Math Skills Laboratory

Lab 11 MS 1

MATH ACTIVITY

Activity: Plotting and Interpreting Graphical Data for Mechanical Transducers

MATH SKILLS LAB OBJECTIVES

When you complete this activity, you should be able to do the following:

1. ***Use manufacturer's specification bulletins to plot graphs of displacement versus output voltage for a specific type of mechanical transducer.***
2. ***Use manufacturer's specification bulletins or a plotted graph to find displacement-versus-voltage data for a transducer.***
3. ***Solve problems that involve transducer characteristics and operation.***

LEARNING PATH

1. ***Read the Math Skills Lab. Give particular attention to the Math Skills Lab Objectives.***
2. ***Study the examples.***
3. ***Work the problems.***

ACTIVITY

Plotting and Interpreting Graphical Data for Mechanical Transducers

MATERIALS

For this activity, you'll need graph paper and a calculator.

DISCUSSION

This lab involves plotting and interpreting data related to mechanical transducers.

One of the most useful mechanical transducers is the linear variable-differential transformer (LVDT). A series-240 LVDT transducer is used to measure physical properties that can be changed into a linear displacement. Typical uses include servo-position feedback, sensor for pressure transducers, strain measurement in structural members, automatic gaging and machine control.

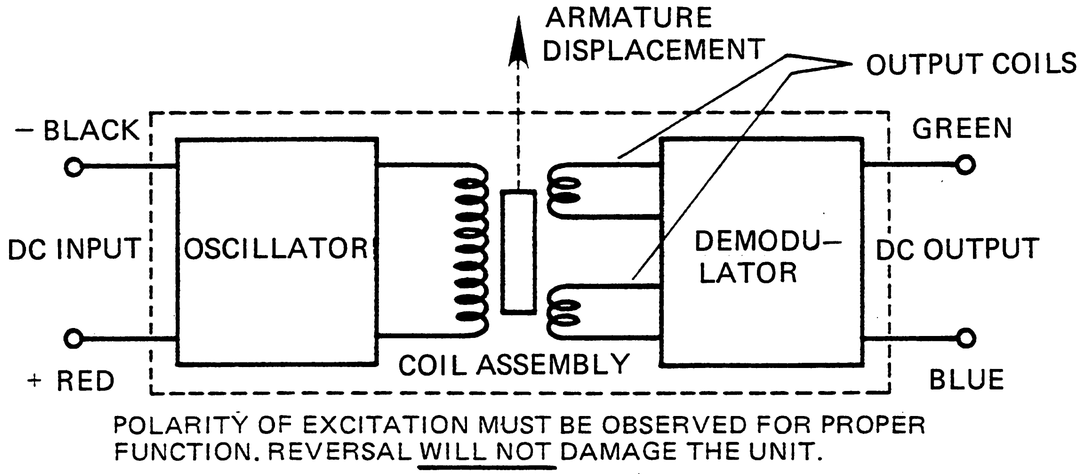


Fig. 1 Circuit diagram.

The LVDT transducer was first introduced in Problem 4 of Math Lab 7MS4, "Force Transformers." Figure 1 shows a circuit diagram of an LVDT. A displacement due to a force—either a push or a pull—causes the LVDT armature (movable core) to move away from the midpoint (null) position.

When located at the ***null*** point, the armature induces equal voltages (with opposite signs) across the two output coils. When voltage from the two coils is added, the resultant output voltage is zero. The result is the same as that for the two D-cells shown in Figure 2a.

For any other armature position, above or below the null point, the resultant voltage across the two output coils is not zero. It depends on the exact position of the armature coil. When the armature is at the top position, the voltages from the two coils add, giving twice the result. That's just like what happens in Figure 2b, when two cells add their voltages.

Look at the graph of output voltage versus armature displacement in Figure 3. It shows that when full-stroke displacement of the armature occurs (armature moves from the bottom of coil assembly in Figure 1 through the null point and on to the top of the coil assembly), there's a shift from maximum negative DC output voltage at the bottom, to zero voltage at the null point, and on to maximum positive DC output voltage at the top.

Use the electrical specifications bulletin (Table 1) given with the series-240 LVDT transducers to construct a graph of armature displacement versus output voltage. This graph becomes a data source for technicians who select, install or calibrate LVDT transducers.

From the series-240 LVDT transducers, choose model number 0244. See Table 1. All required specifications are listed in the column under the model number 0244.

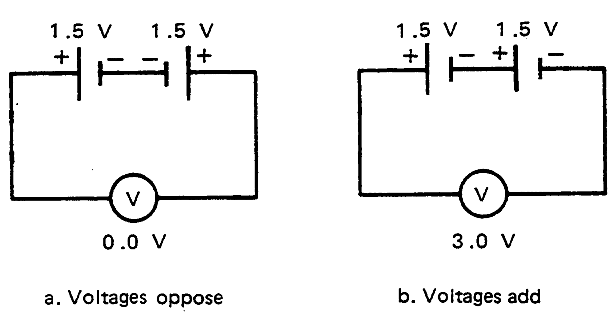


Fig. 2 Cell-orientation diagram.

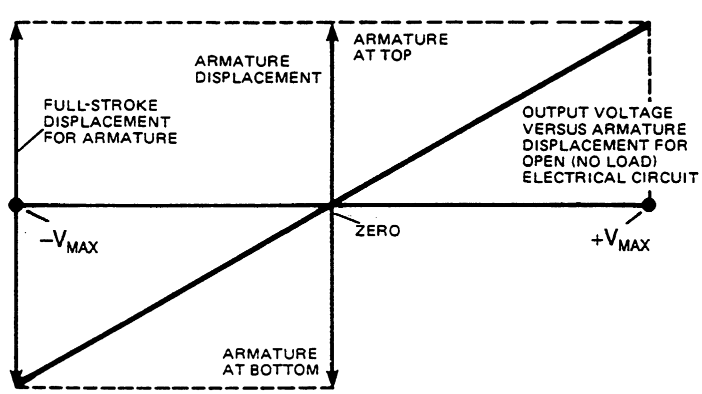


Fig. 3 Output voltage versus armature displacement for an LVDT.

TABLE 1. ELECTRICAL SPECIFICATIONS FOR SERIES-240 LVDT

Model Number	0240	0241	0242	0243	0244	0245	0246
Range, working (inches)	±0.050	±0.100	±0.250	±0.500	±1.00	±2.00	±3.00
Maximum usable	±0.075	±0.150	±0.375	±0.750	±1.50	±2.75	±4.00
Input, volts DC	6.0 minimum to 30 maximum						
Nominal FS Output ±V DC (open circuit)							
@ 6-V input	1.2	2.1	1.6	3.0	4.3	4.0	3.1
@ 15-V input	3.0	5.4	4.2	7.5	10.8	10.0	7.8
@ 24-V input	5.0	9.0	7.0	12.5	18.0	16.0	13.0
@ 30-V input	5.9	10.7	8.3	14.8	21.4	20.0	15.4

Example 1: ***Graph of Armature Displacement Versus Output Voltage***

Given: Electrical specifications table for Model-0244 LVDT transducer with 6-V DC input.

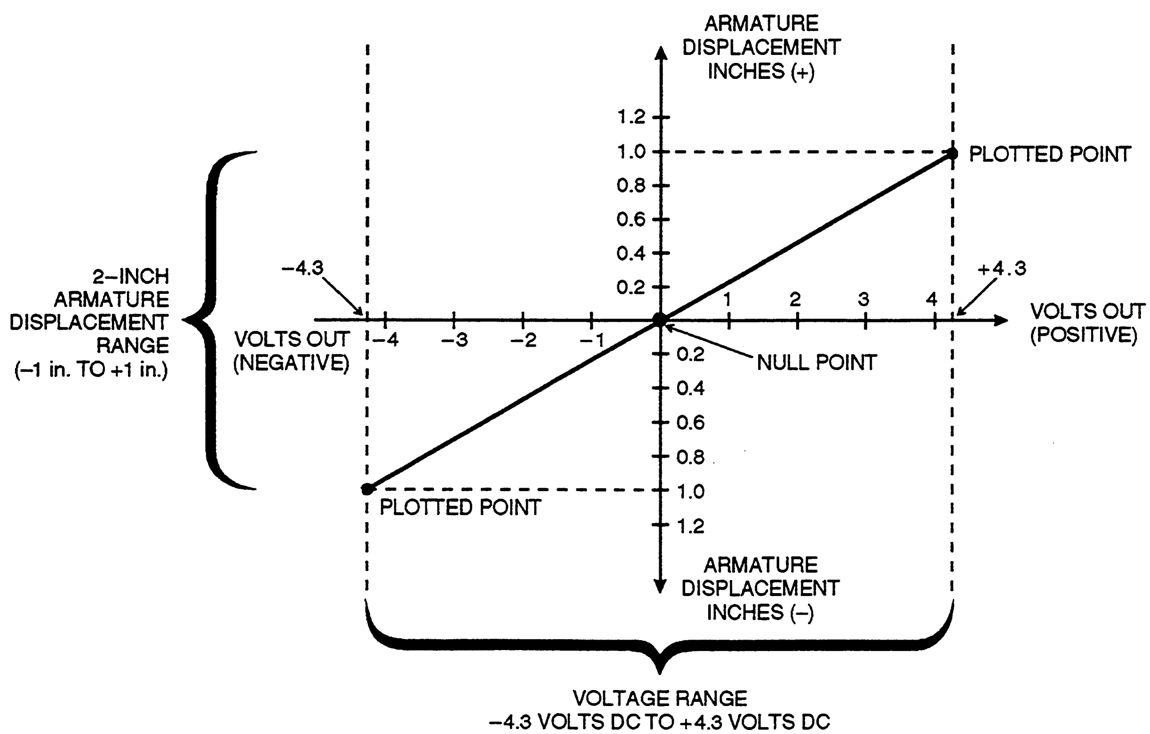
Construct: A graph of armature displacement versus output voltage that will give the displacement and output voltage over the working range of the LVDT.

Solution:

a. From the electrical specifications, you'll find that the 0244 LVDT has—
   - a working range (displacement) of 1.00 inch on either side of the null point
   - at 6-V DC input, the LVDT has an output voltage range of 4.3-V DC on either side of the null point. (***Note:*** "FS" means "full scale.")

b. With this data, you can graph the displacement versus output voltage over the ranges specified. Since the LVDT is a ***linear*** transducer, the plotted data produces a straight line, as shown in the following graph.

GRAPH OF DISPLACEMENT VERSUS OUTPUT VOLTAGE FOR THE MODEL-0244 LVDT WITH 6-V DC INPUT.



With this graph, a technician can choose any value of positive or negative armature displacement and read the corresponding output voltage. Let's use this graph to find some output voltages for given displacements.

Given a displacement of the armature—	*output voltage is:*
a. depressed –0.6 inch from null point	–2.6 V
b. raised +0.6 inch from null point	+2.6 V
c. depressed –0.4 inch from null point	–1.75 V
d. raised +0.9 inch from null point	+ 3.9 V

Now use the graph to find armature displacements that correspond to a certain output voltage.

For the following voltage output—	*armature displacement must be:*
e. +3.5 V	raised +0.8 inch from null point
f. –2.6 V	depressed –0.6 inch from null point
g. +3.0 V	raised +0.7 inch from null point
h. –4.3 V	depressed –1.0 inch from null point

If you know the output voltage for a given displacement, you can write that amount as a ratio or as a proportionality constant (C), where C = voltage/displacement.

Since the LVDT is a linear device, this constant will be valid over the entire range of operation of the transducer. You can calculate "C" from values in Table 1. You know that voltage output is 4.3 V when the armature moves 1 inch from the null position. Thus,

$$C = \frac{V}{d}$$

where: V = output voltage = 4.3 V
d = displacement from null point (±)

$$C = \frac{4.3\ \text{V}}{1\ \text{in}} = 4.3\ \text{volts/inch}$$

Once "C" for the particular LVDT is found, you can find other voltages or displacements as long as either output voltage or displacement is known.

Example 2: ***Using a Proportionality Constant to Find Displacement or Voltage from an LVDT Transducer***

Given: Proportionality constant—

$C = \frac{V}{d}$ where: C = 4.3 V/in for an LVDT transducer (Model 0244, at 6-V input)

Find: Output voltage when LVDT armature is depressed –0.6 inch from null point.

Solution: C = V/d. Solve for "V" by multiplying both sides by "d."

$(d) \times C = \frac{V}{\cancel{d}} \times \cancel{(d)}$ (Cancel like terms. Rearrange equation.)

$V = C \times d = 4.3 \text{ V/in} \times (-0.6 \text{ in})$

$V = -(4.3 \times 0.6) \frac{V \cdot \cancel{in}}{\cancel{in}}$

$V = -2.58 \text{ V} \simeq 2.6 \text{ V}.$

Note: This is the same value of voltage output as the "approximate" reading from the graph for a displacement of -0.6 inch.

PRACTICE EXERCISES

Complete the following exercises.

Problem 1: Given: Table 1, Electrical Specifications for Series-240 LVDT Transducers.

Find:

a. For Model-0243 with 15-V DC input, plot a graph of armature displacement versus ouput voltage. (It should be similar to the graph plotted for Model-0244.)
b. Find the proportionality constant (C) for the LVDT where C = V/d. (Look back at Example 2.)

Solution:

Problem 2: Given: The graph and proportionality constant found in Problem 1 for LVDT transducer Model-0243.

Find:

a. The output voltage for 0.25-in positive displacement, using the graph.
b. The output voltage for 0.25-in positive displacement, using the proportionality constant (C) and the equation, C = V/d.

Solution:

Problem 3: Given: A Model-0244 LVDT transducer, input voltage 6-V DC, similar to the one in Example 1 is used in a sulfuric acid-water mixing vat. This transducer gives data to a microprocessor that controls mixing valves.

In this case, voltage output is related to specific gravity of the liquid. Pure water has a specific gravity of 1.0000. Pure sulfuric acid has a specific gravity of 1.8337.

A hydrometer that measures specific gravity between 1.0000 and 1.8337 sinks in pure water until the 1.000 mark is at the water level. It rises gradually as the ratio of acid to water increases. The hydrometer floats in 100% sulfuric acid with the 1.8337 mark at the sulfuric acid level.

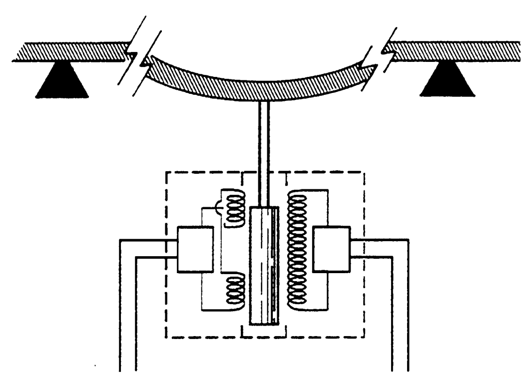
Let the percent mixture vary from pure water (0%) to pure sulfuric acid (100%). At a 50% mixture, the specific gravity is 1.4168. (This is the null point.)

Find:

a. What ratio of acid to water is present when the hydrometer bulb is 0.25 inch ***below*** the null point.
b. What's the proportionality constant if specific gravity is substituted for displacement in the equation, C = V/d = V/sp gr?
c. What voltage output corresponds to a specific gravity of 1.2600?

Solution:

Problem 4: Given: The graph in Example 1 for the Model-0244 LVDT transducer. An elevator-load buzzer is activated by an LVDT transducer when the elevator floor is deformed by an overload as shown in the sketch. The technician knows that the floor deforms 0.70 inch beyond the null position when a 2400-lb load is applied. (At the ***null*** position, the output voltage is zero.)



Find: The voltage output available to trigger the safety buzzer when the load exceeds 2400 lb. Assume that the input voltage is 6-V DC.

Solution: