Linear Variable Differential Transformers—Lab 14

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See https://mviordache.name/EEGR2051 for more information.

Name: ____________________ Date Performed _________ Section_____

LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS

OBJECTIVES:

- Demonstrate the operation of an LVDT and obtain its operation curve.
- Obtain graphs showing the dependence of the mutual inductance on the displacement of the core.
- Continued familiarization with the oscilloscope and correct grounding techniques.

REFERENCE: Student Reference Manual for Electronic Instrumentation Laboratories, Chapter 14.

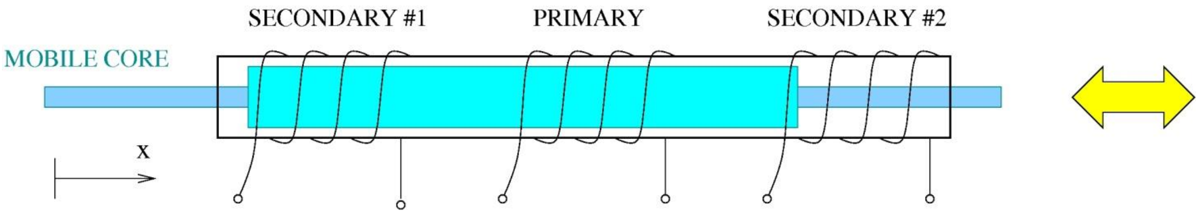
EQUIPMENT:

- One LVDT.
- One 47Ω resistor with binding posts (from the cabinet).
- One waveform generator.
- One oscilloscope.
- One digital multimeter (DMM)

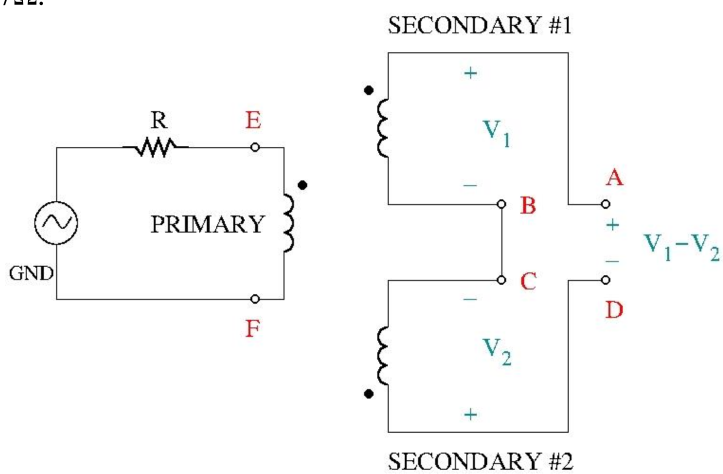
PROCERDURE:

1. Set the waveform generator for a high impedance output load (HiZ), and a 100 kHz sine waveform of 63 mV peak-to-peak.
2. Press *Default Setup* on the front panel of the oscilloscope.
3. Visualize the sinewave on the oscilloscope. Adjust vertical sensitivity so that the waveform has at least 4 divisions on the vertical.
4. Press *Cursors* to activate the cursor functions of the oscilloscope.
5. The cursor functions are useful for **precise** measurements. Measure the peak-to-peak value of the signal using cursors. Be precise. $V_{pp} =$ ______________
6. The oscilloscope also provides automatic measurement functions that are useful for performing **quick** measurements. Such measurements are typically not as precise as the manual measurements performed with cursors. For best results:
    a. Ensure that the signal fits on the screen and covers at least a few vertical divisions.
    b. Ensure that at least one or two periods of the signal appear on the screen.
7. Press the *Meas* button to activate the automatic measurement functions of the oscilloscope.
8. Press the *Clear Meas* soft button, and then *Clear All*.
9. Set *Source* to channel 1 and *Type* to *Peak-Peak*. Press *Add Measurement*. The peak-to-peak value of channel 1 should now be displayed on the screen.
10. Write the peak-to-peak value indicated by the oscilloscope for all the following configurations of the channel.
    a. 2 μs/div and 10 mV/div. $V_{pp} =$ ______________
    b. 500 ns/div and 10 mV/div. $V_{pp} =$ ______________
    c. 200 ns/div and 10 mV/div. $V_{pp} =$ ______________
    d. 2 μs/div and 1 mV/div. $V_{pp} =$ ______________
    e. 2 μs/div and 20 mV/div. $V_{pp} =$ ______________
    f. 2 μs/div and 100 mV/div. $V_{pp} =$ ______________
    g. 2 μs/div and 500 mV/div. $V_{pp} =$ ______________
11. The automatic measurement is most precise when ____
    ____

12. Multimeters perform very precise AC measurements of low frequency signals. Their precision is not as good at higher frequencies, such as 100 kHz.
13. Measure the rms voltage of the waveform generator with a DMM. _____________
14. Convert the DMM measurement to a peak-to-peak value: $V_{pp} =$ _____________
15. Compare the result to the value measured using the oscilloscope cursor functions. ___________________
16. Identify the primary and secondary windings of the LVDT.



17. Set the waveform generator for maximum output voltage.
18. Connect the circuit shown in the figure. Use R = 47Ω.



19. Depending on how you have connected the secondary coils, the voltages V_1 and V_2 should be either in phase or 180° out of phase.
20. Visualize V_1 on channel 1 and V_2 on channel 2 when the LVDT core is in the middle.
21. If V_1 and V_2 are 180° out of phase, reconnect the secondary coils so that V_1 and V_2 are in phase.
22. Visualize the voltage between E and F on channel 1, and the voltage between A and D on channel 2.
23. Let x denote the displacement of the core with respect to the <u>center</u> position.
24. If everything is correct, the voltage between A and D should be zero when the core is in the middle position. If this does not happen, go back to step 21.
25. Measure the phase angle difference of the voltage between E and F (the primary voltage) and the voltage between A and D (the output voltage).

    When x < 0, the phase difference is _____. When x > 0, the phase difference is _____.
26. In the following steps, you will record data in Excel. Open Excel.
27. Measure the peak-to-peak voltage between A and D for displacements of −1'', −0.5'', 0'', 0.5'', and 1'' and record in a table in Excel. Label the table and indicate all units.
28. Note that the primary voltage is not a constant, as the inductance of the primary depends on the position of the core. To obtain a more linear dependence between voltage and displacement, the primary voltage V_{EF} has to be accounted for.
29. In this exercise the operating curve of the LVDT will be obtained. Let $V_{1p\text{-}p}$ denote the peak-to-peak voltage of secondary 1 and $V_{2p\text{-}p}$ the peak-to-peak voltage of secondary 2.
    a. Measure V_{EF}, $V_{1p\text{-}p}$ and $V_{2p\text{-}p}$ for 10 negative values of x, 10 positive values of x, and for x = 0.
    b. Use a DMM for V_{EF} and the two oscilloscope channels for V_1 and V_2.
    c. Use the *measurement* functions of the oscilloscope to speed up data acquisition.
    d. You may use the external trigger to ensure that the waveforms are always stable.
    e. Record your data in a table with four columns, one column for each voltage and one column for x.
    f. To detect when $x = 0$, press *Math*, then *Operator*, and then select *Subtract*. This will display the $V_1 - V_2$ waveform. Note that $x = 0$ when $V_1 - V_2$ is zero. You may adjust the size of the waveform using the vertical sensitivity control located above the *Math* button, to its right.
    g. Let $V_{out,p\text{-}p} = V_{1p\text{-}p} - V_{2p\text{-}p}$. Obtain the graph of $V_{out,p\text{-}p}$ versus the displacement x.
    h. Obtain also the graph of $(V_1 - V_2)/V_{EF}$ versus the displacement x.

30. In this exercise the inductance of the primary will be determined.
   a. Using the oscilloscope, determine the peak-to-peak voltage of the resistor R. Make sure that your grounding connections are correct! Sketch the circuit of the primary and indicate below where you have connected the ground of the source and where the ground of the oscilloscope.

   b. The voltage on the resistor R is V_R = _______
   c. Calculate the peak-to-peak value of the current. I = ___________
   d. DMMs lose some of their accuracy when measuring high frequency AC signals. Measure the rms value of the current with a DMM. I = ____________. Is the value reasonably close to close to the value obtained with the oscilloscope? ____
   e. Given I, what voltage should be measured in order to calculate the inductance? Determine the inductance at x = 0 and describe <u>in detail</u> your method. Make sure that the ground connections are correct! L = ____________

31. In this exercise the mutual inductance between the primary and secondary coils will be determined. Note that the mutual inductance depends on the position of the core.
   a. The peak-to-peak secondary voltage V_s is related to the primary current I by the equation $V_s = M \cdot \omega \cdot I$, where M is the mutual inductance between primary and secondary.
   b. You may assume that I is not changed significantly by the displacement of the core.
   c. Let M_1 denote the mutual inductance of the primary and secondary 1.
   d. Use the data acquired at step 28 to obtain a table describing the dependence of M_1 on x.
   e. Obtain also the graph of M_1 versus x.
   f. Describe the method you have used to calculate M_1.

   g. Determine also the mutual inductance M_2 of the primary and secondary 2.
   h. Obtain also the graph of M_2 versus x.
   i. Compare the results at parts e and h and interpret them.

32. Compare your results to the ideal curve shown in Fig. 14.10 of the textbook. Explain differences.

33. How would you improve the LVDT design that you used in the lab?

34. (Optional) In this exercise the coupling coefficient will be determined. The coupling coefficient between the primary and secondary 1 has the formula $k = \frac{M_1}{\sqrt{L_1 L}}$

a. Determine the inductance of the secondary L_1 and the inductance of the primary L at x = −1'', −0.5'', 0.5'', and 1''.
b. Determine the coupling coefficient. Record the results in your spreadsheet.