Grounding and Shielding Existing Equipment

How to effectively minimize EMI issues when best practices are not available

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White Paper

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 is 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

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.

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 – 35 MHz.

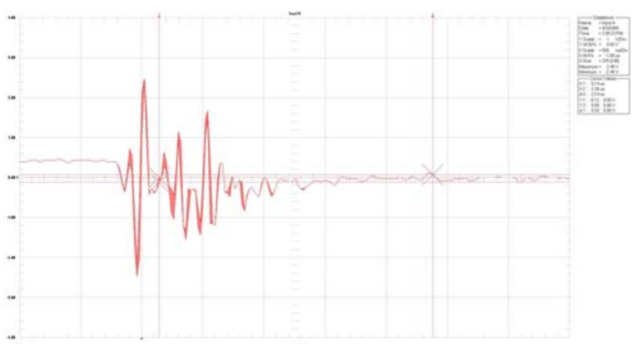
High Magnetic Field

In the first example the data line has high speed noise causing an issue. Unless the data line is single ended, a differential input (RS485 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% 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 is a common occurrence in building machines (see EMI Noise Checklist below 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.

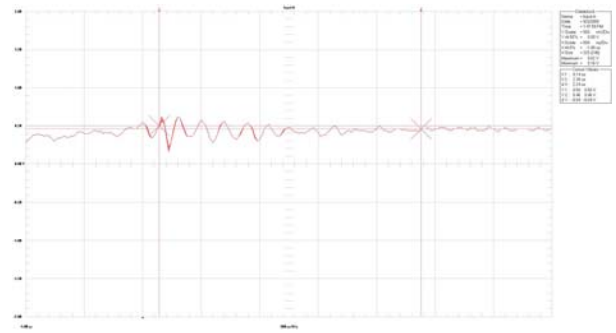
Users should not use un-terminated shields with PWM signals like the power of a servo amplifier. The potential of capacitively coupling high rise time to this exists, perhaps worsening the situation. That’s where understanding of the coupling mechanisms helps.



Without a common Mode Choke, this data line on the machine has been triggering intermittently. The voltage reading here is at 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 Gain Sensitive Signals

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 Opamp 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.



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

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 Opamp 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.

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.

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EMI Noise Checklist

This checklist provides help for applications experiencing problems due to electromagnetic interference (EMI) noise. It collects the experience of Kollmorgen engineers who have solved many noise problems in the field. If users follow these guidelines, they are much less likely to have problems with electrical noise in their application.

Use Kollmorgen cables
Kollmorgen engineers have designed the best cables for use in Kollmorgen servo systems. Experience has shown that machine builders who use Kollmorgen power and feedback cables have far fewer problems than those who build cables.

Use common-mode chokes on motor leads
Cables longer than 25 m (82 ft.) may need motor common-mode chokes. Check product documentation for details.

Separate drive/motor power and signal cables
Bundle and route signal cables separately from motor/power cables. Run cables in separate conduits or maintain at least 100 mm (4 in.) between signal and power bundles for drives under 20 A. Use 150 mm (6 in) for 40 A drives and 200 mm (8 in) for 80 A drives.

If using a separate AC power filter, maintain separation of leads entering and exiting the line power filter. Locate the filter as close as possible to the point where the incoming power enters the cabinet. If using internal power filters (such as with Kollmorgen's SERVOSTAR® 300/600/700 and AKD™ servo drives), maintain at least 100 mm (4 in.) of separation between line power and motor leads. If it is necessary for input power and motor leads to cross, cross them at 90 degrees.

Splice cables properly
If cables need to be divided, use connectors with metal backshells. Ensure that both shells connect along the full 360 degrees of the shields. No portion of the cabling should be unshielded. Never divide a cable across a terminal strip.

Ensure good shield connections
For cables entering a cabinet, connect shields on all 360 degrees of the cable. Never connect a simple "pigtail."

Use differential inputs for analog signals
Noise susceptibility in analog signals is greatly reduced by using differential inputs. Normally, connect the output signal to the + differential input and the ground of the device generating the output to the - differential input. Use twisted-pair, shielded signal lines, connecting shields on both ends. *Many Kollmorgen drives provide internal filtering to reduce effects of electrical noise.*

Ensure good connections between the cabinet components
Connect the back panel and cabinet door to the cabinet body using several conductive braids. Never rely on hinges or mounting bolts for ground connections. Provide an electrical connection across the entire back surface of the drive panel. Electrically-conductive panels such as aluminum or galvanized steel are preferred. For painted and other coated metal panels, remove all coating behind the drive.

Ensure good ground connection
Connect from cabinet to proper earth ground. Ground leads should be the same gauge as the leads to main power or one gauge smaller.

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Conclusion

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.

ABOUT KOLLMORGEN

Kollmorgen is a leading provider of motion systems and components for machine builders around the globe, with over 70 years of motion control design and application expertise.

Through world-class knowledge in motion, industry-leading quality and deep expertise in linking and integrating standard and custom products, Kollmorgen delivers breakthrough solutions unmatched in performance, reliability and ease-of-use, giving machine builders an irrefutable marketplace advantage.

For more information visit www.kollmorgen.com, email support@kollmorgen.com or call 1-540-633-3545.

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