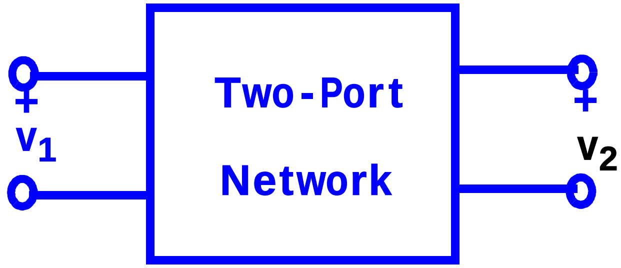
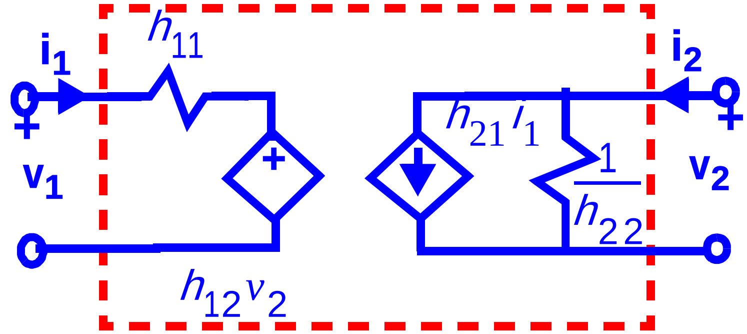
ECE 2EI4 - Lecture 4

Outline/Learning Objectives:

- Describe the concept of linear amplification (and nonlinear distortion).
- Define the quantities used to measure the performance of analog amplifiers, including voltage gain, current gain, power gain, input and output resistances.
- Express the voltage, current, and power gain in terms of the decibel, or dB.
- Describe amplifier biasing for linear operation.
- Model linear amplifiers using simple two-port representations (g-parameters, h-parameters, y-parameters, and z-parameters).
- Define unilateral two-port representations of linear amplifiers.
- Describe mismatched conditions at the input and output ports of an amplifier and the concepts of ideal voltage and current amplifiers.
- Use the electronics laboratory to investigate the electrical behaviour of simple circuits and devices.
- From Chapter 10 in Jaeger

The Hybrid or h-parameters





$$\begin{bmatrix} v_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \bullet \begin{bmatrix} i_1 \\ v_2 \end{bmatrix}$$

$$\begin{bmatrix} v_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} h_{11} i_1 + h_{12} v_2 \\ h_{21} i_1 + h_{22} v_2 \end{bmatrix}$$

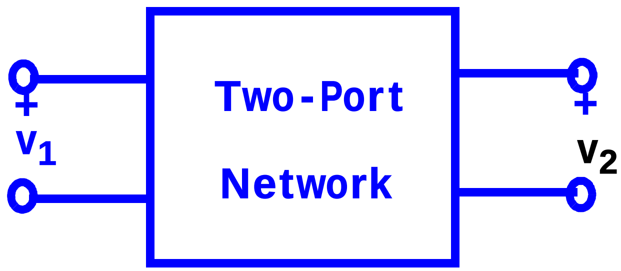
$$h_{11} = \left.\frac{v_1}{i_1}\right|_{v_2 = 0}$$ **SC R_{in}**

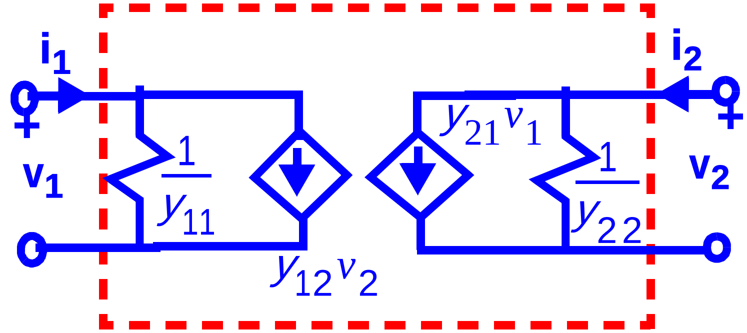
$$h_{12} = \left.\frac{v_1}{v_2}\right|_{i_1 = 0}$$ **Reverse OC V-gain**

$$h_{21} = \left.\frac{i_2}{i_1}\right|_{v_2 = 0}$$ **Forward SC I-gain**

$$h_{22} = \left.\frac{i_2}{v_2}\right|_{i_1 = 0}$$ **OC G_{out}**

The Admittance or y-parameters





$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \bullet \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} v_1 + y_{12} v_2 \\ y_{21} v_1 + y_{22} v_2 \end{bmatrix}$$

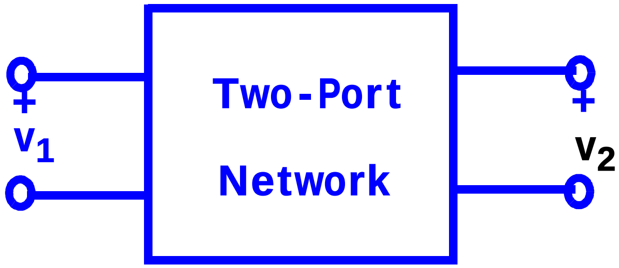
$$y_{11} = \left.\frac{i_1}{v_1}\right|_{v_2 = 0}$$ **SC G_{in}**

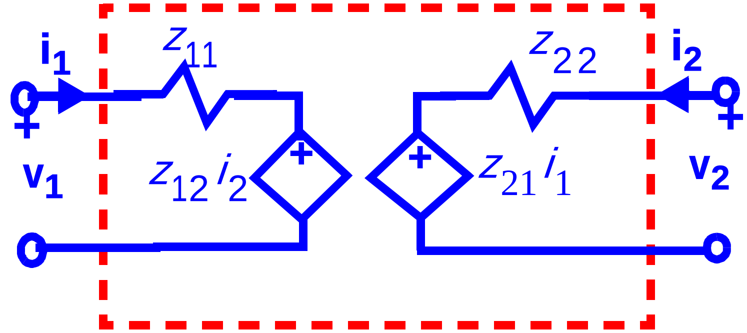
$$y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1 = 0}$$ **Reverse SC trans-G**

$$y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2 = 0}$$ **Forward SC trans-G**

$$y_{22} = \left.\frac{i_2}{v_2}\right|_{v_1 = 0}$$ **SC G_{out}**

The Impedance or z-parameters





$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \bullet \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} z_{11} i_1 + z_{12} i_2 \\ z_{21} i_1 + z_{22} i_2 \end{bmatrix}$$

$$z_{11} = \left.\frac{v_1}{i_1}\right|_{i_2 = 0}$$ **OC R_{in}**

$$z_{12} = \left.\frac{v_1}{i_2}\right|_{i_1 = 0}$$ **Reverse OC trans-R**

$$z_{21} = \left.\frac{v_2}{i_1}\right|_{i_2 = 0}$$ **Forward OC trans-R**

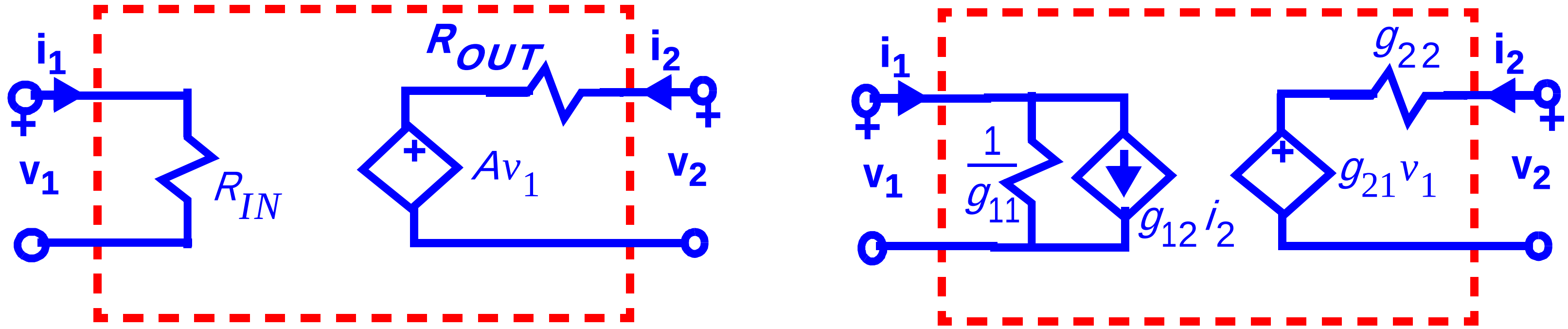
$$z_{22} = \left.\frac{v_2}{i_2}\right|_{i_1 = 0}$$ **OC R_{out}**

Mismatched Source and Load Resistances

Assume that forward voltage or current gain, or transconductance or transresistance is much larger than corresponding reverse parameter.

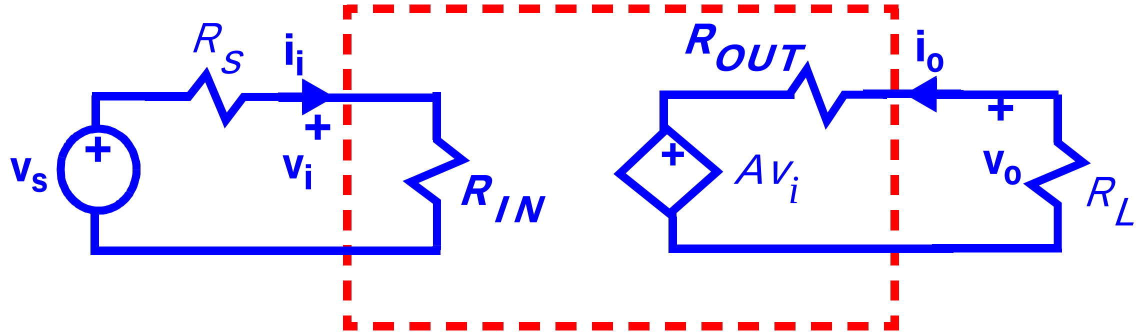
For example, $g_{21} \gg g_{12}$ or $y_{21} \gg y_{12}$.

Two-port g-parameters representation of voltage amplifier



Here, $R_{IN} = (1/g_{11})$, $g_{12} = 0$, $A = g_{21}$ and $R_{OUT} = g_{22}$

Voltage Amplifiers



Here, $v_o = Av_i \bullet \frac{R_L}{R_{OUT} + R_L}$ and $v_i = v_s \bullet \frac{R_{IN}}{R_{IN} + R_S}$. Note $v_s = v_i \bullet \frac{R_{IN} + R_S}{R_{IN}}$

Therefore, $|A_V| = \frac{V_o}{V_s} = A \bullet \frac{R_L}{R_{OUT} + R_L} \bullet \frac{R_{IN}}{R_{IN} + R_S}$.

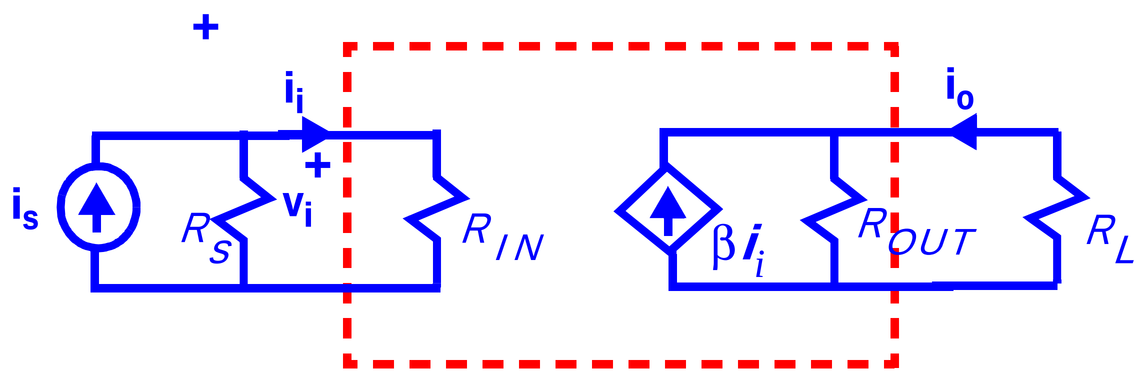
To achieve maximum gain, require $R_{IN} \gg R_S$ and $R_{OUT} \ll R_L$.

In ideal voltage amplifier, $R_{IN} = \infty$ and $R_{OUT} = 0$ => $|A_V| = A$.

Current gain, $|A_I| = \frac{I_o}{I_s} = \frac{V_o / R_L}{V_s / (R_{IN} + R_S)} = \frac{V_o}{V_s} \bullet \frac{R_{IN} + R_S}{R_L}$.

Can also write as $|A_I| = |A_V| \bullet \frac{R_{IN} + R_S}{R_L}$

Current Amplifiers



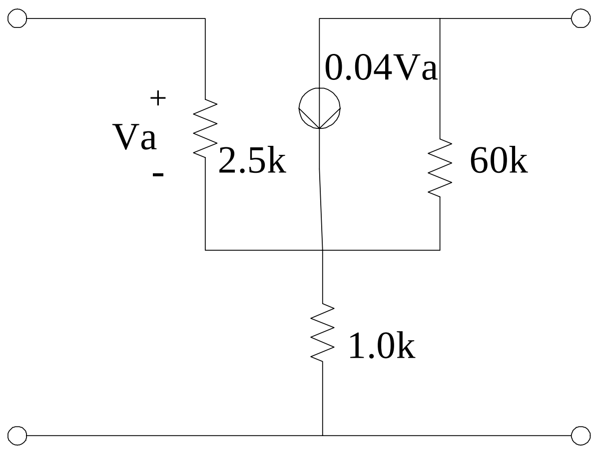
Now, $i_o = \beta i_i \bullet \frac{R_{OUT}}{R_{OUT} + R_L}$ and $i_i = i_s \bullet \frac{R_S}{R_S + R_{IN}}$. Note $i_s = i_i \bullet \frac{R_S + R_{IN}}{R_S}$

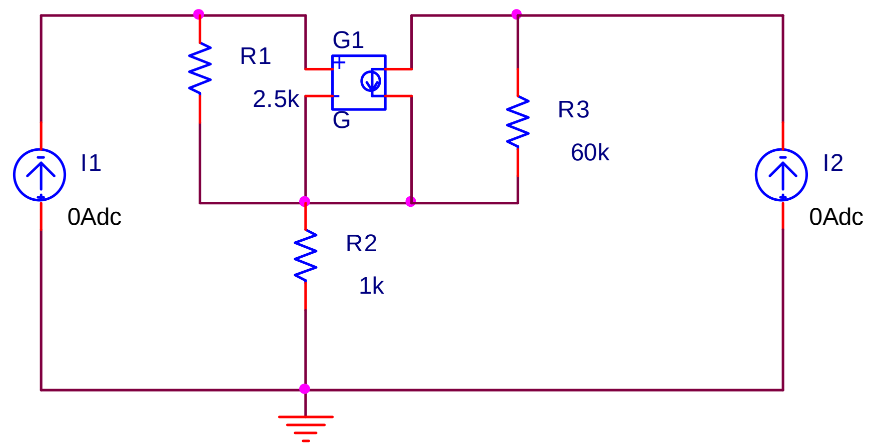
Therefore, $|A_I| = \frac{I_o}{I_s} = \beta \bullet \frac{R_{OUT}}{R_{OUT} + R_L} \bullet \frac{R_S}{R_S + R_{IN}}$.

To achieve maximum gain, require $R_S \gg R_{IN}$ & $R_{OUT} \gg R_L$ => $|A_I| = \beta$

Ideal Current Amplifier has $R_{IN} = 0$ and $R_{OUT} = \infty$.

PSPICE EXAMPLE






```
*Libraries:
* Local Libraries :
* From [PSPICE NETLIST] section of C:\Program Files\OrcadLite\PSpice\PSpice.ini file:
.lib "nom.lib"
*Analysis directives:
.TF V([N00191]) I_I1
.PROBE V(*) I(*) W(*) D(*) NOISE(*)
.INC ".\example1-SCHEMATIC1.net"
**** INCLUDING example1-SCHEMATIC1.net ****
* source EXAMPLE1
R_R1        N00025 N00153  2.5k
R_R3        N00025 N00191  60k
R_R2        0 N00025  1k
I_I1        0 N00153 DC 0Adc
G_G1        N00191 N00025 N00153 N00025 0.04
I_I2        0 N00191 DC 0Adc
.END
```

PSPICE EXAMPLE (Cont'd)

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****     SMALL-SIGNAL CHARACTERISTICS
 V(N00191)/I_I1 = -5.999E+06
 INPUT RESISTANCE AT I_I1 =  3.500E+03
 OUTPUT RESISTANCE AT V(N00191) =  6.100E+04
Z parameters are Z11=3.5K, Z21=-6M, Z12=1K, Z22=61K
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