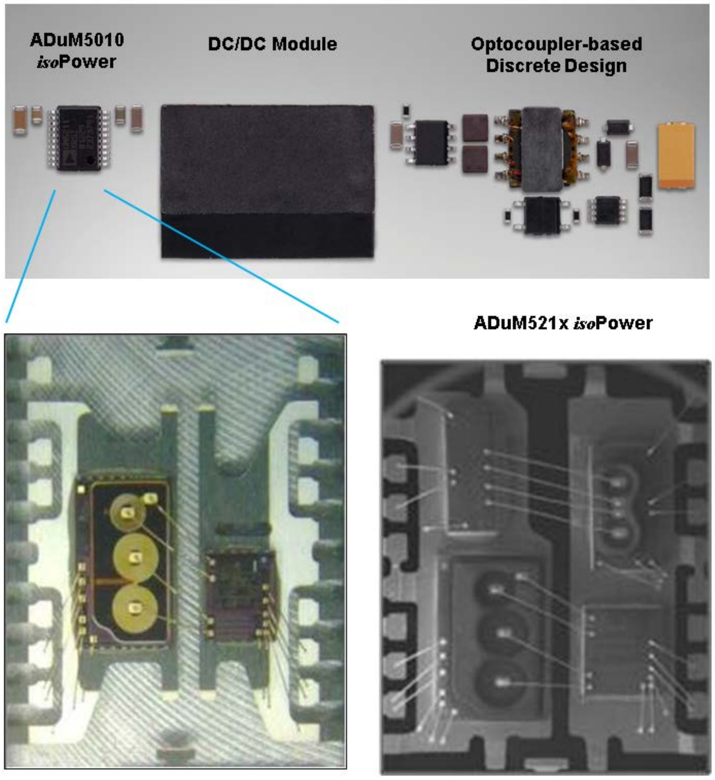
Integrated Signal and Power Isolation Provide Robust and Compact Measurement and Control

by Baoxing Chen

Robust and accurate measurements and controls are important for industrial instrumentation and process control. Various industrial sensors such as RTD or thermocouples usually require input isolation, not only to prevent ground loops that can compromise measurement accuracy, but also to prevent voltage transients that can cause permanent damage to the instrument. Besides a small differential signal of interest, these sensors can carry significant common-mode potential that reduces data acquisition accuracy or large voltage transients that can pose a safety hazard. Similarly, isolated analog outputs are required to operate actuators such as hydraulic actuators, solenoids, or motor starters safely and accurately.Besides isolation for analog inputs and outputs from system ground, isolation is also needed between inputs and between outputs to handle different common-mode potentials for various sensors and actuators and prevent interference among them. Digital isolators have been successful in improving analog system performance and reducing system size by replacing traditional analog isolators, or optocouplers, which are bulky and inaccurate. A high resolution ADC placed right at the sense node converts the precise analog sensing signals into digital streams before they are transmitted across the isolator barrier to the system microcontrollers using highly integrated multichannel digital isolators. Similarly, the digital commands from the system microprocessor are transmitted through the isolation barrier using digital isolators, and then are converted to accurate analog current or voltage controls using high resolution DACs. The digital isolators eliminate the signal distortion and degradation from analog isolators or traditional optocouplers, but for the DACs to interface with controls or the ADCs to interface with these sensors some isolated power is required to operate. While discrete isolated dc-to-dc converters can be used to provide the isolated power from system side, they are bulky and difficult to design as they require many discrete components. The outputs of these discrete dc-to-dc converters are not well regulated either, and they become very inefficient at low loads—typical for low power high resolution ADCs or DACs. To enable robust and compact analog measurement and control systems, small integrated isolated power and digital isolation are needed. *iso*Power®—an extension to *i*Coupler® technology, leading industrial digital isolators—provides isolated signal and power in a shrink small outline package (SSOP).

*iso*Power: Signal and Power Isolation Using Microtransformers

Let us take a close look at some *iso*Power devices, and see how they compare to traditional dc-to-dc implementations. Figure 1a shows a size comparison of the *iso*Power device ADuM5010; an integrated dc-to-dc converter providing up to 150 mW isolated power in a 20-lead SSOP, a dc-to-dc module, and an Optocoupler-based discrete design. The ADuM5010 occupies merely 90 mm² board space including four surface mount ceramic capacitors, while the discrete design consisting of a total of 16 components requires a board space of 470 mm², more than five times that of the *iso*Power device. The sizes for dc-to-dc modules vary, but its thickness is usually prohibitive for surface mounting. An isolated dc-to-dc in a SSOP is made possible with two chip integration as shown in Figure 1b. The left die has the transformer switching circuit while the right die has rectification diodes and the feedback controller. Three transformers are integrated on the left die with the top, smaller transformer providing feedback signal isolation while the bottom two transformers are used for isolated power transfer. Two more dies can be fit into an SSOP to provide additional digital isolation channels as shown in Figure 1c. The ADuM521x *iso*Power device is a dual channel isolator with 150 mW integrated dc-to-dc converter. The two microtransformers on the top right die provide the isolation for the two digital channels. Both the top left die and top right die have encoding and decoding circuits for transmitting digital signals across microtransformers. In order to transmit power across the isolation barrier, these microtransformers are switched resonantly at high frequency—around 120 MHz—to achieve efficient energy transfer; meanwhile, the energy regulation is realized through a low frequency PWM feedback signal—around 500 kHz—which controls the duty cycle that the high frequency resonant action is left on, as shown in Figure 2. Two crosscoupled HVCMOS switches together with a center-tap transformer provide the sustained oscillation, which is enabled or stopped by the feedback PWM signal via a tail switch controller.



Figures 1. (a) Size Comparison of Various Isolated Power Implementations; (b) Inside Look of ADuM5010, a 150 mW Fully Integrated Dc-to-Dc Converter; (c) Inside Look of ADuM521x, a Dual Channel Isolated with Integrated Dc-to-Dc Converter

The Schottky diodes are implemented in Die 2 for efficient rectification at 120 MHz and a modified type II controller. For smooth power-up, a soft start circuit is implemented in Die 1. At power-up, the soft start circuit provides PWM signals with slowly increasing duty to slowly charge the output voltage to a preset level slightly lower than the targeted output voltage. At this point, the feedback signal is enabled, and it takes control of the tail switch over from the soft start output. This soft start sequence ensures minimum output overshoot at power-up, which is important for system reliability.

To transmit the data robustly across the isolation barrier, differential encoding and decoding are used. The leading edge is encoded as a short pulse of positive polarity and the falling edge is encoded as a short pulse of the same duration but of negative polarity. The differential receiver converts these pulses of different polarities into the output with the correct logic state. To ensure the output is updated when the input has not changed state for a long time, periodic refresh pulses are also transmitted across the transformers: a positive pulse for logic high and a negative pulse for logic low. The differential receiver allows the common mode pickup to be rejected during common mode transient events, and large common mode transient immunity greater than 50 kV/µs is achieved. It is possible to achieve 3.75 kV 1 minute UL rated isolation with 32 µm thick polyimide layers

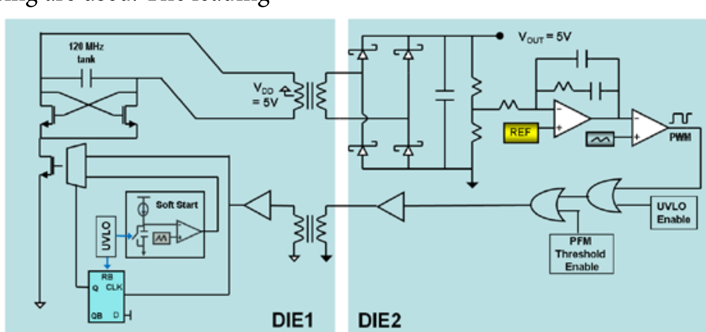


Figure 2. Schematic for Isolated Power Transfer Using Microtransformers

sandwiched between the primary coils and the secondary coils. A cross section for the *iso*Power transformers is shown in Figure 3.

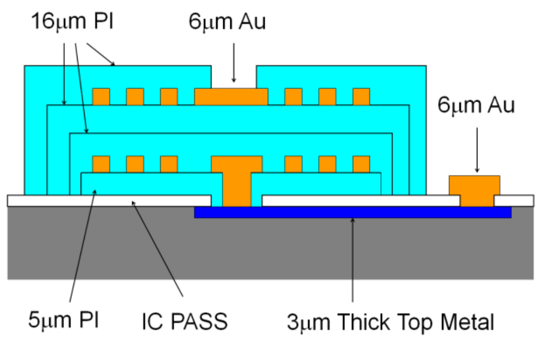


Figure 3. Cross Section of iso*Power Transformers*

Both the top winding and the bottom winding have 6 µm thick Au for efficient power transfer. The polyimide is very good against HV transients, providing over 10 kV surge capability. Besides high surge capability, the polyimide also has well defined aging behavior. The time to failure is collected at various voltages from 1.2 kV to 3 kV, and it is plotted in Figure 4. Based on a fit to a typical polyimide aging model, $L \sim e^{v^{-n}}$, the lifetime is over 100 years at 400 V rms, good enough for many industrial applications.

Besides high voltage behavior, EMC requirements such as radiated emissions are of concern for industrial applications. The *iso*Power transformers are closely coupled with only a few hundred micrometers in diameter, so radiated emissions from the transformers are very limited. The *iso*Power transformers are also implemented in s-type configuration as shown in Figure 5. In far field, the flux from one half of the transformer would cancel out the flux from the other half by designing each half with opposite phase. While the radiation emissions from the transformers are negligible, precautions must be taken in designing PCB for the use of *iso*Power products. Besides good bypassing to contain noises within the part, isolated islands of PCB need to be carefully designed not to form an efficient dipole antenna. CISPR Class A or B can be met for the *iso*Power parts with properly designed PCB.

Signal and Power Isolation Needs for Measurement and Control

To make reliable and safe measurements of current, voltage, temperature, pressure, flow rate, or other parameters for a variety of industrial applications in harsh environments, isolation is essential to maintain data integrity and equipment and user safety by eliminating the ground loops and the direct exposure of the user or equipment to hazardous voltages. Besides signal isolation, power isolation is needed to establish bias for the ADCs or DACs to interface with various sensors or transducers. It is a significant challenge to pack isolation components such as those based on optocouplers in a small area considering the fact that there are many analog inputs or outputs that not only require isolation from the back plane but also between those analog channels. Integrated signal and power isolation is the ideal solution to deliver compact and robust isolation to each of the analog I/O ports.

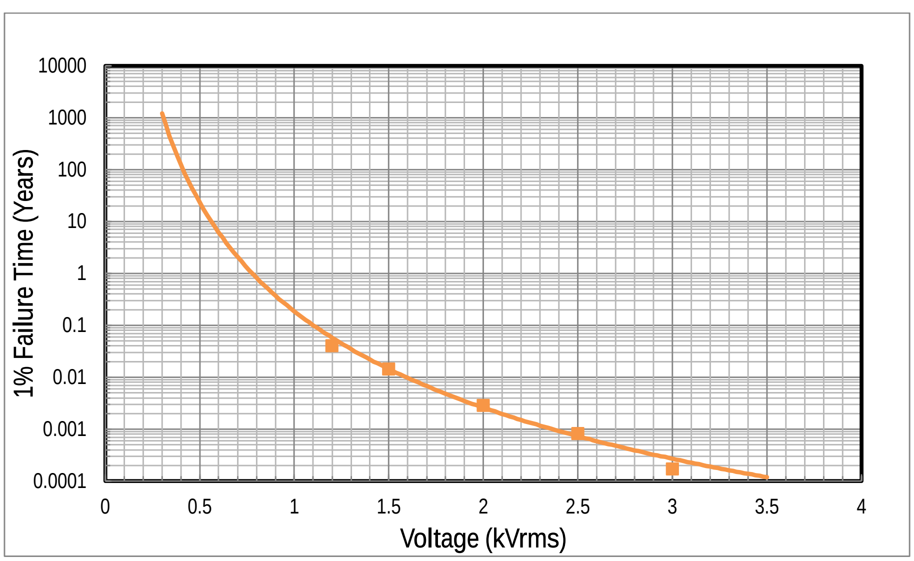


Figure 4. High Voltage Lifetime for iso*Power Products*

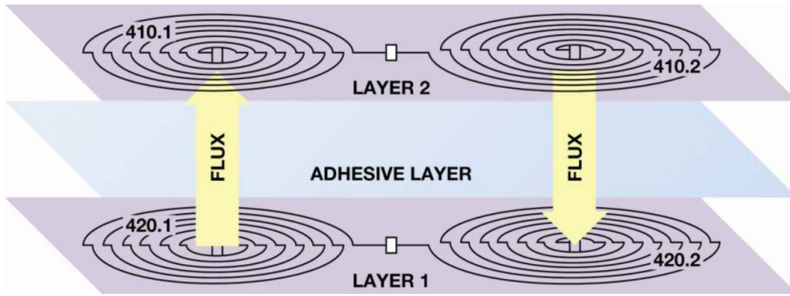


Figure 5. iso*Power Transformer Configuration*

An example of implementation of isolated signal and power for use in industrial instrumentation or process control equipment is shown in Figure 6. A single *iso*Power component such as the ADuM5211, a 2-channel digital isolator with 150 mW isolated power, would satisfy all the isolation needs for a given analog input channel. One isolated data channel is used to send the system clock from the microcontroller to the ADC, and another data channel in the opposite direction sends the acquired data from the sensor back to the microcontroller. Multiple ADuM5211 can be used for multiple sensors that require isolation between them. Similarly, a single *iso*Power component such as the ADuM5210, a two channel digital isolator with 150 mW isolated power, can handle all the isolation needs for a given analog output channel. The two data channels are used to send both the clock and the digital commands from the microcontroller to the DAC to control the actuator. Multiple ADuM5210 can be used for multiple actuators or analog outputs that require isolation between them. The red horizontal dashed lines in Figure 6 illustrate the isolation barriers between various sensors and actuators and the long red vertical dashed line to the right indicates the isolation between the system and analog I/O ports. For communication between many pieces of process control equipment, additional isolation—as shown by the short red vertical dashed line in Figure 6—is needed between the system controller and a communication bus such as RS-485, RS-232, CAN, and others. Again, a single *iso*Power component such as the ADM2587, a full integrated isolated RS-485 transceiver with 500 mW isolated power, can be used for the complete bus interface isolation for a single piece of equipment. Here the ADM2587 provides an integrated RS-485 transceiver and three channels of digital isolation, of which two are used to send Drive and Drive Enable from the microcontroller to the bus, and the other is used to send received data from the bus to the controller. As we can see, integrated signal and power isolation significantly simplify the measurement, control, and communication interface for industrial equipment.

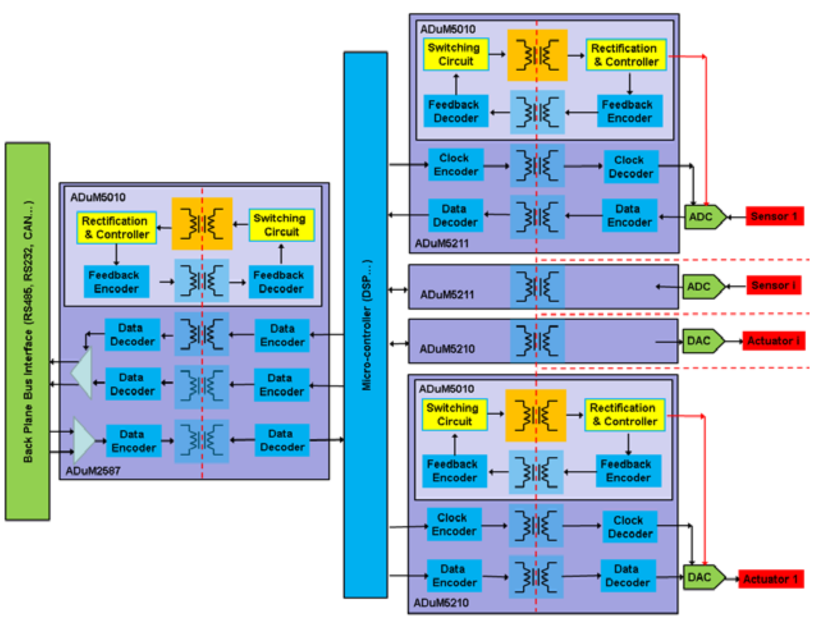


Figure 6. Fully Isolated Industrial Measurement and Control System Using iso*Power*

There are similar signal and power isolation needs for battery measurement or test equipment. Voltages and currents for each battery cell need to be monitored continuously to maintain battery lifespan, but the whole battery stack in series can be hundreds or even thousands of volts in total. Battery monitor ICs, in order to interface with various battery packs in different locations of the stack, need to be isolated from system controllers, and isolated power is needed to allow proper system shutdown in the event of battery failure.

Conclusion

Integrated signal and power isolation using microtransformers in a small package dramatically simplifies the design for industrial measurement and process control systems and significantly reduces board space and cost compared to those based on optocouplers and discrete transformers. It provides reliable and accurate measurement and control in harsh industrial environments.

RESOURCES

ADuM5010 www.analog.com/ADuM5010

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One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A.
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