APPLICATION NOTE

ANP151 | Mastering Galvanic Isolation: Ensuring Safety in High-Power Electronics with Würth Elektronik Products

Uludag, Ihsan-Timur

1. INTRODUCTION

Galvanic isolation is necessary when designing safe and reliable high-power electronics. In this context, galvanic isolation refers to the electrical separation of two circuits with no direct electrical contact between them while still allowing signal or power transfer. The situations where isolation is needed include applications where high-voltage differences exist between circuit sections, where signal integrity must be preserved in noisy environments, and where safety regulations require electrical separation to protect users and equipment from hazardous voltages.

In this application note, we explore the different methods of achieving galvanic isolation, examine their advantages and trade-offs, and discuss how to select the appropriate isolation solution for various industrial applications using Würth Elektronik's product offerings.

2. ISOLATION, WHY IT MATTERS, AND THE DIFFERENT TYPES

In industrial environments, galvanic isolation serves three primary functions.

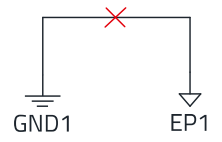
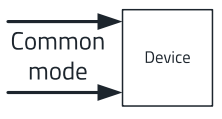
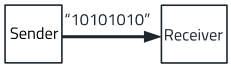
	▪ **First**, it improves safety by preventing lethal voltage transfer to user-accessible circuits and by protecting sensitive electronics from voltage spikes.
	▪ **Second**, it enhances electromagnetic compatibility (EMC) performance by mitigating noise, suppressing common-mode interference, and eliminating ground loops that could lead to erratic system behaviour.
	
	▪ **Finally**, galvanic isolation ensures signal integrity by preventing unwanted interference and, thereby, allowing accurate data transmission even in electrically noisy conditions.

Table 1: Primary functions of galvanic isolation.

2.1 Buzzwords around the topic "galvanic isolation"

When it comes to the topic galvanic isolation the following buzzwords will pop up, see Figure 1.

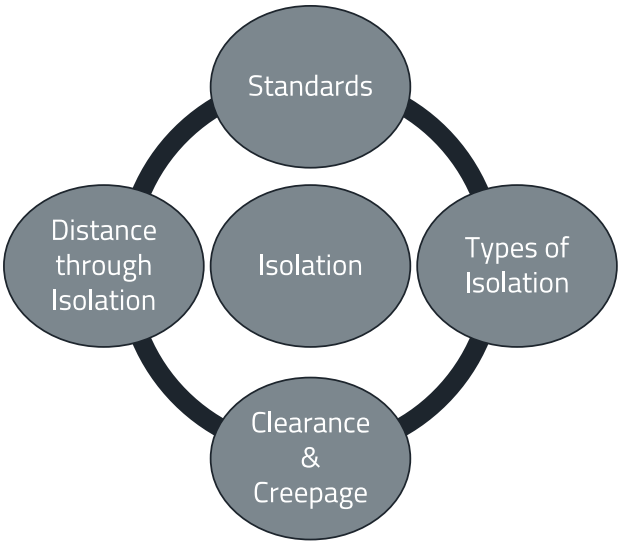
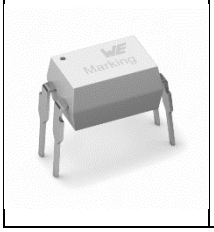
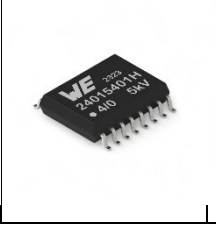
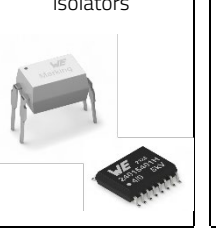
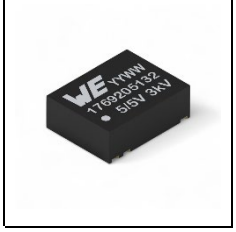


Figure 1: Buzzwords around galvanic isolation.

In the following, we provide a simplified definition for each topic for a better understanding.

2.2 Categories Standards

There are three different categories of standards: component standards, device standards and basic safety standards. Component standards are specifications that apply to individual electronic components, such as resistors, capacitors, inductors, optocouplers. Device standards apply to complete electronic devices or systems, such as smartphones, computers, or industrial machinery. A basic safety standard is a type that provides fundamental safety principles and guidelines applicable across a wide range of products, systems, or industries. The purpose of a basic safety standard is to establish a common understanding of safety requirements and to promote consistency in safety practices. They often serve as a reference for developing more specific standards tailored to particular products or sectors.

Component standard					Device standard
IEC60747-5-5	IEC60747-17	IEC61558-2-16	IEC60384-14	UL1577	IEC62368-1
Optocouplers	Digital Isolators	Transformers	Capacitors	Optocouplers / Digital Isolators	Power Modules
					

Basic Safety Publication IEC60664-1

Table 2: Overview Standard Categories.

Table 2 shows an overview of the most common safety standards and their standard category.

2.3 Types of Isolation

Functional Isolation

Functional isolation refers to the minimum level of separation required for a circuit to operate correctly. It provides no user protection from electrical shock or fault conditions. Designers typically use functional isolation to prevent ground loop errors or minimize signal interference. This type does not guarantee safety in the presence of hazardous voltages, and insulation failure may result in uncontrolled energy transfer.

Basic Isolation

Basic isolation is the first level of user protection against electric shock. It consists of a single insulation barrier between high-voltage and user-accessible parts. Basic isolation can prevent direct contact with hazardous voltages under normal operating conditions, but it does not protect in the event of insulation failure. Therefore, safety standards often require pairing basic isolation with supplementary protection in safety-critical applications.

Supplementary Isolation

Supplementary isolation is an additional layer of insulation independent of the basic isolation. Its purpose is to protect the user if the basic insulation fails. When used in conjunction with basic insulation, supplementary insulation enables compliance with double insulation requirements by forming a composite structure.

Double Isolation

Double isolation combines both basic and supplementary insulation to provide user protection against electric shock without relying on a protective earth connection. Double insulation is required in Class II equipment and is designed to remain safe in the event of a single fault.

Reinforced Isolation

Reinforced isolation provides the same level of protection as double insulation but achieves it through a single insulation system that has been tested to more stringent standards for dielectric strength, creepage, and clearance. Reinforced isolation simplifies design by reducing the number of required insulation barriers while still protecting against both normal and fault conditions.

2.4 Creepage and Clearance in Isolation

Creepage and clearance are two central parameters in the design of isolation systems for electronic and high-voltage equipment. They define the physical distance between conductive parts and directly determine the system's ability to withstand electrical stress without arcing or insulation breakdown.

Clearance is the shortest distance through air between two conductive elements, see Figure 2. It dictates how much electrical potential the air gap can withstand before dielectric breakdown causes a discharge. The required clearance depends on system voltage, overvoltage category, pollution degree (e.g., office vs. industrial environment), and operating altitude. Clearance violations can lead to flashover, where ionized air creates a conductive path between conductors, potentially damaging components or endangering users.

Figure 2: Visualization of Clearance and creepage.

Creepage is the shortest path along the surface of an insulating material between two conductive parts, see Figure 2. It considers the possibility of surface degradation, contamination, or tracking over time, especially relevant in humid or dusty environments. The required creepage depends on the system voltage and the Comparative Tracking Index (CTI) of the insulating material, which measures its resistance to carbonized conductive paths forming on the surface. Higher CTI-rated materials (e.g., CTI ≥ 600) require less creepage than lower-rated ones (e.g., CTI < 175).

In reinforced isolation, both creepage and clearance must meet the strictest requirements, with creepage typically being the longer of the two due to potential contamination.

2.5 Distance through Isolation

Distance through isolation is the shortest path through an insulating material between two conductors, ensuring electrical separation, see Figure 3.

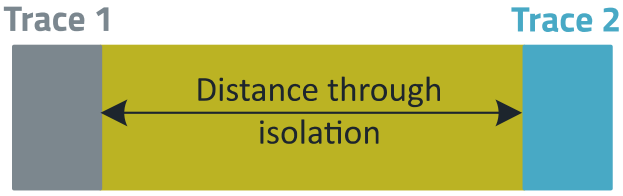


Figure 3: Visualization of Distance through isolation.

3. IMPLEMENTING ISOLATION

There are multiple ways to achieve galvanic isolation, each with its own trade-offs in terms of signal transmission or power transmission. The most common options when implementing galvanic isolation include:

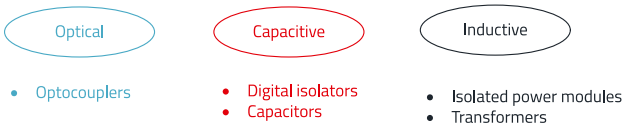


Figure 4: Overview methods of galvanic isolation.

4. OPTOCOUPLERS

Optocouplers, also known as optoisolators, provide galvanic isolation by transmitting signals through an optical medium instead of a direct electrical connection [1]. At its core, an optocoupler uses a light-emitting diode (LED) and a light-sensitive detector, such as a phototransistor or photodiode, to transfer electrical signals across an isolation barrier (Figure 5).

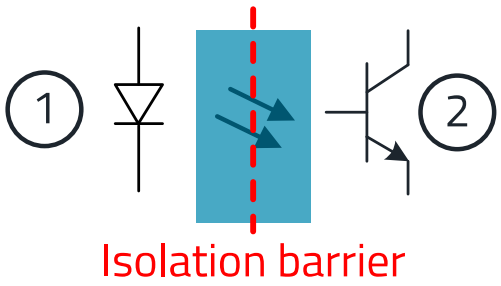


Figure 5: Concept of galvanic isolation with Phototransistor Optocoupler.

The operation of an optocoupler begins when an electrical input signal drives the internal LED. The LED (1) emits infrared light, which is then received by the photodetector (2) on the other side of the isolation barrier. The photodetector converts the optical signal back into an electrical output, effectively transferring information between two electrically isolated circuits. Since the LED and the photodetector share no direct conductive path, the circuits remain electrically separated while still communicating.

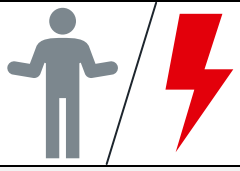
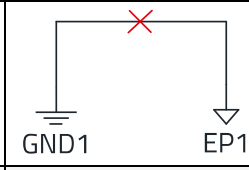
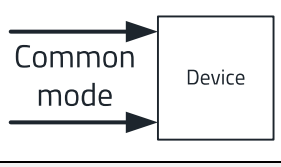
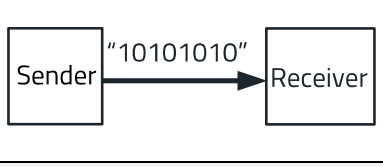
Where to use optocouplers?			
			
✓	✓	✓	✓

Table 3: Optocouplers use cases.

This method of isolation is particularly effective in safety-critical applications where it's necessary to prevent high-voltage transients from reaching sensitive or user-accessible components. For that reason, optocouplers are widely used in industrial automation, power electronics, and communication interfaces to guarantee that signals are transmitted reliably without exposing low-voltage control circuits to dangerous voltages.

4.1 Common Use Cases for Optocouplers

Despite their limitations, such as limited transmission speed, aging and drift in the current transfer ratio (CTR), optocouplers remain the preferred isolation method in various industrial and power applications where high-voltage safety and reliability take precedence over speed and power efficiency.

Power Electronics

In power conversion systems, optocouplers facilitate feedback isolation in switch-mode power supplies (SMPS) and isolated DC-DC converters. By allowing secondary-side regulation while maintaining electrical separation from the high-voltage primary side, optocouplers contribute to stable and efficient power management, see Figure 6.

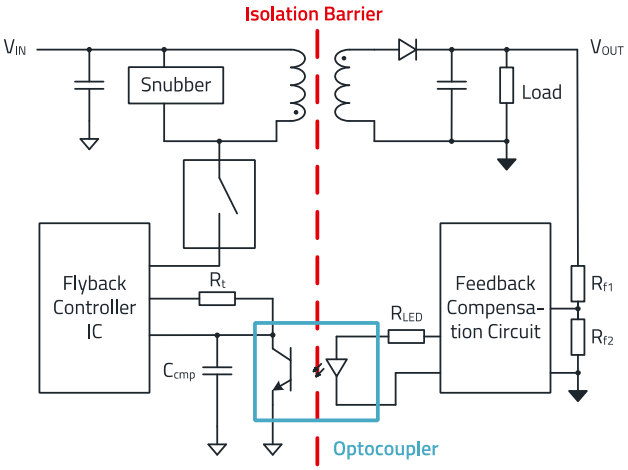


Figure 6: Optocoupler for flyback converter feedback loop.

Low-Speed Communications

In low-speed serial communication interfaces such as RS-232, RS-485, and CAN bus, optocouplers provide effective isolation. These protocols operate within bandwidths that align well with optocoupler performance, which makes optocouplers an excellent choice for isolating data transmission.

Medical Devices

Medical devices are another common use case for optocouplers due to the strict isolation requirements necessary to protect patients and operators from electrical hazards. Applications such as defibrillators, patient monitoring systems, and medical imaging equipment rely on optocouplers to guarantee electrical safety while transmitting signals between different circuit sections.

Industrial Automation

Industrial automation is another domain where optocouplers excel. Their ability to eliminate ground loops and reject common-mode noise makes them essential in programmable logic controller (PLC) inputs, sensor interfaces, and industrial communication networks.

4.2 Würth Elektronik Optocoupler Products

Würth Elektronik offers a comprehensive range of optocouplers designed for industrial and power electronics applications. Our WL-OCPT series includes high-isolation phototransistor optocouplers with robust packaging and high voltage ratings. Notable features of this optocoupler lineup include:

- **High Voltage Ratings**: With isolation voltages up to 5 kV, these optocouplers provide strong electrical separation.
- **Compact Form Factors**: Available in DIP, SOP, and LSOP packages, Würth Elektronik optocouplers support space-constrained designs.
- **Consistent Current Transfer Ratio:** Würth's optocouplers feature tight CTR binning to guarantee predictable performance over the component's lifespan.
- **Industrial- and Automotive-Grade Variants**: Würth optocouplers offer extended temperature ranges and ruggedized construction for harsh environments.

5. DIGITAL ISOLATORS

Digital isolators achieve galvanic isolation by using capacitive coupling instead of the optical transmission method used in optocouplers [4].

The digital isolator (block-diagram Figure 7) consists of an oscillator and a modulator on the primary side. On the secondary side are a demodulator and a buffer. The primary-side components are galvanically separated from the secondary-side components by a capacitor structure with an isolation barrier made of SiO2. Signal transmission through the isolation barrier is realized by a modulation method known as on/off keying. The oscillator integrated in the chip is used to modulate the Schmitt-triggered input signal. The modulator generates a differential signal that is transmitted via the capacitively isolated lines.

The demodulator is located on the secondary side and is used to amplify, filter and reconstruct the input signal. The signal delay and distortion are minimal. Finally, the signal from the output of demodulator is passed through a buffer to the output; the buffer amplifies the signal to the required level.

Digital isolators are particularly effective in safety-critical applications where it's necessary to prevent high-voltage transients from reaching sensitive or user-accessible components. They are known for their high data transmission speed, with some models supporting rates exceeding 100 Mbps. This feature makes digital isolators the preferred choice for high-speed protocols such as SPI, I2C, and USB, where optocouplers would struggle to maintain signal integrity at elevated data rates.

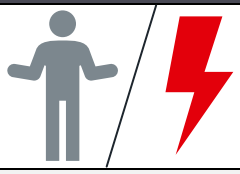
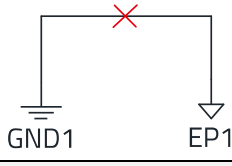
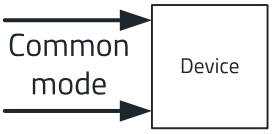
Where to use digital isolators?			
			
✓	✓	✓	✓

Table 4: Digital isolators use cases.

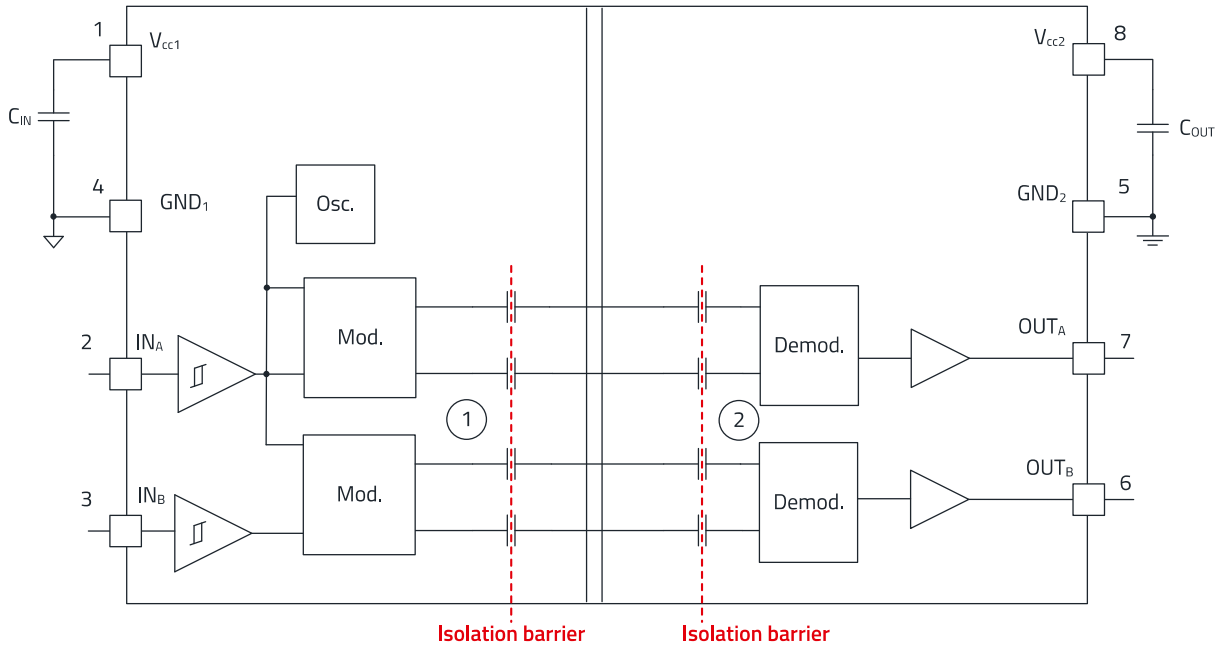


Figure 7: A block diagram of the CDIS 18012x15411x digital isolator, showing the use of modulation techniques to communicate across an isolation barrier.

5.1 Common Use Cases for Digital Isolators

Digital isolators are best for applications requiring high-speed data transmission and power efficiency.

Industrial Automation

In industrial automation, digital isolators are commonly used in fieldbus communication protocols, sensor interfaces, and high-speed microcontroller interconnects. Their ability to handle fast data rates positions them for use in real-time control systems and industrial networking.

Space-Constrained Designs

Space-constrained designs also benefit from using digital isolators, as they offer multiple isolation channels in a single package. Similarly, space-constrained designs are often very power-conscious, which makes digital isolators a great choice. Their combination of compact footprint and power efficiency suits applications like consumer electronics, wearables, and battery-powered devices.

5.2 Würth Elektronik Digital Isolator Products

Würth Elektronik offers a range of high-performance digital isolators. For example, the WPME-CDIS series delivers high-performance signal isolation for industrial automation, motor control, power conversion, and battery management systems. Some of the notable features of this series include:

- **Multiple Channel Configurations**: Available in two and four channel versions to accommodate different isolation needs.
- **High Isolation Voltage:** Supports up to 5000 V_{RMS}
- **Compact Industrial-Grade Packaging:** Offered in SOIC-8NB for basic insulation and SOIC-16WB for reinforced insulation.
- **High-Speed Data Transmission:** Achieves speeds up to 150 Mbps.
- **Superior Noise Immunity:** Features common-mode transient immunity (CMTI) of ±150 kV/µs (typ.).
- **Industry Certifications:** Compliant with UL 1577 and DIN EN IEC 60747-17 (VDE 0884-17) standards.

6. ISOLATED POWER MODULES

A functional isolated DC/DC converter is typically needed when you have to transfer power between two circuits while keeping them electrically isolated. An isolated power module is a fully integrated DC-DC converter that transfers electrical energy across a galvanically isolated barrier using a high-frequency transformer, where the primary and secondary windings are magnetically coupled but electrically separated. The module typically operates through pulse-width modulation (PWM) or resonant switching techniques to convert an input DC voltage into a high-frequency AC waveform, which is then inductively transferred to the secondary winding and rectified back to DC. The isolation barrier prevents direct conduction between input and output while maintaining controlled energy transfer through the transformer's mutual inductance, see Figure 9.

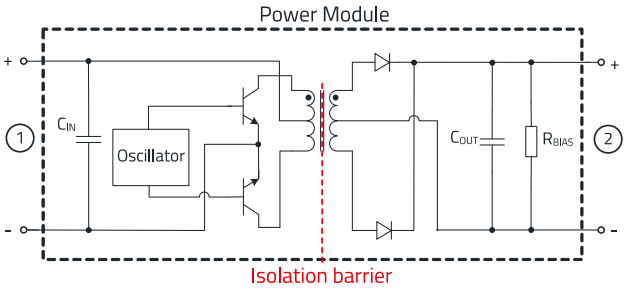


Figure 9: A block diagram of an isolated power module of the FISM series.

By integrating these functions into a single unit, isolated power modules provide a reliable and ready-made solution for delivering isolated power in complex electrical systems.

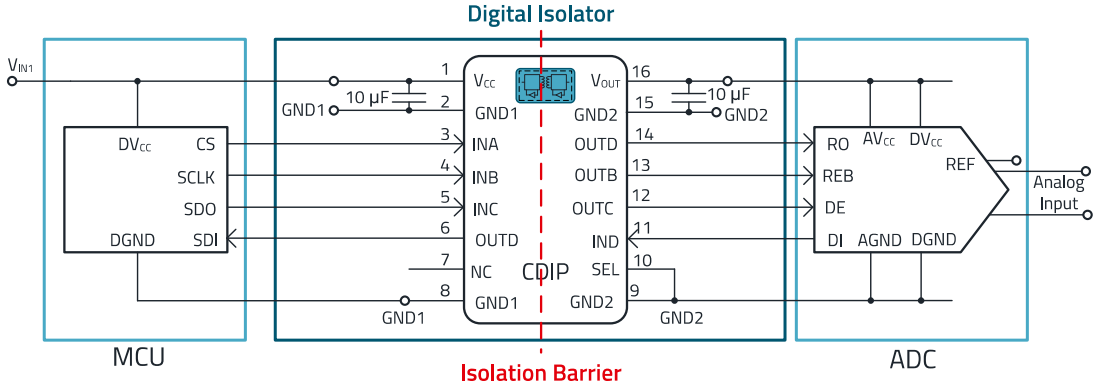


Figure 8: Digital isolator used for isolated SPI bus communication.

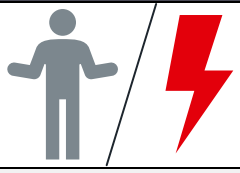
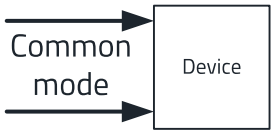
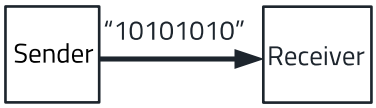
Where to use isolated power modules?			
			
			

Table 5: Isolated power modules use cases.

6.1 Common Use Cases for Isolated Power Modules

Industrial Automation and Control Systems

Industrial automation environments with high-power machinery and extensive communication networks require solutions that are both highly reliable and immune to electrical noise. Isolation plays a critical role by eliminating ground loops, which can otherwise introduce noise, signal interference, or even cause equipment damage. It is essential in applications such as measurement systems, communication interfaces, and audio equipment.

Furthermore, when subsystems operate at different ground potentials, isolation ensures safe and proper operation without short circuits - common scenarios include remote sensors and distributed power systems.

6.2 Würth Elektronik Isolated Power Modules

Würth Elektronik offers a diverse portfolio of isolated power modules designed for applications such as data acquisition, test and measurement systems and industrial controls.

The isolated variant of our MagI³C modules utilizes flyback, full-bridge, and push-pull topologies to provide functional isolation up to 4 kV, eliminate ground loops, and ensure high levels of signal integrity.

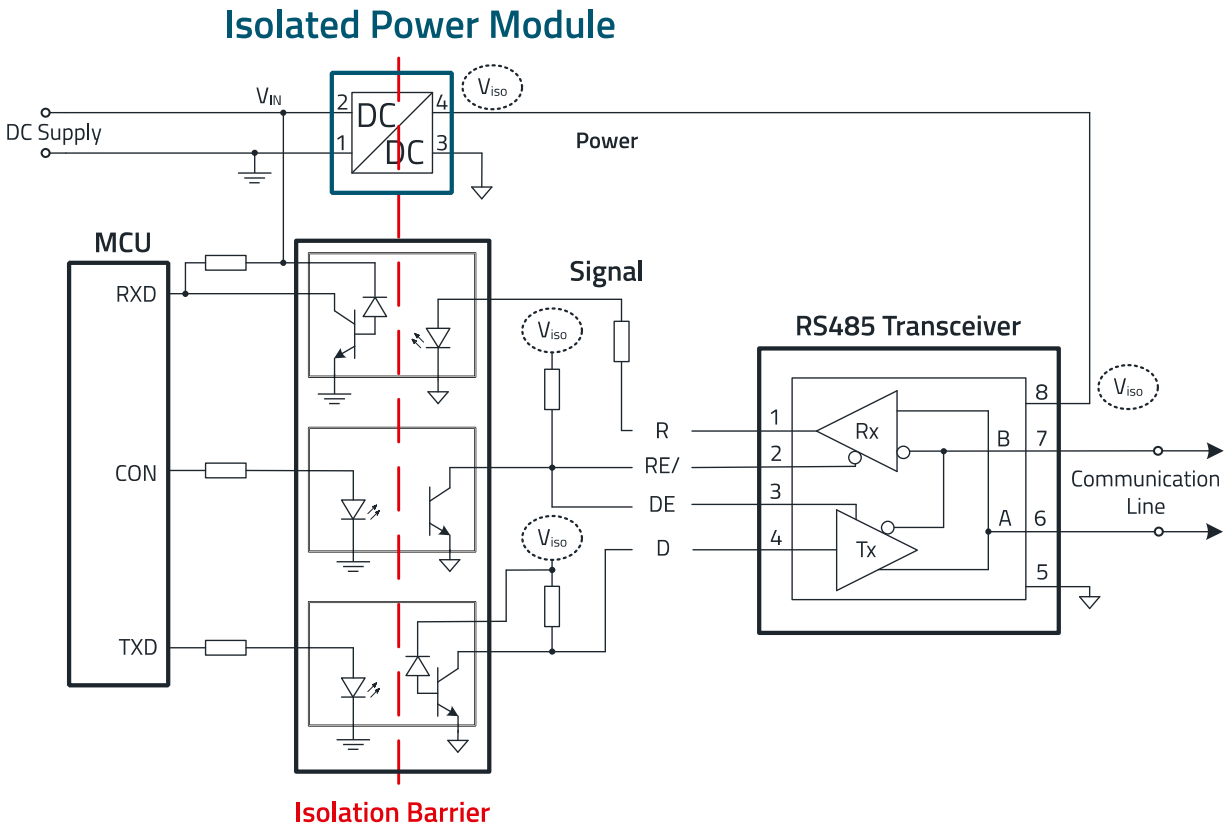


Figure 10: Isolated RS485 communication with an isolated power module for power path isolation.

Some of the notable features of this series include:

- functional isolation with V_{iso} up to 4 kV
- continuous output power up to 2 W
- stand-alone solution (C_{IN} and C_{OUT} integrated, no external components)
- industrial standard package and pin configuration
- low conducted and radiated EMI (compliant to EN55032 class B)
- Industry Certifications: Compliant with UL 62368-1

These modules are also supported by Würth's online design tools, such as REDEXPERT, MagI³C Power Module Designer which allows engineers to simulate and optimize isolated power module performance in their specific applications. Würth also provides reference designs and application notes to facilitate integration into existing power architectures.

7. TRANSFORMERS FOR ISOLATION

Transformers provide galvanic isolation by transferring electrical energy between circuits through magnetic induction while maintaining complete electrical separation between the primary and secondary windings, see Figure 11 detail 1 & 2. In this arrangement, the alternating current (AC) in the primary winding generates a time-varying magnetic field in the transformer's core, which induces a corresponding voltage in the secondary winding. This behaviour allows efficient energy transfer while maintaining electrical separation and preventing direct current (DC) flow between input and output.

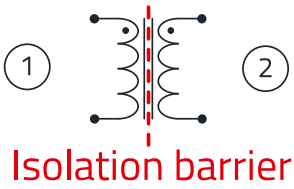


Figure 11: A schematic of a power transformer showing magnetic coupling between primary and secondary windingsl.

7.1 Common Use Cases for Transformers

High Power-Handling Capability

Transformers have high power-handling capabilities because they transfer energy through magnetic induction rather than direct electrical conduction, allowing them to efficiently scale voltage and current without excessive resistive losses. Power transformers used in electrical grids handle hundreds of megawatts, while smaller transformers in power electronics can efficiently manage watts to kilowatts of power.

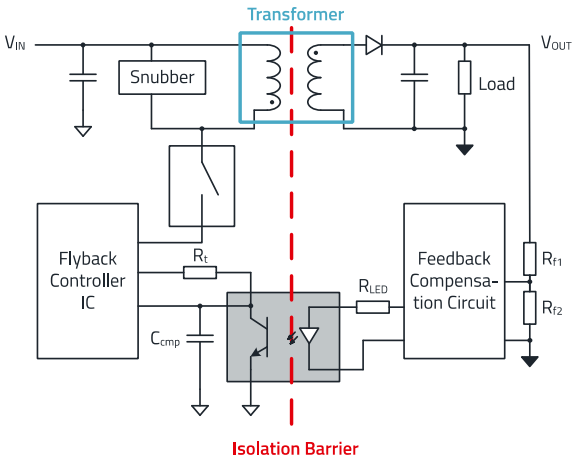


Figure 12: Transformer for flyback converter power transfer.

7.2 High-voltage Isolation Gate Drivers

Transformers are useful in high-isolation gate drivers as they enable isolated control signals for MOSFETs and IGBTs used in motor drives, industrial inverters, and power distribution systems. Gate drive transformers are designed to deliver fast, noise-free signal transmission with high common-mode voltage rejection. Special versions with low parasitic capacitance provide isolated auxiliary power to gate driver ICs.

However, as demands for switching speed and timing precision increase, signal transformers are increasingly reaching their limits. For this reason, integrated, isolated gate drive ICs are increasingly used in modern, high-speed power systems - particularly with wide-bandgap semiconductors like SiC and GaN, where precise control is essential.

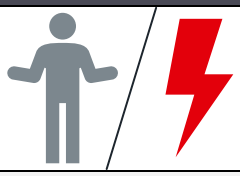
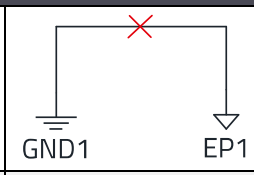
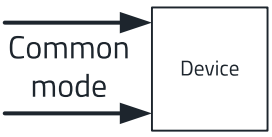
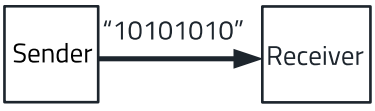
Where to use transformers?			
			
✓	✓	✓	✓

Table 6: Transformers use cases.

While these ICs integrate advanced isolation and timing features, they still require a separate isolated auxiliary supply to bias the gate drive stage. This creates a continued demand for power transformers capable of delivering the required voltages and isolation levels tailored to gate drive applications. To maintain clarity in specification and application context, we refer to these components as **Gate Drive Auxiliary Supply Transformers (WE-AGDT)**, emphasizing their role in supporting isolated gate driver functionality.

Signal Isolation in High-Power AC/DC Systems

High-power AC/DC systems often involve rapid switching transients and strong electromagnetic fields. Transformers are great for signal isolation in this context because they withstand high voltage levels while allowing accurate signal transmission in electrically noisy environments. Additionally, their dual functionality in power and signal isolation allows them to efficiently transfer control signals while also stepping up or stepping down voltages.

Ethernet and RS-485 Signal Isolation

Ethernet transceivers and RS-485 communication networks rely on transformers because the differential signal transmission used in these protocols benefits from transformers' ability to reject common-mode noise (Figure 10). This feature helps confirm that only the intended differential signals are transmitted while external interference is suppressed. Additionally, high-bandwidth transformer designs with low leakage inductance and optimized impedance matching can facilitate fast, low-distortion signal transmission across long cable runs.

Würth Elektronik Transformer Products

Würth Elektronik offers a broad range of transformers for power and signal isolation. Some of these products include:

- WE-AGDT Gate Drive Transformers: Designed for high-speed MOSFET and SiC/GaN switching, these transformers provide, with very low parasitic capacitance, low leakage inductance, and high isolation voltage, the isolated power for gate driver ICs.
- WE-FB Flyback Transformers: Optimized for isolated DC-DC converters and offline AC/DC power supplies, these transformers offer high efficiency, low core losses, and robust isolation performance.
- WE-LPLN Planar Transformers: Designed for high-power-density applications, these transformers offer flat wire windings with low DCR and provide isolation voltages up to 2250 V_{DC}.
- WE-GDTI Gate Drive Transformers: Designed for high-speed MOSFET and IGBT switching, these transformers provide fast signal transmission, low leakage inductance, and high isolation voltage.
- WE-PPTI Push-Pull Transformers: Designed for small power Push-Pull topology with voltage and power levels to fit in most low power industrial applications, like isolated supply for serial communication RS232, RS-485, CAN, PLC I/O modules and more.
- WE-UOST Flyback Transformers: Optimized for isolated offline AC/DC power supplies, these transformers offer high efficiency, low losses, and robust isolation performance, providing Reinforced isolation with dielectric withstand voltages up to 4200 V_{AC}.

8. CAPACITORS FOR ISOLATION

A capacitor can realize galvanic isolation by allowing the transfer of AC signals or transient signals between two circuits while blocking DC signals. This is achieved because a capacitor consists of two conductive plates separated by an insulating material, known as the dielectric, see Figure 13 detail 1 & 2. When an AC voltage is applied across the capacitor, the alternating current can pass through due to the changing electric field, while the dielectric prevents any direct electrical connection between the two sides. This ensures that there is no direct current path, thereby providing galvanic isolation. This property is particularly useful in applications where it is necessary to prevent DC ground loops or to isolate different sections of a circuit for safety or functional reasons.

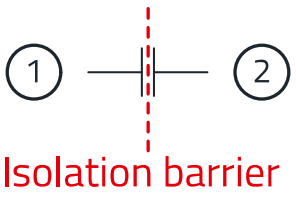


Figure 13: Isolation principal capacitor.

Similarly, capacitors are used in isolated systems because of their ability to redirect and dampen high-frequency noise generated by switching circuits. By strategically placing capacitors between ground-to-ground (GND-GND) or V_{DD}-to-V_{DD} across an isolation barrier, designers can reduce conducted and radiated emissions and reach compliance with EMI regulations such as CISPR 32 and IEC 61000-6-3.

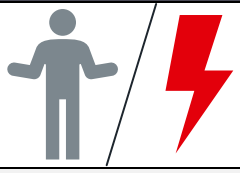
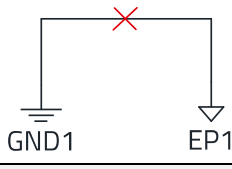
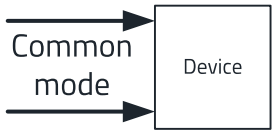
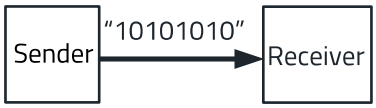
Where to use capacitors?			
			
✓	✓	✓	✓

Table 7: Capacitors use cases.

8.1 Common Use Cases for Capacitors

Bridging Isolation Barriers

Capacitors are widely used for bridging GND-GND or VDD-to-VDD across an isolation barrier to stabilize voltage potentials and reduce noise coupling. In isolated DC-DC converters and switch-mode power supplies, capacitors are strategically placed between isolated ground planes to provide a return path for high-frequency noise currents such that switching transients do not interfere with system performance.

EMC Filtering

In isolated power supplies, capacitors help suppress conducted and radiated emissions to achieve compliance with EMI standards such as CISPR 32, FCC Part 15, and IEC 61000-6-4. By integrating Y-capacitors and X-capacitors into input and output filtering networks, designers can minimize differential-mode and common-mode noise and improve overall power system stability, see Figure 14.

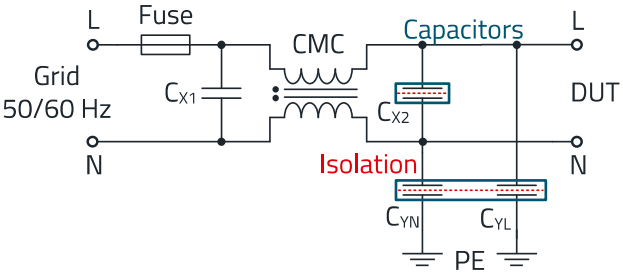


Figure 14: X-& Y-capacitors.

8.2 Würth Elektronik Capacitor Products

Würth Elektronik offers a comprehensive range of capacitors designed for EMI suppression, noise filtering, and isolation applications. Some of these products include:

- WCAP-FTX2 Film Capacitors: These X2 capacitors provide interference suppression and EMI filtering in AC mains applications and offer compliance with ENEC 10, cULus, and CQC safety standards.
- WCAP-CSSA Ceramic Capacitors: These X1/Y2 and X2 safety capacitors offer effective interference suppression and EMI filtering in AC power lines with stable capacitance and robust ceramic dielectric options (NP0, X7R).
- Future WCAP-FTY2 Film Capacitors. Used in AC mains applications up to 310 V_{AC} for connecting each phase to ground and removing common mode interference.

9. WHEN TO USE EACH ISOLATION METHOD

9.1 Optocouplers: Low-Speed, High-Voltage Isolation - SAFETY

Optocouplers are ideal for low-speed digital and analog signal isolation in applications such as industrial control systems, microcontroller interfaces, and medical instrumentation.

- **Use Cases:** Isolated UARTs, low-speed digital I/O isolation, and analog signal transmission.
- **Advantages:** High isolation voltage (up to 10 kV), simple circuit integration, and low cost.
- **Limitations:** Limited bandwidth (<1 Mbps in standard models), LED aging effects, and higher power consumption compared to digital isolators.

9.2 Digital Isolators: High-Speed Communication in Compact Designs - SAFETY

Digital isolators are great in modern industrial automation, high-speed data communication, and safety-critical applications.

- **Use Cases:** Isolated SPI, I^2C, CAN bus, and RS-485 transceivers in automotive, medical, and industrial automation systems.
- **Advantages:** High-speed operation (>100 Mbps), lower power consumption, and long-term reliability with no LED degradation.
- **Limitations:** Lower isolation voltage ratings than optocouplers, susceptibility to common-mode transients, and higher cost in some cases.

9.3 Isolated Power Modules: Simplified Power Isolation Solutions - NO SAFETY

Isolated power modules integrate DC-DC conversion and isolation into a single package and are best for quick design implementation.

- **Use Cases:** Applications needing a simplified implementation of power conversion and isolation, such as microcontroller power isolation and communication.
- **Advantages:** Plug-and-play solution, high efficiency (85% - 95%), and compliance with safety standards for reinforced isolation.
- **Limitations:** Fixed voltage and current ratings may limit flexibility, and cost is higher than discrete transformer-based solutions.

9.4 Transformers: High-Power and High-Voltage Isolation - SAFETY

Transformers provide both power and signal isolation. This makes them a good choice in switch-mode power supplies and industrial motor drives.

- **Use Cases:** Gate driver transformers, flyback converters, high-voltage inverters, and energy storage systems.
- **Advantages**: Handles high power levels, provides reinforced isolation, and supports multi-output power conversion.
- **Limitations:** Bulkier than semiconductor-based isolators, requires careful EMI management and has frequency-dependent behaviour.

9.5 Capacitors: EMI Mitigation and Noise Suppression - SAFETY

Capacitors provide DC isolation but, depending on their capacitance and the frequency of operation, they allow AC signals to pass. Therefore, they are often used to improve EMC performance, reduce conducted and radiated noise, and stabilize voltage references in isolated systems.

- **Use Cases:** Bridging ground planes in isolated circuits, noise suppression in power supplies, and AC filtering in isolated DC-DC converters.
- **Advantages:** Compact, cost-effective, and improves overall system stability.
- **Limitations:** They can provide galvanic isolation but require careful selection to avoid leakage current issues in high-voltage systems.

10. CONCLUSION

Galvanic isolation is a fundamental requirement in modern power and signal processing applications, yet selecting the right isolation technology can be challenging. Engineers have access to a variety of isolation methods, each offering distinct advantages and limitations. The choice of technology depends on application-specific factors such as voltage isolation requirements, signal bandwidth, power efficiency, physical constraints, and cost considerations.

To ensure optimal system performance, engineers must carefully evaluate these trade-offs. A thorough understanding of the selection criteria, ranging from isolation voltage and speed to power consumption and space limitations is essential for choosing the most appropriate solution. While isolation is critical in many applications, determining the correct method requires balancing these technical requirements against design goals.

A APPENDIX

A.1 Literature

[1] Understanding Phototransistor Optocouplers: https://www.we-online.com/en/support/knowledge/application-notes?d=ano007-understanding-optocouplers

[2] Lifetime of Optocouplers: https://www.we-online.com/en/support/knowledge/application-notes?d=ano006-lifetime-of-optocouplers

[3] Feedback loop compensation of a current-mode Flyback converter with optocoupler: https://www.we-online.com/en/support/knowledge/application-notes?d=anp-113-feedback-loop-compensation

[4] ANS020 | Digital isolators: https://www.we-online.com/en/components/media/o823104v410%20ANS020a_EN.pdf

[5] ANS021 | Ensuring Safety without Compromising Data Integrity: Critical Characteristics of Digital Isolators: https://www.we-online.com/en/components/media/o827501v410%20ANS021_EN.pdf

[6] ANS019 | Bipolar power supply and isolated signal transmission with MagI³C-FIMM: https://www.we-online.com/en/components/media/o742200v410%20ANS019a%20EN.pdf

[7] ANS022 | Bridge capacitor for isolated power modules, the whole truth, no myths: https://www.we-online.com/en/components/media/o856424v410%20ANS022a_Bridge%20capacitor%20for%20isolated%20power%20modules_EN.pdf

[8] Abc of Power Modules - Functionality, structure and handling of a Power Module: https://www.we-online.com/en/components/products/ABC_OF_POWER_MODULES_GERMAN

[9] ANP113 | Feedback loop compensation of a current-mode Flyback converter with optocoupler: https://www.we-online.com/components/media/o760916v410%20ANP113a%20EN.pdf

[10] ANP015 | 1-Phase Line Filter Design: https://www.we-online.com/components/media/o109029v410%20ANP015_EN.pdf

[11] ANP109 | Impedance Spectra of Different Capacitor Technologies: https://www.we-online.com/components/media/o720421v410%20ANP109b%20EN.pdf

[12] ABC of Capacitors - Basic Principles, Characteristics and Capacitor Types: https://www.we-online.com/en/components/products/ABC_OF_CAPACITORS_EN

IMPORTANT NOTICE

The Application Note is based on our knowledge and experience of typical requirements concerning these areas. It serves as general guidance and should not be construed as a commitment for the suitability for customer applications by Würth Elektronik eiSos GmbH & Co. KG. The information in the Application Note is subject to change without notice. This document and parts thereof must not be reproduced or copied without written permission, and contents thereof must not be imparted to a third party nor be used for any unauthorized purpose.

Würth Elektronik eiSos GmbH & Co. KG and its subsidiaries and affiliates (WE) are not liable for application assistance of any kind. Customers may use WE's assistance and product recommendations for their applications and design. The responsibility for the applicability and use of WE Products in a particular customer design is always solely within the authority of the customer. Due to this fact it is up to the customer to evaluate and investigate, where appropriate, and decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not.

The technical specifications are stated in the current data sheet of the products. Therefore the customers shall use the data sheets and are cautioned to verify that data sheets are current. The current data sheets can be downloaded at www.we-online.com. Customers shall strictly observe any product-specific notes, cautions and warnings. WE reserves the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services.

WE DOES NOT WARRANT OR REPRESENT THAT ANY LICENSE, EITHER EXPRESS OR IMPLIED, IS GRANTED UNDER ANY PATENT RIGHT, COPYRIGHT, MASK WORK RIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT RELATING TO ANY COMBINATION, MACHINE, OR PROCESS IN WHICH WE PRODUCTS OR SERVICES ARE USED. INFORMATION PUBLISHED BY WE REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE A LICENSE FROM WE TO USE SUCH PRODUCTS OR SERVICES OR A WARRANTY OR ENDORSEMENT THEREOF.

WE products are not authorized for use in safety-critical applications, or where a failure of the product is reasonably expected to cause severe personal injury or death. Moreover, WE products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. Customers shall inform WE about the intent of such usage before design-in stage. In certain customer applications requiring a very high level of safety and in which the malfunction or failure of an electronic component could endanger human life or health, customers must ensure that they have all necessary expertise in the safety and regulatory ramifications of their applications. Customers acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of WE products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by WE.

CUSTOMERS SHALL INDEMNIFY WE AGAINST ANY DAMAGES ARISING OUT OF THE USE OF WE PRODUCTS IN SUCH SAFETY-CRITICAL APPLICATION.

USEFUL LINKS

Application Notes
www.we-online.com/appnotes

REDEXPERT Design Platform
www.we-online.com/redexpert

Toolbox
www.we-online.com/toolbox

Product Catalog
www.we-online.com/products

CONTACT INFORMATION

appnotes@we-online.com
Tel. +49 7942 945 - 0

Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Str. 1 74638 Waldenburg Germany
www.we-online.com

REVISION HISTORY

Document Version	Release Date	Changes
ANP151a	2026/03/23	Initial release of the application note

Note: *The current version of the document and the release date are indicated in the footer of each page of this document.*