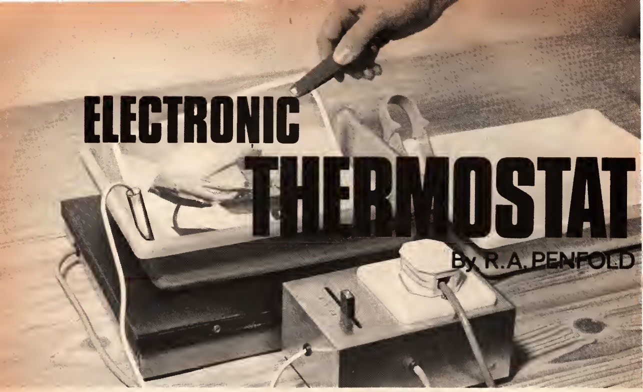
ELECTRONIC THERMOSTAT

By R. A. PENFOLD



IN photographic work it is often necessary to keep solutions at a constant temperature during the printing process. The situation is especially critical when it comes to colour printing, where it may be necessary to maintain the temperature of the solutions to within a fraction of a degree.

The normal method of achieving this is to place the dishes containing the photographic chemicals on a thermostatically controlled dish warmer. However, many devices of this type use mechanical thermostats which are far too insensitive for accurate temperature control, and can often only keep the solutions to within a couple degrees of the required temperature.

PRECISE CONTROL

The device which forms the subject of this article was built to give a much more precise control over a system such as that just described, and has proved to be very successful in use. Exactly how accurately it will maintain a given temperature will depend to a certain extent on the apparatus with which it is employed, and also on the efficiency of the sensor. It should however, be able to maintain a temperature to an accuracy of about plus or minus 0·2 degrees.

It can of course be used for any similar purpose where it is necessary to maintain a liquid at a constant temperature. The range covered by the unit is from slightly below 50°F to a little more than 100°F.

Circuits of this type can be rather complicated, but in this design the utilisation of an i.c. operational amplifier enables a very simple and straightforward circuit to be used.

THE CIRCUIT

A complete circuit diagram of the electronic thermostat is shown in Fig. 1. The unit is designed around the 741C i.c., which is used here as a differential amplifier.

COMPONENTS . . .

Resistors
- R1, R2 5·6Ω (2 off)
- R3 33kΩ
- R4 27kΩ
- R5 10kΩ
- R6 4·7kΩ
- R7 430Ω
- R8 220kΩ
- All ½W 10% carbon

Potentiometer
- VR1 10kΩ linear slider

Capacitors
- C1, C2 220μF 16V elect. (2 off)

Semiconductors
- TR1 BC109
- D1–D4 1N4001 (4 off)
- D5, D6 BZY88 C10 10V 400mW Zener (2 off)
- D7 OA200 or any general purpose silicon diode
- IC1 741C 8-pin d.i.l.

Thermistor
- TH1 VA1066S

Miscellaneous
- SK1 Surface mounting mains socket
- RLA Miniature 12V relay (Omron 1051, 465Ω Home Radio)
- T1 Mains primary, 9–0–9V 80mA secondary (Osmor MT9, Home Radio)
- S1 Single pole on/off
- FS1 500mA with holder
- 0·1in matrix Veroboard 35 × 15 holes
- 6in × 4in × 2½in aluminium chassis with base plate
- Screened cable, hardware for sensor

As the name suggests, this amplifies the difference between the two input voltages. The output will be near ground if the inverting input is at a higher potential than the non-inverting input. On the other hand the output will be near the supply rail if the non-inverting input is at a higher potential than inverting one.

The gain of the i.c. is extremely high, and the voltage difference required at the inputs to cause the output to swing fully one way or the other is only a fraction of a millivolt. This tends to give the circuit built-in triggering, as there is such a restricted range of voltages which will give an intermediate state at the output.

BRIDGE CIRCUIT

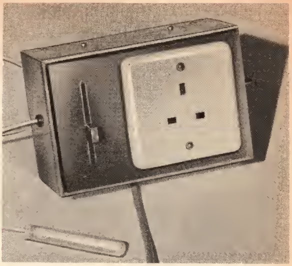
At the inputs to the i.c. there is a bridge circuit. One arm of this is formed by R3, VR1, and R4, and the other by R5, R6, TH1. The supply is connected to the input of the bridge.

Thermistor TH1 is mounted in a probe which is immersed in the liquid to be controlled. Its resistance will therefore increase if the temperature of the liquid drops, and decrease if the temperature increases. This change in resistance will cause the voltage at the non-inverting input to change also, a positive change in temperature causing a negative change in voltage.

The output from IC1 is coupled via R8 to TR1, which has the relay in its collector circuit. The contacts of the relay are taken to a mains socket, into which the dish heater is plugged. When the output of IC1 is high (+20V) the relay is energised. R7 is required in order to reduce the supply to a more suitable level to power the relay. Diode D7 is the normal protective diode. Even when the output of the i.c. is low there is an output potential of about two volts. R8 is therefore required to prevent the relay from being permanently held on.

CALIBRATED SCALE

In practice VR1 is marked with a scale calibrated in degrees. If, for example, this is set to 100°F, at the start the liquid will probably be at about room temperature, and considerably less than 100°F. The voltage at the non-inverting input will be high in comparison to that set at the other



The completed Electronic Thermostat showing layout of controls on the front panel

input by VR1. The output of IC1 will thus be high and the heater will be turned on. As the liquid warms up the voltage at the non-inverting input will decrease, until eventually when the liquid reaches 100°F, this voltage being equal to that at the other input, will cause the output of IC1 to go low, and the heater to be turned off.

The liquid will now of course begin to cool, but will not be allowed to cool much, as this cooling will be sensed by the thermistor, which will unbalance the input voltages resulting in the heater being turned on again. The circuit will continue to oscillate in this way, thus stabilising the temperature of the liquid.

POWER SUPPLY UNIT

A simple stabilised mains power supply is used. This consists of two full wave supplies, each providing 10V, connected in series to give 20V, which is

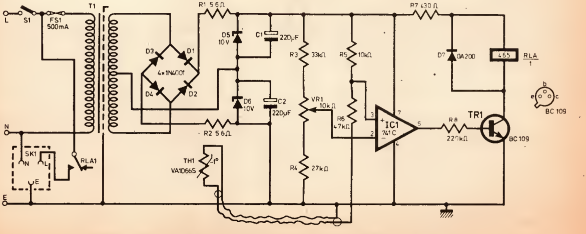


Fig. 1. Complete circuit diagram of the Electronic Thermostat

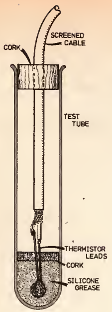
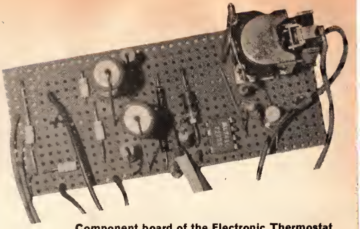


Fig. 2. Construction of the sensor using a small test tube and some silicone grease



Component board of the Electronic Thermostat

adequate for the 741C. D5, and D6 in conjunction with R1 and R2, and the relatively high secondary impedance of T1 give the stabilisation. C1 and C2 provide the necessary smoothing.

SENSOR CONSTRUCTION

The thermistor must be contained in a watertight compartment, and it must also be in good thermal contact with the outer surface of the container. Fig. 2 illustrates the construction of the sensor used with the prototype. The outer casing is a small glass test tube. The thermistor is mounted at the bottom of the tube, and is immersed in silicone grease to ensure a good thermal contact with the test tube.

The small slice of cork above this helps to keep the thermistor firmly in place, and also helps to prevent its leads from shorting together. Also, the silicone grease is rather thick, and needs to be pushed to the bottom of the tube. The slice of cork is very good for this task. Thin microphone cable is used to connect the sensor to the main body of the instrument.

CASE CONSTRUCTION

A suitable case for the unit consists of a 6in × 4in × 2½in aluminium chassis fitted with a base plate. Four rubber cabinet feet are bolted to the base. The general layout of the case can be seen from the photographs. The mains socket is mounted on top of the case on the right hand side. This mounted by two 4BA ¾in bolts.

A large part of the socket fits behind the panel, and a large cut out must be made for this to fit through. This is easily made by drilling a string of ⅛in holes around the perimeter of the cut out, and then using a ⅛in "Abrafile" to join the holes.

The slider potentiometer is mounted on the left of the mains socket, and it is glued into position. The cut out for this can be made in a similar way as that for the mains socket. A nail file can be used to smooth up the edges of the slot.

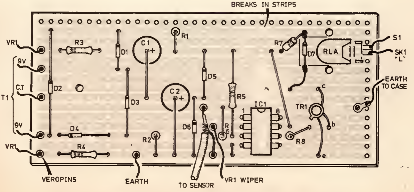


Fig. 3. Layout of components on the Veroboard. The diode D7 is connected directly across the coil contacts of the relay

The on/off switch is mounted on the centre of the right hand side panel. The lead from the sensor enters the case opposite this on the left hand side, and the mains lead enters on the lower edge of the case. The holes for both these leads must be fitted with rubber or p.v.c. grommets.

COMPONENT PANEL

Most of the components, including those of the p.s.u. (except T1), are mounted on a 0·1in matrix Veroboard panel. Fig. 3 shows the layout of this.

The mounting holes for the relay are ⅛in diameter. The mounting screws and washers are supplied with the relay. There are two mounting holes for the board, and these are for 6BA clearance. The outer braiding on the lead from the sensor is too large in diameter to go through the holes in the Veroboard, and is therefore taken to a pin.

When completed, the board is mounted on the upper side of the case by two 6BA ½in bolts. Two stand off insulators are required to hold the board a little way clear of the case.

ADDITIONAL WIRING

T1 is glued to the inside of the case opposite the Veroboard panel. Unfortunately the lead out wires of this are too short to reach the Veroboard panel. The leads from T1 are taken to a miniature three way connector block, and three insulated wires are taken from this to the component panel. The mains input is also taken to one side of a three-way connector block, and from here the connections are made to the various parts of the circuit.

Only the two connections to the relay contacts at the top, and middle of the relay are used, the lower one being ignored. Up to five amps at 250V can be handled by the specified relay.

It is essential that the negative supply is earthed, as if this is not done the relay will not switch over cleanly. For reasons of safety the case must also be earthed. A solder tag on one of the mounting bolts of the component panel is used to make the connection to the case. The two connector blocks can be bolted to the case, but on the prototype these were left supported only by the leads connected to them.

CALIBRATION

A scale is marked along the run of VR1. The various points along this are easily found. If for example it is required to find the setting which corresponds to 100°F, the sensor is placed in some water which has been heated to precisely this temperature. Once the sensor has had time to adjust to the temperature of the water, the slider of VR1 is brought as far down the scale as possible without the relay turning off. This point is then marked 100°F.

The scale is rather broad, as a fairly wide range of temperatures is covered. If absolute accuracy is required, it is advisable to initially use a thermometer to monitor the temperature of the liquid, and then if necessary, small adjustments can be made to the setting of VR1 to bring the temperature to exactly that required. ★