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Texas Instruments New Product Update

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- Phone lines will be muted
- Please post questions in the chat or contact your sales person or field applications engineer

Linear 3D Hall-effect sensor: TMAG5170

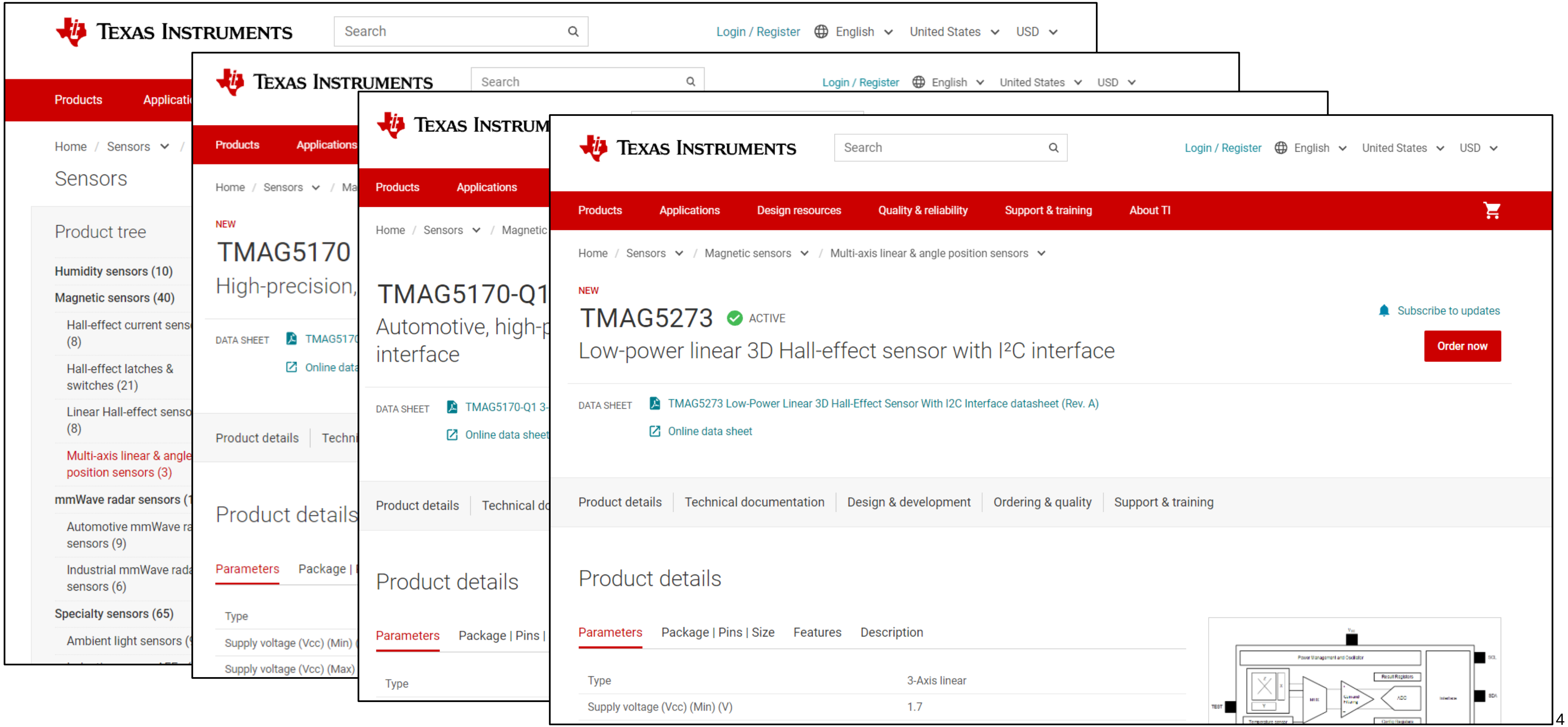
Gloria Kim

October 28th, 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

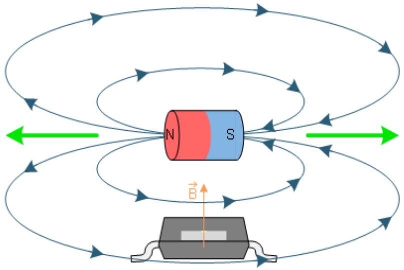


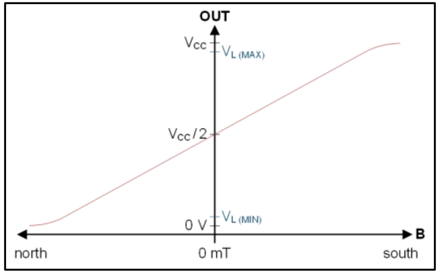
Single-axis linear Hall-effect sensor operation

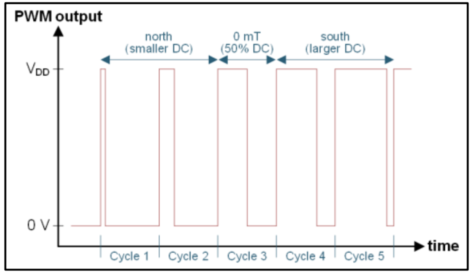
Linear Hall-effect sensor

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

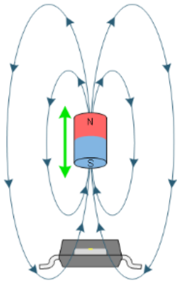
Bipolar

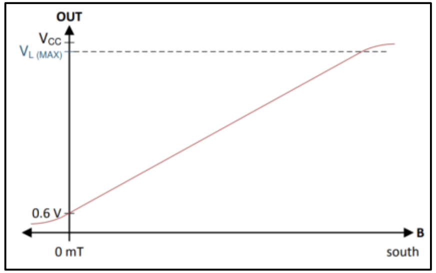






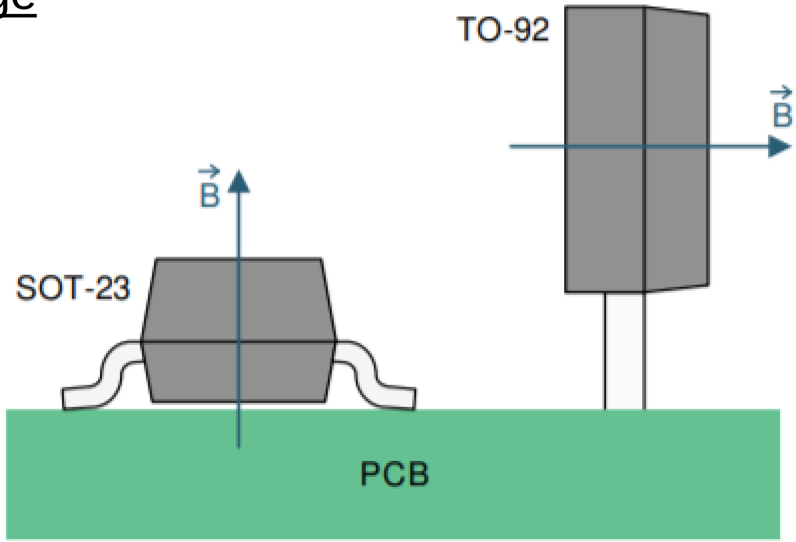
Unipolar



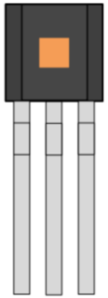


Single-axis linear direction of sensitivity

Surface-mount package

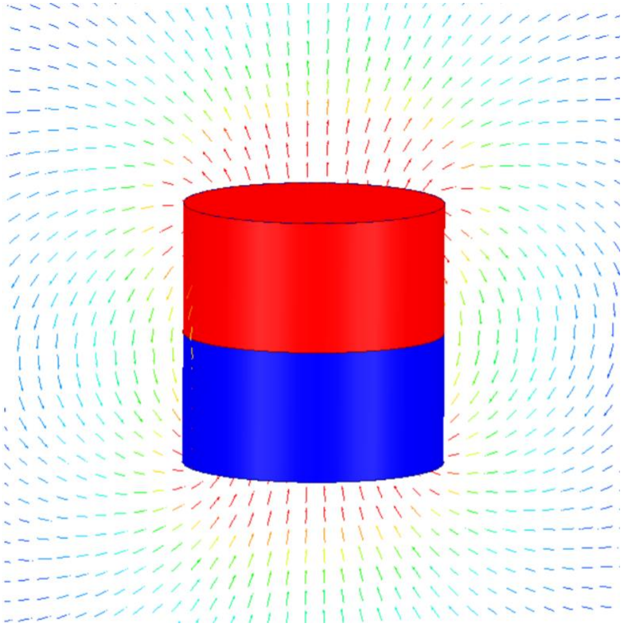


Through-hole package

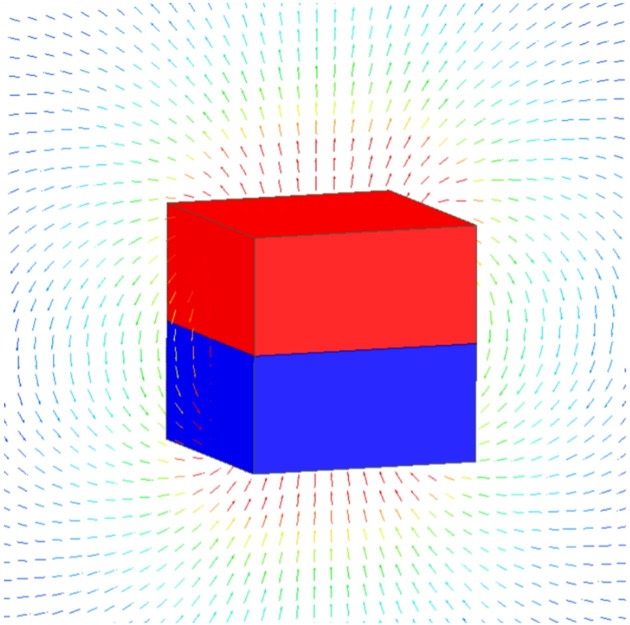


Magnetic field vectors

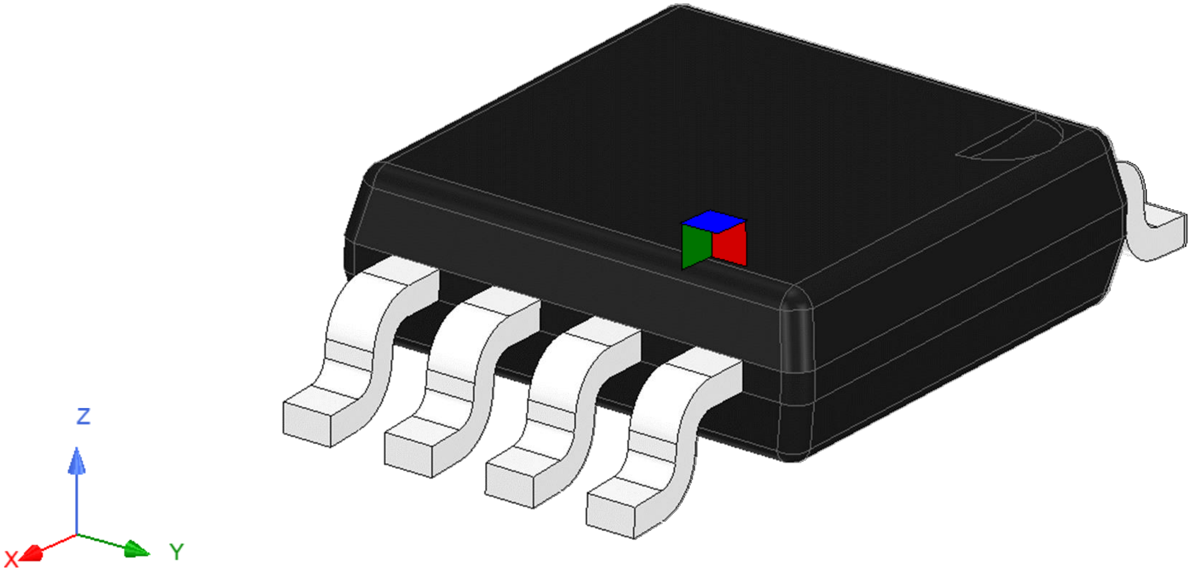
Cylindrical



Rectangular

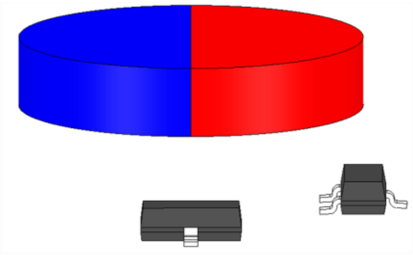


Three-dimensional sensors

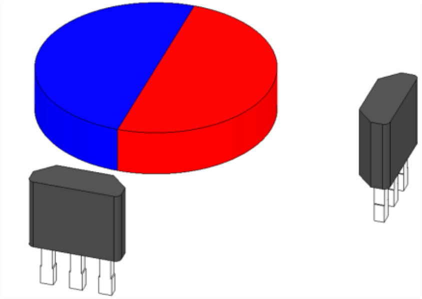


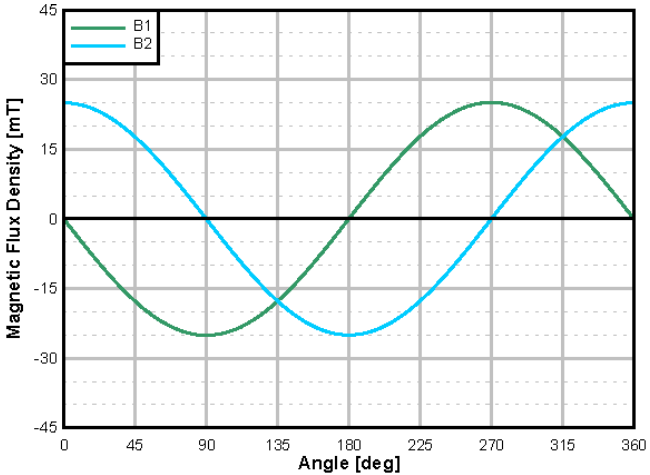
Angle measurement using 1D linears

Sensor out-of-plane



Sensor in-plane

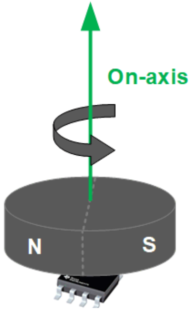


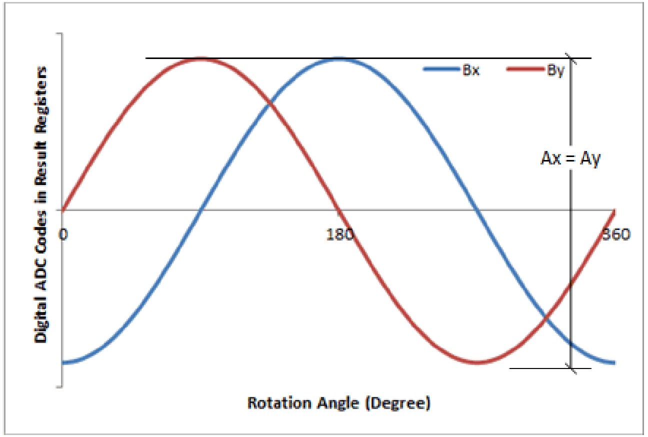


Angle measurement using a 3D linear

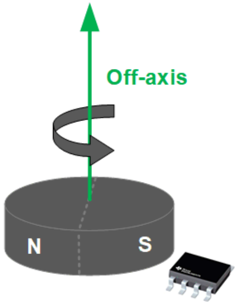
TMAG5170 has an integrated angle CORDIC (Coordinate rotation digital computer) calculation with gain and offset adjustment.

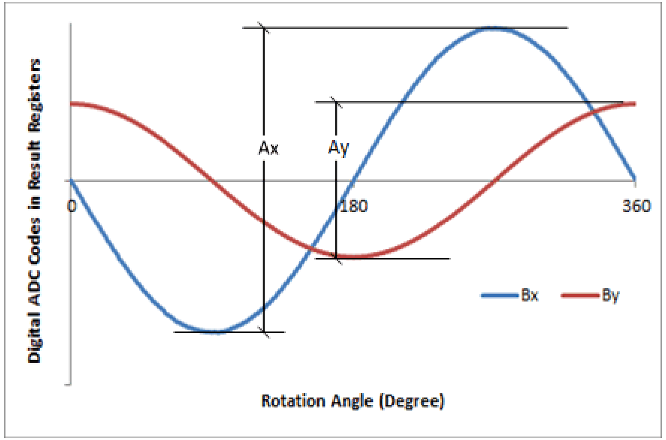
Perfectly aligned on-axis configuration produces ideal inputs for CORDIC calculations.





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: ±2.6% (maximum at 25°C)

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

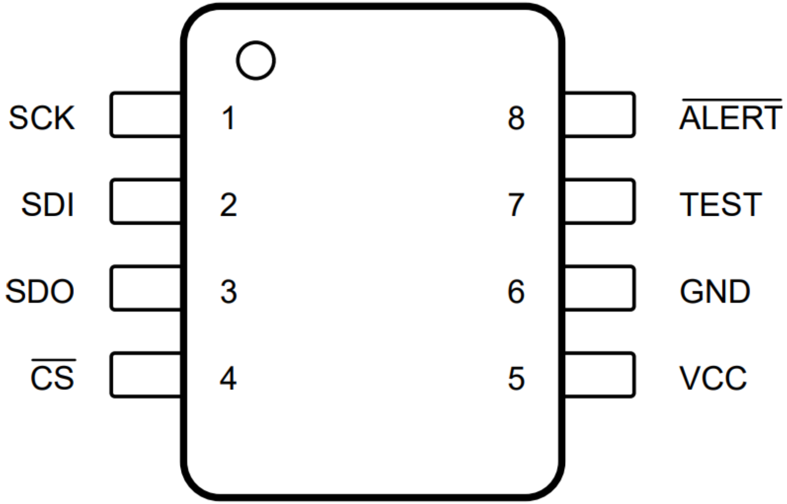
- B, input magnetic field
- $SENS_{ER}$, sensitivity error at 25°C
- B_{off}, offset error at 25°C
- N_{RMS_25}, RMS noise at 25°C

- Sensitivity drift: ±2.8% (maximum)

- Conversion rate for single axis: 20-Ksps

TMAG5170 package and pinout

SPI bus



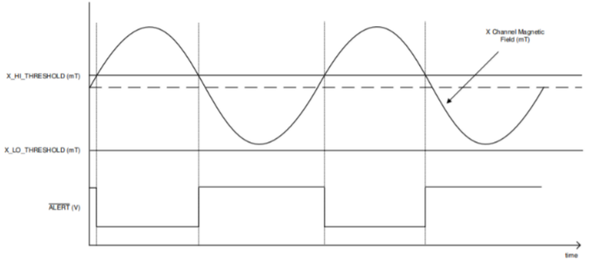
VSSOP DGK package
(5mm × 3mm)

Alert pin functionality:

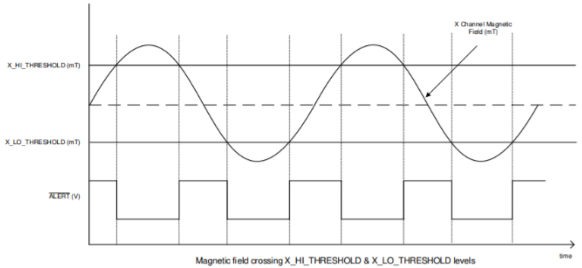
- In *low-power mode*, the TMAG5170 wakes up periodically to check the system status and wakes up the MCU only if the system status changes.
- Used to *trigger* a new conversion
- Indicates *fault detection*
- Used as a *magnetic switch* to indicate a specific magnetic threshold has been crossed

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.



Magnetic field crossing only X_HI_THRESHOLD levels

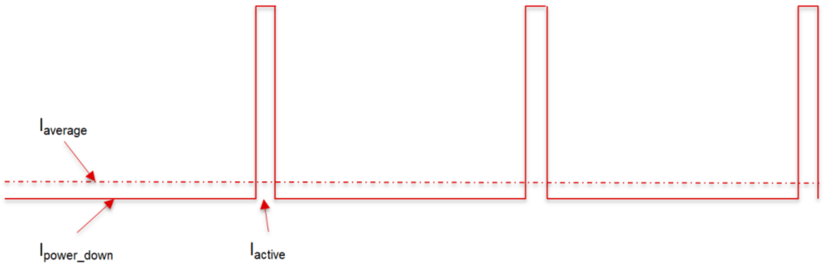


Magnetic field crossing X_HI_THRESHOLD & X_LO_THRESHOLD levels

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

TMAG5170 configurability

- **Magnetic range**
  - A1: ±25mT, ±50mT, ±100mT or A2: ±75mT, ±150mT, ±300mT
- **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 ($I_{average}$)
100Hz	45µA
10Hz	5.7µA
1Hz	1.6µA

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

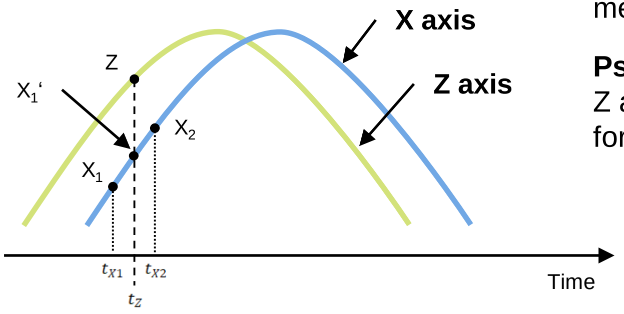
To reduce error due to constantly changing magnetic fields, pseudo simultaneous sampling will repeat first measurement to average out the difference in sample time.

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:

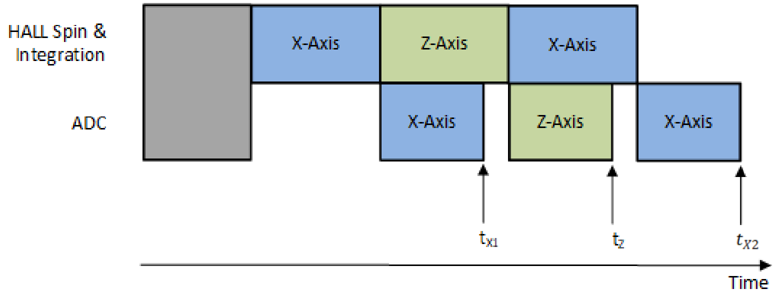
- XYX
- YXY
- YZY
- ZYZ
- ZXZ
- XZX
- XYZYX
- XYZZYX

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



$$t_Z = \frac{t_{X1} + t_{X2}}{2}$$

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

Motor/Magnetic encoder

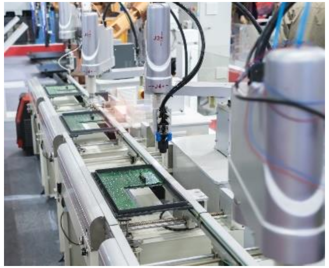


3D absolute position

Joysticks

3D slide-by displacement

Linear movers and actuators



TMAG5170UEVM

Available on ti.com

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

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

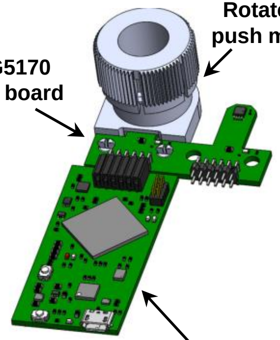
- Lever position measurement
  - Stalk gear shifters, turn signals
  - Industrial joysticks
- Angle measurement
  - e-Shifter knob, electronic power steering, braking systems, steering wheel control, steering angle sensor
  - Magnetic encoder, robotic arm, AGV/AMR wheels, valve positioner, appliance 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

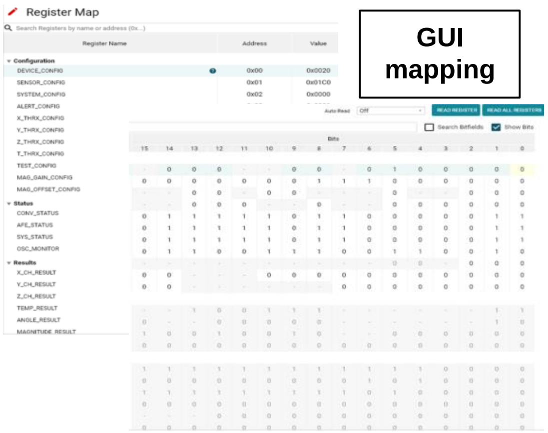
Check out our EVM unboxing video!



Rotate and push module

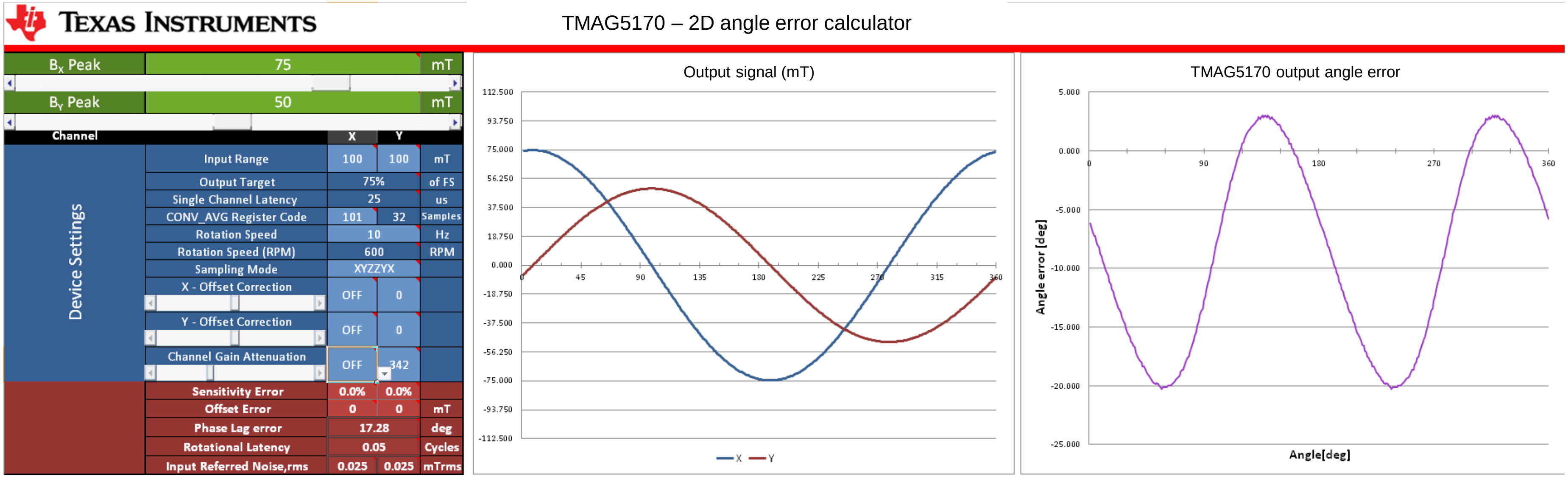
TMAG5170 sensor board

TI SCB controller



GUI mapping

Angle calculator tool



Design tools & simulation

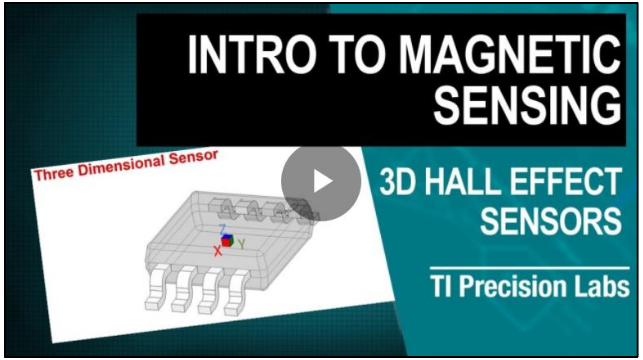
CALCULATION TOOL

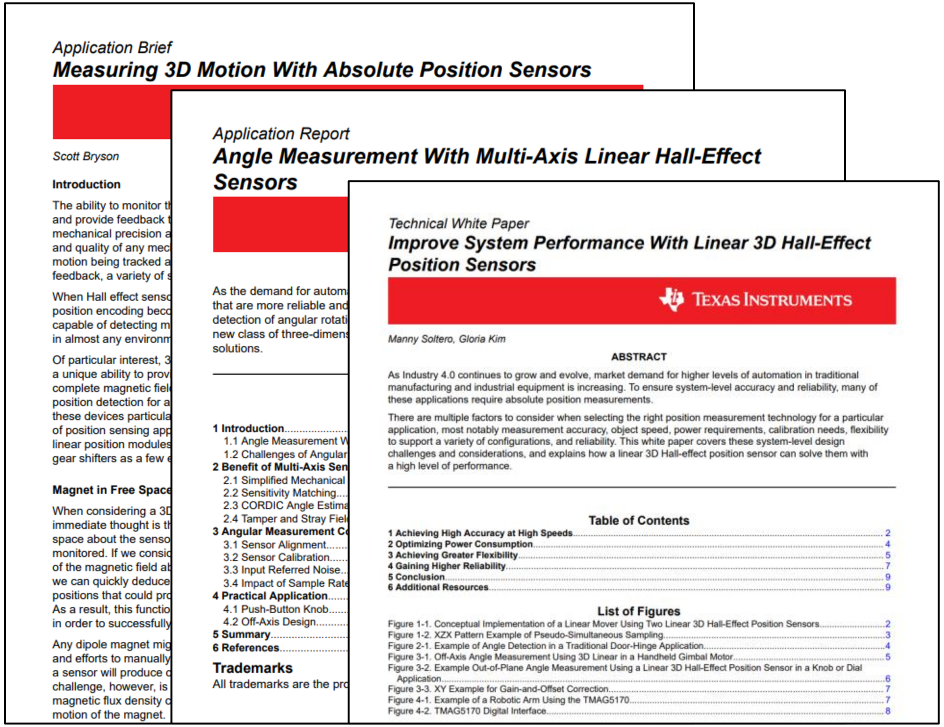
TMAG5170 2D Angle Error Calculator

SBAR012.ZIP (197 KB)

Download

Additional resources





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

Kevyn 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.

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