

Digital Isolators Simplify Design and Ensure System Reliability

IDEA IN BRIEF

Measurement devices used in industrial environments often require isolation for user and system safety, and to ensure accurate measurements in the presence of high common-mode voltages. Digital isolators offer a reliable and easy to use alternative to older technologies such as optocouplers. Utilizing digital isolators, engineers can optimize isolated system designs for reduced power consumption and guaranteed system performance without resorting to excessive design margin to make up for missing or incomplete device specifications.

INTRODUCTION

Designing isolated measurement instruments is challenging and sometimes frustrating. An isolated front end protects users against potentially lethal voltages present on measurement systems and allows engineers to make accurate measurements in the presence of high common-mode voltages. Figure 1 shows a typical example of such a measurement. In a high voltage fuel cell or battery stack, knowing the individual cell voltages helps ensure the system is operating safely and obtains the longest possible battery life. When determining the voltage of a single cell, we must measure it in the presence of up to several hundred volts of common-mode voltage. A similar situation occurs when measuring the temperature of a current-carrying conductor with a thermocouple. In this example, the system must measure millivolt signal resolution while rejecting high levels of common-mode 60 Hz noise and protecting operators from any hazardous voltages.

Isolation amplifiers were an initial solution to this problem, but have been outdated with the need for measurements with higher bandwidth and resolution. Today, the most accurate, economical, and efficient technique for performing these measurements is to isolate the entire measurement

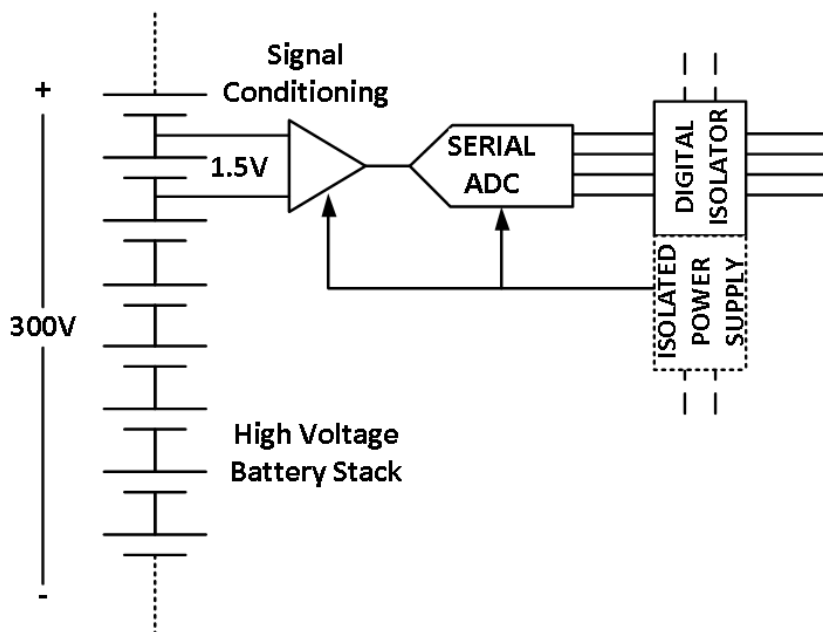


Figure 1. Using an Isolated Front End to Measure the Voltage of a Single Cell in a High Voltage Stack

front end, including the analog-to-digital converter (ADC), and to implement an isolated serial link to the rest of the system, as shown in Figure 1. This link can be either a local bus such as SPI, or an industrial protocol like RS-485 to send the measurement data across long distances to a controller unit.

DESIGNING FOR RELIABILITY

Up until about ten years ago, optocouplers were one of the few practical solutions for isolating digital signals. However, ask any engineer who has had to design with them, and you will quickly learn how challenging it is to develop an efficient and reliable system, especially when trying to keep costs to a minimum. Optocouplers use an LED to generate light across an isolation barrier to turn a phototransistor on and off. When designing with optocouplers, you have to guarantee that the LED will generate enough light to turn on the receiving phototransistor, and that the output rise and fall times will be fast enough to support operation at the desired frequency. One of the most important optocoupler specifications is the current transfer ratio (CTR). The CTR is the ratio of the collector current that appears at the phototransistor to the current through the LED.

Optocoupler CTR not only has a very wide tolerance, it also degrades with time and temperature. In order to guarantee that the optocoupler will continue to operate after several years of service, and at elevated temperatures, engineers have to assume the worst possible CTR, which can be challenging in itself, since optocoupler data sheets list CTR specifications only at room temperature. For example, a typical optocoupler's specification table lists a guaranteed CTR of 50%–600% at 25°C. In addition, most data sheets include a typical chart showing that the CTR at 80°C is only about

50% of the CTR at 20°C. Virtually no data sheet includes a minimum CTR at 85°C so you have to make an assumption as to what it will be. Additionally, some studies exist that model CTR degradation with time, but this is another specification you will not find on a data sheet, so you must make a decision as to how much additional design margin to add so the end product will operate reliably for its expected lifetime. Designing a robust isolator circuit means you must make many engineering assumptions, requiring trade-offs in the form of increased current consumption and slower operating speeds to leave enough margin for reliable operation over the life of the product.

Digital isolators use non-optical means of sending data across the isolation barrier. For example, Analog Devices' isolators use micro-transformer technology to send pulses across the isolation barrier, and do not suffer from the time and temperature degradation effects associated with optocouplers. This makes it possible to publish guaranteed minimum and maximum power consumption, propagation delays, and pulse distortion specifications over the entire operating temperature range of the devices. Having complete specifications removes the need to perform extensive characterization testing of optocouplers under your operating conditions in favor of using the data sheet information to calculate worst-case system performance. You can simply look at the digital isolators' guaranteed propagation delays, skews, and power consumption, and use the data to calculate your top-level system timing specifications like any standard digital integrated circuit. Other non-optical technologies, such as capacitive, radio frequency (RF), and giant magnetoresistive (GMR) coupling are also available.

Table 1. Regulatory agency approvals for Analog Devices' ADuM140x family of digital isolators.

UL	CSA	VDE	TÜV
Recognized under 1577 Component Recognition Program	Approved under CSA Component Acceptance Notice #5A	Certified according to DIN V VDE V 0884-10 (VDE V 0884-10):2006-12	Approved according to IEC 61010-1:2001 (2nd Edition), EN 61010-1:2001 (2nd Edition) UL 61010-1:2004 CSA C22.2.61010.1:2005
Double/reinforced insulation, 2500 Vrms isolation voltage	Basic insulation per CSA 60950-1-03 and IEC 60950-1, 800 V rms (1131 V peak) maximum working voltage reinforced insulation per CSA 60950-1-03 and IEC 60950-1, 400 V rms (566 V peak) maximum working voltage	Reinforced insulation, 560 V peak	Reinforced insulation, 400 V rms maximum working voltage

Because magnetic digital isolators consume most of their power when switching from one state to the other, power consumption scales with operating frequency. Therefore, channels that are idle, or switch at very low speeds, consume very little power. Once you have decided what the maximum serial clock rate will be for an application, you can design a power supply to provide enough current to support this rate. When designing with optocouplers, you must make sure circuits always idle with the LED in the off state to minimize system power consumption.

Optocoupler technology has been available for over 30 years; some engineers are wary of switching to a new isolator technology. Most manufacturers submit their products to regulatory agencies for approval, and clearly show under which standards their isolators have been approved. Parts such as Analog Devices' digital isolators use polyimide as the insulator, which is the same material used in many optocouplers. In some cases, they are tested to the same safety standards as optocouplers, while in other cases (such as VDE V 0884-10) specific standards have been developed for digital isolators. For example, Table 1 shows the agency approvals for the [ADuM140x](#) family of isolators.

Other concerns are regarding digital isolators' ability to withstand overvoltage surges, and their immunity to transients in the form of common-mode voltage and magnetic field disruptions. Fortunately, the polyimide insulation allows Analog Devices' digital isolators to withstand surges of up to 6 kV for up to 10 seconds. Because of the low parasitic capacitance across the isolation barrier, magnetic isolators also have excellent common-mode transient immunity (CMTI) when compared to other technologies. For example, typical high speed optocouplers have CMTI specifications of 1–10 kV/μs, while magnetic digital isolators can reject common-mode transients of more than 35 kV/μs.

Concern over magnetic interference would seem justified at first glance, since isolators with micro-transformers use a magnetic field to transmit pulses across the isolation barrier. One might assume that a strong enough magnetic field could interfere with the pulses, causing erroneous outputs. However, because of the very small radius of the transformers and their air core, it takes an extremely large magnetic field or a very high frequency to induce a fault. Figure 2 shows the maximum allowable current and frequency that still guarantees the output of an [AD344x](#) isolator will remain fault-free. For example, it would take a current of more than 500 Amps at 1 MHz, 5 mm from the

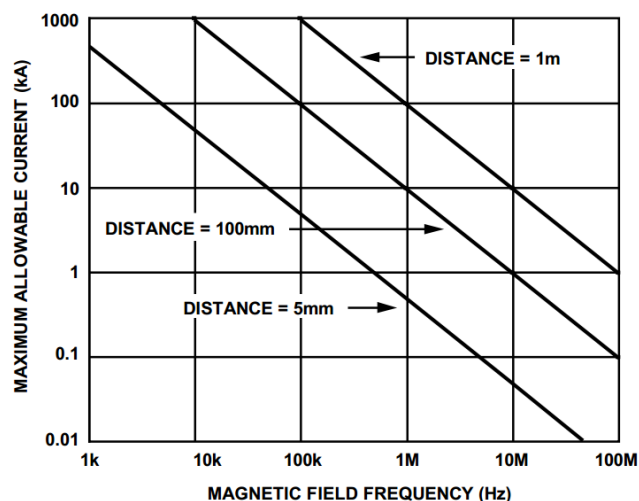


Figure 2. ADuM344x Maximum Allowed Current and Frequency to Guarantee Error-Free Operation

device to potentially trigger faulty outputs. The magnitude and frequency combinations theoretically required to produce an erroneous output are far beyond what would be experienced in the vast majority of applications.

HIGH SPEED OPERATION

When isolated measurement systems use high sample rates, isolating a serial bus with optocouplers can become a daunting task. The parasitic capacitance of the receiver photodiode limits the speed at which an optocoupler can pass digital signals. You can charge this parasitic capacitance faster by increasing the amount of light coming from the LED, but this increases power consumption. In addition, few optocouplers offer more than two channels per package, only in the same direction, and do not typically include timing specifications related to channel-to-channel matching. While it is logical to assume good matching between optocouplers in the same package, not having a printed specification means you must make an engineering assumption. As is the case when relying on unprinted specifications, most prudent engineers will opt to leave ample design margin, operating at a much lower performance than a data sheet would indicate when considering a single optocoupler.

Another advantage of using digital isolators is that products are available as 4-channel devices, with guaranteed speeds up to 150 Mbps. In addition, all digital isolator manufacturers provide guaranteed channel-channel matching specifications in their timing section of the data sheet. For example, Analog Devices' [ADuM344x](#)

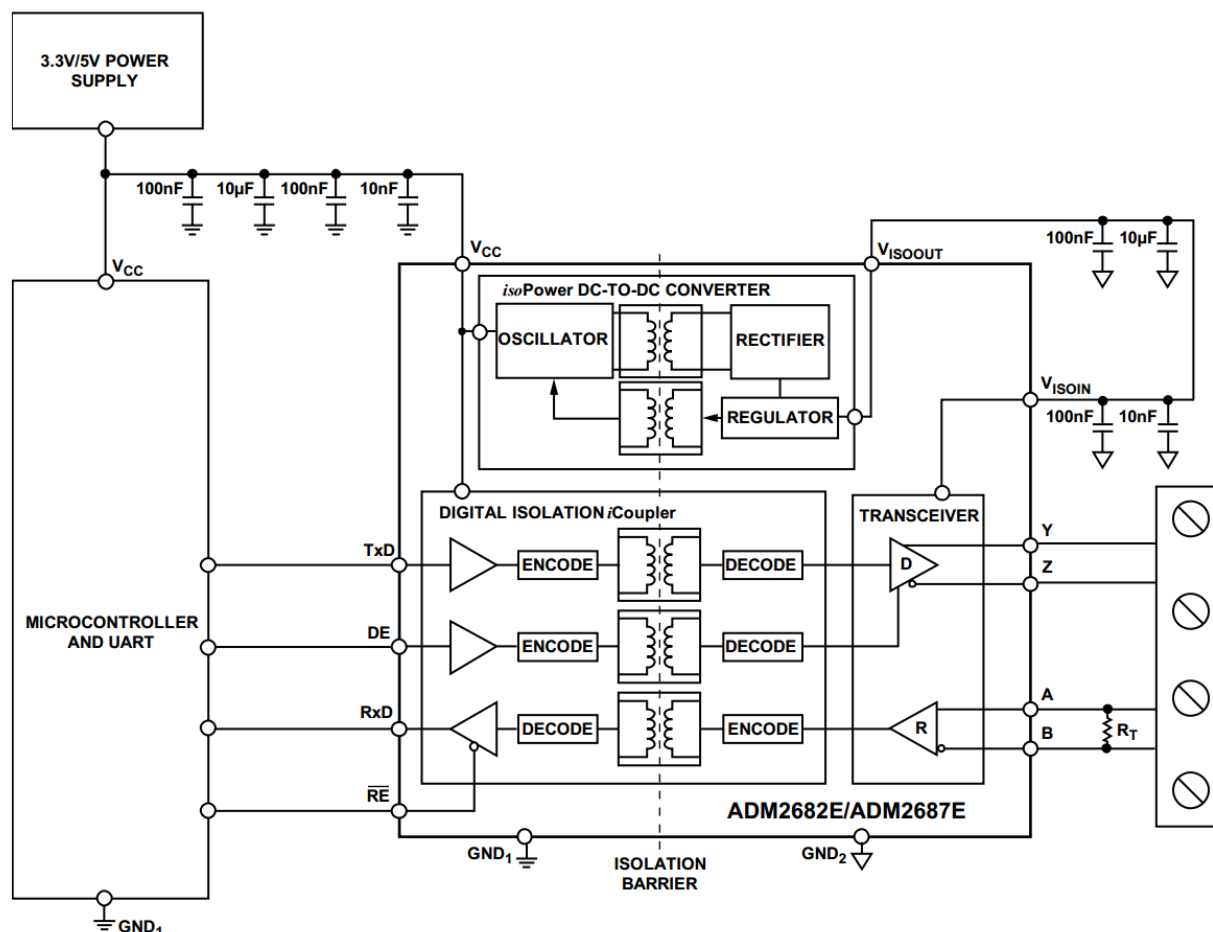


Figure 3. You Can Implement a Full-Duplex, Isolated RS-485 Interface with a Single ADM2682E

isolators have a guaranteed channel-to-channel propagation delay mismatch of less than 2 ns over the entire operating temperature range. In practical terms, this means you can use digital isolators at the speeds listed on the data sheet with no need to de-rate the system for large or unknown part-to-part or channel-to-channel skews.

INTEGRATION

Because digital isolator technology is compatible with standard CMOS processes it is relatively easy to integrate additional functions to simplify system design. For example, a traditional thermocouple measurement device may have used several optocouplers to implement a low speed SPI interface, plus an isolation transformer with a driver and regulator to power the isolated front end. By using a digital isolator with an integrated isolated power supply, such as the [ADuM5401](#), the entire isolation system becomes a single integrated circuit with four channels of data and isolated

power. This results in increased reliability and tremendous board space savings, at a lower cost than using discrete isolators and an isolated power supply.

Many instruments include an isolated RS-485 port for remote monitoring or control. Up to a few years ago, implementing an isolated port like this would have required not only an isolator for the data lines, but also a transceiver compatible with RS-485 differential signaling and a power supply. Figure 3 shows how a single IC like the [ADM2682E](#) integrates all of the functionality into a single package.

SUMMARY

Designing isolated measurement equipment used to be an expensive, challenging, and sometimes frustrating exercise because of the technical challenges involved with optocouplers. Over the last few years, advancements in digital isolation technology have made it much simpler task. Their low cost, increased performance, ease of use, and

integration help engineers meet their development schedule. In addition, the regulatory agency certifications and ability to withstand high levels of interference makes them an ideal fit for the long product lifetimes typical of industrial measurement systems.

For more information on the Analog Devices family of digital isolators, visit www.analog.com/icoupler.

RESOURCES

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