Energy Leak Detector Reveals Home Heat and Cooling Losses

Provides instantaneous readings of temperature changes to check leaks around doors, windows, etc.

BY RALPH TENNY

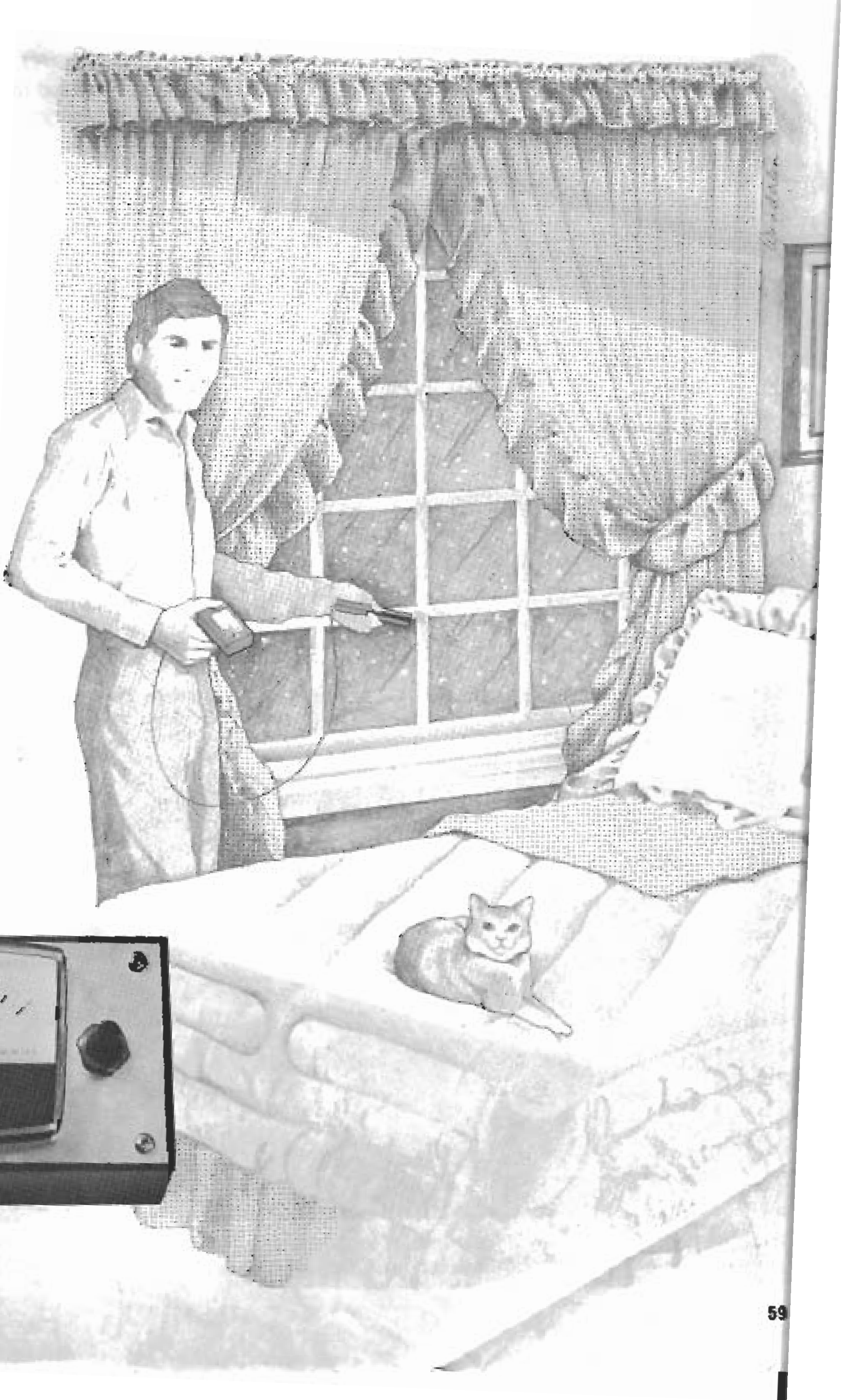
CONSIDERING the high price you pay for the energy to air condition and heat your home, you should be aware of how much of your expensive cooled air escapes and how much cold air leaks into your house at the wrong times of the year.

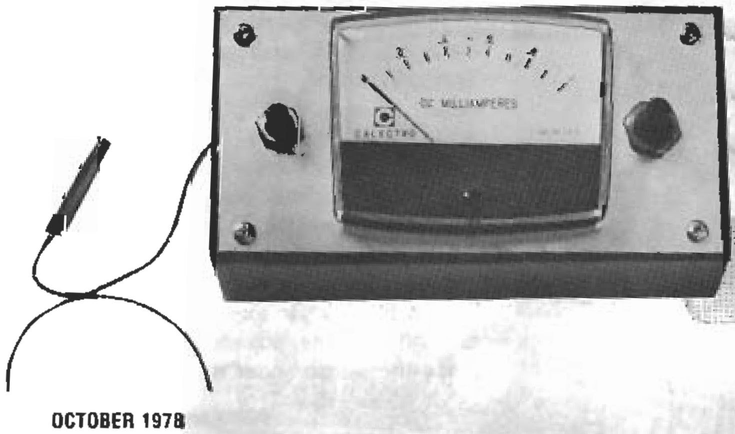
Large air leaks can be easily felt with the hand, of course. But what about those smaller leaks that can add up to a large, expensive one? Now you can find these leaks with the "Energy Leak Detector," described here, and take corrective action.

The Detector, or ELD, is a low-cost differential temperature detector that can be built in an evening. This useful instrument features a new solid-state temperature sensor that has a positive temperature coefficient (PTC). This means that the sensor's resistance increases linearly with temperature.

Circuit Operation. The current-mode amplifier (LM3900) used in the detector amplifies the difference between the current flowing in the two inputs to produce a voltage change at the output.

The input circuit is shown in Fig. 1. Note that there is an arrow between the inverting and noninverting inputs in the diagram for this type of amplifier. Also observe that the inputs are simply base-emitter junctions of grounded emitter transistors.





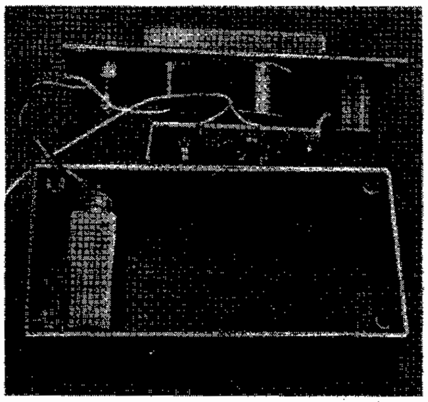


Photo of internal construction shows board attached to meter.

This leads to a very important consideration regarding current-mode amplifiers: *Never apply voltage directly to the inputs that can cause a current flow of 5 mA or more.* This limitation allows for some unusual circuitry that can be an advantage under some circumstances. Two other limitations must also be mentioned. The open-loop gain (gain without feedback) can be as low as 1000:1, and the amplifier will not respond to voltages lower than 0.6 volt.

The amplifier maintains correct operation over a wide variety of power supply voltages, and uses about the same amount of power supply current (exclusive of load current), regardless of the power supply voltage. Thus, the amplifier is well suited for battery operation.

As shown in Fig. 2, temperature sensor *TH1* is connected in a bridge circuit consisting of *R1*, whose value is nominally equal to the *TH1* resistance at 25°C (1000 ohms) plus *R2*, *R3*, and *R12*. Potentiometer *R12* is used to balance the bridge when the sensor is at any given temperature. Voltage for the bridge (+3 volts) is furnished by *IC1C* operated in conjunction with zener diode *D1* as a reference. The resulting +3 volts is stable since the current amplifier regulates the zener current. Power is applied only when pushbutton switch *S1* is depressed, thus extending battery life.

A change in bridge balance that occurs whenever *TH1* changes resistance is amplified by *IC1A*. The output of *IC1A* serves as the reference voltage for one input of *IC1B*, which is used as a current amplifier. When there is a bridge unbalance, the output current of *IC1A* flows through *R7*, forcing *IC1B* to drive *Q1* until the current through feedback resistor *R10* equals the current through *R7*. Since meter *M1* is in series with the *Q1* collector, any current passed through *R11* to bias *R10* also passes through the meter. Resistor *R11* is selected so that *M1* indicates about half scale with the bridge balanced at 25°C. If a different sensitivity is required for the ELD, the ratio of *R7/R10* can be changed and, most likely, the value of *R11* too.

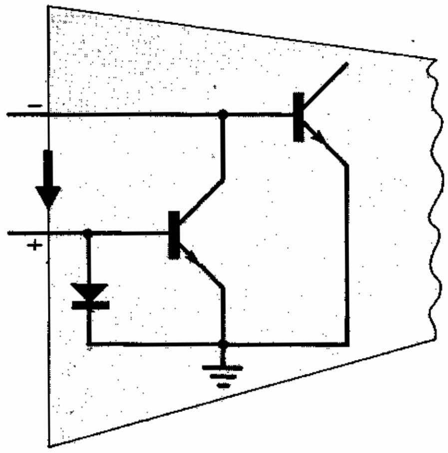


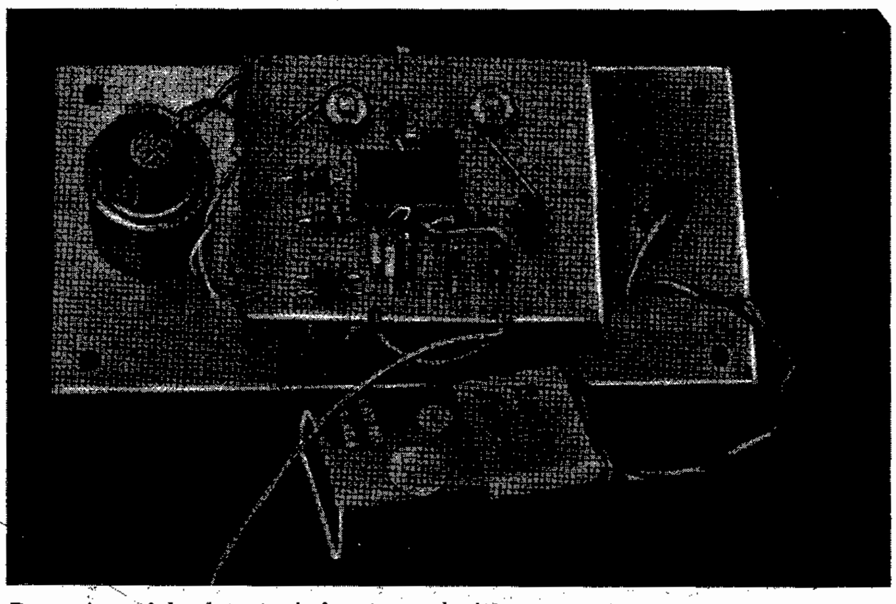
Fig. 1. The input circuits of a current (Norton) amplifier consist of base-emitter transistor junctions.

Construction. The circuit can be assembled by any desired method, using perforated board, Wire-Wrap, or a small pc board. A conventional 14-pin socket may be used for *IC1*.

The author's prototype pictured in this article illustrates how the perforated board (in this case) mounts on the meter lugs. The meter, in turn, is mounted to the metal cover of a small plastic box.

Balance control *R12* and pushbutton switch *S1* are mounted beside the meter. The battery is mounted in a holder affixed to the bottom of the plastic case. A small hole in the cover plate allows the temperature sensor leads to exit.

The temperature sensor (*TH1*) can be mounted at the end of a length of plastic, wood, or even thin metal rod. Make sure the sensor is not surrounded by a large mass that can slow the response of the device.



Rear view of the detector's front panel with perforated board mounted on meter and battery attached.

Use. Although this sensor can be used to measure temperature directly (more on this later), for use as a relative temperature sensor, depress switch *S1* and adjust balance control *R12* for a mid-scale meter indication.

Touching the sensor with your fingertips, which are relatively warm, should cause an up-scale meter movement. Cooling the sensor should cause a down-scale movement.

With the sensor exposed to ambient air, and the meter adjusted to mid-scale, place the sensor near a suspected air

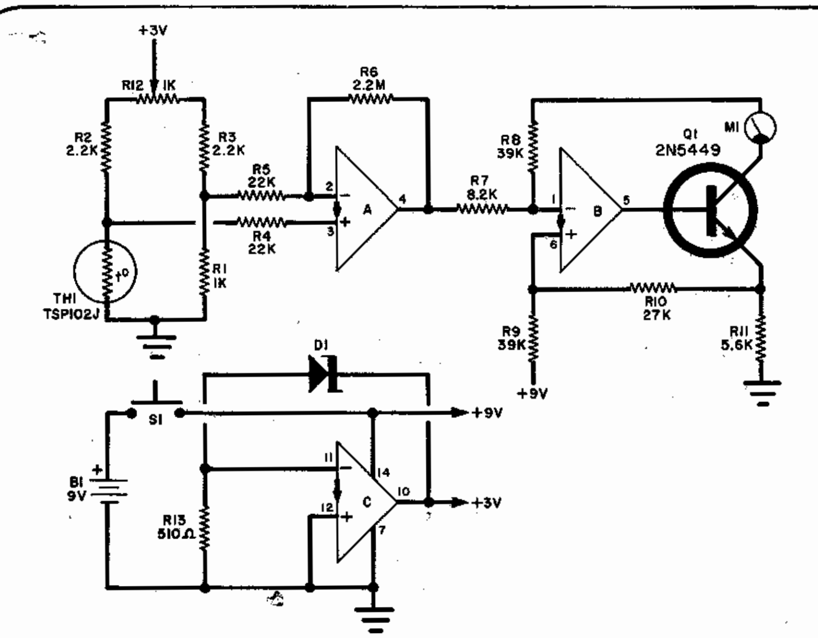


Fig. 2. Any unbalance in bridge circuit, containing TH1, is amplified and indicated on the meter.

PARTS LIST

B1—9-volt battery and holder
D1— 1N5226 diode
IC1—LM3900 quad Norton amplifier
M1—0-1 mA meter (Calectro D1-912, Radio Shack 22-052 or similar)
Q1—2N5449
The following are ¼-watt resistors unless otherwise noted:
R1—1000-ohm
R2, R3—2200-ohm
R4, R5—22,000-ohm
R6—2.2-megohm
R7—8200-ohm
R8, R9—39,000-ohm
R10—27,000-ohm
R11—5600-ohm
R12—1000-ohm, 10-turn potentiometer
R13—510-ohm
S1—spst NO pushbutton switch
TH1—TSP102J positive temperature coefficient thermistor (Texas Instruments)
Misc.—Suitable enclosure, mounting hardware, knob.
Note: Sensor, TSP102J, is available for $1.50 from Tenny, Box 545, Richardson, TX 75080.

leak. If there is cold air leaking in, the meter will show a sharp drop as the sensor gets closer to the air leak. Conversely, if there is a warm air leak, it can be pinpointed with great accuracy by watching the meter move upscale.

Keep in mind that in this configuration you are measuring relative temperature. Also remember that there is a temperature differential between the ceiling and the floor in a room even without an air leak.

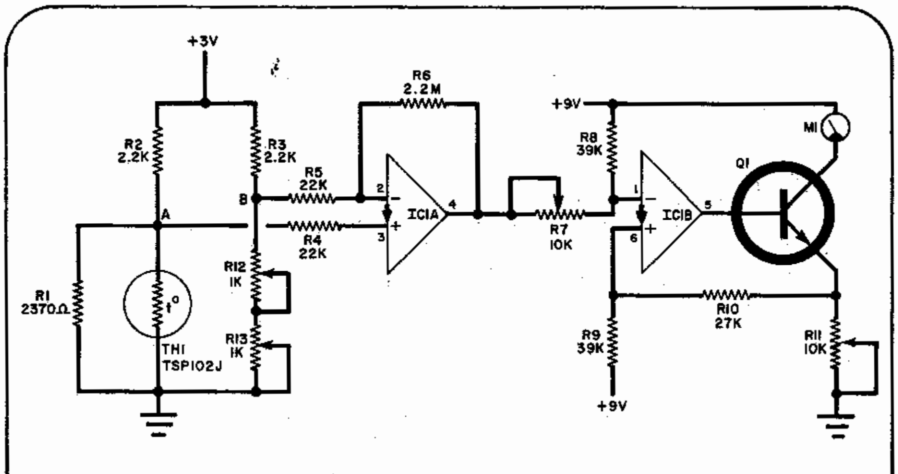


Fig. 3. Optional circuit shows how to convert the leak detector into a conventional thermometer.

Thermometer. The basic probe can be modified to create a thermometer by using the circuit shown in Fig. 3.

Potentiometer *R12*, used to balance the circuit, is still a 1000-ohm, 10-turn potentiometer. But now it has a turns-counting dial. Trimmer potentiometer *R13* is a 1000-ohm, multi-turn type, while *R7* and *R11* have been changed to 10,000-ohm, multi-turn potentiometers.

Since the circuit has now become a thermometer, it must be calibrated. The basic technique is to create two water baths at each end of the desired temperature range. Since water and ice reach an equilibrium at 0°C, and water boils at 100°C (at sea level), these are convenient to duplicate.

Assuming a linear sensor, the circuit is adjusted to 0°C and 100°C with the sensor immersed in the appropriate water bath. With the linear control and turns-counting dial, intermediate temperatures can be read from the dial after the meter is again center-scaled. Compensation for the 100°C range must be made if you live at high altitudes.

To calibrate the circuit, set up the ice bath and keep it stirred as long as the sensor is immersed in it; also prepare a boiling water bath.

Set potentiometers *R7* and *R11* to their maximum resistance, and *R12* to its minimum resistance. Be sure that the counter on *R12* indicates zero when *R12* is at its minimum resistance.

Immerse the sensor in the ice water, short the bridge at points A and B, and adjust *R7* and *R11* until the meter indicates at center scale. Remove the short across the bridge and adjust *R13* to center the meter again.

Then immerse the sensor in boiling water and set the turns counter of *R12* to 10.0. Adjust *R7* until the meter is centered, then return the meter to the ice water. Rotate the *R12* dial to 0.0 and adjust *R11* for a meter center. Return to the hot water and adjust *R7*, repeating the actions until the meter indicates the temperatures at each end of the scale.

Other temperature ranges may be calibrated, but the dial will no longer indicate the temperature directly. A chart can be created to translate dial indications into temperature.

If you wish to use the ELD as a remote thermometer, the circuit will tolerate a considerable length of lead between the circuit and the sensor. Just be sure that you calibrate the system using the long leads so that resistance will be taken into account.

Happy energy savings! ◇