TECHNICAL BRIEF

TB-31, LVDT Basics

TB-31

An Introduction to the Linear Variable Differential Transformer

What is an LVDT?

A Linear Variable Differential Transformer (LVDT) is an electro mechanical device that produces an output proportional to displacement. LVDT's offer many distinct advantages over other displacement measurement devices including: frictionless movement, infinite resolution, null repeatability, temperature stability, and environmental ruggedness. LVDT's can measure displacements from a few microns to several feet in a wide variety of environments. Techkor Instrumentation's 9000D is an example of a modern LVDT amplifier.

An LVDT operates on the principal of magnetic coupling between a primary and two secondary windings. The primary coil is typically energized with a 2-5 Volt sine wave with frequencies between 2-10 kHz. The primary winding produces a magnetic field which passes through the two secondary windings. A magnetically permeable metal core (Ni-Ir) slides through the center of the coils and provides an efficient path for the magnetic flux. The amount of Voltage induced in the secondary windings varies with the core's position.

Figure 1, *Typical LVDT*

Ratiometric vs. Open Style Wiring

There are two signal conditioning styles commonly used with LVDT's: *ratiometric* and *open* wiring. Both are common in a wide range of applications. LVDT's typically provide enough wires so that they may be operated in either mode. When dealing with ratiometric signal conditioning it is often best (but not necessary) to use a ratiometrically wound LVDT. When signal conditioners are properly matched with LVDT styles excellent linearity will result. Ratiometric signal wiring is characterized by the use of both secondary signals (Figure 2) while open signal wiring is characterized by the use of only one secondary signal (Figure 3).

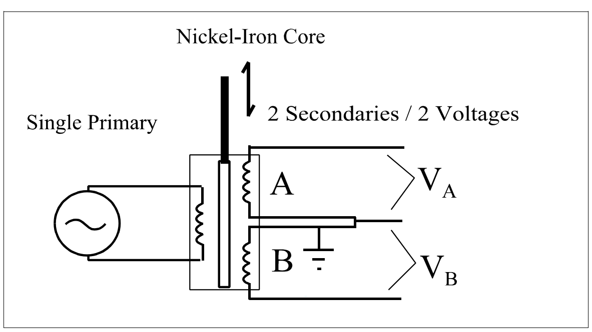

Figure 2, *Ratiometric LVDT Wiring*

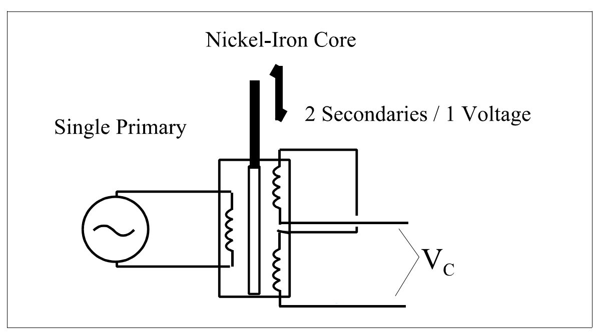

Figure 3, *Open LVDT Wiring*

Ratiometric Wiring for LVDTs

In *ratiometric* signal conditioning, both the Voltage on coil A and coil B are used to determine the position of the core. The following equation is computed by the ratiometric signal conditioner to determine the position where G is the gain or sensitivity.

$$Displacement = G\,\frac{V_A - V_B}{V_A + V_B}$$

The above requires that the sum of the secondaries remain constant for high linearity. Ratiometrically wound LVDTs provide this necessary condition.

Ratiometric LVDT signal conditioning offers several advantages over the *open* style. The *ratiometric* scheme is highly temperature insensitive. Temperature effects the LVDT signal by changing the magnetic induction efficiency. Since both Voltage A and Voltage B are effected equally, the net effect is high temperature immunity. The *ratiometric* scheme is also insensitive to phase shifts between the primary and secondary windings. As a result very long cables may be employed with no loss of accuracy around the null position.

Open Wiring for LVDTs

In *open* signal conditioning, the LVDT is wired so that only one voltage (Voltage C) is measured. Voltage C is directly proportional to the displacement of the core as shown in the following equation where G is the gain or sensitivity.

$$Displacement = G\ V_C$$

In order to determine the direction of the displacement, the output phase of the secondary winding is compared with the phase of the primary winding. The output phase of the secondary changes abruptly when the core passes through the null position.

Disadvantages with the *open* style are the lack of temperature stability and their phase sensitivity. Temperature effects an LVDT signal by changing the magnetic induction efficiency. Since only Voltage V_C is measured, any change in efficiency will directly effect Voltage V_C and the position measurement. The *open* scheme is also sensitive to phase shifts between the primary and secondary windings. As a result, long cables or poor primary excitation can cause problems.

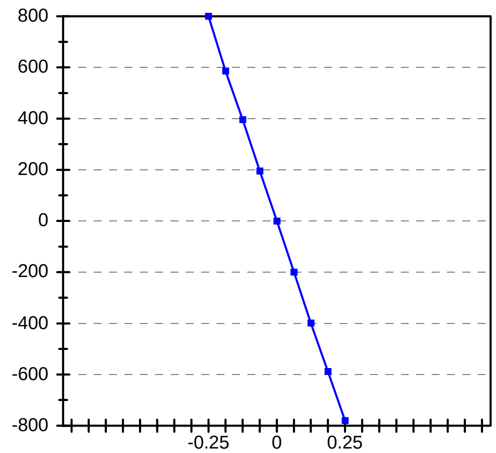

Figure 4, *Ratiometric LVDT Calibration with 9000D Plug-in Card*

LVDT Calibration

Calibration equations for LVDT's can range from highly linear to non-linear depending on the quality of the LVDT and the signal conditioner. In general, LVDT linearities are excellent with typical values from 0.5% to 0.25%. A typical calibration is shown in Figure 4.

The strength of the magnetic field generated by the LVDT primary is not uniform throughout the length of the LVDT. Because the magnetic field must curve around form one of the LVDT to the other, the field will weaken at the ends. Any LVDT will exhibit non-linear behavior when the core is displaced near the ends of the LVDT. Although non-linear, the LVDT response will be highly repeatable in nature. Using ratiometrically wound LVDTs will significantly reduce this error.

Many LVDTs are commonly used in the non-linear region with appropriate calibration equations (3rd order polynomials). Allowing a non-linear calibration extends the useful range of most LVDTs. The reader is referred to Technical Briefs TB-01 for more information on regression analysis and curve fitting.

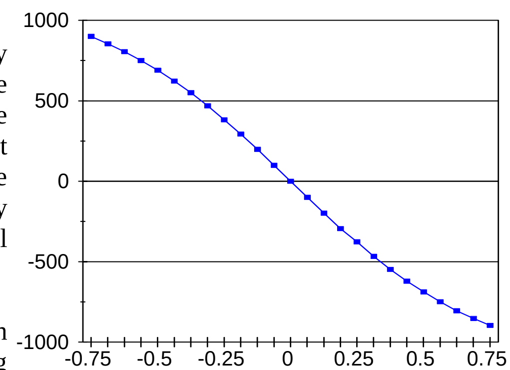

Figure 5, *Effects of LVDT Core Travel Outside the Linear Travel Range*

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