CIRCUIT CELLAR®
THE MAGAZINE FOR COMPUTER APPLICATIONS

FROM THE BENCH

Jeff Bachiochi

You're Not Alone

Dealing with Isolation

Jeff hasn't turned into a self-help writer, but you can help yourself by following along as he outlines the challenges and effects of isolation. Knowing what the options are will help keep your next project on track.

When I think of isolation, I think of Robinson Crusoe and Friday or in more recent times, Tom Hanks as Chuck Noland. When I think isolation in the electronics context, I think of the transformer. For years, transformers have been used to isolate signals. Magnetic properties transfer information without an electrical connection between primary and secondary windings. On most transformers, it's the plastic bobbin that holds the primary and secondary windings separated that creates the isolation barrier. More recently, opto devices have become a popular method of obtaining isolation.

As you can see in Figure 1, opto devices rely on light (or the absence of light) to transfer information between the physically separated primary (input) and secondary (output). Although the transformer is inherently a bidirectional isolation device, most isolation application requirements are unidirectional.

LIGHTSOLATION

Opto devices have the advantage of operating down to DC whereas transformers are specified at some AC bandwidth. From an isolated control point of view, transformers can't be used directly for steady-state isolation. Opto devices work well in this scenario. An opto device does require a chunk of current to operate and the transfer ratio of input current to output current will usually require a trade-off of speed for drive current. This trade-off is not a problem until you want to transfer information at high speeds. Most opto devices have minimum T_{ON}/T_{OFF} times in the microsecond range.

A new device in the isolation flurry takes a step back into the magnetic domain. NVE Corporation uses giant magneto resistive (GMR) sensors to transfer information using the magnetic fields produced by current in a conductor.

MAGNESOLATION

You may already be familiar with Hall effect devices, which can be used to measure the strength of a magnetic field. The Hall effect is the presence of a voltage produced across (x-axis) a current-carrying conductor (y-axis) as a result of exposure to a magnetic field passing through the conductor (z-axis). This differs from the GMR effect.

The GMR effect is a change in a thin film nonmagnetic conductive layer's resistance caused by an external magnetic field overcoming the parallel but opposing magnetic coupling of adjacent magnetized layers (see Figure 2). You'll remember that the spin of electrons in a magnet are aligned to produce a magnetic moment. Magnetic layers with opposing spins (magnetic moments) impede the progress of the electrons (higher scattering) through a sandwiched conductive layer. This arrangement causes the conductor to have a higher resistance to current flow.

An external magnetic field can realign all of the layers into a single magnetic moment. When this happens,

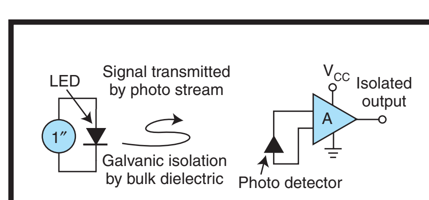

Figure 1—*Optoisolators rely on physical separation between the LED transmitter and photo detector for isolation. Data is passed via photons (or the lack of).*

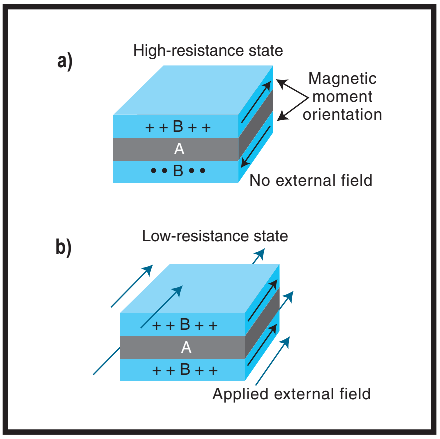

Figure 2—*In both a and b, the A layers are the nonmagnetic conductive layer and the B layers are adjacent magnetic layers of opposing orientation.* **a—***Layer A is high resistance because of higher scattering of electrons flowing through it.* **b—***An applied magnetic field realigns the magnetic moments in the B layers, resulting in a lower resistance in layer A because of a decrease in electron scattering.*

electron flow will be less effected (lower scattering) by the uniform spins of the adjacent ferromagnetic layers. This causes the conduction layer to have a lower resistance to current flow. Note that this phenomenon takes place only when the conduction layer is thin enough (less than 5 nm) for the ferromagnetic layer's electron spins to affect the conductive layer's electron's path.

To put this phenomenon to work, NVE uses a Wheatstone bridge configuration of four GMR sensors (see Figure 3). Their manufacturing process allows thick film magnetic material to be deposited over the sensor elements to provide areas of magnetic shielding or flux concentration. Various op-amp or in-amp configurations can be used to supply signal conditioning from the bridge's outputs. This forms the basis of an isolation receiver. The isolation transmitter is simply coil circuitry deposited on a layer between the GMR sensors layers and the thick film magnetic shielding layer (see Figure 4). Current through this coil layer produce the magnetic field, which overcomes the antiferromagnetic layers thereby reducing the sensor's resistance.

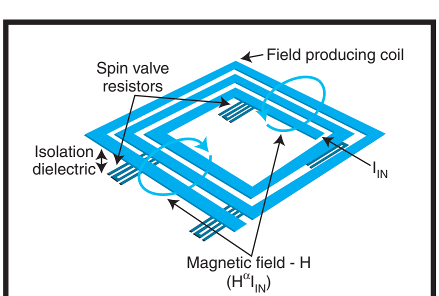

Figure 4—*The magnetic field produced by the field coil of the input affects the spin of electrons in the anti-ferromagnetic layers, reducing the resistance of the bridge sensors.*

NVE obtains isolation specifications of 2500-V_{RMS} using its manufacturing process. Unlike typical microsecond T_{ON}/T_{OFF} times of optoisolators, isoloop-isolators are typically 1 ns, which is more than 1000 times faster than its light-based rival. The isoloop-isolators also have identical T_{ON}/T_{OFF} times, which produce no pulse-width distortion as is the case with many optoisolators having differing T_{ON}/T_{OFF} times.

Propagation delays are less than 10 ns with inter-channel skewing of less than 2 ns. Isoloop-isolators have up to four channels per package in a variety of device direction configurations. These standard devices are great for bus isolation, serial ADCs and DACs, and communication isolation. Figure 5 shows typical RS-232 isolation. Specialty devices include isolated RS-422 and RS-485 communications transceivers (see Figure 6).

POWER ISOLATION

Isolation can't be achieved using a common power supply. This need creates a requirement for additional circuitry beyond the signal isolation. There must be a separate power supply for the circuitry on each side of the isolation barrier. Often this will be more expensive than the signal isolation.

The simplest solution might be to purchase a DC-DC converter. In this case the converter is used as an isolator instead of converting from one voltage to another. Take your time choosing a converter; if you aren't careful you can find yourself being locked into a single-source manufacturer, especially if you choose a converter with a weird pinout or physical size. An alternative might be to build one directly on-board.

Both Linear Technologies and Maxim specialize in power products. Linear's LT1424-5 is good to about 2 W. For lower currents up to a 1-W converter, take a look at Maxim's MAX253. Few external components are required to use the MAX253 as a transformer driver

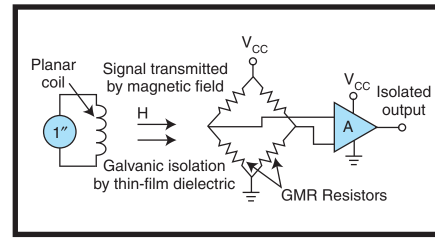

Figure 3—*In a GMR, isolator data travels via a magnetic field through a dielectric isolation to affect the resistance elements arranged in a bridge configuration.*

for an isolated power supply circuit (see Figure 7). C&D Technologies makes an isolation transformer specially designed for the MAX253. The 78250 series transformer is available in 1500-V and 4000-V isolation from Mouser.

I made prototypes of the circuits in Figures 6 and 7 to create an isolated RS-485 transceiver for use with a microcontroller. Notice the surface mount IL-485 mounted on a dip header in Photo 1. Pins 4, 5, 12, and 13 of the IL-485 are soldered to the header and the other pins are wired to the appropriate dip header pins. Using a dip header for surface mount parts makes them easier to handle and reuse elsewhere (after you get past the surgical wiring).

Although the IL-485 is only available in the surface mount variety, the other devices are through-hole components. I measured typical required currents in the isoloop IL-485 circuit in Figure 6 and found the isolated RS-485 side required considerably less than 50 mA without any load on the twisted pair. Using the isolated voltage to supply the termination load adds 50 mA to the load requirements of the MAX253 isolated supply. The MAX253 circuit easily supplied this current at just over 5 V after the Schottky rectifier drop, thanks to the 1:1.31 winding of the transformer. No regulator is needed because this is

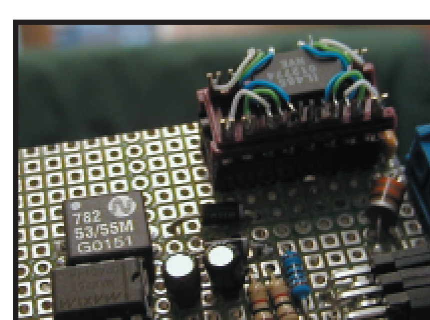

Photo 1—*Mounting an SMD on a DIP header makes it easy to work with.*

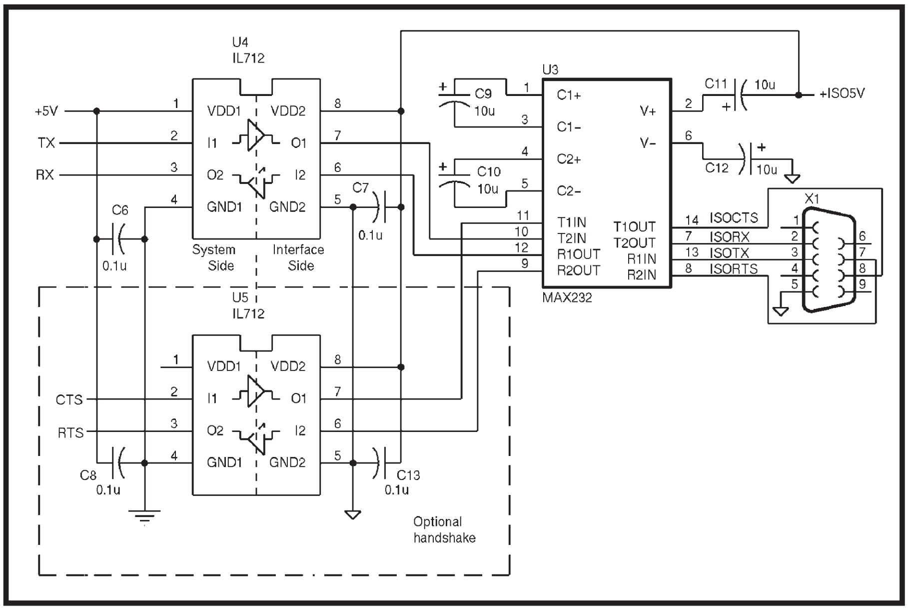

Figure 5—*The IL-712 contains Z isolators, which can easily be used with a MAX-232 for serial isolation. An additional IL-712 will add isolation for hardware handshaking.*

within the recommended range for the IL-485 (4.5–5.5 VDC) and well below the 7-VDC absolute maximum rating.

The 78253 transformer from C&D Technologies is rated at 200 mA, so there is plenty of overhead even with a heavy RS-485 termination. Large spikes were seen on the isolated side of the MAX253's circuitry, but a series choke tamed them nicely (see Photo 2).

Are isolation techniques necessary? In many situations, they aren't necessary. Overlooking the more obvious safety issues (such as distances between devices) in some applications increases the potential for ground loop problems.

GROUND LOOPS

When equipment using different power supplies is tied together (with a common ground connection) there is a potential for ground loop currents to exist. This is an induced current in the common ground line as a result of a difference in ground potentials at each piece of equipment. (Note: improper house wiring can cause ground loops when the neutral side of the line, or the ground, is not properly grounded.)

Photo 2—*The upper trace shows 0.5-V spikes on the isolated output of the power supply. The lower trace shows the same output after a series choke.*

We normally think of all grounds as being of the same potential. If this were so, there would never be a ground loop problem. Here at *Circuit Cellar* world headquarters, I've measured a considerable difference between the grounds of different outlets (and different phases) within the same room.

There are a number of reasons that could explain these findings. It doesn't take a large difference in potential to cause ground currents to flow through a common ground connection. The potentials (and currents created) are also load related, so, most of the time, these currents will not be steady state.

If sensor circuitry is based on its own ground as a reference and the system ground is not the same, you can't expect to be able to take accurate measurements. You'd think that making the common ground heavier might be the solution. But, in many cases, this only increases ground loop current. Breaking this common ground is a better solution. However, if the common ground connection is broken, the differential in ground potentials remains and will affect any signal between the two pieces of equipment. You need to isolate the grounds as well as the other signals, otherwise you run the risk of exceeding the maximum or minimum allowable input specs.

To eliminate ground loop problems when connecting devices using grounded supplies located on different circuits, do not make a common ground connection between the devices you want connected. Although this eliminates ground currents from flowing between devices, it creates a problem for the signals, which are ground referenced.

Take communications interfaces for instance. RS-232 circuitry must have a ground connection because it is the reference for the remaining signal lines. On the other hand, RS-422/485 uses differential signals not referenced to ground. You can use this twisted pair connection without a common ground unless there is a difference of more than 7 V between them. The RS-485 receivers can withstand up to a 7-V ground-referenced difference before exceeding the maximum or minimum ratings. Would you gamble with circuit failure over a 7-V spread? This is where signal isolation payoff comes into play.

When dealing with sensors, ground loop currents cause changes in an analog signal. These changes often look like signal noise. A ground loop can

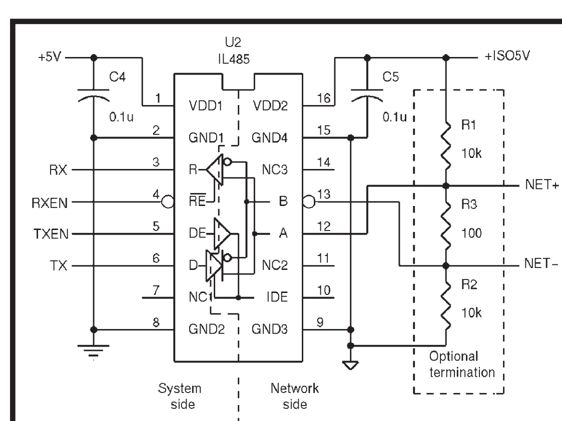

Figure 6—*The IL-485 replaces the RS-485 devices when an isolated twisted pair network is needed.*

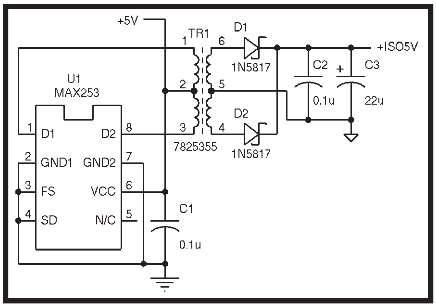

Figure 7—*Maxim's MAX253 makes a great isolation supply. C&D Technologies has a transformer specifically for use with the MAX253.*

even be caused by a mechanical and electrical (if uninsulated) connection to a grounded object being sensed. To eliminate all of the common ground loop problems between sensor and measurement circuitry, always power and measure sensors with the same local supply. By measuring right at the sensor, lengthy leads will carry digital data (easily isolated) rather than analog data (difficult to isolate).

The available IsoLoop products will handle most isolation problems. Besides the speed advantage over most optoisolators, the IsoLoop products have a latching output. Because the output state is latched on magnetic field change (controlled by the input to the device), even if the power is removed from the input side, the output side's logic state would remain latched (memorized). This would require an extra set of latches when using an optoisolator.

NVE introduced its first GMR product in 1994. These days, GMR sensors compete with Hall effect devices for many magnetic sensing applications and additional research continues on the use of GMR materials for magnetoresistive random access memory (MRAM) technology. Can you say core memory? What goes around….

Jeff Bachiochi (pronounced BAH-key-AH-key) is an electrical engineer on Circuit Cellar*'s engineering staff. His background includes product design and manufacturing. He may be reached at jeff.bachiochi@circuitcellar.com.*

SOURCE

IsoLoop high-speed digital isolators
NVE Corporation
1(800) 467-7141
www.isoloop.com