JOHN FRYE

Mac and Barney discuss the frequency, amplitude, dangers, and control of random voltage surges as a storm rages outside.

Taming Transients

IT was a hot, muggy, July afternoon. Even before lunch Mac and Barney had noticed characteristic lightning-caused flashing on the screens of the TV sets on which they were working, and now at one-thirty the sun disappeared behind dark anvil-shaped clouds towering in the southwest and the earth shook with the growl of distant thunder.

"That does it," Mac said as he pulled the big switch that completely disconnected all test equipment and service bench outlets from the line. "I know this will probably break your industrious heart, but we'll take a break until the thunderstorm passes. Lightning-induced voltage surges are not going to get my service equipment, me, or my valued assistant if I can help it."

"Gee, thanks!" Barney retorted as he tilted his stool on two legs so that his back could rest against the wall; "I notice you listed things in the order of their importance."

"Yes, how about that?" Mac said with a teasing grin. "You know I've always been a little hipped on the subject of how lightning damage can ruin electronic equipment, and I'm even more so after reading a short article that appeared in the March, 1963, issue of 'Newsletter,' published by the Rectifier Components Department of *General Electric*."

"You don't need to sell me on the danger," Barney sniffed. "I've seen too many radio and TV sets on the bench that had been clobbered by lightning that 'came in' over the owners' light lines. That stuff sure is freakish. Sometimes it skips all over a set blowing tubes, burning out coils, breaking down the insulation of transformers, and even fusing the plates of a tuning capacitor together. Again it only pops the line bypass capacitors, but what a job it does on those! I've seen dozens of cases in which all that's left of the line bypass is the two wire leads with little disks on the end that originally connected to the foil. The capacitor itself is entirely gone except for a few shreds of foil and paper splattered against the flame-smoked chassis. Those surges must really pack some voltage."

"That's pretty evident, and I've always wondered just *how much* voltage, but I never had equipment suitable for measuring the amplitude and duration of the surges. The boys at *G-E*'s Advance Technology Laboratories in Schenectady apparently got to wondering, too, and they *had* the equipment. Their transient measuring set-up used a *Tektronic* automatic oscilloscope and a *Beattie & Coleman* automatic camera. Every time a transient came along it was displayed on the scope and its picture was automatically taken to indicate the peak-to-peak voltage amplitude and the duration. With this kind of equipment set up in various locations in two different states, 8000 hours of testing time was logged at the time the article was written. The tests are still going on."

Mac stopped speaking, and the thunderstorm hit with roaring wind and sheets of rain splashing against the windows. The thunder was almost continuous.

"You say the equipment was set up in 'various locations.' What kind of locations?" Barney wanted to know.

"All the tests were made across 120-volt lines, but since voltage surges are produced by a wide variety of causes, varying all the way from bolts of lightning striking near the lines to different types of electrical apparatus being connected to and disconnected from the lines, it was decided to monitor a number of locations in order to photograph a wide range of transients. To this end the equipment was set up in seven private homes, two hospitals, one hotel, one motel, and one department store. Results showed the wisdom of this deployment, for some locations had considerably more and higher transients than did others. Equipment that probably would have operated without injury on some of the lines would very likely have suffered transient damage on other lines."

"What was the highest voltage surge measured?"

Before Mac could answer, there was a terrific flash of lightning accompanied by a sharp snapping sound followed almost immediately by a crash of thunder. The lights in the shop flickered momentarily.

"Whew! That was a close one!" Mac said as the unmistakable odor of ozone came in the open door. "I think it was trying to answer your question, for the highest transient measured on a 120-volt line was one that reached 3740 volts peak-to-peak, and this occurred in a Florida home during a lightning storm. That's the kind of surge that pops those line capacitors you were talking about. A voltage of that order can easily hop across the closely spaced contacts of an open line switch in a radio or TV receiver; so just turning the set off during a thunderstorm is no insurance against lightning damage. Pulling the plug during the storm is the only way to be sure lightning can't get at the set *via* the power line."

"I'll buy that," Barney agreed emphatically. "I keep all the plugs of my ham equipment pulled when the station is not in use, especially during the thunderstorm months. More than one of my ham acquaintances has had his entire station wrecked by a single bolt of lightning that struck near the power line feeding the station. While most hams are not stupid enough to operate during a thunderstorm and are careful to ground the transmitting and receiving antennas, a lot of them leave the back door unguarded, so to speak, and forget that lightning damage is much more likely to arrive *via* the power lines than it is to come in over the antenna. What else did the *G-E* boys learn from their surge survey?"

"Well, they found relatively frequent transients occur up to 1600 volts, but the most common ones fall in the 500-600 volt bracket. Most of the voltage surges last less than fifty microseconds."

"Offhand I'd say the presence of these voltage surges on the line is a more serious threat to modern semiconductor apparatus operating from the line than it is to vacuum-tube apparatus," Barney suggested. "Take for instance two radios that use the same tube line-up except for the rectifier. One uses a half-wave vacuum-tube rectifier and the other uses a germanium or silicon diode. Both rectifiers are fed directly from the line so that any transient appearing on the line appears across the rectifier. I've got a hunch the semiconductor would be more likely to suffer damage than would the tube."

"Speaking of ordinary semiconductor rectifiers, I'd go along with your hunch," Mac agreed. "The reason semiconductor diodes are sensitive to transient damage is not too hard to grasp. While a typical 12-ampere silicon rectifier of the conventional type can momentarily dissipate 1000 watts of heat in the forward conduction direction of current, it will be permanently damaged by only a few watts of power dissipation in the reverse or blocking direction."

"How come?"

"In the forward direction the current and its attendant heat losses spread out uniformly over the entire silicon junction area, allowing the rectifier to take maximum advantage of its cooling mechanism and heat capacity. However, under the influence of even a brief voltage transient, the rectifier leakage current driven by a momentary high blocking voltage peak will find some tiny flaw or weakness in the junction at which to concentrate. Such weak spots usually occur at the junction surface where the rectifying junction emerges from the silicon pellet. At these microscopic spots a fraction of a watt of concentrated heat may be enough to destroy the blocking properties of the rectifier, no matter how big it is."

"I notice you keep saying 'ordinary semiconductor rectifiers.' Is there another kind not so easily damaged by voltage surges?"

"Yes. The controlled avalanche silicon rectifier, such as *G-E*'s Model ZJ-218, can dissipate about as much heat in its reverse as in its forward direction. This is accomplished by making the high reverse energy dissipation take place in the avalanche breakdown, or zener, region of the diode characteristic. You know this zener behavior characteristic of a silicon diode permits it to be used as a voltage regulator. As long as you stay within the thermal limitations of a zener diode, it will maintain virtually constant voltage across itself regardless of the avalanche current through it. No damage will result from true avalanche action to a diode with a uniform junction.

"A rectifier diode with uniform avalanche breakdown taking place at a voltage below that at which local dielectric surface breakdown occurs can dissipate hundreds of times more reverse energy caused by transient high voltage than one in which the surface breakdown point is reached before avalanche current starts. Once the avalanche current begins, it holds the voltage down so the level where surface damage to the rectifier might occur is never reached. Such a device has its own 'built-in' transient voltage suppressor."

"How do you go about making a controlled avalanche silicon rectifier?"

"There are two important steps: 1. You control the geometry of the junction surface very precisely to reduce the voltage gradient at that surface and make it capable of supporting high voltage. 2. You carefully control the impurity concentration determining voltage at which avalanche occurs so that avalanche always begins *below* the voltage where surface damage might be encountered.

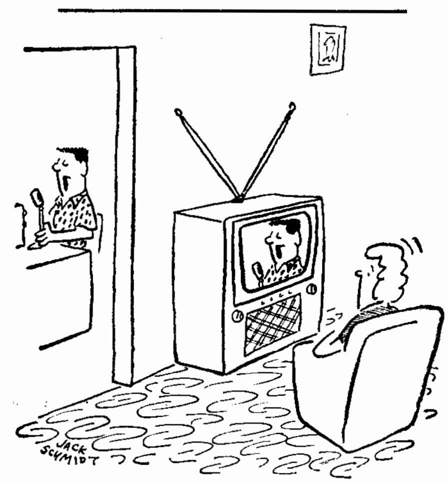
"Is such a rectifier similar in other ways to an ordinary silicon diode?"

"Generally speaking, yes. The CASR's big advantage lies in its ability to cope with high reverse currents. Its forward current handling ability is very similar to that of a conventional diode. However, the high degree of surface stability should pay off in increased reliability. Also CASR's can be operated in long series strings at very high voltage without the use of voltage equalizing resistors, since each cell can be operated in its avalanche region without damage. Voltage safety factors can be greatly reduced. Instead of the usual 2:1 or 3:1 safety factor between rectifier peak reverse voltage and steady-state line peaks, CASR's can often be applied with little or no safety factor. A 1200-volt p.r.v. CASR can be used instead of a 2000-3000 p.r.v. conventional rectifier."

"Sure sounds like they'd be a natural for use in the high-voltage power supplies for table-top kilowatt linear amplifiers now becoming so popular with SSB hams," Barney said, cocking one ear to the sound of the storm. "Sounds like it's coming back," he observed, settling comfortably back against the wall.

"I just was thinking we could be working on that stack of transistor radios with the v.o.m.'s without any danger of the big, bad lightning getting to us," Mac said, standing up. "On your feet, Buster!"

"Your trouble is you think too much," Barney answered disgustedly. ▲



Power supply transients kept under control

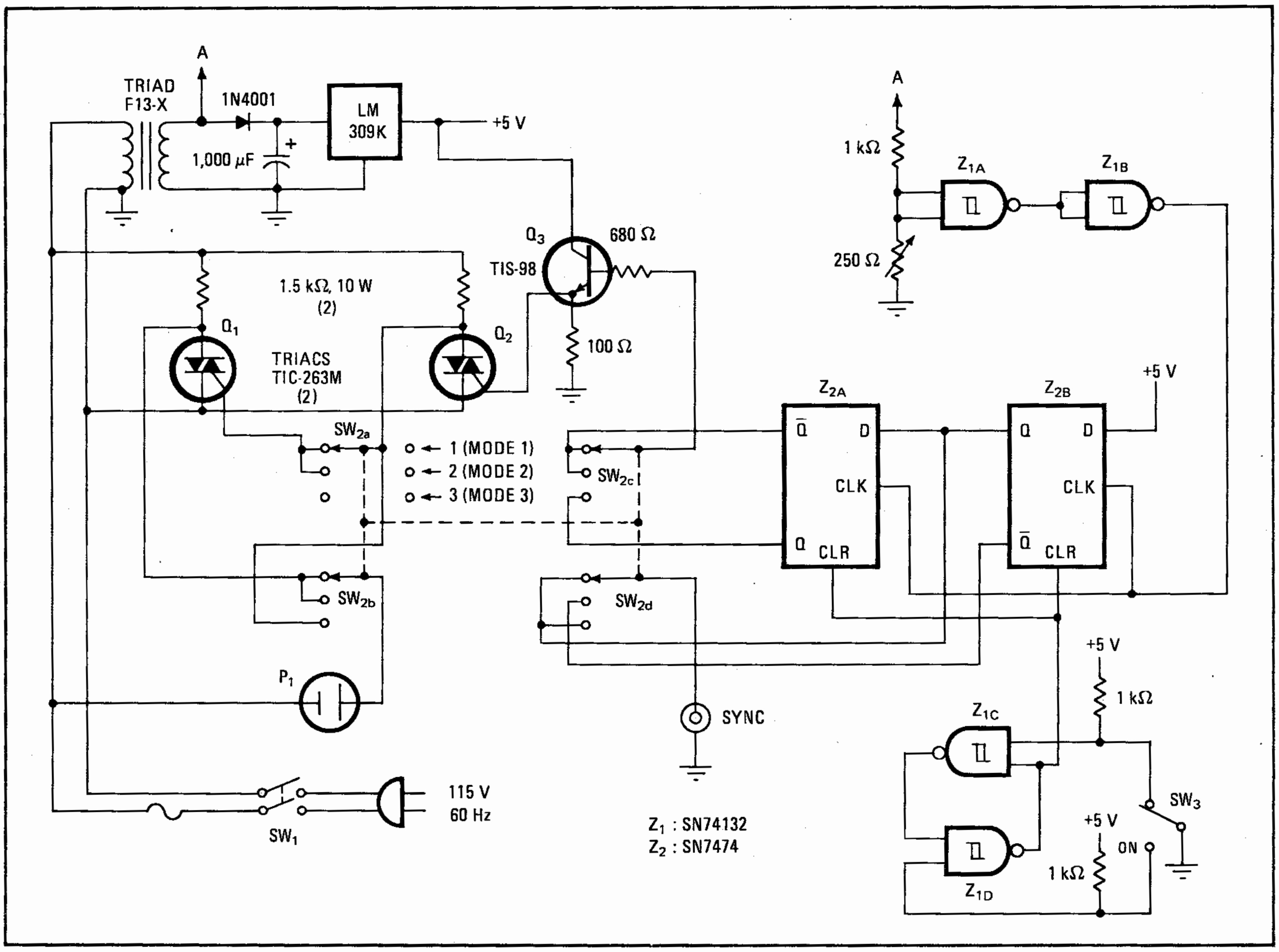
by Ralph Tenny,
Texas Instruments, Dallas, Texas

Two specifications of power supply performance can easily be overlooked, since most manufacturers never mention them. These are turn-on/turn-off spikes and voltage rate-of-rise at turn-on. Most integrated circuits can be damaged or destroyed by power supply spikes which momentarily exceed the device voltage rating. Fortunately, not many commercial supplies do this. However, it is important that in-house designs be checked for spiking during design debugging. In addition, some digital systems with multiple power-supply requirements may lock up if the power supplies come on in a particular order, so it is important to know the voltage rate-of-rise of each supply.

The circuit shown in Fig. 1 will energize ac-powered individual dc supplies or power-supply systems connected to a controlled outlet, P_1. And it will furnish a scope sync signal to allow detailed examination of the power supply output during turn-on. Turn-on can be at line zero crossing or at an adjustable point near line peak to reliably check for worst-case turn-on conditions.

The circuit is based on two triacs which control the ac power to the power supply under test; Q_1 is resistively triggered from the line and turns on and off at zero crossing. Q_1 is controlled by Q_2; when Q_2 is turned on, it diverts gate drive from Q_1. However, if Q_2 turns on in midcycle, Q_1 does not turn off until the next zero crossing. Q_2 is turned on by dc drive from Z_{2A} via Q_3. Z_2 is controlled by a line-derived trigger from Z_1. A line voltage sample (A) is used to generate a phase-variable trigger. This is accomplished by a resistive attenuator and a TTL Schmitt Trigger (Z_{1A}). Adjustment range is sufficient to generate a trigger 90° after zero crossing. After inversion in Z_{1B}, this trigger is applied continuously to a two-bit shift register (Z_2). Z_2 is cleared by a latch or allowed to run at 60 Hertz. At the first trigger after Z_2 is released, Z_{2B} switches and produces a sync signal. On the next trigger, Z_{2A} switches and applies gate drive to Q_2, which turns on. At the next zero crossing, Q_1, which was conducting, turns off (mode 1 operation).

Mode switch SW_2 has three positions to allow these checks: turn-on at zero crossing or at line peak, and turn-off to allow checking for turn-off spikes. In position 1, the power supply is switched by Q_1 at zero crossing.



Transient testing. This power-supply transient-response tester, in conjunction with an oscilloscope, can measure turn-on time at zero crossing (mode 1) or line peak (mode 2) and turn-off time (mode 3).

With SW_3 off, Q_2 is conducting to hold Q_1 off until SW_3 is turned on. Sync is generated a minimum of 16 milliseconds before Q_1 turns on. In mode 2, everything is the same, except that sync is generated just before Q_1 turns off. In mode 3, Q_1 is not triggered and Q_2 switches the power supply on command, 16 milleseconds after sync.

A safety note: SW_1 opens both sides of the line; this is the minimum acceptable arrangement. At best, the entire circuit should be operated on an isolation transformer. When adjusting the trigger for proper phase angle turn-on of Q_2, be sure to use a filament transformer if an isolation transformer is available. □

Powerline Transient Suppressor

All it takes is a single glitch, transient, or surge on a power line to wipe out hours of work on a personal computer. Here's a simple yet effective device that helps eliminate those three serious power-line-related problems.

HERB FRIEDMAN

THERE ARE THREE DIFFERENT TYPES OF power-line disturbances that can affect the operation of small computers: RF interference, line transients, and power-line surges. Each can affect different computers in different ways. Also, some computers are more easily affected than others. For example, short of a direct lightning hit, no power-line disturbance will disrupt a Heathkit/Zenith *H8* or *Z/19* computer. One *H8* we know of was running when the opposite wire of a 120/120 (240 volt) power line took a direct lightning hit only 100 feet away; the *H8* just kept on working. On the other hand, simply turning on one of the most popular printers will cause an equally popular personal computer to re-boot—and wipe the program you've been writing for three hours right out of memory.

Let's look at the three types of disturbances and some of their causes. Turning first to RF interference, we were asked to cure such a problem plaguing a *TRS-80 Model III* used for demonstrations in a Radio Shack store. It turned out that the source of the interference was a *Color Computer* that was also being used for demonstrations. All that was needed for a quick and inexpensive fix was a $12 RF filter that Radio Shack itself sold.

Line transients are another simple-to-cure but nevertheless bothersome problem. They are generated by power transformers and inductors when the current through them is turned on or off (although it's most severe when turned off.) Consider this case involving an Epson Printer and a *TRS-80 Model I* computer. If *scripsit* text-editing software was running, simply turning the printer on caused a line transient that scrambled the memory but not the video display. Everything looked just fine on the video screen, but what was saved to disk or sent to the printer came from memory, and that was pure garbage.

Transient "ride-through" was the reason for the scrambled memory. It's not unusual for line transients caused by inductors and even lightning discharges in the neighborhood to range as high as 1000 volts; and those transients can ride right through the power-supply regulators and into the five-volt computer power supply. The result can be scrambled memory or "blown" ICs. The cure for the problem is a General Electric MOV (*M*etal *O*xide *V*aristor) that more or less clips instantaneous line-transients at about 180 volts, a safe value that is generally handled (as far as we can tell) by all personal computers.

Finally, we can come to the third disturbance, one that causes the "silent death" of software, and sometimes of hardware: power-line surges caused by the local electric company's trying to maintain service after a power interruption. As a general rule, if a power line fails, the utility company will attempt to maintain service; often, the line may surge several times before failing completely, or the line may "hold," and power will be restored. The first interruption will probably wipe out or scramble whatever is in the computer's memory. The transients caused by the surges that follow as the utility tries to maintain power are quite capable of zapping your IC's and disks. If the first failure takes your disk drives out of service, you want to keep them out of service until things are safe for them once more. Applying power again and again—particularly in the case of start-up transients—to a disk drive with the door closed is an odds-on bet to wipe out a disk. For software protection, a good rule of thumb for personal computers is that when the power takes the computer down even for an instant, keep the computer and all its peripheral equipment out of service until you are absolutely certain that steady, reliable power has been restored.

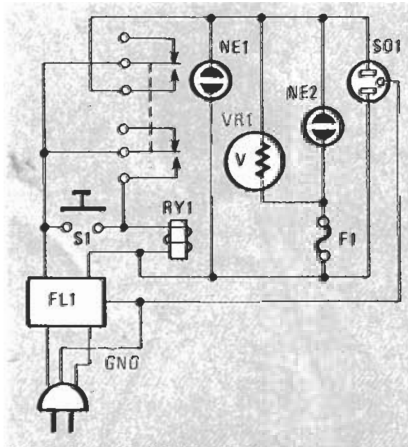


FIG. 1—THIS EASY-TO-BUILD CIRCUIT can provide better power-line protection for a personal computer than many commercial devices costing as much as $150.

Three in one

One way to eliminate, or at least sharply reduce, the problems caused by the unusual power-line conditions we've discussed is with the simple yet effective device described by this article. A schematic diagram of that device is shown in Fig. 1.

Although relatively unsophisticated, it does protect your computer against the three most common forms of power-line disturbances. First, there's FL1, an RF filter that keeps RF from entering into your computer through the power line, and RF from your own computer from getting into the power line (see Fig. 2).

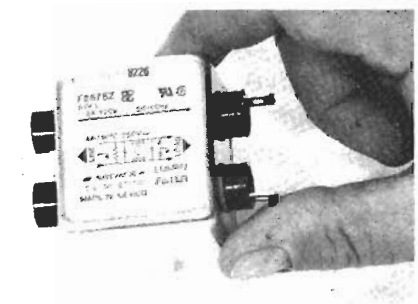


FIG. 2—THIS RF FILTER keeps RF power-line interference from leaking into your computer, and keeps your computer from interfering with other devices. It is particularly good at keeping two computers on the same power line from interfering with each other.

Second, it has a General Electric MOV, VR1, across the outlet receptacle to reduce the effects of line transients (see Fig. 3). Finally, relay RY1 is wired so that it drops out and *stays out* after the first power-line interruption until deliberately reset by the user. If the power fails at night, and in the darkness you forget to turn off your computer system, hours later—when the utility restores power—your disk drives won't start by themselves. Also, if the utility creates surges on the line while trying to maintain power, your computer will be safely disconnected from any consequences of that surging.

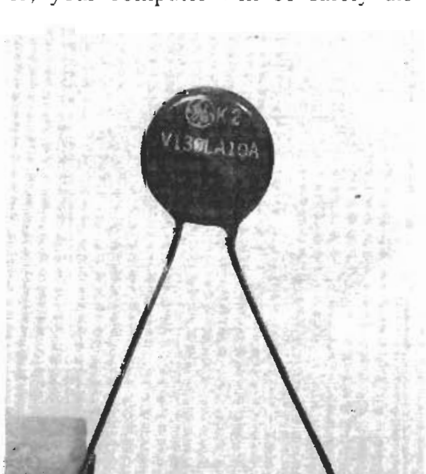


FIG. 3.—IT LOOKS LIKE A DISC CAPACITOR, but it's really a metal oxide varistor that limits transient line-voltage surges to about 180 volts.

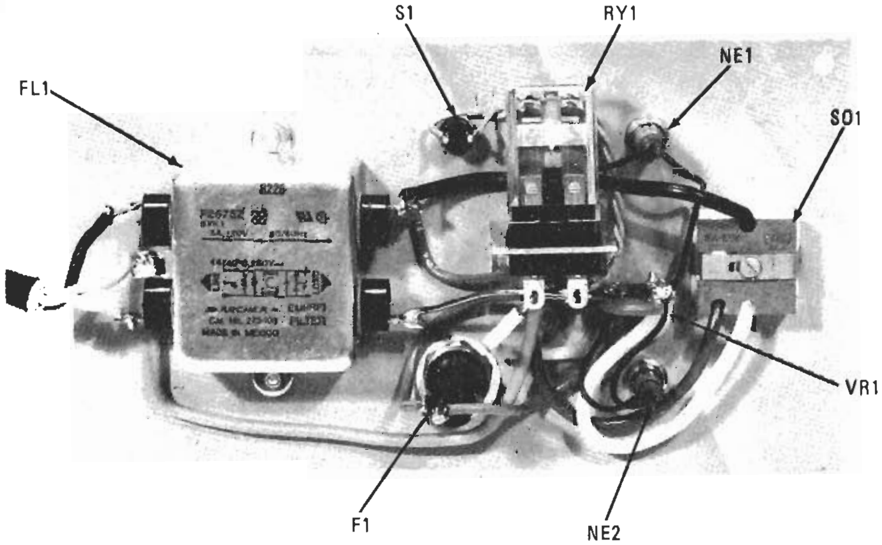


FIG. 4—ALL OF THE COMPONENTS mount on the metal front panel of a plastic utility cabinet.

Two neon indicator lamps show the condition of the power line and of VR1. Lamp NE1, an amber-colored POWER indicator, will always be lit if there was no interruption of the power source. If NE1 is out it means there was a power-line interruption and the power to receptacle SO1 is locked out (RY1 dropped out). Power is restored by pressing RESET switch S1, which causes RY1 to pull in and latch, and apply power to SO1.

Lamp NE2, a green LIMIT indicator, shows that the safety fuse in series with VR1 is intact and the power line is protected against transients. Lamp NE2 must always be on when NE1 is on. If NE2 is out it means there was an excessive transient that caused fuse F1 to blow, or—more seriously—that VR1 is damaged. Replace fuse F1. If it blows again (as indicated by failure of NE2 to light), simply replace the varistor. It is rare for a varistor to be damaged by a transient, but it can happen.

No provision is made for an on-off switch because the unit is intended always to be on; it is simply a safety device. If you want to use the device as a master power-control for your computer system, you can install an on-off switch in series with either power-line connection to the RF-filter input. Keep in mind, however, the fact that S1 must still be depressed to turn the power on.

Construction

The unit described was built on the metal panel supplied with a 7⅝ × 2⅜ × 4$^{5}/_{16}$ plastic utility-cabinet. There are two versions of that cabinet around: the U.S.-made Bakelite cabinet with a sturdy metal panel, and the "imported" model made of soft plastic with a relatively thin metal panel. If the thin panel is all you can get and you want something more sturdy, you can cut a duplicate from a sheet of a heavier grade aircraft-quality aluminum.

As shown in Fig. 4, all components except RY1 mount directly on the metal panel. Relay RY1 is mounted on a small L-bracket fashioned from scrap aluminum. (See Fig. 5.) Form the bracket to the shape required to mount the particular relay you use. The relay specified in the Parts List is easy to obtain, and mounts in a socket that is similarly easy to obtain and install. Its use is recommended.

When you form the L-bracket, make certain there will be clearance for the small terminal-strip used to mount the VR1—that terminal strip is secured by one of the rivets or screws used to mount the bracket on the panel; alternatively, you can leave room for the terminal strip next to the bracket. Take note that the power line for a computer must be 100% free of interruptions. Make sure that all components are tied down and expertly soldered; leave no connections hanging in space even if they are soldered and taped (see Fig. 6).

continued on page 78

PARTS LIST

FL1—EMI/RF filter (Radio Shack 273-100 or equivalent)
VR1— V130LA10A metal-oxide varistor (General Electric)
RY1—DPDT plug-in relay, 125-volts AC (Radio Shack 275-217 or equivalent)
S1—pushbutton switch, normally open
NE1—neon lamp assembly with built in resistor, 120 volts, amber
NE2—neon lamp assembly with built in resistor, 120 volts, green
F1—fuse, 3AG, 10 or 12 amps (see text)
SO1—AC receptacle, three-pronged, grounded type
Miscellaneous—cabinet, fuseholder, 3-wire line cord, relay socket (Radio Shack 275-220 or equivalent), No. 14 solid wire, etc.

TRANSIENT SUPPRESSOR

continued from page 58

The relay specified handles 10 amps, and all circuit wiring should, similarly, be capable of handling 10 amps. This means No. 14 wiring for all circuits associated with receptacle SO1. (The wires to the relay coil and the lamps can be No. 20, or No. 18.) Solid wire is recommended. You can obtain No.14 solid wire by purchasing a few feet of No. 14 Romex electrical-wire at your local hardware store and stripping off the outer skin. Under the skin will be two (or three) insulated No. 14 solid wires and a bare ground-wire. Save the bare wire for some future project.

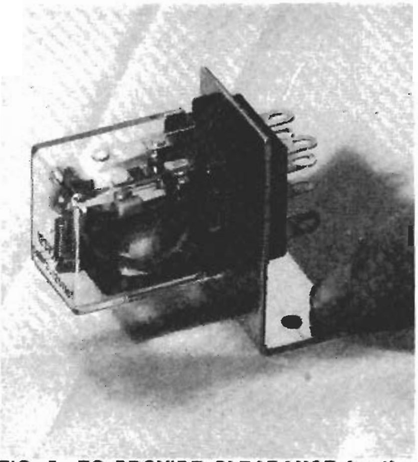


FIG. 5—TO PROVIDE CLEARANCE for the power-drop-out relay, mount it on an L-bracket made from scrap aluminum.

Receptacle SO1 must be of the three-pronged, grounded type. The particular unit you get may have screw or solder terminals, or may be prewired. If there are screw or solder terminals use your No. 14 wire. If the receptacle is prewired the wire is probably No. 12 stranded. Simply twist the free strands together tightly and tin them with solder. Take care to be sure you locate the correct "ground" terminal on SO1. If SO1 is prewired the wires will be color-coded red, black, and green. The green one is the ground wire, and is soldered to the ground lug on FL1. The power-line ground, also green, must be soldered to the filter's ground terminal, as well.

Neatness doesn't count

Insulated No. 14 wire is not the easiest material to work with. Usually, forming "square corner" bends will put undue strain on the associated components. Don't try to be extremely neat; bend the power wires in gentle arcs. There's plenty of room on the panel, so don't crowd the wiring. Bending No. 14 wire around a relay socket's solder lug is a sure way to break the lug, so lay the wire on the lug (use a clamp if necessary) and make a secure tack-solder connection.

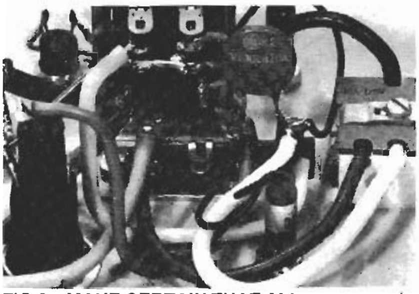


FIG 6—MAKE CERTAIN THAT ALL components and wires are securely soldered to a terminal. No components should "float," and no wires should have in-line splices. Such construction will help ensure glitch-free operation for your computer.

Use a 3AG fuse rated at 12 amps (*not* the "Slo-Blo" type) for F1. If you can't get a 12-amp one, a 10-amp fuse will do. We have never run across a varistor's protection fuse that opened, or a "shorted" varistor, but since the possibility exists that it can happen, don't eliminate F1.

Checkout

Measure the resistance across the line cord's terminals with an ohmmeter. It should be "infinite," even though the RF filter's schematic, printed on the filter's case, shows a resistance across the input terminals.

Check the resistance across SO1's output connections; it should also be "infinite." If not, check the connections to the varistor.

Check the resistance from both sides of the line-cord plug's prongs, and SO1 to ground. It too should be "infinite;" if not, there is a wiring error.

If everything checks out up to this point, connect the unit to the power line. Nothing should happen. Next, press RESET switch S1. You should hear RY1 switch in and both NE1 and NE2 should light. If NE1 does not turn on, check RY1 for a wiring error. If NE1 turns on but NE2 does not, check the wiring of F1 and the varistor.

If both lamps turn on, the device should be OK. As a final check of the device's latching function, simply remove then restore power. To do that, simply plug a load such as a table lamp into SO1 and then cut power either by throwing a circuit breaker or pulling the device's plug. Restore power and if the lamp will not light the device is ready for use. Connect your computer system's main power-cord to SO1, or better yet, connect a power strip to the socket, and the computer and the disk drives to the strip. Your printer should then be plugged into the same socket that's used by the protection device. That ensures that any RF or glitch generated by turning the printer on must feed through the RF filter before reaching the varistor. That provides double protection, and you can never be too safe. **R-E**

ARD

POWERLINE TRANSIENT SUPPRESSOR

In reference to the powerline transient suppressor, **Radio-Electonics**, September 1983, pages 57–58:. As that circuit is presented, when an excessive transient causes fuse F1 to blow, whatever is plugged into the suppressor is not protected from any *further* transients that may occur.

When I built this powerline transient sup-

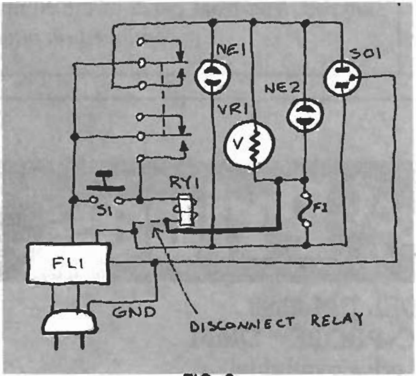


FIG. 2

pressor, I altered the circuit as shown in Fig. 2. If the fuse blows, the relay drops out and stays out to protect the equipment. Disconnect the relay from FL1 and reconnect it to fuse top–see Fig. 2.

I would appreciate it if you would publish this letter, so readers could make this modification to their transient suppressors.

ERIC DEUTSCHMANN
Spence Bay, Canada