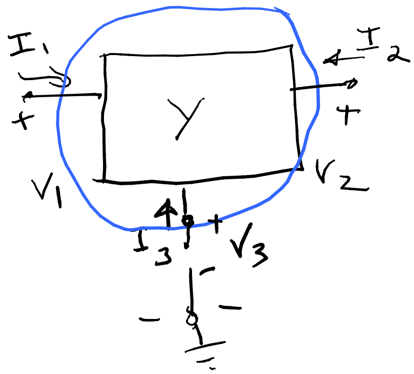
09/14/05
EE610



$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = Y \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = Y_{ind} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} & y_{13} \\ y_{21} & y_{22} & y_{23} \\ y_{31} & y_{32} & y_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

$I_1 + I_2 + I_3 = 0$

look when $V_2 = V_3 = 0$

$$I_1 + I_2 + I_3 = y_{11} V_1 + y_{21} V_1 + y_{31} V_1$$
$$= (y_{11} + y_{21} + y_{31}) V_1 = 0$$

for any V_1

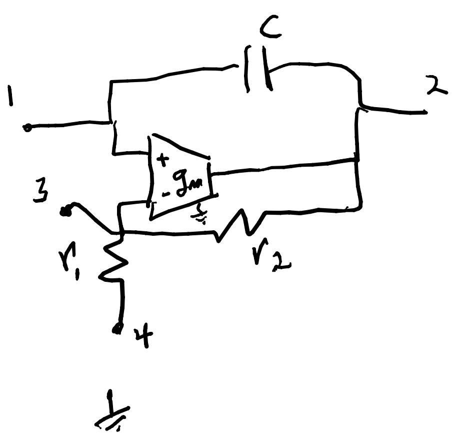
similarly $\sum_{i=1}^{3} y_{ij} = 0$ for each j $\qquad \sum_{i=1}^{3} y_{i1} = 0$

add E a fixed number to all V's replaces $V_1 \to V_1 + E$, $V_2 \to V_2 + E$, $V_3 \to V_3 + E$

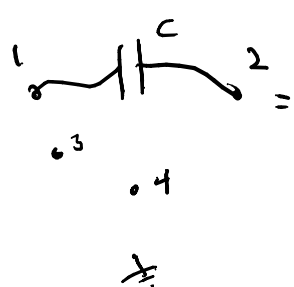
$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = Y_{ind} \begin{bmatrix} V_1 + E \\ V_2 + E \\ V_3 + E \end{bmatrix} = Y_{ind} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} + Y_{ind} \begin{bmatrix} E \\ E \\ E \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{3} y_{1j} E \\ \sum y_{2j} E \\ \sum y_{3j} E \end{bmatrix} \Rightarrow \sum_{j=1}^{3} y_{ij} \text{ for any } i$$

Y_{ind} has rows & columns sum to zero

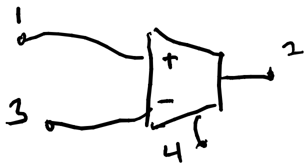


Y_{ind} is 4 x 4



$$= Y_{ind_C} = \begin{bmatrix} sC & -sC & 0 & 0 \\ -sC & +sC & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

DVCCS $\Leftrightarrow$ OTA



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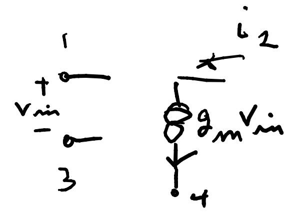
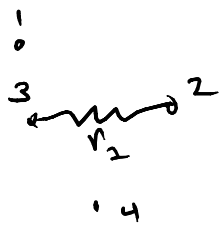


$$Y_{ind_{g_m}} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ g_m & 0 & -g_m & 0 \\ 0 & 0 & 0 & 0 \\ -g_m & 0 & g_m & 0 \end{bmatrix}$$

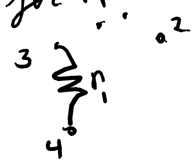
transconductance amplifier



$$Y_{ind_{g_m}}^T = \begin{bmatrix} 0 & g_m & 0 & -g_m \\ 0 & 0 & 0 & 0 \\ 0 & -g_m & 0 & g_m \\ 0 & 0 & 0 & 0 \end{bmatrix} \neq Y_{ind\, g_m}$$

$$Y_{ind_{r_2}} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & g_2 & -g_2 & 0 \\ 0 & -g_2 & g_2 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

for r_1:



$$Y_{ind_{r_1}} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & g_1 & -g_1 \\ 0 & 0 & -g_1 & g_1 \end{bmatrix}$$

$$Y_{ind} = Y_{ind_C} + Y_{ind_{g_m}} + Y_{ind_{r_1}} + Y_{ind_{r_2}}$$

$$= \begin{bmatrix} sC & -sC & 0 & 0 \\ -sC+g_m & +sC+g_2 & -g_m-g_2 & 0 \\ 0 & -g_2 & g_2+g_1 & -g_1 \\ -g_m & 0 & g_m-g_1 & g_1 \end{bmatrix}$$

if ground node 4 $\rightarrow v_4 = 0$, if ignore $I_4 \; (= -I_1 - I_2 - I_3)$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} sC & -sC & 0 \\ -sC+g_m & sC+g_2 & -g_m-g_2 \\ 0 & -g_2 & g_1+g_2 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = Y_{nodal} \cdot V = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix}$$

if don't use node 3 externally, $I_3 = 0$

gives $0 = y_{21} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} + y_{22} V_3 = \begin{bmatrix} 0 & -g_2 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} + [g_1+g_2][V_3] = 0$

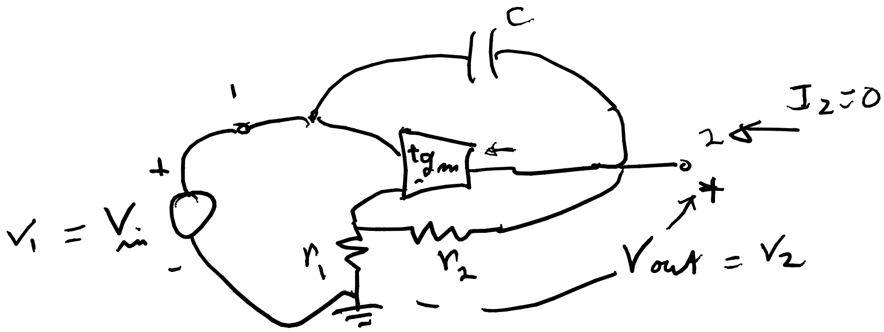
$$V_3 = -y_{22}^{-1} y_{21} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 0 & \frac{+g_2}{g_1+g_2} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

Then $\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = y_{11} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} + y_{12} \cdot (-y_{22}^{-1} y_{21}) \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \Rightarrow Y_{term} = y_{11} - y_{12} y_{22}^{-1} y_{21}$

$$Y_{term} = \begin{bmatrix} sC & -sC \\ -sC + g_m & sC + g_2 \end{bmatrix} - \begin{bmatrix} 0 \\ -g_m - g_2 \end{bmatrix} (g_1 + g_2)^{-1} \begin{bmatrix} 0 & -g_2 \end{bmatrix}$$

$$= \begin{bmatrix} sC & -sC \\ -sC + g_m & sC + g_2 - \dfrac{(g_m + g_2) g_2}{g_1 + g_2} \end{bmatrix} \Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = Y_{term} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$= \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$



as $I_2 = 0$

$0 = Y_{21} V_1 + Y_{22} V_2$

$V_{out} = -Y_{22}^{-1} Y_{21} V_1$

$$\frac{V_{out}}{V_{in}} = -Y_{22}^{-1} Y_{21} = \frac{(+sC - g_m)}{sC + g_2\left(\dfrac{g_1 - g_m}{g_1 + g_2}\right)}$$

zero $\Rightarrow s = g_m / C$

poles $\Rightarrow s = -\dfrac{g_2}{C} \dfrac{(g_1 - g_m)}{g_1 + g_2}$

if $g_1 > g_m$