Protection of RS-232 Serial Connections

White Paper 16

Revision 1

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> Executive summary

This white paper explains the special power protection issues related to RS-232 cabling. First, the special vulnerabilities of RS-232 cabling are explained. Then appropriate protection and mitigation techniques are provided.

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Introduction

Complete protection of a computer system involves an understanding of the vulnerable points of the system, following safe design practices, and the installation of protective equipment. In an interconnected network of computer equipment, RS-232 serial data connections are frequently used for connections to terminals, printers, modems, and in the case of so called "zero slot" LANs, for network wiring connections. The RS-232 port on any device represents a path into the device for damaging noise and transients. The RS-232 port often represents the "Achilles heel" of computer installations which are otherwise well protected by UPS systems and other power protection equipment.

The types of transients which can enter via an RS-232 port originate from a variety of sources. These sources include inter-system ground noise, telephone line surges, and wiring faults.

Link to resource
White Paper 8
Inter-System Ground Noise: Causes and Effects

Inter-system ground noise is the most common problem, causing RS-232 data errors even RS-232 driver or motherboard destruction. Inter-system ground noise results when voltage differences exist between the grounding (green) wires of two pieces of interconnected equipment. The voltage differences occur when the grounds are separately derived or when one ground is subject to unwanted noise or transient injection from another source. These voltage differences can range in size from small radio frequency noise levels to high energy surges. The causes and effects of inter-system ground noise are described in detail in White Paper 8, *Inter-System Ground Noise: Causes and Effects*.

Telephone line surges can enter an RS-232 data connection via a modem. Although modems are supposed to isolate RS-232 wiring from telephone wiring, surges can overcome this isolation barrier with disastrous consequences.

Wiring faults in which AC power distribution voltages come in contact with RS-232 wiring are infrequent accidents, usually resulting from nearby construction. Such accidents are very likely to destroy the devices connected to each end of the RS-232 link.

The recent changes in the design of computer motherboards have caused RS-232 drivers to be integrated into the motherboard chipset. This has caused RS-232 connections to become even more vulnerable than they were a few years ago.

The RS-232 standard

The RS-232 communication standard was developed to allow computers and terminals to interface to communication equipment (modems). In these cases the RS-232 communication links are very short (only 1 to 2 meters) even though the overall communication link (via the modems and phone lines) might be many kilometers long. In modern business usage, RS-232 links are routinely used to connect multiple workstations or terminals to a single multi-user CPU and the lengths of the RS-232 links may extend to as much as 70 meters (250 feet). Although modern cabling is capable of reliably transferring data over RS-232 links of this distance, in many situations a risk of hardware damage is created.

In an RS-232 system, data is transferred using a send data line, a receive data line, hand-shaking data lines (not always used), and a common line. Data signals are transmitted and received as voltages between each of the data lines and the common line. An essential assumption is that the common reference at the workstation or terminal is at exactly the same voltage as the common reference at the CPU. This is supposed to be insured by the common line in the RS-232 cable (pin 7 of a 25 pin connector), which ties these common references to each other. Although in principle the presence of this wire connection between the common points on the workstation and CPU should force the two common points to be at exactly the same voltage, the common wire has characteristics called resistance and inductance which prevent it from acting as an ideal short circuit. The consequence is that in the real world voltage differences can occur between RS-232 data transmitters and receivers which can compromise data transmission and result in serious hardware damage.

Safety grounding

All computer equipment is equipped with three wire grounding type AC power connectors. Many types of equipment, such as lamps, have only two wire type plugs since two wires are all that is necessary to deliver AC power. The third wire is a safety ground wire which is connected to any exposed metal parts on the computer equipment. The grounding connection provided at the wall receptacle is connected within the building to copper water pipes and / or structural metal parts of the building. The purpose of this arrangement is so that if you touch your computer equipment and touch any exposed metal in the building, you will not receive an electrical shock. For safety purposes, connectors such as RS-232 connectors are considered to be exposed metal parts; for this reason, the voltages at the connector pins must be grounded or must be small voltages with respect to ground. The result is that in virtually all computer equipment, the RS-232 common wire is connected to the safety grounding wire (and the enclosure) of the equipment.

The safety grounding arrangement leads to a conflict; every RS-232 workstation has two connections which are attempting to establish the common reference voltage for RS-232 communications: 1) the common wire which connects the workstation to the CPU in the RS-232 cable, and 2) the workstation safety grounding wire. This situation is sometimes known as a "ground loop". The existence of this loop can lead to differences between the common reference voltage at the workstation and CPU which can be damaging to hardware and data depending on the building or data wiring. These ground voltage differences between the workstation and CPU must not be confused with other power problems such as common mode noise, normal mode noise, EMI, or RFI. These ground voltage differences are inter-system ground noise.

RS-232 interconnection design rules

These rules are guidelines based on field experience. Schneider Electric has been involved in solving many unusual power problems involving RS-232 links. The most common problems are found on multi-user systems with remote RS-232 connected terminals, so the rules are outlined describing the interconnections of multi-user CPUs to terminals but are also applicable to any other RS-232 type connection. The rules are intended as guidelines and should be tempered by circumstances and knowledge of the installation environment and actual field experience.

In Europe, VDE standard 0800 requires that some of the rules presented in this white paper be followed. Please consult VDE standard 0800 to determine how to configure your system to satisfy the requirements.

- If you have a system where the terminals are near to the CPU, try to ensure that the workstations are plugged into the same electrical circuit as the CPU. If the system is small enough (less than 10 average workstations), then plug the workstations into the same outlet as the CPU (using outlet strips). If using a UPS and the UPS has been sized to handle the workstations as well as the CPU, then plug all components into the UPS, even if this means running some extension cords from the UPS.
- When preparing for installation of a distributed multi-user system, determine which electrical circuit is the source of power for each workstation. To do this, locate the circuit breaker for each outlet where a workstation will be installed. Record this information.
- If all the workstations will be fed from the same circuit breaker, and none of the workstations is more than 20 meters (60 feet) from the CPU, and no other unusual equipment is

connected to the same circuit breaker, then no precautions other than standard UPS protection are necessary.

- If all the workstations will be fed from the same circuit breaker panel, and none of the workstations is greater than 20 meters (60 feet) from the CPU, then the only precaution that need be taken is that you should try not to share any circuit breaker between computer equipment and motor driven equipment such as fans, air conditioners, or refrigeration equipment. This type of equipment may inject large amounts of noise, fault, or leakage currents into the power line grounds.
- If you suspect that workstations may share the same circuit with motorized equipment, then RS-232 data line surge suppressors should be used. Use in pairs is recommended (one suppressor on each end of the cable) but the suppressor on the CPU end can be used alone if desired (however this setup will not protect the workstation).
- If it appears that a workstation will be supplied from a separate electrical sub-panel from the sub-panel which supplies the CPU, then try to re-arrange the system. In some cases, it is possible to wire in an extra outlet near the workstation which is supplied from the CPU sub-panel. It may be possible to run an extension power cord to the workstation from an outlet near the CPU (consult local electrical codes). If an extra outlet is wired in and metal conduit is required, use special isolated grounding receptacles and do not run the data lines in the same conduit as the power lines.
- Workstations that must be supplied by a separate electrical sub-panel from the sub-panel which supplies the CPU should be connected by an optical link or isolated short-haul modem. This is the ideal solution and may be less expensive than running special power lines. If the two sub-panels are close to each other and you are confident of the electrical wiring quality, then RS-232 data line surge suppressors may be an acceptable lower cost substitute. If a workstation is in a separate building, never use a RS-232 link to the CPU no matter how close the distance. Use of underground data cabling will not solve the problem. Always use a fiber optic link. An RS-232 optical isolation unit is a possible alternative. Short-haul modems may be used but only if they are known to have excellent isolation voltage characteristics.
- If you have a modem connected to a multi-user system, this will present a very large hazard to your system. The telephone lines are likely to have large voltage transients with respect to the utility power line to which your multi-user CPU is grounded (earthed). UPS systems or surge suppressors have absolutely no affect on voltage transients which are introduced via telephone lines. Always use an external modem (not an internal modem) as this offers an additional level of protection from telephone line voltage transients. In selecting a modem, always look for units with an isolation voltage rating. An ideal value for this rating is 6000 Volts. In addition, it is wise to install an RS-232 data line protector between the modem and the CPU. Due to the severe nature of this risk, it is not overkill to additionally place a telephone line surge suppressor at the modem connection (note that a telephone line surge suppressor is not necessarily sufficient by itself). If the system is in a high lightning area where nearby (less than 1 kilometer distant) lightning strikes are likely, then only an optical fiber link between the modem and the CPU of at least 1 meter in length will be adequate.
- If a workstation is a PC which has a modem attached, this is nearly as dangerous as having a modem connected directly to the central CPU. All of the warnings regarding modems apply.

It may be apparent that the source of all of these problems is the ground loop caused by the electrical safety ground. In many cases, disconnection of this ground at the workstation may prevent problems. Ground wire disconnection is illegal, presents a severe shock hazard, and should never be done. It is sometimes suggested that an isolation transformer might be used to solve the ground loop problem. This will not work because all safety agencies require that the ground wire of an isolation transformer be passed through between the input and output (only the power wiring may be isolated).

Choosing the correct protection equipment

Selecting a UPS system

The choice of type of UPS system has no effect on the inter-system ground noise problem and cannot help protect RS-232 data connections. The performance of the UPS in terms of isolation, line conditioning, transfer time, is not important. The only way that a UPS system can completely protect a system of devices interconnected by RS-232 links is if all of the workstations are plugged into the UPS along with the CPU. This is often impractical because it requires purchasing a larger UPS and/or installing special AC power wiring. Therefore, RS-232 protection requires the precautions outlined in this document. A UPS system should be selected based on its reliability, performance, features, and its compatibility with the equipment to be protected.

Selecting a short-haul modem

A short haul modem is a very simple modem designed to connect a workstation to a CPU via inexpensive twisted-pair wiring. In use, 2 modems are required, one at each end of the link. The short-haul modem can be used for runs of up to a few kilometers depending on the model. If you intend to use a short-haul modem to replace a long RS-232 link, make sure that the communication does not require hardware handshaking as most short-haul modems do not support this operating mode. From a power protection point of view, the key rating of a short-haul modem is the isolation voltage rating (some models are not isolated at all; avoid these designs). Look for units with an isolation voltage rating of at least 3 to 6 kilovolts.

Selecting an RS-232 data line protector

Most RS-232 data line protectors sold today are not adequate. Make sure that a RS-232 data line protector has protection on all of the lines that are present in your RS-232 cabling (not just the lines that your software needs). Some models only protect the data lines. Don't simply read the specifications for the unit; take it apart. An RS-232 data line protector should have a minimum of 2 components connected on each data or handshaking line. Each line should have a "shunt" component which should be a power avalanche silicon diode (such as a **transorb**) which is connected between the line and the shell of the connector. Each line should also have a "series" blocking component which should be a special carbon composition resistor connected between the input connector and the output connector on each protected line. Most units do not contain a "series" element and are inferior. Many units use MOV type surge suppression devices as the "shunt" element. While MOV suppressors are excellent in AC power applications, they exhibit poor performance in data line suppression applications.

Selecting a fiber optic link

All RS-232 fiber optic links provide superb protection against inter-system ground noise and surges. They are also capable of very high baud rates. The main factor in deciding which model to use is whether the application requires hardware handshaking, since most optic links only work with software handshaking. Units which are self powered from the RS-232 lines are desirable as they can reduce wiring clutter. One problem with optical link systems is the cost of the cabling. A good low cost alternative for systems which use software handshaking is an optical data isolator block which is easily installed at one end of a standard RS-232 cable. This retrofittable unit provides the isolation benefits of a fiber optic link while using existing RS-232 wiring.

Selecting an isolation transformer

Isolation transformers only shield against common and differential mode power line noise. They offer no protection against inter-system ground noise and cannot help solve RS-232 protection problems.

Selecting RS-232 cables

The ideal RS-232 cable would force the common or ground voltage at each end to be equal. Each RS-232 cable includes 2 wires which attempt to accomplish this, and they should be as large as possible. On a 25 pin connector, these wires connect to pin 1 and 7. Pin 1 should connect to the RS-232 cable shield and must also connect to the connector frame itself. When choosing cable, look for the equivalent wire gauge rating of the shield; the lower the number, the better the power protection job the shield will do (lower gauge numbers mean bigger wires). If the shield is a foil shield, then use the gauge rating of the shield drain wire. Many users make their own cables and fail to make the pin 1 and connector frame connections, as they are not necessary to establish a communication path; this is a major mistake as it forces surge currents to enter pin 7 of the equipment which is not designed to withstand such surge currents. Improperly constructed RS-232 cables are a frequent cause of preventable equipment damage.

Conclusion

The problems associated with RS-232 wiring cannot be solved by typical power protection equipment such as UPS systems or AC surge suppressors. It is important to follow a few simple rules when installing RS-232 data connections. In particular, avoid RS-232 wiring runs of more than a few meters in length if possible, and install high performance surge suppressors on modem connections. Optical fiber or isolators are required for long RS-232 runs in order to prevent risk exposure. Use of properly constructed high quality RS-232 cables can prevent equipment damage.

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About the author

Neil Rasmussen is a Senior VP of Innovation for Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 19 patents related to high-efficiency and high-density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high-efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

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