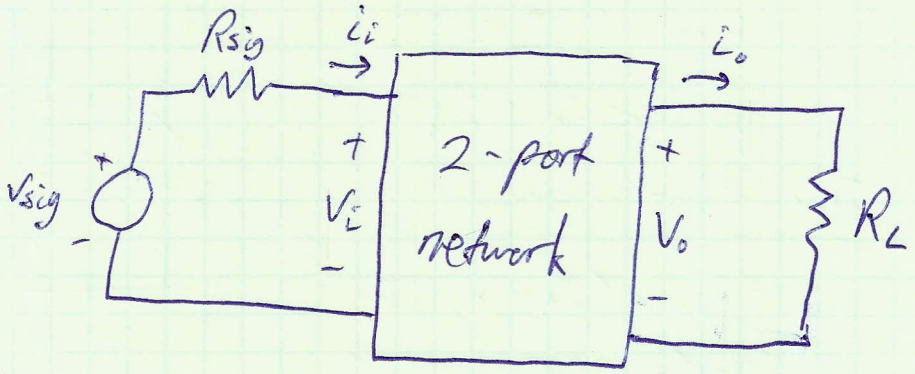
# Transistor Amplifiers

## Two-port network

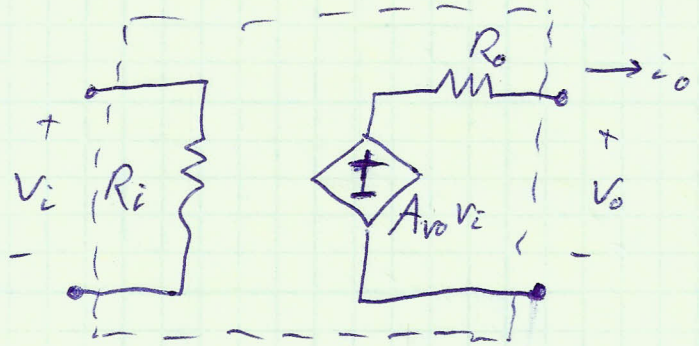



Can be modeled with three elements:

- Input resistance $R_i = \frac{v_i}{i_i}$ (depends on $R_L$ in general)
- Output resistance $R_o = \frac{-v_o}{i_o}\Big|_{v_i=0}$

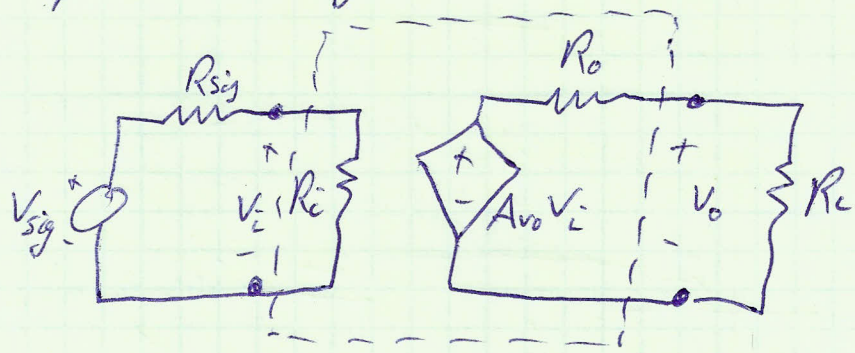
  (note - assume $v_i$ applied directly to input port: $v_{sig} = v_i$, $R_{sig} = 0$)
- Open-loop gain $A_{vo} = \frac{v_{oc}}{v_i} = \frac{v_o}{v_i}\Big|_{R_L \to \infty}$

## Amplifier Model




Can solve any amplifier circuit once to determine these parameters
Similar to Thevenin theorem

Response to $R_{sig}$ and $R_L$:



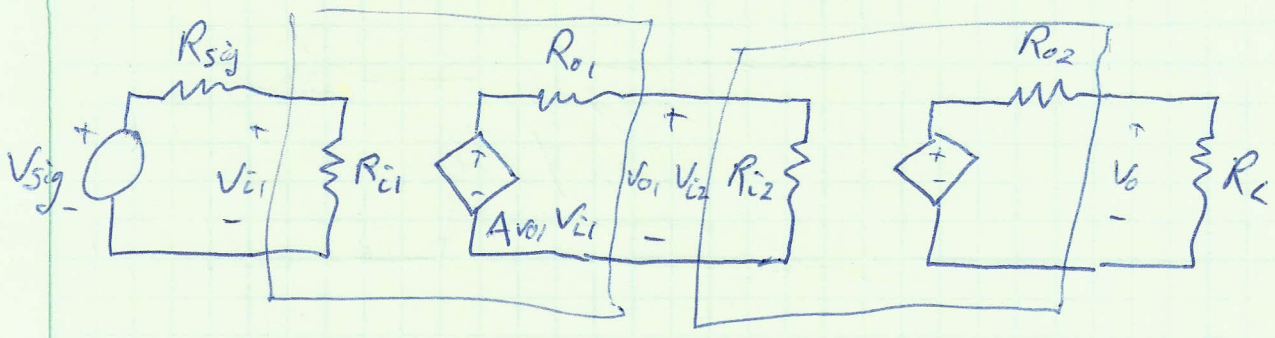

amplifier gain $A_v = \frac{V_o}{V_i} = \frac{R_L}{R_o + R_L} A_{vo}$ (voltage divider at output)

$\frac{V_i}{V_{sig}} = \frac{R_i}{R_i + R_{sig}}$ (voltage divider at input)

$\frac{V_o}{V_{sig}} = \frac{V_i}{V_{sig}} \cdot \frac{V_o}{V_i} = \frac{R_i}{R_i + R_{sig}} \cdot A_v = \frac{R_i}{R_i + R_{sig}} \cdot A_{vo} \cdot \frac{R_L}{R_o + R_L}$

- Note that $A_{vo}$ is the <u>maximum</u> amplifier gain
- to maximize $\frac{V_o}{V_{sig}}$, need $R_i \to \infty$, $R_o \to 0$
  - voltage controlled voltage source is "ideal" amplifier

2-stage amplifier




$$\frac{V_o}{V_{sig}} = \frac{R_{i1}}{R_{i1}+R_{sig}} \times A_{vo1} \times \frac{R_{i2}}{R_{i2}+R_{o1}} \times A_{vo2} \times \frac{R_L}{R_{o2}+R_L}$$

- To maximize voltage gain, input resistance of each stage must be much larger than the output resistance of the previous stage
- Often simpler to calculate $A_v$ instead of $A_{vo}$ ← no load
  ↑ load is present

$$\frac{V_o}{V_{sig}} = \frac{R_{i1}}{R_{i1}+R_{sig}} \times A_{v1}(R_L = R_{i2}) \times A_{v2}(R_L = R_L)$$

- Note that $R_i$ may depend on $R_L$

## Analysis of Transistor Amplifiers

- Calculate Bias conditions
- Calculate small signal response
  - find $g_m$, $r_o$, (and $r_\pi$ for BJT) from bias
  - zero the bias sources
  - assume capacitors are short circuits
  - replace transistor with small signal model
  - inspect circuit:
    - if prototype circuit, use formulas for that circuit
    - otherwise, find $R_i$, $R_o$, $A_v$, $A_{vs}$
- Calculate frequency response
  - we will learn how to calculate low frequency poles due to coupling caps
  - you will learn more details of frequency response in ECE102