

Signal and Power Isolation Considerations for Compact, Efficient Analog Input Modules



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1 Introduction

Programmable Logic Controllers (PLC) and Distributed Control Systems (DCS) are used for automation and control in diverse industries such as oil refineries, paper and pulp, chemicals, cement, and food and beverage. PLC and DCS systems use analog input (AI) modules to receive inputs from temperature, pressure, flow, level, gas and other sensors and detectors. Analog input modules digitize the analog information received from the field and transfer it to the CPU module of the PLC/DCS. Then, the CPU module can take any required action, for example, control a valve or turn a relay on or off.

Isolation is invariably used in the analog input modules and for two reasons:

1. Isolation breaks the ground loop between the sensor and the CPU module - which can be hundreds of meters away from each other - for reliable communication.
2. Isolation offers robustness to electrostatic discharge (ESD), electrical fast transients (EFT), surge and other disturbances present in an industrial environment.

In this article, I discuss the key considerations for choosing signal and power isolation solutions in group isolated and channel-to-channel isolated analog input modules.

2 General Considerations

As the use of automation continues to grow, so too does the amount of information that needs to be monitored and processed. More data means more sensors and actuators and correspondingly more PLC I/O modules. However, space inside a factory is also at a premium. Hence, PLC and DCS manufacturers would like to offer more compact modules with higher and higher channel densities as a benefit to their customers. With many high-channel density modules packed close together, the power consumed by all the channels can lead to high module temperature, potentially causing reliability issues. Thermal concerns force each module to be designed for lower power dissipation than before. Also with increased electrification and cabling, the possibility of electromagnetic interference goes up, leading to an increased focus on electromagnetic compatibility (EMC).

These general considerations hold for group isolated and channel-to-channel isolated analog input modules. Group-isolated modules are lower cost, whereas channel-to-channel isolated modules offer robustness and flexibility of use. Careful choice of Isolation solutions is an important decision in each case and is a major factor that decides module size, power and electromagnetic compatibility.

3 Group-Isolated Analog Input Modules

A group-isolated analog module is shown in [Figure 3-1](#). A group-isolated module receives inputs from several sensors such as temperature, pressure and level. with respect to a single reference field ground (ISOGND in [Figure 3-1](#)). If the common mode voltage difference between the sensor ground and the ISOGND is expected to be large, the analog inputs may be differential as shown in [Figure 3-1](#). Otherwise, the inputs can be single ended. A differential amplifier (AMP) is used to reject input common mode, and provide a single ended signal referenced to ISOGND. Using an amplifier with a high common mode rejection allows for large common mode difference between the different inputs and with respect to ISOGND. Analog inputs are usually designed to be software configurable as voltage inputs (to receive 0 to 5 V, -5 V to +5 V and -10 V to +10 V inputs) or current

input (0-20 mA). For current input mode a burden resistor R_B is switched between the positive and negative terminals of the analog input.

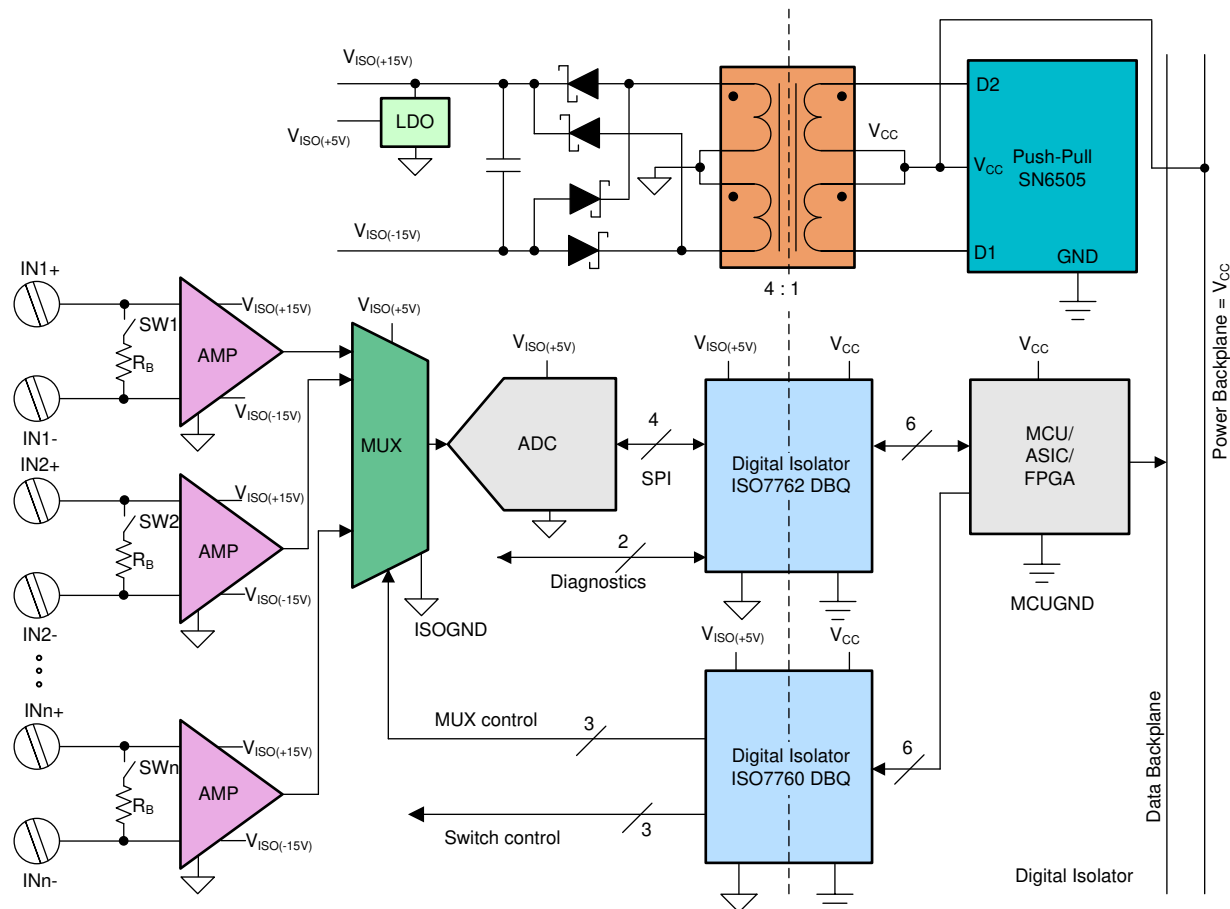


Figure 3-1. Signal and Power Isolation in Group Isolated Analog Input Module

A multiplexer (MUX) is used to periodically multiplex the different channel inputs to the ADC. The ADC interfaces with the system controller (MCU, FPGA or ASIC) using a single isolated SPI interface. The main advantage of group isolation is that it reduces the ADC and signal and power isolation costs, and overall module size. Additional isolation channels are needed to control the MUX and the burden resistor switches. However, the cost still works out cheaper than having to use a dedicated ADC and isolator for every analog input channel.

A single isolated power supply, for example a push-pull converter, can provide power to all the circuits on the isolated side. Depending on the implementation +15-V and -15-V supplies may be needed in addition to a 5-V supply.

Requirements for Digital Isolator in Group-Isolated AI modules:

- Low propagation delay and high data rate:** The digital isolator operates at a high SPI frequency (10 MHz-15 MHz) since it has to handle the aggregate data of all the channels in a serialized manner. To be able to support high SPI frequency, the isolator needs to have very low propagation delay and the ability to operate at high data rate.
- Small footprint and high channel density:** Since most PLC I/O modules don't deal with voltages greater 60 V, there are no electrical safety considerations for the digital isolators. Hence digital isolators that support 2.5 kV_{RMS} withstand voltage in the smallest footprint and the highest channel density are preferable. Some analog input modules support higher input common mode: up to 200 V. Even for these modules, since the input voltages are not directly connected to AC mains, basic isolation is sufficient.

3. **Transient Immunity:** While 2.5-kV_{RMS} isolation suffices, the isolation barrier must still withstand IEC ESD, EFT and surge transients which when applied to the analog inputs with respect to safety earth can stress the isolation barrier [1].

Requirements for Isolated Power in Group-Isolated AI modules:

1. **High Efficiency:** Depending on the number of analog channels and the complexity of the circuits, the power requirement on the isolated side can be in the range of 0.5 W to 1 W. To reduce the power dissipation in the tightly packed and small form factor modules, and to reduce the current draw from the backplane, the isolated power supply must be very efficient.
2. **Low Electromagnetic Emissions:** The cables attached to the AI modules act like transmitting antennas, so the isolated DC-DC must have very low emissions.
3. **Flexible Output Voltage:** Depending on the design requirements +/-15 V, +/-5 V or 5 V isolated supply voltage may be needed.

4 Channel-to-Channel Isolated Analog Input Modules

Channel-to-channel isolated analog input modules use a separate ADC, signal and power isolator for every analog input channel, as shown in [Figure 4-1](#). While group isolated modules offer cost efficiency, they impose restrictions on usage. The analog sensors they interface cannot have large common mode differences between them, and hence they cannot be placed in different physical regions in the factory. A channel-to-channel removes this restriction, and allows the end user maximum flexibility of usage. The common mode difference between channels can be a few kilovolts. Channel-to-channel isolation also improves robustness of the system, and brings benefits to functional safety, since any failures in the ADC or isolation in one channel will not affect the other channels.

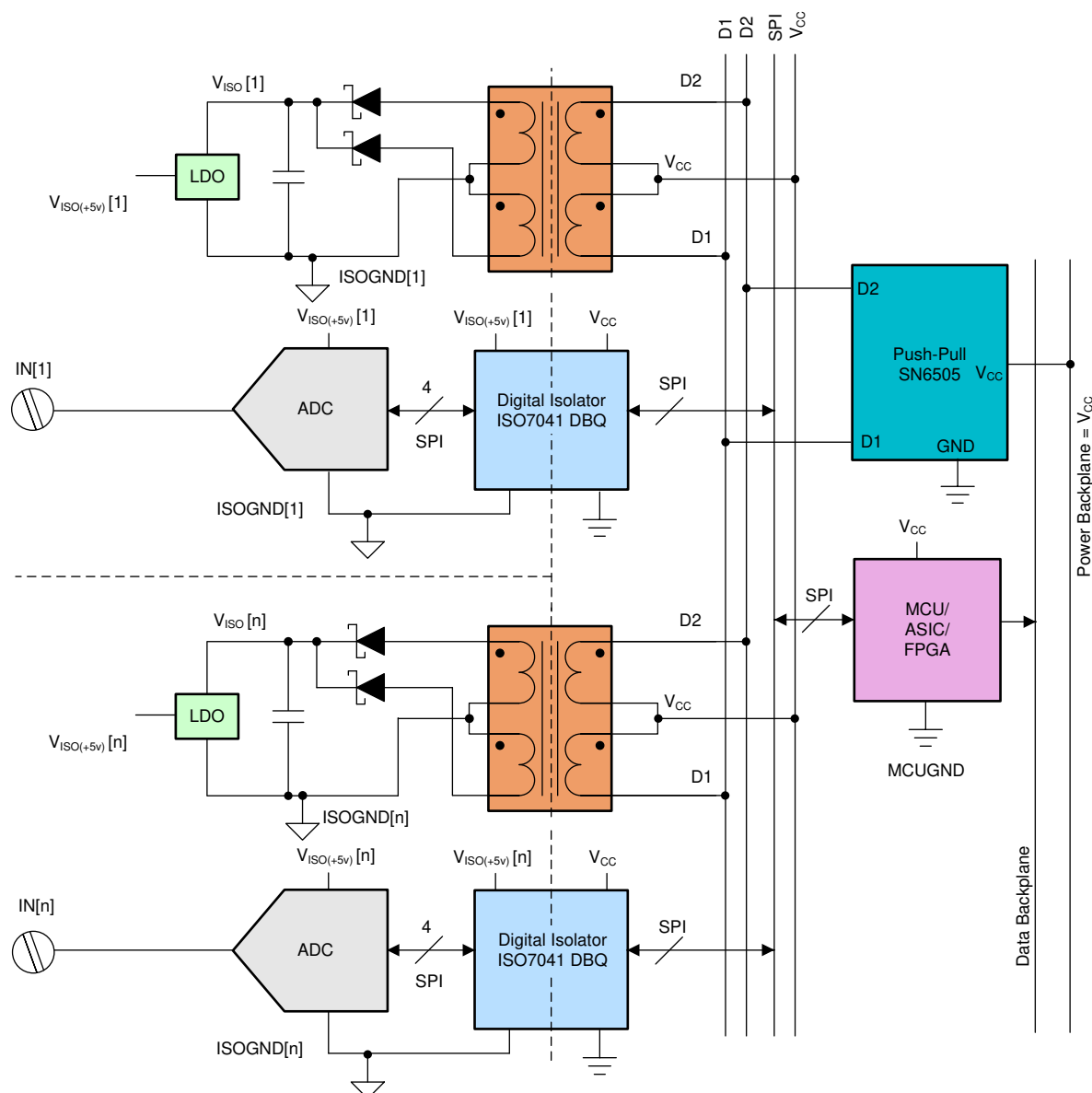


Figure 4-1. Signal and Power Isolation in Channel-to-Channel Isolated Analog Input Modules

Requirements for Digital Isolator in channel-to-channel isolated AI modules

1. **Very Low Power:** Channel-to-channel isolated modules use as many isolators as there are input channels. Usually isolators are among the more power-hungry devices on the board. As module profiles shrink, and many modules are packed close to each other, the air flow is limited, resulting in a higher temperature rise for the same amount of heat dissipated. To reduce overall power consumption in the system, and for thermal considerations, each isolator must consume very low power. On the other hand, since the digital isolator supports only one analog channel, the requirements on high-data rate and low-propagation delay are not as stringent as for group isolated designs.
2. **Small footprint:** Channel density and small form factor of the isolator are even more important than in the case of group isolated modules, due to the large number of isolators used.
3. **Electromagnetic Compatibility (EMC):** In group isolated modules, X or Y capacitors are sometimes used across the isolation barrier to reduce emissions and improve transient immunity [1]. Channel-to-channel isolated analog input modules can ill afford an X capacitor for every channel due to space constraints. Hence

it is imperative for the isolator used to be able to meet level 3 EMC according to IEC 61000-4-x and CISPR standards.

Requirements for Isolated Power in channel-to-channel isolated AI modules

The considerations for isolated power are similar as for group isolated modules. The isolated power supplies operate with very low currents (in the range of 10 mA), so efficiency at light loads is important. In some designs, the 24-V field supply needed for the analog sensors is provided by the analog input module itself, in which case the isolated power supply must also generate 24 V.

5 Isolation Products for Analog Input Modules

The ISO77xx family of digital isolators (example: [ISO7741DBQ](#), [ISO7762DBQ](#)), offer SPI speeds up-to 16 MHz and low power of 2 mA per channel at 10 Mbps, and are suitable for group isolation. Similarly the ISO70xx family of digital isolators ([ISO7041DBQ](#) and [ISO7021D](#)) offer industry leading low power consumption of 15uA/channel at 100 kHz, and fit the needs for channel to channel isolated analog input modules. Both families offer 3 kV_{RMS} isolation in small 5 mm x 6 mm footprint packages. These devices support level 3 transient immunity per IEC 61000-4-x standards, including +/-8 kV ESD contact discharge.

The [SN6505](#) family of push-pull transformer driver devices creates isolated power supplies with efficiency of 80% to 90% at 5-W full load, and 50% to 60% at light loads. Any output voltage can be generated by choosing the right transformer ratio. The feedforward converter is easy to design and does not need an analog feedback channel. The symmetric push-pull topology is well known to achieve very low emissions due to symmetric operation. The built-in spread spectrum in [SN6505](#) avoids sharp peaks in the emissions profile.

6 Conclusion

In this article, I discussed the key considerations while choosing signal and power isolation solutions in group isolated and channel-to-channel isolated analog input modules. For group-isolated modules, low propagation delay and small size are important for the signal isolator, and high efficiency at 0.5 W for the isolated power supply. For channel-to-channel isolated modules, the digital isolator must consume very low power, and the isolated power supply must have high efficiency at light loads. Inherent electromagnetic compatibility in the isolation solutions can save the cost and space of X or Y capacitors.

7 References

1. Texas Instruments, Analog Design Journal, 3Q 2017, [How to use isolation to improve ESD, EFT and surge immunity in industrial systems](#)

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