Application Report

Intrinsic Safety Compliance of Digital Isolators in Explosive Atmospheres

TEXAS INSTRUMENTS

ABSTRACT

As companies that operate their equipment in explosive atmospheres search for ultra-low power, compact, and more efficient isolating devices than optocouplers, the need for digital isolators that comply with intrinsic safety standards continues to grow. Several standards under the IEC 60079 umbrella deal with intrinsic safety compliance of digital isolators. This application note defines some of the terminology in the explosive atmospheres standards and why digital isolators provide a better alternative than inefficient and bulky optocouplers.

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1 Intrinsic Safety in Explosive Atmospheres

Many industries, such as mining, or oil and gas drilling companies, operate their equipment in explosive atmospheres. The International Electrotechnical Commission (IEC) has a set of standards under the IEC 60079 umbrella to regulate equipment used in such environments.

An explosive atmosphere is defined in IEC 60079-0 as an environment which contains gas, vapor, dust, fibers or flyings, which when combined with oxygen, in such proportion that a spark from an electric circuit or heating from a device may cause an explosion. Electrical equipment installed in these environments must eliminate or isolate the source of ignition, thus preventing the simultaneous occurrence of the three components that form the explosion triangle (Figure 1-1): fuel, oxygen, and an ignition source.

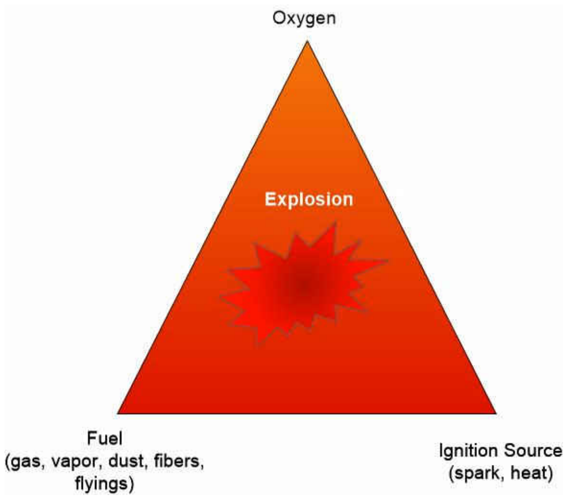

Figure 1-1. Three Ingredients Forming the Explosion Triangle

Intrinsic safety “i” is defined in IEC 60079-11 as the type of protection based on the restriction of electrical energy within equipment and of interconnecting wiring exposed to the explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects. Intrinsic safety refers to equipment and wiring that is inherently safe. In other words, an intrinsically safe system is one with an energy level so low that it cannot lead to a spark or sufficient heating which can cause an explosion. Intrinsic safety is typically achieved through the use of barriers – either Zener diodes and resistors or isolated barriers such as optocouplers and digital isolators – that limit the energy to a hazardous or potentially flammable area.

An IECEx System refers to an International Electrotechnical Commission System for certification to standards relating to equipment for use in explosive atmospheres. Components and equipment used in explosive atmospheres are called ‘Ex’ components and equipment respectively and they require IECEx or other regional certifications such as ATEX in Europe. ATEX is an abbreviation for the French term “ATmosphère EXplosives” and it refers to the European Directive 2014/34/EU.

In Europe, hazardous areas are usually designated by categories, although the international system of groups and zones is becoming increasingly popular.

2 Groups

Electrical equipment for explosive atmospheres is divided into the following groups:

- **Group I** covers electrical equipment intended for use in mines (M) susceptible to firedamp.
- **Group II** covers electrical equipment intended for use in places with an explosive gas (G) atmosphere other than mines susceptible to firedamp. Group II has the following subdivisions:
  – IIA – Typical gas is Propane
  – IIB – Typical gas is Ethylene
  – IIC – Typical gas is Hydrogen

  Equipment marked IIC is also suitable for applications requiring IIA and IIB because allowable ignition energy for Hydrogen (20 µJ) is lower than Ethylene (80 µJ) and Propane (160 µJ).
- **Group III** covers electrical equipment intended for use in places with an explosive dust (D) atmosphere other than mines susceptible to firedamp. Group III has the following subdivisions:
  – IIIA – Combustible flyings
  – IIIB – Non-conductive dust
  – IIIC – Conductive dust

  Equipment marked IIIC is also suitable for applications requiring IIIA and IIIB, respectively.

3 Levels of Protections

IEC 60079-11 defines three levels of protection, ‘ia’, ‘ib’, and ‘ic’ which attempt to balance the probability of an explosive atmosphere being present against the probability of an ignition capable situation occurring. Definitions of these terms follow:

- ‘**ia**’ offers a “very high” level of protection and is considered as being adequately safe for use in the most hazardous locations and it is unlikely to become an ignition source in normal operation, during expected malfunctions or during rare malfunctions, even when left energized in the presence of an outbreak of gas.
- ‘**ib**’ offers a “high” level of protection, which is not a source of ignition in normal operation or during expected malfunctions.
- ‘**ic**’ offers an “enhanced” level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences (for example, the failure of a lamp).

Equipment protection level (EPL) is another term used in IEC 60079-0 to define a level of protection assigned to equipment based on its likelihood of becoming a source of ignition and distinguishing the differences between explosive gas atmospheres, explosive dust atmospheres, and the explosive atmospheres in mines susceptible to firedamp. For example, equipment protection level ‘Ga’ is assigned to equipment for explosive gas atmosphere, having a “very high” level of protection, which is not a source of ignition in normal operation, during expected malfunctions or during rare malfunctions.

4 Temperature Classification

A mixture of hazardous gases and combustible dusts may be ignited by coming into contact with a hot surface. The conditions under which a hot surface will ignite an atmosphere depend on temperature, surface area, and the concentration of gas or dust mixture. The temperature class of a product denotes the maximum surface temperature that a given product will not exceed under a specified ambient temperature. Table 4-1 shows the temperature class of Group II electrical equipment with respect to maximum surface temperature. For example, a product with a temperature class of T3 means that its maximum surface temperature will not exceed 200°C, provided it is operated in an ambient temperature defined by the manufacturer.

Table 4-1. Classification of Maximum Surface Temperatures for Group II Electrical Equipment

Temperature Class	Maximum Surface Temperature (°C)
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

5 Intrinsically-Safe and Non-Intrinsically-Safe Equipment

From the explosive atmosphere standards perspective, the universe is divided into two areas: hazardous and non-hazardous; see Figure 5-1. The equipment used in the hazardous areas is called intrinsically safe (IS) equipment, whereas the equipment used in the non-hazardous area is called non-intrinsically safe (non-IS) equipment. In the hazardous-area, the presence of gas and dust create an explosive environment and therefore the energy level (voltage and current) and storage elements (capacitance and inductance) should be limited to avoid spark or excessive heating. Power and ambient temperature levels should also be restricted in the hazardous area. In the non-hazardous area, there are no dangerous conditions in the environment and therefore there is no cause or fear of explosion and thus no intrinsic safety related constraints on the power and ambient temperature levels. In the hazardous area, since the voltage levels are only allowed to go up so high, the isolation withstand voltage is only tested at 500 V_{RMS} whereas the voltage in the non-IS-area can go much higher and the corresponding isolation withstand voltage can be 3000 V_{RMS} or higher.

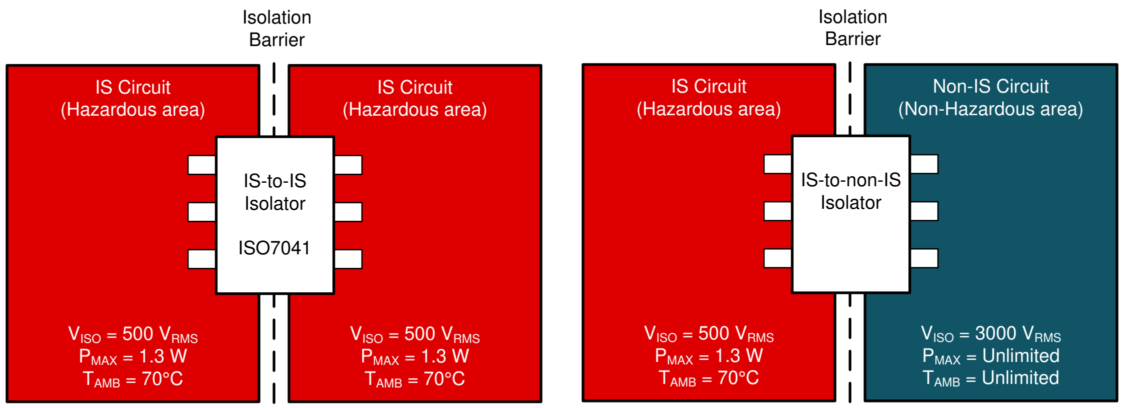

Figure 5-1. Digital Isolator Between Separate Intrinsically Safe (IS) Circuits

Intrinsic safety equipment can be certified by one of two methods: system or parametric approval. With a system approval, every component of the system is specified and then the entire system is evaluated and certified. A variance to any of the components voids the approval. By contrast, a parametric approval is one in which each component is evaluated separately and is assigned a set of safety or entity parameters. With parametric approval, a manufacturer can connect a field device to any barrier with compatible entity parameters. The parametric method makes it easy for equipment manufacturers to select components for their designs.

6 Digital Isolator Certified to IECEx and ATEX

Explosive atmosphere applications have traditionally used optocouplers for isolation between IS-to-IS and IS-to-non-IS circuits. Newer technologies, such as capacitor and transformer based digital isolators, are quickly replacing optocouplers in the market. Optocoupler shortcomings, such as large size, slower speed, high power consumption, and performance degradation over time has increased the demand for faster and more compact digital isolators, such as the ultra-low power, *ISO7041* device. This 4-channel device has the industry's lowest power consumption under normal operating conditions, making it suitable for use in 4–20 mA loop powered field transmitters, factory automation, and Serial Peripheral Interface (SPI) isolation. With per channel power consumption as low as 3.5 μA, system designers can afford more isolation channels and rethink their data transfer architecture, enabling more system features or the ability to distribute additional power budget to the rest of the system.

The ISO7041 device has been fully certified according to IECEx and ATEX standards for use as an isolating component between separate intrinsically safe (IS-to-IS) circuits. The device was subjected to a battery of tests, including, but not limited to, power and temperature rating tests, 500-V_{RMS} dielectric strength test, and so forth. Table 6-1 lists the safety or entity parameters and temperature ratings for the ISO7041 isolator for two different application scenarios based on ambient temperature range and maximum input power available on each side of the isolation barrier:

Table 6-1. ISO7041 Entity Parameters and Temperature Ratings

Application	Entity Parameters Side 1	Entity Parameters Side 2	Ambient Temperature	Maximum Component Temperature
IS-to-IS: Scenario 1	Ui = 50 V Ii =300 mA Pi = 1.3 W Li = 0 H Ci = 4 pF	Ui = 50 V Ii =300 mA Pi = 1.3 W Li = 0 H Ci = 4 pF	–55°C to +70°C	194.3°C
IS-to-IS: Scenario 2	Ui = 50 V Ii =300 mA Pi = 1.1 W Li = 0 H Ci = 4 pF	Ui = 50 V Ii =300 mA Pi = 1.1 W Li = 0 H Ci = 4 pF	–55°C to +85°C	183.1°C

Digital isolators currently do not support IS-to-non-IS application use due to the minimum insulation thickness requirements of IEC 60079-11. Although the insulation used in digital isolators is thinner than optocouplers, the significantly higher quality of the insulation material is being discussed in the explosive atmospheres standard committee to allow the use of reinforced digital isolators in IS-to-non-IS circuits.

7 Summary

'Ex' equipment manufacturers are excited about the entry of ultra-low power digital isolators in the explosive atmosphere applications space. At the moment, digital isolators can be used between separate intrinsically safe circuits. As more digital isolators are certified according to the stringent standards of explosive atmosphere applications, these products are expected to become ubiquitous in this market and quickly replace the bulky and less efficient optocouplers.

8 References

- International Standard IEC 60079-0, Explosive atmospheres - Part 0: Equipment – General requirements, edition 7.0, 2017-12
- International Standard IEC 60079-11, Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i", edition 6.0 2011-06
- For more information on TI's isolation portfolio, see www.ti.com/isolation

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (May 2020) to Revision A (August 2021)	Page
• Updated the numbering format for tables, figures and cross-references throughout the document	2

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265