

MEDICAL ELECTRONICS

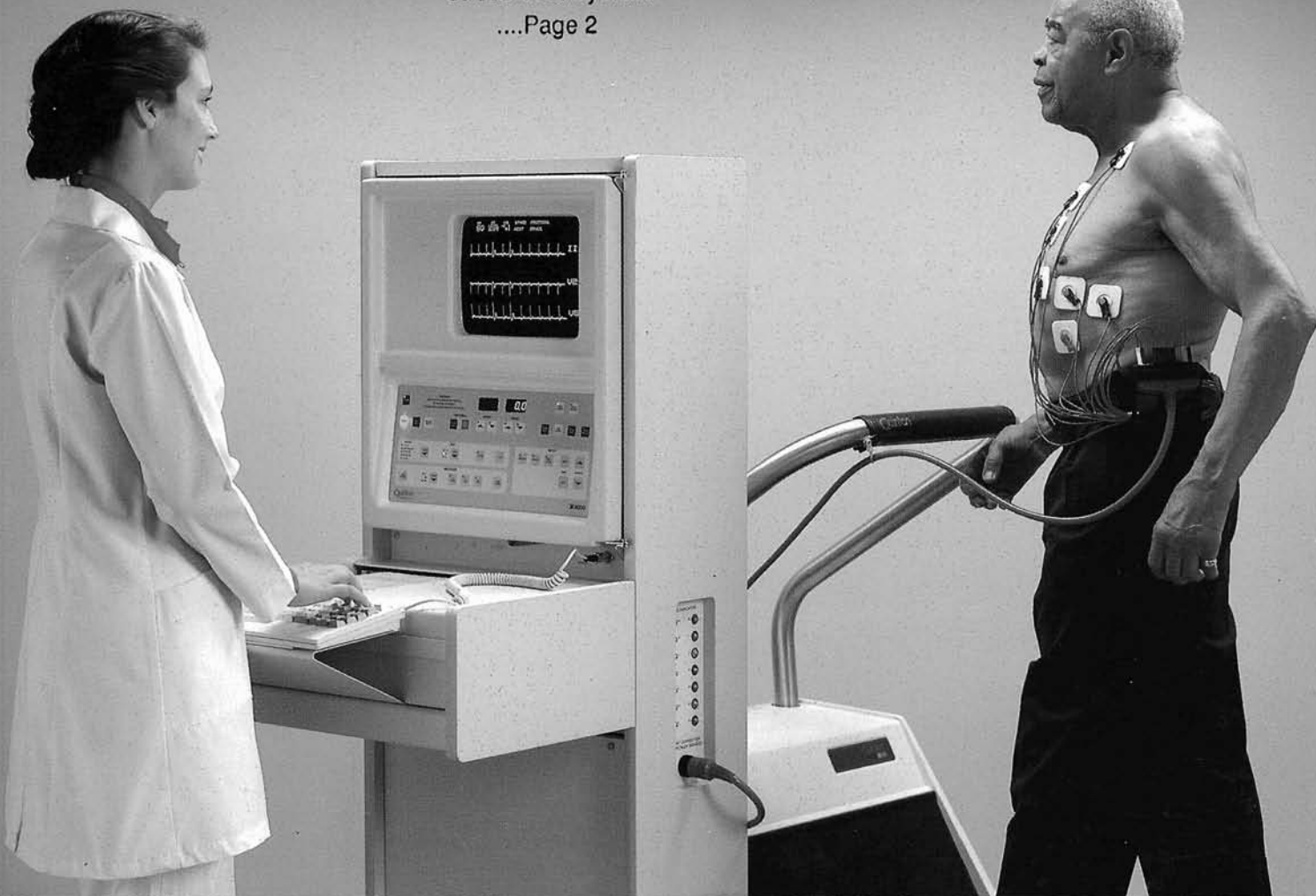
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POWER PROTECTION

As computers, office equipment and electronic control systems become more powerful yet smaller, they become increasingly more vulnerable to malfunction due to power-line disturbances and glitches. Fortunately, inexpensive TVSS (Transient Voltage Surge Suppression) protection can convert commercial-grade power to computer-grade power. With cost of downtime and maintenance so high, and with computers and electronic systems at the heart of our productive capability, the protective Power Specifications for any facility are the keys to cutting costs, increasing productivity, and averting catastrophe.

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New power-conditioning technologies and methods have been introduced in recent years to accommodate and protect sensitive digital circuits from power-line disturbances (Figure 1). "Sensitive" circuits include large-scale integrated circuits (ICs), microprocessors and low-power CMOS chips, all of which are easily damaged or confused by "power glitches". Trying to operate computers, microprocessors, telephone switch equipment and industrial controllers on unprotected commercial-grade power often results in downtime, as shown by the following situations. These are all typical, yet could have been avoided by new, inexpensive line conditioning.

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. Circuit-board failures and security-system malfunctions were not confined to lightning storms; at times, they would occur during "clear blue skies." After prisoners caught on to the situation, they were ready when a storm came: The doors opened, and amid the confusion, five prisoners escaped. A power-protection survey of security and control systems throughout the jail yielded a protection plan for the facility. The total cost of solving the problems was less than \$15,000, only a fraction of the losses incurred by an escape.
2. A major insurance underwriter was affected by lightning three times during its first summer of operation in a new computer facility, causing massive outages in the PBX phone system, the Building Management System microcomputers, and office computer terminals. Although a maintenance contract covered repair costs of the phone system, the insurance company estima-

ted business losses from downtime in the millions of dollars. They contacted the firm which had installed lightning-rod protection on the building. A consultant was called in. Result: the company installed a few grounding changes and proper transient-suppression equipment throughout the building at a cost of \$30,000. This was six years ago; no more problems have appeared to date.

TRANSIENT SUPPRESSION

What are transients? Where do they come from?

A transient is defined by IEEE as a fast rising over-voltage with a total time duration of less than one millisecond. Transients can rise to peak amplitudes of several thousand volts within a few nanoseconds, and decay within several microseconds. In IC chips, thousands of transistors, packed onto a 0.1" square chip, are expected to perform millions of operations per second, detecting voltage level changes between 0-5V. Transients that find their way onto the main 5VDC or logic lines can inject disruptive or destructive havoc. "Disruptive" refers to malfunctions that are temporary — the system often can be rebooted, reloaded with data, and then operate properly. On the other hand, a "destructive" effect destroys the circuit.

Lightning-protection associations such as ULPA and LPI, traditionally charged with installing or engineering lightning-rod fire-protection systems for buildings, now realize that "commercial-grade AC power" must be conditioned to achieve "computer-grade pow-

er". They specify that improved grounding techniques and transient-suppression networks be installed in all buildings with high densities of computers and other sensitive electronic equipment.

Advances in power-supply technology for computers and other electronic equipment have required corresponding changes in the technology needed to protect the sensitive equipment. In the 1970s, most DC power supplies were "series pass" or "linear" DC regulators (Figure 2). Today, however, 90% are "switch mode" (switching) DC regulators (Figure 3). Power-conditioning devices such as isolation transformers and regulation transformers that were appropriate for linear power supplies can hinder the ability of switch-mode power supplies to perform and regulate. A switching power supply needs a low-impedance, low-inductance power source because it draws short but sharp pulses of current to maintain regulated DC output. The switching regulator, which oscillates at 20-200kHz, can cause harmonic ringing, heating problems and poor current draw, especially when supplied by a ferroresonant magnetic transformer. It is strongly recommended by the Institute of Electrical and Electronic Engineers (IEEE) that ferroresonant regulation transformers not be used because they have been known to go into violent oscillations and destroy switching power supplies.

The switching power supply is much smaller, cheaper and more efficient than its linear predecessor, will operate over a wide input voltage range, and does not normally need a voltage-stabilized power source or an expensive power-conditioning transformer. Why is it, then, that most newer equipment with switching power supplies and high-density microprocessor design seem vulnerable to power glitches, transients and lightning storms? Can we cost-effectively protect against these problems?

The switching regulator power supply is, by design, a high-pass filter which allows high-frequency (fast-rise-time) transients to pass through to any following microprocessors, logic chips and sensitive circuitry. The solution is installation of hybrid transient-voltage surge-suppressors (TVSS), which work synergistically with building transformers and EMI/RFI filters to eliminate the high-frequency transients. Once these sharp 500-6,000V transients are removed, the switching power supply does an excellent job of regulating and providing stable power to all electronic circuits.

The circuitry used to do this is called "Pi-Network."

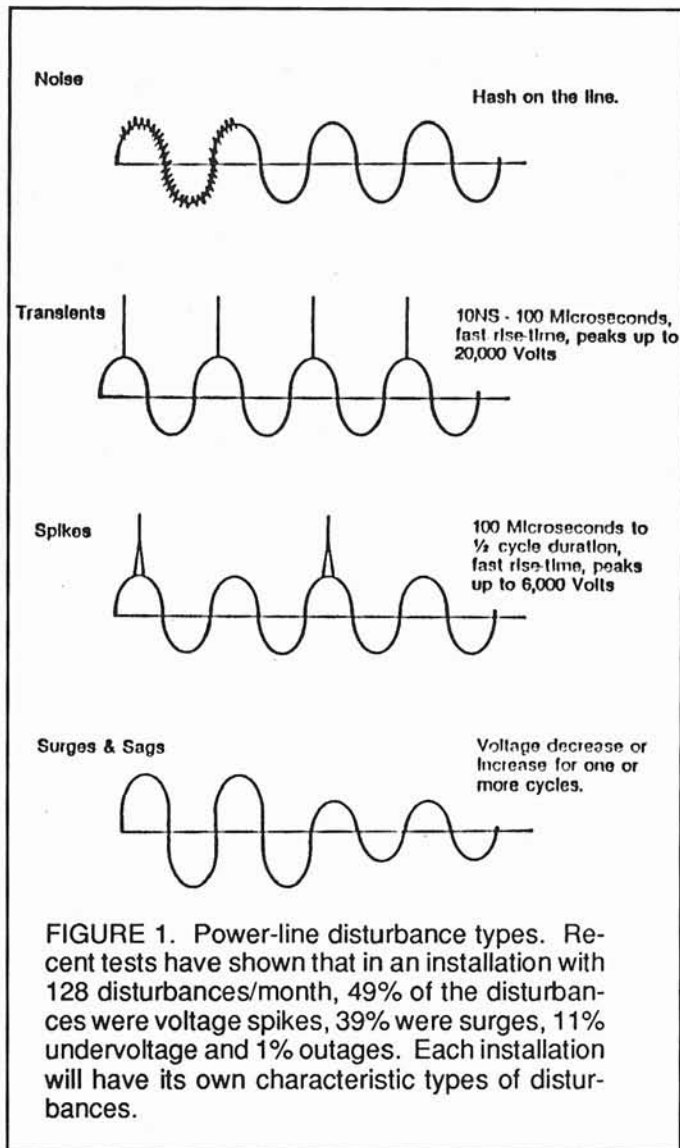


FIGURE 1. Power-line disturbance types. Recent tests have shown that in an installation with 128 disturbances/month, 49% of the disturbances were voltage spikes, 39% were surges, 11% undervoltage and 1% outages. Each installation will have its own characteristic types of disturbances.

POWER PI NETWORK CONCEPT

By using standard control transformers of 3-phase 480V to 120/208V building transformers as the inductive element between a primary hybrid parallel suppressor and a similar secondary suppressor, a pi-network power-filter/suppressor conditioner is formed. The suppressor — like common MOV clamp-only or crowbar-only devices — is a Hybrid Protector that provides high-speed clamping, high-energy clamping and high capacitive EMI/RFI filtering. Transients are clamped by the primary suppressor and then treated as noise by the capacitive EMI/RFI filter and the transformer inductance and the secondary capacitive EFI suppressor. The result is a pi network that is superior to constant-voltage or isolation transformers, as well as more economical in initial cost, and providing a more

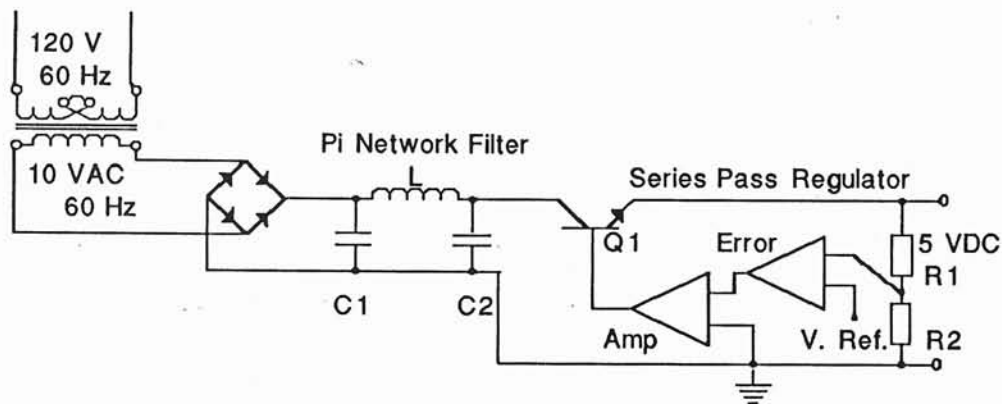


FIGURE 2. Regulated series pass or linear power supply, commonly used in the 70s and 80s. Regulation transformers could be used with this circuitry. The "Pi" (C-L-C) network is only for noise filtering (no suppression).

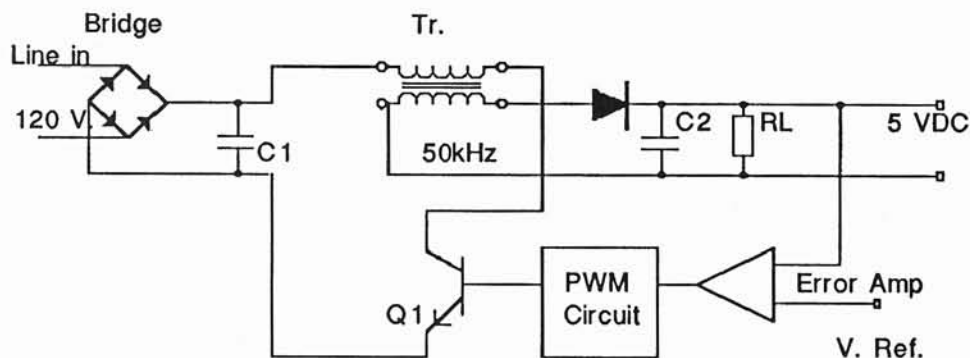


FIGURE 3. Switching power supply can be damaged by regulation transformers used in older linear supplies.

efficient and dependable system. The pi network eliminates high-frequency transients that would normally pass through switch-mode and series-pass DC power supplies, possibly disrupting sensitive electronic devices.

Properly grounding the transformer secondary-neutral output to AC GREEN Wire Ground according to N.E.C. (National Electric Code) will help eliminate common-mode noise problems.

Transient suppression is now recognized by organizations such as the FCC, IEEE, NIST, IBM, etc., as the cost-effective way to reduce power-line problems with computers and sensitive circuitry. Standards have been published by several of these organizations, setting test and evaluation standards and means for proper protection:

1. The FCC Industrial Voltage Transient Withstand Standard.
2. IEEE-587 and ANSI C62.41 Reports, which cover applications and outline four transient waveshapes for testing protectors.
3. UL-1449, by which Underwriters Lab evaluates transient suppression.

Purchasers of power-line conditioning equipment can use these guidelines and standard transient voltages to compare the performance of various suppressors.

STANDARD TEST WAVEFORMS

"Mother nature" generates transients of all sizes and shapes but, for testing and comparing transient-suppression equipment, we must have standard transient waveshapes.

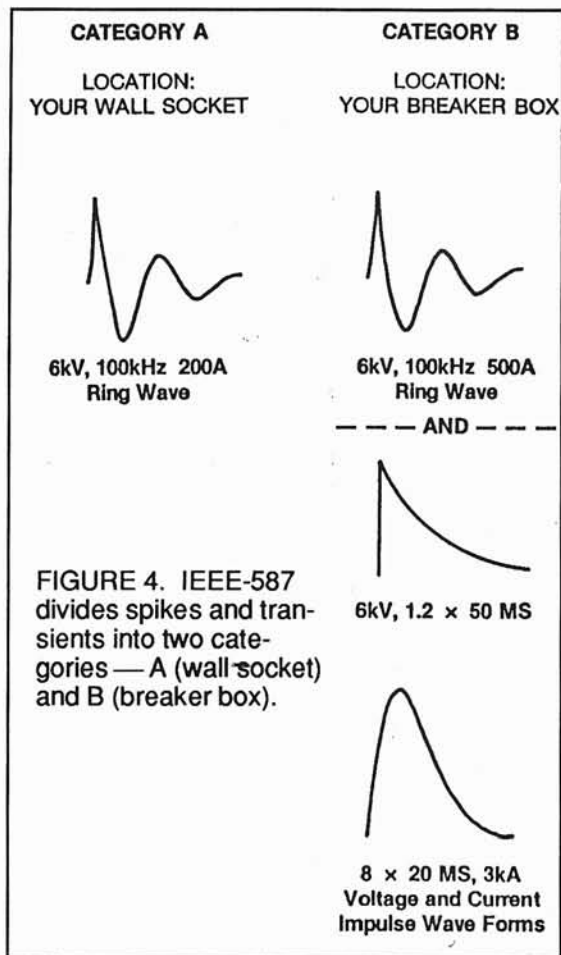


FIGURE 4. IEEE-587 divides spikes and transients into two categories — A (wall socket) and B (breaker box).



FIGURE 5. Generator of standard waveshapes (courtesy KeyTek).

IEEE Standard 587-1980 and ANSI C62.4 outline four waveshapes (Figure 4) to represent transients detected at wall sockets or circuit-breaker cabinets feeding electronic equipment. They are: (1) Category A ring-wave, 6000V, 200A, oscillating at 100 kHz; (2) Category B ringwave, 6000V, 500A, oscillating at 100 kHz and (3) Category B 6000V single-impulse, 1.2 x 50 microseconds which, if shunted through a low-impedance or short circuit, will produce (4) a 3000A current surge of 8x20 microseconds. IEEE and other groups are continuing studies and other standard waveshapes may be introduced.

ANSI C62.41 Standard Transient Generators (Figure 5) are available for testing comparative performance of surge suppressors.

Transients have always existed, but only recently, with digital and IC devices highly affected, have they become a serious concern because of the high costs of destructive downtime.

COST OF DOWNTIME

Table 1 tabulates the costs associated with downtime. The cost of downtime for a small

company computer or a single process controller can be from \$50-\$500 per hour.

In a manufacturing environment using FMS Cells or Just-In-Time (JIT) Cells, this cost can be \$3000-\$9000/hr.

On a large JIT manufacturing line, the cost can be \$300,000-\$500,000/hr.

Downtime can lose lives in medical or military situations. One ship captain left his PHALANX defense system off because he knew shipboard power transients caused problems. When an attack came, there was no time to turn on PHALANX and lives were lost ("60 Minutes" interview Sept. 1988).

POWER CONDITIONERS — ANALOGY TO AUTO SHOCK ABSORBERS

There is a good analogy between surge suppressors and shock absorbers on a car (Table 2). The "shocks" average or smooth bumps, attenuating or reducing road noise. But when a car hits a large pot hole, the shocks do little toward smoothing the huge bump. Both the large pot hole and huge voltage transient can saturate the energy-smoothing capability of a shock absorber or filter and transformer, forc-

TABLE 1 — COST OF DOWNTIME

<u>SYSTEM TYPE</u>	<u>COST</u>
Small company computer, CNC machines, PLCs, robots, process controllers, hospital equipment.	\$50-\$500/hr.
FMS Cells, Just In Time (JIT) Cells in manufacturing environments, larger business computer or controls.	\$3000-\$9000/hr.
JIT manufacturing lines such as in auto manufacturing & factories	\$300,000-\$500,000/hr. (or \$7000-\$9000/min.)

ing its way through the whole system. In the case of a pot hole, the problem could be "disruptive", causing the car to swerve — or the problem could be destructive, causing the front end to go out of alignment, bending wheel rims or causing a crash. The same is true of an electrical surge situation.

Your car shock has "suppressors" that work with shock-absorber "filters"; above the rear axle are two hard-rubber buttons — load limiters which set a threshold or limit beyond which an axle cannot go. A power-line conditioner similarly should have both filters (for small disturbances) and suppression (for larger transients).

HOW TO APPLY SUPPRESSION

A transient-voltage surge-suppressor (TVSS) device should be installed at each change-of-voltage point within the AC distribution system (Figure 6). This allows the inductance of system transformers to work with TVSS devices to achieve tighter clamping and, with some hybrid TVSS, may also achieve better filtering as well.

A local TVSS should be placed at the system being protected to stop transients induced onto lines along the same power branch circuit. These smaller TVSS devices are needed because 65% of all transients are generated by equipment within the building. If this scheme of installation is not possible or cost-justifiable, then a single TVSS device with series inductance and filtering built in should be applied at the sensitive system's AC power input.

Simple transient suppressors do not smooth distortions along the sine wave. Most transient suppressors (MOV, Zener, gas tube, etc.) clamp or crowbar a transient only after the transient exceeds some nominal threshold voltage. This is one reason why hybrid suppressors, which contain various suppression devices with compatible filter devices, yield

TABLE 2 — ELEMENTS OF FILTERS & SUPPRESSORS

<u>FILTERS</u> (Shock Absorber)	<u>SUPPRESSORS</u> (Clamp or Retainer Walls)
LC Network RC Network Isolation Transformers	Arc Gap Gas Tube MOVs Zeners SCRs Triacs Switched Darlington

much better results in protecting electronic and computer equipment.

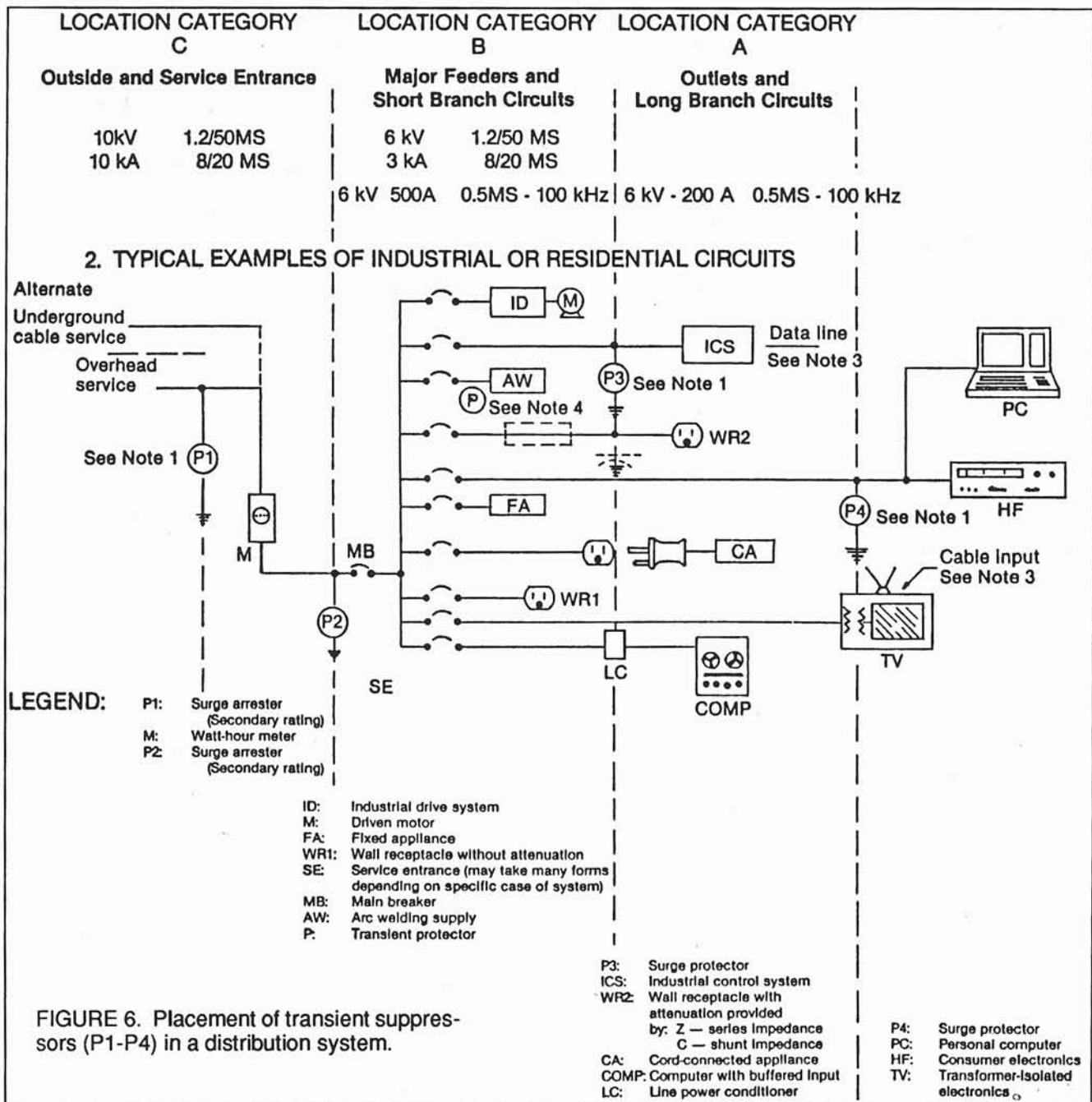
Some crowbar (shunt) the excess energy to ground. A better technique is to use clamping, rather than crowbaring, suppression and to clamp excess energy from line to neutral rather than line to ground. It is line-to-neutral voltage that directly powers all electronic power supplies in computer equipment. Line-to-neutral suppression is known as normal-mode protection. Neutral-to-ground and line-to-ground suppression is known as common-mode protection. Common-mode protection is advantageous in some applications.

Each type of transient suppression component has its limitations and strengths. One successful line of hybrid TVSS, recommended by the authors, combines the advantages of high-speed and high-energy suppression with highly capacitive EMI/RFI filtering.

It is important to select a TVSS supplier with a complete line of suppression devices including: AC-power-plug strips (temporary power taps), dual-outlet devices to cover duplex wall outlets, circuit-breaker main-panel and sub-panel protectors, RS232 line protectors, tip and ring telephone-line protectors, data-line protectors, 48VDC line protectors, CATV and CCTV cable protectors, PC control center protectors, etc. As shown in Figure 6, different types are needed at different points and for different situations.

Specifications for a good TVSS network should include:

1. Speed (or response time) less than one nano-second; slower suppression devices will allow transient energy to enter the sensitive circuitry.
2. Energy-absorbing capability should include maximum transient current of 25,000-70,000 Amps for 20 microseconds.
3. Initial Clamping Voltage should be 5-20% above instantaneous phase angle (called sine-wave tracking).



4. EMI/RFI Voltage-Smoothing Filters should be incorporated into a 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. Figure 7 shows an EFI combination protection system.

GROUNDING

The best grounding connection would be a heavy, continuous ground line from the computer all the way back to the electrical service-entrance ground connection. 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 cabi-

nets or water pipes. This will eliminate common-mode problems and avoid ground-loop currents.

DEDICATED LINES

A dedicated line is not a power-conditioning device, but should be mentioned because it is widely used and often expected to perform as a "cure-all" for computer and electronic equipment problems. A dedicated line is simply a separate power line brought directly from a power distribution panel to the electronic system in question. This does avoid the possibility of common-mode problems between neutral and ground, but it does not stop

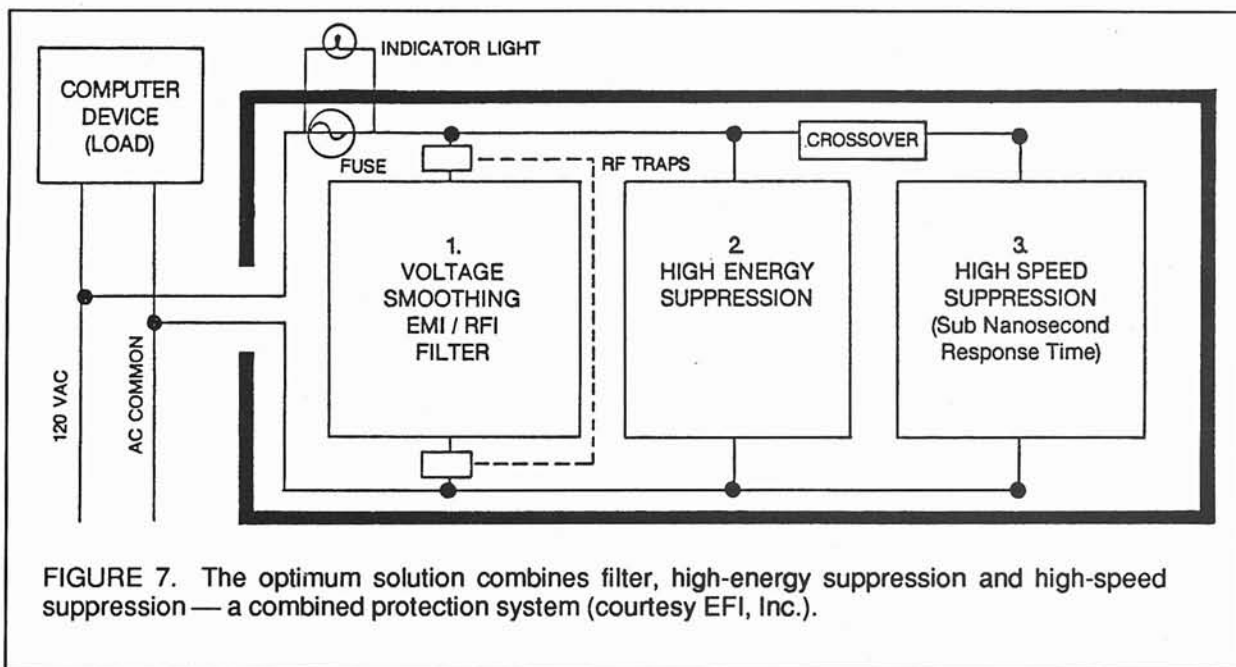


FIGURE 7. The optimum solution combines filter, high-energy suppression and high-speed suppression — a combined protection system (courtesy EFI, Inc.).

transients coming from the utility company lines, mother nature, or other equipment fed by the same power-distribution panel.

CLEAN POWER

The following rules will help obtain clean power within a particular building, computer facility, manufacturing system or process:

FIRST: Adopt a power specification policy as part of company procedure for existing and for future systems.

SECOND: Start with equipment or facilities suffering from power problems. Alter or add power conditioning to adhere with the "Power

Specification." Document improvements as justification of expenses to implement network protection 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, consulting surveys or seminars are available—contact the authors at the addresses given at the end of this article.

FOURTH: Enforce the Power Specifications so that all future facilities and equipment will be protected as they are built or installed. □



HOWARD C. COOPER owns his own consulting firm (AMEMCO), where he develops protective and electronic maintenance programs. Mr. Cooper has a BS degree in Electronic Technology from Southern Utah State, graduating Magna Cum Laude, and has done graduate work at Brigham Young University. He has presented papers at national conventions for the Society of Manufacturing Engineers, American Society of Hospital Engineers, the United Lightning Protection Association and in trade magazines. He has aided on the IEEE-587 Subcommittee. He can be reached at 697 North 700 East, P. O. Box 211, Kaysville, UT 84037-0211, 801/544-9999.

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The Power Specification paper "Pi Network Method" is available from the authors.