BUILD THIS

Digital TEMPERATURE GAUGE

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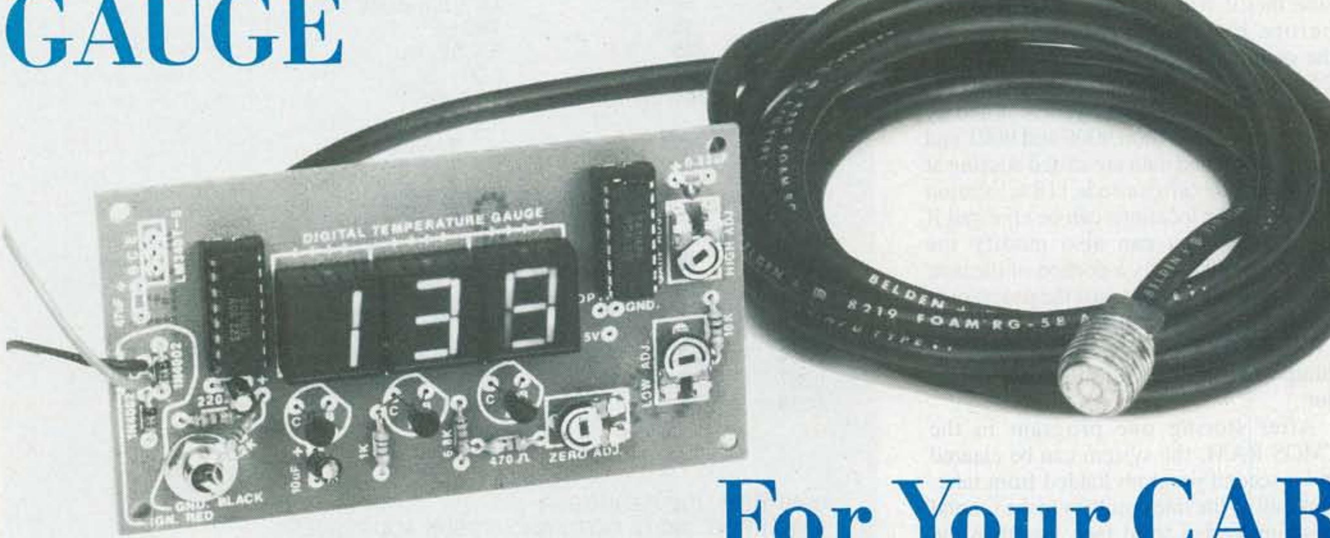

For Your CAR

This is the time of year when automobile engines start to overheat and leave angry motorists stranded by the roadside. This digital temperature gauge for your car will see to it that you're not one of them.

LAST MONTH WE DESCRIBED A DIGITAL voltmeter for your car (or other vehicle) based on the CA3161E and CA3162E IC's. This month we'll use the same IC's to build a digital thermometer that can be used to monitor your car's engine temperature, or in any of many other temperature-measurement applications.

The thermometer's circuit is similar in many respects to that of the voltmeter, and we suggest that you refer to the July 1983 issue of **Radio-Electronics** for a complete description of its operation.

A schematic of the thermometer is shown in Fig. 1. In essence, IC2, a CA3162E dual-slope, dual-rate analog-to-digital converter, translates an incoming analog signal (we'll discuss its source in a moment) into a digital BCD (*B*inary-*C*oded *D*ecimal) number. Then, IC2, a CA3161E, converts that number into signals that cause the segments of DISP1–DISP3 to light up in certain patterns to form numbers. The CA3161E is known as a BCD–7-segment decoder/driver. The power for the entire circuit is derived from IC1, a 340T-5 five-volt regulator.

The temperature probe itself is ridiculously simple—it's just a 1N4002 or 1N914 (1N4148) diode at the end of a piece of coaxial cable. Diodes (and other semiconductor junction-devices) have an unusual—but very useful—characteristic: the forward voltage across them drops as the temperature increases. In the case of diodes, the rate of change is about two millivolts per degree Fahrenheit. The rate of change is linear over a respectable temperature range, and this temperature gauge is accurate from well below zero up to 250°. All we have to do is apply a voltage to the diode and measure the forward voltage, which is then converted by the rest of the circuit into a temperature reading.

(One word of caution, though: If you ever have to change probes, the gauge will have to be recalibrated. While any diode you use will have the same rate of change, each will have a different "base point" from which it is referenced, and recalibration will be necessary to take that into account.)

Construction

Before you start mounting parts on the board, you should prepare the piece of red plastic that will protect the board and display. The plastic should be ⅛-inch thick and just a little larger in area than the circuit board. Place the plastic under the board and, with a sharp point, mark the position of the four mounting holes in the board on the plastic. Then, make a hole at each position for the 4-40 mounting hardware (drill a small pilot hole, and then carefully enlarge it; that way you won't crack the plastic). Temporarily set the plastic aside.

A foil pattern for the digital temperature-gauge circuit board is shown in Fig. 2. If you would rather purchase a ready-to-use board than make your own, see the Parts List for the supplier.

Techniques for PC-board construction were discussed in detail in the article the digital voltmeter, and if this is your first project, you will gain a lot by reading it before you start building.

Figure 3 shows a parts-placement diagram for the board. It's advisable to use sockets for IC2 and IC3; install them first, then the resistors, followed by the capacitors. Do not install IC2 or IC3 until after your initial board-checkout. When you mount the three 7-segment LED's, DISP1–DISP3, solder only two pins at opposite corners at first. That will permit you to adjust their positions fairly easily if you don't put them in straight the first time. Be sure that the ridges at the tops of the LED's face the way shown in the diagram. When you install jack J1, you may have to enlarge the hole in the board so it can fit through. Use a lockwasher on the foil side of board both to keep the jack

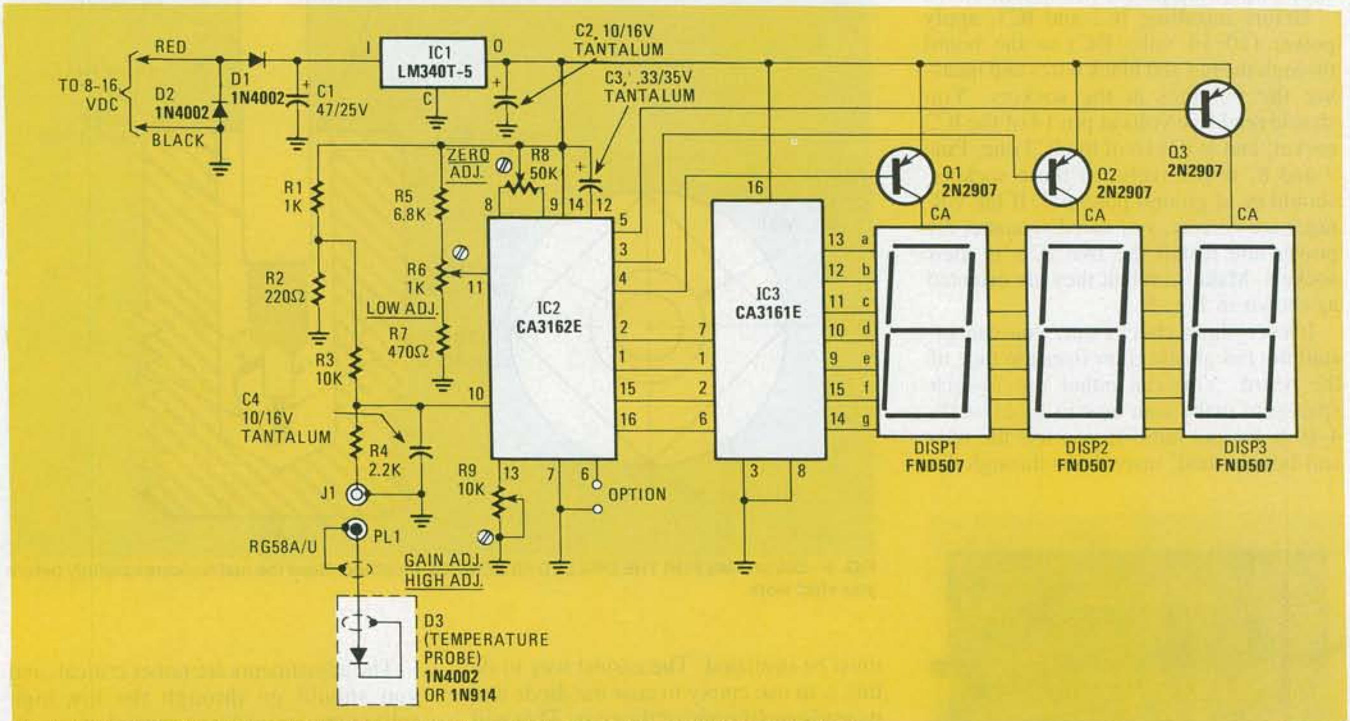

FIG. 1—THE BASIC DIGITAL TEMPERATURE GAUGE consists of a probe, an A/D converter (IC2), a 7-segment LED decoder/driver (IC3) and, of course, the display LED's themselves.

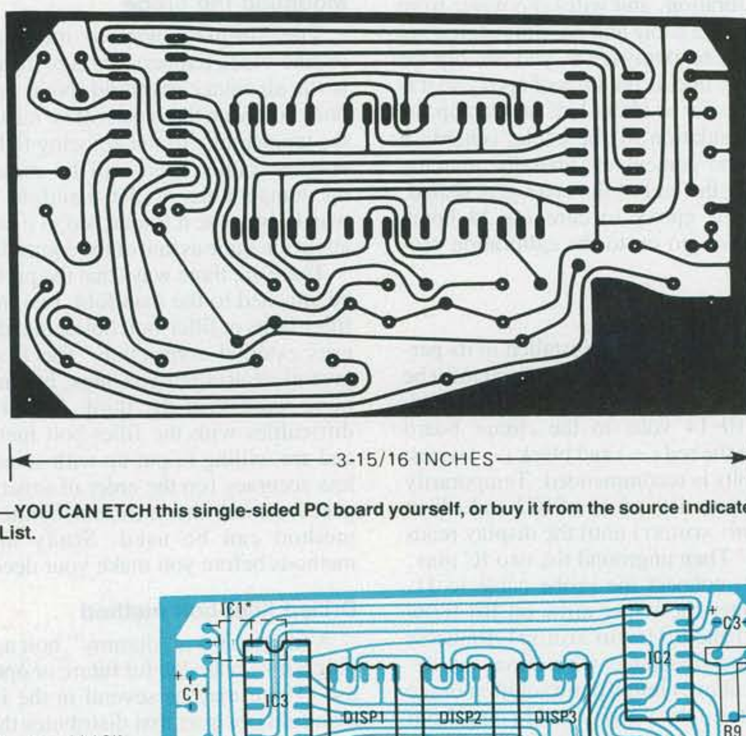

FIG. 2—YOU CAN ETCH this single-sided PC board yourself, or buy it from the source indicated in the Parts List.

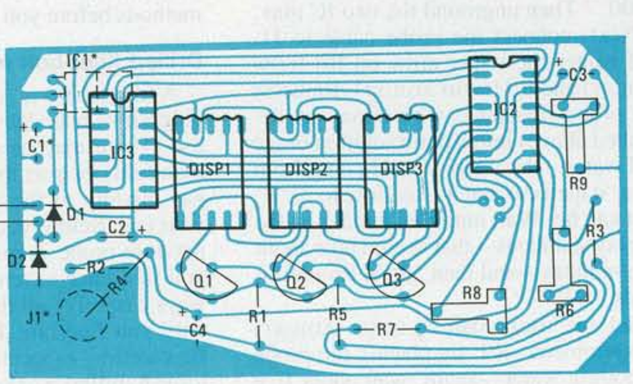

FIG. 3—TWO COMPONENTS (indicated by dashed lines) mount on the foil-side of the board: they are IC1 and C1.

from working loose and to make sure that it makes good electrical contact with the foil. Note that the "business end" of the jack is on the foil side of the board. Connect resistor R4 from the center lug of the jack to the board.

The last two components to be installed (except for the two IC's) are IC1 and C1. They should be mounted on the *foil side* of the board, as shown in Fig. 4. That is done to keep the total height of the component-side of the board down. Make sure that the regulator is arched over backward as shown, but that its case does not contact the board. (A piece of electrical tape on the board beneath the regulator to act as insulation will make sure of that!)

Finally, connect three-foot lengths of

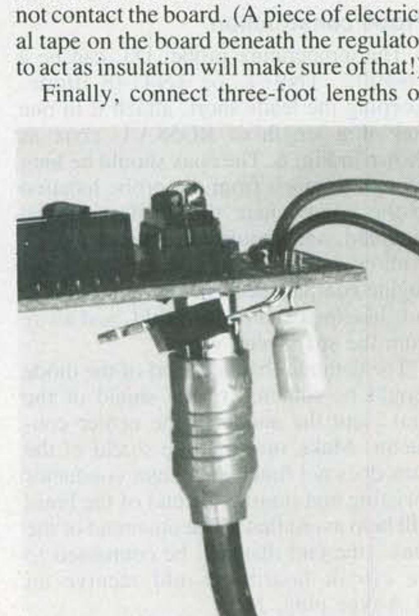

FIG. 4—BEND IC1 OVER BACKWARD on the bottom of the board as shown.

red and black wire to the points on the board indicated in Fig. 3; they will be used to provide power to the circuit.

Before installing IC2 and IC3, apply power (10–14 volts DC) to the board through the red and black wires and measure the voltages at the sockets. You should read five volts at pin 14 of the IC2 socket, and at pin 16 of the IC3 one. Pins 7 and 8, respectively, of those sockets, should be at ground potential. If the voltages are correct, you can disconnect the power and install the two IC's in their sockets. Make sure that they are oriented as shown in Fig. 5.

If everything checks out, you can install the red plastic filter over the face of the board. You can either use ¾-inch spacers or make your own using 1½-inch 4-40 bolts and nuts. If you use the nut-and-bolt method, insert bolts through the

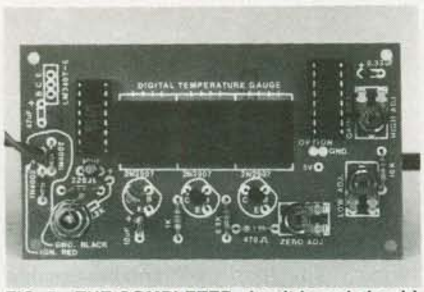

FIG. 5—THE COMPLETED circuit board should look like this. Note the mounting of J1 and how R4 is connected to it.

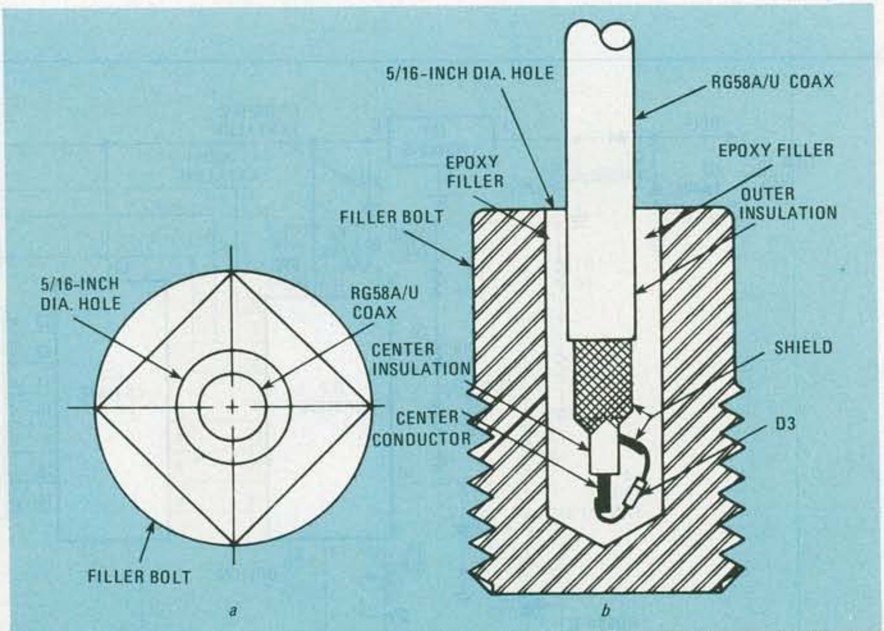

FIG. 6—DIAGRAMS FOR THE DRILLED FILLER-BOLT method. Read the instructions carefully before you start work.

plastic, and secure them with nuts on the reverse side. Then screw a second nut onto each bolt, allowing ¾ inch of space between it and the first one. Insert the bolted-plastic assembly into the holes in the PC board, and secure it with four more nuts.

With that done, you are ready to build the temperature probe and calibrate unit.

Probe construction

The temperature probe, D3, can be a 1N4002, 1N914, or 1N4148 diode. Keeping the leads short, attach it to one end of a length of RG58A/U coax as shown in Fig. 6. The coax should be long enough to reach from the probe location to the point where the display will be mounted, and should have enough slack to allow it to be routed around areas of the engine compartment that get particularly hot, like the exhaust manifold, and away from the spark-plug wires.

The cathode (banded) end of the diode should be soldered to the shield of the coax, and the anode to the center conductor. Make sure that the shield of the coax does not touch the center conductor (twisting and tinning the end of the braid will help avoid that). The other end of the coax—the end that will be connected to the circuit board—should receive an RCA-type plug, PL1.

To avoid errors and contamination during the calibration, the probe assembly must be insulated. The easiest way to do this is to use epoxy to coat the diode and its leads *and* the end of the coax. That will prevent any current leakage when the probe is immersed in the water baths used for calibration, and will keep water from entering the cable and possibly damaging it. If you're extravagant, you can dip the assembly into a container of epoxy so it is coated as far as about half an inch up the outer insulation of the cable; otherwise smear the cement on liberally, making sure that the end of the coax gets sealed. Allow the epoxy to cure for 24 hours before you go on to the calibration procedure.

Calibration

Before the probe is installed in its permanent location, the meter circuit must be calibrated. *Without the probe connected*, apply 10–14 volts to the circuit board through the red (+) and black (−) wires; 13.8 volts is recommended. Temporarily ground pins 10 and 11 of IC2 and adjust R8 (ZERO ADJUST) until the display reads "000." Then unground the two IC pins.

Next, connect the probe cable to J1, and center the wiper arms on R6 (LOW ADJUST) and R9 (HIGH ADJUST). Immerse the probe (insulated with epoxy as described above) into a plain solution of ice and water—the water should come from ice as it melts so that it is as close to 32° F. as it can be. Wait until the reading on the display stabilizes—that should take about five minutes—and then adjust R6 until it reads "032."

Set the HIGH ADJUST (GAIN ADJUST) potentiometer, R9, by placing the probe in boiling water—again, wait about five minutes until the display stabilizes—and adjusting the control until you read "212."

The adjustments are rather critical, and you should go through the low-high calibration procedures several times to eliminate as much error as you can.

Mounting the probe

The simplest way to measure the engine-block temperature is to measure it at the air-intake manifold. Note that that does not mean that you will be measuring the temperature of the air being fed to the engine—rather, you will be measuring the temperature of the manifold itself, which, because it is attached to it, will be about the same as that of the engine block.

There are three ways that the probe can be attached to the manifold: two involve filler-bolts or filler-bolt holes, and the last uses external connection. The first two give more accurate readings, but involve more work than the third. If you have difficulties with the filler-bolt methods, and are willing to put up with somewhat less accuracy (on the order of several degrees), then the external-connection method can be used. Study all the methods before you make your decision.

Drilled filler-bolt method

A filler bolt is a "dummy" bolt used to plug a hole intended for future or optional use. There may be several in the intake manifold (the part that distributes the air/gas mixture to the engine cylinders) of your car. Before you can install the temperature probe in one of the filler bolts, you first have to remove it; that isn't always easy. Try all the unused filler bolts until you find one that unscrews easily. Be careful—especially if you're using a long-handled socket wrench—not to apply too much force. Doing so can shear the bolt, strip its threads, or it can even crack the manifold.

PARTS LIST

All resistors ¼ watt, 5% unless otherwise indicated
R1—1000 ohms
R2—220 ohms
R3—10,000 ohms
R4—2200 ohms
R5—6800 ohms
R6—1000 ohms, trimmer potentiometer
R7—470 ohms
R8—50,000 ohms, trimmer potentiometer
R9—10,000 ohms, trimmer potentiometer
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C4—10 µF, 16 volts, tantalum or electrolytic
C3—0.33 µF, 35 volts, tantalum
Semiconductors
IC1—LM340T-5 (7805) positive 5-volt regulator
IC2—CA3162 dual-slope, dual-speed, A/D converter
IC3—CA3161 BCD–7-segment multiplexing decoder/driver
DISP1–DISP3—FND507 (FND510) 0.5-inch 7-segment LED, common anode
D1, D2—1N4002
D3—1N4002 or 1N914 (1N4148)
J1—RCA phono jack
PL1—RCA phono plug
Miscellaneous: PC board, RG58A/U coax, epoxy, etc.

The following are available from Digital World, PO Box 5508, Augusta, GA 30906: temperature gauge PC-board only, $7.50; temperature gauge PC board with schematic & diagrams, $8.50; IC2 and IC3, $12.00; PC board and IC1–IC3, $20.00; kit of all parts including coax (does not include plastic, solder or chassis), $32.50. The first two items (PC board and PC board with schematic & diagrams) are postpaid within the continental U.S.; all other items add $2.00 shipping & handling. APO, FPO, and other U.S. add $3.00. Canadians add $3.00 (please use U.S.-dollar money order). All others write for prices and shipping costs. Please allow 4 to 6 weeks for delivery.

Sometimes, applying some penetrating oil and allowing it to work overnight will allow you to remove a frozen- or rusted-in filler bolt with several light taps and the *gentle* application of force. If none of the bolts can be removed conveniently, you'll have to connect the probe externally, as described below.

With a bolt removed, use a drill press to drill a 5/16-inch hole in it from the outside to the inside (naturally). Refer again to Fig. 6 (The completed filler-bolt assembly is shown in Fig. 7). The hole should be deep enough to hold the diode and a "dab" of retaining epoxy, but must stop ⅛-inch short of the end of the bolt. If you drill through the end, you'll have to start over with another bolt; it might be a good idea for you to practice on a non-essential piece of material similar to the bolt first, to get a "feel" for the procedure.

FIG. 7—COMPLETED FILLER-BOLT probe with cable attached.

Mix a batch of quick-setting epoxy and fill the hole half-full with it. You'll have to work fairly quickly—after five or ten minutes the epoxy starts to set and becomes difficult to work with.

Then insert the diode assembly into the epoxy in the hole in the bolt until it makes contact with the bottom of the bolt. Now slowly and gently pull on the coax to lift the diode until it is no longer in contact with the bolt. That's just to make sure that the probe will not short out to the bolt even if there's a defect in the probe's epoxy "insulation." A change in position of about ⅛-inch should be enough. Stop! Hold the probe in that position for at least ten minutes, until the epoxy has set enough to be firm.

When the epoxy has started to set, any excess that may have been forced out of the hole can be removed carefully. Allow the epoxy to cure for 24 hours at a temperature between 60° and 90°F. Finally, after the epoxy has cured, check the cable with an ohmmeter to make certain that the probe has not shorted to the bolt. Reinsert the bolt in the manifold, and proceed to the "Installation" section.

Filler-bolt hole method

If you are unable to remove any of the filler bolts, the probe can be inserted in an unused filler-bolt hole in the intake manifold. The hole should be cleaned thoroughly and any accumulated oil or rust removed—epoxy needs a clean surface to bond to and any foreign matter could prevent a solid adhesion and result in the probe's working loose and coming out.

Make sure the engine is cool—not only could you get burned otherwise, but some epoxies are flammable, and could catch fire if applied to a hot surface. The angle of the hole may present a problem in getting the epoxy in and keeping it in; it may be necessary to build up a shelf of wax around the lower rim of the hole to ensure that enough epoxy is retained to encapsulate the probe and to grip the probe-end of the coax securely.

Mix the epoxy and force an amount into the bottom of the hole by using a wooden dowel of about the same diameter as the hole. The hole should be filled completely to make certain that there's enough cement to hold the probe and cable. The rest of the procedure is essentially the same as that given for the "drilled filler-bolt" method: insert the probe so it's about ⅛ inch from the bottom of the hole and allow the epoxy to set and cure while using an ohmmeter to make sure that the probe doesn't short to the side or bottom of the hole. After the epoxy has cured, proceed to the "Installation" section.

External probe-attachment

If neither of the first two methods will work for you, then the probe can be epoxied to the outside of the intake manifold.

Clean the selected surface well so that the epoxy will bond firmly to it and mix some epoxy (do not mix it all; you'll need more shortly). Apply a coating about ⅛-inch thick to an area about 1½-inches square to form a mounting base. Let the cement harden for 20-30 minutes and then mix a second batch of epoxy. Tape the probe/coax assembly in place and use the second batch of epoxy to encapsulate it. Use your ohmmeter to make sure that the probe is not shorting out to the surface on which it's mounted. After the epoxy has cured, you may proceed to the "Installation" section.

Installation

The temperature gauge can be installed either in the dashboard of your car, or in a separate enclosure. The cable from the probe can be routed through a hole in the firewall; you can later seal the hole around the cable to keep dust, water, and fumes out of the car. Remember to plug the probe cable into the board—otherwise you'll go crazy trying to figure out why the gauge doesn't work.

A good place to obtain power for the gauge is from the same fuse terminal to which your car's radio is connected. The red wire should go there, and the black wire to the car's body (so there is a return to the negative post of the battery).

If you find that the operation of the gauge creates interference on your AM radio, there are several "fixes" you can try to get rid of it.

First, try connecting the gauge to a power source other than the radio's fuse. You can also try locating the gauge a distance away from the radio itself. Finally, if the circuit board is not in an enclosure, add one, made of metal and grounded; this solution is usually quite effective.

A last word of advice: Don't disconnect your present temperature gauge or warning light—it's always a good idea to have a backup!

The use of this gauge is not limited to your car, of course. You can use it to monitor the temperature inside your freezer, for example, or just as an electronic indoor or outdoor thermometer. However you use it, you'll find that its speed, accuracy, and readability make it a valuable instrument to have. **R-E**