TIMKEN

Application Note: MSS-7301

Using the MPS160 ASIC

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Reference Documents: MPS160 ASIC Series data sheet

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1.0 Overview

The Timken MPS -160 CMOS IC combines the features of a direction sensing Hall effect encoder with an integrated index pulse and a very accurate resolution multiplying ASIC in one package. This part is a complete Hall effect speed and position sensor system designed for use with polymer bonded multi-pole magnets. The IC produces and processes Hall effect signals producing a quadrature signal as is common with optical encoders. The output signal per channel can be up to 32 times (binary mode) or 40 times (decimal mode) the resolution of the Hall effect sensor's multi-pole magnetic target. {1024 lines (4096 edges) from a 32 pole pair magnet.} The IC is not affected by variations in the sensor to target air gap.   Multiple optional digital index signal outputs are produced on chip and are synchronized with the signal produced by the high resolution circuit.
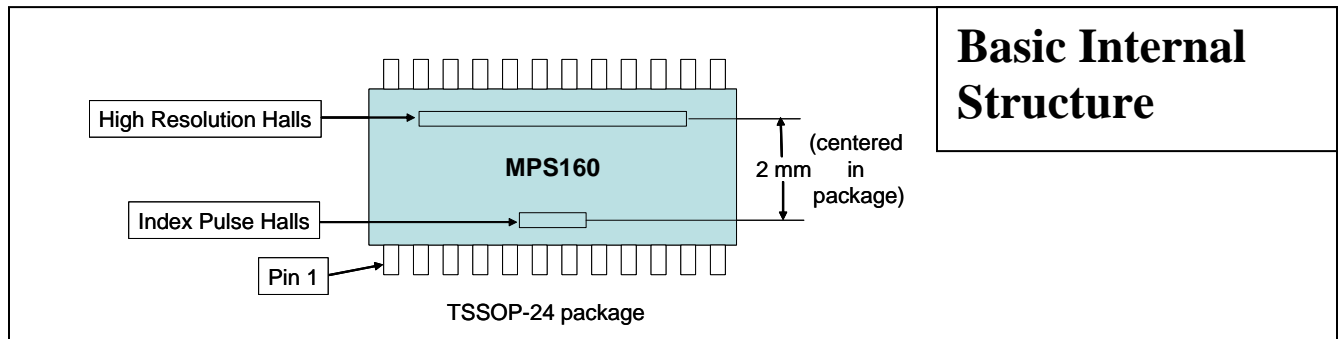
Other Key Features
- Programmable resolution multiplication factors
  - Binary Mode 32X, 16X, 8X, 4X
  - Decimal Mode 40X, 20X, 10X, 5X
- -40°C to +125°C Operating Range
- TSSOP-24 Package (8mm X 6mm X 1mm)
- Current limited O.C. or Push-Pull Outputs
- No External Components
- True Zero Speed Operation
- Absolute position over a motor phase using external halls
- Rotary or linear targets
- Pole size: 0.9 to 3.0 mm, min. field strength: 50 Gauss
- SSI/SPI capable
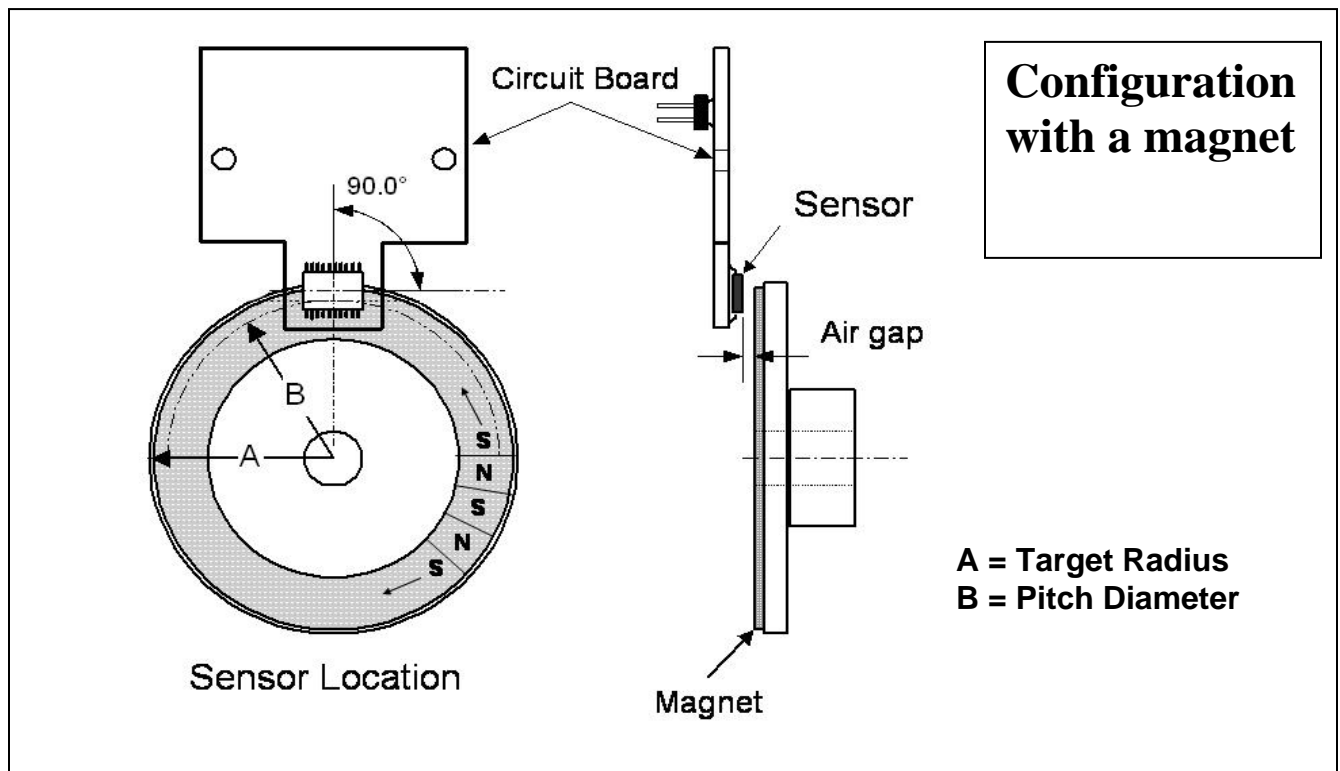
Electrical-
- DC Supply Voltage: 4.75V to 5.5V, 40mA Max.
- Low power (3mA) mode for low speed battery applications
- Maximum output Freq. 250k Hz / Channel
- Multiple Output Drivers On Chip:
  - Open drain - Current sinking, 15mA maximum
  - Line driver Outputs A, B, C
- Quadrature Accuracy +/-12.25°(Elec.)
- Position Accuracy: +/- 1 edges typical in 40X mode over full temp range

2.0 Using the High Resolution Multiplier:

2.1 General

Basic Internal Structure

High Resolution Halls

MPS160

Index Pulse Halls

Pin 1

2 mm (centered in package)

TSSOP-24 package

The MPS160 ASIC is positioned with respect to the multi-pole magnet according to the figure below. Note the orientation of the chip with respect to the magnetic poles. The chip face should be parallel to the magnet so the magnet to sensor air gap is consistent across the sensor face.

Configuration with a magnet

Circuit Board

90.0°

Sensor

Air gap

B

A

Sensor Location

Magnet
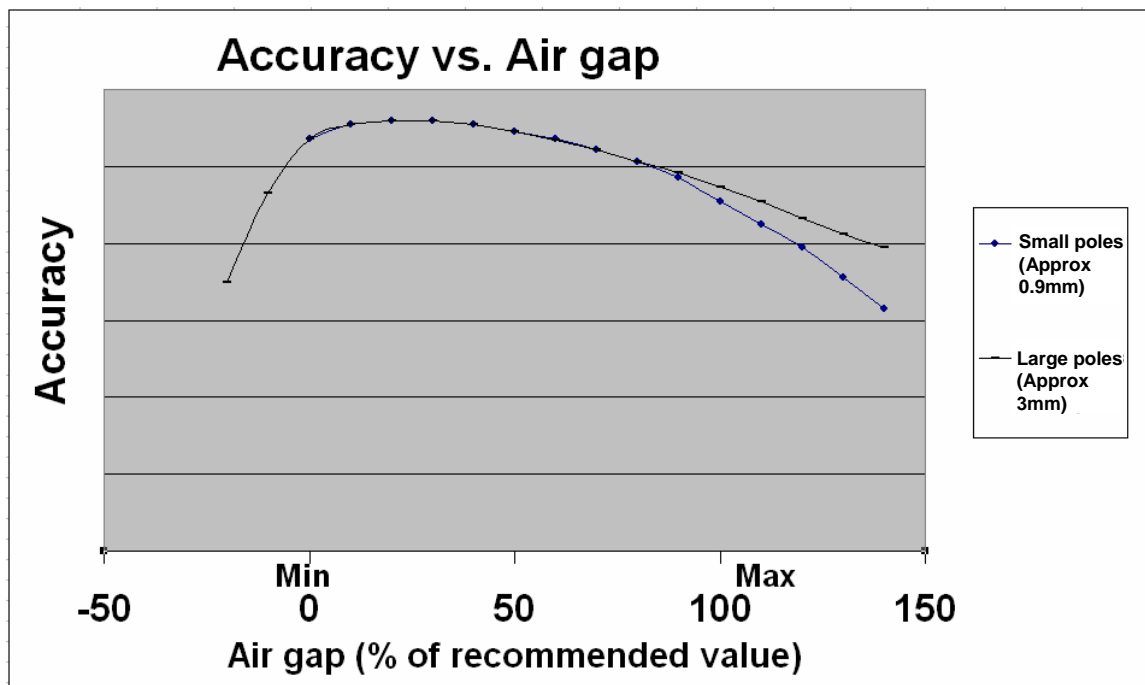
A = Target Radius
B = Pitch Diameter

2.2 Air Gap and magnetic requirements

The MPS160 ASIC is designed to operate over a specific air gap for each application. The operational air gap is determined by the magnetic field strength. The chip operates between 50 gauss and 600 gauss. The MPS 160 ASIC's are programmed around the magnetic field requirements and application parameters prior to shipment.
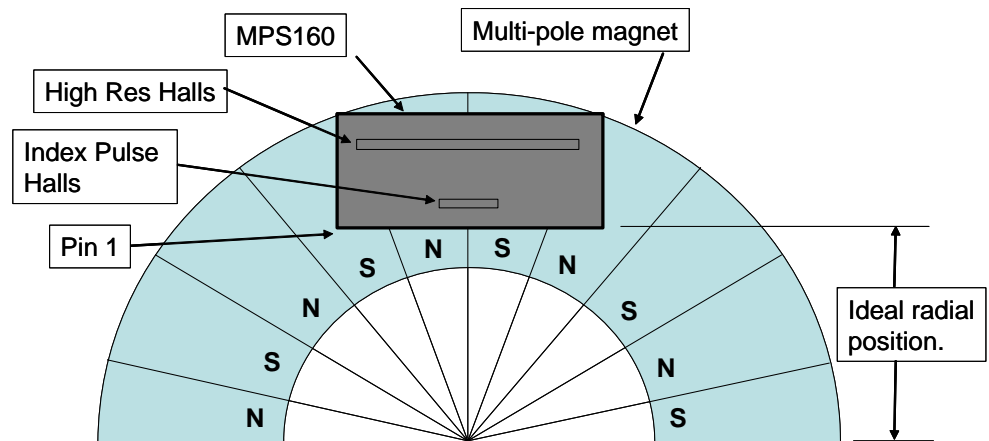
The output accuracy is dependent on the air gap as shown in Fig 1. In general, smaller air gaps provide a more accurate signal as long as the minimum air gap is held. Changing air gaps within the minimum and maximum limits during operation will not affect the sensors performance.

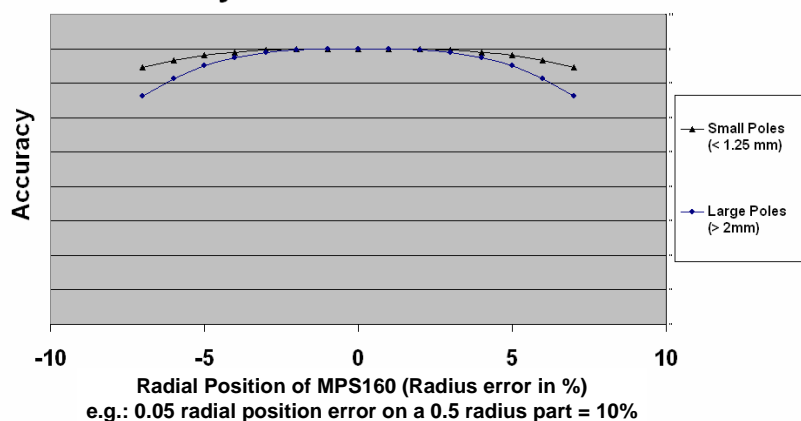Figure 1

2.3 Radial Position of the MPS160 ASIC

The output accuracy is dependent on the radial placement of the ASIC with respect to the target magnet. The ASIC is programmed to achieve the best accuracy at a specific magnetic pole width. It is critical when laying out the ASIC and target orientation that the high resolution Hall device track be positioned over the pole segment with the correct pole width. Location of the high resolution Hall device track at a position where the magnetic pole width is different than programmed will result in increased output signal error or diminished accuracy.

MPS160

Multi-pole magnet

High Res Halls

Index Pulse Halls

Pin 1

N   S
S   N
N   S
S   N
N   S

Ideal radial position.

The relative relationship between accuracy and radial position is shown in the figure below. Radial error is specified as a percentage of the operating diameter. Orientation of the MPS160 ASIC within 5% (+/-) tolerance band will result in no noticeable effect on accuracy. Small diameters are much more sensitive to radial errors. Large poles are more affected by radial position than small poles.

Reference pulse application has additional requirements for radial position (see reference pulse section). Note that the high resolution sensing portion in the chip is offset from the center toward pins 11-20. Pin 1 orientation will be toward the I.D. or O.D. according to the Timken guidelines supplied with the programmed chips.

Accuracy vs. Radial Position

Accuracy

Small Poles (< 1.25 mm)

Large Poles (> 2mm)

-10   -5   0   5   10

Radial Position of MPS160 (Radius error in %)
e.g.: 0.05 radial position error on a 0.5 radius part = 10%

2.4 Obtaining the best system accuracy

Interpolator or tracking error is common for most designs. This small error repeats itself once per magnetic pole pair.   The interpolator error increases when the air gap or radial position is out of the specified range. The error may be slightly worse at temperature extremes.

The centering of the magnet in the final application is critical for optimal system accuracy. Timken's magnets are centered to a specific reference, typically the bore of the magnet or magnet carrier. The tolerance of this reference should be held very tightly to the rotating shaft in the application.

Example: A magnet off-center in the final system by 0.001" using a 1 inch diameter magnet to achieve 1024 PPR output will have a cyclical off-center error on the output signal of about +/- 7 arc minutes or +/- 1.3 edge-to-edge of quadrature.

Additional information on how to obtain the best system performance is found in the application note MSS-7302: "Maximizing the performance of your MPS160 ASIC based system".

2.5 EMC considerations:

The MPS160 ASIC differential sensing arrangement has very good immunity to EMI / electrical and magnetic noise due to its differential sensing and processing. We recommend the use of a 0.01uF ceramic decoupling capacitor placed very near the power and ground pins on the chip.

3.0 Index/Reference Pulse

The MPS160 ASIC sensor is equipped with an internal index pulse Hall-effect. This sensor element is mounted opposite the high resolution hall-effects in the IC, approximately 1mm from center-line towards pins 6 and 7. To use the index pulse feature, you must use a special magnetic target that has a second magnetic track on the target hub.

When using the reference pulse the radial position of the chip with respect to the magnet is critical. The chip needs to be positioned at the ideal radial position with no more than a +/- 0.030 inch radial tolerance. If the chip falls outside of this window then there could be either too many reference pulses on the output or it could miss a reference pulse. Also, if the chip is located radially too far towards the reference pulse track by more the 0.030" radial window then the magnetic reference pulse pattern will start to show up on the high resolution output signal as angular error on the A and B signal lines at the reference pulse location.

4.0 Using low power mode for low speed battery applications

The MPS160 is programmable for operation at lower speeds with a reduced power requirement. This operation reduces long term power consumption of battery applications. There is a typical variation of ± 1 edge on the A and B channel output. This may happen even if the target is held still during power up/down cycles. In this case the digital hysteresis can be enabled to prevent the output from toggling and can be programmed for the application when necessary.

5.0 Absolute position over a motor phase using the SPI/SSI

The MPS 160 is capable of interfacing with external halls and providing absolute position over a motor phase through the SPI/SSI interface. This feature does not have to be preprogrammed into the ASIC.

Up to 4 external Hall signals are routed through the MPS160 to the SPI/SSI line to provide positional data. The number of external Hall needed is dependent on the number of high resolution pole pairs and motor phases. Timken application engineers work with the applications parameters to design target magnets and determine the number of external Hall's needed. The absolute position data output is via Synchronous Serial Interface/Synchronous Peripheral Interface (SSI/SPI).

6.0 Conclusions:

The MPS160 ASIC, when used with a multi-pole magnet, offers a very simple and reliable system to provide a high resolution sensor. The sensor is very compact often taking up no more than 0.200" of axial space. It can be used in harsh environments where many technologies can't survive. The critical tolerances for air gap and radial position are typically within normal manufacturing range. It can be integrated into a larger system with minimal physical impact on the system in either a rotary or linear configuration. Additional features including low power mode and absolute position make this a versatile sensor package.