

Analisis en terminos del loop-gain

$$A_f = A_{ideal} \frac{1}{1 + 1/T}$$

↳ ganancia obtenida usando un modelo ideal del op-amp.  
 ↳  $\beta$  de la conf. non-inv.

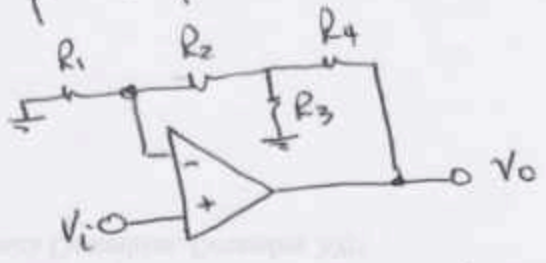
$$T = \text{loop-gain} = A_{NF} \beta$$

↳ ganancia del amp. sin retroalimentación

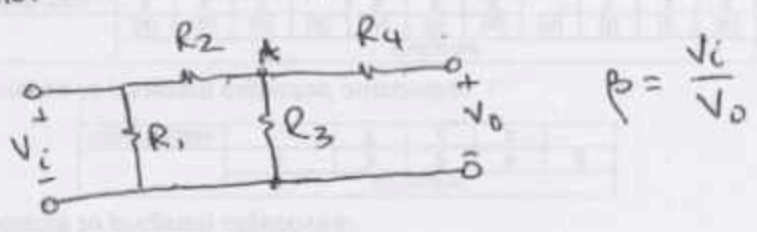
El efecto de la retro-alimentación esta "sumido" en T.

$\frac{1}{1 + 1/T}$  → indica cuan lejos esta la ganancia de la ganancia del amp. ideal.

T → podemos determinar  $A_{NF}$  (muchas veces  $\approx a$ ) y  $\beta$  separadamente, entonces multiplicar.



$A_{NF} \approx a$  (open-loop gain del opamp)



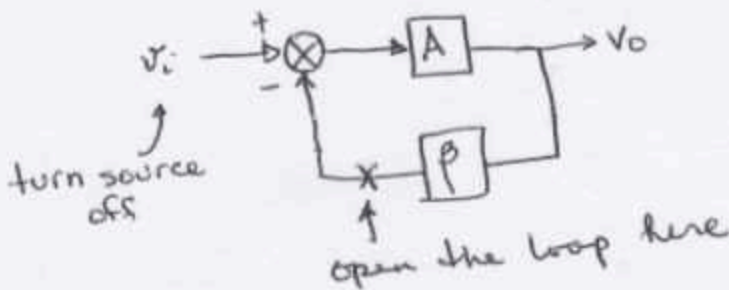
$$\beta = \frac{V_i}{V_o}$$

$$V_i = V_A \frac{R_1}{R_1 + R_2} ; V_A = V_0 \frac{R_{eq}}{R_{eq} + R_4} ; R_{eq} = (R_1 + R_2) \parallel R_3$$

$$\beta = \frac{V_i}{V_0} = \frac{R_1}{R_1 + R_2} \frac{(R_1 + R_2) \parallel R_3}{R_4 + (R_1 + R_2) \parallel R_3}$$

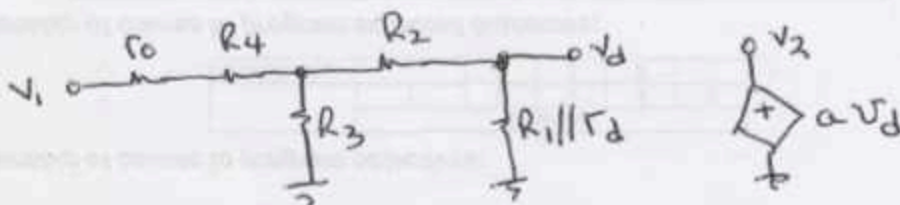
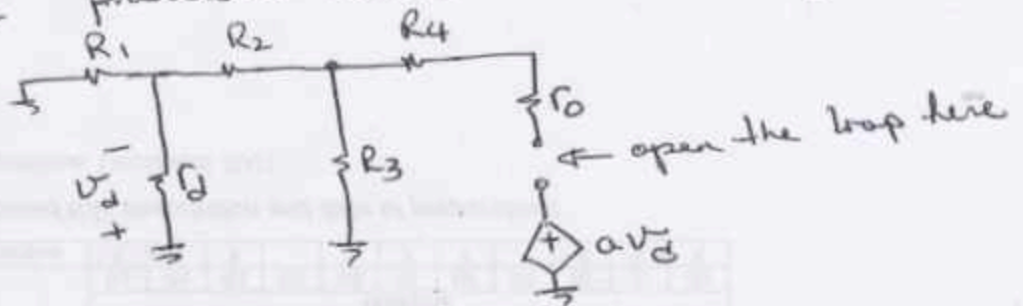
$$\therefore T \approx a\beta = a \frac{R_1}{R_1 + R_2} \frac{(R_1 + R_2) \parallel R_3}{R_4 + (R_1 + R_2) \parallel R_3}$$

Another way of calculating T  $\rightarrow$  opening the loop



$$T = -\frac{v_2}{v_1}$$

Example previous circuit but including  $r_o$  &  $r_d$



$$T = \frac{-v_2}{v_1} = a \frac{R_1 \parallel \Gamma_d}{R_1 \parallel \Gamma_d + R_2} \frac{R_{eq}}{R_{eq} + R_4 + \Gamma_0}$$

$$R_{eq} = R_3 \parallel (R_2 + R_1 \parallel \Gamma_d)$$

If we let  $\Gamma_0 \rightarrow 0, \Gamma_d \rightarrow \infty$

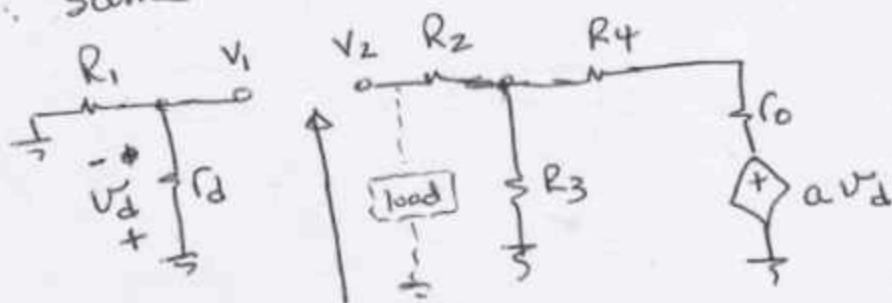
$$T = a \frac{R_1}{R_1 + R_2} \frac{R_{eq}}{R_{eq} + R_4}$$

$$R_{eq} = R_3 \parallel (R_2 + R_1)$$

Same result obtained previously

You can break the loop in many ways, but to get the correct result, loading effects must be included in the analysis.

Example: same circuit



breaking the loop here is ok, but a load equal to  $R_1 \parallel \Gamma_d$  must be added. Otherwise the result is different (and incorrect).

P. 1.55

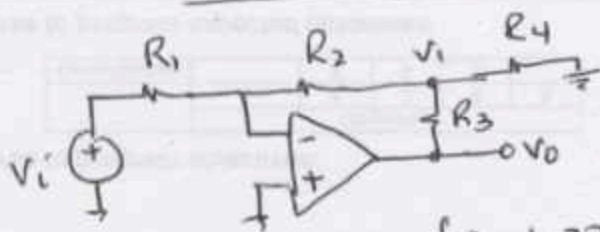


fig. 1.32a

P.1.55 For the ckt. shown in Fig. 1.329

$R_3$  is a pot.  $0 \leq R_3 \leq 1M\Omega$

Specify comp. for

(a)  $R_{in} = 500k\Omega$   
variable gain  $-10^3 V/V \leq A_{ideal} \leq -0.5 V/V$

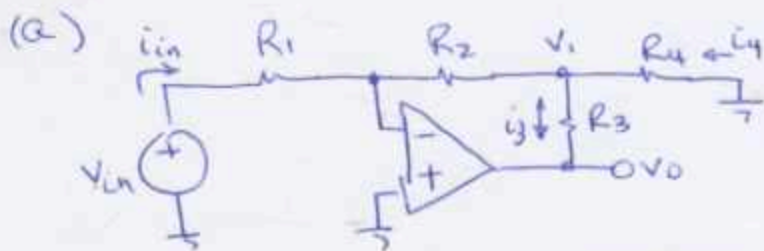
(b) if  $r_d = 1M\Omega$ ,  $a = 10^5 V/V$ ,  $r_o = 100\Omega$  and  $R_L = 2k\Omega$ , estimate the gain departure from the ideal at the two extremes of the range.

~~(100)~~  $R_3$  &  $R_4$  are switched  $\rightarrow$  for this problem

use

$$T = a \frac{R_1 // r_d}{R_1 // r_d + R_2} \frac{R_{eq}}{R_{eq} + R_3 + r_o}$$

$$R_{eq} = R_4 // (R_2 + R_1 // r_d)$$



$$R_{in} = \frac{v_{in}}{i_{in}} \approx \boxed{R_1 = 500k\Omega}$$

$$v_1 = -\frac{R_2}{R_1} v_{in} ; v_o = v_1 - i_3 R_3$$

$$i_3 = i_2 + i_4 ; i_4 = \frac{-v_1}{R_4} = +\frac{R_2}{R_1 R_4} v_{in}$$

$$v_o = -\frac{R_2}{R_1} v_{in} - R_3 \left( \frac{v_{in}}{R_1} + \frac{R_2}{R_1 R_4} v_{in} \right)$$

$$= -\frac{v_{in}}{R_1} \left[ R_2 + R_3 + \frac{R_2 R_3}{R_4} \right] = -\frac{v_{in}}{R_1} \left[ R_2 + R_3 \left( 1 + \frac{R_2}{R_4} \right) \right]$$

$$\frac{V_o}{V_{in}} = - \left( \frac{R_2 + R_3 \left(1 + \frac{R_2}{R_4}\right)}{R_1} \right)$$

When  $R_3 = 0$ ,  $\frac{V_o}{V_{in}} = - \frac{R_2}{R_1} = -0.5 \text{ V/V}$

$$\therefore R_2 = \frac{1}{2} R_1 = 250 \text{ k}\Omega$$

$$\frac{V_o}{V_{in}} = - \frac{250 + R_3 \left(1 + \frac{250}{R_4}\right)}{500}$$

When  $R_3 = 1 \text{ M}\Omega$

$$\frac{V_o}{V_{in}} = -10^3 \text{ V/V} = - \frac{250 + 10^3 \left(1 + \frac{250}{R_4}\right)}{500}$$

↳ resistances in kilos.

$$250 + 10^3 \left(1 + \frac{250}{R_4}\right) = 500 \times 10^3$$

$$\frac{250}{R_4} = \frac{500 \times 10^3 - 250}{10^3} - 1 = 499.75$$

$$R_4 = \frac{250 \text{ k}\Omega}{499.75} = 500.25 \Omega = R_4$$

(b) we can try to use

$$T = a \frac{R_1 // r_d}{R_1 // r_d + R_2} \frac{R_{eq}}{R_{eq} + R_3 + r_o}$$

$$R_{eq} = R_4 // (R_2 + R_1 // r_d)$$

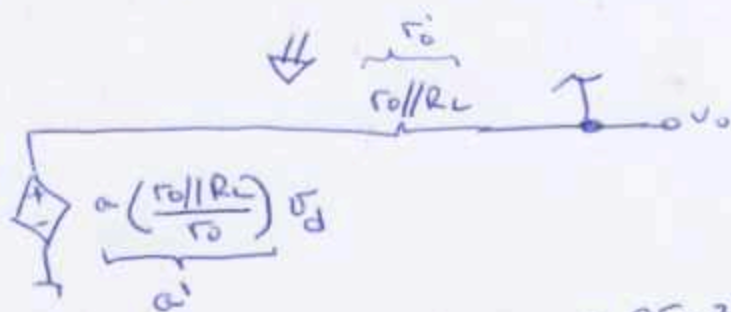
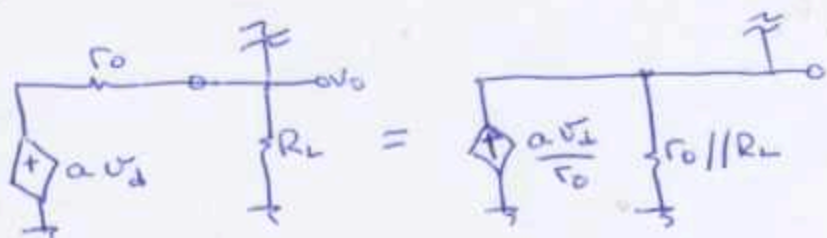
but  $\rightarrow$  This is the non-inv. amp. T; the non-inv. amp. T

amplifier calculations only when  $r_d$  and  $r_o$  are neglected.

$\rightarrow$  this does not take into account the effect of  $R_L$

Nevertheless the textbook uses  $T$  from the non-inv. amplifier for the inv. amp. even if  $r_d$  and  $r_o$  are being taken into account.

One way to take into account the presence of  $R_L$  is by considering the output segment of the opamp as follows:



$$\text{So } a' = 10^5 \left( \frac{100 // 2k\Omega}{100\Omega} \right) = 10^5 \frac{95.24}{100} = 9.52 \times 10^4 \text{ V/V}$$

$$r_o' = r_o // R_L = 100 // 2k\Omega = 95.24 \Omega$$

$$T = a' \frac{R_1 // r_d}{R_1 // r_d + R_2} \frac{R_{eq}}{R_{eq} + R_3 + r_o'}$$

$$R_{eq} = R_4 // (R_2 + R_1 // R_d)$$

$$= 500.25 \Omega // (250k\Omega + \underbrace{500k\Omega // 1M\Omega}_{333k\Omega})$$

$$= 500.25 \Omega // 583k$$

$$= 499.8 \Omega$$

$$T = (9.52 \times 10^4 \text{ V/V}) \left( \frac{500k // 1M\Omega}{500k // 1M\Omega + 250k\Omega} \right) \left( \frac{499.8 \Omega}{499.8 \Omega + R_3 + 95.24 \Omega} \right)$$

$$= 5.44 \times 10^4 \frac{499.8 \Omega}{595 + R_3}$$

$$\text{For } R_3 = 0, T = 5.44 \times 10^4 \frac{499.8}{595} = 45,696^{\circ}$$

$$A = -0.5 \text{ V/V} \frac{1}{1 + 1/45696} = -.499989 \text{ V/V}$$

$$\text{error} \approx \underline{.002\%}$$

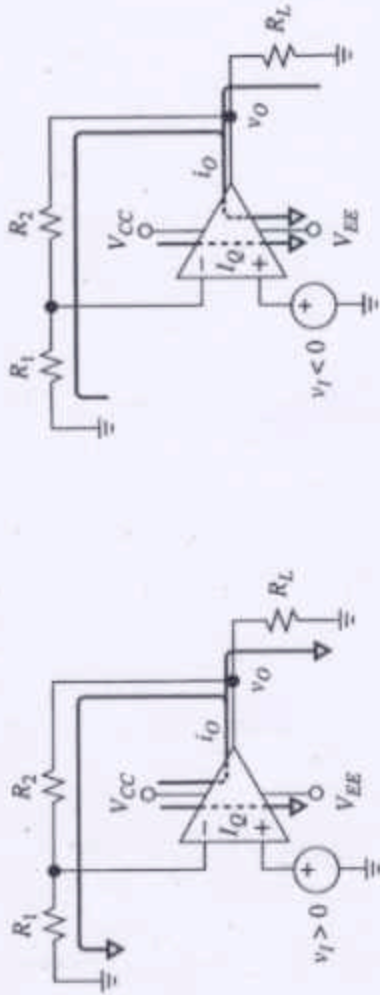
$$\text{For } R_3 = 1 \text{M}\Omega$$

$$T = 5.44 \times 10^4 \frac{499.8}{595 + 10^6} \approx 27$$

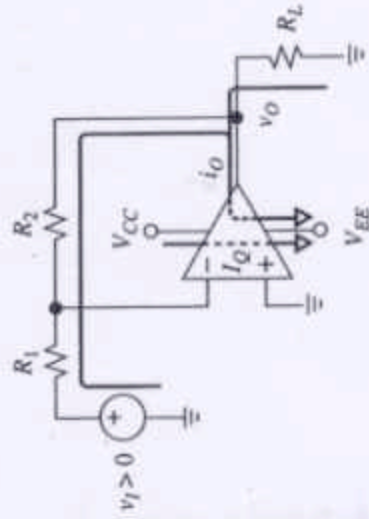
$$A \approx -1000 \frac{1}{1 + 1/27} \approx -964.5 \text{ V/V}$$

$$\text{error} \approx \underline{-3.6\%}$$

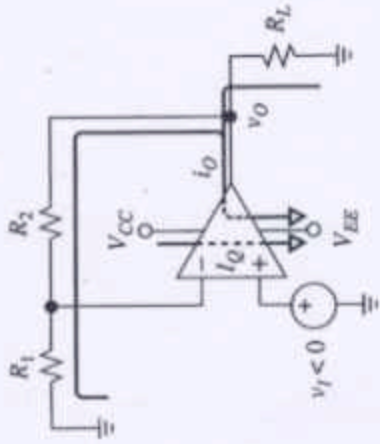
# CURRENT FLOW



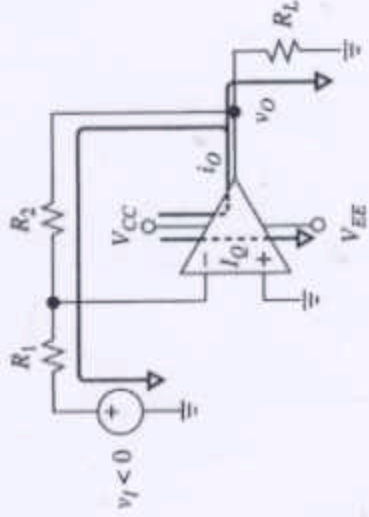
(a)



(c)



(b)



(d)

DISCUSSION OF PROB. 1.65