

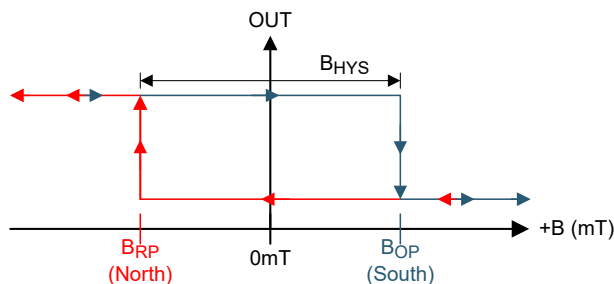
TMAG5213 Hall-Effect Latch for Cost-Optimized Designs

1 Features

- Z-axis Hall-effect bipolar latch
- 30kHz magnetic sampling frequency
- Multiple sensitivity options (B_{OP} / B_{RP})
 - $\pm 2.7\text{mT}$ (AD, see [Device Nomenclature](#))
 - $\pm 6\text{mT}$ (AG, see [Device Nomenclature](#))
- Supports a wide voltage range
 - 2.5V to 28V
 - No external regulator required
- Wide operating temperature range
 - $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$
- Open-drain output (30mA sink)
- 35 μs power-on time
- Industry standard package and footprint
 - Surface mount 3-pin SOT-23 (DBZ)
 - $2.92\text{mm} \times 2.37\text{mm}$
 - Through-hole 3-pin TO-92 (LPG)
 - $4.00\text{mm} \times 1.52\text{mm}$
- **Protection features:**
 - Output short-circuit protection
 - Output current limitation

2 Applications

- [Power tools](#)
- [Vacuum robot](#)
- [Valve and actuator control](#)
- [Servo motors](#)
- [Proximity switch](#)
- [AC Units](#)
- [BLDC motors](#)



Output Behavior

3 Description

The TMAG5213 is a low-cost, chopper-stabilized Hall-effect sensor with excellent sensitivity stability over temperature and integrated protection features.

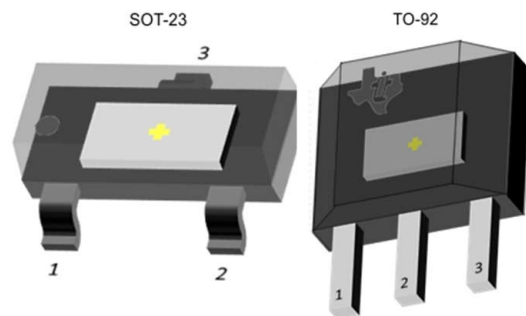
The magnetic field is indicated through a digital bipolar latch output. When the applied magnetic flux density crosses the operating point (B_{OP}) threshold, the device outputs a low voltage. The output stays low until the flux density crosses the release point (B_{RP}), at which point the device output gets pulled high. This bipolar latch magnetic response allows the device output to be sensitive to positive and negative magnetic flux through the Z-axis of the package.

The TMAG5213 has a wide operating voltage range from 2.5V to 28V and operating temperature range from -40°C to $+125^\circ\text{C}$ designed for a variety of industrial applications. Internal protection functions are provided for output short circuit or overcurrent, and the device has an open-drain output stage with 30mA current sink capability.

Package Information

PART NUMBER	PACKAGE ⁽¹⁾	PACKAGE SIZE ⁽²⁾
TMAG5213	DBZ (SOT-23, 3)	$2.92\text{mm} \times 2.37\text{mm}$
	LPG (TO-92, 3)	$4\text{mm} \times 1.52\text{mm}$

- (1) For all available packages, see [Section 11](#).
 (2) The package size (length \times width) is a nominal value and includes pins, where applicable.



Device Packages



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4 Device Comparison

Table 4-1. Device Comparison

VERSION	TYPICAL B_{OP} THRESHOLD	TYPICAL HYSTERESIS	+B MAGNETIC RESPONSE	OUTPUT TYPE	SENSING ORIENTATION	SAMPLING RATE	PACKAGES AVAILABLE
TMAG5213AD	2.7mT	5.4mT	Active Low	Open-drain	Z	30kHz	SOT-23, TO-92
TMAG5213AG	6mT	12mT	Active Low	Open-drain	Z	30kHz	SOT-23, TO-92

5 Pin Configuration and Functions

For additional configuration information, see [Device Markings](#) and [Mechanical, Packaging, and Orderable Information](#).

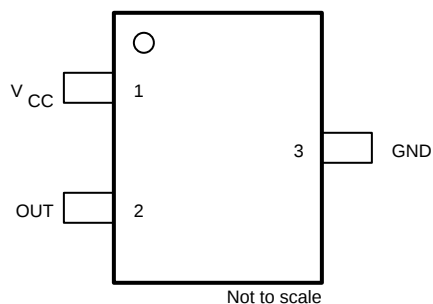


Figure 5-1. DBZ Package (Preview), 3-Pin SOT-23 (Top View)

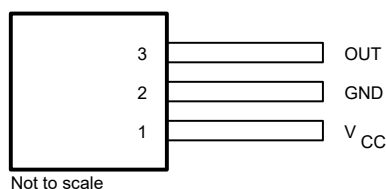


Figure 5-2. LPG Package, 3-Pin TO-92 (Top View)

Table 5-1. Pin Functions

NAME	PIN		TYPE	DESCRIPTION
	SOT-23 (DBZ)	TO-92 (LPG)		
GND	3	2	Ground	Ground pin
OUT	2	3	Output	Hall sensor open-drain output. The open drain requires a resistor pullup.
V_{CC}	1	1	Power	2.5V to 28V power supply. Bypass this pin to the GND pin with a 0.01 μ F (minimum) ceramic capacitor rated for V_{CC} .

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	30	V
Output pin voltage	OUT	−0.5	30	V
Magnetic flux density, B _{MAX}		Unlimited		
Operating junction temperature, T _J		−40	150	°C
Storage temperature, T _{stg}		−65	150	°C

- (1) Operation outside the Absolute 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, all pins ⁽¹⁾	±2500	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins ⁽²⁾	±500	

- (1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
 (2) JEDEC document JEP157 states that 250V 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	2.5	28	V
V _O	Output pin voltage (OUT)	0	28	V
I _{SINK}	Output pin current sink (OUT) ⁽¹⁾	0	30	mA
T _A	Operating ambient temperature	−40	125	°C

- (1) Power dissipation and thermal limits must be observed.

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TMAG5213		UNIT
		SOT-23 (DBZ)	TO-92 (LPG)	
		3 PINS	3 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	197.7	180	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	87.1	98.6	
$R_{\theta JB}$	Junction-to-board thermal resistance	27.4	154.9	
Ψ_{JT}	Junction-to-top characterization parameter	3.7	40	
Ψ_{JB}	Junction-to-board characterization parameter	27.1	154.9	

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

6.5 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLIES (V_{CC})						
V_{CC}	Operating power supply voltage		2.5		28	V
I_{CC}	Operating supply current	$V_{CC} = 2.5V$ to $28V$, $T_A = 25^{\circ}C$		2.7		mA
		$V_{CC} = 2.5V$ to $28V$, $T_A = 125^{\circ}C$		3	3.5	
t_{on}	Power-on time	AD, AG Versions		35	50	μs
OPEN-DRAIN OUTPUT (OUT)						
$r_{DS(on)}$	FET on-resistance	$V_{CC} = 3.3V$, $I_O = 10mA$, $T_A = 25^{\circ}C$		22		Ω
		$V_{CC} = 3.3V$, $I_O = 10mA$, $T_A = 125^{\circ}C$		36	50	
$I_{lkg(off)}$	Off-state leakage current	Output Hi-Z			1	μA
PROTECTION CIRCUITS						
I_{OCP}	Overcurrent protection level	OUT shorted V_{CC}	15	30	45	mA

6.6 Switching Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_d	Output delay time	$B = B_{RP} - 10mT$ to $B_{OP} + 10mT$ in $1\mu s$		13	25	μs
t_r	Output rise time (10% to 90%)	$R1 = 1k\Omega$, $C_O = 50pF$, $V_{CC} = 3.3V$		200		ns
t_f	Output fall time (90% to 10%)	$R1 = 1k\Omega$, $C_O = 50pF$, $V_{CC} = 3.3V$		31		ns
f_{BW}	Bandwidth ⁽¹⁾		20	30		kHz

(1) Bandwidth describes the fastest changing magnetic field that can be detected and translated to the output.

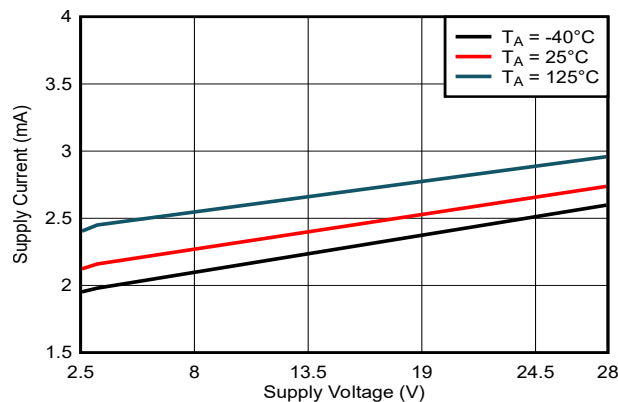
6.7 Magnetic Characteristics

for $V_{CC} = 2.5V$ to $28V$, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT ⁽¹⁾
TMAG5213AD: $\pm 2.7mT$						
B _{OP}	Operate point	T _A = 25°C	1	2.7	5	mT
		T _A = –40°C to 125°C	0.83	2.7	5.23	mT
B _{RP}	Release point	T _A = 25°C	–5	–2.7	–1	mT
		T _A = –40°C to 125°C	–5.23	–2.7	–0.83	mT
B _{HYS}	Hysteresis; B _{HYS} = (B _{OP} – B _{RP})	T _A = –40°C to 125°C		5.4		mT
TMAG5213AG: $\pm 6mT$						
B _{OP}	Operate point	T _A = 25°C	3	6	9	mT
		T _A = –40°C to 125°C	2.7	6	9.3	mT
B _{RP}	Release point	T _A = 25°C	–9	–6	–3	mT
		T _A = –40°C to 125°C	–9.3	–6	–2.7	mT
B _{HYS}	Hysteresis; B _{HYS} = (B _{OP} – B _{RP})	T _A = –40°C to 125°C		12		mT

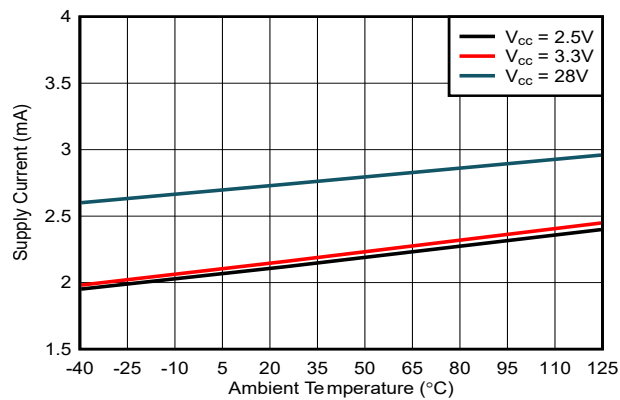
(1) 1mT = 10 Gauss.

6.8 Typical Characteristics



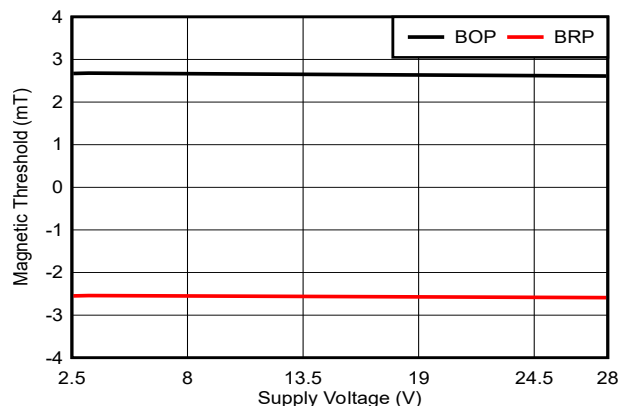
Versions: AD, AG

Figure 6-1. 30kHz: Average I_{CC} vs V_{CC}



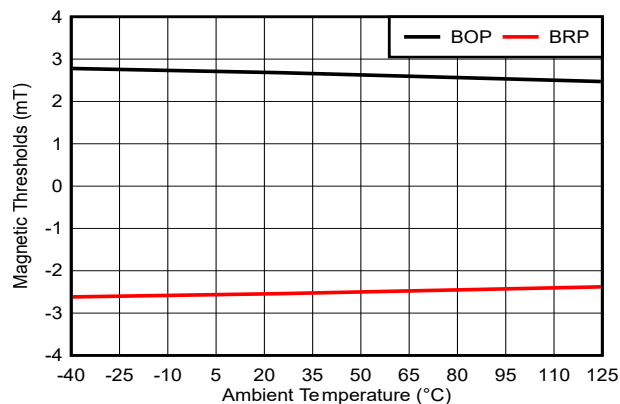
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Figure 6-2. 30kHz: Average I_{CC} vs Temperature



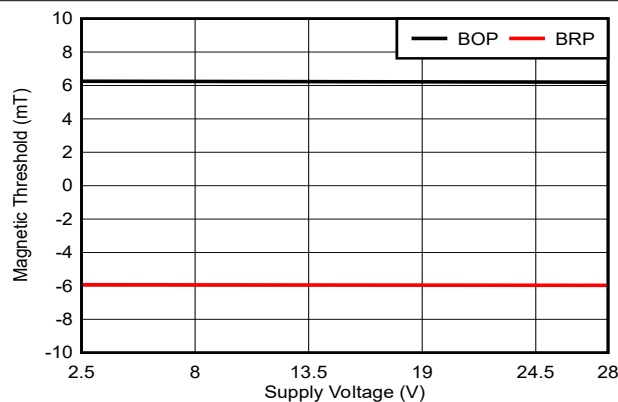
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Figure 6-3. 2.7mT B_{OP} : Thresholds vs V_{CC}



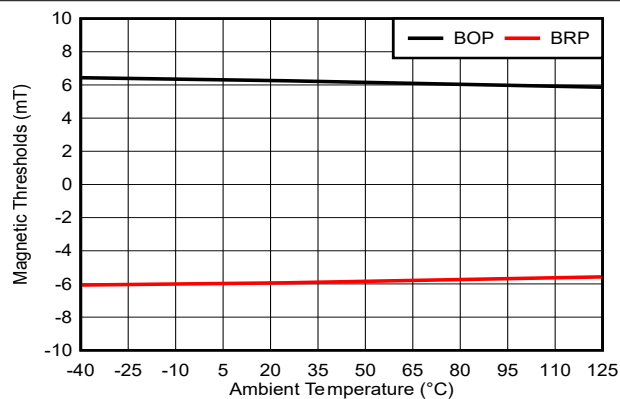
Version: AD

Figure 6-4. 2.7mT B_{OP} : Thresholds vs Temperature



Version: AG

Figure 6-5. 6mT B_{OP} : Thresholds vs V_{CC}



Version: AG

Figure 6-6. 6mT B_{OP} : Thresholds vs Temperature

7 Detailed Description

7.1 Overview

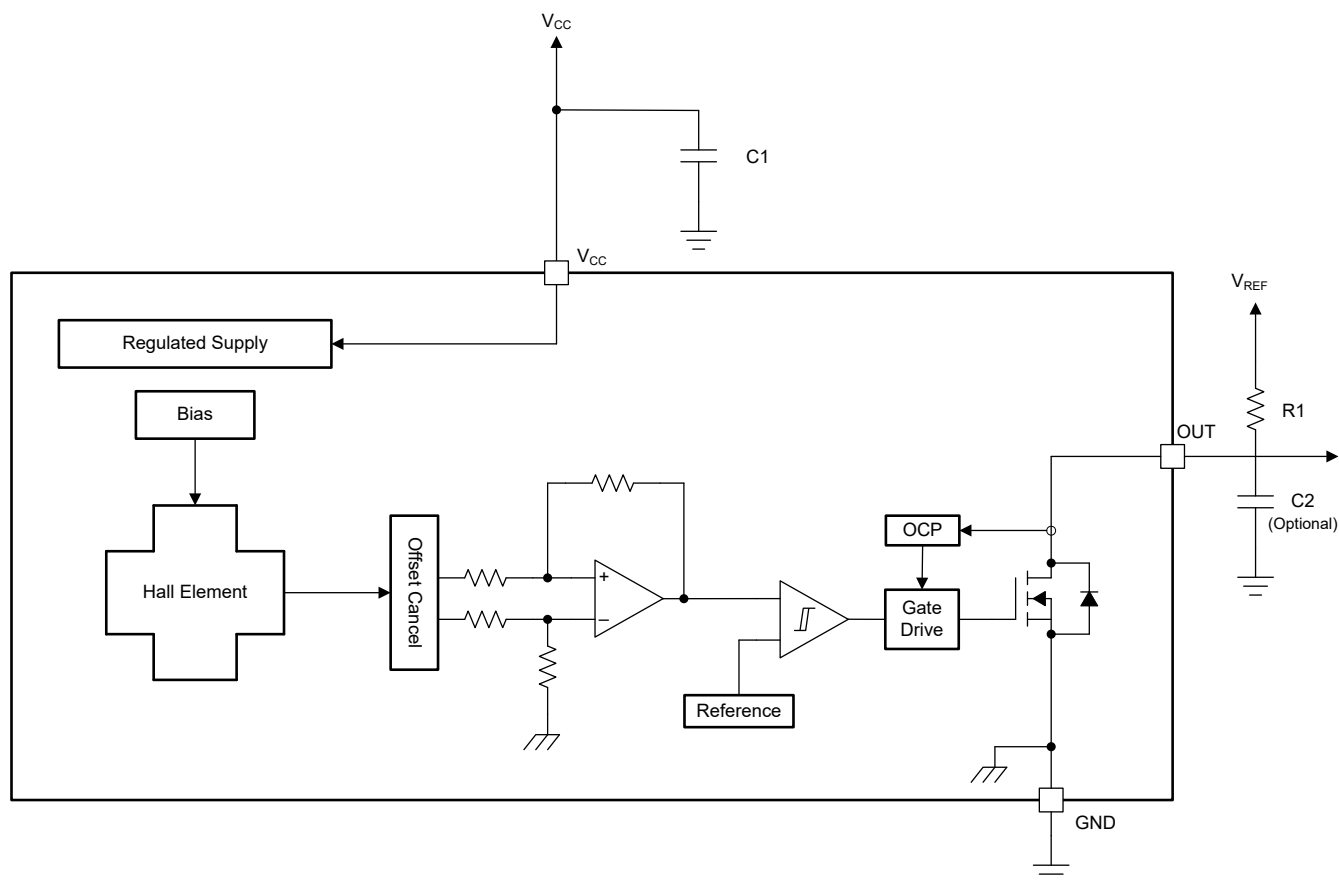
The TMAG5213 is a chopper-stabilized Hall sensor with a digital bipolar latched output for magnetic-sensing applications. The TMAG5213 device can be powered with a supply voltage between 2.5V and 28V.

The field polarity is defined as follows: a **south pole** near the marked side of the package is a positive magnetic field. A **north pole** near the marked side of the package is a negative magnetic field.

The output state is dependent on the magnetic field perpendicular to the package. A **south pole** near the marked side of the package causes the output to pull low (operate point, B_{OP}), and a **north pole** near the marked side of the package causes the output to release (release point, B_{RP}). Hysteresis is included in between the operate point and the release point, therefore magnetic-field noise does not accidentally trip the output.

An external pullup resistor is required on the OUT pin. The OUT pin can be pulled up to V_{CC} , or to a different voltage supply to allow for ease of use with controller circuits.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Field Direction Definition

The TMAG5213 is sensitive to the magnetic field component that is perpendicular to the marked side of the package. This direction is defined as the Z-axis as shown in Figure 7-1. Figure 7-2 shows that a positive magnetic field is defined in this document as what occurs when a south pole is near the marked side of the package. A negative magnetic field occurs when a north pole is near the marked side of the package.

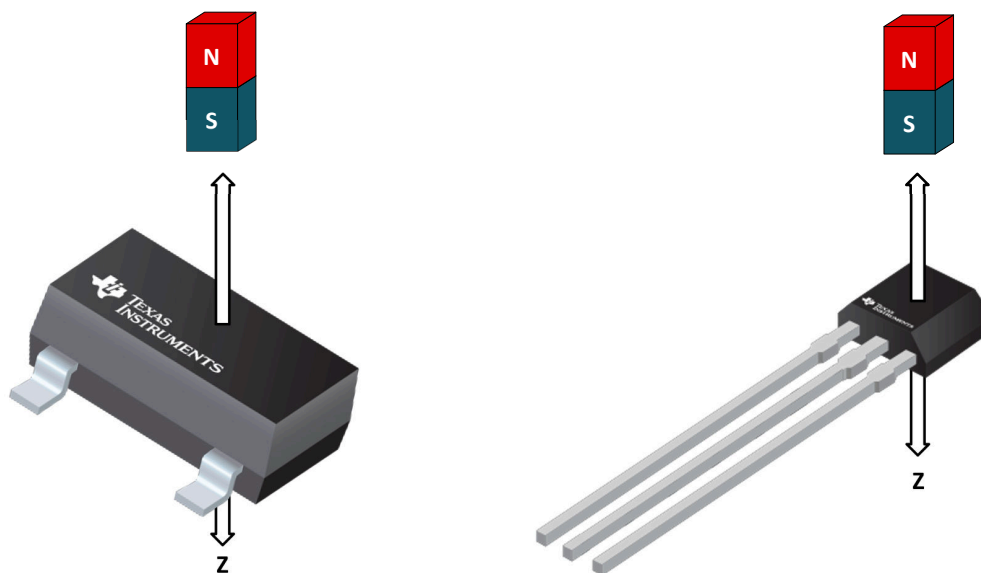


Figure 7-1. Definition of Z-Axis by Package

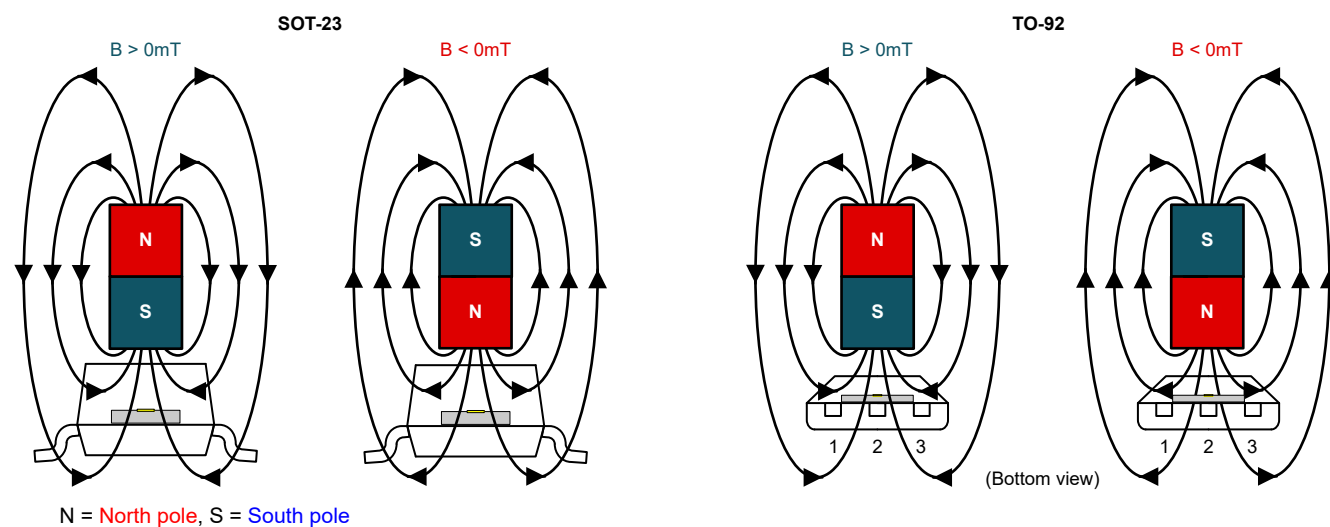


Figure 7-2. Definition of Positive and Negative Field Direction

7.3.2 Device Output

If the device is powered on with a magnetic field strength between B_{RP} and B_{OP} , then the device output is indeterminate and can either be Hi-Z or Low. If the field strength is greater than B_{OP} , then the output is pulled low. If the field strength is less than B_{RP} , then the output is released.

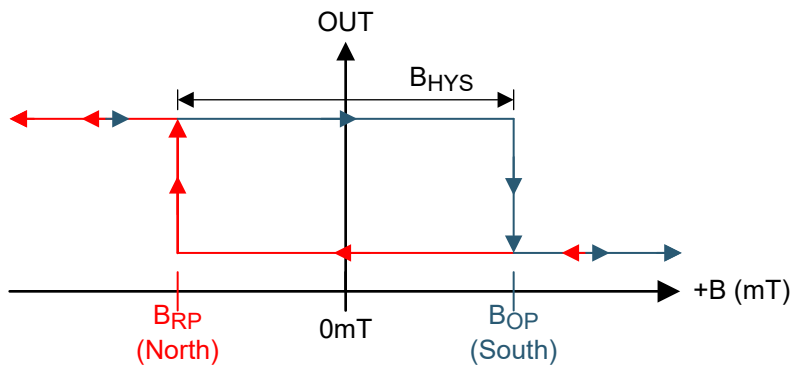


Figure 7-3. Bipolar Latch Active Low Functionality

7.3.3 Power-On Time

After applying V_{CC} to the TMAG5213 device, t_{on} must elapse before the OUT pin is valid. During the power-up sequence, the output is Hi-Z. A pulse as shown in Figure 7-4 and Figure 7-5 occurs at the end of t_{on} . This pulse can allow the host processor to determine when the TMAG5213 output is valid after start-up. In Case 1 (Figure 7-4) and Case 2 (Figure 7-5), the output is defined assuming a constant magnetic field $B > B_{OP}$ and $B < B_{RP}$.

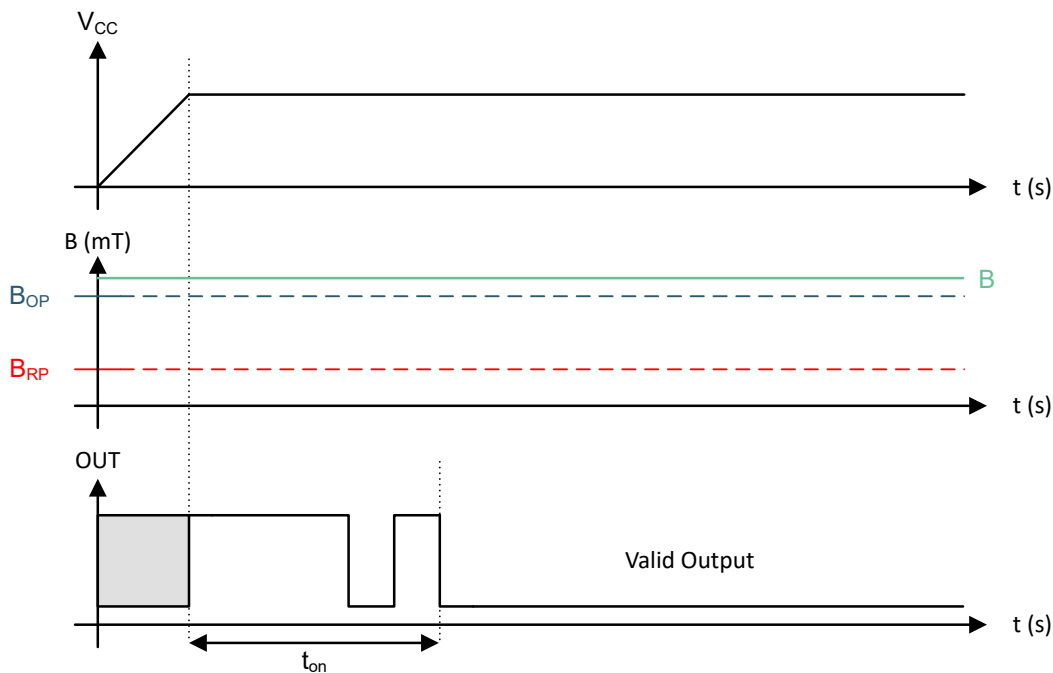


Figure 7-4. Case 1: Power On When $B > B_{OP}$

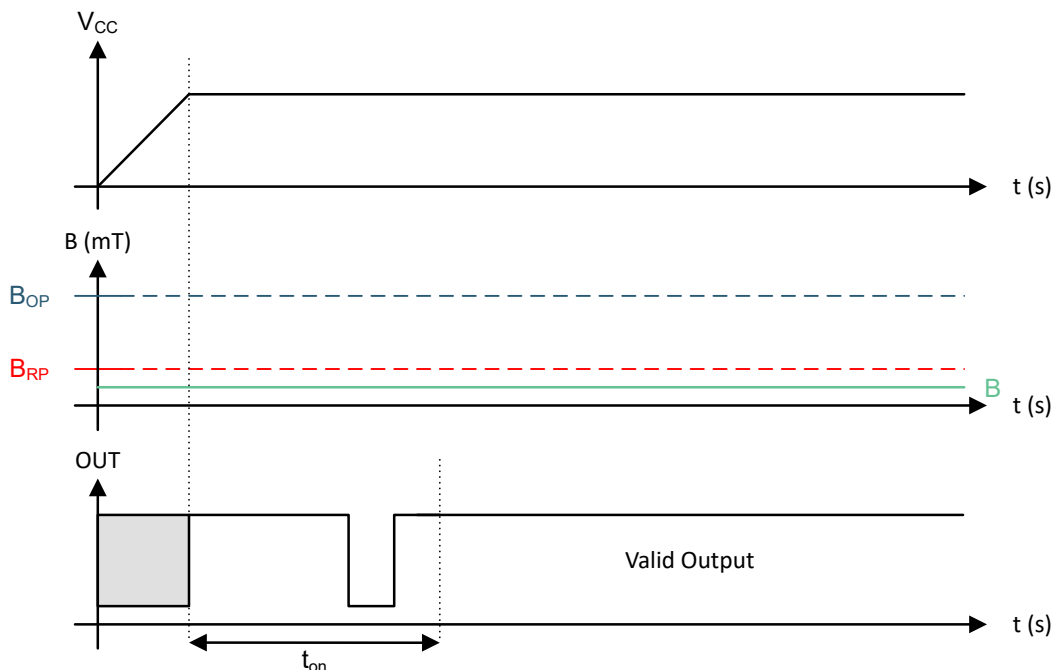


Figure 7-5. Case 2: Power On When $B < B_{RP}$

If the device is powered on with the magnetic field strength $B_{RP} < B < B_{OP}$, then the device output is indeterminate and can either be Hi-Z or pulled low. During the power-up sequence, the output is held Hi-Z until t_{on} has elapsed. At the end of t_{on} , a pulse is given on the OUT pin to indicate that t_{on} has elapsed. After t_{on} , if the magnetic field changes such that $B_{OP} < B$, the output is released. Case 3 (Figure 7-6) and Case 4 (Figure 7-7) show examples of this behavior.

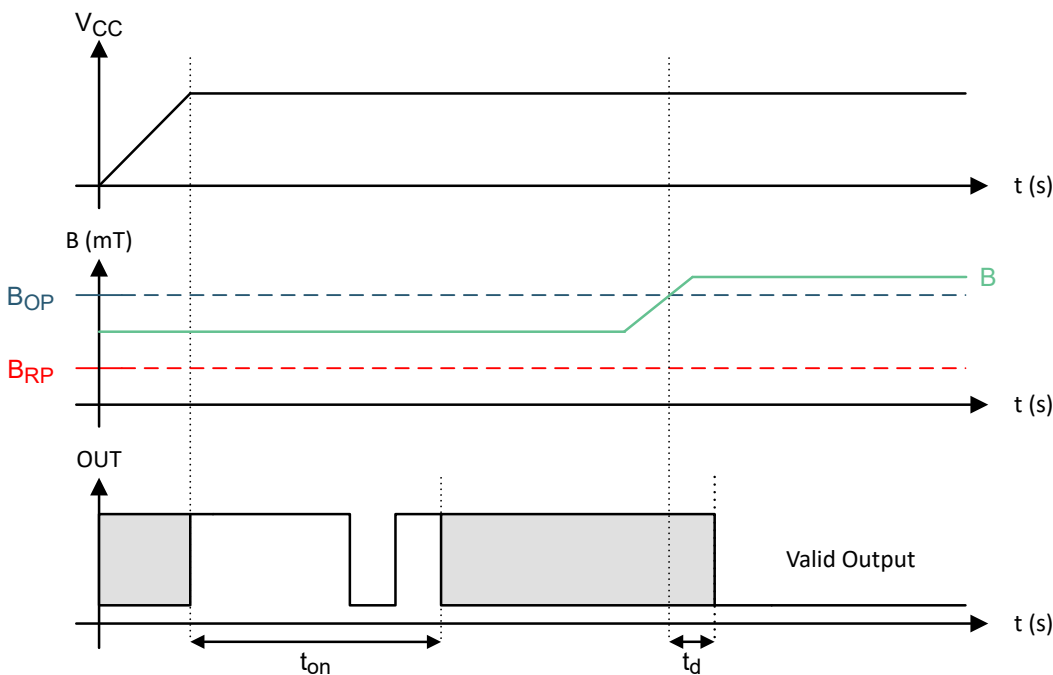


Figure 7-6. Case 3: Power On When $B_{RP} < B < B_{OP}$, Followed by $B > B_{OP}$

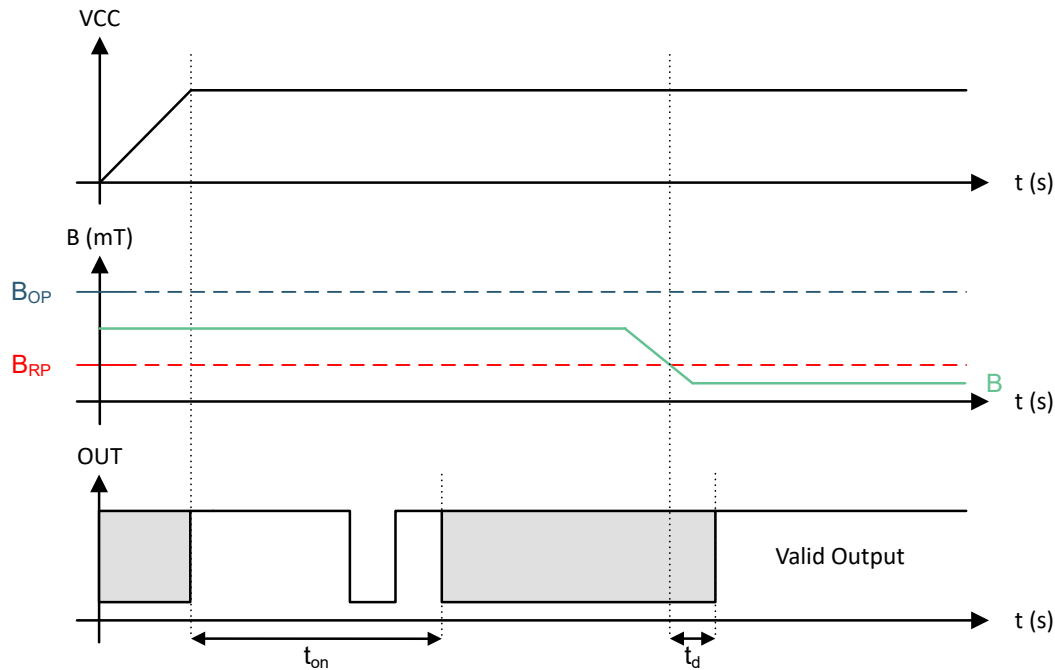


Figure 7-7. Case 4: Power On When $B_{RP} < B < B_{OP}$, Followed by $B < B_{RP}$

7.3.4 Output Stage

Figure 7-8 shows the TMAG5213 open-drain NMOS output structure, rated to sink up to 30mA of current. For proper operation, use Equation 1 to calculate the value of pullup resistor R1.

$$\frac{V_{ref\ max}}{30mA} \leq R1 \leq \frac{V_{ref\ min}}{100\mu A} \quad (1)$$

The size of R1 is a tradeoff between the OUT rise time and the current when OUT is pulled low. A lower current is generally better, however faster transitions and bandwidth require a smaller resistor for faster switching.

In addition, make sure that the value of $R1 > 500\Omega$ so that the output driver can pull the OUT pin close to GND. Generally, TI recommends to use a resistor with a 10k Ω nominal value.

Note

V_{ref} is not restricted to V_{CC} . The allowable voltage range of this pin is specified in the [Absolute Maximum Ratings](#).

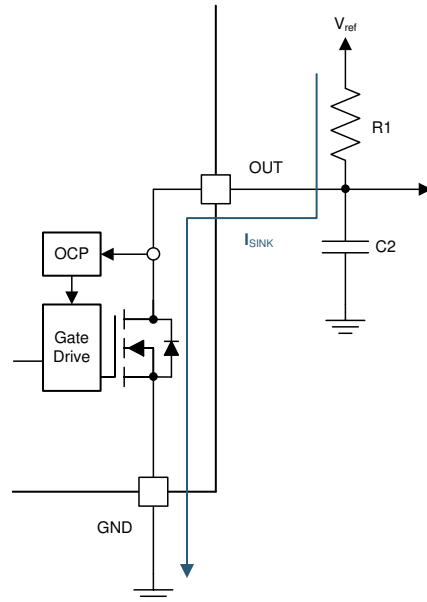


Figure 7-8. NMOS Open-Drain Output

Select a value for C2 based on the system bandwidth specifications as shown in [Equation 2](#).

$$2 \times f_{BW} \text{ (Hz)} < \frac{1}{2\pi \times R1 \times C2} \quad (2)$$

Most applications do not require this C2 filtering capacitor.

7.3.5 Protection Circuits

The TMAG5213 device is protected against overcurrent conditions. [Table 7-1](#) lists a summary of the protection circuits.

Table 7-1. Protection Circuit Summary

FAULT	CONDITION	DEVICE	DESCRIPTION	RECOVERY
FET overload (OCP)	$I_{SINK} \geq I_{OCP}$	Operating	Output current is clamped to I_{OCP}	$I_O < I_{OCP}$

7.3.5.1 Overcurrent Protection (OCP)

An analog current-limit circuit limits the current through the FET. The driver current is clamped to I_{OCP} . During this clamping, the $r_{DS(on)}$ of the output FET is increased from the nominal value.

7.4 Device Functional Modes

The TMAG5213 device has one mode of operation that applies when operated within the [Recommended Operating Conditions](#).

8 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.

8.1 Application Information

The TMAG5213 is used in magnetic position sensing applications. The device features a high-speed architecture to facilitate more precise field measurement. With latching magnetic characteristics, the output is turned low or high respectively with a sufficiently strong south or north pole facing the package top side. When removing the magnetic field, the device keeps its previous state.

For reliable functionality, the magnet must apply a flux density at the sensor greater than the corresponding maximum B_{OP} or B_{RP} numbers specified in the [Magnetic Characteristics](#) table. Add additional margin to account for mechanical tolerance, temperature effects, and magnet variation.

8.2 Typical Applications

8.2.1 Standard Circuit

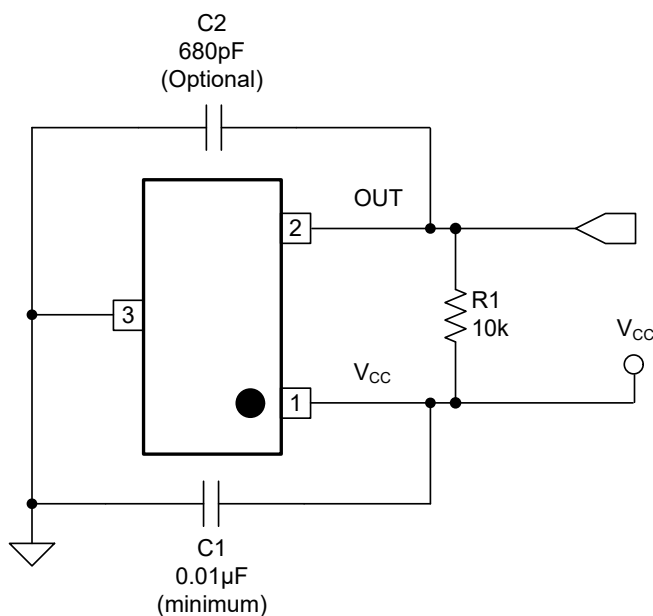


Figure 8-1. Typical Application Circuit

8.2.1.1 Design Requirements

For this design example, use the parameters listed in [Table 8-1](#) as the input parameters.

Table 8-1. Design Parameters

DESIGN PARAMETER	REFERENCE	EXAMPLE VALUE
Supply voltage	V_{CC}	3.2V to 3.4V
System bandwidth	f_{BW}	10kHz

8.2.1.2 Detailed Design Procedure

Table 8-2. External Components

TMAG5213 COMPONENT	PIN 1	PIN 2	RECOMMENDED
C1	V _{CC}	GND	A 0.01μF (minimum) ceramic capacitor rated for V _{CC}
C2	OUT	GND	Optional: Place a ceramic capacitor to GND
R1	OUT	REF ⁽¹⁾	Requires a resistor pullup

(1) REF is not a pin on the TMAG5213 device, but a REF supply-voltage pullup is required for the OUT pin; the OUT pin can be pulled up to V_{CC}.

8.2.1.2.1 Configuration Example

In a 3.3V system, $3.2V \leq V_{ref} \leq 3.4V$. Use Equation 3 to calculate the allowable range for R1.

$$\frac{V_{ref\ max}}{30mA} \leq R1 \leq \frac{V_{ref\ min}}{100\mu A} \quad (3)$$

For this design example, use Equation 4 to calculate the allowable range of R1.

$$\frac{3.4V}{30mA} \leq R1 \leq \frac{3.2V}{100\mu A} \quad (4)$$

Therefore:

$$113\Omega \leq R1 \leq 32k\Omega \quad (5)$$

After finding the allowable range of R1 (Equation 5), select a value between 500Ω and 32kΩ for R1.

Assuming a system bandwidth of 10kHz, use Equation 6 to calculate the value of C2.

$$2 \times f_{BW} \text{ (Hz)} < \frac{1}{2\pi \times R1 \times C2} \quad (6)$$

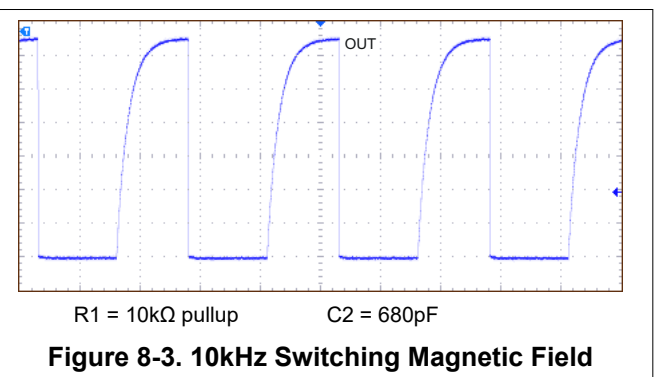
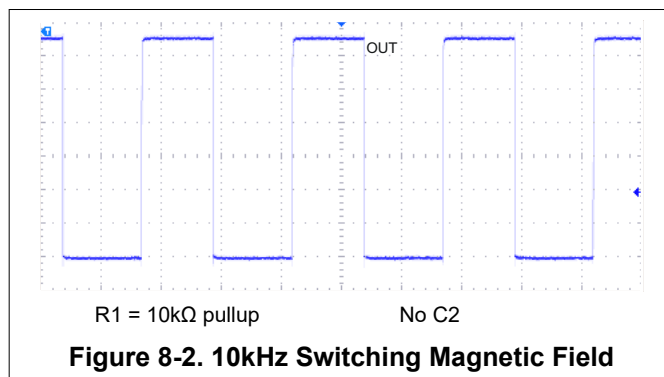
For this design example, use Equation 7 to calculate the value of C2.

$$2 \times 10kHz < \frac{1}{2\pi \times R1 \times C2} \quad (7)$$

An R1 value of 10kΩ and a C2 value less than 820pF satisfy the requirement for a 10kHz system bandwidth.

A selection of R1 = 10kΩ and C2 = 680pF can cause a low-pass filter with a corner frequency of 23.4kHz.

8.2.1.3 Application Curves



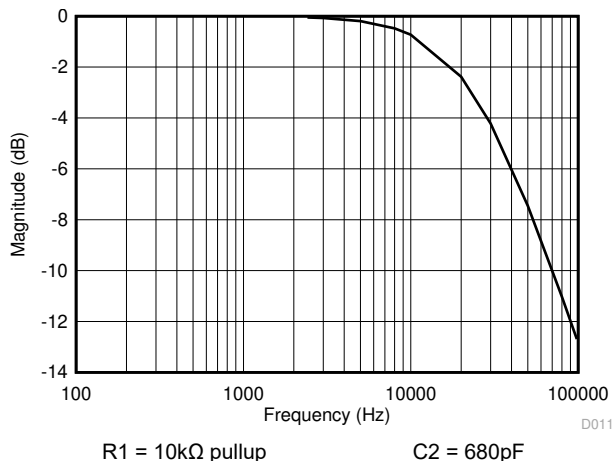


Figure 8-4. Low-Pass Filtering

8.3 Power Supply Recommendations

The TMAG5213 device is designed to operate from an input voltage supply range between 2.5V and 28V. A bypass 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 0.01 μ F (minimum). To attenuate any significant high-frequency ripple and noise components generated by the power source, larger values of the bypass capacitor can be used. TI recommends limiting the supply voltage variation to less than 50mV_{PP}.

8.4 Layout

8.4.1 Layout Guidelines

Place the bypass capacitor near the TMAG5213 device for efficient power delivery with minimal inductance. Place the external pullup resistor near the microcontroller input to provide the most stable voltage at the input. Alternatively, an integrated pullup resistor within the GPIO of the microcontroller can be used.

Magnetic fields pass through most non-ferromagnetic 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 (PCBs), which makes the placement of the magnet on the opposite side possible. Generally, using PCB copper planes underneath the TMAG5213 has no effect on magnetic flux, and does not interfere with device performance. This is because copper is not a ferromagnetic material. However, if nearby system components contain iron or nickel, these components can redirect magnetic flux in unpredictable ways.

8.4.2 Layout Example

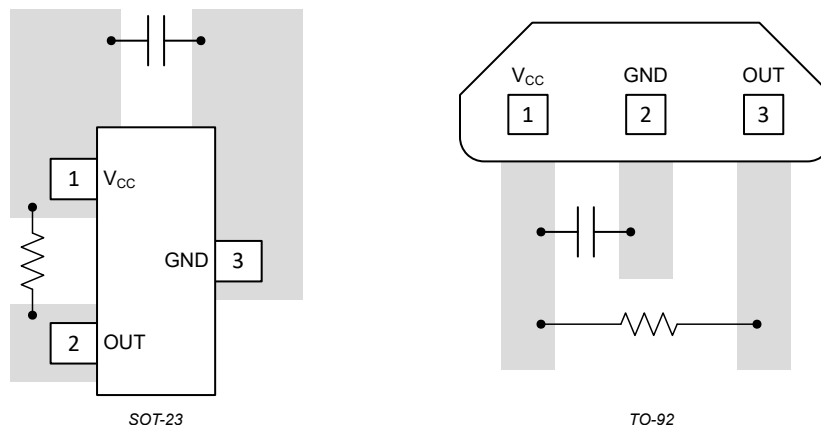


Figure 8-5. TMAG5213 Layout Example

9 Device and Documentation Support

9.1 Device Support

9.1.1 Device Nomenclature

Figure 9-1 shows a legend for reading the complete device name for and TMAG5213 device.

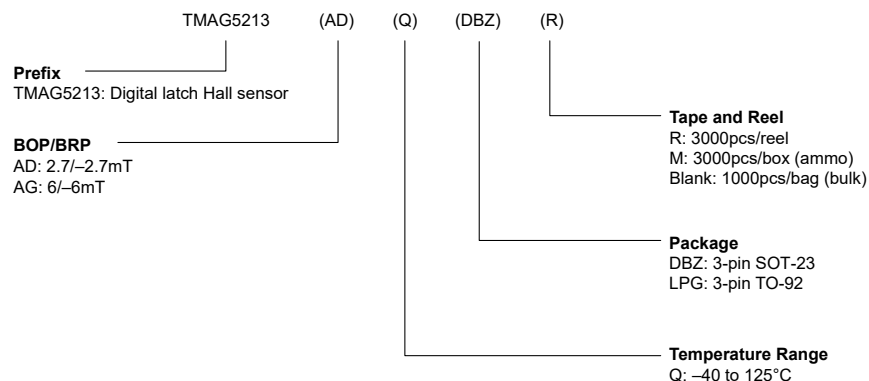
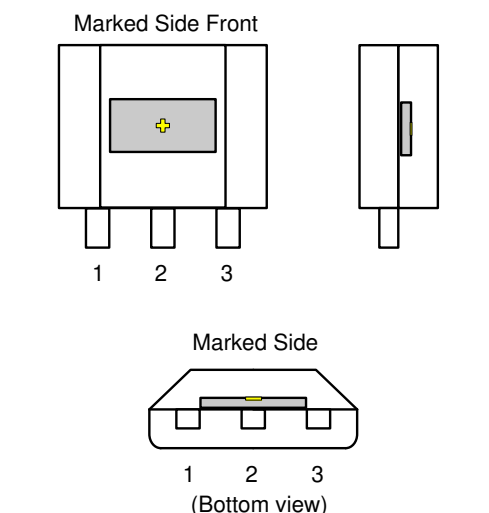
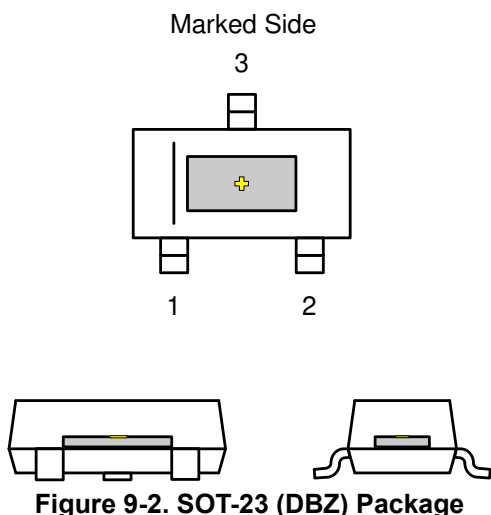


Figure 9-1. Device Nomenclature

9.1.2 Device Markings



9.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.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.

9.3 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](#).

9.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

9.5 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.

9.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

10 Revision History

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

Changes from Revision A (April 2024) to Revision B (August 2024)	Page
• Changed data sheet title.....	1

Changes from Revision * (March 2024) to Revision A (April 2024)	Page
• Removed preview note from the DBZ (SOT-23, 3) package.....	1

11 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 Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TMAG5213ADQDBZR	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	3ECH	Samples
TMAG5213ADQLPG	ACTIVE	TO-92	LPG	3	1000	RoHS & Green	SN	N / A for Pkg Type	-40 to 125	3EEJ	Samples
TMAG5213ADQLPGM	ACTIVE	TO-92	LPG	3	3000	RoHS & Green	SN	N / A for Pkg Type	-40 to 125	3EEJ	Samples
TMAG5213AGQDBZR	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	3EDH	Samples
TMAG5213AGQLPG	ACTIVE	TO-92	LPG	3	1000	RoHS & Green	SN	N / A for Pkg Type	-40 to 125	3EFJ	Samples
TMAG5213AGQLPGM	ACTIVE	TO-92	LPG	3	3000	RoHS & Green	SN	N / A for Pkg Type	-40 to 125	3EFJ	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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