# KwikLink™
# Radiated Immunity Testing

Rockwell
Automation

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## A Brief History of KwikLink

As the acceptance of networking continues to increase with major vendors and OEMs, DeviceNet is moving into the forefront as a viable *and* reliable solution. A group of engineers was assembled to take DeviceNet to the next level. The first step to realizing this goal: dispel DeviceNet's reputation as being cost prohibitive. It was this factor that led to the development of a more cost-effective physical media system. The result of these efforts is KwikLink, a concept that introduces flat cable technology with simple clamp-on insulation displacement connections, addressing the concerns most often stressed by the customer: low cost, flexibility, simplicity and compatibility.

*Figure 1: KwikLink Connector and Cable*

## Introduction to KwikLink

The KwikLink flat media system is a simple, modular cabling method for DeviceNet that uses flat four-wire cable and Insulation Displacement Connectors (IDCs). Designed to achieve 50% savings in installation costs by offering a drastic reduction in labor and materials, the KwikLink system is ODVA approved and allows nodes to be added to the network quickly and easily—without severing the trunkline. Cutting and stripping of the trunkline is eliminated, as is the need for predetermined cable lengths. KwikLink offers maximum simplicity while still supporting 64 nodes. There is, however, a small reduction in maximum trunk length as shown in the figure below.

*Figure 2: KwikLink vs. Round Cable—Distances*

| **Data Rates** | **125 Kbaud** | **250 Kbaud** | **500 Kbaud** |
|---|---|---|---|
| **Thick Trunk Dist.** | 500m (1640ft) | 250m (820ft) | 100m (328ft) |
| **Thin Trunk Dist.** | 100m (328ft) | 100m (328ft) | 100m (328ft) |
| **Flat Trunk Dist.** | 420m (1378ft) | 200m (656ft) | 75m (246ft) |
| **Max. Drop Length** | 6.1m (20ft) | 6.1m (20ft) | 6.1m (20ft) |
| **Cumulative Drop** | 156m (512ft) | 78m (256ft) | 39m (128ft) |
| **Number of Nodes** | 64 | 64 | 64 |

In order to use the quicker IDC type connections, shields were removed and the cable was made in a flat configuration. Removal of the shields also significantly reduced materials costs.

# Noise Testing—DeviceNet Round Media vs KwikLink

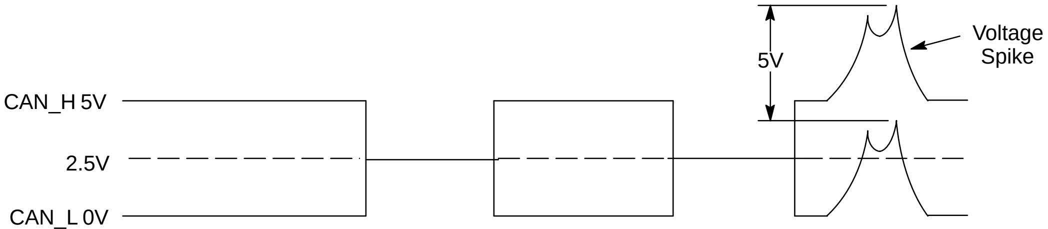
**The Issue**…

Since KwikLink was unveiled, the most common concern: flat cable is unshielded. Why? The simple answer is that the quick IDC connections mentioned above are very difficult if not impossible with shielded cable. And what happens to noise immunity? Noise immunity—the testing procedure, the result and the conclusion—is the issue to be addressed in the following pages.

### Cable Construction and Noise Immunity

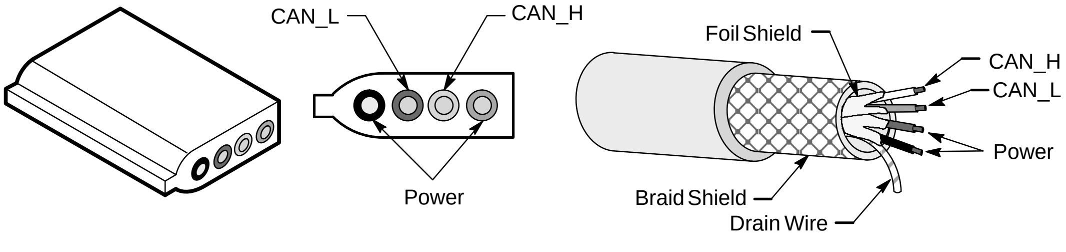
In general, both DeviceNet media systems, round and flat, are high speed, low loss cables. The two signal conductors, CAN_H and CAN_L, allow for a differential transmission system. That is, as CAN_H voltage drops 2.5 Volts, CAN_L increases by 2.5 Volts; it is the difference between them that is used by DeviceNet protocol. The differential between CAN_H and CAN_L is either zero or 5V. When noise is induced in the cable, the voltage spike affects both signal conductors equally—therefore the voltage differential between the two is maintained. By using this technique, DeviceNet has an inherent level of noise immunity.

*Figure 3: Differential Transmission*



There are several physical nuances that differentiate the two cables: TPE jacket as opposed to PVC; varying conductor gauges; twisted versus untwisted pairs. But, in addressing the level of noise immunity between them, the basic construction—the orientation of the conductors as well as shielding or the lack thereof—becomes crucial. Note the conductor spacing in the flat cable (Figure 4):

*Figure 4: KwikLink vs. Round Cable—Construction*



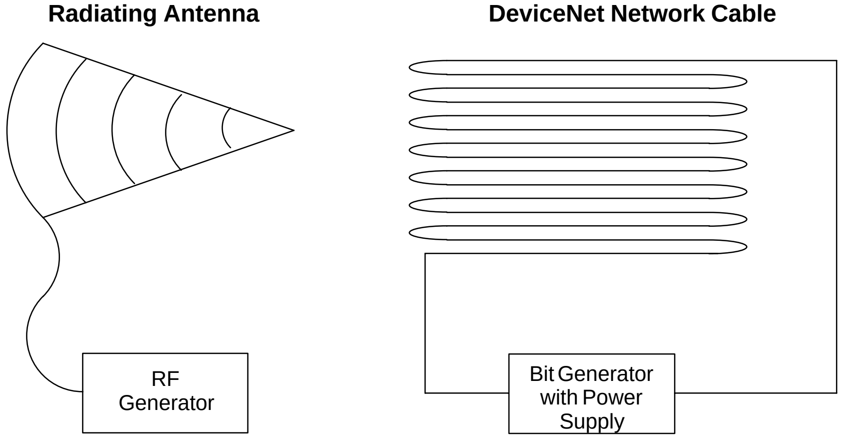
The spacing between the CAN signal conductors is minimal while the distance between the signal and power conductors is relatively great; this greater distance inhibits noise coupling from the power wires to the CAN lines. The horizontal arrangement of the conductors, as opposed to the tightly bundled conductors in the round cable, also plays a large role in the capacitance unbalance of the system.

### Radiated Immunity Testing

All electronic equipment radiate some electromagnetic energy. Radiated immunity is the ability of the equipment, in this case the DeviceNet network, to operate properly without being affected by the electromagnetic interference from neighboring equipment, like walkie-talkies, cellular phones, radio and television broadcasts, RF tagged equipment, and computers. To meet the International Electrotechnical Commissions (IEC) requirements for immunity, electrical equipment is tested to IEC 61000–4–3, *Testing and Measurement Techniques—Section 3: Radiated, Radio Frequency, Electromagnetic Field Immunity Test*.

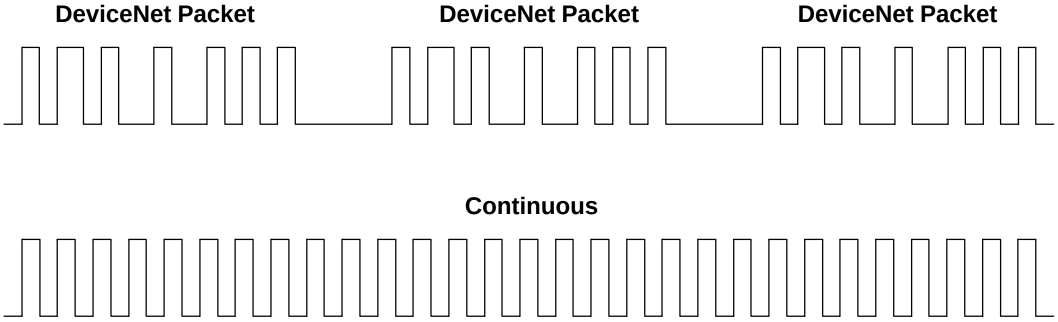
Initial noise immunity tests commenced in a lab setup, pitting standard DeviceNet round cable against KwikLink flat cable. For each instance, equal lengths of round and flat cable were mounted on a wooden panel and zig-zagged to maximize exposure to the RF signal, in a setup as shown in Figure 5.

*Figure 5. Radiated Noise Test Setup*



A special black box produced a continuous stream of traffic on the network, allowing performance to be monitored at the bit level. DeviceNet protocol sends information in packets—small groupings of data bits—with gaps between. A continuous data stream was used to maximize traffic along the wire.

*Figure 6: Packetized Data vs. Continuous Stream*



Both cable systems were first exposed to a radiated field of 10V/m, the IEC specification for industrial environments. Both systems operated without errors. The radiated field was then set to 20V/m, double the IEC specification. Again, there were no errors on either system. This same test was repeated with shielded and unshielded drop cables and actual devices connected to the drops; again, no errors or loss of communications. This test demonstrated that both DeviceNet round and flat cable systems have a high level of immunity to radiated noise as would be expected from a well-balanced, differential transmission system such as DeviceNet.

### Radiated Emissions Testing

As stated earlier, all electronic equipment radiate some electromagnetic energy. In this scenario, the equipment is tested to determine how much energy is radiated over a frequency range of 27MHz to 1GHz. The strategy of the standard is to limit the amount of energy emitted by equipment and ensure the equipment is immune to certain levels of radiated energy. The requirement for radiated emissions is stated in EN50081–2 *Electromagnetic Compatibility—Generic Emission standard, Part 2: Industrial Environment* and CISPR 11.

When the round cable was compared to the flat cable, the results showed that both cable systems met the IEC requirements. The flat cable actually had lower emissions than the round cable; this was attributed to the ground loops formed between the shield of the round cable and the ground of the anechoic (echo-free) test chamber.

### Drives Testing

The next step was to test the cables in a ‘real world’ application and determine DeviceNet’s ability to survive in high voltage environments, more precisely, Class 1 (600V) environments. Drives testing is a new Rockwell Automation/Allen- Bradley requirement; there is no specific IEC test requirement. Field experience has shown that drives using Insulated Gate Bipolar Transistor (IGBT) technology cause transients on the power and ground lines that may affect neighboring equipment in one of three ways: 1) through the ground path, 2) through the same power grid, or 3) through signal wires that run near the power wires.

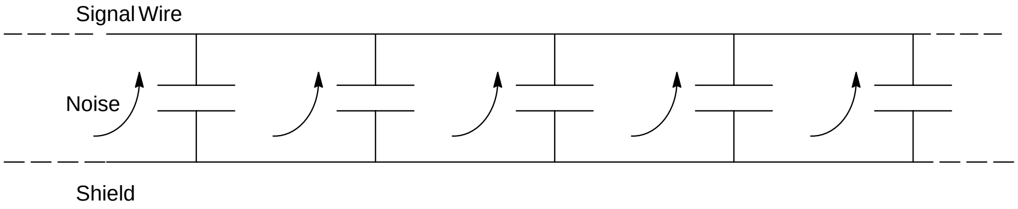
The fast rise times of pulse width modulated, high voltage drive systems (IGBT drives typically have rise times on the order of 50 nanoseconds) can often induce interference in low–level communications. The resulting frequency content of a pulse width modulated drive is therefore also extremely high. The associated rise times and field magnitudes may cause voltage fluctuations on the order of 10kV per microsecond. To test for the effects of these variables on a DeviceNet system, round and flat cables were exposed to the fields associated with IGBT drives.

The procedure required a similar setup to the previous test. Round and flat cables of equal lengths were connected to the special fixture that produced a uniform data stream and allowed for continuous bit-level performance checks. However, the trunk cables in question were routed from the drive output, along the drive cables and to the motor. The drive was a 50HP model running at 460V with a carrier of 60kHz.

The test was conducted using various round cable configurations for connecting the shield and V– to ground. Standard round cable exhibited errors only when V– and the shield were terminated together at drive ground; *not* a recommended grounding scheme. Error rates for this configuration were high enough to cause nodes to enter a bus-off state. **All other configurations, *including those involving the unshielded flat cable*, were error free.**

It was discovered that the inherent distributed capacitance between the shield and the conductors provided coupling for noise. The capacitance between the shield and conductors of the round cable is 24pF/ft. Figure 7 shows an example of how to view distributed capacitance. Distributed capacitance is like adding a small capacitor between the shield and each of the signal wires every foot.

*Figure 7. Distributed Capacitance*



For example, a 152m (500ft) network would provide 12,000pF of capacitance. The impedance of a capacitor is related to frequency of a signal (or noise) as

$$Xc = \frac{1}{2\pi fc}$$

Rise times on the order of 50ns have frequency components up to 20Mhz. Therefore the impedance of the distributed capacitance is

$$Xc = \frac{1}{2\pi * 20{,}000{,}000 * 0.000000000787} = 10 \text{ ohms}$$

Obviously, the impedance of the total distributed capacitance of the 152m (500ft) network is very low to a 20Mhz noise pulse. When the shield is connected to a noisy ground, in this case drive ground, noise can travel along the shield, couple to the power and signal conductors and possibly cause data errors.

### Robotic Welder Testing

In an effort to expound on the ‘real world’ test data established in the drives testing, further KwikLink trials were performed in one of the most demanding industrial environments imaginable—a welding facility. Robotic spot welders are some of the most powerful noise emitting devices on the manufacturing floor; therefore, an automotive body and assembly plant was chosen as the testing ground. It should be noted that the test network did not control the robotic welder and that the installation of the test equipment mimicked the existing system wiring. To subject the KwikLink cable to the worst case with respect to the amount of noise induced into the system, the flat trunkline was installed in the same wire bundle as the high current weld cable. The welder, a resistance type, operated at approximately 20,000 amps inrush, 480 volts AC cycled 36 times per minute.

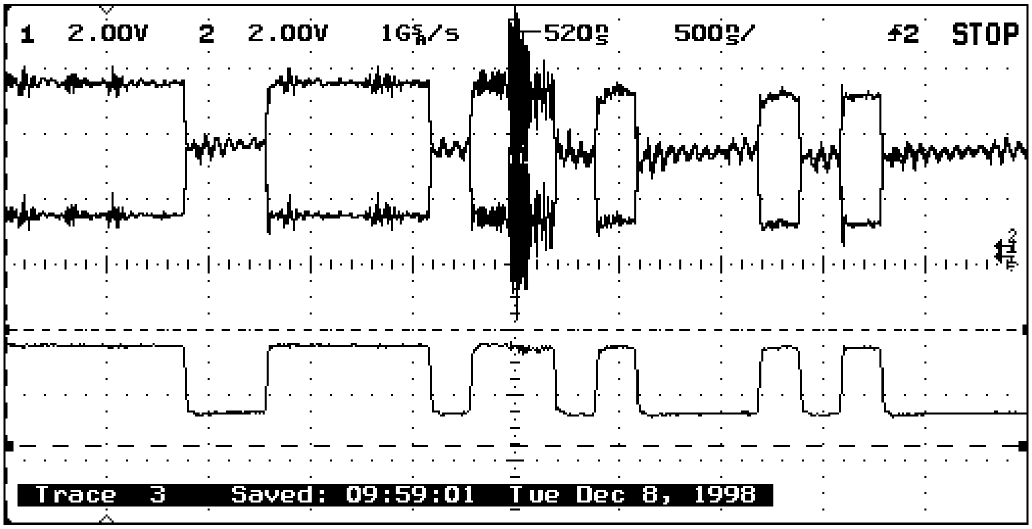
Bit level testing provides a direct count of each error, independent of corrections or network protocol enhancements. Using our bit generator, we created a worst case scenario by consuming 100% of the network bandwidth at the 500kB data rate. The flat cable was installed on the robotic arm along the secondary welding power cable to maximize the noise coupling resulting from the inrush current draw of a spot weld. In addition, KwikLink cable was installed below the welding fixture in the vicinity of the primary power lines and on the side of the welding cell. The bit generator was mounted five feet outside of the cell, near the control equipment. Five data samples were collected:

- 13,171,800 bits, 2 errors @ 500kbs = 1.52E–7 BER (Bit Error Rate)
- 13,826,000 bits, 4 errors @ 500kbs = 2.89E–7 BER
- 13,622,100 bits, 4 errors @ 500kbs = 2.93E–7 BER
- 12,076,200 bits, 7 errors @ 500kbs = 5.79E–7 BER
- 13,197,900 bits, 8 errors @ 500kbs = 6.06E–7 BER
- **Average Bit Error Rate = 3.84E–7**

The performance in this test system is well within acceptable limits—for a CAN node to continue communicating on the network, the Bit Error Rate must be less than 0.111.

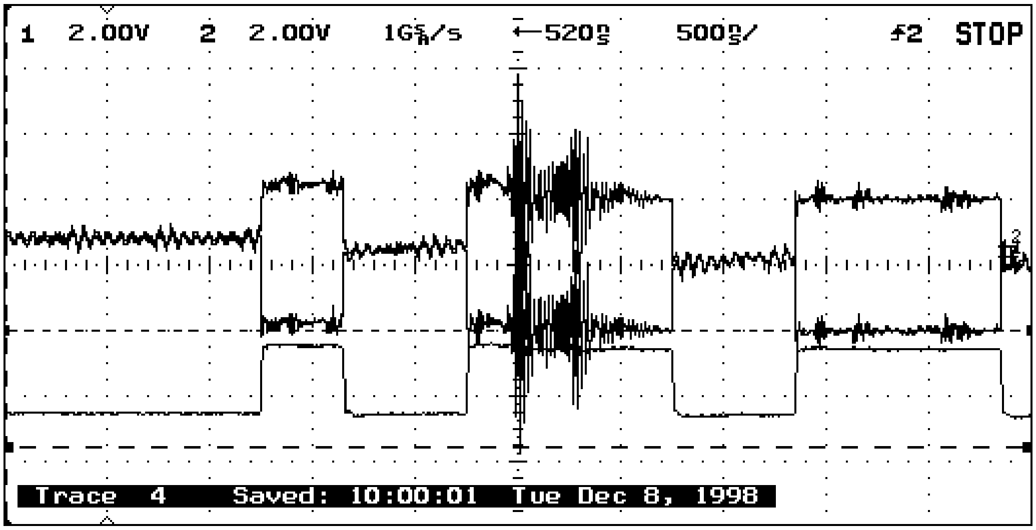
In addition, two oscilloscope captures were recorded where a weld occurred during a data packet transmission. (See Figures 8 and 9.)

*Figure 8: Weld Noise Burst*



There is significant coupling from the weld event to cause common mode transients on the network. However, in a differential system such as DeviceNet, the noise will not produce significant amplitude (differentially), to cause data errors in the receiver.

*Figure 9: Weld Noise Burst—Common Mode*



The network testing setup was more representative of a typical control system on the manufacturing floor. Flat cable was installed on the robotic arm, as close to the weld tip as possible without interfering with the welding process, and strapped tightly to the secondary welding power cable to maximize noise resulting from a spot weld. It was then routed back up the opposite side of the arm to further optimize coupling without potential cancellation of the induced noise currents. To further increase the cable's exposure, additional lengths of KwikLink cable were installed below the welding fixture and on the side of the welding cell.

A network node represents relatively high impedance with respect to a terminated trunk line. When a placed at the end of a drop cable, the node and drop cable combination represents an open stub in the network—a point extremely susceptible to noise. To create such a point, a tap was installed at the top of the robot arm and a proximity sensor with a six-foot drop cable was attached. The sensor was then routed down the secondary welding power cable on the robot arm as close to the weld tip as possible, again to maximize the possibility of induced magnetic currents and coupling of Electromagnetic Interference (EMI) from the welding sparks.

The controller was mounted five feet outside of the cell, below the existing control equipment. In addition, a CAN Analyzer passive node was placed with the controller and configured to count all DeviceNet messages transmitted across the network. The analysis for this testing requires that all invalid CAN messages are recognized, including bit errors, CRC errors, bit stuffing errors, acknowledge errors and form errors. In addition to counting all messages sent over the network, the CAN Analyzer tallied all messages deemed invalid by CAN protocol. It should be noted that this procedure did not check the state of the devices, only the validity of the messages sent over the network; the 'actual' state of the device is an application-dependent function outside the scope of this testing.

The controller/field device/CAN Analyzer configuration ran for two months without a single node going offline. The information recorded by the CAN Analyzer indicated that 65,536,000 DeviceNet messages were sent with only 4 errors detected. The resulting message error rate was 6.10E–8—far below the 0.111 rate required for a node to go offline/bus-off. System response time is also affected by error messages since all errors result in the re-transmission of the affected message. However, depending on the size of the data content of the message, all four of the detected errors could be re-transmitted in under 0.5ms.

Due to a limitation of the design, the CAN Analyzer is only capable of counting the 65,536,000 messages as stated above. So, in fact, more messages were sent during the 60-day timeframe. Based on recordings from the first two days of testing, 2.76 million messages were sent in 15 hours with no errors. Using this data to compute the actual number of messages over two months, 264,960,000 messages were transmitted, resulting in a calculated error rate of 1.51E–8.

To gauge the flat cable's overall fitness for use in welding applications, analysis of the cable's physical attributes was necessary. This testing, performed on the section of the cable closest to the weld tip, consisted of a High Pot test, a cable dimension test and an electrical parameter verification test. The High Pot test was used to determine if weld slag build-up or the high temperatures at the weld tip had broken down the materials in the cable. Run at voltages of up to 2200V AC, the High Pot test resulted in no material breakdown or detectable electrical leakage in the cable. Cable dimensions and electrical parameters were measured and found to be within the tolerances allowed in the DeviceNet specification. The only deviation from the cable specification was the discoloration of the cable. As shown in Figure 10, the cable color was changed from gray to light brown due to weld slag build-up.

*Figure 10: KwikLink Cable Samples*

## Conclusion

In summary, since DeviceNet is a differential transmission based system, it is inherently immune to common mode type noise. While standard round DeviceNet cable provides excellent common mode rejection, currents in the shields can couple noise into the conductors and provide ground loops in noisy ground systems. By carefully designing a parallel four–conductor cable, the common mode noise rejection of the system was not impacted, nor was its ability to withstand the physical rigors of industrial environments.

KwikLink flat cable is *not* shielded, and it exhibits superior resistance to typical industrial types of noise—it has no coupling mechanism for noise. So, not only does KwikLink reduce the installation cost of a DeviceNet network, but it reflects a giant leap in enhancing noise immunity.

## Notes

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