Designing Robust Isolated RS-232 Data Interfaces for Harsh Industrial Applications

By Maurice O'Brien

Introduction

A key requirement in *industrial and instrumentation* (I&I) applications is a reliable data interface for inspecting connected systems via a diagnostic port. The RS-232 bus standard is one of the oldest and most widely used physical-layer bus designs in I&I applications. First introduced in 1962, RS-232 is a single-ended data transmission standard; yet despite rumors of its early demise, it continues to be widely used throughout the industry for communications over a short cable.

To achieve a robust data communications link in harsh industrial environments, the RS-232 diagnostic port must provide an isolated interface between the RS-232 cable network and the connected systems to protect against voltage spikes and ground loops within the noisy environment and improve system reliability (Figure 1). Power isolation of the RS-232 communication link is obtained by using an isolated dc-to-dc power supply or Analog Devices, Inc., *iso*Power® integrated dc-to-dc converter technology. Signal isolation of the RS-232 communication link is implemented using *optocouplers* or Analog Devices *i*Coupler® technology.
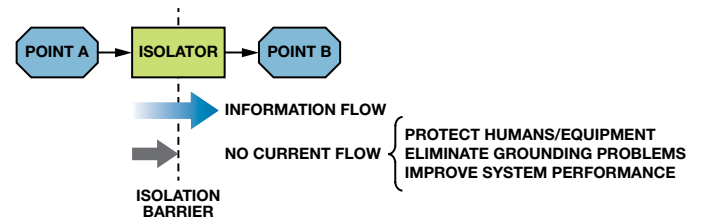

Figure 2. Isolation function.

As shown in Figure 2, an isolation barrier galvanically isolates the RS-232 bus from each system connected to it, allowing digital data to travel between two points but preventing the flow of ground loop currents; this reduces signal distortion and errors by removing noise that gets coupled onto the communications cable.
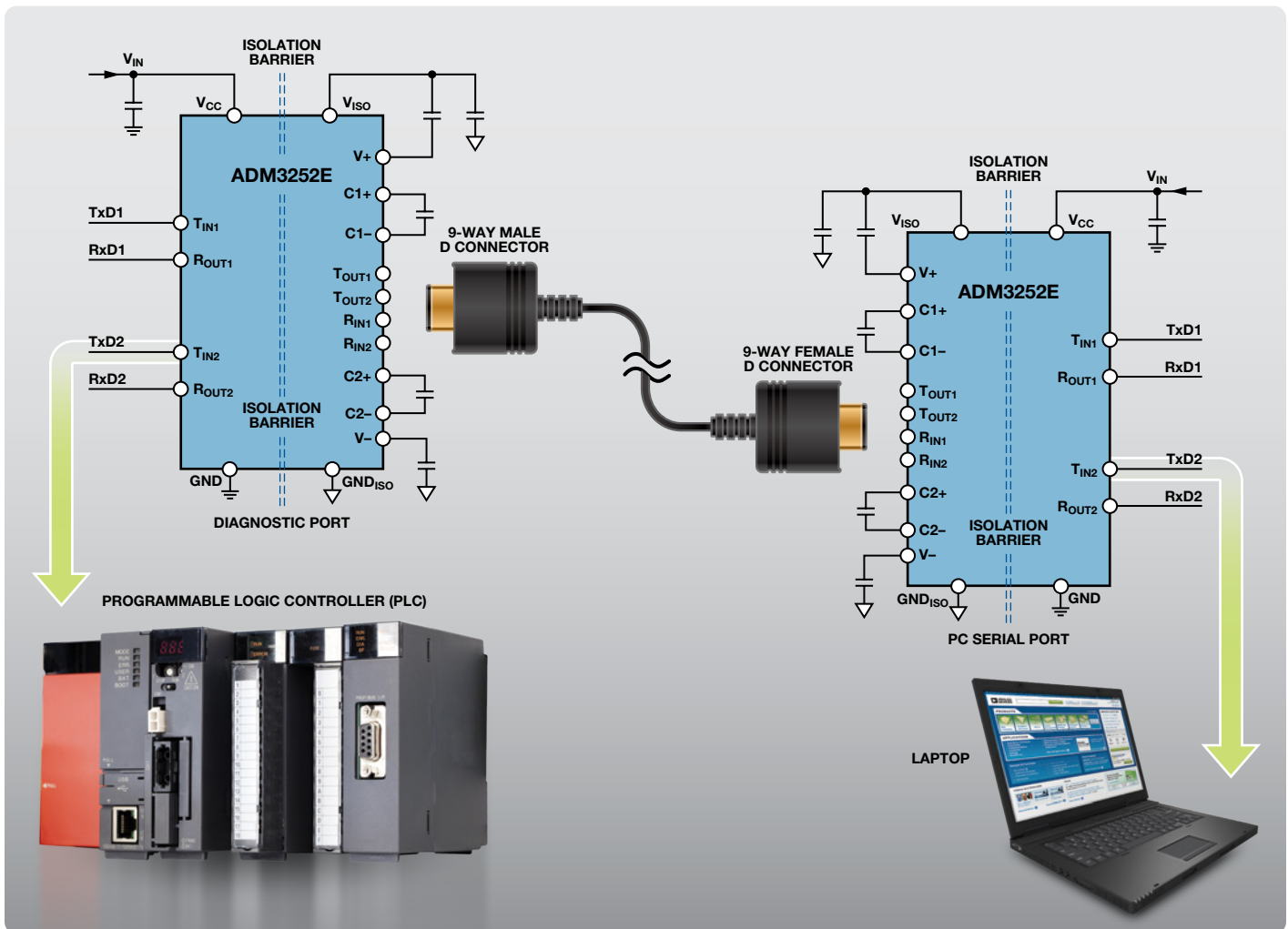

Figure 1. Typical isolated RS-232 communications link.

Implementing an Isolated RS-232 Interface

To provide an isolated RS-232 communications interface, the devices at both ends must be isolated from the RS-232 cable that connects them. To isolate a *data link,* both the data signal lines and the power required to drive the cable must be isolated. The data coming from the UART on the diagnostic port needs to cross the isolation barrier to the RS-232 transceiver on the isolated bus side. The local 5-V/3.3-V power supply also needs to cross the isolation barrier to power the RS-232 transceiver on the isolated bus side. This also needs to happen on the industrial PC side: both the data and power need to cross the isolation barrier (Figure 3).

By isolating both devices from the RS-232 cable network, both the diagnostic port and the industrial PC circuitry are protected from transients that may get coupled onto the RS-232 cable in harsh environments. Ground loops that might occur due to different ground potentials at the diagnostic port and industrial PC side are interrupted by the isolation. The high common-mode voltages that might appear on the RS-232 bus are not allowed across the isolation barrier, protecting human users of the isolated data.

Isolation Technology: Data and Power

Figure 4 compares two principal isolation technologies. *i*Coupler technology, Figure 4(a), provides signal isolation in an RS-232 system by using thick-film processing techniques to build micro-scale on-chip transformers that achieve 2.5-kV isolation. The older, but widely employed, *optocoupler* solution, Figure 4(b), uses light-emitting diodes (LEDs) and photodiodes. The LEDs convert electrical signals to light, and photodetectors 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 photodetectors limits their speed, and aging limits their lifetime.
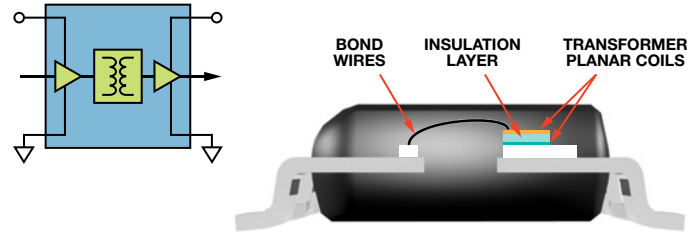
(a). *i*Coupler isolation.
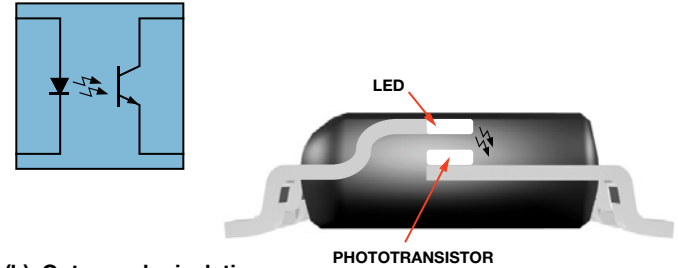
(b). Optocoupler isolation.

Figure 4. Isolation technologies compared.

Fabricating transformers directly on chip, using *wafer-level processing,* allows low-cost integration of *i*Coupler channels with each other and with other semiconductor functions. An example of this is the ADM3252E, an isolated two-channel RS-232 transceiver in a single compact device. *i*Coupler isolation overcomes the limitations imposed by the older optocoupler solution in at least five ways: *integration*—which reduces overall solution size and system cost due to the bidirectional operation of *i*Coupler—higher *performance,* lower *power consumption, ease of use,* and higher *reliability.*
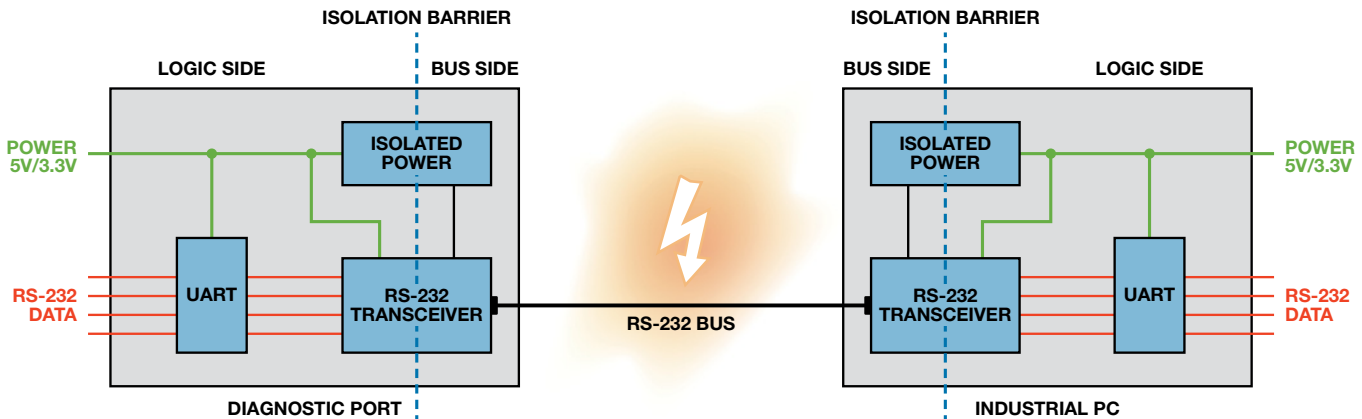
Figure 3. Isolated RS-232 interface.

Until recently, transferring power across an isolation barrier required either a separate dc-to-dc converter, which is relatively large, expensive, and has insufficient isolation, or a custom discrete approach, which is both bulky and difficult to design. These approaches have been the only viable alternatives, even in applications such as isolated RS-232 data communications, where only a small amount of isolated power is needed.

To solve this problem, Analog Devices developed and manufactured a complete, fully integrated solution that combines signal and power transfer across an isolation barrier using microtransformers. This extension of our well established *i*Coupler technology, termed *iso*Power, is a breakthrough alternative. Signal and power isolation within a single component—good up to 2.5 kV—eliminates the need for an isolated power supply that is bulky, expensive, and difficult-to-design. It can significantly reduce board space, design time, and total isolation system cost for a typical isolated RS-232 interface. The following sections describe two typical RS-232 design situations where this technology is applicable.

Isolated, High-Speed Dual-Channel RS-232 Interface

Figure 5 compares a legacy solution using discrete components with a fully integrated solution.

The traditional way of implementing a fully isolated 2-channel RS-232 interface, Figure 5(a), is to use optocouplers to provide data isolation of the RS-232 link. One optocoupler is needed for each data line (TIN1, TIN2, ROUT1, ROUT2), along with an external buffer for each one. The isolated power supply uses a transformer driver IC to drive a discrete transformer, along with a simple rectification circuit and an LDO (low-dropout regulator) to clean up the isolated 5-V or 3.3-V ISO V_{CC} rail. For implementation, this design requires eight ICs and a number of passive components—plus significant board space.

In a single-chip solution, Figure 5(b), a fully isolated (2.5-kV) two-channel RS-232 interface for all four signals can be implemented with just one IC (ADM3252E), plus two decoupling capacitors and four charge-pump capacitors.
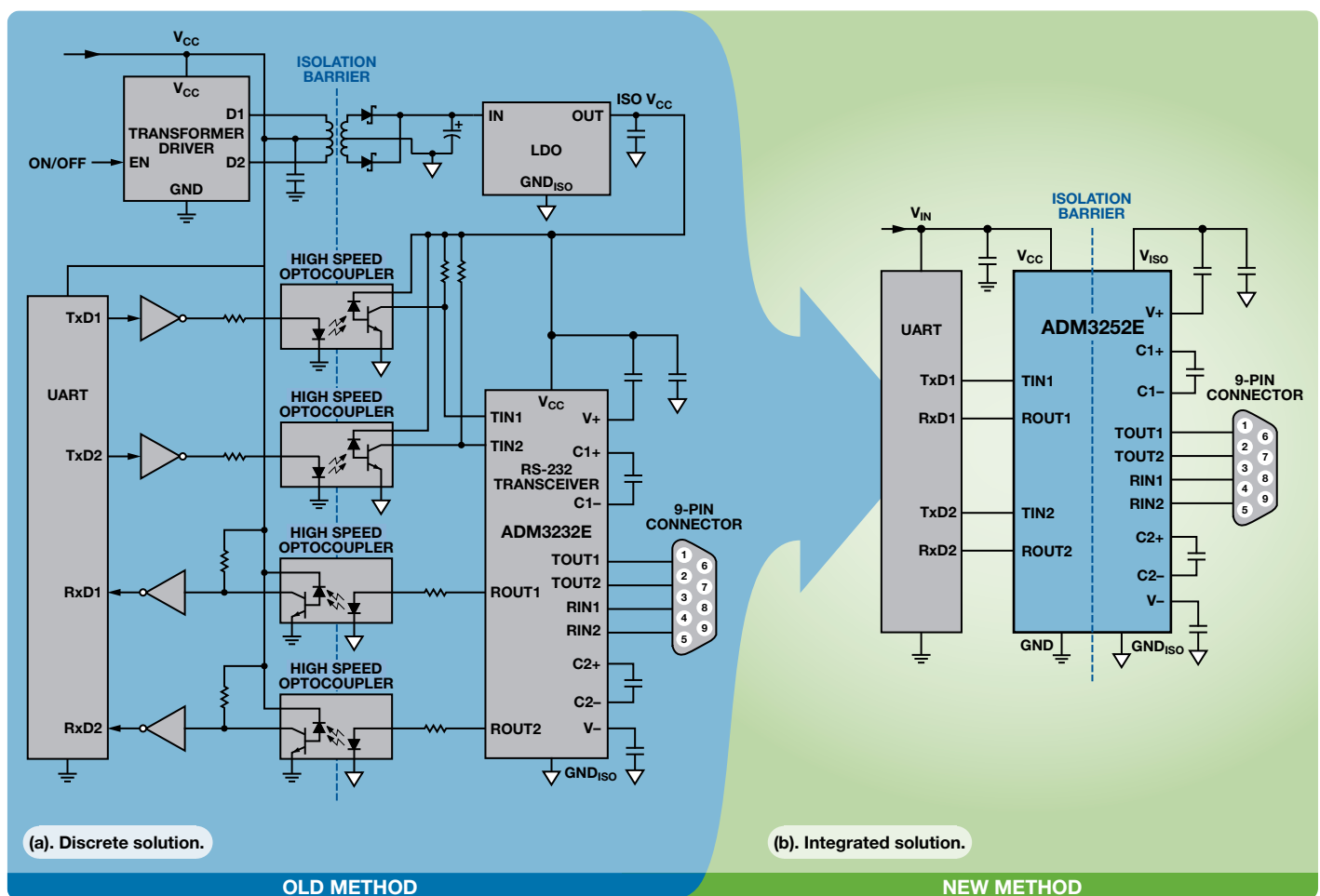

Figure 5. Isolated RS-232 designs compared.

The ADM3252E (Figure 6) combines a standard RS-232 transceiver with a 4-channel *iCoupler*, providing signal isolation of the RS-232 data signals. It also integrates *iso*Power technology to provide on-chip power isolation. Integrating the RS-232 transceiver by combining *iCoupler* and *iso*Power isolation technologies enables the ADM3252E to provide a fully isolated RS-232 interface with 2.5-kV rms isolation in a single package (12 mm × 12 mm), requiring only six external capacitors.

This single-chip solution significantly reduces the design time and board space required for an isolated RS-232 interface. Reliability is enhanced and cost is reduced because of the significantly smaller number of components to be placed on the PCB, which reduces manufacturing costs and improves reliability. Furthermore, the ADM3252E can be used in 5-V or 3.3-V applications without any modification, avoiding the design changes that would be necessary with a discrete design.

The *iso*Power technology provides 2.5-kV power isolation directly on chip within the 44-BGA package, eliminating the need for the expensive discrete transformer used in the traditional solution. In addition, *iCoupler* technology provides the signal (data) isolation, eliminating the need for the four discrete optocoupler channels.

ESD Protection
Because the RS-232 cable is physically connected and disconnected by a user, ESD (*electrostatic discharge*) protection of the RS-232 transmit (Tx) and receive (Rx) pins (TxD1, TxD2, RxD1, RxD2) is very important, to ensure a robust and reliable interface. The ADM3252E is specified with ESD protection to IEC 1000-4-2 (801.2) on RINx and TOUTx pins as follows:

- Contact discharge: ±8 kV
- Air gap discharge: ±15 kV

Transient Protection
To allow the isolated RS-232 transceiver to operate in very harsh operating conditions in industrial applications, the isolation technologies (both *iCoupler* and *iso*Power) are specified with a high (>25 kV/μs) common-mode transient immunity, which is the maximum slew rate of common-mode voltage (potential difference between the logic and bus sides) that can be sustained while maintaining specification-compliance. The *transient magnitude* is the range over which the common-mode voltage is slewed. The common-mode voltage slew rate applies to both rising and falling common-mode edges. This specification ensures that any transients that are coupled onto the RS-232 cable in a harsh environment cannot damage the RS-232 transceiver or cause erroneous data to be communicated, thereby enabling a very high reliability data link.

2.5-kV Isolation Protection and Approvals
The isolated transceivers are specified to 2.5-kV isolation between the logic and bus side of the device. This isolation rating ensures that no current can flow into or out of the logic side onto the RS-232 cable. It also ensures that no voltages or transients that get coupled onto the RS-232 cable are allowed to reach the logic side. The 2.5-kV isolation protection also means that users on the logic side are protected from high voltages or transients that might appear on the RS-232 cable. Approval is pending for the 2.5-kV isolation rating of the ADM3252E at the following agencies: Underwriters Laboratories (UL), *Verband Deutscher Elektrotechniker* (VDE), and Canadian Standards Association (CSA). The UL 1577 approval requires the isolation barrier of all ADM3252E devices (as with optocouplers) to be 100% production tested:

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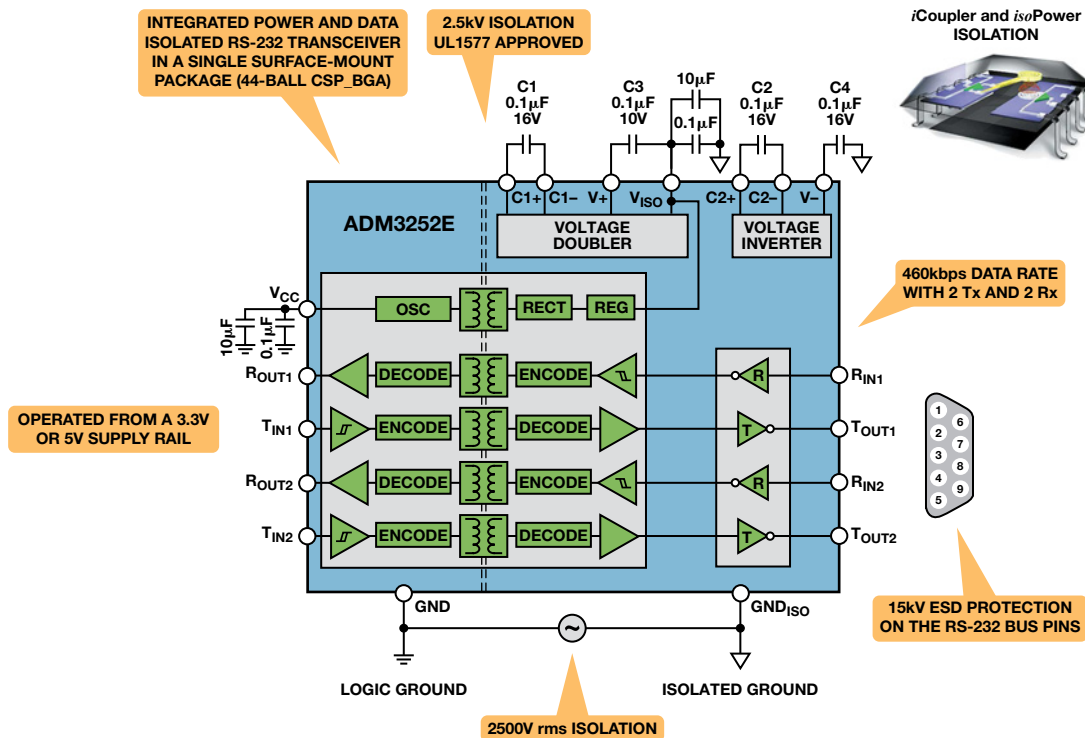 - VIORM = 560 V peak
- CSA Component Acceptance Notice #5A

Figure 6. ADM3252E isolated, two-channel RS-232 transceiver.

ADM3252E Specifications

The ADM3252E 2-channel, high-speed, fully isolated (data and power) RS-232 transceiver is ideally suited to operate in electrically harsh environments—or where RS-232 cables are frequently plugged in and unplugged. Integrating four independent *i*Coupler digital isolation channels (two transmit, two receive) and an *iso*Power chip-scale dc-to-dc converter, it provides 2.5-kV rms isolation, 25-kV/µs transient immunity, and ±15-kV ESD protection. Communicating at data rates up to 460 kbps, it conforms to TIA/EIA-232E specifications. An on-chip voltage doubler and inverter enable single-supply operation. Operating on a single 3.0-V to 5.5-V supply, the ADM3252E draws 20 mA with no load. Available in a 12-mm × 12-mm, 44-ball CSP BGA package, it is specified from −40°C to +85°C and priced at $8.49 in 1000s.

PCB Layout

The PCB layout of the isolated transceiver is critically important to ensure that the specified 2.5-kV isolation is achieved in an actual design. The principal considerations are the *creepage* (shortest distance along the surface between two conductors) and the *clearance* (shortest distance through the air) between the logic side GND and the bus side GND. The ADM3252E requires no external circuitry for its logic interfaces. Power supply bypassing is required at the input and output supply pins (Figure 7). Further information on guidelines for PCB layout and construction for controlling radiated emissions (EMI) can be found in the AN-0971 Application Note, *Recommendations for Control of Radiated Emissions with isoPower Devices*.
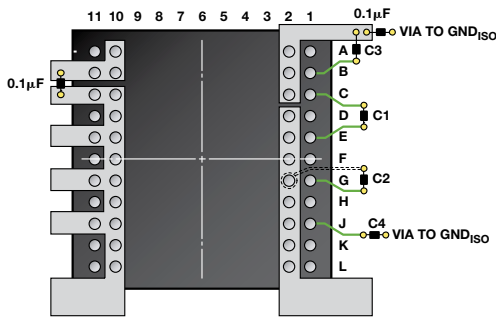

Figure 7. ADM3252E recommended printed circuit board layout.

Isolated, High-Speed Single-Channel RS-232 Interface

For transceiver applications requiring only a single channel (1 Tx, 1 Rx), 5-V isolated RS-232 interface, the ADM3251E provides a single-chip solution in a 20-lead wide-body SOIC. The ADM3251E transceiver incorporates *i*Coupler and *iso*Power isolation technologies; it was the first surface-mount RS-232 transceiver to feature full isolation of both the data lines and power. With a 2.5-kV isolation rating, it complies with industry-standard isolation requirements (UL1577 and DIN VDE 0884-10). This ensures that it will meet the robustness levels required in noisy operating environments, such as isolated RS-232 diagnostic data ports in industrial automation and control applications. The SMT package reduces board space by 45% compared with traditional ICs—and helps to accelerate the manufacturing process and lower system development costs (Figure 8).

Conclusion

Today's RS-232 interface links in industrial and instrumentation applications need to be small, robust, and inexpensive, as well as isolated. By integrating chip-scale transformer isolation with a standard RS-232 interface transceiver, single-chip, fully isolated RS-232 transceivers (including isolated power) can be made available to provide these benefits. The two-channel ADM3252E and single-channel ADM3251E significantly reduce design time and provide a compact, reliable, low-cost, high-performance solution for these demanding applications.

For More Information

- Digital Isolators
- Digital Isolator Product Selection and Resource Guide

Author

Maurice O'Brien [maurice.obrien@analog.com] joined Analog Devices in 2002, following his graduation from the University of Limerick, Ireland, with a Bachelor of 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.

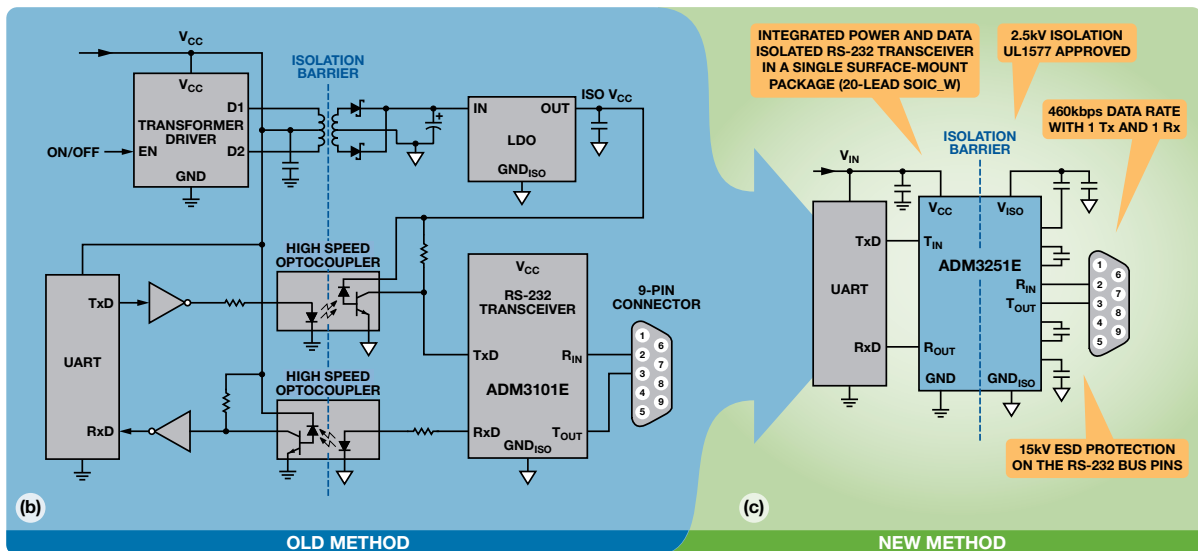| (a) Part Number	Min Positive Supply (V)	Data Rate (kbps)	Isolation (kV rms)	No. of Tx	No. of Rx	ESD Protection (kV)	Low Power Shutdown	Package	Price ($U.S.)¹
ADM3251E	4 .5	460	2 .5	1	1	15	No	20-lead, wide-body SOIC	2 .99

¹1000 to 4999

Figure 8. Single-channel RS232 transceiver application. (a) ADM3251E specifications. (b) legacy approach. (c) *i*Coupler + *iso*Power approach.