Most manufacturers specify the nominal resistance of a source as the "output resistance." A typical value is 50 Ω.

1.4 Thévenin's and Norton's Theorems

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Thévenin's and Norton's theorems yield ways to simplify our models of circuits.

1.4.1 Thévenin's Theorem

The following remarkable theorem has been proven.

Theorem 1.11

Thévenin's theorem: Given a linear network of voltage sources, current sources, and resistors, the behavior at the network's output terminals can be reproduced exactly by a single *voltage source* V_e *in series with a resistor* R_e.

The equivalent circuit has two quantities to determine: V_e and R_e.

1.4.1.1 Determining R_e The **equivalent resistance** R_e of a circuit is the resistance between the output terminals with all inputs set to zero. Setting a voltage source to zero means the voltage on both its terminals are equal, which is equivalent to treating it as a short or wire. Setting a current source to zero means the current through it is zero, which is equivalent to treating it as an open circuit.

1.4.1.2 Determining V_e The **equivalent voltage source** V_e is the voltage at the output terminals of the circuit when they are left open (disconnected from a load). Determining this value typically requires some circuit analysis with the laws of Ohm and Kirchhoff.

1.4.2 Norton's Theorem

Similarly, the following remarkable theorem has been proven.

Theorem 1.12

Norton's theorem: Given a linear network of voltage sources, current sources, and resistors, the behavior at the network's output terminals can be reproduced exactly by a single *current source* I_e *in parallel with a resistor* R_e.

The equivalent circuit has two quantities to determine: I_e and R_e. The equivalent resistance R_e is identical to that of Thévenin's theorem, which leaves the equivalent current source I_e to be determined.

1.4.2.1 Determining I_e The **equivalent current source** I_e is the current through the output terminals of the circuit when they are shorted (connected by a wire). Determining this value typically requires some circuit analysis with the laws of Ohm and Kirchhoff.

1.4.3 Converting Between Thévenin and Norton Equivalents

There is an equivalence between the two equivalent circuit models that allows one to convert from one to another with ease. The equivalent resistance R_e is identical in each and provides the following equation for converting between the two representations: converting between Thévenin and Norton equivalents

Example 1.4

For the circuit shown, find a Thévenin and a Norton equivalent circuits.

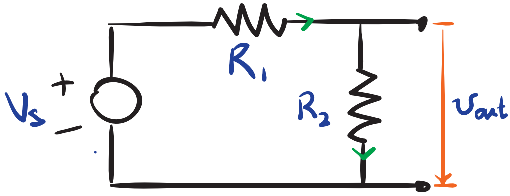

Figure 1.5. A resistor network with a voltage source. The output is indicated as v_{out}.

The Thévenin equivalent is shown. Now to find R_e and V_e. Setting $V_s = 0$, R_1 and R_2 are in parallel, combining to give

$$R_e = \frac{R_1 R_2}{R_1 + R_2}.$$

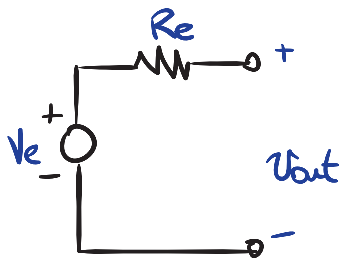

Figure 1.6. The Thévenin equivalent circuit.

Now to find v_{out}. It's a voltage divider:

$$V_e = v_{\text{out}} = \frac{R_2}{R_1 + R_2} V_s.$$

The Norton equivalent is shown. We know R_e from the Thévenin equivalent, which also yields

$$I_e = V_e / R_e.$$

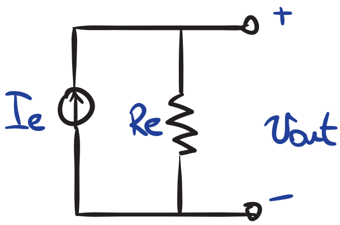

Figure 1.7. The Norton equivalent circuit.

1.5 Output and Input Resistance and Circuit Loading

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When considering a circuit from the perspective of two terminals—either as *input* or *output*—it is often characterized as having a Thévenin/Norton **equivalent resistance** and, if it is considered as an output, as having an equivalent (Thévenin or Norton) source.

If the terminals are considered to be an *output*, its **output resistance** is just the Thévenin/Norton equivalent resistance. Other names for this output resistance are *source* or *internal resisistance*.[3] Figure 1.8 illustrates this model.

3. Sometimes, instead of *resistance*, the term *impedance* is substituted. In these situations, there is no difference in meaning.