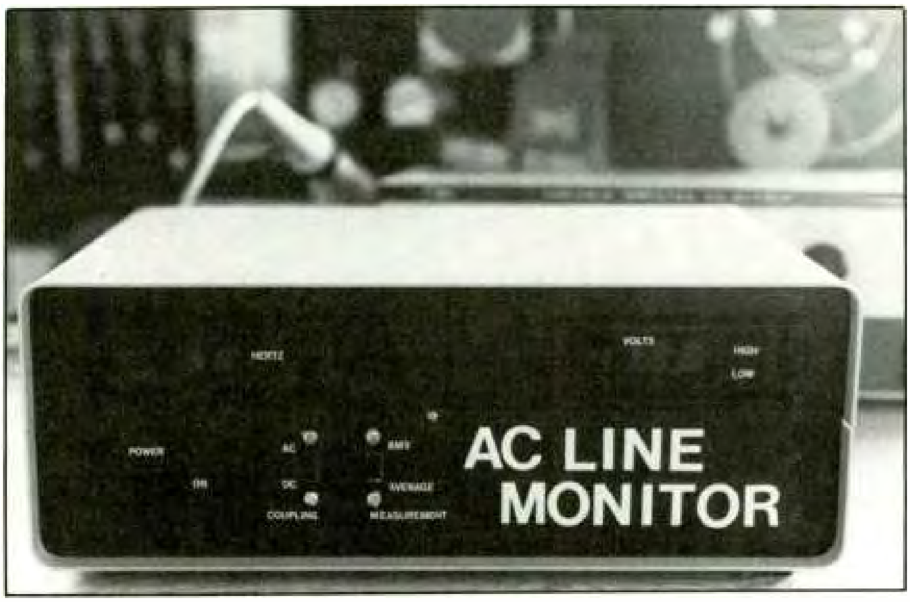
AC Line Monitor

A sophisticated device alerts you when ac line voltage and frequency conditions are detrimental to the health of your computer and other sensitive electrical equipment

By Thomas R. Fox



The quality of power available at a typical ac outlet is far from ideal for computers and other sensitive electronic equipment. Though the waveform on the ac line is rated to be at 117 volts ac rms at 60 Hz, a multitude of periodic effects can raise and lower the actual voltage and cause the frequency to deviate from the ideal.

Typically, there may appear on the ac line thousands of short-duration high-voltage spikes, hundreds of long-duration voltage sags and even several complete blackouts in any given year. None of these is beneficial to computers and other sensitive equipment, and a few are actually capable of physically damaging this equipment.

The AC Line Monitor described here will not correct problems on the ac line, but it will allow you to determine if a problem exists by visually and audibly alerting you to conditions that fall outside set limits for amplitude and frequency of the voltage at an ac outlet. With this Monitor, you can even sometimes predict the onset of a potentially damaging condition so that you can power down in an orderly manner before the condition becomes full-blown.

Our AC Line Monitor constantly samples the condition of the ac line into which it is plugged. It provides numeric display of true rms or average ac line voltage. Warning LEDs and a piezoelectric buzzer alert you when the voltage rises above or drops below preset levels. The LEDs light and buzzer sounds when the Monitor detects brief voltage sags and drops that would normally go unnoticed.

Problems Defined

According to expert Mark Waller, author of several books on the subject, ". . . the quality of [ac-line] power has steadily decreased over the last 10 years and as often as twice a day, one may experience an electrical disturbance that falls outside a typical computer's acceptable limits." Emerson Computer Power adds that a typical computer site experiences about 2,000 high-voltage spikes and surges, more than 500 voltage sags and about seven complete blackouts in a year!

Ideally, an ac outlet should provide 117 volts rms ac at a frequency of 60 Hz. While frequency is usually held to within ±0.01 Hz, average voltage often varies from 120 volts down to about 105 volts—and even less. Harmful high voltages usually last for only short periods of time, about 1 second or less. However, potentials of less than 105 volts are often persistent and are normally caused by inadequacies in the wiring in a home, apartment or commercial building.

Relatively long-term voltage sags are not normally the fault of the local utility power company. However, the utility company can be the cause of such a situation during planned brownouts and peak-usage periods, such as during a hot spell when heavy use of air conditioning strains the company's ability to deliver adequate power.

While the ac-line rms potential

rarely exceeds a steady 117 volts, voltage spikes with amplitudes that are 5 to 10 times this level sometimes occur and can wreak havoc on unprotected electronic equipment. Causes for spiking are many, including lightning strikes, failure of utility company equipment, switching on and off heavy-duty motors, etc. Such spikes usually last only microseconds. Thus, a good surge protector can generally handle these short-duration spikes and provide adequate protection for sensitive equipment.

Voltage surges are potentially more damaging and dangerous because they last for much longer periods of time. Few surge protectors can provide complete protection against the worst of these power-line problems.

Surges are caused by much the same conditions responsible for high-voltage spikes. Some of the worst surges are the result of a high-voltage distribution conductor falling on a 240-volt customer line. Super surges that result from this can "fry" any electronic equipment connected to the line through no surge protector or an inadequately designed one. Although a super surge protector may self-destruct during such a hazardous condition, it often protects the equipment it was there to prevent from coming to harm.

Another problem, especially for computer users, are 0.5- to 2-second blackouts that occur randomly and with increasing frequency throughout a given year. If you are working on a lengthy report, writing a long letter, etc., and have not recently saved your work, even this short an interruption in ac line power will wipe out all your work since the last time you saved your work.

Still another problem is low ac-line voltage. Most electric motors are less efficient at reduced voltage. This inefficiency makes itself apparent as heating of the motor that, under certain conditions, can permanently damage the motor.

Though the AC Line Monitor described here will not correct problems encountered on an ac line, it will alert you to an out-of-tolerance condition so that you can decide if a problem is serious enough to take remedial action. By keeping a watchful eye on the Monitor, it is sometimes possible to predict the onset of a problem on the ac line and save files to disk and power down in an orderly manner computers and other sensitive equipment.

This project is especially useful (actually, practically indispensable) when utility company ac power fails and you are running on back-up power from a generator, standby power system (SPS) or full-blown uninterruptible power system (UPS).

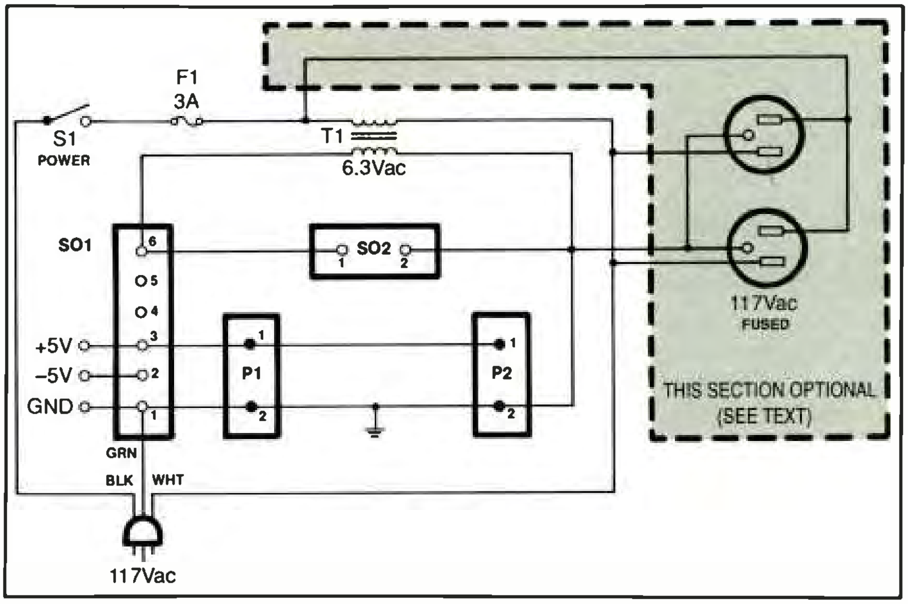


Fig. 1. Wiring diagram for power transformer and ac signal/dc power distribution to rest of project. Power supply can be built from scratch, or a ready-to-use power-supply module can be wired into circuit as shown. Ac receptacles shown at right are optional.

About the Circuit

This AC Line Monitor has a two-digit crystal-controlled frequency counter with separate overrange indication. This counter is especially important if you are using a back-up power system. Quality rather than quantity of power is sometimes more important. With this project, you can estimate the quality of the back-up system by monitoring the frequency and switching the measurement mode between rms and average. If the waveform is not a perfect sinusoid, the rms and average voltages should differ by more than 0.5 volt. The greater the voltage difference, the more the waveform differs from a true sinusoid. (When the project is set to indicate average ac voltage, the display actually shows 1.11 times the average voltage. For a perfect sinusoid waveform, this is the same as rms voltage.)

This is a fairly complex project. Therefore, to adequately describe how it works, the circuitry for it is broken down here into a series of function sections.

Input to the frequency-counter section comes from the circuit shown in Fig. 1. This input consists of the 6.3 volts at the secondary of power transformer *T1* and is applied to the bridge rectifier consisting of *D1* through *D4*, shown at the top of Fig. 2. This produces a train of positive

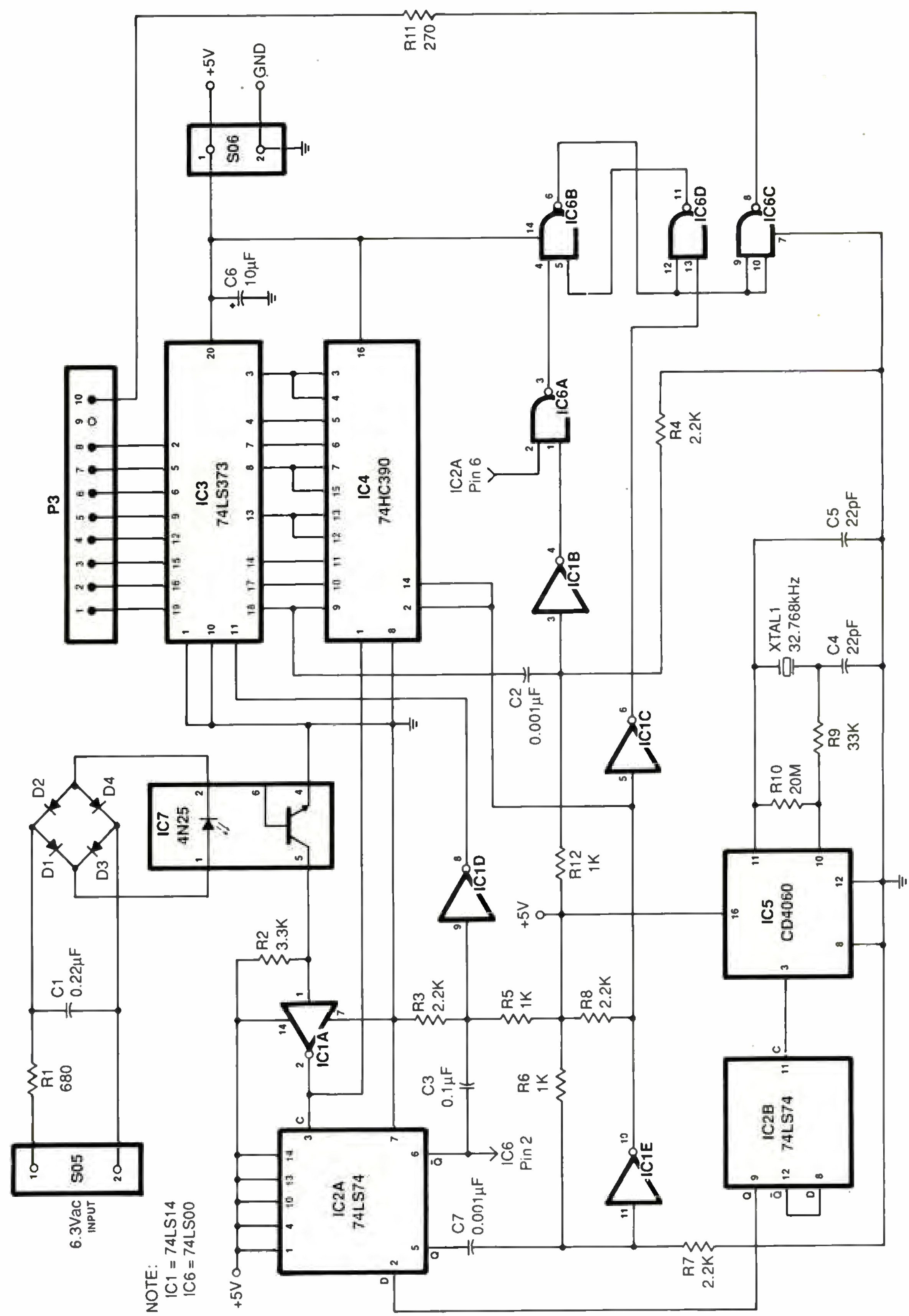


Fig. 2. Schematic diagram of line frequency-counting section of project.

half-sine waves with a repetition rate of 120 Hz (twice that of the ac-line frequency fed to the Fig. 1 circuit).

The pulse train developed by the bridge rectifier drives the internal LED of optical isolator *IC7* through current-limiting resistor *R1*. The output at pin 5 of *IC7* is passed through Schmitt-trigger inverter *IC1A*, which converts the rounded waveform into a train of square waves with rapid rise and fall times.

D-type flip-flop *IC2A* receives the output from *IC1A* at CLOCK input pin 3. It synchronizes the pulse train (of uncertain frequency) with the 0.5-second crystal-controlled timing pulses delivered to pin 3 by *IC2B*.

Dual decade counter *IC4* has a wave-shaped pulse train (also of uncertain frequency) applied to its pin 1 input from the pin 2 output of *IC1A*. Octal D-type latch *IC3* temporarily holds the data delivered to it from *IC4*. Control signals for *IC3* and *IC4* are provided by *IC2A*.

To initiate operation, a short positive-going pulse is applied to the CLEAR input at pins 2 and 14 of *IC4*. This clears all eight flip-flops inside *IC4* and permits counting to start from zero. Exactly 0.5 second later, another positive-going pulse is applied to the ENABLE input to latch the *IC4* value at this instant.

As shown, plug *P3* connects the outputs of *IC3* to seven-segment decoder/drivers *IC8* and *IC9* located in the display section of the project, shown in Fig. 3. (For the following discussion, refer to both Fig. 2 and Fig. 3.) Because the data has been latched inside *IC3*, the information is invisible in displays *DISP1* and *DISP2*, even though *IC4* continues to count. The decade counters inside *IC4* are cleared in 0.5 second to start the cycle again for a new reading.

Overrange detection for this circuit is accomplished with a simple RS flip-flop made up of NAND gates *IC6B* and *IC6D*. The output of this arrangement, at pin 6 of *IC6B* is buffered by *IC6C* and then delivered to

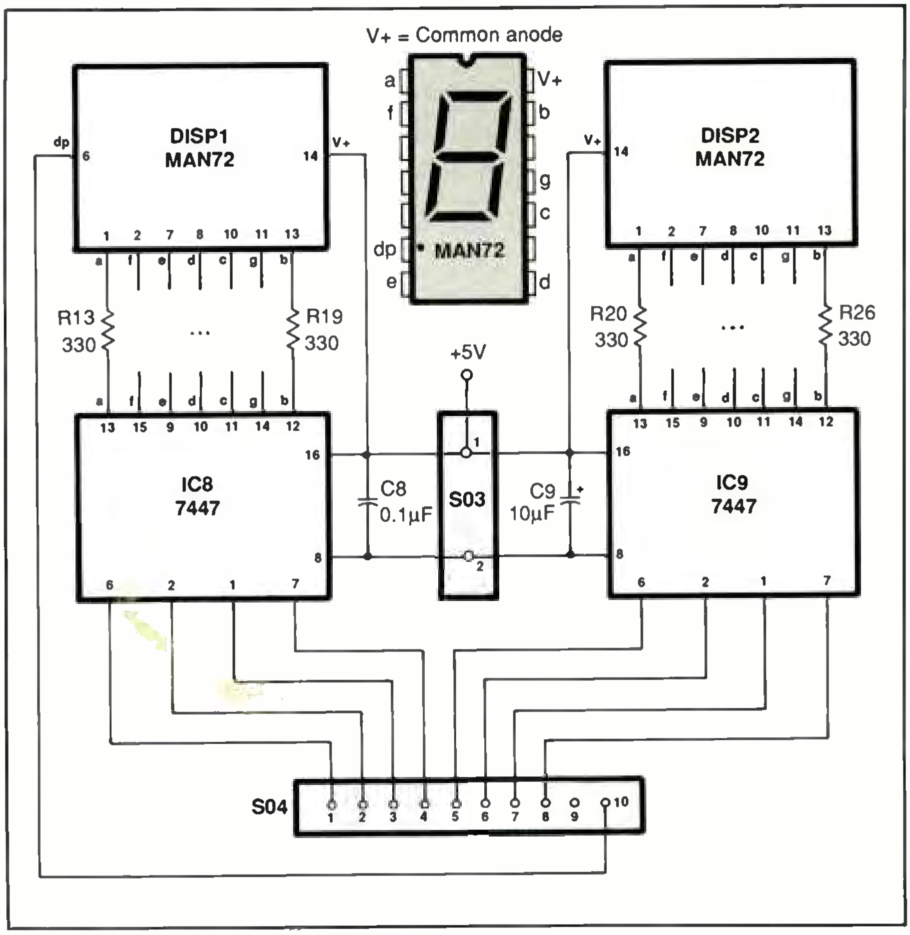


Fig. 3. Schematic diagram of display portion of frequency counting section.

the left-hand decimal point in the display through pin 10 of *P2*.

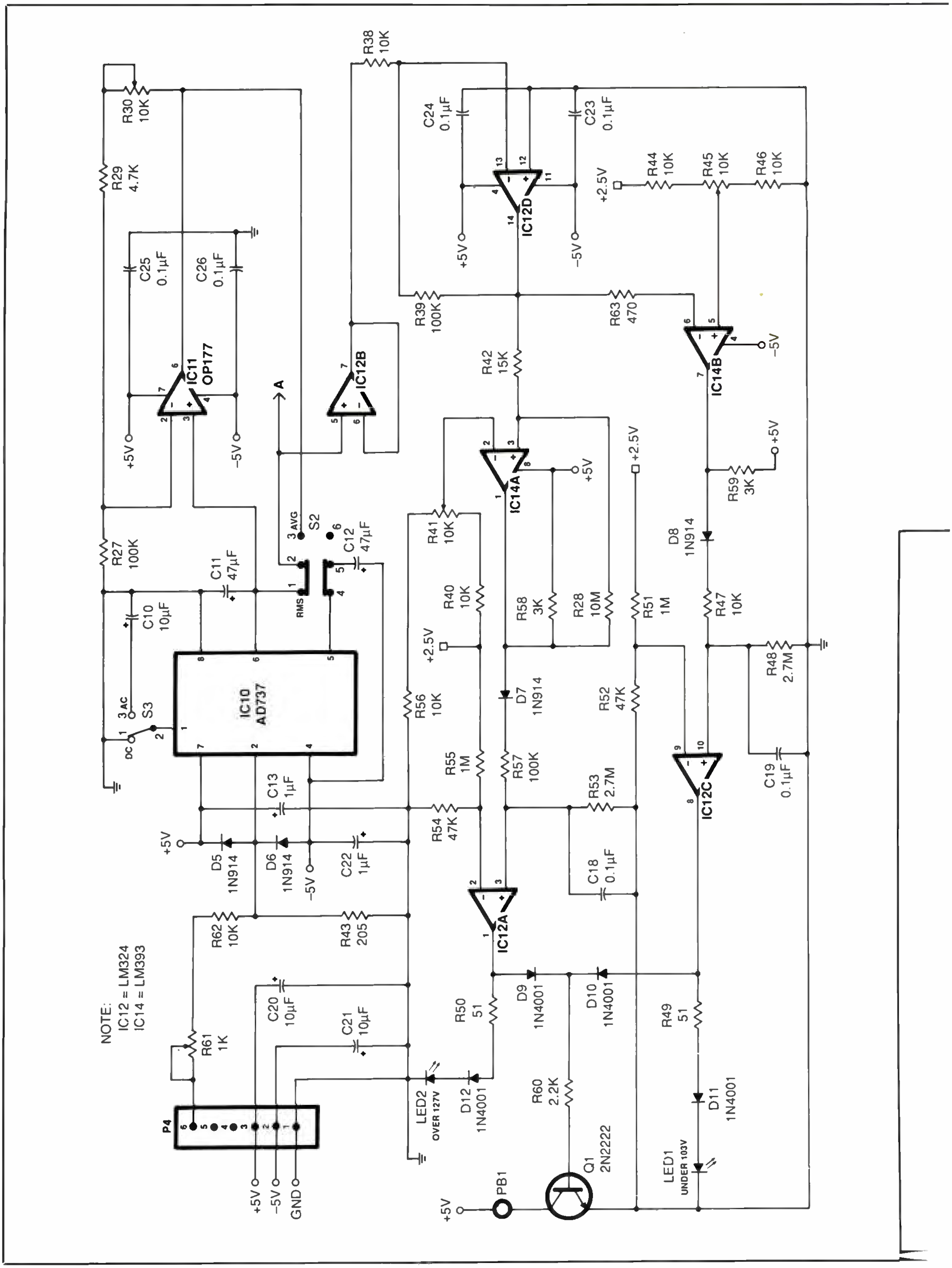
When the output of the eighth flip-flop in *IC4* goes from high to low (clears), the RS flip-flop is set, lighting the OVERRANGE decimal-point (dp) LED in *DISP1*. NAND gate *IC6A* allows only the overrange flip-flop to be set during the period between the clear pulse from *IC4* and enable pulse from *IC3*. This overrange flip-flop is cleared at the same time *IC4* is cleared.

Timing pulses are generated by 32.768-kHz crystal *XTAL1*. The starting frequency is scaled down to 2 Hz by 14-bit binary counter *IC5* and subsequently to 1 Hz by D-type flip-flop *IC2B*. The output of *IC2B* consists of a train of crystal-controlled 0.5-second positive-going pulses.

Shown in Fig. 4 is the schematic diagram for the voltage-measuring portion of the project. This circuit is greatly simplified by use of *IC13*, Intersil's 7107 voltmeter on a chip. This easy-to-use IC not only measures and generates a display of voltage, it even has a built-in voltage standard, although an external voltage reference is used in this project to assure maximum accuracy.

In this circuit, *IC15* is a 2.5-volt reference that is used by *IC13* and several other portions of the circuit. Trimmer control *R33* must be set for a 100-millivolt difference between pins 35 and 36 of *IC13* to provide a usable input range of −199.9 to +199.9 millivolts. Because pin 20 of *IC13* is not connected to any portion of the external circuit, polarity is not shown in the display.

Bear in mind that this project, as


NOTE:
IC12 = LM324
IC14 = LM393
IC10
AD737
IC11
OP177
IC12A
IC12B
IC12C
IC12D
IC14A
IC14B
Q1
2N2222
LED1
UNDER 103V
LED2
OVER 127V
PB1
P4
S2
S3
RMS
AVG
AC
DC
+5V
−5V
GND
+2.5V
A

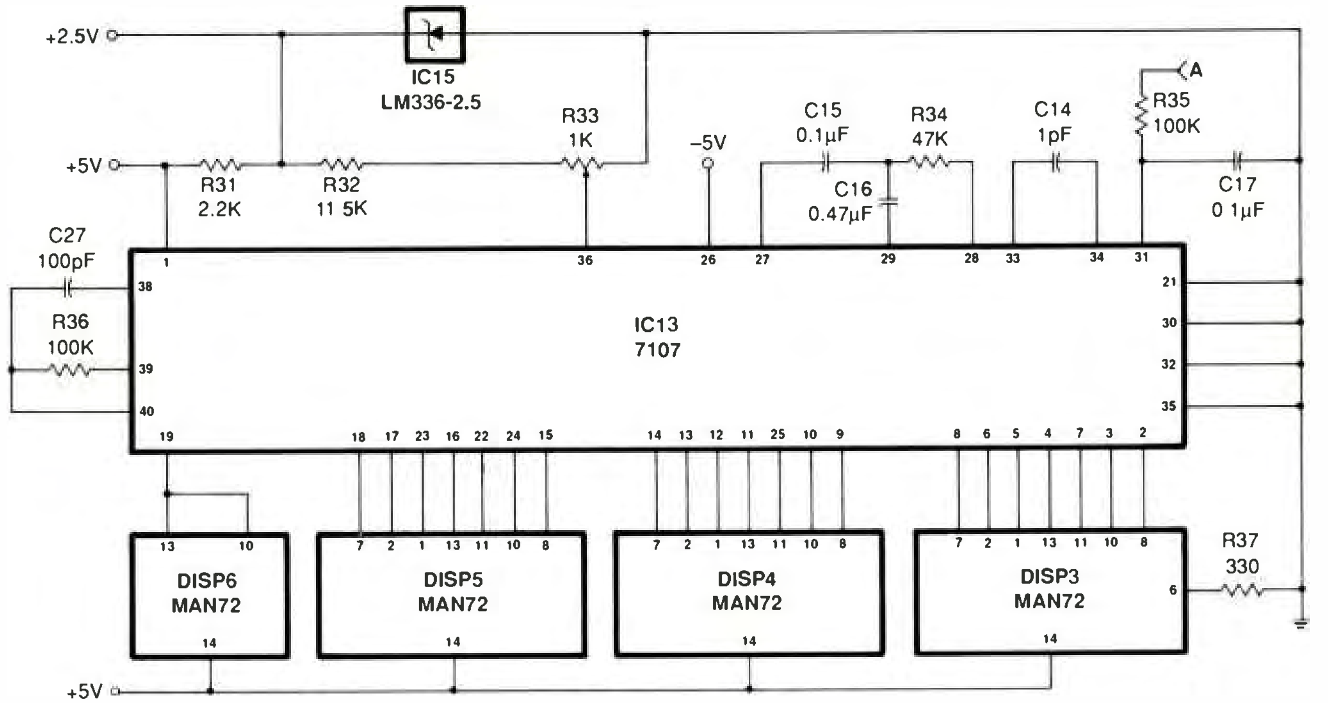


Fig. 4. Schematic diagram of voltage-measuring section, including four-decade numeric-display portion.

designed, measures ac potentials between 66 and 199 volts. Use of a 6.3-volt power transformer, shown as *T1* in Fig. 1, drops the ac line potential to a safe voltage and isolates the circuit from the ac line. This voltage is delivered to the Fig. 4 circuit via pin 6 of *SO7*. It is applied to the voltage divider composed of 1-percent precision resistors *R43* and *R62* and trimmer potentiometer *R61*.

During calibration, *R61* must be set (indirectly) so that the input to pin 2 of *IC10* rms-to-dc converter is exactly $1/_{1,000}$ that of the ac line. This chip has a rated accuracy of ±0.2 millivolts ±0.3 percent when the input is restricted to 200 millivolts rms. If no capacitor is connected between pins 4 and 5, the output voltage is the average of the ac input.

One of the oddities of the AD737 chip is that its output voltage is *less* than the common potential on pin 8. This means that if +5- and −5-volt supply rails are used, the output potential will be negative! This negative output voltage results because, for maximum accuracy, the output of the chip is taken directly from its core. No inverting output buffer is used because it would add offset error.

With no output buffer, the output of the AD737 must be connected to high-input-impedance circuits, such as a voltage follower, noninverting amplifier, etc. (Typical input current to the 7107 used here for *IC13* is just 1 picoampere!) The fact that the output of *IC10* is negative is not important because the 7107 is just as accurate with negative as it is with positive voltages. Since no polarity is indicated in the display in this circuit, there is nothing to cause confusion.

A voltage multiplication factor of 1.11 is provided by *IC1*. Thus, for sine-wave circuits, the average voltage measurement will equal the rms voltage.

Switch *S3* is used for coupling purposes. When set to the AC position, *C9* is placed across pins 1 and 8 of *IC10* to provide ac coupling. Shorting together pins 1 and 8 of *IC10*, by setting *S3* to its DC position, results in dc coupling.

The output voltage from *IC10* or *IC11*, depending on the setting of *S2*, is buffered and then amplified by a factor of 10 before being delivered to the two voltage comparators contained inside *IC14*.

Trimmer control *R41* must be set for a potential of 1.27 volts at its wiper. When the incoming ac line potential exceeds 127 volts rms, pin 3 of *IC14A* exceeds 1.27 volts, causing pin 1 of this chip to go high and trigger *IC12A*. This causes OVER 127V light-emitting diode *LED2* to turn on and triggers buzzer *PB1* to sound.

Detection of brief voltage spikes is accomplished with the network made up of *C18*, *R53* and *D7*. The low-voltage comparator and associated circuitry performs similarly. To be detected, a spike or voltage drop must last for at least several hundredths of a second.

Dc power for the circuits in this project is provided by any ac-operated system that can deliver +5 volts at a minimum of 1.5 amperes and −5 volts at a minimum of 100 milliamperes, both regulated.

Construction

This is a moderately complex project

to build. Almost all components that make up the various sections mount on two medium-size and one small printed-circuit boards. Though you might be able to wire together the circuitry on perforated board if you are very experienced at circuit wiring, pc construction is highly recommended. It reduces the possibility of wiring errors and aids in reliable operation of the various circuits.

Fabricate your pc boards using the actual-size guides shown in Fig. 5. Guide (A) is for the frequency-counter board, guide (B) the voltage-measuring board and guide (C) the small display board. When the boards are ready, refer to the wiring diagrams given in Fig. 6 for details on where to install each component.

Begin construction by mounting the sockets for all DIP ICs, numeric displays and optical isolator on each board in the indicated locations. Do *not* install the ICs in the sockets until after preliminary voltage checks have been conducted and you are certain

PARTS LIST

Semiconductors

D1 thru D4,D9 thru D12—1N4001 or similar silicon rectifier diode
D5 thru D8—1N914 or similar silicon diode
DISP1 thru DISP6—MAN72 or equivalent common-anode seven-segment LED numeric display
IC1—74LS14 low-power Schottky Schmitt trigger
IC2—74LS72 low-power Schottky dual D-type flip-flop
IC3—74LS373 low-power Schottky octal D-type tri-state latch
IC4—74HC390 high-speed CMOS dual decade counter
IC5—CD4060 CMOS 14-stage binary counter/oscillator
IC6—74LS00 low-power Schottky quad NAND gate
IC7—4N25 optical isolator
IC8,IC9—7474 TTL BCD-to-7-segment decoder/driver
IC10—AD737 rms-to-dc converter (see Note below)
IC11—Op-177 precision operational amplifier (see Note below)
IC12—LM324 quad operational amplifier
IC13—7107 3½-decade A/D converter (Intersil)
IC14—LM393 dual comparator
IC15—LM336-2.5 precision 2.5-volt reference
LED1—Yellow jumbo light-emitting diode
LED2—Red jumbo light-emitting diode
Q1—2N2222 or similar npn general-purpose silicon transistor

Capacitors

C1—0.22-μF, 100-volt metallized polyester
C2,C7—0.001-μF, 50-volt ceramic
C3,C8,C15,C17 thru C19,C23 thru C26—0.1-μF, 50-volt ceramic
C4,C5—22-pF. 25-volt ceramic
C6,C9,C10—10-μF, 25-volt electrolytic
C11,C12,—47-μF, 25-volt electrolytic
C13,C22—1-μF, 25-volt electrolytic
C14—1-pF, 50-volt ceramic
C16—0.47-μF, 25-volt ceramic
CX,CY—0.1μF ceramic (not shown in schematics)

Resistors (¼-watt, 5% tolerance)

R1—680 ohms
R2—3,300 ohms
R3,R4,R7,R8,R31,R60—2,200 ohms
R5,R6,R12—1,000 ohms
R9—33,000 ohms
R10—20 megohms
R11—270 ohms
R13 thru R26,R37—330 ohms
R27,R35,R36,R39,R57—100,000 ohms
R28—10 megohms
R29—4,700 ohms
R32—11,500 ohms
R34,R52,R54—47,000 ohms
R38,R40,R44,R46,R47,R56,R62—10,000 ohms
R42—15,000 ohms
R43—205 ohms (1% tolerance)
R48—2.7 megohms
R49,R50—51 ohms
R51,R55—1 megohm (1% tolerance)
R53—2.7 megohms
R58,R59—3,000 ohms
R63—470 ohms
R30,R33,R41,R45—10,000-ohm multi-turn pc-mount trimmer potentiometer
R61—1,000-ohm multi-turn pc-mount trimmer potentiometer

Miscellaneous

F1—3-ampere fast-blow 3AG 250-volt fuse
P1,P2—Two-circuit AMP Mate-N-Lok plug
P3—10-pin header with pins on 0.1" centers and with pin 9 removed (mates with SO6 below)
P4—Six-circuit plug (mates with SO1 below)
PB1—5-volt dc piezoelectric buzzer
SO1—Six-circuit socket with polarizing key in socket 5 with sockets on 0.156" centers (Digi-Key Part No. 2104 or equivalent; also requires WM2301 crimp terminals. Mates with P3)
SO2,SO3,SO5,SO6—Two-circuit socket (mate with P1, P2 and P3 above)
SO4—10-circuit center crimp terminal housing (Digi-Key Part No. WM2008) with polarizing key (Digi-Key Part No. WM2400) in socket 9 (mates with P3 above)
S1—Spst slide or toggle switch
S2—Dpdt slide or toggle switch
S3—Spdt slide or toggle switch
T1—6.3-volt ac power transformer
XTAL1—32.768-kHz crystal
Printed-circuit boards; sockets for all DIP ICs; optical isolator and LED numeric displays; holder for F1; suitable power supply (see text); suitable enclosure (see text); three-conductor ac power cord with plug; chassis-mount ac receptacles and 16-gauge insulated wire (optional—see text); display board cable with connectors at both ends; display filters and bezels (optional—see text); rubber grommet; plastic cable tie; machine hardware; hookup wire; solder; etc.

Note: Sockets, plugs, connecting cables and most other components for this project are available from from Digi-Key, 701 Brooks Ave., Thief River Falls, MN 56701-0677; tel.: 1-800-344-4539. The following items are available from Magicland, 4380 S. Gordon, Fremont, MI 49412: AD737JN, $8.00; OP-177GP, $2.50; data sheets, 50¢ each; heavy-duty Coleco power supply, $25.00 (while supplies last). Add $1.00 P&H per order. Michigan residents, please add state sales tax.

that the boards have been properly wired. Wire each pc board in turn, beginning with frequency-counter board (A), proceeding to voltage-measuring board (B) and finishing with display board (C).

As you wire each board, install first the resistors and then the capacitors, diodes and any transistors. Make sure you properly polarize each electrolytic capacitor and diode and properly base the transistor before soldering any leads into place.

Next, install and solder into place the various board-mounted connectors that will be used for wiring to the power supply and interconnection among the various circuit-board assemblies. If you have any doubt as to which holes a given component is to occupy, refer to the appropriate schematic diagram in Fig. 1 through Fig. 3 for details.

The frequency-counter and voltage-measuring boards must have a number of jumper wires installed at various locations. Use insulated solid hookup wire for these jumpers.

Mount *P3* on the copper-trace (soldering) side of the frequency-counter board. All other components on this and the other two boards mount on the component sides. When mounting the two LEDs on the voltage-measuring board, first temporarily plug a numeric display into the socket for *DISP1*. Plug the two LEDs into the holes in their respective locations (observe polarity) and space them from the top surface of the board so that their domes are at the same height as the numeric display. Solder the LEDs into place.

When you are finished wiring the three circuit-board assemblies, carefully examine each. Make sure all components are mounted in their correct locations and that those that require polarization are properly oriented and based. Turn over the boards and examine your soldering. Solder any connection you might have missed and reflow the solder on any suspicious connections. If you locate any solder bridges, especially between the closely spaced pads for the IC and numeric display sockets, clear them with a vacuum-type desoldering tool or desoldering braid.

If you are building an ac-operated power supply from scratch, you can wire together the rectifier assembly, filter capacitors and regulators on a small piece of perforated board. If they are physically large, any filtering capacitors used in the power supply should be mounted on a solder-lug terminal strip and connected to the rest of the circuit via hookup wires. Use *T1* to power the supply.

In the event you decide to use the Coleco power supply specified in the Parts List, you need only make arrangements for its +5- and −5-volt outputs and ground to be connected to the three circuit-board assemblies through suitable connectors. If you go this route, you still need power transformer *T1* to provide the ac-line input drive to the frequency-counter assembly.

The only components mounted off the circuit-board assemblies, other than those for a from-scratch power supply, are the switches and power transformer.

Select an enclosure that is large enough to accommodate all assemblies that make up the project and has adequate front-panel space for the two displays, LEDs and switches. The enclosure used for the prototype (see lead photo) is a Hammond Manufacturing No. 1401P instrument case. While very attractive and superbly designed, this instrument case is quite costly at about $45 and will set you back more than the total cost of the components it is to house. Therefore, you might want to shop around for a less costly enclosure.

Machine the enclosure as needed to mount the various elements that make up the AC Line Monitor. Drill mounting holes for the circuit-board assemblies. In the floor of the enclosure, drill mounting holes for the transformer and a terminal strip for the filter capacitors if you build a power supply from scratch. Then drill a mounting hole for the fuse holder and an entry hole for the ac line cord through the rear panel. Next, drill mounting holes for the piezoelectric buzzer and switches and cut suitably sized slots for the displays on the display voltage-measuring circuit-board assemblies.

Referring back to Fig. 1, you will note that a pair of ac receptacles have been included in the schematic diagram. These are optional and can be omitted. They were included here only to restore two outlets for the single one that the project occupies in a crowded computer or other arrangement. If you decide to include these in the project, cut the slots and drill the mounting holes for them in the rear or a side panel.

Examining the lead photo, you will also note that optional decorative bezels surround both displays. If you decide to include them, these bezels are available from a number of mail-order suppliers. When you purchase them, be sure to also get the transparent red plastic filters to increase the contrast of the lighted displays.

After machining your enclosure of choice, deburr all holes and cutouts to remove rough edges. Then line the hole drilled for the ac line cord with a rubber grommet. Drill a small hole about 1 inch from the line-cord entry hole to accommodate a 4-40 machine screw. Route the line cord through the grommet and secure it to the inside of the rear wall of the enclosure with a plastic cable tie and 4-40 machine hardware to provide strain relief. Leave about 8 inches of free line cord inside the enclosure.

If you wish, paint the enclosure now. When the paint has completely dried, use a dry-transfer lettering kit or tape labeler to label the switches according to function and position and the displays (see lead photo). If

(Continued on page 70)

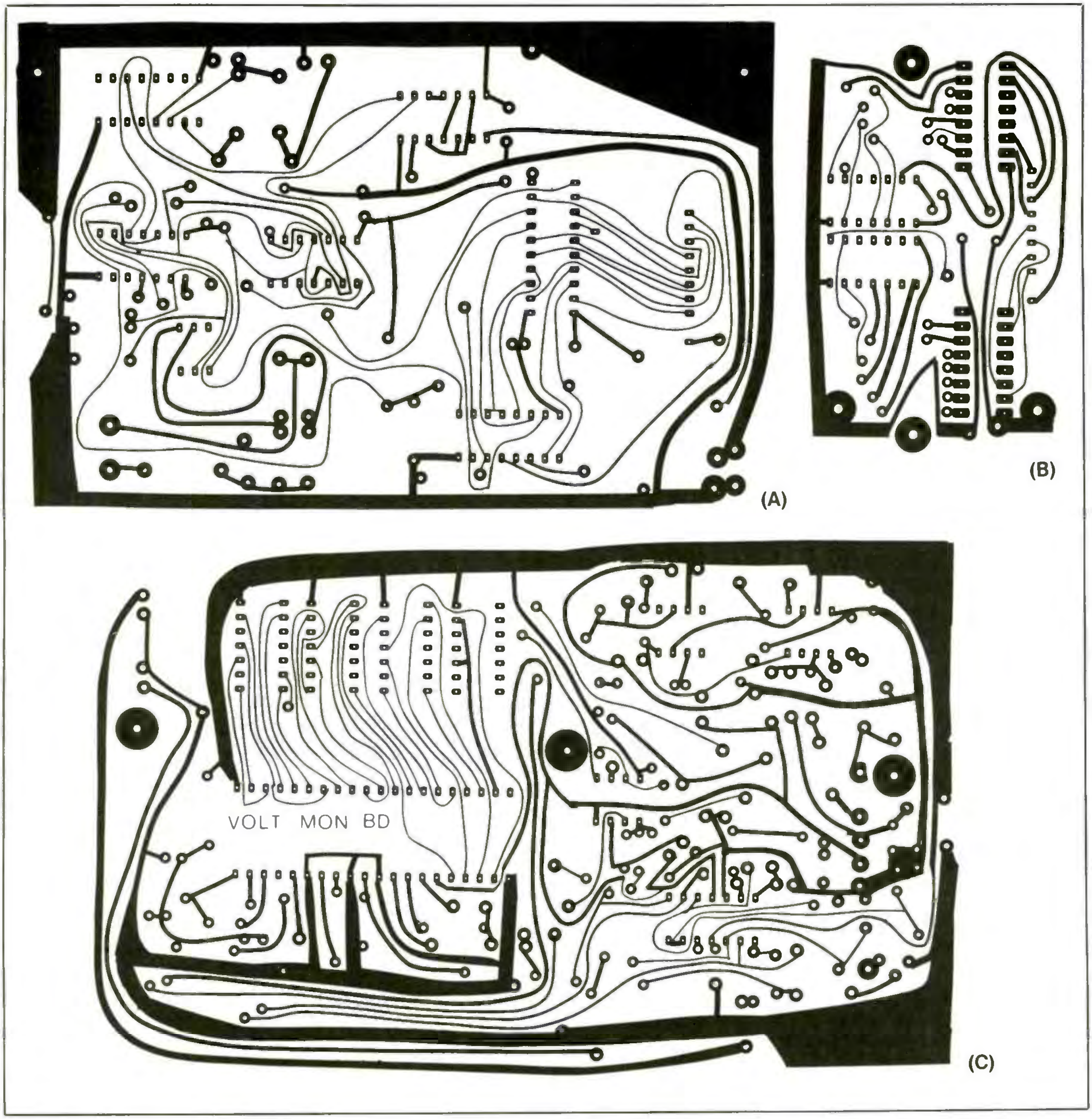


Fig. 5. Actual-size etching-and-drilling guides for printed- circuit boards: (A) frequency-counting module, (B) display module for frequency counter and (C) voltage-measuring module.

you use a dry-transfer kit, protect the legends with two or more light coats of clear acrylic spray.

When you wire the ac line cord, fuse, POWER switch and power transformer, make certain to adequately insulate all points that are at 117-volt ac line potential. Use heat-shrinkable or other insulating tubing.

Connectors and cables are used to supply all power and signals between the various elements that make up the project. The specific types required are detailed in the Parts list. A nine-conductor ribbon cable with connectors at each end interconnects the frequency counter and display circuit-board assemblies. If you wish to economize, you can eliminate the connectors and simply wire together the boards using hookup wire.

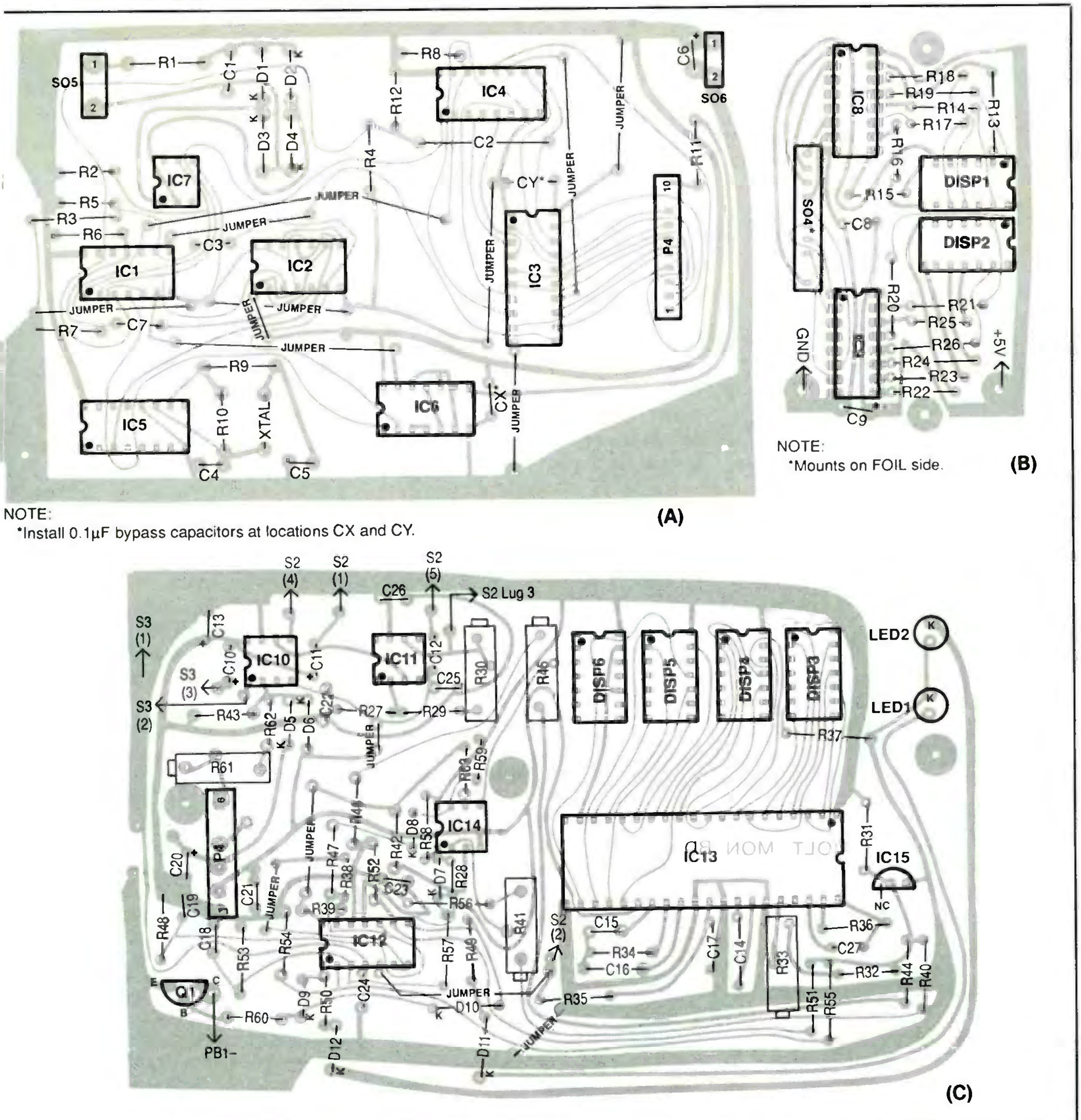


Fig. 6. Wiring guides for: (A) frequency counter board, (B) display board and (C) voltage measuring board.

When you are done wiring the circuit, place a 3-ampere fast-blow fuse in its holder. The project is now ready to be tested and calibrated.

Test & Calibration

Connect the power supply to all circuits with suitable cables, but do *not* plug any ICs, displays or the optical isolator into any of the sockets. Plug the line cord into a nearby ac outlet. Connect the common lead of a dc voltmeter or multimeter set to the dc-volts function to any convenient circuit ground in the project. Then set POWER switch *S1* to "on."

Exercising extreme care to avoid touching any parts of the primary circuit of the power transformer, touch the "hot" probe of the meter to the power pins of the IC sockets on all circuit-board assemblies while monitoring the readings obtained. On the frequency-counter board, you should obtain a +5-volt reading at pin 14 of the *IC1* and *IC6* sockets; pins 1, 4, 10, 13 and 14 of the *IC2* socket; pin 20 of the *IC3* socket; pin 16 of the *IC4* socket; and pin 16 of the *IC5* socket.

On the display board, pin 16 of the *IC8* and *IC9* sockets and pin 14 of all display sockets should also yield a reading of +5 volts. No readings are required on the *IC7* socket. The readings obtained on the voltage-measuring board at pin 7 of the *IC10* socket, pin 7 of the *IC11* socket, pin 4 of the *IC12* socket, pin 1 of the *IC13* socket, pin 8 of the *IC14* socket and pin 14 of all display sockets should also all be +5 volts.

Once you ascertain that the +5-volt bus distribution is correct, touch the "hot" probe of the meter to pin 11 of the *IC12* socket and pin 8 of the *IC4* socket. This time, the meter should display −5 volts.

If you fail to obtain the proper reading at any socket pin, power down the project and disconnect it from the ac power line. Correct any problems encountered.

When you are sure the project has been properly wired, plug the ICs, displays and optical isolator into their respective sockets. Make sure you observe proper orientation in all cases and that no pins overhang the sockets or fold under between devices and sockets. Also, handle any IC, especially the 7107 (*IC13*), that can be damaged by static electricity with the usual precautions for MOS and other such devices. If you are not sure which ICs are static-sensitive, handle all with the same care.

Set AC/DC switch *S3* to the AC position and RMS/AVG switch *S2* to the RMS position. Connect the leads of a high-quality digital multimeter (set

RMS vs. Average Value

The AC Line Monitor described in the main text of this article is capable of measuring the average value as well as the true rms value of the ac line voltage it is monitoring. When in the average responding mode (*S2* set to AVG), the average absolute value of the ac (or ac plus dc if *S3* is set to the DC position) is achieved by full-wave rectification and low-pass filtering. The resulting output is then scaled by multiplying by 1.11 for the rms equivalent value of a sine wave.

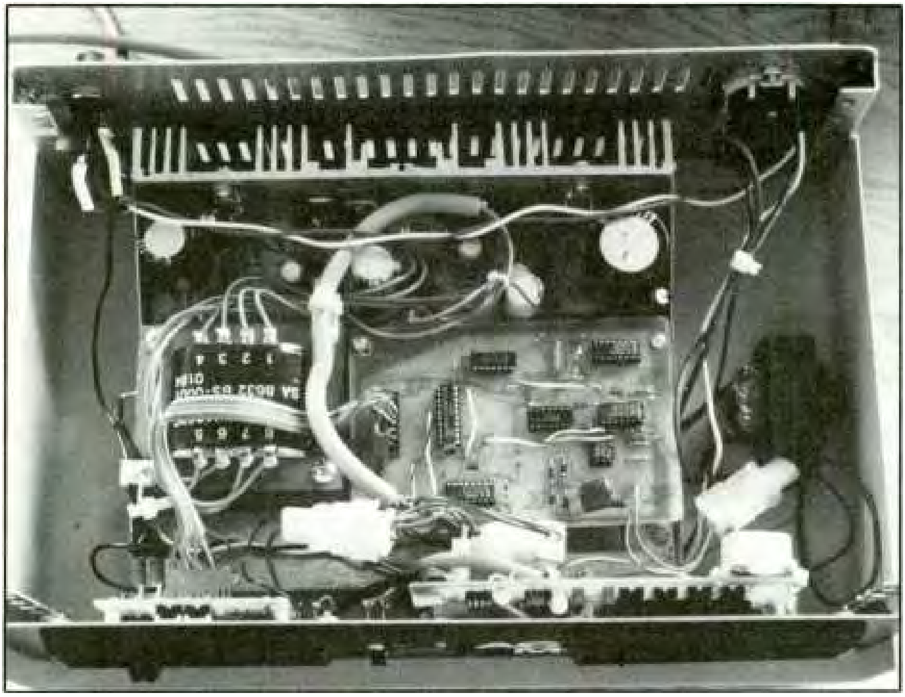
From the definition of rms, the rms value can be determined by squaring the waveform, averaging it and then taking the square root of the result. Rms is a direct measure of the heating value of an ac voltage compared to that of a dc voltage. For example, a 117-volt ac rms signal produces the same heat in a resistive load as a 117-volt dc signal.

For perfect sine-wave voltages, average absolute value is 0.636 that of peak voltage. The corresponding rms value is 0.707 times peak voltage. Therefore, for sine-wave voltages, if you multiply the average value by 1.11, you obtain the equivalent rms value. This is exactly what is done in many ac voltmeters that are designed to measure voltages in terms of rms value.

Bear in mind that 1.11 times the average value of a voltage yields the true rms value for a perfect sine-wave voltage. Attempting to multiply the average value of a square wave by 1.11 will result in an 11-percent too high a reading, while for a triangular wave, the reading will be about 2 percent too low.

Some other types of waveforms, such as rectangular pulse trains, will result in readings that are only a fraction of the true rms value.

From the foregoing, you can use the AC Line Monitor to estimate how close the output waveform of a generator, SPS, UPS or other back-up power source is to a true sine wave.



Interior view of finished prototype of AC Line Monitor.

to read dc volts) across pins 35 and 36 of *IC13*, and adjust *R33* for a reading of exactly 0.100 volt.

Next, switch to the ac-volts function on the multimeter (preferably, the meter being used will have a true rms measuring capability in this function), and measure the ac potential at the ac outlet to which the project is connected. Adjust *R61* for the correct voltage in the display of the AC Line Monitor.

We assume that you want the OVER 127V LED to light when ac line potential exceeds the 127-volt threshold and the UNDER 103V LED to light when the line potential drops below 103 volts. If you wish other voltages for the trip points, divide the warning voltage by 100 to determine proper voltage adjustment.

With the common lead of your multimeter (set to measure dc volts) connected to circuit ground, touch the "hot" probe to pin 2 of *IC14*. Adjust *R41* for a reading of 1.27 volts. To adjust the low voltage trip point, move the "hot" probe to pin 5 of *IC14* and adjust *R45* for a reading of 1.03 volts.

You are now ready to put your AC Line Monitor into service. When you turn on and off power to it, the piezoelectric buzzer will sound for a few seconds. It will also sound when a voltage spike of sufficient duration or voltage drop occurs, the latter even for a few seconds at the onset of a blackout.

When operating from power delivered by a utility company, the project should display a constant 60 Hz, perhaps with a 59 appearing briefly every few minutes or so. If 59, 61 or some frequency other than 60 Hz consistently appears in the display, the crystal oscillator is probably not generating an exact 32,768-Hz ± 1-Hz signal. If this is the case, try replacing the crystal, or replace *C4* with a 10-to-39-picofarad trimmer capacitor.

If the overrange indicator (left-hand decimal point) in the voltage display blinks, the power-line frequency is beyond 99 Hz. **ME**