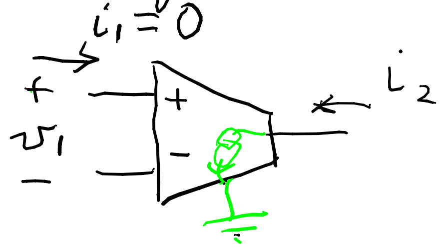
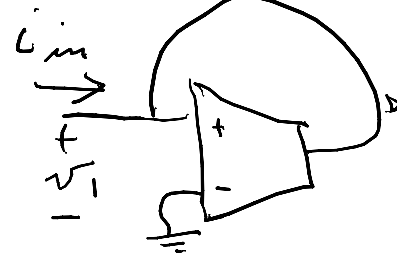
10/03/05

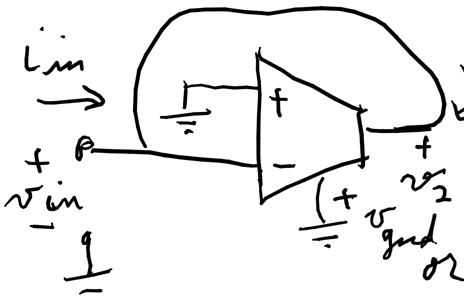
Resistor from G component of Spice





$i_2 = g_m(v_+ - v_-)$

$i_{in} = i_2 = g_m v_1$ input conductance is g_m



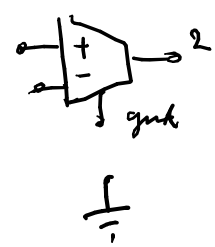
$i_2 = g_m(v_+ - v_-)$

$= g_m(0 - v_{in}) = i_n = -g_m v_{in}$

or gives a negative resistor which is not passive

G components of Spice can be made with transistorized differential pairs (sometimes called OTAs for operational transconductance amplifiers)

$$i_{ind} = \begin{bmatrix} i_+ \\ i_- \\ i_2 \\ i_{gnd} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ g_m & -g_m & 0 & 0 \\ -g_m & g_m & 0 & 0 \end{bmatrix} \begin{bmatrix} v_+ \\ v_- \\ v_2 \\ v_{gnd} \end{bmatrix}$$

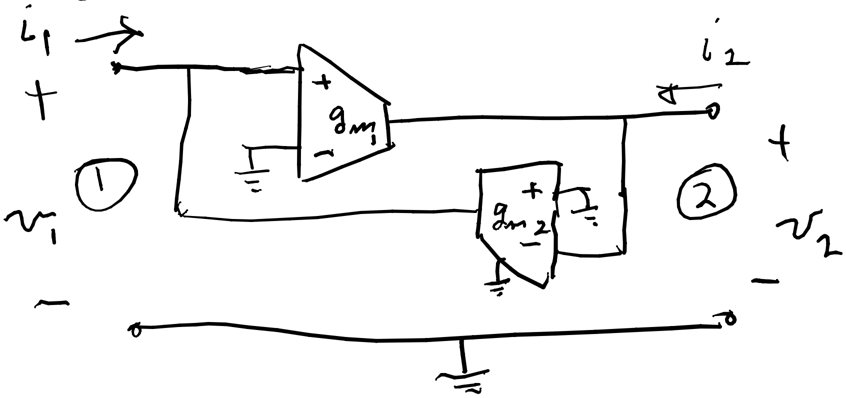


$$Y_{ind} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ g_m & -g_m & 0 & 0 \\ -g_m & g_m & 0 & 0 \end{bmatrix}$$

if gnd the gnd & − node scratch out 4th row & column and second row and column

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

Ex of using

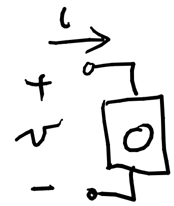


$$\underset{\sim}{Y} = \begin{bmatrix} 0 & -g_{m_2} \\ g_{m_1} & 0 \end{bmatrix}$$

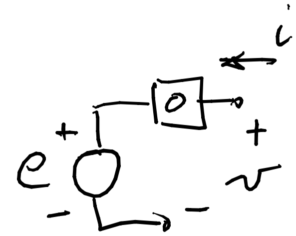
if $g_{m_1} = g_{m_2}$ this is a gyrator

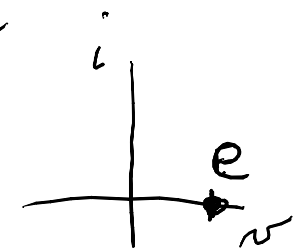
---

nullator

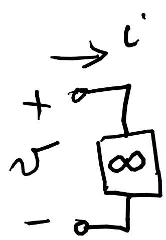


$i = 0$
$v = 0$



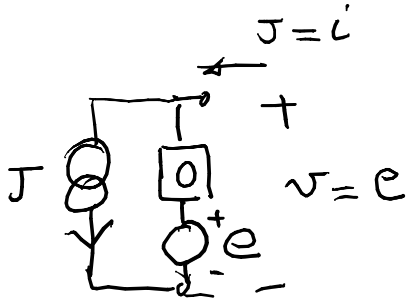


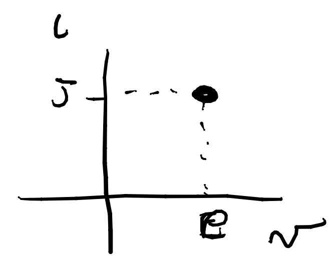
norator



v = arbitrary
i = arbitrary independent of the voltage

introduced by Tellegen (mainly at Phillips) in Holland





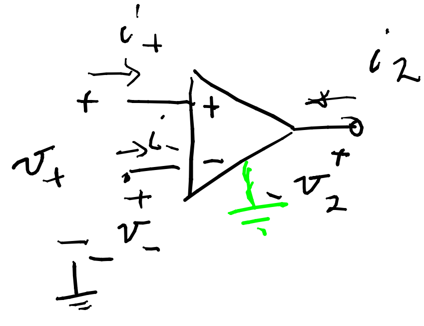
The op-amp (ideal)

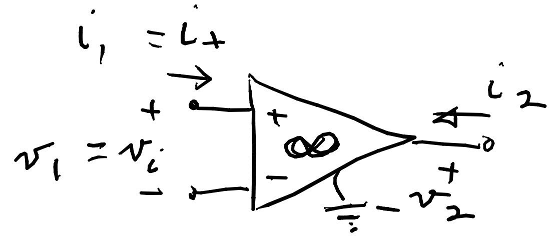
$i_+ = 0 = i_-$

v_2 = arbitrary

i_2 = arbitrary

$v_+ - v_- = 0$ (virtual ground)

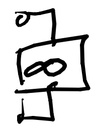


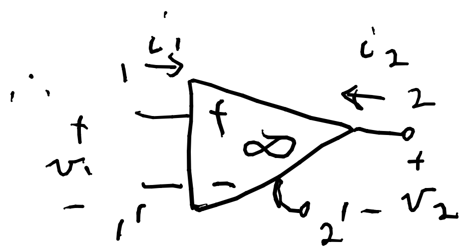


$$\begin{bmatrix}0 & 0\\ 1 & 0\end{bmatrix}\begin{bmatrix}v_1\\ v_2\end{bmatrix}=\begin{bmatrix}1 & 0\\ 0 & 0\end{bmatrix}\begin{bmatrix}i_1\\ i_2\end{bmatrix}$$

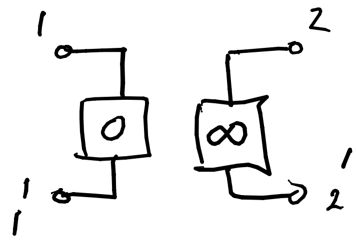
$$av = Bi$$

$\left.\begin{matrix} i_1 = 0 \\ v_1 = 0 \end{matrix}\right\}$ 

$\left.\begin{matrix} v_2 = \text{arbitrary} \\ i_2 = \text{arbitrary} \end{matrix}\right\}$ 



$\equiv$



norator $[0]v = [0]i$

nullator $\begin{bmatrix}1\\ 0\end{bmatrix}v = \begin{bmatrix}0\\ 1\end{bmatrix}i$

adjoint of ideal op amps

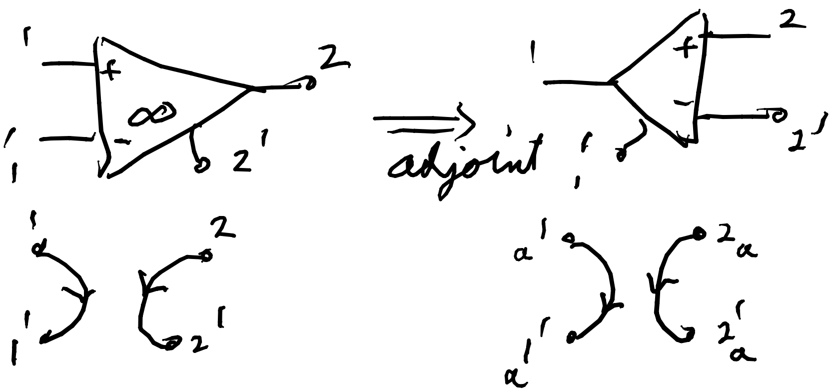
$$\underbrace{i_1}_{=0} v_{1a} + i_2 v_{2a} - i_{1a} \underbrace{v_1}_{=0} - i_{2a} v_2 = 0$$

$i_2 v_{2a} = i_{2a} v_2 \Rightarrow v_{2a} = 0,\ i_{2a} = 0$ since i_2 & v_2 are arbitrary

$\Rightarrow v_{1a}$ = can be anything

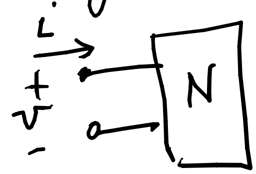
i_{1a} = " " "

∴ the adjoint of an (ideal) op-amp is another op-amp turned around



Passivity ⇒ put in "more" energy than take out

$p(t)$ = power into a circuit, at any instant

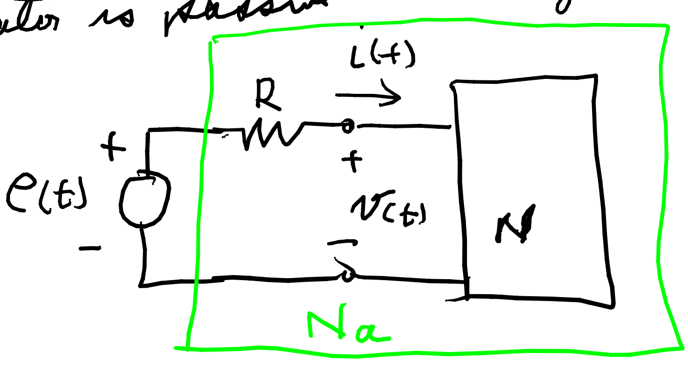


$= i^T(t)\, v(t)$

$$\mathcal{E}(t) = \underbrace{\mathcal{E}(-\infty)}_{\substack{= 0 \\ \text{assume}}} + \int_{-\infty}^{t} p(\tau)\,d\tau$$

By definition N is passive if $\mathcal{E}(t) \geq 0$ for all possible v, i allowed with finite energy; active ≡ not passive

nullator is passive



N_a = augmented voltages & currents are e, i

for N they are v & i

$e = v + Ri$

assume $e(t)$ has finite energy, an $\mathcal{L}_2$ n-vector

$$\int_{-\infty}^{\infty} e^{T*}_{(t)}\, e(t)\, dt \le \infty$$

$$e^{T*}e = (v+Ri)^{T*}(v+Ri) = v^{T*}v + i^{T*}R^{T*}Ri + i^{T*}R^{*T}v + v^{T*}Ri$$

Normally normalize $R = \mathbf{1}_n$ = identity

then $$\int_{-\infty}^{\infty} e^{T*}_{(t)}\, e(t)\, dt = \int_{-\infty}^{\infty} v^{T*}_{(t)}\, v(t) + \int_{-\infty}^{\infty} i^{T*}_{(t)}\, i(t)\, dt + 2\int_{-\infty}^{\infty} i^{T*}_{(t)}\, v(t)\, dt$$

For real signals all the $*$ disappear

$\mathcal{L}_2$ e's give $\mathcal{L}_2$ v's & $\mathcal{L}_2$ i's <u>if N is passive</u>

$$\int_{-\infty}^{\infty} e^{T}(\tau)\, e(\tau)\, d\tau = \int_{-\infty}^{\infty} v^{T}(\tau)\, v(\tau)\, d\tau + \int_{-\infty}^{\infty} i^{T}(\tau)\, i(\tau)\, d\tau + 2\int_{-\infty}^{\infty} i^{T}(\tau)\, v(\tau)\, d\tau$$

$\therefore$ if $e \in \mathcal{L}_2$, v & i also are in $\mathcal{L}_2$ if passive (n-vectors)

if we can excite with $e \in \mathcal{L}_2$ (can't for $N = \boxed{0}$)