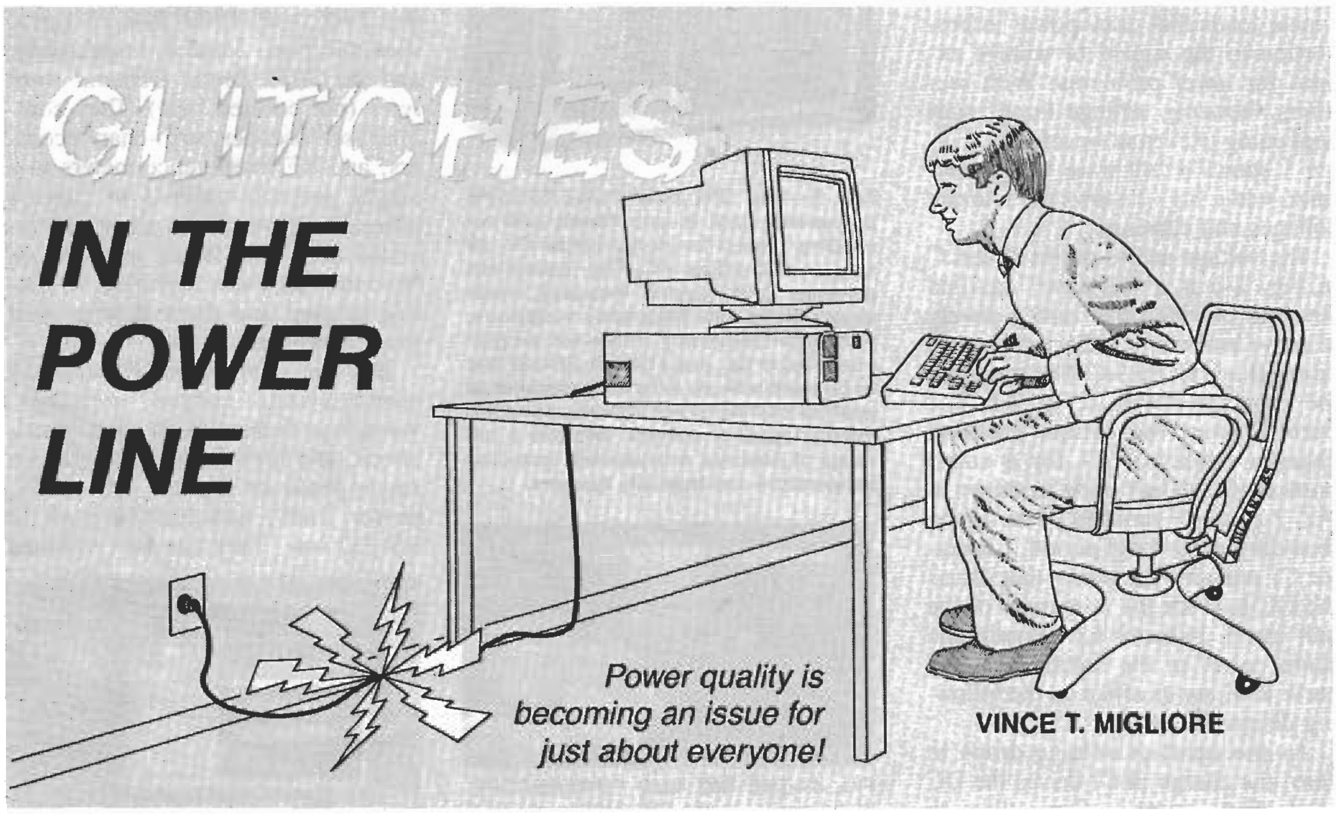

THERE'S A GLITCH IN YOUR POWER LINE and it's going to find you. Imagine that you're right in the middle of saving a file on your PC, or recording a program on your microprocessor-controlled stereo or VCR, and a power-line glitch causes the system to reset. Why? You may never even attempt to find out if it happens only once every month or two, but you should.

In business and industry, the problem becomes more than an inconvenience. Computers, communication devices, sensitive medical instruments, chemical processes, and the like, can succumb to power-line disturbances. A power problem can spell disaster for a small business who can't find a solution.

Power problems can be especially frustrating for the electronics hobbyist. Even you, the solitary electronics buff, can be glitched at home. Your PC boards may burn out for no obvious reason, your PC data may be scrambled, your 10-meter transceiver may run hot, your VCR or stereo may drop dead, and the lights may dim when your refrigerator's compressor turns on. Knowing the causes and cures of power-line disturbances is valuable, technically and financially. You don't have to be a research scientist or utility engineer to discover glitches and take action against them.

The most common way to clean up the power lines is to rely on surge suppressors. But clean power means more than no impulses. It also means eliminating any voltage sags, outages, impulses, surges, frequency errors, harmonics, grounding problems, high-frequency noise, waveshape faults, or RF interference.

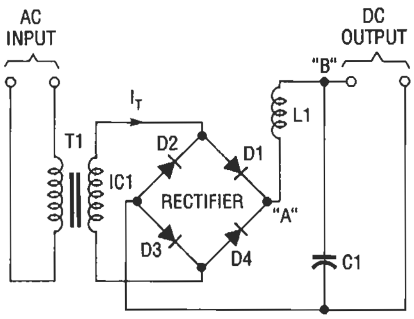

FIG. 1—TYPICAL BRIDGE RECTIFIER, with voltage waveform shaped by an LC filter network. If only a pure resistive network were connected across points *A*, the waveform shown in Fig. 2-*a* would be seen with the aid of an oscilloscope.

Causes

Contrary to popular opinion, the vast majority of power problems aren't caused by power utilities, but by their customers. Occasionally, albeit rarely, utilities are at fault, like when distribution loads are switched, or when large power-factor-correction capacitors kick in. Sometimes lightning or a car can hit a power pole, wreaking havoc with power lines. Such an interruption, if miles away, may not make your lights blink, but the resulting power line hash can blow your PC. Most often, however, transients can travel along a power line from other customers, especially if you're near an industrial area. Major offenders are arc welders or electric-train yards.

However, the above are exceptions, and maybe 95% of disturbances are caused by either home equipment, or faulty or inadequate home wiring. Most utilities bend over backwards to locate problems on their end like low voltages, distribution or switching faults, or line harmonics. Sometimes they'll even attach a monitor or strip-chart recorder to your meter to help find a problem.

Harmonics

One of the most common AC power problems is harmonic distortion, or the unwanted generation of power-line voltage components at frequencies that are multiples of 60 Hz. Linear loads that draw power in proportion to the square of voltage exhibit far fewer problems. With rectifiers, however, strange things start happening to current waveforms. Figure 1 shows a full-wave bridge rectifier, while Fig. 2 shows the relevant voltages and currents.

The voltage across points A and C in Fig. 2-*a* is a full-wave, rectified sinusoid provided that only a purely resistive load were connected. Across points B and C, the LC filter produces the waveform shown in Fig. 2-*b*. The current from the bridge rectifier charges capacitor C1 for a small portion of each half cycle as shown in Fig. 2-*c*, and it supplies power to the load during that brief period. Capacitor C1 provides the power that drives the DC load for the remainder of the half cycle. Inductor L1 smooths the sharp points in the rectified voltage curve at *b*, but its effect on the following discussion is nil.

As the rectifier voltage drops to zero, the charge in C1 drives the DC load. Thus, current flows through transformer T1 for only a small portion of the sinusoid, as shown in Fig. 2-*c*, driving the DC load and recharging C1, so the energy is concentrated in short pulses. This pulsed current generates harmonics, making a transformer run hotter than it would for a pure 60-Hz sinusoid with RMS power identical to that of the corrupt sinusoid *with* its harmonics. This is because the magnetic domains reverse polarity more rapidly than for the pure sinusoid, owing to the harmonics, heating the transformer core.

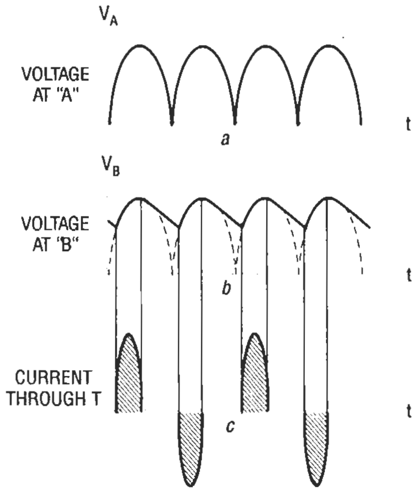

FIG. 2—VOLTAGE AND CURRENT WAVEFORMS at different points in the power supply. At (*a*) is the voltage *exiting* the bridge rectifier, presuming either a resistive load or no load at all, instead of the LC filter; at (*b*) is the voltage exiting the LC filter, and at (*c*) is the current drawn through the transformer.

FIG. 3—THE BMI *2400 POWERSCOPE* power-transient measurement and recording system for single-phase DC, or single- or 3-phase AC. The instrument monitors sags, surges, impulses, waveshape faults, line-frequency variations, and high-frequency noise for single-phase AC or DC, has a built-in RS-232 bus to be used with an external processor to analyze total harmonic distortion and frequency spectral content, and has a full range of available accessories, including temperature and humidity sensors.

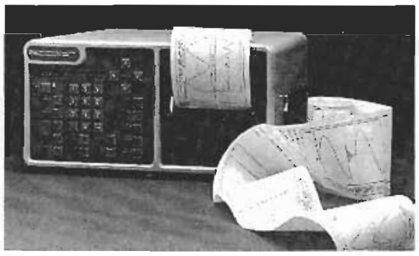

FIG. 4—THE BMI *4800 POWERSCOPE.* While similar to the BMI *2400* in physical appearance, it has considerably more processing power, with up to four main and eight probe channels.

The bridge rectifier shown in Fig. 1 is waning in popularity, although harmonic generation is identical for more recent versions. Most computers and hi-tech gear now use switched-mode power supplies; those varieties are highly nonlinear and a major source of harmonics. If several loads are on one circuit, expect hot motors and transformers. In short, if you're serving up hash, everyone at the table tastes it!

Latest instrumentation

Power-line monitors range from simple beepers or lights that tell you when line voltages and/or currents are out of range, to printing versions that record values numerically and graphically. Two major manufacturers of such gear are *B*asic *M*easuring *I*nstruments or BMI (335 Lakeside Drive, Foster City, CA 94404, 415-570-5355), and Dranetz Technologies (1000 New Durham Road, Edison, NJ 08818, 201-287-3680 or 800-DRAN-TEC).

BMI has three major instruments, the *2400* and *4800 PowerScopes*, shown in Figs. 3 and 4, respectively, and the *3030 Power Demand Analyzer* (not covered here). They combine oscilloscopes, strip-chart recorders, and RF interference meters in a single portable cabinet to capture transients varying from a few milliseconds to several hours in duration. Note the calculator keyboard, single-line display, and thermal strip-chart graphic printers on each.

Both versions of the *PowerScope* monitor sags, surges, impulses, waveshape faults, line-frequency variations, and high-frequency noise for single-phase or 3-phase AC or DC power lines, and have a built-in RS-232 bus. They can be combined

FIG. 5—THE DRANETZ *SERIES 901 POWER HARMONIC ANALYZER,* similar to a BMI *2400*. In one printout for a instant in time, the device records line voltage, the current used, total power, power factor, harmonic power, fundamental power, and a breakdown of the power in the individual harmonic frequencies above the fundamental (in other words, its spectral content).

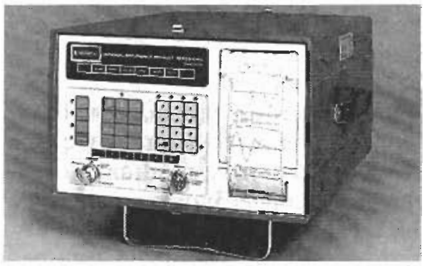

FIG. 6—THE DRANETZ *SERIES 626G* Universal Disturbance Analyzer, similar to a BMI *4800*. This device has several add-on modules that increased the scope of the unit with event monitors.

FIG. 7—THE DRANETZ *SERIES 656* Disturbance Waveform Analyzer. Note the built-in CRT, full keyboard, dual floppies, and thermal printer.

with the A-600 *Parallel Processor* to analyze total harmonic distortion and frequency spectral content (such as in the BMI *2460*), and have a full range of accessories, including temperature and humidity sensors.

The BMI *4800* does everything the BMI *2400* does, but has more processing power. Whereas the BMI *2400* has two main and four environmental or probe channels, the BMI *4800* has up to four main channels and eight probe channels. Both models can be configured to take measurements every 1, 3, 6, 12, or 24 hours, and can do both high-resolution graphics, strip-charts, and text summaries, the sole exception being that the BMI *2400* can't do high-resolution graphics using the probe channels—only the main ones.

The Dranetz Technologies gear is comparable in scope and complexity to that from BMI. Their *Series 901 Power Harmonic Analyzer*, shown in Fig. 5, is comparable to the BMI *2400*, and the *Series 626 Universal Disturbance Analyzer* shown in Fig. 6 and *DRAN-SCAN Multipoint Power Monitoring and Analysis System* (not shown) are comparable to the BMI *4800*.

The Dranetz *Series 656 Disturbance Waveform Analyzer* shown in Fig. 7 has a built-in CRT and full keyboard, two floppy disk drives, and internal thermal printer. Their *Series 800 Electric Power/Demand Analyzers* (not shown) are also available, and are similar to the BMI *3030*. Both BMI and Dranetz also have *extensive* power analysis software for any external controllers used with their monitoring instruments.

Typical power-line disturbances

The graphs shown in Figs. 8–12 were made using BMI gear, and those shown in Figs. 13-16 were made using Dranetz gear; they're of similar format. The user selects thresholds and monitors power. Whenever an impulse, voltage sag, or other disturbance occurs, it's graphed as shown in Figs. 8 and 9. Note that the sinusoidal peaks are somewhat flattened where current or voltage reaches a local maximum. If switching loads change a waveshape, that too is recorded. Fortunately, most disturbances have characteristic "signatures." Figure 10 shows a typical motor starting-voltage sag; the in-rush current drops the voltage to 84.5 volts RMS.

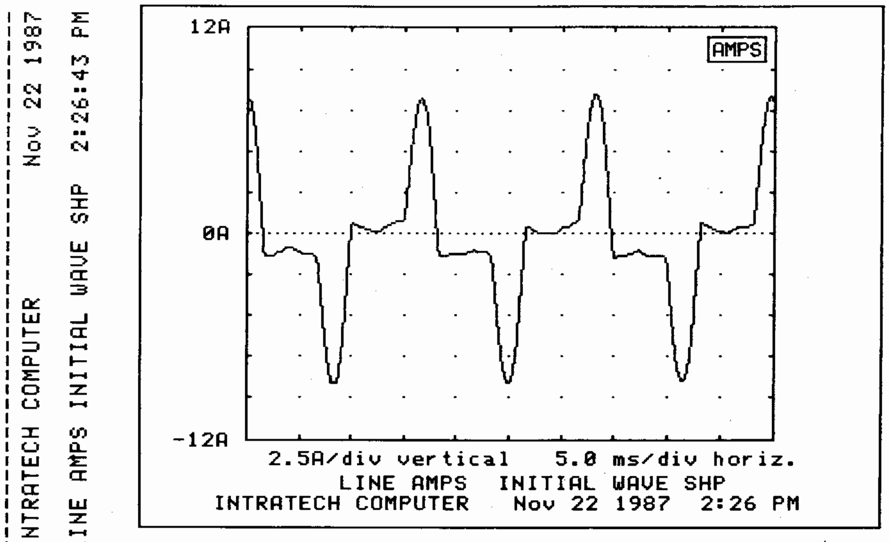

FIG. 8—BMI-GENERATED INITIAL WAVESHAPE REPORT for current for a circuit. Note that the current is drawn in pulses that could seriously compromise the operation of delicate instruments operating on the same or a nearby power line.

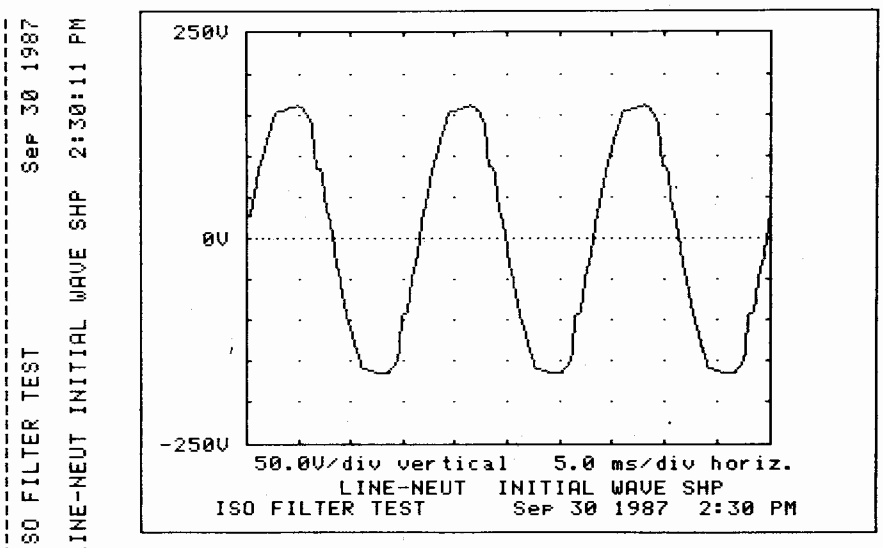

FIG. 9—VOLTAGE WAVEFORM IN A CIRCUIT with harmonics. The voltage sinusoid is distorted at positive and negative peaks, where current flow is maximum.

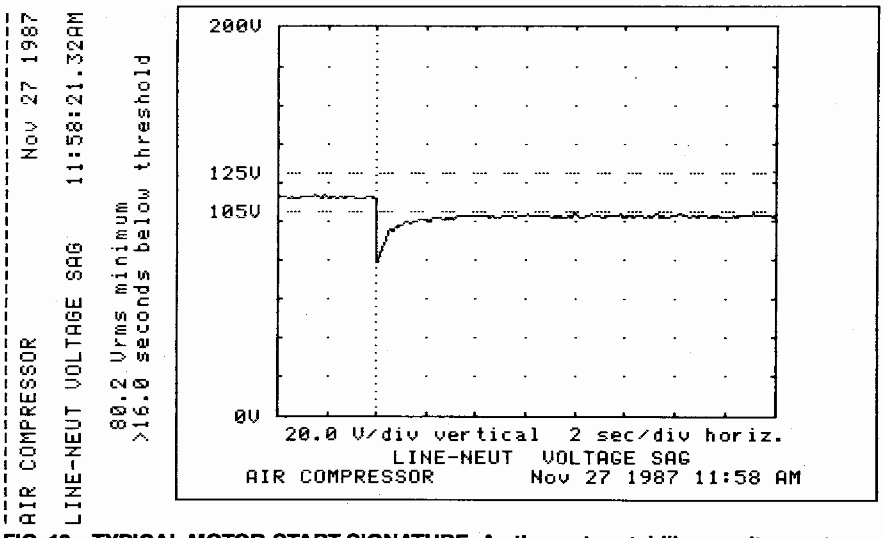

FIG. 10—TYPICAL MOTOR-START SIGNATURE. As the motor stabilizes, voltage returns to normal.

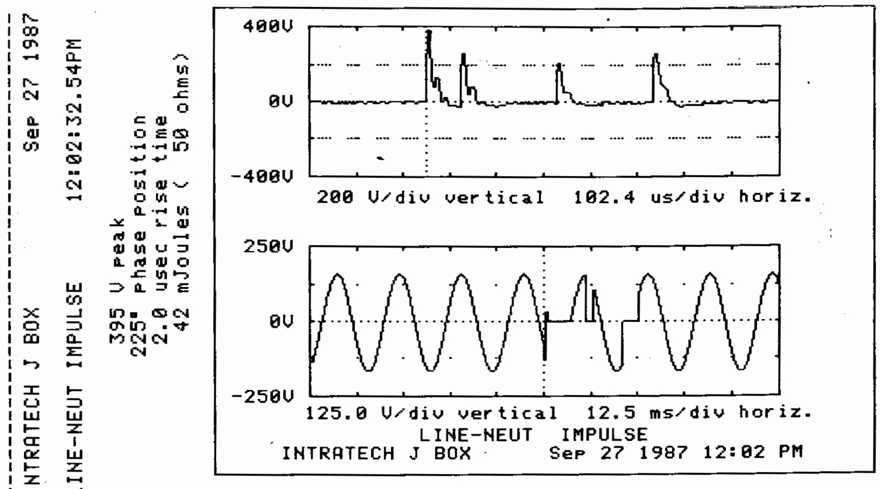

FIG. 11—IMPULSES DUE TO LOOSE WIRING. Sharp- edged dropouts on the sinusoid indicate that the problem is nearby.

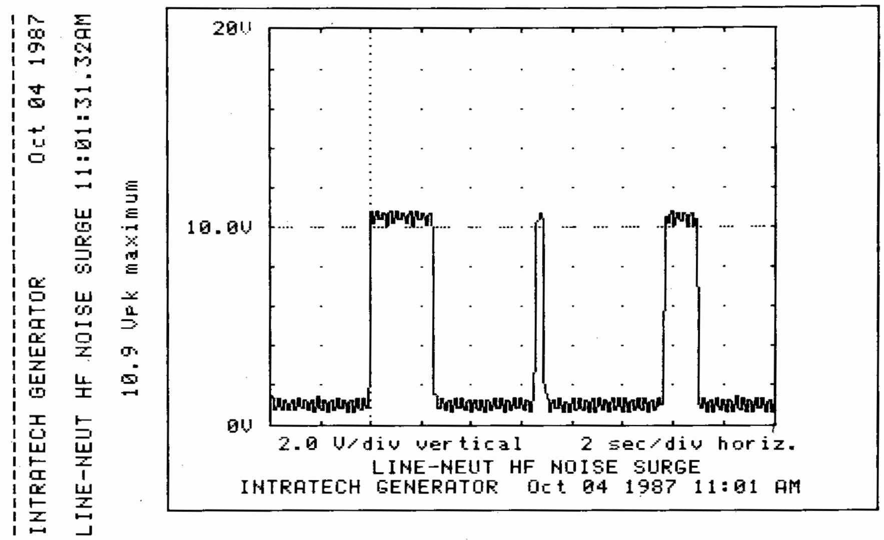

FIG. 12—VOLTAGE SURGES CAUSED BY HIGH-FREQUENCY NOISE. Note the 10-volt peaks that may ride through a power supply to damage memory and program chips in a computer.

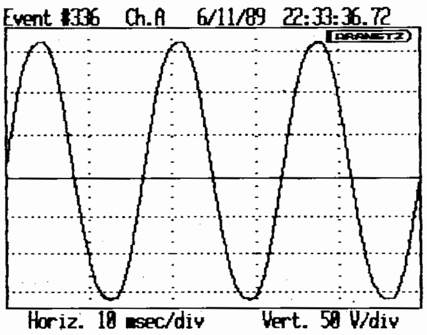

FIG. 13—A NORMAL POWER SINUSOID. The time was 11:33 P.M., when most heavy industrial machinery isn't powered.

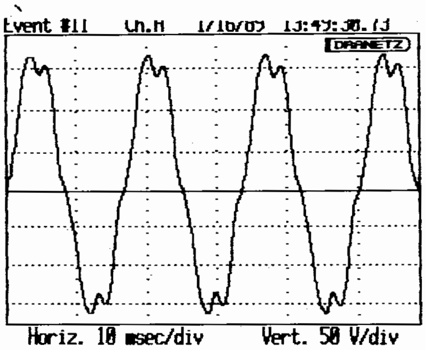

FIG. 14—HARMONIC DISTORTION. This graph was taken at 1:49 P.M. at the same site as that in Fig. 13.

When the motor stabilizes, the voltage returns to near-normal; the low threshold was 105 volts. The potential was below 105 volts for 1.2 seconds, enough to make a computer lose data, shut down, and reboot. If you found that disturbance on a line with sensitive equipment, you'd move the motor to another circuit. A common problem in amateur radio shacks and utility communication gear are impulses due to loose wiring; a typical signature is shown in Fig. 11. The top part shows four impulses. The lower part shows how the voltage dropped out and returned a few times

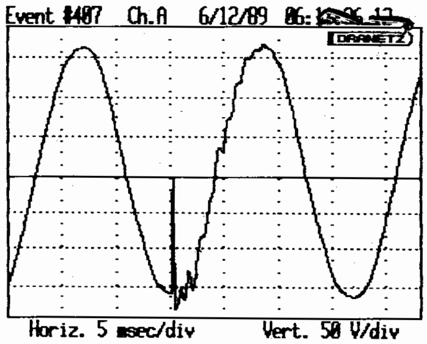

FIG. 15—A POWER GLITCH. Just imagine what the added pulse would due to a counter circuit.

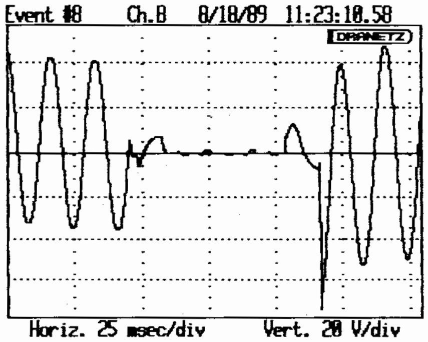

FIG. 16—A BRIEF POWER OUTAGE. Just imagine what this would do to your PC's memory!

over a couple of cycles.

Note the sharp transitions, indicating loose wiring nearby. Had the disturbance occurred farther away, the transitions would've been slower, smoother, and less well-defined, as a result of impedance encountered as the impulse propagated. Power-monitor graphs sometimes need interpretation, but are fairly interesting, and expand your knowledge of power-line problems.

Figure 12 shows bursts of line-to-neutral high-frequency noise, in this case RF interference, while transmitting the letter "K" in Morse code (dah-di-dah) from an amateur radio shack. High-frequency noise is common in such settings, but can also be caused by a CB radio, walkie-talkie, or taxi transmitter. You should check your own transmitter, if you have one, for both neutralization and shielding. The disturbance shown here is only 10 volts, but digital logic circuits work on 5 volts DC. If RF interference can induce 10 volts on a power line, such a level can wreak havoc with even otherwise well-shielded computers or instruments.

Some other waveforms, acquired from Dranetz gear, are shown in Figs.

Continued on page 52