Sensors & Actuator for Automatic Systems

LAB # 01

RESISTIVE TEMPERATURE TRANSDUCERS

Roll No:	**Date:**
Checked by:	**Grade:**

1. Objectives:

- To determine the characteristics of the resistance temperature detector (RTD)
- To determine the characteristics of the negative temperature coefficient (NTC) thermistor
- To determine the characteristics of the positive temperature coefficient (PTC) thermistor

2. Equipment required:

- Experiment module MCM14/EV.
- Digital multimeters
- Power supply Mod. PSUIEV(+12V & -12V)\

3. Theory:

Temperature measurement is very important in all spheres of life and especially so in the process industries. However, it poses particular problems, since temperature measurement cannot be related to a fundamental standard of temperature in the same way that the measurement of other quantities can be related to the primary standards of mass, length and time. If two bodies of lengths L_1 and L_2 are connected together end to end, the result is a body of length $L_1 + L_2$. A similar relationship exists between separate masses and separate times. However, if two bodies at the same temperature are connected together, the joined body has the same temperature as each of the original bodies.

This is a root cause of the fundamental difficulties that exist in establishing an absolute standard for temperature in the form of a relationship between it and other measurable quantities for which a primary standard unit exists. In the absence of such a relationship, it is necessary to establish fixed, reproducible reference points for temperature in the form of freezing and boiling points of substances where the transition between solid, liquid and gaseous states is sharply defined.
Instruments to measure temperature can be divided into separate classes according to the physical principle on which they operate. The main principles used are:

- The thermoelectric effect
- Resistance change
- Sensitivity of semiconductor device
- Radiative heat emission
- Thermography
- Thermal expansion
- Resonant frequency change
- Sensitivity of fiber optic devices
- Acoustic thermometry
- Color change

3.1 Varying resistance devices

Varying resistance devices rely on the physical principle of the variation of resistance with temperature. The devices are known as either resistance thermometers or thermistors according to whether the material used for their construction is a metal or a semiconductor, and both are common measuring devices. The normal method of measuring resistance is to use a d.c. bridge
The excitation voltage of the bridge has to be chosen very carefully because, although a high value is desirable for achieving high measurement sensitivity, the self-heating effect of high currents flowing in the temperature transducer creates an error by increasing the temperature of the device and so changing the resistance value.

3.1.1 Resistance Temperature Detectors (Resistance Thermometers)

Resistance temperature detectors rely on the principle that the resistance of a metal varies with temperature according to the relationship

$$R \approx R_o(1 + \alpha_1 \Delta T)$$

Where

R	= the resistance of the conductor at temperature t (^{0}C)
R_0	= the resistance at the reference temperature, usually 20^{0}C
α	= the temperature coefficient of resistance
ΔT	= the difference between the operating and the reference temperature

This equation is approximately true over a limited temperature range for some metals, notably platinum, copper and nickel. Platinum has the most linear resistance–temperature characteristic, and it also has good chemical inertness, making it the preferred type of resistance thermometer in most applications.

Platinum is the best metal for RTD elements for three reasons. It follows a very linear resistance-to temperature relationship; it follows its resistance-to-temperature relationship in a highly repeatable manner over its temperature range; and it has the widest temperature range among the metals used to make RTDs. Platinum is not the most sensitive metal; however, it is the metal that offers the best long term stability.

Besides having a less linear characteristic, both nickel and copper are inferior to platinum in terms of their greater susceptibility to oxidation and corrosion. This seriously limits their accuracy and longevity. However, because platinum is very expensive compared with nickel and copper, the latter are used in resistance thermometers when cost is important. Another metal, tungsten, is also used in resistance thermometers in some circumstances, particularly for high temperature measurements. Platinum is a better choice than copper or nickel because it is chemically inert, it withstands oxidation well, and works in a higher temperature range as well .The working range of each of these four types of resistance thermometer is as shown below:

- Platinum: −270°C to 1000°C (though use above 650°C is uncommon)
- Copper: −200°C to 260°C
- Nickel: −200°C to 430°C
- Tungsten: −270°C to 1100°C

The sensitive portion of an RTD, called an element, is a coil of small-diameter, high-purity wire, usually constructed of platinum, copper, or nickel. This type of configuration is called a wire-wound element. With thin-film elements, a thin film of platinum is deposited onto a ceramic substrate.

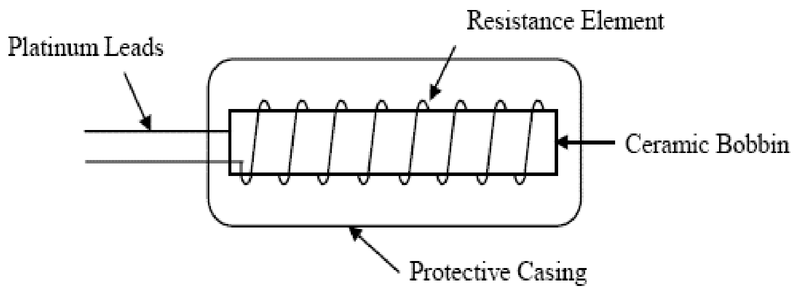

Fig:01 Wire Wound RTD

A platinum RTD is mounted in the module. The platinum RTD has a **α= 3.9 x 10^{-3} $^{o}C^{-1}$**.

3.1.2 Thermistors

A thermistor is a thermally sensitive resistor whose primary function is to exhibit a change in electric resistance with a change in body temperature. Unlike a wire wound or metal film resistance temperature detector (RTD), a thermistor is a ceramic semiconductor. Depending on the type of material system used, a thermistor can have either a large positive temperature coefficient of resistance (PTC device) or a large negative temperature coefficient of resistance (NTC device).

Thermistors are manufactured from beads of semiconductor material prepared from oxides of the iron group of metals such as chromium, cobalt, iron, manganese and nickel. Normally, thermistors have a negative temperature coefficient, i.e. the resistance decreases as the temperature increases.

The materials used for switching-type PTC thermistors are compounds of barium, lead, and strontium titanates. However, alternative forms of heavily doped thermistors are now available (at greater cost) that have a positive temperature coefficient.

Thermistor is very definitely a non-linear sensor. However, the major advantages of thermistors are their relatively low cost and their small size. This size advantage means that the time constant of thermistors operated in sheaths is small, although the size reduction also decreases its heat dissipation capability and so makes the self-heating effect greater.
In consequence, thermistors have to be operated at generally lower current levels than resistance thermometers and so the measurement sensitivity is less.

4. Heating source

The heat necessary to the tests on the temperature transducers is provided by two resistors in parallel. Two resistors heat the aluminum plate on which the transducers are inserted. The temperature range goes from ambient temperature to about 110^{o}C.

5. Calibration:

RTD has a resistance of 100 Ω at 0^{o}C and of 138.5 Ω at 100°C. These resistance values are two calibration points of the conditioner with two sample resistors to be inserted into the proper jumpers.

- Disconnect all jumpers of the TEMPERATURE TRANSDUCERS circuit.
- Connect Jumper J3
- With Jumper J4 connect the 100 Ω resistor and with the potentiometer RV1 adjust the voltage so to obtain 0V on point t (OUT)
- Disconnect jumper J4, with jumper J5 connect the 138.5 Ω resistor, with the potentiometer RV2 adjust the voltage so to obtain 1V of full scale on point 7 (OUT)
- After calibration, voltage changes between 0V and 1 V from 0^{o}C to 100^{o}C. The Coefficient of 10 m V /^{o}C enables a direct temperature reading: e.g.450 mV correspond to 45^{o}C.

6. Lab Procedure

This lab is being conducted using MCM14/EV Transducers Module. Its temperature transducers section as shown in fig: 02 consist of RTD, PTC and NTC thermistor, Thermocouple, a heating element that can heat up to 110°C.

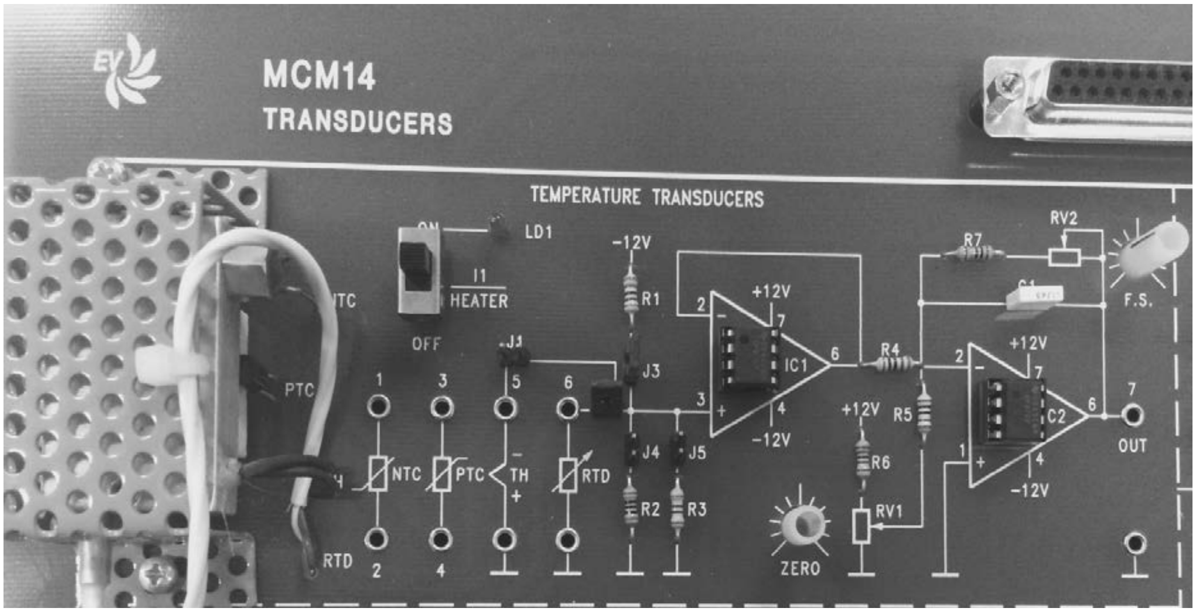

Fig:02 MCM 14/EV Transducers module (Temperature Transducers)

- Disconnect Jumper J5
- Connect jumper J2 to connect the RTD (Keep J3 inserted)
- Activate the heating element with the I1/HEATER switch.
- Measure the voltage and then temperature between OUT (7) and ground.
- Use the temperature measured with RTD as a sample variable to detect the characteristic resistance of PTC and NTC thermistors and fill out the following table.
- Measure the value of NTC resistance between terminal 1 and2.
- Measure the value of PTC resistance between terminal 3 and 4.

RTD (mV)	Temperature (^{o}C)	RTD(Ω) $R \approx R_o(1+\alpha_1 \Delta T)$ $R \approx 100(1+3.9\times10^{-3}\times T)$	NTC (Ω)	PTC (Ω)
300	30			
350	35			
400	40			
450	45			
500	50			
550	55			
600	60			
650	65			
700	70			
750	75			
800	80			

- Plot the graph of temperature vs resistance (using Matlab. Excel, e.t.c) with temperature on x-axis and resistance on y-axis.

7. Short answer questions

1. What is the behavior of NTC thermistor resistance when temperature switches from 30°C to 40°C?

2. What is the behavior of resistance as function of temperature for an RTD?