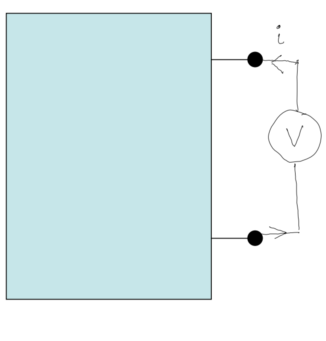
Coping with complexity in engineering design: Computer language models

- Primitives
  - *primitive data, primitive procedures*
- Means of combination
  - *functional composition, data structures*
- Means of abstraction
  - *procedure definition, data abstraction*
- Capturing common patterns
  - *Higher-order procedures, objects, classes*

Coping with complexity in engineering design: Circuit language models

- Primitives
  - *resistor, voltage source*
- Means of combination
  - *wire things together at nodes*
- Means of abstraction
  - *???*
- Capturing common patterns

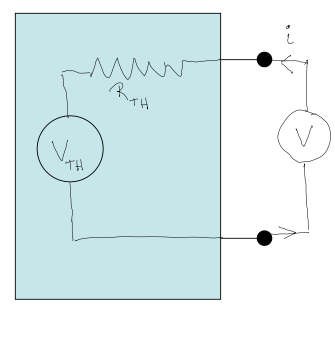
1-port



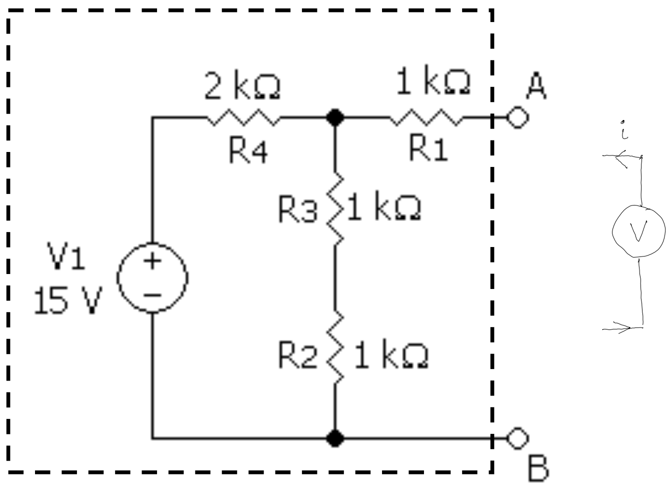
Apply a voltage and measure the current. The 1-port is completely described by the relation of the between the voltage and the current. **It doesn't matter what's in the box, so long as the relation holds.**

Analogy: An abstract data type is described by its API.

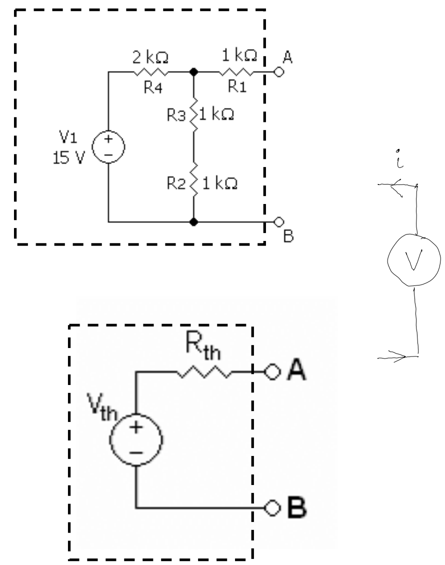
Thévenin's theorem



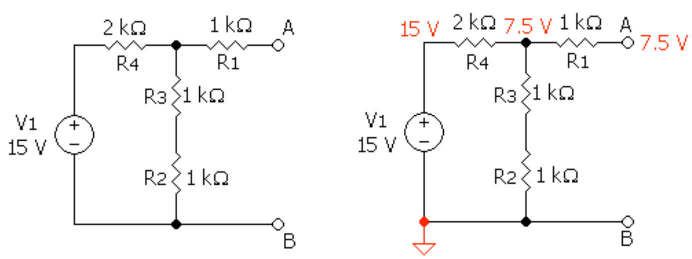
Any two-terminal network made up of resistors and voltage sources, when viewed from the terminals, is **completely electrically equivalent** to a network composed of a single resistor and a single voltage source.



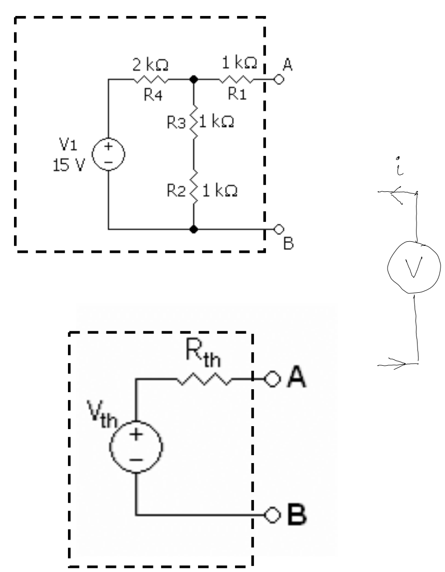
Example: From the Wikipedia



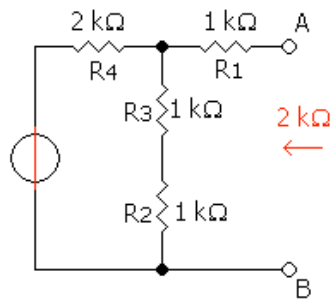
Step 1: The voltage V_{TH} is the voltage we'd see at the terminals



The voltage at the terminals is 7.5V, so V_{TH} is 7.5V



Step 2: The resistance R_{TH} is the resistance we'd see at the terminals (when we set the independent source to zero).



The resistance seen from the terminals is 2kΩ, so R_{TH} is 2kΩ

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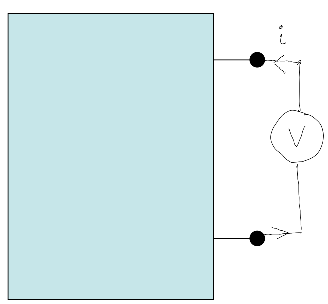
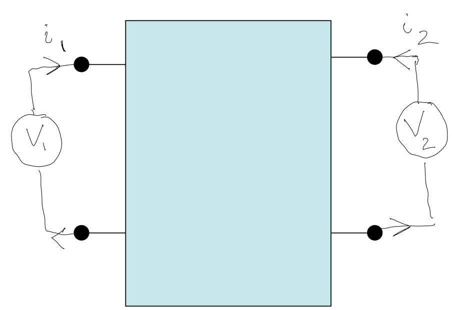
- Means of abstraction
  - *1-ports (Thévenin equivalence)*
- Capturing common patterns

1-port

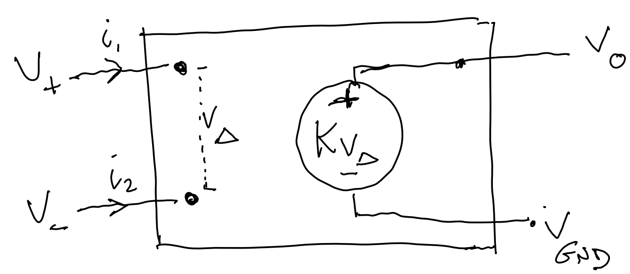


2-port



… and in general, n-ports

Ideal op-amp model

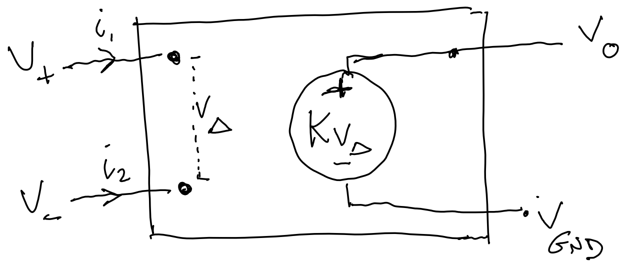


$$V_O - V_{GND} = K(V_+ - V_-)$$

$$i_1 = i_2 = 0$$

K might be around 10,000

Ideal op-amp model

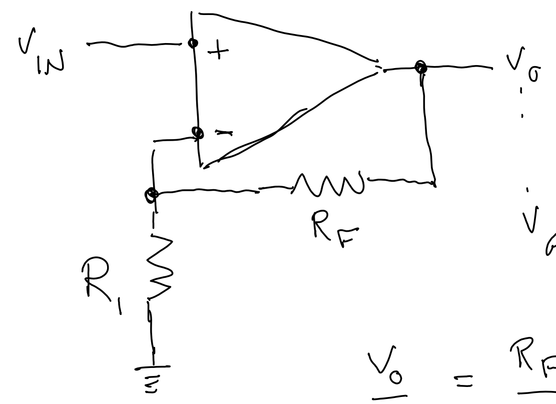


$$V_O - V_{GND} = K(V_+ - V_-)$$

$$i_1 = i_2 = 0$$

K might be around 10,000

Non-inverting amplifier



$$\frac{V_O}{V_{IN}} = \frac{R_F + R_1}{R_1}$$

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- Primitives
  - *resistor, voltage source*
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- Means of abstraction
  - *1-ports (Thévenin equivalence), n-ports*
- Some common patterns
  - feedback