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| **Course Name:** | **Virtual Instrumentation and Automation lab** | **Semester:** | **V** |
| **Date of Performance:** | **20/08/2021** | **Batch No:** | **B1** |
| **Faculty Name:** | **Annu maam** | **Roll No:** | **1912052** |
| **Faculty Sign & Date:** |  | **Grade/Marks:** |  |

**Experiment No: 1A**

**Title: Study of Sensors (RTD, Thermocouple)**

**VLAB-Sensor modelling and simulation lab)**

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| **Aim and Objective of the Experiment:** |
| 1. Characterize the temperature sensor (RTD) 2. Characterize the temperature sensor (Thermocouple) 3. Characteristics of Level sensor (Capacitive level sensor) |

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| **COs to be achieved:** |
| **CO2:** Implement suitable sensors and actuators based on application |

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| **Theory:** |
| **Temperature**  Temperature is a measure of the average heat or thermal energy of the particles in a substance. Since it is an average measurement, it does not depend on the number of particles in an object. In that sense it does not depend on the size of it. For example, the temperature of a small cup of boiling water is the same as the temperature of a large pot of boiling water. Even if the large pot is much bigger than the cup and has millions and millions more water molecules. The basic unit of temperature (T) in the International System of Units (SI) is the Kelvin (K). The commonly used other units of temperature are Degree Celsius (°C) and Degree Fahrenheit (°F).    **Electrical Resistance**  The electrical resistance of an object is a measure of its opposition to the flow of an electric current. For a wide range of materials and conditions, the electrical resistance does not depend on the amount of current through or the potential difference (voltage) across the object. That means the resistance R is constants for the given temperature and material. Therefore, the resistance of an object can be defined as the ratio of voltage to current, in accordance with Ohm’s Law:                                                       R = V/I  The unit of resistance is ohm (Ω).  **Temperature Measurement using RTD**  For measurement of Temperature number of sensors are available. One of the most linear, stable, and reproducible temperature sensors is the RTD, Resistance Temperature Detector. In RTD, the  output resistance changes with temperature. RTD is a positive temperature coefficient device. The resistance of the metal increases with temperature. The resistive property of the metal is called its resistivity. The resistive property defines length and cross sectional area required to fabricate an RTD of a given value. The resistance is proportional to length and inversely proportional to the cross sectional area and is given by the relationship            R = ρl/A   Where 'R' is resistance of the metal, 'ρ' is the resistivity of the metal, 'l' is the length of the metal and 'A' is the area of cross section of the metal.  http://sl-coep.vlabs.ac.in/Rtd/images/RTD_resi%20element(1).jpg  **Resistance Temperature Detector (RTD)** Resistance Temperature Detector (RTD), as the name implies, is a sensor used to measure temperature by correlating the resistance with temperature. Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The RTD element is made from a pure metals as mentioned below. The material property to have predictable change in resistance as the temperature changes, is used to determine temperature.  Commonly used RTD Materials: • Platinum (most popular and accurate) • Nickel • Copper • Balco (rare) • Tungsten (rare)  **What is thermocouple?** A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flows in the thermoelectric circuit (the thermoelectric effect or Seebeck effect).  **Need for reference junction( cold junction):** In thermocouples, voltage is developed due to flow of electric current. This current flow depends upon the difference in temperatures at the two ends of conducting wire. That is thermocouples always measure difference in temperatures and not absolute temperature. To measure the temperature of one junction, the other junction is kept at some reference temperature. As this is done by using ice bath, it is normally called at cold junction. Using ice bath for constant temperature is useful for laboratory calibration, but is not convenient for most measurement and control applications. Instead of ice bath, an effect of cold junction is added using a thermally sensitive device such as a thermistor or diode. This is also called as isothermal block. Special care is taken to minimize any temperature gradient between terminals. Hence, the voltage from a known cold junction can be simulated, and the appropriate correction is applied. This is known as cold junction compensation.  **Software compensation** is the most versatile technique used for measuring thermocouples. Many thermocouples can be connected on the same block. The technique is independent of the types of thermocouples. All of the conversions are performed by the computer. The disadvantage is that the computer requires additional time to calculate the reference junction temperature. For maximum speed we can use hardware compensation.  **Hardware compensation** can be viewed as inserting a battery that cancels the offset voltage produced by the reference junction. These commercially available circuits provide an electronic ice point reference. Their main advantage is speed while the disadvantage is that it is suited to compensate only a particular type of thermocouple.  **Thermocouple properties:** **The selection criteria for thermocouple materials:** 1. Temperature Range 2. Melting point 3. Reaction to various atmospheric conditions 4. Thermoelectric output in combination 5. Electrical conductance 6. Stability 7. Interchangeability 8. Repeatability 9. accuracy 10. resolution 11. Cost 12. Availability 13. Chemical properties 14. Abrasion and vibration resistance 15. Installation requirements 16. Magnetic properties 17. Ease of handling and fabrication |

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| **Circuit Diagram/ Block Diagram:** |
| Attach Following:   * Plot of Characteristics of RTD * Plot of Characteristic of Thermocouple |

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| **Stepwise-Procedure:** |
| **Static Characteristics of RTD**   1. Select the **material** of RTD you want to use.  Temperature coefficient (α) for the same will be displayed on the screen. Note this value. 2. Click on ' **R0**' to get the value of R0 for selected RTD. Note the same. 3. Click on '**Get Temp**'. The temperature for which Rt is to be found will be displayed. 4. Using  formula calculate the value of Rt and enter the answer in the box provided (upto 2 decimals with rounding off). **Submit the answer** using submit button. 5. If your calculation is correct, go to step 3. Repeat the procedure min 3 times. 6. If your calculation is wrong, you will be asked to repeat the same. Please refer to **GET FORMULA** tab and verify your calculations. 7. After finishing minimum 3 set of correct readings, you can see the graph by clicking on '**Plot'**. 8. When the graph is displayed click **Next** tab to repeat the procedure with different reference resistance(R0) value and with  different materials. 9. Minimum 3 calculations are necessary to plot the graph. 10. Study the graphs for RTD performance with different reference resistance values and different materials.   **Static Characteristics of Thermocouple**   1. Select the type of Thermocouple to be used for experimentation. 2. Select the 'Reference Temp' to set the temperature of reference junction from drop down menu. 3. Click on 'Get Temperature’ green colour box. The temperature will be displayed for which output (mV) is to be found. 4. Click on 'thermocouple Reference Table' link below the sketch to refer to standard thermocouple charts. From the particular type of thermocouple chart, find the output millivolt value corresponding to the temperature. Enter it in the box provided and submit. 5. Enter the output millivolt in the answer box. If the answer is correct, it will get indicated in the box below the answer. If not verify it and enter correct output value. If wrong answer is submitted repeatedly for 3 times, the correct answer gets pop-up. 6. Go to step 3. Repeat the procedure at least for 3 times. 7. After finishing the required set of readings 'Plot', 'Next set' and 'Level 2' tabs are enabled. See the graph by clicking on **'Plot'** tab. 8. By clicking **Next** set tab, Repeat the procedure for different types of Thermocouples at various reference temperature values. 9. Click on **'Plot'** to see the graphs for comparative study. When you click on 'Level 2' tab, you can verify the Dynamic response of the thermocouple.   **Prerequisite**  Before performing this experiment, student must have knowledge about  1.   Working of a typical Capacitor  2.   Types of Capacitors  3.   Effect of various factors that affect the output of a capacitor e.g. temperature, dielectric constant of insulator used, distance between the plates, are of the plates used, etc.  **Level measurements**  In industry, liquids such as water, chemicals, and solvents are used in various processes. The amount of such liquid stored can be found by measuring level of the liquid in a container or vessel. The level affects not only the quantity delivered but also pressure and rate of flow in and out of the container. Level sensors detect the level of substances like liquids, slurries, granular materials, and powders. The substance to be measured can be inside a container or can be in its natural form (e.g. a river or a lake). The level measurement can be either continuous or point values.  **Continuous level sensors**measure the level to determine the exact amount of substance in a continuous manner.  **Point-level sensors**indicate whether the substance is above or below the sensing point. This is essential to avoid overflow or emptying of tanks and to protect pumps from dry run.  The selection criteria for level sensor include:  · The physical phase (liquid, solid or slurry)  · Temperature  · Pressure or vacuum  · Chemistry  · Dielectric constant of medium  · Density (specific gravity) of medium  · Agitation (action)  · Acoustical or electrical noise  · Vibration  · Mechanical shock  · Tank or bin size and shape       From the application point of view the considerations are :  · Price  · Accuracy  · Response rate  · Ease of calibration  · Physical size and mounting of the instrument  · Monitoring or control of continuous or discrete levels     Level measurements are broadly classified in two groups:  · Direct methods  · Indirect methods    **In direct methods**, the level is indicated directly by means of simple mechanical devices. The measurement is not affected by changes in material density. Few examples are:  · Dip Stick  · Resistance Tapes  · Sight Glass  · Floats  · Ultrasonic  · Radar    **In Indirect methods**, the level is converted in a measurable signal using a suitable transducer. Change in the material affects the measurement. A corrective factor must be used in recalibrating the instrument. Few examples are:  · Hydrostatic head methods  · Load cell  · Capacitance  · Conductivity    **Capacitance Level Measurement:**  Capacitive level transducer is an example of indirect measurement of level      Capacitance level sensors are used for wide variety of solids, aqueous and organic liquids, and slurries. The technique is frequently referred as **RF** as radio frequency signals applied to the capacitance circuit. The sensors can be designed to sense material with dielectric constants as low as 1.1 (coke and fly ash) and as high as 88 (water) or more. Sludges and slurries such as dehydrated cake and sewage slurry (dielectric constant approx. 50) and liquid chemicals such as quicklime (dielectric constant approx. 90) can also be sensed. **Dual-probe** capacitance level sensors can also be used to sense the interface between two immiscible liquids with substantially different dielectric constants.    Since capacitance level sensors are electronic devices, phase modulation and the use of higher frequencies makes the sensor suitable for applications in which dielectric constants are similar.    **Working Principle:**  The principle of capacitive level measurement is based on change of capacitance. An insulated electrode acts as one plate of capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. The capacitance depends on the fluid level. An empty tank has a lower capacitance while a filled tank has a higher capacitance. A simple capacitor consists of two electrode plate separated by a small thickness of an insulator such as solid, liquid, gas, or vacuum. This insulator is also called as dielectric. Value of C depends on dielectric used, area of the plate and also distance between the plates.            C = E (K A/d)  Where: C = capacitance in picofarads (pF) E = a constant known as the absolute permittivity of free space K = relative dielectric constant of the insulating material A = effective area of the conductors d = distance between the conductors This change in capacitance can be measured using AC bridge.  **Measurement:**  Measurement is made by applying an RF signal between the conductive probe and the vessel wall. The RF signal results in a very low current flow through the dielectric process material in the tank from the probe to the vessel wall. When the level in the tank drops, the dielectric constant drops causing a drop in the capacitance reading and a minute drop in current flow. This change is detected by the level switch's internal circuitry and translated into a change in the relay state of the level switch in case of point level detection. In the case of continuous level detectors, the output is not a relay state, but a scaled analog signal.   Level Measurement can be divided into three categories:  · Measurement of non-conductive material  · Measurement of conductive material  · Non-contact measurement      **Non-conducting material:**  For measuring level of non conducting liquids, bare probe arrangement is used as liquid resistance is sufficiently high to make it dielectric. Since the electrode and tank are fixed in place, the distance (d) is constant, capacitance is directly proportional to the level of the material acting as dielectric.    **Conducting Material:**  In conducting liquids, the probe plates are insulated using thin coating of glass or plastic to avoid short circuiting. The conductive material acts as the ground plate of the capacitor.    **Proximity measurements (Non-contact type measurements):**  In Proximity level measurement is the area of the capacitance plates is fixed, but distance between plates varies. Proximity level measurement does not produce a linear output and are used when the level varies by several inches.    **Advantages of Capacitive level measurement:**    1. Relatively inexpensive  2. Versatile  3. Reliable  4. Requires minimal maintenance  5. Contains no moving parts  6. Easy to install and can be adapted easily for different size of vessels  7. Good range of measurement, from few cm to about 100 m  8. Rugged  9. Simple to use  10. Easy to clean  11. Can be designed for high temperature and pressure applications.  **Applications:**  Capacitance Level Probes are used for measuring level of    1. Liquids  2. Powered and granular solids  3. Liquid metals at very high temperature  4. Liquefied gases at very low temperature  5. Corrosive materials like hydrofluoric acid  6. Very high pressure industrial processes.    **Disadvantages:**  Light density materials under 20 lb/ft3 and materials with particle sizes exceeding 1/2 in. in diameter can be a problem due to their very low dielectric constants (caused by the large amount of air space between particles).  RTD  Level 1    Level 2    **Thermocouple**  Couple- J  Ref Temperature- -5  Level 1    Level 2  Filling Material MGO powder      Capacitive |
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| **Observation Table** |
| RTD Static Characteristics   |  |  |  | | --- | --- | --- | | Sr. No. | Temperature t | Resistance Rt | | 1 | 5 | 103 | | 2 | 58 | 130 | | 3 | 65 | 133 |   Thermo-Couple Static Characteristics   |  |  |  | | --- | --- | --- | | Sr. No. | Temperature t | Output voltage (mv) | | 1 | 129 | 7.16 | | 2 | 326 | 18.04 | | 3 | 122 | 6.77 | |

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| **Post Lab Subjective/Objective type Questions:** |
| 1. RTD is very popular for temperature measurement because of 2. Cost 3. Self-heating 4. **Linearity** 5. In the Pt100, the suffix 100 refers to 6. Resistance at Room Temperature 7. **Resistance at 0 degree** 8. 100% pure platinum 9. Commonly used RTD Material is 10. **Platinum** 11. Aluminium 12. Both the above 13. RTDs are preferred over thermistors because 14. **RTDs have larger temperature range than thermistors** 15. RTDs are more sensitive than thermistors 16. RTD's are less sensitive to lead resistance than thermistors 17. PTC stands for  a. Platinum Temperature Coefficient   b. Partial Temperature Coefficient  **c. Positive Temperature Coefficient**  6) CJC stands for   1. Central Junction Compensation 2. Cold Joint Compensation 3. **Cold Joint Compression** 4. Lead wire compensation is necessary for 5. **RTDs** 6. T/Cs 7. Both RTDs and T/Cs   8. For j type thermocouple materials used are   * 1. **Iron Constantan**   2. Cromel Constantan   3. Cromel Alumel  1. Thermowell is used for protection of 2. Process fluid 3. **Sensing element** 4. Both a and b 5. --- Type thermocouple is used for cryogenic applications    1. **S**    2. T    3. ETop of Form   Bottom of Form  Top of Form  Bottom of Form  Top of Form |
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| **Conclusion:**  We understood the concept of Thermocouple,RTD and level sensors through simulation. |

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| **Signature of faculty in-charge with Date:** |