Analisis en terminos del Loop-gain

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

↳ ganancia obtenida usando un modelo ideal del op-amp.

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

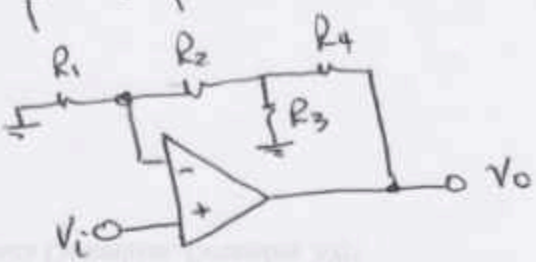
→ β de la conf. non-inv.

↳ ganancia del amp. sin retroalimentación

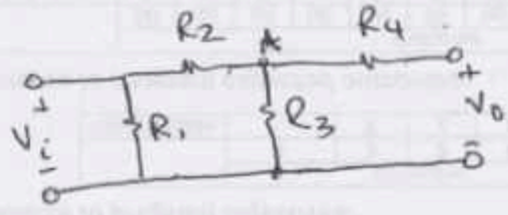
El efecto de la retro-alimentación esta "resumido" en T.

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

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



A_{NF} → a (open-loop gain del op amp)



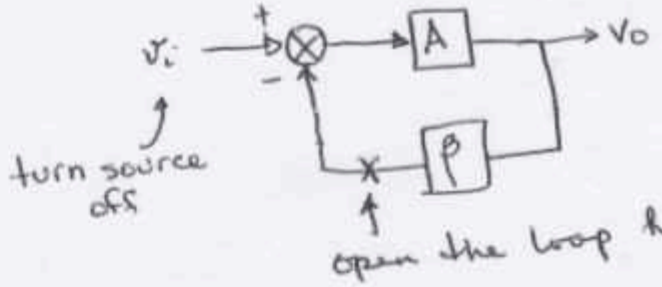
$$\beta = \frac{V_i}{V_o}$$

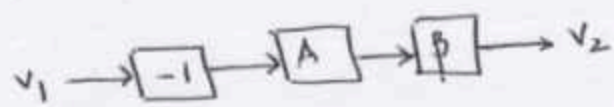
$$v_i = v_A \frac{R_1}{R_1+R_2} \; ; \; v_A = v_o \frac{R_{eq}}{R_{eq}+R_4} \; ; \; R_{eq} = (R_1+R_2) \parallel R_3$$

$$\beta = \frac{v_i}{v_o} = \frac{R_1}{R_1+R_2} \frac{(R_1+R_2)\parallel R_3}{R_4 + (R_1+R_2)\parallel R_3}$$

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

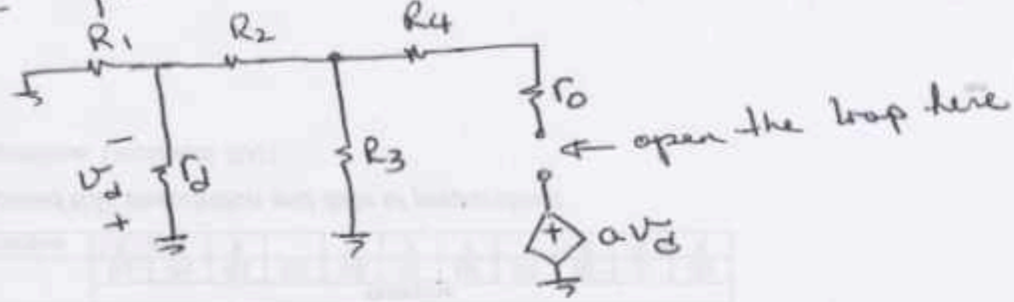
Another way of calculating T $\rightarrow$ opening the loop

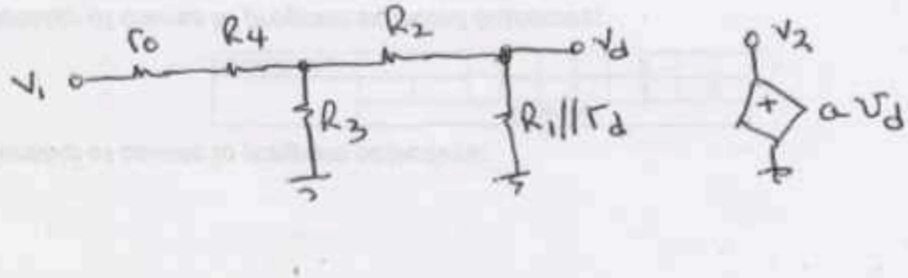




$$T = -\frac{v_2}{v_1}$$

<u>Example</u> previous circuit but including r_o & r_d





$$T = -\frac{v_2}{v_1} = a\,\frac{R_1 \| r_d}{R_1 \| r_d + R_2}\;\frac{R_{eq}}{R_{eq} + R_4 + r_o}$$

$$R_{eq} = R_3 \,\|\, (R_2 + R_1 \| r_d)$$

If we let $r_o \to 0$, $r_d \to \infty$

$$\left.\begin{aligned} T &= a\,\frac{R_1}{R_1 + R_2}\;\frac{R_{eq}}{R_{eq} + R_4} \\ R_{eq} &= R_3 \,\|\, (R_2 + R_1) \end{aligned}\right\}$$ Same result obtained previously

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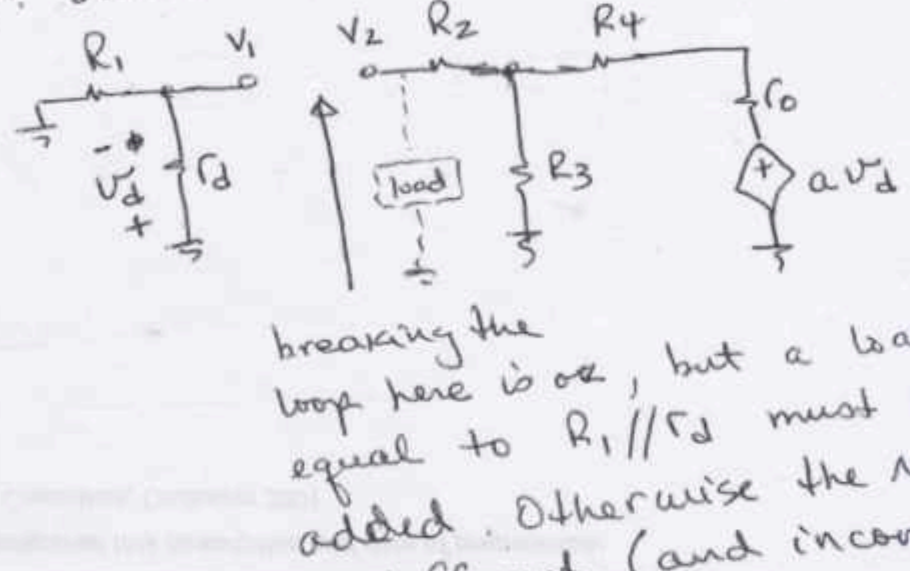
You can break the loop in many ways, but to get the correct result, loading effects must be included in the analysis.

Example: same circuit



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

P. 1.55

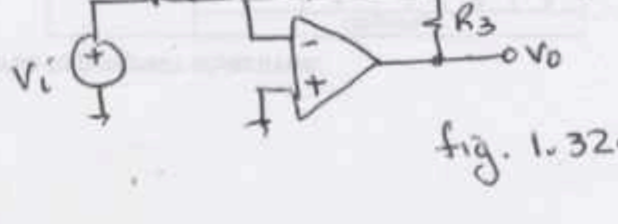


fig. 1.32a

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

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

Specify comps. for

(a) $R_{in} = 500k\Omega$

variable gain $-10^3 V/V \le A_{ideal} \le -0.5 V/V$

(b) if $r_d = 1M\Omega$, $a = 10^5 V/V$, $r_0 = 100\Omega$ and $R_L = 2k\Omega$, estimate the gain departure from the ideal at the two extremes of the range.

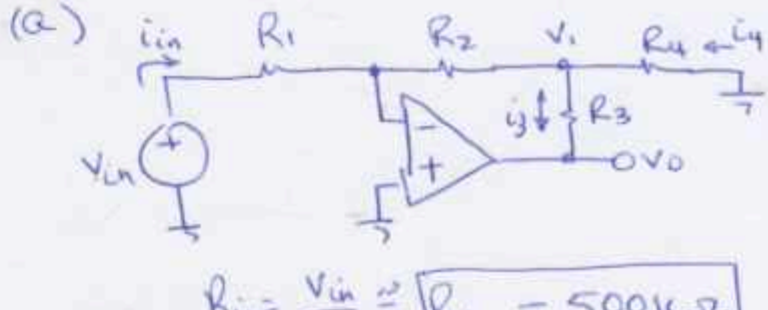
R_3 & R_4 are switched → for this problem

use

$$T = a \frac{R_1 \| r_d}{R_1 \| r_d + R_2} \frac{R_{eq}}{R_{eq} + R_3 + r_0}$$

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

(a)



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

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

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

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

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

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

when $R_3 = 0$, $\frac{v_o}{v_{in}} = -\frac{R_2}{R_1} = -0.5\,V/V$

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

$$\frac{v_o}{v_{in}} = -\frac{250 + R_3\left(1 + 250/R_4\right)}{500}$$

when $R_3 = 1\,M\Omega$

$$\frac{v_o}{v_{in}} = -10^3\,V/V = -\frac{250 + 10^3\left(1 + 250/R_4\right)}{500}$$

↳ resistances in kilos.

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

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

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

(b) we can try to use

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

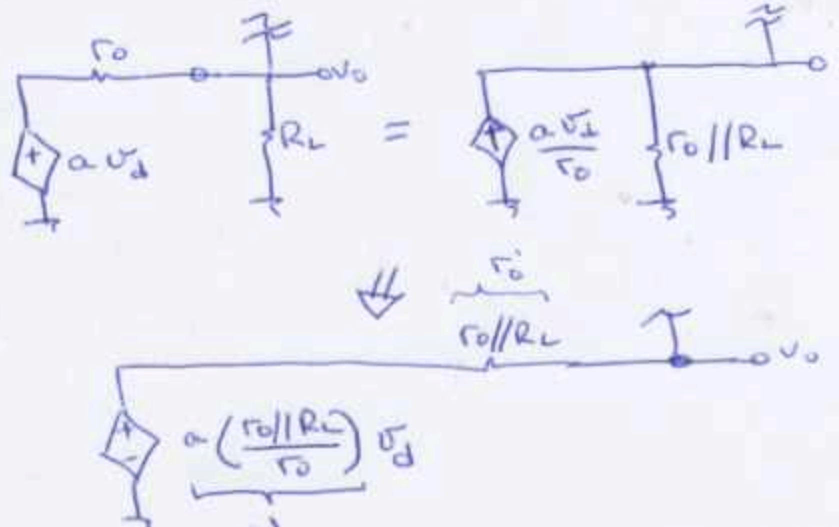
$$R_{eq} = R_4 \,\|\, (R_2 + R_1 \| r_d)$$

but → This is the non-inv. amp. T; the non-inv. amp. T: can be used in the inv. amplifier calculations only when r_d and r_o are neglected.

→ 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:



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

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

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

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

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

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

$$= 499.8\ \Omega$$

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

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

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

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

err $\simeq$ $\underline{.002\%}$

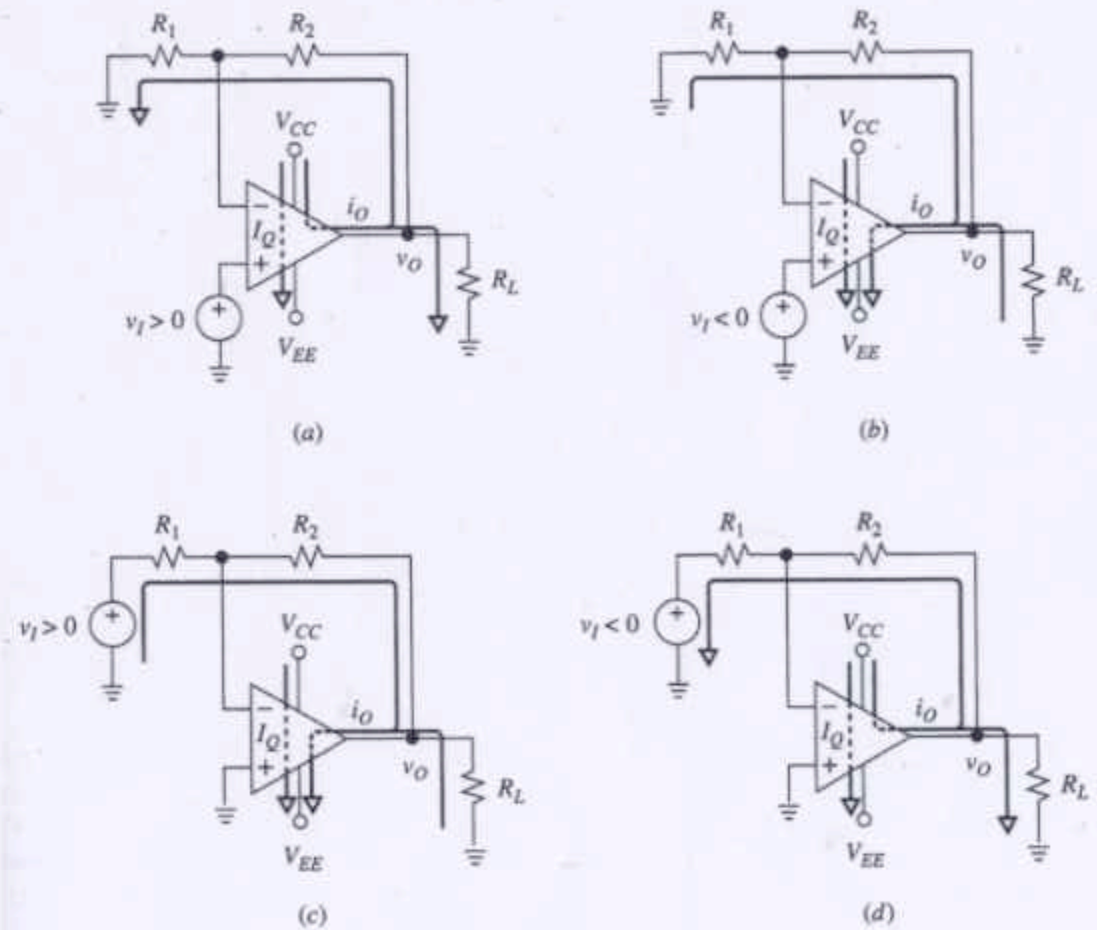
For $R_3 = 1M\Omega$

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

$$A \sim -1000 \frac{1}{1 + 1/27} \simeq -964.5\ V/V$$

err $\simeq$ $\underline{-3.6\%}$

CURRENT FLOW



DISCUSSION OF PROB. 1.65