Fully integrated signal and power isolation – applications and benefits

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To be truly useful, an integrated power and signal isolation solution must offer high efficiency, high power delivery and low emissions while offering high isolation performance.

Isolation is a means of preventing direct current (DC) and unwanted alternating current (AC) between two parts of a system while still enabling signal and power transfer between those two parts. Isolation is used in a wide variety of applications: to protect human operators and low-voltage circuitry from high voltages, to improve noise immunity, and to handle ground potential differences between communicating subsystems.

Isolators with complementary metal-oxide-semiconductor (CMOS)- or transistor-transistor logic (TTL)-level inputs and outputs are called digital isolators. While digital isolators provide signal isolation, complete isolation of the two voltage domains requires power isolation as well (see **Figure 1**).

Traditional approaches to generate isolated power use a DC/DC converter to drive a transformer in flyback, fly-buck or push-pull topologies. Pulsating signals on the secondary side are rectified and filtered to generate an isolated DC supply. Optocoupler-based feedback to the primary side achieves line and load regulation. In certain cases where the DC/DC converter runs in an open-loop configuration, a low-dropout regulator (LDO) is used to post-regulate the converter output. The drawback with this discrete approach is that the complete solution – the transformer and other components – occupies a lot of space on the board. Also, designing a stable and efficient isolated power supply can be challenging.

Let's consider an analog input module of a programmable logic controller (PLC) used in factory automation, as shown in **Figure 2**.

An analog input module interfaces sensor data from the field to the PLC. Analog inputs received from field transmitters convert a physical quantity such as temperature or pressure to an electrical signal. Signals that reach the analog input module can be 0-5 V, 0-10 V, ±10 V or 4-20 mA. These input signals can be group isolated or channel-to-channel isolated.

PLCs are expected to work in harsh industrial environments, and physical separation of the field sensors from the PLC creates ground potential differences, thus necessitating isolation. Sensor signals are converted to the digital domain and coupled via a digital isolator to the control domain.

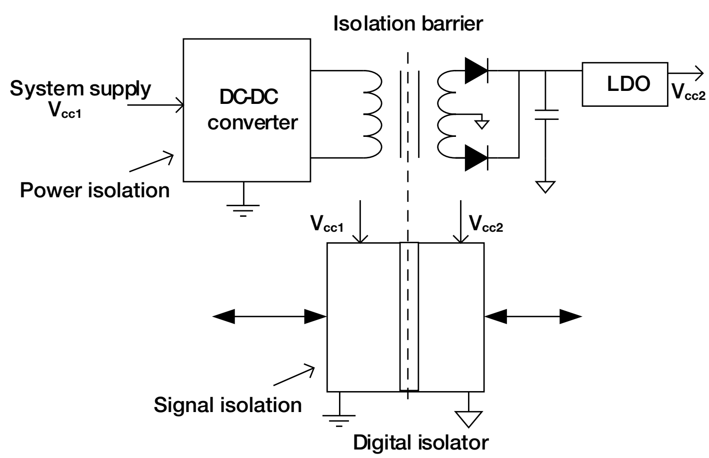

Figure 1. Signal and power isolation.

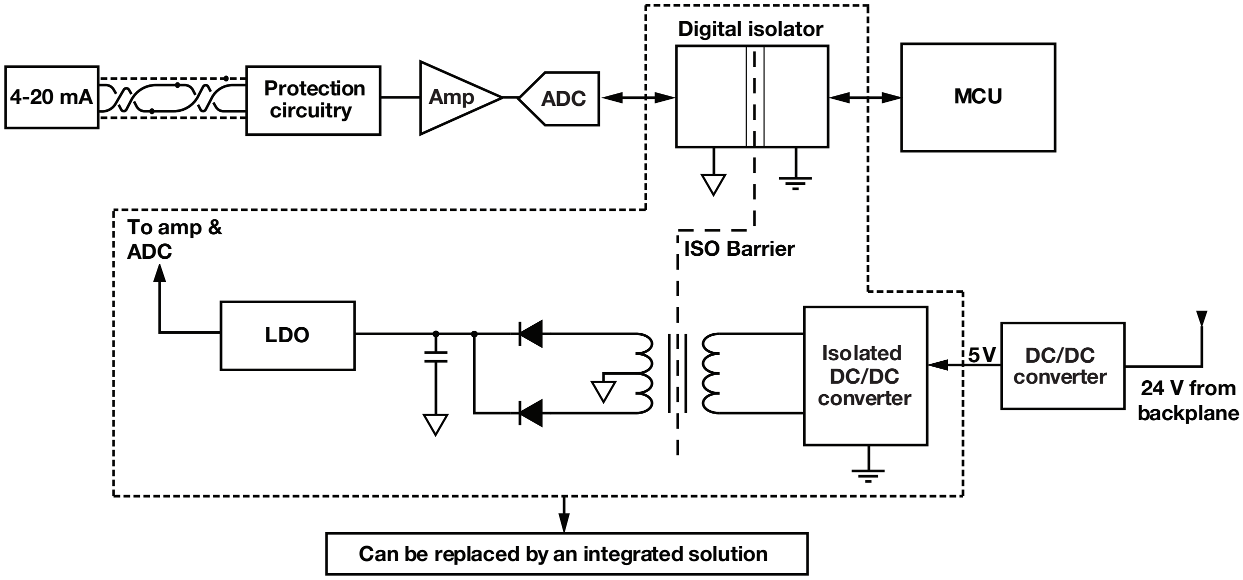

***Figure 2**. An analog input module in a PLC application requires signal and power isolation.*

As **Figure 2** shows, an isolated DC/DC converter derives power from the backplane and generates an isolated power supply for signal-conditioning elements such as the amplifier and analog-to-digital converter (ADC). A device with signal and power isolation in one package can reduce solution size dramatically by integrating all of the discrete components shown within the dotted-line box in **Figure 2**.

Fully integrated power with signal isolation

Figure 3 shows a conceptual block diagram of a n-channel digital isolator with an integrated DC/DC converter. Data channels are isolated by capacitive isolation, whereas chip-scale transformers are used for power isolation.

Benefits of integrated signal and power isolation

Various solutions available today integrate a DC/DC converter with a microtransformer, along with signal-isolation channels, in a single package. Such solutions solve several design challenges faced by system engineers, including:

- **Board-area reduction**. The first benefit of a single-chip solution is a reduction in board area.

The solution size reduces significantly since the power stage, transformer, rectifier diodes, isolated feedback and digital data-isolation channels are integrated in the same device.

Because the digital isolator package dimensions depend on the isolation ratings, creepage and clearance, it is possible to fit these additional components in the same package, leading to a compact solution.

In addition to the surface-area reduction, the use of planar transformers enables the z-dimension or height of the integrated solution to be lower (~3mm) than discrete transformers, which could be two to three times thicker.

Figure 4 illustrates the board-area savings due to integration.

- **Ease of certification**. Helping to ease the customer's safety certification is the second benefit of integration. These isolation devices go into systems that need certification by various agencies. Having more discrete isolation components adds to the customer's time required for safety-related certification at the system

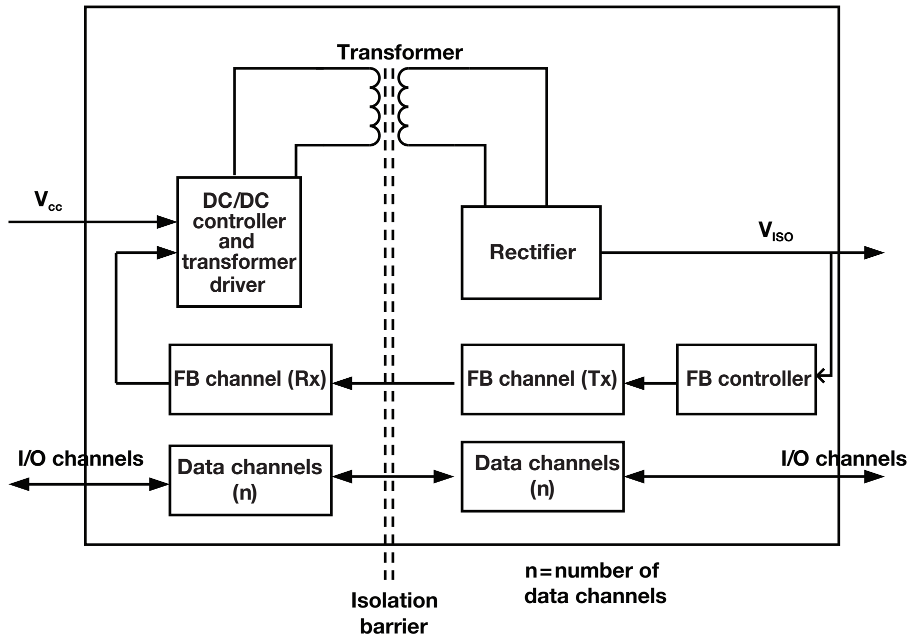

Figure 3. Block diagram of an integrated signal and power isolator.

level. With integrated solutions, both signal and power isolation are certified together according to component standards such as Verband der Elektrotechnik (VDE) 0884-11 and Underwriters Laboratories (UL) 1577. This helps result in a shorter certification process for the end product.

Adhering to various end-equipment safety standards like International Electrotechnical Commission (IEC) 61800-5-1 (motor drives), IEC 61010-1 (test and measurement) and IEC 60601 (medical equipment safety) with discrete transformers is a difficult task, since certified transformers for reinforced power isolation are rarely available, and even if they are available, they are bulky and expensive.

- **Simplicity and robust design**. Lastly, system design becomes much simpler with an integrated solution, since you can integrate the feedback for line/load regulation and all protection mechanisms for the power supply (such as overload and short-circuit protection, thermal shutdown and soft start) on the chip. Boards with bulky transformers perform poorly in vibration tests. Thus, board-level reliability can also improve with an integrated solution.

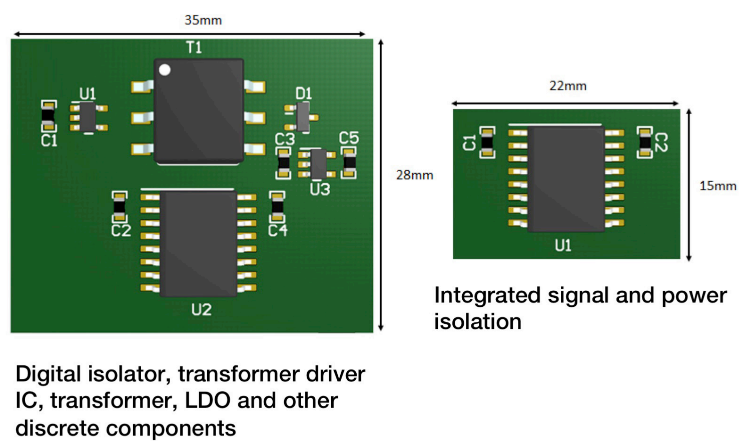

Figure 4. Board space savings of an integrated solution vs. a discrete solution.

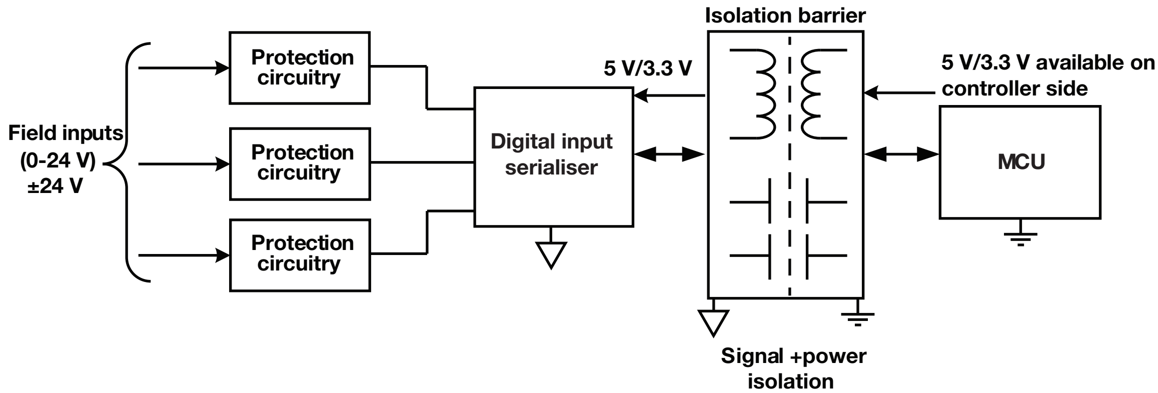

***Figure 5**. PLC digital input module with signal and power isolation.*

More application examples

- **PLCs**. PLCs have been an integral part of factory automation and industrial process control. PLCs use digital and analog input and output modules to interface to sensors, actuators and other equipment on the factory floor. **Figure 5** shows one possible implementation of a PLC digital input module.

  Digital inputs include push-buttons, proximity switches, photo sensors, pressure switches and more. A traditional design approach is to serialize the input data and couple it via a digital isolator to the control domain. A device with signal and power isolation avoids the need for a separate field-side power supply.

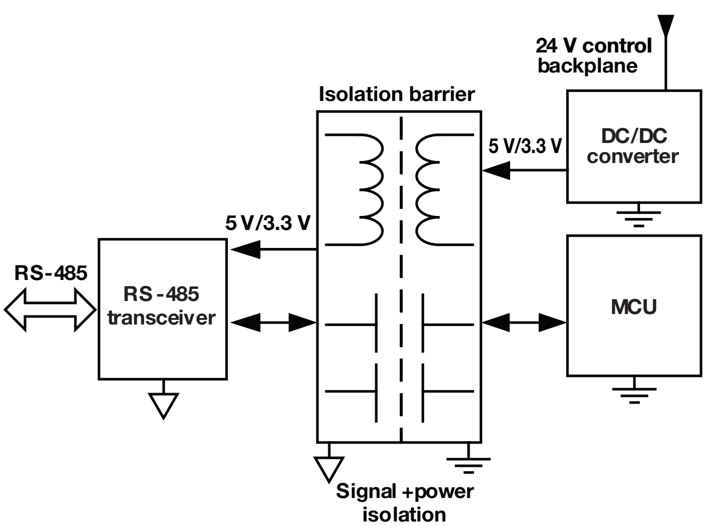

***Figure 6**. Isolated RS-485 communication in a PLC with signal and power isolation.*

Once the data from sensors has reached the PLC communication module, an RS-485 typically transfers data to a central control station, as shown in **Figure 6**. Isolation allows robust communication to distant RS-485 nodes that may be connected to a different ground potential.

In such a scenario, 24 V is available from the backplane, which can be stepped down to 5 V/3.3 V. A device with integrated signal and power isolation can isolate the control signals and generate a supply for the bus-side RS-485 transceiver. The key benefits of an integrated solution in PLC applications are reduction in board area and ease of system design.

- **Test and measurement, metering**. **Figure 7** shows an isolated data-acquisition system in an instrumentation application.

  In a data-acquisition system, it is often necessary to electrically isolate the signals from the system controller. You must prevent high common-mode voltages from reaching the control domain, which can exist at the measurement points. Isolation also eliminates any ground-loop formation between field-side signals and the system controller.

  Isolated power, when integrated with signal isolation, powers up the analog front end and offers space savings on the board. For channel-to-channel isolated data acquisition, which

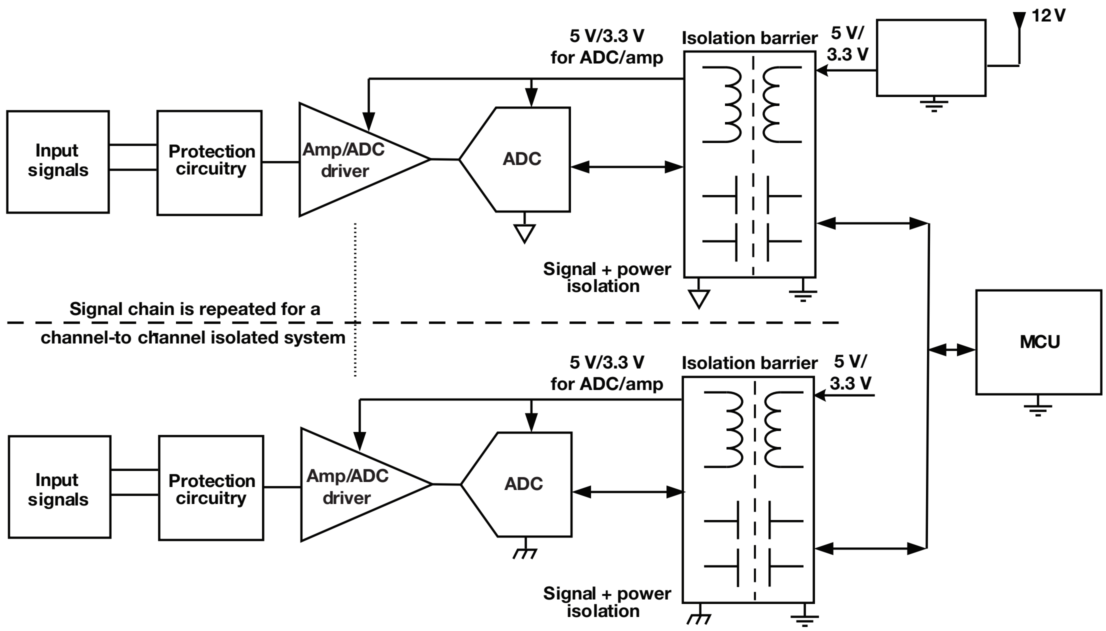

***Figure 7**. Channel-to-channel isolation in test and measurement is simplified with an integrated isolated signal and power solution.*

requires the measurement and isolation of multiple signals from each other, a device with integrated signal and power isolation eliminates the need to generate separate power supplies on board for each channel. This helps in achieving a small form factor for data-acquisition systems, since you no longer need several onboard transformers.

Metering applications that measure AC mains line voltages and currents require high-voltage reinforced isolation. An integrated solution can reduce system costs, since you no longer need a reinforced isolation-rated transformer.

- **Medical electrocardiogram (ECG) front end**. In medical equipment, isolation is important for patient protection. During an ECG (see **Figure 8**), multiple leads are connected to the patient. The signal chain should be robust enough to capture the weak signals, digitize and process them, and pass the signals to the system controller over an isolation barrier.

  The analog front end is typically powered by onboard isolated DC/DC converters. A device that integrates isolation for the signals and provides isolated power to the analog front end is very useful in medical applications to enable a small footprint. Medical safety standards are among the most demanding for insulation performance, resulting in a high cost for discrete power transformers. An integrated solution can thus reduce system cost.

Integration challenges

Achieving high efficiency for power conversion with integrated miniature transformers is difficult. The switching frequency has to be very high in order to achieve a small solution size, thereby increasing switching losses in the power stage. Moreover, this high switching frequency causes radiated emissions and makes it difficult for an application using an integrated device to meet emissions standards such as Comité International Spécial des Perturbations Radioélectriques (CISPR) 22.

Another disadvantage of having limited efficiency in the integrated power stage is that only a limited amount of load current can be supported without

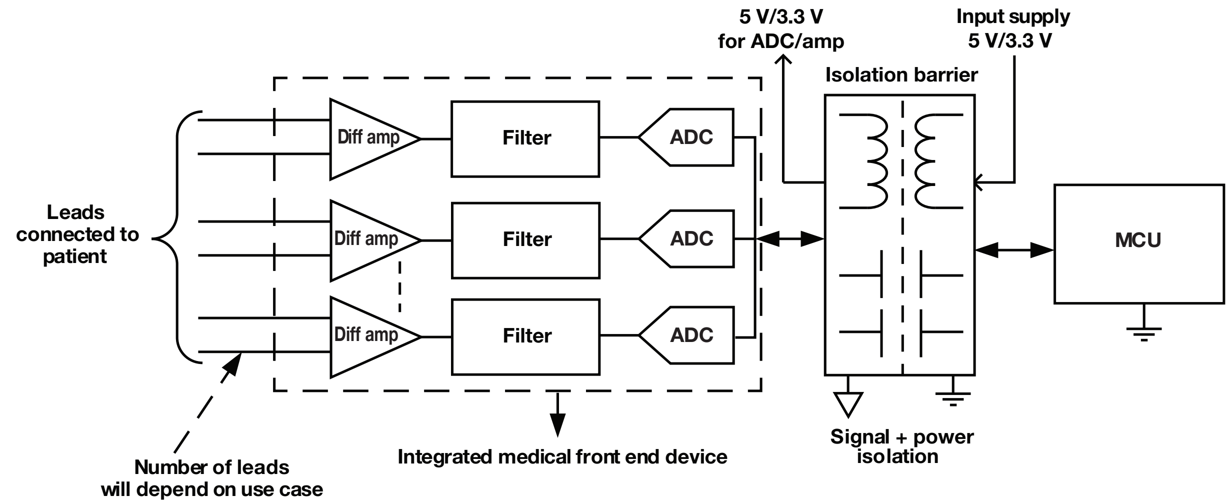

Figure 8. An integrated signal and power solution helps meet medical safety standards in an ECG application.

increasing the junction temperature. The internal temperature rise can be a limitation, especially when operating in environments with high ambient temperatures. To be a viable solution, an integrated solution must offer high efficiency, high power delivery and low emissions, while offering high isolation performance.

TI solution

The Texas Instruments ISOW7841 is part of a family of reinforced quad-channel high-performance digital isolators that integrate a high-efficiency, low-emissions DC/DC converter. The digital isolators operate up to 100 Mbps, with a propagation delay less than 16 ns. The integrated DC/DC switch-mode converter uses advanced circuit techniques to reduce power losses and boost efficiency, supporting 130 mA of load current with 5 V input and 75 mA of load current with 3.3 V input. Integrated closed-loop feedback provides excellent line and load regulation. Special emissions-reduction techniques have been implemented to help meet emissions standards.

This device is up to 80 percent more efficient than comparable solutions in the market, resulting in up to 40°C lower chip temperatures while delivering the same load current (see **Figure 9**). The ISOW7841 is

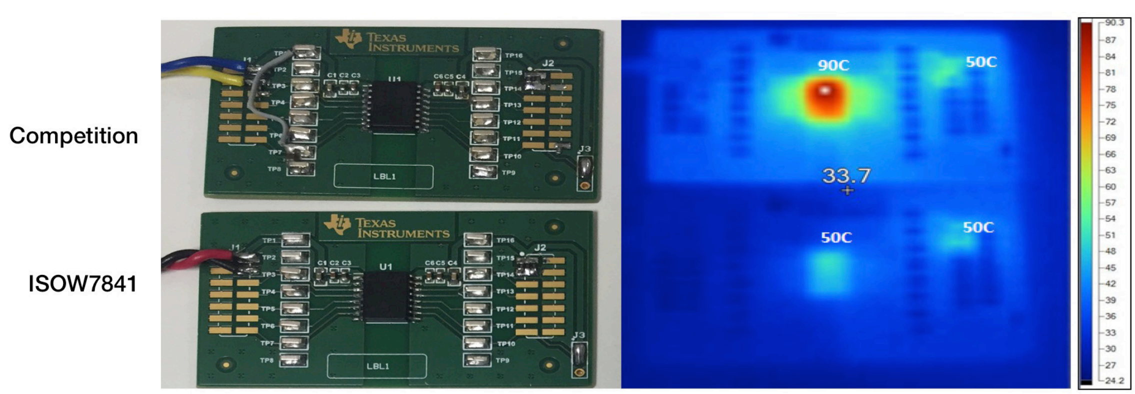

Figure 9. The ISOW7841 has 40°C lower temperature vs. a competing solution while delivering 80 mA at 5 V.

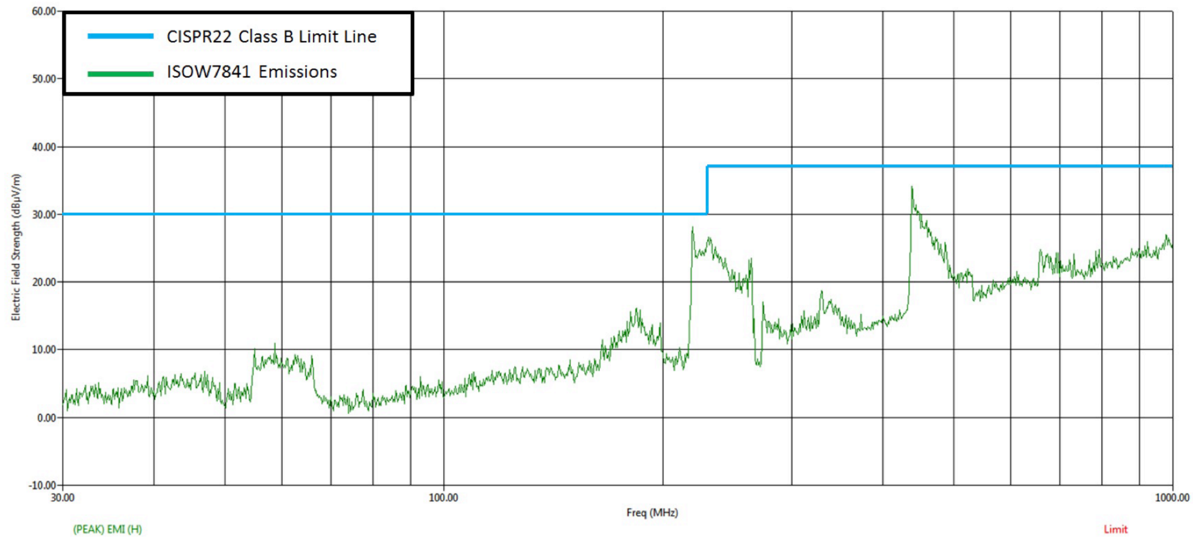

***Figure 10**. The ISOW7841 meets CISPR 22 Class B emissions masks under an 80 mA load.*

able to meet CISPR 22 Class B emissions without needing a complicated board design (see **Figure 10**), and has lower emissions by more than 10 dB compared to similar integrated solutions.

The ISOW7841 is available in a 16-pin wide-body small-outline integrated circuit (SOIC) package, which allows for 8 mm of creepage/clearance. It can withstand 60 seconds of temporary overvoltage of 5 kV_{RMS} (UL 1577), a working voltage up to 1,000 V_{RMS} and a surge voltage of 10 kV_{PK} as per VDE 0884-10. Additionally, these devices use a Comparative Tracking Index (CTI) greater than 600 V (Material Group I) package-mold compound, which enables them to operate at higher working voltages at the system level compared to devices with the same creepage.

The ISOW7841 device offers excellent power and electrical performance, along with industry-leading isolation performance.

Conclusion

Fully integrated power and signal isolation solutions simplify system design in a variety of applications by reducing board area, reducing system cost, simplifying certifications, reducing complexity and increasing robustness. However, integration has its own challenges. To be truly useful, an integrated solution must offer high efficiency, high power delivery and low emissions while offering high isolation performance.

References

1. Visit the ISO7841 and ISO7741 product folders.
2. Download the ISOW7841 datasheet.
3. Read the Isolation glossary.
4. Visit the ADS8681 SAR ADC, ADS1294 ADC with ECG front end and ADS1220 delta-sigma ADC product folders.

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