SENSORS GROUP

Pioneers,
Innovators,
Leaders in
Magnetostrictive
Sensing

APPLICATION GUIDE

Industrial Sensors

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TEMPOSONICS®

ABSOLUTE, NON-CONTACTING POSITION SENSORS

P/N 550660

PIONEERS, INNOVATORS, LEADERS IN MAGNETOSTRICTIVE SENSING

Introduction

The intent of this Application Guide is four-fold:

1. To illustrate how Temposonics® magnetostrictive position sensors work
2. To highlight the wide range of applications where Temposonics sensors are used
3. To showcase the modular design and detail the range of data formats and mechanical configurations offered
4. To provide instruction on the key design elements and performance parameters of Temposonics position sensors

Magnetostrictive Technology

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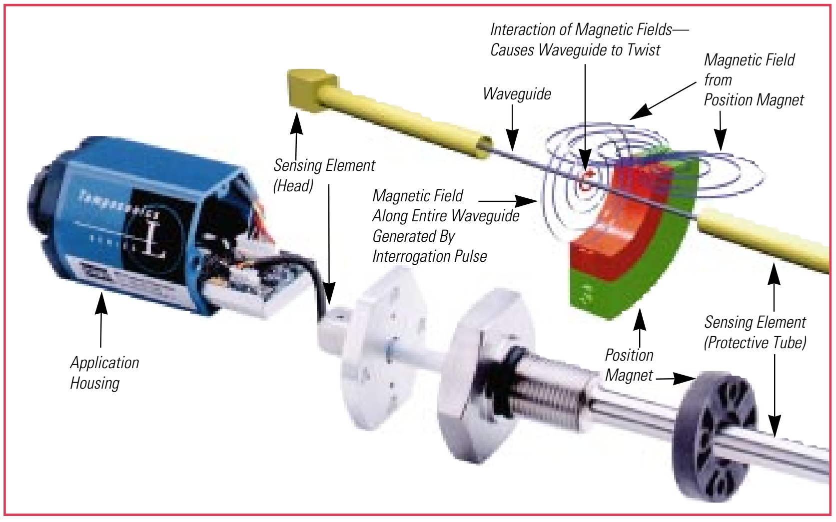
MTS Systems Corporation is the pioneer, innovator, and leader in magnetostrictive sensing technology and is the manufacturer of Temposonics position sensors. The Temposonics brand name was on the original magnetostrictive position sensor invented in 1970. This legacy, a wealth of practical industry experience, and an installed base of nearly 750,000 units is behind every sensor we build and ship to you.

Magnetostriction—How does it work?

A current pulse (interrogation pulse) is launched in a specially-designed magnetostrictive waveguide creating an instantaneous magnetic field along the active length of a sensor. This magnetic field then interacts with the magnetic field emanating from the magnet attached to a moveable machine part. The interaction of the two magnetic fields creates a torsional strain pulse which travels at sonic speed through the waveguide medium and is detected by the sensor's head electronics. The position of the magnet on the moveable machine part is determined by measuring the elapsed time between the launching of the interrogation pulse and the detection of the strain pulse. The result is a very precise, reliable, and repeatable position output which is achieved with no contact between the sensing elements.



Making Effective Use of Magnetostrictive Technology

Highlighted below are some of the industries in which Temposonics position sensors are routinely used. These examples, however, only begin to explore the wide range of industries in which Temposonics sensors have been successfully applied, namely: medical technology, transportation, die-casting, tunnel boring, electronics manufacturing, metalworking, secondary woodworking, earth-moving equipment, aeronautics, robotics, motion platforms, entertainment, and many more.

Injection Molding Machines

Our sensing technology is routinely used on 3 axes of plastic injection molding machines: injector control, ejector control, and mold closure. Superior ruggedness and reliability, as well as a host of other applicable performance features, makes Temposonics the smart choice for this application.

Hydraulic Cylinders

High-performance and durability make Temposonics position sensors the standard in the hydraulics industry. An innovative, modular design allows you to easily replace the sensing element and electronics without breaking the cylinder's high-pressure seal. This feature significantly reduces maintenance costs and downtime.

Primary Woodworking

Temposonics sensors are designed and built to withstand the rigors of sawmill applications. So effective are Temposonics sensors in withstanding the high shock and vibration inherent in this rugged application, they have become the industry standard.

Presses

High performance Temposonics III sensors are required for this exacting application. The Temposonics III line of sensors provide the high-frequency update rates and superior resolution (up to 2 microns) and linearity needed for effective press performance.

Temposonics® Industrial Sensors

For nearly a quarter century, Temposonics magnetostrictive position sensors have proven to be durable and reliable in even the most rugged industrial environments. With nearly three-quarter of a million units installed worldwide, Temposonics is the technology leader. With our newest sensor innovations we have expanded our leadership role, producing even more rugged, more reliable, and higher-performing sensors.

Our latest series of sensors include the Temposonics L Series and Temposonics III. The L Series sensors meet the demands of most applications and offers excellent performance along with a wide selection of outputs: PWM, Start/Stop, and analog (voltage and current).

The Temposonics III line of sensors is our high-performance line. This series of sensors offer faster update rates and increased resolution as well a wide array of data formats including: fieldbus (i.e., CANbus®, DeviceNet™, Profibus®), analog (voltage and current) and SSI (Serial Synchronous Interface).

Our experienced team of Application Engineers are available to help you configure a position sensing system to meet your application demands.

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Temposonics Sensors - Design / Options

3 Choices! That is what you get with the Temposonics line of position sensors. Because of the unique, modular design of the sensor, an array of mounting packages and data formats are available to meet specific needs.

The sensing element, which is the core of our technology, is a separate component housed in a protective shield. This element can be connected to a wide range of output modules and mounted in a variety of mechanical packages thus allowing MTS to provide a sensor that can be ideally configured for a specific application.

SENSING ELEMENT

At the core of the Temposonics magnetostrictive technology is the SE (sensing element). This is a common component in all Temposonics sensors. It contains the waveguide and base electronics. The SE is enclosed in a protective stainless steel housing and has has an integral connector which connects directly to an output module that provides a selection of data formats.

SE (Sensing Element)

OUTPUT MODULES

A wide range of data formats/outputs are available from the output modules. The selection of format offerings (below) meet most controller requirements.

- **Analog:**
  0 to 10 Vdc
  10 to 0 Vdc
  4 to 20 mA
  20 to 4 mA
- **Digital Pulse:**
  Start/Stop
  PWM (Pulse-width Modulated)
- **SSI**
  (Serial Synchronous Interface)
- **FieldBus:**
  CANbus
  DeviceNet™
  Profibus (availability TBD)
  Others TBD
- **Customer Specified:**
  Custom outputs are available for OEM customers with appropriate volume requirements. Contact MTS for details.

Output Modules:
Output modules are available in a variety of data formats (see listing, left). They connect directly to the sensing element of the sensor. These modules contain all of the electronics associated with a particular output and are typically housed within a protective beryllium copper shield which provides noise immunity.

One benefit of the self-contained, modular design of the output modules is that future output requirements can be easily integrated into the product offerings. The design of the output module is independent of the other sensor modules and components.

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MECHANICAL PACKAGES

Cylinder Mount I:
This sensor package is typically mounted inside an hydraulic cylinder (however, it may also be mounted externally). The high-pressure rod can withstand pressures to 5000 psi, static (10,000 psi spike). The modular design allows removal/ replacement of the sensor cartridge without breaking the high-pressure seal when installed in a hydraulic cylinder.

Cylinder Mount II:
With the same high-pressure attributes described above, this version is specifically designed for installation in space-restricted clevis-type cylinders. The sensing element is separate from the electronics module, connected only by an interconnect cable.

External Mount:
The external mount sensor package offers great mounting flexibility and is suitable for use in a wide range of applications. They are especially effective in applications where space is an issue or when high levels of dust and contamination are present.

Custom Packages:
Because of the innovative, modular design of the Temposonics position sensors, custom packages can be produced for OEM customers with appropriate volume requirements. Contact MTS for details.

PERFORMANCE CAPABILITIES

The specifications below are provided to demonstrate the capabilities of Temposonics position sensors. Some of the specifications are model and output dependent and therefore do not apply to all sensor models.

Note:
Refer to the following pages of this document for a detailed discussion on the product specifications.

Parameter	***Specification***
Measured Variable	Displacement, velocity
Measuring Range	Up to 7.62 m (300 in.)
Resolution	Up to 0.002 mm (0.00008 in.)
Non-linearity	± 0.02% of full stroke or ± 0.05 mm (± 0002 in.), whichever is greater
Repeatability	Equal to resolution
Hysteresis	Up to 0.004 mm (0.00015 in.)
Operating Voltage:	+ 13.5 to 26.4 Vdc (± 0%) or + 24 Vdc (+ 20%, - 15%)
Shock Rating	100 g (single hit) IEC standard 68-2-27 survivability
Vibration Rating	5 G/10-150 HZ/IEC standard 68-2-6

Specifications are subject to change without notice. Contact MTS for confirmation of specifications critical your application requirements.

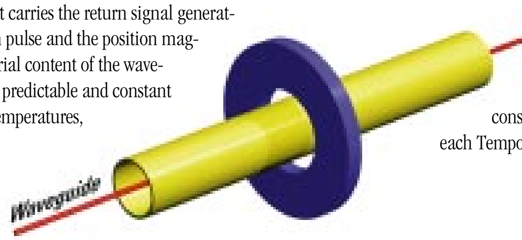
Performance Guide - Making Magnetostrictive Technology Work For You

The guide below gives you a summary of the performance parameters and important terms relating to Temposonics magnetostrictive position sensors. Overall performance of a position sensing system depends on many factors, many of which are particular to your specific application. For instance, the priority of some applications may be very rapid update times, while other applications may rely more on superior precision. Although all Temposonics position sensors provide excellent performance, some models and outputs may provide a specific performance parameter which better meets your application demands.

GENERAL

• Waveguide:
All magnetostrictive sensors require a sensing element called a "waveguide". The waveguide is constructed of proprietary magnetostrictive material usually in the form of a small-diameter tube or wire. It carries the return signal generated by the interaction of an interrogation pulse and the position magnet. Due to the special nature and material content of the waveguide, the return signals travel at a very predictable and constant rate of speed over a very wide range of temperatures, thus providing superior performance.

• Gradient:
In discussing magnetostrictive sensors, the gradient is the rate at which a pulse signal (return pulse) propagates through the magnetostrictive waveguide medium. Gradient values may vary slightly from sensor to sensor, but are predictable and repeatable for any one sensor [approximately 9µs/inch (0.354µs/mm)]. It is important to note that the gradient is an inherent constant in all magnetostrictive sensors. (Gradient values for each Temposonics sensor are noted on the product label.)



Waveguide

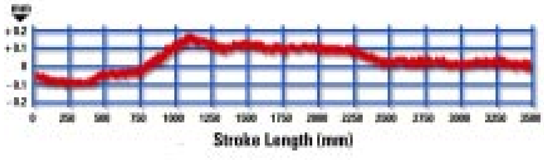
ACCURACY

Overall system accuracy is the sum of many factors. Some of the factors lay outside the performance parameters of the position sensor, such as the precision capabilities of the controller or display device and the integrity of the mechanical linkages and alignments. Below are the performance parameters of the sensor related to system accuracy.

• Non-linearity:
The degree that the indicated position of the magnet at points along the stroke length of the sensor varies from the actual physical position is referred to as non-linearity. In magnetostrictive sensors, this variability is caused by minute differences in the propagation rate of the return signals at different points along the length of the waveguide medium.

Non-linearity:
± 0.02% of F.S. or ± 0.05 mm (± 0.002 in.), whichever is greater

Above is an example of a non-linearity graph for a Temposonics sensor with a stroke length of 3500 mm (137 in.).



Non-linearity Graph (sample)

• Resolution:
Resolution is the smallest incremental change in position along the stroke length of the sensor that can be detected and indicated in an output. When using sensors with an analog output (i.e., voltage or current outputs), resolution is limited by the amount of power supply-induced output ripple and the sensitivity and/or design capabilities of the receiver electronics. Digital system resolution is defined by a specific value.

Resolution:

Analog Systems:
- Temposonics III: Up to 16 bits
- Temposonics L Series: Infinite
  (assuming power supply-induced ripple is averaged by the receiving electronics, thus minimizing the effect on output resolution)

Digital Systems:
- Temposonics III: Up to 0.002 mm (0.00008 in.)
- Temposonics L Series:
  1 ÷ [gradient x counter frequency (mHz) x circulation count]

Resolution is dependent on counter speed and the number of interrogation cycles used. Temposonics III sensors have a very high-speed built-in counter (i.e., 7500 measurements per second). This enables the sensor to provide very high resolution: up to 2 microns with a single interrogation cycle.
The Temposonics L Series typically rely on a 27Mhz counter which provides a resolution of 0.02" with a single circulation. L-Series resolution can be significantly improved by increasing the number of interrogation cycles (i.e., circulation count),

Accuracy continued

which means that the on time of the counter is increased. For instance, by increasing the circulation count to 4, the effective resolution is improved to 0.001''. However, there is a trade off; increasing the circulation count also increases the update time.

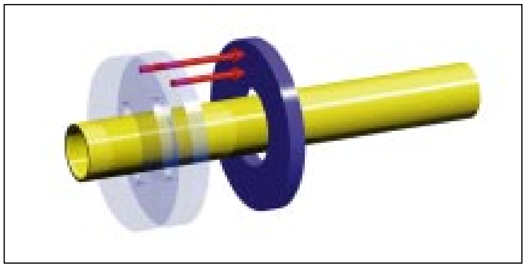
• Resolution vs. Update Time/Frequency:
As a result of the propagation delay through the magnetostrictive waveguide, there is a delay between when the interrogation pulse is launched and when the return signal arrives (i.e., when the data is new or refreshed). This delay varies based on the length of the waveguide. For each inch of waveguide there is a propagation delay of approximately 9 microseconds. Therefore, the update time for a 10 inch sensor is a minimum of 90 microseconds with one circulation. Other system parameters may increase this time period. If the sensor's interrogation signal is circulated to provide an average reading, thus improving resolution, the waveguide travel time must be multiplied by the circulation count to determine the minimum update time. In the same example, if the l0 inch sensor is circulated 4 times, the minimum update time is 360 microseconds.

Resolution (in inches) = (1) ÷ (G x F x C)

Update time (µsec.) = C x G x stroke length in inches

where:
G = gradient (µsec./in.)
F = crystal frequency (typically 28 MHz)
C = circulation count

• Repeatability:
Repeatability is the deviation in indicated position when a point along a stroke length is approached repeatedly from the same direction. The repeatability specification is inherently equal to the resolution of the sensor output.

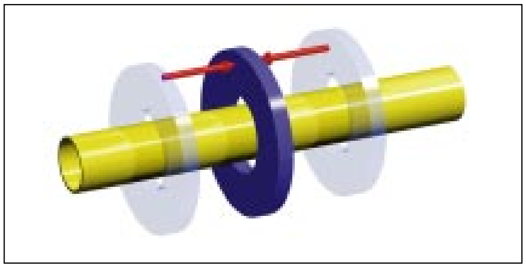


Repeatability -
output accuracy when returning to a
position from the same direction

> ***Example:***
> *Note the indicated position when you arrive at a specific point from a particular direction. If you leave this position and then return to it from the same direction, the potential change in indicated position will be no greater than the output resolution.*

• Hysteresis:
Similar to repeatability, hysteresis is the potential difference in indicated position for the same point along a stroke length when reached from ***opposing*** directions.

Hysteresis:
• Temposonics III: < 0.004 mm (0.00015 in.)
• Temposonics L Series: < 0.02 mm (0.0008 in.)



Hysteresis -
output accuracy when returning to a
defined position from opposite directions

The hysteresis specification for Temposonics position sensors is significantly less than resolution and can, in most applications, be ignored.

• Temperature Coefficient:
Temperature coefficient refers to the potential fluctuation in indicated position over a temperature range. Temposonics sensor are designed using very stable materials and electronics and are very minimally affected by temperature change.

Temperature Coefficient: 15 ppm/°C (7 ppm.°F)

Temperature Range:
Electronics: -40 to 70°C (-40 to 158°F)
Sensing Element: -40 to 105°C (-40 to 221°F)

TIMING

Update Time/Update Frequency:
These terms are used to describe the time period required to interrogate a sensor and obtain an output. This time period, or frequency rate, is primarily dependent on the length of the sensor and the number of circulation counts being used.

Maximum Update Time

Analog Systems:
• Temposonics III: ≤ 1 ms (typical)
• Temposonics L Series: ≤ 1 ms (typical)

Digital Systems:
• Temposonics III: Up to 7500 measurement per second
• Temposonics L Series: (Stroke Length in inches + 3) (9.1) µ

Performance Guide (continued)

TIMING continued

4

• Interrogation Period:

Interrogation period (IP) refers to the time it takes to complete an interrogation cycle. This time period is equal to update time when using a circulation count of one (1).

IP (µsec.) = Gradient (µsec./in.) x stroke length (inches)

Interrogation Cycle:

An interrogation pulse (initiated either locally in the head of the sensor or from a remote source) travels at the speed of light and instantaneously creates a magnetic field along the active length of the sensor. When the movable magnet interacts with this magnetic field, a torsional strain pulse is created. The strain pulse then propagates at sonics speed through the waveguide medium, along the active length of the sensor, and is detected in the head electronics as the return pulse.

• Circulation Count:

This value is equal to the number of times that the sensor is interrogated to produce a position reading.

Temposonics III sensors use an internal, high-speed counter (5 Ghz, up to 7500 measurements per second) which provides output resolutions of up to 2 microns with a single interrogation cycle (i.e., circulation count of 1). No additional circulations are necessary.

Temposonics L Series sensors typically use a 27/28 MHz counter which permits a resolution of 0.004" with one circulation (refer to equation below). By increasing the circulation (interrogation) count and averaging the readings, the effective resolution of the position measurement is increased.

Circulation Count = 1 ÷ (G x F x R)

where:

G = Gradient *(8.6-9.5 µs/inch, or 0.34-0.37 µs/mm)*

F = Crystal frequency of the counter *(standard: 27-28 MHz)*

R = Resolution *(in inches or millimeters)*

For more information contact us at:

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