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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: 1 -b**

**Title: Study of Sensors (Strain gauge sensor, LVDT, VLAB-Sensor modelling and**

**simulation lab)**

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| **Aim and Objective of the Experiment:** |
| 1. Characterize the Strain gauge sensor 2. Characterize the LVDT |

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

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| **Theory:** Introduction to Strain Gauge Strain gauge transducer transforms mechanical elongation and compression into measurable value.  Types of Strain Gauges based on principle of working: 1. Mechanical: It is made up of two separate plastic layers. The bottom layer has a ruled scale on it and the top layer has a red arrow or pointer. One layer is glued to one side of the crack and one layer to the other. As the crack opens,the layers slide very slowly past one another and the pointer moves over the scale. The red crosshairs move on the scale as the crack widens. Some mechanical strain gauges are even more crude than this. The piece of plastic or glass is stick across a crack and observed its nature.  2. Electrical: The most common electrical strain gauges are thin, rectangular-shaped strips of foil with maze-like wiring patterns on them leading to a couple of electrical cables. When the material is strained, the foil strip is very slightly bent out of shape and the maze-like wires are either pulled apart (so their wires are stretched slightly thinner) or pushed together (so the wires are pushed together and become slightly thicker). Changing the width of a metal wire changes its electrical resistance. This change in resistance is proportional to the stress applied. If the forces involved are small, the deformation is elastic and the strain gauge eventually returns to its original shape.  3. Piezoelectric: Some materials such as quartz crystals and various types of ceramics, are effectively "natural" strain gauges. When pushed and pulled, they generate tiny electrical voltages between their opposite faces. This phenomenon is called piezoelectricity. By measuring the voltage from a piezoelectric sensor we can easily calculate the strain. Piezoelectric strain gauges are the most sensitive and reliable devices.  Electrical Strain Gauge: A strain gauge takes advantage of the physical property of electrical conductance. It does not depend on merely the electrical conductivity of a conductor, but also the conductor's geometry. When an electrical conductor is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer. Similarly, when it is compressed, it will broaden and shorten. The change in the resistance is due to variation in the length and cross sectional area of gauge wire. **Gauge Factor**: The characteristics of the strain gauges are described in terms of its sensitivity (gauge factor). Gauge factor is defined as unit change in resistance for per unit change in length of strain gauge wire given as  G.F. = (∆R/RG) / ε  Where, ΔR - the change in resistance caused by strain, RG - is the resistance of the unreformed gauge, and ε – is strain.  **Effect of Temperature**: The resistive type strain gauges are sensitive to temperature variation; therefore it becomes necessary to account for variations in strain gauge resistance due to temperature changes. Using dummy gauge in opposite arm of the active gauge compensates the temperature variation.  **Arrangement**: In certain applications where equal and opposite strains are known to exist it is possible to attach similar gauges in way that one gauge experiences positive strain and other negative strain. Depending on the number of gauges used the bridge, the circuit configurations are :   1. Quarter Bridge : https://sl-coep.vlabs.ac.in/StrainGuage/images/Quarter%20bridge%20strain%20gage1.JPG   2. Half Bridge https://sl-coep.vlabs.ac.in/StrainGuage/images/half%20bridge%20strain%20gage.JPG  3. Full Bridge https://sl-coep.vlabs.ac.in/StrainGuage/images/full%20bridge%20strain%20gage.JPG   In Quarter Bridge, the strain gauge is connected in one arm as shown in the above diagram. In half bridge arrangement two active gauges are used, while in case of full bridge all the gauges are active. In this arrangement two acts in tension while other two are compression. With the help of this type of arrangement temperature compensation is also achieved. When possible, the full-bridge configuration is the best to use. This is true not only because it is more sensitive than the others, but because it is linear while the others are not. Quarter-bridge and half-bridge circuits provide an output (imbalance) signal that is only approximately proportional to applied strain gauge force. Linearity, or proportionality, of these bridge circuits is best when the amount of resistance change due to applied force is very small compared to the nominal resistance of the gauge(s). With a full-bridge, however, the output voltage is directly proportional to applied force, with no approximation.  **Effect of Lead-Wire**: Strain gauges are sometimes mounted at a distance from the measuring equipment. This increases the possibility of errors due to temperature variations, lead desensitization, and lead-wire resistance changes.  **Two wire**: In a **two-wire installation**, as shown in figure, the two leads are in series with the strain-gage element, and any change in the lead-wire resistance (R1) will be indistinguishable from changes in the resistance of the strain gage (Rg). In two-wire installations, the error introduced by lead-wire resistance is a function of the resistance ratio R1/Rg. The lead error is usually not significant if the lead-wire resistance (R1) is small in comparison to the gage resistance (Rg), but if the lead-wire resistance exceeds 0.1% of the nominal gage resistance, this source of error becomes significant. Therefore, in industrial applications, lead-wire lengths should be minimized or eliminated by locating the transmitter directly at the sensor. |

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| **Circuit Diagram/ Block Diagram:** |
| Attach Following:   * Plot of Characteristics Strain gauge sensor * Plot of Characteristic of LVDT |

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| **Stepwise-Procedure:** Characterize of LVDT **The procedure for using simulator is as follows:**  To find the effect of various parameters like change in supply voltage, change in supply frequency on output of given LVDT, click on **Simulator Tab.** The procedure to use the simulator is given below.  **Procedure**:   1. First you need to configure the LVDT. Click on ' Show panel' tab at the right bottom For making the circuit, drag and drop the primary coil, Armature and secondary coils at the loactions shown on left hand side. 2. Now select No of Turns, peak to peak supply volatge and frequency from the drag and drop menu, available below LVDT diagram. Click on configure block to configure LVDT. 3. Now click on the black rectangular core placed between primary and secondary windings. 4. Drag the core to left hand side and observe the effect on the output magnitude. This can be observed on the time vs output volatge waveform and on the Distance vs output voltage graph. The core displacement is indicated in the square box below the diagram. 5. Drag the core to right hand side and observe the effect on the output magnitude. Also observe the change in the phase. 6. Repeat steps 2 to 4 by changing supply volatge keeping frequency and no of turns constant. Study the effect on the output voltage. For this click on blue color 'Configure' tab in the right side panel. You need to select required parameter value from drop down menu. After selecting the values click on green ' Configure' tab to set the parameter values. 7. Repeat steps 2 to 4 by changing supply frequency keeping and no of turns constant. Study the effect on the output voltage. 8. Now keep supply voltage and frequency constant. Change the no of turns and observe the effect on the output voltage by repeating steps 2 to 4.  Characterize the strain gauge sensor   The procedure for using simulator is as follows: **Step by step Procedure**:   1. First select the material of the strain gauge from the available drop down menu. 2. Select the value of input voltage V for the bridge in which strain gauge is connected. 3. Select the strain gauge resistance in ohms. 4. Select the bridge configuration. Observe the connection diagram, by changing the selected configuration. 5. Select the gauge factor value from available drop down menu. 6. Click on **configure** tab. The system is configured once the user confirm the values. 7. Now the weight tab gets enabled. Select the weight in Kg to be applied to the cantilever beam. Now the value of Rg is displayed. 8. Enter the expected **output value (e) in millivolts**. For calculations of output, click on **formula** tab. 9. Using formula, calculate the value of the output voltage and enter the answer in the box provided (0.00 format). Submit the answer using submit button. 10. If your calculation is correct you will get the message accordingly. If not you need to repeat the calculations. 11. Change the value of **weight** and repeat the steps 7 to 10. 12. Minimum three calculations are necessary to plot the graph. After three calculations, the **plot** tab will be activated. 13. Click on Plot to see the graph. Study the graph of output voltage variation when weight is changed. 14. Hide the graph and repeat the experiment by varying the values of inputs or bridge types. Observe the graphs. For this use ' **Next set of values**' tab which is enabled now. Otherwise go to next level by clicking **'Level 2'** enabled tab.   **Level 2  Study of effect of change in position of weight applied on Strain Gauge performance**   1. When you move from level 1 to level 2, the configuration and selected weight remains same. 2. Now you can select the position of the weight attached to the beam. Originally the distance between strain gauge and the applied weight is 16 cm. Now if 14 cm position is selected the distance is reduced by 2 cm i.e. the distance between strain gauges fixed on the beam and the applied weight is 14 cm. You can observe this change in available diagram. 3. **Observe** the displayed output value. Compare this value with previous value. Refer to **formula** tab for calculations. 4. Minimum three calculations are necessary to plot the graph. After three calculations the **plot** tab will be activated. 5. Click on **Plot** to see the graph. Study the graph of output voltage variation when position is changed. Observe the graph carefully. 6. Hide the graph and move on to next level by clicking on **'Level3'** tab.   **Level 3 Study of effect of change in temperature on the performance of Strain Gauge**  When you move from level 2 to level 3, all the parameters including the position of the weight for level 1 and level 2 are freeze. The user can now select the **temperature** to which strain gauges are exposed i.e. ambient temperature.   1. Select the temperature in oC from the drop down menu. The reference temperature considered for previous level calculations is 20 oC. 2. **Observe** the displayed value of Rg i.e. Resistance of strain gauge. Compare this value with previous value. Refer to **formula** tab for calculations. 3. Minimum three calculations are necessary to plot the graph. After three calculations the **plot** tab will be activated. 4. Click on **Plot** to see the graph. Study the graph of Rg value variation with change in temperature. After completion of all the parts, you can proceed to Post Test to find if you have understood all aspects of the experiment.  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | https://sl-coep.vlabs.ac.in/StrainGuage/images/SG_2&3%20wire.JPG  **Three wire**: To correct for lead-wire effects, an additional, third lead can be introduced to the top arm of the bridge, **as shown in the above Figure**. In this configuration, wire C acts as a sense lead with no current flowing in it, and wires A and B are in opposite legs of the bridge. This is the minimum acceptable method of wiring strain gages to a bridge to cancel at least part of the effect of extension wire errors. Theoretically, if the lead wires to the sensor have the same nominal resistance, the same temperature coefficient, and are maintained at the same temperature, full compensation is obtained. In reality, wires are manufactured to a tolerance of about 10%, and three-wire installation does not completely eliminate two-wire errors, but it does reduce them by an order of magnitude. If further improvement is desired, four-wire and offset-compensated installations should be considered.  **Types of strain gauge based on construction**: **Optical sensors** are sensitive and accurate, but are delicate and not very popular in industrial applications. They use interference fringes produced by optical flats to measure strain. Optical sensors operate best under laboratory conditions. **The photoelectric gauge** uses a light beam, two fine gratings, and a photocell detector to generate an electrical current that is proportional to strain. The gage length of these devices can be as short as 1/16 inch, but they are costly and delicate. **Semiconductor strain gauges**: For measurements of small strain, semiconductor strain gauges, so called piezoresistors, are often preferred over foil gauges. Semiconductor strain gauges depend on the piezoresistive effects of silicon or germanium and measure the change in  resistance with stress as opposed to strain. The semiconductor bonded strain gauge is a wafer  with the resistance element diffused into a substrate of silicon. The wafer element usually is not provided with a backing, and bonding it to the strained surface requires great care as only a thin layer of epoxy is used to attach it. The size is much smaller and the cost much lower than for a metallic foil sensor. The same epoxies that are used to attach foil gages are used to bond semiconductor gages. The advantages are higher unit resistance and sensitivity whereas, greater sensitivity to temperature variations and tendency to drift are disadvantages in comparison to metallic foil sensors. Another disadvantage of semiconductor strain gages is that the resistance-to-strain relationship is nonlinear. With software compensation this can be avoided.  https://sl-coep.vlabs.ac.in/StrainGuage/images/Semiconductor%20strain%20gauges.JPG **Thin-film strain gauge**: These gauges eliminate the need for adhesive bonding. The gauge is produced by first depositing an electrical insulation (typically a ceramic) onto the stressed metal surface, and then depositing the strain gauge onto this insulation layer. Vacuum deposition or sputtering techniques are used to bond the materials molecularly. Because the thin-film gauge is molecularly bonded to the specimen, the installation is much more stable and the resistance values experience less drift. Another advantage is that the stressed force detector can be a metallic diaphragm or beam with a deposited layer of ceramic insulation. **Diffused semiconductor strain gauges**: This is a further improvement in strain gage technology as they eliminate the need for bonding agents. By eliminating bonding agents, errors due to creep and hysteresis also are eliminated. The diffused semiconductor strain gage uses photolithography masking techniques and solid-state diffusion of boron to molecularly bond the resistance elements. Electrical leads are directly attached to the pattern. The diffused gauge is limited to moderate-temperature applications and requires temperature compensation. Diffused semiconductors often are used as sensing elements in pressure transducers. They are small, inexpensive, accurate and repeatable, provide a wide pressure range, and generate a strong output signal. Their limitations include sensitivity to ambient temperature variations, which can be compensated for in intelligent transmitter designs.  **Types of strain gauge based on mounting**: **Bonded strain gauge**: A bonded strain-gage element, consisting of a metallic wire, etched foil, vacuum-deposited film, or semiconductor bar, is cemented to the strained surface. https://sl-coep.vlabs.ac.in/StrainGuage/images/SG_bonded.JPG  **Unbonded Strain Gauge**: The unbonded strain gage consists of a wire stretched between two points in an insulating medium such as air. One end of the wire is fixed and the other end is attached to a movable element. https://sl-coep.vlabs.ac.in/StrainGuage/images/Unbonded%20Strain%20Gauge.JPG  **Strain gauge selection criteria:** - Gauge Length - Number of Gauges in Gauge Pattern - Arrangement of Gauges in Gauge Pattern - Grid Resistance - mass - stability - temperature sensitivity - Carrier Material - Gauge Width - Availability - low cost - effect of ambient conditions Characterize of LVDT LVDT is linear Variable Differential Transformer. It is electromechanical transducer. It converts the rectilinear displacement of any object to which it is coupled mechanically in electrical signal proportional to it.  **Construction:**  LVDT is made of two main components: the movable armature and the outer transformer windings.  LVDT consists of 3 windings. Centre one is Primary winding while the other two are secondary  windings. The secondary's are identical and placed symmetrical about the primary.  The secondary coils are connected in series-opposition.  Moving element of LVDT is called core. It is a cylindrical armature made of ferromagnetic material. It is free to move along the axis of the tube. At one end, the core is coupled to an object whose displacement is to be measured, while the other end moves freely inside the coil's hollow bore.  **Working:**  An alternating current is connected to the primary. This current must be of appropriate amplitude and frequency.  It is also called as Primary Excitation. The frequency is usually in the range 1 to 10 kHz. This current causes a voltage to be induced in each secondary proportional to its mutual inductance with the primary.  While the frequency of induced voltage is same as that of excitation frequency, its amplitude varies with the position of the iron core.  As the core moves, the voltages induced in the secondary's changes due to change in mutual inductance.  The coils are connected in series but in opposite phase , so that the output voltage is the difference between the two secondary voltages. When the core is exactly at central position, i.e at equal distance from the two secondary's, equal but opposite voltages are induced in these two coils, so the output voltage is zero.  When the core is displaced in one direction, the voltage in one coil increases with respect to the other, causing the output voltage to increase from zero to a maximum value. This voltage is in phase with the primary voltage.  When the core moves in the other direction, the output voltage also increases from zero to a maximum value, but the phase is opposite to that of the primary. The magnitude of the output voltage is proportional to the distance moved by the core. The phase of the voltage indicates the direction of the displacement.  https://sl-coep.vlabs.ac.in/LinearVariableDifferntialTransformer/images/SMD_LVDT1.JPG  Case 1:  When no displacement is applied to the core and the core remains in the null position without any movement then the voltage induced in both the secondary windings is equal which results in net output is equal to zero  i.e., E s1 - E s2 = 0  Case 2:  When displacement is applied in such a way that the core moves in the left direction then the voltage induced in that (left) secondary coil is greater as compared to the emf induced in the other secondary coil. Therefore the net output is E s1-E s2  Case 3:  When force is applied to core such that it moves in the right hand side direction then the emf  induced in the secondary coil 2 is greater compared to the emf voltage induced in the secondary coil 1,therefore the net output voltage is E s2- E s1.  As seen, the voltage undergoes 180 degrees phase shift while going through null. The output E is out of phase with the excitation.  Usually this AC output voltage is converted by suitable electronic circuitry to high level DC voltage or current that is more convenient to use.  Residual Voltage: Output voltage at the null position is ideally zero. But because of harmonics in the excitation voltage and stray capacitance coupling between primary and secondary a non zero voltage exists at null position. This is called residual voltage. If it is less than 1 % of full scale output voltage ( which is the normal case) it is in the acceptable limits.  Eddy Currents: When alternating current is passed through the coil, a magnetic field is generated in and around the coil. When a rod is brought in close proximity to a conductive material, the rod's changing magnetic  field generates current flow in the material. These are called as eddy currents.  The eddy currents produce their own magnetic fields that interact with the primary magnetic field of the coil.  As the eddy current flows through conducting core, it creates heat. This causes power loss in the core. To reduce the eddy current losses, the core is provided with a slot. This slot cut the magnetic field created hence reducing the flux. Laminated core is also used for the same purpose.  **Types of LVDT based on applications:**  1. General Purpose LVDT: for use in many industrial and research applications.  2. Precision LVDT: for sensitive gauging and quality control applications  3. Submersible LVDT: Hermetically sealed for use in industrial and research environments involving corrosive fluids and gases, high temperature and vibrations, etc.  **Types of LVDT based on range of operation:**  1. Short stroked: full-scale linear ranges from ±0.01 inch (±0.25 mm) to ±0.5 inch (±12.7 mm)  2. Long stroked: full-scale linear ranges from ±0.5 inch (±12.7 mm) to ±18.5 inch (±470 mm)  **Types of LVDT based on excitation used**  1. **AC LVDT:** AC LVDTs are excited by a AC voltage having frequency between 50 hertz and 25 Kilohertz with 2.5 Kilohertz as a nominal value. The carrier frequency is generally selected to be at least 10 times greater than the highest expected frequency of the core motion. AC-operated LVDT's are generally smaller in size and more accurate than DC versions. They are able to tolerate the extreme variations in operating temperature than the DC LVDT.  Modern circuits often supply phase detection circuits along with the LVDT. A phase sensitive detector circuit (PSD) is useful to make the measurement direction sensitive. It is connected at the output of the LVDT and compares the phase of the secondary output with the primary signal to judge the direction of movement. The output of the phase sensitive detector after passing through low pass filter is in the dc voltage form used for steady deflection.    **2. DC LVDT:** The DC LVDT is provided with onboard oscillator, carrier amplifier, and demodulator circuitry.  The major advantages of DC-operated ("DC-to-DC") LVDT's are ease of installation and signal conditioning, the ability to operate from dry cell batteries in remote locations, and lower system cost (especially in multipoint applications). The DC LVDT is temperature limited operating from typically - 40 deg C to +120degC  **Types of LVDT based on armature:**  1. **Unguided Armature:** This is simplest configuration in which armature fits loosely in the cavity of the coils bore. This requires proper installation to ensure proper movement along the axis. This allows frictionless movement with no wear. This type have unlimited fatigue life, good repeatability with infinite resolution. Free armature is mainly suitable for short range, high speed applications.  2. **Guided (Captive) Armature:** In this type, armature is restrained and guided by low friction bearing assembly.These are suitable for long working ranges. To avoid possibility of misalignment the armature is guided.  3. **Spring Extended Armature** – This armature is similar to guided armature LVDT with an addition that , it has internal spring to push the armature continuously to its fullest possible extension. This maintains light and reliable contact with the measured object.  Most suitable for static or slow moving applications.  https://sl-coep.vlabs.ac.in/LinearVariableDifferntialTransformer/images/SMD_LVDT2.JPG  **Applications:**  LVDTs are commonly used for  -position feedback in servomechanisms  -automated measurement in machine tools and many other industrial and scientific applications.  -measurement of displacement ranging from fraction of mm to cm  -Acting as a secondary transducer, it can be used for force, weight and pressure measurement.  LVDT  Configurations  Turns- 1000  Supply Voltage- 5  Supply Frequency- 1000 Hz      Strain Guage  Configurations   |  |  |  | | --- | --- | --- | | Material | : | Copper | | Input Voltage | : | 5 | | Resistance | : | 120 | | Gauge Factor | : | 0.9 | | Configuration | : | Quarter Bridge | | Weight | : | 2 | | Output Voltage | : | 0.49 | | |

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| **Post Lab Subjective/Objective type Questions:** |
| Characterize of LVDT Top of Form  **1. LVDT can be used as**  a) Primary transducer  b) Secondary transducer  **c) Both primary as well as secondary transducer**  **2) The magnetic field in secondary of LVDT**  **a) Increases in one and decreses in other seconday depending upon direction of displacement**  b) Decreases with displacement  c) Increases with displacement  **3) Change in frequency of supply voltage of LVDT causes**  a) No change in output  **b) Change in the output frequency with displacement**  c) Increase in the output frequency with displacement  **4) LVDT**  a) can measure very fast moving operations  **b) is used for very slow operations only**  c) can measure fast moving operations only upto 2 kHz  **5) Residual voltage in LVDT**  **a) Is usually acceptable if less than 1% of FS**  b) Is always 0  c) Is not acceptable at all  **Characterize the strain gauge sensor**  **1. Piezo-resistive strain gauge has**  **a) non-linear resistance characteristic**  b) has no relation with strain  c) linear resistance characteristic  **2) While mounting the strain gage**  a) strain gauge backing is responsible for the accuracy of measurement  b) adhesive is responsible for the accuracy of measurement  **c) both are responsible for the accuracy of measurement**  **3) The characteristics of strain gauge is defined by**  a) Poisson’s ratio  **b) Gauge factor**  c) Young’s modulus  **4) Strain gauge cannot be used to measure**  a) Force  **b) level**  c) Torque  **5) The strain gauges don’t need any bonding material**  a) semiconductor strain gauges  b) thin film strain gauges  **c) diffused semiconductor strain gauges**  c) Increases with displacement Bottom of Form  Bottom of Form  Top of Form  Bottom of Form  Top of Form |

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| **Conclusion:**  We studied about Strain gauge sensor, LVDT  The simulation was done on VLAB COEP platform.. |

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