TMAG5231 低功率，霍尔效应开关

1 特性

- 低功耗：
  - 20Hz 版本：2μA（3V 时）
- 1.65V 至 5.5V 工作 V_{CC} 范围
- 磁性阈值选项（典型 B_{OP}）：
  - 2.85mT（1.35mT 磁滞）
- 全极响应
- 推挽式输出
- 业界通用的封装和引脚
  - SOT-23 封装
- 工作温度范围：–40°C 至 +125°C

2 应用

- 手机、笔记本电脑或平板电脑保护壳感应
- 电表篡改检测
- 电子锁
- 烟雾探测器
- 家用电器开关检测
- 医疗设备
- 物联网系统
- 阀和电磁阀位置检测
- 非接触式诊断或激活

3 说明

TMAG5231 是第二代低功耗霍尔效应开关传感器，专为降低紧凑型电池供电消费类和工业应用的总系统成本而设计。

当施加的磁通量密度超过工作点 (B_{OP}) 阈值时，器件会输出低电压。输出会保持低电平，直到磁通密度降至低于释放点 (B_{RP})，随后器件输出高电压。全极磁响应可以使输出对南北磁场都很敏感。

TMAG5231 能够以非常低的电流消耗运行。为了实现 2μA 的电流消耗，该器件在内部以 20Hz 的频率进行上电下电。

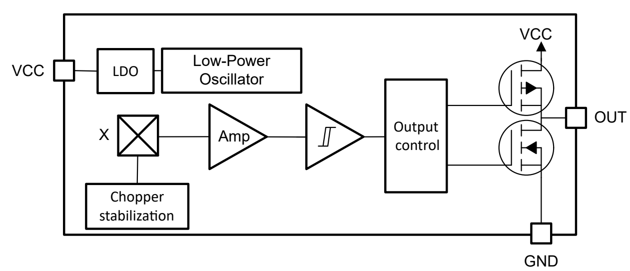
TMAG5231 采用业界通用的封装和引脚排列 SOT-23。

该器件可在 1.65V 至 5.5V 的 V_{CC} 范围以及 –40°C 至 125°C 的工作温度范围内正常运行。

器件信息(1)

器件型号	封装	封装尺寸（标称值）
TMAG5231	SOT-23 (3)	2.92mm × 1.30mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。



方框图

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4 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision * (August 2021) to Revision A (November 2021) **Page**

- 将数据表状态从“预告信息”更改为“量产数据” 1
- 添加了 FA 和 FD 器件版本.. 1

5 Device Comparison

表 5-1. Device Comparison

VERSION	TYPICAL THRESHOLD	TYPICAL HYSTERESIS	MAGNETIC RESPONSE	OUTPUT TYPE	SENSOR ORIENTATION	SAMPLING RATE	PACKAGES AVAILABLE
TMAG5231B1 DIDBZ	3 mT	1.35mT	Omnipolar active Low	Push-pull	Z	20 HZ	SOT-23

6 Pin Configuration and Functions

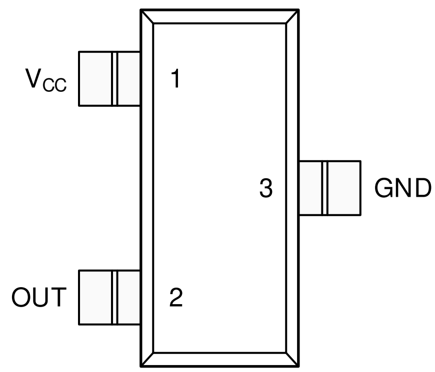


图 6-1. DBZ Package 3-Pin SOT-23 Top View

表 6-1. Pin Functions

PIN		I/O	DESCRIPTION
NAME	SOT-23		
GND	3	—	Ground reference
OUT	2	O	Omnipolar output that responds to north and south magnetic poles
V_{CC}	1	—	1.65-V to 5.5-V power supply. TI recommends connecting this pin to a ceramic capacitor to ground with a value of at least 0.1 µF.

7 Specifications

7.1 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 Pin Voltage	OUT	GND − 0.3	V_{CC} + 0.3	
Output Pin current	OUT	-5	5	mA
Magnetic Flux Density,BMAX		Unlimited		T
Junction temperature, T_J	Junction temperature, T_J		150	°C
Storage temperature, T_{stg}		−65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Rating* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins[(1)]	±5500	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins[(2)]	± 500	

(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.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{CC}	Power supply voltage	1.65	5.5	V
Vo	Output voltage	0	5.5	V
Io	Output current	-5	5	mA
T_A	Ambient temperature	−40	125	°C

7.4 Thermal Information

THERMAL METRIC[(1)]		TMAG5231 SOT-23 (DBV) PIN3	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	227.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	122.7	
$R_{\theta JB}$	Junction-to-board thermal resistance	61.2	
Ψ_{JT}	Junction-to-top characterization parameter	21.3	
Ψ_{JB}	Junction-to-board characterization parameter	60.8	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	

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

7.5 Electrical Characteristics

for VCC = 1.65 V to 5.5 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
PUSH-PULL OUTPUT DRIVER						
V_{OH}	High-level output voltage	I_{OUT} = -0.5mA	Vcc-0.35	Vcc-0.1		V
V_{OL}	Low-level output voltage	I_{OUT} = 0.5mA		0.1	0.3	V
TMAG5231xxD						
fs	Frequency of magnetic sampling		13	20	29	Hz
ts	Period of magnetic sampling			50		ms
$I_{CC(AVG)}$	Average current consumption	Vcc=3V over temperature		2	3	µA
ALL VERSIONS						
$I_{CC(PK)}$	Peak current consumption		0.8	1.25	2	mA
$I_{CC(SLP)}$	Sleep current consumption			0.8	1.4	µA
t_{ON}	Power-on time		65	140	425	µs
t_{ACTIVE}	Active time period		45	60	75	µs

7.6 Magnetic Characteristics

for VCC = 1.65 V to 5.5 V

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
TMAG5231B1D						
B_{OP}	Magnetic threshold operate point	Temperature = 25°C	±1.9	±2.85	±3.8	mT
B_{RP}	Magnetic release operate point	Temperature = 25°C	±0.5	±1.5	±2.5	mT
B_{HYS}	Magnetic hysteresis	Temperature = 25°C	±0.5	±1.35	±2.2	mT

7.7 Typical Characteristics

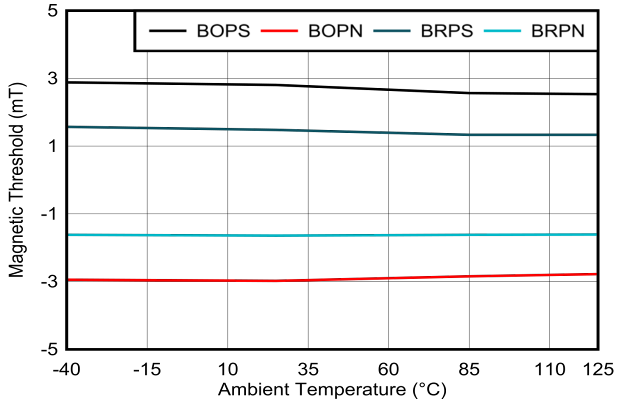


图 7-1. Thresholds vs. Temperature

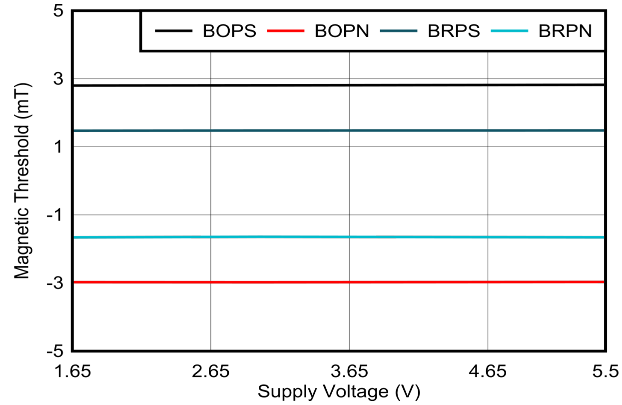


图 7-2. Thresholds vs. Supply Voltage

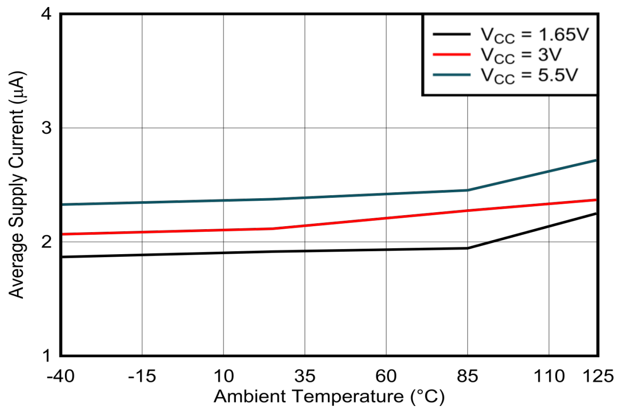


图 7-3. ICC vs. Temperature

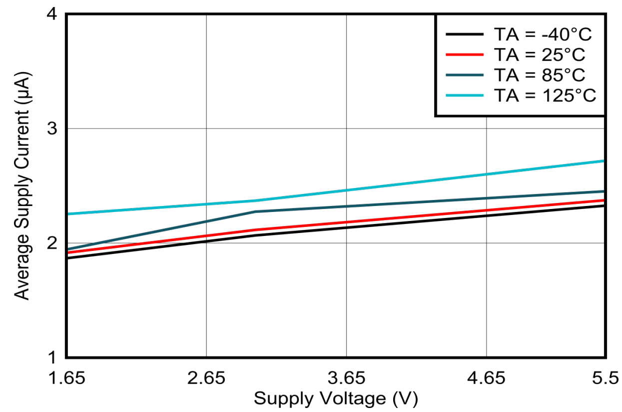


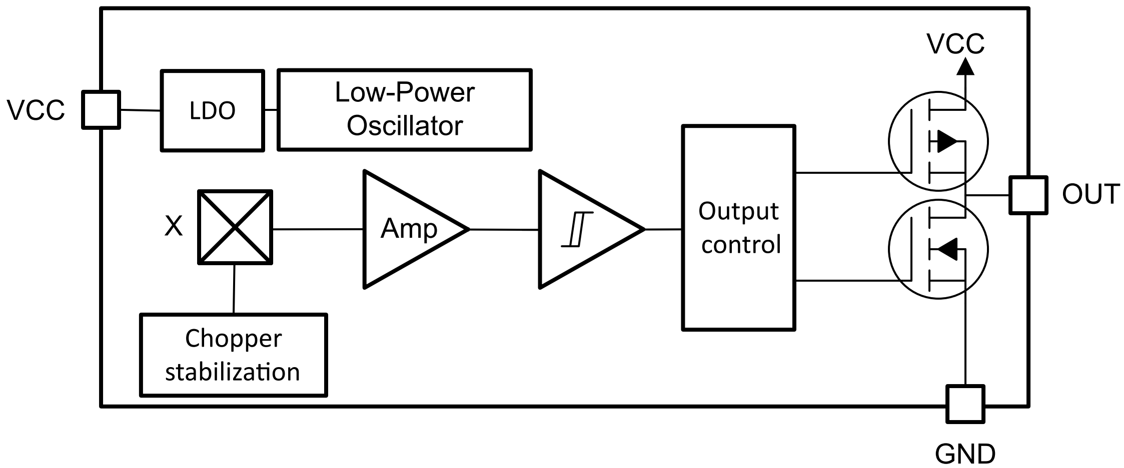
图 7-4. ICC vs. Supply Voltage

8 Detailed Description

8.1 Overview

The TMAG5231 device is a magnetic sensor with a digital output that indicates when the magnetic flux density threshold has been crossed. The output consists of a push-pull turning low when a field is present or turning high when no field is present. As an omnipolar switch the output is sensitive to both the South and the North Pole. The device integrates a Hall Effect element, analog signal conditioning, and a low-frequency oscillator that enables ultra-low average power consumption. To achieve low-power consumption the device periodically measures magnetic flux density, updates the output, and enters into a low-power sleep state. With a range of 1.65-V to 5.5-V, this device is designed for battery-operated applications.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Magnetic Flux Direction

The TMAG5231 device is sensitive to the magnetic field component that is perpendicular to the top of the package (see 图 8-1).

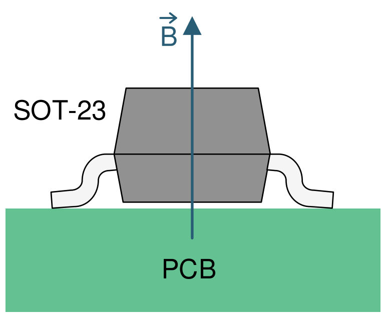


图 8-1. Direction of Sensitivity

Magnetic flux that travels from the bottom to the top of the package is considered positive in this data sheet. This condition exists when a south magnetic pole is near the top of the package. Magnetic flux that travels from the top to the bottom of the package results in negative millitesla values.

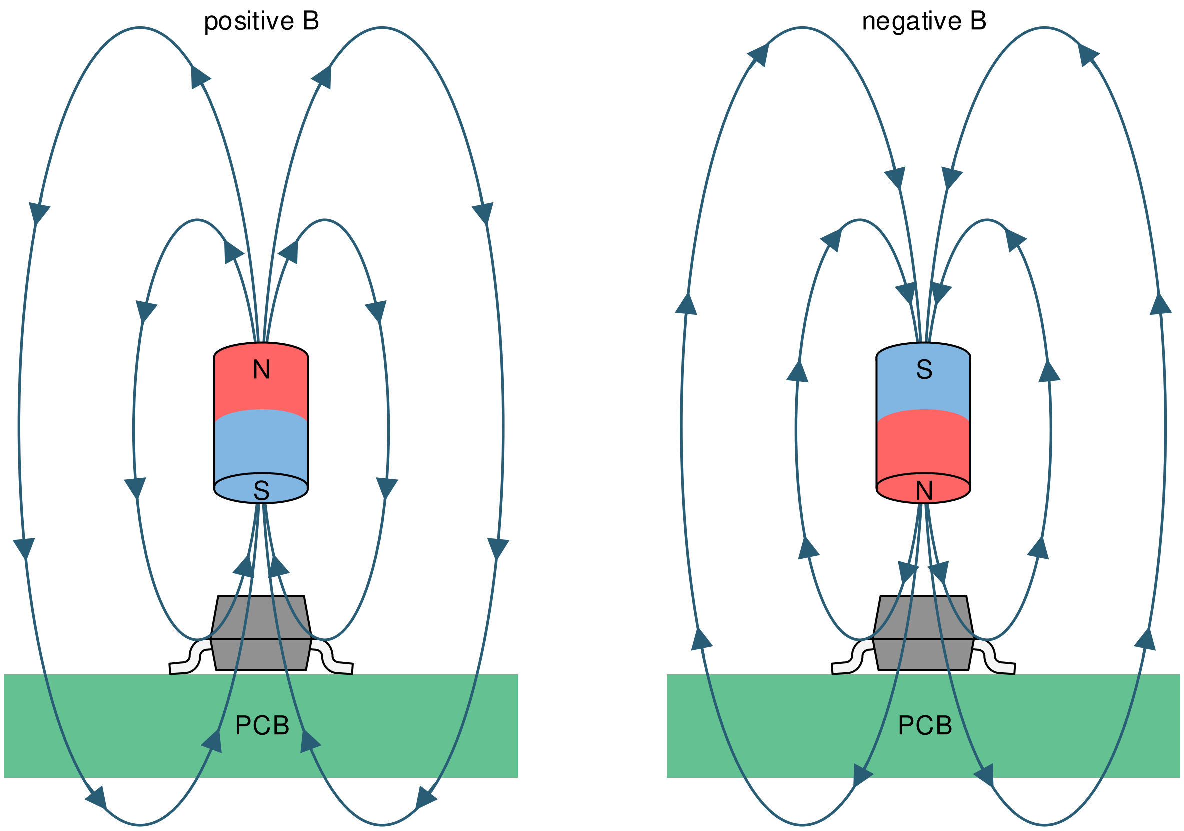


图 8-2. Flux Direction Polarity

8.3.2 Magnetic Response

The TMAG5231 is an omnipolar switch. The output responds to both north and south poles (see 图 8-3).

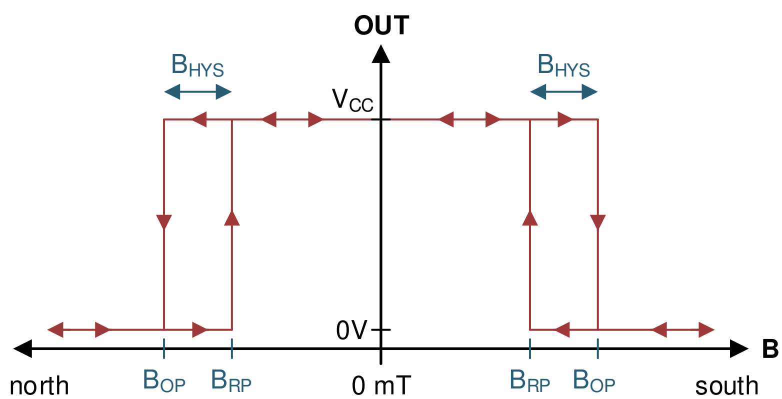


图 8-3. Omnipolar Functionality

8.3.3 Output Type

The TMAG5231 has a push-pull CMOS output that can drive the output voltage near a V_{CC} or ground level.

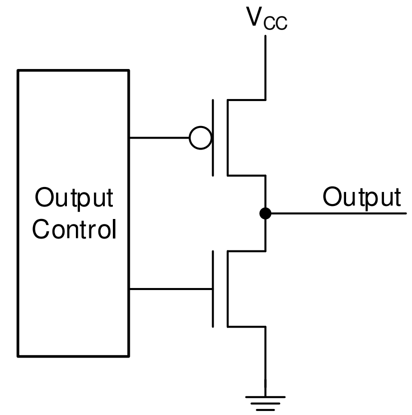


图 8-4. Push-Pull Output (Simplified)

8.3.4 Sampling Rate

When the TMAG5231 powers up, the device measures the first magnetic sample and sets the output within the t_{ON} time. The output is latched, and the device enters an ultra-low-power sleep state. After each t_S time has passed, the device measures a new sample and updates the output if necessary. If the magnetic field does not change between periods, the output also does not change.

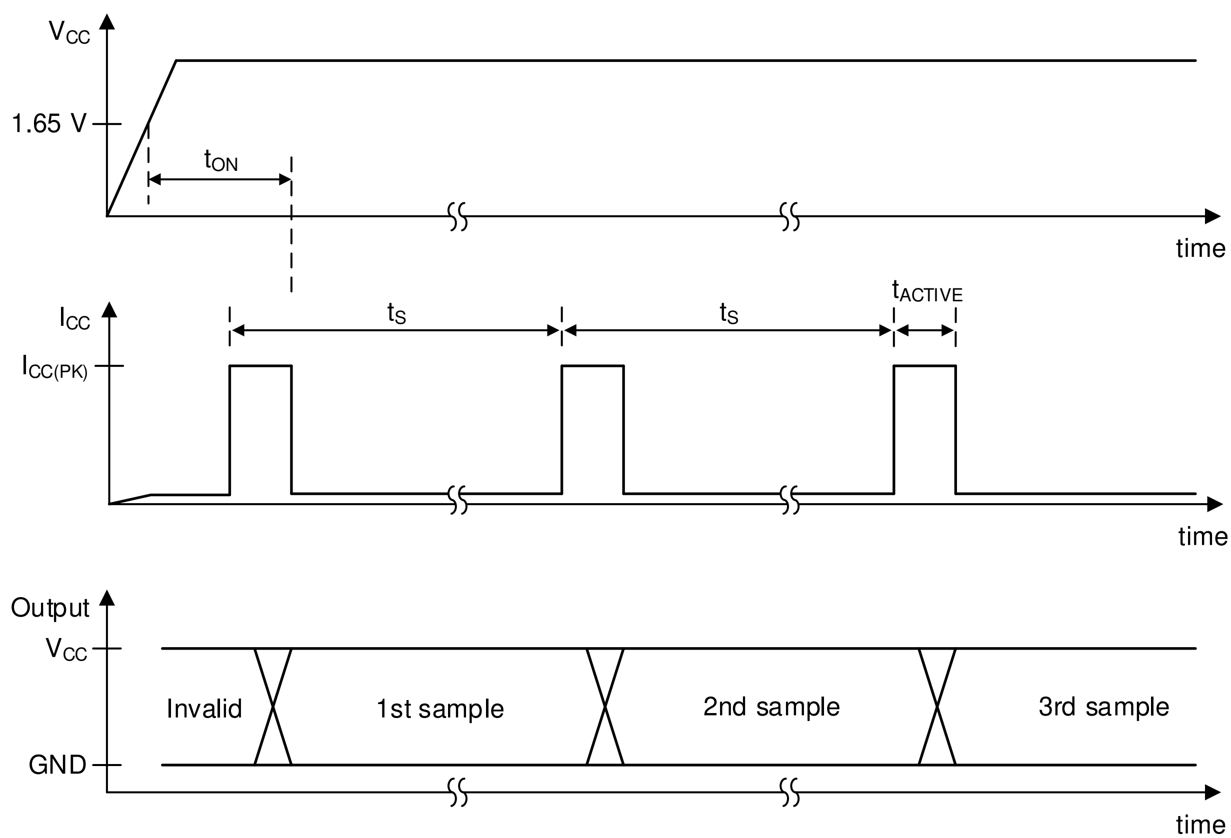


图 8-5. Timing Diagram

8.3.5 Hall Element Location

The sensing element inside the device is in the center of both packages when viewed from the top. 图 8-6 shows the tolerances and side-view dimensions.

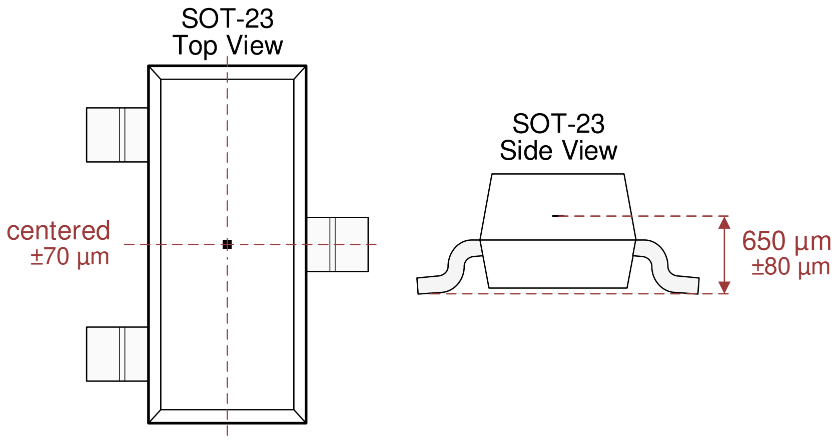


图 8-6. Hall Element Location

8.4 Device Functional Modes

The TMAG5231 device has one mode of operation that applies when the *Recommended Operating Conditions* are met.

9 Application and Implementation

Note

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客 户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

9.1 Application Information

The TMAG5231 device is typically used to detect the proximity of a magnet. The magnet is often attached to a movable component in the system.

9.1.1 Defining the Design Implementation

The first step of design is identifying your general design implementation, which means you will define whether you are detecting a magnet sliding past the sensor, moving head-on toward the sensor, or swinging toward the sensor on a hinge. 图 9-1 shows examples for each of the aforementioned design implementations.

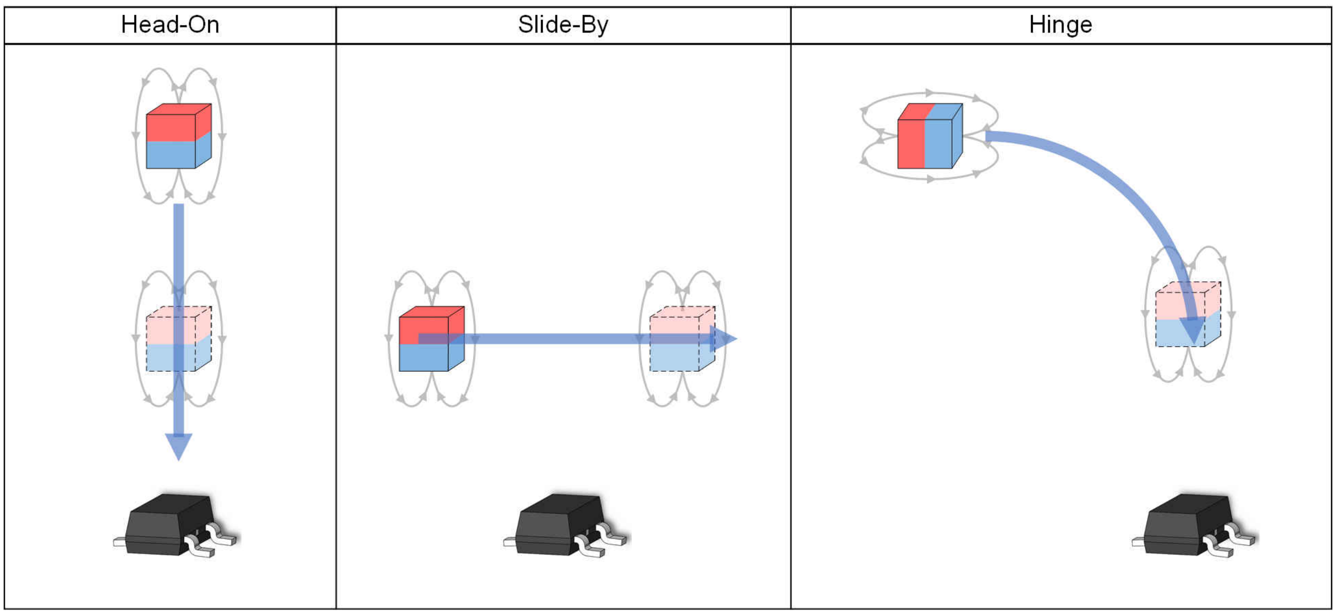


图 9-1. Design Implementations

With each implementation, the objective is to design the system such that the spatial coordinates of the transition region fall within the spatial coordinates associated with the BOP max and BRP min specifications. 图 9-2 shows a head-on example that illustrates how the location corresponding to the device BOPmax and BRPmin fall within the desired transition region. To facilitate rapid design iteration, TI’s Magnetic Sensing Proximiy Tool is leveraged in the following design examples.

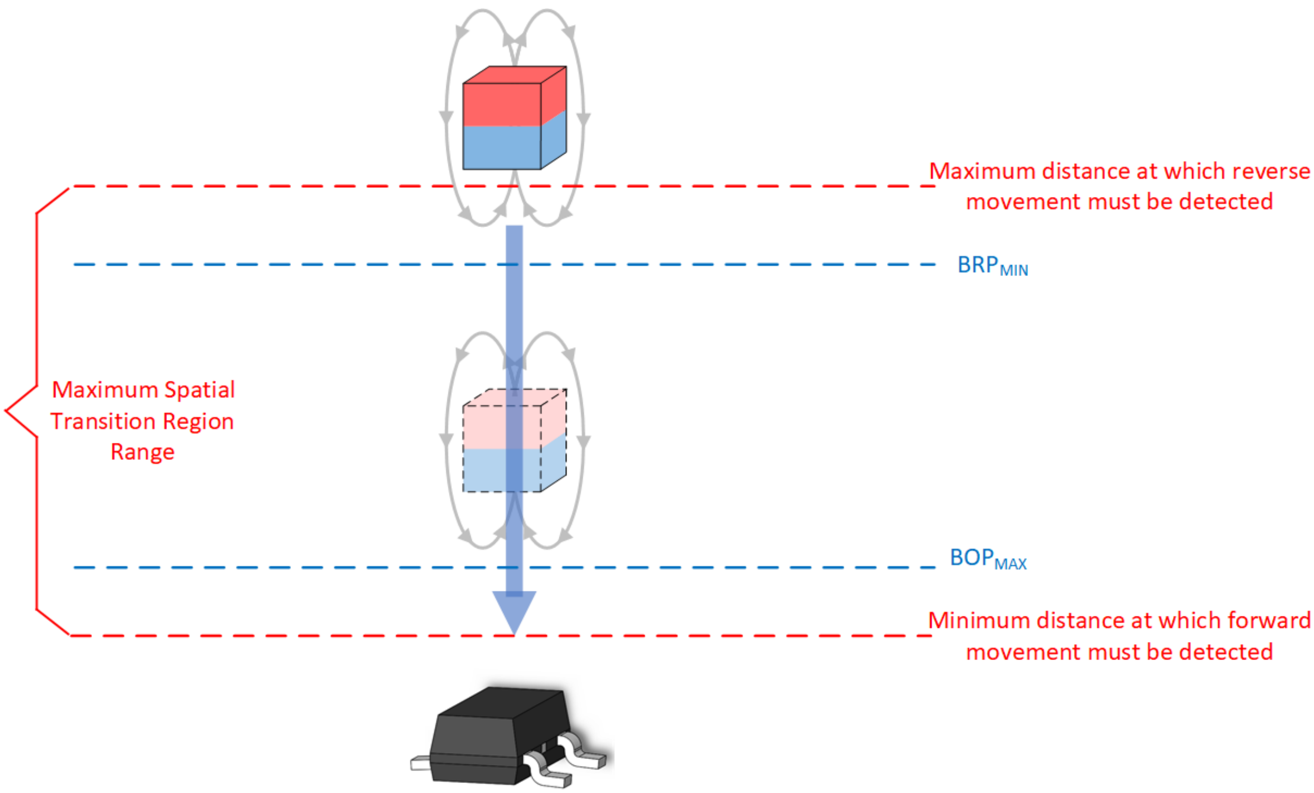


图 9-2. Head-On Example

9.2 Typical Applications

9.2.1 Hinge

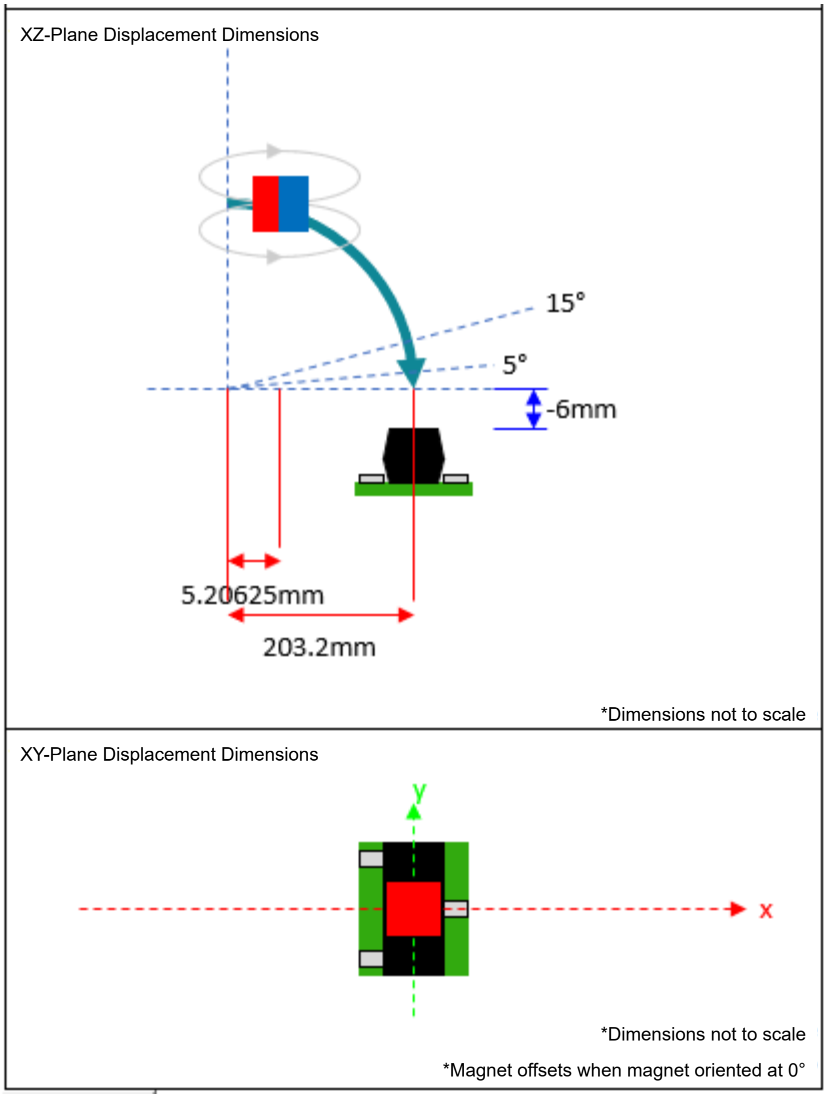


图 9-3. Typical Application Diagram

9.2.1.1 Design Requirements

表 9-1 lists the design parameters for this example.

表 9-1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{CC}	3.3 V
Switch Region	5° to 15°
Max Magnet	1/4” (6.35 mm)
Max Magnet Width or Legnth	1” (25.4 mm)
Fixture Width	12” (304.8 mm)
Fixture Length	9” (228.6 mm)
Sensor Distance From Hing Origin	0.23622 “ (6 mm)

表 9-1. Design Parameters (continued)

DESIGN PARAMETER	EXAMPLE VALUE
Center Of Magnet Offset From Hinge Origin	⩾(6 mm – Magnet Height/2)

9.2.1.2 Detailed Design Procedure

Due to the complex non-linear behavior magnets and the number of variables that can influence it, some experimentation is required to solve for a design that will work. This application uses a simple axial, dipole, block magnet. Other shapes might be considered for different field strengths or prices. A neodymium type of magnet (N52) is used. At the time of this writing, N52 can be commonly found with heights of 1/16” , 1/8” , 3/16” , and 1/4". As price often increases with size, the first design attempt will be with a 1/16” thick magnet, which has a width and length equal to 0.25” . Based on the sensor distance from hinge origin and fixture dimension constraints, there is a lot of flexibility on where the sensor can be placed. Due to other hardware within our fixture we decide to place the sensor 8” (203.2 mm) from the origin. From there, the user can assess a design with the following displacement dimensions.

图 9-4 shows that a b-field magnitude is not adequate for the spatial constraints of 5° and 15°, as the Bz magnitude only surpasses the BRP minimum. There are a few options on how to proceed. As the BOPmin does not fall within our range,the user must increase field strength. This can be accomplished with a thicker magnet or by adjusting sensor and magnet z-offsets. The magnet cannot get any closer as the hinge is expected travel to 0° in this case, therefore the only option allowed is to increase the magnet thickness. After a few more iterations with the tool, a 0.25” × 0.25” × 0.25” magnet can work (see 图 9-5 and 图 9-6).

9.2.1.3 Application Curves

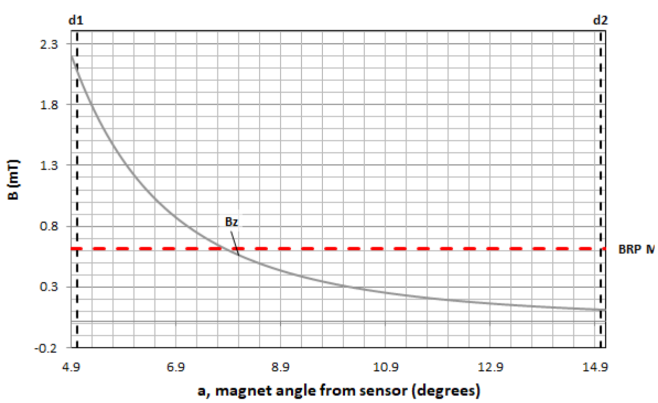


图 9-4. B-Field Hypothesis One

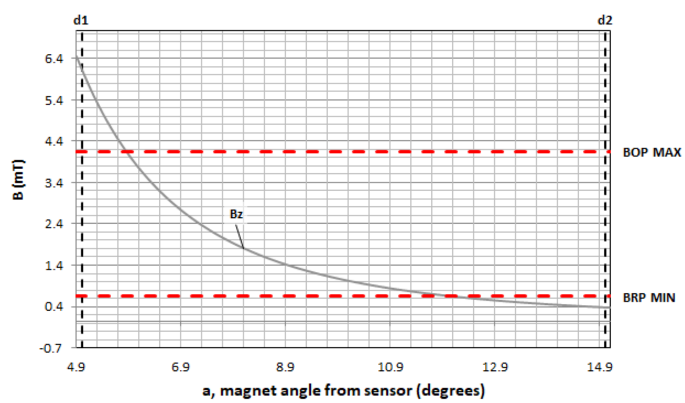


图 9-5. B-Field Hypothesis Two

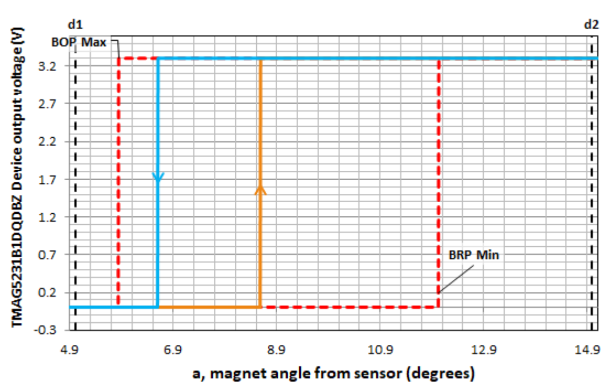


图 9-6. Thresholds

9.2.2 Head-On

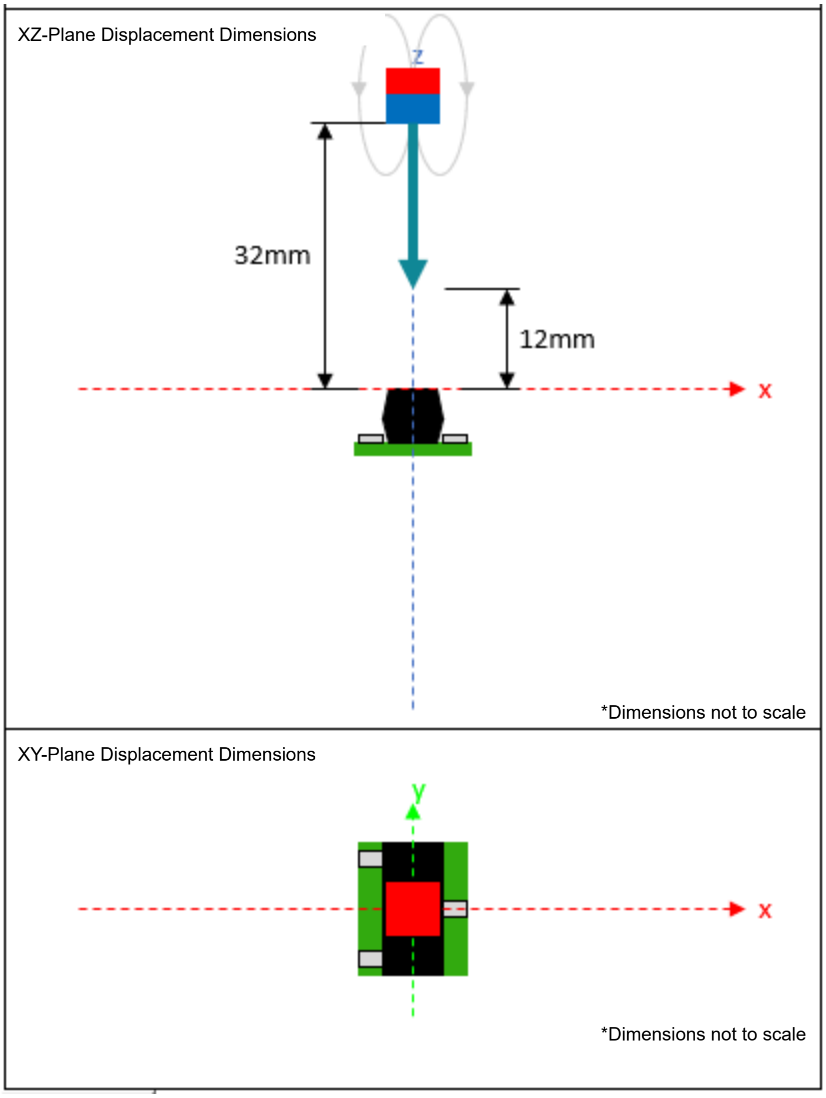


图 9-7. Typical Application Diagram

9.2.2.1 Design Requirements

表 9-1 lists the design parameters for this example.

表 9-2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{CC}	3.3 V
Switch Region	Between 10 mm and 30 mm from sensor fixture Surface
Sensor Distance From Equipment Outer Surface	0.0787" (2 mm)
Magnet Length	<1” (25.4 mm)
Magnet Width	<1” (25.4 mm)
Magnet Height	<1/4" (6.35 mm)
Magnet Type	N42

9.2.2.2 Detailed Design Procedure

In this particular case, there are several N42 magnets available from other prior projects. As the desired transition region is where the magnet surface is at least 12 mm (10 mm + 2 mm) away from the sensor, we try an initial design with one of our larger magnets (3/8” × 3/16” × 3/16”). 图 9-8 shows the respective curve for this magnet along the movement path.

While the Bz magnitude adequately exceeds the BOPmax, it does not quite reach the BRPmin. Therefore, the user must make some adjustments so that Bz falls below BRPmin within the desired operating range. To reduce Bz, there are a few options. The user can offset the magnet or choose a smaller magnet. After iterating through increasing x-offsets and y-offsets as well as decreasing magnet thicknesses, the user can eventually find a solution that works. In this case, a 3/8" × 3/16" × 1/16" N42 magnet with no x or y offset from the sensor center is used. 图 9-9 and 图 9-10 illustrate the curves corresponding to the final magnet parameters.

9.2.2.3 Application Curve

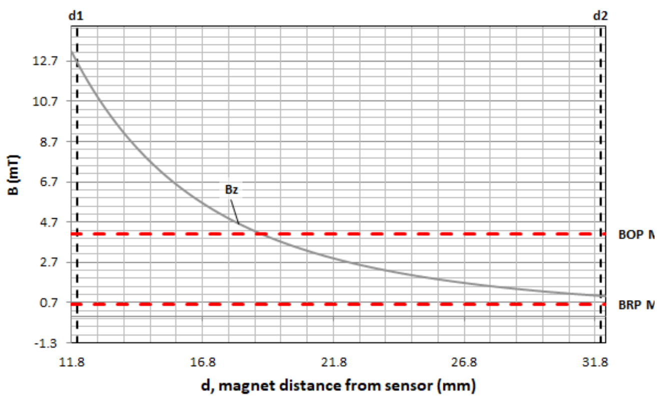


图 9-8. B-Field Hypothesis One

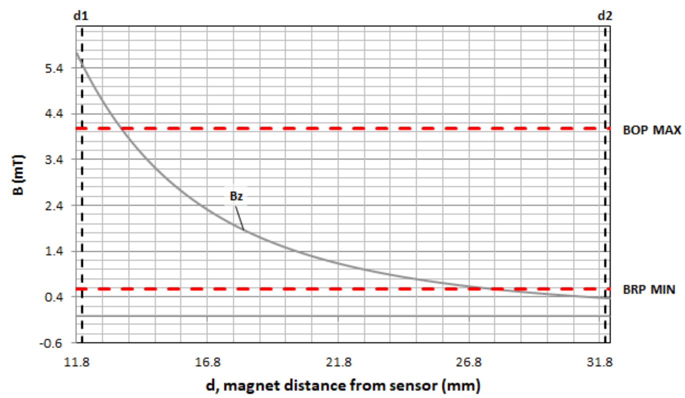


图 9-9. B-Field Hypothesis Two

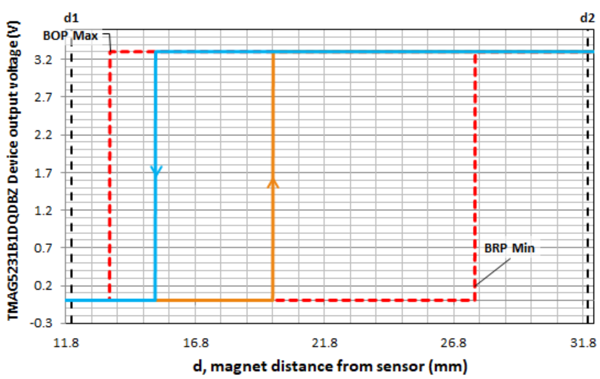


图 9-10. Thresholds

9.2.3 Slide-By

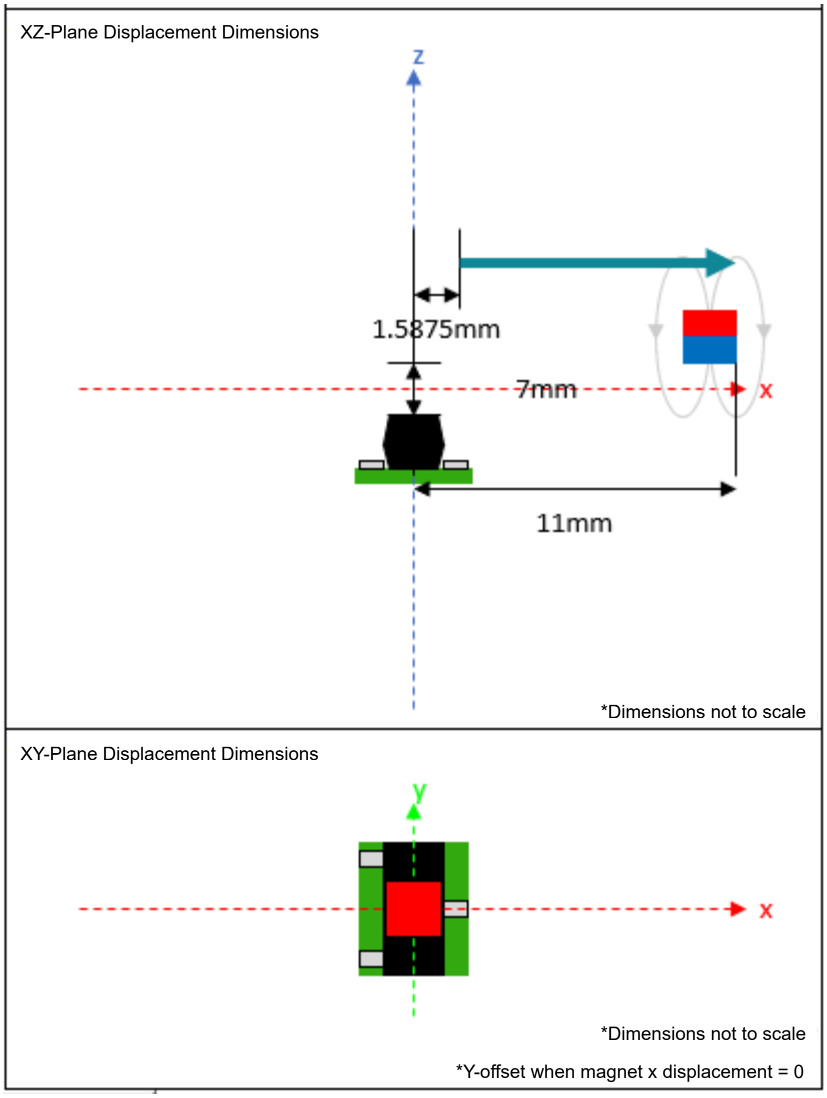


图 9-11. Typical Application Diagram

9.2.3.1 Design Requirements

表 9-1 lists the design parameters for this example.

表 9-3. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
V_{CC}	3.3 V
Magnet Range Of Motio	<0.433" (11mm)
Sensor Distance From Equipment Outer Surface	>0.236" (6mm)
Magnet Length	<1/2” (12.7mm)
Magnet Width	<1/2” (12.7mm)
Magnet Height	<1/8" (3.175mm)
Magnet Type	N42

9.2.3.2 Detailed Design Procedure

For this particular case, the user can arbitrarily start with a 1/8" × 1/8" × 1/16" magnet, a z-offset of 7 mm (>6 mm), and an initial displacement of one half of the magnet length (1/8” /2 = 1/16”) and serendipitously get something that works (see 图 9-12 and 图 9-13). Had the B-field not exceeded BOPmax, we would try moving the magnet closer on the z-axis, made the magnet larger, or changed the magnet to one with higher permeability. Alternatively, if the b-field was too large, the magnet can be moved further away in each axis or a smaller magnet can be used.

9.2.3.3 Application Curve

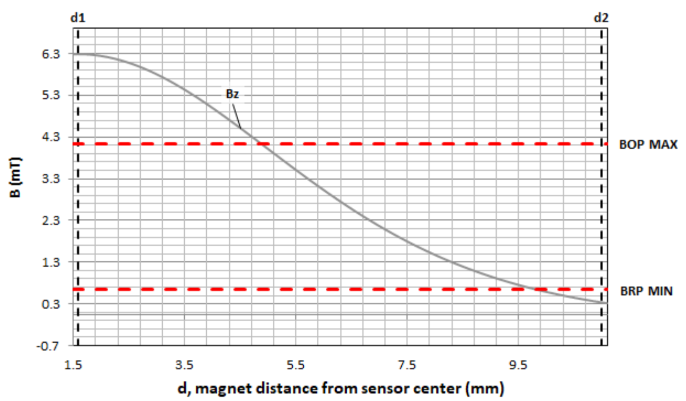


图 9-12. B-Field Hypothesis

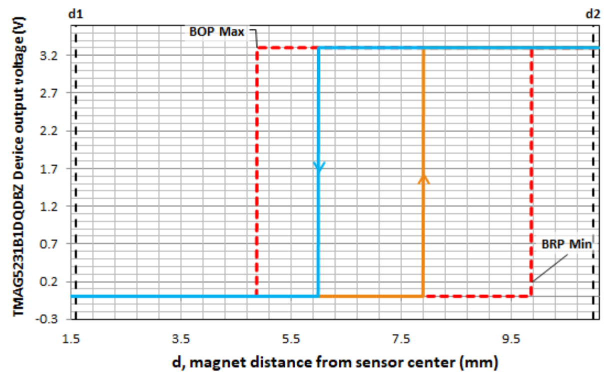


图 9-13. Thresholds

10 Power Supply Recommendations

The TMAG5231 device is powered from 1.65-V to 5.5-V DC power supplies. 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.

11 Layout

11.1 Layout Guidelines

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.

11.2 Layout Examples

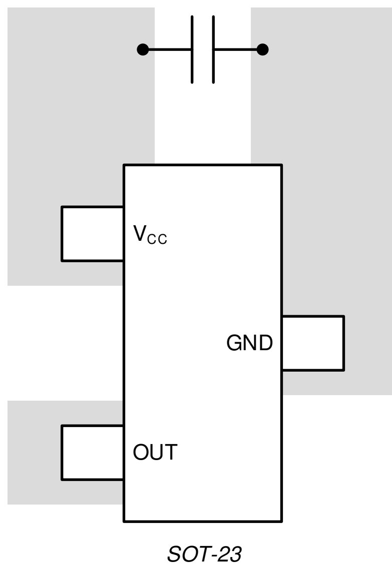


图 11-1. Layout Example

12 Device and Documentation Support

12.1 支持资源

TI E2E™ 支持论坛是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《使用条款》。

12.2 Trademarks

TI E2E™ is a trademark of Texas Instruments.
所有商标均为其各自所有者的财产。

12.3 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.

12.4 术语表

TI 术语表　　本术语表列出并解释了术语、首字母缩略词和定义。

13 Mechanical and Packaging 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
PTMAG5231B1DQDBZR	ACTIVE	SOT-23	DBZ	3	3000	TBD	Call TI	Call TI	-40 to 125		Samples
TMAG5231B1DQDBZR	ACTIVE	SOT-23	DBZ	3	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	1B1D	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.

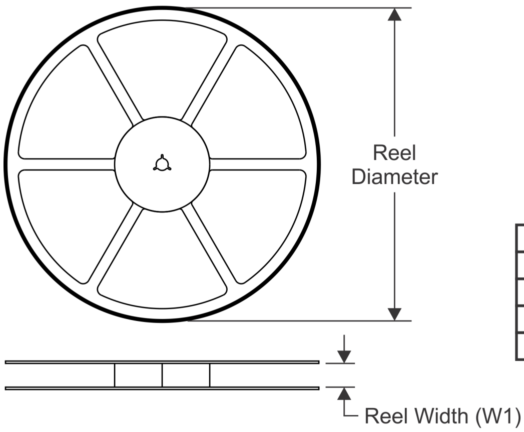
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

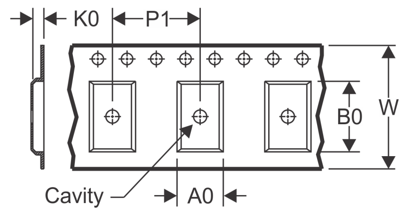
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

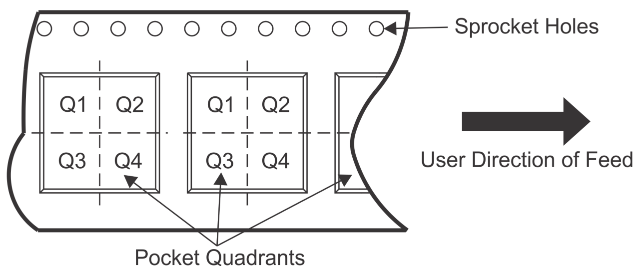


TAPE DIMENSIONS



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

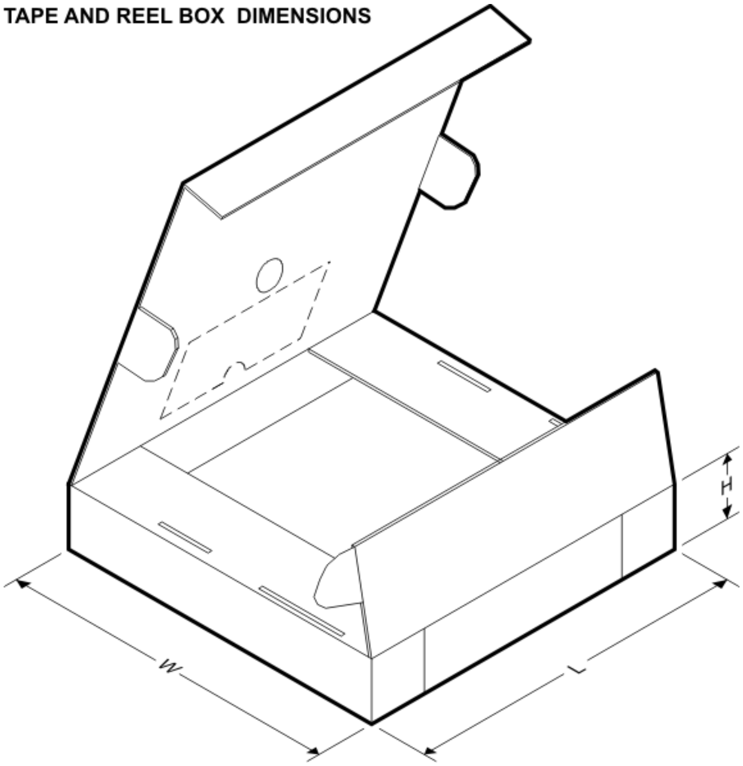
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

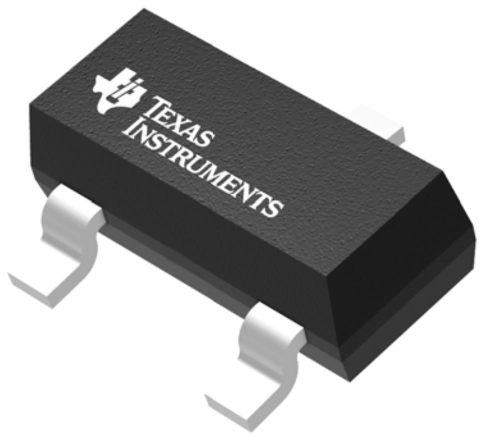
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TMAG5231B1DQDBZR	SOT-23	DBZ	3	3000	178.0	9.0	3.15	2.77	1.22	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS

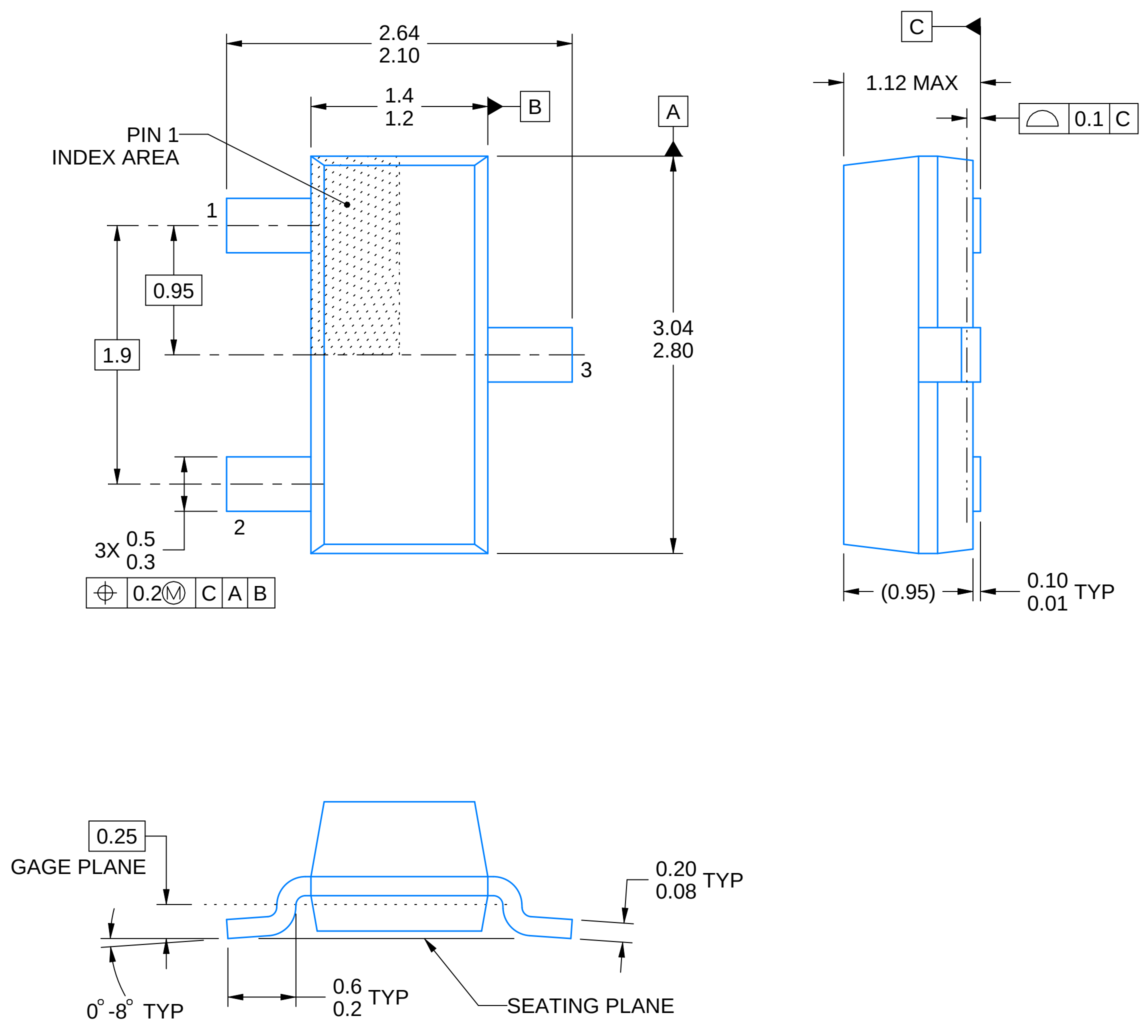


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TMAG5231B1DQDBZR	SOT-23	DBZ	3	3000	180.0	180.0	18.0



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



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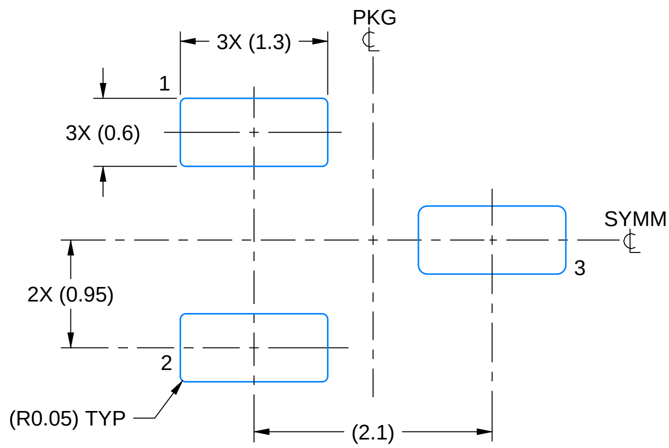
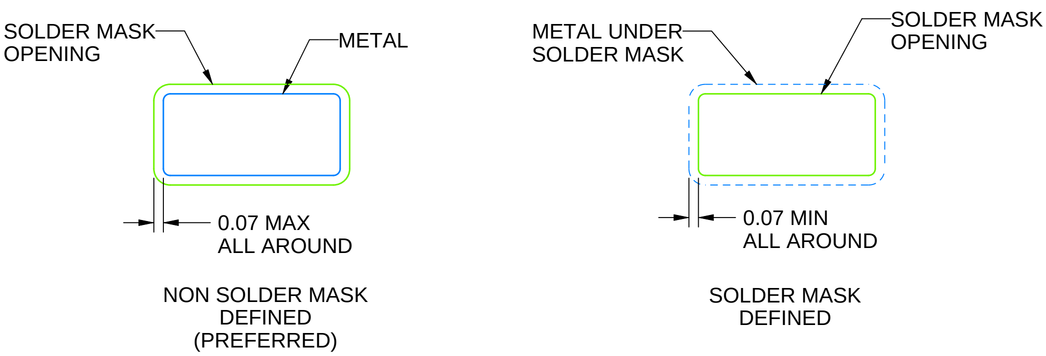
NOTES:

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. Reference JEDEC registration TO-236, except minimum foot length.



LAND PATTERN EXAMPLE
SCALE:15X



SOLDER MASK DETAILS

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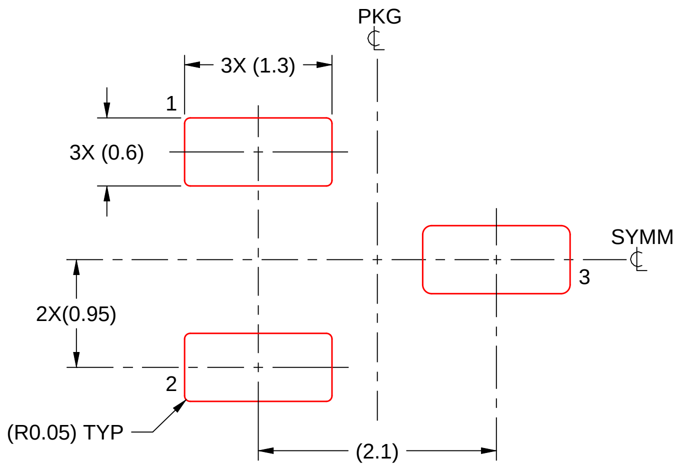
NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:15X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

重要声明和免责声明

邮寄地址：Texas Instruments, Post Office Box 655303, Dallas, Texas 75265