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CHAPTER 12
Electrical Fundamentals

It is easy to forget that digital systems are really large collections of analog electrical circuits being operated in a digital manner. It is easy to forget this until the digital components need to be connected to adequate power supplies, until digital circuits experience noise problems, and until digital systems need to exchange stimulus and control with our analog world. An understanding of basic circuit theory and a working knowledge of fundamental analog principles provide a digital engineer with confidence and the ability to design a system that will work reliably at the end of the day.

This chapter begins to peel back the veil of analog circuit theory by starting with the basics of Ohm's law, units of measure, and basic circuit analysis techniques. After presenting DC circuits composed of resistors and capacitors, the discussion moves on to frequency-domain analysis and AC circuits. These topics are presented with a minimum of mathematical complexity, because the goal is to support a digital system rather than focusing on analog signal processing. Filters are introduced in the second half of the chapter. Relatively simple filters are common in digital systems, partly because of the need to reduce noise so that more sensitive components such as oscillators and interface ICs can operate properly.

Constructing digital systems in a reliable manner requires a foundation in analog circuit behavior, and the remainder of this book assumes a basic knowledge of circuit theory that is covered in this chapter. Some or all of the topics presented here may be a review for some readers. A quick skim of the chapter's material will confirm whether it can be skipped.

12.1 BASIC CIRCUITS

Electric potential, called *voltage*, and current are the two basic parameters used in the analysis of electric circuits. Voltage is measured in *volts,* and current is measured in *amperes*, or *amps*. Using the analogy of a hose filled with water, voltage is akin to the water's pressure, and current is akin to the quantity of water flowing through the hose at a given pressure. Unlike water in a hose, electricity only flows when a complete loop, or *circuit*, is present. Electric charge (expressed in units of coulombs) is emitted from one terminal of a power source, flows through a circuit, and then returns in the same quantity to another terminal of that power source. Per the law of conservation of charge, the charge cannot simply disappear in the circuit; it must return to its source to complete the loop.

Georg Ohm, a nineteenth century German physicist, discovered the mathematical relationship between voltage and current that is now known as Ohm's law: $V = IR$. It states that a voltage (V) drop results by passing a current (I) through a resistance (R). Appropriately, the unit of resistance is the *ohm* and it is represented with the Greek letter omega, Ω. Consider the simple circuit in Fig. 12.1, consisting of a 10-V battery and a 50-Ω resistor. Assuming that the connecting wires have zero resistance, there is one and only one solution to Ohm's law: the current through the circuit is $I = V \div R =$