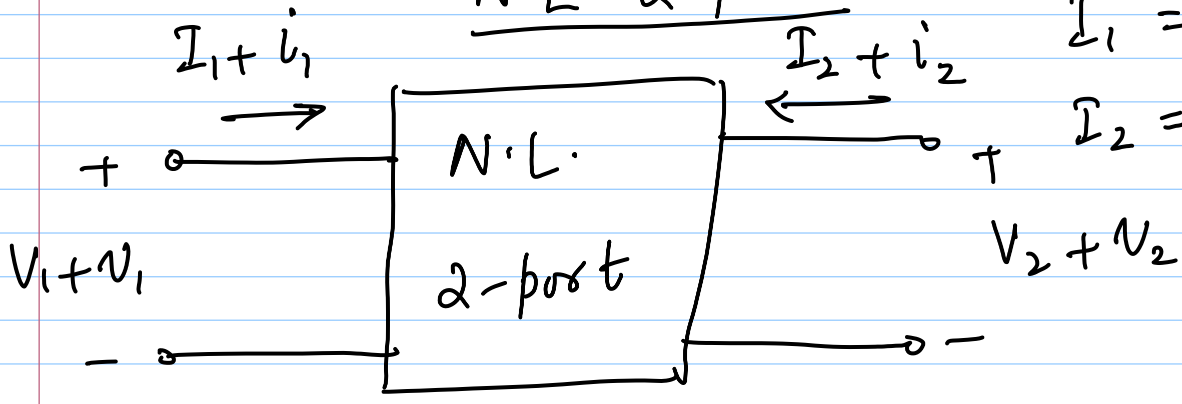
7-8-12

Lec - 5

N.L. 2-port

$$I_1 = f(V_1, V_2)$$
$$I_2 = g(V_1, V_2)$$



$$I_1 + i_1 = f(V_1 + v_1, V_2 + v_2)$$

$$I_1 = f(V_1, V_2)$$

* If v_1 & v_2 are very small, $f(\,)$ & $g(\,)$ can be expanded in a 2-D Taylor Series around O.P. – $\begin{pmatrix} V_1, I_1 \\ V_2, I_2 \end{pmatrix}$

* Approximate surface by a plane @ O.P.

$$I_1 + i_1 \approx I_1 + \frac{\partial f}{\partial V_1} \cdot v_1 + \frac{\partial f}{\partial V_2} \cdot v_2$$

$$\Rightarrow \quad i_1 = \frac{\partial f}{\partial V_1} \cdot v_1 + \frac{\partial f}{\partial V_2} \cdot v_2$$

III $i_2' = \frac{\partial g}{\partial V_1} \cdot v_1 + \frac{\partial g}{\partial V_2} \cdot v_2$

$\Rightarrow$ incremental 2-port quantities are linearly related

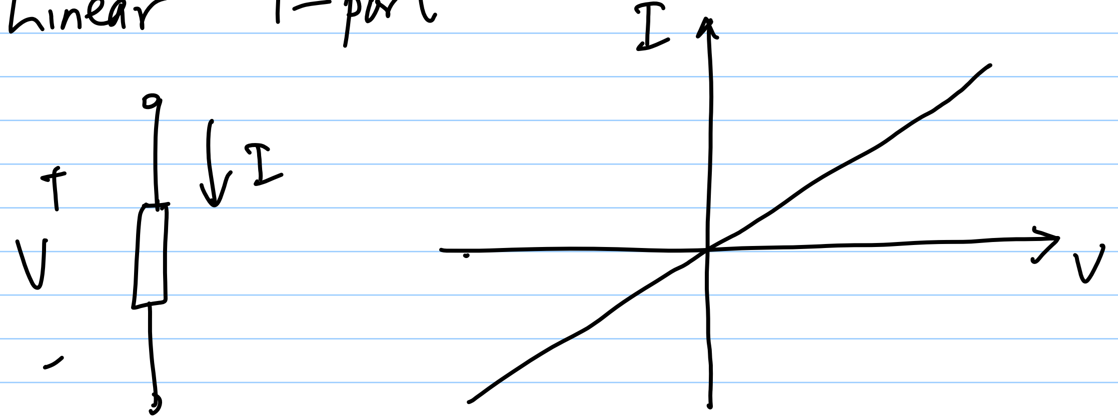
$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \underbrace{\begin{bmatrix} \partial f/\partial V_1 & \partial f/\partial V_2 \\ \partial g/\partial V_1 & \partial g/\partial V_2 \end{bmatrix}}_{\text{incremental } y\text{-matrix}} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$[i] = [y][v]$ for "small signals"

* You could similarly conceive of incremental [Z], [h] & [g] parameters

<u>Graphical Representation</u>

I 1) Linear 1-port

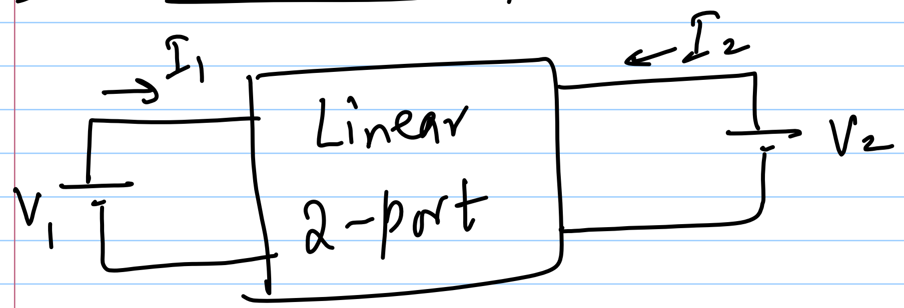


* passive 1-port : $V \cdot I \geq 0 \Rightarrow 1^{st}$ & 3^{rd} quadrants

2) Non-linear 1-port

passive ⇒ 1st & 3rd Q

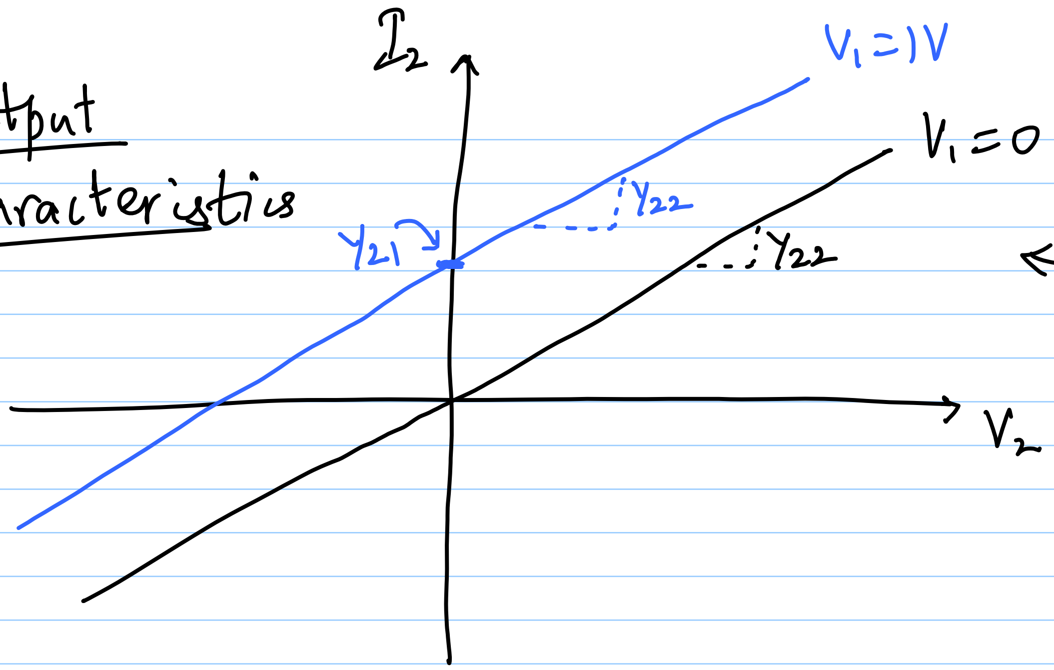
II Linear 2-port



$$I_1 = Y_{11}V_1 + Y_{12}V_2$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2$$

Output Characteristics

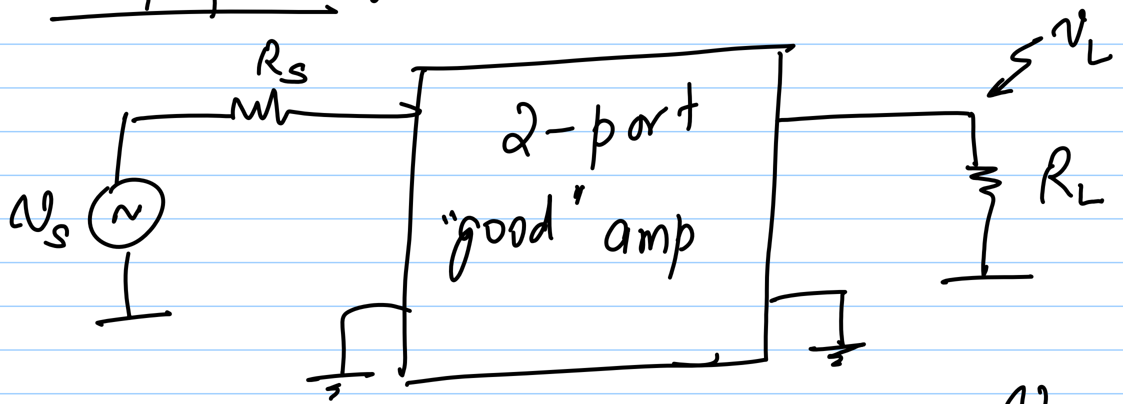


← instead of plotting a surface

I_1 vs V_1 plot ⇒ Input characteristics

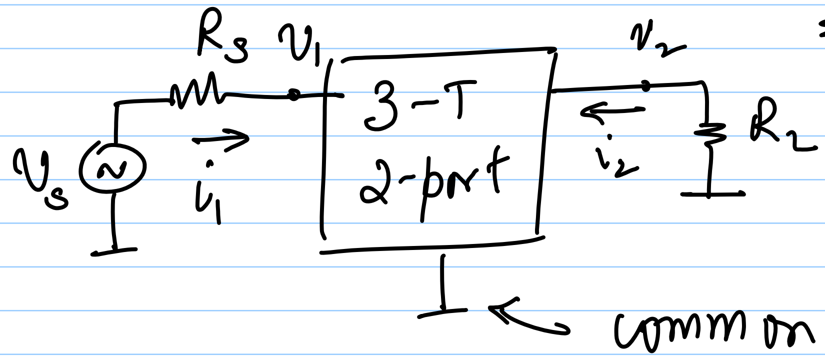
passive linear (or NL) 2-port ⇒ $V_1 I_1 + V_2 I_2 \geq 0$

Amplifiers:



* we want large gain $= \frac{v_L}{v_s}$
* we want v_L to be independent of R_s (i.e. independent of source quality) — i.e. gain should not change if source is changed

* We would also like gain to be independent of R_L too.

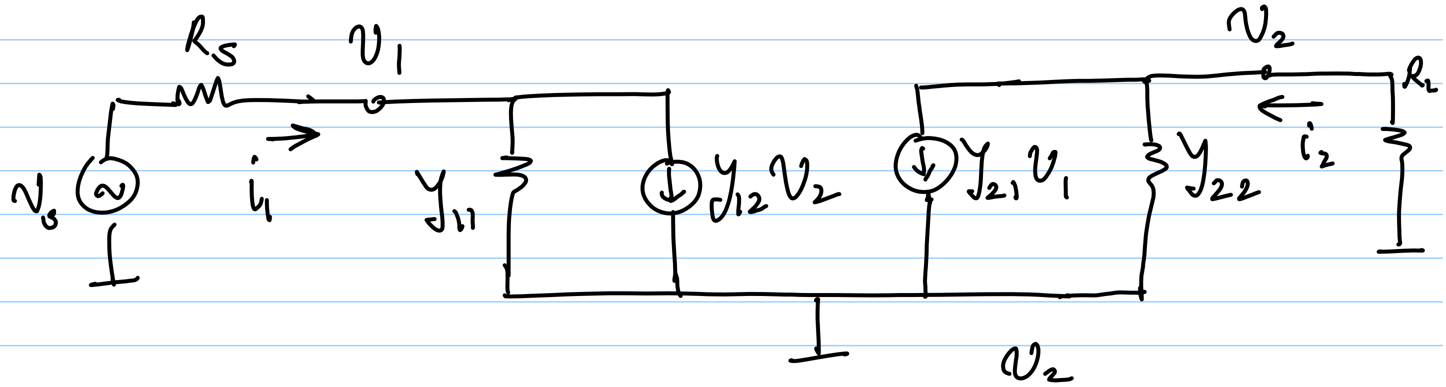


$\Rightarrow$ 3-T easier to analyse than 4-T

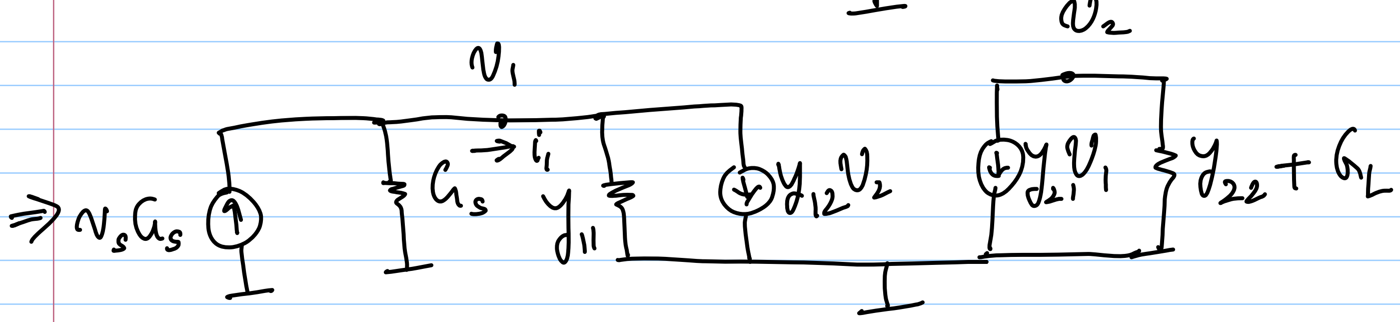
What are the constraints on [y] so that we can achieve a "good" amplifier?

$$i_1 = y_{11} v_1 + y_{12} v_2$$
$$i_2 = y_{21} v_1 + y_{22} v_2$$

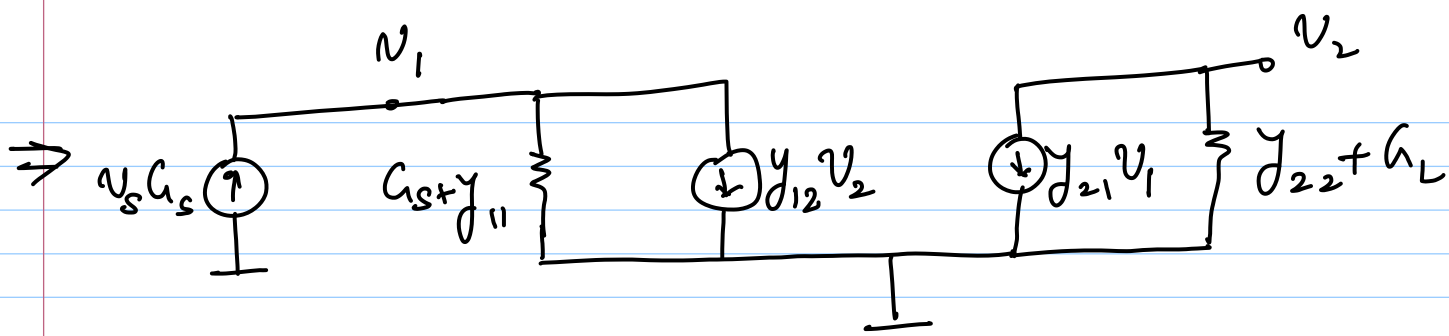
replace by a network



$\Rightarrow$



$\Rightarrow$



KCL @ input & output:

$$v_s G_s = v_1 (G_s + y_{11}) + y_{12} v_2 \quad \text{——} (1)$$

$$y_{21} v_1 + v_2 (y_{22} + G_L) = 0 \quad \text{——} (2)$$

gives

$$v_1 = \frac{v_s G_s - y_{12} v_2}{G_s + y_{11}}$$

plug into (2)

$$y_{21}\left[\frac{v_s G_s - y_{12} v_2}{y_{11}+G_s}\right] + (y_{22}+G_L)\cdot v_2 = 0$$

$$v_s\left[\frac{y_{21} G_s}{y_{11}+G_s}\right] = v_2\left[-(y_{22}+G_L) + \frac{y_{12}y_{21}}{y_{11}+G_s}\right]$$

$$\Rightarrow v_s\left[\frac{y_{21} G_s}{y_{11}+G_s}\right] = v_2\left[\frac{y_{12}y_{21} - (y_{22}+G_L)(y_{11}+G_s)}{y_{11}+G_s}\right]$$

$$\Rightarrow \frac{v_2}{v_s} = \frac{y_{21} G_s}{\underbrace{y_{12}y_{21}}_{A} - \underbrace{(y_{22}+G_L)(y_{11}+G_s)}_{B}}$$

1) * If $y_{12}y_{21} = (y_{22}+G_L)(y_{11}+G_s)$,

Gain $= \infty$! {instability}

* y_{21} = quantifies effect of i/p port on output port (desired)

* y_{12} = effect of o/p port on i/p port (undesired)

$\Rightarrow$ $\boxed{\text{design for } y_{12} = 0}$

$$\Rightarrow \boxed{\frac{v_2}{v_s} = \frac{y_{21} G_s}{-(y_{22}+G_L)(y_{11}+G_s)}}$$