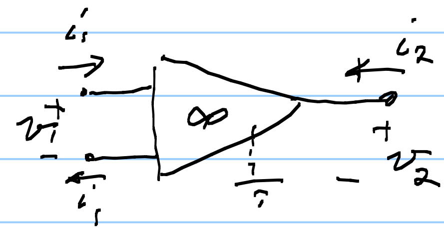
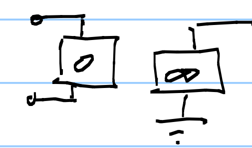
Note Title 9/22/2015

EE610
09/22/15

op-amp (ideal)



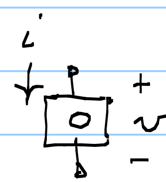
$i_1 = 0$
$v_1 = 0$ $\equiv$



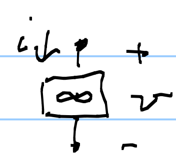
$Av = Bi$ $\quad \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$

$i = B^{-1} A v$; $Y = B^{-1} A$

$v = A^{-1} B i$; $Z = A^{-1} B$



$i = 0$
$v = 0$

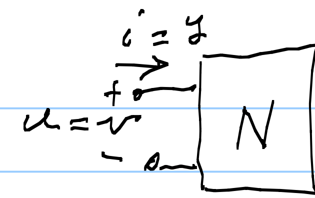


i = arbitrary
v = arbitrary (independent of i)

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

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

design from state equations



$\dot{x} = Ax + Bu$, $x = n$-vector

$y = Cx + Du$ desire N given state eqs.

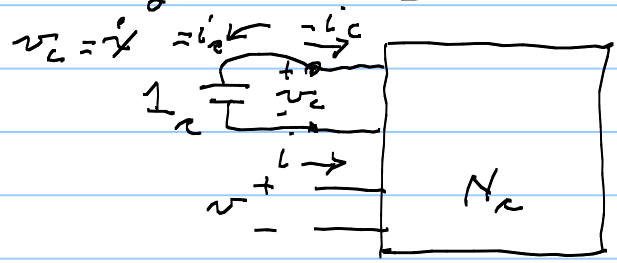
$x = v_c$ = capacitor voltages

$\dot{i}_{cap} = A v_c + B v$

$y = i = C v_c + D v$

$= \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} v_c \\ v \end{bmatrix} = \begin{bmatrix} i_{cap} \\ i \end{bmatrix} \Rightarrow \underbrace{\begin{bmatrix} A & B \\ C & D \end{bmatrix}}_{\text{constant}} = Y$

can make with differential pairs



$Y_c \cdot \begin{bmatrix} v_c \\ v \end{bmatrix} = \begin{bmatrix} -i_c \\ i \end{bmatrix}$

$Y_c = \begin{bmatrix} -A & -B \\ C & D \end{bmatrix}$

y of states

$y = i/v(s) = D + C[s1_n - A]^{-1} B$

admittance

Example: $\displaystyle y(s) = \frac{5s+3}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2} = D + C\left[s\mathbb{1}_2 - A\right]^{-1}\cdot B$, $D = y(\infty)$

$= 0$ here

$$s\mathbb{1}_2 - A = \begin{bmatrix} s-0 & +1 \\ -\omega_0^2 & s+\omega_0/Q \end{bmatrix}$$

$\det(s\mathbb{1}_2 - A) = $ denominator

$$s^2 + \frac{\omega_0}{Q}s + \omega_0^2 = (s-0)\left(s+\frac{\omega_0}{Q}\right) - 1(-\omega_0^2)$$

$$= s^2 + \frac{\omega_0}{Q}s + \omega_0^2$$

$$A = \begin{bmatrix} 0 & -1 \\ +\omega_0^2 & -\omega_0/Q \end{bmatrix}$$

$$\frac{5s+3}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2} = C(s\mathbb{1}_2 - A)^{-1}B = [c_1\ c_2]\frac{1}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2}\begin{bmatrix} s+\omega_0/Q & -1 \\ \omega_0^2 & s \end{bmatrix}\begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

$$5s+3 = \text{numerator} = [c_1\ c_2]\begin{bmatrix} s+\omega_0/Q & -1 \\ \omega_0^2 & s \end{bmatrix}\begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

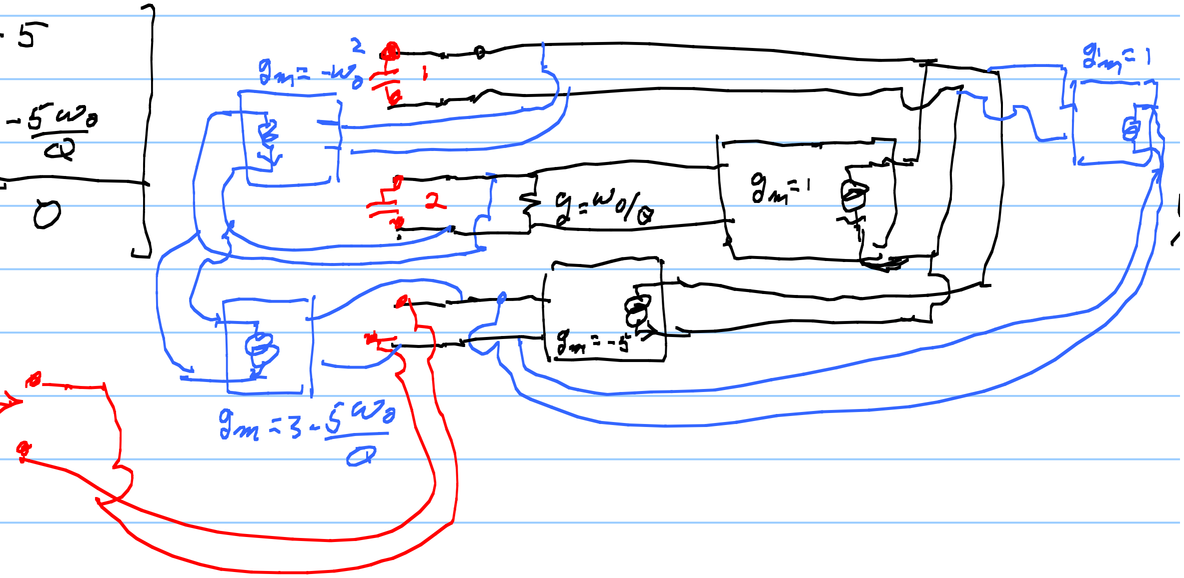
$$= [c_1\ c_2]\begin{bmatrix} b_1(s+\omega_0/Q) - b_2 \\ \omega_0^2 b_1 + b_2 s \end{bmatrix} = c_1 b_1 (s+\omega_0/Q) - c_1 b_2 + c_2\omega_0^2 b_1 + c_2 b_2 s$$

$$\left.\begin{array}{l} 5s = c_1 b_1 s + c_2 b_1 s = (c_1 b_1 + c_2 b_2) s \\ 3 = c_1 b_1 \omega_0/Q - c_1 b_2 + b_1 c_2 \omega_0^2 \end{array}\right\} \begin{array}{l} \text{try } c_2 = 0 \Rightarrow c_1 b_1 = 5 \\ c_1 (b_1 \omega_0/Q - b_2) = 3 \end{array}$$

Let $c_1 = 1,\ b_1 = 5 \Rightarrow 1 \cdot (5\omega_0/Q) - b_2 = 3 \Rightarrow b_2 = \dfrac{5\omega_0}{Q} - 3$

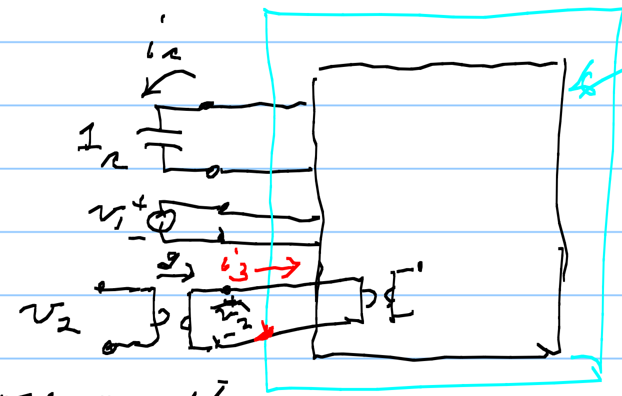
$$Y_c = \left[\begin{array}{cc|c} 0 & 1 & -5 \\ -\omega_0^2 & \omega_0/Q & 3 - \frac{5\omega_0}{Q} \\ \hline 1 & 0 & 0 \end{array}\right]$$

$$\frac{Y_c}{g_m}(s) = \frac{5s + 3}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2}$$



If $y = v_2$ & $u = v_1$ then $T(s) \cdot v_1 = v_2$

$$\dot{x}_c = A x_c + B v_1$$
$$v_2 = C x_c + D v_1$$



desire admittance of this

make as Y_c

attach gyrator for 3rd ports

choose gyrator

g so $i_3 = v_2$; if $g = 1 \Rightarrow i_3 = v_2 = i_{gy_2} = g\, v_{1\text{st port } gy}$

$$-\dot{x}_c = \begin{bmatrix} -i_c \\ i_{v_1} \\ i_3 = v_3 \end{bmatrix} = \begin{array}{c} \begin{array}{ccc} & & D_c \end{array} \\ \begin{bmatrix} -A & -B & \cancel{0} \\ D_c & D_c & D_c \\ C & D & 0 \end{bmatrix} \end{array} \begin{bmatrix} x_c \\ v_1 \\ \hat{v}_2 \end{bmatrix} \Rightarrow\ \equiv 0$$

D_c = don't care

choose to give nice circuit

choose $Y_c = \begin{bmatrix} -A & -B & -C^T \\ B^T & 0 & -D^T \\ C & D & 0 \end{bmatrix}$ build this