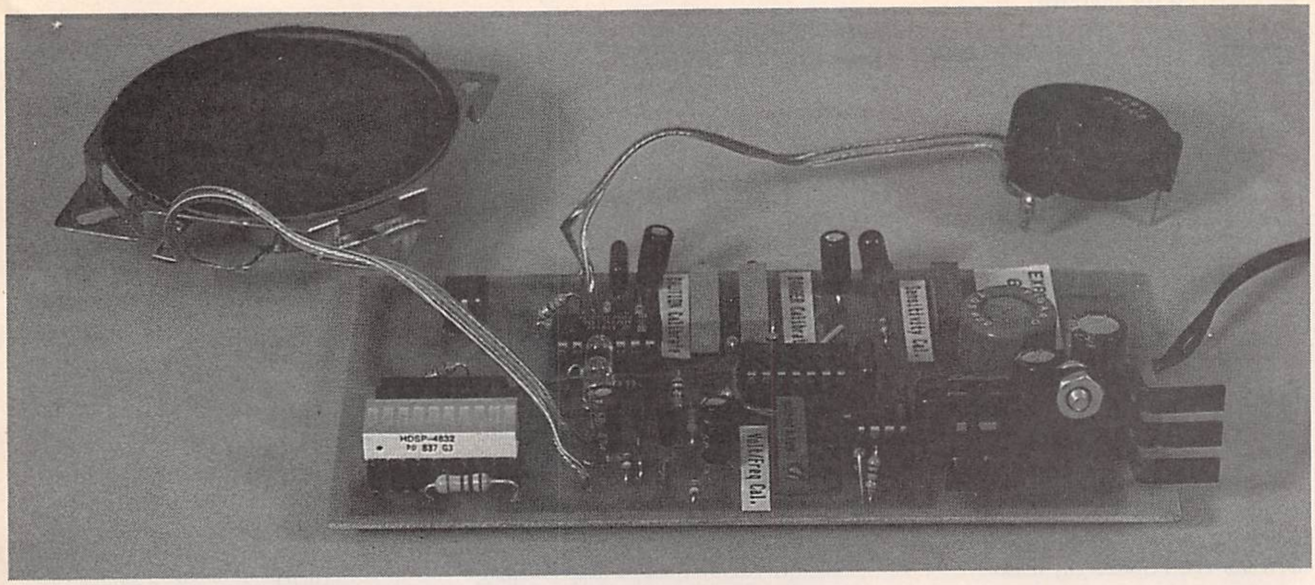

Build an Explosive Gas Detector

Protect your family and property from dangerous gas concentrations by detecting them before they reach combustible levels.

BY ANTHONY CHARLTON

Gas! To many, that very word is synonymous with explosion. Thankfully, modern gas appliances and their delivery systems (supply lines) are cause for much less concern now than in the past—although one still hears about the occasional catastrophe where an explosion has caused misery, property damage, and/or death. Fortunately, such catastrophes are now preventable. Using today's electronic circuitry, you can detect and dissipate hazardous gases before they can accumulate to the ignition level.

The *Explosive Gas Detector* described in this article can identify a whole range of potentially explosive gaseous materials (including invisible, odorless, and highly poisonous carbon monoxide)—making it essentially an all-purpose vapor sensor.

The Explosive Gas Detector offers four types of output; an audible tone that rises in pitch as gas concentration increases; a bargraph display that visually shows relative concentration; an alarm that's activated when the user-set threshold is exceeded; and an optoelectronic (Triac driver) output that can used to trigger a range of AC operated devices (a fan, for instance, to bring fresh air).

The Sensor. At the heart of the circuit is a TGS822 gas sensor (see Fig. 1), which contains a miniature nichrome wire heater (that has a nominal resistance of 38 ohms), which is used keep the surface of the tin dioxide ($Sn0_2$) semiconductor element at a temperature of between 400 and 750°F. Heating that semiconductor element has two effects: It allows greater molecular activity (and hence a more rapid response) and it creates a small convective air current, which draws the monitored air through the unit, thereby eliminating the need for a forced-air system. The sensor also has a double layer of stainless steel gauze at the bottom and top that arrests any flame that may begin inside the sensor due to the hot heater contacting concentrated gas.

Although the TGS822 is highly sensitive, it cannot differentiate between vapors without an external chemical filter, which is beyond the scope of this article. The TGS822's operation is really simple; gas molecules touching the sensing surface causes the unit's internal resistance, depending on the level of concentration, to decrease. (Note that different gases at the scme concentration produce vastly different resistance changes. That's because, generally speaking, the higher the molecular weight of the gas, the greater a change in sensor resistance for a given concentration.) The reduction in resistance allows a correspon-

WARNING!! This article deals with and involves subject matter and the use of materials and substances that may be hazardous to health and life. Do not attempt to implement or use the information contained herein unless you are experienced and skilled with respect to such subject matter, materials and substances. Furthermore, the information contained in this article is being provided solely to readers for educational purposes. Nothing contained herein suggests that the monitoring system described herein can be or should be used by the assembler or anyone else in place of or as an adjunct to professional advice regarding the presence of gas. Neither the publisher nor the author make any representations as for the completeness or the accuracy of the information contained herein and disclaim any liability for damages or injuries, whether caused by or arising from the lack of completeness, inaccuracies of the information, misinterpretations of the directions, misapplication of the information or otherwise.

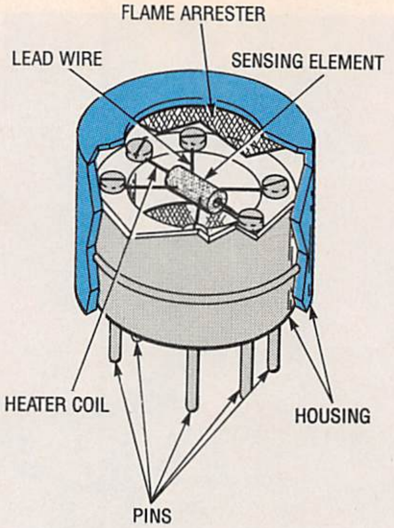

Fig. 1. At the heart of the Explosive Gas Detector is a TGS822 gas sensor.

dingly greater amount of current to pass through the sensor, which can then be interpreted by monitoring/level-detection circuitry.

About the Circuit. Figure 2 shows a complete schematic diagram of the Explosive Gas Detector. The circuit is built around seven integrated circuits (of various types), along with a few additional semiconductors and support components.

The circuit is broken down into several subassemblies, each with its own alarm enunciator, and performing slightly different monitoring functions. Let's examine those subassemblies individually, starting with the sensory portion of the circuit.

At the heart of the sensory portion of the circuit is the aforementioned TGS822 gas sensor (SEN1), which acts as a gas-variable resistor. A regulated +5-volt source is applied to SEN1's heater terminal at pin 5 to keep its semiconductor sensory element at between 400 and 750°F.

Another regulated source, this one +8 volts, is applied to SEN1 at pins 4 and 6 (the input to the gas-variable resistor). The output of the sensor, taken from pins 1 and 3 is fed to R1 (a 10k, 15-turn, trimmer potentiometer), which serves as the circuit's SENSITIVITY ADJUST, allowing the circuit to be set to a user-determined trigger threshold. The output of the sensory circuit, taken from the wiper of R1, divides along several circuit paths.

In one of those paths, the sensor output is fed to U5 (an LM331N voltage-to-frequency converter), which produces an output frequency that is proportional to the magnitude of the input voltage. At zero gas concentration, SEN1 has a high resistance, so the output voltage delivered to U5 is low, thus the output frequency of U5 is low (roughly, as low 100 Hz in clean air). That low-frequency signal quickly rises (to around 8 kHz in an atmosphere contaminated with a near-explosive level of gas) as gas concentrations rise. Trimmer potentiometer, R7, is used to cancel out component tolerances for accuracy.

The output of U5 at pin 3 is fed through C8 to a simple single-transistor audio amplifier (built around Q1), which is used to drive an 8- to 32-ohm speaker (SPKR1). As gas con-

PARTS LIST FOR THE EXPLOSIVE GAS DETECTOR

SEMICONDUCTORS

U1—MOC3042IS-ND, zero-crossing optoisolator/coupler Triac-driver, integrated circuit
U2—AN7805, 5-volt, 1.5-amp, voltage regulator, integrated circuit
UC3—AN7808, 8-volt, 1.5-amp, voltage regulator, integrated circuit
U4—LM324N, general-purpose, quad op-amp, integrated circuit
U5—LM331N, precision voltage-to-frequency converter, integrated circuit
U6—74C14N, hex inverting Schmitt trigger, integrated circuit
U7—LM3914N, dot/bargraph display driver, integrated circuit
Q1—PN2222 or similar general-purpose NPN silicon transistor
SEN1—TGS822 gas sensor
D1, D2—1N4148 or similar general-purpose small-signal silicon diode
LED1—Light-emitting diode
LED2, LED3—High-brightness, light-emitting diode
DISP1—LED bargraph display (Hosfelt Electronics #25-116 or similar)
BR1—1-amp, 50-PIV, full-wave bridge rectifier

RESISTORS

(All fixed resistors are ¼-watt, 5% units unless otherwise indicated.)
R1—10,000-ohm, 15-turn, trimmer potentiometer
R2, R12, R18, R22—1000-ohm
R3, R8—100,000-ohm, 1% metal-film
R4—6810-ohm, 1% metal-film
R5, R15, R16, R19, R20—10,000-ohm
R6—12,100-ohm, 1% metal-film
R7—5,000-ohm, 15-turn, trimmer potentiometer
R9—47.5-ohm, 1% metal-film
R10—22,000-ohm
R11—27,000-ohm
R13, R14—100,000-ohm, 15-turn, trimmer potentiometer
R17, R21—10-megohm
R23—560-ohm
R24—47,000-ohm
R25—4700-ohm
R26—100-ohm, ½-watt
R27—1210-ohm, 1% metal-film
R28—3830-ohm, 1% metal-film

CAPACITORS

C1—1000-µF, 16-WVDC, electrolytic
C2, C3, C10—0.1-µF, ceramic-disc
C4—22-µF, 16-WVDC, electrolytic
C5—100-µF, 16-WVDC, electrolytic
C6—0.1-µF, polyester or Mylar
C7—0.01-µF, polyester or Mylar
C8—0.47-µF, 50-WVDC, electrolytic
C9—1-µF, polyester or Mylar
C11, C12—10-µF, 16-WVDC, electrolytic
C13—0.047-µF, polyester or Mylar
C14—1-µF, 50-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

SPKR1—8–32-ohm speaker
BZ1—Piezo buzzer
T1—12-volt, 250-mA (or more) transformer
PL1—AC molded power plug with line cord
S1—SPDT toggle switch
B1—12-volt Gel-cell battery
Printed-circuit materials, enclosure, battery charger (see text), TO-220 heat sink, IC sockets, wire, solder, hardware, etc.

Note: The following parts are available from Allegro Electronic Systems, Dept-GS, 3 Mine Mountain Road, Cornwall Bridge, CT 06754: The TGS822 toxic-gas sensor with special socket—$23 postpaid. For C.O.D. orders, free catalog of gas sensors, and circuitry call 203-672-0123.

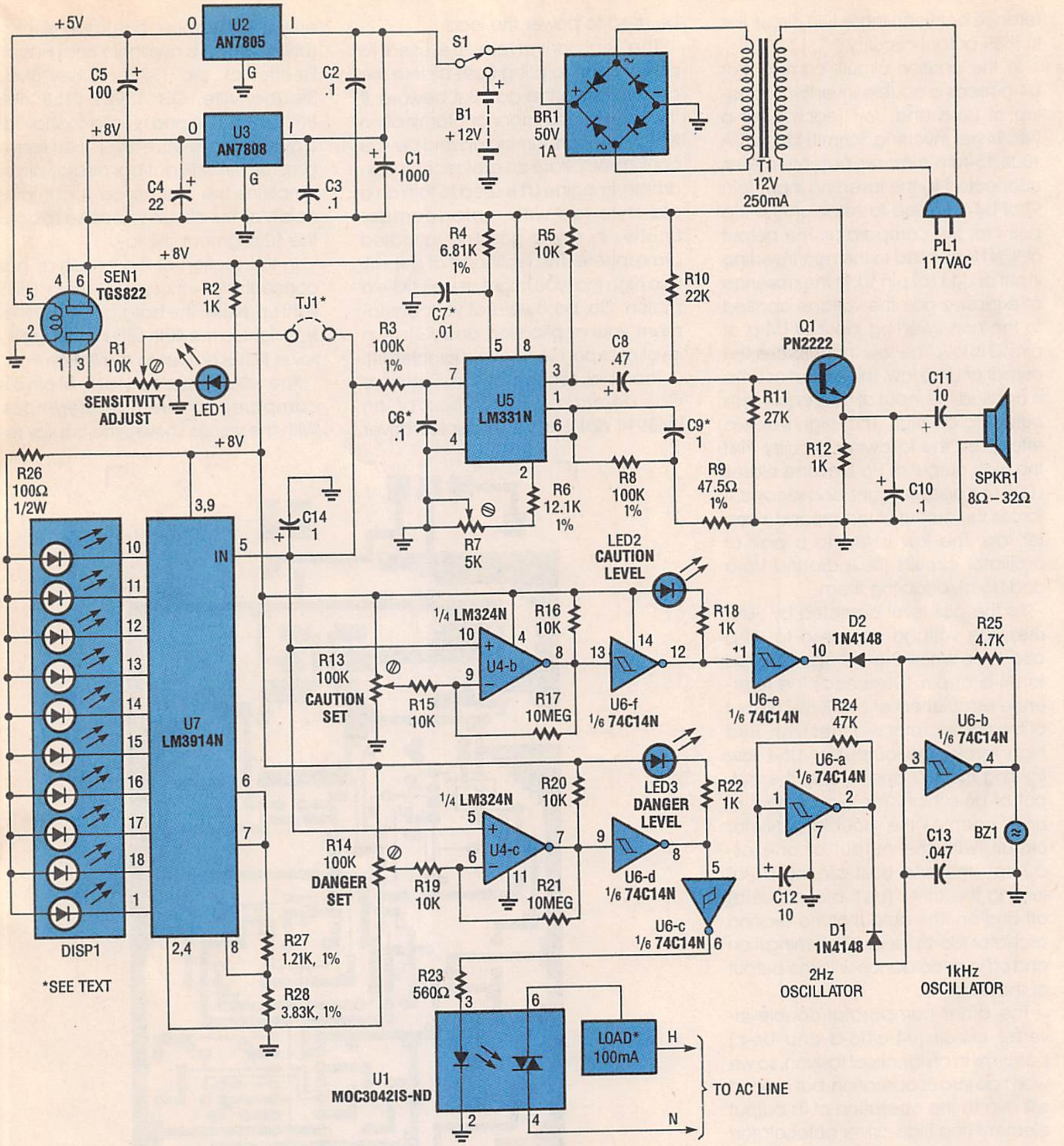

Fig. 2. The Explosive Gas Detector is built around seven integrated circuits (of various types), along with a few additional semiconductors and support components, that comprise several subassemblies, each, with its own alarm enunciator, and performing slightly different monitoring functions.

tamination rises from zero, the tone produced in the speaker goes from a low buzzing to a rather shrill sound.

In the next circuit path, the signal is fed to the alarm section of the circuit—a two-part circuit, which is comprised of half of an LM324 quad op-amp (U4); a 74C14 inverting Schmitt trigger (U6); an MOC3042IS-ND Triac driver, optoisolator/coupler (U1); a buzzer (BZ1); and assorted support components.

In this two-fold section of the Explosive Gas Detector, the output voltage of the sensor circuit is fed to identical comparator circuits (built around U4-b and U4-c), with each comparator circuit feeding identical double-inversion circuits, which we'll refer to as the "caution" and "danger" circuits. Each comparator circuit has a 10k and 10-megohm resistor on the input and feedback, respectively, which provides some degree of hysteresis, so each comparator trips fully on when activated rather than oscillate a little initially. The only real difference between those two circuit lies in their output circuitry.

In the caution circuit, comparator U4-b feeds a double inverter, consisting of U6-e and U6-f (each 1/6 of a 74C14 hex inverting Schmitt trigger). A 100k 15-turn trimmer potentiometer, connected to the inverting input (pin 9) of U4-b is used to establish the trip point for the comparator. The output of SEN1 is applied to the non-inverting input of U4-b at pin 10. In the absence of explosive gas, the voltage applied to the non-inverting input of U4-b at pin 10 is low. The low input forces the output of U4-b low. The output of U4-b is applied the input of U6-f, causing its output to go high. That high has two effects on the following circuitry. First the high output of U6-f reverse biases LED2 so it does not light, and second, it forces the output of the second inverter low. The low is fed to a pair of oscillator circuits (built around U6-a and U6-b), disabling them.

As the gas level detected by SEN1 rises, the voltage delivered to U4-b also rises. When the voltage applied to U4-b at pin 10 exceeds the reference established at pin 9, the output of the comparator switches high. That high forces the output of U6-f low, lighting the LED and forcing the output of U6-e high. The high output of U6-e enables the double-oscillator circuit, with the output of one oscillator (the one built around U6-a) turning the other (built around U6-b) off and on. The output of the second oscillator (U6-b) feeds BZ1, turning it on and off in accordance with the output of the U6-a.

The other comparator/double-inverter circuit (U4-c/U6-d and U6-c) performs in an identical fashion, so we won't go into its operation, but instead will skip to the operation of its output element (the Triac-driver optoisolator/coupler, U1). When the gas concentration detected by the sensory circuit causes the voltage applied to comparator U4-c at pin 5 to exceed the reference established at pin 6 via R14, U1's internal LED lights, turning on its Triac-driver output. With the output turned on, an AC voltage is delivered to the load device, causing it to turn on. The Triac driver can handle low-current, 117-volt AC loads of up to 100 mA. For higher load capacities, the Triac driver can be used to trigger a Triac into conduction, which can then be used to power the load.

The Triac driver can be used to power a fan to bring fresh air into the area to dilute the gas. But beware: If the level of gas/vapor contamination is high enough, turning on said device could precipitate an explosion! For example, imagine U1 is used to turn on a old-style fan with motor-contact brushes in say, a gasoline-saturated atmosphere. The likelihood of a spark is so high that you might as well strike a match. (So, be aware of your equipment, your application, and your own level of expertise to avoid problems!)

The final section of the Explosive Gas Detector is comprised of an LM3914 dot/bargraph display driver and a 10-segment bargraph display (DISP1), which is available from Hosfelt Electronics, Inc. (2700 Sunset Blvd., Steubenville, OH 43952-1158; Tel. 800-524-6464) and is used to show at a glance the relative level of explosive gas. The LM3914 dot/bar display driver simplifies the task, since it contains nearly all the circuitry needed to drive the 10-segment display.

In this section of the circuit, as gas concentration increases, more LED's light up. **Note**: The bargraph is not likely to light to the 10th LED if the SENSITIVITY ADJUST (R1) is not set to maximum.

The voltage applied to U7 at pin 5 is compared to internal references. With the values shown, the display re-

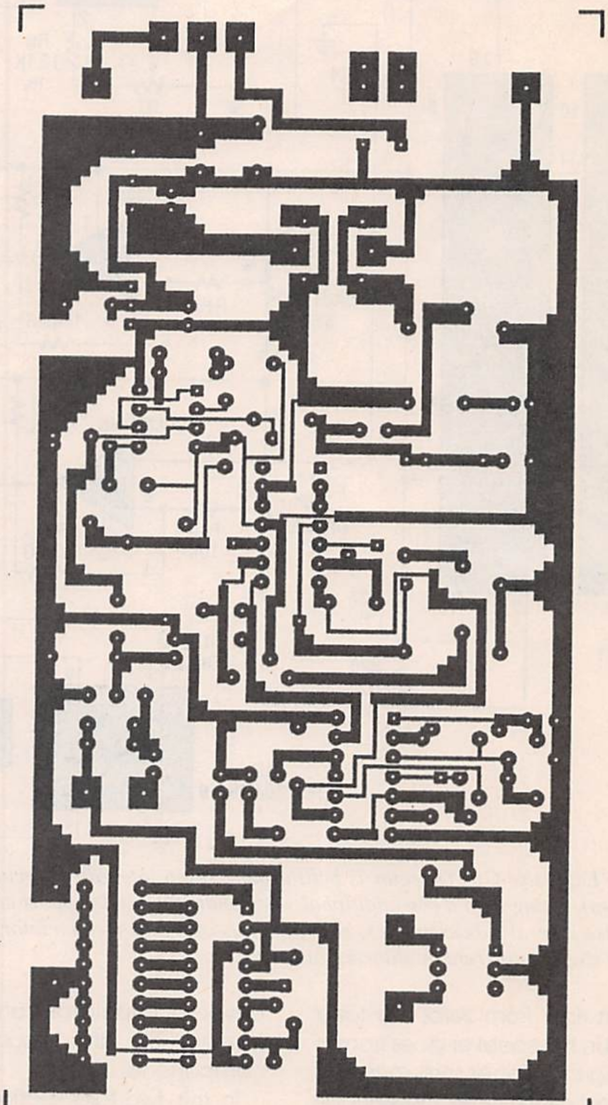

Fig. 3. The Explosive Gas Detector was assembled on a printed-circuit board measuring about 3 1/16 by 5 9/16 inches. A template for that printed-circuit pattern is shown here.

sponds to 0.5-volt increments from 0 to 5 (and over) volts. Normally, one LED (the first one, which is connected to pin 1 of U7) will be lit at all times. As the gas concentration rises, each successive LED lights. Resistor R26 is used to reduce power consumption at a slight sacrifice in brightness when several LED's are lit.

Note that the circuit is designed to be operated either as a stationary device, drawing power from an AC-line derived power source, or as a portable unit, powered from a 12-volt battery. An SPDT switch (S1) is used to select between power sources. The AC-derived, power-supply portion of the circuit is comprised of PL1 (a 117-volt AC power plug with line cord), a 12-volt step-down transformer (T1), a fullwave-bridge rectifier (BR1), and a pair of 3-terminal regulators (U2 and U3). The output of U2 (an AN7805, 5-volt, 1.5-amp regulator) serves only to provide the necessary heater voltage for SEN1. The other regulator (U3, an AN7808 8-volt, 1.5-amp regulator), in conjunction with several dropping resistors, provides all the additional voltages required by the circuit.

In the case of battery operation, the circuit is powered from a 12-volt gel-cell. If you opt for battery operation, it will be necessary to acquire a special charger (sold separately by gel-cell vendors, such as Digi-Key). In addition, be aware that the heating element of SEN1 uses about 130 mA; so if you use a battery, purchase one with several amp/hours capacity for a reasonable running time between charges.

Assembly. The Explosive Gas Detector was assembled on a printed-circuit board measuring about 3 1/16 by 5 9/16 inches. A template for that printed-circuit pattern is shown in Fig. 3, with the corresponding parts-placement diagram appearing in Fig. 4. Since space is at a premium, it is recommended that miniature parts be used to facilitate assembly. Remember that the bargraph display (DISP1) and alarms section are optional, and can be omitted as desired.

Once you've obtained all of the parts (all of which, except DISP1 and SEN1, are available from Digi-Key Corp., P.O. Box 677, 701 Brooks Ave. South, Thief River Falls, MN 56701-0677; Tel. 800-344-4539) listed

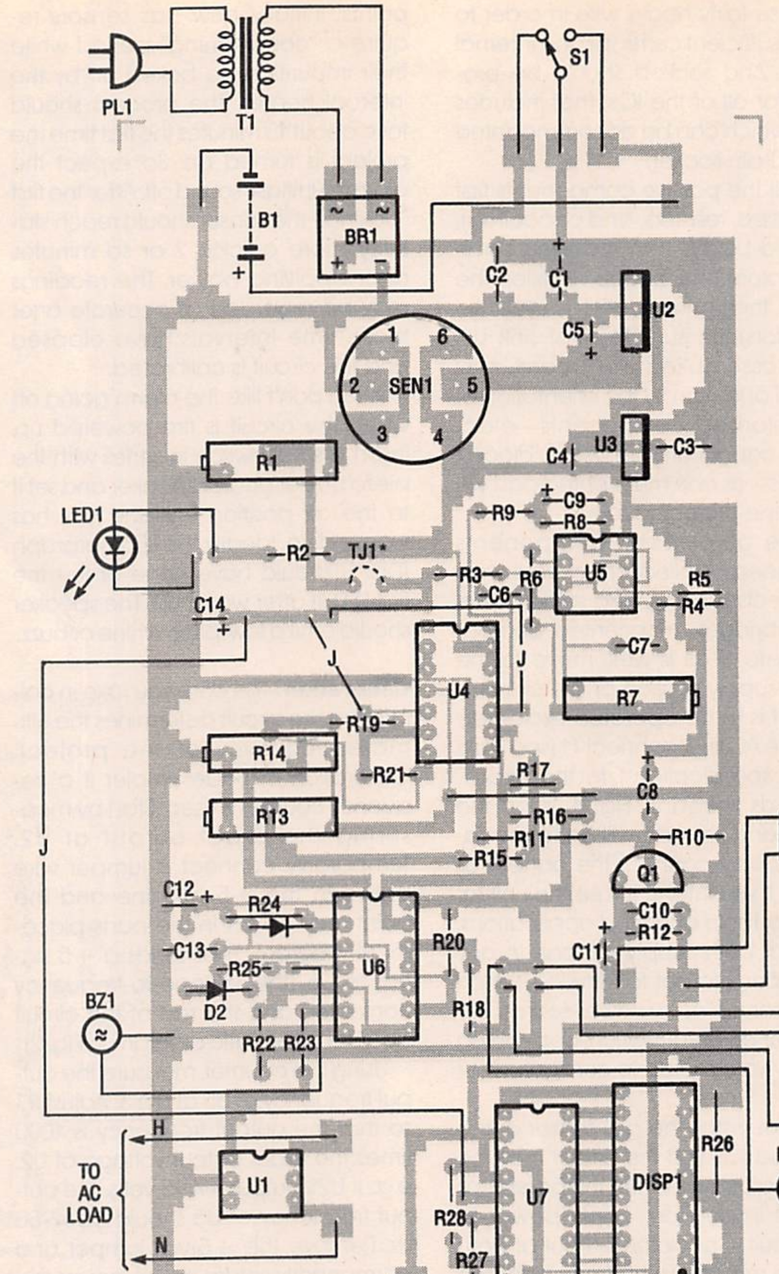

Fig. 4. Assemble the circuit using this parts-placement diagram as a guide. Since space is at a premium, it is recommended that miniature parts be used. Remember that the bargraph display (DISP1) and alarm sections are optional, and can be omitted as desired.

in the Parts List (or those necessary for your version of the circuit) and etched a printed-circuit from the pattern provided, construction can begin. Note from Fig. 4 that the board contains several jumper connections; those jumpers should be installed near the end of the assembly process, since some of them must be routed around some board-mounted components. While we're on the subject of jumpers, be sure not to install the *test jumper (TJ1) until instructed to do so.

A special socket for SEN1 is available from the sensor supplier. The socket can then be wired to the board, allowing the sensor to be located in the open and exposed to free air. The sensor should be mounted vertically with space underneath to allow convection of air through the sensor's case. If the sensor is located a significant distance from the power supply (more than a few feet), use fairly heavy wire in order to supply sufficient current to the internal heater. And sockets should be provided for all of the IC's; that includes DISP1, which can be accommodated by a 20-pin socket.

Install the passive components first (IC sockets, resistors, and capacitors), followed by the non-socketed semiconductors (the bridge rectifier, the diodes, the transistor, and the voltage regulators). Be sure to heat sink U2. When assembling the board, pay special attention to the orientation of the polarized components—electrolytic capacitors, transistors, diodes, and IC's—as one misoriented part will cause the project to fail.

Once all of those components have been installed, check your work for defects such as cold solder joints, solder bridges, misoriented components, etc. If all is well, move to the power-supply section of the circuit. If the unit is to be operated exclusively from the AC line, connect T1 (see Parts List for specifications) to the circuit-board as shown in Fig. 4. If, on the other hand, the unit will be for portable use only, connect the battery as shown. If you intend to use the unit for both portable and fixed applications, connect both supply options. In any event, don't forget to install S1, which either serves as a power-source selector, or an on/off switch, depending on how you decide to configure your unit.

Do not install the gas sensor or the socketed IC's yet; the circuit must be checked out first. When the board has passed inspection, apply power to the circuit. Check the output of both voltage regulators; U2 (+5-volts) and U3 (+8 volts). Once the proper voltages are verified, power-down the circuit and insert the IC's, making sure that they are properly oriented. Also, take precautions against electrostatic discharge when handling U6 (the MM74C14N inverting Schmitt trigger). Using insulated wire, attach a small speaker (8 to 32 ohms) to the board at the points indicated in the parts-placement diagram. The piezo buzzer, BZ1, is also located off-board to save space. Attach its positive (+) lead to the point shown and the ground wire to any point on the ground (−) buss.

Now turn the power on, and adjust R1 and R7 to their approximate midpoints. Initially, new gas sensors require a "conditioning" period while their impurities are baked off by the internal heater. The process should take about 15 minutes the first time the project is turned on. So expect the alarm to initially sound off. After the first "baking," the sensor should reach stability more quickly, 2 or so minutes after applying power. The readings may be regarded as accurate after those time intervals have elapsed and the circuit is calibrated.

If you don't like the alarm going off when the circuit is first powered up, insert a small switch in series with the piezo buzzer and/or speaker and set it to the off position until the unit has warmed up. Ideally, the LED bargraph (DISP1) should have none or just the first LED lit after warm-up. The speaker should emit a low-pitch whine or buzz.

Calibration. The care you take in calibrating the circuit determines the ultimate accuracy of the project. Calibration is made simpler if a frequency counter is used. Start by measuring the exact output of U2. Temporarily connect a jumper wire between the +5 volt line and the point marked TJ1 in the parts-placement diagram. That sends a +5 signal to U5 (the voltage-to-frequency converter) and the rest of the circuit (see the schematic diagram in Fig. 2).

Using the counter, measure the output frequency of U5 at pin 3. Adjust R7 so that the output frequency is 1000 times the exact output voltage of U2; *e.g.*, if U2's output is 4.95 volts, the output frequency of U5 should be 4950 Hz. Remove the +5-volt jumper and permanently solder a wire across the test-jumper pads (a piece of discarded resistor lead will do). Now the voltage-to-frequency circuit is calibrated.

Another approach can be used by those who do not have access to a frequency counter. First you must find a way to produce a stable 0.44 volts DC; to accomplish that, a potentiometer wired to one of the on-board voltage regulators can be used as a voltage divider. Connect the 0.44-volt output of the divider to the test-jumper pad on the R3 side. Adjust R7 until the tone at the speaker is about middle "A" (440 Hz). The circuit can be tuned by ear, using an A-440 tuning fork (a common item in a musician's toolbox) or by comparing it to an instrument or audio generator that will play A-440.

The SENSITIVITY-ADJUST (R1) calibration is a user-specific one. For example, if you want to detect carbon monoxide, as discussed earlier, set the sensitivity to maximum by turning the knob fully counter-clockwise. Note that if you have the sensitivity control turned down too far it will take a large concentration of gas to activate the warning portions of the circuit—avoid turning it too far down at all costs. That feature was designed with a large dynamic range so industrial users who want to scientifically measure high concentrations of explosive gas have the option to do so; users should be very conservative when setting this function.

For example, if your application is precise and you need to detect a specific level of, say, lacquer thinner (as set by OSHA standards for the workplace), you might not want maximum sensitivity so as to eliminate nuisance alarms, but would instead balance the setting of the control along with the CAUTION SET and DANGER SET controls (R13 and R14, respectively). You could also borrow or rent an industrial meter to calibrate the Explosive Gas Detector, perhaps for a specific application and gas.

Builders should be cautioned that large swings in temperature and relative humidity (RH) will affect the sensitivity of the gas sensor. Once you have exactly calibrated your unit for, say, 60% RH at 72°F, you would have to re-calibrate it if the environment changes to, say, 90°F at 40% RH. However, most builders need not be concerned by the changes in temperature and RH on the sensor, since (as we discussed) the object is to detect explosive gas long before it has reached a flammable level.

The final calibration is to adjust the circuit so that nuisance alarms do not occur, while keeping it sensitive enough to sound-off immediately if a bad situation arises. Again, your application will determine the settings. In the case of propane or cooking gas (which has a chemical odor added so you can smell it at low concentrations), I suggest the following: Set R1 at maximum sensitivity, set R13 so that the alarm comes on as LED2

(Continued on page 94)

EXPLOSIVE GAS DETECTOR

(Continued from page 36)

lights, set R14 so that the alarm goes off when LED3 lights. Those settings are for concentrations way below an explosive amount of gas.

Gas Sensing in the Real World. There are two basic kinds of potentially dangerous gas situations. One is a *localized* concentration of gas, such as a leak from a pipe or container holding a flammable liquid, which can cause a fire if ignited or an explosion if the area is leaked into for a long period without incoming fresh air. The second is a *general* concentration, such as might fill a room, building, or the hold of a boat with explosive fumes, perhaps periodically.

I recollect a weekend home whose damp basement contained a large deposit of old coal that generated enough carbon monoxide and other gases via decomposition to give its busy owners painful headaches. Their relaxing "getaway" home had become a nightmare until I identified the antagonist as odorless gas. Ventilation and eventual removal of the coal solved their problem. Even barn silos can accumulate flammable gas from the byproducts of organic decomposition. Such situations pose a real threat for violent explosions, or at least can cause serious health problems after prolonged exposure.

You can use this project to "sniff" out gas by mounting the sensor to a flexible cable, and following the pipe or whatever to find a leak. Just remember if the detector sounds off or you begin feeling ill, the gas concentration is likely high—so get out of that area fast! Peace of mind may be had by permanently mounting the project in an area at risk such as a storage shed for flammable liquid.

Another, heavier Triac may be turned on by the Triac-driver to handle a higher current load if needed. Just remember to exercise utmost caution when dealing with any external device that could heat up or spark around explosive gas.

Conclusion. Well, that's it! Now you can protect yourself, your loved ones, and your property from the hazards of invisible explosive gas. ■