TPS92541-Q1 65V 汽车级同步升压控制器、2A 同步 CC/CV 降压转换器

1 特性

- 符合面向汽车应用的 AEC-Q100 标准
  - 1 级：–40°C 至 125°C 环境工作温度范围
  - 器件 HBM 分类等级 H1C
  - 器件 CDM 分类等级 C5
- 功能安全型
  - 提供协助功能安全系统设计的文档
- 4.5V 到 65V 的宽输入电压范围
- 具有集成开关的同步降压
- 可配置恒压 (CV) 和恒流 (CC) 运行
  - 持续输出电流高达 2A，精度为 4%
  - 4% 调节精度（电压和电流模式）
- 同步升压控制器
  - 可编程输出电压高达 65V
- 用于降低 EMI 的升压和降压展频
- 降压开关过热保护
- UART 串行通信
  - 用于系统时钟的内部振荡器
  - LMM 兼容
- 内部 EEPROM
  - 默认设置
  - 客户校准数据

2 应用

- 汽车前照灯和自适应 LED 驱动模块

3 说明

TPS92541-Q1 器件包含一个同步升压控制器和一个单片同步降压 LED 驱动器，具有 4.5V 至 65V 的宽降压输入工作电压范围。

同步升压控制器实现了一个峰值电流模式控制器，可在恒定电压模式下运行。该升压控制器经过编程，可与其他 TPS92541-Q1 器件一起实现双相或三相运行。可使用可编程 8 位 DAC 对输出电压进行编程。该升压控制器采用可编程频率调制技术来降低 EMI。

该单片同步降压控制器实施了自适应导通时间平均电流模式控制功能，经设计可生成恒压 (CV) 或恒流 (CC) 输出。在 CC 模式下，该降压控制器与分流 FET 调光技术和基于 LED 矩阵管理器的动态光束前照灯兼容。在 CV 模式下，自适应导通时间控制功能支持高带宽运行并提供快速瞬态响应。自适应导通时间控制功能可提供近乎恒定的开关频率，频率设置范围为 100kHz 至 1.0MHz。电感器电流检测和闭环反馈功能可在宽的输入电压、输出电压和环境温度范围内实现优于 ±4% 的精度。在 CC 模式下，该降压控制器可使用模拟调光或 PWM 调光技术来单独调制 LED 电流。

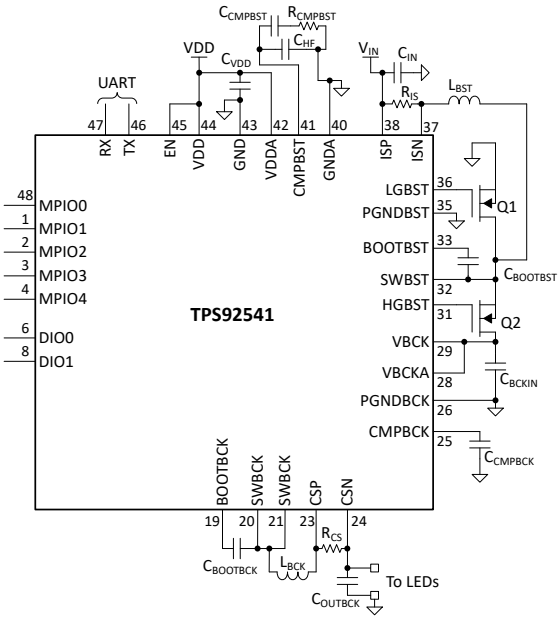
TPS92541-Q1 包括一个内部振荡器。UART 串行接口与 TPS9266x 和 TPS9254x 器件兼容。内部 EEPROM 可存储系统默认值以及校准和照明模块数据。七个可配置的 MPIO 和 DIO 可设置为数字输入或输出，或者 ADC 输入，用于系统温度补偿、LED 分级和编码等应用场景。

TPS92541-Q1 采用 7.0mm × 7.0mm 热增强型 48 引脚 HTQFP 封装。

器件信息

器件型号(1)	封装	封装尺寸（标称值）(2)
TPS92541-Q1	PKD、PHP（HTQFP，48）	7.0mm × 7.0mm

(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。
(2) 封装尺寸（长 × 宽）为标称值并包括引脚（如适用）



简化版原理图

内容

4 引脚配置和功能

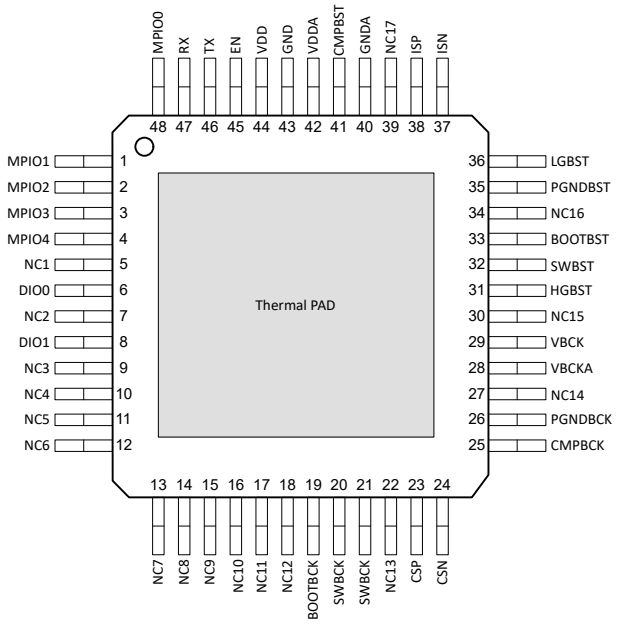


图 4-1. PKD 封装 48 引脚 HTQFP（顶部外露焊盘）顶视图

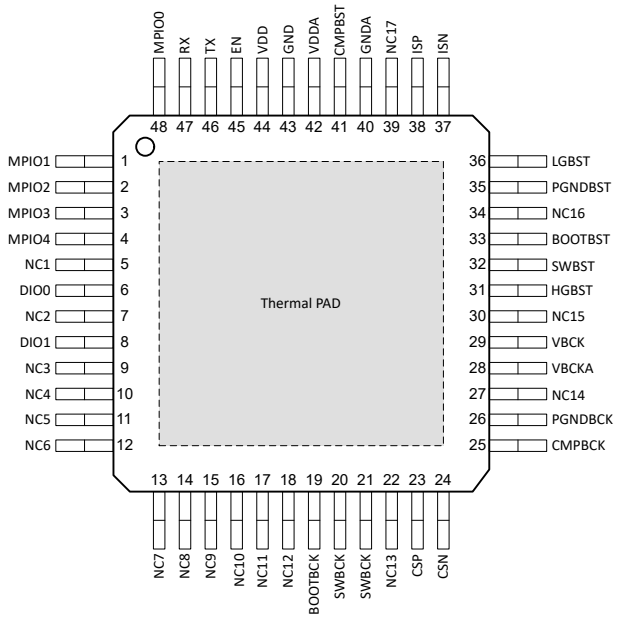


图 4-2. PHP 封装 48 引脚 HTQFP（底部外露焊盘）顶视图

表 4-1. 引脚功能

引脚		I/O	说明
名称	编号 PKD/PHP		
BOOTBCK	19	P	降压高侧 MOSFET 栅极驱动电路的电源输入。在 BOOTBCK 和 SWBCK 引脚之间连接一个陶瓷电容器。内部二极管连接在 VDD 和 BOOTBCK 之间。
BOOTBST	33	P	升压高侧 MOSFET 栅极驱动电路的电源输入。在 BOOTBST 和 SWBST 之间连接一个陶瓷电容器。内部二极管连接在 VDD 和 BOOTBST 之间。
CMPBCK	25	I/O	降压内部跨导误差放大器的输出。连接整体式补偿网络以确保稳定性。
CMPBST	41	I/O	升压内部跨导误差放大器的输出。连接比例积分补偿网络以确保稳定性。
CSN	24	I	内部轨到轨跨导误差放大器的负输入 (–)。直接连接到 LED 电流检测电阻 R_{CS} 的负节点。
CSP	23	I	内部轨到轨跨导误差放大器的正输入 (+)。直接连接到 LED 电流检测电阻 R_{CS} 的正节点。
DIO0	6	I/O	数字 IO。引脚可配置为数字输入或数字输出。
DIO1	8	I/O	
EN	45	I	硬件启用。将该引脚拉至低电平，进入关断状态。
GND	43	G	信号和模拟地。内部电压基准和模拟电路的回路。连接到电路接地以形成完整的返回路径。
GNDA	40		
HGBST	31	I/O	升压高侧栅极驱动器输出。
ISN	37	O	升压电流检测放大器的负输入 (–)。直接连接到电流检测电阻 R_{IS}。
ISP	38	I	升压电流检测放大器的正输入 (+)。直接连接到电流检测电阻 R_{IS}。
LGBST	36	I/O	升压低侧栅极驱动器输出。
MPIO0	48	I/O	多用途 IO。引脚可配置为 ADC 输入、数字输入或数字输出。MPIO0 用于进入 CTM。

表 4-1. 引脚功能（续）

引脚		I/O	说明
名称	编号 PKD/PHP		
MPIO1	1	I/O	多用途 IO。引脚可配置为 ADC 输入、数字输入或数字输出。
MPIO2	2	I/O	
MPIO3	3	I/O	
MPIO4	4	I/O	
NC1、NC2、NC3、NC4、NC5、NC6、NC7、NC8、NC9、NC10、NC11、NC12、NC13、NC14、NC15、NC16、NC17	5、7、9、10、11、12、13、14、15、16、17、18、22、27、30、34、39	NC	请勿连接。可接地。
PGNDBCK	26	G	降压低侧 MOSFET 的接地回路
PGNDBST	35	G	升压高侧栅极驱动器的接地回路
RX	47	I	UART 接收数据输入。连接到 CAN 收发器的 RX。
SWBCK	20、21	P	降压稳压器的开关输出。内部连接到两个功率 MOSFET。连接到功率电感器。
SWBST	32	P	升压控制器的开关节点。
TX	46	O	UART 传输数据输出。连接到 CAN 收发器的 TX。
VBCK	29	P	电源输入以及与降压高侧 MOSFET 漏极节点的连接。连接到降压输出电压和旁路电容 C_{IN}。从 VBCK 引脚到高频旁路 C_{IN} 和 PGND 的路径必须尽可能短。
VBCKA	28	P	降压稳压器的内部模拟块的电源。连接到 VBCK 引脚和高频旁路电容。
VDD	44	P	数字输入电源电压。使用靠近器件的 2.2μF 至 4.7μF 陶瓷电容器在本地去耦至 GND。
VDDA	42	P	模拟输入电源电压。使用靠近器件的 100nF 至 1μF 陶瓷电容器在本地去耦至 GND。

5 修订历史记录

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision * (March 2025) to Revision A (September 2025)	Page
• 向数据表添加了 PHP 封装。	1

6 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可用的最新数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。有关此数据表的浏览器版本，请查阅左侧的导航栏。

6.1 封装选项附录

封装信息

可订购器件	状态 (1)	封装类型	封装图	引脚	包装数量	环保计划 (2)	铅/焊球镀层(4)	MSL 峰值温度 (3)	工作温度 (°C)	器件标识(5) (6)
TPS92541QPKDRQ1	运行	HTQFP	PKD	48	1000	环保（符合 RoHS 标准，无锑/溴）	NIPDAU	Level-3-260C-168 HR	-40 至 125	TPS92541
TPS92541QPHPRQ1	运行	HTQFP	PHP	48	1000	环保（符合 RoHS 标准，无锑/溴）	NIPDAU	Level-3-260C-168 HR	-40 至 125	TPS92541Q

(1) 销售状态值定义如下：
正在供货：建议用于新设计的产品器件。
限期购买：TI 已宣布器件即将停产，但仍在购买期限内。
NRND：不推荐用于新设计。为支持现有客户，器件仍在生产，但 TI 不建议在新设计中使用此器件。
PRE_PROD：器件未发布，尚未量产，未向大众市场供货，也未在网络上供应，未提供样片。
预发布：器件已发布，但未量产。可能提供样片，也可能无法提供样片。
已停产：TI 已停止生产该器件。

(2) 环保计划 - 规划的环保分级包括：无铅 (RoHS)，无铅（RoHS 豁免）或绿色环保（RoHS，无锑/溴）- 如需了解最新供货信息及更多产品内容详情，请访问 http://www.ti.com/productcontent。
待定：无铅/绿色环保转换计划尚未确定。
无铅 (RoHS)：TI 所说的“无铅”或“无 Pb”是指半导体产品符合针对所有 6 种物质的现行 RoHS 要求，包括要求铅的重量不超过同质材料总重量的 0.1%。因在设计时就考虑到了高温焊接要求，因此 TI 的无铅产品适用于指定的无铅作业。
无铅（RoHS 豁免）：该元件在以下两种情况下可享受 RoHS 豁免：1) 芯片和封装之间使用铅基倒装芯片焊接凸点；2) 芯片和引线框之间使用铅基芯片粘合剂。否则，元件将根据上述规定视为无铅（符合 RoHS）。
绿色环保（RoHS，无锑/溴）：TI 将“绿色环保”定义为无铅（符合 RoHS 标准）、无溴 (Br) 和无锑 (Sb) 基阻燃剂（Br 或 Sb 在同质材料中的质量不超过总质量的 0.1%）

(3) MSL，峰值温度-- 湿敏等级额定值（符合 JEDEC 工业标准分级）和峰值焊接温度。

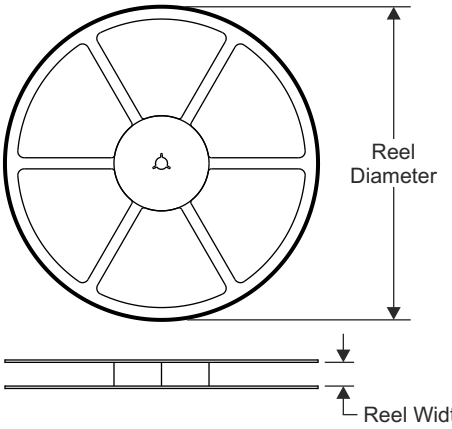
(4) 铅/焊球镀层 - 可订购器件可能有多种镀层材料选项。各镀层选项用垂直线隔开。如果铅/焊球镀层值超出最大列宽，则会折为两行。

(5) 器件上可能还有与标识、批次跟踪代码信息或环境分级相关的标记

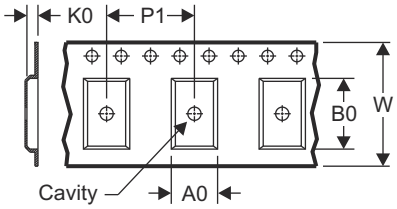
(6) 如有多个器件标识，将用括号括起来。不过，器件上仅显示括号中以“~”隔开的其中一个器件标识。如果某一行缩进，说明该行续接上一行，这两行合在一起表示该器件的完整器件标识。

6.2 卷带包装信息

REEL DIMENSIONS

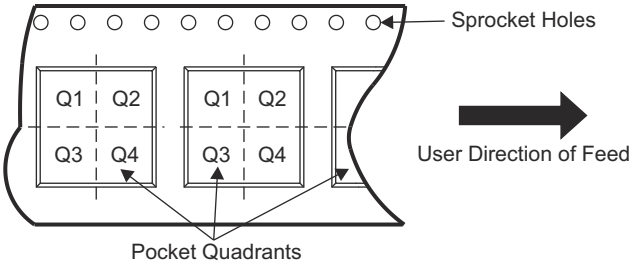


TAPE DIMENSIONS



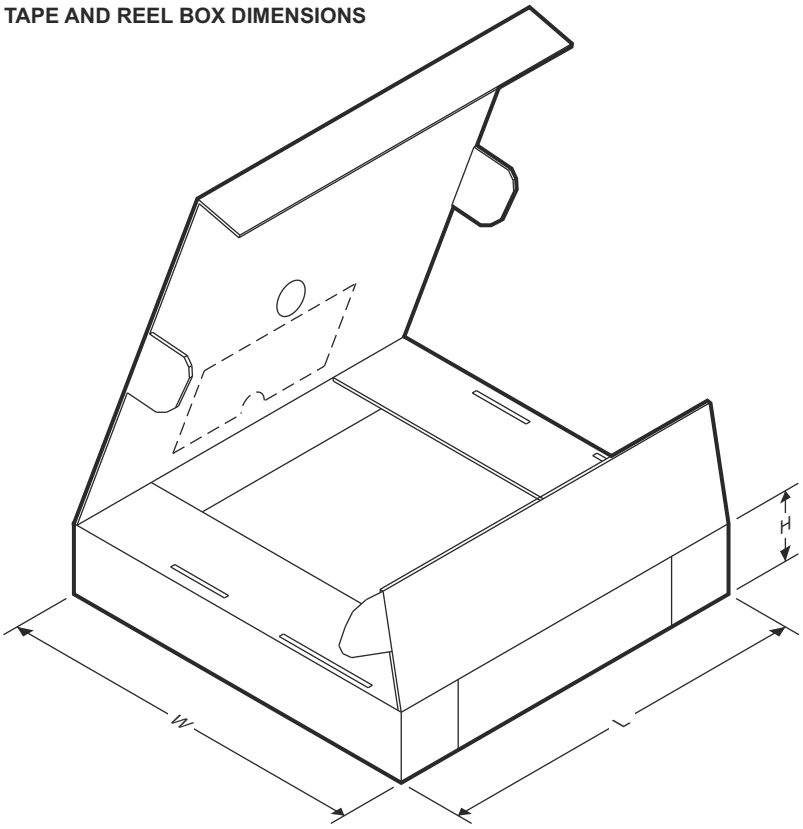
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



器件	封装类型	封装图	引脚	SPQ	卷带直径 (mm)	卷带宽度 W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1象限
TPS92541QPKDRQ1	HTQFP	PKD	48	1000	330	16.4	9.6	9.6	1.5	12	16	Q2
TPS92541QPHPRQ1	HTQFP	PHP	48	1000	330	16.4	9.6	9.6	1.5	12	16	Q2

TAPE AND REEL BOX DIMENSIONS



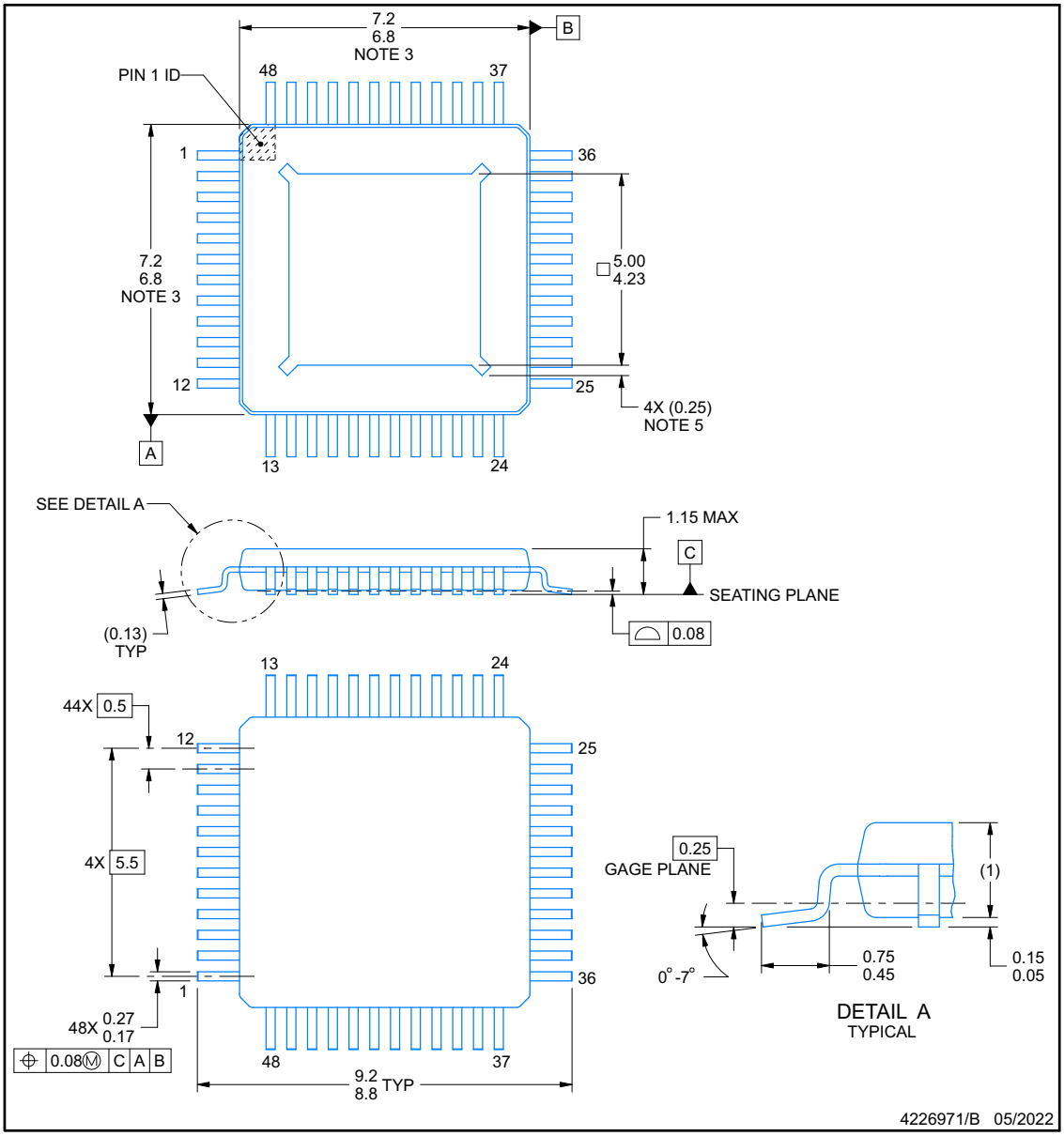
器件	封装类型	封装图	引脚	SPQ	长度 (mm)	宽度 (mm)	高度 (mm)
TPS92541QPKDRQ1	HTQFP	PKD	48	1000	336.6	336.6	31.8
TPS92541QPHPRQ1	HTQFP	PHP	48	1000	336.6	336.6	31.8

PACKAGE OUTLINE

PKD0048A

PowerPAD™ HTQFP - 1.15 mm max height

PLASTIC QUAD FLATPACK



PowerPAD is a trademark of Texas Instruments.

NOTES:

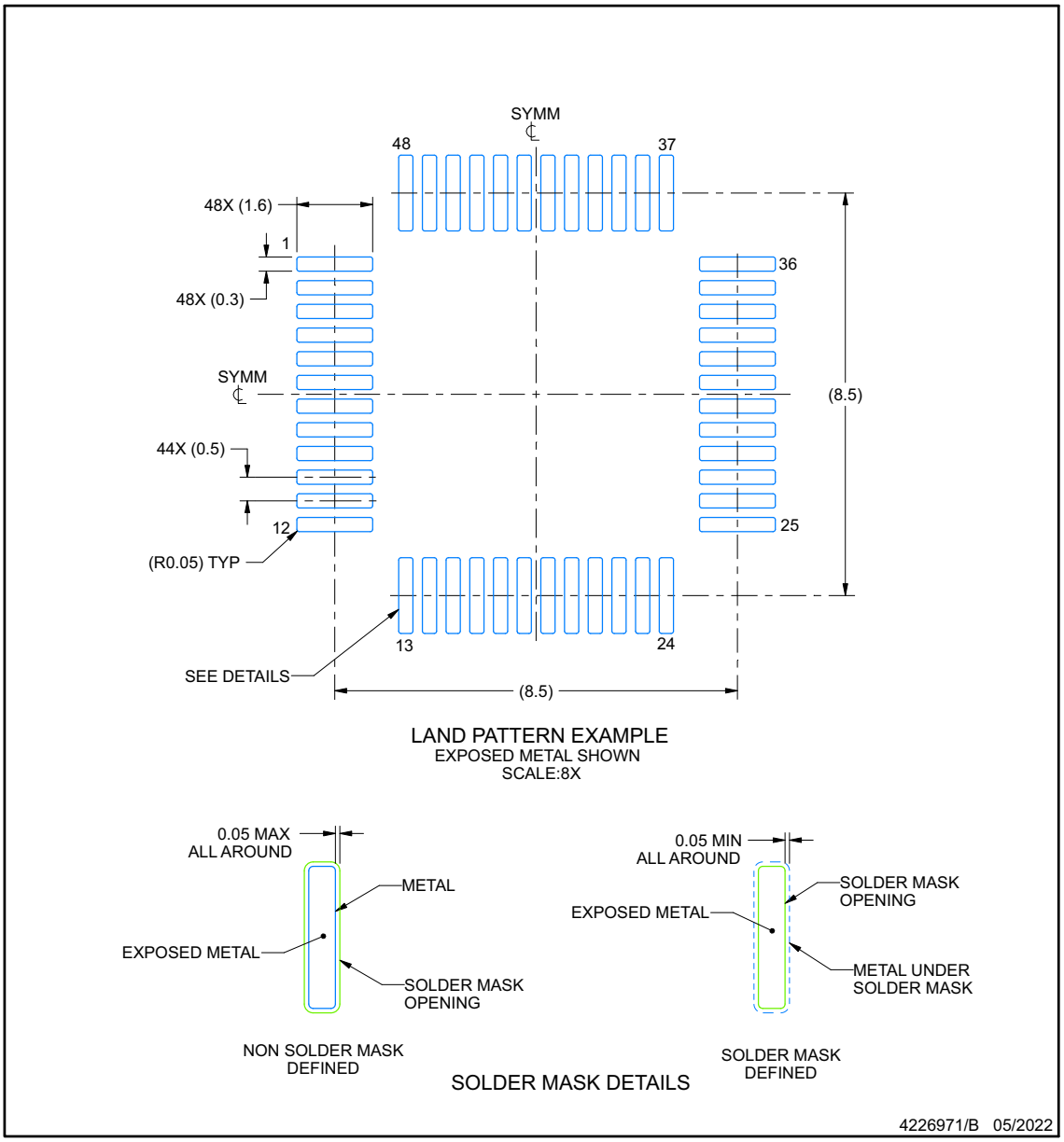
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MS-026.
5. Feature may not be present.

EXAMPLE BOARD LAYOUT

PKD0048A

PowerPAD ™HTQFP - 1.15 mm max height

PLASTIC QUAD FLATPACK



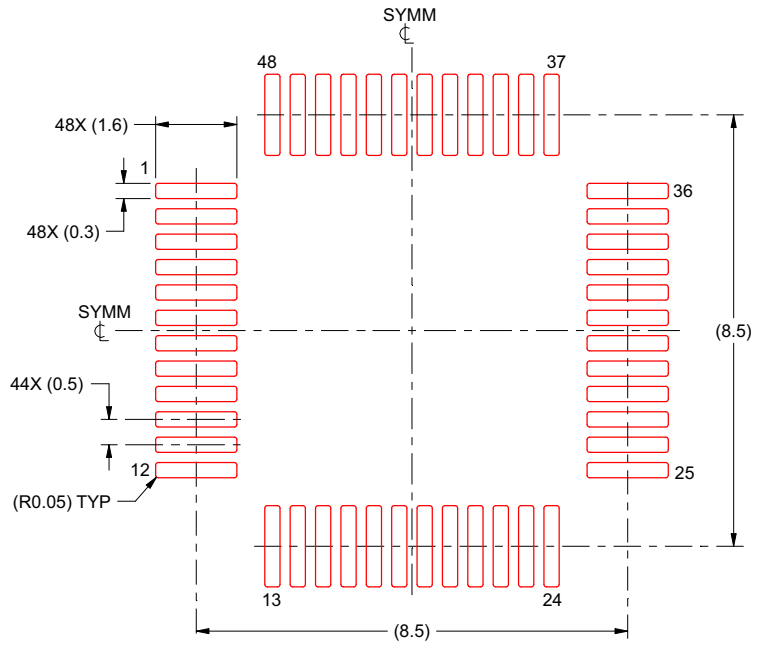
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. See technical brief, Powerpad thermally enhanced package, Texas Instruments Literature No. SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.
10. Size of metal pad may vary due to creepage requirement.

EXAMPLE STENCIL DESIGN

PKD0048A — **PowerPAD ™HTQFP - 1.15 mm max height**

PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE
SCALE:8X

4226971/B 05/2022

NOTES: (continued)

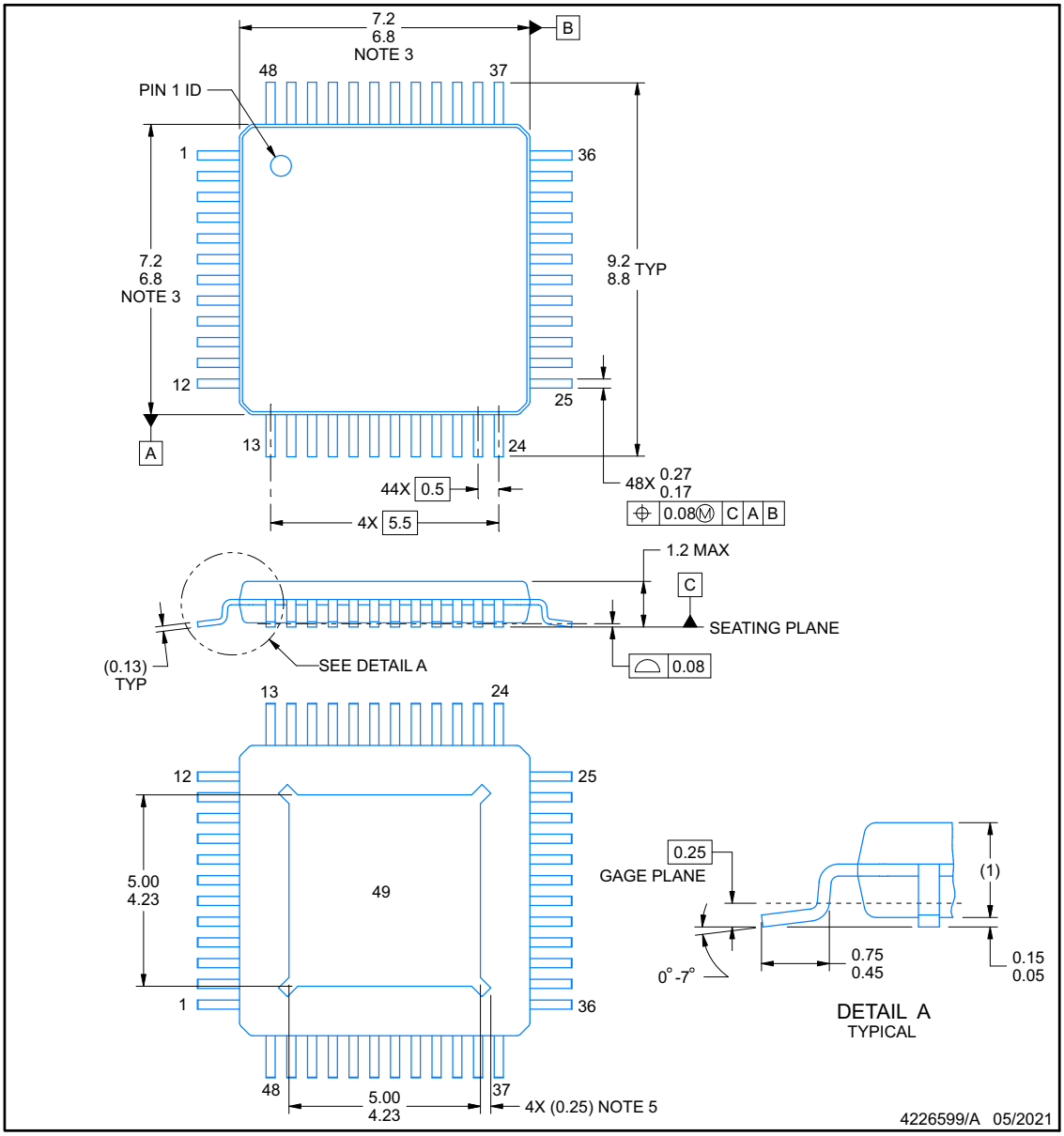
11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

PHP0048L

PowerPAD™ HTQFP - 1.2 mm max height

PLASTIC QUAD FLATPACK



PowerPAD is a trademark of Texas Instruments.

NOTES:

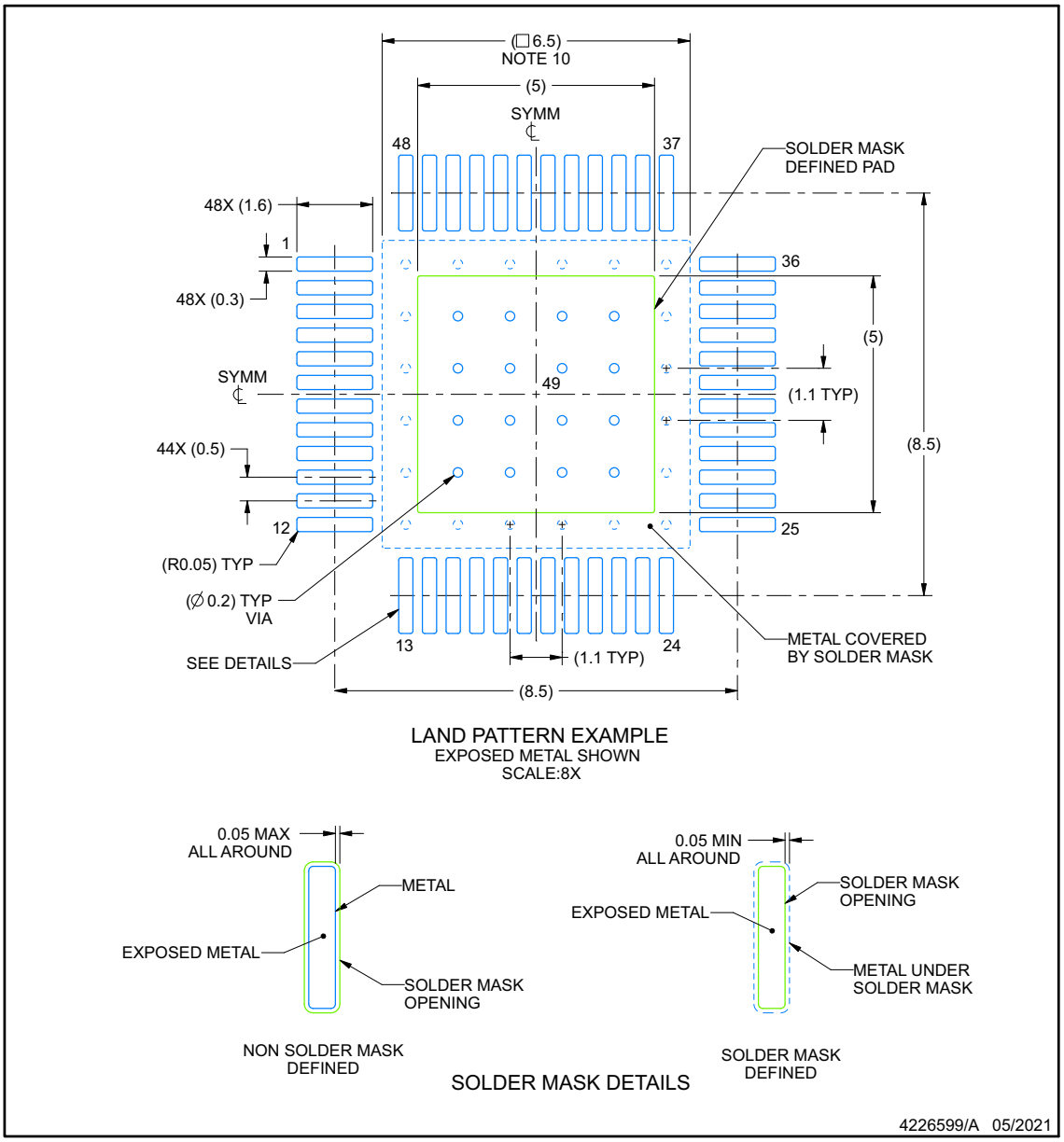
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MS-026.
5. Feature may not be present.

EXAMPLE BOARD LAYOUT

PHP0048L

PowerPAD™ HTQFP - 1.2 mm max height

PLASTIC QUAD FLATPACK



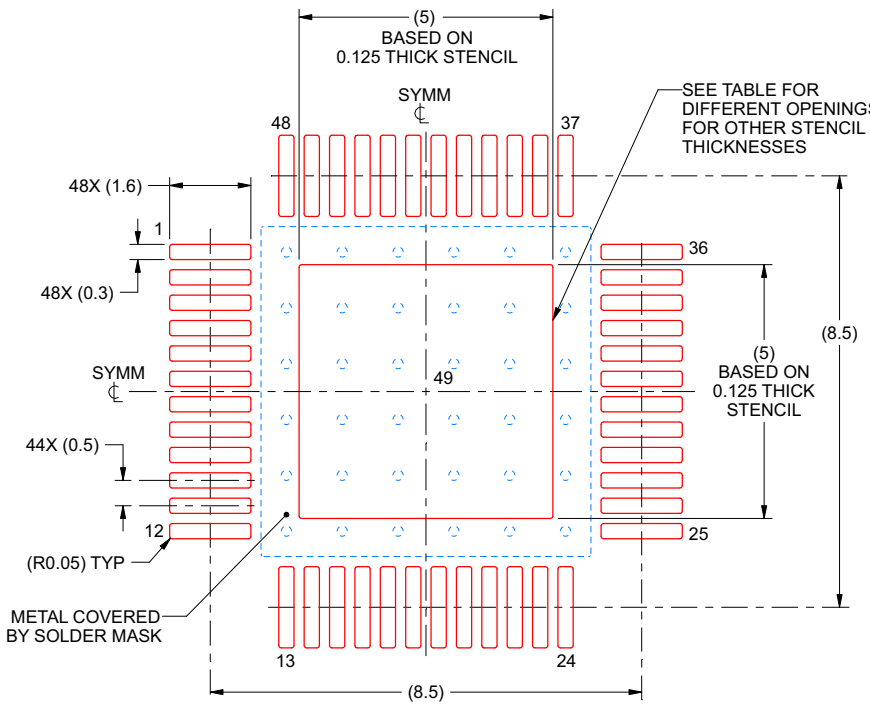
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. See technical brief, Powerpad thermally enhanced package, Texas Instruments Literature No. SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.
10. Size of metal pad may vary due to creepage requirement.

EXAMPLE STENCIL DESIGN

PHP0048L — **PowerPAD™ HTQFP - 1.2 mm max height**

PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE
EXPOSED PAD
100% PRINTED SOLDER COVERAGE BY AREA
SCALE:8X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	5.59 X 5.59
0.125	5.00 X 5.00 (SHOWN)
0.150	4.56 X 4.56
0.175	4.23 X 4.23

4226599/A 05/2021

NOTES: (continued)

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

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)
TPS92541QPHPRQ1	Active	Production	HTQFP (PHP) | 48	1000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	TPS92541Q
TPS92541QPKDRQ1	Active	Production	HTQFP (PKD) | 48	1000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	TPS92541
TPS92541QPKDRQ1.A	Active	Production	HTQFP (PKD) | 48	1000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	TPS92541

(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.

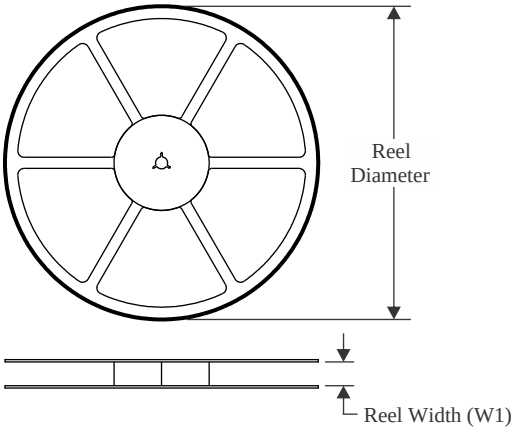
(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will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

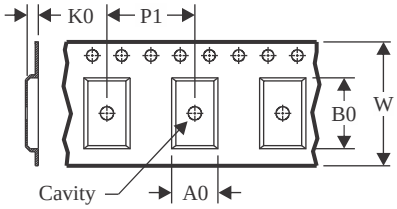
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

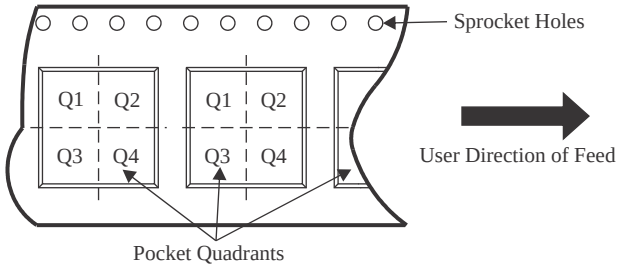


TAPE DIMENSIONS



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

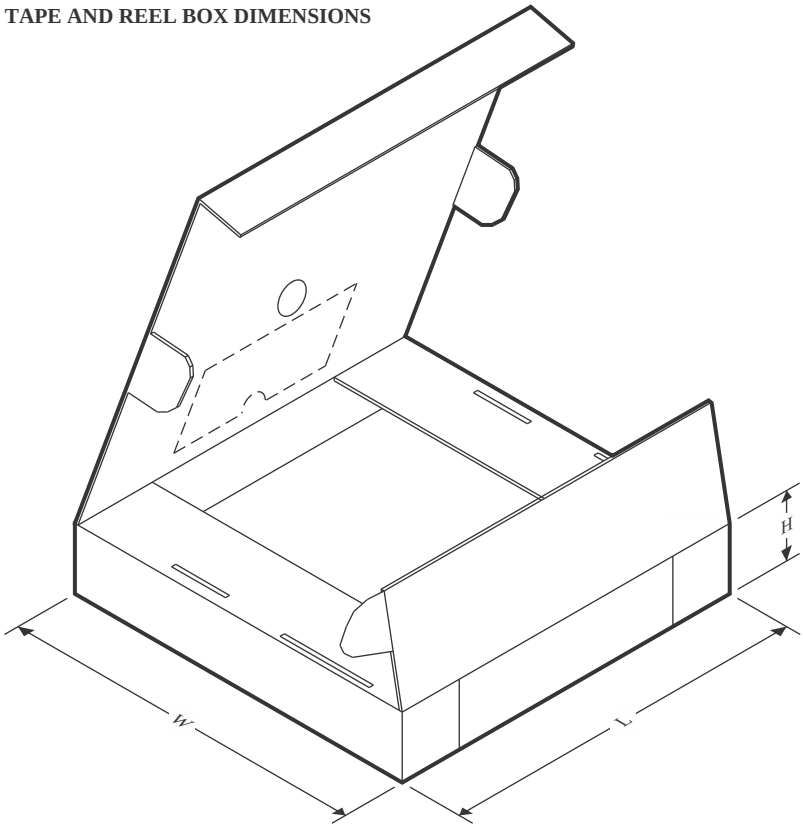
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TPS92541QPHPRQ1	HTQFP	PHP	48	1000	330.0	16.4	9.6	9.6	1.5	12.0	16.0	Q2
TPS92541QPKDRQ1	HTQFP	PKD	48	1000	330.0	16.4	9.6	9.6	1.5	12.0	16.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS92541QPHPRQ1	HTQFP	PHP	48	1000	336.6	336.6	31.8
TPS92541QPKDRQ1	HTQFP	PKD	48	1000	336.6	336.6	31.8

GENERIC PACKAGE VIEW

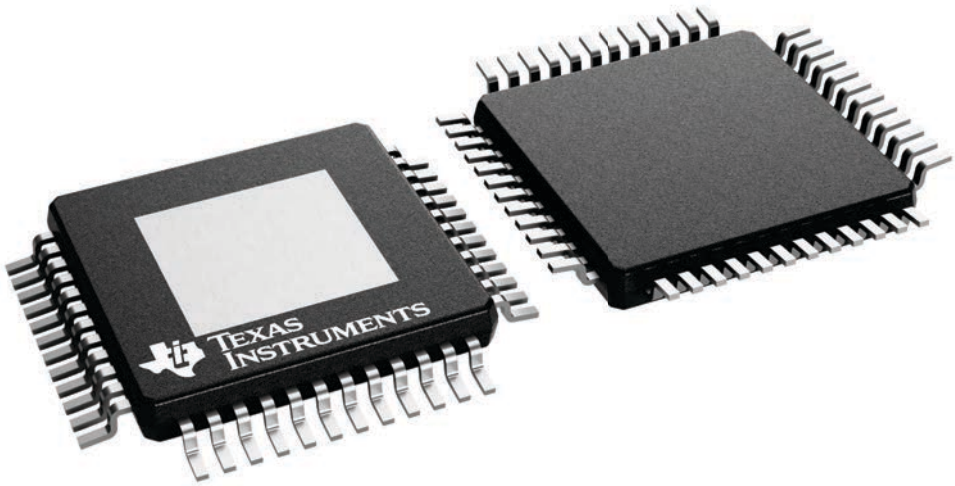
PKD 48

PowerPAD™ HTQFP - 1.15 mm max height

7 x 7, 0.5 mm pitch

PLASTIC QUAD FLATPACK

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



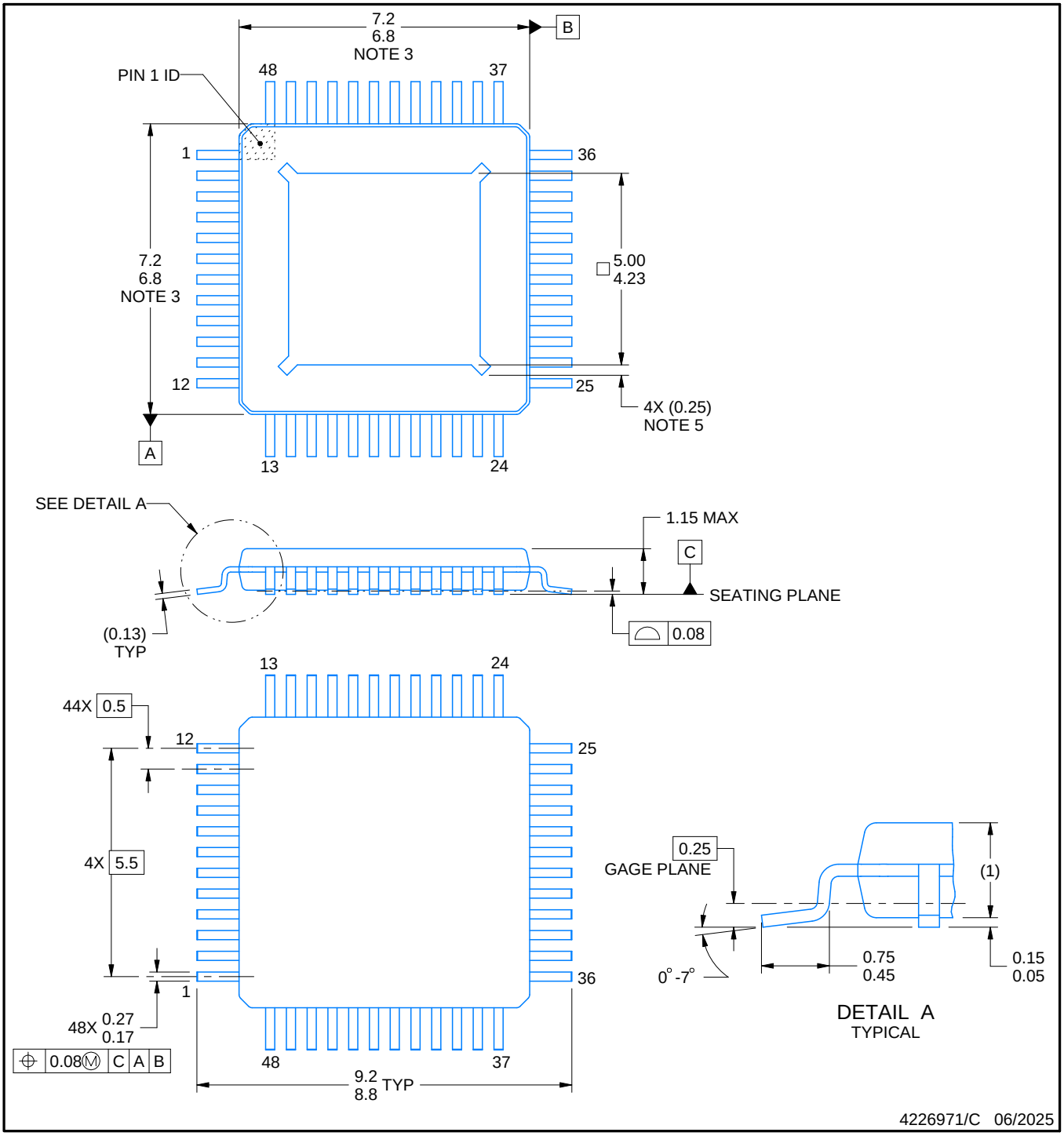
4231748/A

PACKAGE OUTLINE

PKD0048A

PowerPAD ™HTQFP - 1.15 mm max height

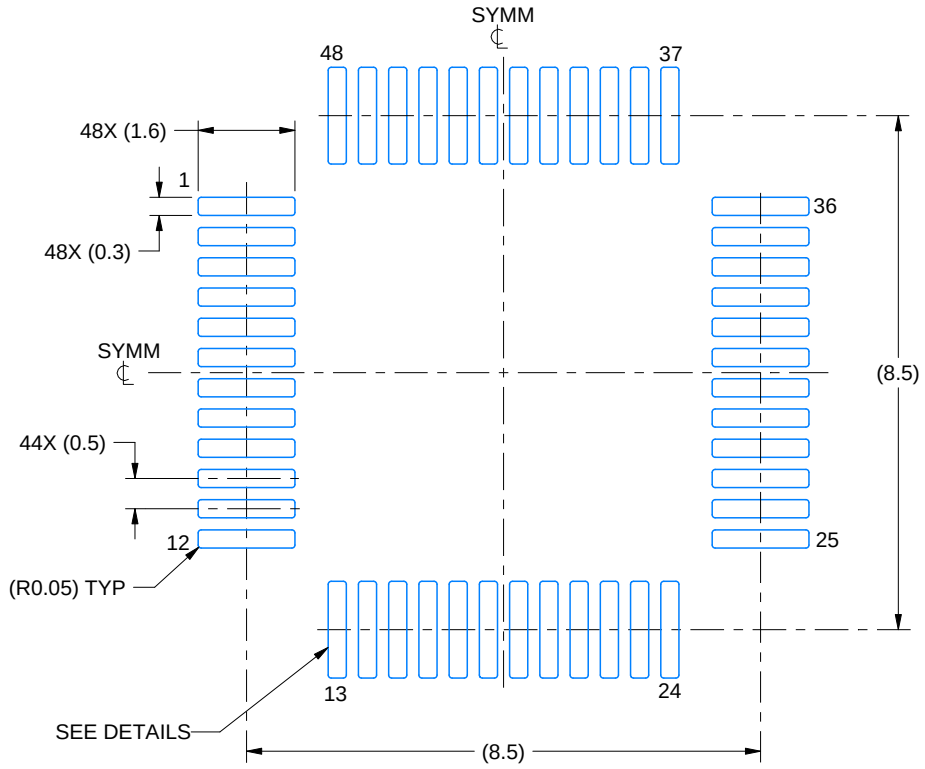
PLASTIC QUAD FLATPACK



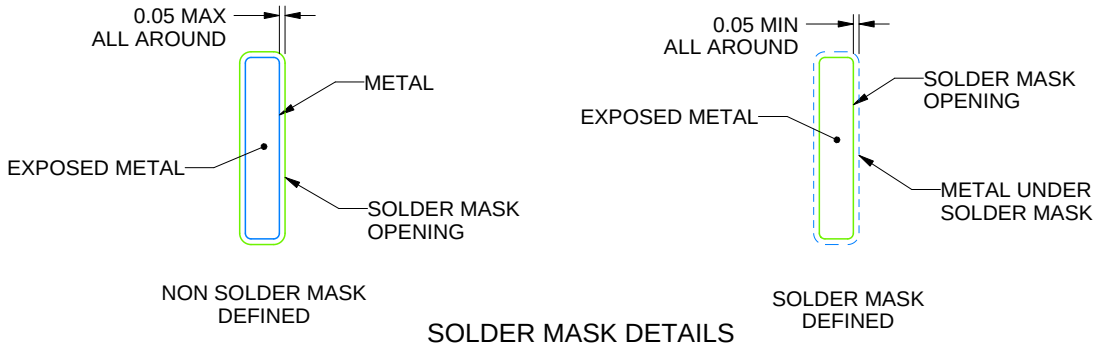
PowerPAD is a trademark of Texas Instruments.

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MS-026.
5. Feature may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4226971/C 06/2025

NOTES: (continued)

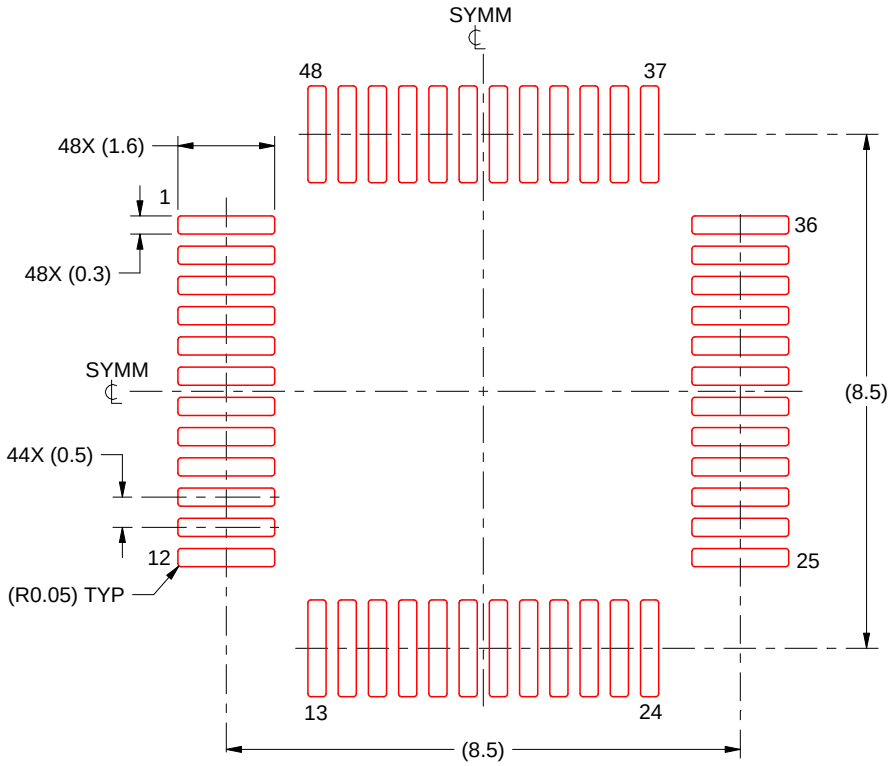
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. See technical brief, Powerpad thermally enhanced package, Texas Instruments Literature No. SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.
10. Size of metal pad may vary due to creepage requirement.

EXAMPLE STENCIL DESIGN

PKD0048A

PowerPAD ™HTQFP - 1.15 mm max height

PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

4226971/C 06/2025

NOTES: (continued)

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

GENERIC PACKAGE VIEW

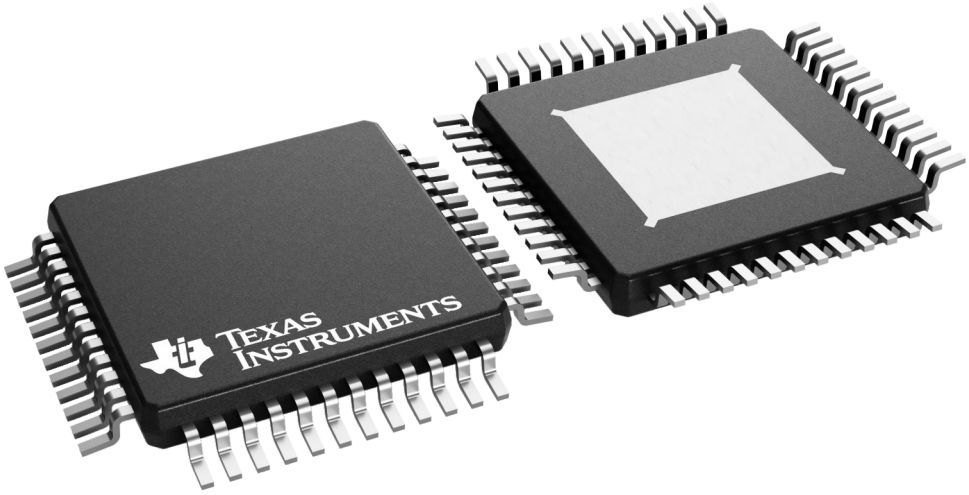
PHP 48

TQFP - 1.2 mm max height

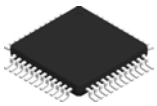
7 x 7, 0.5 mm pitch

QUAD FLATPACK

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4226443/A

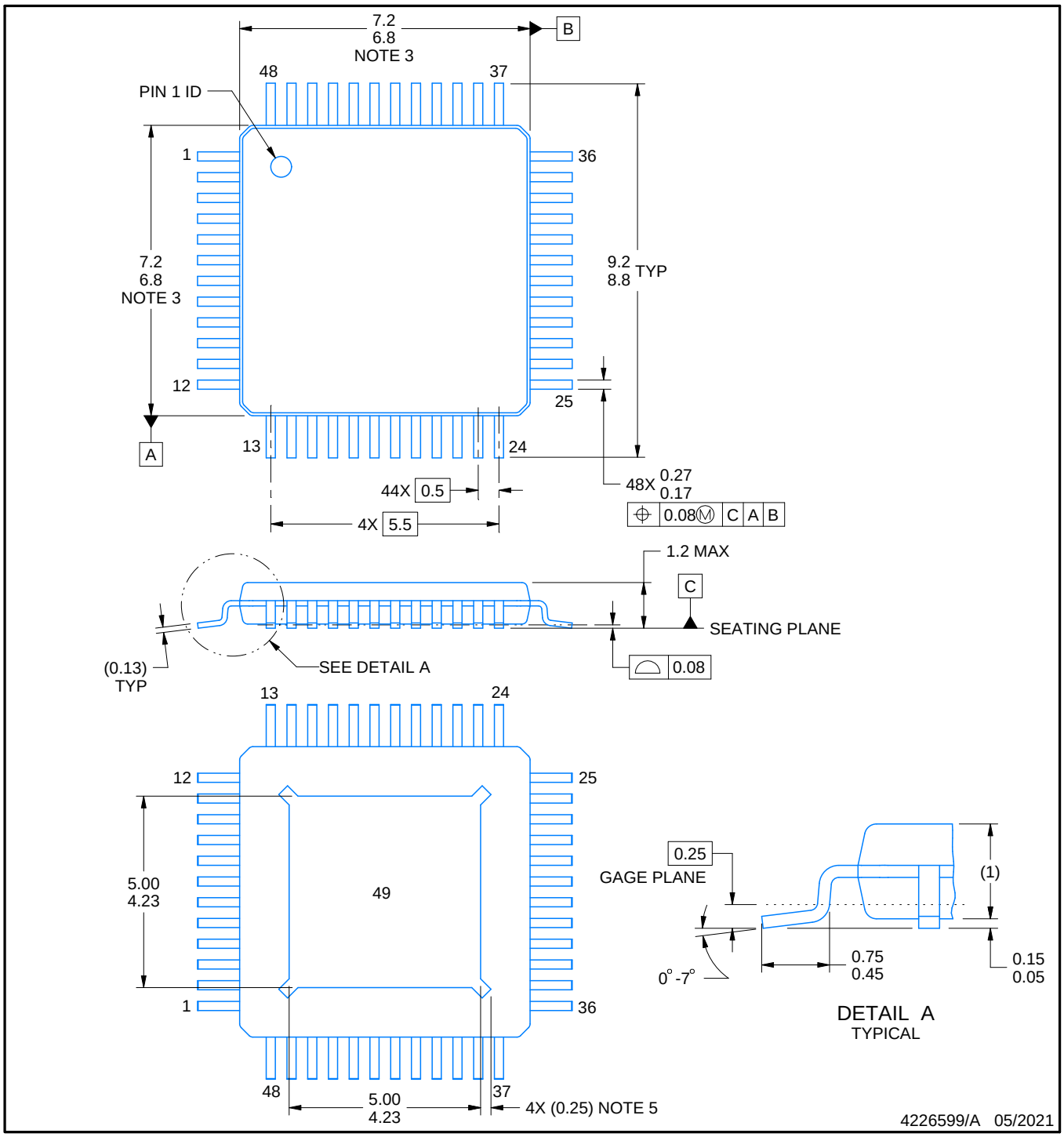


PACKAGE OUTLINE

PHP0048L

PowerPAD™ HTQFP - 1.2 mm max height

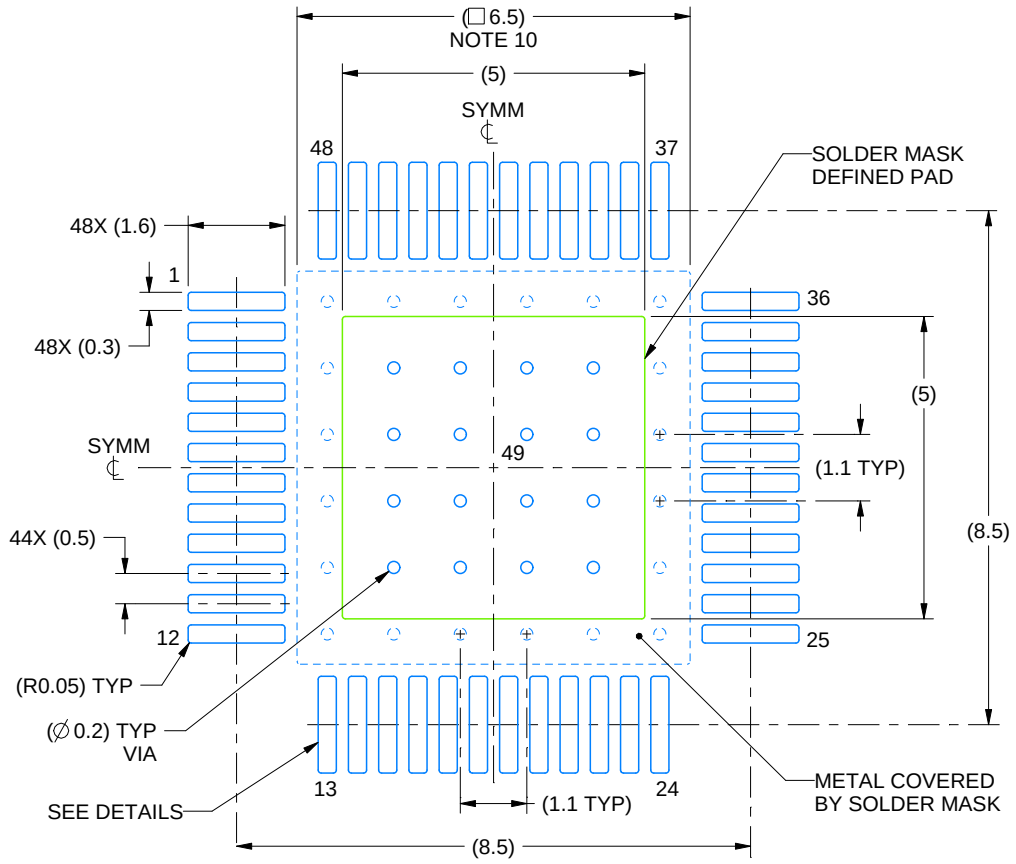
PLASTIC QUAD FLATPACK



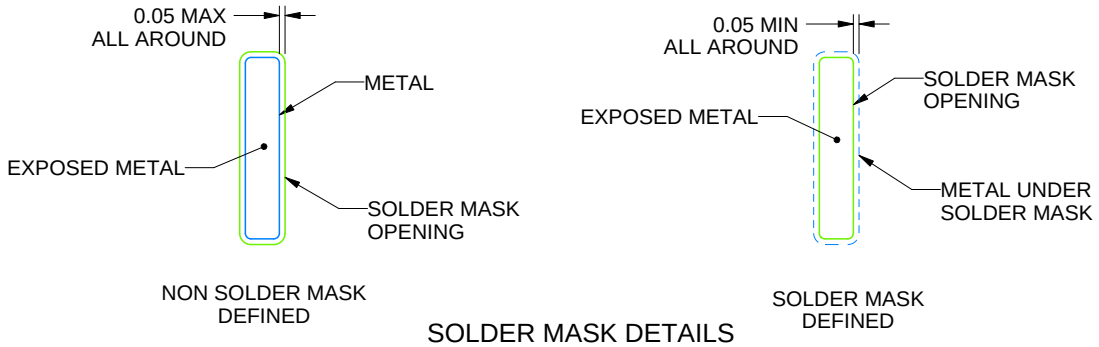
PowerPAD is a trademark of Texas Instruments.

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MS-026.
5. Feature may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X

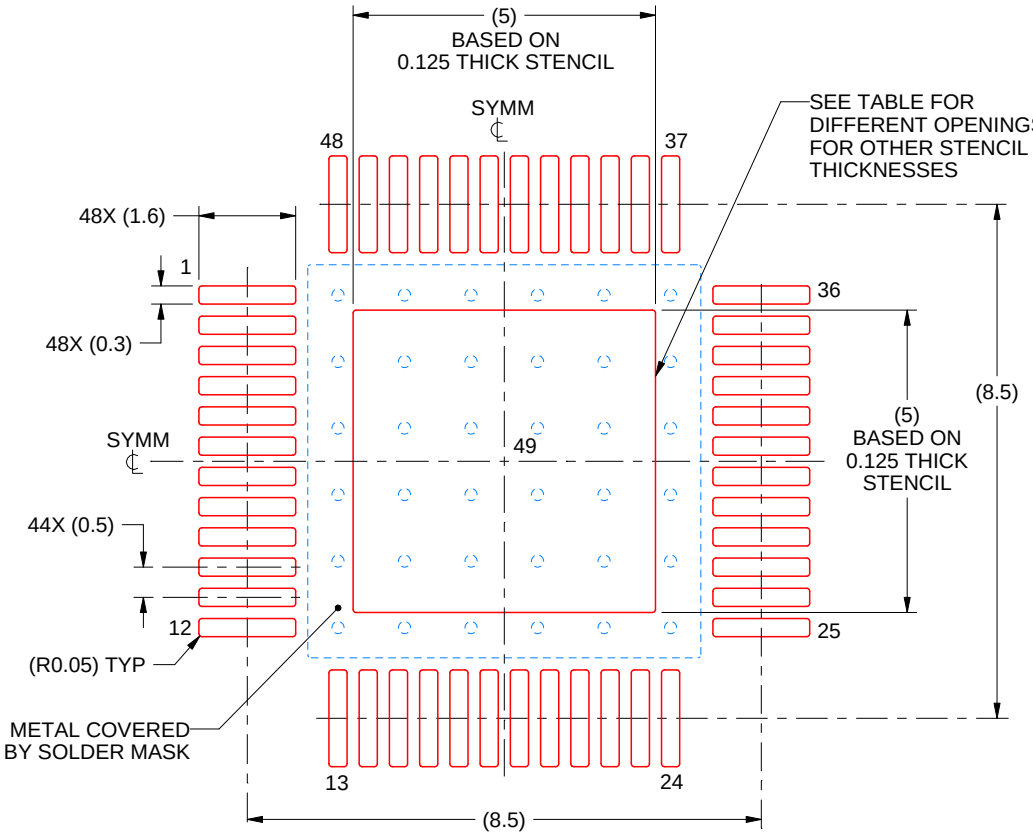


SOLDER MASK DETAILS

4226599/A 05/2021

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. See technical brief, Powerpad thermally enhanced package, Texas Instruments Literature No. SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.
10. Size of metal pad may vary due to creepage requirement.



SOLDER PASTE EXAMPLE
EXPOSED PAD
100% PRINTED SOLDER COVERAGE BY AREA
SCALE:8X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	5.59 X 5.59
0.125	5.00 X 5.00 (SHOWN)
0.150	4.56 X 4.56
0.175	4.23 X 4.23

4226599/A 05/2021

NOTES: (continued)

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

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最后更新日期：2025 年 10 月