Integrating Digital Isolators in Smart Home Devices

By George Chen, Product Marketing Manager and
Tomas Hudson, Applications Engineer at MPS

Introduction

Smart home devices are becoming increasingly popular with many households adopting smart thermostats, lighting systems, security systems, and home entertainment systems. These devices provide automation and wireless control of household functions, allowing users to monitor and control their homes from a mobile app or digital interface. Despite the advantages of smart home devices, users also face an increased risk of electrical malfunctions that may result in electric shock, fire, or direct damage to the device.

This article discusses the importance of integrating digital isolators in smart home devices to ensure safety and reliability.

Definition of a Digital Isolator

A digital isolator is an electronic device that provides electrical isolation between two circuits while allowing digital signals to pass between the circuits. By using electromagnetic or capacitive coupling, the digital isolator transmits data across the isolation barrier without requiring a direct electrical connection.

Digital isolators are often used in applications where electrical isolation is necessary to protect sensitive circuitry from high voltages, noise, or other hazards. They can be used in power supplies, motor control, medical devices, industrial automation, and other applications where safety and reliability are critical. Figure 1 shows a capacitive isolation diagram.

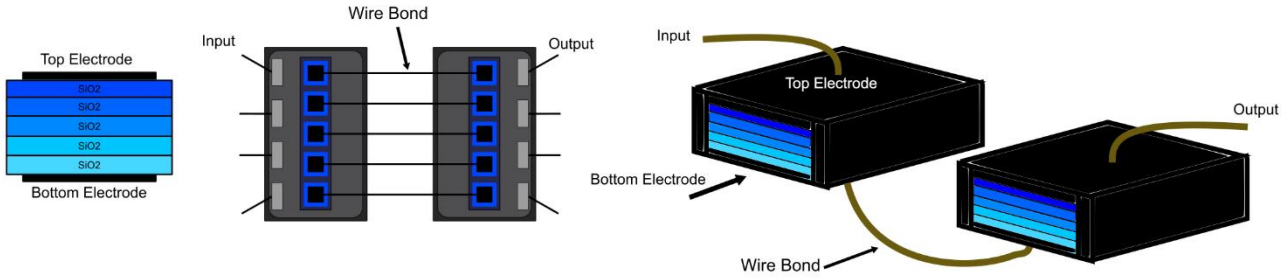

Figure 1: Capacitive Isolation Diagram

Understanding Isolation Rating

The required isolation voltage is an important consideration when choosing a digital isolator, since it impacts the total solution cost. Isolators generally have one of two isolation classifications: basic isolation or reinforced isolation.

- Basic isolation: This provides sufficient insulation material to protect a person or device from electrical harm; however, the risk of electrical malfunctions is still present if the isolation barrier is broken. Some devices use two layers of basic isolation as a protective measure in the case of the first layer breaking; this is called double isolation.
- Reinforced isolation: This is equivalent to dual basic isolation and is implemented by strengthening the isolation barrier to decrease the chances of the barrier breaking compared to basic isolation.

IEC 62368-1 provides a more comprehensive specification for the isolation voltage. Basic isolation is defined as having a minimum creepage distance of 3.2mm, with the capacity to withstand 2,500V_{RMS} for one minute and 3kV_{RMS} for one second. Reinforced isolation requires a minimum creepage of 6.4mm and the capacity to withstand a minimum 5kV_{RMS} for one minute and 6kV_{RMS} for one second.

Figure 2 shows the three types of isolation: basic isolation, double isolation, and reinforced isolation.

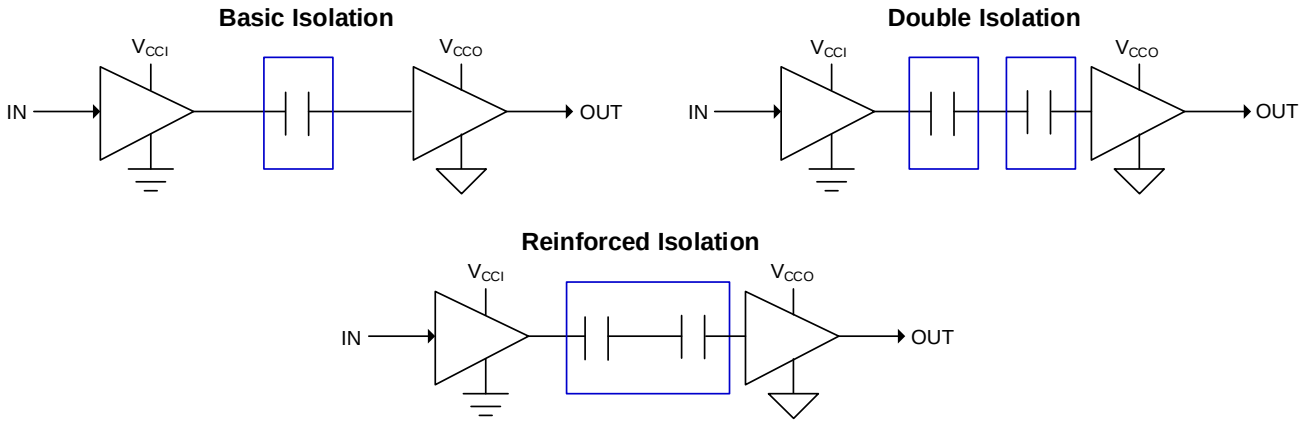

Figure 2: Basic, Double, and Reinforced Isolation

Creepage distance is the shortest distance between two conductive elements on opposite sides of the isolation barrier, and is measured along the isolation surface. Clearance distance is a common parameter that is similar to creepage distance, but is measured along a direct path through the air. As a result, creepage distance is always equal to or greater than the clearance distance, but both are heavily dependent on the IC's package structure. Parameters such as pin-to-pin distance and body width have a strong correlation with the isolation voltage for isolated components. Wider pin-to-pin spacing and packages have larger isolation voltages, but they also take up more board space and increase the overall system cost.

Depending on the system design and isolation voltage requirements, different isolation ratings are available, typically corresponding to the package type. Small outline integrated circuit (SOIC) packages often have 1.27mm pin-to-pin spacing and are available in narrow body (3.9mm package width) or wide body (7.5mm package width) formats. The wide-body package is commonly used for meeting reinforced $5kV_{RMS}$ requirements, while the narrow-body package is used in applications where the maximum withstand isolation voltage is $3kV_{RMS}$. In some cases, extra wide-body packages are used with >14.5mm creepage for certain 800V+ systems to meet the creepage and clearance requirements.

Figure 3 shows the clearance and creepage distances in an SOIC package.

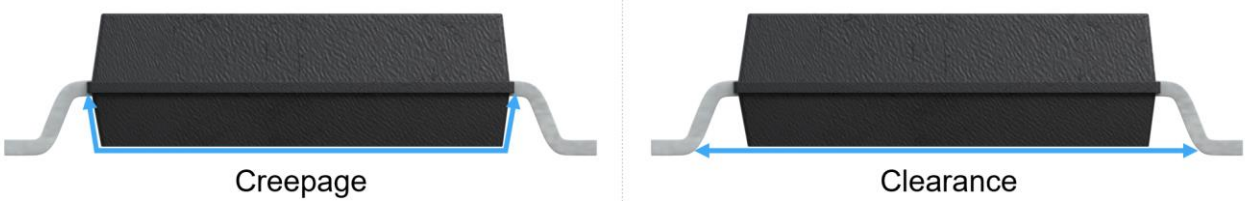

Figure 3: Clearance and Creepage Distances in an SOIC Package

Safety Regulations for Digital Isolators

Safety certifications such as UL 1577, VDE, CSA, and CQC play a pivotal role in ensuring the reliability and safety of digital isolators within various electronic systems. These certifications are described below:

- UL 1577: This certification was established by Underwriters Laboratories and sets stringent standards to evaluate the insulation and isolation performance of digital isolators. Factors including voltage isolation, leakage current, and insulation resistance are examined to ensure compliance with safety requirements.
- VDE: This certification is predominantly recognized in Europe and verifies the quality and safety of electrical products, including digital isolators, through rigorous testing methodologies. VDE certification indicates that the isolators meet the specified safety criteria and conform to European safety standards, ensuring their reliability and functionality in diverse applications.
- Canadian Standards Association (CSA): This certification guarantees that digital isolators adhere to Canadian safety regulations and standards, ensuring their reliability and safety in electronic systems deployed across Canada.
- China Quality Certification (CQC): The China Quality Certification GB 4943.1-2022 standard safety certificate emphasizes conformity assessment and quality control in audio/video, information, and communication technology equipment.

These certifications collectively provide manufacturers, engineers, and consumers with the confidence that digital isolators have undergone comprehensive testing and comply with stringent safety measures, contributing to the overall safety and reliability of the electronic devices and systems in which they are utilized across global markets.

Features of Digital Isolators vs. Optocouplers

Traditionally, the isolated transfer of digital signals has been carried out using optocouplers. These devices harness light to transfer signals through the isolation barrier, using an LED and a photosensitive device (typically a phototransistor). The signal on one side of the isolation barrier turns the LED on and off. When the photons emitted by the LED impact the phototransistor's base-collector junction, a current is formed in the base and becomes amplified by the transistor's current gain, transmitting the same digital signal on the opposite side of the isolation barrier.

Digital isolators provide four key features that make them better suited for smart home devices than optocouplers:

1. Low-power consumption: Digital isolators do not need to supply a light source, and instead use more efficient channels to transfer the signal. This makes digital isolators ideal for battery-powered devices (e.g. smart thermostats or security sensors).
2. High-speed data transmission: Phototransistors have long response times, which limits the bandwidth of optical isolators. Digital isolators can transfer signals much quicker, enabling fast and reliable communication between smart home devices and control systems.
3. Low electromagnetic interference (EMI): EMI can interfere with electronic devices in the home. By adopting capacitive isolation technology, digital isolators are more immune to EMI.
4. Wide operating temperature range: This makes digital isolators suitable for a variety of robust environments, including outdoor applications.

Types of Digital Isolation

There are two types of digital isolation that can be implemented: magnetic isolation and capacitive isolation. Magnetic isolation relies on a transformer to transmit signals, while capacitive isolation uses a capacitor to transmit signals across the isolator, which creates an electrical barrier. This barrier prevents direct current flow and provides isolation between the input and output circuits.

Capacitive isolation is the most commonly used method due to several advantages:

- Higher data rates: Compared to magnetic isolation, the higher data rates of capacitive isolation can be used for applications that require fast and reliable communication.
- Lower power consumption: Compared to magnetic isolation or optical isolation, capacitive isolation typically consumes less power, making it a more energy-efficient choice for battery-powered devices.
- Smaller size: Capacitive isolators are typically smaller than magnetic isolators or optical isolators, which eases their integration into small electronic devices.
- Lower cost: Capacitive isolators are typically less expensive than optical isolators, which rely on expensive optoelectronic components (e.g. LEDs and photodiodes).
- Higher immunity to EMI: Compared to magnetic isolation, capacitive isolation is less susceptible to EMI, resulting in capacitive isolation being a more reliable choice in noisy environments.

Figure 4 shows a comparison of traditional optical isolation compared to magnetic and capacitive isolation.

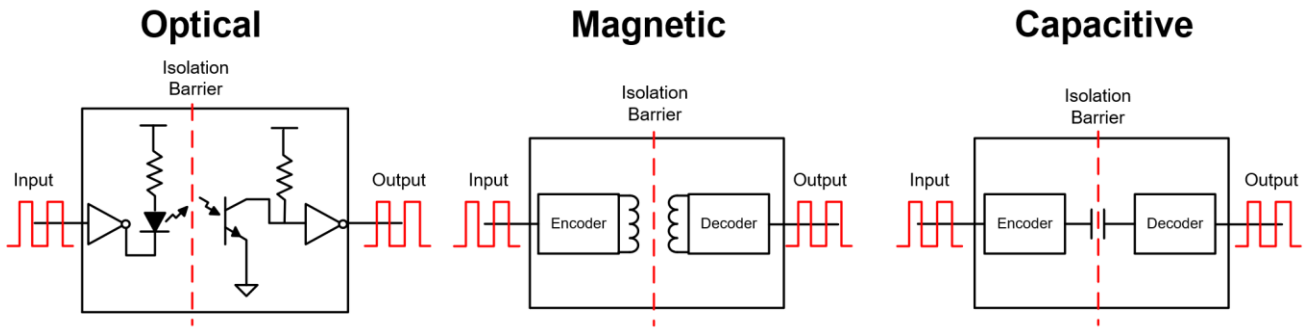

Figure 4: Optical, Magnetic, and Capacitive Isolation

The type of digital isolation used depends on the application specifications, such as the required data rate, temperature range, or the level of electrical noise in the environment. Figure 5 shows a block diagram of a smart refrigerator, which requires three digital isolators.

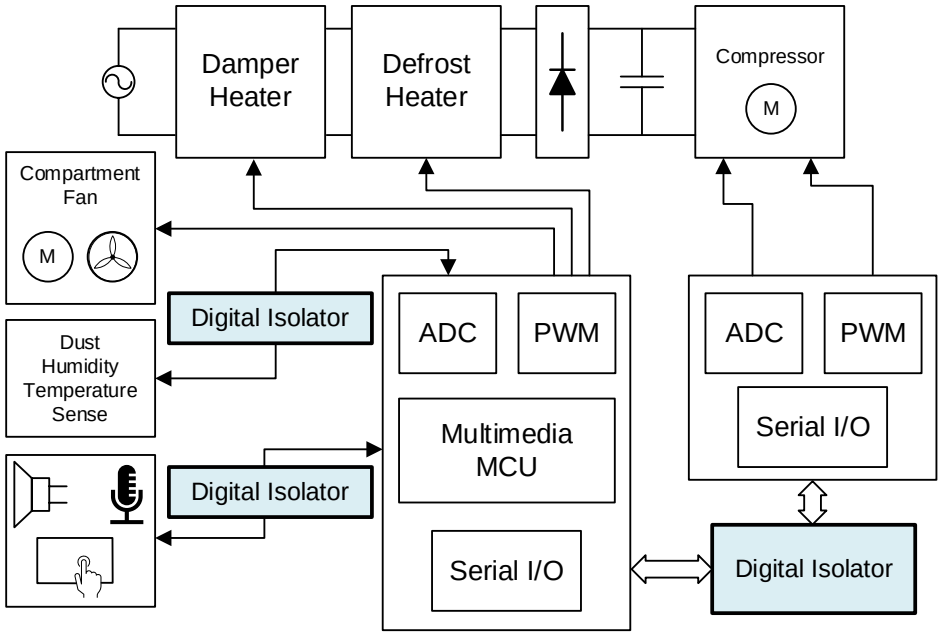

Figure 5: Smart Refrigerator Block Diagram

Introducing the MP279xx Family

MPS offers a selection of high-performing digital isolators with the MP279xx family, which is comprised of the MP27922, MP27931, MP27933, MP27940, MP27942, MP27933, and the MP27960. The MP279xx family can be integrated in smart home devices and includes two, four and six-channel digital isolators, with multiple configurations of forward and reverse channels. The last two digits of the part number represent the number of forward and reverse channels. For example, the MP27922 is a four-channel digital isolator with two forward channels and two reverse channels.

The MP279xx family of digital isolators is optimized to replace traditional optocouplers, with advantages including:

- 5000V_{RMS} isolation rating per UL 1577, which is ideal for robust applications
- Smaller size, lower power consumption, and more reliable operation compared to traditional optocoupler isolators
- Maintains performance across a wide temperature range while minimizing power consumption
- Supports a high data rate of up to 150Mbps

With capacitive isolation technology, the MP279xx family supports an insulation voltage rating up to 5kV_{RMS}. These devices include safety-related certifications according to UL 1577, VDE, CSA, and CQC. In addition, they provide a Schmitt trigger input and isolated encoding/decoding for high electromagnetic immunity in noisy environments. A high/low selectable failsafe output is provided to support a fixed output, even if the input signal power fails.

Applications of Digital Isolators in Smart Home Devices

Providing electrical isolation between the control system and appliance circuitry is crucial to ensure user safety as well as to protect smart home devices from outside interference or hacking. Some examples of smart home devices that integrate digital isolators include smart lighting systems, smart security systems, smart thermostats, and smart home entertainment systems, which are described in further detail below.

Smart Lighting Systems

In smart lighting systems, digital isolators provide isolation between the control system and the high-voltage lighting circuitry. This prevents the user from coming into contact with high-voltage electrical signals.

Smart Security Systems

In smart home security systems, digital isolators provide isolation between the control system and the sensors or cameras. Isolating the sensitive control circuitry from the outside world addresses concerns with outside interference to the security system.

Smart Thermostats

In smart thermostats, digital isolators provide isolation between the control system and the heating or cooling circuits. This minimizes damage to the control system from high-voltage or high-current signals in the heating or cooling circuits.

Smart Home Entertainment Systems

In smart home entertainment systems (e.g. smart speakers), digital isolators provide isolation between the control system and the audio or video circuits. This achieves high-quality playback by preventing interference or noise in the audio or video signals.

Conclusion

Digital isolators are an important component of many electronic devices, including smart home devices, that provide a safe and efficient method for transmitting signals between isolated circuits. They eliminate physical connections and the accompanying safety hazards as well as interferences with performance. While there are several types of digital isolators available, the MP279xx family provides robust solutions using capacitive isolation technology, which offers several key advantages over other forms of isolation including higher data rates, lower power consumption, smaller size, lower cost, and better immunity to EMI. For more information, explore MPS's broad portfolio of isolation solutions.