



**NFPA**

*Solutions through motion technology*

**NFPA Recommended Practice  
NFPA/T2.30.4 R1-2002**

Second edition  
22 August 2002

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**AN INDUSTRY STANDARD FOR FLUID POWER**

**Recommended practice – Fluid power systems – Application  
guidelines for selection of fluid power position transducers**

**(Revision of NFPA/T2.30.4-1996)**

**Descriptors:** recommended practice fluid power systems application guidelines selection position transducers

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published by

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## Foreword

This foreword is not part of NFPA/T2.30.4 R1-2002, *Recommended practice – Fluid power systems – Application guidelines for selection of fluid power position transducers*.

On 18 May 2000, the project group reviewed NFPA/T2.30.4-1996 for a five-year systematic review, and determined that changes and additions were necessary.

At the 10 February 2000 project group meeting, members reviewed draft no. 1 and made corrections to the document. Members agreed the target date for this project would be 1.5 years.

At the 18 May 2000 project group meeting, members reviewed and commented on draft no. 2 of NFPA/T3.20.4 R1-200x.

At the 21 September 2000 project group meeting, members reviewed draft no. 3 and suggested changes to the document. A copy of draft no. 4 would include the recommended changes and a copy would be circulated to members for additional comments.

At the 8 February 2001 project group meeting, members reviewed draft no. 4 and suggested corrections to the document.

During the 16 August 2001 conference call, Mr. Zahrobsky discussed Mr. Osinski's submitted comments, reviewed draft no. 5 and suggested corrections to the document. Mr. Zahrobsky agreed to send new figures 1 and 10 to NFPA Headquarters. Project group members would review draft no. 6 at the next September 2001 meeting and make a recommendation to circulate NFPA/T2.30.4-200x for general review.

At the 20 September 2001 project group meeting, members reviewed draft no. 6 and suggested corrections to the document.

At the 7 February 2002 project group meeting, comments received from the general review ballot were reviewed and changes were made to the document. A motion was approved to circulate NFPA/T2.30.4 R1-200x for final ballot.

At the 16 May 2002 project group meeting, comments received from the final ballot were reviewed (all were editorial) and changes were made to the document. A motion was approved to publish NFPA/T2.30.4 R1-200x.

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## Introduction

Today's hydraulic and pneumatic applications involve interfacing a number of fluid power components with electronic instrumentation to form a complete system. The system designer must bring a variety of technical disciplines into play to achieve the desired end result – a functional and controllable transfer of energy. The components involved can include pumps, cylinders, valves, transducers and electronic controllers. The disciplines include hydraulics, pneumatics, mechanics and electronics.

The National Fluid Power Association (NFPA) is increasingly aware of the multidisciplinary approach necessary to achieve a realistic and successful system. The NFPA also recognizes properly designed systems as a strong proponent to the growth of fluid power. To broaden our understanding of electronic control in today's fluid power, NFPA has formed an Electronics Technology Committee to provide technical information and background on electronic components. A project group was formed to develop this guide.

Fluid power is frequently used to move or displace various parts of a mechanism or “load” in response to commanded inputs. For control or quality purposes, it is often required to measure displacement that the load undergoes. A position transducer provides a measure of the displacement of some portion of a mechanism relative to a reference point. Two specific types of displacement can generally be measured. The first is linear displacement, which is commonly referred to as “distance.” The second is angular or rotary displacement.

Position transducers produce an electrical output proportional in amplitude or time to the position of the load relative to a reference point. The actual sensing mechanism may utilize one of many different technologies. Typical sensing technologies include the following: acoustics, capacitance, induction, magnetism, Hall effect, magnetostriction, optical gratings, optical interferometry, RF/microwaves and resistance, as well as mechanical means.

The selection of an appropriate position-sensing transducer requires consideration of a number of criteria involving both measurement and environmental parameters. Considering the typical characteristics and environments of fluid power systems, some of the above sensing technologies have proven more commonly used than others. This guide will be limited to the most commonly used proportional position sensing technologies and will not include discrete “on/off” position sensors, such as mid-stroke and end-of-stroke switching. This guide is aimed at technical personnel with limited exposure to the subject matter or those desiring a quick overview. It is not intended to provide a comprehensive discussion of all forms of position measurement.

Developers of fluid power position transducers can be found in the NFPA Product Locator at <http://www.nfpa.com/default.asp?pid=99>.





# Recommended practice – Fluid power systems – Application guidelines for selection of fluid power position transducers

NOTE These application guidelines rely heavily on information generally in the public domain and were excerpted from a substantial number of previously published documents given on these topics.

## 1 Scope

**1.1** The technical presentation of this document identifies the factors involved in selecting a reliable and functional position transducer. The selection of components and the success of the installation remain the responsibility of the individuals actually involved in the process. The National Fluid Power Association (NFPA) assumes no responsibility for improper application of any of the technologies described in this guide.

**1.2** This guide presents parameters and requirements of position transducers for use in mobile and industrial fluid power systems. The intent is to make readers aware of the type of information needed to select fluid power position transducers. Lastly, transducer manufacturers may find this guide helpful in communicating with potential users within the fluid power industry.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this NFPA document. For dated references, subsequent amendments to or revisions of, any of these publications do not apply. However, parties to agreements based on this NFPA document are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referenced applies. NFPA maintains registers of currently valid NFPA and ANSI/(NFPA) Standards. Standards development organization contact information and links can be found on the NFPA website ([www.nfpa.com](http://www.nfpa.com)).

ANSI ISA-S37.12 (*latest edition*), *Specification and tests for potentiometric displacement transducers*.

ANSI/(NFPA)T2.30.1 (*latest edition*), *Guide for selection of fluid power pressure transducers*.

ISO 5598 (*latest edition*), *Fluid power systems and components – Vocabulary*.

## 3 Definitions

For the purposes of this recommended practice, the terms and definitions given in ISO 5598 and the following apply:

**3.1 accuracy:** The degree to which the output (or reading) is free from errors.

**3.2 analog:** A system in which the information is carried in the amplitude of the signal.

**3.3 digital (binary):** A system in which information is represented as a combination of bits.

**3.4 digital output:** An electronic pulse train proportional to the distance moved by the transducer.

**3.5 displacement:** An object's physical position with respect to a reference point.

**3.6 hysteresis:** Difference in controlled parameters, at the same control setting, when adjusting the quantity upwards and then downwards or vice versa.

**3.7 impedance (electrical):** A mathematical representation showing the ratio of the magnitude and phase of the voltage across a device divided by the magnitude and phase of the current flowing through that device. The impedance of electrical devices, which do not alter the phase relationship between applied voltage and current, is frequently referred to as “resistance.”

**3.8 input impedance:** The impedance measured across the input terminals of an electronic device.

**3.9 linearity:** The closeness of a calibration curve to a specified straight line. Manufacturers use different methods of determining the specified straight line.

**3.10 repeatability:** Quantitative expression of the random error associated with a single tester in a given laboratory, obtaining successive results with the same apparatus under constant operating conditions on identical test material.

**3.11 resolution:** The smallest increment of position change that the transducer can detect and register as a measurable output signal.

**3.12 stroke:** The distance of a single movement of a piston or similar device.

**3.13 temperature sensitivity:** The degree to which the output signal and, therefore, the indicated position, is affected by ambient temperature changes.

## 4 Position transduction – general

**4.1** A position transducer typically consists of two fundamental parts: one part remains fixed in position while the other part moves with the mechanism whose displacement is being measured. The exact nature and, therefore, the size of the fixed and moving portions depend upon the sensing technology being used. Some transducers are intended to be mounted integral to the mechanism (see figure 1), while others are designed to be mounted external to the mechanism.

**4.2** If a transducer is configured for mounting inside a cylinder, a hole usually is drilled down the center of the piston rod and the cylinder end cap is machined to accommodate the transducer. This method usually consumes the least amount of space, but makes the transducer less accessible than mounting it externally. Mounting the transducer alongside the cylinder eliminates the time, effort and expense of machining, but exposes the transducer to the environment.

**4.3** An electrical power source is required for all position transducers. The power is applied to one of the two fundamental parts. The other part is passive and does not require power. Normally, it is desirable to have the powered part be stationary to avoid problems associated with moving cables, cable strain and cable routing. In addition to position and displacement outputs, these transducers, through supporting electronics, can provide speed and velocity or acceleration outputs.

**4.4** Primary consideration should be given to the mounting space available and type of electrical power to be used when selecting a transducer. For example, a transducer that requires 120 VAC is not as appropriate for mobile equipment as one that needs 12 VDC. Additional considerations should be given to environmental conditions of the application.

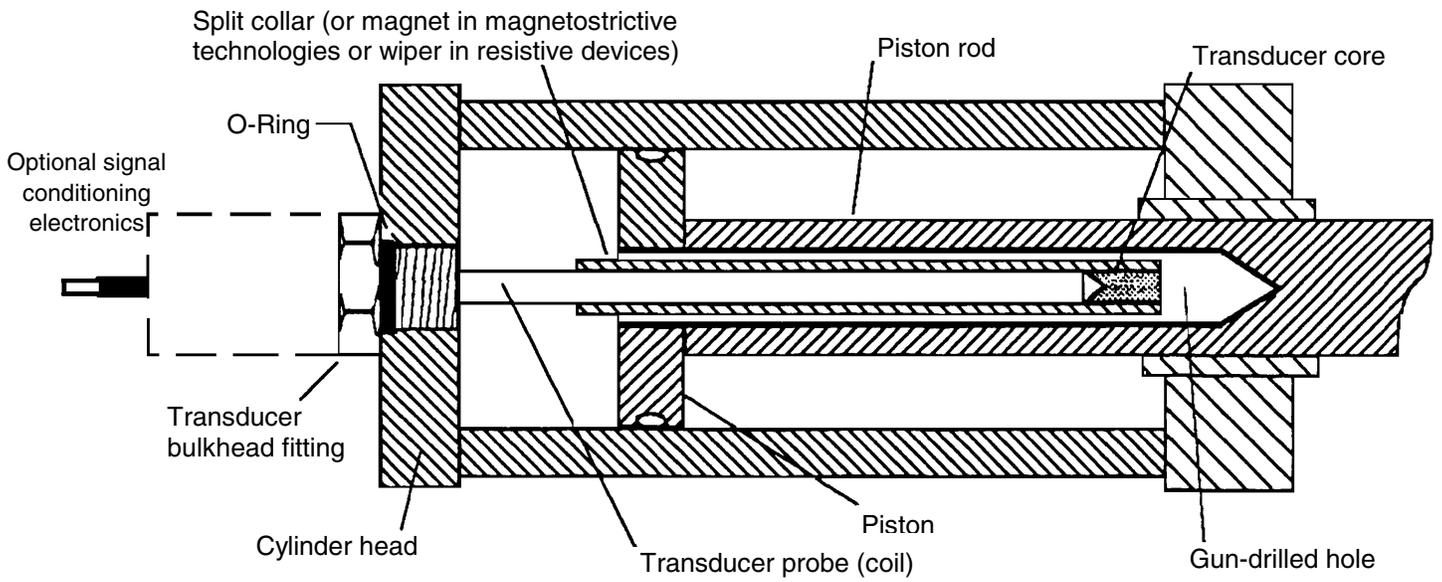


Figure 1 – Cross section of cylinder with internal transducer

4.5 Output from the position transducer can be a signal whose amplitude is proportional to position (i.e. an analog voltage or current signal) or proportional to time (i.e. a digital pulse whose duration is proportional to position). This can be a series of pulses where each pulse represents movement of a fixed increment or it may be a unique code for each measured position.

## 5 Types of position transducers

There are a variety of transducer designs used in a vast array of relatively long-stroke applications. The inherent design of a particular type usually determines whether or not it is suitable for a specific fluid power application.

### 5.1 Encoders

5.1.1 Encoders are non-contact digital devices that, in their simplest configuration, provide a defined number of pulses per revolution or per unit of linear displacement. Encoders produce digital pulses typically in 5 VDC by consecutively completing and breaking an electronic circuit. This on/off sequence allows changes in position to be detected and measured. There are two typical transduction methods used in encoders: optical and magnetic.

5.1.2 An optical encoder (see figure 2) consists of a light source, a light sensor and a grid. The grid can be constructed of glass, metal or plastic. It consists of alternate transparent and opaque areas that either allow or prohibit the passage of light from the source to the sensor. This blocking and unblocking of light causes the associated electronics to generate a string of pulses. Magnetic encoders replace the grid with magnets, and the light source and sensor are replaced with devices that sense the changes in magnetic fields.

5.1.3 There are two types of encoders: incremental and absolute. An incremental optical encoder is shown in figure 2 and an absolute encoder is shown in figure 4.

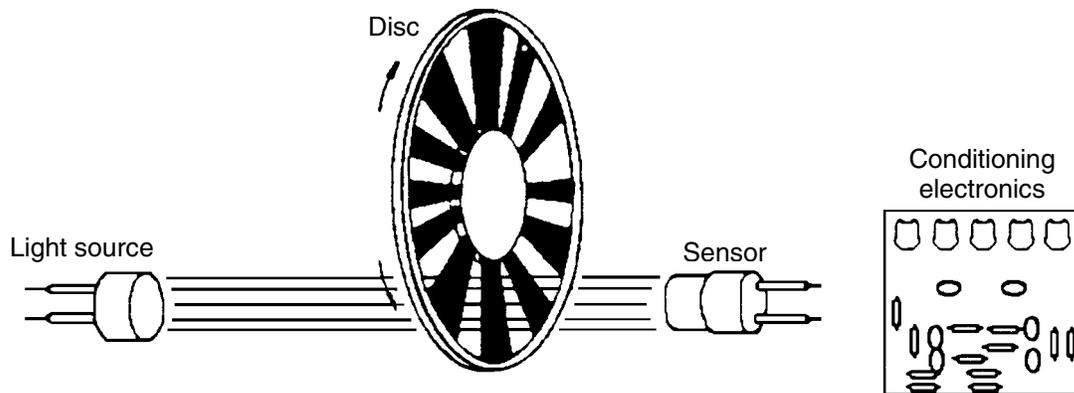
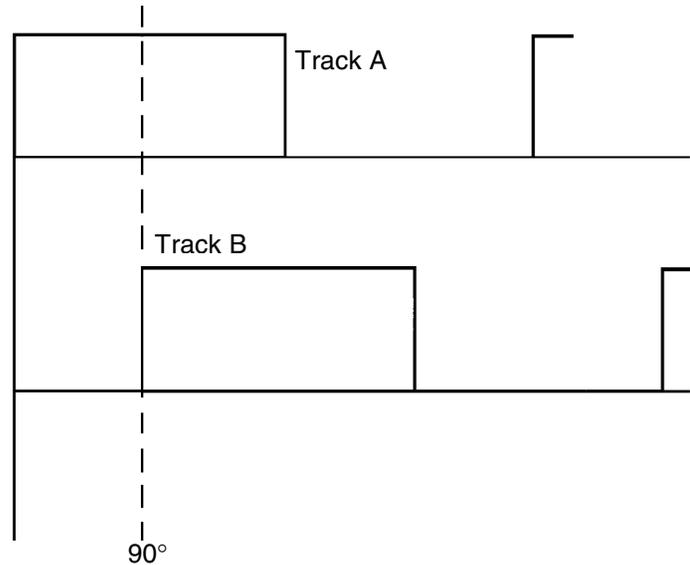


Figure 2 – Components of an optical incremental encoder

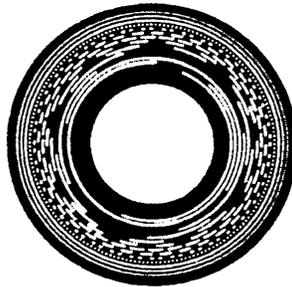
5.1.4 For incremental encoders, a separate electronic controller determines position by counting the pulses. Incremental encoders, whether linear or rotary, will lose position when the electrical power is removed. Since counting must commence from a known point, a reference or home position must be established upon powering up the encoder and its electronics. In practice, the operator of a machine generally initiates a homing routine to set the reference position before the machine is brought into use.

**5.1.5** To ensure that an incremental encoder can determine direction, a second pulse output is added  $90^\circ$  out of phase with the first output. This phase shift is referred to as quadrature output (see figure 3) and it allows the controller to determine direction of travel and eliminates false counts caused by vibration when motion has stopped. A third output generates a single index pulse at a discrete position. This output is generally used for homing or indexing routines and for counting turns in rotary multiturn applications.



**Figure 3 – Quadrature =  $90^\circ$**

**5.1.6** Typical absolute encoders overcome this loss of position sensing by using an elaborate pattern on the grid with eight or more light source detector pairs that generate parallel pulse outputs, which are available in a variety of output formats. The combination of elaborate patterns and number of light source detector pairs provides a number of unique outputs for the travel of the device.



**Figure 4 – Absolute encoder disc**

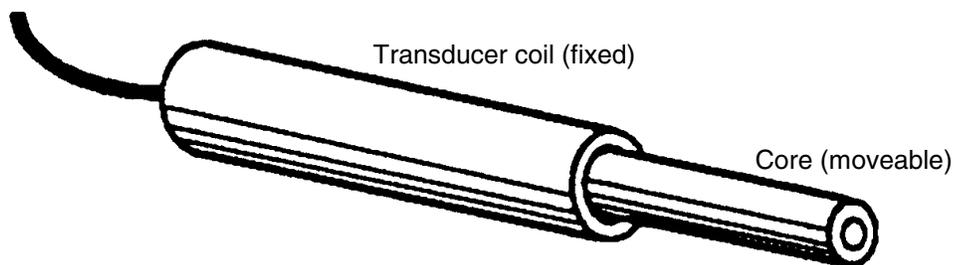
**5.1.7** For incremental encoders, the higher the line count, the greater the resolution of the device. For absolute encoders, the greater the number of outputs, the greater the resolution of the device. The cost of the encoder increases as resolution becomes greater.

## 5.2 Inductive sensors

**5.2.1** An inductive sensor is a non-contact device that measures the change in impedance (effective resistance) of a coil. The operation is similar to that of an inductive proximity switch. Alternating current flowing through a coil forms a magnetic field around the coil. Ferrous metal or non-ferrous metal at higher frequencies disrupts the field when the metal enters it. The disruption of the field causes the inductance of the coil to change.

**5.2.2** A proximity switch reacts to a metal target approaching the face of the switch. Position sensors replace the target with a core or “spoiler,” which is essentially the same length as the coil. The amount of overlap between the coil and the core determines the inductance of the coil (i.e. if the core is fully inserted, then the inductance is at minimum or maximum depending on the physics of operation). Conversely, when there is no overlap between coil and core, the opposite is true. The output between these limits is a linear analog signal proportional to the amount of overlap.

**5.2.3** Transducer designs are available with the core penetrating the inside diameter of the coil, while others have the core slide over the outside of the coil (see figures 1 and 5). The internal core design of the externally mounted cylinder device is best suited for retrofit applications where gun drilling is not desired. The external core is normally used for mounting inside hydraulic cylinders having a gun-drilled piston and piston rod.



**Figure 5 – Typical inductive transducer for external mounting**

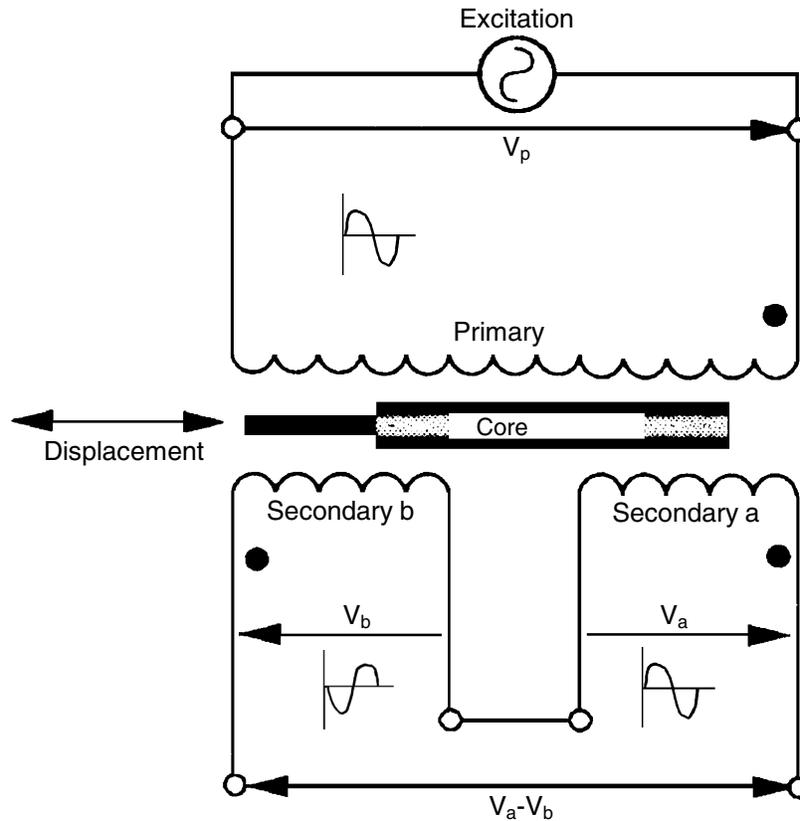
**5.2.4** All inductive position transducers use a signal conditioner or signal processor to generate the excitation current to the coil and to detect and amplify the inductance change. The physical location of the signal processor may be on the rear of the transducer (see figure 12) or at the end of a cable between the two. The length of the cable may vary from 1 m to as much as 75 m, depending on the application. These transducers may be powered by low voltage DC to 115/230 VAC, depending on the manufacturer and model. For example, the transducers provide a 0 to 10 VDC or 4 to 20 mA output, which is usable by most programmable, motion or dedicated controllers.

### **5.3 Linear and rotary variable differential transformers (LVDTs and RVDTs)**

**5.3.1** A linear or rotary variable differential transformer (LVDT or RVDT) is a non-contact transducer that converts, respectively, a linear or rotational displacement into an analog electrical output signal. The LVDT consists of a primary transformer coil wound on a non-magnetic cylindrical coil form. Two secondary transformer coils are wound on each side of the primary one. This coil assembly is then installed in a mechanical housing. The other major component is a ferromagnetic core moving inside the coil form.

**5.3.2** In operation, the primary coil is excited typically at 3 to -8 VAC at 60 Hz to 20 kHz. The alternating current in the primary winding creates an axial magnetic flux field that is concentrated in the core. This flux is coupled to the secondary windings through the core, inducing an output voltage in each secondary winding.

**5.3.3** When the core is centered between the two identical secondary windings, the voltage induced in each is identical (see figure 6). The voltage induced in Secondary a ( $V_a$ ) is in phase and Secondary b ( $V_b$ ) will be 180° out of phase with the excitation voltage. The output,  $V_a - V_b$  will be zero. The core position where the output voltage ( $V_a - V_b$ ) is zero is referred to as the null position.



NOTE The physical appearance of an LVDT maybe similar to that of an inductive sensor.

**Figure 6 – Typical LVDT**

**5.3.4** When the core is moved in either direction from the null position, the amplitude of  $V_a - V_b$  changes in direct proportion to the displacement. The phase relationships of the summed output with the excitation also change. In one direction, the summed output signal will be in phase with the excitation and 180° out of phase in the other direction. The summed output voltage, therefore, has two components: 1) amplitude indicating the magnitude of the displacement and 2) phase relationship indicating direction of displacement. A typical in-cylinder mounting configuration is shown in figure 1. The LVDT normally uses a special signal conditioning circuit called a phase sensitive demodulator, which reconstructs the polarity of the DC output voltage.

**5.3.5** For most applications, such as the one shown in figure 7, you will not need to be concerned with connecting directly with the AC voltage coils. A signal conditioner, either external or internal to the transducer, will generate the excitation and provide DC voltage or current output that is proportional to displacement of the core. When the signal conditioner is included in the package, the package is referred to as a DCDT. If the input motion is rotational, the device is referred to as a RVDT.

## 5.4 Magnetostriction

**5.4.1** Magnetostriction is a property of some ferromagnetic materials in which the material expands or contracts when placed in a magnetic field (see figure 8). The sensing element of a magnetostrictive position sensor is the waveguide, a long, thin ferromagnetic wire or tube. Another property of these materials is the Wiedemann effect: when a current is passed through the waveguide in the presence of an axial magnetic field, a torsional force is exerted on the waveguide.

**5.4.2** The sequence of events in a position measurement is:

- a) a current pulse, called the interrogation pulse, is applied to the waveguide (the circuit is completed with a copper return wire) and a timer is started;
- b) a torsional force is generated at the location of the position magnet due to the Wiedemann effect. This produces a sonic pulse that travels down the waveguide, traveling at the speed of sound in the waveguide material;
- c) when the sonic pulse arrives at the sensor element head, it is detected and the timer is stopped;
- d) the elapsed time represents the distance between the position magnet and the sensor element head. Long-term stability and temperature sensitivity are controlled by the speed of sound in the waveguide material;
- e) the time period measurement is used to produce the desired output, such as analog voltage, 4 to 20 mA, pulse width modulation, CANbus, Synchronous Serial Interface (SSI), etc.

**5.4.3** Accurate, non-contact position sensing is thus achieved with absolutely no wear to any of the sensing elements. Since a return pulse will be generated for each magnet located along the sensor, sensors can be designed with multiple marker magnets.

**5.4.4** The magnetostrictive linear displacement transducer (MLDT) relies on the basic principle of magnetostriction, which causes some ferromagnetic materials to change dimension when subjected to magnetic fields. The construction of a typical MLDT includes an electronic sensing head and a conducting wire coaxially mounted in a waveguide. The waveguide is made of a magnetostrictive material that is mounted within a protective housing made of a non-magnetic material. The waveguide is spring mounted on one end for damping. An external magnet moves along the exterior of the housing.

**5.4.5** A current (interrogation) pulse is launched along the conducting wire in the waveguide. This generates a circumferential magnetic field around the waveguide as the current in the pulse travels down the conducting wire. When the magnetic field from the current (interrogation) pulse intersects the field of the external magnet, the interaction of the two fields form a third field that causes the waveguide to experience a minute torsional strain or twist. The strain pulse travels at ultrasonic speeds along the waveguide and into a pickup mounted in the head of the instrument.

**5.4.6** There are different methods of sensing the torsional strain pulse. Each of the variations of strain pulse sensing detects the dynamic strain induced in the waveguide and produces a signal that is sent to the conditioning electronics for amplification and shaping.

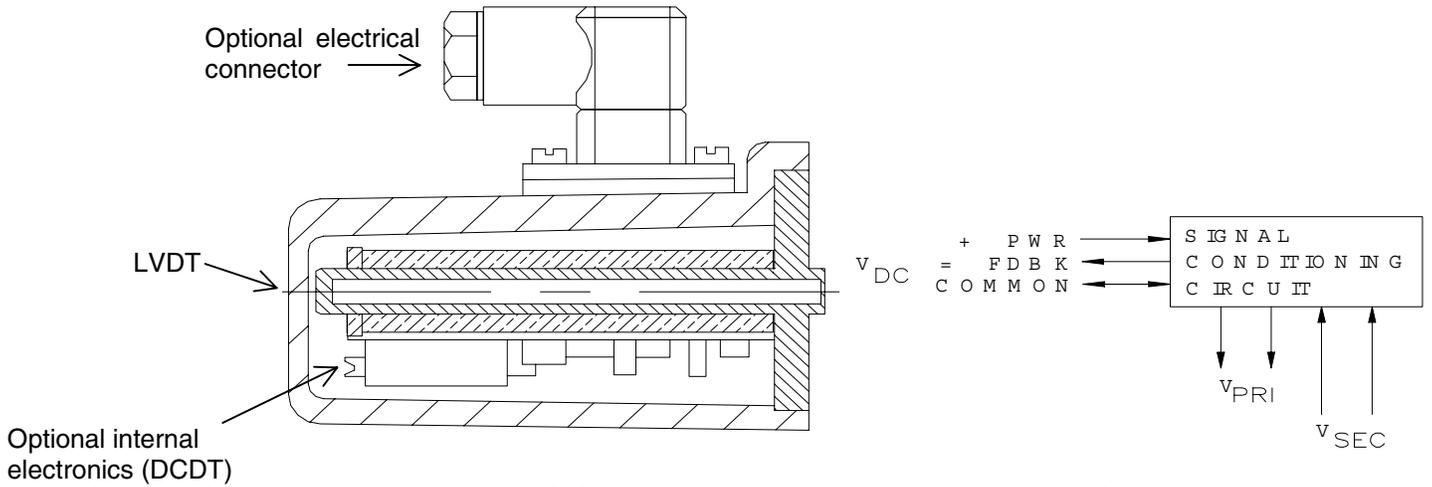
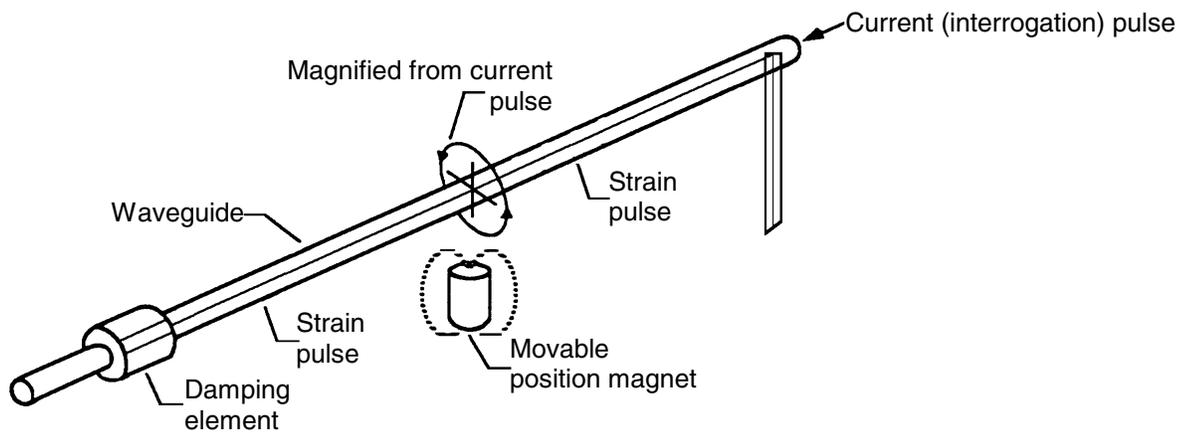


Figure 7 – LVDT/DCDT (for valving element position sensing)



NOTE Current (interrogation) pulse and the position magnet generate strain pulse, which is sensed by the pickup.

Figure 8 – Typical magnetostrictive linear displacement transducer (MLDT)

5.4.7 The precise position of the magnet is determined from the time interval between the initiation of the current (interrogation) pulse and the arrival of the torsional strain pulse in the head, as seen in figure 9. This time interval multiplied by the travel speed of the strain pulse along the waveguide indicates the position.

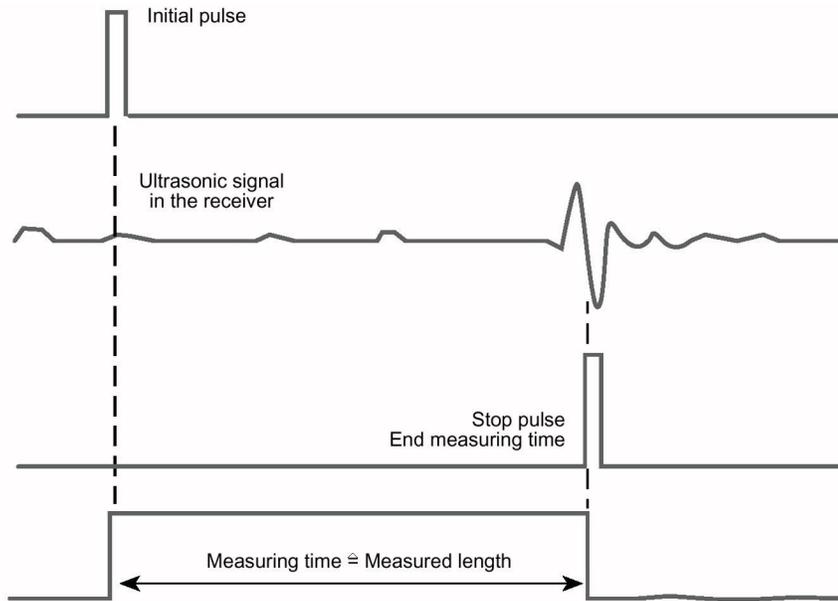
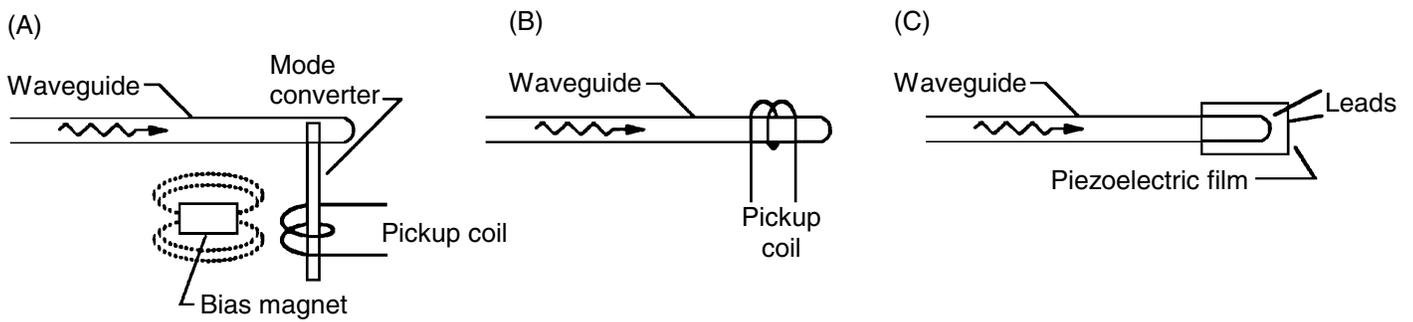


Figure 9 – Waveshapes

5.4.8 The output is digital in nature. The most common are start/stop and pulse width modulated (PWM). These electronic circuits are either self-contained or available as a separate module. An analog conversion is readily available that generally provides 0-10 VDC or 4-20 mA as an output interface. Most units use DC excitation. The output is available in SSI, CANbus, Profibus, DeviceNet, Ethernet and others.

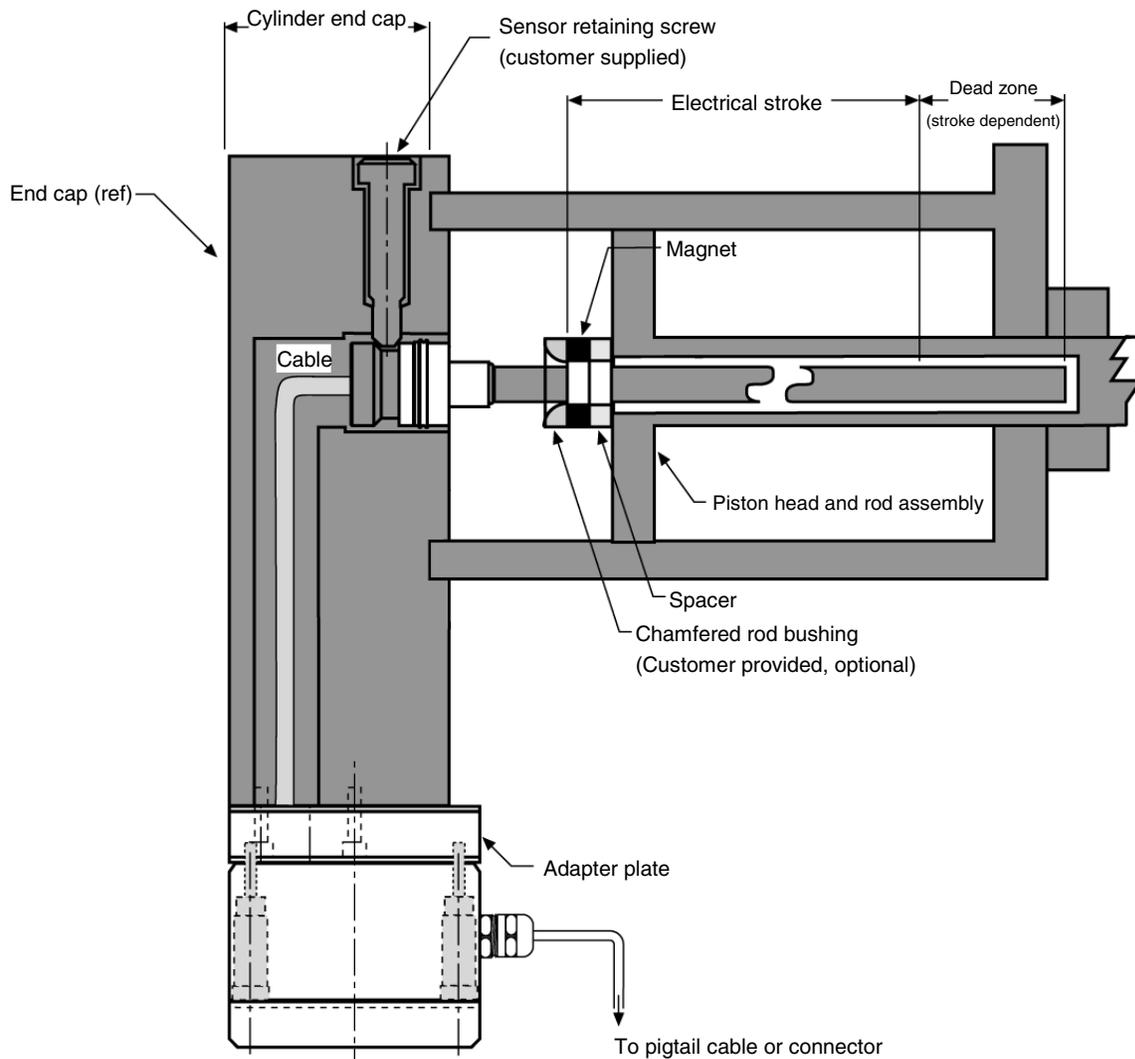
5.4.9 MLDTs are available in external and internal mounting configurations. Internal mounting resembles the one shown in figure 10. The piston rod is hollow to allow the stationary waveguide tube to fit inside as the piston rod retracts. A magnet is embedded in the piston to allow the MLDT to generate a feedback signal representing position of the piston and, therefore, the load.



- (A) a thin ribbon passing through a coil
- (B) a coil directly sensing the pulse
- (C) a piezoelectric element mechanically sensing the pulse

Figure 10 – Three methods of sensing a strain pulse

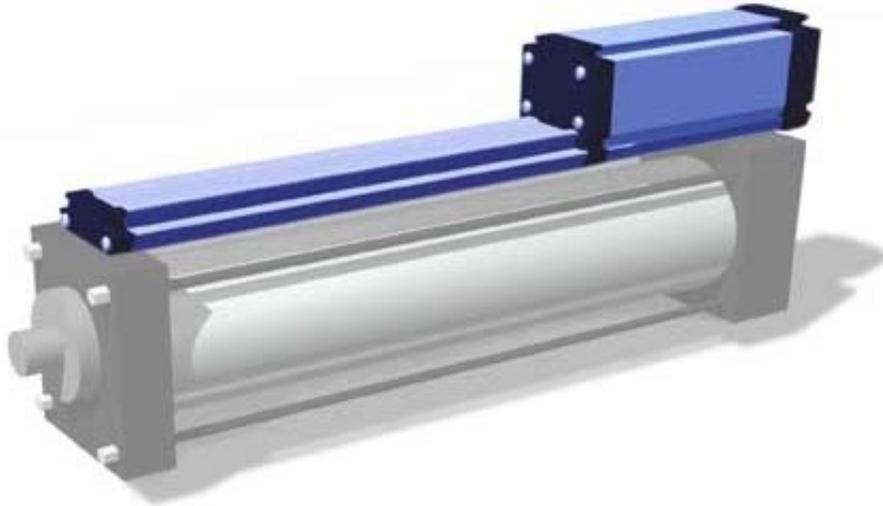
**5.4.10** Recently, new applications referred to as “embedded” have positioned the electronics housing adjacent to the cylinder end cap instead of inline with the probe on the back of the end cap, as illustrated in figure 11.



**NOTE** The illustration above represents a typical cylinder with a 3- to 8-inch bore. Some installation requirements may be application specific.

**Figure 11 – Adjacent magnostriuctive**

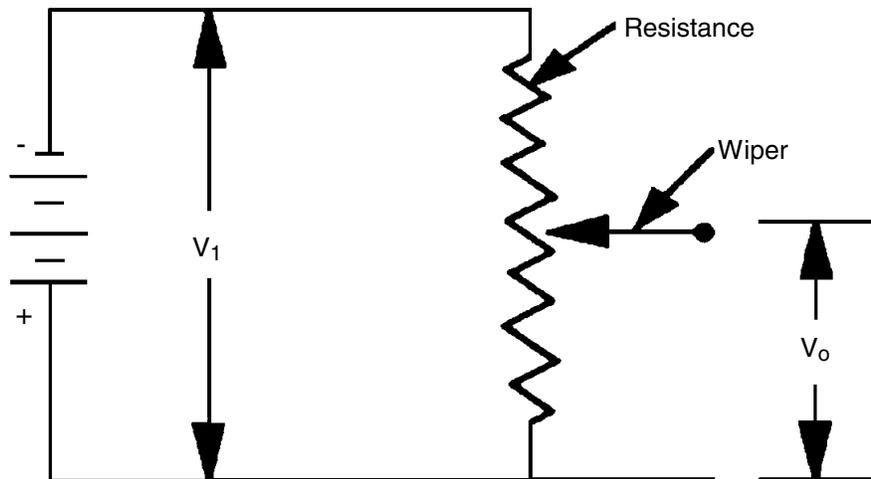
**5.4.11** Where aluminum, stainless steel or non-metallic cylinder tubes are used, non-contact external mounting without the need to mechanically couple the transducer to the piston rod may be used, as illustrated in figure 12. In this technology, the transducer waveguide element obtains position information from magnetic fields induced from piston-mounted magnets used for standard reed and Hall switches.



**Figure 12 – Non-contact external mount**

**5.5 Resistive sensors**

**5.5.1** A resistive sensor, commonly called a potentiometer, uses electrical resistance as a means of measuring position. An electrical circuit is established between the two ends of the conductive strip of material (see figure 13). A constant voltage is applied across the conductive strip. A wiper moves along the strip and picks up the voltage along the strip. Voltage increases as the wiper moves closer to the positive end of the strip. These resistive sensors are available in either linear motion or rotary motion designs.

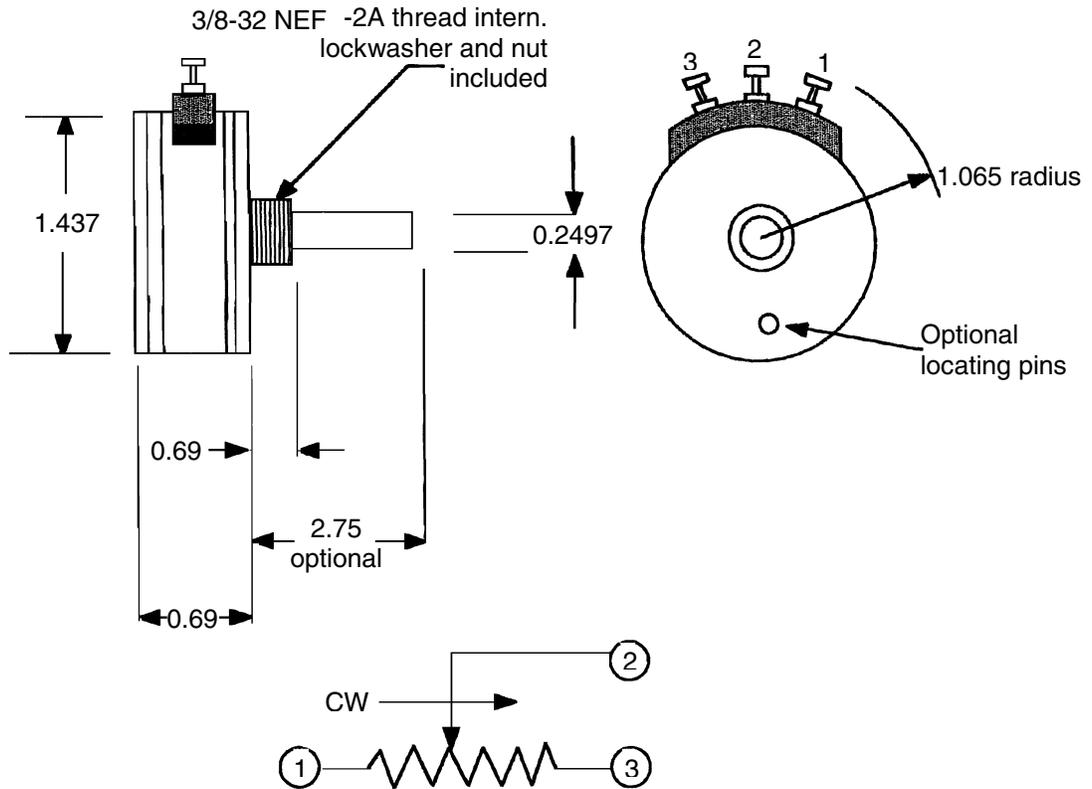


NOTE With  $V_1$  constant, a hydraulic cylinder or other component moving up or down with the wiper causes voltage  $V_0$  to increase or decrease, respectively.

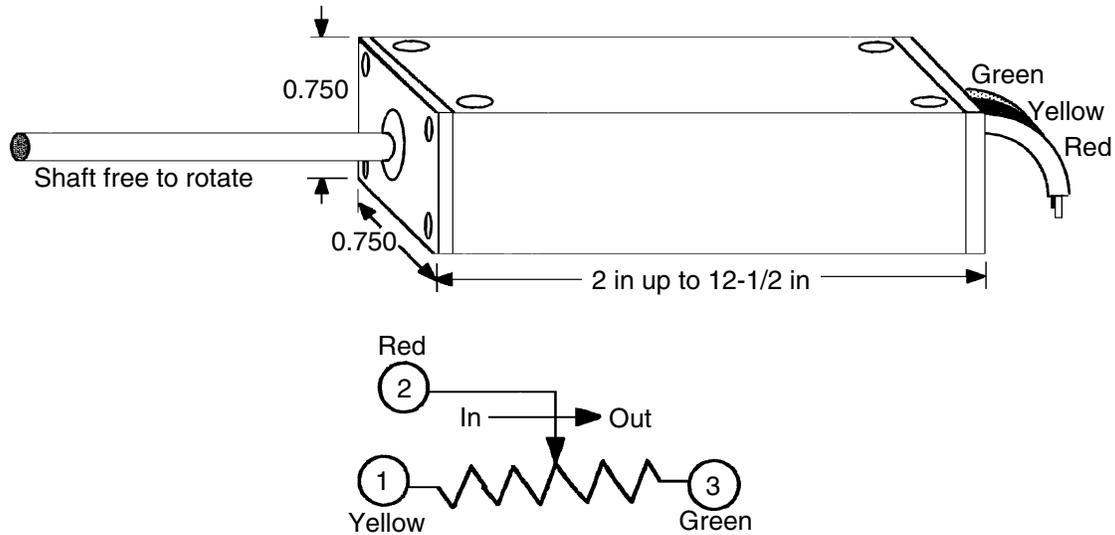
**Figure 13 – Electrical schematic of resistive transducer**

**5.5.2** The linear motion version can be mounted internally or externally to the cylinder. The rotary unit is generally mounted externally and measures angular position directly, but some rotary potentiometers measure linear position by using a spring-loaded drum and fine cable that pays in and out with changes in position. These are called “string pots” and are useful for long stroke lengths.

Dimensions in inches  
(equivalent values in millimeters in parentheses) *These need to be added.*



**Figure 14A – Rotary motion resistive sensor**



**Figure 14B – Linear motion resistive sensor**

**5.5.3** The output of a resistive sensor is ratiometric to the voltage the user applies. Since resistive sensors are not generally provided with any form of signal conditioning electronics, the user is responsible to ensure appropriate electrical parameters are evaluated. These parameters include, but are not limited to, excitation voltage, power dissipation and wiper current as it relates to the input impedance of the controller. As a rule of thumb, the resistance of the device should be less than 0,1 times the resistance of the controller to assure better linearity.

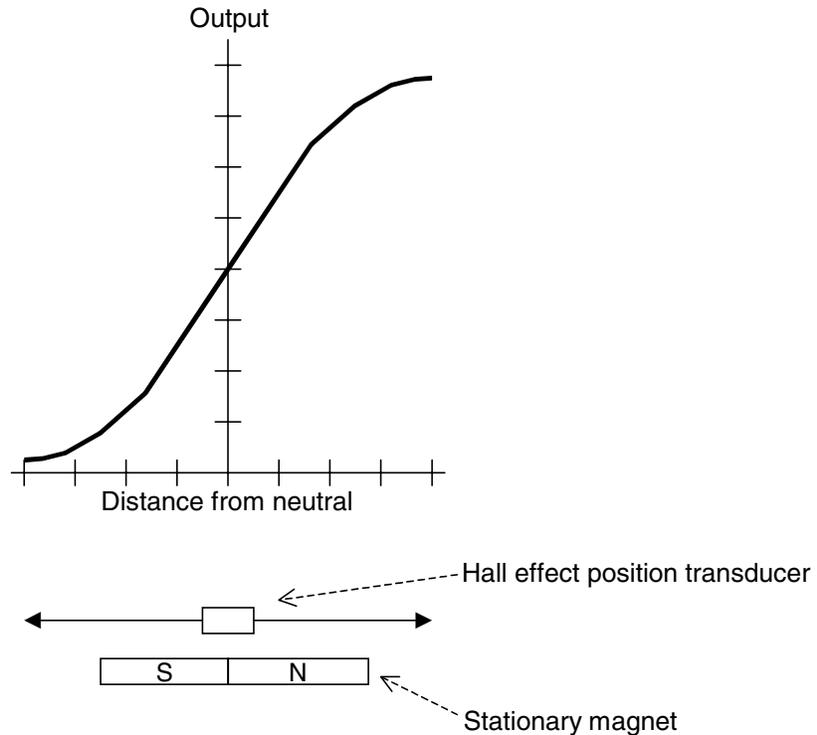
**5.6 Hall effect position transducers (Hall effect sensors)**

**5.6.1** A Hall effect position transducer is a non-contact device that detects the position of a magnet. The magnet moves along the length of the sensing element and is attached to the object whose position is to be determined.

**5.6.2** The Hall effect position transducer relies on the basic principle of magnetic flux, forcing electrons to one side of a plate generating a voltage. The generation of voltage is known as the Hall effect. Only the perpendicular component of the flux is measured on the sensor.

**5.6.3** There are different types of Hall effect position transducers available. The least expensive Hall effect position transducers are switches and latches, which have a digital output in response to the presence of a magnetic signal. More expensive are the linear devices, which output a voltage proportional to the perpendicular flux. Sensors are available in a variety of packages from small printed circuit board mounted sensors to fully enclosed fluid tight sensors used on hydraulic valves. The voltage and current requirements vary widely depending on manufacturer and type.

**5.6.4** The flux path can be created for different purposes. For linear position feedback, the magnet would be moved in front of a linear Hall effect position transducer to obtain a linear voltage signal proportional to position, as shown in figure 15.



**Figure 15 – Linear position feedback using Hall effect position transducer and magnet**

**5.6.5** Alternatively, a pulse waveform can be created from a digital output Hall effect position transducer and a series of varying flux fields moved in front of the sensor. Placing a small magnet in the package with the Hall effect position transducer sometimes augments this application. By adding the magnet to the sensor, the assembly becomes a sensor to ferrous materials. If there is no ferrous material present, the Hall effect switch is off. If there is ferrous material, the flux increases and the digital Hall effect switches on. Classically, this application is used for gear tooth timing and counting on engines.

**5.6.6** For hydraulic applications, Hall effect position transducers can be used for valving element position feedback, cylinder position feedback, safety presence or rotary position feedback. In general, linear Hall effect position transducers are good candidates for short motion measurement (<0.1 m) or limited rotary motion measurement (<180°).

## 6 Measurement error

**6.1** All position transducers are electromechanical devices and are made from more than one material. For this and other reasons, they respond not only to changes in position, but also to variations in temperature, shock, vibration and excitation. The output of the transducer will likely vary if operated from one end of its specified temperature range to the other end. The electronics may also experience catastrophic failure if subjected to prolonged exposure at temperature, vibration and humidity levels beyond the manufacturer's specifications.

**6.2** There are many other characteristics such as linearity, hysteresis, repeatability, etc., that help quantify the measurement accuracy of a position transducer. Other factors, though equally important, are more elusive and include

packaging, configuration, materials of construction and internal design. Each of these can be appraised only on the basis of field-testing and/or experience.

**6.3** All of the above factors must be considered along with the particulars of the application and the expertise of the individuals involved in making the system perform as required. The wise buyer will choose a transducer based on operating principles, specifications, price and the reputation of the seller.

## **7 Physical considerations**

**7.1** Two important considerations are the operating principle and the construction of the transducer. Both of these considerations affect size, life, accessibility, maintainability and durability. The operating principle also influences linearity, repeatability, resolution, temperature sensitivity, maximum velocity/response time and interface.

**7.2** The operating principle involves the choice between a contact vs. non-contact type device. A properly installed non-contact type device will typically have less maintenance and greater longevity than a contact type device.

**7.3** The operating principle also determines the complexity of the signal-conducting electronics. A contact type device, such as a resistive sensor, requires simpler electronics than non-contacting devices and, thus, is generally less expensive. Additionally, the package length is closer to the operating length of the resistive sensor.

**7.4** A transducer's internal construction must be rugged enough to stand up to physical abuse. The construction of the position transducer installed in a cylinder may be dictated by the fluid media temperature or pressure. A protruding transducer can make a convenient step for maintenance personnel climbing on the equipment. Falling debris is another potential source of physical damage to the transducer or interconnect cables. When possible, transducers should be accessible, but not in areas subjected to potentially damaging conditions. Internal mounting of the transducers may be the best way of protecting the device.

## **8 Other specifications**

**8.1** There are many design features that do not appear in published specifications but that may be important over the life of the application. These design factors and technologies all need to be examined against the user's actual applications.

**8.2** For transducers mounted on moving structures, one needs to consider mounting orientation, cable length and routing. Certain locations or attitudes subject the transducer to severe vibration that can cause catastrophic failure.

**8.3** External mounting is often preferred for retrofit applications because the expense of gun drilling and machining the cylinder is avoided.

## **9 Application considerations**

**9.1** One of the first operating characteristics that should be considered is whether the transducer is a contact or non-contact device. These considerations are summarized in table 1.

**Table 1 – Initial considerations**

<b>Consider a contact device when the following criteria are important:</b>	<b>Consider a non-contact device when the following criteria are important:</b>
Low initial cost	Longer life
Small size	Wider variety of outputs
Stroke length vs. package length	High velocity (for in-cylinder hydraulic applications)
Simplicity	Noise immunity
	Hostile environment/media

**9.2** The application checklist in annex B was developed to highlight some of the main points to consider when selecting a transducer. The list illustrates the type of information that must be gathered before specifying a transducer.

**9.3** Always consider the total system when selecting a transducer.

**9.3.1** If reference voltages from a controller are to be used as a power source for the transducer, make sure there is enough current capability.

**9.3.2** Make sure the controller can process the transducer output (digital or analog).

**9.3.3** The controller is usually easier to set up if the command and feedback input signals are the same: both 1 to +10 or both 4 to -20 mA. If they are not the same, the controller needs to be able to scale and bias the feedback.

**9.3.4** If the transducer provides a 4 to -20 mA signal, which is often used for longer distances, verify that the controller input impedance is acceptable to the transducer. Typical value is 500 Ω. Also verify whether the input to the controller is differential (floating) or if the return side is connected to common. Some transducer outputs can be common.

**9.3.5** Consider the failsafe position, and define the command signals and required result. For example, if the feedback cable breaks, should the cylinder retract or extend? Should a command of 0 V cause the cylinder to retract or extend?

**9.3.6** Update the speed.

## 10 Summary

It is evident that no one transducer can meet the design criteria of all applications. It is important to understand the features and benefits of each position transducer. One must also be able to interpret the specifications and how they will be affected by the particular application.

## **Annex A (informative) Glossary**

- A.1 ambient conditions:** The conditions of the medium surrounding the case of the transducer.
- A.2 CPC:** Counts per centimeter.
- A.3 CPI:** Counts per inch.
- A.4 CPR:** Counts per revolution. The output pulses from an encoder. This is related to the number of light source interruptions made by the scale. This quantity is also referred to as pulses per revolution (PPR).
- A.5 compensation:** Provision of a supplemental device, circuit or special materials to counteract known sources of error. Its manufacturer typically builds these circuits into the transducer.
- A.6 continuous rating:** The rating applicable to a specified operation for an uninterrupted length of time.
- A.7 drift:** An undesired change in output over a period of time, which is not a function of displacement.
- A.8 electromagnetic interference (EMI):** An undesired change in the output of the transducer due to the presence of magnetic or electric fields near the transducer or system wiring. This is a complex subject treated by other standards writing organizations such as SAE, IEEE, FCC and ISO.
- A.9 end points:** The outputs at the specified upper and lower limits of the range of travel.
- A.10 gradient:** The inverse of the velocity of propagation of the magnetostrictive pulses through the waveguide.
- A.11 insulation resistance:** The resistance measured between specified insulated portions of a transducer when a specified DC voltage is applied at room conditions, unless otherwise stated.
- A.12 load impedance:** The impedance presented to the output terminals of a transducer by the associated external circuitry.
- A.13 misalignment:** The error resulting from mechanical deformation of the transducer during the mounting phase.
- A.14 non-linearity:** Linearity error. See also linearity (3.9).
- A.15 sensitivity:** The ratio of the change in transducer output to a change in the value of displacement.
- A.16 span:** The algebraic difference between the end points of the range.

## Annex B (informative) Application checklist

Use this checklist to help determine the type of position transducer needed for your application. Refer to the document or glossary for explanation, clarification and elaboration of the terminology and concepts contained in the checklist.

### Performance

Mechanical stroke: \_\_\_\_\_ units \_\_\_\_\_  
 Measurement stroke: \_\_\_\_\_ units \_\_\_\_\_  
 Maximum pressure (in hyd. cyl., if so mounted): \_\_\_\_\_ units \_\_\_\_\_  
 Desired repeatability: \_\_\_\_\_ units \_\_\_\_\_  
 Resolution: \_\_\_\_\_ units \_\_\_\_\_  
 Maximum hysteresis/linearity: \_\_\_\_\_ units \_\_\_\_\_  
 Maximum velocity: \_\_\_\_\_ units \_\_\_\_\_

### Environment

Type of application: \_\_\_\_\_ Industrial \_\_\_\_\_ Mobile  
 \_\_\_\_\_ Laboratory \_\_\_\_\_ Other \_\_\_\_\_  
 Pressure media (type of fluid): \_\_\_\_\_  
 Vibration: Low \_\_\_\_\_ Medium \_\_\_\_\_ High \_\_\_\_\_  
 Shock: Low \_\_\_\_\_ Medium \_\_\_\_\_ High \_\_\_\_\_  
 Humidity: Low \_\_\_\_\_ Normal \_\_\_\_\_ High \_\_\_\_\_  
 Hazardous environment exposure (yes or no) \_\_\_\_\_ If yes type \_\_\_\_\_  
 Operating temperature:  
     of fluid: Minimum \_\_\_\_\_ Maximum \_\_\_\_\_  
     ambient: Minimum \_\_\_\_\_ Maximum \_\_\_\_\_  
 Storage temperature:  
     of fluid: Minimum \_\_\_\_\_ Maximum \_\_\_\_\_  
     ambient: Minimum \_\_\_\_\_ Maximum \_\_\_\_\_  
 Agency/certification: \_\_\_\_\_  
 CE mark: \_\_\_\_\_  
 NEMA/IP class: \_\_\_\_\_

### Electrical

Input (excitation): AC \_\_\_\_\_ DC \_\_\_\_\_ Current \_\_\_\_\_ Other \_\_\_\_\_  
 Output requirements: mV \_\_\_\_\_ V \_\_\_\_\_ 4 – 20 mA \_\_\_\_\_  
 Hz \_\_\_\_\_ CPC (CPI) or CPR \_\_\_\_\_ Other \_\_\_\_\_  
 EMI exposure: low \_\_\_\_\_ medium \_\_\_\_\_ high \_\_\_\_\_  
 Other \_\_\_\_\_  
 Zero adjust: (yes or no) \_\_\_\_\_  
 Full scale adjust: (yes or no) \_\_\_\_\_  
 Response time: \_\_\_\_\_ units \_\_\_\_\_

### Current consumption:

	<b>Other</b>	<b>Physical</b>
Maximum size: _____ x _____	x _____	units _____
Weight: _____	units _____	
Mounting: Foot _____	Rod end(s) _____	Shaft _____ Integral _____ Other _____
Termination:		
Cable _____	length _____	units _____
Terminals _____	type _____	
Connector _____	type _____	