Teaching NEW

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Key points:

- LVDTs produce a linear electrical output directly proportional to the position of a movable ferrous core of nickel-iron alloy.
- Two secondary windings in the LVDT produce identical output voltages that are 180° out of phase with the core centered.
- LVDTs work well with wire lengths up to 100 ft (31 m.)

Resources:

Macro Sensors, *www.macrosensors.com*

High-temperature LVDTs, *www.tinyurl.com/yh5xqdo*

The hot and cold of LVDTs, *www.tinyurl.com/ylxwlml*

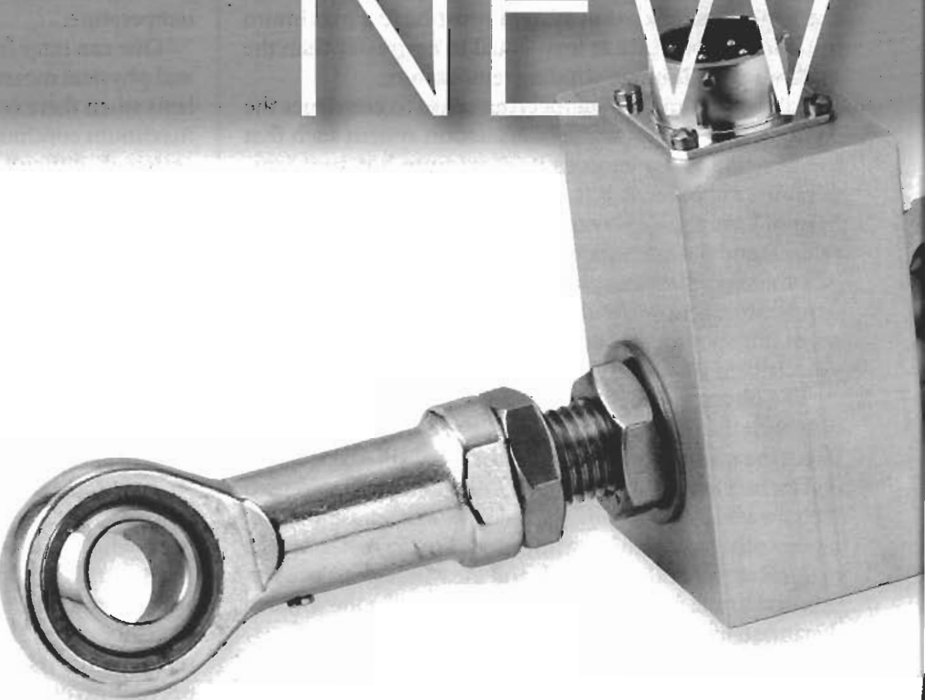
The linear variable-differential transformer, or LVDT, first saw use in laboratory measurements for the military during World War II. Industry got its first look at the device after the war, when Herman Schaevitz of **Schaevitz Engineering** wrote an article entitled, "The Linear Variable Transformer." Schaevitz proclaimed the LVDT viable technology for linear-displacement measurement.

The popularity of the LVDT grew to the point that it's become the first choice for linear-displacement measurements by many design and systems engineers around the world. Sometimes referred to as a linear position sensor, the LVDT is found in many critical industrial, military, aerospace, and subsea applications including down-hole drilling, nuclear power, and process control.

Microcontroller-based electronics coupled with new corrosion-resistant, high-temperature materials keep LVDT technology competitive. It continues to offer high durability and excellent cost of ownership compared to other displacement-sensing technologies.

The basic concept of LVDTs hasn't changed in 65 years. An electromechanical sensor, the LVDT produces a linear electrical output that is directly proportional to the position of a movable ferrous core of nickel-iron alloy. Typically, the LVDT body is fixed in place and the ferrous core is attached to the moving element on the piece of equipment for position feedback.

Inside the LVDT are three windings: one primary and two secondary coils that are 180° out of phase. Typically, a sinusoidal 3-Vac RMS voltage between 2.5 and 10 kHz excites the primary winding. The two secondary coils share the magnetic field generated by the primary coil, inducing a voltage in the secondary windings similar to a transformer. However, the



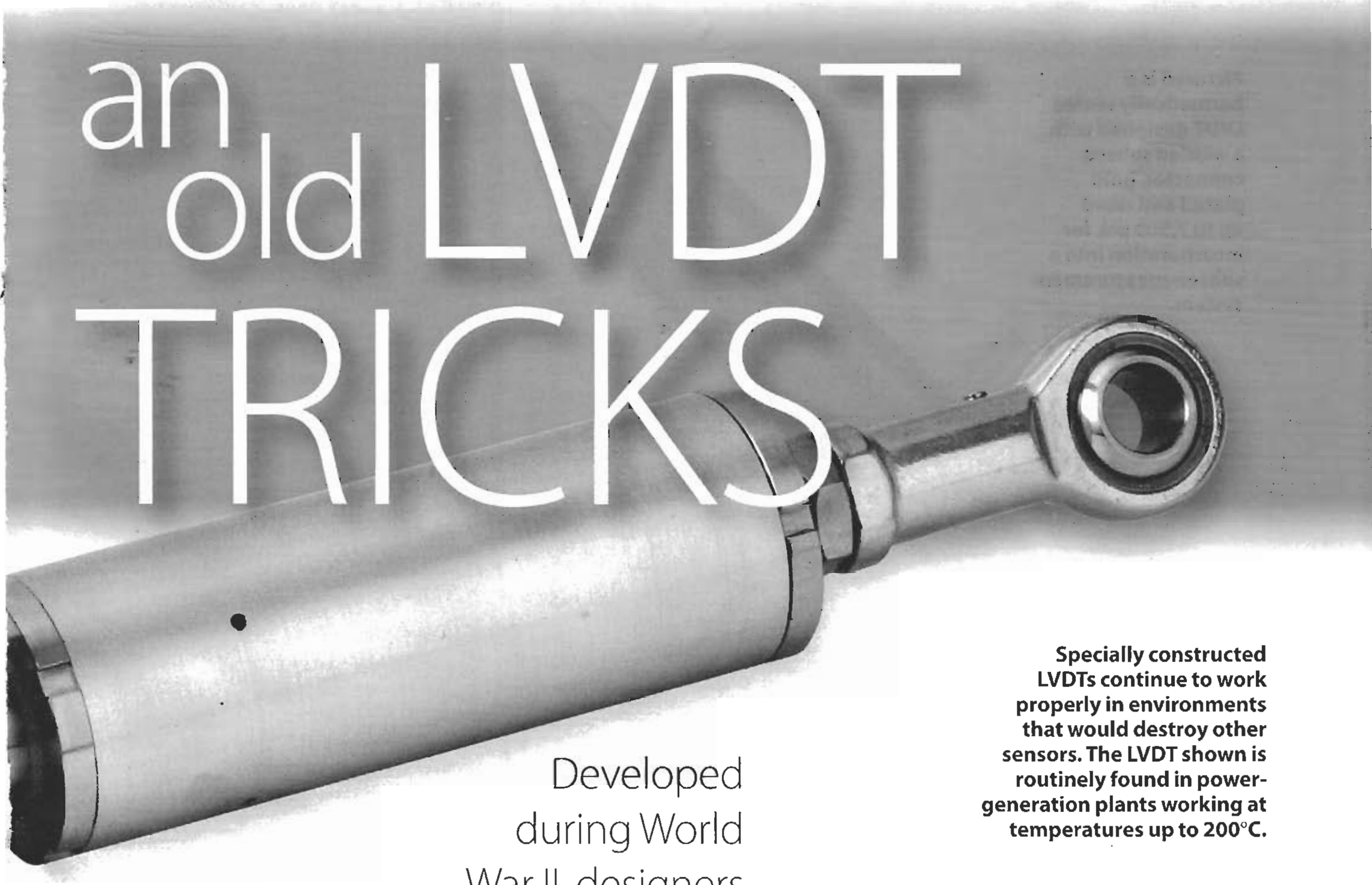
position of the ferrous core determines how much magnetic flux each winding sees and thus the resulting output voltage. At an end-of-travel position, one secondary sees almost all of the magnetic flux while the other winding sees almost none. The two secondaries flip division of the magnetic field when the core moves to the opposite extreme. When the core is in the center, both secondaries receive equal amounts of the primary magnetic field, producing output voltages that are identical, though 180° out of phase.

The LVDT is a natural contender for high-temperature applications when compared to other displacement technologies such as potentiometers, magnetostrictive transducers, and capacitive sensors. Using off-the-shelf materials and components, LVDTs generally operate from –60 to 200°C. A change in materials and assembly techniques can expand the temperature range from –200 to 500°C.

For example, an LVDT made from an alloy of cobalt, nickel, and chromium with mineral insulation continues to function in sulfidation environments with high concentrations of H_2-H_2S and temperatures up to 425°C. Other wide-temperature LVDTs find use in power generation, down-hole oil and gas exploration, nuclear fuel-rod gaging, steam-valve control systems, blast furnaces, and aircraft engine and flap controls — environments where other technologies do not survive.

Besides high temperatures, LVDTs can also handle extreme pressure as found at the bottom of the sea in search of oil and natural gas deposits. Depending upon the temperature, salinity, oxygen levels, and the depths of the oil and gas fields, the LVDT's hermetic seal and noncontacting operation is the only technology that delivers accurate and reliable performance. Even at operating pressures up

an old LVDT TRICKS



Specially constructed LVDTs continue to work properly in environments that would destroy other sensors. The LVDT shown is routinely found in power-generation plants working at temperatures up to 200°C.

Developed during World War II, designers continually find new uses for the venerable LVDT.

to 7,500 psi (500 Bar), LVDTs still maintain a mean-time-between-failure (MTBF) rate of 5 million hr. That translates into years of trouble-free operation in deep-sea well heads, subsea control valves, chokes, safety cable extension monitoring on subsea towers, remote-operating vehicles (ROVs), and drilling platform stabilizers.

The nonmagnetic housing of the LVDT is normally made from 316L stainless steel for depths greater than 1,000 ft (305 m). An optional material is Inconel 718, a nickel-based, high-strength alloy normally used in such corrosive environments as seawater and H_2S. Typical applications involve pipe line monitoring and cleaning equipment such as pigs and actuators. For shallow and warm waters with high levels of oxygen, the special nickel-based alloy Monel 400 provides excellent resistance against attack and pitting by microorganisms.

While the basic construction of an LVDT can be ruggedized against harsh environments, the electronics associated with sensor operation is another matter. Fortunately, LVDTs work well with wire lengths up to 100 ft (31 m). The low-power sinusoidal frequency operates below the radio-frequency (RF) spectrum and hardly radiates any electrical noise. There's no problem locating the signal-processing electronics some distance from the sensing device. In comparison, capacitive, magnetostrictive, and other high-frequency technologies cannot segregate the electronic circuitry from the sensing elements. Thus those sensors are more prone to fail in certain critical and demanding applications characterized by high temperatures, excessive radiation, and heavy shock and vibration.

Pictured is a hermetically sealed LVDT designed with a welded subsea connector, gold plated and rated up to 7,500 psi, for incorporation into a subsea-measurement system.

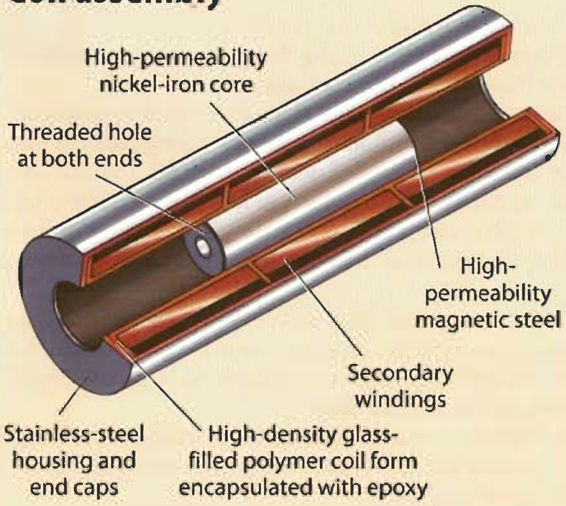
History of the LVDT

Until the 1930s, most all sensors, including the LVDT linear-position sensor, were relatively unknown because no one had seriously considered the need for electrical outputs from position measuring. Then, at the beginning of World War II, some engineers began to think about using sensors, including the LVDT, for laboratory measurements as well as in some process and control applications. Although there were all sorts of applications where the LVDT would have been the ideal sensor, only a small number of instrumentation engineers had any knowledge of the LVDT and its advantages.

Herman Schaevitz became intrigued with the LVDT during World War II and began winding the sensors in his basement workshop. He envisioned a myriad of applications for the LVDT, outlining many of those applications in a paper he authored in 1946 for the Society for Experimental Stress Analysis titled, "The Linear Variable Differential Transformer."

This paper presented the future development of LVDT as it documented complete technical data for the LVDT along with a majority of applications in which the LVDT is still used today. In addition, it listed the first commercial LVDTs, manufactured by Herman Schaevitz himself, available for off-the-shelf purchase by instrumentation engineers.

Coil assembly



LVDT construction involves three sets of winding: one primary and two secondaries. The primary coil is driven from an ac signal with a frequency between 2.5 and 10 kHz. The amount of signal the secondary coils pick up through magnetic induction depends on the position of the core.

Thanks to microcontroller-based electronics, LVDT drive and processing circuitry is compact and easy to use. These devices let customers select drive frequency, filter options for speed and noise, and how data is displayed in engineering units.

Emerging markets in fossil fuel and nuclear-power generation, wind power, subsea, structural safety, and water management will likely make heavy use of LVDTs. New winding techniques and computer-based winding machines reduce sensor body lengths while maintaining or even lengthening stroke distance. This has opened the long-stroke hydraulic cylinder market to LVDTs with strokes from 24 to 80 in. Previously this technology was considered too long for LVDT applications. New electronics are also making the LVDT easier to calibrate and use as well as priced competitively with other distance measuring technologies such as magnetostrictive transducers. **MD**

Microcomputer technology has simplified LVDT data displays. On the left, a DIN-rail-mounted, single-channel signal conditioner supports standard LVDT sensors. It operates on 10 to 30 Vdc and requires an external meter or process controller. A self-contained system is shown on the right, incorporating the LVDT drive electronics, signal conditioning, and display.