ELECTRÓNICA 1

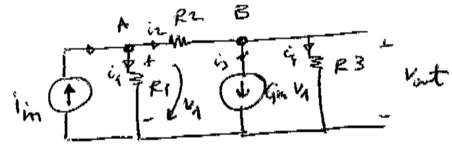
AULA 1 — LEI DAS MALHAS E LEI DOS NODOS. TEOREMA DE THEVENIN, NORTON, MILLER

Leis de kirchoff: lei das malhas $\sum_i V_i = 0$

lei dos nodos $\sum_i I_i = 0$

- soma das correntes entrando num nodo é zero
- soma das quedas de tensão ao longo de uma malha é zero

Exemplo: análise dos nodos



nodo A

$$i_{in} = i_1 + i_2$$

$$i_{in} = \frac{V_1}{R1} + \frac{V_1 - V_{out}}{R_2}$$

$$i_{in} = G_1 \cancel{R1} + G_2 V_1 - G_2 V_{out}$$

$$i_{in} = (G_1 + G_2) V_1 - G_2 V_{out}$$

$$G_1 = \frac{1}{R1}$$

$$G_2 = \frac{1}{R2}$$

nodo B

$$i_2 = i_3 + i_4$$

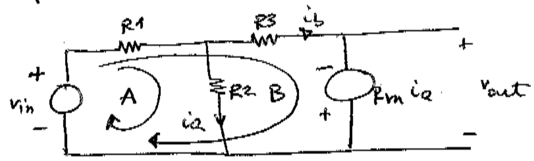
$$G_2 V_1 - G_2 V_{out} = G_M V_1 + G_3 V_{out}$$

$$0 = (G_M - G_2) V_1 + (G_3 + G_2) V_{out}$$

usando a regra de Cramer

$$V_{out} = \frac{\begin{vmatrix} (G_1+G_2) & i_{in} \\ (G_M - G_2) & 0 \end{vmatrix}}{\begin{vmatrix} (G_1 + G_2) & -G_2 \\ (G_M - G_2) & (G_3 + G_2) \end{vmatrix}} = \frac{(G_M - G_2)}{G_1 G_2 + G_1 G_3 + G_2 G_3 + G_m G_2} i_{in}$$

Exemplo: lei das malhas



malha A

$$v_{in} = R1\,(ia+ib) + R2\,(ia)$$

$$v_{in} = (R1+R2)\,ia + R1\,ib$$

malha B

$$v_{in} = R1\,(ia+ib) + R3\,ib - Rm\,ia$$

$$v_{in} = (R1-Rm)\,ia + (R1+R3)\,ib$$

regra de cramer

$$ia = \frac{\begin{vmatrix} v_{in} & R1 \\ v_{in} & R1+R3 \end{vmatrix}}{\begin{vmatrix} R1+R2 & R1 \\ R1-Rm & R1+R3 \end{vmatrix}} = \frac{R3\,v_{in}}{R1\,R2 + R1\,R3 + R2\,R3 + Rm\,R1}$$

Como

$$v_{out} = -Rm\,ia$$

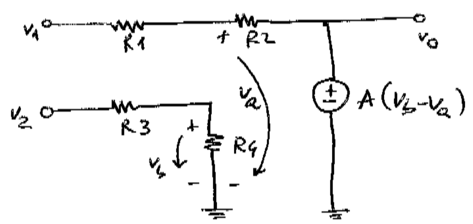
vem

$$\frac{v_{out}}{v_{in}} = \frac{-Rm\,R3}{R1\,R2 + R1\,R3 + R2R3 + Rm\,R1}$$

PRINCIPIO DA SOBREPOSIÇÃO

- válido em circuitos lineares e apenas com fontes independentes

Exemplo



$$V_o = A\,(V_b - V_a)$$

PASSO 1 — $V_1 = 0$

$$V_b = \frac{R4}{R3+R4}\,V2$$

$$V_a = \frac{R1}{R1+R2}\,V_o$$

logo $$V_o = A\left(\frac{R4}{R3+R4}\,V2 - \frac{R1}{R1+R2}\,V_o\right)$$

$$\left(1 + \frac{A\,R1}{R1+R2}\right) V_o = A\,\frac{R4}{R3+R4}\,V_2$$

$$V_o = \frac{A}{1 + \frac{A\,R1}{R1+R2}}\;\frac{R4}{R3+R4}\;V2$$

PASSO 2 — $V2 = 0$

Logo $V_b = 0$

$$V_o = -A\,V_a$$

$$V_a = \frac{R1}{R1+R2}\left(V_o - V_1\right) + V_1$$

Logo

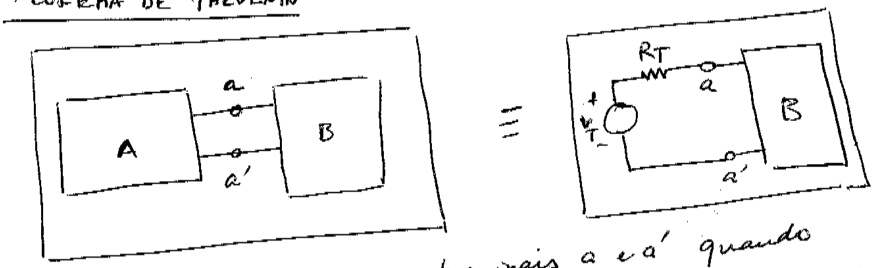
$$V_o\left(1 + \frac{A\,R1}{R1+R2}\right) = A\left(\frac{R1}{R1+R2} - 1\right) V_1$$

$$V_o = \frac{A}{1 + \frac{A\,R1}{R1+R2}}\left(-\frac{R2}{R1+R2}\right) V_1$$

logo, pelo principio da sobreposição

$$V_o = \frac{A}{1 + \frac{A\,R1}{R1+R2}}\left(\frac{R4}{R3+R4}\,V2 - \frac{R2}{R1+R2}\,V_1\right)$$

TEOREMA DE THEVENIN

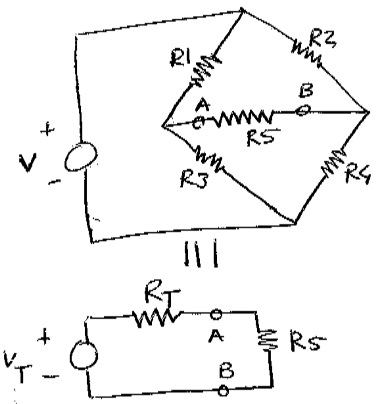


R_T — resistência vista dos terminais a e a' quando se retiram do circuito todas as fontes independentes

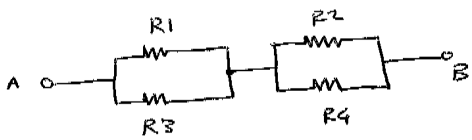
V_T — tensão nos terminais a e a' em circuito aberto

Exemplo

circuito equivalente visto dos pontos A e B



- resistência R_T entre os pontos A e B



$$R_T = (R1 \parallel R3) + (R2 \parallel R4)$$
$$= \frac{R1\,R3}{R1+R3} + \frac{R2\,R4}{R2+R4}$$

- tensão entre os pontos A e B em circuito aberto (retirando R5)

$$V_T = V_A - V_B$$
$$V_A = \frac{R3}{R1+R3} V \quad ; \quad V_B = \frac{R4}{R2+R4} V$$

logo
$$V_T = \left(\frac{R3}{R1+R3} - \frac{R4}{R2+R4} \right) V$$

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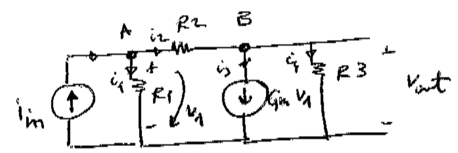

nodo A

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$$G_1 = \frac{1}{R_1}$$

$$G_2 = \frac{1}{R_2}$$

$$i_{in} = G_1 V_1 + G_2 V_1 - G_2 V_{out}$$

$$i_{in} = (G_1 + G_2) V_1 - G_2 V_{out}$$

nodo B

$$i_2 = i_3 + i_4$$

$$G_2 V_1 - G_2 V_{out} = G_m V_1 + G_3 V_{out}$$

$$0 = (G_m - G_2) V_1 + (G_3 + G_2) V_{out}$$

usando a regra de Cramer

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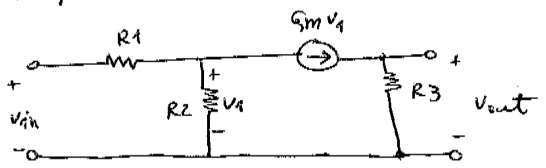
SUBSTITUIÇÃO DE FONTE

Exemplo



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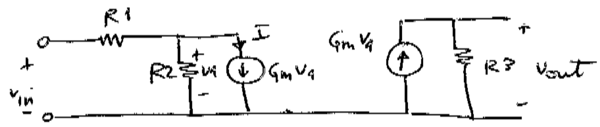

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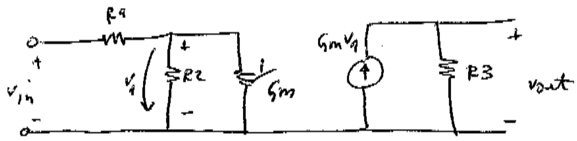
$$I = G_m V_1$$

$$R = \frac{V_1}{I} = \frac{1}{G_m}$$



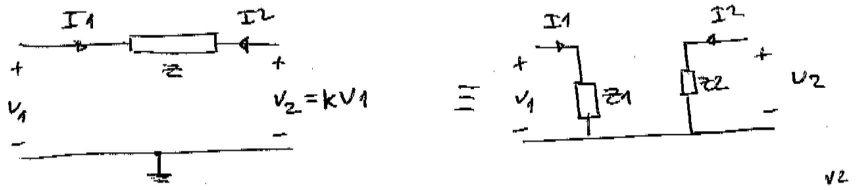
Logo $\quad V_{out} = R3\, G_m\, V_1$

mas $\quad V_1 = \dfrac{R2 \| \frac{1}{G_m}}{\left(R2 \| \frac{1}{G_m}\right) + R1} V_{in} = \dfrac{\frac{R2\, R_m}{R2 + R_m}}{\frac{R2\, R_m}{R2+R_m} + R1} V_{in}$

Logo

$$V_{out} = \frac{R3}{R_m} \, \frac{\frac{R2\, R_m}{R2+R_m}}{\frac{R2\, R_m}{R2+R_m} + R1} V_{in}$$

TEOREMA DE MILLER



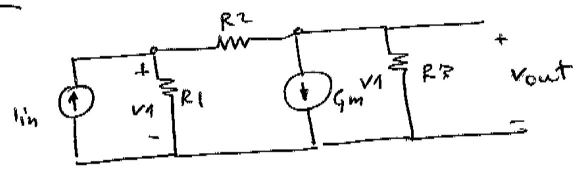
$$I1 = \frac{V_1 - V2}{Z} = \frac{(1-k)\,V_1}{Z} \qquad I_1 = \frac{V1}{Z1} \; ; \; I2 = \frac{V2}{Z2}$$

$$I2 = \frac{V2 - V1}{Z} = \frac{\left(1 - \frac{1}{k}\right) V2}{Z}$$

Logo, para os circuitos serem equivalentes

$$Z1 = \frac{Z}{1-k} \quad e \quad Z2 = \frac{Z\,k}{k-1}$$

exemplo



R2 >> R3

Logo $V_{out} = -G_m V_1 R3$

Logo $k = -G_m R3$

Circuito equivalente

$$\frac{+R2\,R3\,G_m}{G_M R3 + 1} \simeq R2$$