Reinforced Isolation in Data Couplers

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IDEA IN BRIEF

Reinforced insulation in data isolators is designed and qualified to provide the protection of double insulation systems while providing the data transmission performance available with a single isolation barrier.

The primary tenet of electric shock safety is that there must be the equivalent of two independent insulation systems between dangerously energized circuits and any conductor that can be accessed by the user of an electrical device. One of these insulation systems could be a safety grounded enclosure paired with a single layer of internal insulation. Another approach is to use two insulation systems arranged to provide redundant protection. As a result, complex electrical systems using the double insulation approach require galvanically isolated communications across two layers of insulation without losing signal integrity. This created the need for devices with the equivalent electrical strength and reliability of two redundant insulation systems. This is called a reinforced insulation device, and it relies on a combination of construction, type testing and continuous monitoring in production to ensure safety equivalence to two independent systems.

We will examine how reinforced insulation is achieved in optocouplers and digital isolators with respect to construction and test requirements under IEC 60950 and the related IEC 60747-5-5 and VDE-0884-10 standards, as well as differences with other accepted IEC standards for both types of isolators.

Safety Isolation

Isolation is required in modern systems for many reasons: communication to high side components in battery charging systems or motor drives, breaking ground loops in communications systems, or protecting users from dangerous line or secondary voltages. The level of isolation is determined by the level of safety required for the specific application. Functional isolation provides no protection to a user, only the insulation required for the component to
function properly. Basic insulation provides a level of insulation from shock that is adequate for protection of an operator if the insulation is fully intact. However, to protect people from hazardous voltages, regulations require 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. This type of arrangement is called double insulation. When evaluating insulation systems, the primary requirement is safety, not electrical functionality, so the failure criterion during evaluation is whether the isolation barrier is intact after the qualification—if the part still functions to the original specifications, it is an added bonus.

An example of a reinforced insulation system is the feedback control loop in a power supply. Information about the current output voltage level must flow from the SELV (safety extra low voltage) side of the ac-to-dc converter to the line side of the power supply. Operators can be in contact with the SELV side of the power supply, so two independent isolation systems or a reinforced insulation system must be present in the data paths to protect operators from shock. Passive components like resistors or capacitors can be run 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. Secondly, it 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 created the need for single components that directly connect across a double insulation boundary without sacrificing safety. This type of component (Figure 1) is classified as having reinforced insulation.

**Component Level Requirements**

Component reinforced insulation is evaluated in two ways: external dimensions of the component such as creepage, clearance, and tracking index; and 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 the shortest distance between isolated conductive structures in a component, but it is not constrained to be on the surface, so the path can jump over grooves and be suspended over ridges. In simple geometries, the creepage and clearance path are often the same. The illustration shows the creepage path for a JEDEC standard SOIC since this style of package is used for many isolation devices. For this style of package, the creepage and clearance 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 Comparative Tracking Index (CTI). This is a measure of how easily an insulating material will erode under electrical discharge. Higher tracking voltages will allow smaller creepage while still maintaining safety.
External dimensions must be equivalent to the total distances provided by basic and supplemental layers of a double insulation system. In general, all creepage and clearance requirements are twice as large for reinforced components as for basic/supplemental rated components. An example is shown in Figure 2 of two common operating conditions and the creepage and clearances required. This approach is taken since the external environment and surface properties determines the external spacing requirements. These include the amount of contaminants expected, the air pressure, and the tendency of the outer surface of a component to be eroded by surface discharges, called tracking.

For internal properties of components, the quality of the insulation is more important than having a specific quantity or thickness of insulation. The manufacturer can demonstrate that the part has the required electrical properties to withstand the voltage stresses both long and short term.

The requirements of the IEC 60950 standard are for office and telecom equipment and to a large extent for medical devices. The external dimensions and materials are readily verified with a micrometer and some bulk material testing for tracking index. For internal requirements, there are three approaches for qualifying the component.

- The component can be evaluated as if it contained only solid insulation. This is the simplest approach since it requires that all of the internal distances through the insulation or along cemented joints are greater than 0.4mm. 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; this is not the case and is a point of confusion for many engineers.
- If the component is an optocoupler, then the IEC 60747-5-5 standard must be applied. This is a rigorous standard specifically designed to qualify optocouplers for reinforced insulation and has a battery of type tests and life tests with isolation withstand verification tests after each one.
- The component can be treated as a semiconductor device. This category of devices has a set of type tests similar to the IEC 60747-5-5 requirements. This approach is used by digital isolators since the testing requirements of the optocoupler standard are specifically tailored to optocoupler structures.

Qualification to and maintenance of a reinforced rating is accomplished in three phases.

1. Materials and dimensions are evaluated, and electrical type testing is conducted. 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. IEC 60747 type testing is summarized in Table 1.

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<td><strong>Materials</strong></td>
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2. After the part has been approved based on its dimensions and type testing, insulation integrity is checked for each device as it is manufactured by a voltage withstand test. In the case of IEC 60747-5-5 or equivalent certifications, a partial discharge insulation quality test is also performed on each device.

3. Periodic audits are conducted by the certifying body to verify material sets and dimensions have not changed and that all assembly line tests are being properly conducted with calibrated equipment. Some of the type tests periodically repeated on a sample basis and reviewed by the auditor.

**Trends in Isolation Requirements**

The previous discussion centered around one of the most widely applied standards. Different standards can have disparate requirements at the component level. It even varies from edition to edition within a single standard. This is becoming less problematic as IEC is trending toward a unified approach. This will likely take a significant amount of time to achieve since the individual standards committees still have significant independence. A unifying trend in application of system level standards is the availability component level standard, such as IEC 60747-5-5. If such a standard exists for a component, it can be applied instead of
the particular requirements of a system level standard. Currently this standard only applies to optocouplers, not other newer digital isolators; however VDE has created a draft standard VDE0884-10 which applies the insulation tests of the IEC 60747-5-5 standard to digital isolators.

Both standards set a high bar for reinforced insulation including surge testing at levels of 10 kV or higher. Very thin insulation layers will not pass this test, and it has proven to be 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 IEC 60747-5-2 standard which can be applied to basic insulation. This is yet another confusing point for designers of isolated systems where it is assumed that an IEC 60747-5 qualification automatically confers reinforced status. The IEC committees are currently working to revise the IEC 60747-5-5 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.

**Conclusion**

Reinforced insulation in data isolators is designed and qualified to provide the protection of double insulation systems while providing the data transmission performance available with a single isolation barrier. Externally, the components have a creepage and clearance requirement that is equivalent to 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 which is verified by test rather than detailed structural requirements allows innovation in insulation technology to be qualified without rewriting the standards for each new technology.

**RESOURCES**

For information and resources on isolation products, visit www.analog.com/iCoupler.

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**ABOUT THE AUTHOR**

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