Application Brief

How To Simplify Isolated 24V PLC Digital Input Module Designs

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Digital Input Modules

Digital Input (DI) modules are used in Programmable Logic Controllers (PLCs) and Motor Drives to receive 24V digital inputs from field sensors and switches. Isolation is used to manage ground potential differences. The input signal is interpreted as a logic high or low using a voltage comparator with hysteresis. Some form of current limit is also implemented to avoid excess current draw from the 24V inputs; power dissipation is a critical concern in high-density compact multichannel designs.

The IEC 61131-2 standard for programmable controllers specifies three different types of digital input receivers: Types 1, 2, and 3. Ideal implementations for Type 1 and 3 need to draw as close to 2mA as possible in the ON-state, and have voltage transition thresholds between 5V and 11V.

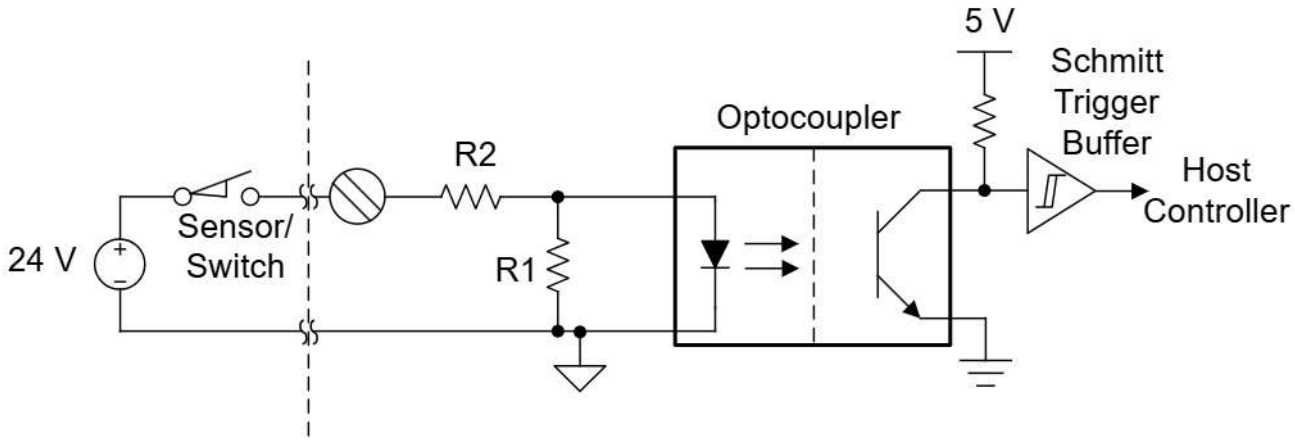

Figure 1. Traditional DI Modules with Basic Current Limit

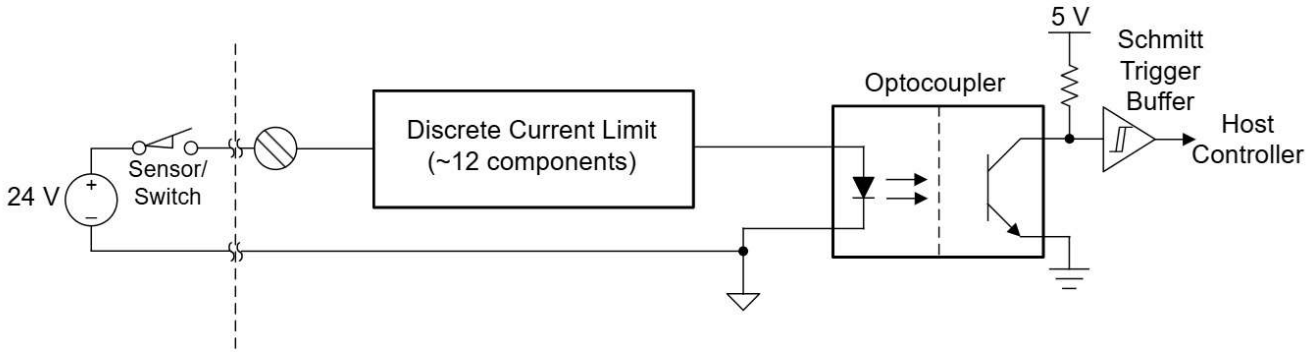

Figure 2. Traditional DI Modules with More Accurate but Complex Current Limit

Common Digital Input Implementations

Figure 1 and Figure 2 shows the two most common implementations of Digital Input receivers in use today. In the first case shown in Figure 1 the voltage thresholds are set by resistors R1 and R2, and R2 serves as a basic current limit. Such an implementation for Type 3 inputs can easily draw up to 12mA at 32V input. The second implementation shown in Figure 2 uses several discrete components (9 to 15) to implement a better current limit and controlled voltage thresholds. In this case, for Type 3, the current draw can be as high as 6mA across temperature depending on the design. In both cases, the current limit is much higher than the ideal current limit of 2mA for type 3 inputs. A Schmitt trigger buffer is usually needed after the optocoupler to provide hysteresis for noise immunity.

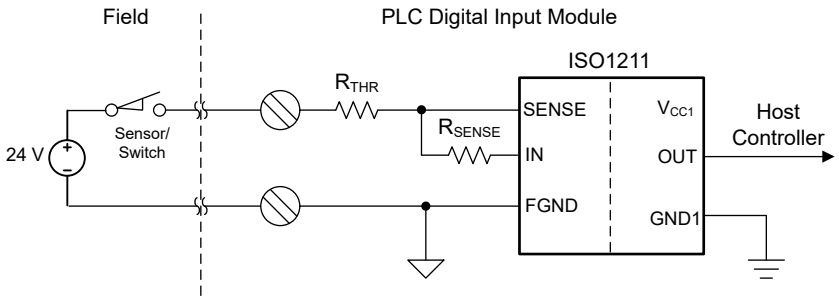

Figure 3. One Channel of a Digital Input Module With ISO1211

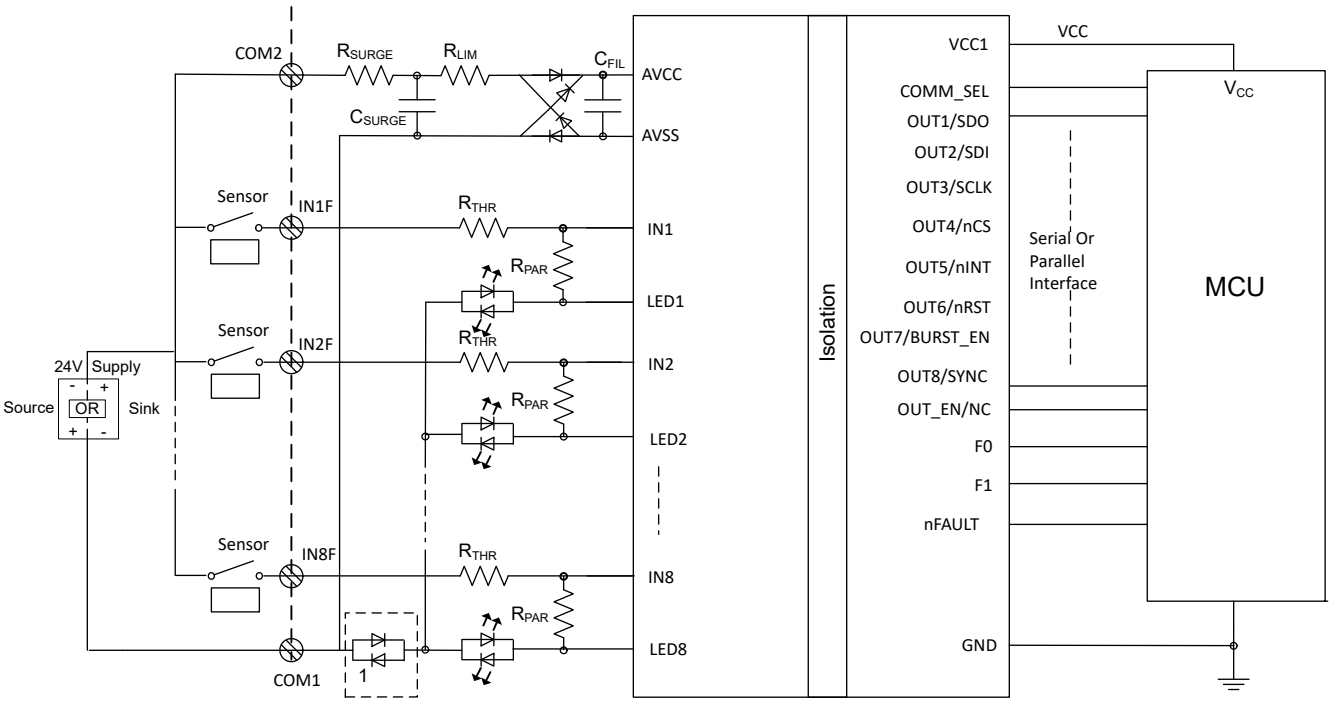

Figure 4. 8 Channel Operation of a Digital Input Module In Source or Sink Mode With ISO1228

New Designs for Digital Input Modules

Texas Instruments' ISO1211 1-channel, ISO1212 2-channel, and ISO1228 8-channel devices are isolated digital input receivers with integrated current limit, compliant to IEC 61131-2 Type 1, 2, and 3 characteristics. The ISO1211 and ISO1212 is designed for channel-to-channel isolation needed for functional safety use case and ISO1228 is designed for multichannel designs. Figure 3 shows the implementation of one channel of a Digital Input module with ISO1211. The resistor R_{SENSE} controls the current limit, and the resistor R_{THR}, the voltage transition thresholds. The recommended values of R_{SENSE} and R_{THR} and application circuits for multichannel and other scenarios are provided in the ISO121x product data sheet. The ISO121x simplifies system design by integrating an accurate current limit, voltage comparator with hysteresis, reverse polarity protection and isolation,

while not needing field-side power. For Type 3 characteristics, ISO121x limits the input current draw to < 2.5mA, a factor of 5 × lower than traditional approaches. Figure 4 shows the implementation of 8 channel of a Digital Isolator using ISO1228. ISO1228 supports both the Sink and Source mode in the same device and can be configured in as shown in Figure 4. The R_{ILIM} resistor sets the current limit value for all the channels. The Recommended values of R_{ILIM}, R_{THR} and R_{PAR} are provided in the *ISO1228 Eight-Channel Isolated Digital Input with Current Limit and Diagnostics*, data sheet.

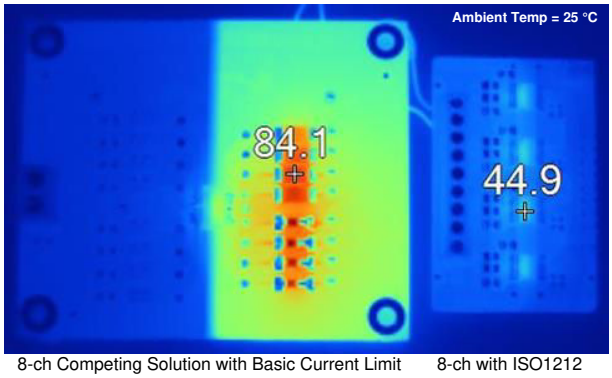

Figure 5. Board Temperature Comparison: Traditional Design vs ISO1212

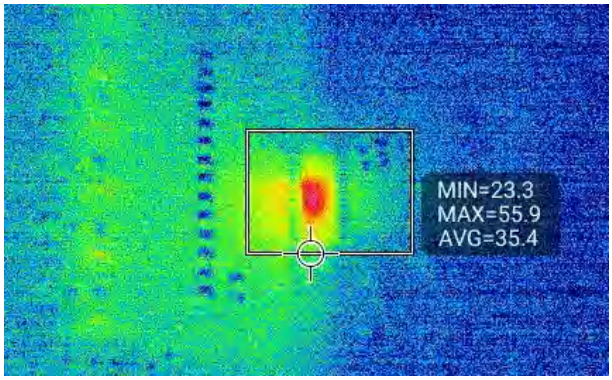

Figure 6. Board Temperature For ISO1228 With all Channels on for Ambient Temperature of 25°C

Compared to traditional approaches using optocouplers, designing with ISO121x has the following advantages:

1. **Lower Power Dissipation:** The precise current limit in the ISO121x can reduce the current drawn from digital inputs by up-to a factor of 5 reducing power dissipation and board temperature. As shown in Figure 5, a traditional design can heat up to 84°C during a room temperature test, where as ISO121x-based design is much cooler at 45°C.
2. **Smaller boards and modules :** ISO121x-based designs reduce component count leading to smaller boards. Lower power dissipation also allows packing more channels in a smaller module.
3. **Simplified System Design :** With ISO121x, the IEC 61131-2 input characteristics, current limit and isolation are provided by the data sheet. No additional Schmitt trigger buffer is needed. This simplifies system design.
4. **High Speed Operation :** ISO121x offers 4Mbps data rate and 150ns latency - allowing much faster interfaces than general purpose optocouplers.
5. **No need for field side power supply:** This saves cost on connectors and terminals for the 24V field side supply as well as the corresponding surge protection.
6. **Channel independence:** Damage to one channel on the field side (say, due to short circuit) does not impact any of the other channels.
7. **Higher speeds:** Serialization in multichannel devices limits speeds to <20kHz, while ISO121x devices can support up to 2MHz clocking.

Multichannel Single-Chip Designs

Figure 7 compares the layout of a design with four ISO1212 devices with a competing 8-channel single-chip design. The Y-dimension of the board is limited by the placement of the input screw terminals and connectors. However, the X-dimension is higher for the 8-channel single-chip design. This is because of additional space taken due to routing congestion close to the IC. Conversely, since ISO1212 has only two channels, there is more flexibility in placing the IC closer to the input terminals resulting in much simpler routing, leading to a smaller design.

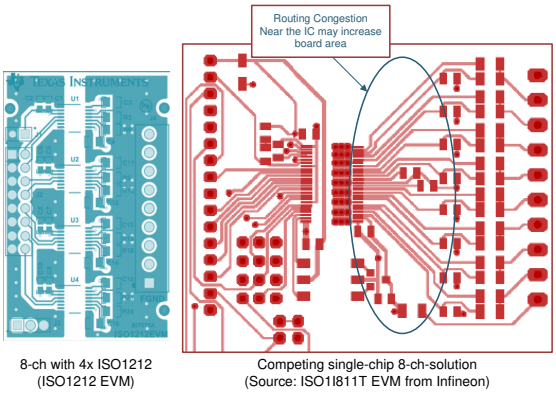

Figure 7. Layout of ISO1212-Based Design vs Competing 8-Channel Single-Chip Design

Key advantages of ISO1228-based design over traditional implementation:

1. **Source-Sink Mode:** ISO1228 can support both the sink and source mode in same device. So, there is no need for external Rectifier. Figure 4 shows the implementation of 8 channel of a Digital Isolator using ISO1228 in sink and source mode respectably.
2. **Improved Thermal performance using negative resistance input structure :** ISO1228 input structure has a negative resistance, for higher input voltage the pin current reduces to balance for the increase in current through the $R_{PAR.}$ This keeps the total pin current < 3.3mA for all pin voltages as shown in Figure 8. This improves the thermal performance of the part. Figure 6. Shows the thermal image of the part with all the inputs sinking current at 30V. The device only heats up to 55°C for room temperature test.
3. **Wire break detection feature :** For PLC market sensor wires travel a very long distance from the PLC to the Sensor and due to any physical damage to the wires the MCU will never get to know the sensor is disconnected. To prevent this situation the Wire-break feature is added to ISO1228. It uses the leakage current of the Sensor to detect the wire is intact and there is no physical damage. If the leakage current of the sensor is not received by the digital input then ISO1228 reports the wire break fault to the MCU.
4. **Superior EMC :** When all the 8 channels of the DI part is receiving signals from the field than communication across the Isolation barrier can create high EMC for the galvanic isolated competitor parts. High RE can cause miss-communication with the MCU/FPGA next to the digital input part. TI's ISO1228 uses a patented technology for communication across isolation barrier that enables negligible EMC as shown in Figure 9.
5. **Input filter :** Digital inputs are mostly mechanical switches that suffers from fluctuations during turning on and off. ISO1228 has 8 programmable input filters for every channel to filter out the noise generated by the switches.
6. **Loss-less LED indication :** For input state indication and manual maintenance, LED indication is very essential. ISO1228 uses the Field side input current of nearly 3mA to turn on the LED for every input. Figure 4 shows how the LED is connected for every channel. This saves from taking any extra power for the LEDs and helps to improve the thermals.
7. **Board Space saving :** This is an integrated solution that replaces 8 channel discrete implementation with a single device as shown in Figure 4. This saves significant PCB space and help to make higher channel count PLC cards in same board space.

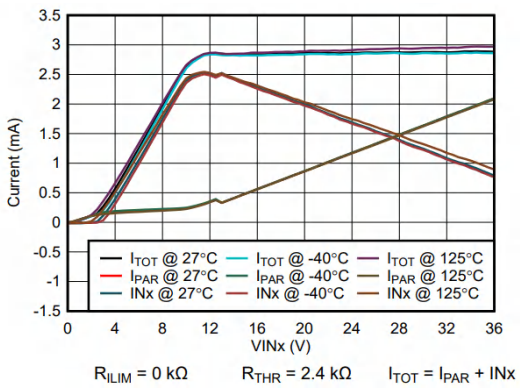

Figure 8. Pin Current for ISO1228 Always Maintained Constant for Changing Voltage at Input

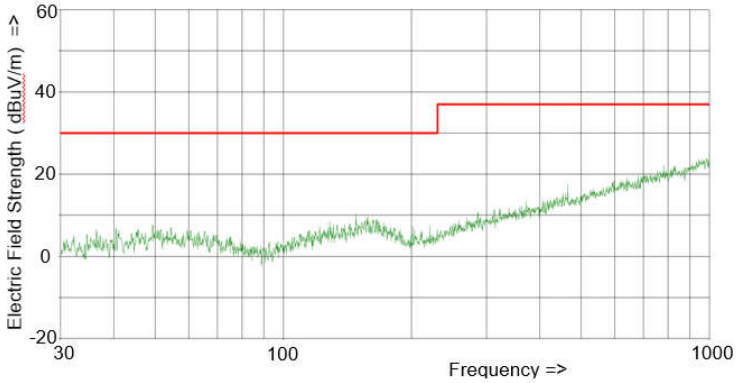

Figure 9. EMC Data for ISO1228 With all Channels on

Design for Surge, EFT, and ESD Immunity

The ISO12xx devices have been designed for Surge, EFT and ESD immunity according to IEC 61000-4-x standards. Please refer to the application section of the product data sheet for design, and layout guidelines to achieve the best transient immunity.

Conclusion

The ISO1212, ISO1211, and ISO1228 devices bring a modern design to Digital Input Modules, integrating IEC 61131-2 input characteristics, voltage comparator with hysteresis, a precise current limit and galvanic isolation in a small package. Modules designed with ISO121x have lower power dissipation, allow higher channel density, are compact and simple to design compared to traditional designs.

Table 1. Alternative Device Recommendations

Device	Optimized Parameters	Performance Trade-Off
SN65HVS880	8-channel digital input serializer	Non-isolated, 3.6mA current limit, Needs field side supply
SN65HVS885	8-channel digital input serializer	Non-isolated, 3.6mA current limit, Needs isolated DC-DC

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