Application Note

NOVOSENSE

Isolation Failure Modes in Capacitive Isolated Devices

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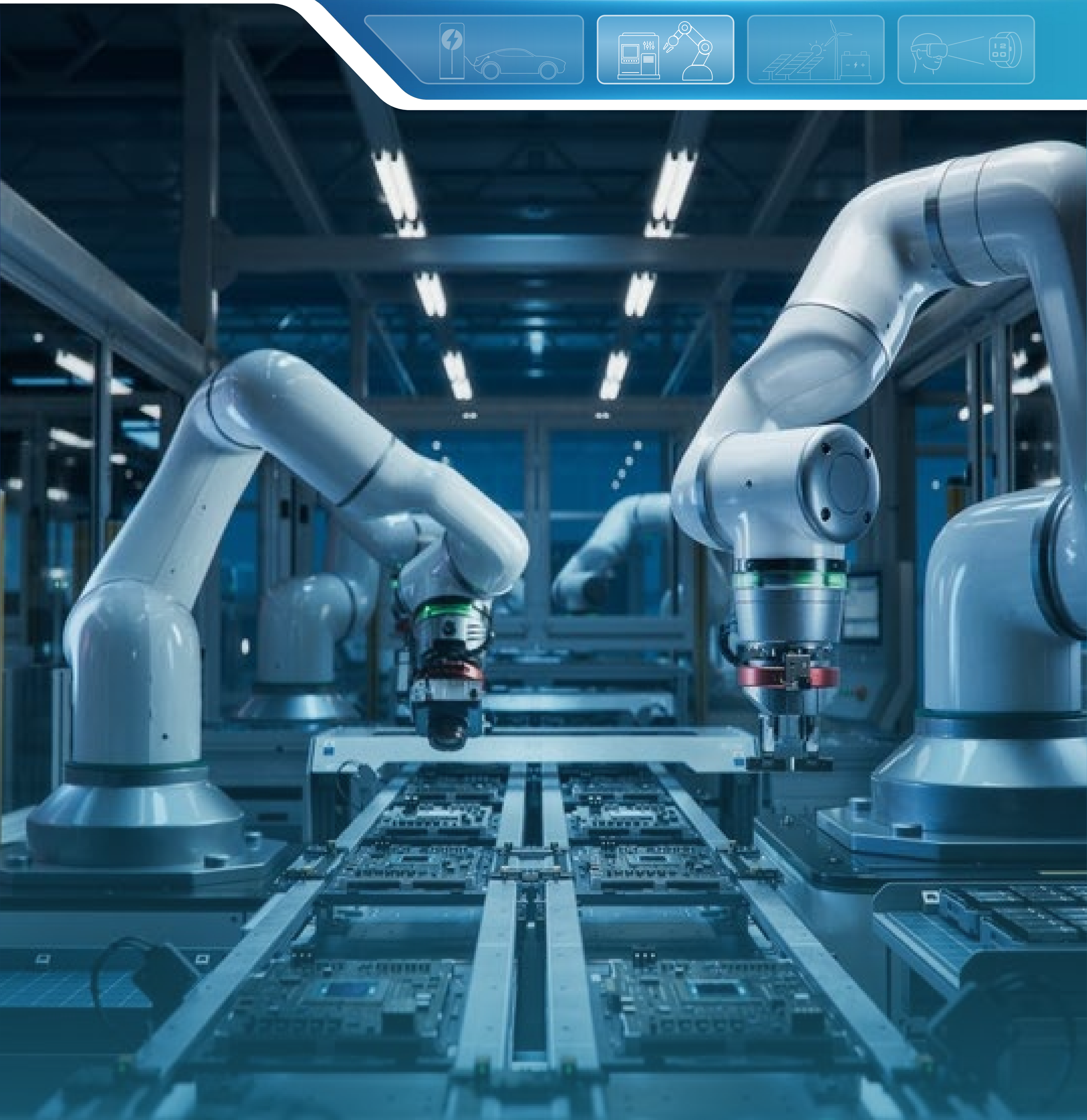

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ABSTRACT

Capacitive isolated products (such as isolators, isolated amplifiers, isolated power products, etc) are devices that separate output from input and avoid unwanted direct and transient current between two systems, while signal and power can be transmit correctly. For example, isolators can shift signals referenced to different levels, protect the sensitive control module from high voltage and minimize the fault coverage when an electrical malfunction occurs.

For these isolated products, a failure of the isolation barrier can result in system malfunction and a potential operator safety hazard. Here we discuss the mechanism of isolation failure modes and the recommended application of capacitive isolated devices to avoid isolation failure.

INDEX

1.Mechanism of Isolation Failure Modes

1.1.Structure of Capacitive Isolators

Figure 1 shows the structure of a serious-capacitor isolators. There are two isolation capacitors in series respectively on different dies, and SiO2 isolation dielectric with the thickness of more than 28 μm can achieve reinforced insulation. SiO2 has the advantages of high reliability and dielectric strength compared with other insulator materials, such as epoxies, Polyimide, etc.

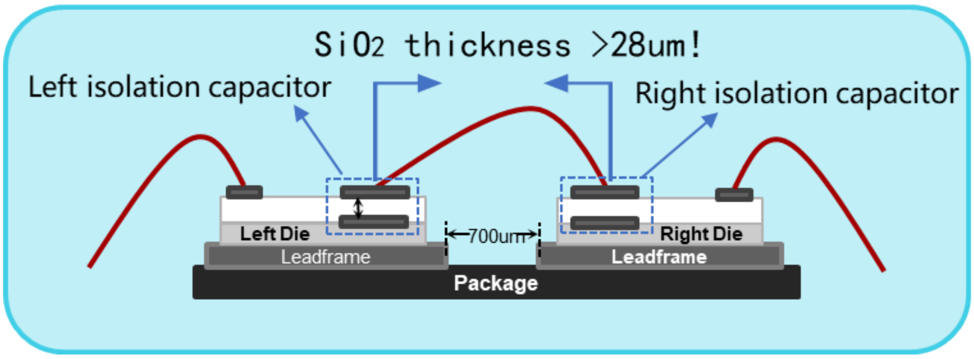

Figure 1. Structure of a serious-capacitor isolator

According to the structure of capacitive isolators, two possible failure modes are discussed in this paper for users to understand the causes of isolation failure.

1.2.Failure Mode 1: Overvoltage across the Isolation Barriers

The first failure mode is overvoltage across the isolation barriers shown in Figure 2(a). The failure occurs when the voltage applied to the isolated sides exceeds the isolation withstand voltage. Figure 2(b) shows photographs of the first isolation failure mode.

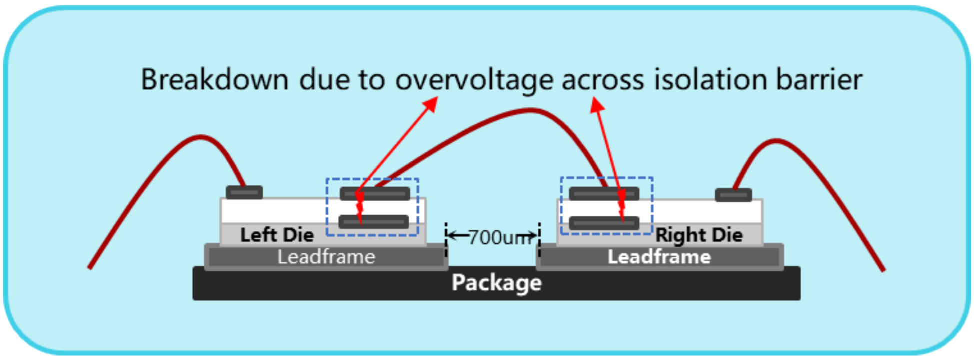

Figure 2(a) Overvoltage across isolation barrier

For destructive test, the sample NSI1300D25 is tested at insulation voltage VISO =13kVrms per UL1577. The isolation capacitors are damaged and shorted out due to electrical overstress. To avoid this failure, it is suggested to choose isolated products that meet the system voltage level and allow sufficient margin. The NOVOSENSE capacitive isolated products provides industry leading isolation performance, which help users furtherly reduce the risk of failure mode 1 because of higher margin.

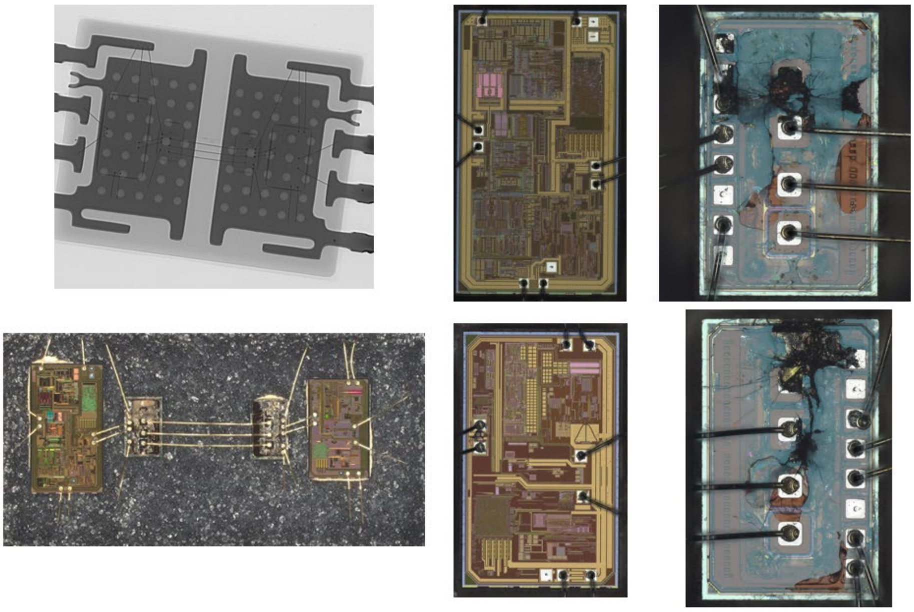

Figure 2(b). Photographs of the first isolation failure mode

The NOVOSENSE capacitive isolators provides industry leading isolation performance, which help users reduce the risk of failure mode 1 further because of higher margin.

1.3.Failure Mode 2: High Power on One Side of the Isolator

The second failure mode is high power on one side of the isolator shown in Figure3(a). Within safety limits, which are defined as the boundary range of the operating conditions, insulation performance can be maintained even if function is lost. The second failure mode happens when the isolator operates beyond the safety limits, such as short circuit, excessive electrostatic discharge (ESD) and power transistor breakdown, etc. and the circuits suffer severe structural damage. With abnormally high voltage and high current in the isolator for a period of time, the circuits and components integrated in the same die with the isolation capacitors are damaged from the excessive heat stress, causing damage to the isolation dielectric.
The failure influences the isolation performance of the damaged die. In the NOVOSENSE capacitive isolation technology, the reinforced isolation is realized by two separate capacitors in serious placed on two separate dies. When the second failure mode occurs, one side of the isolation capacitor may be damaged while the other side is still intact, providing basic isolation.
Figure 3(b) shows the photograph of the second isolation failure mode. The sample is NSI8131 after VDD to GND electrical overstress (EOS) test. The isolation capacitor of the left die is influenced by the surrounding damaged circuits. The damaged sample still pass 3kVrms insulation voltage per UL1577. In this occasion, an operator safety hazard can still be avoided.

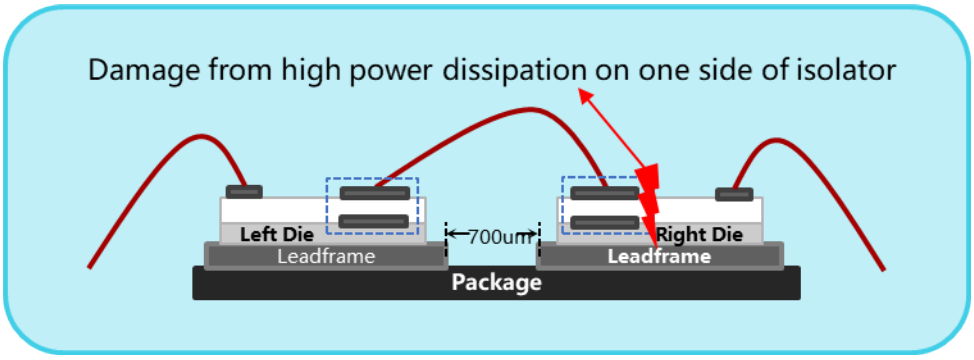

Figure 3(a) High power on one side of the isolator

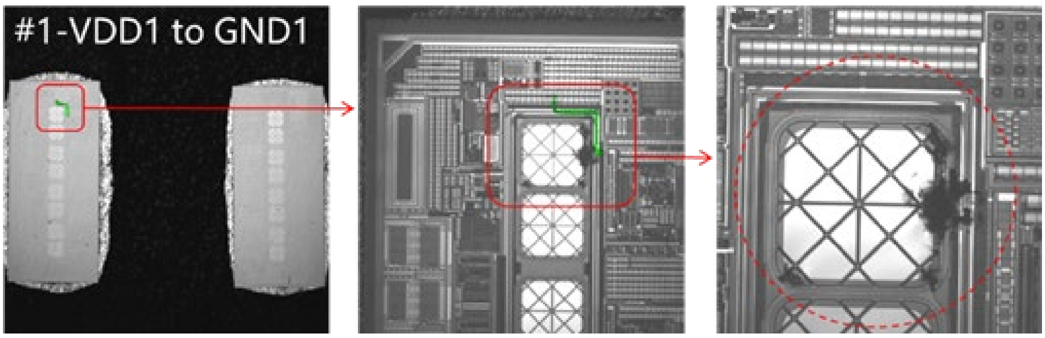

Figure 3(b). Photograph of the second isolation failure mode

To further verify the limited damage of the second failure mode, some other test results are shown in Table 1. All of the samples still pass 3kVrms insulation voltage per UL1577 after damaged due to severe overpower events, providing basic isolation.

Table 1. Insulation test results after specific overpower tests (failure mode2)

Test description	Number of devices tested	failure phenomenon	V_{ISO} test per UL1577, $3000V_{RMS}$, 60s
VDD1 EOS destructive test: VDD1=15V (absolute maximum value of 6.5V), 300mA limited	3	VDD1 short to GND1, input side die damaged	Pass
VDD2 EOS destructive test: VDD2=15V(absolute maximum value of 6.5V), 300mA limited	3	VDD2 short to GND2, output side die damaged	Pass
System ESD destructive test: 30kV on VDD1 to GND1, discharge model: R=330Ω and C=330pF, 10 times each polarity	2	VDD1 short to GND1, input side die damaged	Pass
System ESD destructive test: 30kV on VDD2 to GND2, discharge model: R=330Ω and C=330pF, 10 times each polarity	2	VDD2 short to GND2, output side die damaged	Pass

2.Application Example

In this section, we take the typical motor drive system as an example to discuss the selection and application of capacitive isolators to avoid the above two failure modes.

The typical motor drive system shown in Figure 4 transfers the AC grid to the motor drive output, including rectifier circuit, inverter circuit and control MCU. The control module MCU are accessible to humans through the communication bus. For safety requirements human-machine interface (HMI) must have insulation barriers from the high voltage and power circuits. The voltage and current sensing ICs provide isolated signals for closed-loop control and system protection. The isolated drivers transfer PWM signals to the isolated driving signals for the IGBT module. The isolation barriers are set for functional purposes, safety requirements or both.

The IEC 61800-5-1 specifies the safety requirements of isolation in motor drive systems. The isolation ICs are selected to satisfy the requirements of the system voltage, temporary overvoltage, impulse voltage, working voltage, clearance, creepage, etc. and reserve sufficient margin. The greater the margin, the higher the isolation reliability.

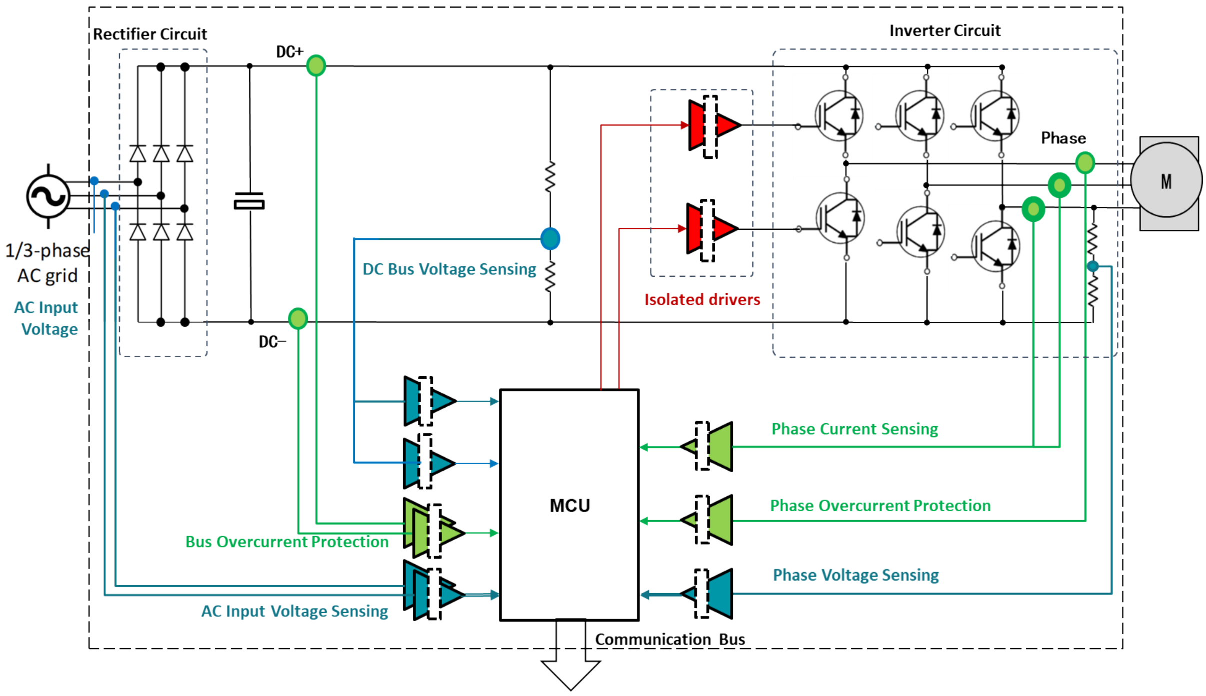

Figure 4. Typical application circuit in motor drive system

Through the appropriate selection and application of isolators, the first failure mode: overvoltage across the isolation barriers can dramatically be avoided. NOVOSENSE isolators allow more margin against the first failure mode and have higher isolation reliability.

To avoid the second failure mode: high power on one side of the isolator, current limiting measures such as applying resistors in serious with the power supply pins and IO pins of the isolators, can limit the power of abnormal conditions and make the isolators operate within the safety limits. Once the second failure mode occurs unfortunately, one side of the isolator is shorted while the isolation performance of the other side remains. The isolator keeps basic isolation and the HMI is still isolated from high power motor drive system.

3.Conclusion

The mechanism of two failure modes of the capacitive isolators is introduced in this paper for users to understand the causes of isolation failure. The first failure mode: overvoltage across the isolation barriers can be avoided through the appropriate selection and application of isolators, allowing sufficient margin for isolation specifications. The second failure mode may occur because of high power outside the safety limits on one side of the isolator. In this case, the isolator preserves basic isolation and an operator safety hazard can still be avoided.

4.Revision History

Revision	Description	Author	Date
1.0	Initial version	Jiahua Xu, Michelle Zhao	19/12/2023

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