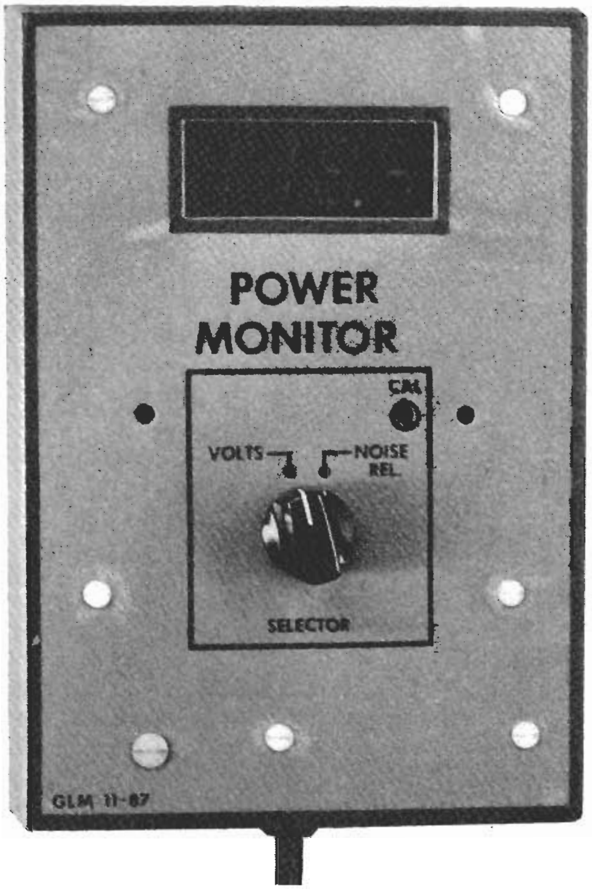
BUILD THIS

POWERLINE MONITOR



Solve those power problems with this power monitor!

GARY McCLELLAN

UNTIL RECENTLY WE SAFELY could give little thought to the quality of the AC power coming out of our wall outlets. But the world is changing, and so are the power requirements of electronic equipment. Noisy, fluctuating, line power may not bother lamps, irons, or other appliances, but dirty power can raise havoc with sensitive electronic devices such as personal computers. If you have ever lost data or "trashed" a program running on your computer, you may have been a victim of a power brownout or excessive line noise, without realizing it. That could cause you to waste time troubleshooting the unit for an intermittent problem, when all that was wrong was a power glitch.

Power monitors

A power monitor lets you keep an eye on the condition of your AC power. At a glance you can read the line voltage and be aware of brownouts and surges that might damage your equipment. It even lets you monitor the relative noise level on the line; a feature that helps you spot high-noise conditions that cause equipment problems. Also, as we'll show later, a power monitor's noise-level feature lets you test line filters quickly and easily.

Although a professional-grade power monitor having those features is usually very clostly, this month we'll show you a hobbyist-grade version of the device that can be built for as little as $45. Even so, if precision components are used it can read the powerline voltage down to tenths of a volt with an accuracy that exceeds ±0.5%. Also, relatively large 0.56-inch LED's displays make it easy to read the line voltage and relative noise levels at a glance.

How it works

The schematic of the circuit is shown in Fig. 1. The dashed lines represent the edges of a printed-circuit board. The lettered terminals on the dashed lines correspond to lettered solder pads on the PC-board to which the external components are connected. For example, switch S1-b connects to solder pads on the PC board labeled A, B, and C.

The power monitor is a simple, straightforward device using an Intersil ICM71076 digital voltmeter (IC2), which reads 0–1.999 volts DC. For AC-voltage measurements, the applied voltage is simply rectified to DC before being fed to the digital voltmeter. For noise readings, a high-pass filter and peak-reading rectifier circuit are substituted for the conventional AC rectifier. A regulated power supply, IC1, provides the reference voltage needed by IC2.

The basic digital-voltmeter circuit is built around IC1 and IC2. DC inputs from the volts- or noise-measuring circuits appear across resistor R8 and capacitor C9. Those components attenuate and filter the signal from the volts- and noise-measuring circuitry. The signal is then applied to IC2, pin 31, via resistor R11 and is measured. (Resistor R11 and capacitor C10 provide overload protection for IC2.) The applied voltage is converted by IC2 into driving signals for displays DSP1 and DSP2.

A key part of the digital voltmeter is a reference voltage source from IC1. It determines the overall accuracy of the unit because IC2 makes measurements by comparing a known reference voltage with the unknown input. In this instance the reference voltage is provided by adjustable voltage regulator IC1, a low-cost adjustable voltage regulator. The regulated output voltage of 1 volt appears at the wiper of potentiometer R6 and is applied to IC2 pin 36. Because IC1 will not regulate the output voltage if too little current is drawn, resistor R4 ensures

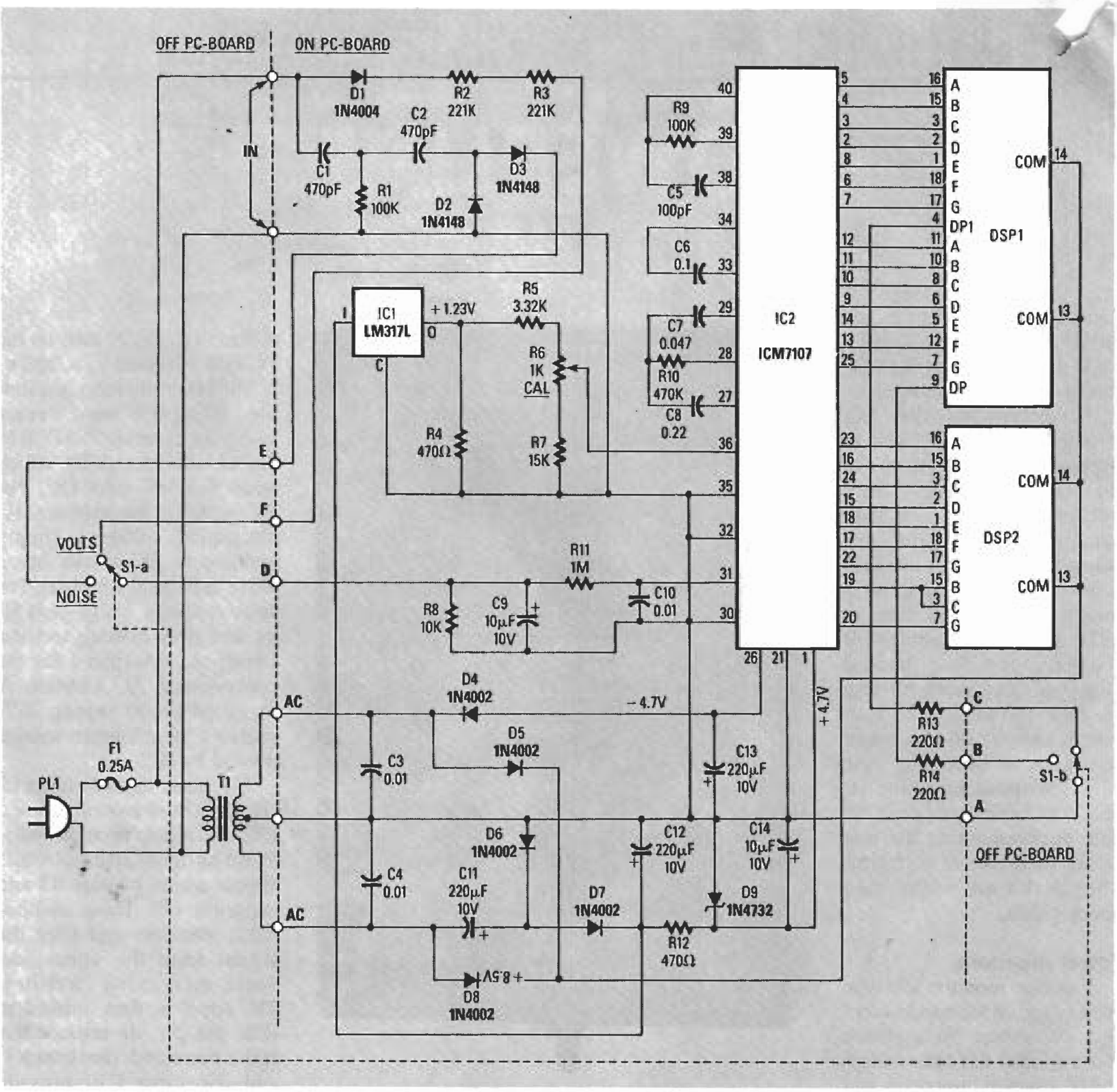


FIG. 1—THE POWER MONITOR INDICATES either the applied line voltage or the powerline noise. The noise level is determined by passing the line voltage through high-pass filter C1/R1/C2.

regulation by providing a minimum output current drain for IC1; the current loading caused by R4 ensures that IC1 will provide a constant 1.23-volt output.

The AC-voltage circuit is simple and easy to understand. Line voltage appearing across the IN terminals on the PC board is rectified by diode D1. The pulsating DC output from D1 is scaled down to the 1.2-volt range by resistors R2, R3, and R8. Capacitor C9 filters the pulsating DC so it can be measured. For improved safety and reliability, two separate resistors, R2 and R3, are used instead of a single resistor. That is necessary because small precision resistors are usually rated at only 250 volts DC, which is marginal for use in this application.

Noise measurements

The noise-measuring circuit consists of a high-pass filter and a voltage-doubler rectifier circuit. Capacitors C1 and C2, and resistor R1, filter out the 60-Hz hum component, leaving only line noises to be measured. Diodes D2 and D3 rectify noise components into DC values. The output from D3 drives resistor R8 and charges capacitor C9 to the peak value of the noise signal.

Understand that the noise readings are relative because they are determined by the duration, waveshape, and peak value of the noise pulses. In normal use, that limitation should not cause problems for the user.

The power supply

Both regulated and unregulated voltages are used. Diode D4 and capacitor C13 provide −4.7 volts for the analog circuitry inside IC2. Diodes D5 and D8 provide pulsating DC for powering LED displays DSP1 and DSP2. Using pulsating DC for the

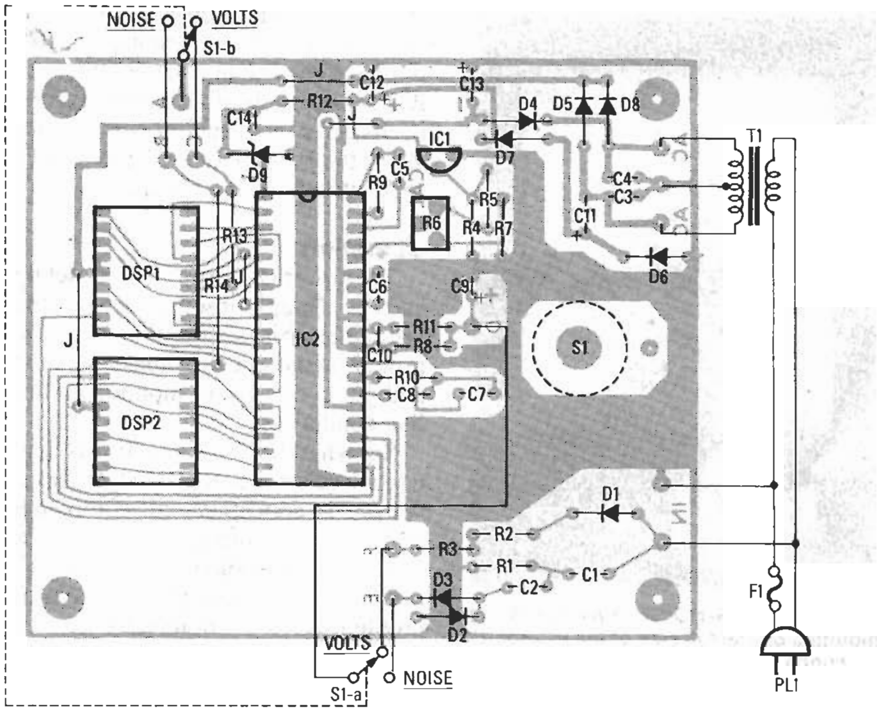


FIG. 2—USE A SOCKET FOR IC2, and do not install the IC itself until all other PC-board components are installed.

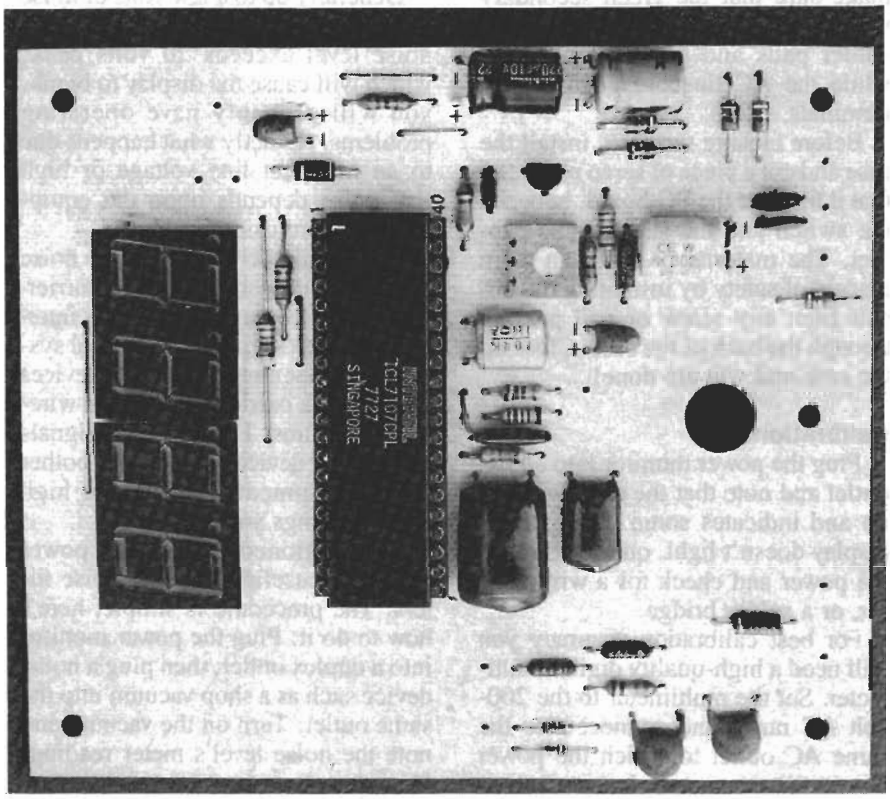


FIG. 3—FOLD THE CAPACITORS FLAT AGAINST THE BOARD to ensure clearance between the board and the cabinet. To prevent strain on the leads, bend them before soldering.

displays rather than using a steady DC voltage lowers IC2's power dissipation. Finally, a regulated +4.7-volt source for IC2 is provided via Zener diode D9.

Parts

A few parts that might prove difficult to get are the precision resistors and capacitors, and the plastic case. Precision resistors tend to be tough to buy in small quantities from local sources, but several **Radio-Electronics** advertisers do stock them. In a pinch, you can substitute the nearest value ¼-watt carbon-film resistors, but then the unit's precision will suffer. The polyester capacitors are widely available from many sources, but the electrolytic capacitors may prove difficult to get. You may prefer to use 220-µF, 16-volt units and mount them on the foil side of the board where there is more room. And finally, the

PARTS LIST

All resistors ¼-watt, 5%, carbon film unless otherwise noted.
R1—100,000 ohms
R2, R3—221,000 ohms, ⅛-watt, 1% metal film
R4, R12—470 ohms
R5—3300 ohms, ⅛-watt, 1% metal film
R6—1000-ohm cermet trimmer potentiometer (Digi-Key OFA13)
R7—15,000 ohms, ⅛-watt, 1% metal film
R8—10,000 ohms, ⅛-watt, 1% metal film
R9—100,000 ohms
R10—470,000 ohms
R11—1 megohm
R13, R14—220 ohms
Capacitors
C1, C2—470 pF, 1000 volts, ceramic disc
C3, C4, C10—0.01 µF, 50 volts, ceramic disc
C5—100 pF, 500 volts, ceramic disc
C6—0.1 µF, 50 volts, polyester film
C7—.047 µF, 50 volts, polyester film
C8—0.22 µF, 50 volts, polyester film
C9, C14—10 µF, 16 volts, radial tantalum
C11–C13—220 µF, 10 volts, radial electrolytic
Semiconductors
IC1—LM317L, voltage regulator
IC2—ICM7107CPL, A/D converter
DSP1, DSP2—Dual 0.5-inch common-anode LED display (Digi-Key P337ND or equivalent)
D1—1N4004 rectifier diode
D2, D3—1N4148 switching diode
D4–D8—1N4002 rectifier diode
D9—1N4732 Zener diode
Other components
F1—Fuse, ¼ ampere
PL1—Linecord plug
S1—3P3P rotary switch, see text
T1—Filament transformer: 6.3 VCT, 600 mA, Stancor P-6465 or equivalent part
Miscellaneous: Cabinet, printed-circuit materials, IC socket, hardware, wire, solder, etc.

plastic case is a product from LMB/Heeger, Inc. Their products are widely available from distributors, so ask your local dealer if it can be special-ordered. Otherwise, you can substitute any kind of plastic case and plastic mounting hardware.

Construction

The circuit should be assembled on a printed-circuit board. The template is provided in PC Service.

For ease-of-assembly, using Figs. 2 and 3 as a guide, mount the PC-board's components in the following order: First, the socket for IC2, then all other semiconductors. (Do not insert IC2 into its socket until the entire board is stuffed.) Next, all resistors and jumper wires; then the capacitors. To ensure clearance between the board and the cabinet's front panel, install the electrolytic capacitors and the larger Mylar/polyester types so they lie flat on the board.

Finally, install the LED displays. Position the displays so that their decimal points (dots) are at the bottom.

As shown in Fig. 4, switch S1 is installed on the foil side of the board and its terminals are connected by short lengths of insulated wire that are tack-soldered to the foils. Although S1 can be any kind of DPDT switch, a 3P3P rotary switch is recommended because they are inexpensive and generally available. (One section of the switch is not used.)

The cabinet

Finally, install the PC board and its external components in a plastic cabinet. First, drill all the necessary holes in the front of the cabinet and smooth the edges of the display cutout with a file. Then use press-on letters to label the project. Mark a location in the center of the rear case half and drill a ¼-inch hole that will be use for a hanger bracket.

To install the parts in the case, install threaded spacers on the component side of the board and then push the board into the case and secure it with nylon screws. Turn S1 fully counter clockwise and install the knob on its shaft so it's pointing to VOLTS. Then install the fuseholder and transformer T1 adjacent to the PC-board with nylon screws. Push the linecord through a hole in the bottom of the case and knot it inside the case for extra security.

Finish the project by wiring the cord, fuseholder, and transformer to the board. Double check your work to make sure that the green secondary wires from T1 go to the board's AC solder pads and ground terminals, while the AC linecord go to the IN terminals.

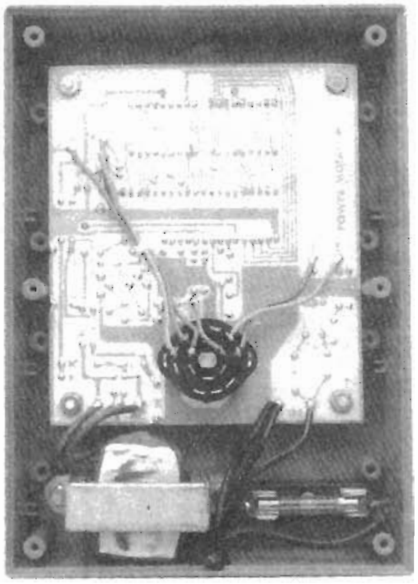


FIG. 4—VOLTS-NOISE SWITCH S1 is mounted on the foil side of the PC-board. Its connections are tack-soldered to the appropriate solder pads.

Before closing the case, install the fuse and cut a piece of scrap plastic so that it fits over the PC-board, between the switch and the sides of the cabinet. The material provides an extra margin of safety by insulating the circuit from any screw or nail passing through the back of the case. Close up the case and you are done!

Calibration

Plug the power monitor into an AC outlet and note that the display lights up and indicates some value. If the display doesn't light, quickly turn off the power and check for a wiring error, or a solder bridge.

For best calibration accuracy you will need a high-quality digital multimeter. Set the multimeter to the 200-volt AC range and connect it to the same AC outlet to which the power monitor is connected. Insert a screwdriver through the case hole that allows access to CAL control R6 and adjust R6 until both meters read the same value.

Troubleshooting

If the power monitor doesn't work at all, or is inaccurate, and the problem doesn't appear to be a wiring error, check the power-supply voltages and the reference voltage at IC2 pin 36. If the voltages are good, either IC2 is bad or installed wrong. Lastly, if displays continually show 000, check the position of the knob on S1's shaft, it is probably wrong.

Operation

The power monitor is easy to set up and use. Simply insert a screw in the wall where you want it, then hang the project on the screw. Connect the plug and you are ready to monitor power-line conditions.

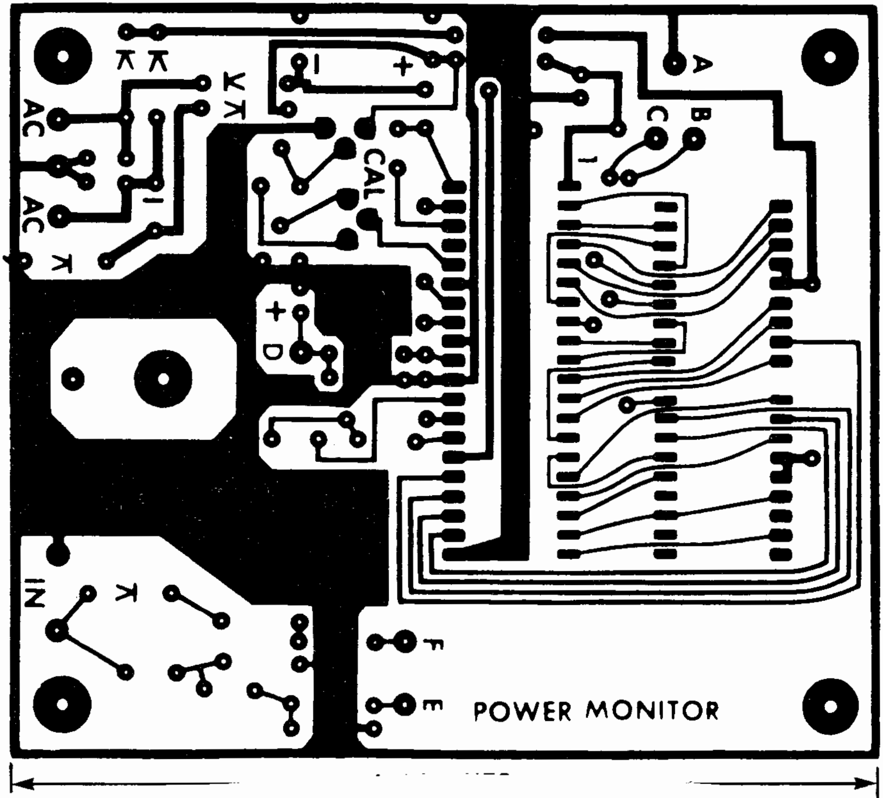
So what line voltage limits and noise levels are acceptable? As far as voltage is concerned, all equipment will work on voltages from 110–125 VAC with no problems. But as you go beyond those limits, your chances of problems increase tremendously.

Understand that typically most appliances are erratic at 100–105 volts and run hot at 130–135 volts. As for noise levels, the values are highly variable.

Generally up to a few volts of noise will cause no problems, but if the noise level exceeds 20 volts peak, which will cause the display to blank, you will probably have operating problems. (Exactly what happens due to an incorrect line voltage or high line noise depends upon the equipment you are using.)

You should be aware that the noise circuitry will also respond to carrier-current devices such as wireless intercoms and *X10*-type home-control systems or other communication devices such as line carrier modems or wireless intercoms. However, the signals from those devices should not bother other equipment, despite the high noise readings you get.

As mentioned earlier, the power monitor is useful in testing noise filters. The procedure is simple; here's how to do it. Plug the power monitor into a duplex outlet; then plug a noisy device such as a shop vacuum into the same outlet. Turn on the vacuum and note the noise level's meter reading. Disconnect the power monitor and connect the noise filter between the outlet and the power monitor. If you see the same noise-level reading on the meter as you did before you connected the noise filter, then something's wrong with your noise filter. The power monitor's reading will be lower if the noise filter is working properly. **R-E**



POWER MONITOR
CAL
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