Isolated Analog I/O Designs Benefit from New Family of *i*Coupler® Devices

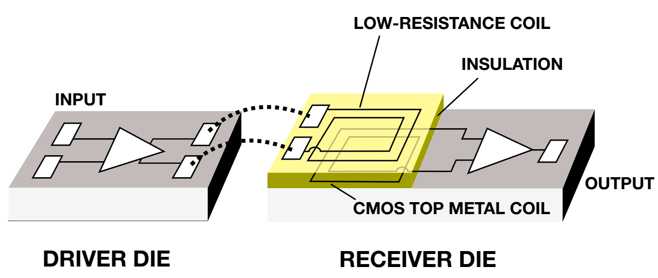
The 3-channel ADuM130x and 4-channel ADuM140x digital isolators avoid many of the difficulties commonly encountered with optocoupler based designs. The isolators are based on award-winning* *i*Coupler technology and employ magnetic coupling via signal transformers. The 3-channel ADuM130x and the 4-channel ADuM140x isolators provide a variety of channel configurations and data rates to suit most applications.

One area where *i*Coupler technology can make a dramatic impact is in the design of an SPI® interface for an isolated PLC (programmable logic controller) front-end. The table below summarizes the most significant benefits for a 4-wire *i*Coupler interface versus a standard interface based on optocouplers.

Table I. Benefits of *i*Coupler Solution over Optocoupler Solution

	Optocoupler Solution	*i*Coupler Solution
Required Board Space	425 mm^2	160 mm^2
Total Cost	$4.75	$3.15
Thermal Rise	10°–15°C	2°C

What is *i*Coupler Technology?
*i*Coupler isolation technology combines the dc isolation properties of microtransformers with semiconductor processing techniques to provide performance, power, and integration benefits superior to those offered by traditional optocoupler technology. *i*Coupler components operate at higher data rates, provide better timing accuracy and common-mode transient immunity, and operate at lower power levels than optocouplers. They operate over wider temperature and supply voltage ranges than their optical competition. The *i*Coupler technology rescues modern designs from the poorly controlled, temperature sensitive, and time-dependent current transfer characteristics of standard optocouplers.



*The first iCoupler® device, the ADuM1100, a single-channel digital isolator, won the Product of the Year award in 2000 from Electronics Products Magazine.

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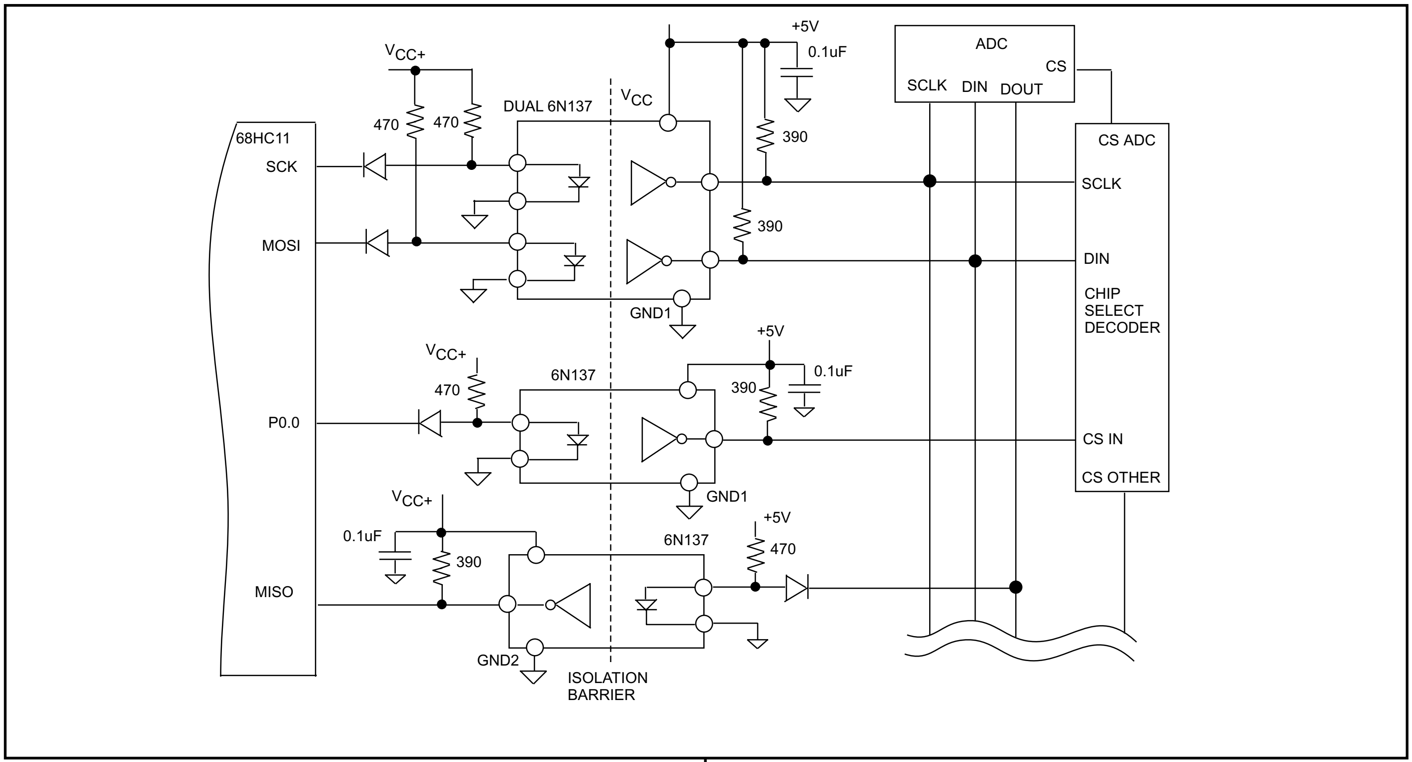

Figure 1. The 4-Wire Optocoupler Solution

Figures 1 and 2 compare a 4-wire optocoupler interface with a 4-wire *i*Coupler interface in an isolated PLC system. The very different number of external components required—just two decoupling capacitors in Figure 2 versus a total of fifteen for Figure 1, as recommended on the optocoupler data sheets—is the fundamental reason *i*Couplers can occupy a much smaller board layout area than an optocoupler solution. The 4-wire optocoupler interface actually requires a dual optocoupler and two single optocouplers. That's three packages for the interface alone. The optocouplers used in this example are the 10 Mbps single-channel 6N137 type and a dual-channel 6N137 equivalent. Both devices are available in 8-lead, small-outline, surface-mount packages. In contrast, the *i*Coupler technology allows mixing transmit and receive channels within the same package; hence a single 10 Mbps ADuM1401BRW would provide the four channels with the required directionality. This device is in a 16-lead, wide-body, small-outline, surface-mount package. The number of packages and extra components required for the optocoupler solution is an important factor when the end product is a microPLC no larger than a box of playing cards. Table II compares the approximate board space consumed by the two solutions. Surface-mount components were used with 0603 format for the capacitors, 0805 format for the resistors, with the diodes in SOT-23 packages.

Table II. Comparison of Board Space Required by Optocoupler and *i*Coupler Solutions

	Optocoupler Solution	*i*Coupler Solution
Required Board Space	18 Components total occupying 425 mm^2	3 Components total occupying 160 mm^2

In addition to the average $0.014 cost per discrete component (@ 10k pricing), there will be a more significant placement cost of typically $0.03 per component. The extra component cost incurred by the optocoupler solution plus the placement cost add considerably to the total solution cost. Table III compares the component cost for each of the two solutions and the estimated placement cost to arrive at a finished cost for each solution. The placement cost for a 16-lead SOIC package is assumed to be $0.06 with an 8-lead SOIC placement at $0.03.

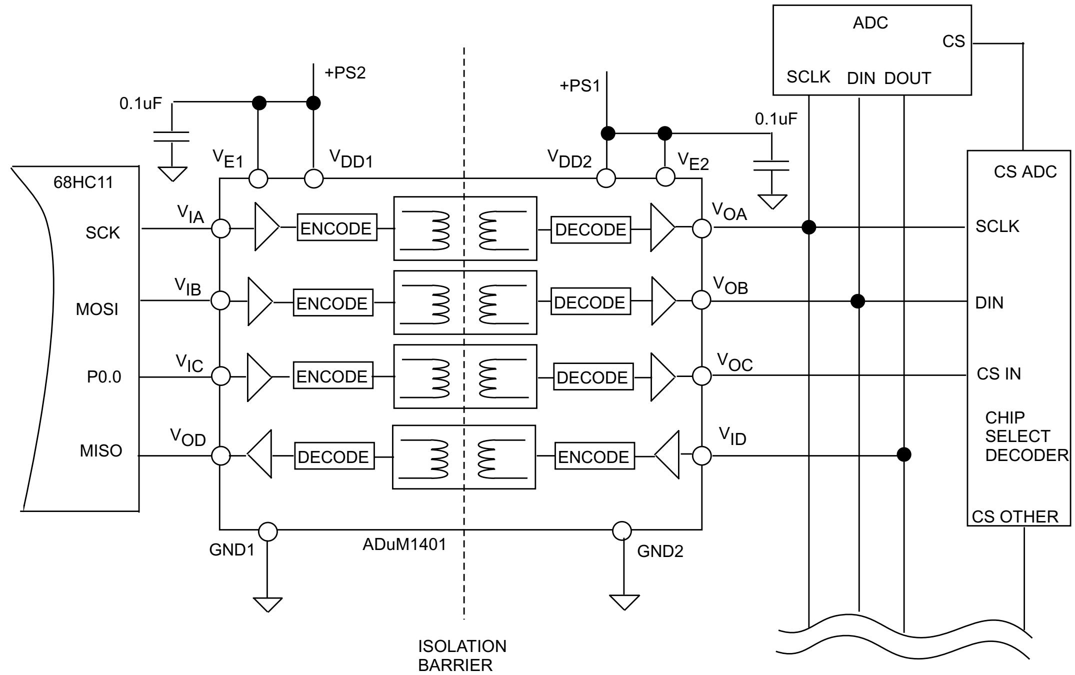

Figure 2. The 4-Wire iCoupler Solution

Table III. Comparison of Solution Costs for Optocoupler and *i*Coupler Solutions

	Optocoupler Solution	*i*Coupler Solution
External Component Cost	$0.21	$0.03
ADuM1401B		$3.00**
Dual 6N137 Equivalent	$2.00*	
6N137 Equivalent (x2)	$2.00*	
Placement Cost	$0.54	$0.12
Total Cost	$4.75	$3.15

*Estimated 10k pricing **USD 10k, FOB USA

If the interface speed permits, it may be possible to reduce the component cost of Figure 1 by using lower speed and hence, lower cost optocouplers. However, these lower speed devices can introduce another problem because of their slow rise and fall times. They can be so slow as to cause multiple triggering (or ringing) in any following logic input stage. To prevent such multiple triggering it is necessary to employ standalone Schmitt-trigger buffers to clean up the signals or ensure that all following logic inputs have Schmitt-trigger inputs.

In addition to the lower solution cost and reduced printed circuit board area, another advantage of an *i*Coupler solution over an optocoupler solution in PLC applications is reduced heat dissipation. In both solutions, the power consumption varies, depending on whether the interface is idle (no transmission) or not. For PLC designs where there are additional components such as digital-to-analog converters (DACs) or a digital I/O port sharing the serial interface, the bus activity can be significant, with power consumption significantly higher than the idle power consumption. For the optocoupler interface with + 5V supplies on either side, the typical power consumption, with a 1 MHz squarewave clock frequency, is 340 mW, while it is only 25 mW, more than thirteen times less, for the *i*Coupler interface.

With the average power consumed by the dual optocoupler equal to 180 mW and the two single optocouplers consuming 140 mW, a conservative estimate of thermal rise is at least 10ºC above the surrounding components. As noted, the optocoupler required for the chip select function need not be a high speed type; a lower cost, lower speed optocoupler can work here, although the power consumed will be similar to the higher speed device. Table IV compares the power consumed by both solutions and the resultant thermal rise.

Table IV. Comparison of Typical Power Consumption and Thermal Rise for Optocoupler and *i*Coupler Solutions

	Optocoupler Solution	*i*Coupler Solution
Power Consumed, Both Sides	340 mW typical	25 mW typical
Thermal Rise above Ambient	10ºC–15ºC	2ºC

Isolated power for the front end electronics such as ADCs and DACs and for the isolation elements themselves is usually supplied by means of a transformer, rectifier diodes, and a voltage regulator. For the optocoupler solution, the power transformer will be physically larger and more expensive and will run hotter than for the *i*Coupler solution, leading to yet more heat being generated. Note that due to the gradual current transfer ratio (CTR) degradation of optocouplers over time, optocouplers must be considerably overdriven initially to ensure adequate signaling efficiency at their end-of-life. Overdriving the optocouplers will consume more power.

Hot components such as these optocouplers and power transformers play havoc with all other precision components within the PLC enclosure. All analog signal conditioning components and voltage references will experience increased drift, while any discrete matched resistors will experience ratio shifts depending on their relative location on the printed circuit board. Specifically with regard to a thermocouple measurement channel, the isothermal block used for CJC compensation will be subject to a number of temperature gradients dependent upon the placement of the optocoupler packages with respect to the block. Any significant resultant thermal gradient across this block will obliterate any chance of accurate cold junction compensation and with it, any chance of an accurate temperature measurement. High temperatures within a PLC casing especially affect the reliability of electrolytic capacitors by increasing their leakage and shortening their usable lifetime. This effect puts a very real limit on the number of optocouplers that can be placed within the same enclosure.

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