DRV5012 超低功耗数字锁存器霍尔效应传感器

1 特性

- 行业领先的低功耗特性
- 可通过引脚选择的采样率：
  - SEL = 低电平：使用 1.3µA (1.8V) 时为 20Hz
  - SEL = 高电平：使用 142µA (1.8V) 时为 2.5kHz
- V_{CC} 工作电压范围为 1.65V 至 5.5V
- 高磁性灵敏度：±2mT（典型值）
- 可靠磁滞：4mT（典型值）
- 推挽式 CMOS 输出
- 小型纤薄 X2SON 封装
- 运行温度范围：–40°C 至 +85°C

2 应用

- 无刷直流电机传感器
- 增量旋转编码：
  - 电机速度
  - 机械行程
  - 流体测量
  - 旋钮转动
  - 轮速
- 便携式医疗设备
- 电子锁、电动自行车、电动百叶窗
- 流量计
- 非接触式激活

3 说明

DRV5012 器件是可通过引脚选择采样率的超低功耗数字锁存器霍尔效应传感器。

当南磁极靠近封装顶部并且超出 B_{OP} 阈值时，该器件会驱动低电压。输出会保持低电平，直到应用北极并且超出 B_{RP} 阈值，这将使输出驱动高电压。必须交换北极和南极才能切换输出，且集成的磁滞会分开 B_{OP} 和 B_{RP} 以提供可靠切换。

通过使用内部振荡器，DRV5012 器件对磁场进行采样，并根据 SEL 引脚以 20Hz 或 2.5kHz 的速率更新输出。这种双带宽特性可让系统在使用最小功率的情况下监控移动变化。

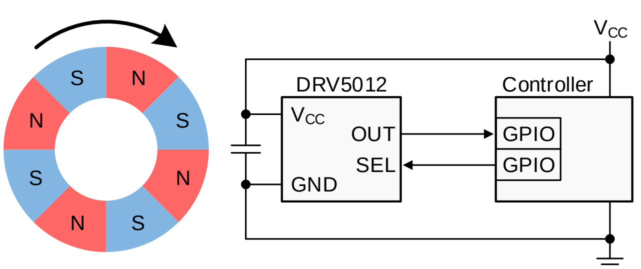
此器件通过 1.65V 至 5.5V 的 V_{CC} 工作，并采用小型 X2SON 封装。

器件信息[(1)]

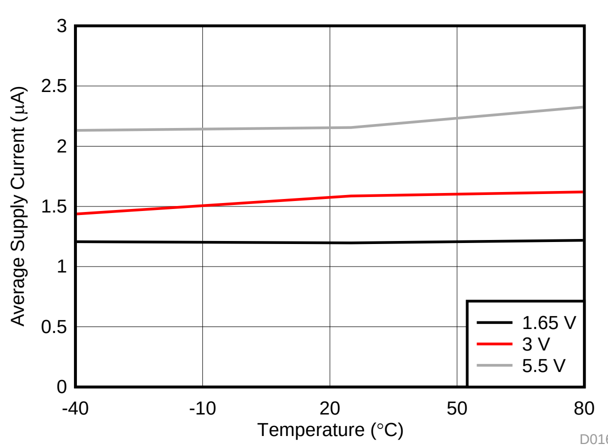
器件型号	封装	封装尺寸（标称值）
DRV5012	X2SON (4)	1.10mm × 1.40mm

(1) 如需了解所有可用封装，请参阅产品说明书末尾的可订购产品附录。

典型原理图



20Hz 模式下的电流消耗



目录

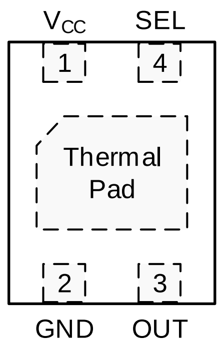
4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

日期	修订版本	说明
2017 年 8 月	*	初始发行版。

5 Pin Configuration and Functions

DMR Package
4-Pin X2SON With Exposed Thermal Pad
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
GND	2	—	Ground reference
OUT	3	O	Push-pull CMOS output. Drives a V_{CC} or ground level.
SEL	4	I	CMOS input that selects the sampling rate: a low voltage sets 20 Hz; a high voltage sets 2.5 kHz.
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.
Thermal Pad	PAD	—	No-connect. This pin should be left floating or tied to ground. It should be soldered to the board for mechanical support.

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
Power supply voltage slew rate	V_{CC}	Unlimited		V / µs
Output voltage	OUT	–0.3	V_{CC} + 0.3	V
Output current	OUT	–5	5	mA
Input voltage	SEL	–0.3	V_{CC} + 0.3	V
Magnetic flux density, B_{MAX}		Unlimited		T
Junction temperature, T_J			105	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* 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 Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±6000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(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 (VCC)	1.65	5.5	V
V_O	Output voltage (OUT)	0	V_{CC}	V
I_O	Output current (OUT)	–5	5	mA
V_I	Input voltage (SEL)	0	V_{CC}	V
T_A	Operating ambient temperature	–40	85	°C

6.4 Thermal Information

THERMAL METRIC(1)		DRV5012 DMR (X2SON) 4 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	159	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	77	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	102	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	100	°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 5.5 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OUT pin							
V_{OH}	High-level output voltage	I_{OUT} = –1 mA		V_{CC} – 0.35	V_{CC} – 0.1		V
V_{OL}	Low-level output voltage	I_{OUT} = 1 mA			0.1	0.3	V
SEL pin							
V_{IH}	High-level input voltage	V_{CC} = 1.65 to 2.5 V		0.8 × V_{CC}			V
		V_{CC} = 2.5 to 5.5 V		2			
V_{IL}	Low-level input voltage					0.15 × V_{CC}	V
I_{IH}	High-level input leakage current	SEL = V_{CC}			1		nA
I_{IL}	Low-level input leakage current	SEL = 0 V			1		nA
DYNAMIC CHARACTERISTICS							
f_S	Frequency of magnetic sampling	SEL = Low		13.3	20	37	Hz
		SEL = High		1665	2500	4700	
t_S	Period of magnetic sampling	SEL = Low		27	50	75	ms
		SEL = High		0.21	0.4	0.6	
$I_{CC(AVG)}$	Average current consumption	V_{CC} = 1.8 V	SEL = Low		1.3		µA
			SEL = High		142		
		V_{CC} = 3 V	SEL = Low		1.6	3.3	
			SEL = High		153	370	
		V_{CC} = 5 V	SEL = Low		2		
			SEL = High		160		
$I_{CC(PK)}$	Peak current consumption				2	2.7	mA
t_{ON}	Power-on time (see 图 11)				55	100	µs
t_{ACTIVE}	Active time period (see 图 11)				40		µs

6.6 Magnetic Characteristics

for V_{CC} = 1.65 V to 5.5 V, over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
B_{OP}	Magnetic threshold operate point (see 图 9)		0.6	2	3.3	mT
B_{RP}	Magnetic threshold release point (see 图 9)		–3.3	–2	–0.6	mT
B_{HYS}	Magnetic hysteresis: $\|B_{OP} – B_{RP}\|$		2	4		mT

6.7 Typical Characteristics

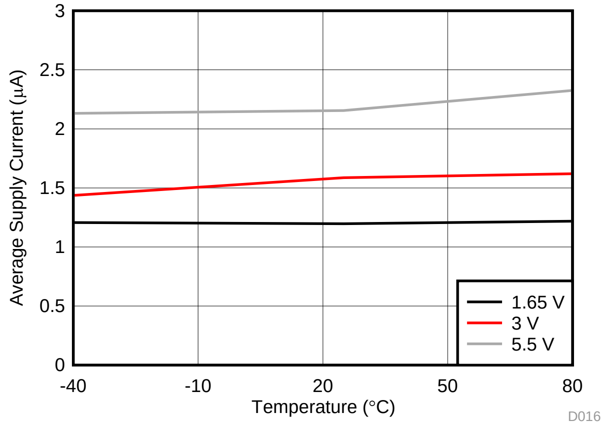


图 1. $I_{CC(AVG)}$ vs Temperature (20-Hz Mode)

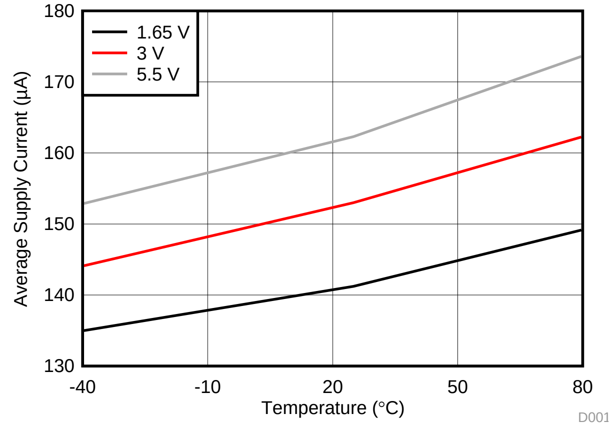


图 2. $I_{CC(AVG)}$ vs Temperature (2.5-kHz Mode)

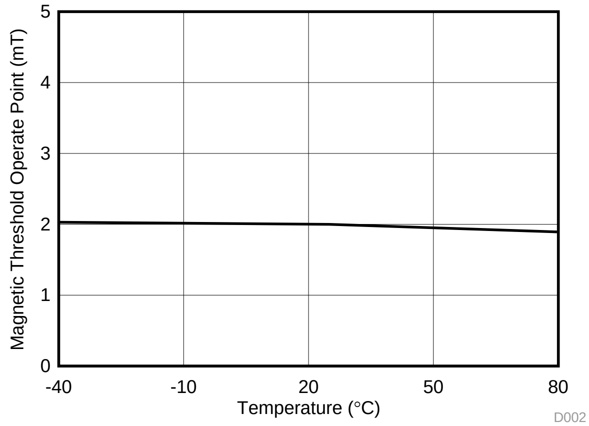


图 3. B_{OP} vs Temperature

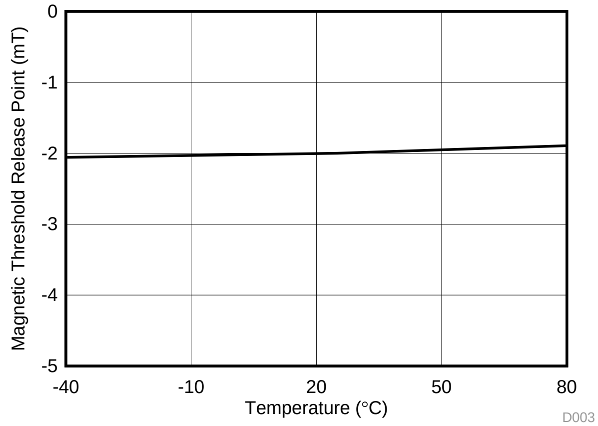


图 4. B_{RP} vs Temperature

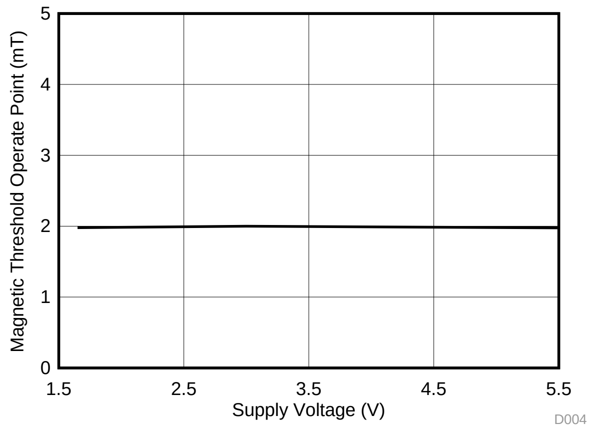


图 5. B_{OP} vs V_{CC}

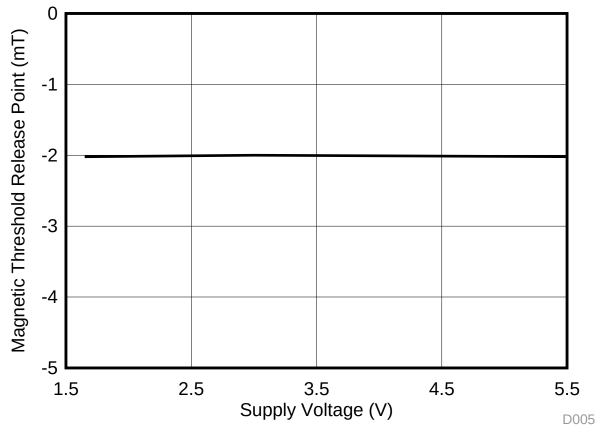


图 6. B_{RP} vs V_{CC}

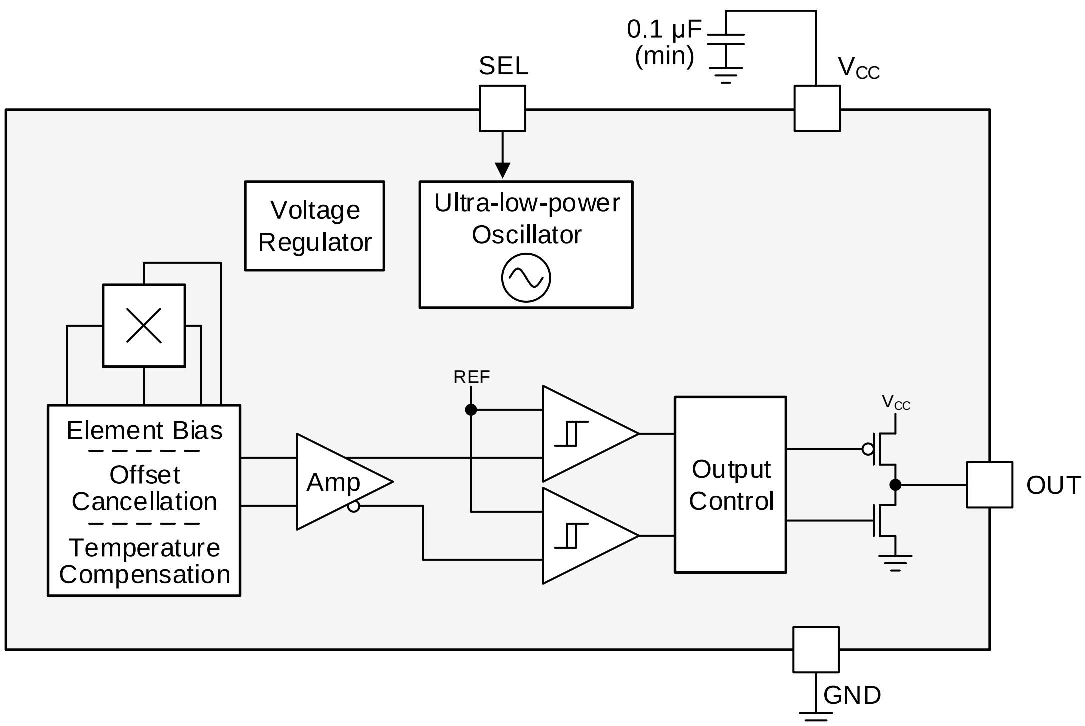
7 Detailed Description

7.1 Overview

The DRV5012 device is a magnetic sensor with a digital output that latches the most recent pole measured. Applying a south magnetic pole near the top of the package causes the output to drive low, a north pole causes the output to drive high, and the absence of a magnetic field causes the output to continue to drive the previous state, whether low or high.

The device integrates a Hall effect element, analog signal conditioning, and a low-frequency oscillator that enables ultra-low average power consumption. By operating from a 1.65-V to 5.5-V supply, the device periodically measures magnetic flux density, updates the output, and enters a low-power sleep state. A logic input pin, SEL, sets the sampling frequency to 20 Hz or 2.5 kHz with a tradeoff in power consumption.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Magnetic Flux Direction

The DRV5012 device is sensitive to the magnetic field component that is perpendicular to the top of the package (as shown in 图 7).

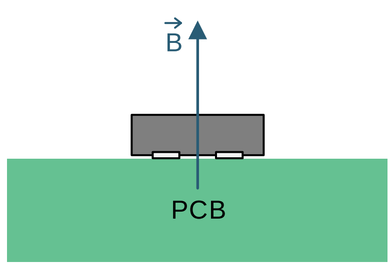


图 7. Direction of Sensitivity

Feature Description (接下页)

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.

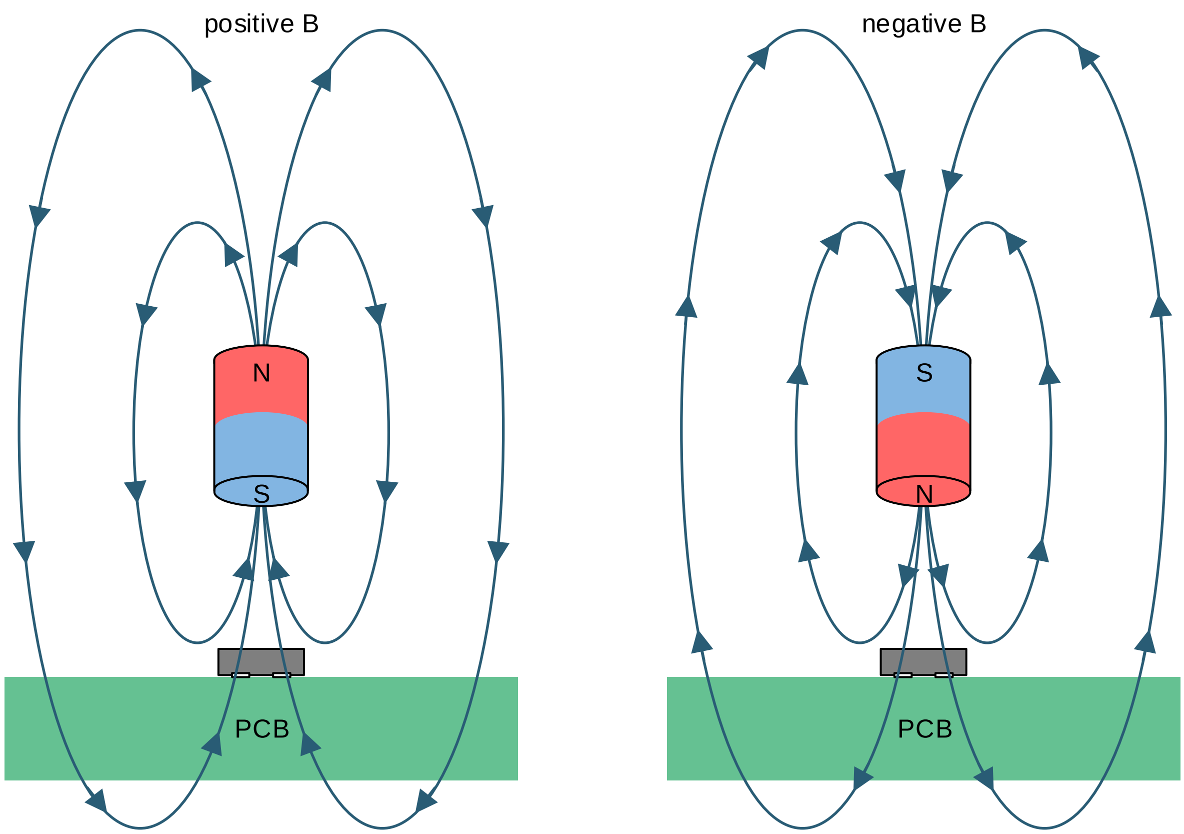


图 8. Flux Direction Polarity

7.3.2 Magnetic Response

图 9 shows the device functionality and hysteresis.

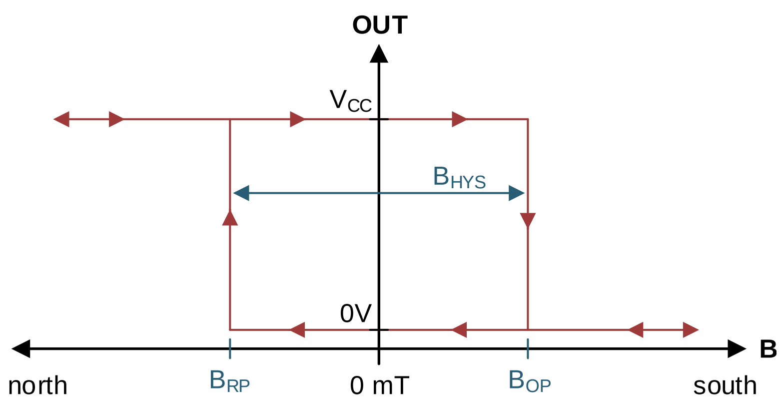


图 9. Device Functionality

Feature Description (接下页)

7.3.3 Output Driver

The device features a push-pull CMOS output that can drive a V_{CC} or ground level.

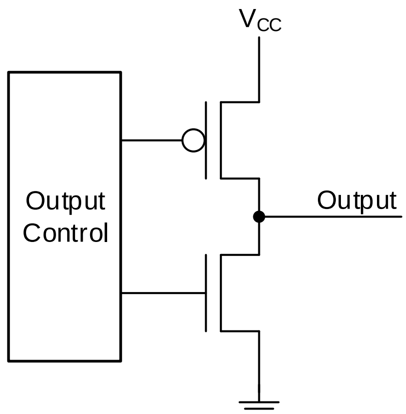


图 10. Push-Pull Output (Simplified)

7.3.4 Sampling Rate

When the DRV5012 device powers up, it 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.

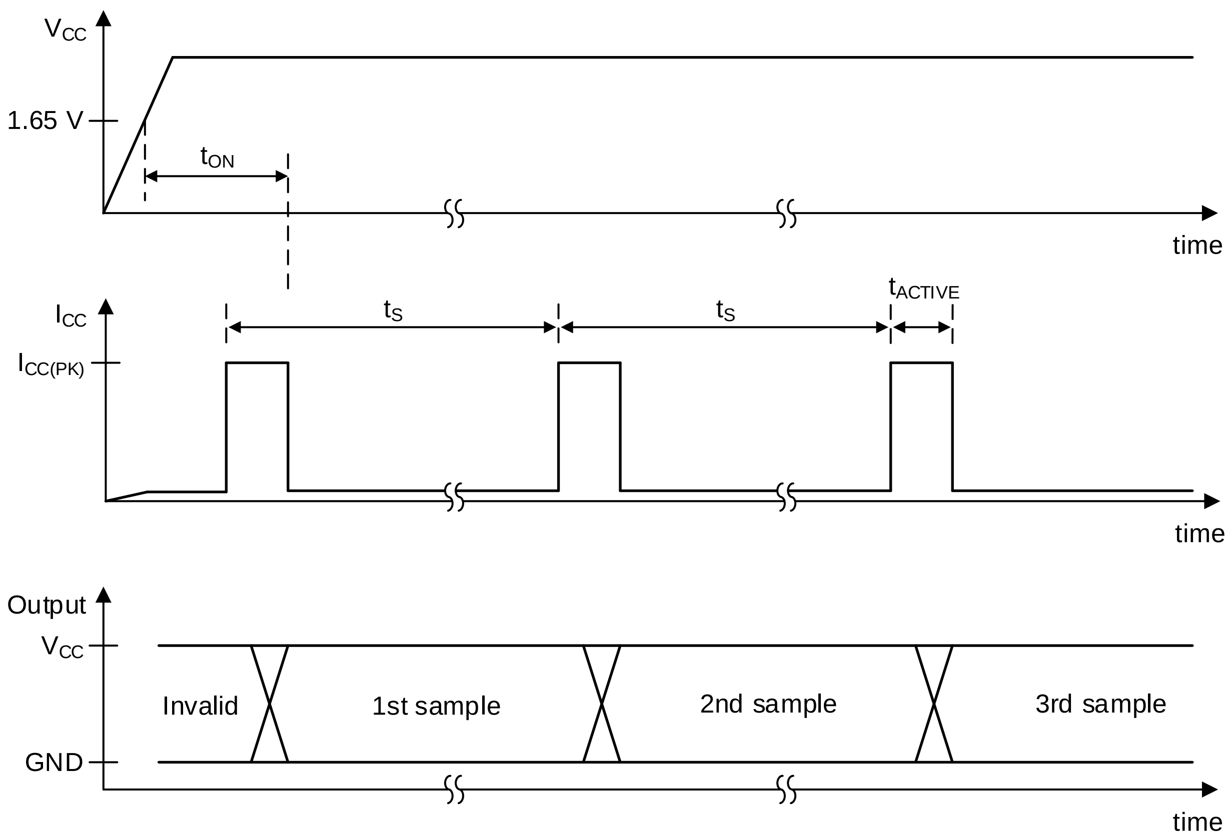


图 11. Timing Diagram

Feature Description (接下页)

7.3.5 SEL Pin

The SEL pin is a CMOS input that selects between two sampling rates. When the pin is low, the device samples at 20 Hz and uses low power. When the pin is high, the device samples at 2500 Hz and uses more power. The SEL pin can be tied directly high or low, or it can be changed during device operation. If the SEL voltage changes, the device detects the new voltage during the next t_{ACTIVE} time.

7.3.6 Hall Element Location

The sensing element inside the device is in the center of the package when viewed from the top. 图 12 shows the tolerances and side-view dimensions.

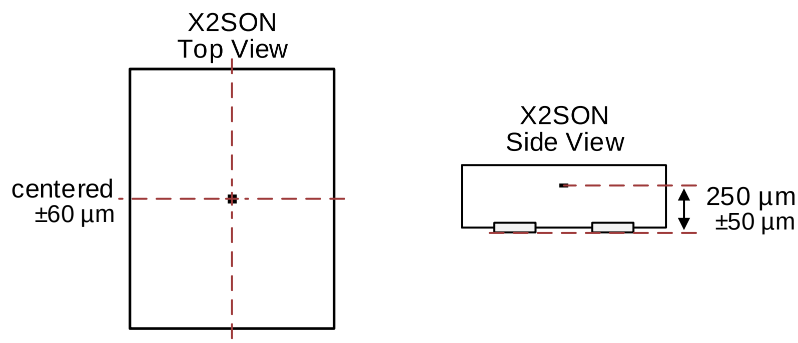


图 12. Hall Element Location

7.4 Device Functional Modes

The DRV5012 device has two operating modes, 20 Hz and 2.5 kHz, as set by the SEL pin. In both cases the *Recommended Operating Conditions* must be met.

8 Application and Implementation

注

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. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The DRV5012 device is typically used in rotary applications for brushless DC (BLDC) motor sensors or incremental rotary encoding.

To ensure reliable functionality, the magnet should apply a flux density at the sensor greater than the maximum B_{OP} and less than the minimum B_{RP} thresholds. It is good practice to add additional margin to account for mechanical tolerance, temperature effects, and magnet variation.

8.2 Typical Applications

8.2.1 BLDC Motor Sensors Application

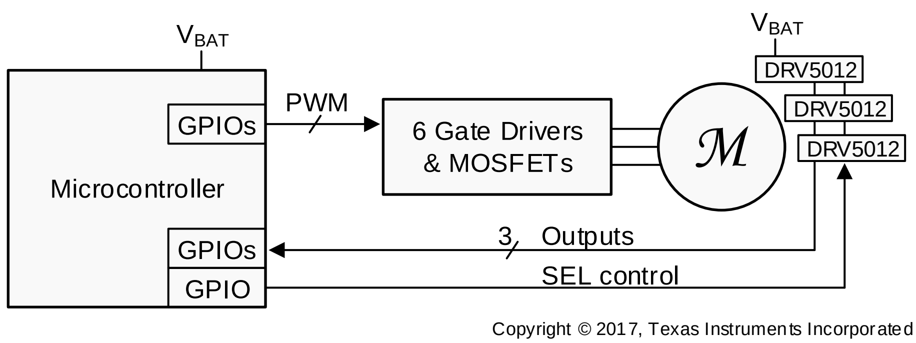


图 13. BLDC Motor System

8.2.1.1 Design Requirements

For this design example, use the parameters listed in 表 1.

表 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Number of motor phases	3
Motor RPM	3000
Number of magnet poles on the rotor	6
Magnetic material	Bonded Neodymium
Peak magnetic flux density at the Hall sensors	±15 mT
Battery voltage range (V_{BAT})	2 to 3.5 V

8.2.1.2 Detailed Design Procedure

Three-phase brushless DC motors often use 3 Hall effect latch devices to measure the electrical angle of the rotor and tell the controller how to drive the 3 wires. These wires connect to electromagnet windings, which generate magnetic fields that apply forces to the permanent magnets on the rotor.

The 3 Hall sensors should be spaced across the printed-circuit board (PCB) so that they are 120° electrical degrees apart. This configuration creates six 3-bit states with equal time duration for each electrical cycle, which consists of 1 north and 1 south magnetic pole. From the center of the motor axis, the number of degrees each sensor should be spaced equals **2 / [number of poles] × 120°**. In this design example, 1 sensor is placed at 0°, 1 sensor is placed 40° rotated, and 1 sensor is placed 80° rotated. Alternatively, a 3× degree offset can be added or subtracted to any sensor, meaning the third sensor could alternatively be placed at 80° – (3 × 40°) = –40°.

While an ideal BLDC motor would energize the phases at the exact correct times, the DRV5012 device introduces variable lag because of the sampling architecture that achieves low power. An acceptable amount of lag can be measured by the sampling time error as a percentage of the electrical period. This design example uses 3000 RPM, which is 50 revolutions per second. Each revolution has 6 poles (3 electrical cycles), so the electrical frequency is 150 Hz, a period of 6.7 ms. The DRV5012 device in 2.5 kHz mode has a sampling period of 0.4 ms, which is 6% of the electrical period. Generally, the maximum timing error should be kept under 10% to ensure the BLDC motor spins, and timing error can reduce motor efficiency.

When the motor in this example is not driven, the SEL pins of the DRV5012 devices are set to a low voltage, and the sensor outputs are monitored for changes. If a change occurs, the microcontroller wakes the system into a higher power state and takes other appropriate action.

8.2.1.3 Application Curve

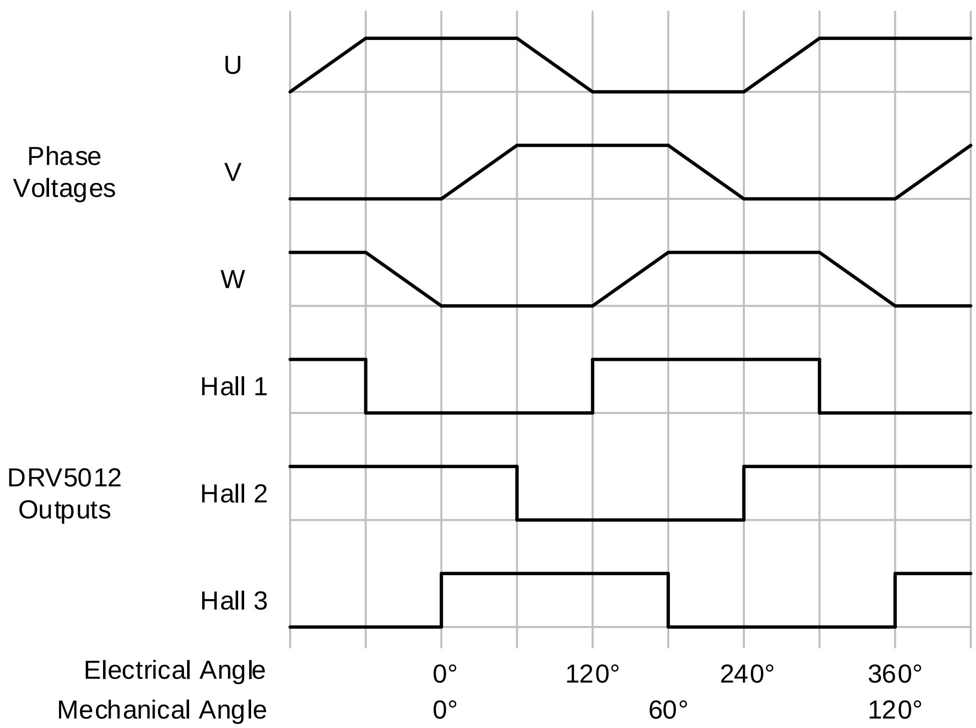


图 14. 3-Phase BLDC Motor Phase Voltages and Hall Signals

8.2.2 Incremental Rotary Encoding Application

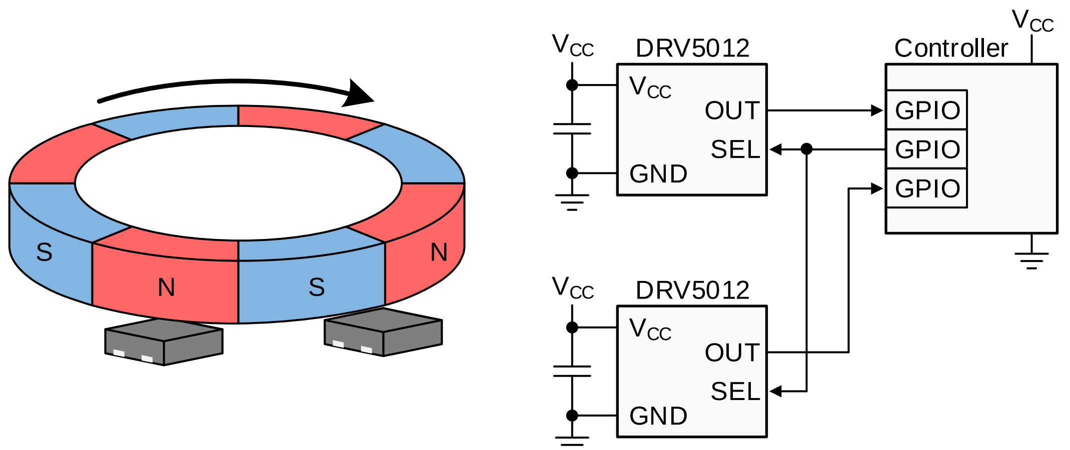


图 15. Incremental Rotary Encoding System

8.2.2.1 Design Requirements

For this design example, use the parameters listed in 表 2.

表 2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
RPM range	0 to 4000
Number of magnet poles	8
Magnetic material	Ferrite
Air gap above the Hall sensors	2.5 mm
Peak magnetic flux density at the sensors	±7 mT

8.2.2.2 Detailed Design Procedure

Incremental encoders are used on knobs, wheels, motors, and flow meters to measure relative rotary movement. By attaching a ring magnet to the rotating component and placing a DRV5012 device nearby, the sensor generates voltage pulses as the magnet turns. If directional information is also needed (clockwise versus counterclockwise), a second DRV5012 device can be added with a phase offset, and then the order of transitions between the two signals describes the direction.

Creating this phase offset requires spacing the two sensors apart on the PCB, and an ideal 90° quadrature offset is attained when the sensors are separated by half the length of each magnet pole, plus any integer number of pole lengths. 图 15 shows this configuration, as the sensors are 1.5 pole lengths apart. One of the sensors changes its output every **360° / 8 poles / 2 sensors** = 22.5° of rotation. For reference, the TI Design TIDA-00480 uses a 66-pole magnet with changes every 2.7°.

Because the DRV5012 device periodically samples the magnetic field, there is a limit to the maximum rotational speed that can be measured. Generally, the device sampling rate should be faster than 2 times the number of poles per second. In this design example, the maximum speed is 4000 RPM, which involves 533 poles per second. The DRV5012 has a minimum sampling frequency of 1665 Hz (when the SEL pin is high), which is approximately 3 × 533 poles per second.

In systems where the sensor sampling rate is close to 2 times the number of poles per second, most of the samples will measure a magnetic field that is significantly lower than the peak value, since the peaks only occur when the sensor and pole are perfectly aligned. In this case, margin should be added by applying a stronger magnetic field that has peaks significantly higher than the maximum B_{OP} of the DRV5012 device.

8.2.2.3 Application Curve

Two signals in quadrature provide movement and direction information. Each 2-bit state has unique adjacent 2-bit states for clockwise and counterclockwise.

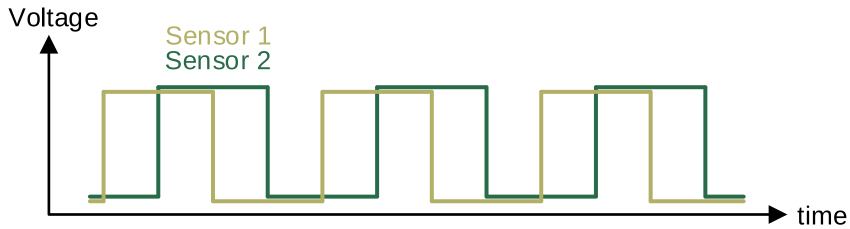


图 16. 2-bit Quadrature Output

8.3 Do's and Don'ts

Because the Hall element is sensitive to magnetic fields that are perpendicular to the top of the package, a correct magnet orientation must be used for the sensor to detect the field. 图 17 shows correct and incorrect orientations when using a ring magnet.

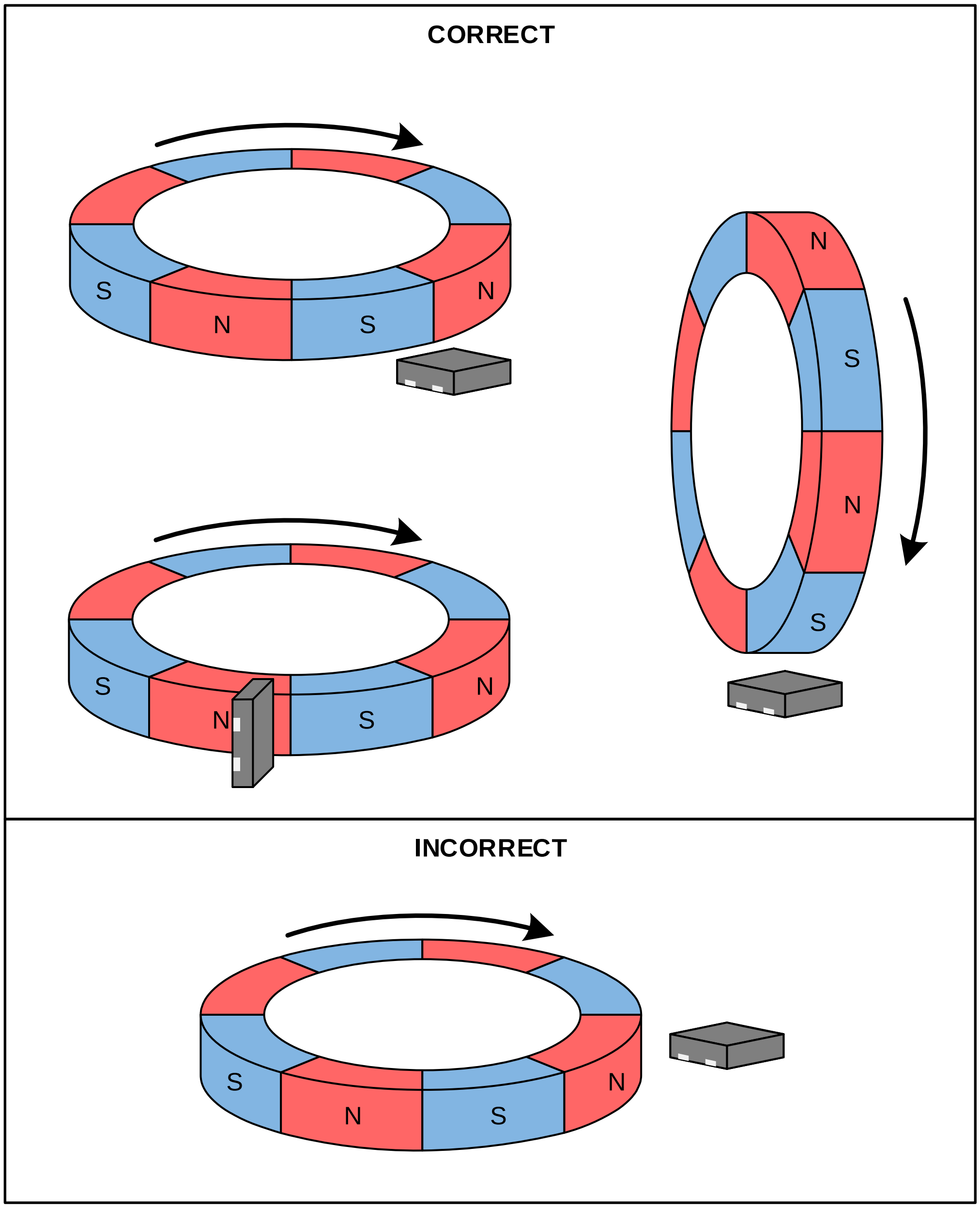


图 17. Correct and Incorrect Magnet Orientations

9 Power Supply Recommendations

The DRV5012 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.

10 Layout

10.1 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 PCBs, which makes placing the magnet on the opposite side possible.

10.2 Layout Example

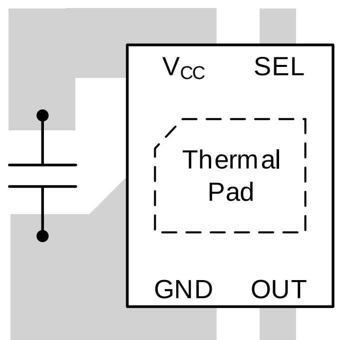


图 18. Layout Example

11 器件和文档支持

11.1 器件支持

11.1.1 开发支持

有关其他设计参考，请参阅*汽车霍尔传感器旋转编码器* TI 设计 (TIDA-00480)。

11.2 接收文档更新通知

要接收文档更新通知，请导航至 TI.com 上的器件产品文件夹。单击右上角的*通知我* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

11.3 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”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》。

TI E2E™ 在线社区 ***TI 的工程师对工程师 (E2E) 社区。***此社区的创建目的在于促进工程师之间的协作。在 e2e.ti.com 中，您可以咨询问题、分享知识、拓展思路并与同行工程师一道帮助解决问题。

设计支持 ***TI 参考设计支持*** 可帮助您快速查找有帮助的 E2E 论坛、设计支持工具以及技术支持的联系信息。

11.4 商标

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.5 静电放电警告

这些装置包含有限的内置 ESD 保护。 存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

11.6 Glossary

SLYZ022 — *TI Glossary*.

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

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。这些数据如有变更，恕不另行通知和修订此文档。如欲获取此产品说明书的浏览器版本，请参阅左侧的导航。

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
DRV5012AEDMRR	ACTIVE	X2SON	DMR	4	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 85	2AE	Samples
DRV5012AEDMRT	OBSOLETE	X2SON	DMR	4		TBD	Call TI	Call TI	-40 to 85	2AE	

(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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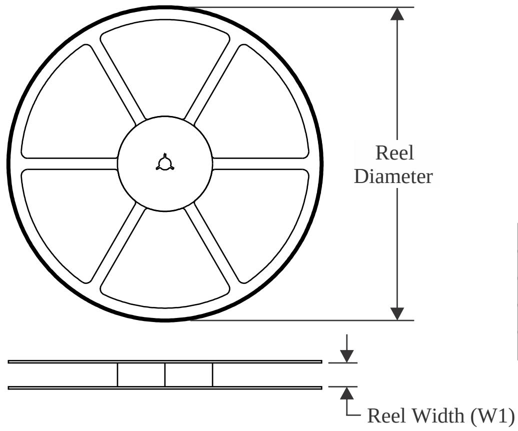
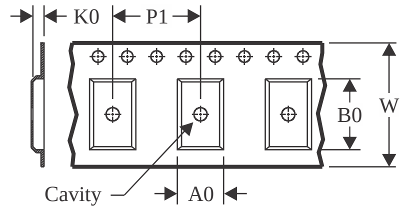
TAPE AND REEL INFORMATION

REEL DIMENSIONS

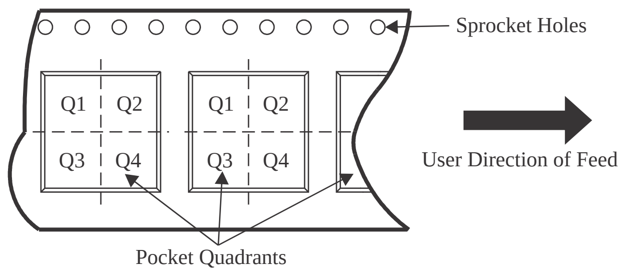


TAPE DIMENSIONS



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

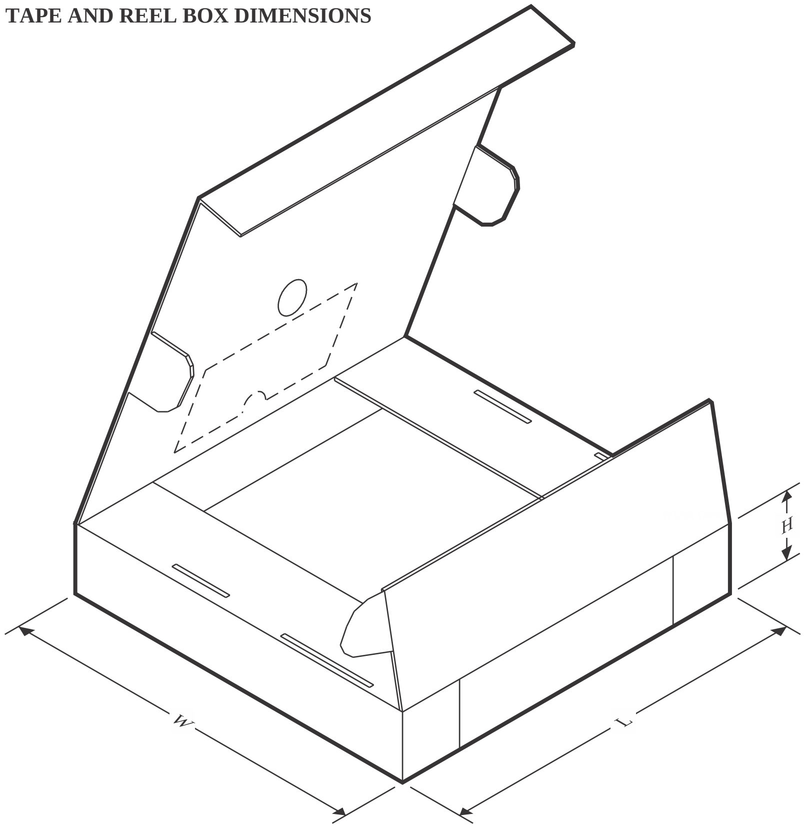
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
DRV5012AEDMRR	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)
DRV5012AEDMRR	X2SON	DMR	4	3000	200.0	183.0	25.0

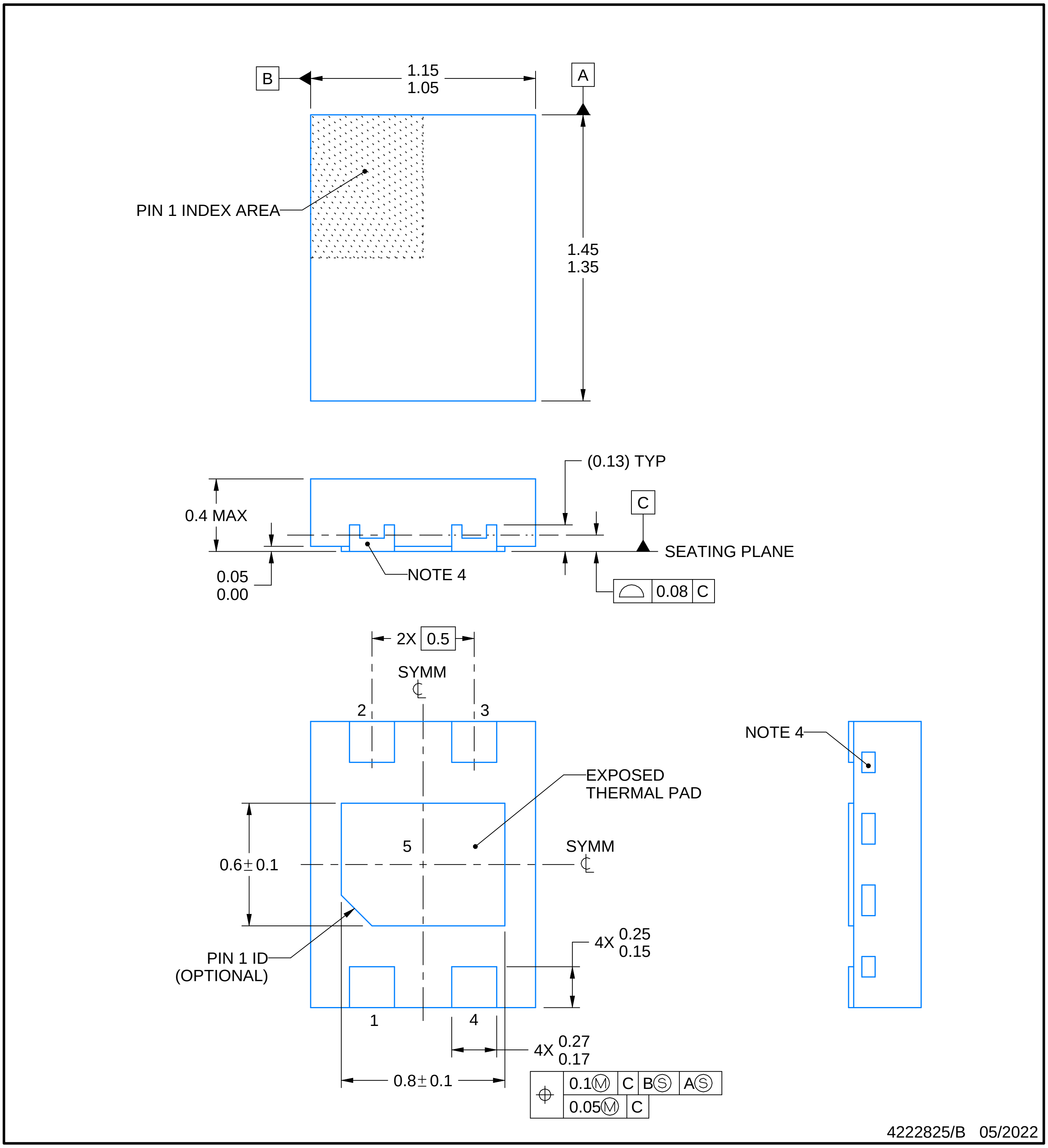
DMR 4

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.



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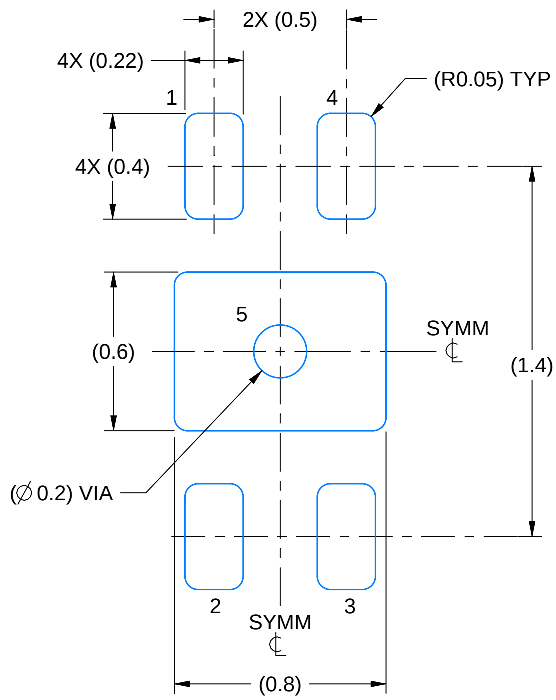
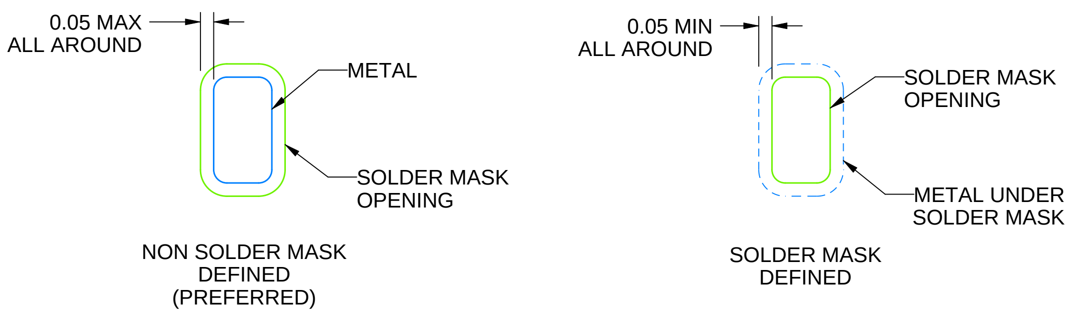
NOTES:

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



SOLDER MASK DETAILS

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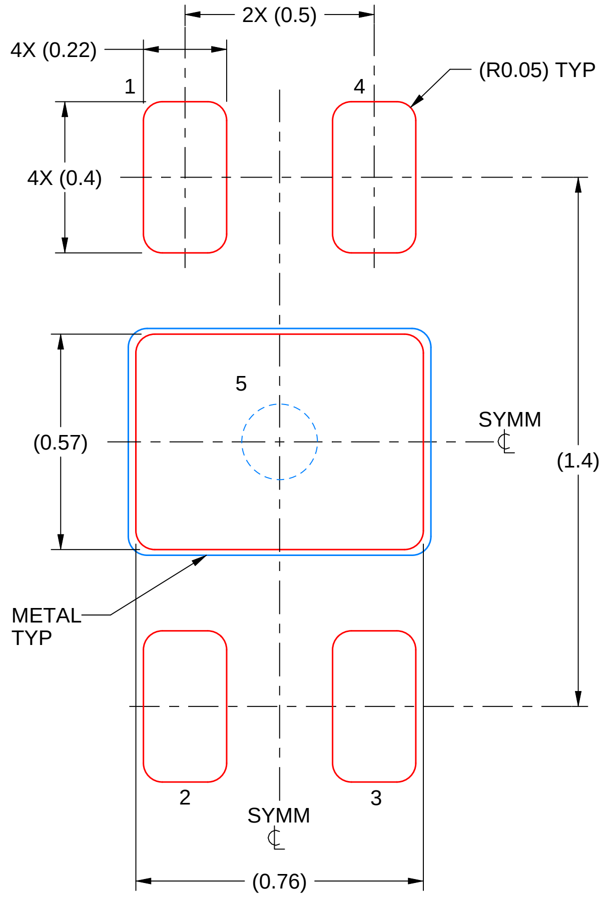
NOTES: (continued)

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.