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Poor power quality in the laboratory: A possible source of instrument operating problems

BY DENNIS VER MULM

IN ANY MODERN laboratory, laboratory managers are often plagued by mysterious problems that are unreproducible, are unpredictable, and always seem to occur at the most critical portion of a run. If a computer, instrument, or analyzer aborts, hangs up, or produces obviously erroneous results, the cost of using new test strips and assays or obtaining more samples is considerable, and it cannot be billed back to the customer. Calling a service technician to diagnose the problem usually results in the report "No problem found." Unfortunately, the frequency of these mysterious operational problems seems to be increasing every year.

Poor power quality may be the culprit in many cases, and the reason problems are escalating can be found in the equipment itself. Modern instrumentation, analyzers, and medical equipment rely extensively on the latest high-performance microprocessor and semiconductor technology, which is extremely susceptible to damage from electrical power transients, noise, spikes, and other problems on the incoming ac power line.

Power quality problems

Years ago, a major problem in laboratories was fluctuations in line voltage, which adversely affected the linear, isolated power supplies in use at the time. Today, now that almost all computers and instrumentation are microprocessor-based and have nonisolated switch-mode power supplies, voltage fluctuations have little effect. Instead, electrical noise, voltage transients, common-mode voltages, and neutral-to-ground problems have become increasingly troublesome.

Electrical transients on the power line can actually punch a hole through a sensitive semiconductor substrate, leading to immediate failure of a critical component, or they can erode microscopic bits of silicon. Lightning causes the largest transients; if a voltage spike from a nearby lightning strike reaches an instrument through the power or communication lines, it can literally fry the system. Large voltage transients can also be generated by electric utility transformer switching, motors turning on and off in the building, or even the photocopier in the next room.

Noise on the power line can be generated by a number of electrical devices. One of the biggest noise polluters is an uninterruptible power supply (UPS) that might be protecting a nearby computer. Excessive noise on the power line will lead to erosion of semiconductor components. Erosion is much like rust in a car: It may not be visible, have no effect on parts, and be difficult to find—until the day it rusts through and causes a failure. Electronic equipment subjected to constant electrical noise will erode in the same way: One day, a critical component will stop working for no discernible reason.

Electronic erosion can cause sporadic data disturbances, such as incorrect or unrecognizable characters. Such failures are difficult to diagnose and may lead to frequent service calls without finding the problem. As advancing semiconductor technology creates smaller and smaller microscopic line widths (distance between circuits), the chips become even more susceptible to damage.

The change in computer power supplies over the past 10 years has made equipment much more susceptible to common-mode voltage problems; even systems that are free of spikes and transients can have severe common-mode voltage problems that prevent systems from communicating with each other or that corrupt data.

All of this creates a major problem for laboratories and instrumentation users, who are caught in a quandary: The more modern and sophisticated the instrumentation, the more susceptible it is to power problems.

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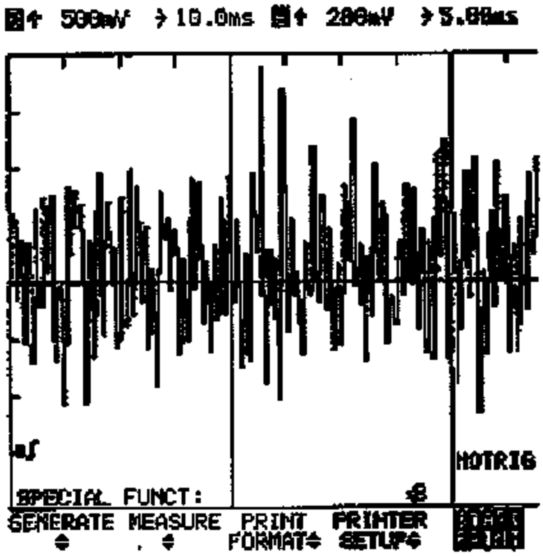

Figure 1 *Oscilloscope display showing common-mode noise. Ordinary electrical devices such as computers, motors, pencil sharpeners, elevators, copy machines, etc., all are responsible for creating common-mode noise disturbances that disrupt the operation of sensitive electronic systems.*

Paradoxically, laboratories, clinics, and end users invest large amounts of money to reap the rewards of increasingly sophisticated electronic instrumentation and analyzers, but very few take any steps to protect valuable equipment from damage, eliminate the cause of long-term erosion of microcircuitry, or eliminate common-mode voltages for more accurate data acquisition and communications.

Curing common-mode voltage problems

Most sophisticated electronic instrumentation is designed to run only on clean, transient-free, stable, and isolated voltage. Anything else, such as high common-mode voltages, can cause problems. Common-mode voltage refers to any stray voltage that appears between the neutral and safety ground of a circuit (*Figure 1*).

One problem related to high common-mode voltages is the inability to make two devices "talk" to each other. Instruments and analyzers typically connect to computers over an RS232C or RS422 link, a local area network (LAN) or data highway, or a parallel interface. When any two devices are electrically connected by a physical wire, they must have the same reference ground voltage. If they are near each other, the reference ground most likely will be the third wire (safety ground) in an ac receptacle.

Problems first arise when the receptacle does not have a third wire or is not connected, because then neither system can find a reference ground. Although each device can operate by itself, the lack of a reference ground usually means the two systems will be unable to communicate.

Problems also occur if the reference ground has considerable stray common-mode (also called neutral-to-ground) voltage, because it will offset the reference ground in a system and adversely affect any external device connected to a computer or analyzer, such as sensors, peripheral devices, probes, digital inputs and outputs, and analogue-to-digital (A/D) and digital-to-analogue (D/A) converters. This is because the computer input/output (I/O) logic voltages are measured with reference to the safety ground. If the common-mode voltage is too high (more than 0.5 V), it shifts the logic reference; data errors occur when the computer's circuitry cannot determine if a digital signal is a 0 or 1. Such a data glitch may not be repeatable or predictable, but it can cause considerable errors or a processor hangup.

The only solution to common-mode problems is an isolation transformer, because it eliminates all neutral-to-ground voltages and establishes a true zero volt logic reference on the safety ground. Isolation transformers are used in all power conditioners and some UPS systems (*Figure 2*).

Complete power protection

A typical building will experience 6244 power disturbances per year, but only 3–5% of those disturbances will be brownouts or power failures. The rest of the measurable disturbances are sags, surges, transients, spikes, lightning strikes, common- and normal-mode voltage swings, low-voltage impulses, and voltage frequency changes. These can be more damaging than a power loss, often cause long-term degradation to semiconductor circuits, and can disrupt operations if equipment is not adequately protected.

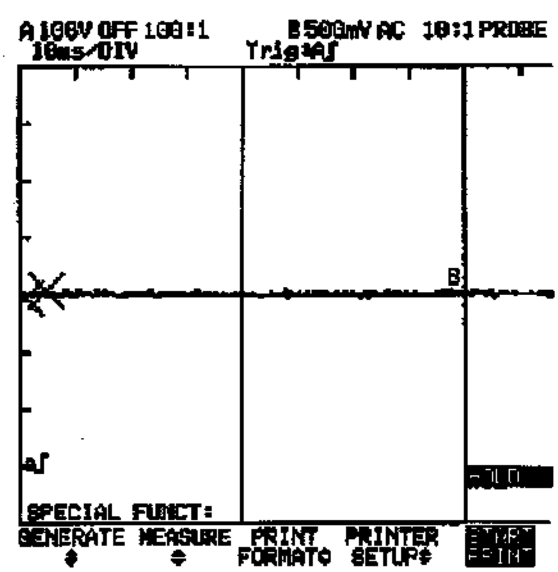

Figure 2 *Oscilloscope display showing absence of common-mode noise after proper power conditioning. Power conditioners should always contain an isolation transformer as a method of eliminating common-mode noise.*

Many people have the mistaken idea that purchasing a UPS will offer protection from all of these problems when, in fact, a UPS is designed only to provide backup power. An off-line or standby UPS provides little protection, because it is not even in the circuit until a power failure occurs. In an on-line UPS, ac power passes through battery chargers and voltage regulation circuits constantly, which tends to clean up the power considerably. Only an on-line UPS with an isolation transformer can provide the kind of protection that many users believe all UPS systems provide.

Complete power protection includes the following six elements:

A. Surge diverter. Sometimes called a surge suppressor, a surge diverter protects equipment from spikes or transients in excess of 250 V. These surges are caused by lightning; switching of heavy loads on power lines; or the turning on and off of loads in the building or plant, such as air conditioners, switch-mode power supplies, elevators, and ac motors.

B. Isolation transformer. An isolation transformer protects against common-mode voltage changes. It blocks disturbances by establishing the vital connection between neutral and ground as defined by the National Electrical Code, ensuring that no voltage disturbances appear between neutral and ground at the output of the isolation transformer.

C. Power line filter. A power line filter attenuates low-voltage impulses, providing a high degree of normal-mode noise protection. It ensures that no disturbing voltages appear between hot and neutral at the output. A power line filter is the one piece of equipment missing from most power protection systems.

D. Voltage regulator. A voltage regulator adjusts voltage to meet the exact needs of electronic equipment. Most computers, because of their switch-mode power supplies, do not need voltage regulation. Some instrumentation and analyzers, however, may have linear power supplies and may need voltage regulation. If so, a tapswitching type should be used instead of a ferroresonant regulator to prevent the introduction of new transients.

E. Battery backup/UPS. A battery backup/UPS provides continuing power in case of a power failure or brownout.

F. Frequency regulator. A frequency regulator provides constant power by continually regenerating the ac waveform from a dc source, typically an on-line UPS.

As a general rule, a power strip surge suppressor will provide A protection. However, most surge suppressors will actually wear out in a few months, the same way that electronic components do, and for essentially the same reason. Note that the higher the cost of the surge suppressor, the more effective it is and the longer it will last. The typical price for a high-quality surge suppressor is $50 to $100.

A UPS, even an expensive one, may only provide A and E protection. The typical cost for a low-price, off-line UPS suitable for a PC is about $250. If the UPS has an isolation transformer, it will provide A, B, and E protection. High-end, on-line UPS systems provide A–F protection. The cost of a PC-sized, high-end UPS is about $1500.

If cost is a factor, it should be remembered that the batteries in a UPS wear out and must be replaced every three years. The price of a battery pack for a PC-sized UPS is about $75. Also, if a UPS is used to protect a computer, it may create a considerable amount of electrical noise; all nearby instrumentation may have to be protected from the UPS.

Power conditioners provide A, B, and C protection, and cost about $225 for a PC-sized unit. If backup power protection is not needed, a power conditioner is a much better solution than a UPS.

Not all systems require complete A–F protection; the art of designing a power protection system is knowing which parts are needed and how to specify them for a given installation. Those who are experiencing mysterious problems that might be attributable to power quality should call in a power professional to look at an installation and determine the proper power protection solution.

Real-world applications

Several examples of real-world situations involving poor power quality problems follow.

Bacterial testing system

Unreliable operation of a bacterial testing system caused numerous problems at a hospital in California. The laboratory was falling behind in its test schedule, results were not dependable, samples and assays were being wasted, and costs were becoming uncontrollable. The instrument manufacturer could find no reasonable explanation for the problems.

Other electronic systems in the hospital were experiencing similar problems. Luckily, another system vendor had acquired the help of a POWERVAR (Lake Forest, IL) power quality specialist to identify and analyze power disturbances, and the findings applied to the bacterial testing laboratory.

The analysis revealed numerous power quality problems, including transient noise, missing safety grounds, inadequate wiring, and high common- and normal-mode voltages at the facility, which was more than 40 years old. One solution was to upgrade all electrical wiring facility-wide. Declining to accept the high cost of this option, the hospital elected to install power-conditioning devices on all of its sophisticated electronic systems.

The power specialist analyzed the power requirements of each instrument; evaluated its voltage and amperage needs; and recommended individual power-conditioning systems that included a surge diverter, isolation transformer, and power line filter.

The result was dramatically improved performance at a substantial cost saving over upgrading facility wiring. The hospital paid for the power conditioners from the savings in eliminating wasted assays and revenue from improved productivity.

Hematology instrumentation

A hospital in the Midwest was experiencing difficulties with its hematology instruments. Laboratory technicians were baffled by mysteriously changing background counts and constantly rebooted the instruments in a vain attempt to recalibrate them.

Frustrated by decreasing laboratory productivity, the hospital asked its instrument vendor for assistance. Repeated service calls by the vendor's field service department all had the same result: No problem was found. In desperation, the vendor replaced the entire instrument, but the problems persisted.

Finally, after exhausting all other options, the instrument vendor called in a POWERVAR power quality specialist to assess the situation.

During the investigation, the power specialist found that the site was experiencing numerous high-voltage noise impulses and high levels of common-mode (neutral-to-ground) noise. After verifying electrical wiring and grounding practices, he recommended installation of power-conditioning equipment with a surge diverter, isolation transformer, and power line filter.

This cured the immediate power problems and restored proper operation of the hematology instruments, but the hospital learned that its power quality deficiencies were long-standing and would continue to cause problems elsewhere in the facility unless corrected.

Ink analyzer

The industrial laboratory of a large ink manufacturer experienced unreliable performance of a computer-based instrument that analyzed the chemical composition of inks used in the printing industry. When functioning properly, the instrument could take an unknown sample of ink and duplicate its formula with imperceptible differences in color and quality.

For no apparent reason, the computer system would suddenly return erroneous results. The manufacturer could not rely on the analysis, because producing a large amount of incorrect or unusable ink would result in a sizable financial loss.

The ink manufacturer turned to the instrument's field service engineer for help, but was repeatedly advised that there was no problem. The field engineer suggested that the problem might stem from poor power quality; thus, the laboratory secured the services of a POWERVAR power quality specialist.

The specialist found that the instrument was particularly sensitive to transient noise spikes on the ac line plus common-mode noise that appeared in the neutral-to-ground wiring powering the computer. The computer system was powered from an electrical distribution panel that was common to other devices in the plant, including motors, dryer, mixers, and lights, and these devices were creating spikes when they were turned on and off. The high level of common-mode noise made it very difficult for the computer and analyzer to communicate.

A power conditioner with surge diverter, isolation transformer, and power line filter was installed to solve both problems.

Automated microbiology system

A hospital laboratory in the south of France was plagued by repeated problems with an automated microbiology system. It would return unreliable results, lock up for no reason, display strange characters on the monitor, and experience other unexplainable problems.

Fortunately, the instrument manufacturer had trained all of its field service engineers in the importance of clean, noise-free electrical power. It had also provided its engineers with the tools and training necessary to locate and define power quality problems at an installation site.

The manufacturer's field service engineer investigated the site and found that the electrical system powering the instrument had an unusual amount of high-voltage impulses and high-frequency common-mode noise. It was learned that hospital staff had already installed power protection devices in an attempt to protect their expensive investment in microbiology instrumentation.

Unfortunately, the devices installed by the hospital were incompatible with the power needs of the instrument. The hospital had installed a power conditioner designed for computers, not instrumentation; thus, it did not have an isolated output or transient suppression. The power conditioner was actually creating the high level of common-mode noise. The hospital had also installed a UPS on a computer in the laboratory, and the UPS was creating considerable noise on the ac line.

The field service engineer solved the problem by specifying the correct power conditioner for instrumentation, one that included a surge diverter, isolation transformer, and power line filter.