Designing Robust, Isolated I²C/PMBus Data Interfaces for Industrial, Telecommunications, and Medical Applications

By Maurice O'Brien

Introduction

A key requirement for industrial and instrumentation (I&I), telecommunications, and medical applications is a reliable interface for transmitting data. The Inter-Integrated Circuit (I^2C) bus is a 2-wire, bidirectional bus used for low-speed, short-distance communication between integrated circuits. Developed by Philips in the early 1980s for ICs on a single board, I^2C usage is still increasing. The power management bus (PMBus), a relatively slow 2-wire communications protocol based on I^2C, is targeted at digital management of power supplies. The PMBus protocol defines an open-standard, digital-power-management protocol that facilitates communication with a power converter or other connected device.

Figure 1 shows how an isolation barrier galvanically isolates the I^2C interface from each system connected to it, allowing digital data to travel between two points but preventing the flow of ground current; this reduces signal distortion and errors by removing noise that gets coupled onto the communications bus.

PC boards used in telecommunications applications often include digitally controlled power converters and circuits that operate at different ground potentials. To ensure trouble-free card insertion/removal and robust operation, each interface must be isolated, but isolating I^2C interfaces is complicated because the bus is bidirectional. This requirement is not compatible with optocouplers, which are unidirectional. Figure 2 shows a PMBus communications link that isolates the ADM1075 −48-V hot swap and digital power monitor on the primary side from the secondary side, which operates with 12-V and 3.3-V supplies. The ADM3260 dual I^2C isolator with dc-to-dc converter isolates the SDA and SCL signals. Its isolated power supply (3.3V_ISO) powers the ADuM3200 2-channel digital isolator that isolates the SHDN and RESTART signals.

Isolation is required because the primary side is referenced to −48 V, while the secondary side is referenced to ground in a low-voltage domain. Isolation prevents permanent damage that could occur if the I^2C port was inadvertently connected

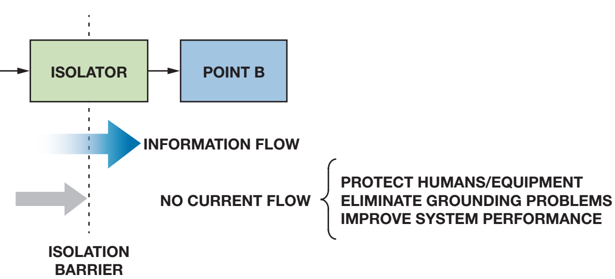

***Figure 1.** Isolation function.*

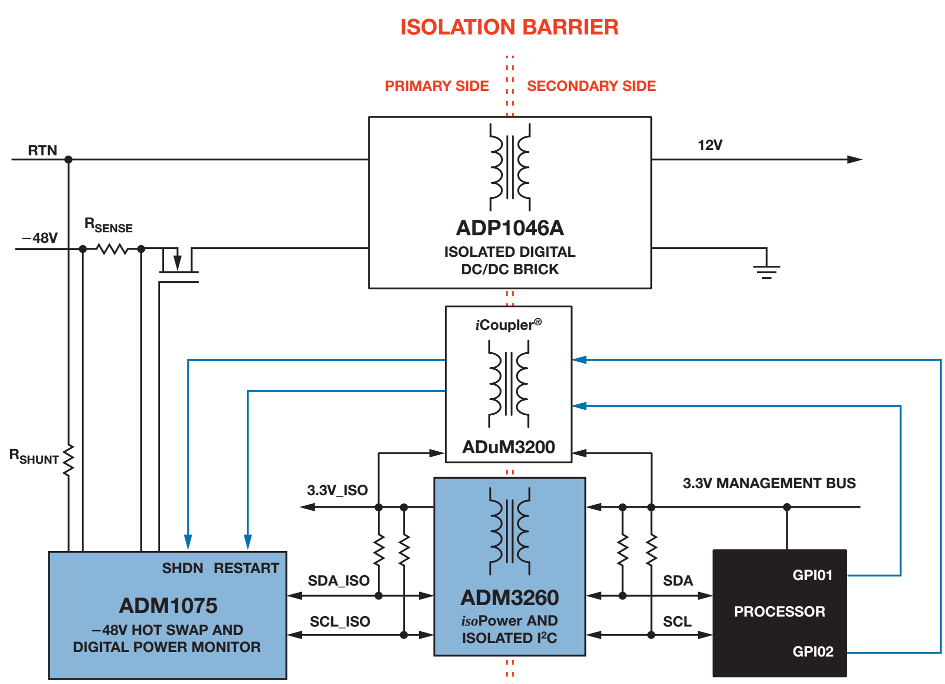

***Figure 2.** Typical isolated PMBus communications link.*

directly to the −48-V supply. Isolation also provides protection against high voltages or currents caused by the line surges or ground loops that can occur in a system with multiple grounds. The isolated power channel (3.3 V_ISO) allows the primary-side circuitry to be powered from the secondary side, removing the requirement for a separate low-voltage power source, which is not commonly available in the −48-V domain and is problematic to generate. All additional I/O signals crossing the isolation barrier require isolators that can also be powered by the ADM3260. To achieve a robust data communications link, each I²C device connected to the I²C bus must be isolated.

Examples of isolated I²C applications include:

- Isolated I²C, SMBus, or PMBus interfaces
- Level-translating I²C interfaces for power supplies
- Networking
- Power-over-Ethernet
- Central office switching
- Telecommunication and data communication equipment
- Isolated data acquisition systems
- −48 V distributed power systems
- −48 V power supply modules

It is often necessary to bring data from a precision converter (ADC or DAC) across an isolation barrier via an I²C bus. Figure 3 shows two isolated data-acquisition systems. These applications also require an isolated power supply to power the converters and amplifiers on the secondary side.

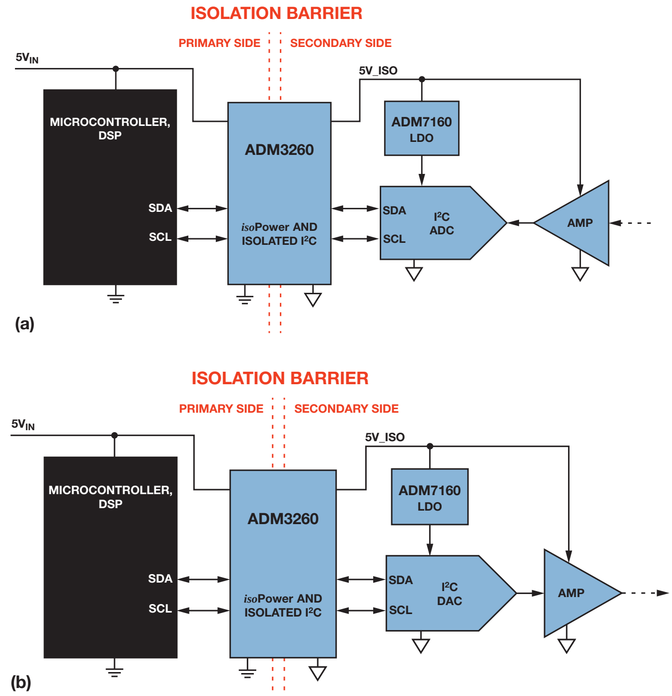

Figure 3. *(a) Isolated I²C ADC and amplifier, and (b) Isolated I²C DAC and amplifier.*

Some applications require channel-to-channel isolation, where each channel is isolated from every other channel, as shown in Figure 4.

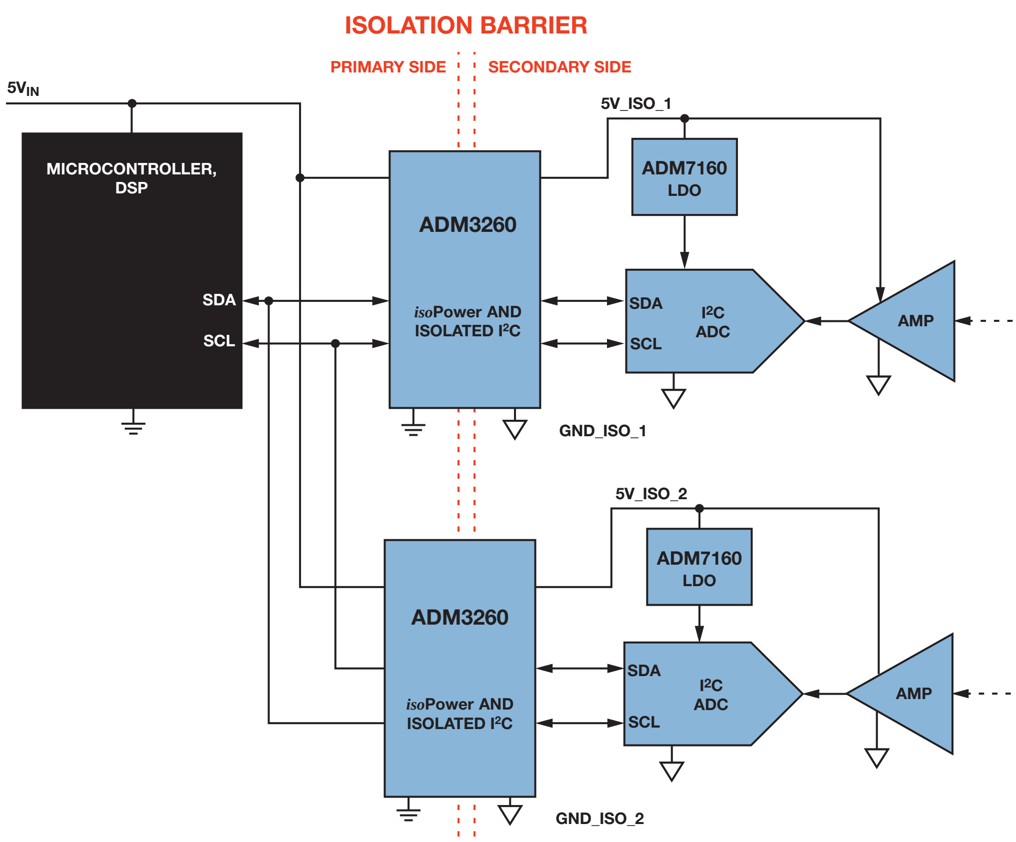

Figure 4. *Channel-to-channel isolated I²C ADC and amplifier.*

In larger systems, level translation is required between different voltage domains. An example of this is isolating the PMBus on each line card in a telecommunications rack-mounted system. Figure 5 shows a typical telecommunications application featuring multiple line cards that can be inserted into a −48-V backplane. In this application, the isolators level shift the I²C logic signals from the −48-V backplane to the fully isolated +12-V system.

Isolated power for the I²C communication link is obtained by using an isolated dc-to-dc power supply or *iso*Power® integrated dc-to-dc converter technology from Analog Devices. Signal isolation is implemented using optocouplers or *i*Coupler® technology from Analog Devices.

Implementing an Isolated I²C Interface

Bidirectional data must pass between an intelligent device (such as an ADC or DAC) on the primary side to a processor on the secondary side and power must pass from the primary side to the secondary side. To isolate a data link, the data lines and the power supply must all be isolated. For an I²C link, all connected devices must be isolated from the I²C bus, as shown in Figure 6.

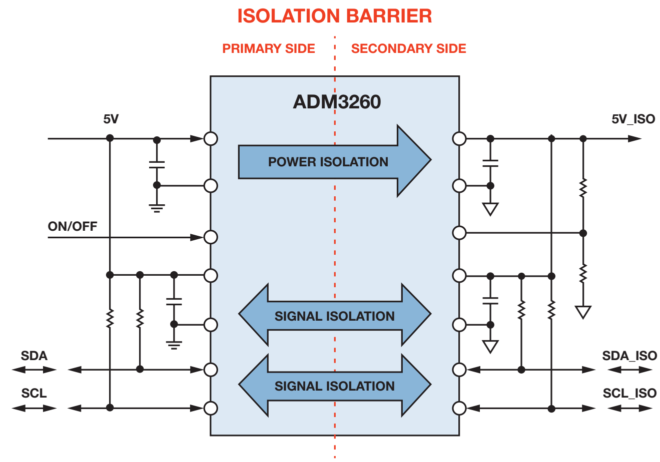

Figure 6. *Isolated I²C interface.*

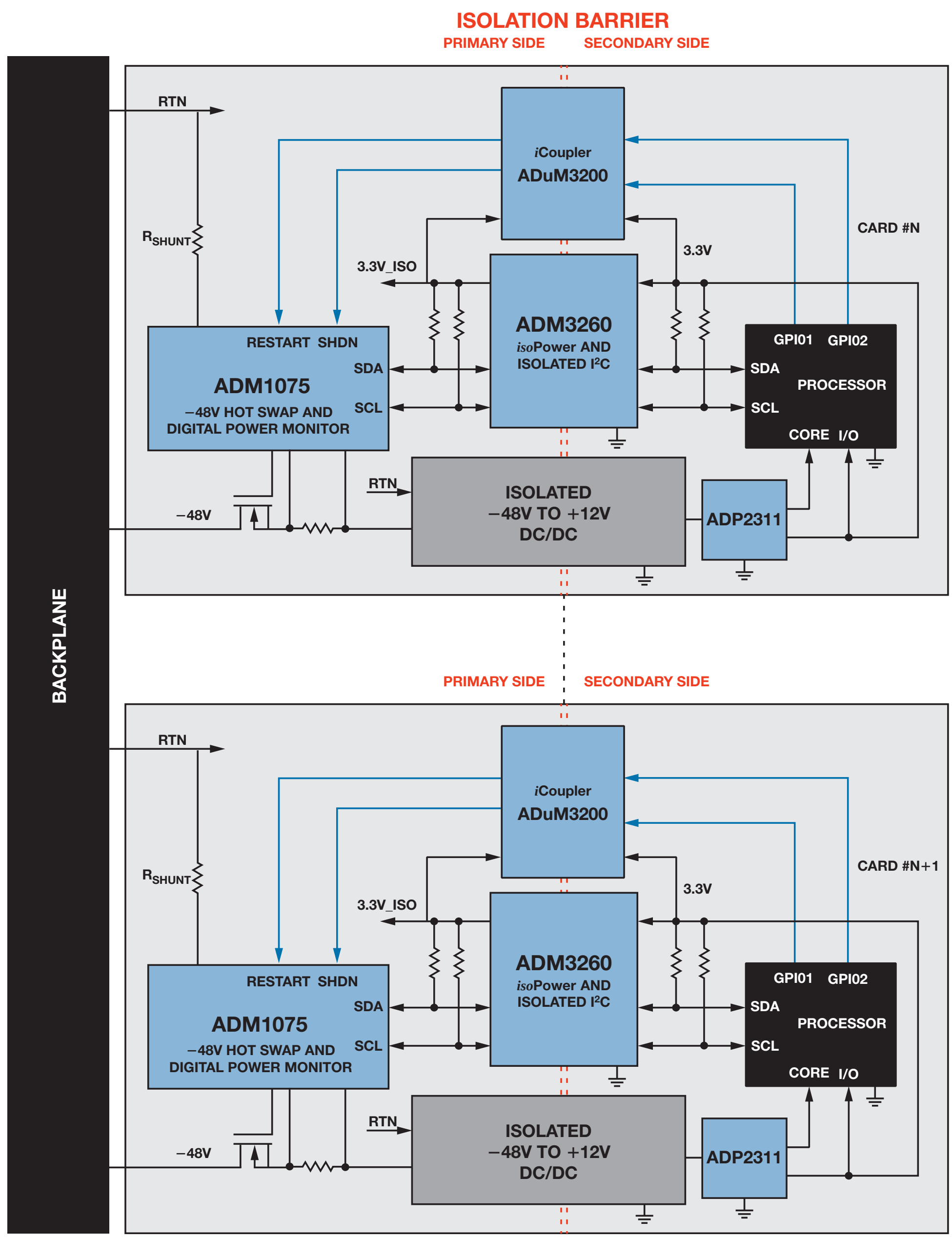

Figure 5. *Isolating and level translating PMBus signals in a −48-V application.*

The Challenge of Isolated I²C Interfaces

Because the I²C interface is bidirectional, providing isolation while avoiding bus glitches and lock-up can be a challenge. Figure 7 shows an optocoupler-based interface. Optocouplers are inherently unidirectional, so each bidirectional I²C line must be split into two unidirectional lines. Isolating a complete I²C interface requires four optocouplers and several passive components. The resulting cost, PC board area, and complexity diminishes the inherent value of the otherwise simple, low-cost, 2-wire I²C interface. Note that an isolated power supply is also required.

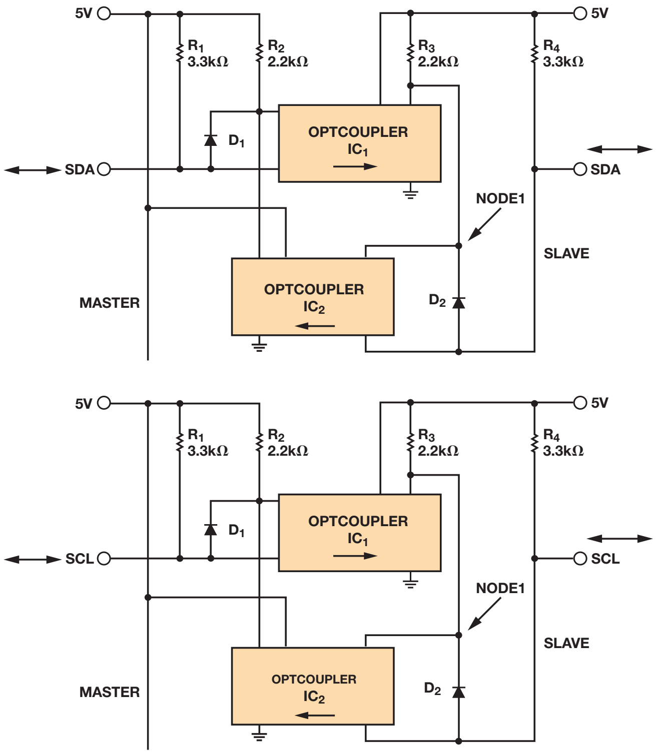

Figure 7. An optocoupler-based I²C interface.

Isolation Technology: Data and Power

Figure 8 compares two principal isolation technologies. *i*Coupler technology (a) uses thick-film processing techniques to build microscale on-chip transformers that achieve 2.5-kV isolation. The older, but widely employed, optocoupler solution (b) uses light-emitting diodes (LEDs) and photodiodes. The LEDs convert electrical signals to light, and photodiodes convert the light back to electrical signals. The intrinsically low conversion efficiency for electrical-to-light conversion leads to relatively high power consumption, the slow response of photodiodes limits their speed, and aging limits their lifetime.

Using wafer-level processing to fabricate on-chip transformers allows low-cost integration of *i*Coupler channels with each other and with other semiconductor functions. One example is the ADM3260 hot swappable, dual I²C isolator with integrated dc-to-dc converter. *i*Coupler isolation overcomes the limitations imposed by optocouplers in many ways: these easy to use devices reduce overall solution size, system cost, and power consumption, while increasing performance and reliability. In addition, *i*Coupler technology does not suffer performance degradation caused by current transfer ratio (CTR) aging of standard optocouplers over time and *i*Coupler is bidirectional technology, whereas optocoupler technology is inherently unidirectional.

Until recently, creating a low-voltage supply on the isolated side required either a separate dc-to-dc converter, which is relatively large and expensive, or a custom discrete circuit as shown in Figure 9. These approaches were the only viable alternatives, even for I²C data communication or other applications requiring only a small amount of isolated power.

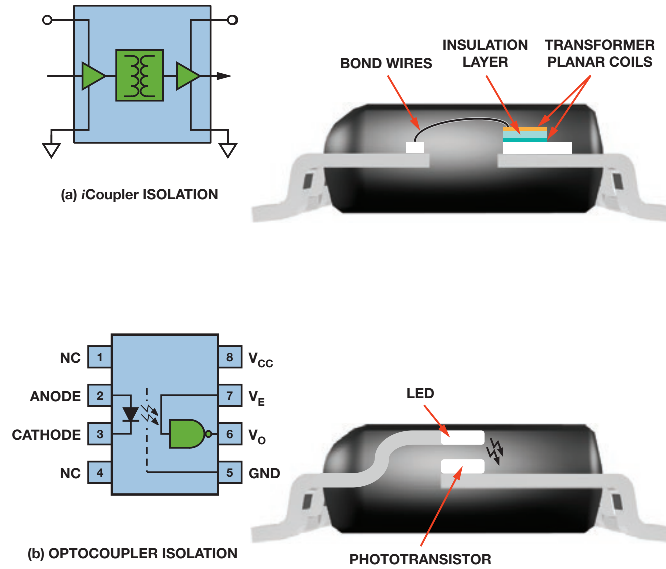

Figure 8. Isolation technologies compared: (a) iCoupler isolation. (b) Optocoupler isolation.

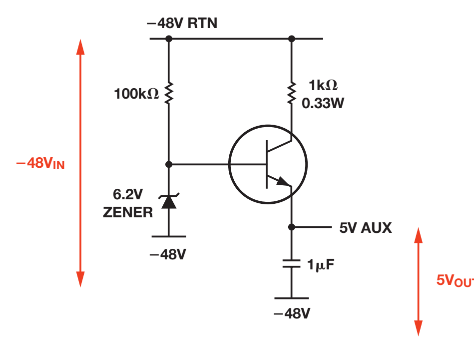

Figure 9. Discrete –48-V-to-5-V power solution to power isolators.

To solve this problem, Analog Devices developed a complete, fully integrated solution that combines signal and power transfer across an isolation barrier using microtransformers. An extension of the well-established *i*Coupler technology, *iso*Power is a breakthrough alternative. Achieving up to 5 kV signal and power isolation within a single component, it eliminates the need for an isolated power supply, and significantly reduces PC board area, design time, and total system cost for a typical I²C bus.

Dual I²C Isolators with Integrated DC-to-DC Converter

Figure 10 compares PMBus isolation using discrete components with a fully integrated solution. The discrete approach requires four optocouplers for isolation, an isolated power supply, and complex analog circuits to prevent latch-up and suppress glitches. The isolated power supply uses a transformer driver IC to drive a discrete transformer, along with a simple rectifier and low-dropout regulator to clean up the isolated rail. This design requires eight ICs and several passive components, and burdens the interface with higher cost, increased PC board area, and lower reliability.

The integrated solution provides a fully isolated bidirectional I²C interface and isolated power with a single IC, plus the decoupling capacitors and pull-up resistors associated with any I²C interface. The ADM3260 is free of glitch and lock-up issues, has UL approved 2.5-kV rms-isolation ratings, and is offered in a 20-lead SSOP package. It provides bidirectional isolated data and clock lines and isolated power without the size, cost, and complexity of optocouplers.

This single-chip solution significantly reduces the cost, design time, and PC board area required for an isolated I²C interface, while enhancing reliability. It operates from 3.3-V or 5-V supplies without modification, avoiding the design changes that would be necessary with a discrete design, and provides 150 mW of output power at 5 V or 65 mW at 3.3 V, allowing it to power ADCs, DACs, or other small systems on the isolated side.

Transient Protection

To allow the isolated interface to operate under the harsh operating conditions found in industrial applications, *i*Coupler and *iso*Power isolation technologies provide >25-kV/µs common-mode transient immunity. This specifies the maximum slew rate on the rising and falling edges of the potential difference between primary and isolated sides, ensuring that transients coupled onto the bus will not damage devices connected to the bus or corrupt the transmitted data and enhancing the reliability of the data link.

2.5-kV Isolation Protection and Approvals

The isolated solution specified 2.5-kV rms isolation between the primary and isolated side of the device. This isolation rating ensures that current can't flow from the primary side to the I²C bus, and that voltages or transients coupled onto the bus won't reach the logic side. The 2.5-kV isolation protection also means that people and equipment on the logic side are protected from high voltages or transients on the bus side. Approval is pending for the 2.5-kV isolation rating of the ADM3260 at the following agencies: Underwriters Laboratories (UL), Verband Deutscher Elektrotechniker (VDE), and Canadian Standards Association (CSA). UL 1577 approval requires the isolation barrier of all devices to be 100% production tested. The ADM3260 provides:

- UL recognition
- 2500 V rms for 1 minute per UL 1577
- VDE certificate of conformity
- IEC 60747-5-2 (VDE 0884, Part 2)
- VIORM = 560 V_{PEAK}
- CSA Component Acceptance Notice #5A

PCB Layout

Proper PCB layout is critically important to ensure that the specified 2.5-kV isolation is achieved in an actual design. The principal considerations are creepage (shortest distance along the surface between two conductors) and clearance (shortest distance through the air) between the logic-side GND and the bus-side GND. The ADM3260 requires no external circuitry for its logic interfaces. Power-supply bypassing is required at the input and output supply pins, as shown in Figure 11. Further information on PCB layout guidelines for controlling electromagnetic interference (EMI) can be found in AN-0971 Application Note, *Recommendations for Control of Radiated Emissions with isoPower Devices*.

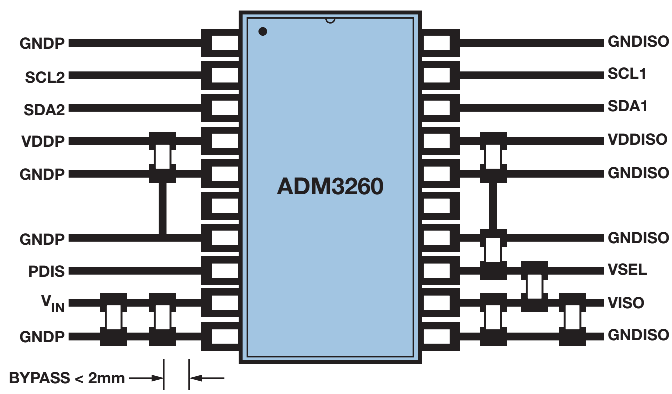

Figure 11: *ADM3260 recommended printed circuit board layout.*

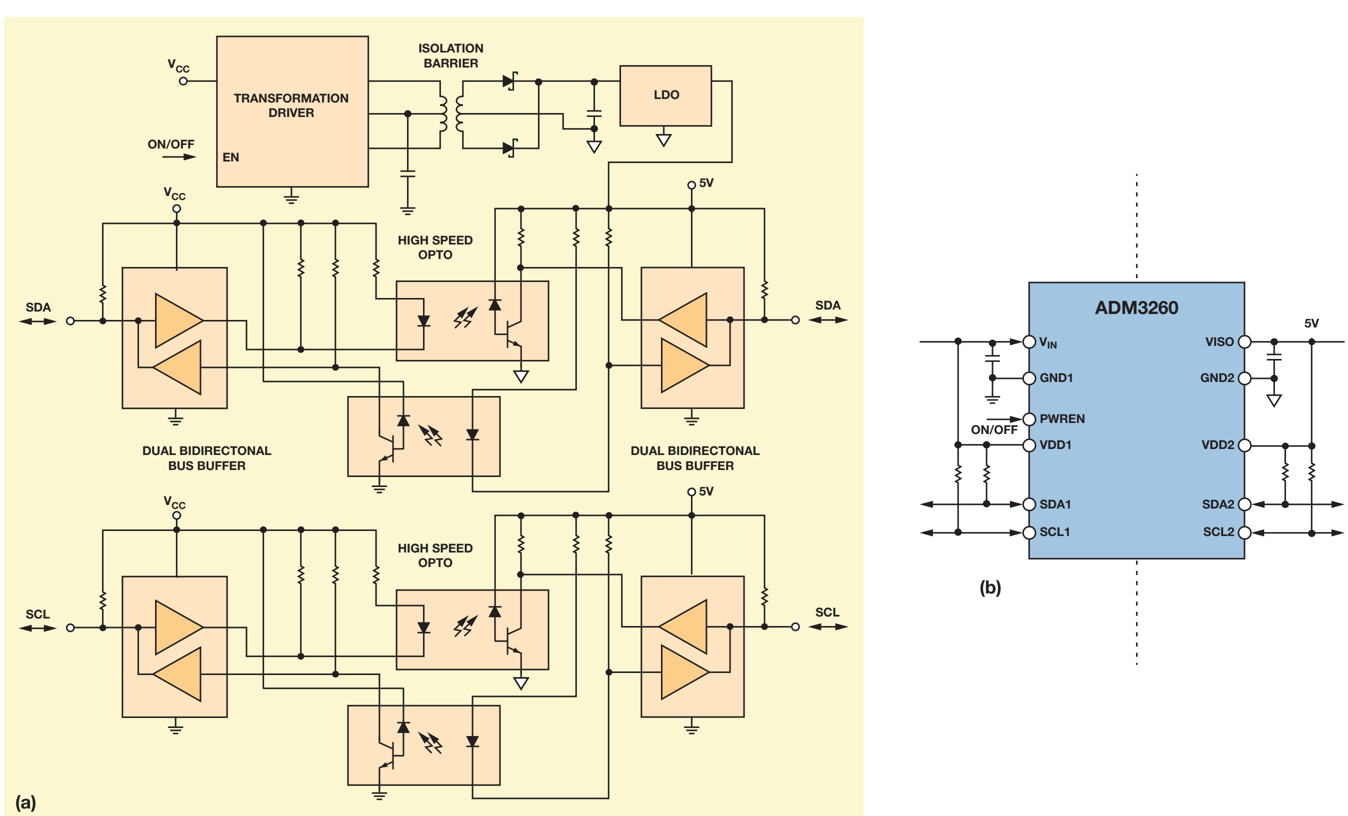

Figure 10. *Isolated I²C designs compared: (a) Discrete solution and (b) Integrated solution.*

ADM3260 Applications and Benefits

The ADM3260 hot swappable isolator provides both data and power isolation. Two nonlatching, bidirectional communication channels support a complete isolated I^2C/PMBus interface, and an integrated dc-to-dc converter provides up to 150 mW of isolated power at 3.15 V to 5.25 V. The bidirectional channels eliminate the need for splitting I^2C/PMBus signals into separate transmit and receive signals for use with standalone optocouplers, and the integrated dc-to-dc converter enables a complete isolated I^2C/PMBus interface to be implemented in a small form factor. The ADM3260, shown in Figure 12, is available in a 20-lead SSOP package with 5.3-mm creepage, operates from −40°C to +105°C, and is priced at $2.99 in 1000s.

In addition to isolating I^2C buses for hot-swappable central-office line cards, the ADM3260 can be used to isolate data-acquisition equipment in harsh industrial environments, to provide power and level translation over Ethernet, and in many other applications.

Conclusion

Isolated I^2C/PMBus links in industrial and instrumentation, telecommunications, and medical applications need to be small, robust, and inexpensive. By integrating chip-scale transformer isolation, a single chip can implement a fully isolated I^2C/PMBus data link including isolated power. The ADM3260 hot-swappable, dual I^2C isolator with integrated dc-to-dc converter can provide a compact, reliable, low-cost, high-performance solution for these demanding applications while significantly reducing circuit complexity and design time.

References

Digital Isolators

Digital Isolator Product Selection and Resource Guide

*i*Coupler® Products with *iso*Power™ Technology: Signal and Power Transfer Across Isolation Barrier Using Microtransformers

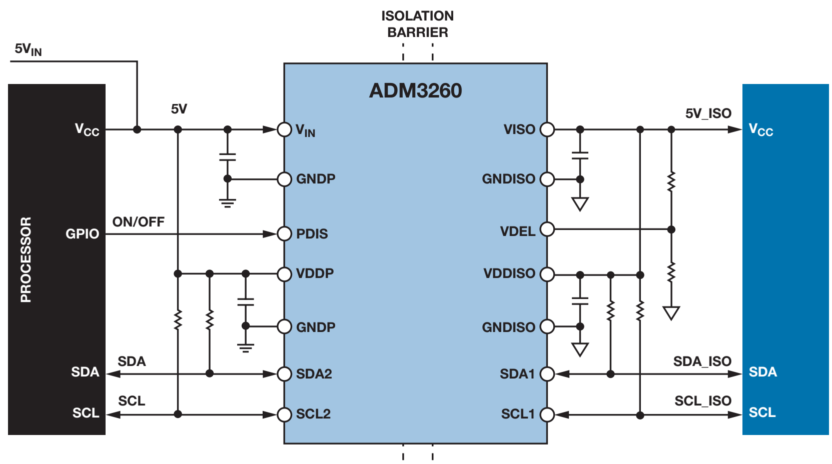

Figure 12. *ADM3260 isolated I^2C/PMBus interface.*

I^2C Digital Isolators

Part Number	Insulation Rating (kV rms)	Max Data Rate (Mbps)	Serial Check	Serial Data	Min P_{OS} Supply	Max P_{OS} Supply	Supply Current (mA)	Max Operating Temp (°C)	Automotive Recommended	Price ($U.S.)[1]
ADM3260	2.5	1	Bidirectional	Bidirectional	3	5.5	9.5	105	–	$2.99
ADUM2551	5	1	Unidirectional	Bidirectional	3	5.5	–	105	–	$2.77
ADUM2250	5	1	Bidirectional	Bidirectional	3	5.5	–	105	–	$3.00
ADUM1251	2.5	1	Unidirectional	Bidirectional	3	5.5	–	105	Yes	$2.20
ADUM1251	2.5	1	Bidirectional	Bidirectional	3	5.5	5	105	Yes	$2.20

[1]All prices are in USD in quantities of 1000 to 4999.

Maurice O'Brien [maurice.obrien@analog.com] joined Analog Devices in 2002, following his graduation from the University of Limerick, Ireland, with a bachelor's degree in electronic engineering. He currently works as a product marketing manager in the Power Management product line. In his spare time, Maurice enjoys horse riding, outdoor sports, and travel.

Maurice O'Brien

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Volume 47, Number 4