ANALOG DEVICES
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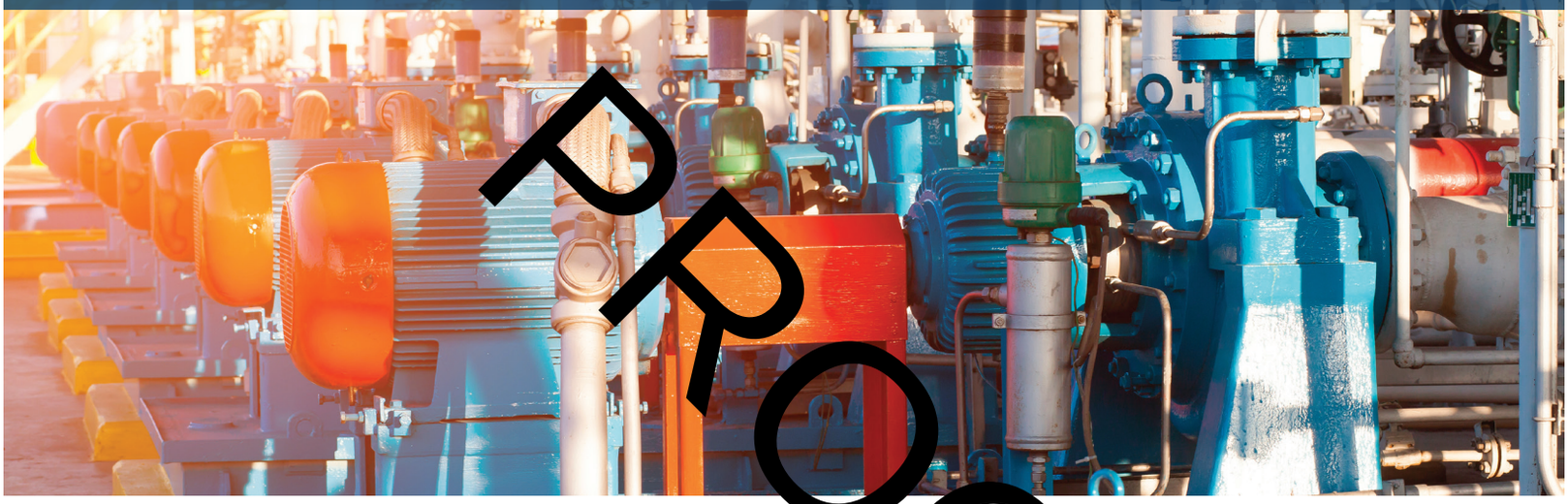
ISOLATION IN VARIABLE FREQUENCY DRIVE AND POWER SUPPLY APPLICATIONS



Application Introduction

Among all the parts used in electronic devices, the isolation component is one of the most important parts. This is especially the case in high voltage and high power applications. In variable frequency drive (VFD) and power supply designs, isolation components are typically used in both functional and safety isolation circuits to separate the low voltage control circuit from the high voltage power part, and to keep interface circuits separate from circuits that are dangerous to touch.

Why Use Isolation

VFDs and power applications require isolation for the following reasons:

- Reducing noise interference—modern power converters depend on a PWM scheme to control output voltage and current. However, in higher power applications, di/dt and dV/dt signal introduced by power switching can introduce noise in circuits via parasitic parameter coupling in the PCB layout. By adopting galvanic isolation between power and control circuits, the noise in control circuits can be reduced.
- Voltage levels—the power circuits of VFD and power devices are usually connected to dangerous voltages—typically 220 V/380 V ac—in which the rectified dc voltage can be up to 540 V and above, while the control circuit is usually referenced to a safe ground. Thus, isolation is needed between power and control circuits.
- Device interconnection—power supply devices are often needed to be connected with other controllers by fieldbuses. However, a power device and a controller may not be connected to the same ground. Therefore, without an isolation barrier, the components in the signal routine could be damaged by the voltage difference between grounds.

Moreover, some circuits—for instance, a long communication cable or an encoder cable—would face the impact of powers surges and lightning and should be isolated from internal circuits for protection reasons.

- Safety and insulation—parts of a circuit might be touched by the human body or have contact with a device's metal shell. Those parts should operate within safe voltage ranges and have galvanic isolation from dangerous voltage circuitry to prevent electrical shock. Typically, an HMI or communication interface should be isolated from the primary circuit by components that can meet the safety and insulation standards.

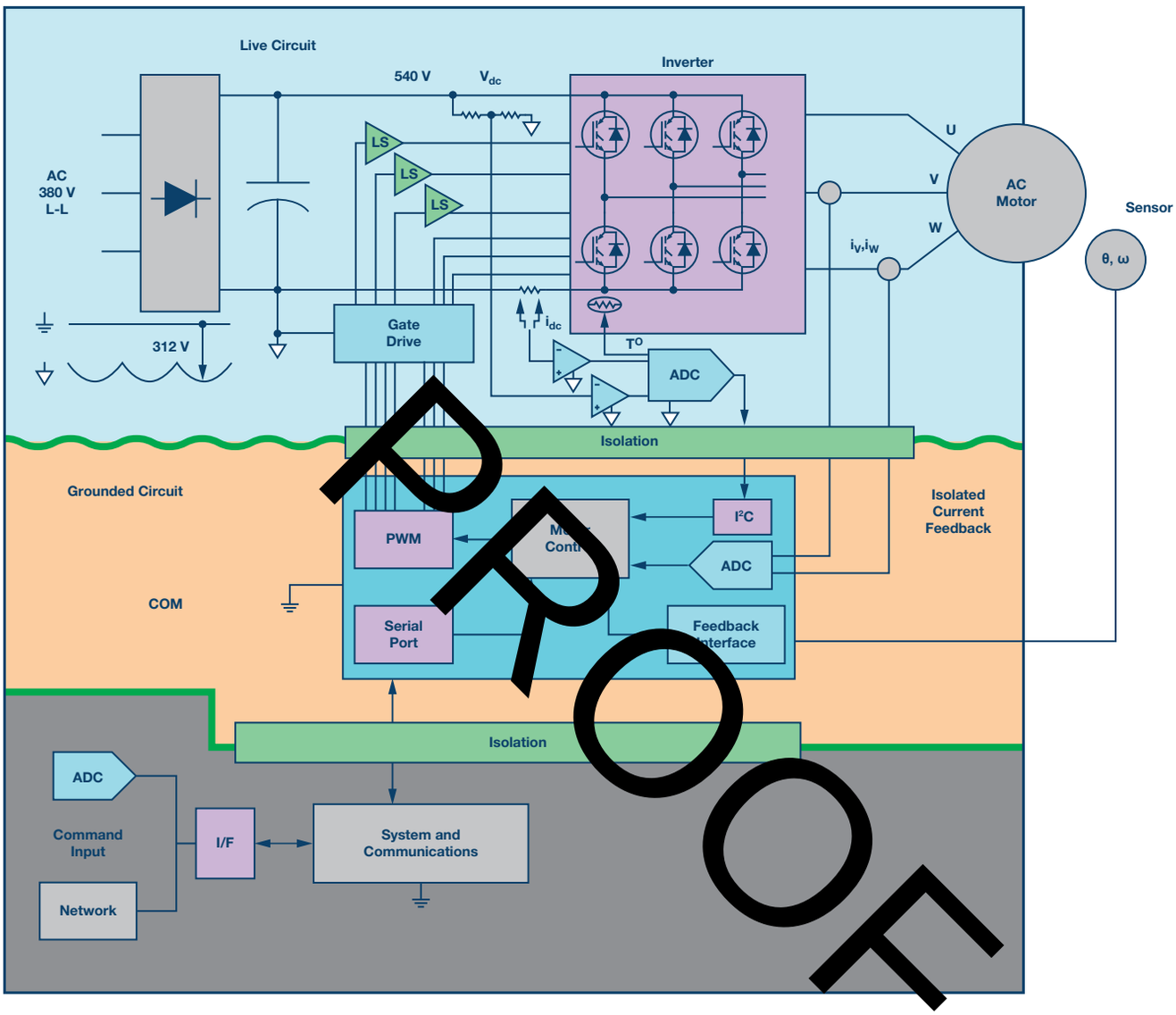
Isolation Applications

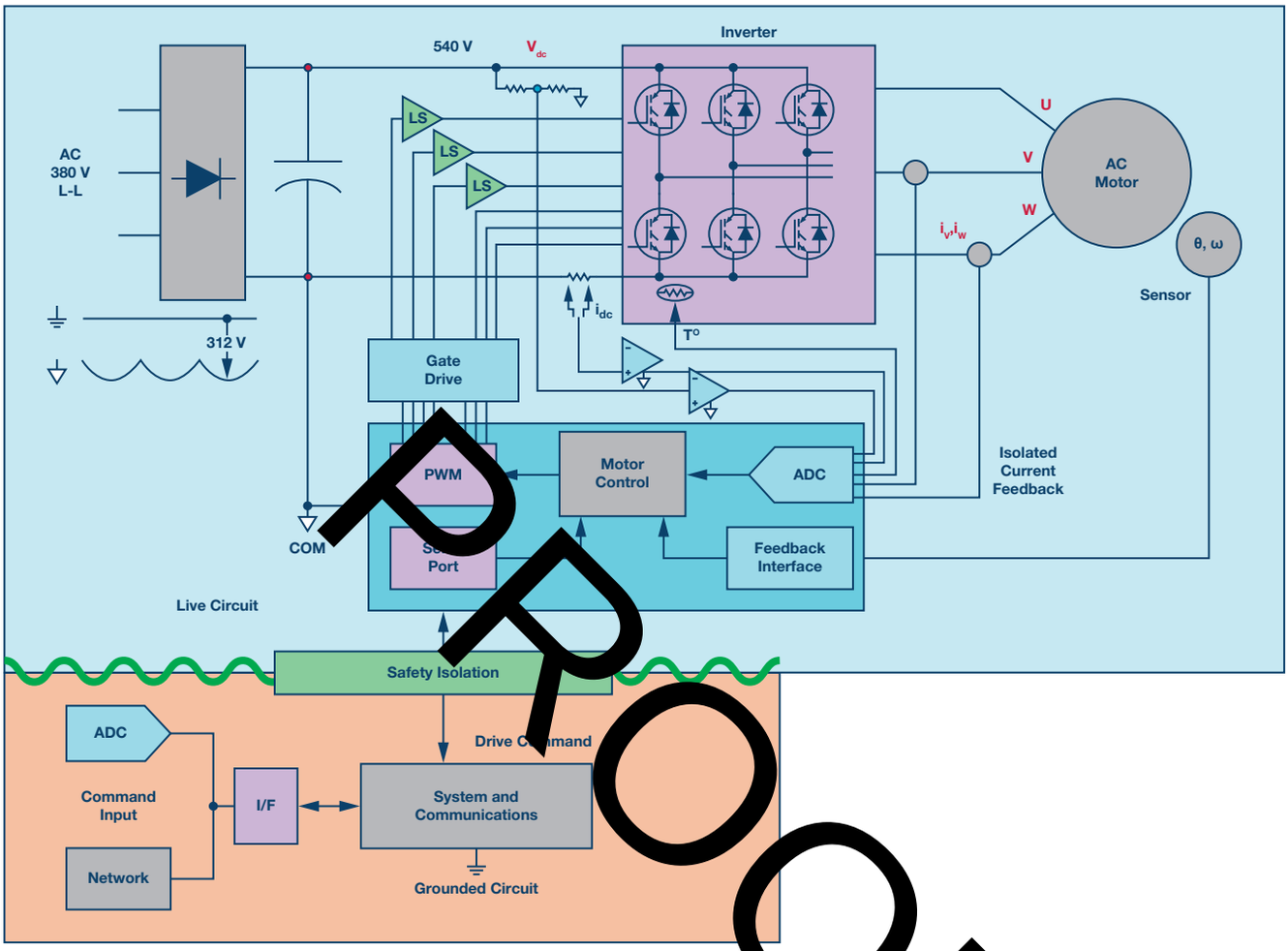
In the system structure of a VFD or power supply, circuits are separated into three parts: power circuits, control circuits, and the interface. Voltage levels and safety requirements are different in each part and galvanic isolation is needed between them.

Different isolation schemes can be used in different applications, which will depend on:

- The voltage level of the power circuit.
- Insulation and safety regulations. For example, system-level safety standards, such as IEC61800-5-1 and IEC62040-1-1, and component level standards, such as IEC 60747-5-5, VDE 0884-10, and UL1577.
- Components combination in different isolation barriers and cost-down saving considerations.

Isolated System Architecture





From a system point of view, minimizing the number of signal channels requiring isolation and reducing the use of reinforced level insulation components are important design concerns. The following architectures are commonly used in VFD and power supply systems:

- Two isolation barriers design—isolation between power and control circuits and isolation between control and interface circuits. Isolation between power and control circuits can be achieved by using an isolated IGBT/MOSFET gate driver and, isolated current/voltage detection components. Meanwhile, standard digital isolators, isolated ADCs, and isolated DACs can be used to separate control and interface circuits.

  This type of configuration is suitable for a VFD or power supply with various types of interface or for higher power applications. In these cases, signals between power and control circuits are usually fixed—this includes PWM signals, current/voltage feedback, and fault protection feedback. Comparatively, there could be various types of interface ports and may include optional accessories. For example, 0 V to 10 V, 4 mA to 20 mA analog input/output, 0 V to 24 V digital I/O, relay, RS-232/RS-485, Ethernet, USB, and CAN. Therefore, by implementing power control isolation and control interface isolation, respectively, designers can lower the system cost and have more freedom in component choice since there are two isolation barriers in the system and the requirements for each isolation layer could be lower. Additionally, the separation of power and control can also reduce power switching noise impact.

  Interface isolation can be unnecessary if the isolation between the power and control circuits already meets the system safety requirements. Furthermore, double insulation can be achieved by a combination of components in the two barriers.

- Power and control circuit connected to the same ground. In small power or low voltage applications, if the number of interfaces is limited, this type of configuration prevails. By connecting the controller ground to the power ground, one isolation barrier can be omitted, but the isolation requirement between the interface circuit and power part is generally higher than those in the previous configuration. However, with a limited interface requirement, the overall cost can still be lower.

ADI Isolation Technology and Products

- *i*Coupler® digital isolators transmit the information across isolation barriers using transformers, and the primary side's current change causes the secondary side's current change using the transformers. A 20 µm of an *i*Coupler polyimide is rated for a working voltage of 400 V rms for 50 years and a surge rating of greater than 6 kV (10 kV

test requirement) meeting VDE reinforced isolation requirements. The major advantages of *i*Coupler technology are

- High insulation reliability under high temperature and high voltage. *i*Coupler products have a 50 year lifespan operating under 400 V rms, by using the CMOS process, and working temperatures can be as high as 125°C.
- Common-mode transient immunity (CMTI) up to 100 kV/µS. More capable for motor drive, power inverter applications than conventional optocouplers.
- *i*Coupler data isolation products can meet CISPR 22 Class B (and FCC Class B) standards.
- *i*Coupler isolators can exceed the 10 kV peak surge requirement for a VDE V 0884-10 reinforced rating.
- Higher speed, better timing specifications, up to 150 Mbps data rate, 50 ns propagation delay, good channel-to-channel match performance, and low power consumption.
- Multiple isolation channels integrated with oth[illegible]ions reduce size and cost.

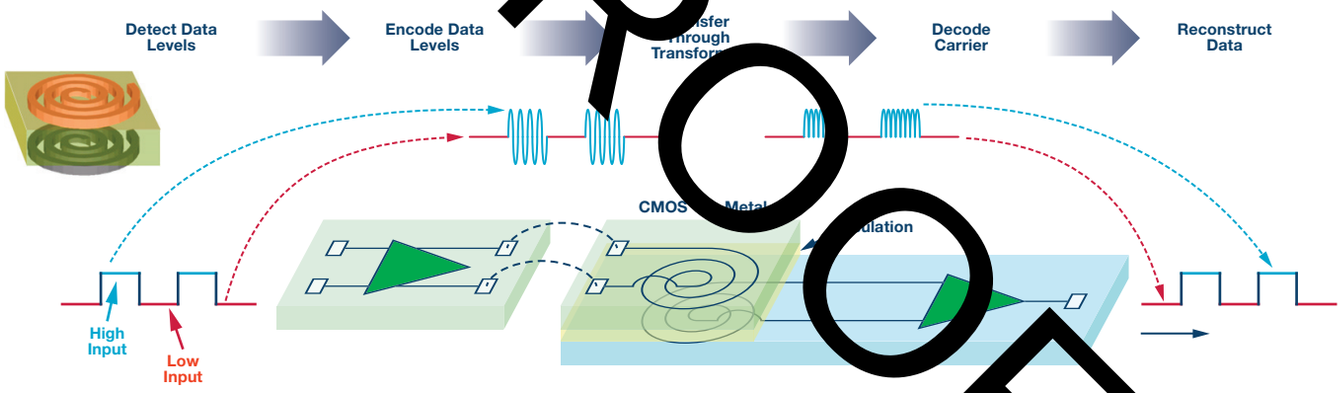
ADI provides a series of standard data isola[illegible] pr[illegible]ction, is[illegible]ated RS-232, RS-485, USB, CAN, SPI, I²C transc[illegible]ivers, amp[illegible]DCs, [illegible] gate driver devices.

- Isolated current and voltage sensing

ADI provides a range of products for isolated current and voltage sensing. AD740x series Σ-Δ modulators are dedicated current sensors for VFD and power applications. Currently, there is a significant trend for system designers to migrate from Hall effect sensors to shunt resistors, with an additional trend to move to the isolated modulator vs. an isolated amplifier approach. Quite often, system designers replacing HESes with shunt resistors opt for an isolated amplifier and continue using the ADC previously used in the HES-based design. In that case, the performance will be limited by the isolated amplifier regardless of the analog-to-digital performance.

Replacing the isolated amplifier and ADC with an isolated Σ-Δ modulator will eliminate the performance bottleneck and greatly improve the design—typically taking it from a 9-bit to 10-bit quality feedback to a 12-bit level. Analog overcurrent protection circuitry (OCP) can also potentially be eliminated, as the digital filter required to process the Σ-Δ modulator output can also be configured to implement a fast OCP loop.

- The isolated IGBT/MOSFET gate driver circuit is critically important in VFD and power designs. Driver circuits should possess high performance to reduce switching losses and improve system reliability. ADI's ADuM413x and ADuM3223/ADuM4223/ADuM7223 have a propagation delay of only 50 ns and CMTI up to 100 kV/µs, which makes it easier for driver circuit design.



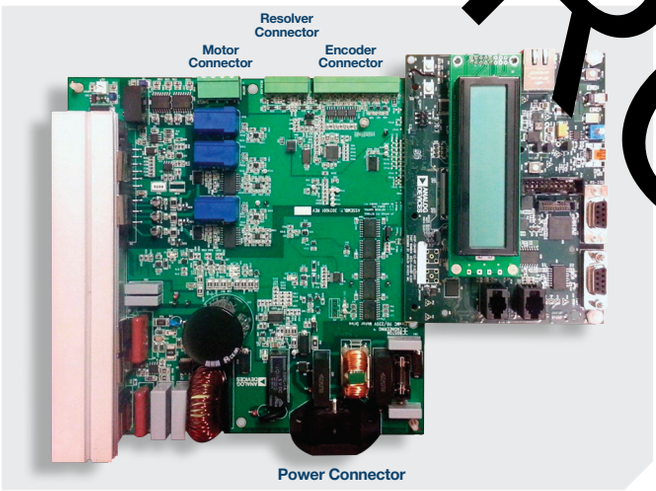
Key Product Technologies

Part Number	Description	Key Features	Benefit
Standard Digital Isolators			
ADuM1100/ ADuM120x/ ADuM130x/ ADuM140x	1-channel to 4-channel standard digital isolators	2.5 kV rms isolation rating, −40°C to +125°C, reverse channels	Maximum data rate 90 Mbps
ADuM14x	4-channel standard digital isolator	Next generation, 3.75 kV rms isolation rating, −40°C to +125°C, reverse channels	CMTI 100 kV/µs, low propagation delay (13 ns), maximum data rate 150 Mbps
Isolated Sensing			
AD7403	Isolated Σ-Δ ADC	5 MHz to 20 MHz external clock input rate, second-order Σ-Δ modulator, 16 bits, no missing codes, typical offset drift vs. temperature: 1.6 µV/°C, 88 dB SNR, 830 V rms maximum working voltage, −40°C to +125°C	14-bit ENOB, ±320 mV full-scale analog input range, UL1577, CSA60950, VDE0884-10
AD7401A	Isolated Σ-Δ ADC	5 MHz to 20 MHz external clock input rate, second-order Σ-Δ modulator, 16 bits, no missing codes, typical offset drift vs. temperature: 1.6 µV/°C, 88 dB SNR, 630 V rms maximum working voltage, −40°C to +125°C	14-bit ENOB, ±250 mV full-scale analog input range, UL1577, CSA60950, VDE0884-10
Isolated Gate Drivers			
ADuM4135	Isolated IGBT gate driver	4 A peak drive output capability, 500 V rms, 1200 V dc working voltage, −40°C to +125°C	50 ns propagation delay, UVLO, desat protection, soft-shutdown on fault, Miller clamp output with gate sense input, UL, CSA, VDE
ADuM4223	Isolated MOSFET/IGBT gate driver	4 A peak output current, high frequency operation: 1 MHz, high-side and low-side isolation: 537 V peak and 800 V peak for differential input, −40°C to +125°C	High-side and low-side isolation, UL, CSA, VDE

Part Number	Description	Key Features	Benefit
Isolated Communication			
ADM3251E	Isolated RS-232 transceiver	460 kbps data rate, 2.5 kV isolation	*iso*Power® integrated, isolated dc-to-dc converter, ±15 kV ESD protection on, UL, CSA, VDE
ADM2687E	Isolated RS-485/ RS-422 transceiver	Configurable as half or full duplex, 5 kV rms isolation rating, 500 kbps data rate, 5 V or 3.3 V operation	*iso*Power integrated isolated dc-to-dc converter, ±15 kV ESD protection on, open-and short-circuit, fail-safe receiver inputs, CMTI>25 kV/µS
ADuM4160	USB port isolator	Fully USB 2.0 compliant, low and full speed data rate: 1.5 Mbps and 12 Mbps, 5 kV rms isolation rating, 3.3 V and 5 V (dual mode power configuration) operation	Bidirectional communication, short-circuit protection for xD+ and xD− lines
ADM3054	Isolated controller area network (CAN)	Complies with the ISO 11898 standard, 1 Mbps, 5 kV rms isolation rating, 3.3 V or 5 V supply	Thermal shutdown protection
ADuM4150	Isolator for high speed SPI interfaces	40 MHz clock, wide supply voltage range, 5 kV rms isolation rating	Delayed compensation clock line
ADuM2250	Dual I²C isolator	1000 kHz operation, bidirectional I²C communication, 5 kV rms isolated, 3.0 V to 5.5 V supply	Hot swappable, UL, CSA
ADuM4190	Isolated error amplifier	5 kV isolation rating, 400 kHz bandwidth, 3 V to 20 V, −40°C to +125°C	1% accuracy over the full temperature range
*iso*Power Devices			
ADuM5000/ ADuM6000	Isolated dc-to-dc converter	500 m[illegible]400 mW, [illegible]gulated 3.3 V or 5 V output 2.5 kV/5 kV iso[illegible]rating	Thermal overload protection, UL, CSA, VDE

Reference Design and Demo Boards

FlexMC Motor Control HV MPC Platform™



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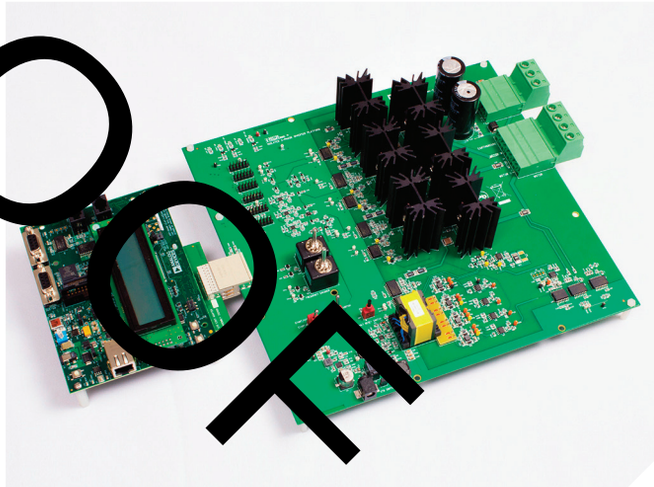
Isolator Inverter Platform



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Technical Articles/Application Notes

- Digital Isolator Product Selection and Resource Guide—*www.analog.com/Digital_Isolator_Product_Selection_and_Resource_Guide.pdf*
- Gate Drive and Current Feedback Signal Isolation in Industrial Motor Drives—*www.analog.com/Gate-Drive-and-Current-Feedback-Signal-Isolation-in-Industrial-Motor-Drives.pdf*
- *i*Coupler Products with *iso*Power Technology: Signal and Power Transfer Across Isolation Barrier Using Microtransformers—*www.analog.com/isoPower.pdf*
- IGBT Overcurrent and Short-Circuit Protection in Industrial Motor Drives—*http://www.analog.com/media/en/technical-documentation/technical-articles/IGBT-Overcurrent-and-Short-Circuit-Protection-in-Industrial-Motor-Drives.pdf*
- Digital Isolation for AC Voltage Motor Drives (MS-2488)—*www.analog.com/en/ms-2488.pdf*
- AN-0971 Application Note, *Recommendations for Control of Radiated Emissions with isoPower Devices*—*www.analog.com/en/an-0971.pdf*
- AN-1109 Application Note, *Recommendations for Control of Radiated Emisions with iCoupler Devices*—*www.analog.com/en/an-1109.pdf*
- AN-1349 Application Note, *PCB Implementation Guidelines to Minimize Radiated Emissions on the ADM2582/ADM2587E RS-485/RS-422 Transceivers*—*www.analog.com/en/an-1349.pdf*
- AN-727 Application Note, *iCoupler Isolation in RS-485 Applications*—*www.analog.com/en/an-727.pdf*
- AN-740 Application Note, *iCoupler Isolation in RS-232 Applications*—*www.analog.com/en/an-740.pdf*

- AN-770 Application Note, *i Coupler Isolation in CAN Bus Applications*—*www.analog.com/en/an-770.pdf*
- AN-913 Application Note, *Isolating I²C Interfaces*—*www.analog.com/en/an-913.pdf*

Circuits from the Lab® Reference Circuits for Isolation

Reference circuits are subsystem-level building blocks that have been engineered and tested for quick and easy system integration.

- A Novel Analog-to-Analog Isolator Using an Isolated Sigma-Delta Modulator, Isolated DC-to-DC Converter, and Active Filter—*www.analog.com/en/cn-0185*
- H-Bridge Driver Circuit Using Isolated Half-Bridge Drivers—*www.analog.com/en/cn-0196*
- Universal Serial Bus (USB) Hub Isolator Circuit—*www.analog.com/en/cn-0158*
- EMC Compliant RS-485 Transceiver Protection Circ—*www.analog.com/en/cn-0313*
- More reference circuits are available at—*www.analog.com/en/circuits*

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