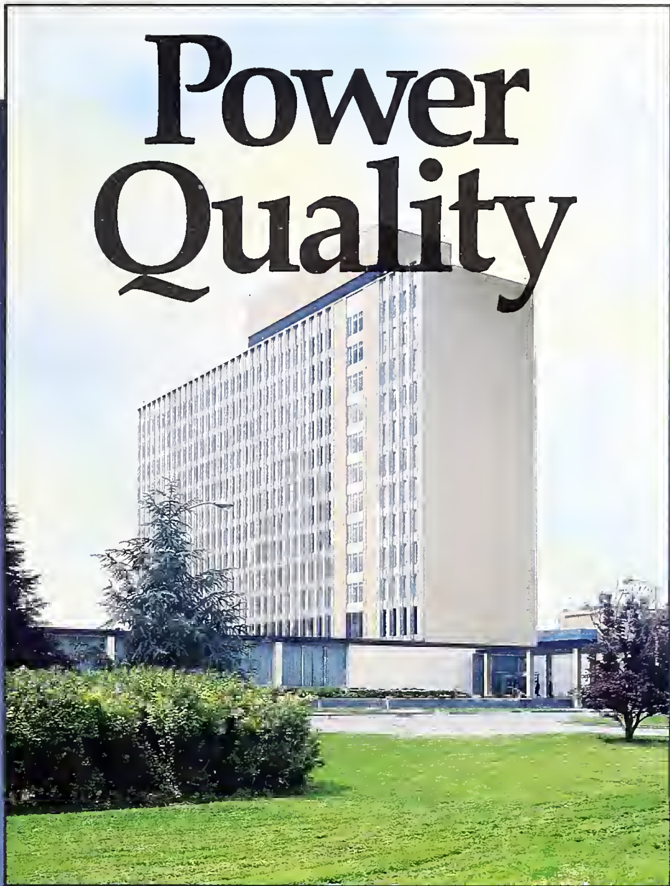
NIST SP768

Power Quality



U.S. Department of Commerce
National Institute of Standards and Technology

Infor

A poster prepared by the NIST Power Quality Committee to inform users of sensitive equipment about problems with and solutions for protecting their equipment from power disturbances.

This poster contains:

- Answers to seven common questions about power quality that should help you pinpoint problems and solutions related to power disturbances.
- A chart describing the types of power disturbances, the equipment affected, and a brief summary of the types of protection equipment that is effective against the disturbance.
- A glossary of common power terms.

Glossary

critical load—A critical load is equipment that is sensitive to power disturbances. (also referred to as a sensitive load)

common mode noise—Electrical noise between the power conductors and ground, i.e., between line and ground or between neutral and ground.

impulse—See spike.

inverter—An inverter takes dc power and converts it into ac power.

kilovolt-ampere (kVA)—An electrical unit related to the power rating of a piece of equipment. It is calculated by multiplying the rated voltage of equipment by the current required (or produced). For resistive loads 1 kilovolt-ampere equals 1 kilowatt.

line—A designation of one or more power-carrying conductors for power distribution. The black (or red or blue) wire is the line conductor, the white wire is the neutral, and the green wire is ground. The voltage difference between the line conductor and the neutral is the supply voltage, i.e., 120 volts.

line conditioner—A line conditioner contains multiple protection devices in one package to provide, for example, electrical noise isolation and voltage regulation.

momentary overvoltage—A momentary overvoltage (or "swell") is an increase in voltage outside the normal tolerance for a few seconds or less. Voltage swells are often caused by sudden load decreases or turn-off of heavy equipment.

motor generator—A motor generator consists of an ac motor coupled to a generator. The utility power energizes the motor to drive the generator, which powers the critical load. Motor generators provide protection against noise and spikes, and, if equipped with a heavy flywheel, they may also protect against sags and swells.

neutral—A designation of one of the two power carrying conductors for power distribution. This is the white wire and is normally at or near the voltage of the ground wire. Thus the line or black conductor is at a high voltage (i.e., 120 volts) with respect to the neutral and ground wires.

noise—Electrical noise is a distortion of the normal sinewave power and can be caused by radar and radio transmitters, fluorescent lights, power electronics control circuits, arcing utility and industrial equipment, and loads with solid-state rectifiers.

outage—An outage is a complete loss of power that may last from several milliseconds to several hours and may be caused by power system faults, accidents involving power lines, transformer failures, and generator failures. Some sensitive equipment may be disrupted by outages as short as 15 milliseconds.

power conditioner—See line conditioner.

sag—A voltage sag is a momentary (less than 2 seconds) decrease in voltage outside the normal tolerance. Voltage sags are often caused by stating heavy loads, such as motors or welding equipment, and by power system faults.

spike (or impulse, switching surge, lightning surge)—These terms refer to a voltage increase of very short duration (microsecond to millisecond). Spikes can range in amplitude from 200 volts to 6,000 volts and are caused by lightning, switching of heavy loads, and short circuits or power system faults.

spike suppressor—An inexpensive device that provides protection against short duration (microsecond to millisecond) voltage increases known as spikes, impulses, transients, or high-frequency surges.

standby power supply (SPS)—See uninterruptible power supply.

surge—The word "surge" has different meanings in different engineering communities. To the protection engineer a "surge" is a transient overvoltage with a duration of a few microseconds, i.e., a spike. To others a "surge" is a momentary overvoltage lasting up to a few seconds. To avoid confusion we will use the word "swell" as an abbreviation for momentary overvoltage.

surge suppressor—See spike suppressor (and "surge" above).

swell—See momentary overvoltage.

uninterruptible power supply (UPS) (see also motor-generator)—Non-mechanical (static) uninterruptible power supplies can provide protection against all power disturbances. As on-line or "true" UPS converts the utility ac power to dc and uses the dc to charge a battery and to power an inverter that delivers power to the critical load. An off-line UPS, more properly called a Standby Power Supply (SPS), supplies the utility power directly to the critical load and transfers the load to a battery-powered inverter to supply power during outages.

utility power—Alternating current supplied to the user by the (usually commercial) electrical utility. May be subject to spikes, sags, swells, electrical noise, and outages.

voltage regulator—Voltage regulators control the output voltage, eliminating voltage sags and swells in the input voltage that last from 15 milliseconds to one-half second. They are typically relatively inexpensive feedback controlled transformers.

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Informational Poster on Power Quality

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This poster contains:

- Answers to seven common questions about power quality that should help you pinpoint problems and solutions related to power disturbances.
- A chart describing the types of power disturbances, the equipment affected, and a brief summary of the types of protection equipment that is effective against the disturbance.
- A glossary of common power terms.

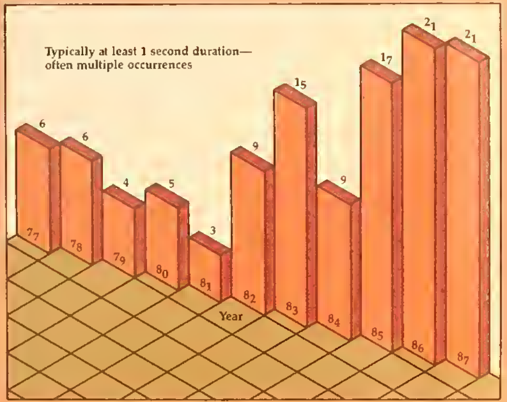
Who is this poster intended for?

Anyone who is using a computer or other equipment that may be sensitive to power-line disturbances or to momentary power outages.

Why should I be interested?

In some locations, the number of power outages experienced by users is increasing each year. For example, data taken over a period of 11 years at a particular location on the NIST Gaithersburg campus show an increase in the incidence of major power interruptions.

NIST Gaithersburg Number of Gross Electrical Outages



This chart shows only those outages lasting long enough to disturb electromechanical equipment. Electronic equipment can be disturbed by much shorter (and more frequent) outages.

Furthermore, the power quality problem has become more visible because of the recent increase in the use of computers for experiment control and data and word processing, as well as the proliferation of switched-mode power supplies, which are more sensitive to power disturbances. The use of the wrong kind of protection equipment, or no protection equipment at all, may cause:

- lost or scrambled data,
- damaged equipment, or
- ruined experiments.

Many electronic systems will safely restart following an outage, but may be damaged or severely disturbed if a second outage occurs during the restart period.

Why can't the power company supply clean power?

Power quality is a problem that involves the supplying electric utility, end users operating sensitive equipment, and their physical and electrical neighbors. Many disturbances are created between the utility and the user or even pass from one user to another and cannot be controlled by the utility. Such sources of power disturbances may include lightning striking near a power line, tree limbs falling on power lines, motors starting or stopping, and operating industrial processes such as welding. Even seemingly innocuous actions such as turning on or off a small appliance can upset sensitive operations. A personal computer user at NIST discovered this when a coffee pot was plugged into the same receptacle as the computer. The computer corrupted the data every time the coffee pot heater cycled on or off

For any organization attempting to provide a centralized, site-wide solution, the results would be extremely costly and would not be effective. Not all equipment needs the same level of protection, and providing "better" protection than required is unnecessarily costly. Providing protection at a central location does not protect users from their neighbors For complete protection, the power conditioning equipment that is appropriate for the sensitive equipment being used, should be installed near that sensitive equipment and *supply power only to that equipment*.

By the way, at NIST Gaithersburg the nearest electrical neighbor in the general purpose laboratory buildings is the person in the module above or below you, rather than adjacent to you on the same floor! It is important that you understand the power distribution system in your building

What is NIST doing about power quality?

To address these concerns, the NIST Executive Board has appointed a committee to investigate the quality and reliability of the ac power being delivered to the NIST Gaithersburg site, a typical power consumer, and to judge the effects on equipment and personnel. These tasks will be accomplished through a combination of surveys of users on their power problems and actual monitoring of the quality of the power at various locations in NIST for a 1 year period. Additionally, a risk assessment study will be completed to determine what specific types of equipment are sensitive to what types of disturbances and what the cost would be of ameliorating any resulting damage.

The goal is to provide information to the users for making informed decisions In the meantime, this poster is but one step in the process of informing users about the problems and solutions of power quality

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What can I do about power quality?

There are a number of ways you can reduce or eliminate the effects of power disturbances. But first you should be sure you have a power problem. Start with the five steps below.

1. Document the problem. Exactly how did the equipment malfunction? Did the computer reset itself? Was there lost or scrambled data? Was there physical damage to the equipment? Was a fuse blown? Did anything else happen at the same time? Did the lights blink? Was there a thunderstorm going on? Keeping a log of the symptoms will be an invaluable aid if you need to call someone in to help with your problem. By continuing the log even after protection equipment is added you can tell if the solution is effective.

2. Check the wiring. Although building power wiring may have been installed correctly, worn receptacles, loosened connections, and improper use of extension cords, multiple outlet strips, or other "temporary" solutions may sometimes cause problems. Make sure that all equipment is properly installed and grounded and that plugs fit snugly in their receptacles. If possible, measure the voltage at the receptacle. It should be within 108 to 132 volts for a nominal 120 volt circuit.

3. Relocate the equipment to a different electrical circuit or receptacle. Two pieces of equipment operating on the same circuit may interfere with each other. Try to isolate sensitive equipment to its own receptacle. Avoid plugging photocopy machines or machine tools into the same receptacle as a computer.

4. Review the chart below that describes the types of disturbances and the protection equipment available and then consider purchasing protection equipment.

5. Periodically test and maintain your power-protection equipment.

$1000–$4000 UPS

Uninterruptible power supplies (UPS) typically used for small loads are non-mechanical static devices as opposed to rotating motor generators. The *static* UPS can be one of two basic types.

A "true" or *on-line* UPS rectifies the utility ac power to dc and uses the dc to charge a battery and power an inverter. Under normal conditions the inverter converts the dc back to ac to supply the sensitive equipment load. When an outage occurs, the battery supplies the inverter with no interruption of the output power.

The second type of UPS is an *off-line* UPS and is more properly called a Standby Power Supply (SPS). Under normal operating conditions this type of UPS supplies the utility power directly to the sensitive load with perhaps some filtering or noise isolation and also charges a battery. When an outage is sensed, the load is quickly transferred (in about 4 milliseconds) to the output of an inverter powered by the battery. When utility power is restored the load is transferred back to the utility power. This type of system is somewhat less expensive than a true UPS but may introduce a brief power interruption during the transfer.

Both systems typically allow 5 to 15 minutes for the user to shut down the critical system in an orderly manner or ride through the outage, depending upon its duration and the size of the battery and the load. The true UPS protects against voltage spikes, noise, sags, surges, and outages, while the SPS generally protects against only outages.

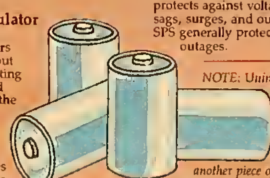
NOTE: Uninterruptible power supplies contain batteries that must be periodically tested. Sticking an UPS under a desk or behind another piece of equipment and forgetting about it is a guarantee that it will not work when needed. Test the UPS every month by interrupting the incoming power and making sure the sensitive equipment continues to function properly. Follow the manufacturers recommendation on replacing the batteries, but if no recommendation is given, replace them every 2 years.

How much is power protection going to cost me?

The exact cost of power protection will, of course, depend on the sensitivity and power consumption of the equipment being protected and the level of protection required. The problem can be reduced to an economic tradeoff of how much is the protection going to cost versus how much is lost if the equipment fails or is disturbed? Three levels of protection from low cost basic protection to a comprehensive solution are discussed.

NOTE: The costs shown below apply for small loads of less than 2 kilovolt-amperes (kVA). Loads of this sort include two or three desktop computers and a laser printer.

$300–800 Voltage Regulator



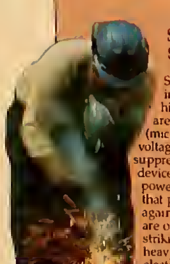
Voltage regulators control the output voltage, eliminating voltage sags and overvoltages in the input voltage. Regulators do not protect against spikes, noise, or outages of more than one-half second duration. Some voltage regulators are built using electrostatically shielded transformers to eliminate common mode noise.

Line conditioners or power conditioners are voltage regulator systems that often contain multiple devices in one package and usually cost less than the combination of the individual devices. Although according to many experts, line conditioners should isolate electrical noise and regulate voltage, a number of products do not accomplish all these functions. For applications of low power ratings where switched-mode power supplies are used in the load equipment the voltage regulation function is not essential. However, voltage regulation should explicitly be a feature of larger line conditioners.

Don't forget . . .

In addition to purchase cost, there may be installation, maintenance, and efficiency costs (UPS systems deliver less power than they consume). Also the reliability of the protection equipment should be considered; in some cases, redundant systems may be required.

$20–$100 Spike Suppressor

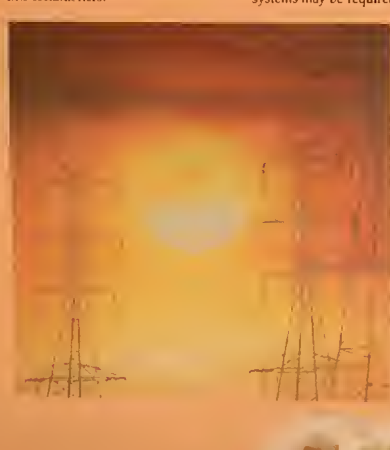


Spikes, also known as impulses, transients, or high-frequency surges, are short duration (microsecond to millisecond) voltage increases. Spike suppressors are inexpensive devices often packaged as a power strip or extension cord that provide protection against these spikes. Spikes are often caused by lightning striking near a power line or heavy equipment such as electric power tools and business machines turning on or off. Spikes can destroy data stored in computers, alter running programs, and cause hardware damage.

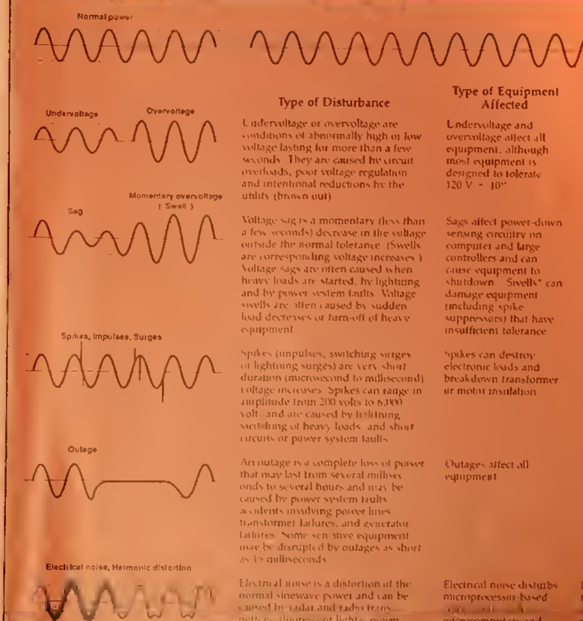
Spike suppressors provide no protection against longer duration voltage drops (sags), momentary increases ("swells"), or outages (blackouts). In its simple form, a spike suppressor does not eliminate low-level electrical noise problems; however, some suppressors have additional filters to reduce this noise. Electrical noise can be generated by radios, TVs, microwave transmission, brush-type motors, and arc welding and is generally less destructive than spikes. But, noise can destroy stored computer data or alter running programs.

Spike suppressors are a basic first line defense and should be seriously considered to be minimum protection for desktop computers and peripherals because of their low cost, high availability, and easy installation.

A spike suppressor with EMI filtering, packaged as a power strip, is currently available in the NIST storerooms.

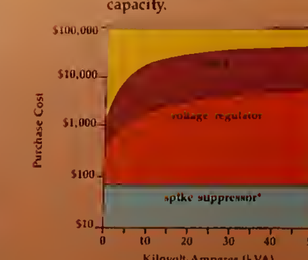


Types of Disturbances and Protection Equipment Effectiveness



	Type of Disturbance	Type of Equipment Affected	Effective Protection Equipment
Undervoltage / Overvoltage	Undervoltage or overvoltage are conditions of abnormally high or low voltage lasting for more than a few seconds. They are caused by circuit overloads, poor voltage regulation and intentional reductions by the utility (brown out).	Undervoltage and overvoltage affect all equipment, although most equipment is designed to tolerate 120 V ± 10%	Voltage regulator, line conditioner, or uninterruptible power supply (UPS)
Sag / Momentary overvoltage (Swell)	Voltage sag is a momentary (less than a few seconds) decrease in the voltage outside the normal tolerance. (Swells are corresponding voltage increases.) Voltage sags are often caused when heavy loads are started, by lightning and by power system faults. Voltage swells are often caused by sudden load decreases or turn-off of heavy equipment.	Sags affect power-down sensing circuitry on computer and large controllers and can cause equipment to shutdown. "Swells" can damage equipment (including spike suppressors) that have insufficient tolerance	Voltage regulator, ferroresonant transformer, line conditioner, or uninterruptible power supply (UPS)
Spikes, Impulses, Surges	Spikes (impulses, switching surges or lightning surges) are very short duration (microsecond to millisecond) voltage increases. Spikes can range in amplitude from 200 volts to 6,000 volts and are caused by lightning, switching of heavy loads, and short circuits or power system faults.	Spikes can destroy electronic loads and breakdown transformer or motor insulation	Spike suppressor (also called surge suppressor), or some line conditioners
Outage	An outage is a complete loss of power that may last from several milliseconds to several hours and may be caused by power system faults, accidents involving power lines, transformer failures, and generator failures. Some sensitive equipment may be disrupted by outages as short as 15 milliseconds.	Outages affect all equipment	Uninterruptible power supply (UPS) or standby power supply (SPS)
Electrical noise, Harmonic distortion	Electrical noise is a distortion of the normal sinewave power and can be caused by radar and radio transmitters, fluorescent lights, power electronic control circuits, arcing utility and industrial equipment, loads with solid state rectifiers, and switching power supplies typically used in computer systems.	Electrical noise disturbs microprocessor-based [illegible] microcomputers and programmable controllers. Harmonic distortion causes motor loads, such as compressors, pumps, and disk drives, to overheat	Filter, isolation transformer, [illegible] power supply (UPS), or some line conditioners

Approximate purchase cost for large capacity protection systems versus their power capacity.



*The purchase cost of spike suppressors is independent of the size of the load being protected. High power spike suppressors designed for installation in building entrance service panels are typically available for $1000

Where do I go for more technical information?

Federal Information Processing Standards Publication (FIPS PUB) 94, "Guideline on Electrical Power for ADP Installations" provides information for ADP installations on typical loads, larger power conditioners, and control of static electricity. FIPS PUB 94 is available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161, (703) 487-4650, for $19.95 in unit quantities plus shipping.

In addition, a bibliography of technical papers on power quality and power conditioning has been compiled and is available in limited quantities from the NIST Power Quality Committee, Room B162 Bldg. 220, Gaithersburg, MD 20899.

For technical advice concerning the power distribution/conditioning system in your building, contact

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Issued July, 1989