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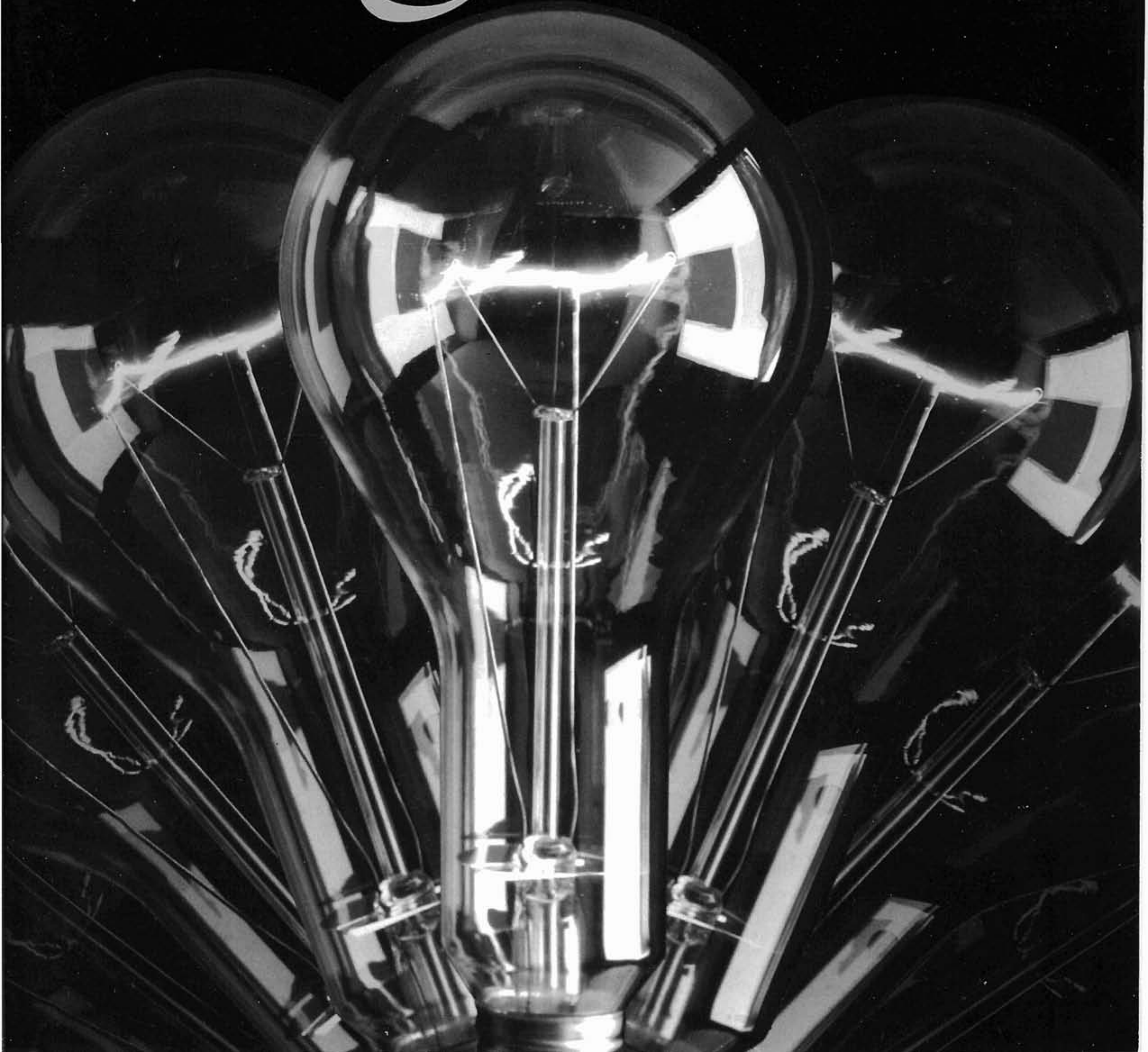

Power Protection

Key to Cutting Costs and Increased Productivity

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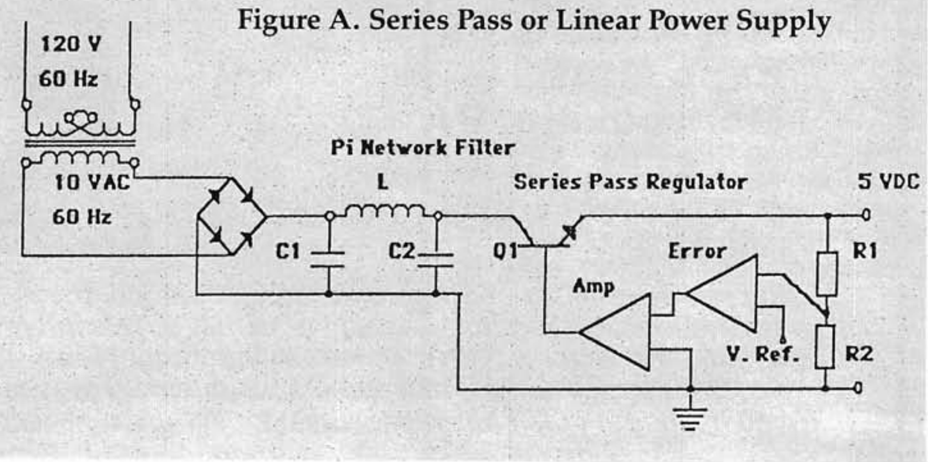
New power conditioning technologies and methods have been introduced in recent years to accommodate and protect new computer devices from power line disturbances. A computer's greatest strength is its greatest weakness. Technologies such as large-scale integrated circuits, micro-processors and low-power CMOS chips are easily damaged or confused by "power glitches." Trying to run computers, present-day telephone switch equipment, or industrial controllers on "commercial grade power" often results in downtime and the following type situations. These are typical yet tragic, because they could have been easily avoided.

1. A brand new county/state prison in Louisiana found that lightning storms affected security systems and at times would cause all prison doors to unlock. They then noticed that circuit board failure and security system malfunction were not confined to lightning storms but at times would occur during "clear, blue skies." After prisoners caught onto the situation, they were sitting ready, a storm came, the doors opened and, amid the confusion, five prisoners escaped. A nearby manufacturer was needlessly having similar malfunctions with his Computer Numerical Control (CNC) machine tools. Businesses often think these problems are isolated cases. A survey through the jail and through all security and control systems by a power protection consultant yielded a protection plan for the facility. The total cost in solving the problem was only a fraction of the losses incurred.

2. An international insurance company in the eastern states was affected by lightning three times during their first summer of operation in a new computer facility, causing massive outages in the PBX phone system, the building management systems microcomputers and in-office computer terminals.

Figure A. Series Pass or Linear Power Supply



A maintenance contract covered repair costs of the phone system but the insurance company estimated business losses in the millions. They contacted the firm which had installed lightning rod protection on the building, which brought in a consultant. Result: the company installed a couple of grounding changes and proper transient suppression equipment throughout the building. The cost of protection: $30,000.

Simple protective steps can be taken to eliminate such power disturbance failures in computers, industrial controls, electronic key systems, building management HVAC systems, telephone "switch" equipment, PABX, etc., thus reducing maintenance frustrations, costs and lost business.

Lightning protection associations such as ULPA and LIP, traditionally charged with installing or engineering lightning rod fire protection systems for buildings, now realize "commercial grade A.C. power" must be properly conditioned to achieve "computer grade power." Therefore, they specify improved grounding techniques and transient suppression networks be installed in all buildings with high densities of electronic equipment and computers.

Because of changes in power supply technology for computers and other electronic equipment, we have seen a change in the technology needed to properly protect this equipment. In the 1970s, most D.C. power supplies were "series pass" or "linear" D.C. regulators (see fig. A). Today, 90 percent or better are "switch mode" or switching D.C. regulators (see fig. B). Traditional power conditioning devices such as isolation transformers and regulations transformers, when applied to new equipment with switch mode power supplies can actually retard or hinder their ability to perform well and regulate. This new power supply needs a low impedance, low inductance power source as it draws short but sharp pulses of current to maintain regulated D.C. output. The switching regulator oscillates at 20kHz-200kHz, thus it can cause harmonic ringing, heating problems and poor current draw when supplied by a ferroresonant magnetic regulation transformer. The Institute of Electrical and Electronic Engineers (IEEE) guidelines note that these regulation transformers have been known to go into violent oscillations and destroy switching power supplies. By design, the switching power supply will operate over a wide input voltage range and does not normally need a voltage stabilized power source. This is good because the switching power supply is of itself much smaller, cheaper and more efficient than its linear predecessor. Power conditioning transformers were also very expensive and inefficient.

Why is it, then, that most new equipment with switching power supplies and high-density microprocessor design seem so vulnerable to power glitches, transients and lightning storms? And, how can we cost-effectively protect against these problems? The switching regulator supply is, by design, a high-pass filter which allows high-frequency (fast rise time) transients to pass through to the micro-processor, logic chips and other sensitive circuits. The answer is installation of properly-designed hybrid transient voltage surge suppressors (TVSS), which work synergistically with building transformers and EMI/RFI filters, rather than fight against them. Once these sharp, 500- to 6000-volt transients are removed, the switching power supply does an excellent job of regulating and providing stable power to all electronic circuits.

Transient suppression has been recently recognized by organizations such as the FCC, IEEE, National Bureau of Standards, IBM, U.S. Department of Commerce, General Semiconductor Industries, General Electric Co., KeyTek Instruments Corp., Wang, U.S. Consumer Protection Agency, etc., as the most cost-effective step which can be taken to reduce computer and electronic equipment problems. Standards have been published by several of these, setting test and evaluation standards and means for proper protection: 1) The FCC industrial voltage transient withstand standard; 2) The IEEE-587 and ANSI C62.41 reports, which cover application as well as outline four transient wave shapes for testing protectors; 3) UL0-1449, by which Underwriters Lab evaluates transient voltage surge suppression devices.

Transient Suppression

What are transients? Where do they come from? Why do they cause problems in electronic systems? How does one protect himself from transients?

Transients are fast-rising over-voltages, with total time duration of less than one millisecond. Transients can rise to peak amplitudes of several thousand volts within a few nanoseconds and decay away within several microseconds. Since these can force or find their way through D.C. power supplies and into electronic circuits, they have become the subject of great concern, research and study. In I.C. chips we pack several thousand transistors onto a 0.1-inch-square chip and expect them to perform several million operations per second, by detecting fast voltage level changes between zero and five volts. When a transient finds its way into the main 5 volt D.C. or onto logic lines, it injects disruptive or destructive havoc. Transients are interpreted as data pulses which shouldn't be there. The system will perform functions not called for, or the system may temporarily forget what it is doing. CMOS microprocessors will lock up if transients take I/O lines lower than -0.6 volts. We commonly hear the phrase "it just lost memory" or "the system just locked up." These are typical disruptive ef-

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Figure B. Switching Power Supply

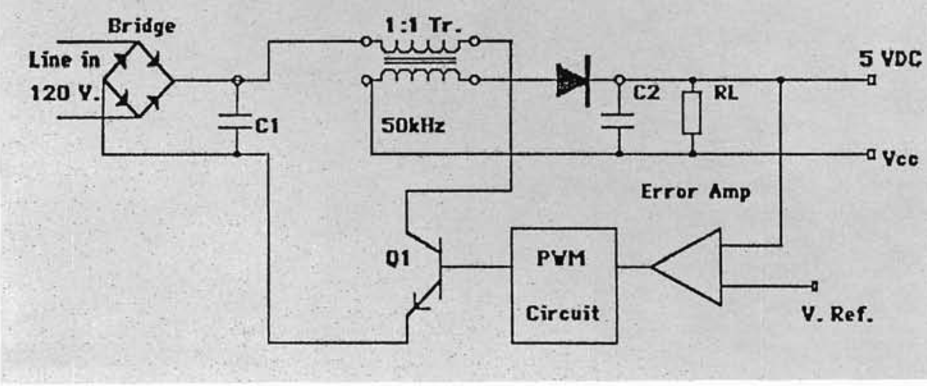
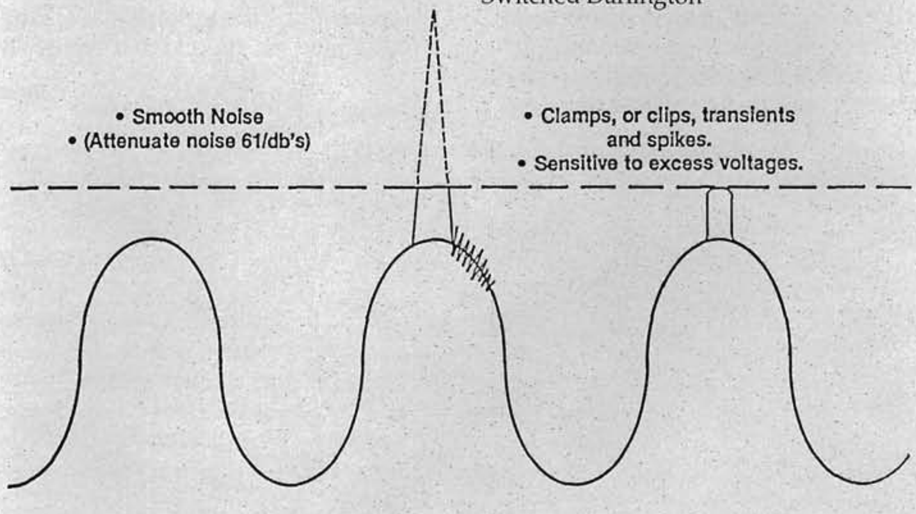


Figure 4

Filters	Suppressors
(Shock Absorber)	(Clamp or Retainer Walls)
LC Network	Arc Gap
RC Network	Gas Tube
Isolation Transformers	MOVs
	Zeners
	SCRs
	Triacs
	Switched Darlington



Filters versus suppressors and suppressed transient

fects of transients. Disruptive because, once the system is rebooted, circuits are reset and proper memory data loaded back into the system, it runs just fine again.

The effect of lightning storm transients or transients from motor equipment is stressful on I.C.s and damage accumulates inside the I.C. until, one day, a small transient or surge is generated as the system is turned on and a circuit board fails.

Several standard transient wave shapes have been suggested in recent years for testing purposes. The FCC proposed a 10 X 160 and a 10 X 560 pulse (Docket 19528 Part 68). UL proposed a 1.2 X 50 pulse and IEEE proposed an 8 X 20 pulse. In each of these, the number preceding the X is the rise time to the pulse peak in microseconds and the number following the X is the number of microseconds it takes for the pulse to decay to half energy. In the real world, "Mother Nature" will generate transients of all sizes and shapes, which may look similar to or nothing like these standard wave shapes. But for testing and for transient suppression equipment comparison, we must have standard wave shapes. More recently, IEEE has outlined three wave shapes in IEEE Standard 587, which somewhat represent transients seen at sockets or circuit breaker cabinets feeding electronic equipment. They are: 1) a Category A ringwave, 6,000-volt, 200-amp., oscillating at 100 KHz; 2) a Category B ringwave, 6,000-volt, 500- amp., oscillating at 100 KHz; and 3) a Category B 6,000-volt, single-impulse 1.2 X 50 microseconds, which, if shunted through a low impedance or short circuit, will produce a current surge of 8 X 20 microsecond, 3,000 amps. IEEE and other groups are continuing studies and other standard wave shapes may be introduced.

The transient has always existed but was only recently defined with faster and better monitoring equipment. Transients are frequent on power lines and are of recent concern because of their adverse effect on I.C. chips (the basic component in all modern electronic systems and computers).

Cost of Downtime

So what? I don't see that many problems on a weekly basis where I work. Is the problem worth addressing? The answer to these questions comes by way of another question. What is the cost of downtime? These authors have worked with many companies during the past ten years, helping them eliminate transient stresses and other stresses which can cause malfunction or failure. We have asked them all, "What is the cost of downtime?" Here are the tabulated results:

Cost of Downtime

System Type

Small company computer, CNC machines, PLCs, robots, process controllers, hospital equipment

Cost

$200-$500/hour

FMS Cells, Just-In-Time (JIT) Cells in manufacturing environments, larger business computer or controls

Cost

$7,000-$9,000/hour

JIT manufacturing lines such as in auto manufacturing and factories

Cost

$300,000-$500,000/hour

$7,000-$9,000/minute

Of course, if you work for a government agency, there is no cost to downtime, right? Wrong! Downtime still raises the cost of doing the job. It raises operating budgets all the way around and rips away at the national wealth. In defense systems and in medical systems, the cost of systems downtime can be counted in human lives, such as in the recent situation where a ship captain, in the Persian Gulf, left his PHALANX system off because he knew shipboard power transients could cause problems in the PHALANX. When the attack came, there was no time to turn on PHALANX and lives were lost ("60 Minutes" interview, September 1988).

The following methods to eliminate downtime by eliminating transients are most cost-effective, even at $50-$200 per hour downtime. How much more imperative are they, then, on more complex computer and control systems and in facility power systems which feed business operations?

Power Conditioners — A Comparative Analogy

Keep in mind the analogy that transformers and filters are like shock absorbers on a car. They average, or smooth the bumps, thereby attenuating or reducing road noise by so many decibels. But, when your car hits a bad pot hole, the shocks do little toward smoothing the bump. The large shock of a pot hole is like a voltage transient. It completely saturates the energy smoothing capability of filters and forces through the whole system, causing problems. In the case of a pot hole, the problems could be disruptive, causing the car to jump out of its lane of traffic or wake up the driver, or the problem could be destructive, causing the front end to go out of alignment and bending wheel rims. When computer equipment is hit by transients, it causes disruptive and destructive problems, as described above, even though filter devices are present to smooth noises.

Your car does have a suppressor to work with the shock absorber filters (see fig. 4). Up above the rear axle are two heavy hard rubber buttons (load limiters). These set a threshold or limit beyond which a pot hole-disturbed axle cannot go. That is suppression. Another suppressor is the large cement retainer walls that go down both sides of the freeway. As cars travel down the road (as electrons travel down a wire), these suppressors do nothing to smooth bumps. You know, however, if you try to transient off the road (voltage path) and hit the cement wall, you have been suppressed. Beyond that threshold you will not go.

How to Apply Suppression

A TVSS (transient voltage surge suppressor) device should be installed at each "change of voltage point" within the A.C. distribution system. This allows the inductance of system transformers to work with TVSS devices to achieve tighter clamping and, with some hybrid TVSS, achieve better filtering as well. Also, a "local TVSS" should be placed at the system being protected to stop transients induced onto lines along the same power branch circuit. These are smaller TVSS devices, needed because 65 percent of all transients are generated by equipment within the building. If this scheme of installation is not possible or not cost justifiable, then a single TVSS device with series inductance and filtering built in should be applied at the sensitive system's A.C. power input.

Simple suppressors do not smooth distortions along the sine wave. Simple suppression components (see fig. 4) clamp or crowbar on a transient after the transient has exceeded the

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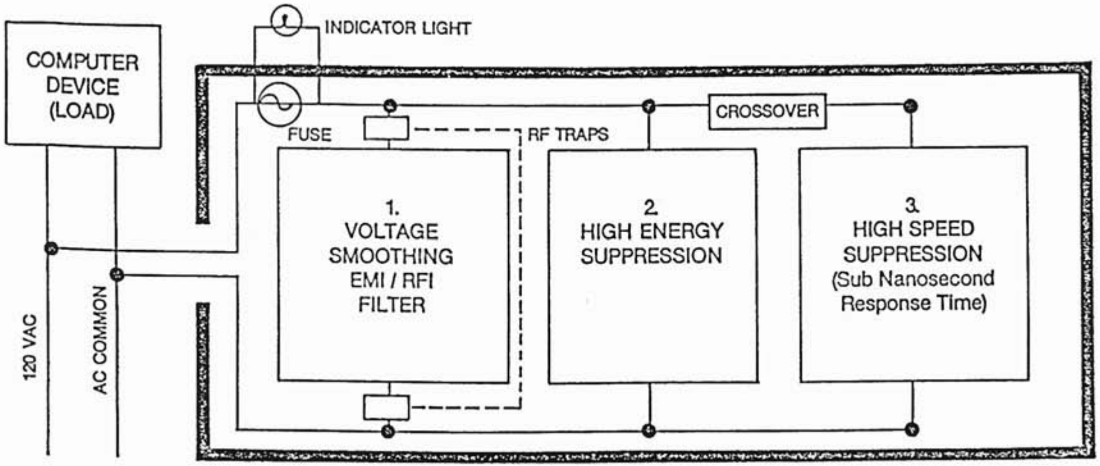
The Solution:
EFI Combination Protection

Figure 5



General block diagram of EFI, Inc., Suppression Network

nominal peak voltage of the sine wave. A threshold is set which triggers the suppression circuit or device. Transients are stopped at that threshold like hitting a cement wall. Some suppression devices crowbar or shunt the excess energy to ground, while a better technique is to clamp and force the voltage between A.C. Hot and A.C. Neutral to stay within thresholds by dissipating transient energy as heat within the TVSS and back along line side power wires.

Whereas individual suppression components each have limitations and strengths, this writer, as a power conditioning consultant, has been most successful by applying a line of hybrid suppressors which combine advantages of high-speed and high-energy suppression with highly capacitive EMI/RFI filtering, to most effectively eliminate transients. It is important to select a TVSS supplier with a complete product line of suppressing devices, including A.C. power plug strips (temporary power taps), dual outlet devices to cover duplex wall outlets, circuit breaker main panel and sub panel protectors, RS-232 line protectors, tip and ring telephone line protectors, data line protectors, 48 VDC line protectors, CATV and CCTV cable protectors, PC computer control center protectors, etc.

Key Capabilities or Specifications for a Good TVSS Network

1. Speed or response time (less than one nanosecond). Slower suppression devices will allow transient energy to pass by before they are able to respond.

2. Energy absorbing capability, maximum transient current (25,000 amps. for 20 microseconds).

3. Initial clamping voltage of 15-20 percent above normal peak voltage (140 VRMS or 200 V Peak for nominal 120 (V.A.C.), and maximum clamping voltage of no more than double the initial clamp volts.

4. EMI/RFI voltage smoothing filters should also be incorporated into the network of high-speed and high-energy suppressors to kill harmonic ringing, which is sometimes generated as the transient is clipped off to a low amplitude, high energy, square wave (See fig. 4 and fig. 5).

Good Grounding

Although not a power conditioning device, good grounding is definitely recommended to improve performance of any and all types of power conditioning equipment being used. Over the years, we have made earth ground a common reference for all power systems. This was necessary for several reasons, foremost being personnel safety against shock hazard. Metal equipment cabinets and equipment casings are all electrically bonded to earth ground, zero volts, to avoid shock when these exposed conductive surfaces are touched. When noise induces itself into these and other conductive surfaces, the noise will have less chance of getting into the electronics, if an excellent connection to ground is present to drain noise. This keeps common mode noise levels low by providing a short circuit to voltage source common, zero volt reference. Grounding will not, however, prevent disruptions on the A.C. power lines from rippling through electronic equipment. If transient suppressors and filters are well grounded, they will be more efficient. The best grounding connection would be a heavy, continuous ground line from the computer all the way back to electrical service ground connection. Local ground rods should have less then 3 Ohms resistance through ground back to service entrance or electrical system common ground. If local ground rods or building steel grounds are used, they should connect to the transformer output neutral "ground tie point" and not to metal cabinets, nor to water pipes. This will eliminate common mode problems and avoid ground loop currents.

Dedicated Lines

A dedicated line also is not a power conditioning device but should be mentioned here because it is so widely used and often expected to perform as a "cure all" for computer and electronic equipment problems. A dedicated line is nothing more than a separate power line brought directly from a power distribution panel to the electronic system in question. What this does is avoid the possibility of common mode problems between neutral and ground and avoids power disruptions caused by other pieces of equipment on that same line. It does not, however, stop transients coming from the utility company lines, Mother Nature, or other equipment fed by the same power distribution panel.

(continued on page 29)

Get Your Company Onto Clean Power

So how do I get started? How can all this be implemented within my building power systems, computer facilities, or within my industrial robots, CNC machines, PLC Controls and process controllers?

First: Adopt the insert "Power Specification" as part of the company policy for existing and for future systems. (For a free, more complete specifications dealing specifically with industrial controllers and one dealing specifically with computer building facility power, contact the authors.)

Second: Start with equipment or facilities that may now be suffering from power problems. Alter or add power conditioning to adhere with the insert "Power Specification." Document the improvements as justification of expenses to implement this pi network protection method on all computer and electronic equipment.

Third: If your engineers are pressed for time or would like guidance in implementing the power specification in complex facilities or systems, a concept seminar and consulting survey are available by contacting the authors.

Fourth: Enforce such power specifications so that all future facilities and equipment will be protected as they are built or upon installation.

Summary

New computers, office equipment and electronic control systems are far more intelligent and powerful, in much smaller packages, than only ten years ago. They are, however, vulnerable to malfunction and failure during power glitches and lightning storms. Inexpensive TVSS protection can be installed, which will convert commercial grade power to computer grade power. This concept has been proven in many Fortune 500 companies to eliminate 90 percent or more of computer and automation controls malfunctions and failure. With the cost of downtime so high and maintenance being one of the highest overhead expenses in most company budgets and with computers and electronic systems at the very heart of our productive capability, this is one of the most cost-effective and positive steps that has been taken by the many companies which have worked with the authors during the past five years. ■