Voltage and Current Sources

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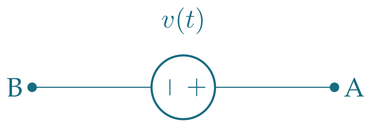
This lesson provides an introduction to some basic circuit elements that are used to control the voltage and current in electric circuits. When you complete this lesson, you should know the following:

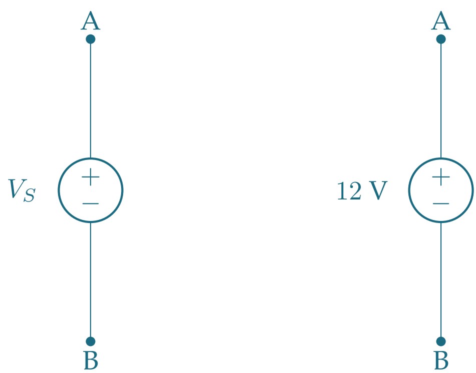
1. The circuit-diagram symbols that are commonly used to represent independent voltage and current sources.
2. The circuit-diagram symbols that are commonly used to represent dependent (or controlled) voltage and current sources in circuit diagrams.
3. The fundamental contraints the govern the use of voltage and current sources in circuits.
4. The basic ways in which controlled sources depend on another voltage or current in a circuit.

The Independent Voltage Source

An independent voltage source in an electric circuit is an element that provides a predetermined voltage drop across its terminals. The symbol for a voltage source looks like this:

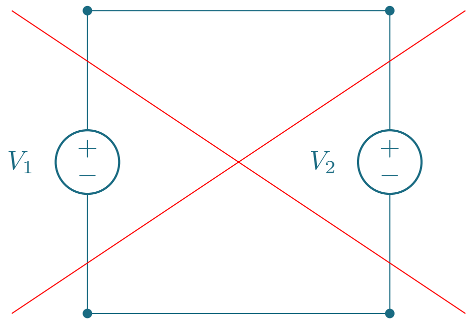


where the voltage across the terminals is equal to $v(t)$ with the specified positive-negative polarity. That is, the voltage *drops* from **A** to **B** (or the voltage *increases* from **B** to **A**) by an amount equal to $v(t)$. For a DC voltage source we might label the source with a symbolic designation like V_S, or we might label the source with a particular voltage like 12 V as shown in the following diagrams:



An example of common DC voltage source is a simple battery, which might provide 1.5 V, 6 V, 9 V, 12 V, or some other specified voltage across its terminals. This model is an ideal approximation; most voltage sources will have some limit to their capability to provide a specified voltage. For nearly all of the circuit models you'll encounter in your initial study of electric circuits, though, you won't need to be concerned with that. It is, however, important to keep the limitation in mind when you work with real-world circuits.

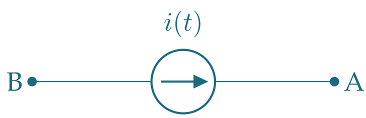
Voltage sources will appear in many ways in the electric circuits you will analyze and design. There is one way, however, that voltage sources should NEVER appear in a circuit:



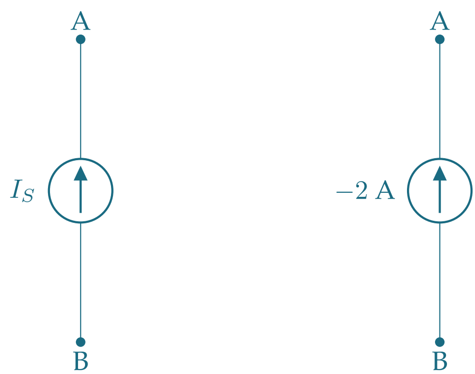
That is, you should not connect a voltage source in *parallel* with another. You should immediately question this configuration if you encounter it in a circuit diagram. Think about how confusing this would be, for instance, if $V_1 = 5$ V and $V_2 = 10$ V. The voltage across the two sources would have to be equal to both 5 V and 10 V.

Independent Current Sources

A simple current source in an electric circuit is an element that provides a predetermined current through its terminals. The symbol for a current source looks like this:



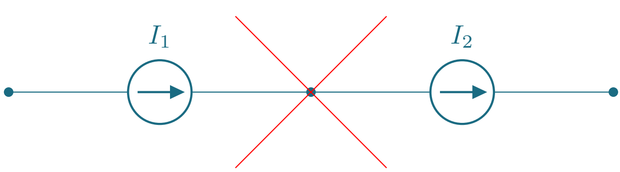
where the current through the terminals is equal to $i(t)$ with the direction specified in the symbol. That is, the current that flows from terminal **B** to **A** is equal to $i(t)$, and the current that flows from terminal **A** to **B** is equal to $-i(t)$. For a DC current source, we might label the source with a symbolic designation like I_S, or we might label the source with a particular current like -2 A as shown in the following diagrams:



For the second source, a current of -2 A flows from terminal **B** to **A**, or, equivalently, a current of $+2$ A flows from terminal **A** to **B**.

As with voltage sources, current sources will always have some limit on their ability to provide the specified current, but, for nearly all of our circuit models, we won't need to be concerned with that limitation.

Current sources will appear in many ways in the electric circuits you will analyze and design. There is one way, however, that current sources should NEVER appear in a circuit:

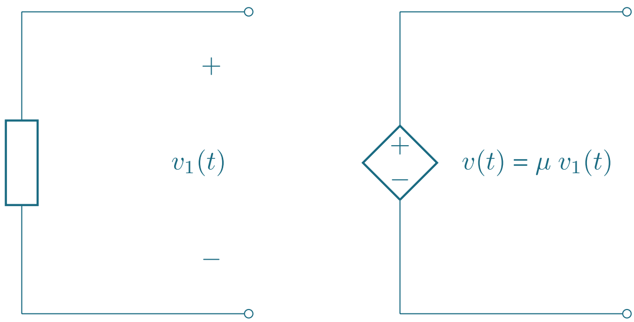


That is, you should not connect a current source in *series* with another. You should immediately question this configuration if you encounter it in a circuit diagram. Think about how confusing this would be, for instance, if $I_1 = 5$ A and $I_2 = 10$ A. The current through the two sources would have to be equal to both 5 A and 10 A.

Dependent Voltage Sources

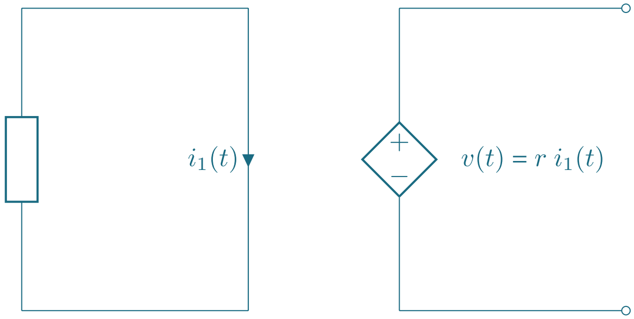
The voltage supplied by a voltage source will sometimes be determined by the voltage or current elsewhere in a circuit. When this happens, we use a different symbol for the voltage source—a diamond instead of a circle—and specify the voltage as a function of the other voltage or current.

The source voltage might, for example, be proportional to some other voltage as is shown here with a proportionality factor μ.



If, for instance, μ is equal to 4 and $v_1(t)$ is equal to 3 V, then the voltage across the source would be 4×3 V $= 12$ V.

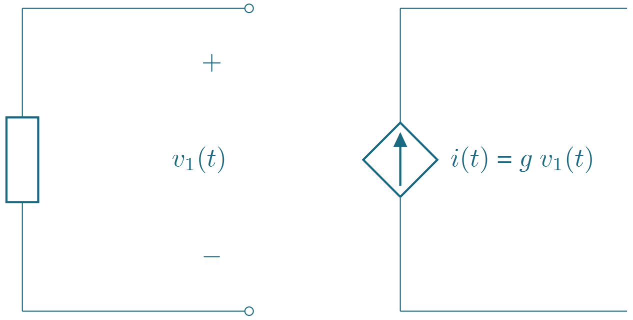
It is also possible for the voltage provided by a source to be a function of a current somewhere in a circuit. Again, we use a diamond symbol for the source, but in this case the voltage is a function of a current. As with voltage-controlled voltage sources, the most common situation for a current-controlled voltage source is for the source voltage to be proportional to the current, as is shown here with a proportionality factor r.



For a voltage-controlled voltage source, the proportionality constant is unitless. For a current-controlled voltage source, the proportionality constant has units equal to volts per amp.

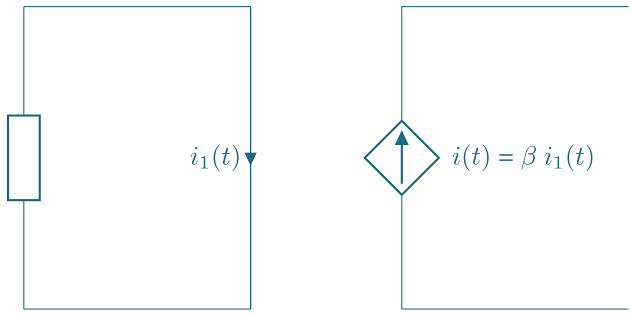
Dependent Current Sources

We can also have current sources whose current depends on a voltage or current elsewhere in the circuit. Here, for instance, is a voltage-controlled current source.



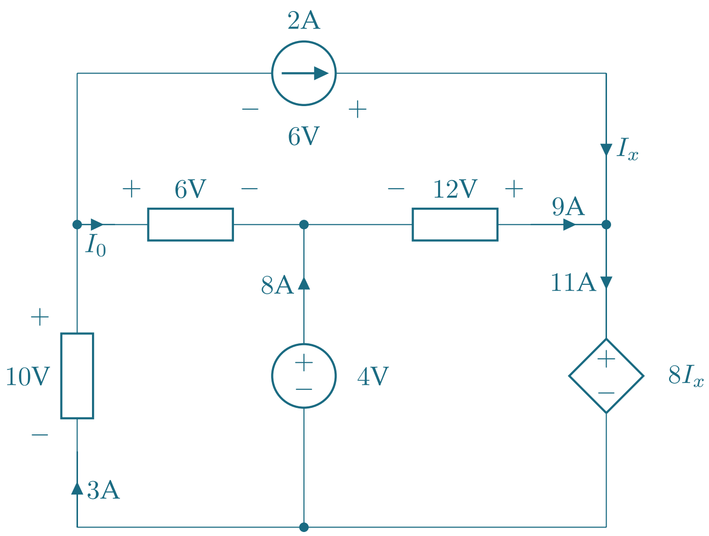
Again, we use a diamond instead of a circle for the source symbol, and the arrow shows the reference direction for the current. As we've shown here, in most situations the current will be proportional to the controlling voltage. In this case, the proportionality factor is g, where g has units of amps per volt.

Our final example of a controlled source is a current-controlled current source.



For this example, the current supplied by the source is proportional to some controlling current with a proportionality constant equal to β.

Let's conclude with an example of a circuit that contains a current-controlled voltage source, and let's use the conservation of power principle to solve for the unknown current I_0.



The power for the 2 A source is

$$P_{2A} = -(2 \text{ A})(6 \text{ V}) = -12 \text{ W}.$$

The power for the 4 V source is

$$P_{4V} = -(8 \text{ A})(4 \text{ V}) = -32 \text{ W}.$$

The power for the controlled source is

$$P_{8I_x} = (11 \text{ A})(8I_x),$$

but I_x is the current provided by the 2 A source, so

$$P_{8I_x} = (11 \text{ A})(16 \text{ V}) = 176 \text{ W}.$$

The power for the device with 12 V across it is

$$P_{12V} = -(9 \text{ A})(12 \text{ V}) = -108 \text{ W}.$$

The power for the device with 10 V across it is

$$P_{10V} = -(3 \text{ A})(10 \text{ V}) = -30 \text{ W}.$$

The only remaining device is the one with 6 V across its terminals, but we don't know the current I_0 through the device. The sum of the power for all the other devices, however, is equal to

$$P_{\text{others}} = (-12 - 32 + 176 - 108 - 30) \text{ W} = -6 \text{ W}.$$

Because of conservation of power, then, the power associated with the remaining element must be 6 W. Therefore,

$$I_0(6 \text{ V}) = 6 \text{ W} \Longrightarrow I_0 = 6 \text{ W}/6 \text{ V} = 1 \text{ A}.$$