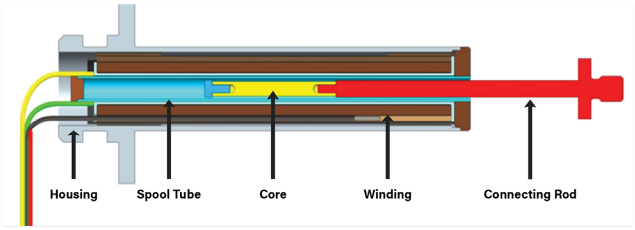
## Introduction

An LVDT is a transducer that converts a linear displacement into an electrical output signal which can be used to measure position, velocity and acceleration. Its name is an acronym for Linear Variable Differential Transformer.

## What is an LVDT?

The LVDT consists of a primary transformer coil wound on a nonmagnetic cylindrical coil form. Two secondary transformer coils are wound on top of the primary. This coil assembly is then installed in a mechanical housing. The other major component is a ferromagnetic core moving inside the coil form.

Typical LVDT Construction



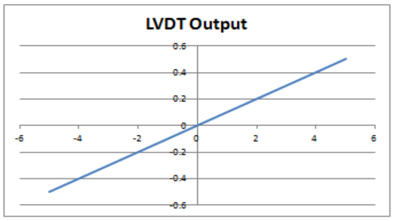

In operation, the primary coil is excited with a sine wave typically 5 to 8 VRMS at 1500 to 3500 Hertz. The alternating current in the primary creates an axial magnetic flux field which is concentrated in the core. This flux is coupled to the secondary windings through the core, inducing an output voltage in each secondary winding.

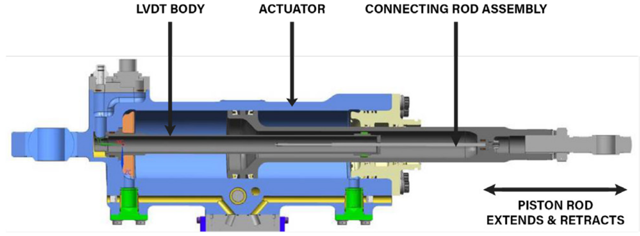
When the core is centered between the two secondary windings the voltage induced in each is identical. The voltage induced in secondary 'a' (Va) and secondary 'b' (Vb) will be in phase with the excitation voltage. The vector difference between Va - Vb will be zero. The core position where the output voltage is zero is referred to as the "null" position.

When the core is moved in either direction from the null position, the amplitude of Va - Vb changes in direct proportion to the displacement. But the phase relationship with the excitation also changes. In one direction the output signal will be in phase with the excitation and 180° out of phase in the other direction. The output voltage, therefore, has two components: 1) amplitude indicating the magnitude of the displacement and 2) phase relationship indicating direction of displacement.

Because of their long life and rugged construction, LVDTs are widely used as feedback devices in closed loop aircraft flight control systems.

LVDT Inside An Actuator



# LVDT Jargon

Null voltage, null position, zero position, full scale, full range, full stroke... like every specialty, the LVDT transducer has its own jargon. To assist the non-specialist, LISK has prepared this glossary of LVDT terminology.

## DISPLACEMENT

Null (Mid-Stroke) Position:
The core (also called armature or probe) position where the in-phase component of the output voltage Va - Vb is 0 volts.

Zero (rig) Position:
The core position for a specified reference output voltage. In most cases the zero position is the null position.

Electrical Stroke:
The range of core displacement each direction from the null position over which the performance requirements are met; for example ± 1 inch.

Mechanical Stroke:
The range of core displacement each direction from the null position over which the output voltage is continuously increasing with the displacement; for example ± 1.1 inch.

Full Stroke, Full Range, Full Scale:
Interchangeable terms for the maximum core displacement from one end of the electrical stroke to the other end; in our examples, 2 inches.

Core Velocity:
(Applies when the LVDT is immersed in hydraulic fluid). The core velocity is used to compute the minimum clearance between the core and the inside diameter of the spool tube for a specified fluid viscosity (temperature sensitive)

## INPUT

Excitation:
A sine wave defined by its RMS amplitude, frequency and total harmonic distortion (THD)

Input Impedance:
The excitation voltage divided by the input current, expressed in ohms. A minimum value consistent with the input current available should be specified. Specifying a minimum and maximum value complicates the design and may impact the cost.

Input Power Factor:
The cosine of the phase angle between the input current and the excitation voltage. Specifying the power factor complicates the coil design and may affect cost.

Real Input Power:
Product of the excitation RMS voltage, RMS input current and power factor. Expressed in watts.

Apparent Input Power:
Product of the excitation RMS voltage and RMS input current. Expressed in volt amps.

## OUTPUT

Output Voltage:
The output voltage Va -Vb can be the total RMS amplitude of the output voltage or the "in-phase" component (the voltage that is in-phase with the excitation). When a synchronous demodulation is used, the latter should be specified.

Phase Shift:
Phase angle of the vector Va-Vb or Va and Vb with respect to the excitation vector Vp.

Null Voltage:
The total RMS amplitude of the output voltage when the "in-phase" component of Va - Vb is 0 volts. The null voltage is therefore a quadrature voltage (90° out of phase with the excitation) and is due to various imperfections inherent to the LVDT such as distortion of output waveform, inter-winding and turn-to-turn capacitance effects, non-symmetries of windings and non-symmetry of magnetic properties of the core.

Output Impedance:
The drop in output voltage when the secondary winding is loaded with a resistor, divided by the current through the resistor. A maximum value should be specified. Specifying a minimum and a maximum value complicates the design and may impact cost.

COMPUTED

Gain (Sensitivity):
The slope of the Best Fit Least Squares Straight Line computed from the output voltages corresponding to a set of displacements. Expressed in volts per volt of excitation per inch of displacement.

Transfer Ratio or Ratiometric Output:
The ratio of the output voltage divided by the secondary summation [(Va-Vb)/(Va+Vb)]. Va and Vb to be taken individually as total voltage (or in phase, whichever is specified). This offers optimal accuracy without added cost.

Transfer Ratio Sensitivity:
The slope of the Least Square Best Fit Straight Line computed from the transfer ratio data corresponding to a set of displacements. Expressed in Vrms/Vrms/inch of displacement.

Non-Linearity:
The maximum deviation of the output voltage from the straight line defined above, expressed in perfect of full range (typically ± .25% of full range).

Accuracy:
The combination of gain tolerance and non-linearity at 77°F. Generally, an error brand is specified in percent of full range.

Sum Voltage Percent:
The RMS amplitude of the sum Va + Vb. When required, the LVDT coil can be designed so that the sum of secondary voltages Va + Vb remains constant over the electrical stroke. If a value is specified, the complexity of the winding is generally increased. Typical tolerance is ± 10%.

Tracking:
In multichannel LVDTs, the maximum difference of output voltage from one channel to another for the same core position. The tracking error is due to the difference in gain, output voltage is zero (rig) position, non-linearity and output voltage variation with temperature.

Thermal Coefficient of Gain:
Variation of gain in percent per 100°F over the operating temperature range. Mainly due to the change in resistance of the coil wires with temperature.

## Additional Resources