TMAG5253 Low-Power Linear Hall Effect Sensor With EN Pin in Ultra-Small Package

1 Features

- Industry-leading low power:
  - Supply voltage, V_{CC}: 1.65V – 3.6V
  - Shutdown current: < 20nA (1.8V at 25°C)
  - Active current: 2mA (1.8V at 25°C)
  - Average current: <10µA at 100Hz duty cycling
- Dedicated enable pin
- Fast power-on time: < 25µs
- Ratiometric analog output proportional to V_{CC}
- High impedance output during shutdown mode
- Low-noise output with ±1mA drive
- Bipolar sensitivity option to support both positive and negative magnetic fields
- Magnetic sensitivity range options:
  - A1: ±20mT Range
  - A2: ±40mT Range
  - A3: ±80mT Range
  - A4: ±160mT Range
- Sensitivity compensation to support temperature drift of Neodymium magnet
- Ultra-small X2SON 4-pin package: 1.54mm^2
- Wide operating temperature range: –40°C to 125°C

2 Applications

- Gaming controller & peripherals
- Magnetic proximity sensor
- Mobile robot motor control
- Cordless power tools
- Vacuum robots
- Drone payload control

3 Description

The TMAG5253 is a low-power linear Hall effect sensor that responds proportionally to magnetic flux density. The device features an enable pin to enter ultra-low power (nA) shutdown mode. The TMAG5253 features a fast start-up time (< 25µs) designed for low-power position sensing applications. The device is available in an industry-leading 1.54mm^2 ultra-small footprint for space-constrained applications. The device has a wide supply range and can operate from 1.65V to 3.6V.

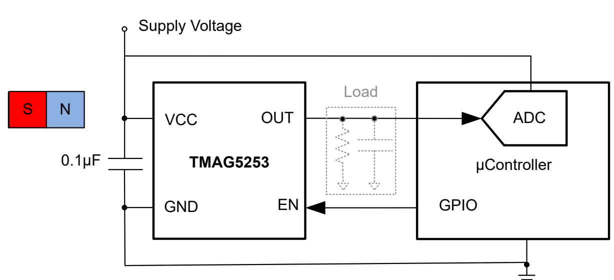
Magnetic flux perpendicular to the top of the package is sensed by the device and the TMAG5253 is available in bipolar sensitivity polarity option, where the north and south magnetic poles produce unique output voltages. The output changes linearly with the applied magnetic flux density, and four sensitivity options enable maximal output voltage swing based on the required sensing range.

The device uses a ratiometric architecture that can eliminate error from V_{CC} tolerance when the external analog-to-digital converter (ADC) uses the same V_{CC} for its reference. Additionally, the device features magnet temperature compensation to counteract the magnetic sensitivity drifts across a wide –40°C to 125°C temperature range. The device also features the ability to place the output in a high impedance state during shutdown mode. This enables multiple devices to be connected to a single ADC.

Package Information (1)

PART NUMBER	PACKAGE	PACKAGE SIZE(2)
TMAG5253	DMR (X2SON. 4)	1.40mm × 1.10mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Schematic

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4 Device Comparison

Table 4-1. Device Comparison

ORDERABLE	MAGNETIC RESPONSE TYPE	MINIMUM LINEAR MAGNETIC SENSING RANGE (mT)	TYPICAL SENSITIVITY TEMPERATURE COEFFICIENT (%/°C)
TMAG5253BA1	Bipolar	±20	0.12
TMAG5253BA2	Bipolar	±40	0.12
TMAG5253BA3	Bipolar	±80	0.12
TMAG5253BA4	Bipolar	±160	0.12
TMAG5253UA3IQDMRR	Unipolar	+100	0.12

5 Pin Configuration and Functions

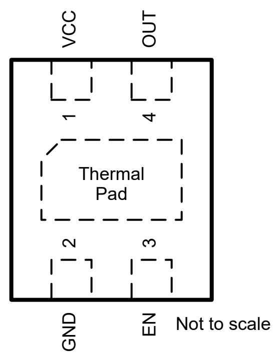


Figure 5-1. DMR Package 4-Pin X2SON Top View

Table 5-1. Pin Functions

PIN		TYPE[(1)]	DESCRIPTION
NAME	X2SON		
V_{CC}	1	P	Power supply. TI recommends connecting this pin to a ceramic capacitor to ground with a value of at least 0.1 µF.
GND	2	G	Ground reference
EN	3	I	Enable pin
OUT	4	O	Analog output
Thermal Pad	5	NC	No connect. This pin should be left floating or tied to ground. The pin should be soldered to the board for mechanical support.

(1) I = Input, O = Output, I/O = Input and Output, G = Ground, P = Power, NC = No Connect

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

		MIN	MAX	UNIT
Power supply voltage	V_{CC}	–0.3	5.5	V
Output voltage	OUT	–0.3	V_{CC} + 0.3	V
Magnetic flux density, B_{MAX}		Unlimited		T
Operating junction temperature, T_J		–40	125	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Operation outside theAbsolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2000	V
		Charged-device model (CDM), per JEDEC specification ANSI/ESDA/JEDEC JS-002[2]	±750	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_{CC}	Power supply voltage[1]	1.65	3.6	V
C_L	Load capacitance on OUT pin		1	nF
I_O	Output continuous current	–1	1	mA
T_A	Operating ambient temperature[2]	–40	125	°C

(1) These are recommended supply ranges. For more details refer to *Operating Vcc Ranges* section
(2) Power dissipation and thermal limits must be observed.

6.4 Thermal Information

THERMAL METRIC[1]		TMAG5253	UNIT
		DMR(X2SON)	
		4 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	157.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	110.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	105	°C/W
Y_{JT}	Junction-to-top characterization parameter	2.4	°C/W
Y_{JB}	Junction-to-board characterization parameter	101.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-board (bottom) thermal resistance	85.7	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

for V_{CC} = 1.65 V to 3.6 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)		MIN	TYP	MAX	UNIT
I_{CC_ACTIVE}	Operating supply current	EN > V_{IH}	VCC = 1.8 V		2	3.3	mA
			VCC = 3.3 V		2.6	5	
I_{CC_SHDN}	Shutdown current	VCC = 3.3 V, EN < V_{IL}			8		nA
t_{ON}	Power-on time	VCC > VCC(min)			20	45	µs
VCC_{ramp}	VCC ramp rate	T = 25 C		0.001		1	V / µs
V_{IH}	Input high voltage for EN pin			0.65 × V_{CC}			V
V_{IL}	Input low voltage for EN pin					0.35 × V_{CC}	V
V_{hys}	Input hysteresis voltage for EN pin			0.1 × V_{CC}			V
f_{BW}	Sensing bandwidth (-3 dB)	Rload = 100 KΩ, Cload=100 pF			15		kHz
R_{OUT}	DC output resistance	EN > V_{IH}			1.27		Ω
R_{OUT}	DC output resistance	EN < V_{IL}			9		MΩ

(1) B is the applied magnetic flux density.

6.6 Magnetic Characteristics

for V_{CC} = 1.65 V to 3.6 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)		MIN	TYP	MAX	UNIT
V_Q	Quiescent voltage	B = 0 mT, T_A = 25°C	V_{CC} = 3.3 V, TMAG5253BA1	1.585	1.65	1.715	V
			V_{CC} = 3.3 V, TMAG5253BA2	1.61	1.65	1.69	
			V_{CC} = 3.3 V, TMAG5253BA3	1.61	1.65	1.69	
			V_{CC} = 3.3 V, TMAG5253BA4	1.61	1.65	1.69	
			V_{CC} = 1.8 V, TMAG5253BA1	0.845	0.9	0.945	
			V_{CC} = 1.8 V, TMAG5253BA2	0.850	0.9	0.940	
			V_{CC} = 1.8 V, TMAG5253BA3	0.850	0.9	0.940	
			V_{CC} = 1.8 V, TMAG5253BA4	0.870	0.9	0.930	
$V_{QΔT}$	Quiescent voltage temperature drift	B = 0 mT	V_{CC} = 3.3 V, T_A = 0°C to 85°C versus 25°C , TMAG5253B	-30		30	mV
			V_{CC} = 3.3 V, T_A = -40°C to 125°C versus 25°C , TMAG5253B	-50		50	mV
			V_{CC} = 1.8 V, T_A = 0°C to 85°C versus 25°C , TMAG5253B	-25		25	mV
			V_{CC} = 1.8 V, T_A = 0°C to 50°C versus 25°C, TMAG5253BA4	-5		5	mV
			V_{CC} = 1.8 V, T_A = -40°C to 125°C versus 25°C , TMAG5253B	-35		35	mV
V_{QRE}	Quiescent voltage ratiometry error(2)	TMAG5253B/U			±0.2		%

for V_{CC} = 1.65 V to 3.6 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS[1]		MIN	TYP	MAX	UNIT
$V_{Q\Delta L}$	Quiescent voltage lifetime drift	V_{CC} = 3.3 V, High-temperature operating stress for 1000 hours			10		mV
S	Sensitivity	V_{CC} = 3.3 V, T_A = 25°C	TMAG5253BA1	51	60	69	mV/mT
			TMAG5253BA2	25.5	30	34.5	
			TMAG5253BA3	12.75	15	17.25	
			TMAG5253BA4	6.37	7.5	8.62	
		V_{CC} = 1.8 V, T_A = 25°C	TMAG5253BA1	25.5	30	34.5	
			TMAG5253BA2	13.6	16	18.4	
			TMAG5253BA3	6.9	8.12	9.33	
			TMAG5253BA4	3	3.5	4.0	
B_L	Linear magnetic sensing range[3] [4]	V_{CC} = 3.3 V	TMAG5253BA1	±20			mT
			TMAG5253BA2	±40			
			TMAG5253BA3	±80			
			TMAG5253BA4	±160			
		V_{CC} = 1.8 V	TMAG5253BA1	±20			
			TMAG5253BA2	±40			
			TMAG5253BA3	±80			
			TMAG5253BA4	±160			
V_L	Linear range of output voltage[4]	TMAG5253U		V_Q		V_{CC} – 0.2	V
V_L	Linear range of output voltage[4]	TMAG5253B		0.2		V_{CC} – 0.2	V
S_{TC}	Sensitivity temperature coefficient[5]	TA = -40°C to 125°C versus 25°C	TMAG5253UA, TMAG5253BA	0.04	0.12	0.2	%/°C
S_{LE}	Sensitivity linearity error[4]	V_{OUT} is within V_L			±0.1	±0.55	%
S_{SE}	Sensitivity symmetry error[4]	V_{OUT} is within V_L	TMAG5253B/U		±0.1		%
S_{RE}	Sensitivity ratiometry error[2]	T_A = 25°C, V_{CC} = 1.65 V -1.9 V , with respect to V_{CC} = 1.8V		–2		2	%
		T_A = 25°C, V_{CC} = 3 V - 3.6 V , with respect to VCC = 3.3 V		–3		3	%
$S_{\Delta L}$	Sensitivity lifetime drift	High-temperature operating stress for 1000 hours			0.5		%
B_{ND}	Input-referred RMS noise density	V_{CC} = 3.3 V , Cload=100 pF			220		nT/√Hz
		V_{CC} = 1.8V , Cload=100 pF			400		
B_N	Input-referred peak-to-peak noise	B_{ND} × 6.6 × $\sqrt{f_{BW}}$, Cload = 100 pF	V_{CC} = 3.3 V		0.17		mT_{PP}
			V_{CC} = 1.8 V		0.35		
V_N	Output-referred peak-to-peak noise	B_N × S , VCC=3.3 V, BW = 15 kHz	TMAG5253BA1		9.2		mV_{PP}
			TMAG5253BA2		4.6		
			TMAG5253BA3		2.3		
			TMAG5253BA4		1.2		

(1) B is the applied magnetic flux density.
(2) Refer to the *Ratiometric Architecture* section
(3) B_L describes the minimum linear sensing range at 25°C taking into account the maximum V_Q and Sensitivity tolerances.
(4) Refer to the *Sensitivity Linearity* section
(5) S_{TC} describes the rate the device increases Sensitivity with temperature. For more information, see the *Magnetic Response* section.

6.7 Typical Characteristics

T_A = 25°C (unless otherwise noted)

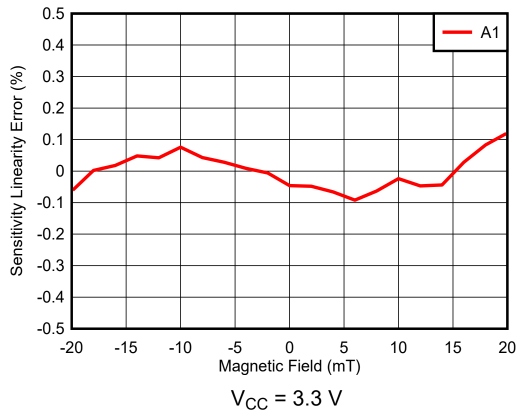


Figure 6-1. TMAG5253BA1 Sensitivity Linearity Error vs Magnetic Field

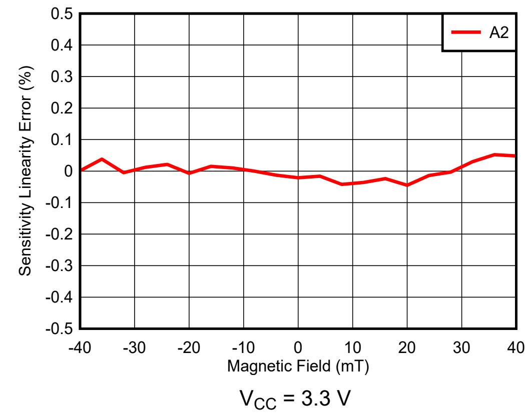


Figure 6-2. TMAG5253BA2 Sensitivity Linearity Error vs Magnetic Field

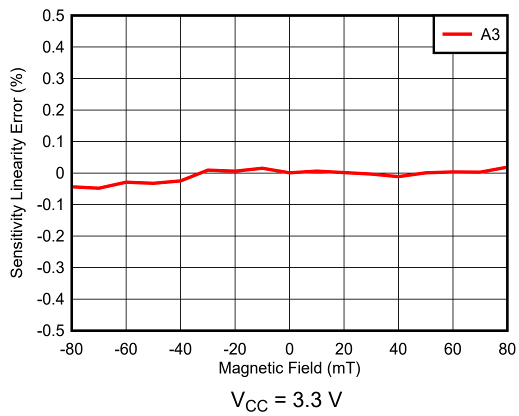


Figure 6-3. TMAG5253BA3 Sensitivity Linearity Error vs Magnetic Field

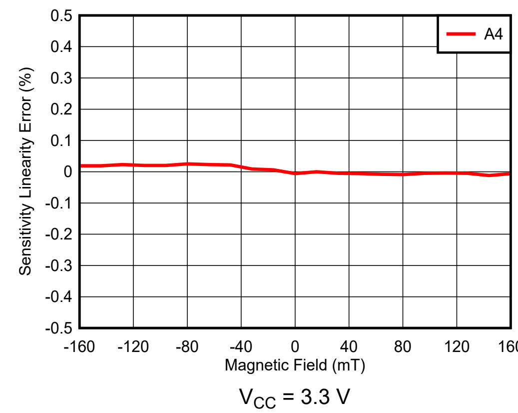


Figure 6-4. TMAG5253BA4 Sensitivity Linearity Error vs Magnetic Field

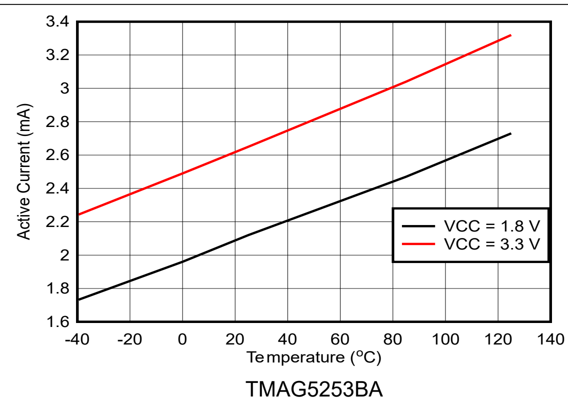


Figure 6-5. TMAG5253BA Active Current vs Temperature

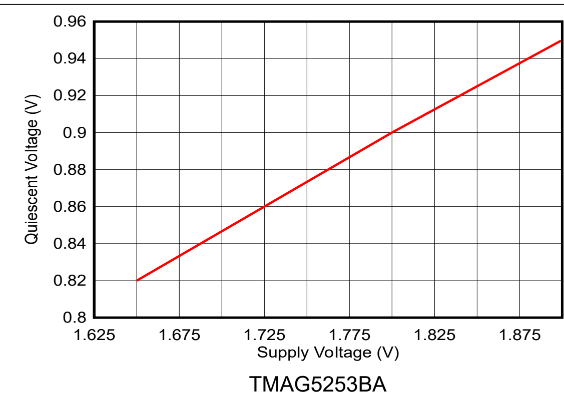


Figure 6-6. TMAG5253BA Quiescent Voltage vs Supply Voltage

6.7 Typical Characteristics (continued)

T_A = 25°C (unless otherwise noted)

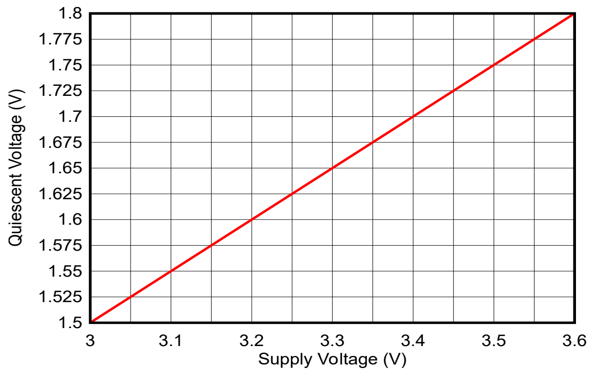
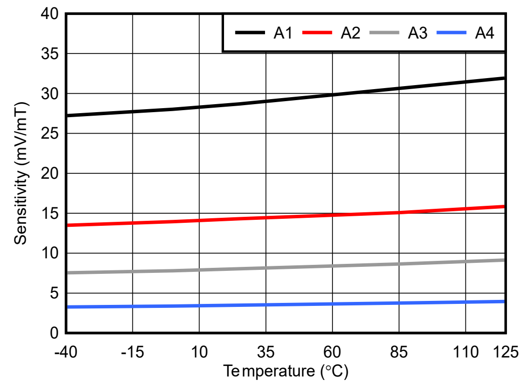
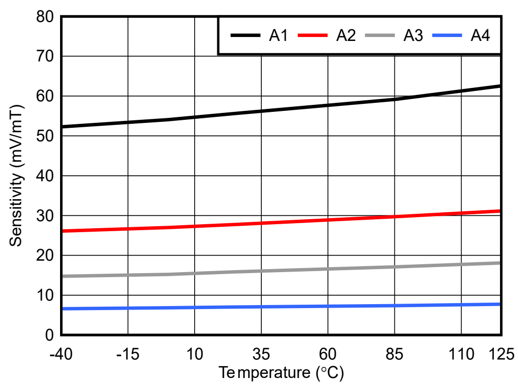


Figure 6-7. TMAG5253BA Quiescent Voltage vs Supply Voltage



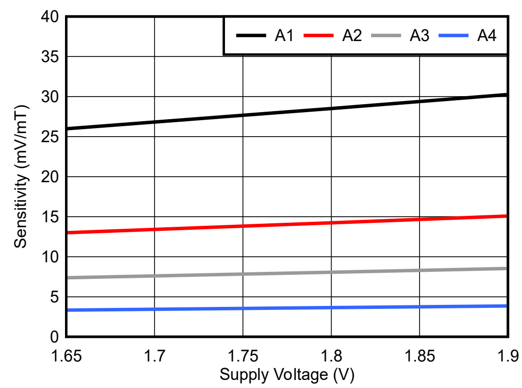
V_{CC} = 1.8 V

Figure 6-8. TMAG5253BA Sensitivity vs Temperature



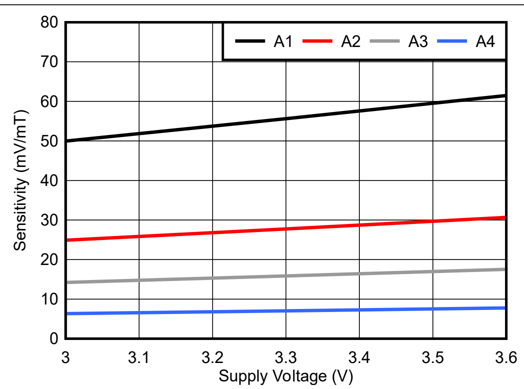
V_{CC} = 3.3 V

Figure 6-9. TMAG5253BA Sensitivity vs Temperature



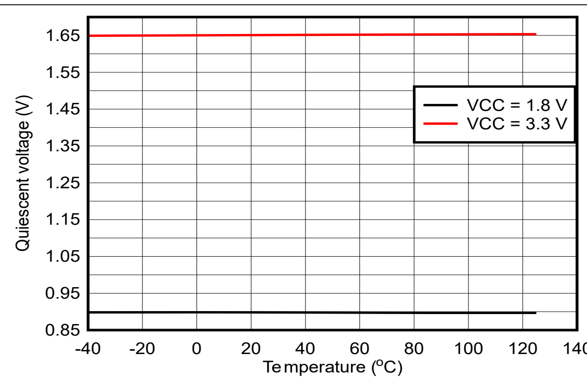
V_{CC} = 1.8 V ±10%

Figure 6-10. TMAG5253BA Sensitivity vs Supply Voltage



V_{CC} = 3.3V ±10%

Figure 6-11. TMAG5253BA Sensitivity vs Supply Voltage



TMAG5253BA

Figure 6-12. TMAG5253BA Quiescent Voltage vs Temperature

7 Parameter Measurement Information

7.1 Sensitivity Linearity

The device produces a linear response when the output voltage is within the specified V_L range. Outside this range, sensitivity is reduced and nonlinear. Figure 7-1 shows the linearity of the magnetic response for bipolar version.

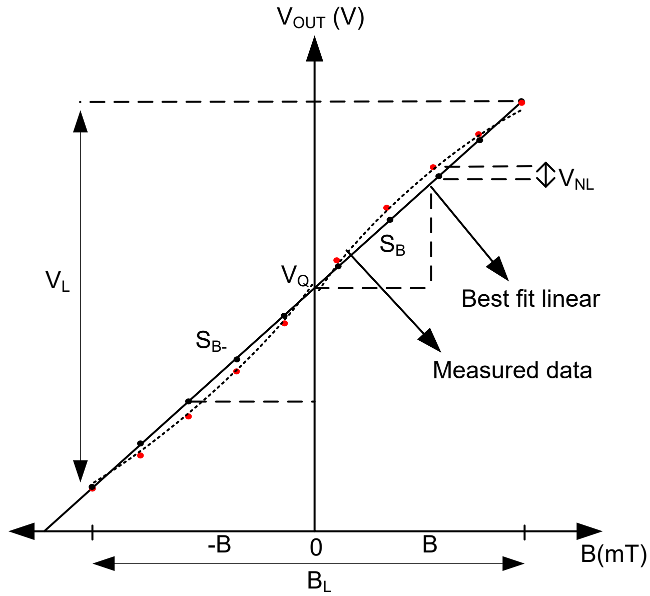


Figure 7-1. Linearity of the Magnetic Response (Bipolar)

Equation 1 calculates parameter B_L, the minimum linear sensing range at 25°C, and takes the maximum quiescent voltage and sensitivity tolerance into account.

$$B_{L(MIN)} = \frac{V_{L(MAX)} - V_{Q(MAX)}}{S_{(MAX)}} \tag{1}$$

Nonlinearity is the deviation of the output voltage from a linear relationship to the input current. Nonlinearity voltage, as shown in Figure 7-1, is the maximum voltage deviation from the best-fit line based on measured parameters (see Equation 2).

$$V_{NL} = V_{OUT} - \left(B_{IN} \times S_{FIT} + V_Q\right) \tag{2}$$

where

- V_{OUT} is the voltage output at maximum deviation from best fit
- B_{IN} is the magnetic flux density at maximum deviation from best fit
- S_{FIT} is the best fit sensitivity of the device
- V_Q is quiescent voltage at zero magnetic field = $V_{CC}/2$

The parameter S_{LE}, Sensitivity Linearity error is the nonlinearity voltage ,V_{NL} specified as a percentage of the full-scale linear output range (V_{FS}) shown in Equation 3.

$$S_{LE} = \left(\frac{V_{NL}}{V_{FS}}\right) \times 100\% \tag{3}$$

The parameter S_{SE} defines symmetry error as the difference in sensitivity between any positive B value, S_B and the negative B value of the same magnitude, S_{-B} while the output voltage is within the V_L range. This error only applies to the bipolar device option. Use Equation 4 to calculate the symmetry error.

$$S_{SE} = \left(\frac{S_B - S_{-B}}{0.5 \times (S_B + S_{-B})}\right) \times 100\% \quad (4)$$

where

- S_B refers to the sensitivity at a positive field B
- S_{-B} refers to the sensitivity at a negative field B

7.2 Ratiometric Architecture

The TMAG5253 has a ratiometric analog architecture that scales the quiescent voltage and sensitivity linearly with the power-supply voltage. For example, the quiescent voltage and sensitivity are 5% higher when V_{CC} = 3.465 V compared to V_{CC} = 3.3 V. This ratiometric behavior enables an external ADC to digitize a consistent value regardless of the power-supply voltage tolerance when the ADC uses V_{CC} as its reference.

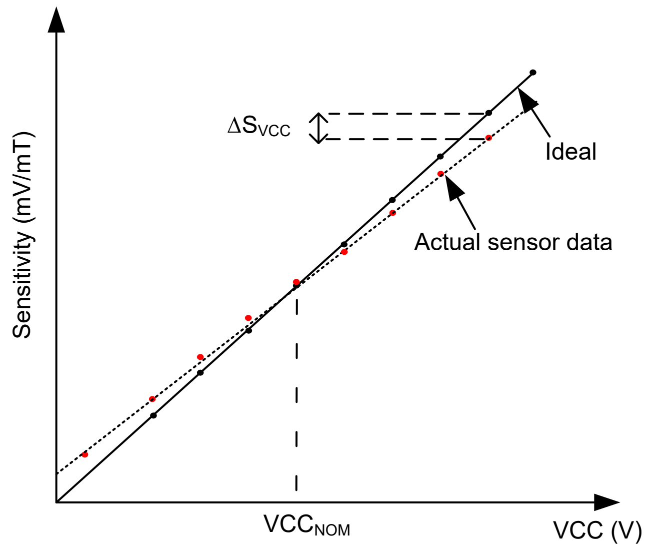


Figure 7-2. Sensitivity Ratiometry Error

Use Equation 5 to calculate the sensitivity ratiometry error:

$$S_{RE} = \left(1 - \frac{S_{VCC}/S_{VCC,\,NOM}}{V_{VCC}/V_{VCC,\,NOM}}\right) \times 100\% \quad (5)$$

where

- $S_{(VCC)}$ is the sensitivity at the current V_{CC} voltage
- $S_{(NOM)}$ is the sensitivity at a nominal V_{CC} voltage
- V_{VCC} is the current V_{CC} voltage
- $V_{VCC,NOM}$ is the nominal V_{CC} voltage that is 1.8 V or 3.3 V

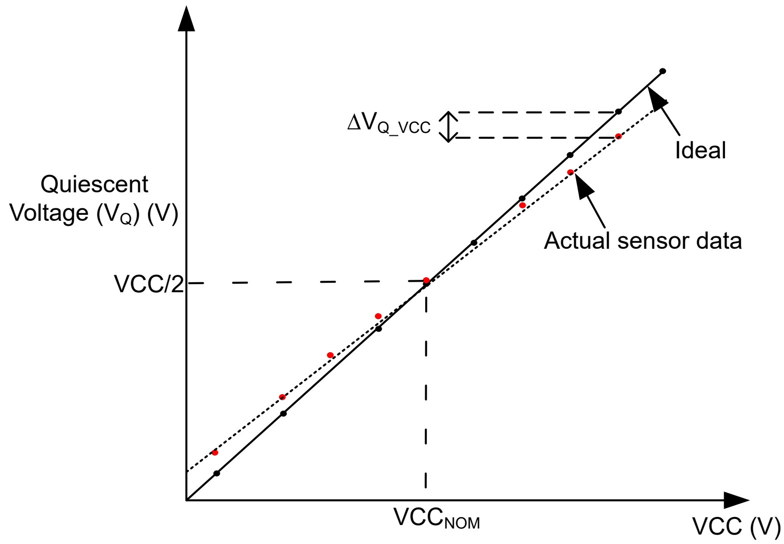


Figure 7-3. Quiescent Ratiometry Error

The TMAG5253 has a ratiometric architecture for the quiescent voltage of the bipolar device option. For the bipolar device option, at 0 mT, the quiescent voltage is typically half of the supply voltage, V_{CC}. Use Equation 6 to calculate the quiescent voltage ratiometry error:

$$Q_{RE} = \left(1 - \frac{V_{Q(VCC)}/V_{Q(NOM)}}{V_{VCC}/V_{VCC,NOM}}\right) \times 100\% \quad (6)$$

where

- $V_{Q(VCC)}$ is the quiescent voltage at the current V_{CC} voltage
- $V_{Q(NOM)}$ is the quiescent voltage at a nominal V_{CC} voltage
- V_{CC} is the current V_{CC} voltage
- $V_{VCC,NOM}$ is the nominal V_{CC} voltage that is 1.8 V or 3.3 V

7.3 Sensitivity Temperature Compensation

Magnets generally produce weaker fields as temperature increases. Different types of magnets have different sensitivity temperature coefficients. The TMAG5253 compensates by increasing sensitivity with temperature, as defined by the parameter S_{TC}. Use Equation 7 and Equation 8 to calculate the sensitivity at a fixed supply voltage.

$$\text{Sensitivity} = \text{Sensitivity}_{25°C} \times (1 + S_{TC} \times (T_A - 25°C)) \quad (7)$$

$$S_{TC} = \frac{100}{\text{Gain at 25°C}} \times \frac{\text{Gain at Temp} - \text{Gain at 25°C}}{\text{Temp} - 25} \quad (8)$$

where

- $\text{Sensitivity}_{(25°C)}$ depends on the polarity (unipolar/bipolar) and the four different device options (1, 2, 3, 4)
- S_{TC} is the Sensitivity temperature coefficient
- T_A is the ambient temperature

7.4 Quiescent Voltage Temperature Drift

Quiescent voltage temperature drift is defined in the Magnetic Characteristic section. This can be calculated using the following equation:

$$VQ\Delta T = VQ_{(VCC)}\ \text{at}\ 25°C\ - VQ_{(VCC)}\ \text{at Temp} \tag{9}$$

where

- $V_{Q(VCC)}$ is the quiescent voltage at the current V_{CC} voltage

7.5 Power-On Time

After the V_{CC} voltage is applied, the TMAG5253 requires a short initialization time before the output settles to its final value. The parameter T_{ON} describes the time from when V_{CC} crosses $V_{CC(MIN)}$ until OUT is within 5% of the final value, with a constant magnetic field and a typical load of 100 pF from OUT to ground. Figure 7-4 shows this timing diagram.

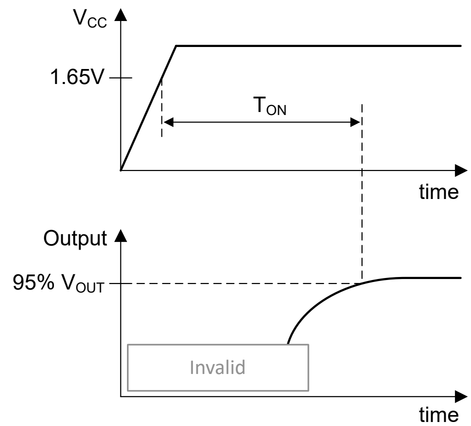


Figure 7-4. T_{ON} for V_{CC} Ramp

T_{ON} is also used to describe the time from when EN pin is pulled above V_{IH} until OUT is within 5% of the final value, with a constant magnetic field and a typical load of 100 pF from OUT to ground. Figure 7-4 shows this timing diagram.

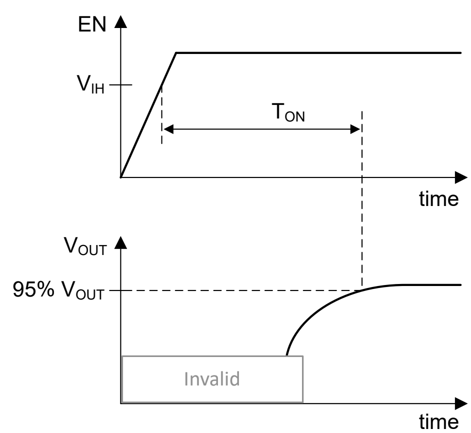


Figure 7-5. T_{ON} When Using EN Pin

8 Detailed Description

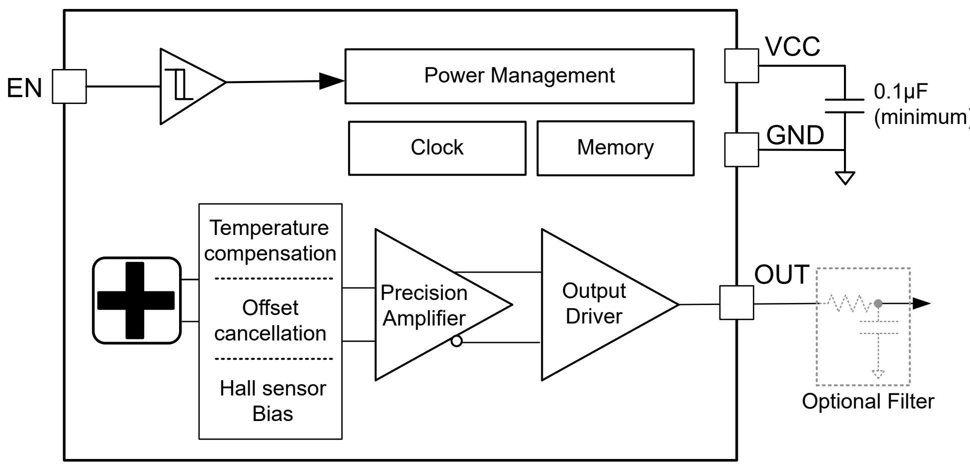
8.1 Overview

The TMAG5253 is a 4-pin, low-power linear Hall effect sensor with fully integrated signal conditioning, temperature compensation circuits, mechanical stress cancellation, and output driver. The device supports wide supply range and can operate on 1.8-V or 3.3-V power supplies, measures magnetic flux density, and outputs a proportional analog voltage that is referenced to V_{CC}. The device also features an enable pin that is used to place the device in a ultra-low power (nA) mode when needed.

The device is offered in bipolar magnetic response version that is sensitive to both the north and the south pole. TMAG5253 is also offered in 4 different sensitivity versions (±20 mT, ±40 mT, ±80 mT, or ±160 mT). This allows the user to trade off sensitivity range and resolution to support low cost magnet selections or wider range wherever it is needed.

The device is offered in magnetic temperature coefficient of 0.12%/°C to compensate for magnetic sensitivity temperature coefficient of Neodymium magnet type.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Magnetic Flux Direction

As shown in Figure 8-1, the TMAG5253 is sensitive to the magnetic field component that is perpendicular to the top of the package.

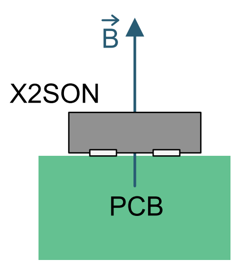


Figure 8-1. Direction of Sensitivity

Magnetic flux that travels from the bottom to the top of the package is considered positive in this document. This condition exists when a south magnetic pole is near the top (marked-side) of the package as shown in Figure 8-2. Magnetic flux that travels from the top to the bottom of the package results in negative millitesla values.

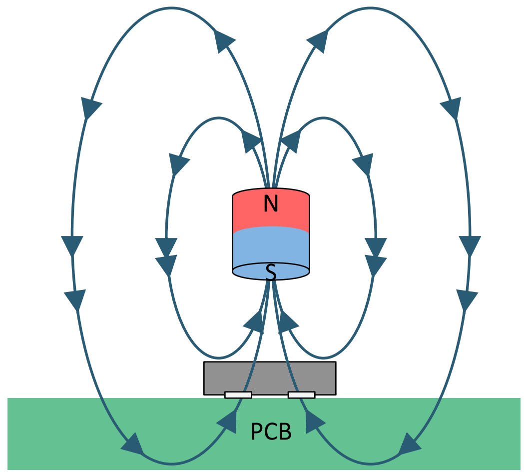


Figure 8-2. The Flux Direction for Positive B

8.3.2 Hall Element Location

Figure 8-3 shows the location of the sensing element inside each package option along with the tolerances.

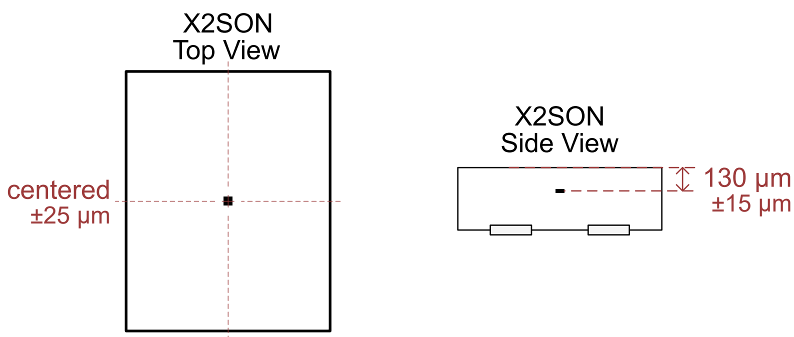


Figure 8-3. Hall Element Location

8.3.3 Magnetic Response

Figure 8-4 shows the response of the bipolar device option (B), which is sensitive to both the positive and negative magnetic fields.

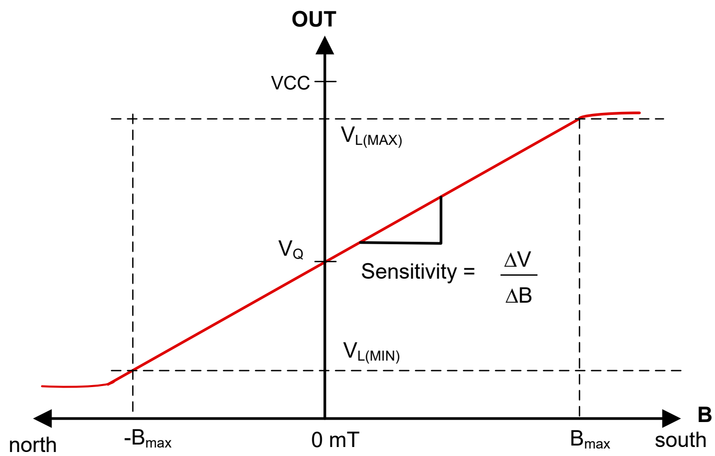


Figure 8-4. Magnetic Response for TMAG5253B (Bipolar) Version

At room temperature, use Equation 10 to calculate the ideal first-order transfer function of the TMAG5253, where the output voltage is a linear function of the input magnetic field and the supply voltage.

$$V_{OUT} = V_Q + B \times \text{Sensitivity} \times \frac{V_{CC}}{V_{CC,\,NOM}} \tag{10}$$

where

- V_Q is the quiescent output voltage for a field of 0 mT.
  - $V_Q = V_{CC} / 2$ for Bipolar device option (B)
- B is the applied magnetic flux density
- Sensitivity refers to the magnetic sensitivity of the device
- V_{OUT} is the analog output voltage within the V_L range
- V_{CC} refers to the supply voltage of the device
- $V_{CC,NOM}$ is the nominal supply voltage where the sensitivity is defined, such as 1.8 V or 3.3 V

As an example, consider the TMAG5253BA3, a bipolar magnetic response version with a sensitivity of 15 mV/mT at 3.3-V supply voltage and at room temperature. With V_{CC} = 3.4 V and an input field of 67 mT, you can calculate the output voltage, V_{OUT} for this example.

$$V_{OUT} = 1.7\text{ V} + 67\text{ mT} \times 0.015\,\frac{\text{V}}{\text{mT}} \times \frac{3.4\text{ V}}{3.3\text{ V}} = 2.735\text{ V} \tag{11}$$

8.4 Device Functional Modes

The TMAG5253 has two modes of operations that apply when the *Recommended Operating Conditions* are met.

When the EN pin is connected to V_{CC}, the part enters active mode, where the OUT pin provides an analog output that corresponds to the magnetic sensitivity and the supply voltage.

When the EN pin is tied to GND, the TMAG5253 enters an ultra-low power shutdown mode that consumes only 20-nA current. During the shutdown mode, the OUT pin is driven to a high-impedance state.

9 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

9.1 Application Information

9.1.1 Selecting the Sensitivity Option

Select the highest TMAG5253 sensitivity option that can measure the required range of magnetic flux density so that the output voltage swing is maximized.

Larger-sized magnets and farther sensing distances can generally enable better positional accuracy than very small magnets at close distances, because magnetic flux density increases exponentially with the proximity to a magnet. TI has developed online tools to provide assistance with magnetic field calculations that assist with magnet selections and the mechanical placement of the sensor for the most common use cases.

9.1.2 Temperature Compensation for Magnets

The magnetic field of magnets based on Neodymium or the Ferrite magnets have a high temperature coefficient. The residual induction (B_r) of a magnet typically reduces by 0.12%/°C for NdFeB, and 0.20%/°C for ferrite material. The TMAG5253 features sensitivity temperature compensation that is designed to directly compensate the average drift of magnets. When the operating temperature range of a system is reduced, temperature drift errors are also reduced.

For device options A1 – A4, the sensitivity at T_A = 125°C is typically 12% higher than at T_A = 25°C. These device options are typically used when Neodymium magnets are used along with the TMAG5253. The device options B1 – B4 are recommended when using along with Ferrite magnets. For device options B1 – B4, the sensitivity at T_A = 125°C is typically 20% higher than at T_A = 25°C. For device options , Z1 – Z4, the sensitivity at T_A = 125°C is typically same as the value at T_A = 25°C. These options are typically used when measuring ambient currents or when the magnetic field does not vary with temperature.

9.1.3 Adding a Low-Pass Filter

As shown in *Functional Block Diagram*, an RC low-pass filter can be added to the device output for the purpose of minimizing voltage noise when the full 15-kHz bandwidth is not needed. This output filter can improve the signal-to-noise ratio (SNR) but at the expense of additional latency based on the external filter time constants.

9.1.4 Designing With Multiple Sensors

Some applications require multiple linear Hall sensors to detect position in different parts of the system. In those cases, the primary challenge would be the availability of multiple ADC that are required to digitize the information from the sensors. In cases where the sensor is placed remotely away from the microcontroller, this would also mean multiple output lines between the sensor and microcontroller.

With the ability to place the output in high-impedance state during shutdown mode, multiple TMAG5253s can share the analog output. This can minimize the system cost by using a single ADC. Figure 9-1 shows two devices that share the same analog output, with their respective EN pins controlled by the microcontroller. A pulldown resistor can be used to pull the output to ground when both the devices are placed in shutdown mode.

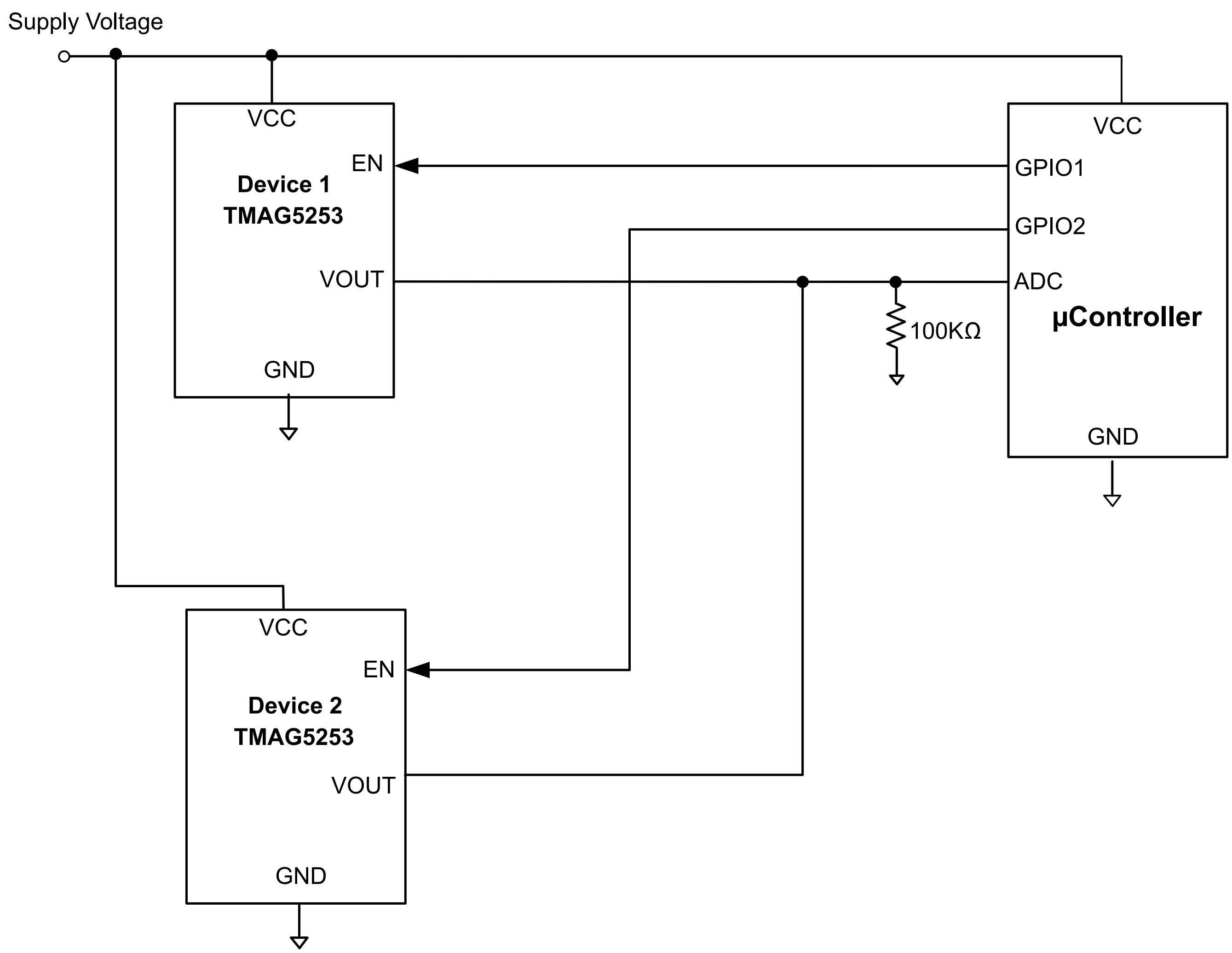


Figure 9-1. Multiple Sensors With Shared Output

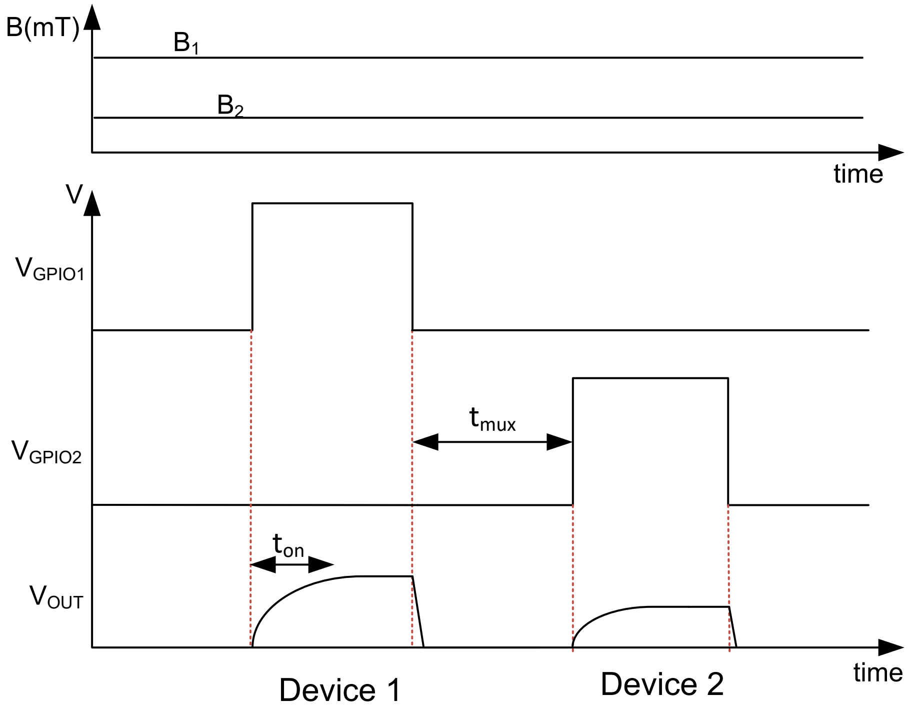


Figure 9-2. Timing Diagram for Multiplexing the Sensor Outputs

Figure 9-2 shows how the GPIOs of the microcontroller can be used to multiplex the outputs from the two sensors. When the GPIO1 goes high, Device 1 is enabled and drives the output line to the corresponding output after the power-on time. During this time, GPIO2 is driven low and Device 2 is placed in shutdown mode. When the output from the second device has to be measured, the first device must be turned off before the second device is enabled, indicated by t_{mux} in the timing diagram. B_1 and B_2 correspond to the magnetic fields seen by Device 1 and Device 2, respectively.

With the ability to support up to 1-nF capacitive loads, the TMAG5253 enables multiple sensors to be connected to the same output. If the load capacitance on each sensor is about 20 pF, this would translate up to the ability of 50 sensors sharing the same output.

9.1.5 Duty-Cycled, Low-Power Design

For battery-powered applications where power is critical, the sensor can be duty-cycled using the EN pin. This will ensure the average current consumption remains low to meet the system level power targets. In duty-cycled applications, the start-up time must be very fast so the external ADC can sample the signal faster and shutdown the device quickly to minimize average power. With very fast start-up and power-off times, the TMAG5253 enables low average power consumption for the system.

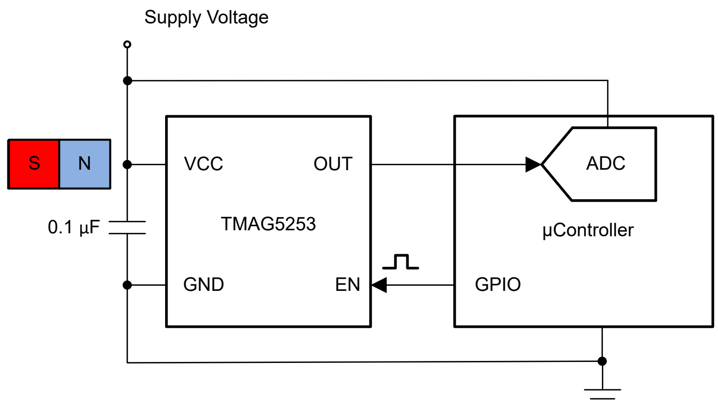


Figure 9-3. Typical Application Diagram for Duty-Cycled Application

Figure 9-3 shows the typical application diagram when the EN pin is controlled by the microcontroller. Figure 9-4 shows the waveforms for this application where the EN pin is duty-cycled. The sampling time of the ADC should be scheduled after the output settles down to the required resolution. Notice that the output line is pulled down by the external resistor when EN is driven low. Also, if the input magnetic field is changed when the part is in shutdown, the device provides the new output corresponding to the field after the device enters active state.

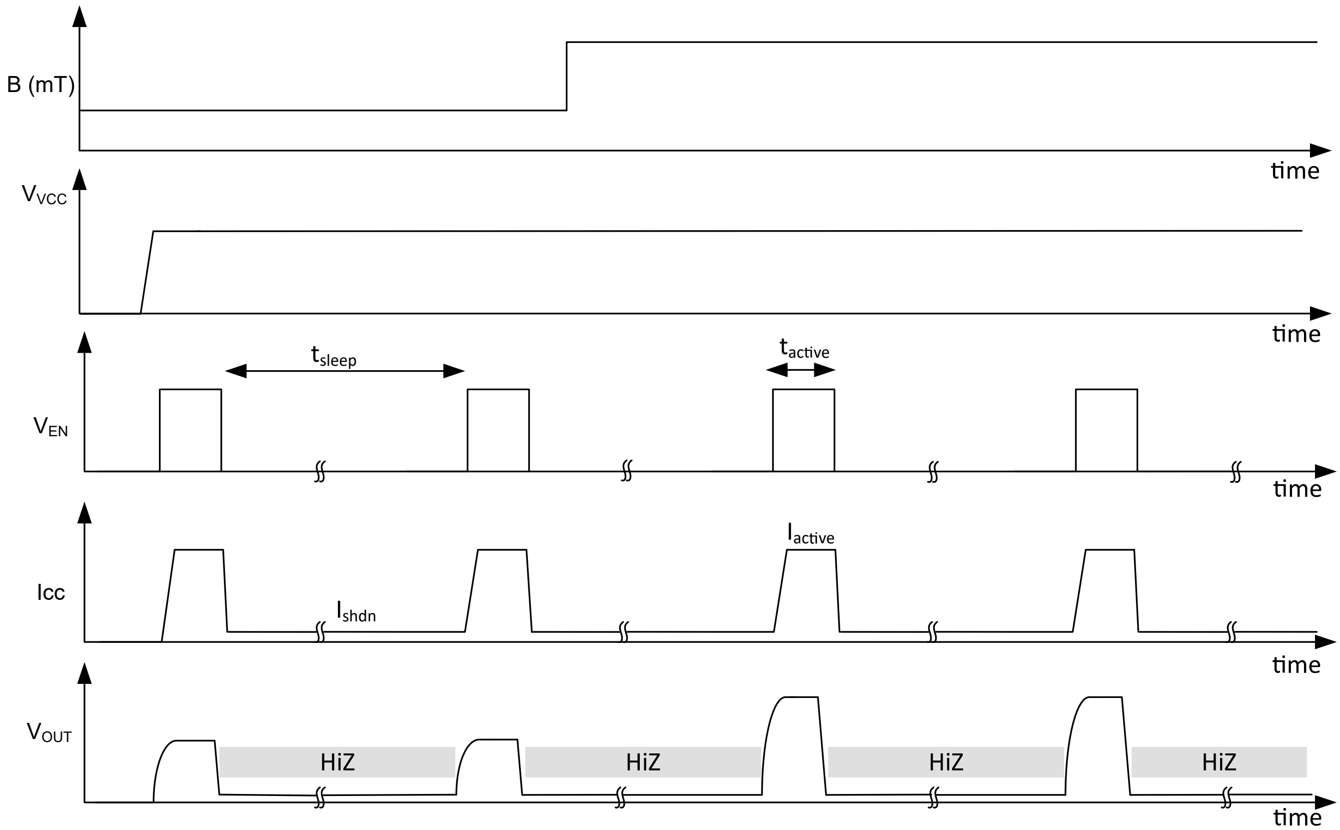


Figure 9-4. Timing Diagram for Duty-Cycled Application

Table 9-1 shows the estimated average current consumption for the TMAG5253 versus the sleep time, for V_{CC} = 1.8 V and the EN pin is tied high for 50 µs.

Table 9-1. Average Current Consumption

SLEEP TIME (ms)	AVERAGE CURRENT (µA)
1	90.5
10	9.4
50	1.9
100	0.9
1000	0.1

9.2 Typical Applications

Magnetic 1D sensors are very popular due to contactless and reliable measurements, especially in applications requiring long-term measurements in rugged environments. The TMAG5253 offers design flexibility in a wide range of industrial and personal electronics applications, because many possible magnet orientations and movements produce a usable response from the sensor. In this section three common application examples are discussed in detail.

9.2.1 Slide-By Displacement Sensing

Figure 9-5 shows one of the most common orientations, which uses the full north to south range of the sensor and causes a close-to-linear change in magnetic flux density as the magnet moves across.

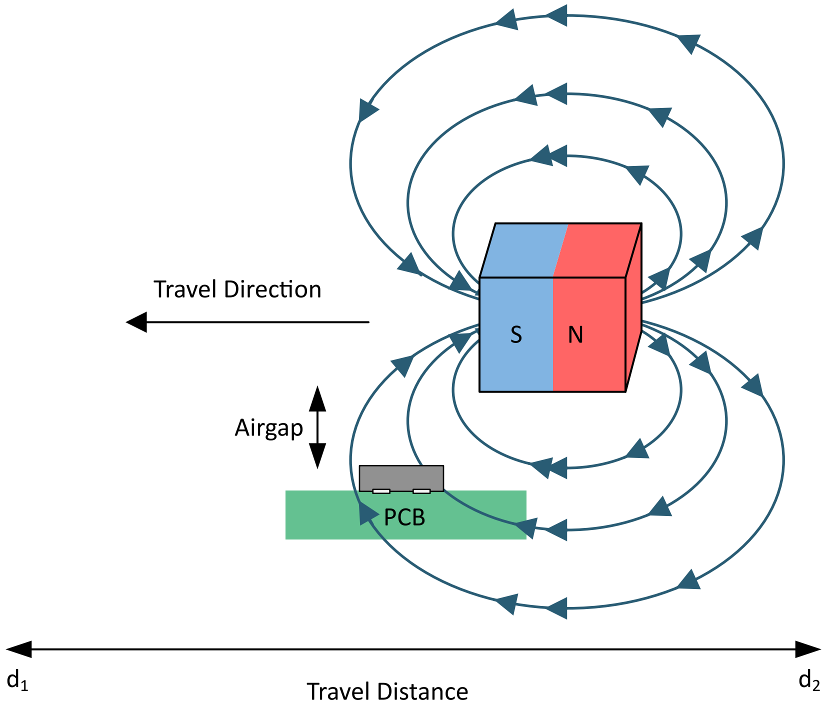


Figure 9-5. Slide-By Sensing Magnet Orientation

9.2.1.1 Design Requirements

Use the parameters listed in Table 9-2 for this design example.

Table 9-2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{CC}	3.3 V
Magnet	5 × 5 × 5 mm NdFeB (Grade N52)
Travel distance ($d_2 – d_1$)	20 mm
Airgap	3.0 mm (top of package to magnet) + 0.13 mm (distance from top of package to sensor location)
Maximum B at sensor at 25°C	±80 mT
Device option	TMAG5253BA3

9.2.1.2 Detailed Design Procedure

When designing a linear magnetic sensing system, always consider these three variables: the magnet, sensing distance, and the range of the sensor. Notice from Figure 9-5, the magnetic flux density versus distance has both positive and negative values as the magnet slides on top of the sensor. There is a region approximately the same length of the magnet which produces a linear change in field. To measure the magnetic flux density across the entire range, select the TMAG5253B version with the highest sensitivity that has a B_L (linear magnetic sensing range) that is larger than the maximum magnetic flux density in the application. With this input, the user can monitor the change in position by measuring in the linear input region. Figure 9-6 shows the magnetic flux density across the three axes in the sensor location. The sensor is sensitive only to the magnetic field on Z axis, and Figure 9-7 shows the output voltage from the sensor, as the magnet slides on top of the sensor.

Notice that the linear region of sensing is only around ±3.0 mm, where the sensor output varies linearly with the position of the magnet. This linear range of operation will increase linearly with the size of the magnet. Based on the output voltage, it is determined that the sensor version with magnetic range of ±80 mT is able to cover the entire magnetic field range that is seen by the sensor. TI recommends using magnetic field simulation software and referring to magnet specifications and the mechanical placements to determine if the sensor with the right sensitivity.

9.2.1.3 Application Curves

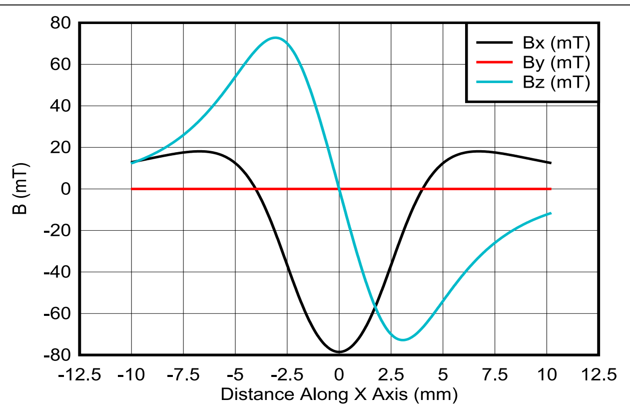


Figure 9-6. Magnetic Field Across X, Y and Z Axes When The Magnet Slides by on Top of the Sensor

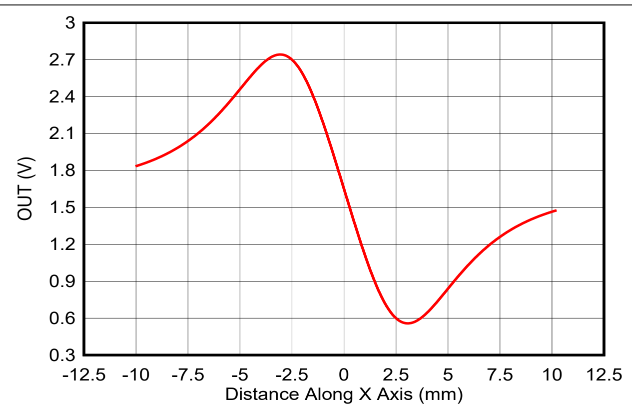


Figure 9-7. Output Voltage of TMAG5253 When The Magnet Slides by on Top of the Sensor

9.2.2 Head-On Displacement Sensing

Figure 9-8 shows another robust method for measuring linear position by using a magnet and the TMAG5253 in a head-on configuration. For this configuration, the linear axis of measurement of the Hall position sensor is along the path of travel, which results in a unique mapping of distance to magnetic flux density if the magnet is inline with the sensing axis of the Hall position sensor.

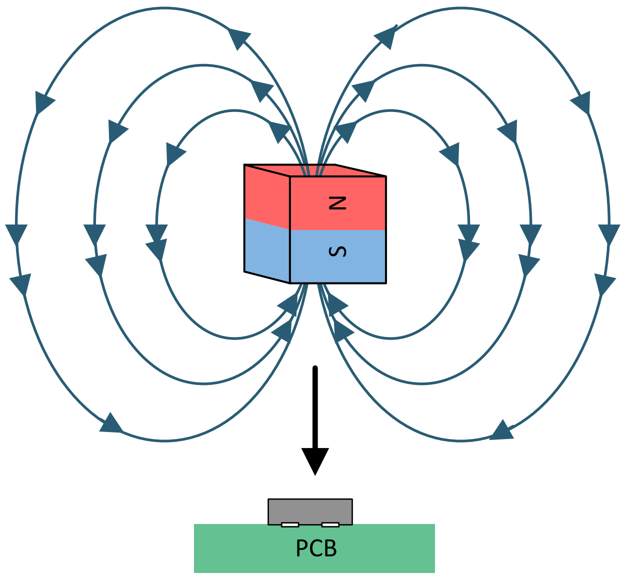


Figure 9-8. Head-On Displacement Sensing

9.2.2.1 Design Requirements

Use the parameters listed in Table 9-3 for this design example.

Table 9-3. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{CC}	3.3 V
Magnet	5 × 5 × 5 mm NdFeB N45
Travel distance	5 mm
Travel distance range from magnet to sensor surfaces	10 mm to 5 mm
Magnetic field range at the sensor at 25°C	80mT to 13 mT
Device option	TMAG5253BA3

9.2.2.2 Detailed Design Procedure

Unlike the *Slide-By Displacement Sensing* configuration, the head-on displacement configuration has a magnetic flux density that is either entirely positive or entirely negative, depending on whether the south or north pole of the magnet is closest to the sensor. As a result, the user can choose the sensors that are sensitive only to south field for this mechanical configuration. In cases where it is not possible to control the polarity of the magnet, the bipolar version (TMAG5253B) is chosen. The mapping of magnetic flux density to distance depends on various factors, such as the material and dimensions of the magnet. Figure 9-9 shows that the magnetic flux density is always positive as the magnet travels towards the sensor. Based on the magnetic field range, TMAG5253BA3 version with ±80 mT full scale range is chosen. Figure 9-9 shows the output voltage of this sensor as the magnet travels from a distance of 10 mm to a distance of 5 mm towards the sensor. The DRV5056 Distance Measurement Tool calculates the expected magnetic flux density to distance mapping in a head-on configuration for different magnet specifications.

9.2.2.3 Application Curve

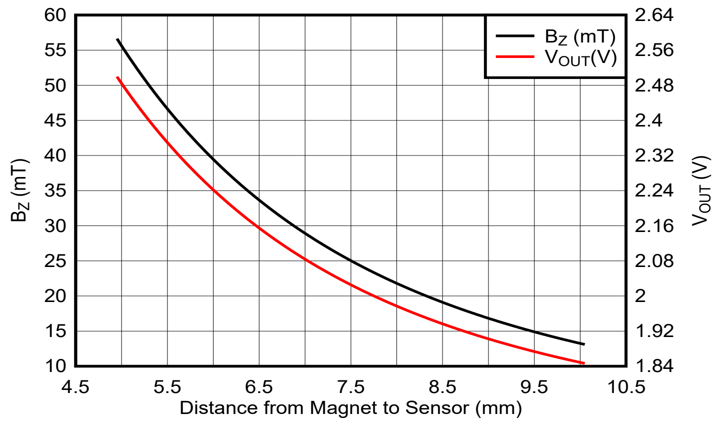


Figure 9-9. Magnetic Field (B_Z) and the Output Voltage of the Sensor (V_{OUT}) vs the Distance from Magnet to the Sensor

9.2.3 Remote-Sensing Applications

For remote-sensing applications where the sensor is not physically placed on the same board as the ADC or the microcontroller, it is important to have the ability to drive a capacitive load from the wiring harness. The TMAG5253 enables remote-sensing applications with the ability to support up to 1-nF capacitive load on the OUT pin. With a typical cable capacitance of about 100 pF/m, the TMAG5253 can support up to 10 m in cable length.

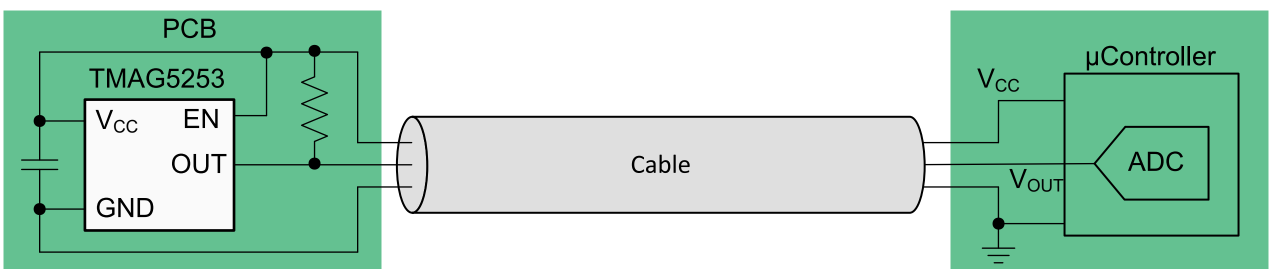


Figure 9-10. Remote-Sensing Application With Wire Break Detection

Some remote-sensing applications might require a device to detect if interconnect wires open or short. The TMAG5253 can support this feature with the ability to drive up to ±1-mA current load on the output. To design for wire break detection, first select a sensitivity option that causes the output voltage to stay within the V_L range during normal operation. Second, add a pullup resistor between OUT and V_{CC}. TI recommends a value between 20 kΩ to 100 kΩ, and the current through OUT must not exceed the IO specification, including current going into an external ADC. Then, if the output voltage is ever measured to be within 100 mV of V_{CC} or GND, a fault condition exists. Figure 9-10 shows the circuit, and Table 9-4 describes fault scenarios.

Table 9-4. Fault Scenarios and the Resulting V_{OUT}

FAULT SCENARIO	V_{OUT}
V_{CC} disconnects	Close to GND
GND disconnects	Close to V_{CC}
V_{CC} shorts to OUT	Close to V_{CC}
GND shorts to OUT	Close to GND

9.3 Best Design Practices

The Hall element is sensitive to magnetic fields that are perpendicular to the top of the package, therefore a correct magnet approach must be used for the sensor to detect the field. Figure 9-11 shows correct and incorrect approaches.

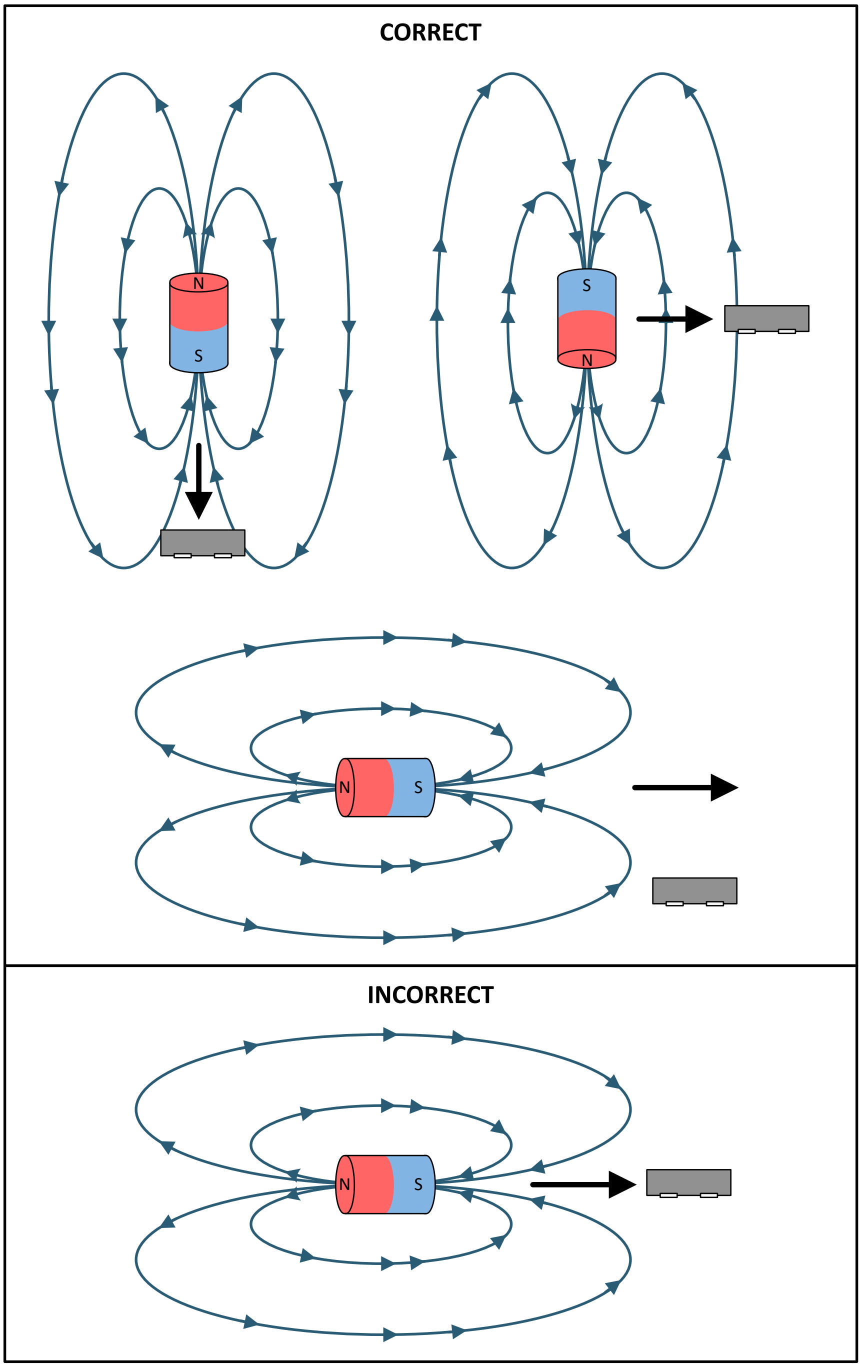


Figure 9-11. Correct and Incorrect Magnet Approaches

9.4 Power Supply Recommendations

A decoupling capacitor close to the device must be used to provide local energy with minimal inductance. TI recommends using a ceramic capacitor with a value of at least 0.1 µF.

9.5 Layout

9.5.1 Layout Guidelines

Magnetic fields pass through most nonferromagnetic materials with no significant disturbance. Embedding Hall effect sensors within plastic or aluminum enclosures and sensing magnets on the outside is common practice. Magnetic fields also easily pass through most printed circuit boards, which makes placing the magnet on the opposite side possible.

9.5.2 Layout Example

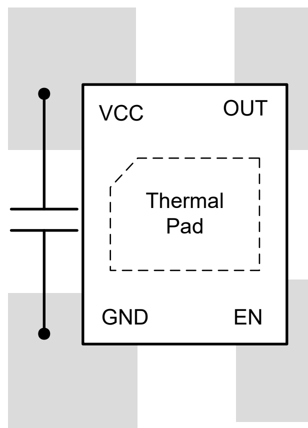


Figure 9-12. Layout Example

10 Device and Documentation Support

10.1 Documentation Support

10.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *Absolute Angle Measurements for Rotational Motion Using Hall-Effect Sensors* application brief
- Texas Instruments, *Tracking Slide-By Displacement with Hall Effect Sensors* application brief
- Texas Instruments, *Head-on Linear Displacement Sensing using Hall Effect Sensors* application brief
- Texas Instruments, *TMAG5253EVM User's Guide*

10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

10.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

10.4 Trademarks

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10.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

10.6 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

11 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (November 2023) to Revision C (August 2025) **Page**

- Changed the minimum quiescent voltage for V_{CC}=3.3V on the BA2, BA3, BA4 variants from: 1.585V to: 1.61V 5
- Changed the maximum quiescent voltage for V_{CC}=3.3V on the BA2, BA3, BA4 variants from: 1.715V to: 1.69V 5
- Changed the minimum quiescent voltage for V_{CC}=1.8V on the BA2 and BA3 variants from: 0.845V to: 0.85V 5
- Changed the maximum quiescent voltage for V_{CC}=1.8V on the BA2 and BA3 variants from: 0.945V to: 0.94V 5
- Changed the minimum quiescent voltage for V_{CC}=1.8V on the BA4 variant from: 0.845V to: 0.87V........ 5
- Changed the maximum quiescent voltage for V_{CC}=1.8V on the BA4 variant from 0.945V to 0.93V........ 5
- Changed the minimum quiescent voltage temperature drift for V_{CC} = 3.3 V, T_A = 0°C to 85°C versus 25°C, TMAG5253B from: -60mV to: -30V........ 5

- Changed the maximum quiescent voltage temperature drift for V_{CC} = 3.3 V, T_A = 0°C to 85°C versus 25°C, TMAG5253B from: 60mV to 30mV.......... 5
- Changed the minimum quiescent voltage temperature drift for V_{CC} = 3.3 V, T_A =-40°C to 125°C versus 25°C, TMAG5253B from: -100mV to: -50V.......... 5
- Changed the maximum quiescent voltage temperature drift for V_{CC} = 3.3 V, T_A =-40°C to 125°C versus 25°C, TMAG5253B from: 100mV to: 50mV.......... 5
- Changed the minimum quiescent voltage temperature drift for V_{CC} = 1.8 V, T_A = 0°C to 85°C versus 25°C, TMAG5253B from: -30mV to: -25V.......... 5
- Changed the maximum quiescent voltage temperature drift for V_{CC} = 1.8 V, T_A = 0°C to 85°C versus 25°C, TMAG5253B from: 30mV to: 25mV.......... 5
- Added quiescent voltage temperature drift parameters for the T_A = 0°C to 50°C range.......... 5
- Changed the minimum quiescent voltage temperature drift for V_{CC} = 1.8 V, T_A = -40°C to 125°C versus 25°C, TMAG5253B from: -50mV to: -35V.......... 5
- Changed the maximum quiescent voltage temperature drift for V_{CC} = 1.8 V, T_A = -40°C to 125°C versus 25°C, TMAG5253B from: 50mV to: 35mV.......... 5
- Changed Linear mangetic sensing range to include full temperature range.......... 5

Changes from Revision A (September 2023) to Revision B (November 2023) **Page**

- Removed the preview note from the A1, A2 and A4 orderables in the *Device Comparison* table.......... 3

Changes from Revision * (May 2023) to Revision A (September 2023) **Page**

- Changed the data sheet status from: Advanced Information to: Production Data 1

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TMAG5253BA1IQDMRR	Active	Production	X2SON (DMR) | 4	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	BA1
TMAG5253BA1IQDMRR.A	Active	Production	null (null) |	3000 | LARGE T&R	-	SN	Level-1-260C-UNLIM	See TMAG5253BA1IQDMRR	BA1
TMAG5253BA2IQDMRR	Active	Production	X2SON (DMR) | 4	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	BA2
TMAG5253BA2IQDMRR.A	Active	Production	null (null) |	3000 | LARGE T&R	-	SN	Level-1-260C-UNLIM	See TMAG5253BA2IQDMRR	BA2
TMAG5253BA3IQDMRR	Active	Production	X2SON (DMR) | 4	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	BA3
TMAG5253BA3IQDMRR.A	Active	Production	null (null) |	3000 | LARGE T&R	-	SN	Level-1-260C-UNLIM	See TMAG5253BA3IQDMRR	BA3
TMAG5253BA4IQDMRR	Active	Production	X2SON (DMR) | 4	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	BA4
TMAG5253BA4IQDMRR.A	Active	Production	null (null) |	3000 | LARGE T&R	-	SN	Level-1-260C-UNLIM	See TMAG5253BA4IQDMRR	BA4

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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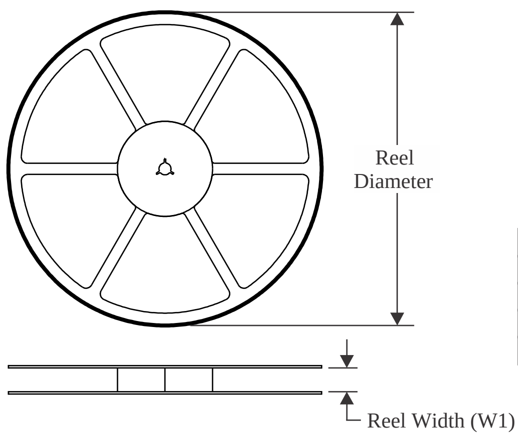
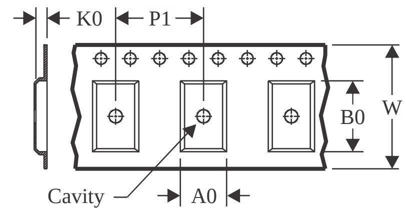
TAPE AND REEL INFORMATION

REEL DIMENSIONS

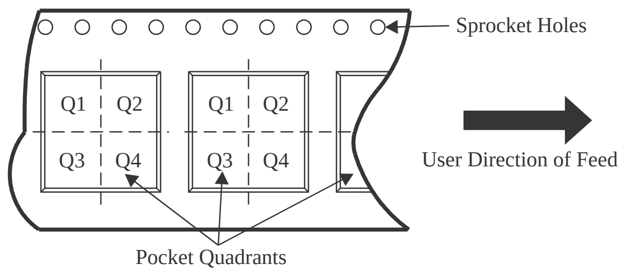


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

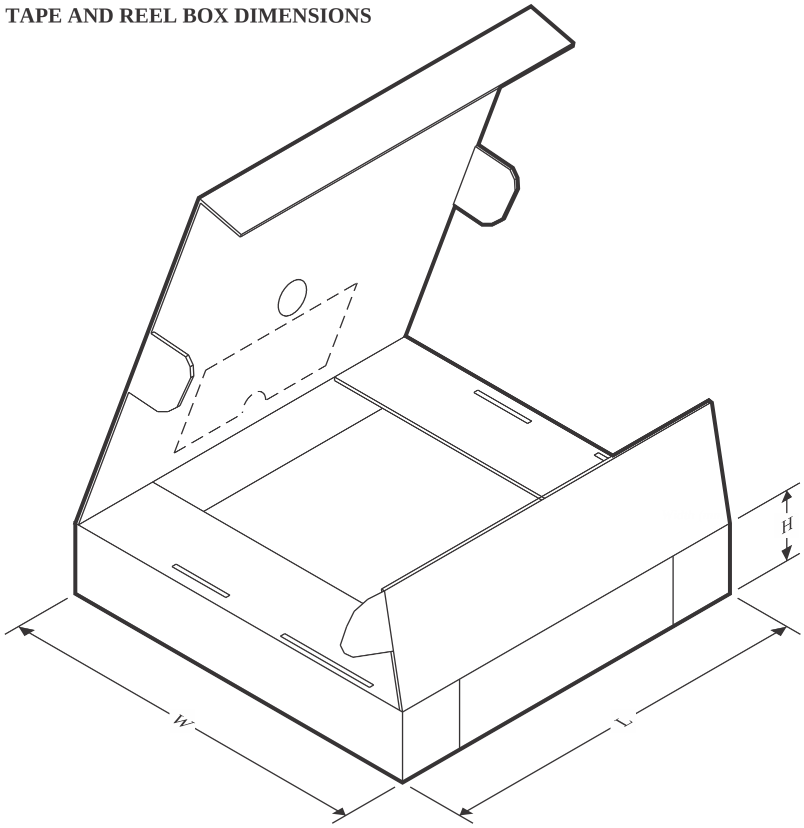
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TMAG5253BA1IQDMRR	X2SON	DMR	4	3000	179.0	8.4	1.27	1.57	0.5	4.0	8.0	Q1
TMAG5253BA2IQDMRR	X2SON	DMR	4	3000	179.0	8.4	1.27	1.57	0.5	4.0	8.0	Q1
TMAG5253BA3IQDMRR	X2SON	DMR	4	3000	179.0	8.4	1.27	1.57	0.5	4.0	8.0	Q1
TMAG5253BA4IQDMRR	X2SON	DMR	4	3000	179.0	8.4	1.27	1.57	0.5	4.0	8.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TMAG5253BA1IQDMRR	X2SON	DMR	4	3000	200.0	183.0	25.0
TMAG5253BA2IQDMRR	X2SON	DMR	4	3000	200.0	183.0	25.0
TMAG5253BA3IQDMRR	X2SON	DMR	4	3000	200.0	183.0	25.0
TMAG5253BA4IQDMRR	X2SON	DMR	4	3000	200.0	183.0	25.0

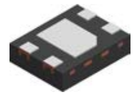
DMR 4

X2SON - 0.4 mm max height

1.1 x 1.4, 0.5 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

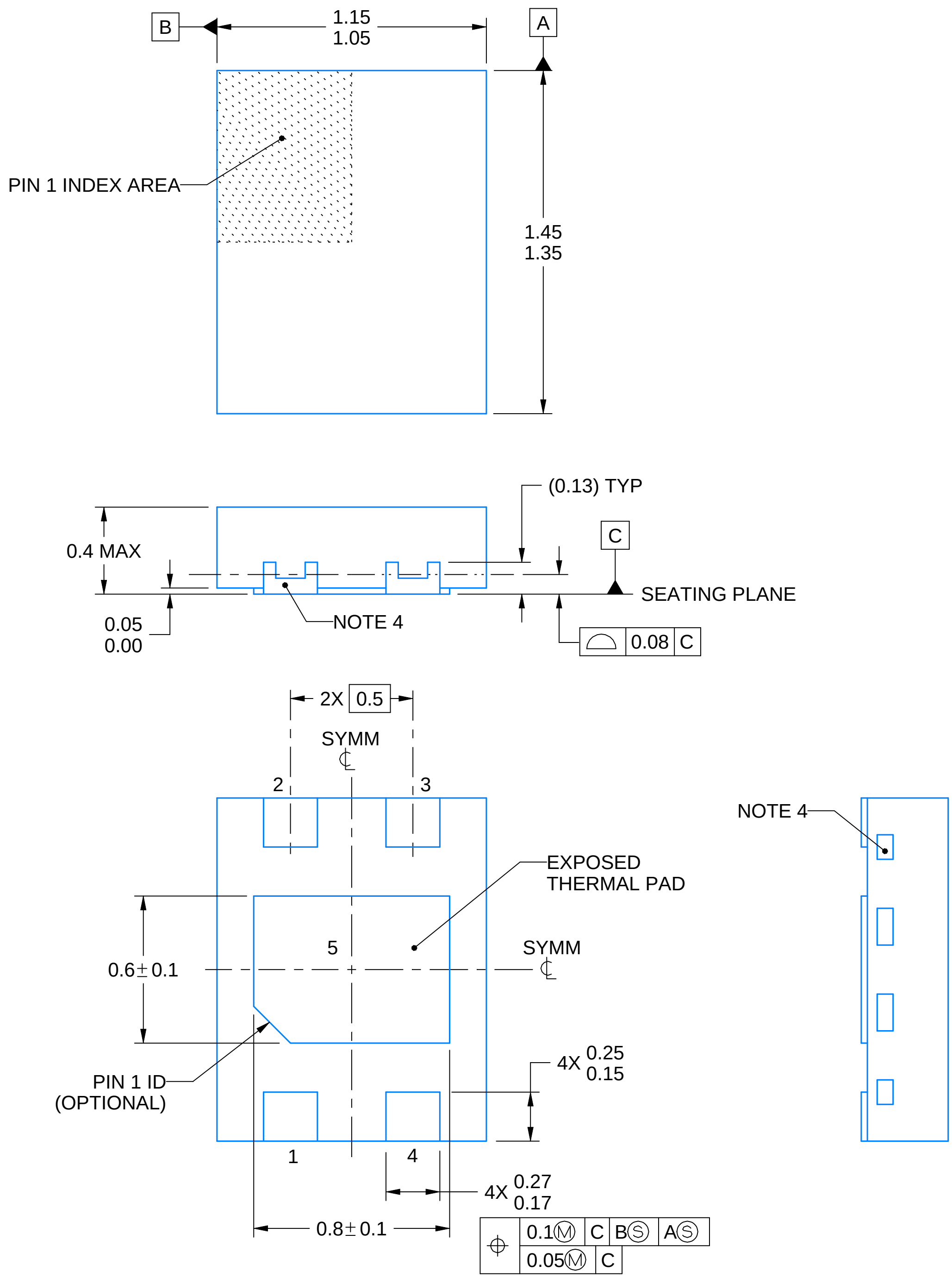
This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



PACKAGE OUTLINE

X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



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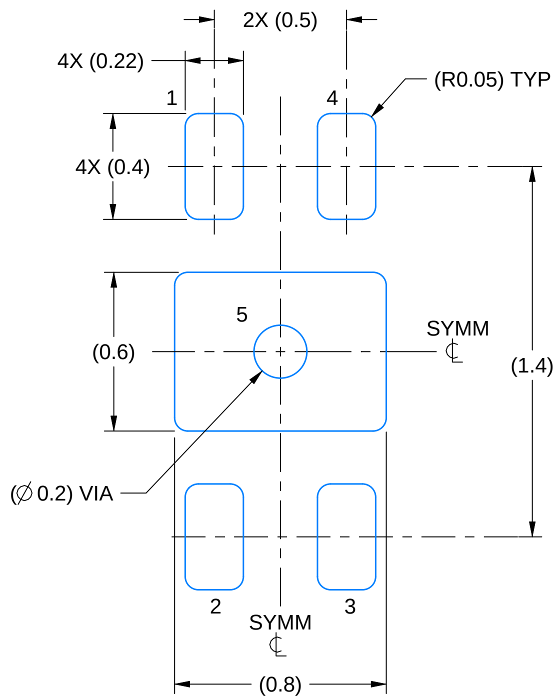
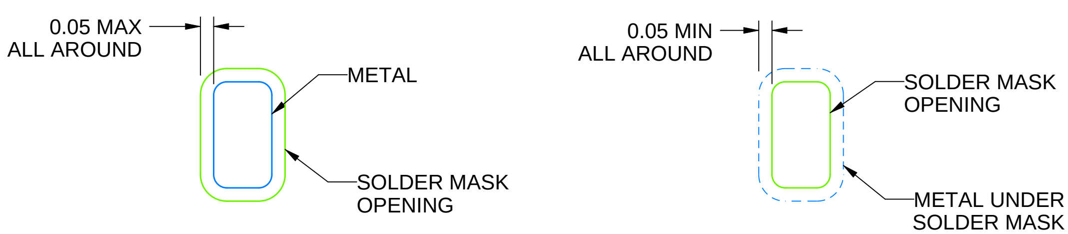
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.
4. Quantity and shape of side wall metal may vary.



LAND PATTERN EXAMPLE
SCALE:35X



NON SOLDER MASK DEFINED (PREFERRED)

SOLDER MASK DEFINED

SOLDER MASK DETAILS

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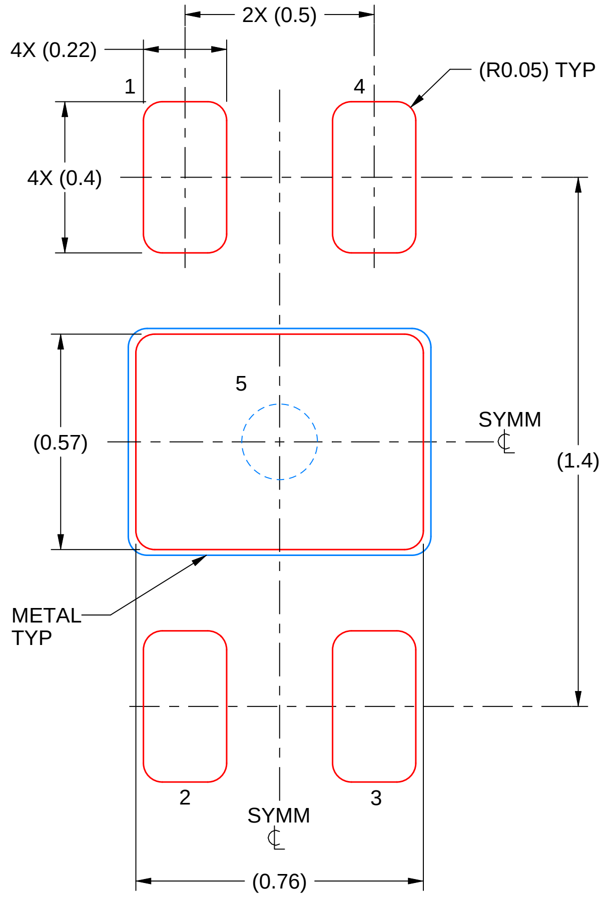
NOTES: (continued)

5. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
6. Vias are optional depending on application, refer to device data sheet. If all or some are implemented, recommended via locations are shown. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

EXPOSED PAD 5:
90% PRINTED SOLDER COVERAGE BY AREA
SCALE:50X

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NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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