Industry’s Traditional Digital-Input Architecture

Digital/binary sensors and switches are essential for signal monitoring and system control in industrial control, industrial automation, motor control, and process automation. All the sensors’ outputs need to be detected and monitored by a central processing unit (CPU). To do this, typically two high-power resistor-dividers, which are located in the digital input module of a programmable logic controller (PLC), detect the sensors’ output voltages. Individual optocouplers are required for isolating each sensor channel. Based on the complexity of the industrial system, many optocouplers might be in use simultaneously during normal operation (Figure 1).

Figure 1. Schematic of a traditional industrial sensor monitoring system shows the resistor-dividers and optocouplers that monitor and detect sensor outputs into the system’s PLC.

In this traditional architecture the resistor-dividers consume high power and generate PC board (PCB) “hot spots” that can require the design to support a higher operating temperature and add a heatsink. Hot spots can even reduce system reliability. For high-channel-count modules, moreover, the multiple optocouplers increment system costs and power consumption, while consuming valuable board space. Clearly the industry would benefit from a compact and simple, isolated digital-input interface.

Simplify the Digital Input to a PLC

Integration is the answer. Simple enough to say or plan, but not easy to do. First, increase the channel inputs to expand the system’s capacity, but keep the interface simple. Now turn to data serialization and find a way to eliminate the optocouplers used for isolation. Use configurable
 current limiting to lower the power dissipation. (See Figure 4.) Improve error detection and make data transfer very reliable over that same simple interface. Integrate all this functionality and you make the digital input far more versatile and robust, generate less heat and use less power, save space, and lower costs significantly. That is the goal.

**Implementing an Isolated Digital-Input Reference Design**

The solution to the above design objectives is the Corona isolated subsystem reference design utilizing a digital-input translator/serializer and a data isolator. The Corona design provides the front-end interface circuit of a PLC digital input module. The design accepts high-voltage inputs (36V, max) and features isolated power and data, all integrated into a small 90mm x 20mm form factor. The design integrates an octal digital-input translator/serializer, a 6-channel data isolation device, and an H-bridge transformer driver for an isolated power supply if field power is not available. Let’s take a closer look at the hardware and software.

**Hardware Description**

The Corona input module is seen in Figure 2 with the system diagram in Figure 3.

![Figure 2. The Corona reference design board, (MAXREFDES12#).](image-url)
In this design the industrial digital-input serializer (U1) translates, conditions, and serializes the 24V digital output of sensors and switches to CMOS-compatible signals required by microcontrollers. It provides the front-end interface to a PLC digital-input module. Input current limiting significantly reduces the power consumed from the field voltage supply when compared to traditional discrete resistor-divider implementations. Figure 4 compares the current-voltage relationship of a single input channel in both approaches. Selectable on-chip lowpass filters allow flexible debouncing and filtering of sensor outputs. On-chip 8-to-1 serialization eliminates optocouplers needed for isolation. A multibit CRC code, transmitted through the SPI port for each 8 bits of data, ensures reliable communication in noisy industrial environments. For additional flexibility, the integrated 5V voltage regulator can power external optocouplers, digital isolators, or other external 5V circuitry.

U3 (MAX14850) accomplishes 6-channel data isolation in a Pmod™-compatible form factor. The Pmod specification allows for both 3.3V and 5V modules as well as various pin assignments. On the Pmod side, the voltage supply can be 3.3V or 5V; on the U1 side, the voltage supply is 5V. The data isolation achieved is $600V_{\text{RMS}}$.

U1 (MAX31911) is powered by a 24V field power supply in most cases. If the field power supply is not available, then U1 can be powered from the controller side. In this latter case, an H-bridge transformer driver (U2, MAX13256) and a transformer on the Corona board provide a functional class, isolated power supply for the MAX31911.

Software Description
The Corona design was verified using the Nexys™ 3 and ZedBoard™ platforms. Project files, device drivers, and example code are currently available for these two platforms. However, the Corona design can easily be used by any microcontroller or FPGA development board because of the simplicity of the onboard Pmod-compatible connector. The complete source code and documentation are provided at www.maximintegrated.com/AN5611.

Summary

This article has explained how the Corona (MAXREFDES12#) subsystem reference design is a compact and simple, isolated digital-input interface for industrial control and automation. The Corona design provides eight digital input channels. Additional channels can easily be added in multiples of eight by simply cascading more octal digital-input ICs on the same SPI interface—no extra chip-select lines are needed. Having only a single SPI interface for transferring sensor data to the PLC eliminates the need for isolating additional channels. The number of isolators needed in the input module is significantly reduced. The design dramatically lowers cost, uses less space, and there is higher channel density per PCB area. Example software has been written for the Nexys 3 or ZedBoard platforms. Hardware and firmware design files are provided at www.maximintegrated.com/AN5611.

High integration. Reduced power consumption. On-chip data serializer with no optocouplers. Ultimately, the story is power, flexibility, and regained space—all powerful benefits for industrial applications.

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