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## Texas Instruments New Product Update

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# Linear 3D Hall-effect sensor: TMAG5170

Gloria Kim

October 28<sup>th</sup>, 2021

# Agenda

- Multi-axis linear and angle position sensor portfolio
- Linear Hall functionality overview
- Comparing 1D and 3D
  - Angle measurement
- TI's new linear 3D Hall-effect IC: TMAG5170
  - High-precision
  - ALERT function
  - Configurability
  - Diagnostics
- Example applications
- Tool and resources

# Multi-axis linear & angle position sensors

The screenshots illustrate the navigation path for multi-axis linear and angle position sensors on the Texas Instruments website:

- Screenshot 1:** Shows the main navigation menu with 'Sensors' highlighted. The 'Product tree' on the left lists various sensor categories, including 'Multi-axis linear & angle position sensors (3)'.
- Screenshot 2:** Shows the 'Sensors' category page with 'Multi-axis linear & angle position sensors (3)' selected. The 'Product details' section is visible.
- Screenshot 3:** Shows the 'TMA5170-Q1' product page, which is an 'Automotive, high-precision, I2C interface' sensor. The 'Product details' section is visible.
- Screenshot 4:** Shows the 'TMA5273' product page, which is a 'Low-power linear 3D Hall-effect sensor with I2C interface'. The 'Product details' section is visible, showing the 'Parameters' table.

Parameters	Package   Pins   Size	Features	Description
Type			3-Axis linear
Supply voltage (Vcc) (Min) (V)			1.7

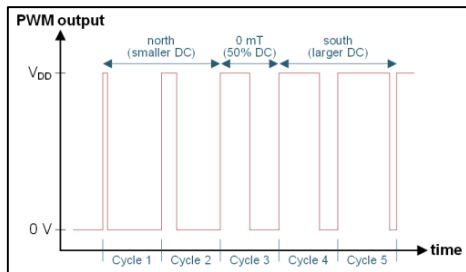
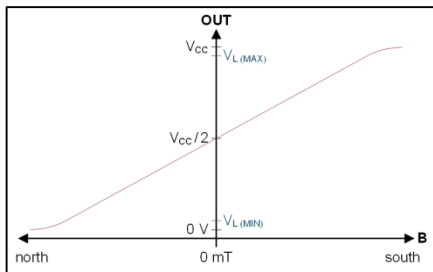
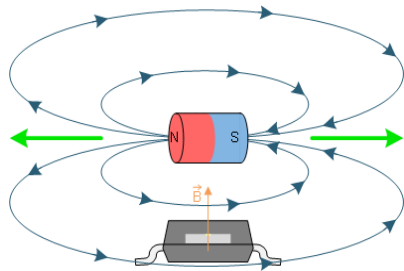
The final screenshot also includes a block diagram of the sensor's internal structure, showing the 'Power Management and Controller', 'Analog Front-End', 'ADC', and 'Interface' blocks.

# Single-axis linear Hall-effect sensor operation

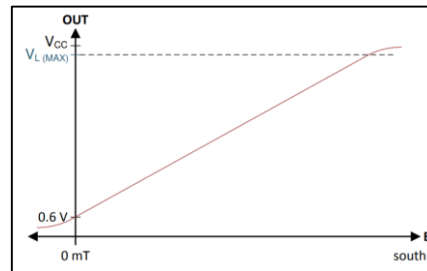
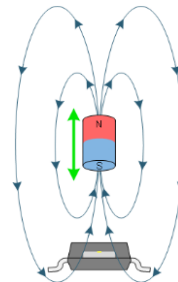
## Linear Hall-effect sensor

Outputs a signal that is proportional to magnetic flux density to measure precise movement.

Bipolar

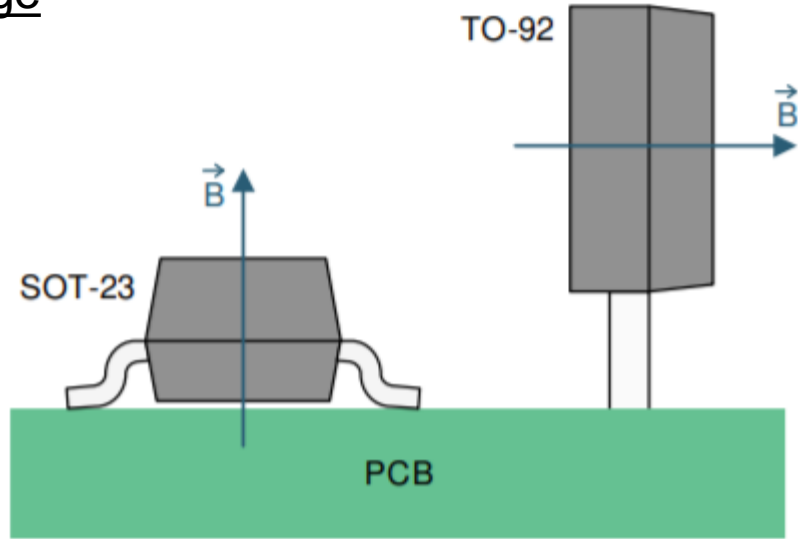


Unipolar

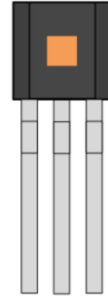


# Single-axis linear direction of sensitivity

## Surface-mount package

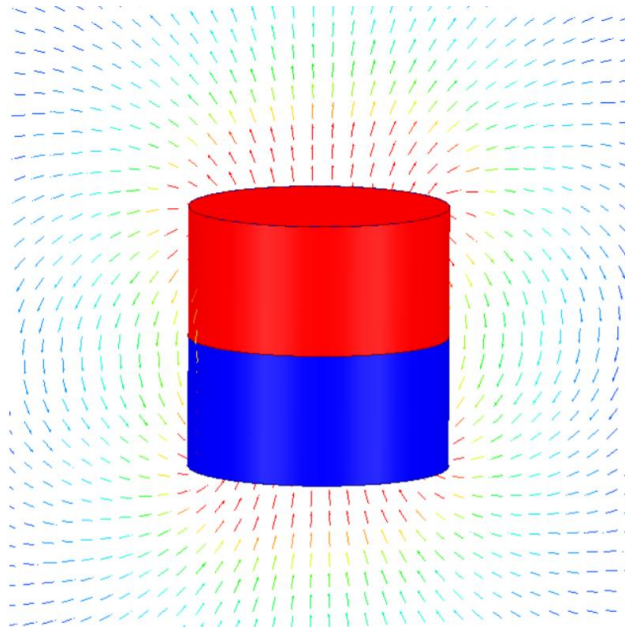


## Through-hole package

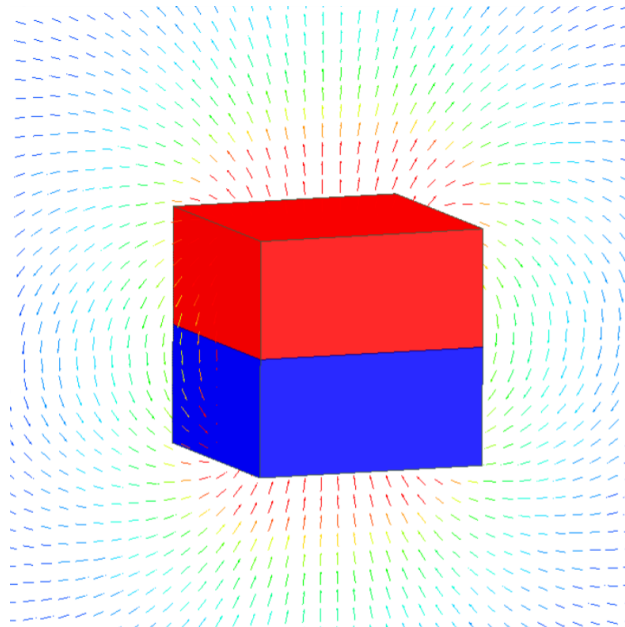


# Magnetic field vectors

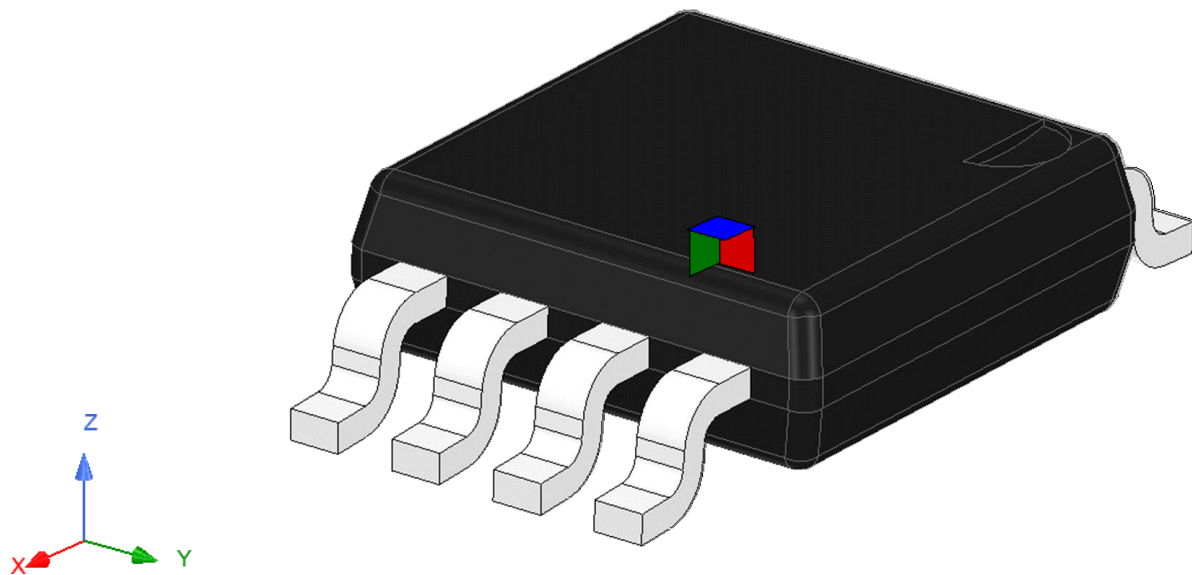
Cylindrical



Rectangular



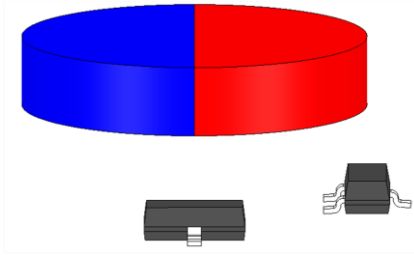
# Three-dimensional sensors



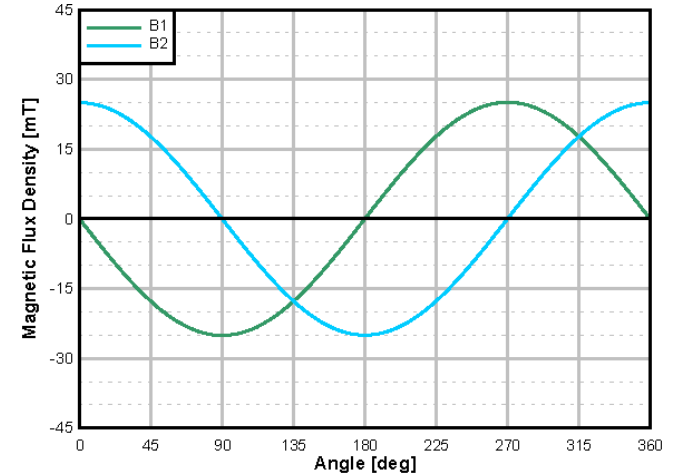
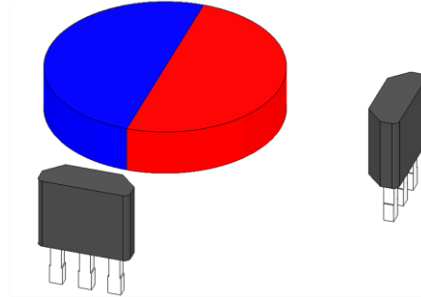


# Angle measurement using 1D linears

Sensor out-of-plane



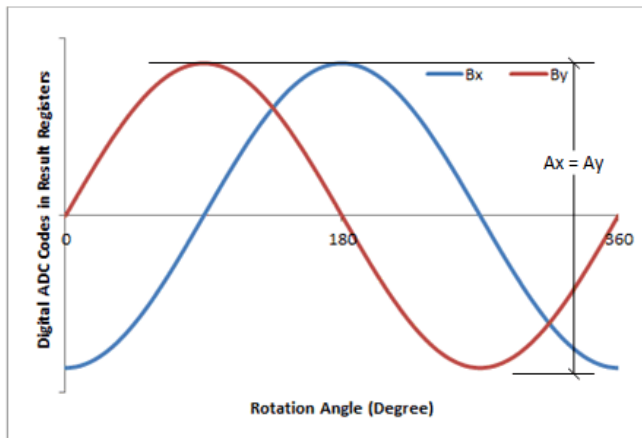
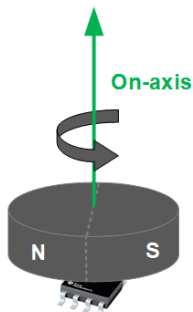
Sensor in-plane



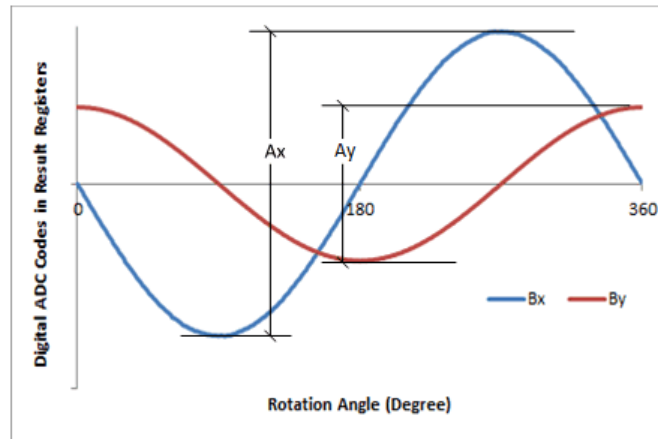
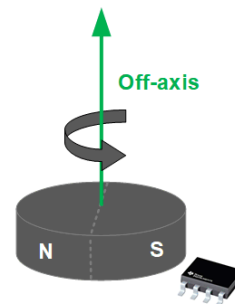
# Angle measurement using a 3D linear

TMA5170 has an integrated angle CORDIC (Coordinate rotation digital computer) calculation with gain and offset adjustment.

Perfectly aligned on-axis configuration produces ideal inputs for CORDIC calculations.



The device also supports off-axis measurements where the gain and offset compensation required to produce correct results.



# TMAG5170 high precision

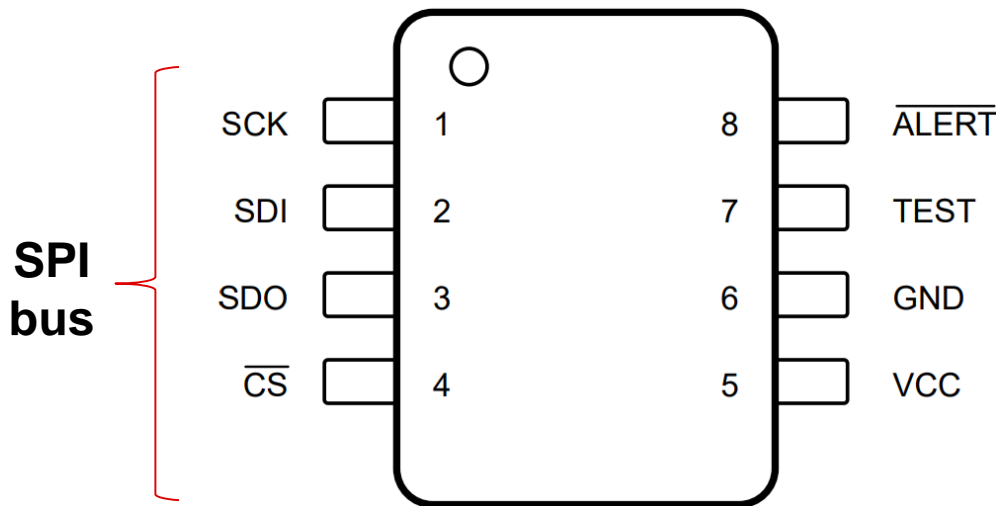
- Total linear measurement error:  $\pm 2.6\%$  (maximum at 25°C)

$$Error_{LM\_25C} = \frac{\sqrt{(B \times SENS_{ER})^2 + B_{off}^2 + N_{RMS\_25}^2}}{B} \times 100\%$$

- $B$ , input magnetic field
- $SENS_{ER}$ , sensitivity error at 25°C
- $B_{off}$ , offset error at 25°C
- $N_{RMS\_25}$ , RMS noise at 25°C

- Sensitivity drift:  $\pm 2.8\%$  (maximum)
- Conversion rate for single axis: 20-Ksps

# TMAG5170 package and pinout



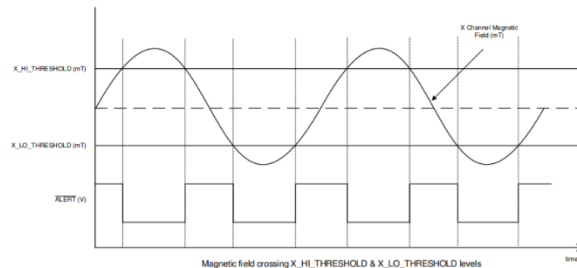
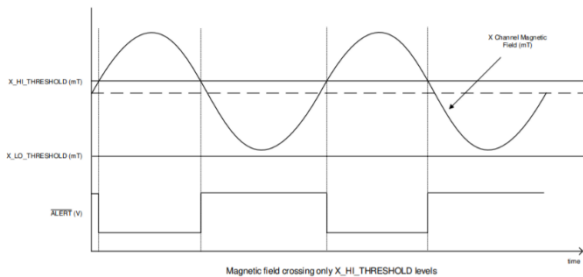
VSSOP DGK package  
(5mm × 3mm)

## Alert pin functionality:

- In low-power mode, the TMAG5170 wakes up periodically to check the system status and wakes up the MCU only if the system status changes.
- Used to trigger a new conversion
- Indicates fault detection
- Used as a magnetic switch to indicate a specific magnetic threshold has been crossed

# Programmable thresholds and tamper detection

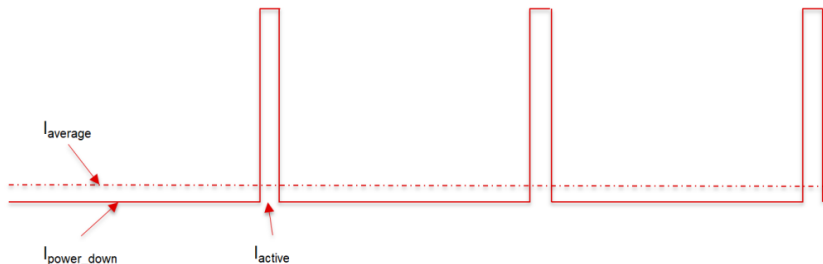
- Programmable magnetic field thresholds (high and low) to trigger ALERT
  - Independent X, Y and Z axis thresholds
  - Unused channel offers an additional input source to detect tampering or reject inputs when stray fields are present
    - Angle calculations only require two axes. The third axis may be used to trigger ALERT and force the MCU to protect the system.



- Programmable temperature threshold to trigger ALERT
- Multiple alerts can be set up simultaneously

# TMAG5170 configurability

- **Magnetic range**
  - A1:  $\pm 25\text{mT}$ ,  $\pm 50\text{mT}$ ,  $\pm 100\text{mT}$  or A2:  $\pm 75\text{mT}$ ,  $\pm 150\text{mT}$ ,  $\pm 300\text{mT}$
- **Update rate**
  - 20, 10, 5, 2.5, & 1.25-Kbps per Axis
- **Temperature compensation**
  - 0%/C, 0.03%/C (ceramic magnets), 0.12%/C (neodymium magnets), 0.2%/C (samarium magnets)
- **User-defined flexible diagnostic scheduling**
  - Option to run all the diagnostics or run only user-enabled sensor diagnostics
  - Option to run diagnostics all together or in sequence with each measurement
- **Wake-up and sleep mode**
  - 1.5, 10, 15, 20, 30, 100, 500 & 1000-ms



Wake-up duty cycle	Average current ( $I_{\text{average}}$ )
100Hz	45 $\mu\text{A}$
10Hz	5.7 $\mu\text{A}$
1Hz	1.6 $\mu\text{A}$

# TMAG5170 power modes

	Time start new measurement*	Average current	Operating mode description	Trigger mode# active	SPI bus and user registers accessible	Measurement result retained	Configuration retained
<b>Configuration mode</b> (Default at power-up)	70μs	60μA	Allows register configuration	✓	✓	✓	✓
<b>Active conversion mode</b>	10μs	3.4mA	Continuously performs magnetic field or temperature measurements	✓	✓	✓	✓
<b>Standby mode</b>	35μs	0.84mA	Ready to start a measurement by having support circuitry active for fast turn ON	✓	✓	✓	✓
<b>Wake-up and sleep mode</b>	160μs	1.5μA	Sleeps and wakes at specified intervals to take measurements		✓	✓	✓
<b>Sleep mode</b>	160μs	1.5μA	In low-power state. Wakes up upon Primary <u>CS</u> / <u>ALERT</u> assertion or via SPI bus			✓	✓
<b>Deep-sleep mode</b>	170μs	5nA	Powered-down state which is initiated by <u>CS</u> pin.				

Notes:

\* All values are typical values

# While in trigger mode, a Primary can trigger a conversion via a SPI command, ALERT pin or CS signal.

# Pseudo simultaneous sampling

Measurement process involves two steps:

1. Hall Spin & Integration
2. ADC Conversion

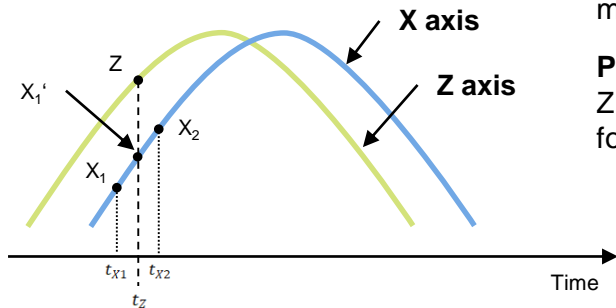
To reduce error due to constantly changing magnetic fields, pseudo simultaneous sampling will repeat first measurement to average out the difference in sample time.

Assuming that changes in B-field are linear over small intervals, this creates a result similar to both channels being sampled at the same time.

Patterns available:

- XYX
- YXY
- YZY
- ZYZ
- ZXZ
- XZX
- XYZYX
- XYZZYX

XZX pattern example:

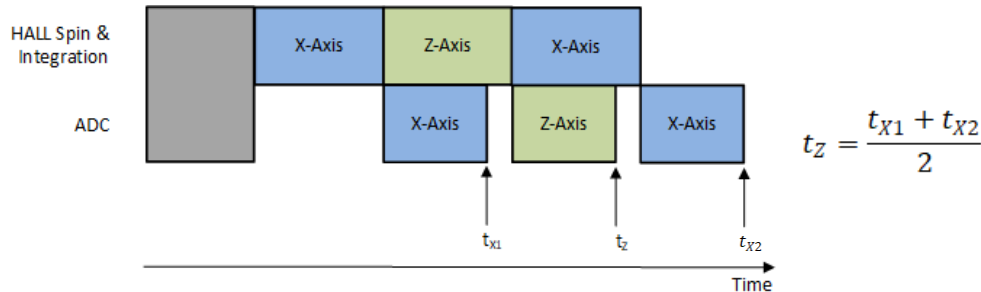


**Ideal case:**

Z and  $X_1'$  are used for angle measurement

**Pseudo simultaneous sampling:**

Z and an average of  $X_1$  and  $X_2$  used for angle measurement





# TMAG5170 diagnostics



## **Device level checks**

- Reliable communication check
- Internal memory and register checks
- Signal-path diagnostics
- Per-axis Hall-sensor diagnostics

## **System level checks**

- Pin continuity
- Magnetic field outside range
- System temperature outside range
- External supply outside range

## **Device error communication methods**

- Register flags read via SPI
- Device status in SPI response
- ALERT pin (optional)
- No response or CRC error in SPI communication

# Example applications

## Angle measurement

### HMI knobs



## 3D absolute position

### Joysticks



## Motor/Magnetic encoder



## 3D slide-by displacement

### Linear movers and actuators



# TMAG5170UEVM

3-Axis linear Hall-effect sensor EVM with **SPI** output interface

Available on [ti.com](https://www.ti.com)

## Features

- Snap Apart PCB for evaluation of both TMAG5170A1 and TMAG5170A2 sensitivities
- TI sensor control board (SCB) included to interface the EVM with the GUI using an MSP432 microcontroller
- GUI support to read and write device registers, as well as view and save measurement results
- 3D print rotate and push module
- Detachable EVM for custom use cases
- Conveniently powered from a common micro-USB connector
- Read GUI register settings for configuration, status and results:
  - CONFIG:
    - DEVICE, SENSOR, SYSTEM, ALERT, X, Y & Z MAGNETIC THRESHOLD, TEMPERATURE THRESHOLD, TEST, MAG\_GAIN, and MAG\_OFFSET
  - STATUS:
    - CONV, AFE, SYS, OSC\_MONITOR
  - RESULTS:
    - X, Y & Z CHANNEL, TEMPERATURE, ANGLE, MAGNITUDE

## Applications

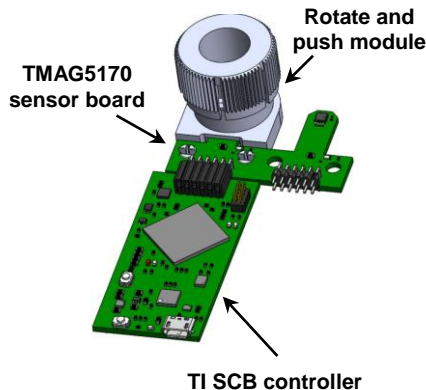
- Lever position measurement
  - Stalk gear shifters, turn signals
  - Industrial joysticks
- Angle measurement
  - e-Shifters knob, electronic power steering, braking systems, steering wheel control, steering angle sensor
  - Magnetic encoder, robotic arm, AGV/AMR wheels, valve positioner, appliance multifunction knobs – cooking top, oven, washer and dryer
- Linear movement
  - Actuators, fluid measurement, factory automation linear mover
- Ambient Current Sensing
  - HEV/ EV
  - Isolated AC motor drive

## Benefits

- Ability to test and monitor X, Y, and Z magnetic fields with 3D knob
- Freedom to position a particular magnet without 3D knob
- Selectable sensitivity ranges allows last minute design adjustments
- GUI allows real-time viewing of measured results



TMAG5170EVM



Check out our EVM unboxing video!

Register Map

Register Name	Address	Value
CONFIG	0x00	0x0000
STATUS	0x01	0x0000
RESULTS	0x02	0x0000

GUI mapping

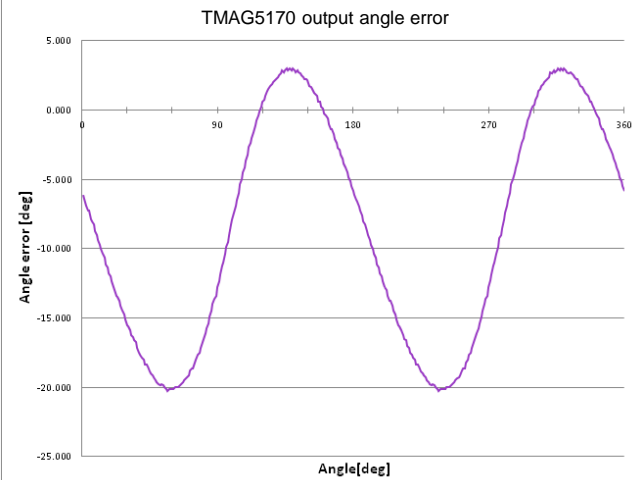
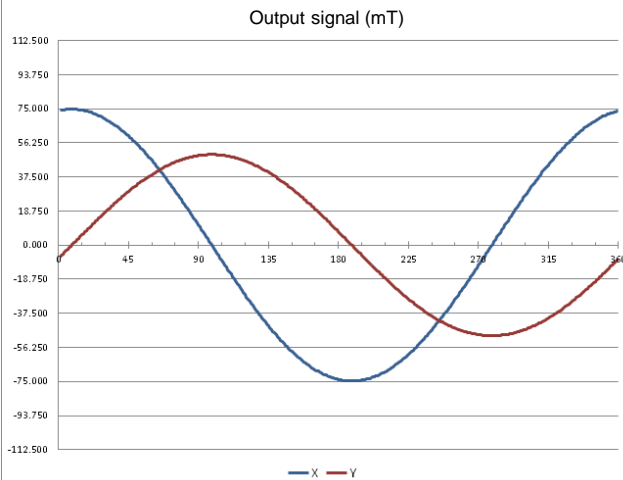
Register Name	Address	Value
CONFIG	0x00	0x0000
STATUS	0x01	0x0000
RESULTS	0x02	0x0000

# Angle calculator tool



## TMAG5170 – 2D angle error calculator

B <sub>x</sub> Peak		75	mT
B <sub>y</sub> Peak		50	mT
Channel			
Device Settings	Input Range	100	100 mT
	Output Target	75%	of FS
	Single Channel Latency	25	us
	CONV_AVG Register Code	101	32 Samples
	Rotation Speed	10	Hz
	Rotation Speed (RPM)	600	RPM
	Sampling Mode	XYZZYX	
	X - Offset Correction	OFF	0
	Y - Offset Correction	OFF	0
	Channel Gain Attenuation	OFF	342
Sensitivity Error		0.0%	0.0%
Offset Error		0	0 mT
Phase Lag error		17.28	deg
Rotational Latency		0.05	Cycles
Input Referred Noise,rms		0.025	0.025 mTrms



Design tools & simulation



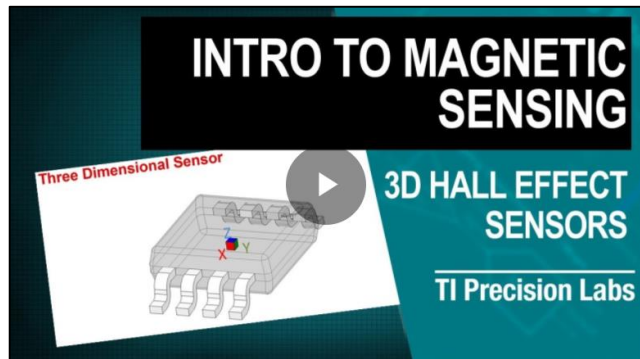
CALCULATION TOOL

TMAG5170 2D Angle Error Calculator

SBAR012.ZIP (197 KB)

Download

# Additional resources



## How 3D Hall-effect sensors deliver precise, real-time position control to autonomous systems



Kevin Robins Oct 11, 2021

Other Parts Discussed in Post: TMAG5170

As Industry 4.0 spreads advanced manufacturing processes across global markets, demand for highly automated systems that operate with an integrated manufacturing flow and constantly collect process control data is increasing drastically. Most of these systems – including magnetic encoders in robotic arms, proximity sensors, actuators, pressure transmitters, linear motors and autonomous mobile robots – require advanced position-sensing solutions to control performance and collect factory-level data for better decision-making and safer, more reliable operation of equipment.

Autonomous mobile robots like those shown in Figure 1 automate menial tasks, such as transporting materials throughout a warehouse. These industrial robots help optimize manufacturing flows, increase throughput and improve productivity. To safely and efficiently navigate a factory or warehouse floor, an autonomous mobile robot must incorporate high-precision system controls such as position sensing and speed control within the wheels.

### Application Brief

## Measuring 3D Motion With Absolute Position Sensors

Scott Bryson

### Introduction

The ability to monitor the motion of a system and provide feedback for mechanical precision and quality of any motion being tracked with feedback, a variety of sensors can be used.

When Hall effect sensors position encoding become capable of detecting motion in almost any environment, a new class of three-dimensional solutions.

Of particular interest, 3D sensors provide a unique ability to provide complete magnetic field position detection for applications such as linear position modules and gear shifters as a few examples.

### Magnet in Free Space

When considering a 3D magnet in free space, the immediate thought is the space about the sensor monitored. If we consider the magnetic field at a point, we can quickly deduce positions that could produce that field.

As a result, this function in order to successfully monitor a magnet's position. Any dipole magnet might produce a magnetic field, but a sensor will produce a challenge, however, is magnetic flux density of motion of the magnet.

### Application Report

## Angle Measurement With Multi-Axis Linear Hall-Effect Sensors

As the demand for automation that are more reliable and detection of angular rotation new class of three-dimensional solutions.

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### Technical White Paper

## Improve System Performance With Linear 3D Hall-Effect Position Sensors



Manny Soltero, Gloria Kim

### ABSTRACT

As Industry 4.0 continues to grow and evolve, market demand for higher levels of automation in traditional manufacturing and industrial equipment is increasing. To ensure system-level accuracy and reliability, many of these applications require absolute position measurements.

There are multiple factors to consider when selecting the right position measurement technology for a particular application, most notably measurement accuracy, object speed, power requirements, calibration needs, flexibility to support a variety of configurations, and reliability. This white paper covers these system-level design challenges and considerations, and explains how a linear 3D Hall-effect position sensor can solve them with a high level of performance.

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