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APPLICATION NOTE

Measuring LVDT/RVDT Performance

The versatile and flexible **Model 2250 Digital Phase Angle Voltmeter** allows a wide range of tests to be done on LVDT and RVDT devices. The tests can be done manually using the front panel controls, or automatically, using the IEEE-488 bus.

This application note gives a set-up and test method to perform some of the various measurements normally done on these devices.

NAI's 2250 Digital Phase Angle Voltmeter presents a new level of accuracy and versatility in AC measurement.

LVDT/RVDT Basics

LVDTs and RVDTs are electromagnetic displacement transducers designed to provide output voltages proportional to linear and rotary displacement, respectively. LVDTs are available in a variety of sizes to accommodate linear travels from less than two inches to over 15 inches. RVDTs will typically operate over a limited angular travel; e.g., ±30 degrees.

Fig. 1 – Typical LVDT

These transducers (Figure 2) consist of three basic elements:

1. A primary winding.
2. Two secondary windings.
3. A movable armature made of a soft ferromagnetic material.

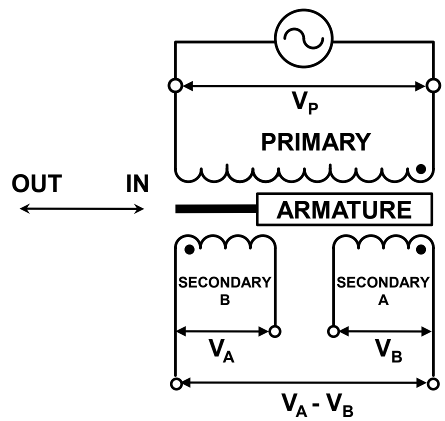

Fig. 2 – Elements of an LVDT.

How to Test an LVDT or RVDT

The primary is excited with a sine-wave voltage that the frequency of which, depending on the design, may be from 200Hz to over 10kHz. As in any transformer, the output voltage is a function of the turns ratio and the coupling efficiency between the primary and secondary windings.

The secondary windings are wired in a series-opposing configuration. When the movable core is equidistant between the primary and secondary windings, the resultant voltage, measured across the secondary winding, is zero. A core displacement either side of this zero position will generate an AC secondary

North Atlantic Industries, Inc.
110 Wilbur Place, Bohemia, NY 11716 631.567.1100 / 631.567.1823 (fax) www.naii.com / e-mail:sales@naii.com

voltage that will change linearly over a specified range of movement. The phase of this secondary AC voltage will be nominally either zero degrees or 180 degrees (with respect to the AC primary voltage reference excitation), depending on the direction the core has moved from the "zero position" (Figure 3).

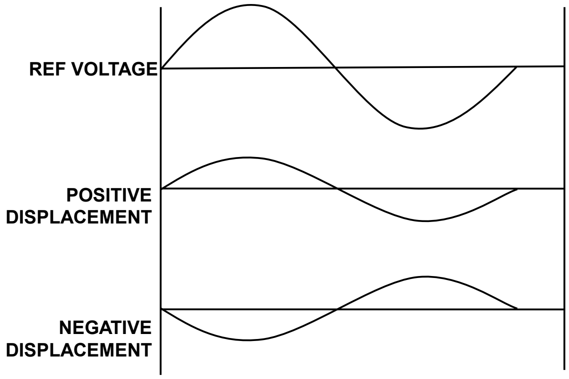

Figure 3 – AC signal from LVDT

This AC secondary voltage is fed into a phase-sensitive detector. The output is a DC voltage whose polarity depends on its phase, and whose amplitude is proportional to the amount of movement from zero (Figure 4).

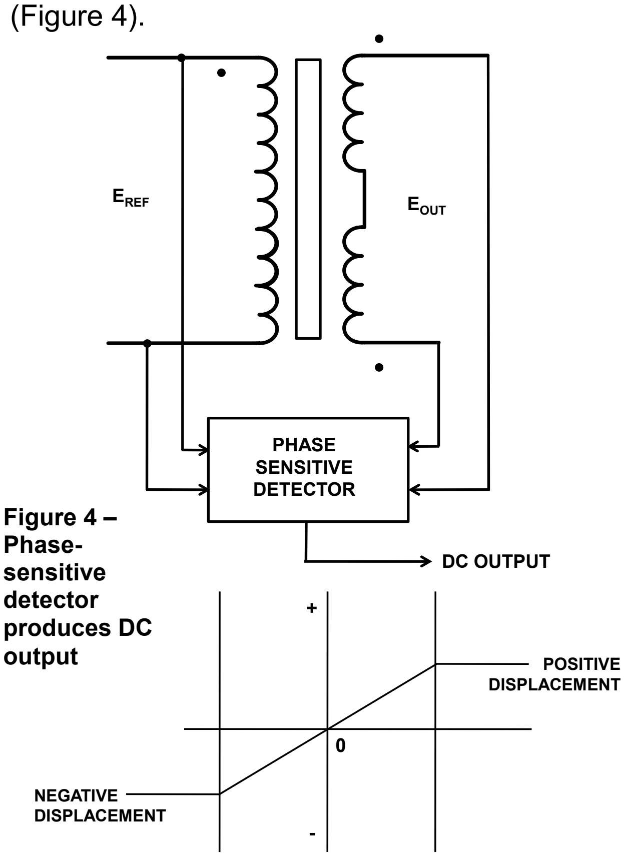

Figure 4 – Phase-sensitive detector produces DC output

Performance Parameters

To ascertain the performance of these devices, a number of parameters must be measured:

- Transducer Linearity
- Transformation Ratio
- Phase Shift
- Null Voltage (residual quadrature)
- Input Impedance
- Output Impedance
- THD

The North Atlantic Model 2250 Digital Phase Angle Voltmeter provides the means for conducting all these tests. A typical test system will employ (1) the Voltmeter, (2) an LVDT/RVDT positioning fixture and (3) a voltage source capable of delivering required *voltage,* frequency and power for the device under test.

The LVDT/RVDT *positioning fixture* can be either a manual device or a fully automated test set. The manual fixture consists of a holding mechanism for the device under test, and a micrometer with its movable shaft connected to the movable magnetic core of the LVDT (or an indexing device for the RVDT shaft).

The fully automatic test set might employ a PC controlled stepper motor drive. This drive allows precise positioning of the LVDT/RVDT magnetic core. Position monitoring may consist of a linear encoder which accurately measures the actual core position. This position data is normally fed to the PC.

Figure 5 shows system connections. The LVDT/RVDT primary winding is excited at the required frequency and voltage level by the manually adjustable oscillator or an IEEE-488 programmable oscillator for the fully automated test set. The excitation signal is also connected to the Reference terminals of the Model 2250.

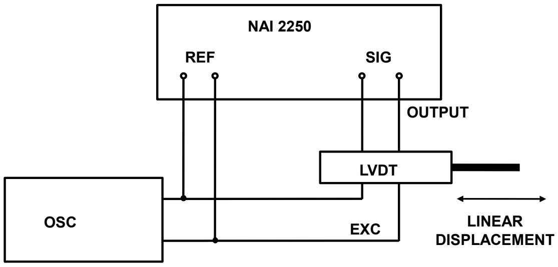

Figure 5 – Test system connections.

Test Measures

All desired parameters can now be measured and displayed, or stored in the computer for the automated configuration, as follows:

1. Linearity/Gain: This measurement will determine the linearity characteristics of the LVDT/RVDT over its specified operating range, and the transformation ratio of the device at maximum coupling. This parameter is computed from the In-Phase ratio of the output as read on the Model 2250 display. The In-Phase ratio is the measurement of the In-Phase voltage (Fundamental RMS • Cos 0) compared to the reference excitation voltage. The Model 2250 will measure, display and deliver to the host computer these values. The 2250 can also be commanded to compute this ratio directly without burdening the computer to generate this value.

In practice, the magnetic core is displaced, either side of zero, to a number of preselected positions. The Model 2250 measures the output signal, at each preselected position, and divides this value by the value of the reference signal and computes the desired ratio value. Each of these ratio values can be manually logged or fed to the computer to generate the true linear curve for the LVDT/RVDT under test. In the fully automated test set, the computer provides the deviation data which is then used to determine acceptance or rejection of the device. At maximum coupling, the ratio of the output signal to input excitation will represent the gain or transformation ratio function of the device at the selected frequency.

2. Phase Shift: The 2250 measures this parameter with high accuracy (±0.05^{o}) at typical operating frequencies. Most important is the ability to measure phase-shifted voltage components at small signal levels. This is especially important when measuring at the null voltage position.

3. Null Voltage and Zero Offset: The null position is measured by monitoring the In-Phase voltage. The movable core is positioned to zero with the 2250 in the In-Phase mode. When nulled, the 2250 can be switched to measure the Quadrature voltage. If a voltage (offset) appears at the "zero position" point, the operator can, either manually or via the computer, program a value that will reduce this offset to zero (Figure 6).

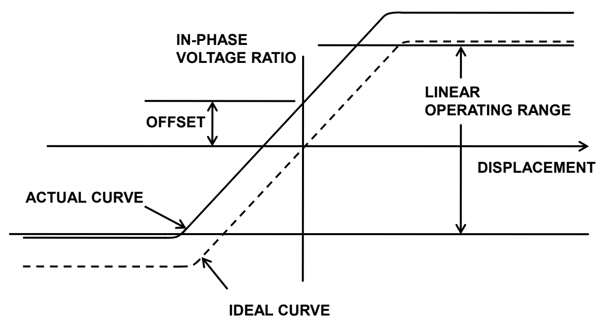

Figure 6 – Offset can be eliminated either manually or by computer.

4. Input and Output Impedance: Figure 7 illustrates the typical method for measuring input impedance. R is a precision resistor (usually of a value less than the primary impedance of the LVDT). The fully isolated channels of the 2250 makes this procedure possible. By measuring the In-Phase and Quadrature voltages, one can calculate the complex impedance of the primary winding.

Rs is typically 1 Ω or 10 Ω, selected to be much smaller than Zin:

$$Z_{in} = \frac{E}{I}\ ,\ E_R = IR\ ,\quad Z_{in} \cong \frac{E}{E_R} \bullet R$$

where ER is measured in the Fundamental Mode of the 2250. The impedance computed in this manner is equivalent to a resistor (Rin.) in parallel with a reactance

(Xin.). By selecting the "In Phase" and "Quadrature" voltage modes, these parameters will be computed as follows:

$$R_{in} = \frac{E}{E_{RI}} \bullet R \qquad X_{in} = \frac{E}{E_{RQ}} \bullet R$$

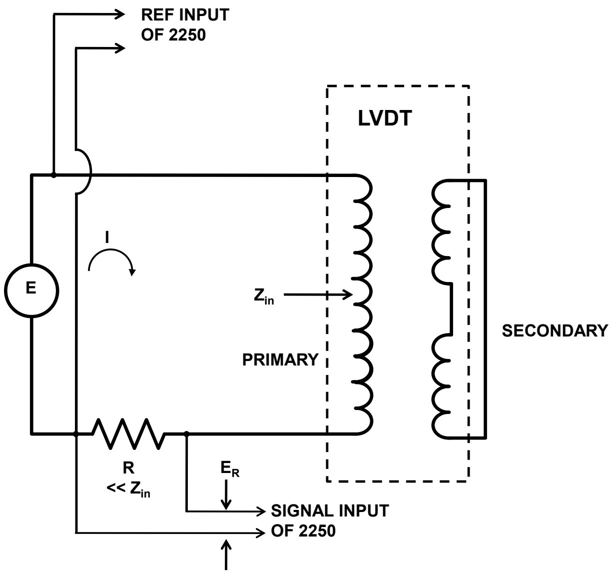

Figure 7 – Measurement of the input complex impedance of the primary winding.

Similarly, the output impedance can be measured as shown in Figure 8. Since R»Zo, the current in the circuit is:

$$I \cong \frac{E}{R}$$

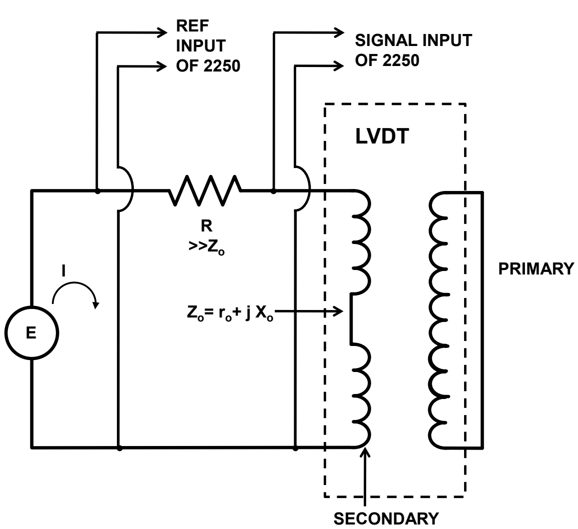

Figure 8 – Measurement of the output impedance

The In-phase voltage **($E_{in}Ø$)** as read by the 2250 would be **$E/R \bullet r_o$.** Therefore:

$$r_o = R \bullet \frac{E_{in}Ø}{E}$$

Similarly;

$$Z_o = \frac{R \bullet E_{FUND}}{E} \quad \text{and} \quad X_o = R \bullet \frac{E_Q}{E}$$

Additional Measurements

Linear Distance: A common requirement is to convert the output voltage to read directly in linear distance. This function is easily accomplished by using the "Variable Scale" function in the Model 2250. Assume that at a linear displacement of 0.1 inch from zero, the output In-Phase voltage reads 35mv (0.035 volt). The Model 2250 is placed into the variable scale mode (either manually or over the IEEE-488 bus) and the value of 2.86 (0.1:0.035) is entered through the keypad or over the bus. The readout will now display 0.100, the reading equivalent to the actual linear position. At each subsequent point, the readout will now display "position" instead of output voltage.

Total Harmonic Distortion: Since the output signal quality can be directly affected by "Core saturation", there is a need to determine the maximum level of excitation which can be safely applied before generating unwanted harmonics. The Model 2250 is set into the "THD" mode, and the excitation voltage is increased until this nominal THD reading begins to increase. This will establish the maximum allowable excitation level for low distortion operation of the transducer. The 2250 Digital Analyzing Voltmeter is widely used both in the engineering prototype stage of transducer development and in production line testing. Many end users install these devices in systems or products.

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