IsoLoop Magnetic Couplers Replace Opto-Couplers in Industrial Systems

A new generation of couplers weathers the storm of noise with high speed and multiple channels

by John Myers

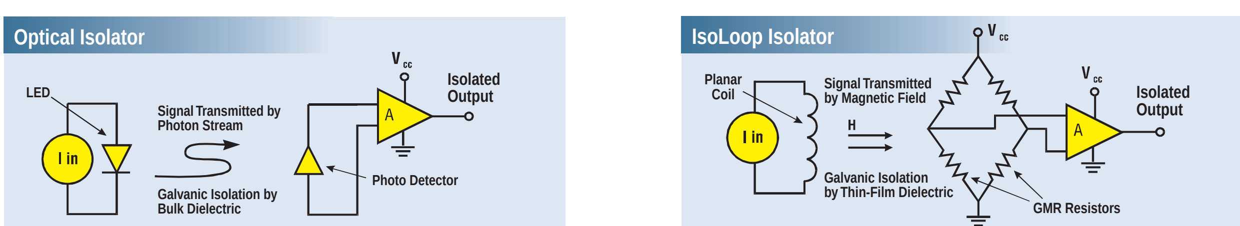
Sensing is only part of the battle in industrial control systems. Getting the data where it needs to go is the other part. In the treacherous seas of industrial environments, that data path can be strewn with ground loops, noise, temperature extremes, and speed bottlenecks.

For years, optical couplers were the only bridges over these troubled waters. Revolutionary when they came on the scene a generation ago, opto-couplers have failed to keep pace with advances in industrial networks and sensor technology, leaving many designers frustrated by their bulk, slow speed, high power consumption, and limited temperature range.

But in the past year a new generation of solid-state couplers—magnetic couplers—has been introduced which promise smoother sailing by overcoming many opto-coupler limitations.

Galvanic couplers

Magnetic couplers are analogous to opto-couplers in a number of ways. Opto-couplers transmit signals by light through a bulk dielectric that provides galvanic isolation (Figure 1a). Magnetic couplers transmit signals via a magnetic field



Figures 1a and 1b: Optical couplers compared to magnetic couplers.

(instead of a photon transmission) across a thin-film dielectric that provides the galvanic isolation (Figure 1b).

Like opto-couplers, magnetic couplers are unidirectional and operate down to DC. But unlike opto-couplers, magnetic couplers offer the high-frequency performance of an isolation transformer, covering nearly the entire combined bandwidth of the two conventional isolation technologies.

Industrial networks need isolation

Widespread electrical and communications networks often have nodes with different ground domains. The potential difference between these grounds can be AC or DC, and can contain various noise components. Grounds connected by cable shielding or logic line ground can create a ground loop—unwanted current flow in the cable. Ground-loop currents can degrade data signals, produce excessive EMI, damage components, and—if the current is large enough—present a shock hazard.

Galvanic isolation between circuits or nodes in different ground domains eliminates these problems, seamlessly passing signal information while isolating ground potential differences and common-mode transients. Adding isolation components to a circuit or network is considered good design practice, and is often mandated by industry standards. Isolation is frequently used in modems, LAN and industrial network interfaces (such as network hubs, routers, and switches), telephones, printers, fax machines, and switched-mode power supplies.

Magnetic technology and GMR isolation

Magnetic couplers are based on the Giant Magnetoresistance (GMR) effect, discovered by French scientists in 1988. GMR materials are made from exotic metal alloys deposited in extremely thin layers and formed into tiny resistors. The resistors provide a large change in resistance when subjected to a magnetic field (the “Giant” in “Giant Magnetoresistance”). GMR sensors have been available for several years, offering high sensitivity and stable, repeatable switch points. The technology also enables today’s ultra high-speed hard-disk drives.

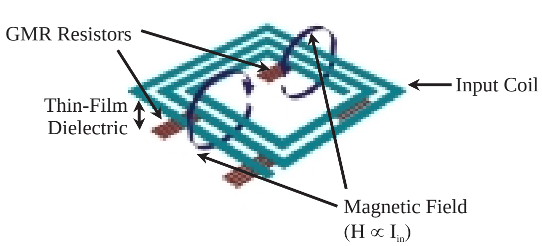


Figure 2: Magnetic coupler construction.

IsoLoop® couplers add an integrated insulating layer and a microscopic coil on top of a small sensor element bridge. A magnetic field proportional to the input current signal is generated beneath the coil winding (see Figure 2). The resulting magnetic field is sensed across the dielectric film. The dielectric provides 4,500 volts DC of galvanic isolation.

The GMR resistors are sensitive to magnetic fields in the plane of the substrate. This enables a more compact integration scheme than would be possible with a Hall sensor, for example, that measures fields perpendicular to the substrate. And because of GMR's high sensitivity, its propagation delay is shorter and more stable than a simple MEMs pick-up coil.

The sensed magnetic field is amplified and conditioned with integrated electronic circuits to produce an isolated replica of the input signal. Ground potential variations, however, are common to both sides of the input coil, so they do not generate a current. Thus no magnetic field results and these variations are not sensed by the GMR structures. In this way, the signal is transparently passed from the input to the output circuits while ground potential variations are rejected to achieve a very large common-mode rejection ratio (CMRR) and true galvanic isolation.

Advantages of magnetic coupling

Magnetic coupling advantages include high bandwidth, small footprint, excellent noise immunity, and temperature stability.

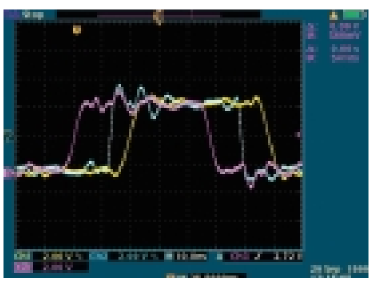


Figure 3: Magnetic couplers (blue trace) have faster rise, fall, and propagation times than the fastest opto-couplers (yellow trace) for the same input (purple trace).

Bandwidth—IsoLoop couplers are five to ten times faster than the fastest opto-couplers, and have correspondingly faster rise, fall, and propagation times (see Figure 3). The faster rise and fall times also reduce power consumption in the device and system by minimizing time in active regions.

Small footprint—Unlike optical couplers, which are inherently discrete devices, and transformers, which are inherently bulky, IsoLoop couplers can be fabricated in less than 1 mm^2 of die area per channel (see Figure 4). This allows multi-channel devices in SSOP packages. Less board real estate means more room for other functions and lower costs. Furthermore, because of their small die size, IsoLoop couplers cost no more than high-performance opto-couplers.

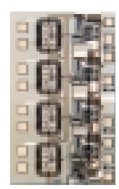


Figure 4: A four-channel magnetic coupler die (actual size 1.1 mm by 1.9 mm).

Noise immunity—Magnetic couplers provide transient immunity up to 25 kV/µs, compared to 10 kV/µs for opto-couplers. This is especially important in harsh industrial and process control environments.

Temperature stability—Because the transmission and sensing elements are not subject to semiconductor temperature variations, magnetic couplers operate to very high temperatures, 100ºC and above, compared to 75ºC for most opto-couplers. Magnetic couplers are also immune to opto-couplers' innate performance decay with age.

Magnetic couplers available now

In the past year, NVE introduced the IsoLoop line of single and multi-channel couplers in both unidirectional and bi-directional configurations and in DIP and SOIC packages.

Because they are fabricated using a semiconductor process, GMR isolation elements are easily combined with silicon processes to provide single-chip isolated transceivers. The first single-package, magnetically-isolated bus transceiver is NVE's IsoLoop IL485, which combines magnetic isolation with an RS485 driver in a 16-pin SOIC package. The device has a data rate of 35 megabaud—over 100 times faster than other single-package isolated transceivers.

Numerous magnetic coupler applications

Magnetic isolators are quickly finding their way into process control and industrial applications. One popular use of the new technology, for example, is for isolating A/D interfaces. In addition, magnetic isolators' combination of speed and packaging density provides a perfect vehicle for efficient data channel management when multiple A/Ds need to be interfaced on the same circuit card. A four-channel part with three channels going one way and one going the other way is available for A/D interface applications.

Magnetic couplers also enable higher speed factory networks, such as Profibus and other protocols. In the past, speeds have been speed constrained by available opto-couplers. IsoLoop couplers recently became the only components registered for Profibus isolation.

The future of magnetic couplers

Current products only scratch the surface of what may prove to be an isolation revolution. In the future, magnetic couplers are expected from more manufacturers, they will be even faster, they will have more channels, and more types of integrated bus transceivers will be made available.

Several manufacturers are planning to introduce magnetic couplers either by licensing NVE's technology or developing their own. In addition, the U.S. military is providing significant funding for advanced magnetic coupler development because of the value of their high speed and noise immunity in aircraft and other systems.

Higher speed magnetic couplers are under development. Speeds are currently limited by the silicon electronics, not the coil/GMR structure. Available device speed is expected to increase as ICs scale down and become faster. NVE has reported prototype devices with speeds of 300 megabaud and less than one nanosecond switching times.

Also under development are higher-density parts such as full byte-wide couplers and more functionality such as latching bus transceivers. In addition to the isolated RS485 transceivers available now, CAN bus, USB, and RS-232 are on the horizon. Furthermore, the inherent linearity of a resistive coil and resistive sensing elements make magnetic couplers ideal for linear data protocols such as low-voltage differential signaling (LVDS).

With a solid base of magnetic couplers available today and more in the future, perhaps the wild seas of industrial data transmission will finally be tamed.

For more information on magnetic isolators, visit www.IsoLoop.com.

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