# University Of Jordan
# Faculty of Engineering and Technology
## Mechanical Engineering Department

# Measurement Lab.

### EXPERIMENT 10:

## Temperature Measurements by THERMISTORS

# INTRODUCTION:

The thermistor is a semiconductor device that has a negative temperature coefficient of resistance, in contrast to the positive coefficient displayed by most metals. Furthermore, the resistance follows an exponential variation with temperature.
The thermistor is a very sensitive device, and consistent performance within 0.01°C may be anticipated with proper calibration, a rather nice feature of the thermistor is that it may be used for temperature compensation of electric circuits. This is possible because of the negative temperature characteristic that it exhibits so that it can be used to counteract the increase in resistance of a circuit with a temperature increase.
I have noted that the thermistor is an extremely sensitive device because its resistance changes so rapidly with temperature; however, it has the disadvantage of highly nonlinear behavior. This is not a particularly severe problem because data acquisition systems can employ computing programs to provide direct temperature readout from the resistance measurement.

## OBJECTIVES:

After completion of the study and laboratory experimental measurements, you should be able to:
- ☒ Discover temperature measurement with thermistor and describe the characteristics of a thermistor.
- ☒ Describe the advantages and disadvantages of the thermistor.
- ☒ Design a circuit using a thermistor for this measurement of temperature.

## THEORY:

Thermistor as shown in figure (1) is temperature-sensitive resistor that exhibits a negative temperature coefficient. To put more simply, as the temperature increases, the thermistor resistance decreases. The thermistor is sensitive to both indirect & direct heat. The thermistor is versatile in that it is useful not only for measurement change, but it can also detect the effect of a heat rise in any resistor.
Thermistors has a very high sensitivity, but the resistance change with temperature is **nonlinear,** but also thermistors cannot be used to measure high temperatures, the maximum temperature of operation is sometimes only 100 or 200 °C. A typical thermistor circuit is shown below. As the thermistor is heated, it's resistance decreases and the current flow increases.

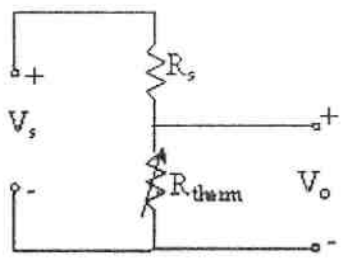

Fig (1): Basic Thermistor Circuit

From the circuit diagram, it is clear that this is a simple voltage divider. $R_s$ is some fixed (supply) resistor. $R_s$ and the supply voltage, $V_s$, can be adjusted to obtain the desired range of output voltage $V_0$ for a given range of temperature.

When a thermistor is connected in an electrical circuit, Ohm's law applies and power is dissipated as heat. This heat then raises the body temperature of the thermistor above the ambient level. This statement is expressed by this equation

$$T = T_A + \Delta T$$

where:
T is the thermistor temperature
$T_A$ is the ambient temperature
$\Delta T$ is the temperature rise due to the power dissipated

The rate at which power is supplied to a thermistor in an electrical circuit is shown in this equation:

$$dH/dt = P$$
$$= I^2R - EI$$

where:
dH/dt is the change in thermal energy per unit time
P is the power in Watts

The rate at which a thermistor loses heat energy to the environment is proportional to the temperature rise of the thermistor. The relation is shown in the following equation

$$dH_L/dt = \delta\,(T - T_A)$$

where:
$dH_L/dt$ = the heat energy loss per unit time
$\delta$ = the dissipation constant
T= the thermistor temperature
$T_A$= the ambient temperature

The dissipation constant, $\delta$, is defined as the ratio, at a specified ambient temperature, of a change in the power dissipation of a thermistor to the resulting change in body temperature. This constant is not truly a constant, since it varies slightly with temperature. The dissipation constant depends on the thermal conductivity and motion of the medium in which the thermistor is operating, as well as heat transfer from the circuit diagram, it is clear that this is a simple voltage divider. $R_s$ is some fixed (supply) resistor. $R_s$ and the supply voltage, $V_s$, can be adjusted to obtain the desired range of output voltage $V_0$ for a given range of temperature.

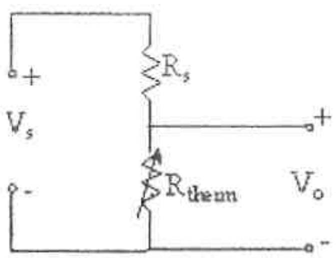

Fig (1): Basic Thermistor Circuit

When a thermistor is connected in an electrical circuit, Ohm's law applies and power is dissipated as heat. This heat then raises the body temperature of the thermistor above the ambient level. This statement is expressed by this equation:

$$T = T_A + AT$$

where:
T is the thermistor temperature
$T_A$ is the ambient temperature
AT is the temperature rise due to the power dissipated

The rate at which power is supplied to a thermistor in an electrical circuit is shown in the following equation

$$dH/dt = P$$
$$= I^2R$$
$$= EI$$

where;
dH/dt is the change in thermal energy per unit time
P Power in Watt

The rate at which a thermistor loses heat energy to the environment is proportional to the temperature rise of the thermistor. The relation is shown in the following equation

$$dH_L/dt = \delta\,(T - T_A)$$

where:
dHi/dt = the heat energy loss per unit time
δ = the dissipation constant
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The dissipation constant, δ, is defined as the ratio, at a specified ambient temperature, of a change in the power dissipation of a thermistor to the resulting change in body temperature. This constant is not truly a constant, since it varies slightly with temperature. The dissipation constant depends on the thermal conductivity and motion of the medium in which the thermistor is operating, as well as heat transfer from the thermistor to its surrounding through conduction (the leads), convection, and radiation.
When the power dissipation of a thermistor is reduced to an insignificant level (thus self-heating can be ignored), the heat transfer equation for a thermistor can be expressed as shown in this next equation

$$dT/dt = - \delta /C(T - T_A)$$

where:
dT/dt = the change in temperature per unit time
δ = the dissipation constant
C = the heat capacity of the thermistor, dependent on the construction of the device

A solution to the differential equation shown above is known as Newton's law of cooling. This is stated below

$$T = T_A + (T_I - T_A)e^{-(t/\tau)}$$

where:
T = the temperature at time t
$T_A$ = the ambient temperature
Ti = the initial temperature
e = the base of natural logarithms, 2.72
t = time
τ = the thermal time constant
Note that $\tau = C/\delta$.

Another important characteristic of the thermistor is its thermal time constant. The time constant is the time required for a thermistor to change 63.2% of the total difference between its initial & final body temperature when subjected to a step change in temperature. The current flowing through a thermistor is proportional to its temperature change and the relationship stated in terms of time constants. The time constant is probably the most important characteristic of the thermistor, since most engineers want to observe the temperature change in the shortest possible time.

Thermistors, are resistors made from oxides of nickel, manganese, iron, copper and other materials. These metals do not exhibit linear changes with temperature. Most thermistors follow a logarithmic curve and if a linear output is desired, the amplifier used with the thermistor should have an anti-log gain curve as shown in figure (2) which enter balances the logarithmic curve.

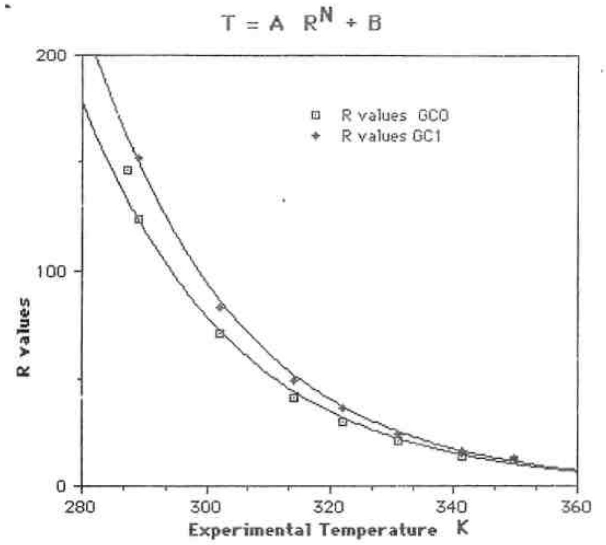


Fig (3): Thermistor Curve

## APPARATUS:

- ❖ Master builder (S300B)
- ❖ Insertion Panel SIP380-1
- ❖ Digital Multimeter (DMM)
- ❖ Clip leads

## TESTS AND MEASUREMENTS:

In the experiment, the characteristics and performance of a thermistor temperature sensor are evaluated. Included in the experiment are the measurement of a thermistor's resistance change and its thermal time constant. The experimental circuit is located on the experimental panel in section G.

## PROCEDURES:

1. Place switches SWg-1, 2, 3, and 4 in the OFF position.
2. Use connection leads to connect the 0 to 1 mA meter (TP1 & TP2) with its protective diode, to test points TP46 & TP47.
3. With the power on, initially adjust the variable +15V DC power supply to OV DC.
4. Connect a DMM to the ground and to the positive 15V DC power supply terminal.
5. Turn Switch on SWg-2, which connects the power supply to the thermistor.
6. Increase the positive power supply to the following voltages as read on the DMM.

At each DMM reading, allow the thermistor current to stabilize. Record the stabilized thermistor current for DMM reading As shown in the table below

7. Describe your plotted data.
8. Make the ammeter reads 0.4 mA, Turn SWg-1 and allow the heating resistor to reach its full temperature.

**HAZARD:** After this step, the heating resistor become very hot, when you want to cool it don't use your finger.

9. Touch the thermistor element against the heater and hold it, describe what happen to DC current meter, does it make sense with what should happened to resistance?, what is the value of current after 30 seconds?

10. Compute the current at one time constant after the thermistor has been removed from the source of heat. ______________________ mA

11. set the voltage source so that the meter reads 0.5 mA touch the thermistor to the heating element only long enough for the current to reach the maximum value obtained before. Measure the time it takes for the current to drop to the value calculated in "the last step. This time is the thermal time constant of the thermistor sec.

12. Open SWg-2, use the Ohmmeter to measure the thermistor resistance ______ kΩ

Table (1) : The observed readings

| DMM (V DC) | 1.0 mA Meter |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |

## REVIEW QUESTION:

1. What is the physical meaning of temperature coefficient?
2. Mention three applications for thermistor
3. Are thermistor linear or nonlinear device?
4. What is the dissipation factor of a thermistor?
5. What is the common range for thermistor for measuring purpose?
6. As temperature increases, what happens to thermistor's resistance, voltage?
7. What are the sources of error in this experiment? Identify each error as a bias or a precision error?