BY MARK CANTRELL • ANALOG DEVICES INC

Use reinforced isolation for effective data couplers

UNDERSTAND THE REQUIREMENTS AND MANDATES FOR ELECTRIC-SHOCK SAFETY WITH RESPECT TO THIS COMMON COMPONENT.

The primary tenet of electric-shock safety is that the equivalent of two independent insulation systems must lie between dangerously energized circuits and any conductor that a user of an electrical device can access. One of these insulation systems could be a safety-grounded enclosure with a single layer of internal insulation. Another approach is to use two insulation systems to provide redundant protection.

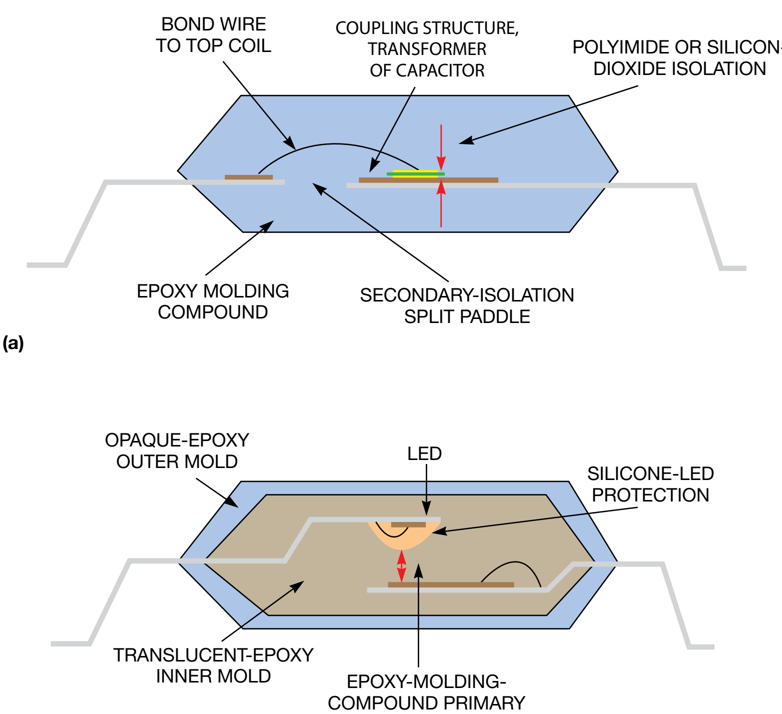
Complex electrical systems using the double-insulation approach require galvanically isolated communications across two layers of insulation without losing signal integrity. This requirement creates the need for devices with the equivalent electrical strength and reliability of two redundant-insulation systems. The so-called reinforced-insulation device relies on a combination of construction, type testing, and continuous monitoring in production to ensure safety equivalence to two independent systems. This article examines how to achieve reinforced insulation in optocouplers and digital isolators with respect to construction and the test requirements of the IEC's (International Electrotechnical Commission's) IEC60950 and the related IEC60747-5-5 and VDE (Verband der Elektrotechnik, Elektronik und Informationstechnik)-0884-10, as well as differences with other accepted IEC standards for both types of isolators.

SAFETY ISOLATION

Modern systems require isolation to communicate with high-side components in battery-charging systems or motor drives, to break ground loops in communications systems, and to protect users from dangerous line or secondary voltages. The level of safety an application requires determines the level of isolation the application needs.

Functional isolation provides only the insulation necessary for the component to function properly but provides no protection to a user. Basic insulation provides a level of insulation from shock that is adequate for protecting an operator if the insulation is fully intact. However, to protect people from hazardous voltages, regulations require double insulation: the stipulation that two independent insulation systems be present—basic insulation for shock protection and a supplemental layer so that, if a fault breaches one insulation system, a redundant system will still provide safety to the operator. When evaluating insulation systems, the primary requirement is safety, not electrical function, so the failure criterion during evaluation is whether the isolation barrier is intact after the qualification. It is an added bonus if the part still functions to the original specifications.

An example of a reinforced-insulation system is the feedback-control loop in a power supply. Information about the output-voltage level must flow from the SELV (safety-extra-low-voltage) side of the ac/dc converter to the line side of the power supply. Operators can be in contact with the SELV side



(a) (b)

Figure 1 The component structure of both digital-isolator construction (a) and optoisolator construction (b) has reinforced insulation.

TABLE 1 CREEPAGE AND CLEARANCE REQUIREMENTS

AC mains (V rms)	**Mains category** (V rms)	**Class II transient voltage** (V rms)	**Basic creepage/ clearance** (mm)	**Reinforced creepage/ clearance** (mm)
240	300	2500	2.5/2	5/4
400	600	4000	4/3.2	8/6.4

of the power supply, so two independent isolation systems or a reinforced-insulation system must be present in the datapaths to protect operators from shock.

Passive components, such as resistors or capacitors, can operate in series without significant functional degradation, but putting two data isolators into the path would be impractical for several reasons. First, analog data would lose fidelity, and digital data would have long propagation delays and added jitter. Second, this scenario would create the need for an intermediate power supply to run the coupler interfaces between the two layers of isolation. The impracticality of doubling up data-isolation devices creates the need for components that directly connect across a double-insulation boundary without sacrificing safety. The use of this type of component means that a system has reinforced insulation (**Figure 1**).

COMPONENT-LEVEL REQUIREMENTS

You can evaluate component-reinforced insulation either using the external dimensions of the component, such as creepage, clearance, and tracking index, or using internal electrical performance. Internal and external requirements are handled in very different ways. Creepage is the shortest distance along the surface of a component between electrically isolated conductive structures, such as component pins. Clearance is also the shortest distance between isolated conductive structures in a component, but it need not be on the surface, so the path can jump over grooves and be suspended over ridges.

In simple geometries, the creepage and clearance paths are often the same. **Figure 1** shows the creepage path for a JEDEC Solid State Technology Association standard SOIC (small-outline integrated circuit) because many isolation devices use this style of package. The creepage and clearance for this package have the same path and length. Creepage is always greater than or equal to the clearance. An additional external property of components that is critical to insulation ratings is the CTI (comparative tracking index), a measure of how easily an insulating material will erode under electrical discharge. Higher tracking voltages will allow smaller creepage and still maintain safety.

External dimensions must be equivalent to the total distances that the basic and supplemental layers of a double-insulation system provide. In general, all creepage and clear-

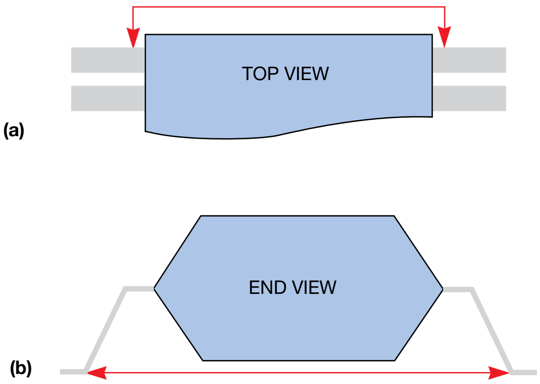


Figure 2 Two common operating conditions show the required package creepage (a) and clearance (b).

ance requirements are twice as large for reinforced components as for basic and supplemental components. **Table 1** and **Figure 2** show two common operating conditions and the required creepage and clearances. With this approach, the external environment and the surface properties determine the external spacing requirements, including the amount of expected contaminants, the air pressure, and tracking: the tendency of surface discharges to erode the outer surface of a component.

For internal properties of components, the quality of the insulation is more important than the quantity or the thickness of the insulation. The manufacturer can demonstrate that the part has the required electrical properties to withstand the voltage stresses in both the long term and the short term. The requirements of the IEC60950 standard are for office and telecom equipment and, to a large extent, for medical devices. You can readily verify the external dimensions and materials with a micrometer and some bulk material testing for a tracking index.

For internal requirements, you can use any of three approaches for qualifying the component. The simplest approach is to evaluate the component as if it contained only solid insulation. This approach requires that all of the internal distances through the insulation or along cemented joints are greater than 0.4 mm. No further type testing is required. However, it is difficult to make a high-performance data coupler that meets these requirements. It is widely believed that the 0.4-mm minimum insulation thickness applies to all reinforced isolation devices, but it does not, and this misconception is a point of confusion for many engineers.

Another approach is to apply the rigorous IEC60747-55 standard, which qualifies optocouplers for reinforced insulation and has a battery of type tests and life tests with isolation-withstand verification tests after each one. This standard currently applies only to optocouplers, not other newer digital isolators; however, VDE has created a draft standard, VDE0884-10, which applies the insulation tests of the IEC60747-5-5 standard to digital isolators.

Alternatively, you can treat the component as a semiconductor device. This category of devices has a set of type tests similar to the IEC60747-5-5 requirements. You use this approach with digital isolators because the testing requirements of the optocoupler standard target use in optocoupler structures.

Qualification to and maintenance of a reinforcement rating is accomplished in three phases. First, you evaluate materials and dimensions and conduct electrical type testing. Testing includes thermal cycling, limited life testing, and electrical overstress that would cause heating or catastrophic insulation failure. The integrity of the isolation is checked with a voltage-withstand test after each environment or test. IEC60747 type testing covers materials tests for CTI and flammability; electrical tests for withstand, partial discharge, insulation resistance, surge, and overload; and mechanical tests for thermal cycle, thermal shock, vibration, high-temperature storage, and creepage and clearance.

After the part receives approval based on its dimensions and type testing, a voltage-withstand test checks insulation integrity for each device during manufacture. IEC60747-5-5 and equivalent certifications perform a partial-discharge insulation-quality test on each device. The certifying body conducts periodic audits to verify that material sets and dimensions have not changed and that calibrated equipment is properly conducting all assembly-line tests. The auditor may periodically repeat and review a sample of some of the tests.

TRENDS IN ISOLATION REQUIREMENTS

Different standards can have disparate requirements at the component level. One standard may even vary from edition to edition. This trend is becoming less problematic as IEC is moving toward a unified approach. This approach will likely take a significant amount of time to achieve because each standards committee has significant independence. A unifying trend in the application of system-level standards is the availability of component-level standards, such as IEC60747-5-5. If such a standard exists for a component, you can apply it instead of the requirements of a system-level standard.

The IEC and VDE standards set a high bar for reinforced insulation, including surge testing at levels of 10 kV or higher. Thin insulation layers cannot pass this test, which is the discriminating test for many optocouplers and digital isolators for qualification as reinforced insulation. Components that cannot meet the requirements usually fall back to the IEC60747-5-2 standard, which can be applied to basic insulation.

Yet another confusing point for designers of isolated systems is the assumption that an IEC60747-5 qualification automatically confers reinforced status. The IEC committees are currently working to revise the IEC60747-5-5 standard to include digital isolators. The next unified standard will be applicable across all IEC system-level standards and should help to eliminate confusion in the future.

Manufacturers design and qualify reinforced insulation in data isolators to provide the protection of double-insulation systems and the data-transmission performance available with a single isolation barrier. Externally, the components have a creepage and clearance requirement that is twice the basic insulation requirement. Internally, insulation either meets the requirements of solid insulation, including through the insulation minimum distance, or it receives extensive type testing and assembly-line testing during production. The availability of a reinforced insulation rating that is verified by testing rather than detailed structural requirements allows innovation in insulation technology to be qualified without rewriting the standards for each new technology. **EDN**

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