**Demands:**

- Conveyor control system activates motor once every 12 seconds, 10-year service life
- Automotive carrier system with 24/7/365 operational availability
- High-speed RFID system that can operate near drives, solenoids and power lines.

Industrial automation equipment is used under the harshest conditions imaginable, and the demands that users have in terms of performance, functionality, 24/7 availability, and longevity are at an all time high. With more and more electronic equipment being used, the rules of the factory game change constantly. Electronic noise cannot be ignored any longer and device manufacturers, machine builders, and users need to be aware of the issues.

**Maxwell lives**

Believe it or not, the right-hand rule (fig. 1) relating to electric currents and magnetic fields — the one that every engineer learned at one point or another — is more than just a nice final exam question: It is the basis for our day-to-day-problems with electromagnetic plant noise. Fortunately, understanding it also gives us the tools we need to design systems that operate well in those environments. And it all starts with “a moving charge results in a magnetic field.” Ever wondered why control and power signals should not be too close and only cross at a right angle?

What can device manufacturers do during the design phase to develop good, reliable automation equipment? How can machine builders layout their systems to reduce noise susceptibility? And what do users need to look out for when applying a product?

**Keep emissions in check**

Well-designed hardware plays along nicely. This means that its own field emissions are low, thus not putting an undue burden on its neighbors. This sounds almost too trivial to be mentioned but unfortunately, with the price pressures we all feel, it is just too easy to leave out what engineers know works in order to save a few dollars. Properly designed PCBs and the correct layout of components on the PCB have a huge impact on the emissions. PCBs with continuous grounding planes, the shape of wire traces, and limited use of blue wires should be evaluated. A board that looks bad, with extra leads running all over the place is very likely to be bad, and will create a great deal of electromagnetic dirt. Re-spinning boards costs engineering time and money while multi-layer PCBs that make blue wire connections entirely unnecessary are also slightly more expensive. Still, the possible results are worth the effort. Our European colleagues are at an advantage, where all equipment must carry the CE mark. IEC61000-6-2 and IEC61000-6-4 regulate field emission (how strong and at what frequencies a device radiates) and permissible field emissions (how much noise at what frequencies a device can accept without failure) as a function of frequency.

**Good fences make good neighbors**

But what if the device next door does not abide by the rules and freely emits into the environment? Any good design inherently rejects as much noise as possible. Digital I/O networks should be designed symmetrically so that any noise pulse influences the signal’s plus and minus side by an equal amount. By working with a differential signal instead of absolute, ground-referenced levels, these networks effectively cancel out external noise. AS-Interface is an example of such an industrial I/O network taking this idea to the extreme, enabling bulletproof transmission of data and power over an unshielded, unterminated, completely topology-free, two-conductor cable several hundred feet long! RS232 is a well-known counter example,
where signal levels are ground referenced, limiting its ability to operate in noisy plant environments.

Shielding is another strategy, adding an additional layer of protection as it makes it harder for any noise to penetrate devices and cables in the first place. Unfortunately, improperly executed shielding may actually increase the amount of noise the hardware must deal with. And not all so-called shielded cable is built the same. Traditionally, many shielded cables do not provide a physical ground connection into the coupling nuts. This means that a noise pulse is not diverted to a machine ground but instead travels along the cable, possibly jumping into the signal leads at one of the cable ends. At best these cables add mechanical strength and protection but have no positive effect in terms of noise protection.

An example of a well thought-out shielding/grounding concept is Pepperl+Fuchs’ IDENT Control, an RFID solution heavily used in automotive, material handling, and assembly applications. The shield is continues from the R/W heads to the control interface. The control interface utilizes a metal housing and offers dedicated grounding lugs (fig. 2). As a result, noise that makes it onto the cable shield does not have any opportunity to get into the cable or interface housing but instead is directly diverted to machine ground. And invisible to the user, the 24 VDC connection makes use of a metal feed-through designed to filter out and divert any noise coming in over the supply line. As a result, plant noise-related issues are not just reduced as much as possible but generally eliminated with this system.

Noise detection and error correction

And what if the unthinkable still happens? What if the external noise sources are still sneaky enough to penetrate a device? After all, most communicating devices have an operating frequency that cannot be suppressed or they would simply not function. An RFID system operating at 13.56 MHz, for instance, cannot suppress reception at this frequency or it could not read tags.

The situation is similar for many other systems. In a sense, the operating frequency of the hardware is its Achilles heel. To deal with this necessary weakness, a successful implementation must detect data corruption and take measures to ensure that the intended information still gets through to the recipient. This is where error detection methods combined with automatic transmission retries come into play. Many solutions exist, including long checksums, signal-shape monitoring, and simple parity bit checks, all of which are suitable only in conjunction with proper retry procedures. RFID system designers can do a few simple things to help out. Because noise frequently appears in short bursts, sending large data blocks over the air-interface (the air gap between a tag and the read/write head) may not be the best strategy. The longer the data block, the higher the probability that a noise burst occurs just at the right (or rather wrong) time, rendering the entire data block useless. On the other hand, splitting the data into smaller units allows several of them to make it through before noise interferes with just one. Retrying a single small packet takes much less time than repeating the large packet and the overall throughput is a lot better.

Bus systems also need such detection and retry procedures. In conjunction with clever coding mechanisms, amazing performance levels can be reached. Getting back to AS-Interface, the Manchester II coding mechanism combined with a few additional protection bits results in a networking solution with the following performance characteristics: Assuming typical plant noise conditions and 24/7/365 operation, it will take over 2300 years for a so-called substitution error* to occur!

In cases where retries are simply not possible, the data must be transmitted using a method that includes forward error correct. The Reed-Solomon algorithm

---

*A substitution error occurs when a transmitter sends data and noise corrupts a portion of the data but the receiver is not able to identify that the data is, in fact, invalid. More specifically, when a sensor network reports an input as being in the OFF state and the PLC receives a data packet identifying the sensor as being in the ON state.
used with the optical readers evaluating 2D DataMatrix codes is such an example. Frequently, these symbols are used in high-speed applications where the object literally flies by so fast that the camera can only capture a single image. Consequently, there is no chance to retake the image. The Reed-Solomon algorithm is powerful enough to allow the mathematical recreation of data in cases where up to 30% of the original image is unreadable. CDs, DVDs, and satellite data transmission from probes orbiting far-away celestial bodies** are other applications where forward error correction is applied.

If it’s FREE, use it!
There are many things the installer can do enhance the quality of a system. Many of them cost very little or are free. Main controls cabinets can be the source of many problems as they typically hold both, devices that create strong interference fields (power supplies, motor and safety contactors, fluorescent bulbs …) and devices that are susceptible to noise interference (PLCs, I/O cards, signal converters, HMI screens …). To reduce the potential for problems, it is very important to keep strongly emitting and susceptible devices well separated. A metal barrier, ideally not painted or anodized, should be used to further reduce problems. And do not discount fluorescent bulbs. They emit over a wide spectrum and should always be switched off when the enclosure doors are closed.

When routing cables inside the enclosure, it is fairly common to separate the plus leads from the minus leads running them in separate plastic cable channels. This is actually not a good idea. Keeping both signal paths together reduces the emissions at a noise source as well as the susceptibility of the more delicate devices.

Outside the controls enclosure, cables are frequently routed and supported by cable trays. Plastic is never a good choice and it is best to use a metal tray with a metal cover. Obviously, a cable tray with low-voltage control cables must not also carry high-voltage power lines—especially not if unshielded cable is used. Frequently, open cable trays (without cover) are used to bridge large distances. In this case, the shielding effect offered by the side walls should be used, in particular when unshielded cable is used (fig. 3).

Life can be simple
Most component designers expend time, money, and effort to come up with products that work well in industrial applications. Installers should not negate this by taking unnecessary shortcuts. In fact, observing a few basic installation techniques results in reliable automation systems with superior uptime. After all, life can be simple.

Installation checklist
Assuming that the hardware is well designed, controls engineers and installers have the power to create an excellent automation solution or make mistakes that limit their reliability. The following, granted incomplete, checklist can be used to weed out a few typical errors

- Keep sensor cable short – The cable between a field mounted sensor and a PLC I/O card is an antenna allowing noise pulses into the system. The longer the cable the higher the probability of this happening. **Solution** – Instead of long (and by the way expensive) cable runs, a highly distributed I/O system with field mounted connection modules can be used. This keeps the cable runs short, limiting noise problems.

- Cable routing and power distribution – Since any power wire is a potential noise source it is a good idea to always separate low-voltage (≤24 VDC) control leads from high-voltage power cables. **Solution** – Depending on the devices being powered, experts suggest cable separations between 4” to 20”. And when such cables need to cross paths, make sure that they cross at right angles.

**It is intuitively clear that a retry mechanism is not a practical method when signals travel between minutes and hours before reaching earth.**
• Ground faults – Any system or technology that utilizes differential signals should implement some kind of ground fault detection. In many cases the hardware is designed so well that it will run with a ground fault, but secondary correction methods are working hard to get the data where it needs to be, making use of internal retries. Unfortunately, this extra burden costs time and limits system performance. More importantly, there will be a point where even the best corrective measures will not work any longer, resulting in the automation equivalent of a cardiac arrest.

• Solid machine grounds – Going back to the right-hand rule, it is clear how an external, varying magnetic field will induce a resulting current. **Solution** – This current must be given an easy path to ground, emphasizing the importance of a solid machine ground. And when several cable trays are used to span long distances it is important to create good electrical connections between them.

• Shielded cables – Using shielded cables is typically a good idea and engineers should always follow the manufacture’s recommendations. But simply installing a shielded cable is not enough. After all, if two systems are not properly grounded they can be at different potentials relative to ground. If this happens, the shield acts as a connection to equalize the different potentials and high electric current can flow over relatively thin shields and drain wires. This is not what they are designed for and solid, heavy gauge grounding straps must be used. Conveyor belts that build up electrostatic changes fall into this category and discharge brushes are an absolute must.

Helge Hornis  
Manager Intelligent Systems Group  
Pepperl+Fuchs  
Twinsburg, OH 44087  
330-486-0001  
[www.pepperl-fuchs.com](http://www.pepperl-fuchs.com)  
fa-info@us.pepperl-fuchs.com

Dr. Thomas Sebastiany  
Director Business Unit SYSTEMS  
Pepperl+Fuchs GmbH