DRV5012 Ultra-Low-Power Digital-Latch Hall-Effect Sensor

1 Features

- Industry-Leading Low-Power Consumption
- Pin-Selectable Sampling Rate:
  - SEL = Low: 20 Hz Using 1.3 µA (1.8 V)
  - SEL = High: 2.5 kHz Using 142 µA (1.8 V)
- 1.65- to 5.5-V Operating V_{CC} Range
- High Magnetic Sensitivity: ±2 mT (Typical)
- Robust Hysteresis: 4 mT (Typical)
- Push-Pull CMOS Output
- Small and Thin X2SON Package
- –40°C to +85°C Operating Temperature Range

2 Applications

- Brushless DC Motor Sensors
- Incremental Rotary Encoding:
  - Motor Speed
  - Mechanical Travel
  - Fluid Measurement
  - Knob Turning
  - Wheel Speed
- Portable Medical Devices
- E-Locks, E-Bikes, Motorized Blinds
- Flow Meters
- Contactless Activation

3 Description

The DRV5012 device is an ultra-low-power digital-latch Hall effect sensor with a pin-selectable sampling rate.

When a south magnetic pole is near the top of the package and the B_{OP} threshold is exceeded, the device drives a low voltage. The output stays low until a north pole is applied and the B_{RP} threshold is crossed, which causes the output to drive a high voltage. Alternating north and south poles are required to toggle the output, and integrated hysteresis separates B_{OP} and B_{RP} to provide robust switching.

Using an internal oscillator, the DRV5012 device samples the magnetic field and updates the output at a rate of 20 Hz or 2.5 kHz, depending on the SEL pin. This dual-bandwidth feature can allow systems to monitor changes in movement while using minimal power.

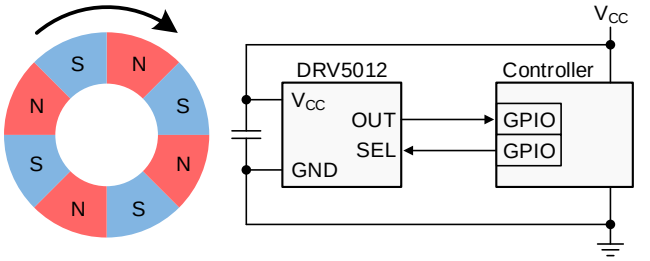
The device operates from a V_{CC} range of 1.65 V to 5.5 V, and is packaged in a small X2SON.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
DRV5012	X2SON (4)	1.10 mm × 1.40 mm

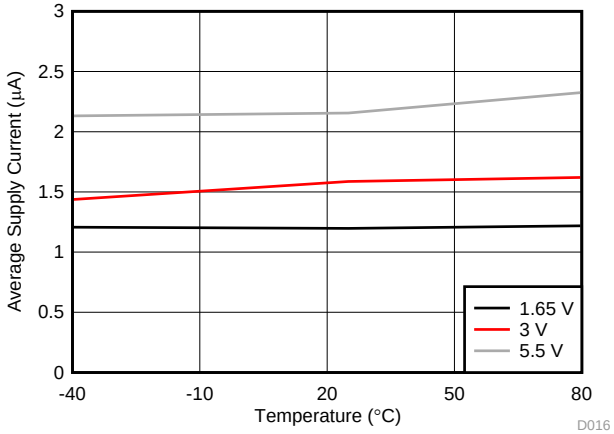
(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Schematic



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Current Consumption in 20-Hz Mode



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4 Revision History

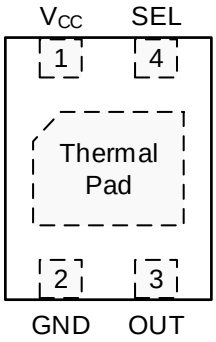
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
August 2017	*	Initial release.

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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.

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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.

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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 Figure 11)				55	100	µs
t_{ACTIVE}	Active time period (see Figure 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 Figure 9)		0.6	2	3.3	mT
B_{RP}	Magnetic threshold release point (see Figure 9)		–3.3	–2	–0.6	mT
B_{HYS}	Magnetic hysteresis: $\lvert B_{OP} - B_{RP} \rvert$		2	4		mT

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6.7 Typical Characteristics

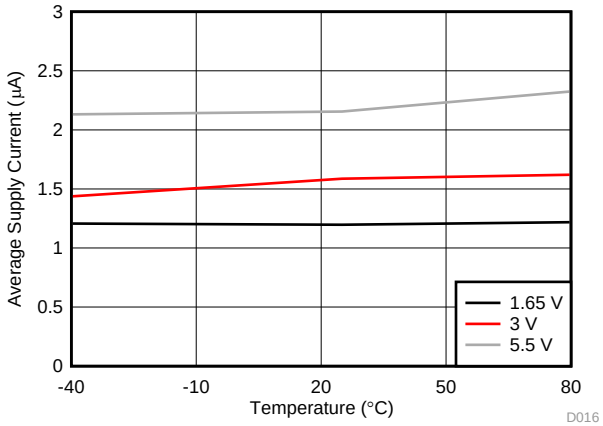


Figure 1. $I_{CC(AVG)}$ vs Temperature (20-Hz Mode)

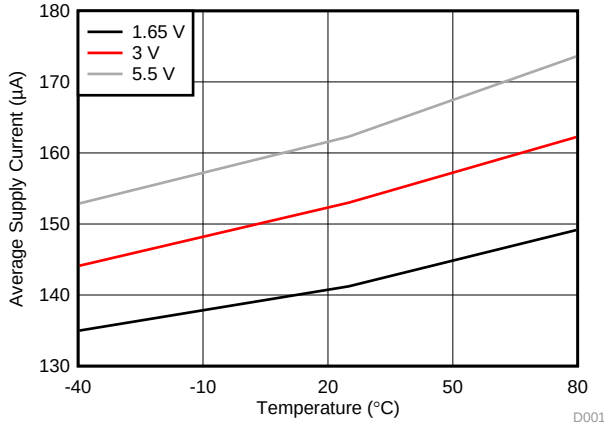


Figure 2. $I_{CC(AVG)}$ vs Temperature (2.5-kHz Mode)

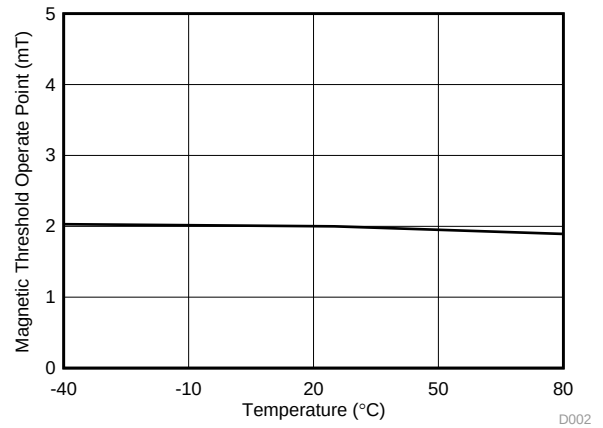


Figure 3. B_{OP} vs Temperature

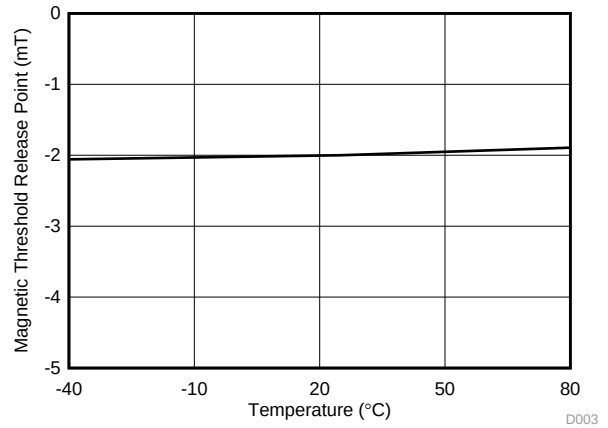


Figure 4. B_{RP} vs Temperature

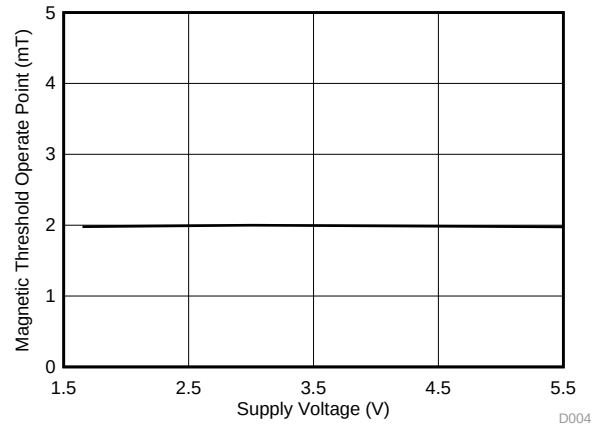


Figure 5. B_{OP} vs V_{CC}

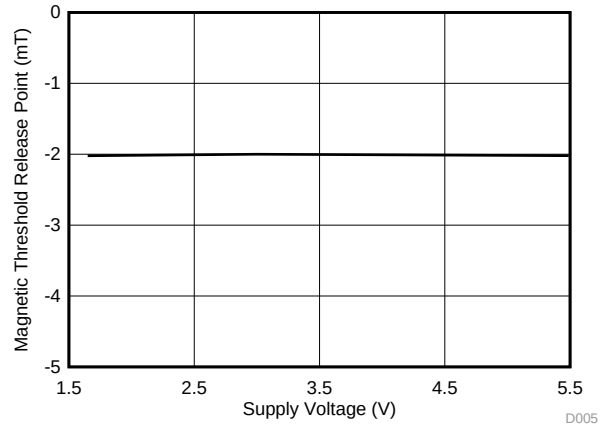


Figure 6. B_{RP} vs V_{CC}

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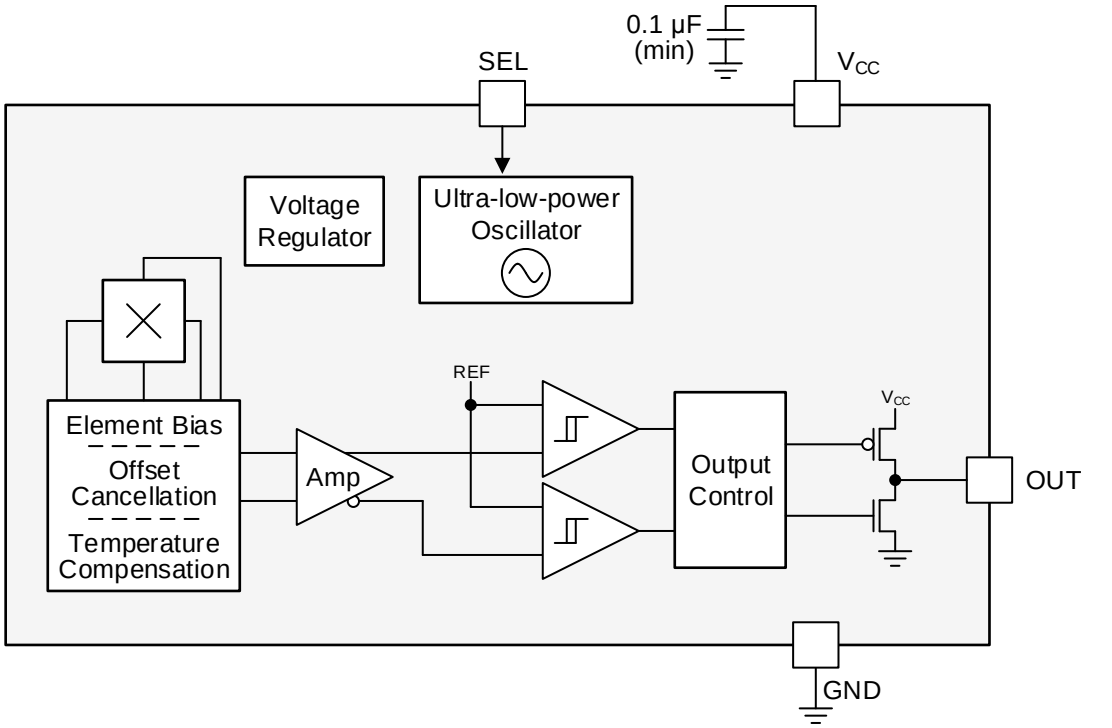
7 Detailed Description

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



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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 Figure 7).

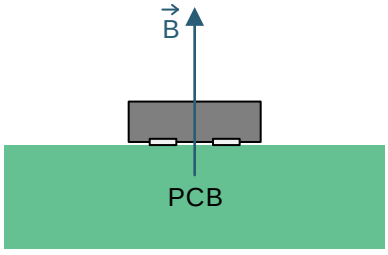


Figure 7. Direction of Sensitivity

Feature Description (continued)

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.

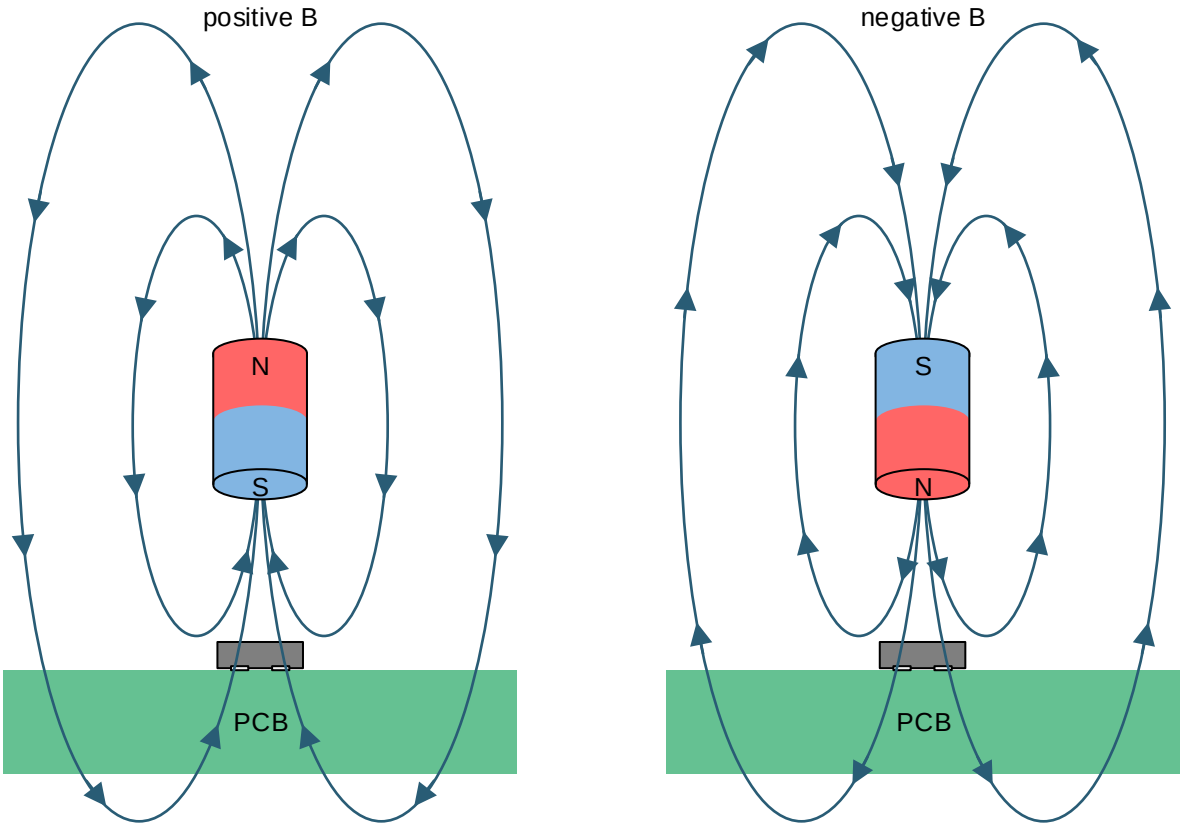


Figure 8. Flux Direction Polarity

7.3.2 Magnetic Response

Figure 9 shows the device functionality and hysteresis.

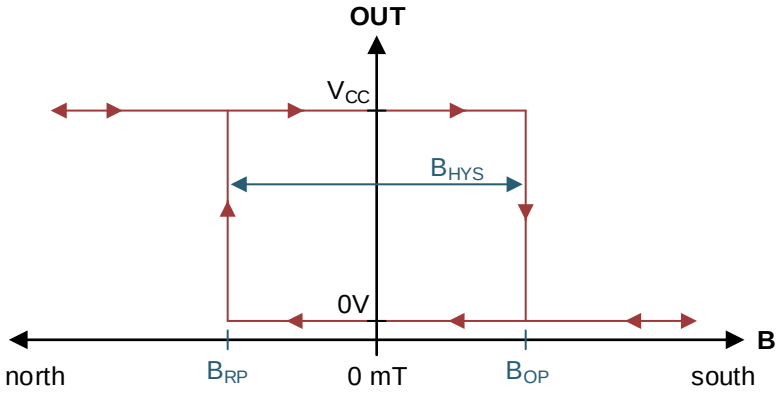


Figure 9. Device Functionality

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Feature Description (continued)

7.3.3 Output Driver

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

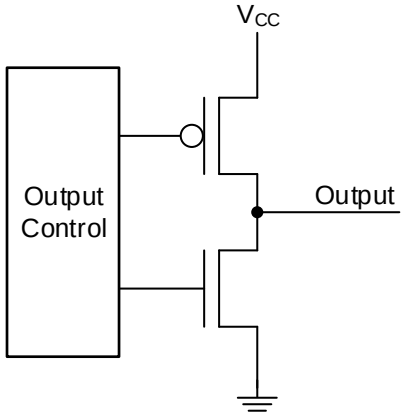


Figure 10. Push-Pull Output (Simplified)

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.

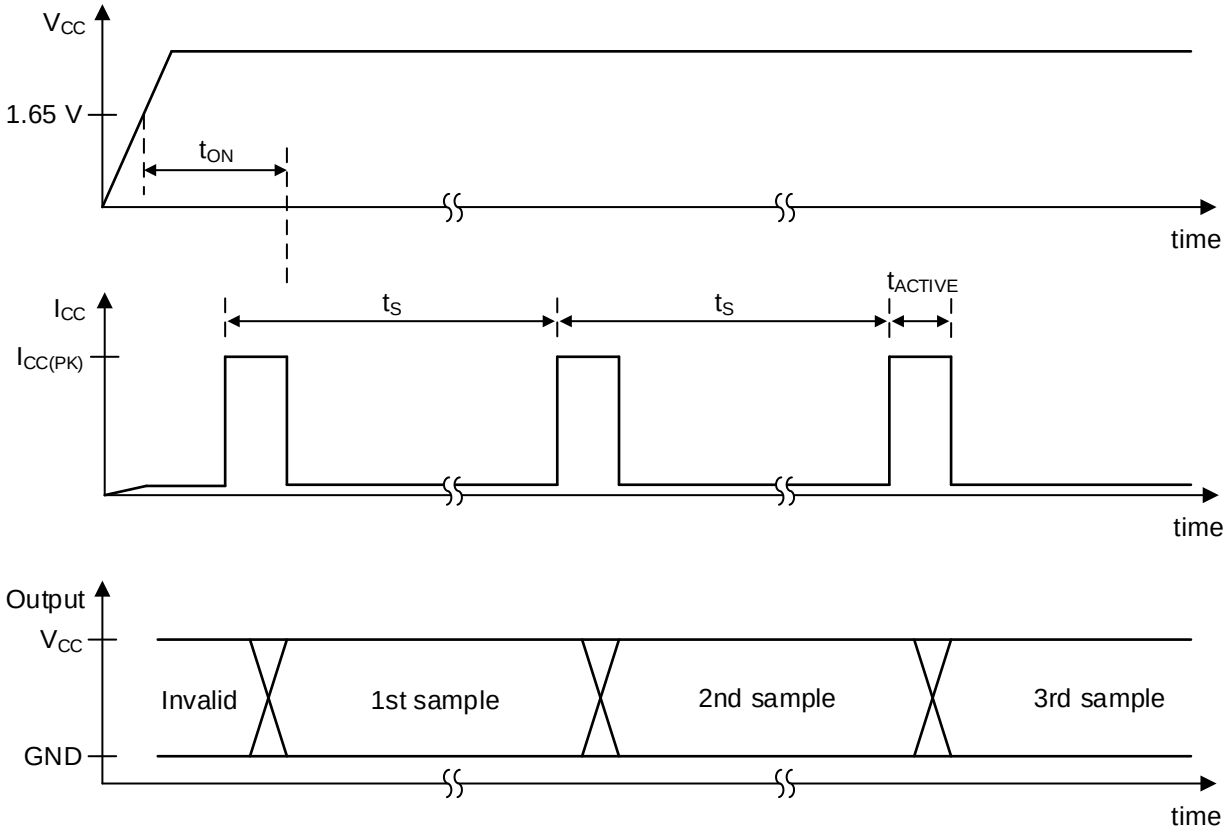


Figure 11. Timing Diagram

Feature Description (continued)

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. Figure 12 shows the tolerances and side-view dimensions.

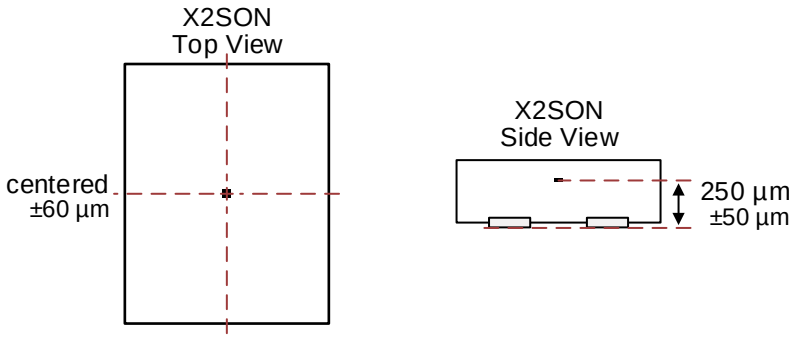


Figure 12. Hall Element Location

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.

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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. 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

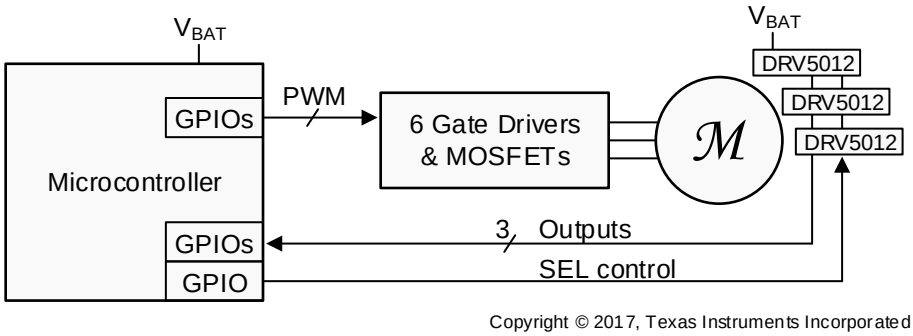


Figure 13. BLDC Motor System

8.2.1.1 Design Requirements

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

Table 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

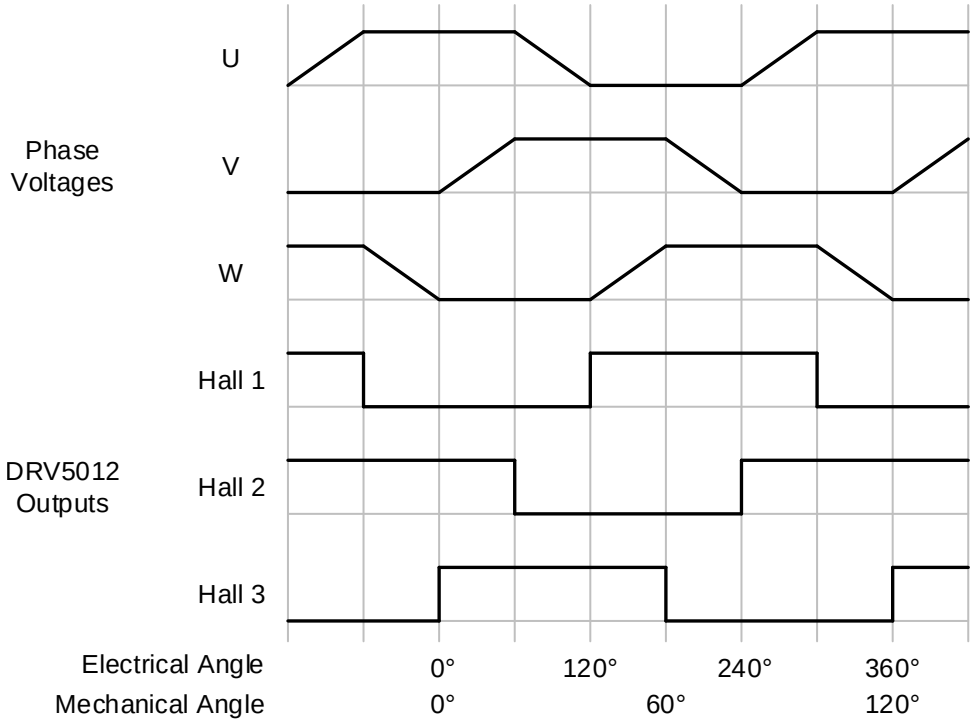
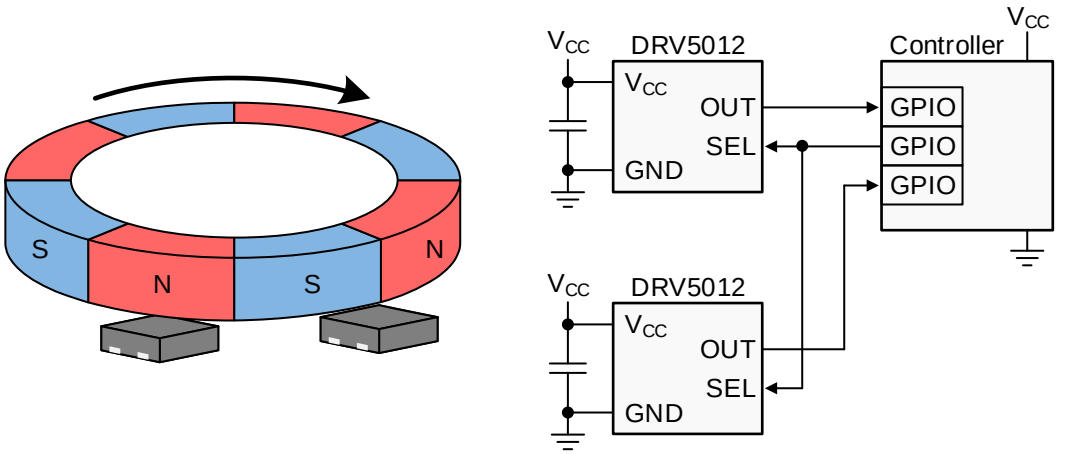


Figure 14. 3-Phase BLDC Motor Phase Voltages and Hall Signals

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8.2.2 Incremental Rotary Encoding Application



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Figure 15. Incremental Rotary Encoding System

8.2.2.1 Design Requirements

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

Table 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. Figure 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.

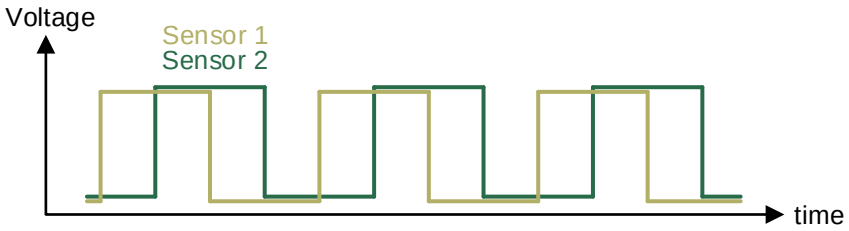


Figure 16. 2-bit Quadrature Output

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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. Figure 17 shows correct and incorrect orientations when using a ring magnet.

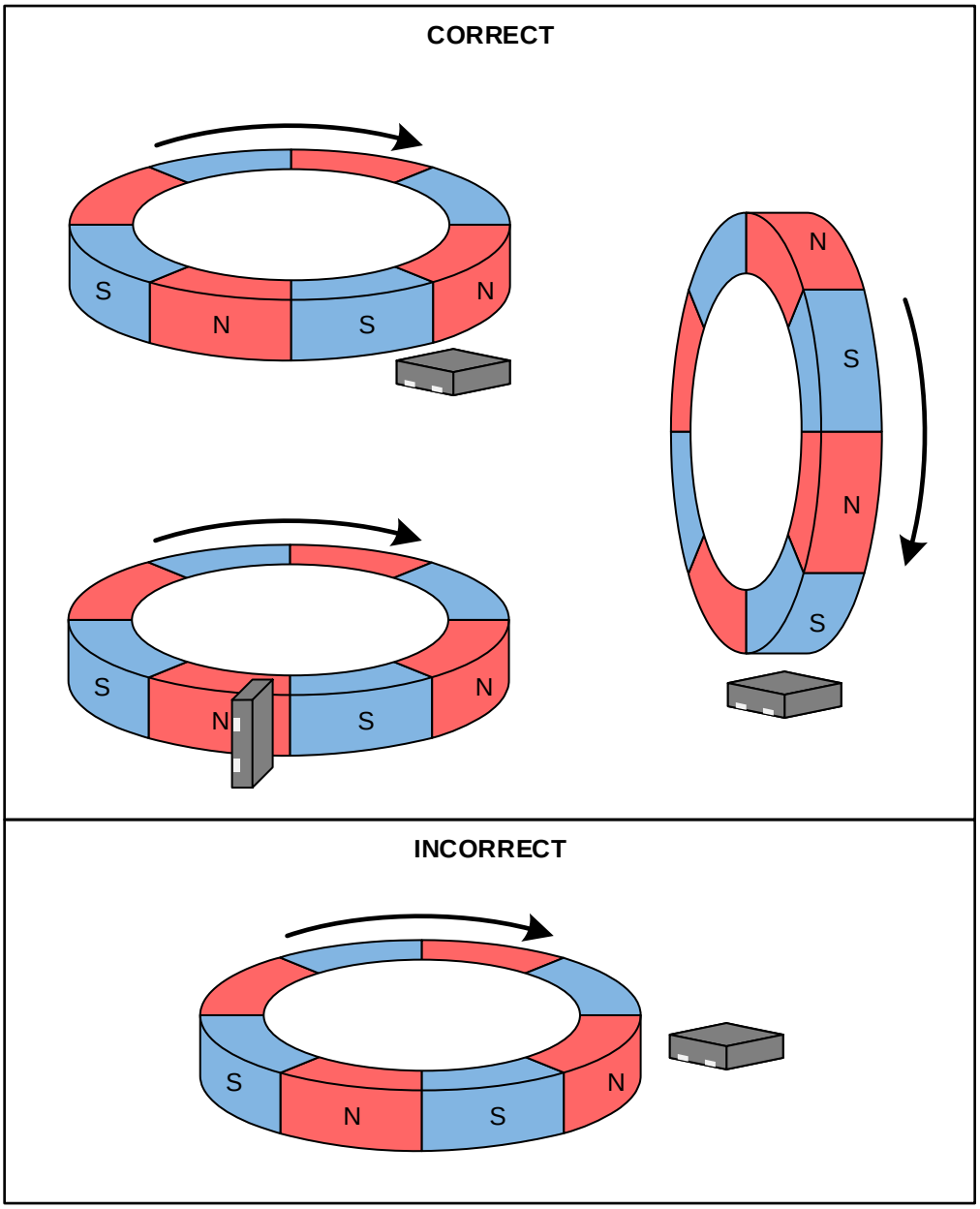


Figure 17. Correct and Incorrect Magnet Orientations

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

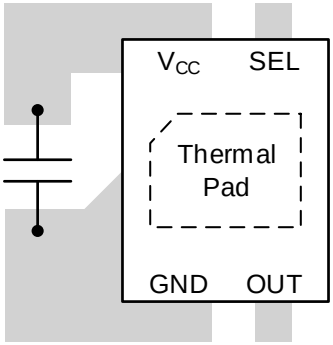


Figure 18. Layout Example

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11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

For additional design reference, refer to the *Automotive Hall Sensor Rotary Encoder* TI Design (TIDA-00480).

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* 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.

11.3 Community Resources

The following links connect to TI community resources. Linked contents are 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.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.4 Trademarks

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

11.5 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.6 Glossary

SLYZ022 — *TI Glossary*.

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

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.

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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)
DRV5012AEDMRR	Active	Production	X2SON (DMR) | 4	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 85	2AE
DRV5012AEDMRR.A	Active	Production	X2SON (DMR) | 4	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 85	2AE
DRV5012AEDMRT	Obsolete	Production	X2SON (DMR) | 4	-	-	Call TI	Call TI	-40 to 85	2AE

(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.

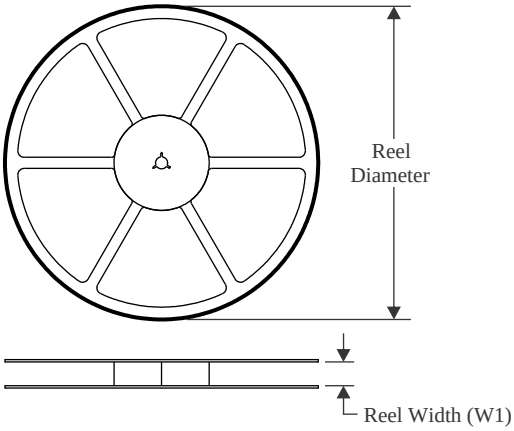
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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.

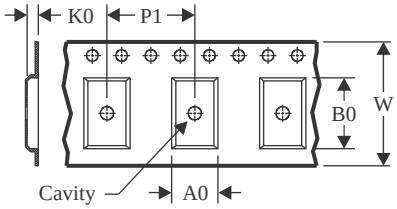
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

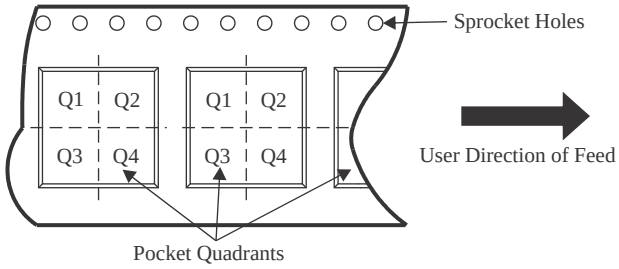


TAPE DIMENSIONS



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

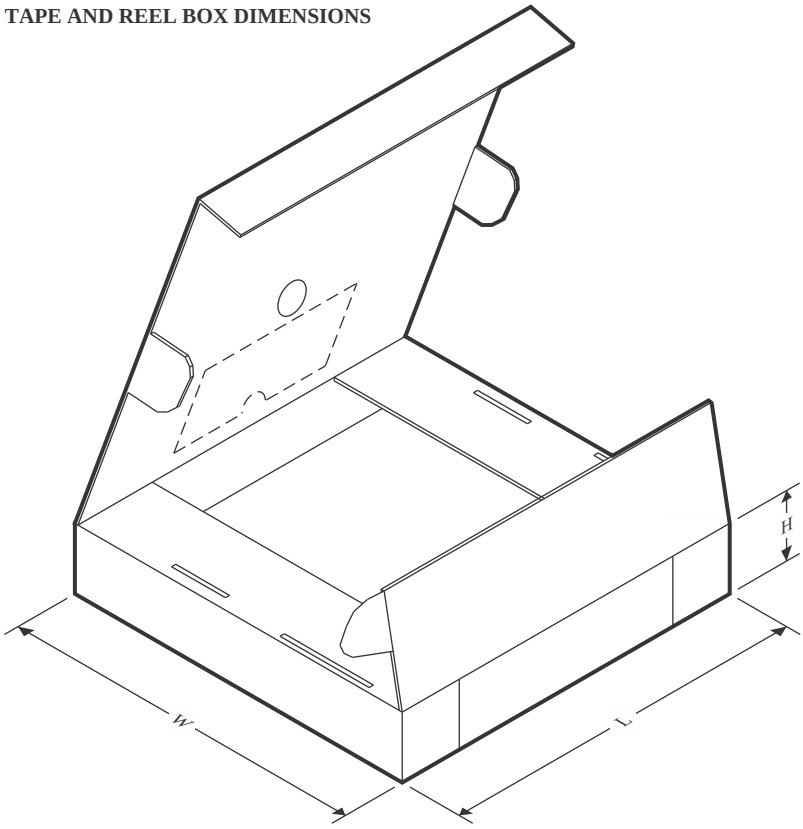
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
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

GENERIC PACKAGE VIEW

DMR 4

X2SON - 0.4 mm max height

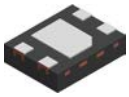
1.1 x 1.4, 0.5 mm pitch

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.



4229480/A

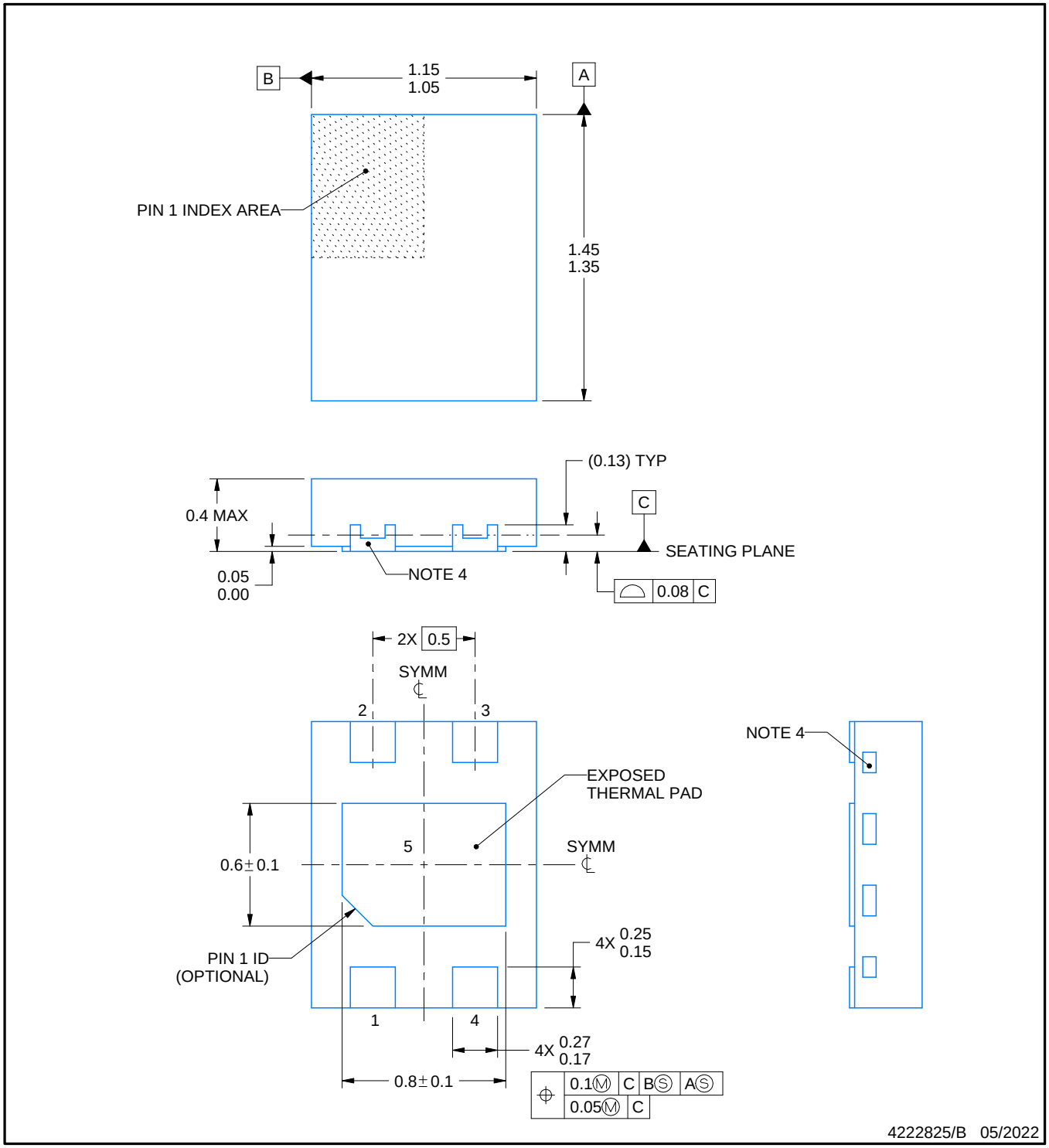


PACKAGE OUTLINE

DMR0004A

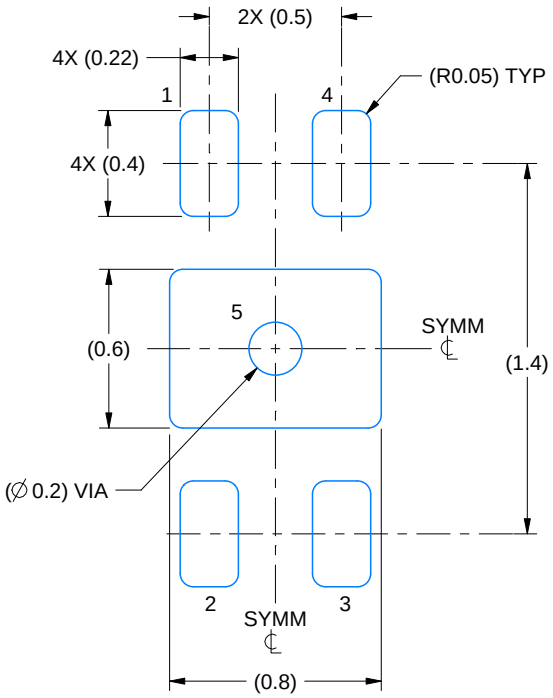
X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

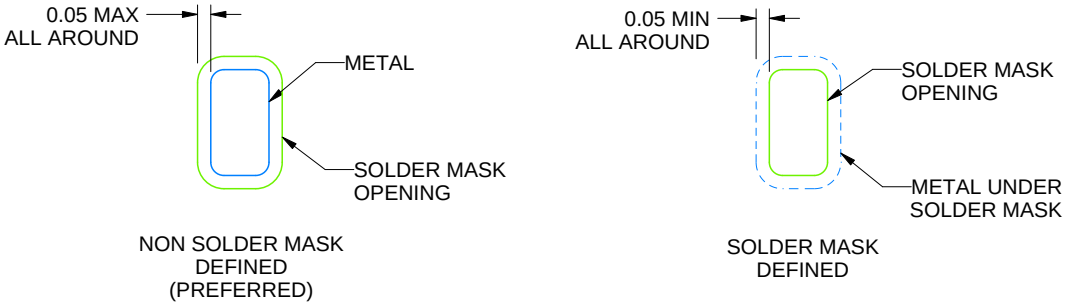


NOTES:

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

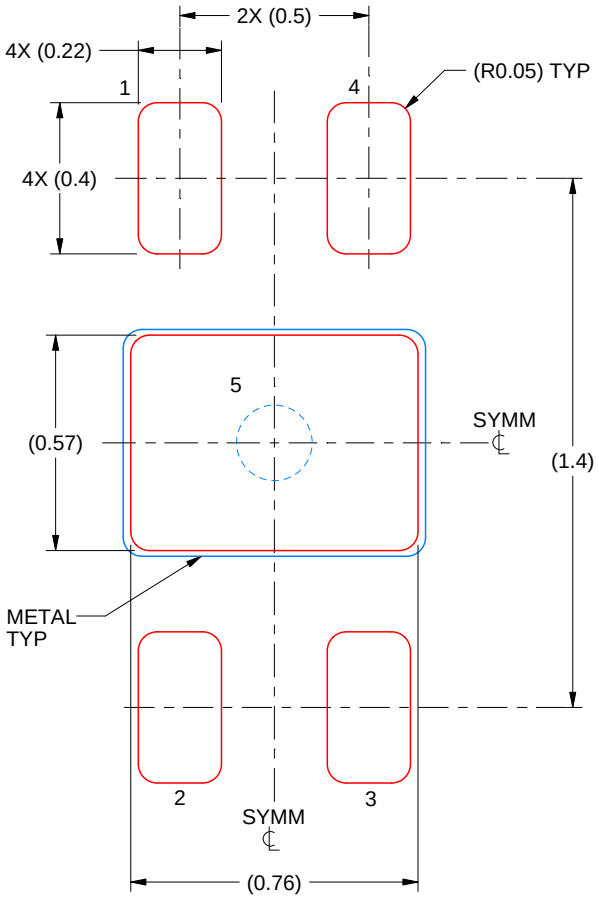


SOLDER MASK DETAILS

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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.

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