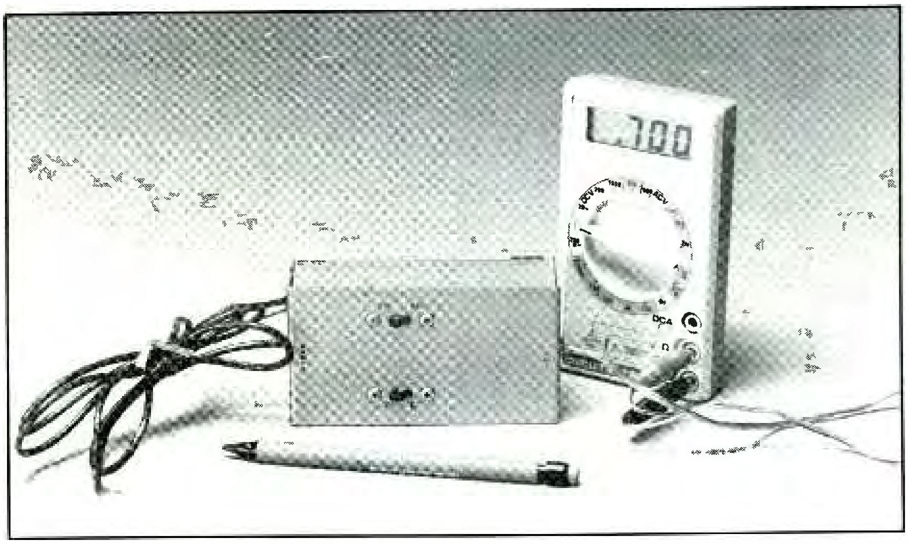
A °C/ °F Thermometer Accessory

Simple construction project lets you measure temperatures with any voltmeter

By Bill Owen



An accurate electronic thermometer can be a very useful item, both on your workbench and for general use around your home. It can be used to monitor heat build-up in and around all types of powered equipment and to track down heat-related problems in malfunctioning circuits and systems. Around the home, it can be used to monitor ambient room and outdoor temperatures; keep tabs on air-conditioning and heating systems; monitor refrigerators and freezers; and much more. In fact, once you use an easy-to-read and accurate electronic thermometer, you are likely to find all sorts of uses for it you never considered before.

Our electronic thermometer accessory starts off with the premise that you have on hand an accurate dc voltmeter. A garden-variety DMM will do nicely. Actually, this accessory can be used with any digital or analog multimeter, basic voltmeter or panel meter. The accessory is built around special solid-state circuitry, including the temperature sensor, that provides a linear 10 mV/degree output. It is switch-selectable to allow you to measure temperatures in both °C and °F. Furthermore, its active-circuit design allows the temperature sensor to be located literally thousands of feet away without the attendant problem of noise pickup.

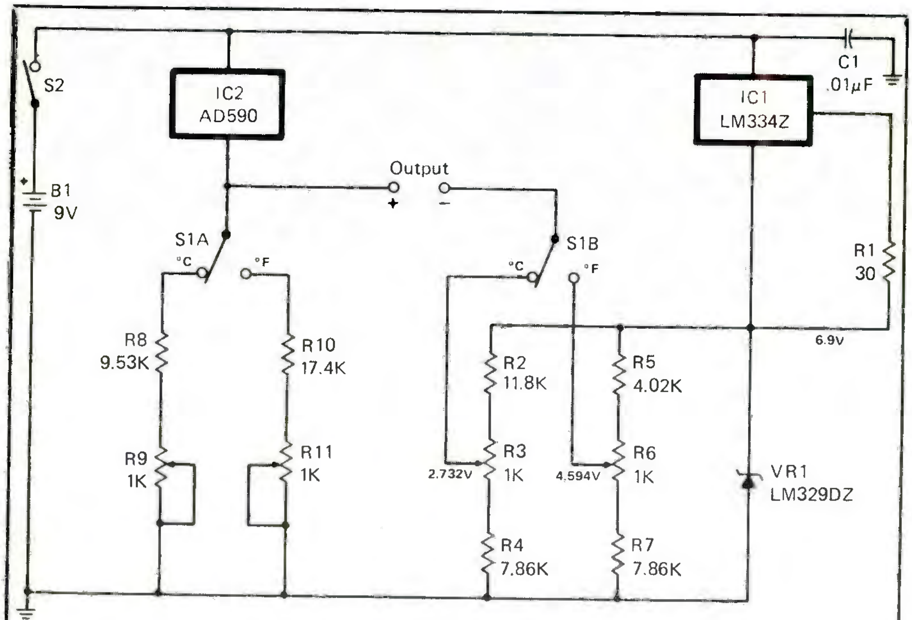
About the Circuit

Though the temperature accessory circuit (Fig. 1) appears to be very simple, it is really quite sophisticated in terms of performance and the technology it uses. The AD590 temperature sensor integrated circuit used for *IC2* produces an output current that is proportional to temperature. The output current produced when the device is connected to a voltage source is equal to 1 μA per degree on the Kelvin temperature scale. The Kelvin degree is equal to the Celsius degree, but the °K temperature scale has its zero at $-273.2\,°C$, or absolute zero. The relationship between Kelvin, Celsius and Fahrenheit temperature scales is as follows:

$$°C = °K - 273.2$$
$$°F = [(9 \times °C)/5] + 32$$
$$°F = [9(°K - 273.2)/5] + 32.$$

It should also be noted that there is a little-used Rankine temperature scale that starts at absolute zero and has Fahrenheit-scaled degrees. Rankine degrees are offset 459.7 higher than Fahrenheit degrees. Rankine to Fahrenheit conversion is as follows: $°F = °R - 459.7$.

Connecting the sensor's output to a microammeter makes a °K thermometer. The next step, then, is to remove the 273.2 °C or 459.7 °F offset to obtain the more useful °C and °F outputs. To achieve this, sensor



PARTS LIST

Semiconductors
IC1—LM334Z current source
IC2—AD590 sensor
VR1—LM329DZ voltage reference
Capacitors
C1—0.01-μF disc
Resistors (¼-watt, 1%)
R1—30 ohms (2%)
R2—11,800 ohms
R4,R7—7860 ohms
R5—4020 ohms
R8—9530 ohms
R10—17,400 ohms
R3,R6,R9,R11—1000-ohm pc-mount trimmer potentiometers

Miscellaneous
B1—9-volt transistor battery
S1,S2—Dpdt switch
Printed-circuit board; one each red and black banana jacks and plugs; 4″ × 2¼″ × 1¼″ aluminum cabinet; 9-volt battery connector; 4-ft. RG174 coaxial cable; 2-ft. miniature zip cord; dry-transfer lettering kit; clear spray acrylic; ¼″ rubber grommets (2); 4-40 × ⅛″ machine scres (6); solder; etc.
Note: The following is available from NRG Electronics, P.O. Box 24138, Ft. Lauderdale, FL 33037: Complete Model T-100 kit, less battery, for $19.95 + $1.50 P&H + 5% sales tax for Florida residents.

Fig. 1. This overall schematic of the thermometer accessory is deceptively simple. The circuit is actually quite sophisticated. Almost any analog or digital voltmeter or multimeter can be used as the temperature display device. Power for the accessory is provided by a 9-volt transistor battery.

output current is converted to a voltage when passed through a scaling resistor. A voltmeter is then used to measure the difference between the scaled temperature output and an appropriate voltage reference.

The °C scaling resistance is formed by the series network made up of resistor *R8* and trimmer potentiometer *R9*, while °F scaling is accomplished with *R10* and trimmer *R11*. Switch *S1A* routes sensor output current through the appropriate scaling network to select either °C or °F. Switch *S1B* selects either the 2.73- or the 4.59-volt reference so that the differential output is 10 mA per °C or °F.

The two reference voltages are tapped from resistive dividers connected to precision 6.9-volt reference *VR1*. Resistors *R2* and *R4* and trimmer control *R3* make up the °C divider, and resistors *R5* and *R7* and trimmer *R6* make up the °F divider.

Precision reference *VR1* is an LM329DZ, which is biased by the LM334Z current source used for *IC1*. Resistor *R1* sets the current source's output to 2 mA. The combination LM334/LM329 reference is very stable over wide temperature and voltage changes and uses very little current, assuring long battery life.

Construction

To make the thermometer accessory as compact as possible and to facilitate easy assembly, it is suggested that you assemble the circuit on a printed-circuit board. You can purchase a ready-to-go pc board from the source given in the Parts List. Alternatively, you can fabricate your own pc board, using the actual-size etching guide given in Fig. 2.

Wire the circuit board as shown in the components-placement/orientation diagram in Fig. 2. Note that all components except sensor *IC2* and battery *B1* mount directly on the pc board and that controls *R3, R6, R9* and *R11* mount on the *foil* side of the board. When you have finished wiring the pc board, temporarily set it aside and proceed to machining the small metal utility or project box in which the project, with battery, is to be housed. You must drill a hole through each side wall of the box to provide the means for the meter and sensor cables to enter the box.

The only other holes that must be drilled or cut will be in the top of the box, which will serve as the project's front panel. You must cut two rectangular slots, one for each switch's toggle and drill two mounting holes for each switch. When you are finished machining the box, temporarily install the circuit-board assembly to make sure all parts fit as they should. Make whatever adjustments are needed. Then disassemble the

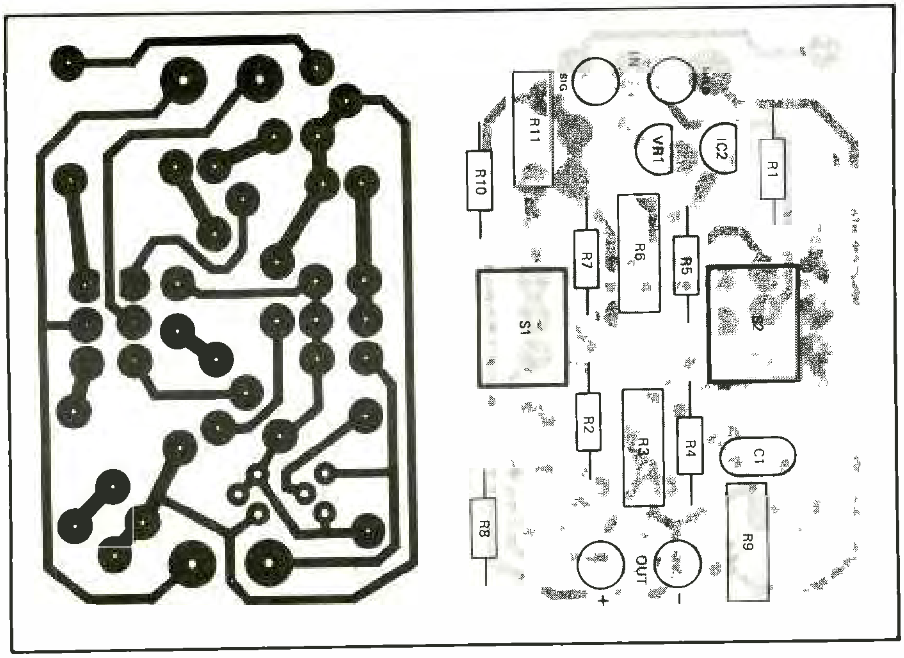


Fig. 2. Fabricate the printed-circuit board for the project using the actual-size etching-and-drilling guide at left. Install the components on the board exactly as shown in the placement/orientation diagram shown at right.

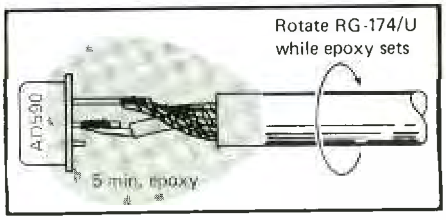


Fig. 3. After tack-soldering a 4-ft. length of coaxial cable to the shortened leads of the AD590 sensor, flow epoxy cement over connections, sensor and cable as shown and slowly rotate the assembly as the cement sets to obtain an air-tight, symmetrical seal.

box, remove the pc assembly and clean all exterior surfaces of the metal box with fine steel wool. Using a dry-transfer lettering kit, label (on the top of the box) the legends PROBE and METER just above the entry holes on the left and right sides of the box, respectively. Then label the two switches with the legends °C and °F for the alternate positions of *S1* and ON and OFF for the appropriate positions of *S2*. If you wish, you can also label the legend THERMOMETER ACCESSORY on the top of the box for future identification.

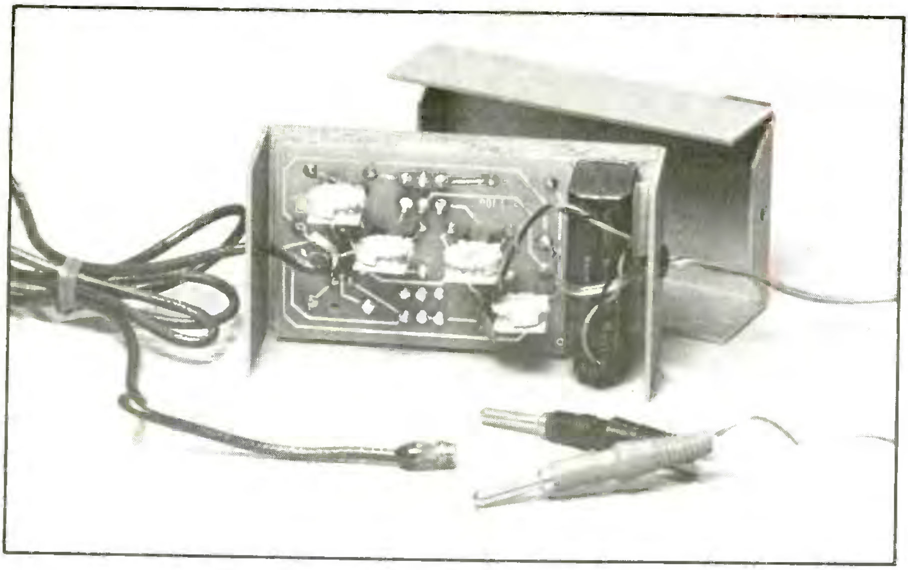
When all lettering is completed, spray two or more *light* coats of clear acrylic on all exterior surfaces of the box to give the project a professional finished appearance and to protect the lettering. Allow each coat to dry before spraying on the next.

Referring to Fig. 3, prepare the probe/cable assembly. Trim the leads of the AD590 so that they are just long enough to permit good electrical and mechanical connection of the coaxial cable. To prepare the ends of the 4-ft. length of coax, first trim away ¼" and ¾" of outer insulation from opposite ends. Separate the shield from the inner conductor at both ends back to the outer insulation. Then, making sure not to cut any of the inner-conductor wires, trim ⅛" of insulation at the ¼" prepared end and ¼" of insulation from the ¾" prepared end. Tightly twist together the shields and inner conductors and lightly tin with solder. Connect and solder the conductors at the ¼" prepared end of the cable to the shortened pins of the AD590 sensor as shown in Fig. 3. Use heat and solder sparingly and make certain you do not create any solder bridges. When the solder cools, gently separate the connections to obviate any possibility that the two can short together. Then apply 5-minute epoxy cement to the connection, flowing it over only the skirt of the AD590 and about ¼" beyond the point where the outer insulation was removed from the coax. As the cement sets, slowly rotate the cable assembly to allow it to assume a symmetrical form. Then allow the cement to set solidly for a couple of hours.

Now prepare the meter cable. For this, you will need a 3-ft. length of miniature zip cord and a pair of red and black color-coded banana jacks. Split the cord apart for a distance of about 5" at one end and 1" at the other end. Trim away ¼" of insulation from all conductors at both ends, taking care to avoid cutting through any fine wires. Tightly twist the wires into neat bundles and sparingly tin with solder. Install a banana jack on each conductor at the long split end.

When the acrylic spray paint on the box has completely dried, place small rubber grommets in the holes in the box's sides. Then feed the free ends of the prepared cables into the box through the grommets and tie a knot in each cable about 3" from the free ends on the *inside* of the box. Connect and solder these to the appropriate pads on the pc board. Do the same with the battery-connector wires.

Position the pc board assembly in the box and secure it in place with four 4-40 × ¼" screws via the mounting tabs on *S1* and *S2*. Gently pull on both cables until the knots touch the rubber grommets. Mount



All components except the battery and sensor mount on the pc board.

the battery at one end of the pc assembly inside the cabinet (see photo) and clip on the battery connector.

Calibration

The voltage reference in the thermometer accessory is very stable and will assure linear measurement results in both the °C and °F modes when properly calibrated. It is very important for you to perform calibration with the voltmeter or other readout device that will be used to display temperature.

Connect the negative (COM) lead of the preferably digital voltmeter to the negative (black) battery connector pad and the positive (red) meter lead to the wiper (center) lug of trimmer control *R3*. Turn on the power and adjust the setting of *R3* for a 2.73-volt meter reading. Then connect the voltmeter's positive lead to the wiper lug of *R6* and adjust this control for a 4.59-volt reading.

Accuracy of the accessory is very good when calibration is done around the temperature range where the project is to be most frequently used. For general use, it is convenient to calibrate at the freezing and boiling points of fresh water. To calibrate for the freezing point, place a 50/50 mixture of water and crushed ice in a styrofoam cup and stir for a minute or so to stabilize the temperature; then immerse the probe. To calibrate at the boiling point, bring to a boil fresh water and immerse the sensor probe in this.

Fresh water freezes at 0° C and boils at 100° C. So, setting the mode switch to °C, first immerse the sensor probe in the ice/water mixture and adjust *R9* to obtain a 0° C reading on the meter when the latter is connected to the METER cable on the accessory. Then immerse the sensor probe in the boiling water and readjust *R9* to obtain a 100° C reading. Repeat this calibration procedure several times to determine which end of the scale is the most accurate.

Once the thermometer accessory is properly calibrated for the °C mode, switch to the °F range and use *R11* to calibrate the scale for the freezing (32° F) and boiling (212° F) points of water. This completes calibration of the accessory. Set the power switch to OFF and assemble the case. **ME**