

# Why Use Linear Variable Differential Transformers

## Technical Note

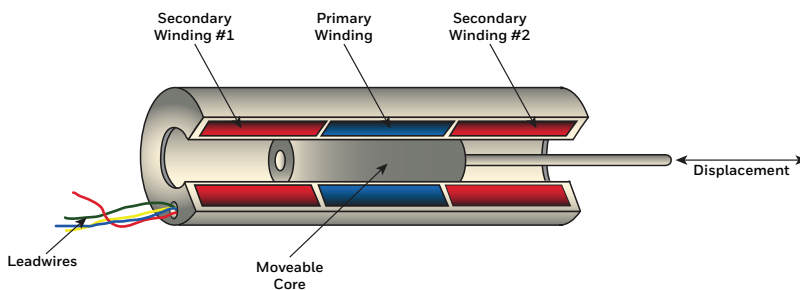
### Background

Linear Variable Differential Transformers (LVDTs) are used to measure linear displacement - straight line distance travel along a single axis. It converts the linear displacement from a mechanical reference (zero or null position) into a proportional electrical signal containing phase (for direction) and amplitude (for distance). They are robust, absolute linear position/displacement transformers that have inherently minimal friction (ie non-contact sensing), a long life when properly used, infinite resolution, enhanced linearity, low hysteresis and high repeatability. LVDTs are mainly used in the aerospace, industrial, and military industries in a wide range of applications including: aerospace valves, actuators on aerospace engines, flight control systems, power turbines, hydraulics, automation, aircraft mechanisms, satellites, and nuclear reactors.

### How are LVDTs constructed?

At the most basic level, an LVDT consists of a transformer and a probe assembly. It has the following seven components, not including the conditioning circuitry: primary coil, secondary coil 1, secondary coil 2, ferromagnetic core (slug), tube (bobbin), shield, and shaft (measurand).

Figure 1. LVDT cutaway



The ferromagnetic core is the moving component whose position within the shaft is sensed. There are many types of windings used to construct an LVDT, however the most traditional use three separate sets of windings: the primary winding in the middle, and the secondary windings are wound in opposite direction (series-opposed) on either side of the primary. Each of the secondary coils should have the same number of turns and be of the same length so as not to affect the null position and linearity. A cylindrical shield protects the windings from damage and also serves to contain the magnetic field used for sensing. The measurand is mechanically coupled to the ferromagnetic core using an attached (and non-ferromagnetic) shaft.



### What technical principles allow an LVDT to function?

As the name suggests, LVDTs are transformers built in a linear configuration that facilitate using the electro-magnetic coupling affect to measure linear displacement. The primary coil is excited by an ac voltage source. The magnetic flux produced by the primary is coupled to the two secondary coils, inducing an ac voltage in each coil. As the ferrite core moves, so does the primary coil's link to the two secondary coils, which causes the induced voltages to change. Displacement is then measured by associating specific output signal values to their respective ferrite core positions.

The main advantage of the LVDT transducer over other types of displacement transducers is the high degree of robustness. Because there is no physical contact across the sensing element, there is no wear in the sensing element. Additionally, because the device relies on the coupling of magnetic flux, a LVDT can have infinite resolution. Therefore, very small movements can be detected by suitable signal conditioning hardware, and the resolution of the transducer is determined by the resolution of the data acquisition system.

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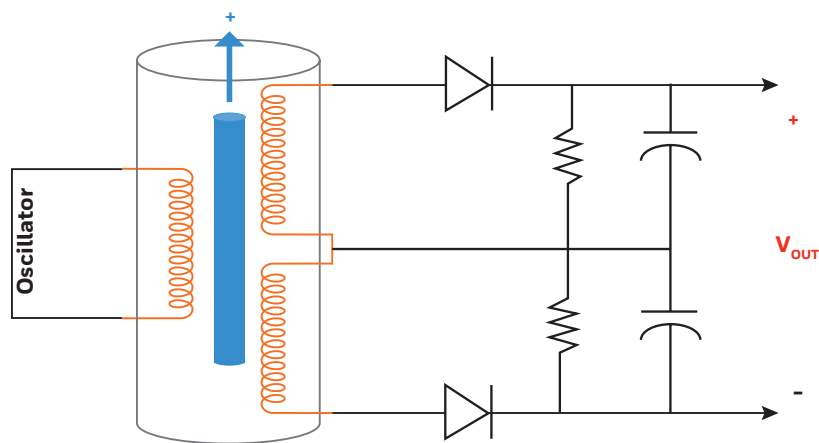
### What is signal conditioning?

The conditioning circuit for an LVDT plays an important role in the linearity and precision of the device. A complete signal conditioning circuit is characterized by three sections: a signal generator, a demodulator, and a dc voltmeter.

A signal generator is an oscillator that excites the primary windings. Sine wave oscillations are most often used to drive the circuit. Square-wave oscillations are suitable for some circuits, like FET synchronous demodulators. Response time of the sensor increases with an increasing oscillation frequency, however, the output signal level dissipates and temperature sensitivity increases above 10 kHz. Therefore, signal generator oscillation frequencies typically range from 250 Hz to 10 kHz.

The demodulator converts the ac output of the LVDT into a dc signal. In a simple case, this can be achieved with a diode demodulator or rectifier circuit. A differential amplifier allows one to scale the output voltage to a suitable range for an Analog-to-Digital Converter.

**Figure 2. Basic LVDT signal conditioning circuit with demodulator and oscillator**



**LVDT Signal Conditioning Circuit**

### For more information

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LVDT signal conditioning circuits can be bought as complete solutions, which contain the signal generator, demodulator, and dc voltmeter in one chip, or as separate elements. Some LVDTs come with the signal conditioning circuits built into the device, which are usually called dc LVDTs, since the input and output signal is a dc voltage. Design notes from companies like Analog Devices and Linear Technologies have helped to ease the customization and construction process of LVDT signal conditioning circuits.

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