Spring 2019 Purdue University

ECE 255: L2

Signals and Amplifiers

(Sedra and Smith, Secs. 1.1-1.6)

School of ECE
Purdue University
West Lafayette, IN USA

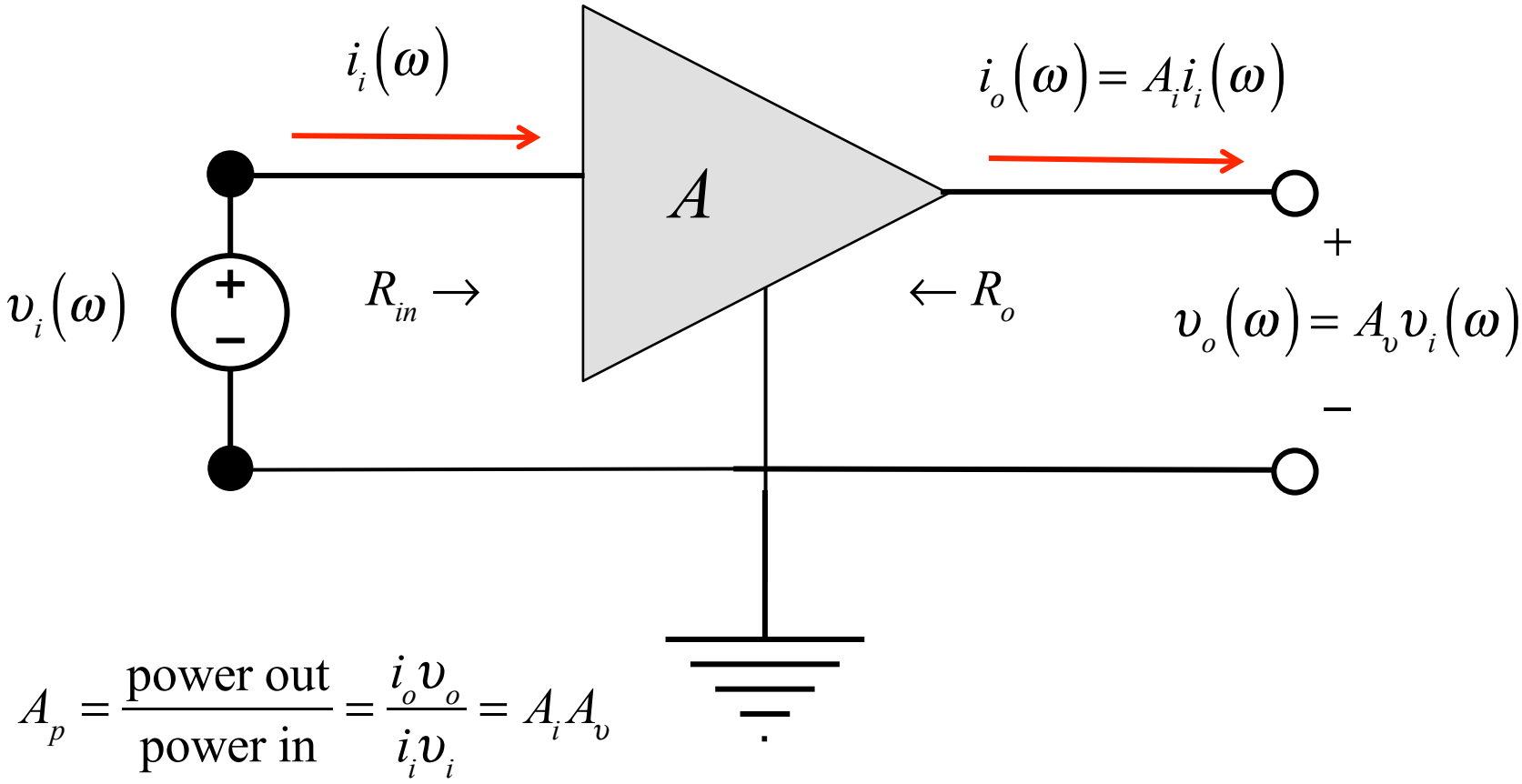
Adapted from Lundstrom: 2019

PURDUE UNIVERSITY

Signals

Analog	$\upsilon_D(t)$
Digital	$\upsilon_D(t)$
DC	V_D
DC+ small signal AC	$\upsilon_D(t) = V_D + \upsilon_d(t)$

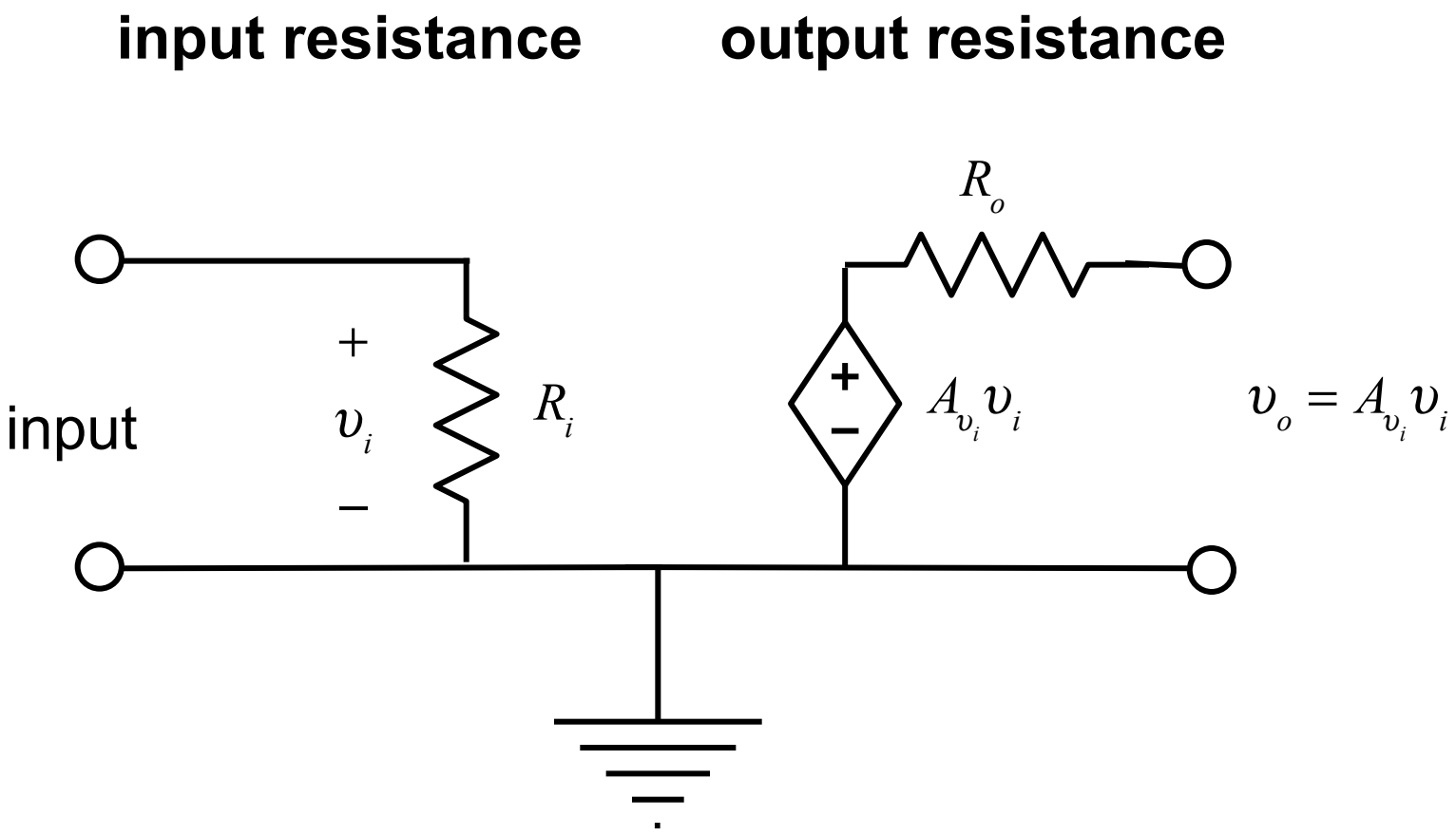
Linear amplifiers



$$A_p = \frac{\text{power out}}{\text{power in}} = \frac{i_o v_o}{i_i v_i} = A_i A_v$$

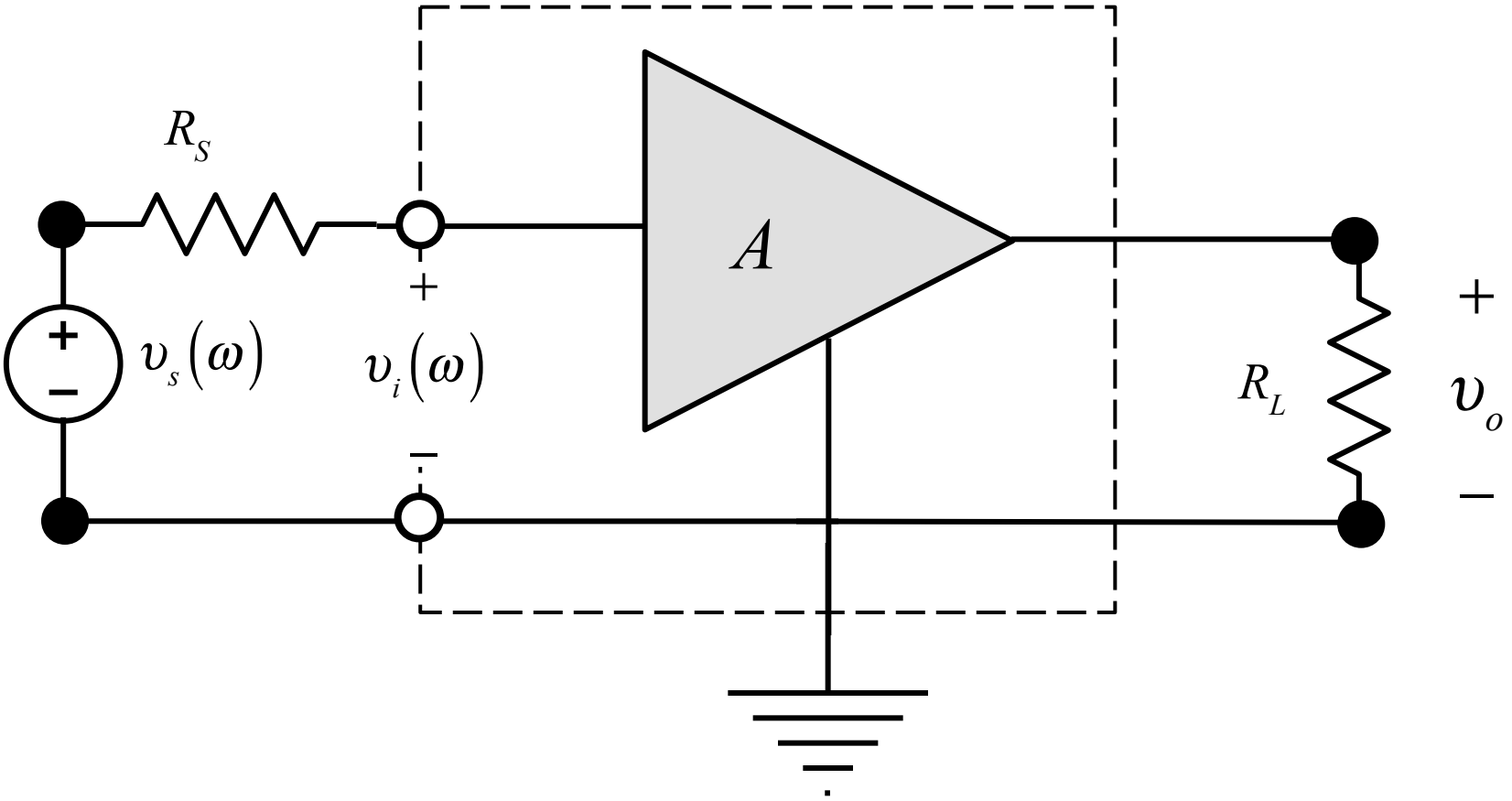
Generally, want one or more of: voltage gain, current gain, power gain

Circuit model of an amplifier

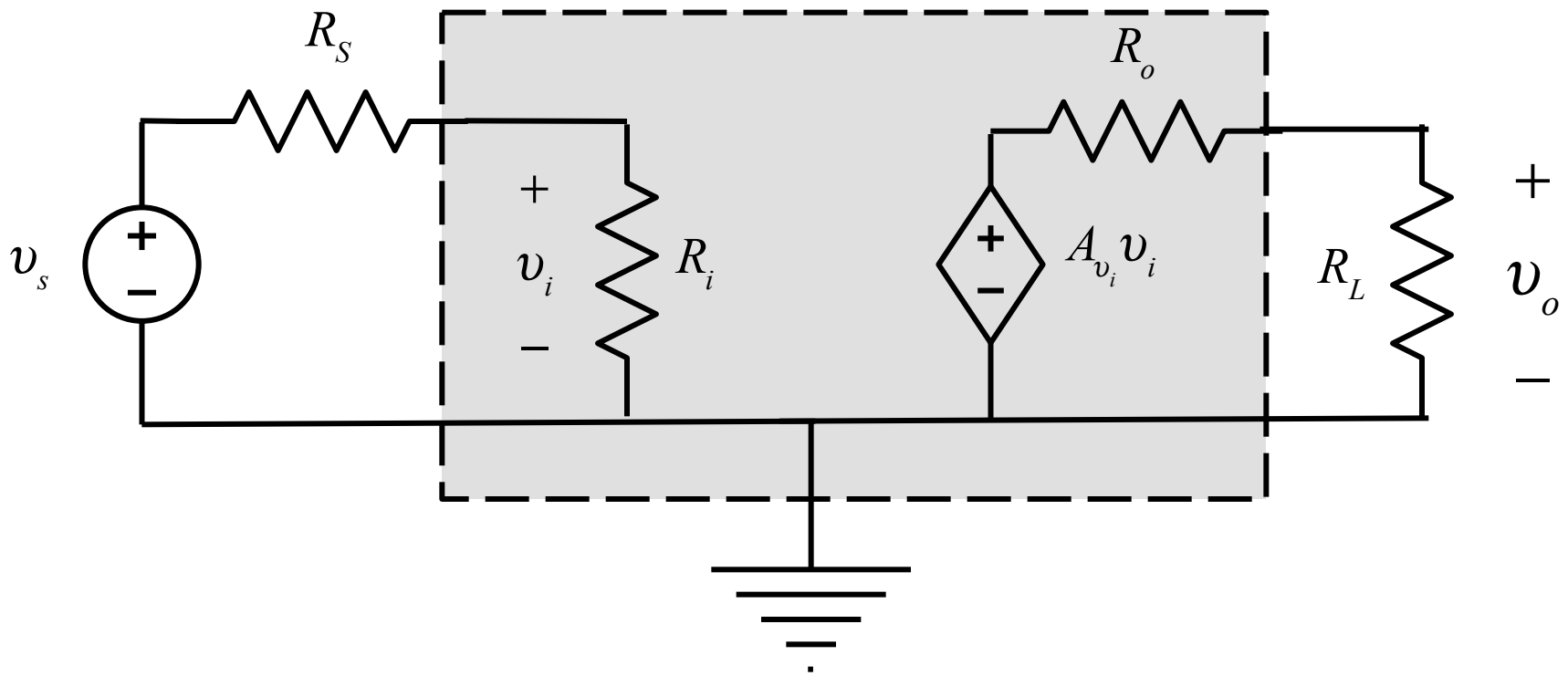


Represented in terms of voltage gain – will be our default representation.

Source and load resistances



Circuit model of an amplifier



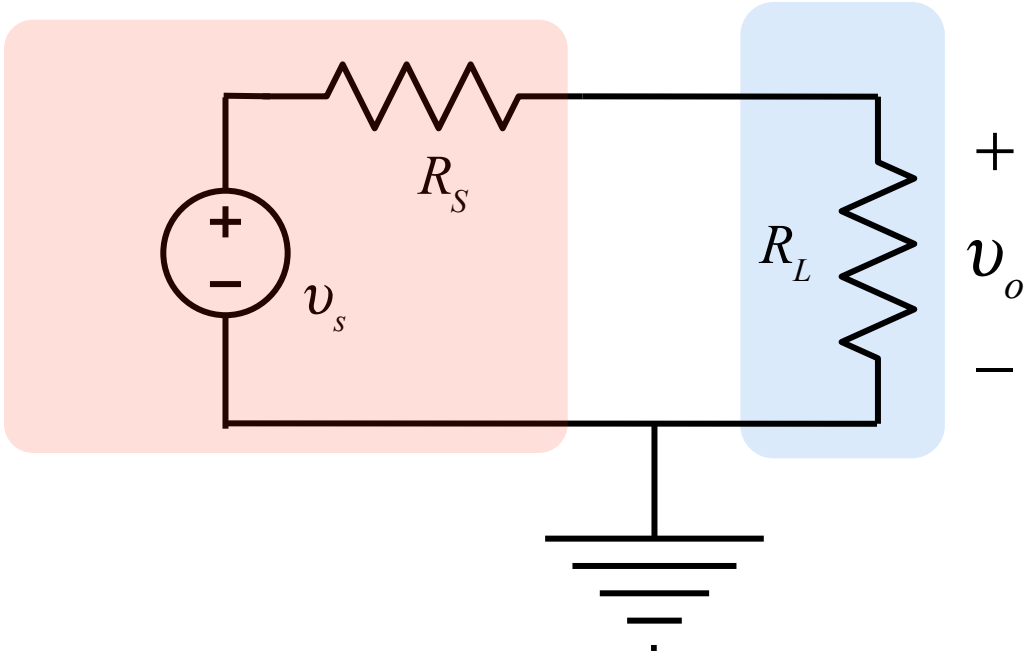
$$v_i = \frac{R_i}{R_i + R_S} v_s \qquad A_{v_s} = \frac{v_o}{v_s} = A_{v_i} \left(\frac{R_i}{R_i + R_S} \right) \left(\frac{R_L}{R_L + R_o} \right) \qquad v_o = A_{v_i} v_i \frac{R_L}{R_L + R_o}$$

“Impedance Mismatch”

Output of Microcontroller

$R_S = 10\,\text{k}\Omega$

$v_s = 1\,\text{V}$



Ear bud

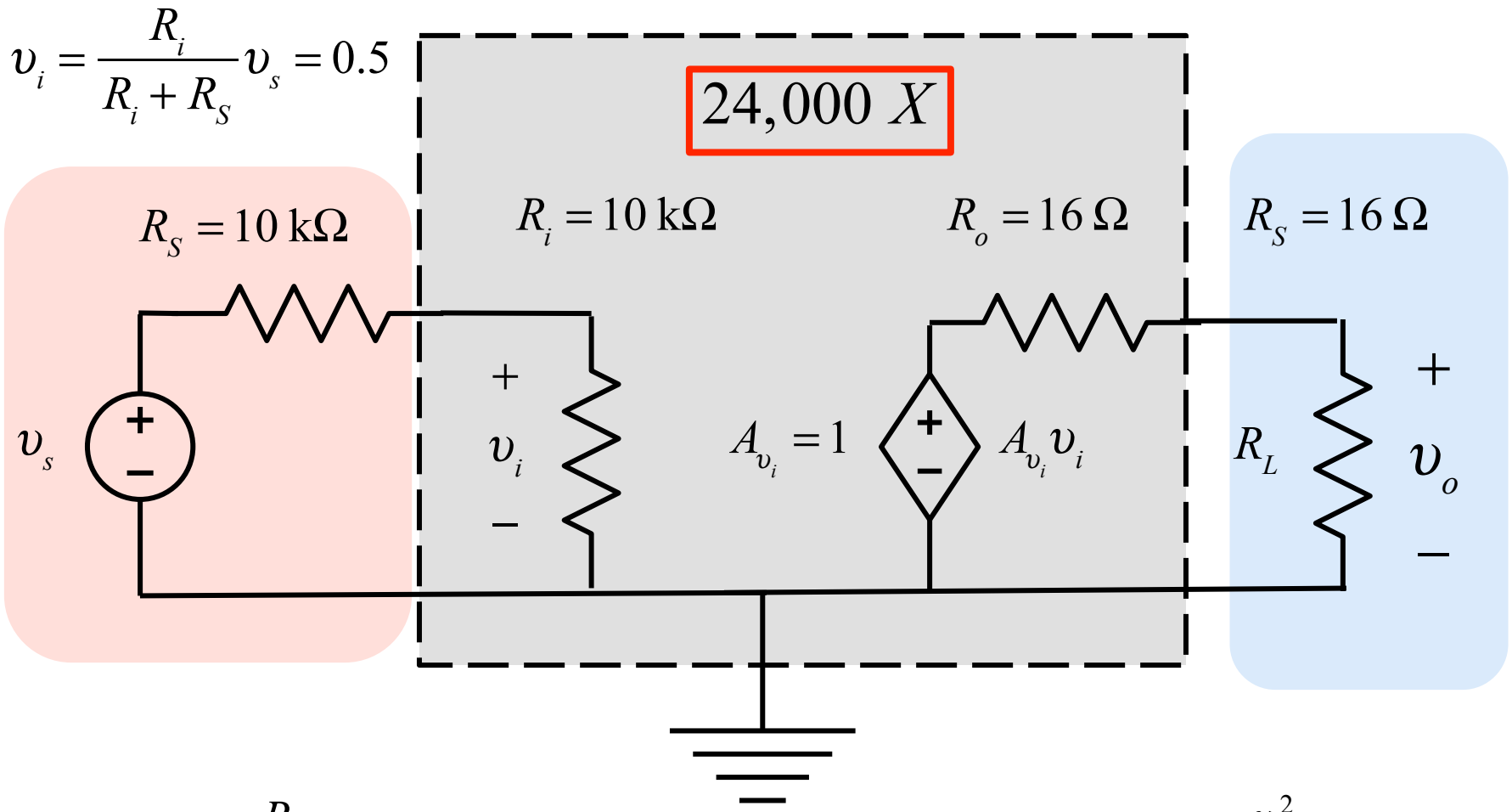
$R_L = 16\,\Omega$

How much power (volume) do we deliver?

$$v_o = v_s \frac{16}{16 + 10{,}000} = 0.0016\,\text{V}$$

$$P_o = \frac{v_o^2}{R_L} \approx 0.16\,\mu\text{W}$$

“Impedance Transformation”



$$v_o = A_{v_i} v_i \frac{R_L}{R_L + R_o} = 1(0.5)(0.5) = 0.25\ \text{V}$$

$$P_o = \frac{v_o^2}{R_L} = 3.9\ \text{mW}$$

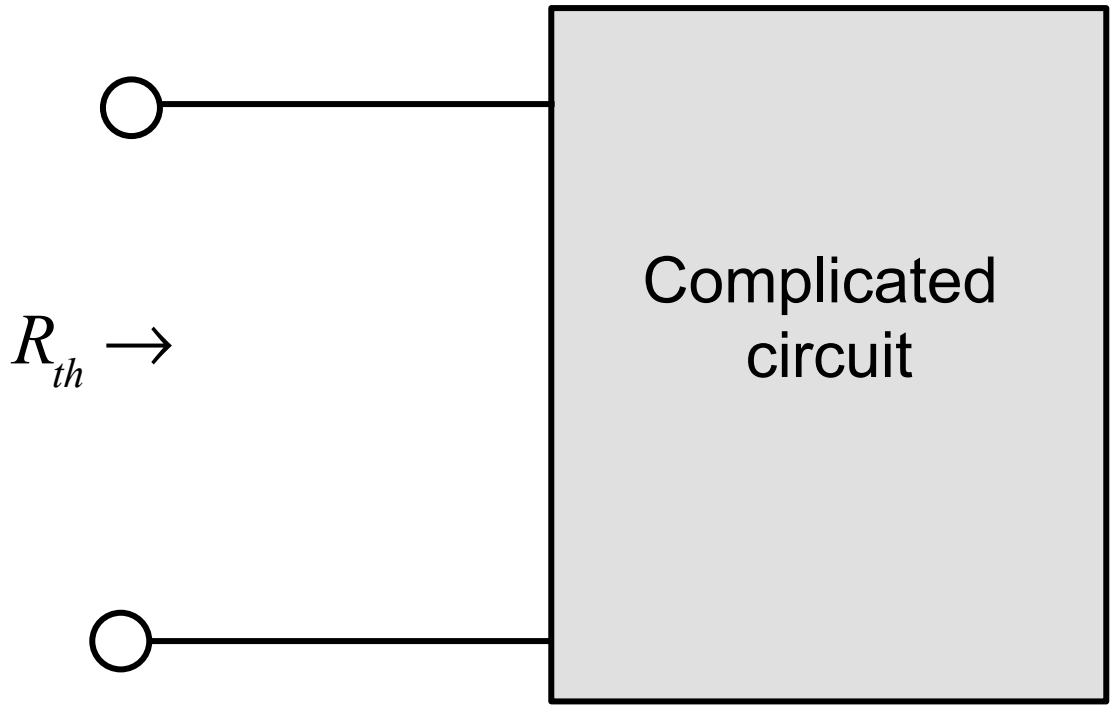
Frequency response

Sec. 1.6 also discusses the frequency response amplifiers, a topic that we will get to near the end of ECE 255.

Given a specific amplifier, we will ask:

1) What is its voltage (current, power) gain?
2) What is its input resistance?
3) What is its output resistance?

Finding Thevenin equivalent circuits

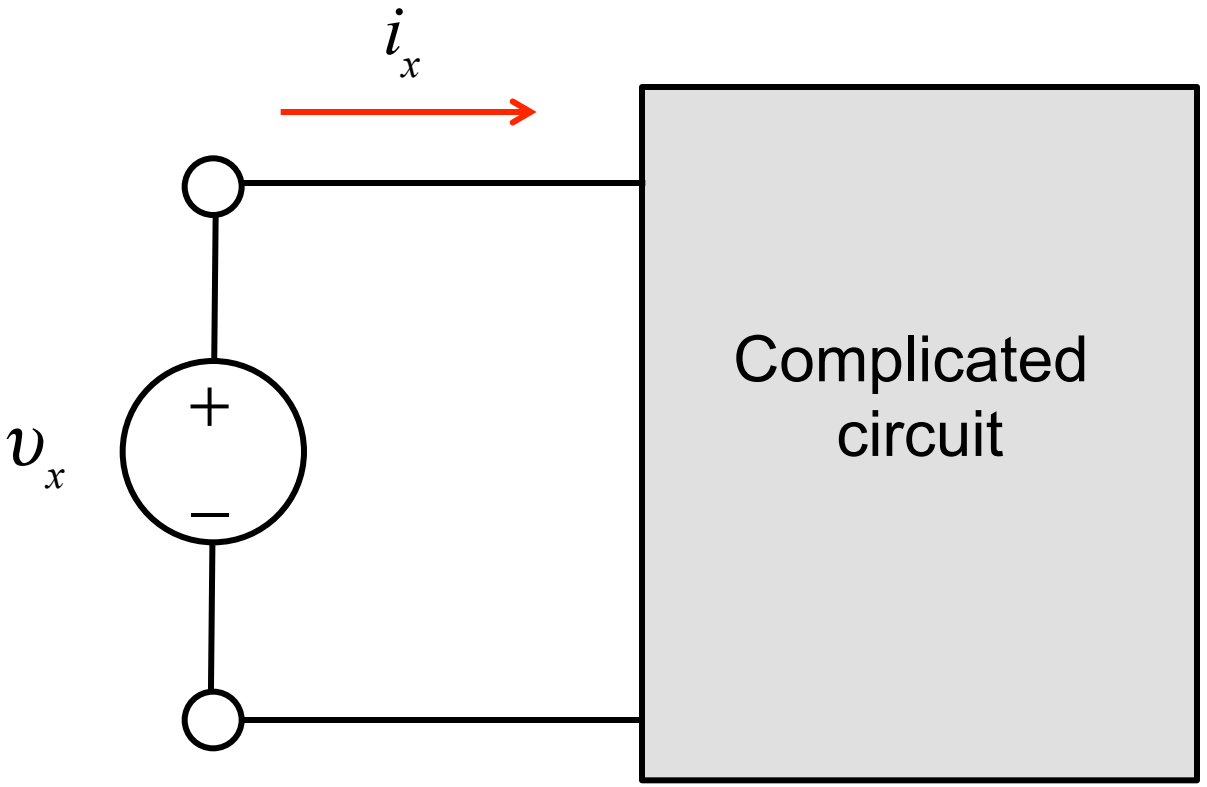


Resistor network: series/parallel combinations may work

Generally need another approach if sources present (particularly dependent)

Finding Thevenin equivalent circuits

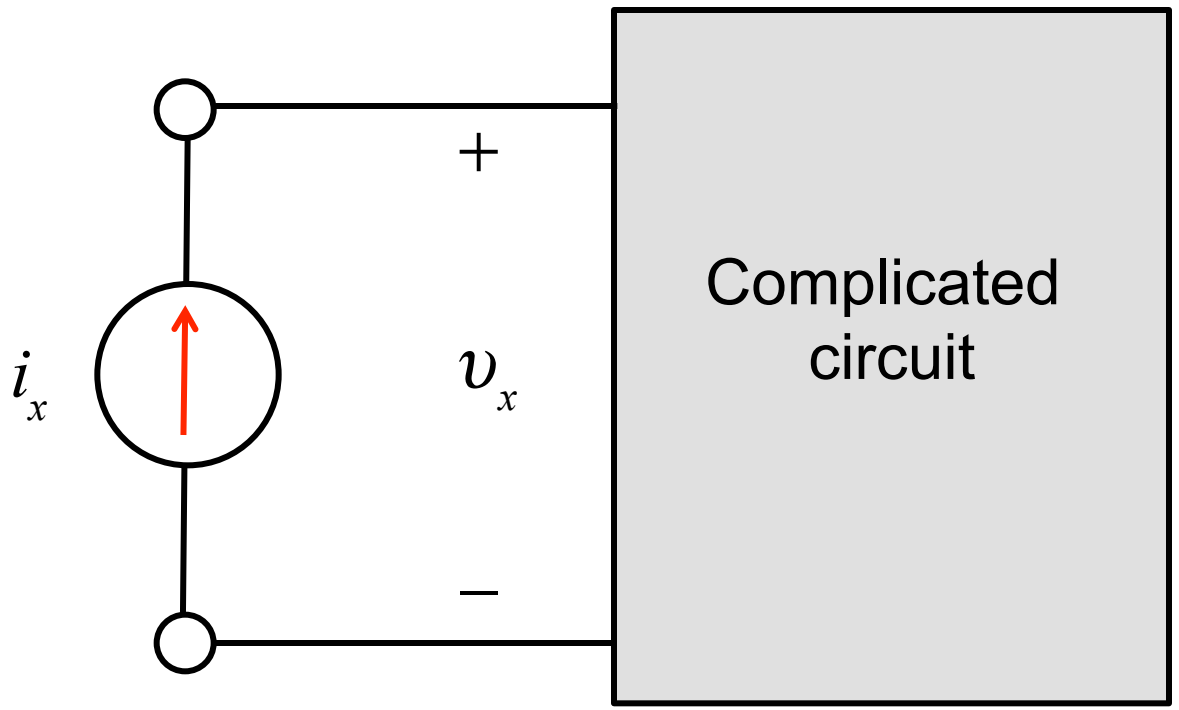
$$R_{th} = \frac{v_x}{i_x}$$



Apply a test voltage, then find the current

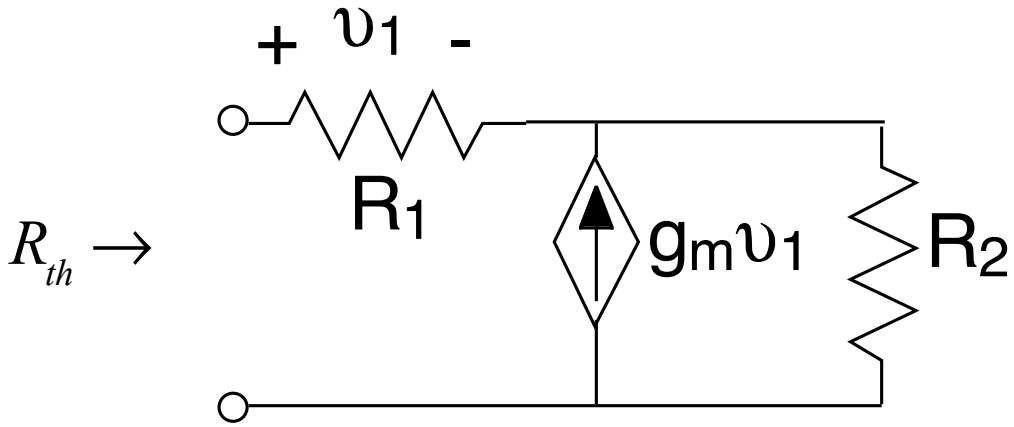
Finding Thevenin equivalent circuits (2)

$$R_{th} = \frac{v_x}{i_x}$$



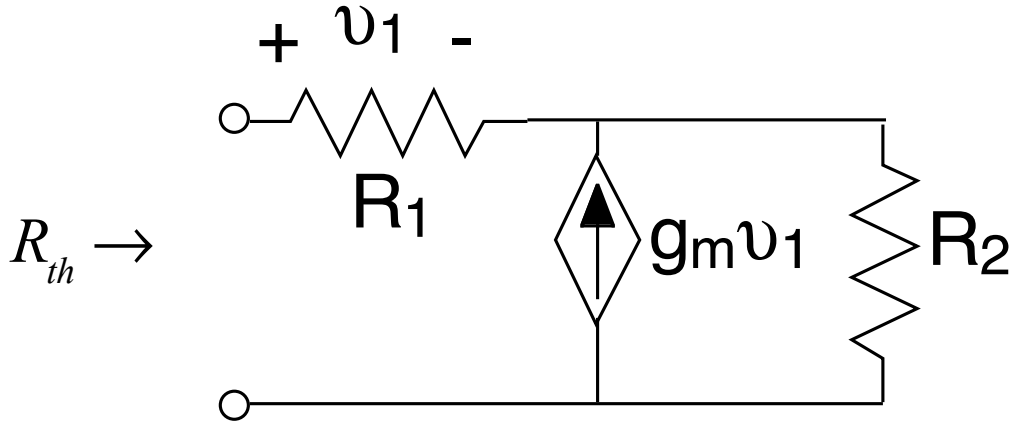
Inject a test current, then find the voltage

Exercise 1



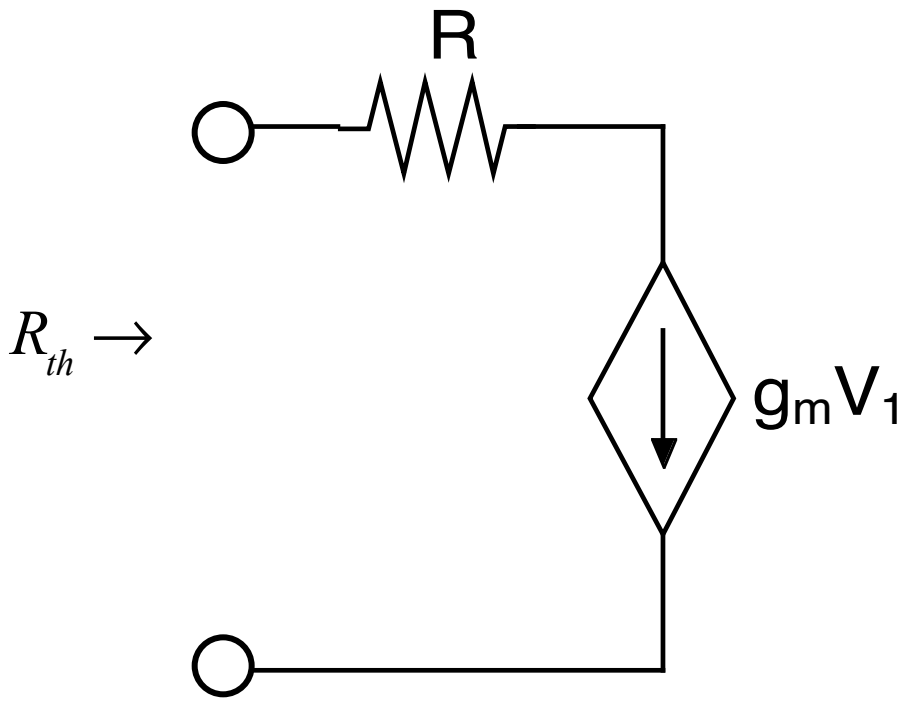
- "Kill" all independent sources (open I sources, short V sources)
- Keep all dependent sources (and control elements)
  - Apply a test voltage, then find the current
  - Or
  - Apply a test current, then find voltage
- Likely need to apply KCL or KVL within circuit

Exercise 1



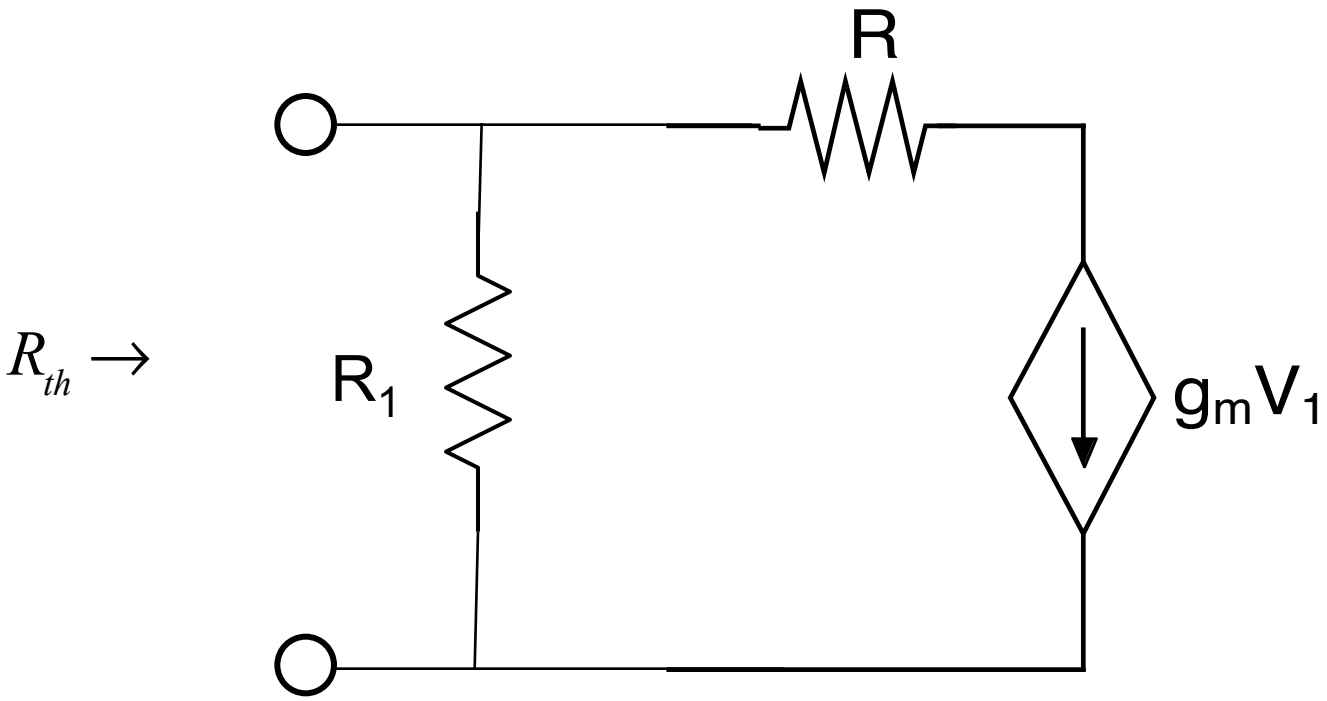
Answer: $R_{th} = R_1 + \left(1 + g_m R_1\right) R_2$

Exercise 2



Answer: $R_{th} = \frac{1}{g_m}$

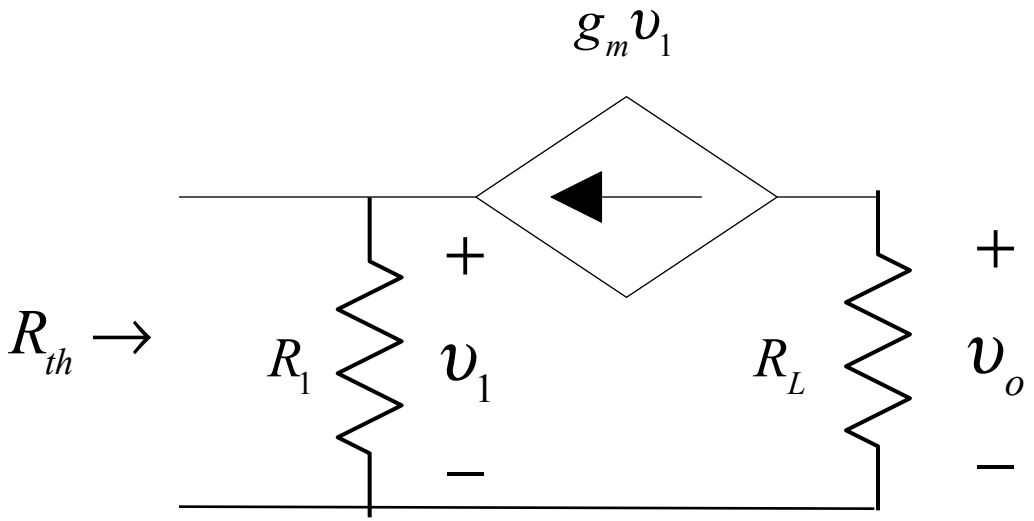
Exercise 3



Answer: $R_{th} = R_1 \| \frac{1}{g_m}$

Exercise 4

Find the input resistance seen by the source, v_s.



Answer: $R_{in} = \dfrac{R_1}{1 - g_m R_1}$