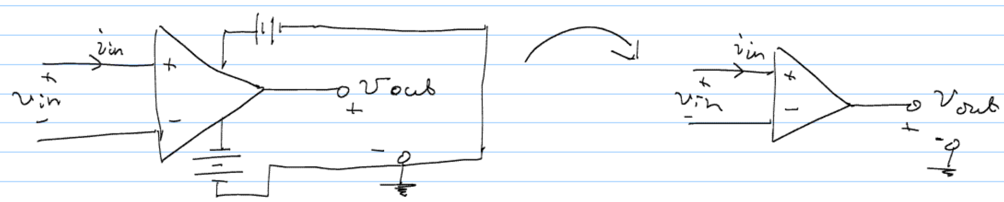
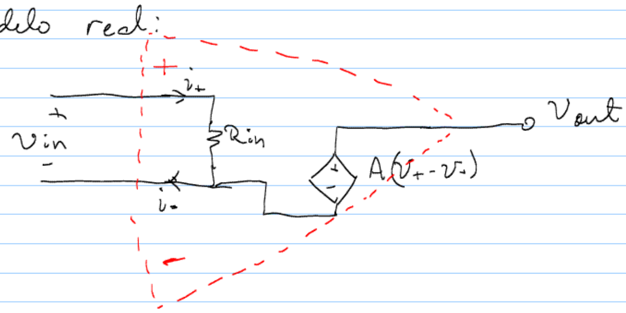
INEL 3105 8th lecture.

Note Title 8/28/2009

OP-Amps (Operational Amplifiers)



Modelo real:



Ri = Resistencia de entrada (10^5–10^{12})

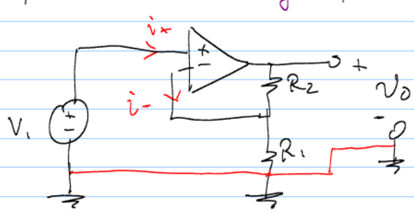
Ro = Resistencia de salida (1–50 Ω)

A = Ganancia del amplificador (10^5–10^7)

Modelo ideal:

$A \to \infty$; $V_0 = A(V_+ - V_-)$; $i_+ = 0 = i_-$; $R_i \to \infty$; $R_{out} = 0$

Ejemplo: Non-inverting amplifier



Evalúe V_0 utilizando el modelo ideal

Solución: $V_+ = V_1 = V_-$

$i_+ = i_- = 0$

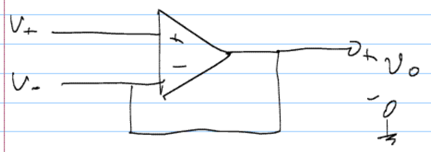
Divisor de voltaje:

$V_- = V_0 \left(\frac{R_1}{R_1+R_2}\right) = V_1$; V_0 del mismo signo que V_1.

$V_0 = \left(\frac{R_1+R_2}{R_1}\right)V_1 = \left(1 + \frac{R_2}{R_1}\right)V_1 = V_0$

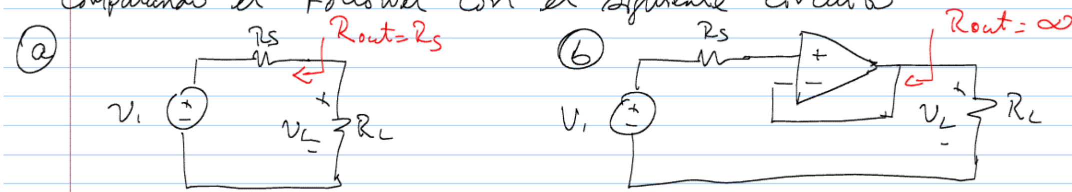
Caso especial de amplificador no-inversor

"Follower"



$V_o = V_1$

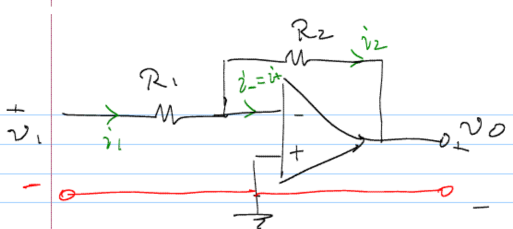
Comparando el "Follower" con el siguiente circuito



(a) $V_L = V_1 \left(\frac{R_L}{R_S + R_L} \right)$

(b) $V_L = V_+ + V_1$

Otro ejemplo: "Inverting Amplifier"



Evaluar v_o:

$i_+ = i_- = 0 \; ; \; V_+ = V_-$

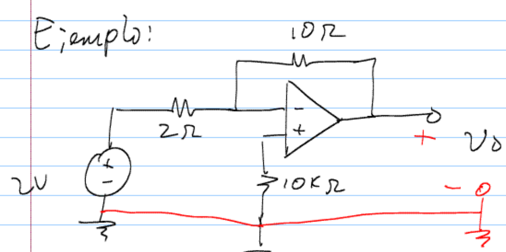
KCL: $i_1 - i_+ = i_2 \; ; \; i_1 = i_2$

Ecuaciones auxiliares: $i_1 = \frac{V_1 - V_-}{R_1} \; ; \; i_2 = \frac{V_- - V_o}{R_2}$

Sustituyendo ecuaciones auxiliares en KCL:

$\frac{V_1 - V_-}{R_1} = \frac{V_+ - V_o}{R_2} \; ; \quad V_- = V_+ = 0 \; \therefore \; \frac{V_1}{R_1} = \frac{-V_o}{R_2} \; ; \quad \boxed{V_o = -\frac{R_2}{R_1} V_1}$

Ejemplo:



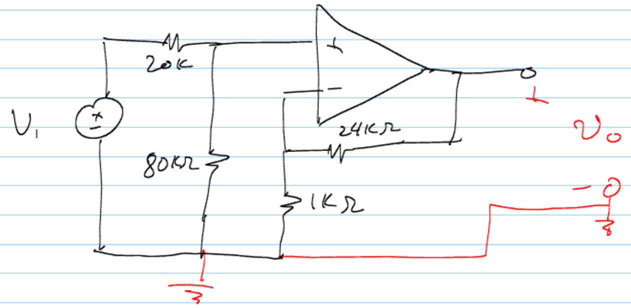
$i_+ = 0$

$V_+ = 10\, i_+ \; ; \; V_+ = 0$ since $i_+ = 0$

$V_+ = 0 = V_-$

$V_o = -\frac{R_2}{R_1} V_1 = \frac{-10}{2}(2) = -10\,V$

Más ejemplos:



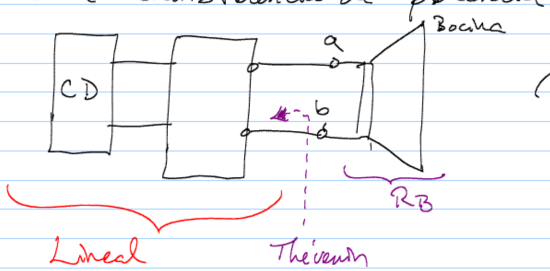
Evaluar V_o/V_1

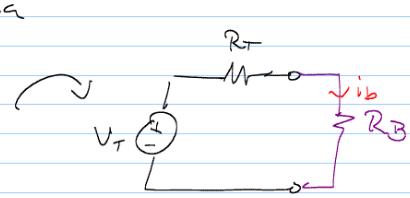
Divisor de voltaje: $V_+ = V_1\left(\frac{80K}{80K+20K}\right) = 0.8\,V_1$

$V_- = V_o\left(\frac{1K}{25K}\right) = \frac{1}{25}V_o\,;\quad V_o = 25\,V_- = 25\,(0.8\,V_1)$

$$\boxed{\frac{V_o}{V_1} = 20}$$

Máxima transferencia de potencia





$i_b = \frac{V_T}{R_T + R_B}$

$P_B = R_B\, i_b^2$

$P_B = R_B\left(\frac{V_T}{R_T+R_B}\right)^2$

$P_B = V_T^2\left(\frac{R_B}{(R_B+R_T)^2}\right)$

Take $\frac{dP_B}{dR_B}$

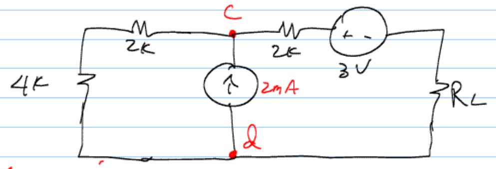
$$\frac{dP_B}{dR_B} = V_T^2\left(\frac{(R_B+R_T)^2(1) - R_B\,(2R_B+2R_T)}{(R_B+R_T)^4}\right) = 0$$

$(R_B+R_T)^2 - 2R_B^2 - 2R_BR_T = 0$

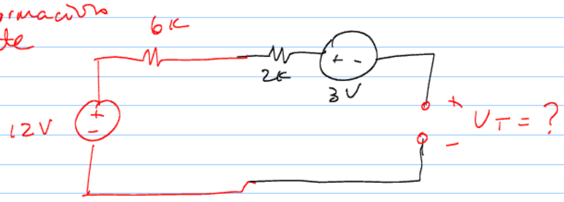
$R_B^2 + 2R_BR_T + R_T^2 - 2R_B^2 - 2R_BR_T = 0$

True when $R_B = R_T$ ∴ Máxima transferencia de potencia ocurre cuando $R_B = R_T$

Ejemplo: Evalúe R_L para M.T.P.



Transformación de fuente

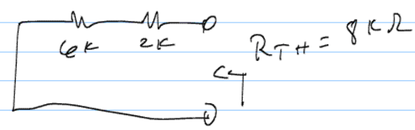


$i = 0$

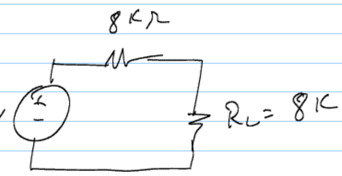
$$12 - 6K i - 2K i - 3 - V_T = 0$$

$V_T = 9V$

Evaluación de R_T:



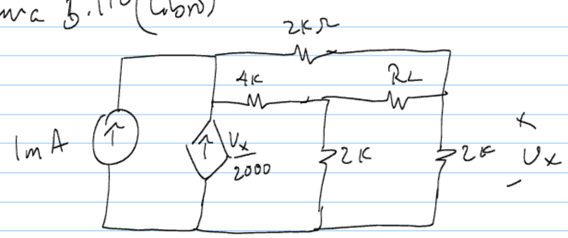
Dibujo de circuito equivalente



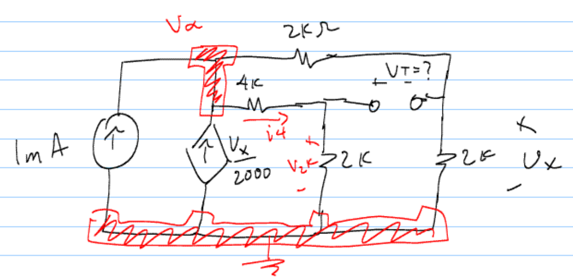
for M.T.P

$$P_L = R_L I_L^2 = 8K\left(\frac{9}{16K}\right)^2 = 8\left(\frac{81}{256}\right) mW.$$

Otro ejemplo:
Problema 5.110 (Libro)



Step 1: Calcular V_{TH}



Análisis por nodos

KCL @ V_α:

$$1mA + \frac{V_x}{2000} - \frac{V_\alpha}{6K} - \frac{V_\alpha}{4K} = 0$$

1 ecuación, 2 desconocidas:

Ecuaciones auxiliares: $V_x = V_\alpha\left(\frac{2K}{4K}\right) = V_\alpha\left(\frac{1}{2}\right)$; Re-writing KCL:

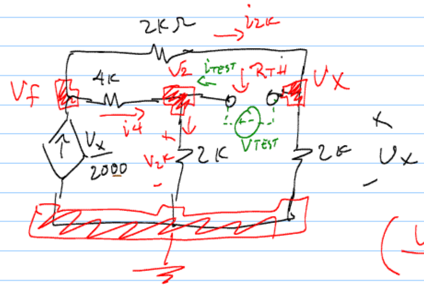
$$1mA + \frac{V_\alpha}{4000} - \frac{V_\alpha}{6K} - \frac{V_\alpha}{4K} = 0$$

$$-1mA = V_\alpha\left(\frac{1}{4000} - \frac{1}{4000} - \frac{1}{6000}\right) \; ; \; V_\alpha = 6V$$

$V_x = \frac{V_\alpha}{2} = 3V$; $V_{2K} = 2K(i_4)$; $i_4 = \frac{V_\alpha}{6K} = \frac{6}{6K} = 1mA$

$V_{2K} = 2V$

$V_T = V_{2K} - V_x = 2 - 3 = -1V$



Análisis por nodos

KCL @ Vf:

$$\frac{V_x}{2000} - \left(\frac{V_f - V_x}{2K}\right) - \left(\frac{V_f - V_2}{4K}\right) = 0 \quad I$$

KCL @ V2:

$$\left(\frac{V_f - V_2}{4K}\right) - \frac{V_2}{2K} + i_{TEST} = 0 \quad II$$

KCL @ Vx

$$\left(\frac{V_f - V_x}{2K}\right) - i_{TEST} - \frac{V_x}{2K} = 0 \quad III$$

Ecuaciones auxiliares:

$V_2 - V_x = V_{TEST}$ (1)

$\frac{V_x}{2K} + \frac{V_2}{2K} - \frac{V_x}{2K} = 0$ (2)

⇓

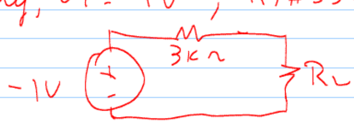
$V_2 = 0$ ⇒ rearranging (1); $V_{TEST} = -V_x$

$II: \frac{V_f}{4K} + i_{TEST} = 0$; $i_{TEST} = -\frac{V_f}{4K}$; $V_f = -i_{TEST}(4K)$

$I: \frac{-V_{TEST}}{2K} - \left(\frac{-4K\, i_{TEST} + V_{TEST}}{2K}\right) + i_{TEST} = 0$; $-\frac{V_{TEST}}{2K} + 2i_{TEST} - \frac{V_{TEST}}{2K} + i_{TEST} = 0$

$\frac{V_{TEST}}{1K} = 3i_{test}$; $\frac{V_{TEST}}{i_{TEST}} = 3K\Omega$

Finally; $V_T = -1V$; $R_{TH} = 3K\Omega$



for M.P.T; $R_L = 3K\Omega$