DUST AND WATER VAPOR on electronic components can pose risks to product users, so design your products to resist the shorts and shocks that can result from buildup.

DESIGN for DUST

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Just because you work in an air-conditioned office or a temperature-controlled lab and breathe filtered air doesn't mean your equipment won't suffer from indoor air pollution. Dust and moisture still accumulate on printed-circuit boards (PCBs) inside product enclosures, increasing the chance of an electrical breakdown (arc-over) between circuits. Electrical breakdown can put users at shock risk or can result in a product fire. To guard against the negative effects of airborne pollution, you must design products to meet insulation requirements.

Air is a mixture of nitrogen, oxygen, carbon dioxide, argon, and trace gases. When you add dust (particulate matter) and water (vapor), you get indoor air pollution. Studies from state and federal environmental agencies show that indoor pollution levels can sometimes range between two and five times higher than outdoor levels (Refs. 1, 2).

Most indoor dust pollution comes from building materials such as airborne fiberglass, partition fibers, and carpets as well as office machines, copiers, and smoke. The insides of computers in service for only a few months can often be coated with layers of dust, which can cause electrical shorts (**Figure 1**). Metallic dust particles present in industrial environments cause more trouble because they're more conductive than typical office dust. Conductive dust sources include motors, paper shredders, conveyors, and manufacturing and construction processes. Electronic equipment manufacturers often suggest cleaning internal PCBs and air filters in products to prevent dust buildup.

Water pollution also raises safety risks. Water vapor can come from many sources including cleaning products, air conditioners, water coolers, carpets, and fumes, and from the heating of food and beverages. Your breath contains hundreds of drops of water vapor, which you can see form when you breathe on a cold pair of eyeglasses. One person's breathing can produce ¼ cup of water per hour.

Condensation coats the surface of electrical circuitry and can saturate dust coatings. Moisture can

increase conductivity between electrical circuits, which can cause short circuits resulting in product damage, fire, or electrical shock (Ref. 3).

Safety standards address pollution

Although modern buildings use air-filtration systems, dust and water will still build up over time. Product safety standards take air pollution into account, and by designing your product to comply with these standards, you will minimize safety risks.

One thing you need to do is use the proper insulating materials and then provide sufficient distance between components and PCB traces. Electrical insulation, a dielectric, resists the flow of electric current. Dielectric strength is a measure of an insulating material's ability to withstand voltage stress without failure. The amount of insulation you need depends on the voltage and intended environment of your product.

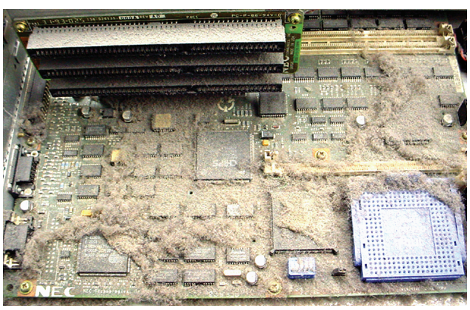

FIGURE 1. Dust can accumulate on PCBs, which can cause electrical failures and safety hazards.
Courtesy of www.computerservicesusa.com/dirty_computers.html.

Plastics and air are two common insulators used to separate circuits and prevent unsafe current flow. Using air as insulation raises concerns about environmental pollution. The addition of solids, liquids, or ionized gases and moisture can reduce dielectric strength. Product standards such as IEC 60947-1 classify environmental conditions according to the amount and frequency of occurrence of hygroscopic dust, ionized gas, and salt, with regard to relative humidity (Ref. 4).

Product standards also specify "pollution degrees" for various types of products. The pollution degree defines the level of dust and water pollution within a product's operating environment. Pollution degrees range from 1 to 4, with higher numbers indicating more dust and water in the environment. **Table 1** explains the four pollution degrees.

Table 1. Pollution degrees and their descriptions

Pollution degree level	Description
1	No pollution or only dry, nonconductive pollution, which has no influence on safety. You can achieve pollution degree 1 through encapsulation or the use of hermetically sealed components or through conformal coating of PCBs.
2	Nonconductive pollution where occasional temporary condensation can occur. This is the most common environment and generally is required for products used in homes, offices, and laboratories.
3	Conductive pollution or dry nonconductive pollution, which could become conductive due to expected condensation. This generally applies to industrial environments. You can use ingress protection (IP) enclosures to achieve pollution degree 3.
4	Pollution that generates persistent conductivity, such as by rain, snow, or conductive dust. This category applies to outdoor environments and is not applicable when the product standard specifies indoor use.

Pollution degree 2 generally applies to homes, offices, and laboratories (**Figure 2**). For example, pollution degree 2 is appropriate for information technology equipment (IEC 60950-1), test and measurement equipment (IEC 61010-1), household appliances (IEC 60335-1), audio-visual equipment (IEC 60065), electronic equipment (ECMA-287), and industrial control products (UL 508).

Insulation, creepage, and clearance

An environment's pollution degree, combined with electrical and environmental factors such as working voltage and overvoltage category, can affect a product's insulation. The working voltage is the highest AC RMS or DC voltage across the insulation that a product can withstand. The overvoltage category classifies the power source according to potential voltage transients (spikes) on the power line.

Overvoltage category II, for example, applies to 120/230 VAC mains outlet power. Home, office, laboratory, and manufacturing power typically fall into category II, which includes computers, measurement instruments, appliances, and televisions.

Inadequately insulated hazardous voltages can cause fires or shock. Hazardous voltages are those greater than $30\,V_{RMS}$ and $42.4\,V_{pk}$ or 60 VDC. Many products contain both hazardous and nonhazardous voltages.

User-touchable voltages must be nonhazardous; such voltages are also called safety extra-low voltage (SELV). SELV circuits often run at low power and logic levels, such as ±3.3 to ±24 VDC. Examples of user-touchable circuits are input/output connectors and cables used to attach peripheral devices such as printers, keyboards, monitors, and external drives.

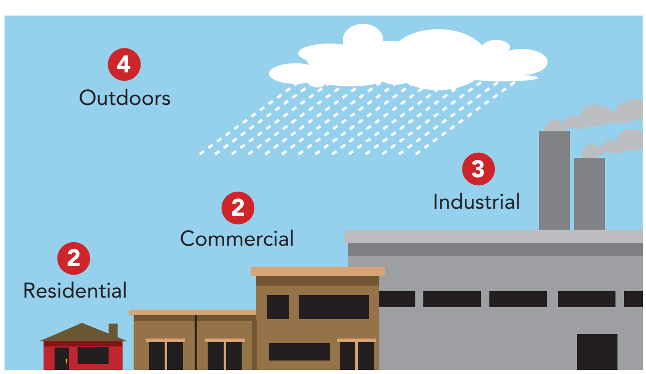

FIGURE 2. Pollution degrees describe indoor and outdoor environments. Artwork by Melinda Vaughan, National Instruments.

You must insulate hazardous voltages from user-touchable circuits. There are several types of insulation:

- *Functional* insulation ensures correct product operation but does not provide safety protection.
- *Basic* insulation provides a single layer of insulation.
- *Supplementary* insulation is the addition of an independent layer of insulation to basic insulation.

(continued)

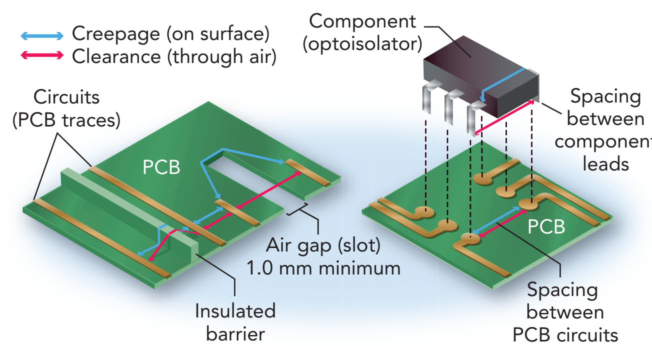

FIGURE 3. Safety standards specify creepage and clearance spacing. Artwork by Melinda Vaughan, National Instruments.

- *Double* insulation combines basic and supplementary insulation.
- *Reinforced* insulation is a single system that provides the same protection as double insulation.

Safety standards require that you protect users from hazards during the normal operation of a product and under an abnormal (single-fault) condition. Double or reinforced insulation provides this protection; in the event of a failure of the basic insulation, a second layer remains for protection.

Tables in the standards specify insulation spacing values between two circuits. To prevent electrical breakdown, you need to increase the spacing distance as the pollution degree increases (**Table 2**).

Two other factors to consider are creepage and clearance, which define circuit spacings measured from the closest two points across the insulation, such as between PCB traces or between the edges of PCB pads around soldered connections (**Figure 3**). *Creepage* is the shortest distance across a surface between conductive circuits. *Clearance* is the shortest path through air between the circuits. Insulating barriers or slots can influence design decisions about spacing between circuits. Pollution, relative humidity, and condensation can affect creepage distances. Clearance is most affected by air pressure and temperature.

Figure 4 illustrates a 300-V digital multimeter (DMM) designed for use in a pollution degree 2 environment. The DMM needs reinforced spacing of 3.0 mm minimum between the 300-V input and the 5-V communication ports. *(continued)*

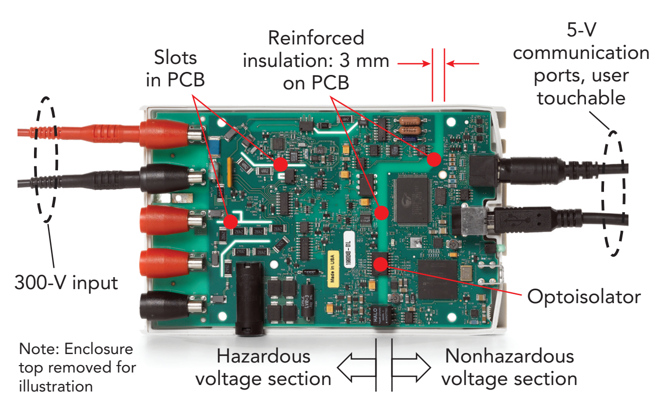

FIGURE 4. Insulation separates the hazardous voltages from nonhazardous voltages on a PCB.

Testing for safety compliance

The IEC standards also specify an electric strength test that stresses the insulation beyond what it should encounter in normal operation. This test is called a dielectric-withstand or high-potential (hipot) test. Dielectric tests consist of measuring the leakage current through the product's insulation under a high voltage (overvoltage) for 1 min. Insulation failure occurs when an arc-over occurs, causing excessive current to flow.

Table 2. Double or reinforced insulation for a 300-V product

	Pollution degree	
Spacing type	2 (typical products)	3 (industrial areas)
Clearance	3.0 mm	3.0 mm
Creepage on PCBs	3.0 mm	10.0 mm

The dielectric test voltage is based on the working voltage and the required insulation, such as 2500 V_{RMS} hipot from the input-to-communication connections in the DMM in Figure 4. To simulate water pollution on PCBs and components, you should perform dielectric tests after 48 hr of humidity preconditioning. Product designers should focus on insulation spacings first, because dielectric testing does not reduce or eliminate the required spacing distances. T&MW.

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FOR FURTHER READING

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