1.2 Power Sources

Overview

Circuit elements are commonly categorized as either passive or active. A circuit element is passive if the total amount of energy it delivers to the rest of the circuit (over all time) is non-positive. (Passive elements can temporarily deliver energy to a circuit, but only if the energy was previously stored in the passive element by the circuit.) An active circuit element has the ability to create and provide power to a circuit from mechanisms external to the circuit. Examples of active circuit elements are batteries (which create electrical energy from chemical processes) and generators (which create electrical energy from mechanical processes, such spinning a turbine).

In this chapter we consider some very important active circuit elements: voltage and current sources. We will discuss two basic types of sources: independent sources and dependent sources. Independent sources provide a specified voltage or current, regardless of what is happening elsewhere in the circuit to which they are connected—batteries and generators are generally considered to be independent sources. Dependent sources provide a voltage or current based on a voltage or current elsewhere in the circuit. (The source voltage or current is dependent upon some other voltage or current.) Dependent sources are often used in the mathematical modeling of common devices such as Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) and Bipolar Junction Transistors (BJTs).

Before beginning this chapter, you should be able to:

- Perform basic algebra
- Define voltage and current in terms of electrical charge (Chapter 1.1)
- State common prefixes and the symbols used to represent them in scientific notation (Chapter 1.1)
- State the passive sign convention from memory (Chapter 1.1)

After completing this chapter, you should be able to:

- Write symbols for independent voltage and current sources
- State from memory the function of independent voltage and current sources
- Write symbols for dependent voltage and current sources
- State governing equations for the four types of dependent sources

This chapter requires:

- N/A

Independent Voltage Sources

An independent voltage source maintains a specified voltage across its terminals. The symbol used to indicate a voltage source delivering a voltage \( v_s(t) \) is shown in Figure 1. As indicated in Figure 1, the voltage supplied by the source can be time varying or constant (a constant voltage is a special case of a time varying voltage). An alternate symbol that is often used to denote a constant voltage source is shown in Figure 2; we, however, will generally use the symbol of Figure 1 for both time-varying and constant voltages.
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Note that the sign of the voltage being applied by the source is provided on the source symbol – there is no need to assume a voltage polarity for voltage sources. The current direction, however, is unknown and must be determined (if necessary) from an analysis of the overall circuit.

*Ideal* voltage sources provide a specified voltage regardless of the current flowing through the device. Ideal sources can, obviously, provide infinite power; all real sources will provide only limited power to the circuit. We will discuss approaches for modeling non-ideal sources in later chapters.

![Figure 1. Independent voltage source](image1)

**Ideal voltage sources provide a specified voltage regardless of the current flowing through the device. Ideal sources can, obviously, provide infinite power; all real sources will provide only limited power to the circuit. We will discuss approaches for modeling non-ideal sources in later chapters.**

![Figure 2. Constant voltage source.](image2)

**Independent current sources:**

An independent current source maintains a specified current. This current is maintained regardless of the voltage difference across the terminals. The symbol used to indicate a current source delivering a current $i_s(t)$ is shown in Figure 3. The current supplied by the source can be time varying or constant.

Note that the sign of the current being applied by the source is provided on the source symbol – there is no need to assume a current direction. The voltage polarity, however, is unknown and must be determined (if necessary) from an analysis of the overall circuit.

*Ideal* current sources provide a specified current regardless of the voltage difference across the device. Ideal current sources can, like ideal voltage sources, provide infinite power; all real sources will provide only limited power to the circuit. We will discuss approaches for modeling non-ideal current sources in later chapters.
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Dependent Sources:

Dependent sources can be either voltage or current sources; Figure 4(a) shows the symbol for a dependent voltage source and Figure 4(b) shows the symbol for a dependent current source. Since each type of source can be controlled by either a voltage or current, there are four types of dependent current sources:

- Voltage-controlled voltage source (VCVS)
- Current-controlled voltage source (CCVS)
- Voltage-controlled current source (VCCS)
- Current-controlled current source (CCCS)

Figure 5 illustrates the voltage-controlled dependent sources, and Figure 6 illustrates the current-controlled dependent sources. In all cases, some electrical circuit exists which has some voltage and current combination at its terminals. Either the voltage or current at these terminals is used to set the voltage or current of the dependent source. The parameters $\mu$ and $\beta$ in Figures 5 and 6 are dimensionless constants. $\mu$ is the voltage gain of a VCVS and $\beta$ is the current gain of a CCCS. The parameter $r$ is the voltage-to-current ratio of a CCVS and has units of volts/ampere, or ohms. The parameter $g$ is the current-to-voltage ratio of a VCCS and has units of amperes/volt, or siemens. The units of ohms and siemens will be discussed in more depth in Chapter 1.3.
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(a) Voltage controlled voltage source

(b) Voltage controlled current source

Figure 5. Voltage-controlled dependent sources

(a) Current controlled voltage source

(b) Current controlled current source

Figure 6. Current-controlled dependent sources