entities for a couple of reasons. First, they are usually associated with different levels of safety standards. AC power supplies must conform to strict standards, because they have the potential to short circuit an AC wiring system with the resultant risk of serious injury and damage. Second, DC-to-DC converters are tailored specifically to the voltages required by a digital logic circuit, whereas AC power supplies can provide more standardized voltages given the widespread availability of DC regulators.

The example also shows two distinct ground nodes: Earth ground and signal ground. A grounded AC wall outlet or other connection provides an absolute 0-V Earth ground connection into which excess charge can drain. This path prevents the accumulation of charge to the point of damaging sensitive electronic components when a sudden electrostatic discharge may occur. It also ties separate pieces of equipment to the same ground potential so that they can be connected without adverse consequences. For example, if a printer and a computer are both connected via a cable, and each has a different ground potential, a ground loop may develop whereby unexpected current flows between the two dissimilar voltages. A ground loop can be disruptive to communication between the printer and computer by manifesting itself as noise on the cable. In contrast to Earth ground, signal ground is the return path to the voltage regulators. Signal and Earth ground are usually connected so that there is a uniform DC ground potential throughout a system. However, many styles exist for making this connection. Some engineers and situations favor connecting the two grounds at a single point, often in the AC power supply. Others favor connecting the grounds at many points throughout the system. Grounding is an important topic that is discussed later in the context of signal integrity.

Given their different treatment, different symbols are used for each type of ground. Purists have a valid argument in favor of consistent representation for each type of ground. When drawing circuit diagrams that must pass official certification standards, consistent representation may be enforced. In other circumstances, it is common for individuals to use whatever representation they prefer. When multiple ground symbols are present in a circuit diagram, the meaning of each symbol should be explicitly determined, because different engineers and companies use their own styles.

As with household AC wiring, strict safety standards should always be observed when using AC-to-DC power supplies. Underwriters Laboratories (UL) has become the de facto standard for safe product certification in the United States, and UL certification is widely considered a mandatory requirement despite not always being dictated by law. All reputable AC power supply vendors seek UL certification before offering their products for sale. Safe power supply design has long since become a well understood and economical practice, and there is no significant burden on the system design and no incentive—financial or otherwise—to not employ a certified design. When designing a digital system, it is almost always best to purchase a precertified AC power supply module from a third party. Well known power supply vendors include Artesyn, Astec, Cherokee, Condor, and Lambda. These power supplies incorporate standard safety features including overload protection devices that automatically shut down the supply when it gets too hot or is called upon to source too much current. Some supplies contain internal fuses and are ready to plug into a wall outlet. Others require that a separate AC wiring harness with fuse be connected.

Off-the-shelf power supplies are available in wide varieties of overall wattages and combinations of output voltages and currents. In many cases, a single module can directly provide a digital system's necessary voltage supplies. There are also many instances in which a digital system has voltage and current requirements that are not directly served by one of these off-the-shelf configurations. The proliferation of low-voltage digital supplies (e.g., 2.5, 1.8, and 1.5 V) has decreased the likelihood of a one-size-fits-all power supply.

Safety requirements for DC-to-DC converters are usually less stringent than for AC-to-DC converters, but the same concepts of fusing and overload protection can be applied. In applications in which a DC power connection is externally accessible by the end-user, fusing and current limiting precautions may be required for safety certification. Many switching regulator modules contain overload protection mechanisms that shut down in the event of excessive current draw. Safety standards for DC-to-DC converters are less uniform and strict, because it is often sufficient to rely on the safety cut-off mechanisms in the AC power module. If a DC regulator fails, the worst-case scenario is often that the AC supply's overload protection will be activated and prevent damage to other equipment and the AC wiring infrastructure.

Whenever power is distributed between two points, the conductors carrying that current must be adequately sized for the flow. Wires have current ratings based on their resistance, the ambient operating temperature, the maximum allowable insulation temperature, and the number of wires bundled together. It is important to conservatively specify wire capacity, because wire has a positive temperature coefficient, meaning that resistance increases with temperature. If a wire is operated beyond its safe capacity, a dangerous situation can develop in which heating increases resistance, which causes more heating in a self-destructive cycle. Wire manufacturers should always be consulted on the ratings for their products when selecting the necessary gauge wires for an application. The American Wire Gauge (AWG) standard provides a measure of wire size, with thicker wires indicated by smaller gauge numbers. Table 17.2 lists the resistance of solid copper wire per 1000 ft (304.8 m) at 25°C.* Current ratings are based on the allowable temperature rise over ambient, which is why a wire's environment directly affects its rating. AC wires enclosed in the walls of your home are rated more conservatively because of the risk of fire in confined spaces. The conservative use of lower-gauge wire results in less power loss and heating, with a resulting increase in safety and reliability.

TABLE 17.2 Resistance of Solid Copper Wire at 25°C

Wire Gauge (AWG)	Ω per 1000 ft (304.8 m)	Wire Gauge (AWG)	Ω per 1000 ft (304.8 m)
30	104	20	10.0
28	65	18	6.4
26	41	16	4.0
24	26	14	2.5
22	16	12	1.6

An example of a distributed power regulation scheme is shown in Fig. 17.16. This system uses an off-the-shelf AC-to-DC power supply to provide a 12-VDC intermediate power bus. Common intermediate voltages include 48, 24, 12, and 5 V. The advantage of using a higher voltage is less current flow through the intermediate distribution wiring for a given power level and hence lower resistive losses ($P_D = I^2R$) in that wiring. Lower voltages have the benefit of easier component selection because of the lower voltage ratings. When using a switching regulator, there is a compromise between very low and very high input voltages. Too high an input requires a small switching duty cycle, which results in higher losses as the transistors turn on and off more often relative to the time that they are in a static state. Too low an input causes higher current to be drawn from the source, which leads to higher I^2R losses in the regulator components. Often, 12 V is a good compromise between switching losses and easier regulator design. Additionally, some systems require 12 V for analog interface circuits or low-power motors such as a disk drive. This system can use whatever 12-V power supply is easily available, as long as its capacity is greater than 43 W.

* *The ARRL Handbook for Radio Amateurs,* American Radio Relay League, 1994, pp. 35–36.