Chapter 11

Linear variable differential transformers

TEC/NOT/014

This paper introduces Linear Variable Differential Transformers (LVDTs), its uses and the signal conditioning required. The following topics are discussed:

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11.1 Overview

From the early part of the twentieth century, differential transformers have been used in control applications. However, it was not until the 1940s that their use in instrumentation systems became popular. In 1946 Herman Schaevitz published a paper entitled The Linear Variable Differential Transformer.

LVDTs are used to measure mechanical displacement. As illustrated in the following figure, two secondary coils are wound around a movable core, around which is also wound around a primary coil. The primary coil is connected to an AC excitation.

In the midpoint (null position), the voltage induced on both secondary coils is the same. As the core moves up (or down), the voltage on each becomes larger or smaller.

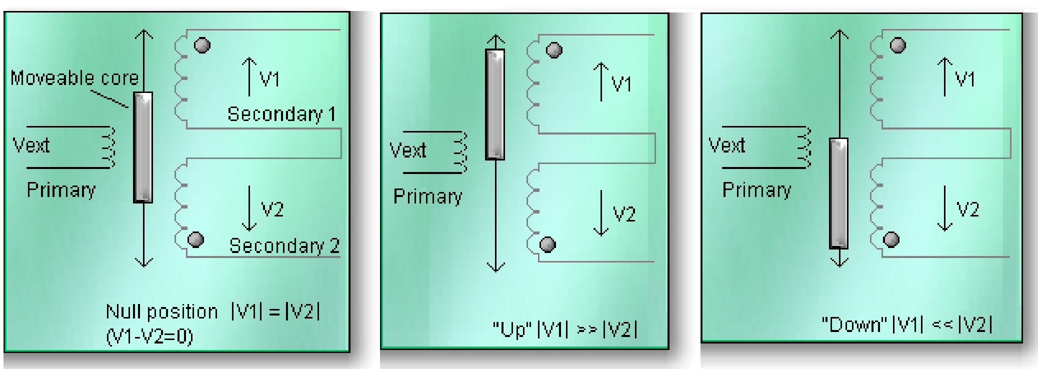

Figure 11-1: Illustration of a full-bridge LVDT

LVDTs operate on the principle that the position of the core may be deduced by observing the voltage(s) induced on the secondary coils. This paper examines various methods of doing just that.

This paper also examines the half-bridge LVDT. The analysis that follows also holds for Rotational Variable Differential Transformers (RVDT) where the coils are wound around a circular movable core so that the device can be used for rotational (angular) measurement.

11.2 Full-bridge LVTD basics

In general the excitation voltage to the primary can be represented as a sine wave with no dc component:

$$V_{ext}(t) = A_{exc} \cdot Sin(2 \cdot \pi \cdot f)$$

Often the excitation frequency (*f*) is chosen so that it is many times (>10) greater than the bandwidth of the movement being measured, so as to simplify the signal conditioning circuitry. If so, the analysis can be simplified using root-mean-square (rms) values as:

$$V_0 = V_{rms_{\sec 1}} - V_{rms_{\sec 2}} \cong P \cdot V_{rms_{ext}} \cdot S + V_{rms_{ext}} \cdot O$$

where *P* is the position of the core, and *S* is the sensitivity of the LVDT as specified by the manufacturer (for example 2.4 mV / V / inch).

S·P is the voltage induced on the secondaries as a function of core position and *O* is the voltage induced irrespective of core position.

If the LVDT manufacturer has designed the device so that the difference in the primaries is zero at the mid-point (null position), the equation becomes:

$$V_0 \cong P \cdot V_{rms_{ext}} \cdot S$$

In other words, by knowing the excitation and the sensitivity of the LVDT, the position (*P*) can be deduced from the rms value of the output voltage.

11.3 Compensating for variations in the excitation

In the previous section, it was stated that for an LVDT designed to output 0V difference in the null-position, the position (P) of the core can be deduced from the rms of the output voltage using:

$$V_0 \cong P \cdot V_{rms_{ext}} \cdot S$$

If the excitation voltage varies with lead resistance, temperature or aging, it should be measured accurately and the position (*P*) can be deduced from the ratio:

$$P \cong \frac{V_0}{V_{rms_{ext}}} \frac{1}{S}$$

This circuit is shown in the following figure and is the principle used on Curtiss-Wright's KAM/LDC/001.

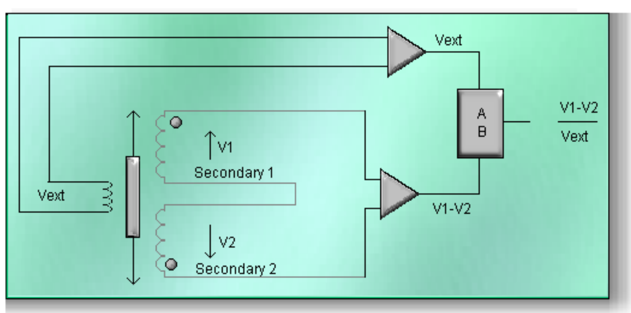

Figure 11-2: Ratiometric full-bridge LVDT circuit

The circuit used assumes that a frequency has been chosen such that the phase difference between the primary and secondary is 0° (or 180° by swapping lines).

11.4 Half-bridge LVTD basics

In a full-bridge LVDT, the voltage induced on each secondary varies with core position. In a half-bridge LVDT circuit, the inductance of two coils varies with core position (analogous to resistance change in a potentiometer).

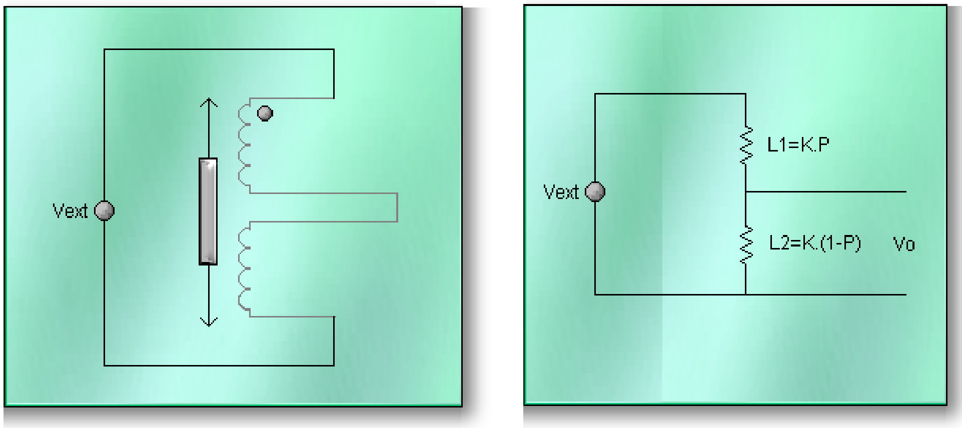

Figure 11-3: Illustration of half-bridge LVDT

The output voltage (rms) for this device can be approximated by:

$$V_0 \cong V_{rms_{ext}} \frac{L1}{L1 + L2} = V_{rms} \cdot P$$

This is similar to the equation for the full-bridge LVDT, so the ratiometric circuitry used on the KAM/CDC/001 can also be used.

11.5 Conclusion

In this paper, some of the uses of the Linear Variable Differential Transformer (LVDT) and the signal conditioning required were introduced.

11.6 References

LVDT Signal Conditioning Techniques, Jackson Szczyrbak, Principal Engineer, Schaevitz Products. Dr Ernest D.D. Schmidt, Director of Technology, Sensors, Lucas Control Systems

AD698 and AD598 data sheets, Analog Devices, One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106 USA

In 1946, Herman Schaevitz published a paper entitled The Linear Variable Differential Transformer.

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