3

Thermometer

An electronic thermometer (Fig. 3.1) makes an extremely interesting constructional project and has uses in a number of fields. Although a unit of this type does have certain disadvantages over a more conventional thermometer, such as the need for a power source, there is the advantage of being able to locate the temperature sensing element

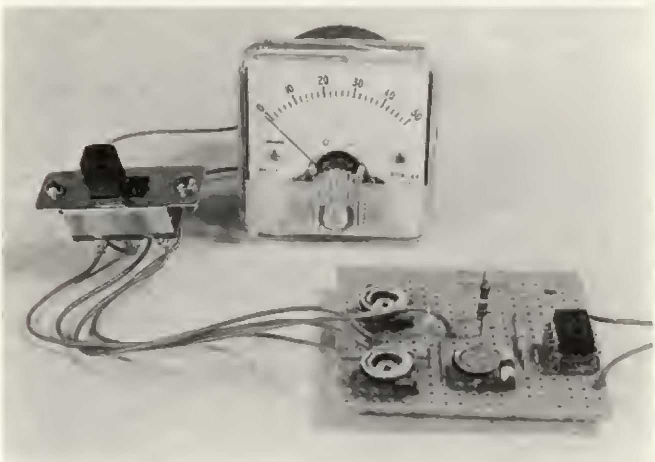

Figure 3.1

Electronic thermometer

remotely from the rest of the circuitry. Thus, for example, it is possible to monitor the temperature in an outbuilding such as a greenhouse from inside one's house.

The unit is also suitable for use in many other applications such as in photography, in heat experiments in schools, as a room temperature thermometer, etc. It has the advantage over most mercury and alcohol thermometers of having a large easy-to-read scale. A range of 0 to 50 degrees Celsius is covered, and the temperature is displayed on a 50μA meter. The scaling is linear.

A special purpose integrated circuit is used as the basis of the unit, and this provides a very high level of performance despite the apparently simplicity.

The circuit

Fig. 3.2 shows the complete circuit diagram of the electronic thermometer, and the only active device employed in the unit is an LM3911N integrated circuit; very few discrete components are required.

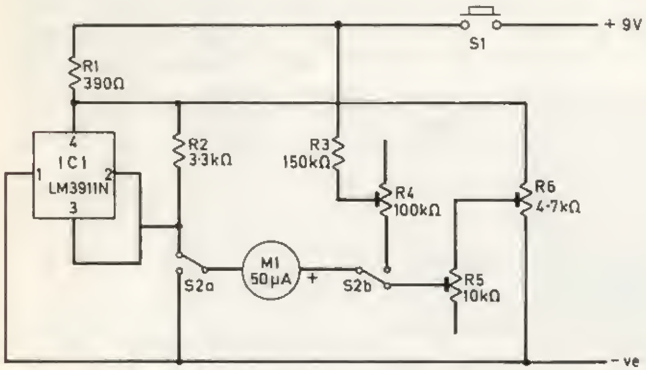

Figure 3.2

Circuit diagram

A stabilised power supply is required for the unit, and the necessary zener diode is connected between pins 1 and 4 of the LM3911N. In conjunction with R1 this provides a simple shunt stabiliser action which gives a highly stable voltage having a nominal potential of 6.8V.

The circuit is really deceptively simple as the LM3911N has quite a sophisticated internal circuit which includes a temperature sensing section. This operates by virtue of the fact that the voltage across a forward biased silicon diode reduces with increasing temperature by a couple of millivolts or so per degree Celsius. Actually the diode is the base emitter junction of a transistor, and there are two sensing circuits operating at different currents. The two outputs are compared and the

differential voltage is amplified to produce an output voltage change of 10mV per degree C. The i.c. operates over a temperature range of –25 to +85 °C with a tracking linearity of 0.5%.

An operational amplifier is incorporated in the device and the non-inverting input of this connects to the output of the temperature sensing circuit. The inverting input and output of the operational amplifier are available at pins 2 and 3 of the device, but in this case these are simply wired together so that the operational amplifier provides unity gain buffering. No voltage amplification is required since over a range of 0 to 50 degrees Celsius the LM3911N will provide an output voltage swing of 500mV (50 degrees x 10mV per degree) which is more than adequate to produce full scale deflection of any normal 50μA meter. The internal operational amplifier of the i.c. has an open collector output and so an external load resistor must be provided. This is R2.

R6 is adjusted so that the voltage at its slider is the same as the voltage produced at the output of the i.c. when it is at a temperature of zero °C. There is then no voltage developed across the meter circuit and the meter reads zero in consequence. R5 is adjusted to give the meter circuit a sensitivity of 500mV f.s.d. Therefore, if the i.c. is raised to a temperature of 50°C, the voltage at the output will decrease by 500mV. This will cause a voltage of 500mV to be developed across the meter circuit and will produce a reading of 50 on the meter. Intermediate temperatures will give intermediate readings on the meter.

Of course, although the meter scale is marked in terms of micro-amperes, the number indicated by the meter also corresponds to the temperature of the i.c. sensing circuit in degrees Celsius, and there is no need to recalibrate the meter. S2 enables the meter to be used as a 0 to 10 voltmeter with which the battery voltage can be checked. It is important that the unit should not be used with a battery having a voltage which has fallen to much less than 8V. If this is done there may be insufficient supply voltage to operate the stabilisation circuit properly, and only a minute drop in this voltage is needed to produce wildly inaccurate readings. R4 enables the sensitivity of the voltmeter circuit to be varied so that the unit can be accurately calibrated against a multimeter.

A pushbutton switch of the non-locking type is used to provide on/off switching as presumably in most applications the unit will not be needed to provide continuous monitoring. With this method S1 is operated when a reading is required, and then released once a reading has been taken. In this way there is a minimum of battery drain. S1 can be replaced by an ordinary slider or toggle switch if preferred. The current consumption of the unit is approximately 6mA from a 9V supply, but the current consumption varies greatly with changes in supply potential owing to the use of a shunt regulator circuit.

Construction

A suitable 0.1in matrix stripboard layout for the unit is provided in Fig. 3.3. The panel has 17 copper strips by 19 holes and once a suitable board has been cut out, the two 3.2mm diameter mounting holes and the five breaks in the copper strips are made. The components and the two link wires can then be soldered into position.

Construction should be quite straightforward mechanically, apart, perhaps, from the mounting of the meter. This usually requires a large

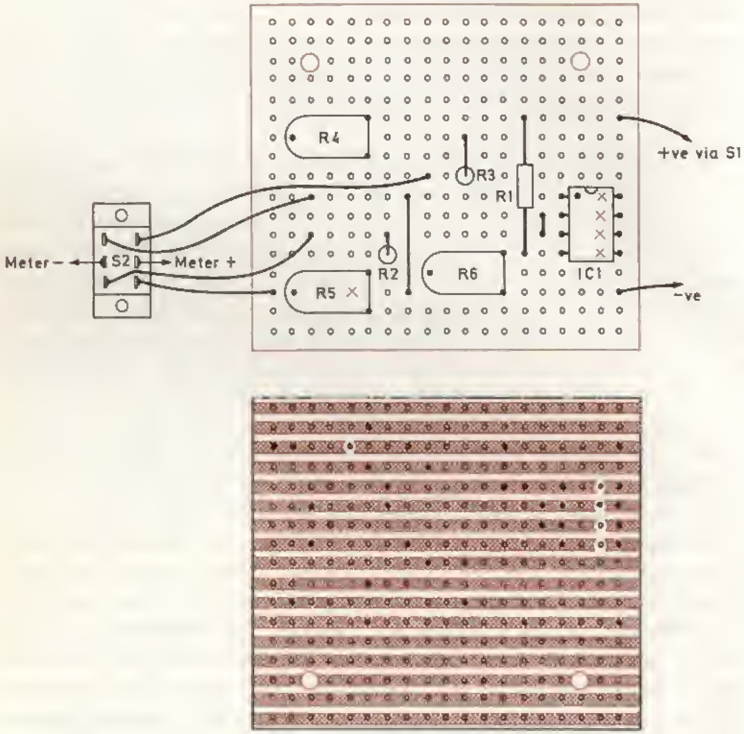

Figure 3.3

Top and underside views of the board

central cutout and four small holes for the threaded rods which take the mounting nuts. It is probably easiest to make the large cutout first using either a fretsaw or a small round file, and then locate the positions of the smaller holes using the meter as a sort of template. The four holes can then be drilled and the meter mounted in position.

The unit will work using any normal 50μA moving coil meter, and the accuracy of the unit fully justifies the use of a large meter.

Adjustment

Ideally the unit should be calibrated by bringing the temperature of the i.c. to 0°C and then adjusting R6 to zero the meter. The i.c. should then be raised to a temperature of 50°C or some other known temperature which represents something approaching f.s.d. of the meter, and then R5 is adjusted to produce the appropriate reading on the meter. The procedure should be repeated once or twice to check that the calibration is accurate.

In practice this may not be easy to carry out unless the i.c. is housed in a waterproof probe of some kind. This is quite feasible, and there is no need to mount the i.c. on the component panel. It can be mounted in a probe and connected to the component panel via a 3-way cable. This cable may be quite long if necessary, but if it is more than a few metres long it would probably be best to use twin screened cable (with twin or common screening) with the negative supply line connecting to the outer braiding(s) and the positive supply line and output being carried by the inner conductors.

A suitable probe can consist simply of a small test tube, or something similar, into which the i.c. is fitted. It is advisable to use silicon grease or a substitute to fill the gaps around the i.c. so that there is a good thermal contact between the outside of the test tube and the temperature sensing circuit inside the i.c.

With the i.c. mounted in a probe it is an easy matter to bring the i.c. to 0°C. If some ice cubes are stirred into some water until no more will dissolve, the water will be at almost exactly the right temperature (any error will be too small to be of significance). Some warmed water of known temperature can be used to provide the higher calibration point.

If the i.c. is not mounted in a probe, then the same basic method can be used. Two environments of significantly different temperature are required, and their precise temperatures must be known. First the unit is placed in the colder environment and allowed to adjust to its temperature, then R6 is adjusted to produce the appropriate reading on th meter. Next the unit is placed in the warmer environment and after it has adjusted to the new conditions, R5 is adjusted to produce the correct reading on the meter. This procedure is repeated until no further adjustment is necessary.

It is a good idea to solder a heat fin onto pins 5 to 8 of the i.c. as it is these pins which conduct the outside temperature to the sensing circuit. A heatfin will help to pick-up the heat in the outside environment and conduct it to the chip, or pick up the small amount of heat generated by the chip and disperse it, as appropriate. This will provide more reliable readings and will help the unit to respond more rapidly to temperature changes. A heatfin can simply consist of a small piece of copper plate or copper laminate board.

Components list for the electronic thermometer

Resistors	
R1	390Ω miniature ¼W, 5%
R2	3.3kΩ miniature ¼W, 5%
R3	150kΩ miniature ¼W, 5%
R4	100kΩ subminiature (0.1W) horizontal preset
R5	10kΩ subminiature (0.1W) horizontal preset
R6	4.7kΩ subminiature (0.1W) horizontal preset
Semiconductor	
IC1	LM3911N (8 pin DIL package)
Switches	
S1	push-to-make release-to-break pushbutton type
S2	D.P.D.T. slider switch
Meter	
M1	50μA moving coil panel meter (any desired size)
Miscellaneous	
0.1in matrix stripboard panel	
Metal or plastics case	
PP3 battery and connector to suit	
Wire, solder, etc.	

R4 is given the correct adjustment by first carefully measuring the supply voltage using a multimeter, then switching S2 to the battery check position, and finally adjusting R4 for the correct meter reading. S1 should be depressed when measuring the supply voltage using the multimeter and while adjusting R4.