Applicabilityof DIST Technology in Harsh Environments

By
Leonard Goldman, PhD - Director of R&D

LRT Sensors LLC

114 Windsor Ave, Suite 110, Narberth, PA 19072
Email: info@lrtsensors.com
Tel: 877-299-8595
Fax: 877-299-0844

LRT Sensors designs and manufactures a standard series of non-contact linear sensors using our patented DIST (**D**istributed **I**mpedance **S**ensor **T**echnology) technology. This know-how is also applicable to rotary, gap sensing and liquid level applications on a custom basis. LRT's sensors compare favorably to traditional technologies such as LVDT's and magnetostrictive sensors from a cost, accuracy and resolution perspective and are impervious to harsh environments such as high temperature (225° C), high shock and vibration, high magnetic fields and high radiation. They are used in a wide variety of applications in the aircraft, medical, recreation, farm and construction equipment industries. DIST sensors are easily adapted to replace existing LVDT's and magnetostrictive sensors and can readily be incorporated internally into hydraulic and pneumatic cylinders. The sensors have no wear parts and can therefore deliver long trouble-free service. For a description of the basic DIST technology and a comparison to conventional sensor technologies, LVDT's and magnetostrictive sensors, please refer to the applicable LRT Sensors White Paper. This paper details the use DIST technology in harsh environments.

In addition to being economical, the DIST sensor is also capable of operating in harsh environments such as at temperatures in excess of 225°C, high radiation, high magnetic fields, vibration and high-shock. It requires only one wire for both power and output signal and can transmit the signal over lengths in excess of 10 meters. It is an absolute linear encoder which can measure lengths from a few millimeters up to one meter while maintaining accuracies in the micron region. The output of the sensor is frequency, a digital signal, and is not sensitive to noise and attenuations in the signal path. The sensor requires only a standard frequency meter to interpret the position. It requires no magnets or magnetic material and is insensitive to external magnetic fields.

The DIST sensor consists of a double coil wound on a round non- conductive rod (usually fiberglass). The wire is wound as a helix with a large pitch. Upon reaching the end of the shaft, the pitch is reversed and a returning helix is laid over the first coil. This is shown in Figure 1 below where the enlarged view shows the position of both coils. In the electronics section, a simple circuit consisting of a single transistor is connected to the ends of the coil, producing a resonant circuit that oscillates in the 2-4 Mhz region. The result is two coils in series with one having current flowing clockwise and the other counterclockwise. The magnetic fields of these two coils are parallel to the sensor, point in opposite directions and cancel each other by the "right hand rule". At the same time the electric fields from these circulating currents are perpendicular to the rod and again by the “right hand rule” they are additive. The resulting electromagnetic field outside the coil is then mostly electric with a minimal magnetic component.

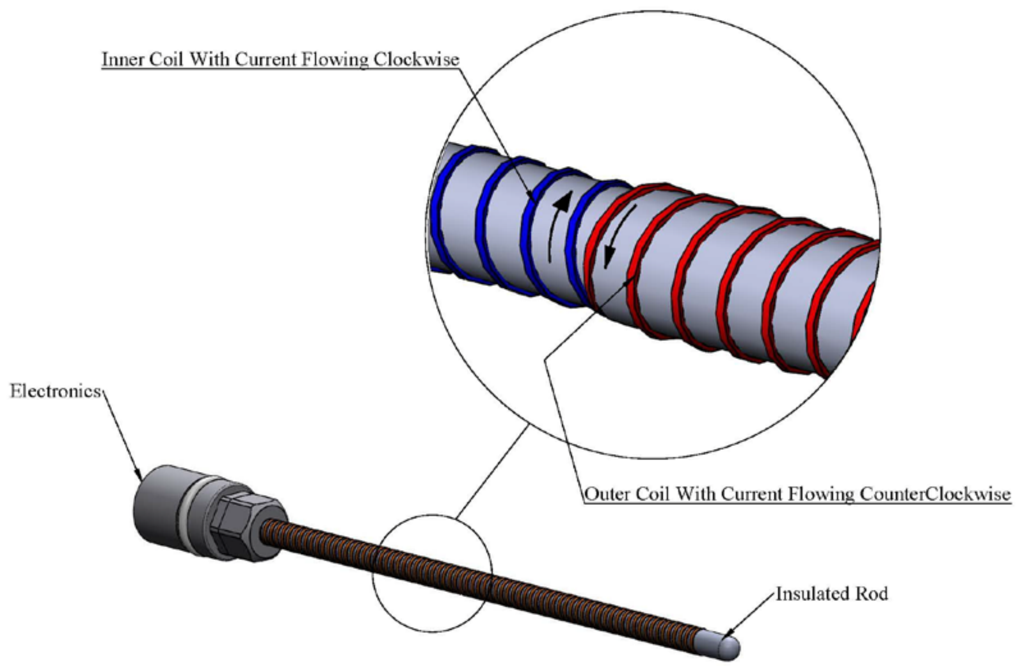

Figure 1

The frequency of this circuit is determined by the inductance (L) and capacitance (C) of the coil. Based on the physical configuration of the DIST sensor the inductance remains constant and the capacitance can be varied based on the interaction of the strong electric field of the sensor with any nearby conductive surface. If we begin to cover the coil with a conductive surface, such as a metallic tube, the capacitance and resonant frequency of the sensing element changes dramatically. We observe ~ 1 MHz changes in resonant frequency when the tube moves the full length of the sensor. The change in frequency is linear with the movement of the tube, can be transmitted great distances with no loss of information and is easily converted to a digital signal for further processing. These attributes, among others, enable the DIST sensor to operate in harsh environments.

In the DIST sensor there is no need to use extremely fine wire as with an LVDT. Wire diameter is intentionally minimized in an LVDT to produce a large inductance and a negligible capacitance, both LVDT characteristics. A DIST sensor can use a much heavier wire since we are trying to maximize capacitance. A more robust wire becomes practical and is in fact advantageous. The heavier wire wound on a flexible rod can withstand extremely high levels of shock and vibration and overcomes these susceptibilities of other sensors.

Having an output that is a digital frequency rather than a voltage has many advantages. The amplitude of a frequency signal in the DIST system is not significant so long as it remains above the threshold of detection. Typical inductive sensors have analog outputs which make them susceptible to noise, attenuations and other distortions. They require that the system electronics be near to the sensor or have extensive correction software to compensate for these errors. Because of these and other problems it is difficult for an analog sensor to have accuracies better than one part in one-thousand of (0.1%) of full scale. The DIST sensor accuracy is one part in one-million (0.0001%) of full scale. The frequency signal can be replicated and sent over separate wires for redundancy or multiplexed giving it great flexibility in its mode of transmission. In addition, since the signal analyzer is nothing more than a frequency counter, the DIST sensor does not lose its calibration if it becomes necessary to change the electronics in the signal analysis portion.

The electronic section of the DIST sensor requires only a single active device (an inverter) which is available commercially in versions that can operate at 225^{o}C and high radiation. The output frequency can be piggybacked on the DC power so that only one wire is required and the receiver can be located remotely. All of this circuitry (along with a temperature sensor to be discussed later) easily fits on a very small circuit board. This gives the DIST sensor the ability to operate in harsh environments with only a single wire (plus a ground) to transmit information to a remote computer. Additionally, the ability to have a signal wire in excess of 10 meters in length, and longer with repeaters, allows great flexibility in locating the signal analysis electronics.

The single signal wire output from the DIST sensor is also very beneficial when operating in a high pressure environment. Conductor transitions from high to low pressure are expensive, vulnerable (usually glass seals) and could cause distortion of analog signals. With only one wire, these problems are minimized.

The DIST sensor utilizes a single dual-helix coil (not a ratio of coils as in the LVDT) that is slightly more sensitive to temperature changes than comparable technologies. To compensate for this change, the DIST sensor has an integral temperature sensor whose output is converted to a lower frequency, transmitted on the single wire and used to correct these changes. When calibrated with high temperature use in mind, the errors associated with extreme temperature become insignificant.

The DIST sensor, having its signals multiplexed onto the single wire output, requires a simple passive filter network at the receiving end so as to direct them to their respective frequency meters. In applications that do not require operation in hazardous conditions and/or have no space limitation, the conversion of the frequency to standard outputs can be performed in an electronics module attached to the sensor. This eliminates the need for external filter networks but limits operation to temperatures below 125°C and increases the size of the electronics package.

The DIST sensor compares favorably to LVDT's and magnetostrictive sensors from both an economic and technological perspective. The simplicity of its mechanical (no wear parts) and electronic systems makes the DIST sensor a low cost alternative while offering comparable or superior performance. The robust design allows for excellent service in high magnetic fields and in high shock and vibration applications. The sensor can also easily be adapted to high temperature (225°C) and high radiation environments. The single wire output also simplifies the selection of the location of the signal analysis electronics allowing for design flexibility. It also does not require recalibration if replaced in the field, is easily designed for double or triple redundancy and offers accuracy of 0.0001% of full scale.

In summary, the DIST sensor is a simple, economical and compact device that can make accurate and reliable linear measurements in almost any environment with only a single wire for power and signal. It is currently available in custom configurations for OEM users and is also available off-the-shelf in standard configurations.