TLV4011-Q1 具有精密基准的低功耗比较器

1 特性

- 符合汽车应用要求
- 具有符合 AEC-Q100 标准的下列特性：
  - 器件温度等级 1：-40°C 至 125°C 的环境工作温度范围
  - 器件 HBM ESD 分级等级 H1C
  - 器件 CDM ESD 分类等级 C6
- 低至 1.226V 的可调节阈值
- ±1.5% 阈值电压精度
- 电源电流：3 µA
- 开漏输出
- 温度范围：–40°C 至 125°C
- 5 引脚 SC-70 封装

2 应用

- 紧急呼叫 (eCall)
- 远程信息处理控制单元
- 车载充电器 (OBC) 和无线充电器
- 直流/直流转换器
- 电池管理系统 (BMS)

3 说明

TLV4011-Q1 是一款具有精密集成基准的低功耗、高精度比较器。可通过将两个外部电阻器连接到输入端，实现低至 1.226V 的可调电压阈值。

经过工厂校准的开关阈值和精密迟滞相结合，使得 TLV4011-Q1 非常适合在必须将慢速输入信号转换为纯净数字输出的严苛、嘈杂环境中进行电压和电流监测。同样地，输入端的短时毛刺脉冲也得以抑制，因此可确保稳定的输出运行，不会引起误触发。

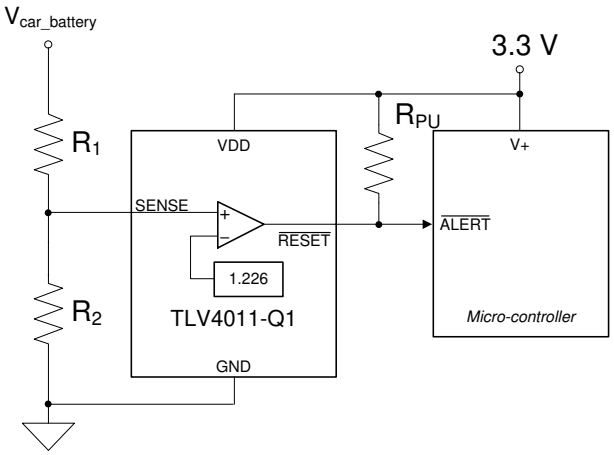
上电期间，当电源电压 V_{DD} 大于 0.8V 时，$\overline{RESET}$ 有效运行（低电平）。因此，TLV4011-Q1 会监测输入并使 $\overline{RESET}$ 运行（低电平），同时输入仍保持在阈值电压 V_{IT} 以下。一旦输入电压升至阈值电压 V_{IT} 以上，$\overline{RESET}$ 则不再运行（高电平）。该产品系列专为 1.8V、3.3V、5V 和可调电源电压而设计。

TLV4011-Q1 采用 5 引脚 SC-70 封装，工作温度范围为 -40°C 至 125°C。

器件信息(1)

器件型号	封装	封装尺寸（标称值）
TLV4011-Q1	SC-70 (5)	2.00mm × 1.25mm

(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。



典型应用原理图

本文档旨在为方便起见，提供有关 TI 产品中文版本的信息，以确认产品的概要。有关适用的官方英文版本的最新信息，请访问 www.ti.com，其内容始终优先。TI 不保证翻译的准确性和有效性。在实际设计之前，请务必参考最新版本的英文版本。

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4 Revision History

DATE	REVISION	NOTES
September 2020	*	Initial release

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5 Pin Configuration and Functions

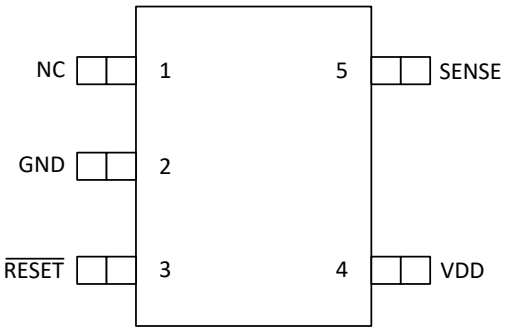


图 5-1. DCK Package, 5-Pin SC-70, Top View

Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
GND	2	I	Ground
$\overline{\text{RESET}}$	3	O	Active-low reset output (open-drain)
SENSE	5	I	Input
NC	1	—	No internal connection
V_{DD}	4	I	Input supply voltage

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6 Specifications

6.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V_{DD}	Supply voltage(2)		–0.3	7	V
	Voltage applied to all other pins(2)		–0.3	7	V
I_{OL}	Maximum low-level output current			5	mA
I_{OH}	Maximum high-level output current			–5	mA
I_{IK}	Input clamp current	$V_I < 0$ or $V_I > V_{DD}$		±10	mA
I_{OK}	Output clamp current	$V_O < 0$ or $V_O > V_{DD}$		±10	mA
P_D	Continuous total power dissipation		See 节 6.8		
T_A	Operating free-air temperature		–40	125	°C
T_{solder}	Soldering temperature			260	°C
T_{stg}	Storage temperature		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to GND. For reliable operation, the device should not be continuously operated at 7 V for more than t = 1000 h.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002(1)	±2000	V
		Charged-device model (CDM), per AEC Q100-011	±1000	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

		MIN	MAX	UNIT
V_{DD}	Supply voltage	1.3	6	V
V_I	Input voltage	0	V_{DD} + 0.3	V
T_A	Operating free-air temperature	–40	125	°C

6.4 Thermal Information

THERMAL METRIC(1)		TLV4011-Q1 DCK (SC-70) 5 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	246.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	68.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	78.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	77.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

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6.5 Electrical Characteristics

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

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OL}	Low-level output voltage		V_{DD} = 1.5 V, I_{OL} = 1 mA				V
			V_{DD} = 3.3 V, I_{OL} = 2 mA			0.3	
			V_{DD} = 6 V, I_{OL} = 3 mA				
V_{POR}	Power-up reset voltage(1)		VOL(max) = 0.2 V, IOL = 50 µA, T_A = 25°C	0.8			V
V_{IT}	Negative-going input threshold voltage(2)	SENSE		1.2	1.226	1.244	V
V_{hys}	Hysteresis		T_A = 25°C		15		mV
I_I	Input current	SENSE		–25		25	nA
I_{OH}	High-level output current at $\overline{\text{RESET}}$	$\overline{\text{RESET}}$	SENSE = V_{IT} + 0.2 V, V_{OH} = V_{DD}			300	nA
I_{DD}	Supply current		V_{DD} = 3.3 V, Output unconnected		2	4	µA
			V_{DD} = 6 V, Output unconnected		2	4	
C_I	Input capacitance		V_I = 0 V to V_{DD}		1		pF

(1) The lowest supply voltage at which $\overline{\text{RESET}}$ (V_{OL}(max) = 0.2 V, I_{OL} = 50 µA) becomes active. $t_r(V_{DD}) \geq 15$ µs/V.
(2) To ensure the best stability of the threshold voltage, place a bypass capacitor (ceramic, 0.1-µF) near the supply terminals.

6.6 Timing Requirements

R_L = 1 MΩ, C_L = 50 pF, T_A = –40°C to 125°C (unless otherwise noted)

				MIN	MAX	UNIT
t_w	Pulse duration	SENSE	V_{IH} = 1.05 × V_{IT}, V_{IL} = 0.95 × V_{IT}	5.5		µs

6.7 Switching Characteristics

R_L = 1 MΩ, C_L = 50 pF, T_A = –40°C to 125°C (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PHL}	Propagation (delay) time, high-to-low-level output	SENSE to $\overline{\text{RESET}}$ delay	V_{IH} = 1.05 × V_{IT}, V_{IL} = 0.95 × V_{IT}		5	100	µs
t_{PLH}	Propagation (delay) time, low-to-high-level output	SENSE to $\overline{\text{RESET}}$ delay	V_{IH} = 1.05 × V_{IT}, V_{IL} = 0.95 × V_{IT}		5	100	µs

6.8 Dissipation Ratings

PACKAGE	POWER RATING T_A < 25°C	DERATING FACTOR ABOVE T_A = 25°C	POWER RATING T_A = 70°C	POWER RATING T_A = 85°C
DCK	321 mW	2.6 mW/°C	206 mW	167 mW

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6.9 Timing Diagrams

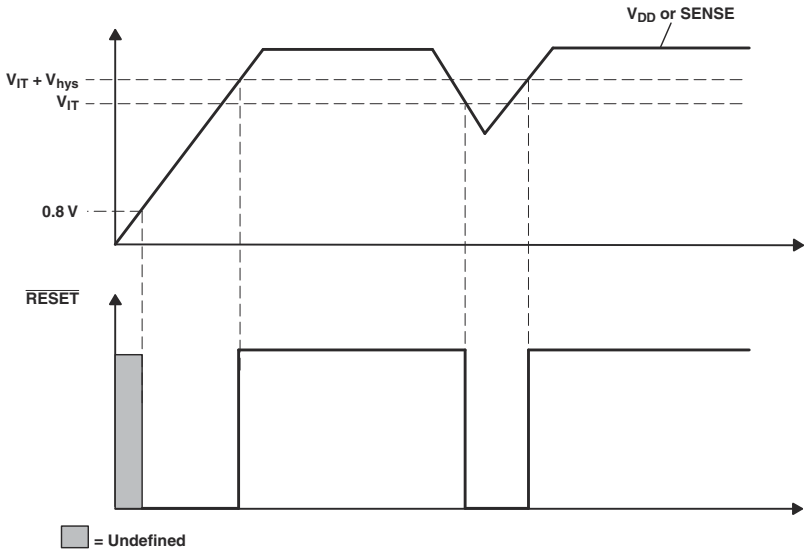


图 6-1. Timing Requirements

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6.10 Typical Characteristics

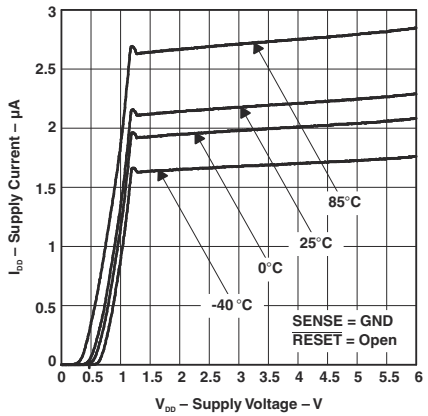


图 6-2. Supply Current vs Supply Voltage

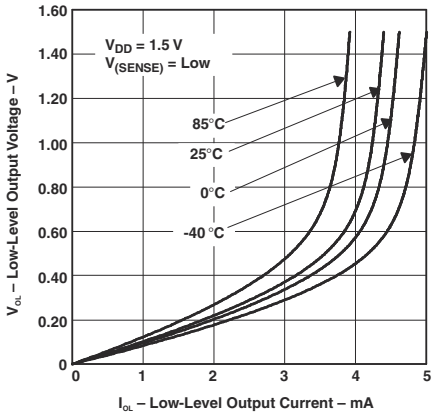


图 6-3. Low-Level Output Voltage vs Low-Level Output Current

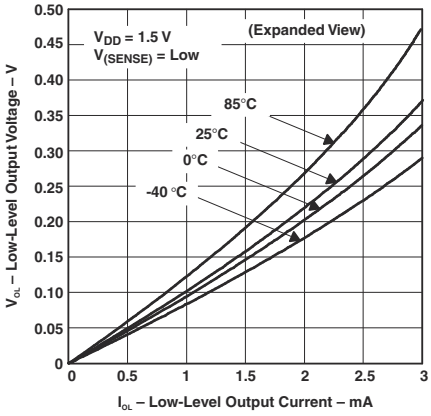


图 6-4. Low-Level Output Voltage vs Low-Level Output Current

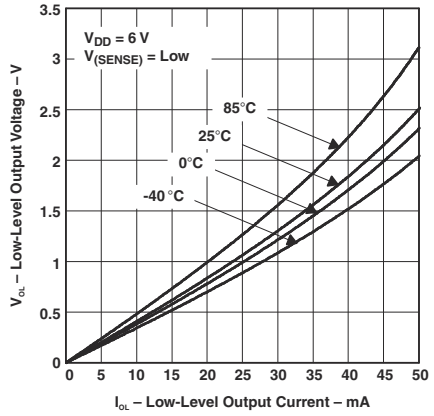


图 6-5. Low-Level Output Voltage vs Low-Level Output Current

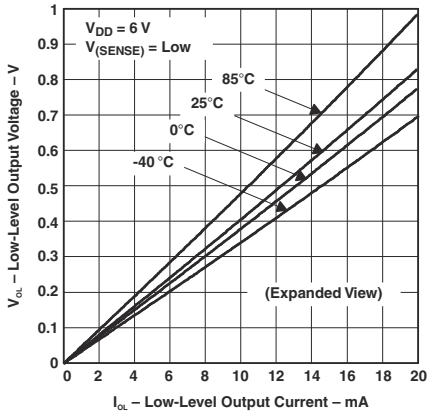


图 6-6. Low-Level Output Voltage vs Low-Level Output Current

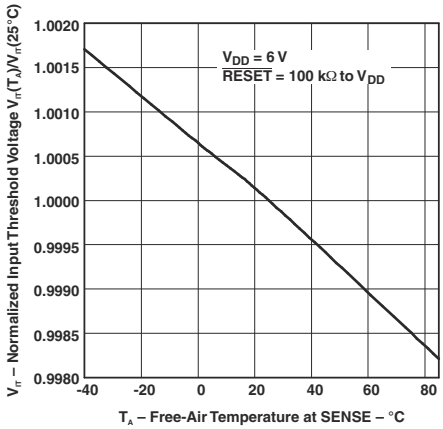


图 6-7. Normalized Input Threshold Voltage vs Free-Air Temperature At Sense

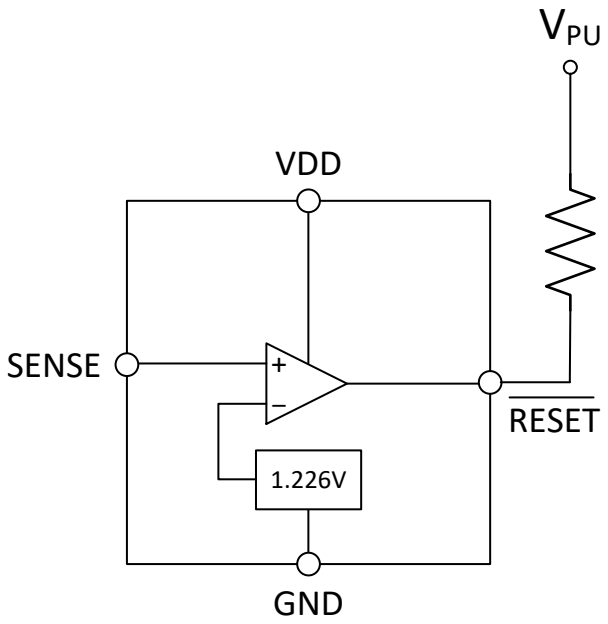
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7 Detailed Description

7.1 Overview

The TLV4011-Q1 is a low-current comparator used to monitor system voltages above 1.226 V. The comparators assert an active low $\overline{\text{RESET}}$ signal when the SENSE voltages drop below VIT. The $\overline{\text{RESET}}$ output remains low until the SENSE voltage returns above VIT plus the integrated hysteresis level. The TLV4011-Q1 is also designed to be immune to short negative transients on the SENSE pin.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 SENSE Monitoring

The SENSE input is where a system voltage can be monitored. If the voltage on this pin drops below V_{IT}, $\overline{\text{RESET}}$ is asserted low. The comparator has a built-in hysteresis to ensure smooth $\overline{\text{RESET}}$ assertions and de-assertions. By connecting a resistor divider network to the SENSE input as shown in the circuit below, VIN is divided down so $\overline{\text{RESET}}$ will assert when the divided down value of VIN reaches VIT (1.226 V). The TLV4011-Q1 is capable of monitoring any input voltage down to 1.226 V.

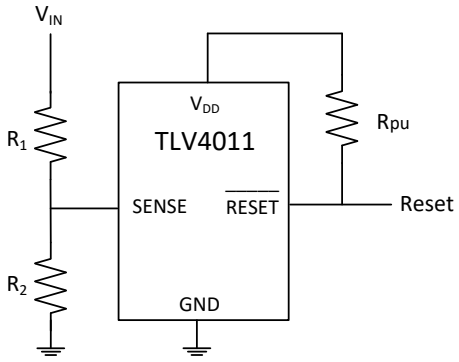


图 7-1. Voltage Monitor

7.3.2 Transient Immunity

The TLV4011-Q1 is immune to short negative transients on the SENSE pin. Sensitivity to transients is dependent on threshold overdrive as shown in 图 7-2 and 图 7-3. These graphs show the duration that the transient is below

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V_{IT} compared to the magnitude of the voltage drop below V_{IT}, called the threshold overdrive voltage. Any combination of transient duration and overdrive voltage which lies above the curves will result in $\overline{RESET}$ being asserted low. Any transient which lies below the curves will be ignored by the device.

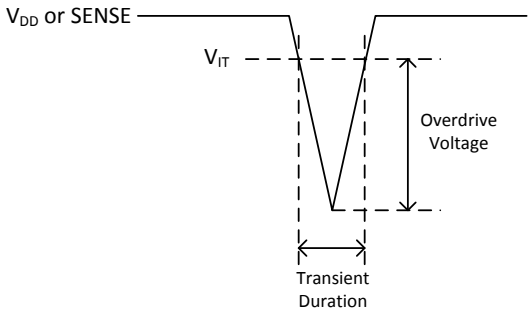


图 7-2. SENSE Overdrive Voltage

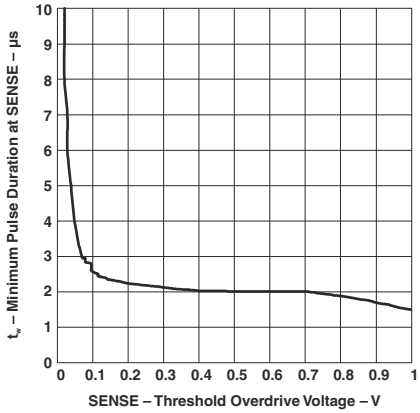


图 7-3. Minimum Pulse Duration at Sense vs Sense Threshold Overdrive Voltage

7.4 Device Functional Modes

The SENSE input is used to monitor one supply. When that supply is above the V_{IT} threshold, $\overline{RESET}$ will be high. Otherwise, $\overline{RESET}$ will be low.

表 7-1. Function and Truth Table

TLV4011-Q1	
SENSE > V_{IT}	**$\overline{RESET}$**
0 (False)	L
1 (True)	H

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8 Application and Implementation

备注

以下应用部分的信息不属于 TI 组件规范，TI 不担保其准确性和完整性。客户应负责确定 TI 组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。

8.1 Application Information

The TLV4011-Q1 comparator is designed to assert an active-low $\overline{\text{RESET}}$ signal when the SENSE input drops below the voltage threshold V_{IT}. The $\overline{\text{RESET}}$ signal remains low until the voltages return above their respective threshold plus the hysteresis. If additional hysteresis is required, positive feedback can be implemented similar to how it is done on a discrete comparator. See Application Note for details on how to implement external hysteresis in a non-inverting configuration.

8.2 Typical Application

8.2.1 Undervoltage Detection

Undervoltage detection is frequently required in battery-powered, portable electronics to alert the system that a battery voltage has dropped below the usable voltage level. 图 8-1 shows a simple undervoltage detection circuit using the TLV4011-Q1 which is a non-inverting comparator with an integrated 1.226 V reference and an open-drain output stage. A non-inverting is well suited for this application since the micro-controller requires an active low signal when an undervoltage level occurs.

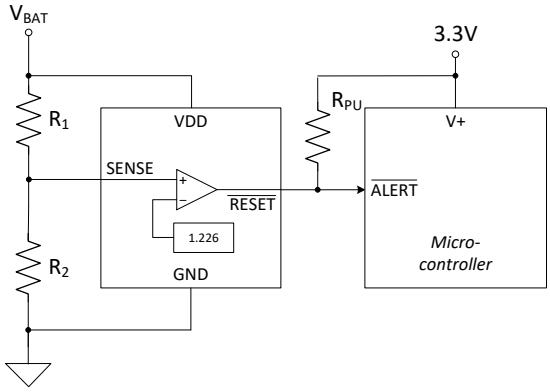


图 8-1. Undervoltage Detection

8.2.1.1 Design Requirements

For this design, follow these design requirements:

- TLV4011-Q1 operates from the V_{BAT} directly
- Output is level-shifted to the 3.3 V power supply that powers the microcontroller.
- Undervoltage alert is active low.
- Logic low output when V_{BAT} decreases below 2.0V.

8.2.1.2 Detailed Design Procedure

Configure the circuit as shown in 图 8-1. Note that VDD of the comparator is connected directly to V_{BAT} (the battery being monitored) and the output of the comparator is level shifted with its open-drain ouput to 3.3 V which powers the micro-controller. Resistors R_1 and R_2 divide down V_{BAT} so that the resistor divided output equals 1.226 V when V_{BAT} reaches an undervoltage alert level of 2.0 V.

When the battery voltage sags down to 2.0 V, the resistor divider voltage crosses the (V_{IT} = 1.226 V) threshold of the TLV4011-Q1. This causes the comparator output to transition from a logic high to a logic low. An open-drainj comparator is selected so the comparator output is compatible with the input logic level of the microcontroller. In addition, selecting a comparator with an integrated reference value of 1.226 V is favorable because it is the

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closest internal reference option that is less than the critical undervoltage level of 2.0 V. Choosing the internal reference option that is closest to the critical undervoltage level minimizes the resistor divider ratio which optimizes the accuracy of the circuit. Error at the falling edge threshold of (V_{IT}) is amplified by the inverse of the resistor divider ratio. So minimizing the resistor divider ratio is a way of optimizing voltage monitoring accuracy.

方程式 1 is derived from the analysis of 图 8-1.

$$V_{IT} = \frac{R_2}{R_1 + R_2} \times V_{BAT} \quad (1)$$

where

- R_1 and R_2 are the resistor values for the resistor divider connected to SENSE
- V_{BAT} is the voltage source that is being monitored for an undervoltage condition.
- V_{IT} is the falling edge threshold where the comparator output changes state from high to low

Rearranging 方程式 1 and solving for R_1 yields 方程式 2.

$$R_1 = \frac{(V_{BAT} - V_{IT})}{V_{IT}} \times R_2 \quad (2)$$

For the specific undervoltage detection of 2.0 V using the TLV4011-Q1, the following results are calculated.

$$R_1 = \frac{(2.0 - 1.226)}{1.226} \times 1M = 631\ k\Omega \quad (3)$$

where

- R_2 is set to 1 MΩ
- V_{BAT} is set to 2.0 V
- V_{IT} is set to1.226 V

Choose R_{TOTAL} (R_1 + R_2) such that the current through the divider is at approximately 100 times higher than the input bias current (I_{BIAS}). The resistors can have high values to minimize current consumption in the circuit without adding significant error to the resistive divider.

8.2.1.3 Application Curve

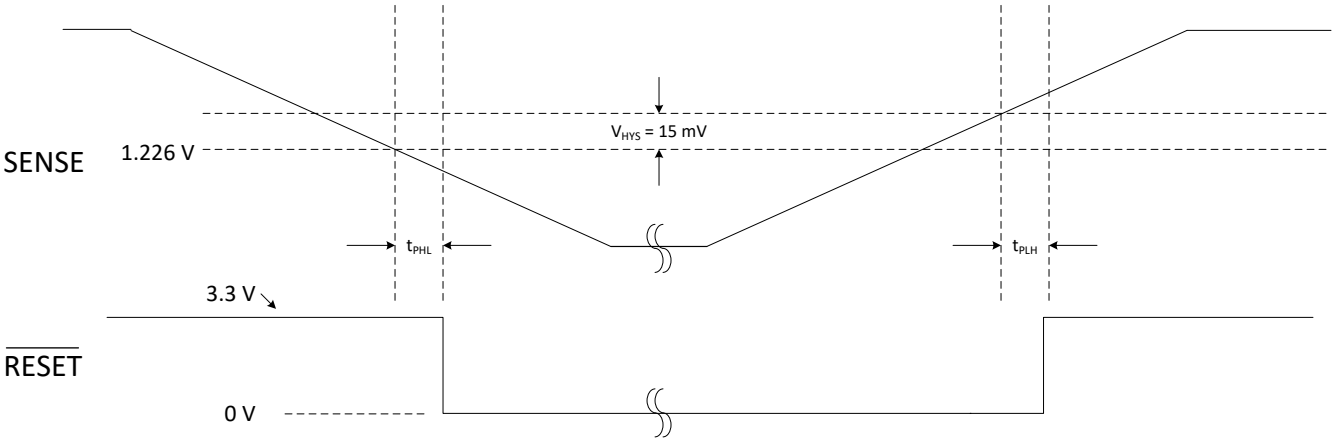


图 8-2. Undervoltage Detection

8.2.2 Additional Application Information

8.2.2.1 Pull-up Resistor Selection

Since the TLV4011-Q1 has an open drain output, care should be taken in selecting the pull-up resistor (R_{PU}) value to ensure proper output voltage levels. First, consider the required output high logic level requirement of the logic device that is being driven by the comparator when calculating the maximum R_{PU} value. When in a logic high output state, the output impedance of the comparator is very high but there is a finite amount of leakage current that needs to be accounted for. Use I_{OH} from the EC Table and the V_{IH} minimum from the logic device being driven to determine R_{PU} maximum using 方程式 4.

$$R_{PU}(max) = \frac{(V_{PU} - V_{IH(min)})}{I_{OH}} \quad (4)$$

Next, determine the minimum value for R_{PU} by using the V_{IL} maximum from the logic device being driven. In order for the comparator output to be recognized as a logic low, V_{IL} maximum is used to determine the upper boundary of the comparator's V_{OL}. V_{OL} maximum for the comparator is available in the EC Table for specific sink current levels and can also be found from the V_{OUT} versus I_{SINK} curve in the Typical Application curves. A good design practice is to choose a value for V_{OL} maximum that is 1/2 the value of V_{IL} maximum for the input logic device. The corresponding sink current and V_{OL} maximum value will be needed to calculate the minimum R_{PU}. This method will ensure enough noise margin for the logic low level. With V_{OL} maximum determined and the corresponding I_{SINK} obtained, the minimum R_{PU} value is calculated with 方程式 5.

$$R_{PU}(min) = \frac{(V_{PU} - V_{OL(max)})}{I_{SINK}} \quad (5)$$

Since the range of possible R_{PU} values is large, a value between 5 kΩ and 100 kΩ is generally recommended. A smaller R_{PU} value provides faster output transition time and better noise immunity, while a larger R_{PU} value consumes less power when in a logic low output state.

8.2.2.2 Input Supply Capacitor

Although an input capacitor is not required for stability, for good analog design practice, connect a 100 nF low equivalent series resistance (ESR) capacitor from (VDD) to (GND).

8.2.2.3 Sense Capacitor

Although not required in most cases, for extremely noisy applications, place a 1 nF to 100 nF bypass capacitor from the comparator input (SENSE) to the (GND) for good analog design practice. This capacitor placement reduces device sensitivity to transients.

9 Power Supply Recommendations

The TLV4011-Q1 comparator is designed to operate from an input supply from 1.3 V to 6 V. It is recommended to place a 0.1-µF capacitor from the VDD pin to GND.

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10 Layout

10.1 Layout Guidelines

TI recommends to place the 0.1-µF decoupling capacitor close to the VDD pin. The VDD trace should be able to carry 6 µA without a significant drop in voltage. Avoid a long trace from the SENSE pin to the resistor divider.

10.2 Layout Examples

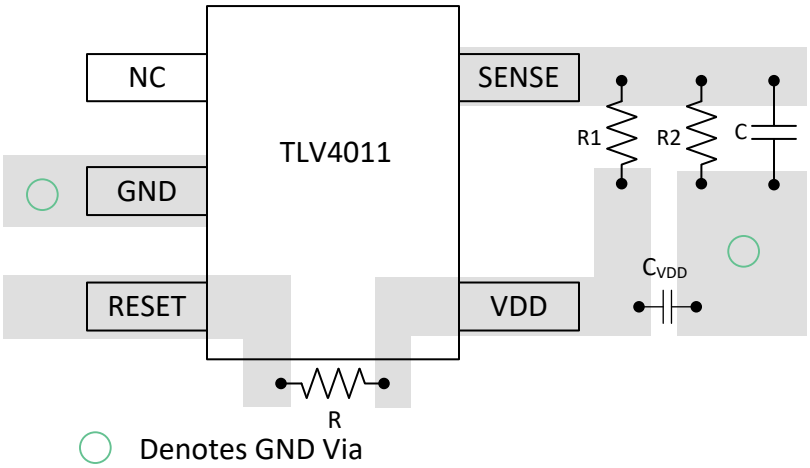


图 10-1. Layout Example

11 Device and Documentation Support

11.1 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。点击 *订阅更新* 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。

11.2 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》。

11.3 Trademarks

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11.4 静电放电警告



静电放电 (ESD) 会损坏这个集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

11.5 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。

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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)
TLV4011QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	1I9
TLV4011QDCKRQ1.Z	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	1I9

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

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

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

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

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

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

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

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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.

OTHER QUALIFIED VERSIONS OF TLV4011-Q1 :

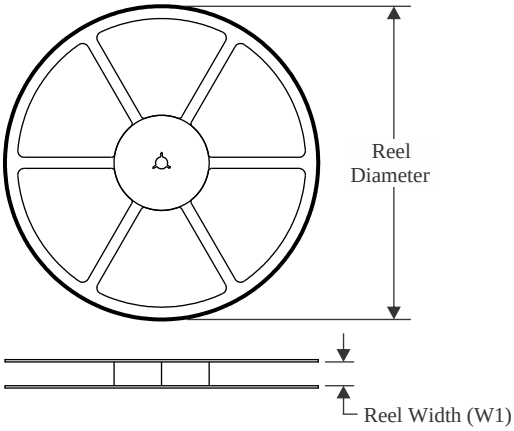
- Catalog : TLV4011

NOTE: Qualified Version Definitions:

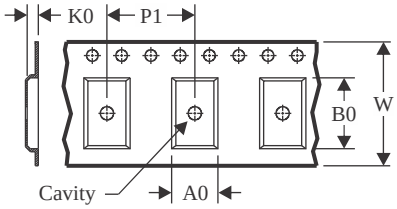
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

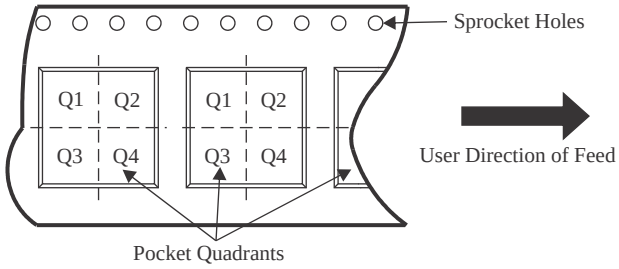


TAPE DIMENSIONS



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

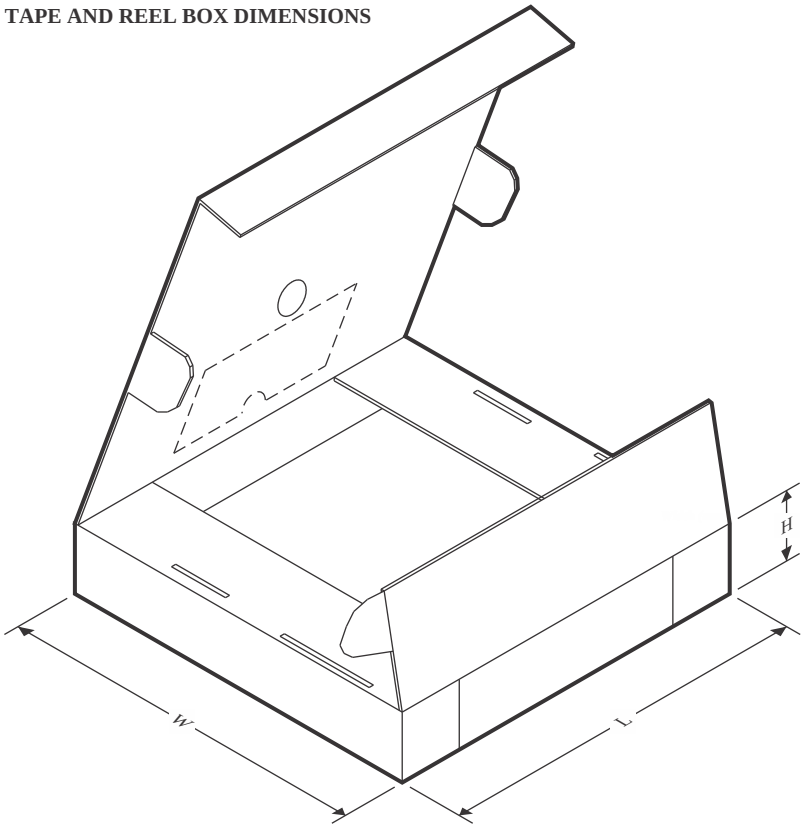
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TLV4011QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.47	2.3	1.25	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

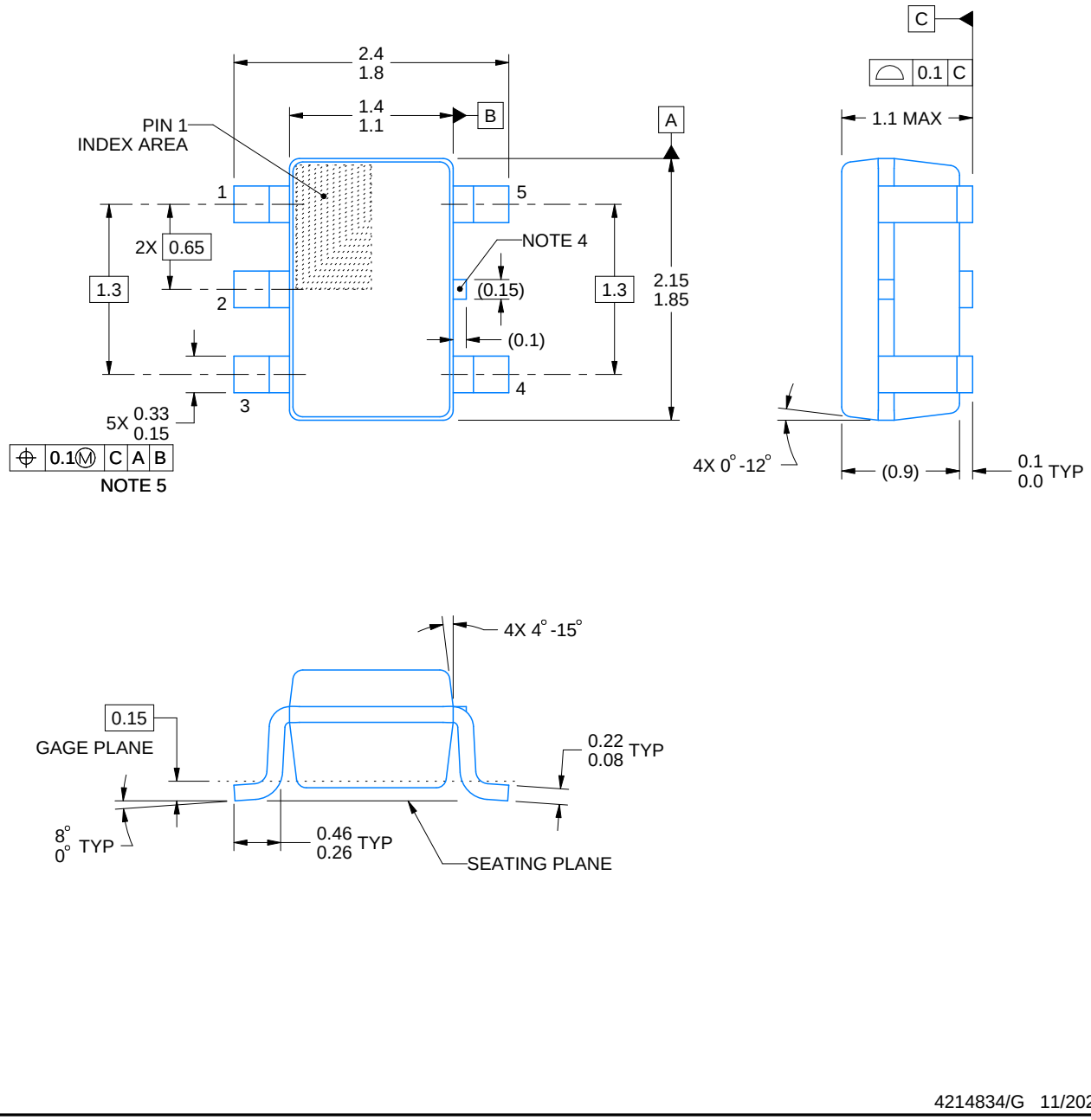
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV4011QDCKRQ1	SC70	DCK	5	3000	183.0	183.0	20.0

PACKAGE OUTLINE

DCK0005A

SOT - 1.1 max height

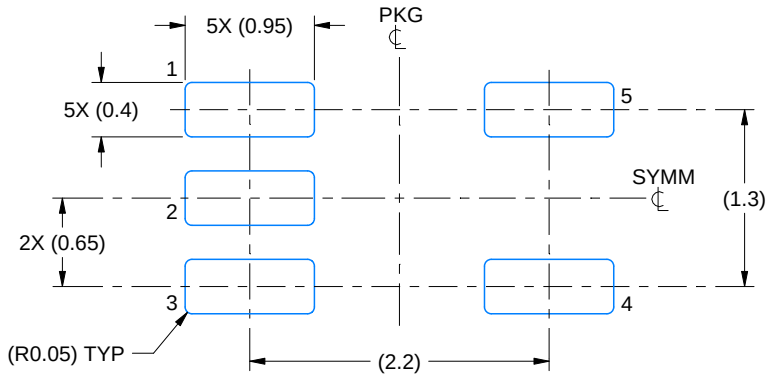
SMALL OUTLINE TRANSISTOR



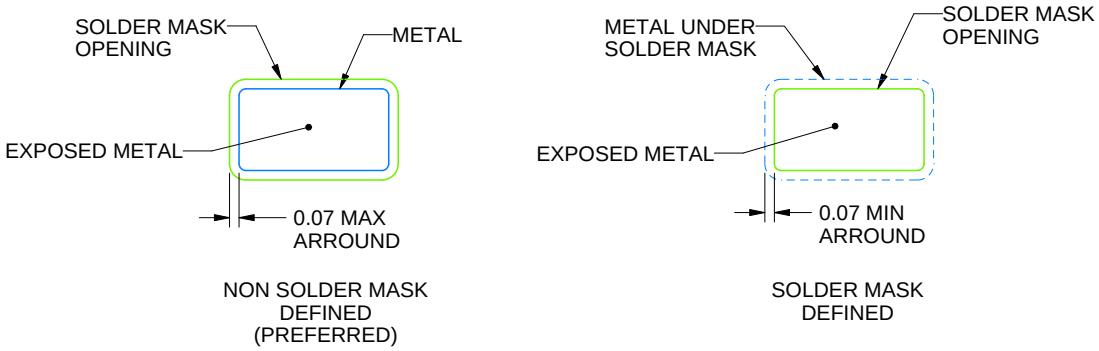
4214834/G 11/2024

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. Refernce JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

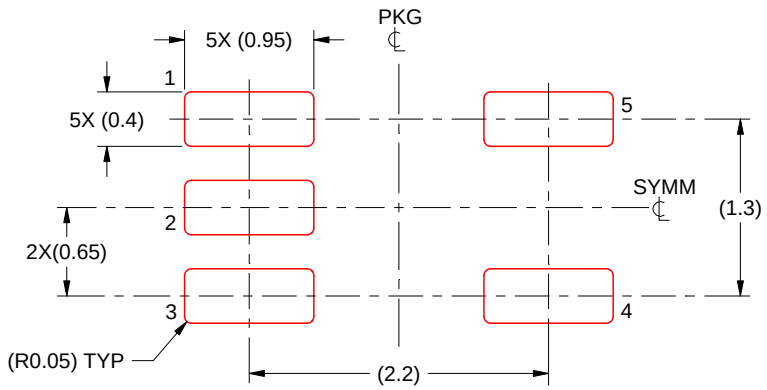


SOLDER MASK DETAILS

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NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. 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:18X

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NOTES: (continued)

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

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