GLOSSARY OF ISOLATION-RELATED TERMS FOR INTEGRATED CURRENT SENSORS

Current Sensors System Engineering
Allegro MicroSystems

STANDARDS, AGENCIES AND CERTIFICATIONS

Electrical safety standard: A safety standard is a document that sets the requirements for a system or component to meet in order to provide the level of protection needed. For example, IEC-62368 is the safety standard for most consumer electronics and is the standard to which most safety-rated current sensors are certified, because it is considered a broad standard that covers the requirements of many other standards. IEC-62368 replaced IEC-60950 for information systems and IEC-60065 for audio/video.

Certification bodies: Certification bodies create safety standards. The International Electrical Commission (IEC) creates international standards while other bodies create regional standards based on the IEC standard and their own local needs; for example, UL (Underwriters Laboratories, US), VDE (Verband der Elektrotechnik, Germany), and CCC (China Compulsory Certification) created UL-62368, EN-62368, and GB-4943.1 respectively.

Certification agencies: Certification agencies issue certificates of compliance to standards and can be the certification bodies listed above or accredited third party laboratories, such as TUV, CSA, and BSA. IEC creates standards but does not provide certifications.

Safety certification: A safety certification is an assurance by a body or agency that a system or component meets the requirements of a safety standard. This is accomplished by product testing against the standard as well as performing factory inspections to ensure the product is continuing to be manufactured as it was when tested.

CB certification: An IEC certification body report (CB Scheme) is a set of tests performed on a component or system that ensures the component or system would meet the certification requirements of all of the other certification bodies around the world that are part of the scheme. Since regional certification bodies (e.g., UL, VDE, and CCC) apply modified or unique requirements on top of the IEC standard requirements, this testing combined with a regional certification validates its applicability worldwide. Generally, a CB certificate will cover the requirements worldwide and is what Allegro provides on its website when available.

INSULATION RATINGS

Safety-related isolation: It is required to provide safety-rated isolation between a person and any voltages above 71 V_{RMS} or 120 V_{DC}. It can be comprised of basic, supplemental, and reinforced isolation barriers and components.

Galvanic isolation: Galvanic isolation means that the metallic parts of two systems are separated from each other; the insulation used to achieve isolation can be air, plastic, glass, or some other dielectric.

Basic/Single Insulation

Basic insulation: Basic insulation is used in conjunction with an additional redundant insulation system to create a fault-tolerant double insulation system and may be all that is required if there is another insulation system already in place. Basic insulation is allowed to create a fault (the insulation can short), but the system should remain safe. On the other hand, two basic systems may not add up to the requirements of double insulation. Care must be taken when deciding the architecture of a final system. The LC and LH packages are examples of Allegro packages with basic insulation (refer to Figure 1). See the Allegro website for a more extensive list of Allegro packages and devices.

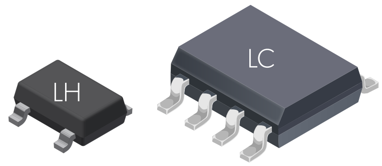

Figure 1: Allegro packages with basic insulation

Single protection: Basic insulation and single protection give a similar level of protection from dangerous voltages. They are not the same because the terms are used in two fundamentally different systems of standards. Basic insulation is a term from the IEC system of standards and has implications for creating double insulation in an IEC certified system. Single insulation is a term from the UL system of standards and says that the insulation is adequate for use up to 600 V_{RMS} working voltage, which is sufficient for most systems.

Reinforced/Double Insulation

Any time a person must interact with a system that contains dangerous voltages including line voltages, a system must have double insulation. Double insulation may be a single layer of reinforced insulation or multiple layers of other grades. Exceptions exist for trained personnel.

Double insulation: Double insulation is the application of a second redundant isolation system to a basic insulation system. Double insulation is a general requirement for personnel safety and is a concept from IEC standards.

Reinforced insulation: Reinforced insulation is a single insulation system that has been tested to provide the same level of protection as double insulation. Reinforced insulation is used for many components where it is not practical to create two layers of insulation with two separate components. The LZ, MA, and MC are examples of Allegro packages with reinforced insulation (refer to Figure 2). See the Allegro website for a more extensive list of Allegro packages and devices.

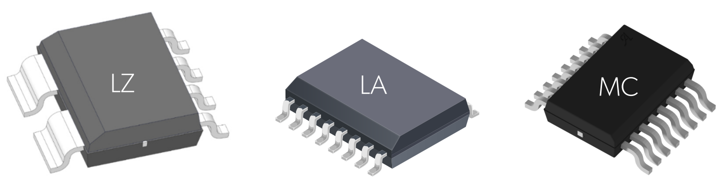

Figure 2: Allegro packages with reinforced insulation

UL double protection: This is narrowly required for audio and video equipment in the US for use up to 250 V_{RMS} and is not generally applicable to other equipment.

Functional Insulation

Functional insulation is good enough for the component to function as intended but does not carry any safety rating and cannot be used to build basic or double insulation systems. It is recommended that functional insulation meet the same creepage and clearance as basic insulation, but it is not required.

Supplemental Insulation

Supplemental insulation must be added to (supplement) basic insulation to meet the requirements for double insulation. These requirements can be different than simply requiring two layers of basic insulation.

MECHANICAL PROPERTIES

Creepage (D_{CR}): Creepage is the minimum distance along the surface of the package between the IP loop and the other pins. The path may not count any surface features less than a fixed size (1 mm for pollution degree 2) and cannot count distance across unconnected metal which could act to short out the distance. The shortest distance from input to output on a sensor is typically around the end of the package; the shortest path intersects a piece of floating metal used in the production process called a tie bar, which must be jumped over (refer to Figure 3).

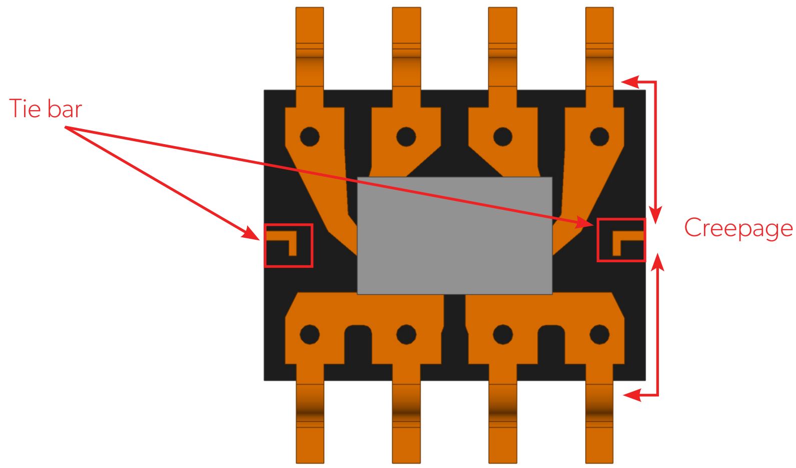

Figure 3: Creepage path in JEDEC packages

Clearance (D_{CL}): Clearance is the minimum distance through air between the IP loop and the I/O power pins (refer to Figure 4). It may or may not be line-of-sight distance since electric fields and sparks are able to go around corners. It may or may not be the same path as the creepage, but for the case of JEDEC packages, it is typically the same path. Clearance is used to determine the maximum voltage that can be put across the body of a part before the air can break down and cause a spark. Generally, the maximum voltage in an application is determined by the overvoltage category, therefore clearance will limit the overvoltage for a part.

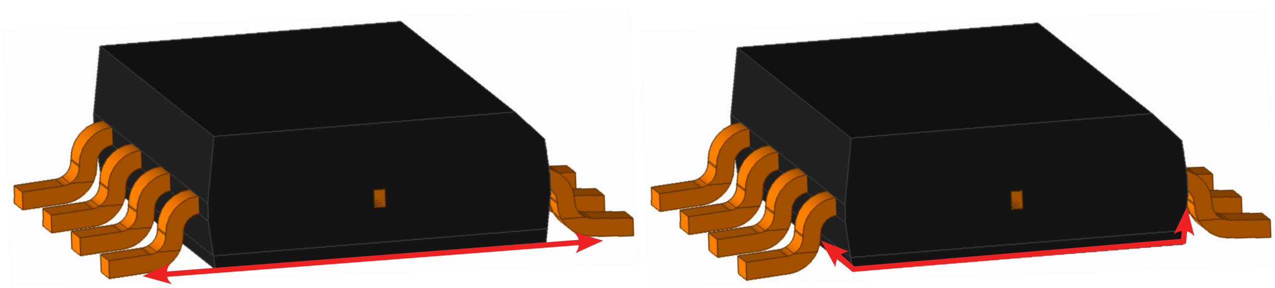

Figure 4: Clearance path in JEDEC packages

Distance through insulation (DTI): DTI is the minimum distance through the internal insulation between the IP loop and the die (see Figure 5). The standard requires either a minimum DTI or extra testing to verify that the insulation system is adequate for the ratings. Allegro current sensor insulation undergoes extensive high-voltage testing to meet the requirements.

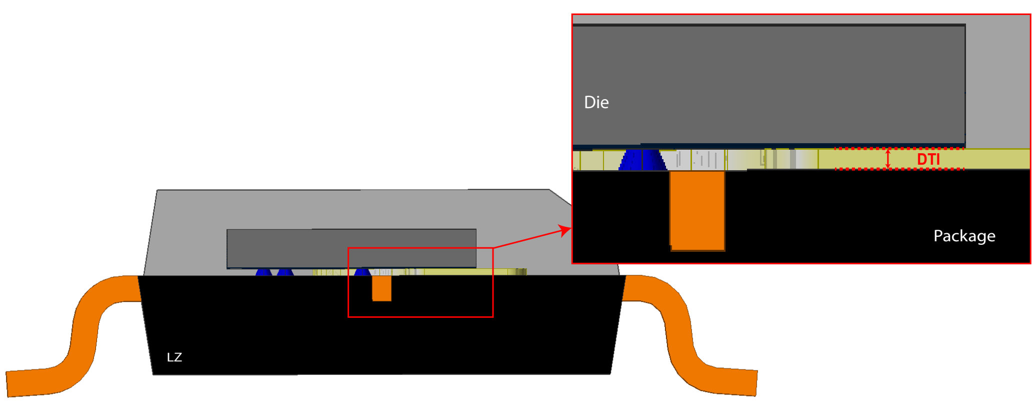

Figure 5: Distance through insulation (DTI)

Comparative tracking index (CTI)/material group: CTI is a measure of the resistance of a material to formation of conductive carbon tracks and erosion depth due to constant electrical fields. This test drips nitric acid on the material then applies a voltage through electrodes placed on the material and then measures the surface etch depth when complete. If the etch depth is <0.1 mm, then it passes that CTI voltage level (refer to Table 1). Most Allegro packages use Material Group II mold compound.

Table 1: Relation of CTI to Material Group

CTI [V]	Definition
>600	I
400-599	II
175-399	IIIa
100-174	IIIb

Pollution degree: Pollution, with regards to isolation, means the degree that conductive material can accumulate on the surfaces of components. Conductive pollution accelerates the formation of carbon tracks by concentrating fields along the surfaces. If there is more pollution, more creepage is required for the same working voltage. Pollution is characterized by degree, with one being the cleanest, three being the dirtiest (refer to Table 2). Most electronic enclosures are expected to be pollution degree two. A way to reduce pollution is to add conformal coating to a PCB to prevent material buildup along the surface of the package. This allows the pollution degree to be moved to degree one, even in dirty environments, thus allowing smaller creepages (and smaller devices) in the application. Keep in mind that conformal coating is not considered insulation and does not affect the required clearance.

Table 2: Relation of Pollution Degrees to Environment

Pollution Degree	Definition
1	Clean and dry application, non-conducting dust
2	Occasional conductive dust due to moisture
3	Conductive pollution, can be moisture activated

VOLTAGE LEVELS

Working voltage for basic isolation (V_{WVBI}): Working voltage for basic isolation is the voltage at which the part can operate in accordance with the manufacturer and certification body for a specific amount of time (generally >20 years) without having insulation degradation to a dangerous point. This metric is usually met by requiring a certain amount of package creepage, according to the tables in the standards documents. The working voltage is limited by how dirty the environment is (pollution degree) and the properties of the surface of the device (material group). Having a clean environment and a resistant outer shell (like conformal coating) can allow much more voltage for a given amount of creepage. Allegro current sensors internally use thin film materials that are designed and tested to exceed the working voltage limited by creepage.

Working voltage for reinforced isolation (V_{WVRI}): Reinforced insulation is like double insulation but in a single system. The allowed working voltage for reinforced isolation is half of that for basic.

Working voltage wave forms: The standards assume that the driving voltage is derived from the AC mains, so the working voltage is indexed to the AC_{RMS} voltage. In some systems, the working voltage can be anything between DC and high-frequency square waves. The standards assume that high frequency starts at 30 kHz and there are recommended derating values for using insulation above this frequency (refer to IEC60664-4). DC is considered less damaging than AC since charge does not move much along surfaces or inside solid insulation; DC ratings are usually considered the peak of the AC working voltage.

Working voltage specifications (V_{IORM} and V_{IOWM}): The voltage across a barrier can be any arbitrary wave form. Anything that is repetitive is considered a working voltage. This creates difficulty describing the working voltage in a simple inclusive manner. The standards consider both sinusoidal and non-sinusoidal waveforms. For sinusoidal voltages, such as the mains voltage, the working voltage is the RMS value of the sine wave (V_{IOWM}, voltage input to output working mains). For any other waveform, the only parameter that makes sense is the peak voltage since it could be a square wave, a DC voltage, or an arbitrary waveform

(V_{IORM}, voltage input to output repetitive mains). When certification agencies test these voltages, it is typically with a pure sine wave, so typically the ratings for V_{IOWM} and V_{IORM} are usually related by a factor of √2.

Dielectric withstand (V_{ISO}): Dielectric withstand is the minimum voltage in which the package insulation is guaranteed not to break down when it is applied for one minute. This is specified as an AC_{RMS} voltage, and the test voltage applied is a pure sine wave. It carries two important pieces of information:

1. Insulation will not break down due to partial discharge during that one minute.
2. Insulation will not break down at the peak of the sine wave. The peak of the sine wave is long compared to the peak voltages in an impulse test, so it is considered a more conservative measure of peak voltage.

V_{ISO} is applicable to designs that experience power line transients called temporary over voltages. Temporary overvoltages are due to interferences of the power coming into a building. This may include something like dropping a high-voltage line across a lower voltage line during service.

Impulse withstand voltage ($V_{IMPULSE}$): Impulse withstand voltage is a measure of the maximum voltage that a part can withstand when hit by a lightning surge pulse. Impulse withstand voltage applies to systems that are connected to the power grid. In most cases, it is specified as the peak of the sinusoidal one-minute overvoltage rating (V_{ISO}); however, it can be higher than it in some cases. The impulse is a 1.2 × 50 µs pulse, typical of a lightning strike, but it has a much smaller duration. Typically, a part can withstand 1.3 times higher than the one minute withstand peak. It is not usually specified in the certifications, so the more conservative peak of the overvoltage is usually specified. This is the primary metric that sets clearance distances for mains powered systems.

Partial discharge: Partial discharge is a wear-out mechanism that occurs whenever there is interface between high and low breakdown media. The discharges occur in solid insulation if there are voids or discontinuities in insulation materials such as layers of mold compound and polyimide cemented together. Voids can be treated like a small capacitor in the middle of the solid insulation filled with air, as shown in Figure 6. Since the air has a much lower permittivity than the mold compound around it, its capacitance is lower. In a set of series capacitors, the lower capacitance will have higher voltage across it. The void has higher electric fields than the surrounding solid insulation. Voids are filled with a significantly lower breakdown material: air. This leads the air inside of a void to breakdown and creates a plasma discharge which enlarges the void. This eventually extends the void through the remaining solid insulation and creates a low-resistance path through the insulation which the causes breakdown of the insulating material.

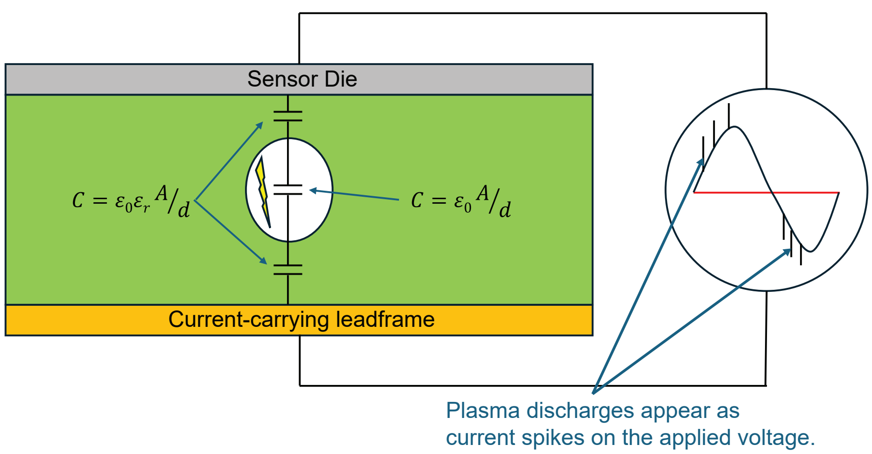

Figure 6: Partial discharge in voids

Partial discharge can be detected with a straightforward electrical test. The plasma discharges show up as current spikes on the applied voltage. Partial discharge will happen in all types of insulation if the voltage is high enough. If partial discharge is present close to the working voltage, it is an indicator of potential low lifetime devices. Many standards now require partial discharge testing be performed on the assembly line for reinforced insulation devices as part of the isolation testing.

Overvoltage category: Overvoltage category is used to determine the magnitude of a lightning impulse transient voltage ($V_{IMPULSE}$) that a piece of equipment may see when it is tied to the power grid. The more removed an application is from the power grid, the lower the overvoltage category, and the lower the transient expected at that point (refer to Table 3).

Table 3: Overvoltage Categories

Overvoltage Category	Definition
I	Highly protected from the power grid
II	Powered through building wiring (plugged into an outlet)
III	Directly wired into building power distribution
IV	Connected at the source of building power

For example, equipment using a 240 V mains installed outside of a building is overvoltage category IV and would need to be designed for 6000 V_{PK} lightning strike, but equipment that plugs into an outlet inside a building is overvoltage category II and would only need to be designed to withstand 2500 V_{PK}.

Revision History

Number	Date	Description
–	May 7, 2024	Initial release