MEASUREMENT OF TEMPERATURE WITH THERMISTOR

OBJECT:

1. To calibrate the ammeter for temperature measurement using in-built electrical oven and an Mercury thermometer.
2. To measure temperature of a hot object.

FEATURES:

The board consists of the following built-in parts:

1. +12V D.C. at 50 mA, IC regulated Power Supply internally connected.
2. 20V A.C. at 1.2A, for oven.
3. D.C. Microammeter, 65mm rectangular dial with switch selectable ranges of 500µA and 1mA.
4. Potentiometer and three fixed value resistors.
5. NTC type 1K thermistor provided as a probe.
6. Elelctrically heated oven.
7. Glass thermometer.
8. Mains ON/OFF switch, Fuse and Jewel light.

- The unit is operative on 230 V ±10% at 50Hz A.C. Mains.
- Adequate no. of patch cords stackable from rear both ends 4mm spring loaded plug length ½ meter.
- Good quality, reliable terminal/sockets are provided at appropriate places on panel for connections/observation of waveforms.
- Weight 3.9 Kg. (Approx.)
- Dimension 317 mm L × 229 mm D × 106 mm H.

PANEL DESCRIPTION

Mains ON/OFF switch, fuse and Neon indicator are located along the lower left hand corner in a block marked POWER.

Electrical oven with ON/OFF switch is provided along the right hand lower corner. Besides the oven, there is a clamp for holding the mercury thermometer in place.

The Wheatstone bridge configuration with provision for connecting 1K, NTC Thermistor as one of its arms is located in the middle of the panel. A part of the resistor R2 is made variable with the 2K2 potentiometer. This will help in zero sitting of the meter. A sensitive two range ammeter is provided in the upper middle part of the panel. Meter range is selectable by a toggle switch just below the meter. Resistors R1 and R3 are precision ± 1% resistors.

INTRODUCTION

Although thermistors have many other applications, but they are best known for their function in the measurement of temperature. Thermisters are basically of two types:

1. *NTC Type*

   Where the resistance decreases with an increase in temperature.

2. *PTC Type*

   Where the resistance increase with an increase in temperature. This ETB uses a NTC type thermistor.

The thermistor's relatively large resistance change per degree change in temperature (called the Sensitivity) makes it obvious choice as a temperature transducer.

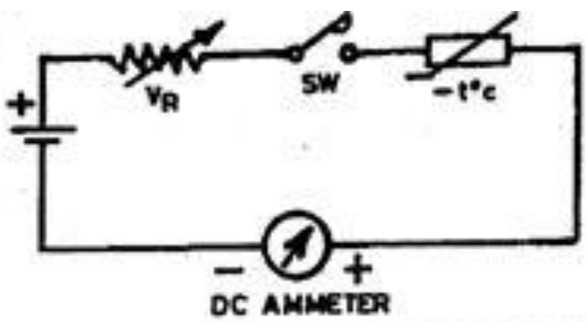

FIG. 1. SIMPLE TEMPERATURE MEASUREMENT CIRCUIT USING A THERMISTOR

When a thermistor is connected in a simple circuit of Fig.1, consisting of a battery and a D.C. ammeter, any variation in temperature causes a change in thermistor resistance and a corresponding change in circuit current. The meter can be calibrated directly in terms of temperature.

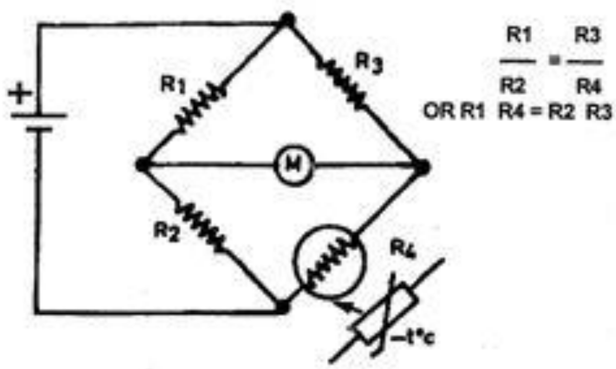

FIG. 2 THERMISTOR CONNECTED AS ONE OF THE ARMS OF A WHEATSTONE BRIDGE CIRCUIT FOR ACCURATE TEMPERATURE MEASUREMENTS

For more accuracy the thermistor is connected in a Wheatstone bridge circuit such as shown in Fig. 2. This experimental training board uses a Wheatstone bridge circuit for temperature measurements.

THEORY

1. GENERAL DESCRIPTION

A thermistor is a semiconductor device with a negative temperature coefficient of resistance, opposite to most metals. The resistance follows an exponential variation with temperature which is given by the following relation:

$$R = R_{\circ} \exp \left[\beta \left(\frac{1}{T} - \frac{1}{T_{\circ}}\right)\right] \qquad \text{..........(1)}$$

Where $R_{\circ}$ = Resistance of the thermistor at $T_{\circ}$ = Temperature.

β = An experimental constant that can have a value between 3500-4500° K.

2. CONSTRUCTION

Physically, thermistors are made by compressing mixtures of compounds usually oxides of manganese, cobalt, calcium, uranium, iron, zinc, titanium, aluminium and magnesium. This starts out in a powder form, and the material can be formed into rods, beads or discs, by a process called sintering. This is merely a process of forming a blob of material under high pressure and temperature. Wire leads can be attached to the thermistor, and sometimes it is enclosed in an envelope of some king, glass for example. Fig.3 shows various shapes in which thermistors are commercially available. The thermistor provided with this training board is a bead type.

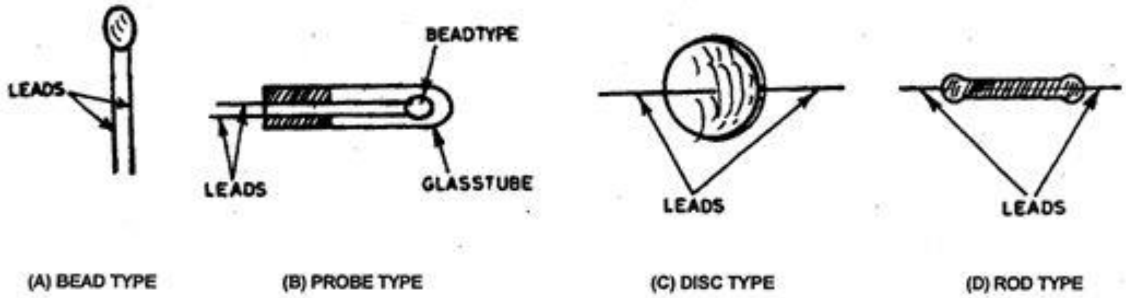

FIG. 3 VARIOUS SHAPES OF COMMERCIALLY AVAILABLE THERMISTORS.

3. ***THERMISTOR CHARACTERISTICS***

The resistance, temperature relationship at 1 above shows how the resistance of a thermistor can vary with temperature. A typical characterstics curve is shown in Fig. 4.

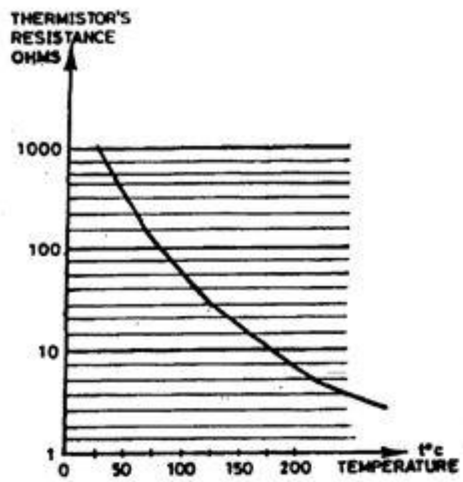

FIG. 4 RESISTANCE – TEMPERATURE CHARACTERISTICS OF A THERMISTOR (NTC TYPE)

The characteristics show that even for a small change in temperature the change in resistance of a thermistor is very large.

The characteristics of thermistor are no doubt non-linear but a linear approximation of the resistance temperature curve can be obtained over a small range of temperatures.

Thus for a small limited range of temperature the resistance of a thermistor varies as:

$R_{T2} = R_{T1}\,[1 + \alpha_{T1}\Delta T]$ ……………………………………………………….(2)

e.g. A thermistor has a resistance temperature coefficient i.e. α of -5% over a temperature range of 25°C to 50°C. Now if the resistance of this thermistor at 25°C is 100 ohms, what is its resistance at say 35°C.

The above can be worked out using the relation at (2) above.

$$R_{35}°C = 100\,[1 - 0.05(35 - 25)]$$

= 100 (1-0.5)

= 50 ohm

4. TEMPRATURE MEASUREMENT WITH THERMISTOR IN A WHEATSTONE BRIDGE CIRCUIT

In most practical temperature measurement circuit a thermistor is used as one of the arms of a Wheatstone bridge circuit as shown in Fig.2.

Here for balance :

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Or $R_1 R_4 = R_2 R_3$

5. USING A THERMISTOR AS A TEMPERATURE COMPENSATING NETWORK

Because thermistor have a negative temperature coefficient of resistance where as most electrical conductors have the positive temperature coefficient, thermistors are used as a temperature compensating network. Fig.5 shows such a network, where S is a shunt resistance in parallel with a thermistor. Let us consider an electrical conductor represented by a thick line between points AB this could also be the coil of a meter. With an increase of temperature the resistance of this conductor also increases but this will be compensated by the series temperature compensating network.

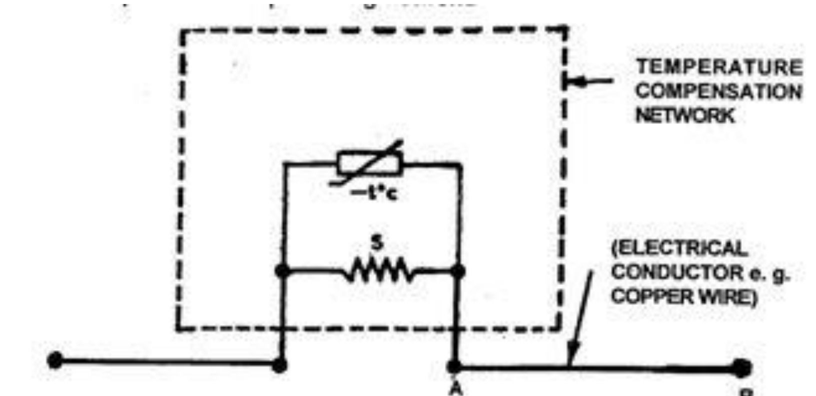

FIG. 5 TEMPERATURE COMPENSATION OF A CONDUCTOR (e. g. COPPER WIRE) BY MEANS OF A THERMISTOR TEMPERATURE COMPENSATING NETWORK.

As the resistance increase of small length of conductors are negligible the effect of a compensating network is difficult to demonstrate in a simple training board as this one.

Experiment 1

To calibrate the ammeter for temperature measurement using in-built electrical oven and a Mercury thermometer.

Procedure

1.1 Please refer to Fig. 6 for connection. Select the meter range of ImA with the toggle switch.

1.2 Connect the thermistor probe plugs to the sockets of the arm R_4 of the bridge configuration as shown in Fig.6.

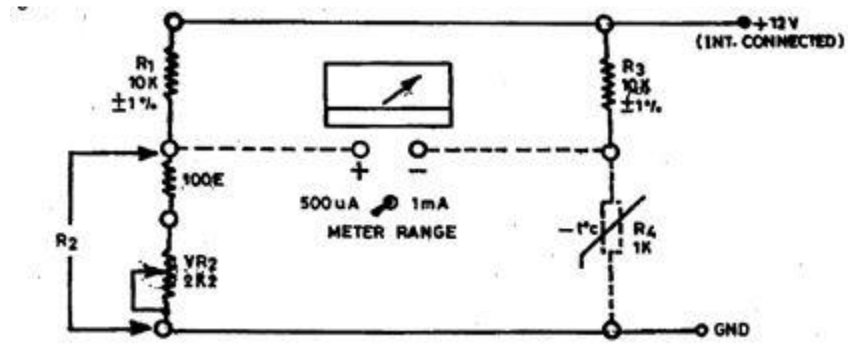

FIG. 6. INTERCONNECTIONS FOR CARRYING OUT THE EXPERIMENTS. PATCH CORDS TO BE USED FOR CONNECTING METER AS SHOWN BY DOTTED LINES.

1.3 Place the thermistor probe in the cavity provided on the Oven. Also insert the mercury thermometer in the clamp so that its glass bulb is inserted in the cavity provided on the Oven.

1.4 Keep the 2K2 potentiometer knob to the mid position. Keep the Oven ON/OFF switch to OFF position.

1.5 Insert the mains plug of the training board into a 230V ± 10% AC at 50 Hz, mains socket. Switch ON the training board.

1.6 Bring the ammeter needle to zero position by adjusting the 2K2 potentiometer.

Now the ammeter range switch to 500 microamperes range and if necessary again adjust the 2K2 potentiometer for zero setting of the ammeter. Now do not move the potentiometer knob during rest of the experiment.

1.7 Switch ON the Oven.

1.8 Carefully and promptly record the meter readings against the temperature readings as shown by the mercury thermometer starting from the room temperature.

NOTE: At higher temperature if the ammeter reading exceeds 500 microampere, select 1mA range.

Record the reading in TABLE-1

TABLE-1

Sr. No.	Temperature as on mercury Thermometer °C	Ammeter reading µA	Sr. No.	Temperature as on mercury Thermometer °C	Ammeter reading µA

Take a graph paper and plot the readings by taking Temperaturealong X-axis and current along the Y-axis.

A typical plot is shown in Fig. 7. Draw a horizontal line for a desired meter reading. Now where this line intersects the plot, from these draw a vertical line parallel to Y-axis, thus temperature reading corresponding to that meter reading can be interpreted.

EXPERIMENT: 2

To measure temperature of a hot object

PROCEDURE:

2.1 After the meter is calibrated as in Experiment 1 above, switch OFF the Oven. Remove the thermistor probe from the Oven cavity and place it on table away from any hot object till the ammeter needle come back to zero position.

2.2 Select 1mA range of ammeter, place the thermistor probe in contact with the hot object whose temperature is to be known. There should be a good contact.

2.3 Take ammeter reading selecting the suitable range (i.e. 500 µA or 1mA) and interpret the temperature of the object from the graph of Fig. 7.

NOTE : 1. Take care that after once setting the ammeter needle to zero as in the beginning of EXP.1.

2. The 2K2 potentiometer is not disturbed, otherwise results will be inaccurate.

3. Temperature measurements from 0°C to above 100°C can be easily made. The range can be extended both ways by calibrating the ammeter with its zero setting at lower or higher temperature than the above range.

QUESTIONS:

1. What features of thermistor make it a versatile temperature transducer?
2. Why a bridge circuit is better than the simple circuit of Fig. 1?
3. Can we use a PTC type thermistor in a temperature compensating network?
4. From Fig. 3. Select the right thermistor for measuring temperature of a chemical liquid?

REFERENCES

1. Electronic Device and Circuits : By A. MOTTERSHEAD
2. Electronic instrumentation and Measurement Techniques : By W.D.COOPER
3. Electrical and electronic Measurement and Instrumentation : By A.K.SAWHNEY
4. Electrical Technology : By A.K. and B.L.THERAJA

ACCESSORIES : 4mm-multipin patch cord 50cm. Red-1, 4mm- multipin patch cord 50 cm. Black-3.