Use Ingenuity to Ground and Shield Existing Electronic Equipment

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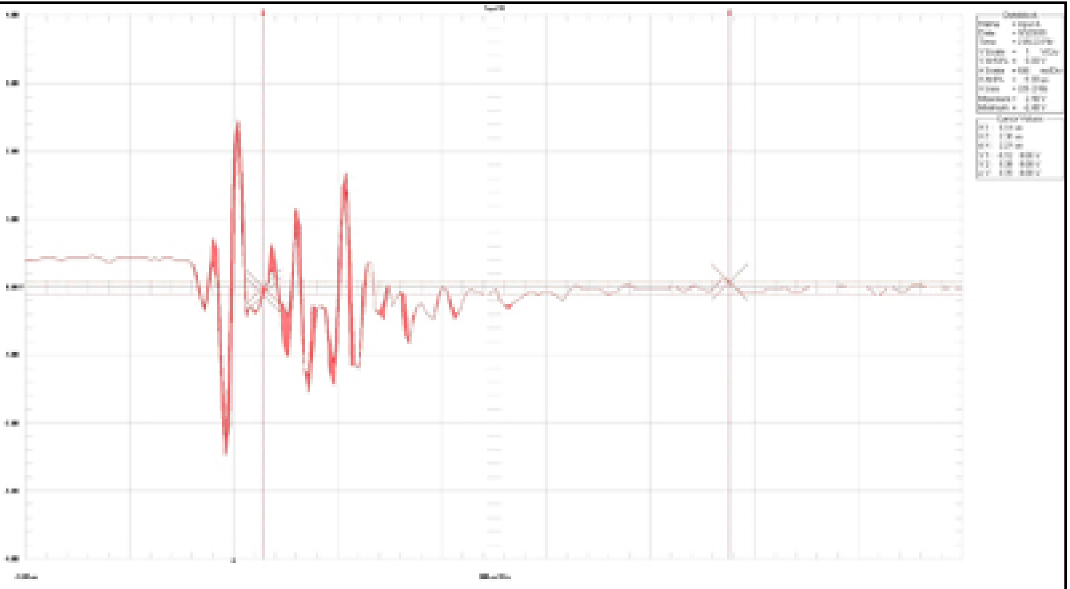
When building electronic equipment, it is imperative to understand the coupling mechanisms of electrical noise that creates Electro-Magnetic Interference (EMI). It is also much easier to preplan a method of abatement during the build of a machine rather than try to initiate a resolution once the equipment is built. However, in reality, it’s common to have to improve or otherwise develop procedures to prevent the noise from disrupting intended signals of existing equipment or designs. In those cases, there are compromises to make and users need to make them with a superior understanding of this phenomenon.

Good, Better Best, What Do You Do?

Taking a realistic approach to the issue, the premise is that a machine build has been compromised by way of some assembly or practice used. That said, the best process – pre-planning - has already been taken away, so some ingenuity must be used to achieve a best grounding method; or perhaps a best practice method cannot be achieved and an improved grounding and shielding method must be used instead.

One example is a servo amplifier power output connection that is cross coupling magnetically to the data line from a servo amplifier (high stray magnetic currents) resulting in spurious signals. A second example is interference with a single ended analog signal that is physically parallel to the AC line currents.

Both of these are resolved with similar techniques, but understanding the differences will also indicate whether the improvement is sound, or just plain lucky.



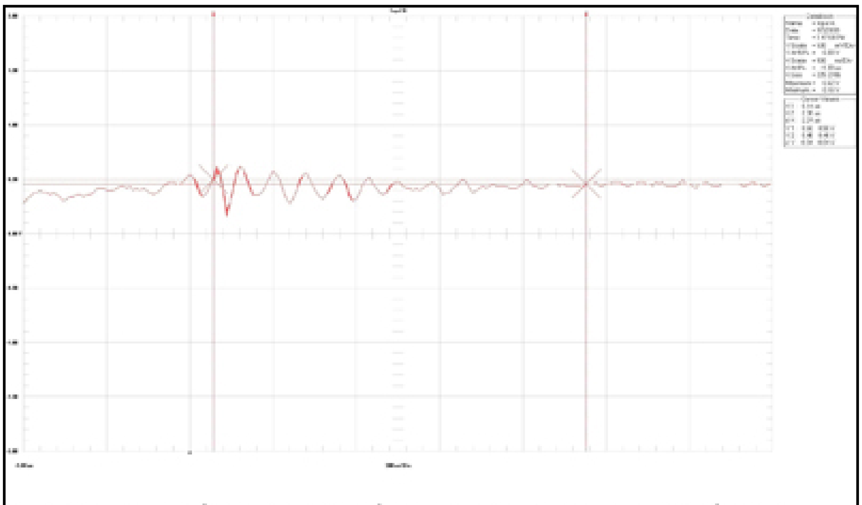
Without a common mode choke, this data line on the machine has been triggering intermittently. The voltage reading here is a 1 Volt per division, making it obvious that the magnetic pulses are indeed affecting the system. With roughly a signal that is symmetrical around zero Volts and a significant power level, one can also conclude that it is likely to be a magnetic coupled event relating to the aforementioned measurement.

High Magnetic Field

In the first example the data line has high speed noise causing an issue. Unless the data line is single ended, a differential input (RS-485 or similar) will reject the 60 Hz noise. The solution has to take into consideration the source and the receiver. The best practice is for these two signals to be laid out in such a way that they don’t cross couple, with the individual conductors surrounded by a magnetic shield (braided or twisted wire shield of minimum 80 percent coverage) and grounded at both ends. If the cable can’t be relocated, then a good practice is to shield both the receiver and emitters as described and measure the interference with a magnetic probe.

As described, this problem is not a “straw man” example; it’s a common occurrence in building machines (see sidebar "EMI Noise Checklist", http://bit.ly/qZi2En [1] for step by step procedures from Kollmorgen for machine builders). The placement of the grounds are best at both ends of the signals near the inputs and outputs of both. If this cannot be achieved, users are much better served with a braided shield grounded at one end than with no shield at all. Users should not use un-terminated shields with PWM signals like the power of a servo amplifier. The potential of capacitively coupling high rise time to this exists, perhaps worsening the situation. That’s where understanding of the coupling mechanisms helps.

High Gain Sensitive Signals

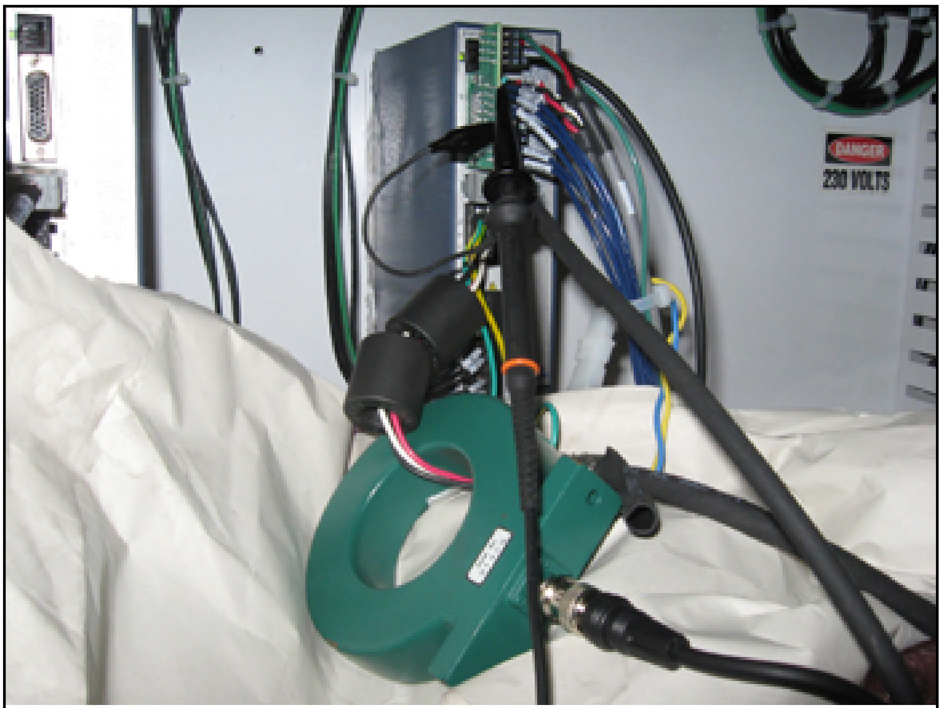


With the addition of common mode ferrites, the noise level was significantly reduced, resulting in no false triggering. Using an expanded measurement at 500 mV/div, the noise is seen at 250 mV at its highest peak verifying that the common mode noise in the system was in fact, the coupling source. A standard park choke from Kollmorgen (3YL-20) was installed, resolving the issue completely.

The second example is likely a 60 Hz noise issue. This is very low frequency and caused by the long run of parallel signals and the lack of shielding or a directly coupled noise source. If the analog signal is single ended and a differential low impedance Op amp input cannot easily be used because the system was designed single ended, then another method must be considered. The resolution of the problem is similar, but not exactly the same.

When dealing with 60 Hz noise there is magnetic coupling and direct coupling, so in this instance the focus is on the two coupling mechanisms. Why? Because radiated and capacitively coupled signals are high frequency, with radiated coupled signals requiring a transmission antenna (lambda/20 min), a reception antenna (lambda/2 for full reception) and more importantly users must be ½ wavelengths away.

Concentrating on the magnetic field generated by the input currents, this signal and the gain of the Op amp are compromised to further amplify this into the system. The magnetic coupling needs to be broken, which is accomplished with a braided shield that is “Reflective” to that coupling. Full coverage of these signals is needed as well, both the emitter (PWM from the drive) and the receiver (Input of the Opamp). In effect, this creates a “Faraday cage” around each, which is the best that can be achieved in the existing layout.



Using a battery powered oscilloscope and current probe or transformer, the measurement of common mode noise (probe across all three power leads) was conducted with and without the additional ferrite inductors. These inductors were rated to add reactance from 10 MHz to 35 MHz.

Users will need to ground the magnetic shield, but sometimes with low frequency that will generate currents in two ground points between single ended signals called “ground loops”. Now what? Users still have a readily available and common option that doesn’t include a complete re-layout, namely a multi-shield connector. Using a multi-shield connector, the outer shield is grounded at both ends while the inner shield is ground referenced at the source of the signal. A diagram representation is included.

With some thought and armed with the knowledge of coupling mechanisms, users can be equipped to effectively minimize EMI issues when best practices are not available.

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