INTRODUCTION TO ISOLATION CONCEPTS IN ALLEGRO INTEGRATED CURRENT SENSORS

Current Sensors System Engineering
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INTRODUCTION

Isolation in integrated current sensor ICs refers to the separation between the sensor's input and output, preventing direct electrical conduction. This separation ensures that high voltages on one side do not directly affect the low-voltage side, providing a barrier that protects sensitive components and circuits from potentially damaging high-voltage levels. This article discusses what isolation in integrated current sensor ICs is, why it is crucial, and the value it brings to different applications.

WHAT IS INSULATION? WHAT IS ISOLATION?

Two concepts that are used interchangeably in many cases are insulation and isolation. They are related but there is a difference.

Insulation refers to the use of materials that prevent the flow of electric current. These materials, known as insulators, have high resistance to electrical conductivity and are used to cover or encase electrical conductors to prevent accidental contact, short circuits, and electrical shocks.

Isolation, on the other hand, involves separating different parts of an electrical system to prevent direct electrical connection. 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.

Figure 1: Insulation Between Primary (IP) and Secondary Sides (Input/Output Signal Pins) of the LZ Package through Insulating Barriers

WHAT PROBLEM DOES USING INSULATION SOLVE?

There are two primary reasons why isolation is needed:

1. **Safety**: In applications involving high voltages, isolation is vital to protect users and maintenance personnel from electric shocks. For instance, in industrial automation and electric vehicles, where high voltages are prevalent, isolation ensures that the control systems and human interfaces are shielded from these hazardous voltages. If a person needs to interact with a system, the system must provide robust separation of the parts that will be touched from dangerous voltages in the equipment.
2. **Functionality**:
   A. **System Protection**: Isolation helps in protecting low-voltage control circuits from high-voltage transients and surges. This is particularly important in power management systems and renewable energy applications, where voltage fluctuations are common. This is also important for control elements and monitoring elements that need to communicate between parts of the circuit that operate at different potentials or do not share a common ground reference.
   B. **Compliance with Standards**: Many industries have stringent safety and performance standards. Isolation in current sensor ICs helps meet these regulations, ensuring product reliability and market acceptance.
   C. **Signal Integrity**: Isolation minimizes electrical noise and interference from high-power circuits, ensuring that the sensor's output remains accurate and reliable.

WHEN IS INSULATION REQUIRED?

Isolation is required any time a person must interact with equipment that has high voltages, including line voltage. The isolation protects against two things:

1. Long-term wear-out of materials over years of use at the maximum working voltage of the application.
2. Instantaneous breakdown of the separation due to very high transients from environmental or internal sources.

Modern safety standards require two independent isolation systems, or one specially tested insulation system between any circuit greater than about 50 V that can be accessed by a person. This is to ensure that, if a circuit is touched, there is not sufficient voltage and current available to pass through the person to ground to cause hazardous electrical shock to the operator.

Isolation is useful but not required in systems when galvanic connections are impractical or problematic. In most nonsafety-related applications, there are direct solutions that work, but these come with the cost of performance, efficiency, or control.

Isolation is also needed in control systems when voltages become so high that silicon junction isolation is not possible. For example, in solar arrays or battery monitors, if the control system must monitor currents, a Hall sensor offers a practical way to do that in a small package. This isolation can be for functionality or safety depending on how the entire safety system is designed, but isolation is still required.

Isolation can block noise, high voltage, or unintended current paths. When isolation is required, the insulation system must be designed to handle the operating voltage at a minimum and must not fail when transients from inside and outside of the system are applied. The component and entire system must be designed to operate for years at its intended rating and for minutes to microseconds for transients.

WHAT ARE THE METHODS OF ISOLATION?

Isolation can be achieved in many ways. The following examples are all used in systems for safety and functionality:

1. **Basic dielectrics**: Plastic, glass, and ceramic dielectrics can be used effectively in isolation systems. They can be simple barriers, like boxes and covers, or they can be combined with electric, magnetic, or optical fields to transmit signals and power through them without direct electrical connection.
2. **Transformers**: Transformers use electromagnetic induction to transfer energy between two or more windings. By having separate primary and secondary windings, transformers provide galvanic isolation while allowing AC signals and power to pass through.
3. **Capacitors**: Capacitive isolation uses capacitors to pass high-frequency signals across an isolation barrier while blocking DC and low-frequency AC signals. The capacitors provide a physical barrier that prevents direct current flow and large voltages.
4. **Resistors**: If sufficiently high values of resistance (usually series redundant for safety reasons) are between dangerous voltages and people, the current can be limited to a point that it is not dangerous for an operator.
5. **Hall-effect sensors**: Hall-effect sensors, including Allegro integrated current sensor ICs, offer a wide range of benefits pertaining to insolation. The primary current-carrying conductor is physically separate from the Hall sensor's measurement circuitry. The magnetic field coupling ensures there is no direct electrical connection between the high-current path and the low-voltage signal path.
6. **Optical:** Optocouplers (or optoisolators) use light to transmit electrical signals across an isolation barrier. An LED and a photodetector are housed within the same package but are separated by an insulating layer. The LED converts the electrical input signal into light, which is then detected by the photodetector and converted back into an electrical signal on the output side.
7. **Grounded conductive equipment chassis**: With an independent connection to a safety ground, grounded conductive equipment chassis are recognized as safety isolation.

All of these methods are used in modern electrical systems for safety, control, and feedback. The method chosen depends on what must be stopped at the insulation barrier, what is required to cross the barrier, and what level of safety is required.

LEVELS OF ISOLATION

There are levels of isolation that depend on what is being protected and the damage caused by a fault. When choosing an isolation component, the architecture of the entire system determines the required level of isolation for each barrier. Choosing where to put system isolation barriers can dramatically affect the complexity and cost of the full system. For additional information about the levels of isolation, and other isolation related concepts, refer to the Glossary of Isolation-Related Terms for Integrated Current Sensors [1] on the Allegro website.

THE IMPORTANCE OF ISOLATION IN APPLICATION

Electric Vehicles (EVs): EVs operate at high voltages for battery management and motor control systems. Isolated current sensors ensure the safety and efficiency of these systems by preventing high-voltage faults from reaching vehicle control units and passengers.

Renewable Energy: Solar inverters and wind turbine controllers use isolation to protect control electronics from the high voltages generated. This is crucial for the longevity and reliability of renewable energy systems.

Consumer Electronics: In everyday electronics like smartphones and laptops, isolation helps protect sensitive components from power surges, enhancing overall device reliability and user safety.

CONCLUSION

Isolation in integrated current sensor ICs is a fundamental feature that enhances safety and functionality of various applications. By providing a reliable barrier between high- and low-voltage circuits, isolation not only ensures compliance with safety standards but also improves the accuracy and longevity of electronic systems.

[1] https://www.allegromicro.com/-/media/files/application-notes/an296307-current-sensor-isolation-glossary.pdf?sc_lang=en

Revision History

Number	Date	Description
–	June 14, 2024	Initial release