Experiment 1 Sensors

This experiment investigates sensors suitable to monitor several engineering variables. For each sensor, provide the assigned information and show the method used for analysis.

Temperature Sensors

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Four different temperature sensors are characterized by placing each in a water bath and varying the bath temperature between 0^o C and 100^o C. The water bath temperature is measured with a digital thermometer.

NTC Thermistor

A thermistor is a highly temperature sensitive resistor that is used as a temperature sensor. NTC (negative temperature coefficient) thermistors are formulated from metal oxide compositions to produce a semi-conducting ceramic body. These sensors exhibit an exponential decrease in resistance R with increasing absolute temperature T shown by:

$$R = R_o e^{E/kT} \quad (1)$$

Where E is the activation energy required both to create and to move charge carriers, R_o is a pre-exponential, and k is Boltzmann's constant (8.62 x 10^{-5} ev/K). Both E and R_o are assumed to remain constant. Equation (1) shows the basis of relating the temperature to resistance, a readily measurable electrical quantity.

Required:

1. Measure and tabulate the resistance of the thermistor as a function of temperature.
2. Based on the assumption that equation (1) represents the thermistor's relationship between resistance and temperature, use a suitable graph to linearize your thermistor data and display the trend-line.
3. Determine the value of the constants R_o and E for the thermistor.
4. Determine the ***room temperature*** sensitivity of the thermistor.
5. Solve Equation (1) for temperature T.
6. Determine the expected thermistor resistance at 130 ^{o}C.

Resistance Temperature Detector

Resistance temperature detectors (RTD) are resistors made out of metal wire or thin films. The nearly linear increase in resistance with temperature characteristic of metallic conduction near and above room temperature controls the response of these sensors. The detector's resistance R as a function of temperature T is given by:

$$R = R_{0^oC}(1 + \alpha_{TCR} T) \quad (2)$$

Where R_{0^oC} is the resistance at 0^o C, α_{TCR} is the detector's temperature coefficient of resistance, and T is temperature on the Celsius scale. Both α_{TCR} and R_{0^oC} are assumed to remain constant.

Required:

1. Measure and tabulate the resistance of the resistance temperature detector as a function of temperature.
2. Based on the assumption that equation (2) represents the detector's relationship between resistance and temperature, use a suitable graph to linearize your resistance temperature detector data and display the trend-line.
3. Determine the value of the constants R_{0^oC} and α_{TCR} for the resistance temperature detector.
4. Determine the sensitivity of the RTD.
5. Solve Equation (2) for temperature T.
6. Determine the expected detector resistance at 150 ^{o}C.

Thermocouple

A thermocouple is formed when two dissimilar conductors are joined together at both ends to form a single closed circuit. If the two junctions are maintained at different temperatures, a current will flow. If the circuit is opened, a thermal voltage can be measured across the open leads. The thermocouple can be used as a sensor since the thermal voltage tends to vary monotonically with temperature. The standard output voltages, $V_{T,0^oC}$, for commonly used thermocouples are given in reference tables that assume that the cold junction is held at 0^o C. If the cold junction is at some other temperature, then the measured voltage, $V_{T,CJ}$, must be corrected by adding to it the electrical equivalent of the cold junction temperature referenced to 0^o C, $V_{CJ,0^oC}$.

Over a limited temperature range, the thermocouple output voltage $V_{T,0^oC}$ can be force-fit to:

$$V_{T,\,0^oC} = aT + b \quad (3)$$

where T is the temperature in degrees Celsius and both "a" and "b" are constant.

Required:

1. Measure and tabulate the voltage $V_{T,RT}$ of the Type K (Chromel-Alumel) thermocouple as a function of temperature. (Be sure to measure and record room temperature.)
2. Obtain $V_{T,0^oC}$ by adding the room temperature cold junction correction $V_{RT,\,0^oC}$ to $V_{T,RT}$.
3. Based on the assumption that equation (3) represents the thermocouple's voltage as a function of temperature, use a suitable graph to linearize your thermocouple data and display the trend-line.
4. Determine the value of the constants "a" and "b" for the thermocouple.
5. Determine the sensitivity of the thermocouple.
6. Solve Equation (3) for temperature T.

Diode Temperature Sensor

The temperature dependence of the I-V characteristic of a forward biased diode yields a convenient basis for sensing temperature. If a constant current on the order of 1 mA is passed through the diode, the diode voltage V_D decreases linearly with increasing temperature T as given by:

$$V_D = \beta T + V_{D(0^oC)} \qquad (4)$$

Where β is constant for a constant current through a particular diode, T is temperature on the Celsius scale, and $V_{D(0^oC)}$ is the diode voltage at 0^o C.

Required:

1. Use the circuit shown in Figure 1 to supply a sensibly constant current of approximately 1 mA through one of the rectifying diodes (1N4004 or 1N4005). Use R = 10 KΩ and fix the supply voltage between 10 to 12 v. The exact voltage is not important, but be careful not to alter the voltage once it is set.
2. Measure and tabulate the voltage across the diode as a function of temperature.
3. Based on the assumption that equation (4) represents the relationship between diode voltage and temperature, use a suitable graph to linearize your diode temperature sensor data and display the trend-line.
4. Determine the value of the constants β and $V_{D(0^oC)}$ for the diode temperature sensor.
5. Determine the sensitivity of the diode temperature sensor.

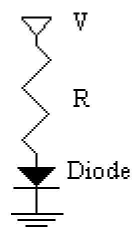

Figure 1 Diode temperature sensor circuit.