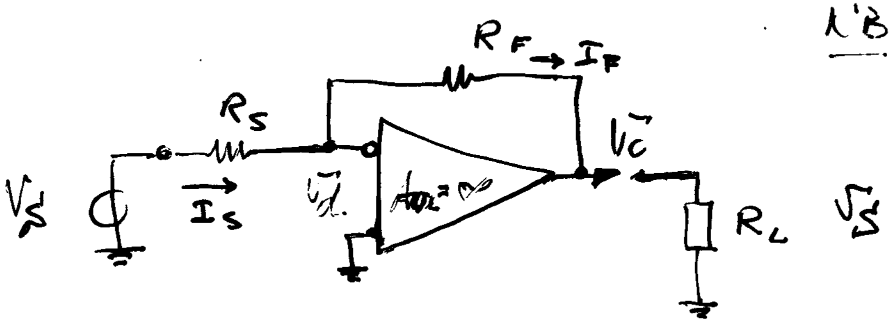
OP. AMP. REQUIREMENTS :

$A_{OL} \to \infty \quad (10^4 \div 10^5) \qquad A_{OL} = \frac{V_o}{V_d}$

$R_{inOL} \to \infty \quad (10^5 \div 10^8)\Omega$

$Z_{OOL} \to 0 \quad (50 \div 200)\Omega$

IDEAL ↑ ↑ REAL LIFE



N.B. $\frac{V_o}{V_d} \to \infty$ THAT MEANS $V_d \to 0$

$$\frac{V_S - V_d}{R_S} = \frac{V_d - V_o}{R_F}$$

COMBINING WITH $V_d = -\frac{V_o}{A_{OL}}$

$$\boxed{A_f =} \; V_o/V_S = \frac{A_{OL} R_F}{R_F + R_S - A_{OL} R_S} \underset{A_{OL} \to \infty}{\simeq} -R_F/R_S \; \boxed{= A_{f\,ideal}}$$

& $V_d = 0$ VIRTUAL GROUND AS $I_S \equiv I_F$

BECOUSE $Z_{inf} = \frac{R_F Z_{inOL}}{(1-A) Z_{inOL} + R_F} \simeq \frac{R_F}{1-A} \underset{A \to \infty}{\to} 0$

IS INFINITE A_{OL} GAIN NECESSARY TO HAVE

$$A_f = A_{f\,ideal} = -R_F/R_S' \qquad ?$$

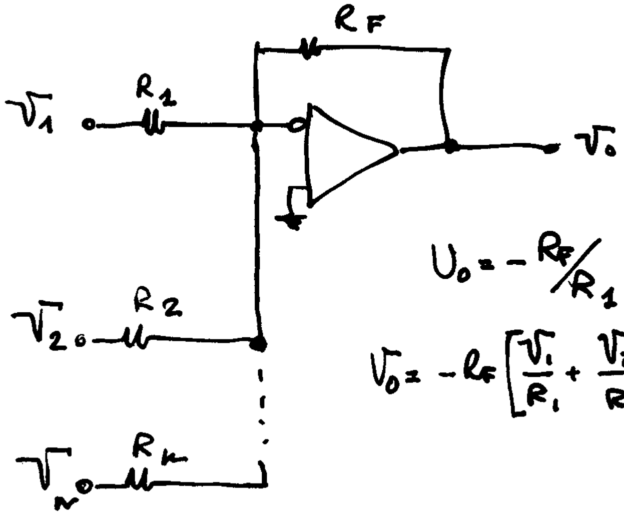
REMINDING THAT

$$A_f = \frac{A_{OL} R_F}{R_F + R_S - A_{OL} R_S'} = \frac{A_{OL}\, R_F/R_S}{R_F/R_S + 1 - A_{OL}}$$

$$= \frac{A_{OL} A_{fi}}{A_{OL} - 1 + A_{fi}} \simeq \frac{A_{fi}}{1 - 1/A_{OL} + A_{fi}/A_{OL}}$$

$$\simeq \frac{A_{fi}}{1 + A_{fi}/A_{OL}} \xrightarrow[A_{OL}\to\infty]{} A_{fi}$$

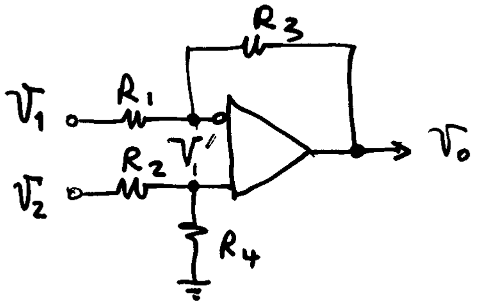
OR FOR $A_{OL} \gg A_{fi}$!



$$U_0 = -R_F/R_1 \, V_1$$

$$V_0 = -R_F\left[\frac{V_1}{R_1} + \frac{V_2}{R_2} + \dots + \frac{V_n}{R_n}\right]$$

Σ WITHOUT COUPLING OF V_x, AS THE SUMMING NODE AS ZERO VOLTAGE.



FROM $V' = \frac{V_2}{R_2 + R_4} * R_4$

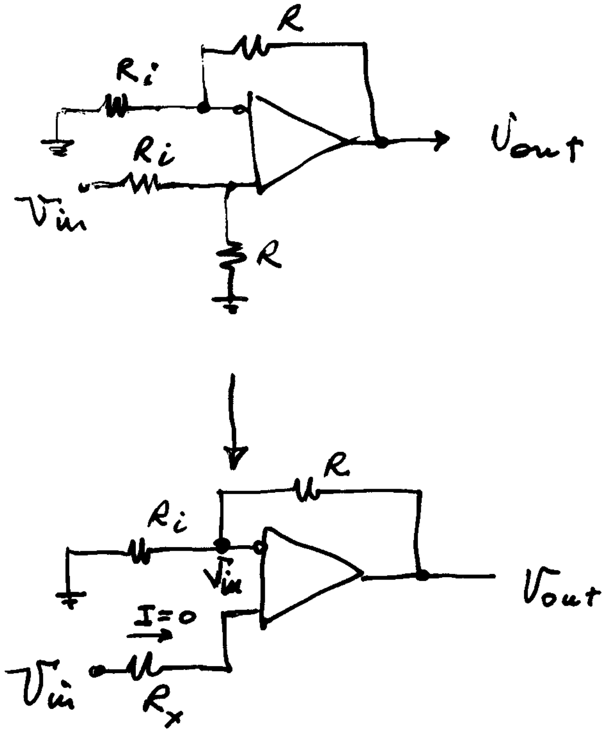
$$\frac{V_1 - V'}{R_1} = \frac{V' - V_0}{R_3}$$

$$V_0 = V_2 \frac{R_4}{R_2 + R_4} \frac{R_1 + R_3}{R_1} - V_1 \frac{R_3}{R_1}$$

IF $R_1 = R_2 = R_i$

$R_3 = R_4 = R$

$$V_0 = (V_2 - V_1)\, R/R_i$$



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

$$V_{out} = (1 + R/R_i)\, V_{in}$$

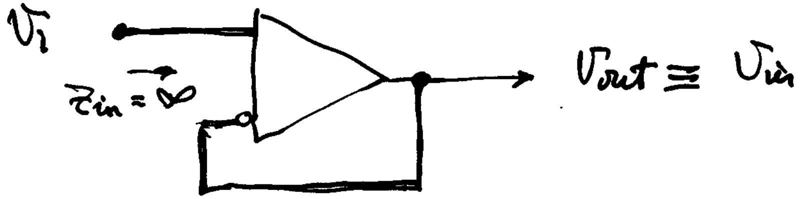
$$Z_{in} \Rightarrow \infty$$

$$A_{f+} = 1 + R_F/R_S \geqslant 1$$

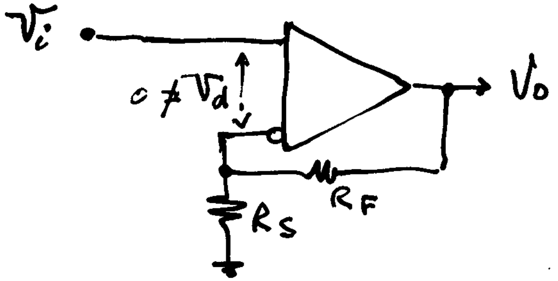
WHILE

$$A_{f-} = -R_S/R_S$$ NEGATIVE BOT "ANY" VALUE

$A_{f+} = 1$ if R_F/R_S THAT MEANS $R_S = \infty$ THEN R_F DON'T CARE, THEN:



AGAIN IN THE ASSUMPTION $A_{OL} = \infty$. DO WE NEED IT?



$$A_{fi} = \frac{R_S + R_F}{R_S} = 1 + \frac{R_F}{R_S}$$

$$V_d = V_i - \frac{V_o}{R_S + R_F} \cdot R_S$$

$$V_{OUT} = A_{OL} V_d = A_{OL} V_i - A_{OL} \frac{V_o}{R_S + R_F} R_S$$

$$A_{f+} = \frac{V_{OUT}}{V_{in}} = \frac{A_{OL}}{1 + A_{OL} \, {R_S}/{(R_S + R_F)}} \xrightarrow[A_{OL} \to \infty]{} = \frac{R_S + R_F}{R_S} = A_{fi}$$

$$A_{f+} = \frac{A_{OL}}{1 + A_{OL}/A_{fi}}$$

$A_{f+} = A_{fi}$ IF $A_{OL} \to \infty$ OR $A_{fi} \ll A_{OL}$

LET'S CALCULATE THE REAL UNITY GAIN FOR $A_{OL} = 5 * 10^4$

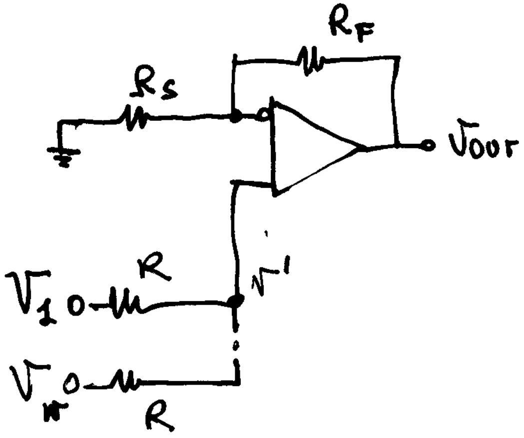
$$A_f = \frac{A_{OL}}{1 + A_{OL}} = \frac{5*10^4}{1+5*10^4} = .999980000 4 \approx$$

AND FOR $A_{OL} = 1000$

$$A_f = \frac{10^3}{1+10^3} = .99900$$ STILL QUITE GOOD.

CAN WE MAKE NON INVERTING SUM ?

YES, BUT...



$$V_1' = \frac{V_1}{R + \frac{R}{N-1}} \cdot \frac{R}{N-1} = \frac{V_1}{N}$$

. . .

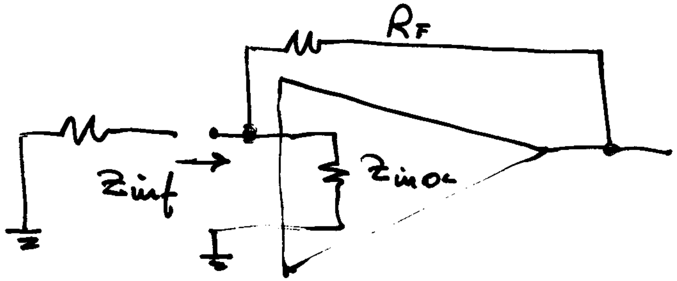
$$V_N' = \frac{V_N}{N}$$

$$V_0 = \left(1 + R_F/R_S\right) \frac{1}{N} \left(V_1 + V_2 + \ldots V_N\right)$$

EACH GENERATOR V_N SEES THE OTHERS, SO ITS LOAD IS NOT CONSTANT!

LET'S USE ANOTHER METHOD TO CALCULATE MORE PRECISELY THE Z_{inf}, INPUT IMPEDANDE WITH FEEDBACK.

WE USE THE MILLER EFFECT



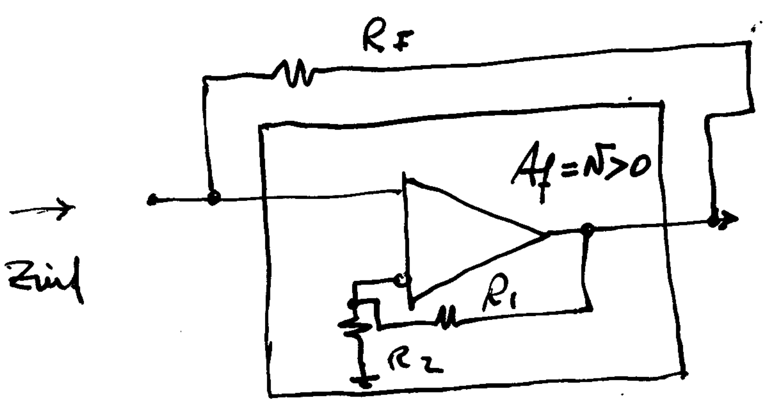
$\Rightarrow$

$$Z_{inf} = Z_{inOL} // \left[\frac{R_F}{1-A_{OL}} \right]$$

$$= \frac{Z_{inOL} R_F}{R_F + Z_{inOF}(1-A_{OL})} \rightarrow \frac{R_F}{1-A_{OL}} \rightarrow 0$$

BUT THIS HOLDS FOR ANY SIGN OF A_{OL}

EVEN FOR $A_{OL} > 0$ ...



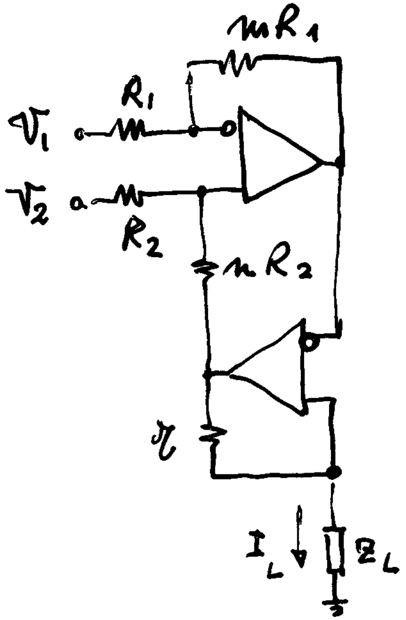
$A_f = 1 + R_1/R_2 \geq 1$

$$Z_{inf} = \frac{Z_{inOL} \quad R_F}{R_F + Z_{inOL}\,(1 - A_{OL})}$$

$Z_{inOL} = \infty$ NOW AND $A_{OL} = N > 0$ THEN (REMEMBER $A_{OL} > 1$ ALSO)

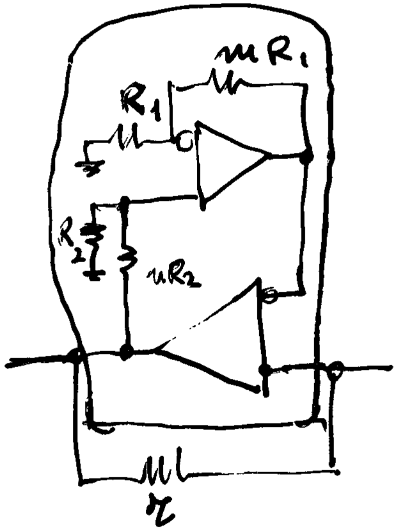
$$Z_{inf} = \frac{-R_F}{N - 1} \leq 0 \quad !$$

WE CAN USE IT TO GENERATE INFINITE IMPEDANCES!



WE WANT TO MAKE A VOLTAGE ($V_2 - V_1$) CORRENT GENERATOR.

THE IMPEDANCE SEEN FROM LOAD Z_L MUST BE ∞.



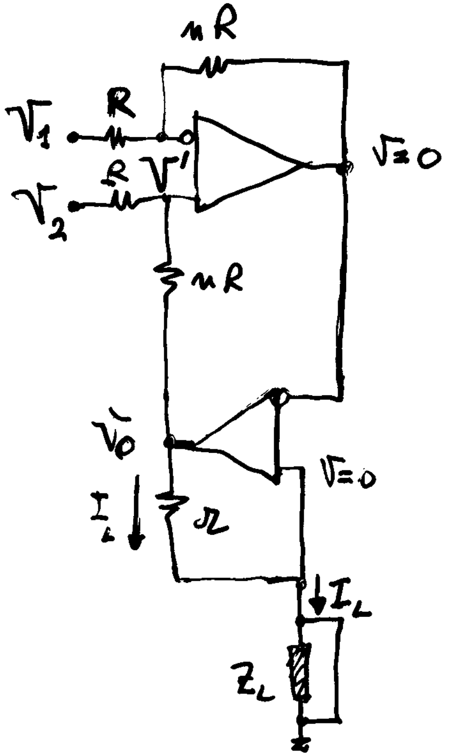
$$Z_{inf} = \frac{Z_{inOL} \, R_F}{R_F + Z_{inOL}(1 - A_{OL})}$$

$R_F = r$ $Z_{inOL} = \infty$

$$Z_{inf} = \frac{r}{1 - A_{OL}}$$ TO HAVE $Z_{inf} = \infty$

A_{OL} MUST BE $= 1$

THAT MEANS $\boxed{m = n}$ CONDITION TO
HAVE I_L INDEPENDENT FROM Z_L. BUT WHICH IS
THE VALUE OF I_L ?



$$V' = \frac{V_1}{R+nR} \cdot nR = \frac{V_1 n}{1+n}$$

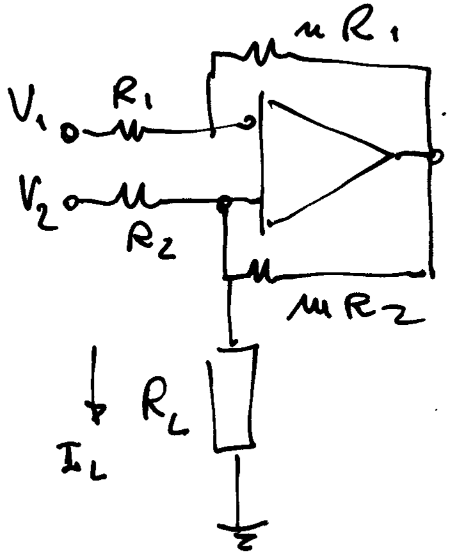
$$V' = \frac{V_2 - V_0}{R+nR} \cdot nR + V_0 = \frac{V_2 - V_0}{1+n} n + V_0$$

$$V_1 \frac{n}{1+n} = \frac{V_2 n}{1+n} - V_0 \left[\frac{n}{1+n} - 1 \right]$$

$$= \frac{V_2 n}{1+n} + V_0 \left[\frac{1}{1+n} \right]$$

$$V_0 = (V_1 - V_2) n$$

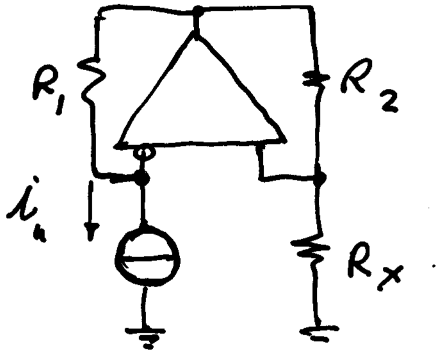
$$\boxed{I_L = \frac{V_0}{r} = \frac{V_1 - V_2}{r} n}$$



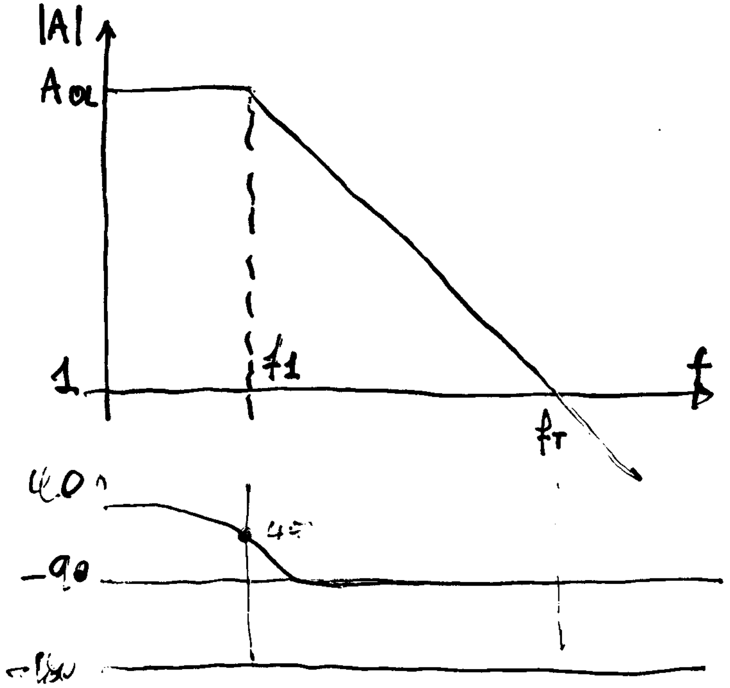
TRY TO FIND THE CONDITION
TO HAVE $I_L = f(V_1, V_2)$

OR

⊛ CALCULATE I_L ON R_x AS A FUCTION OF
R_1 & R_2

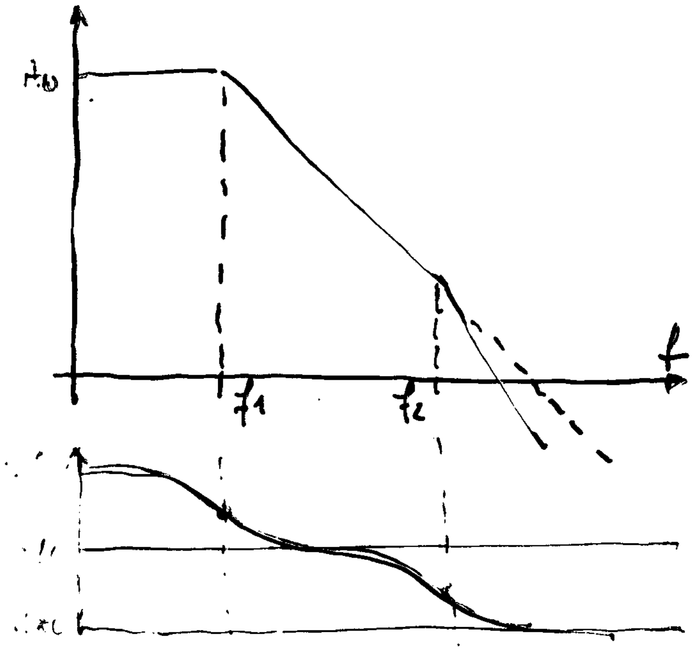


Single pole system



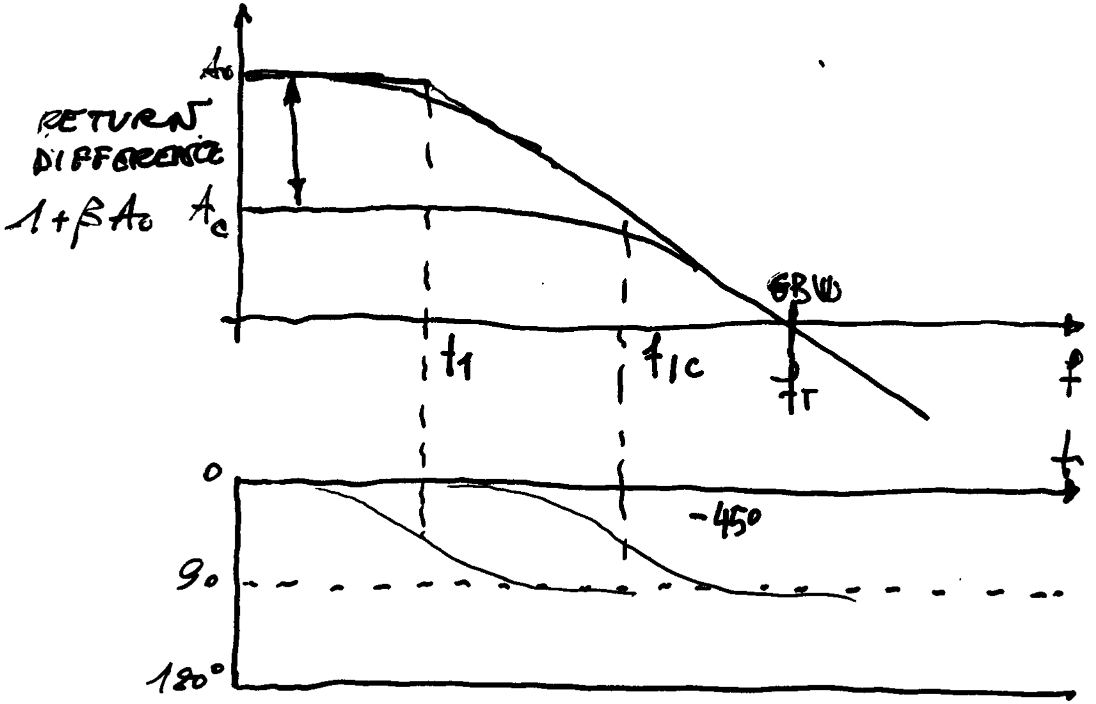
$$A = \frac{A_0}{1 + j\,f/f_1}$$

Two pole system



$$\frac{A_0}{\left(1 + j\,f/f_1\right)\left(1 + j\,f/f_2\right)}$$

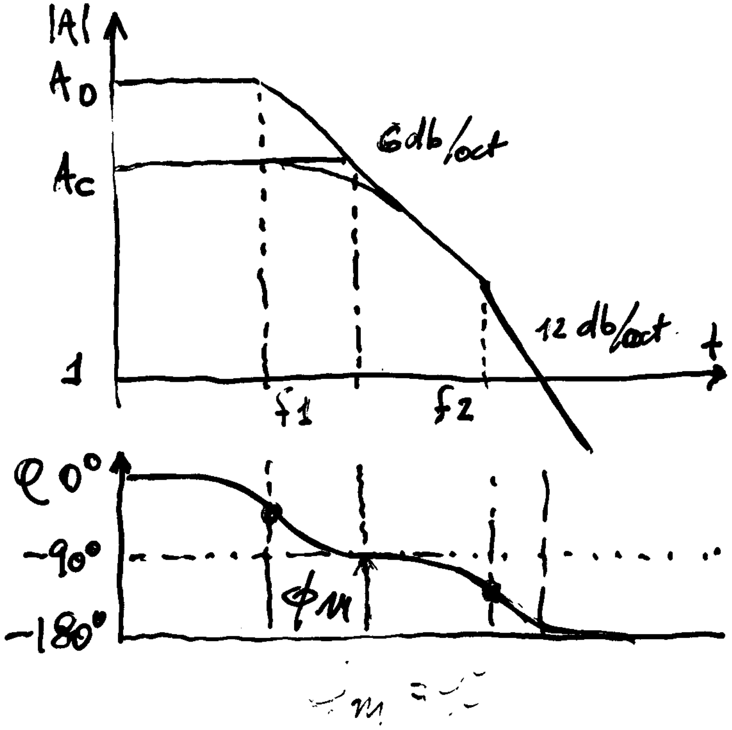
CLOSED LOOP GAIN A_C IN A ONE_POLE SYSTEM

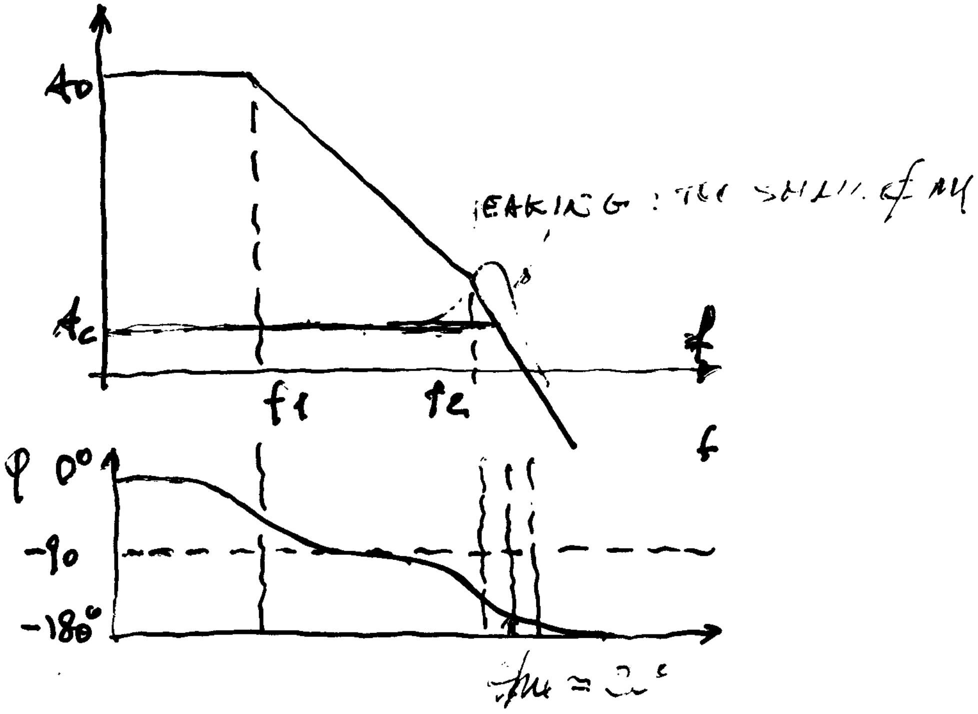


$$A_0 f_1 = 1 * f_T$$
$$A_C f_{1C} = f_T$$

GBW

TWO POLES SYSTEM WITH DIFFERENT CLOSED LOOP GAIN A_c





ALMOST READY TO OSCILLATE

THE CRITERION FOR STABILITY AGAINST OSCILLATION AL CLOSED LOOP IS:

THE OPEN LOOP PHASE SHIFT MUST BE LESS THAN 180°
AT THE FREQUENCY AT WHICH THE LOOP GAIN (IN THE
FEEDBACK CONFIGURATION) IS UNITY.

NB $A_c = \frac{A_0}{1+\beta A_0}$

$1+\beta A_0$ RETURN DIFFERENCE

βA LOOP GAIN

$$\underset{A_0 \to \infty}{\simeq} 1/\beta$$

THE HARDEST CONDITION IS THEN THE AMPLIFIER CONNECTED AS
FOLLOWER AS LOOP GAIN EQUALS THE OPEN LOOP GAIN AT THE
f WHERE THE PHASE SHIFT IS 180°.