BY ROBERT MEIJER

AN "RFI-FREE" SOLID-STATE THERMOSTAT

Noise-free thyristor circuit is triggered by thin-film temperature sensor.

AN ELECTRONIC circuit including a triac and/or an SCR (connected to a suitable sensor) is often considered a desirable substitute for a bimetallic thermostat. However, the radio frequency interference (RFI) generated by such a circuit has impeded any large-scale movement toward its use. Presented here is a thyristor thermostat which generates no RFI, uses inexpensive components, and is mechanically stable.

The circuit, which employs one of the new Moxie™ thin-film thermal sensors, has other interesting features:

- Uses true zero firing of the thyristor.
- Provides symmetrical line loading (an even number of half cycles).
- Is adaptable to any size triac and load.
- Has essentially no deadband (hysteresis).

Circuit Operation. As the power line's phase angle increases from 0°, the voltage at point A in Fig 1 becomes progressively more positive with respect to point B. Diodes *D1* and *D2* are both forward biased, and the voltage across *R1* (the thermal sensor) continues to rise as the phase angle approaches 90°. The value of *R2* is chosen so that, at some point before 90°, sufficient voltage develops across *R1* to turn it on, and its impedance drops from a high to a low value. The lower the Moxie's temperature, the higher the voltage across it must be to turn it on. Thus, the value of *R2* is determined by the minimum control temperature required.

When *R1* turns on, the cathode of *D1* becomes highly positive with respect to point A. The value of the voltage developed on the cathode of *D1* depends on the required "firing" voltage of *R1*. This in turn depends only on sensor temperature.

If a sufficiently positive voltage develops on the cathode of *D1* (referenced to point A) and voltage divider

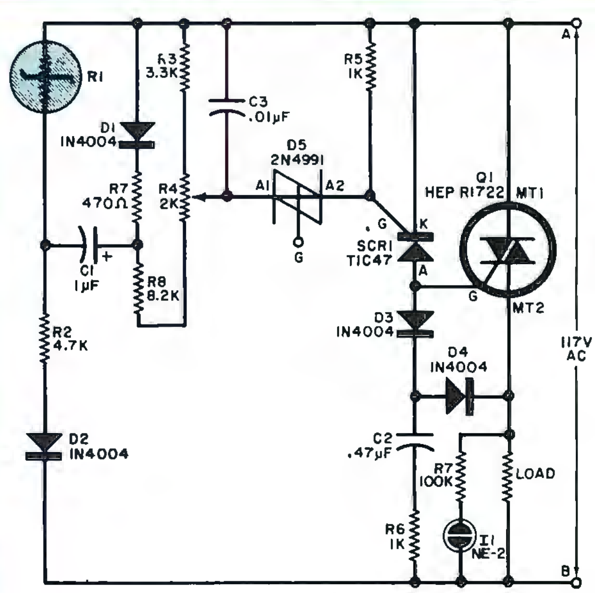

Fig. 1. Sensor R1 triggers thyristor firing circuit when heat is needed

PARTS LIST

C1—1-μF, 200-WVDC electrolytic capacitor
C2—0.47-μF, 200-WVDC Mylar film capacitor
C3—0.01-μF, 25 WVDC disc capacitor
D1 to D4—1N4004 rectifier
D5—2N4991, ECG6404 (Sylvania) silicon bilateral switch
I1—NE-2 neon indicator
Q1—HEP R1723 triac (see text)
R1—TS3-57S Moxie™ thermal sensor
R2—4700-ohm, 2-watt resistor
R3—3300-ohm, ¼-watt resistor
R4—20,000-ohm, 1-watt, linear taper, 10% tolerance potentiometer
R5—1000-ohm, ¼-watt resistor
R6—1000-ohm, 2-watt resistor
R7—100,000-ohm, ¼-watt resistor
R8—8200-ohm, ¼-watt resistor
SCR1—TIC47, ECG5404
Misc.—Printed circuit or perforated board, solder, hookup wire, suitable enclosure, thermal paste, machine hardware, etc.
Note—The Moxie thermal sensor is available for $1.09 from Elcom Sales, Box 9112, Rochester, NY 14625, and from Multi-State Devices Ltd., 1330 Trans Canada Highway S., Dorval, P. Q., Canada, H9P 1H8.

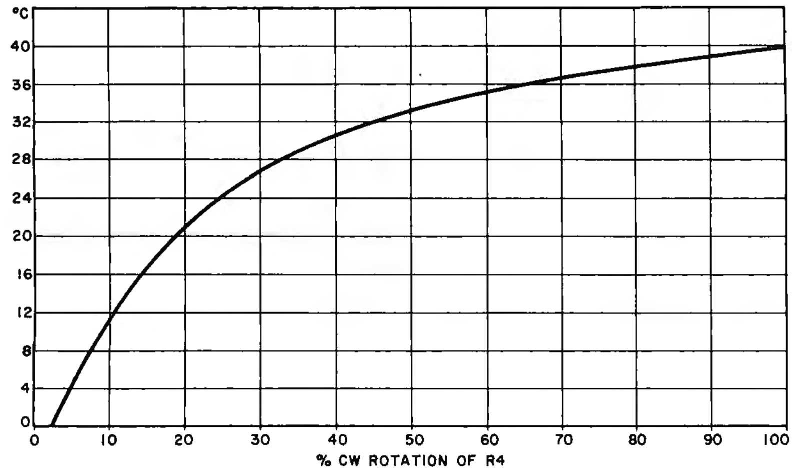

Fig. 2. Curve shows how thermostat setting is affected by R4.

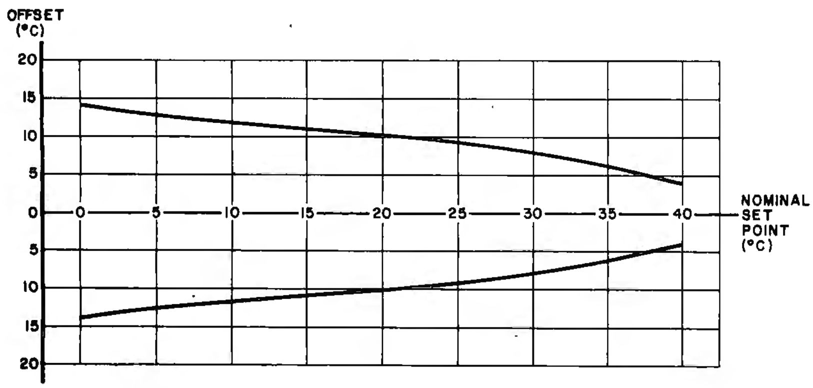

Fig. 3. Worst-case recalibration curve for a nontypical D5.

R4 is set properly, then the diac *D5* (also called a silicon bilateral switch, or SBS) will turn on and latch. Capacitor *C1* is sufficiently large to hold *D5* in its on state from the firing point of *TDR1* (less than 90°) to at least 180°. Of course, if *TDR1* fires at a sufficiently low voltage (sensor hot), then there will not be enough voltage to fire diode *D5*.

But if *D5* does fire, it will do so prior to 90° and remain in this state through 180°. Therefore, *SCR1* has positive gate current at 180°. Prior to this phase angle, *SCR1* remains off since its anode is negative with respect to its cathode. As soon as the phase angle passes 180°, *SCR1* conducts current into the gate of the triac *Q1*. The current through *SCR1* is limited to the minimum turn-on current of *Q1*, as it serves as a shunt around *SCR1*.

So, the triac is on from 180° to 360°, when the current through it falls below its holding point. The slaving circuit consisting of *D3*, *D4*, *C2*, and *R6* serves to store the peak voltage across the load on *C2*. This stored voltage provides the triac with gate current between 270° and 450°, insuring zero-cross firing at 360°.

In this way, the load will be energized for at least two half cycles when heat is required. If still more heat is needed, two more half cycles will follow to keep the load energized.

Construction. Since the circuit is fairly simple, either pc or perforated-board techniques can be used. In any event, the circuit should be mounted in a suitable enclosure, observing the safety practices that are necessary when dealing with line-powered equipment. Thermal sensor *TDR1* should be mounted so that it samples the average temperature of the room, not that of any heat-generating component in the circuit. For example, it could be mounted in one corner of the enclosure away from triac *Q1*, with numerous holes drilled around it for unimpeded air flow. Alternatively, it could be mounted in a small metal box a short distance away from the rest of the circuit, with short interconnecting leads between the two. Thermal paste could then be used to keep sensor and enclosure at the same temperature.

Calibration and Use. Potentiometer *R4* acts as the thermostat's sensitivity control. Figure 2 shows how the thermostat's set point varies as *R4* is rotated. This curve is valid when all components are at their "typical" values. Of course, solid-state and thin-film devices are subject to some variations. Figure 3 shows the worst-case recalibration required with a "non-typical" *D5*. Worst-case variations of the thermal sensor will affect the calibration curve as well, and the resulting recalibration is shown in Fig. 4. All thermostats can be calibrated to within 2° C of Fig. 2 by trimming *R3* and *R8*.

You will most probably want to make a calibrated dial for adjusting *R4* to the desired room temperature. This is best done empirically. Thermally couple a good-quality thermometer to *R1* and adjust *R4* until the neon indicator *I1* flickers or glows. At that point current is flowing through the heating element (LOAD), and the temperature of the sensor can be read off the thermometer. For temperatures higher than the room temperature, *R1* can be *gently* heated.

One final note—the triac specified for *Q1* (HEP R1722) is rated at 10 amperes forward current. If your heating element draws more current, simply use a higher-power triac. Of course, adequate heat-sinking is necessary for *any* thyristor. ◈

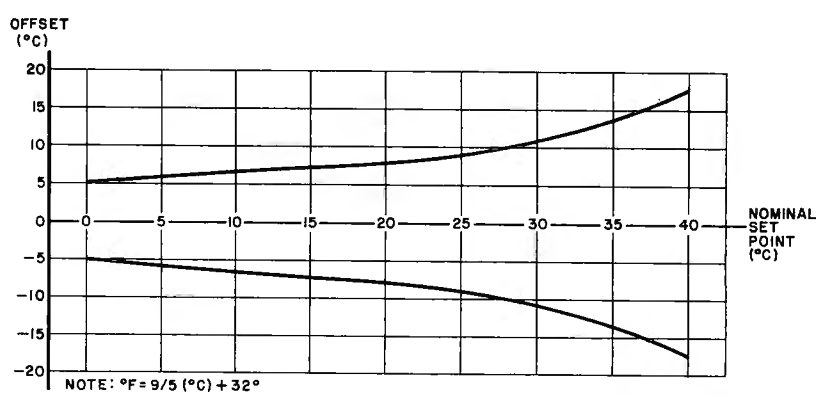

Fig. 4. Variations in R1 can be corrected using these curves.