

TPS65224-Q1 Power Management IC (PMIC) with 4 BUCKs and 3 LDOs for Safety-Relevant Applications

1 Features

- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
 - Input supply: 3V to 5.5V
 - Temperature grade 1: –40°C to +125°C (ambient)
 - HBM classification level 2
 - CDM classification level C4A
- **Functional safety-compliant**
 - Developed for functional safety applications
 - Documentation available to aid ISO26262 system design
 - Documentation available to aid IEC61508 system design
 - Systematic integrity up to ASIL-D
 - Systematic integrity up to SIL-3
 - Hardware integrity up to ASIL-B
 - Hardware integrity up to SIL-2
 - Undervoltage and overvoltage monitors and current limit on all output supply rails
 - Undervoltage and overvoltage monitors for two external supply rails and for input supply
 - Watchdog (trigger or Q&A)
 - Error signal monitor (level or PWM)
 - Temperature warning and thermal shutdown
 - Built-in self-test on voltage monitors
- BUCK1 + BUCK2 high-efficiency step-down DC/DC converters
 - Output voltage: 0.5V to 3.3V (0.5V to 1.2V for dual-phase output)
 - Output current: 5.5A in single-phase, 10A in dual-phase
 - Switching frequency: 2.2MHz or 4.4MHz
- BUCK3 + BUCK4 high-efficiency step-down DC/DC converters
 - Output voltage: 0.5V to 3.3V
 - Output current: 2.4A
 - Switching frequency: 2.2MHz or 4.4MHz
- Two low-dropout (LDO) linear regulators with configurable load-switch mode
 - Output voltage: 0.6V to 3.3V in LDO-mode

– Output current: 400mA

- One low-dropout (LDO) linear regulator with low-noise performance and with configurable load-switch mode
 - Output voltage: 1.2V to 3.3V in LDO-mode
 - Output current: 300mA
- Six configurable general-purpose input-output (GPIO) pins, reset and safe state outputs
- One 12-bit ADC
- OTP configurable power sequence
- 36-pin, 5mm × 6mm, QFN package, 0.5mm pitch

2 Applications

- Processors such as [AM62A3-Q1](#), [AM62A3](#), [AM62A7-Q1](#), [AM62A7](#), AM67, AM62P(-Q1), AM62D(-Q1), AM275, TDA4VEN, TDA4AEN, or processors of other vendors
- [Automotive infotainment and digital cluster](#), eMirror, [Camera Mirror System \(CMS\)](#)
- [Driver Monitoring System \(DMS\)](#), [Occupancy Monitoring System \(OMS\)](#), [ADAS Front Camera](#)
- [Industrial control and automation](#), [Machine Vision Camera](#), [Autonomous Mobile Robots \(AGV/AMR\)](#)

3 Description

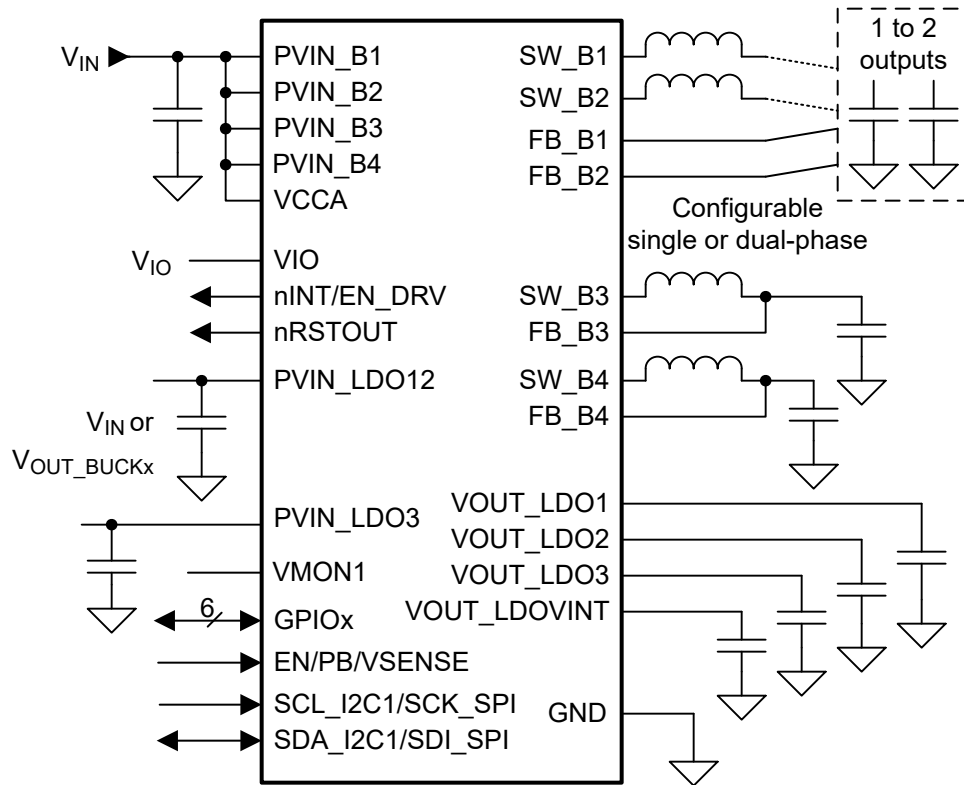
The TPS65224-Q1 device meets the power management requirements of the latest processors and platforms in various safety-relevant applications. The device is characterized across an ambient temperature range of –40°C to +125°C, making the PMIC an excellent choice for various automotive applications. The device has four step-down DC/DC (BUCK) converters, of which two can be used in a dual-phase configuration. Furthermore, the device has three low drop-out (LDO) regulators, which can also be used as load-switches.

Packaging Information

PART NUMBER	PACKAGE ⁽¹⁾	PACKAGE SIZE ⁽²⁾
TPS65224-Q1	VQFN-HR (36)	5.00mm × 6.00mm

- (1) For all available packages, see the orderable addendum at the end of the data sheet.
- (2) The package size (length × width) is a nominal value and includes pins, where applicable





Simplified Application

4 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed in www.ti.com/product/TPS65224-Q1.

4.1 Device Support

4.1.1 Device Nomenclature

The following acronyms and terms are used in this data sheet. For a detailed list of terms, acronyms, and definitions, see the [TI glossary](#).

ABIST	Analog Built-In Self-Test
ADC	Analog-to-Digital Converter
AVS	Adaptive Voltage Scaling
BIST	Built-In Self-Test
CRC	Cyclic Redundancy Check
DAC	Digital-to-Analog Converter
DCR	DC Resistance of an inductor
DVS	Dynamic Voltage Scaling
EMC	Electromagnetic Compatibility
ESM	Error Signal Monitor
ESR	Equivalent Series Resistance
FSD	First Supply Detection
GPIO	General-Purpose Input and Output
I²C	Inter-Integrated Circuit
LDO	Low-Dropout voltage linear regulator
NA	Not Applicable
MCU	Micro Controller Unit
NVM	Non-Volatile Memory
OPN	Orderable Part Number
OTP	One Time Programmable
OV	Overvoltage
OVP	Overvoltage Protection
PD	Pull-Down
PDN	Power Delivery Network
PFM	Pulse Frequency Modulation
PFSM	Pre-configured Finite State Machine
PGOOD	Power Good (signal which indicates that the monitored power supply rail is in range)
PLL	Phase Locked Loop
PMIC	Power-Management Integrated Circuit
POR	Power On Reset
PU	Pull-Up
PP	Push-Pull

PSRR	Power Supply Rejection Ratio
PWM	Pulse Width Modulation
SoC	System on Chip
SPI	Serial Peripheral Interface
TSD	Thermal Shut-Down
UV	Undervoltage
UVLO	Undervoltage Lockout
VMON	Voltage Monitor

4.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Notifications* 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.

4.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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4.5 Trademarks

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4.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

4.7 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

5 Revision History

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

Changes from Revision * (December 2023) to Revision A (October 2024)	Page
• Changed the device status from Advance Information to Production Data.....	1

6 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.

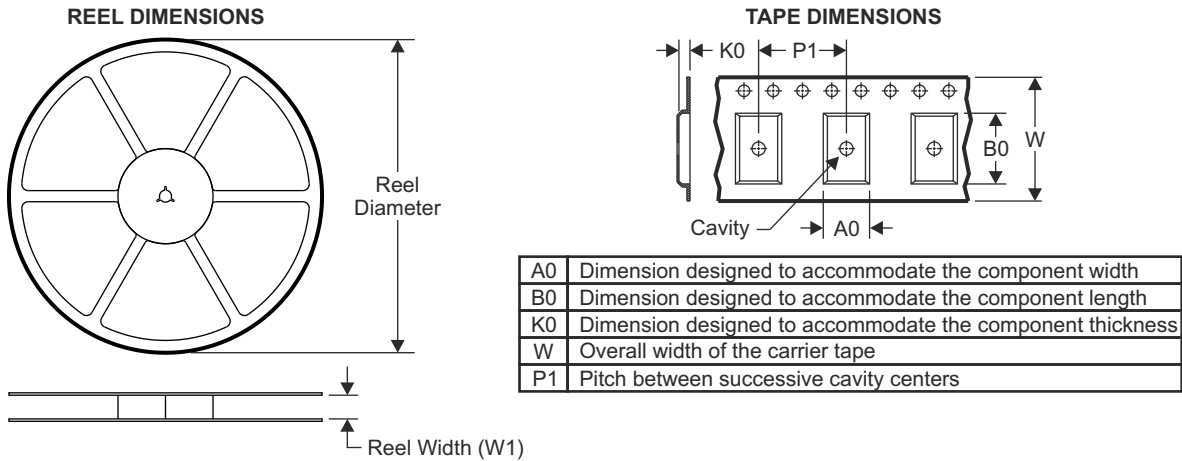
6.1 Package Option Addendum

6.1.1 Packaging Information

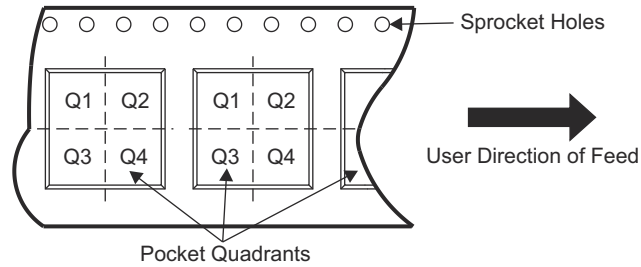
Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾	Op Temp (°C)	Device Marking ^{(4) (5)}
TPS65224RAHRQ1	ACTIVE	VQFN-HR	RAH	36	3000	Green (RoHS & no Sb/Br)	SN	Level-2-260C-1 YEAR	-40 to 125	TPS65224-Q1

- (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.
PRE_PROD Unannounced device, not in production, not available for mass market, nor on the web, samples not available.
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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)
- (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 on 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.
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6.1.2 Tape and Reel Information

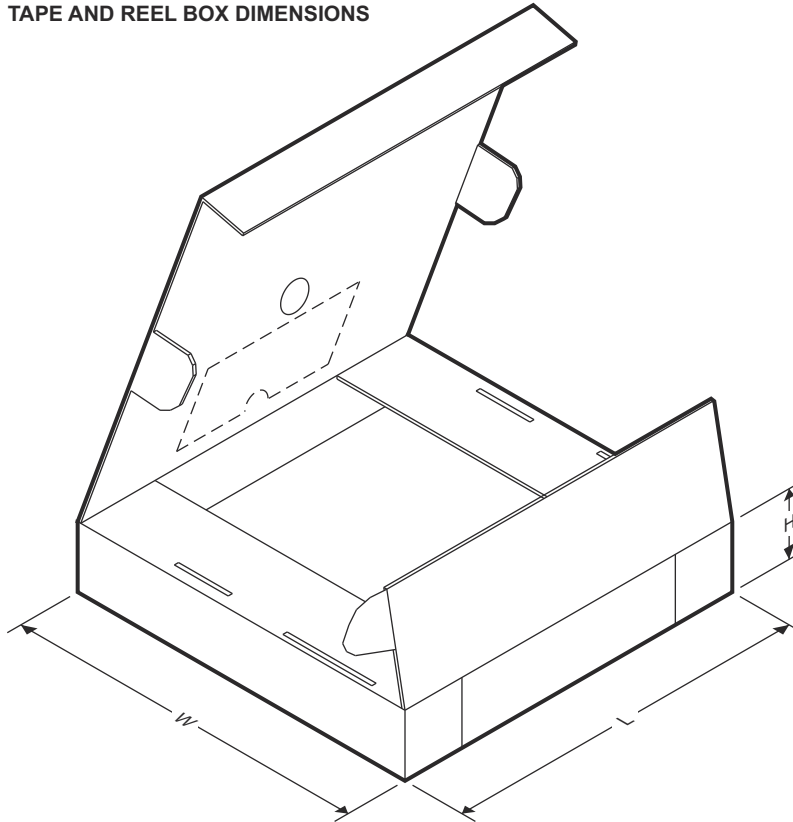


QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



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
TPS65224RAHRQ1	VQFN-HR	RAH	36	3000	330.0	12.4	5.3	6.3	1.15	8.0	12	Q2

TAPE AND REEL BOX DIMENSIONS



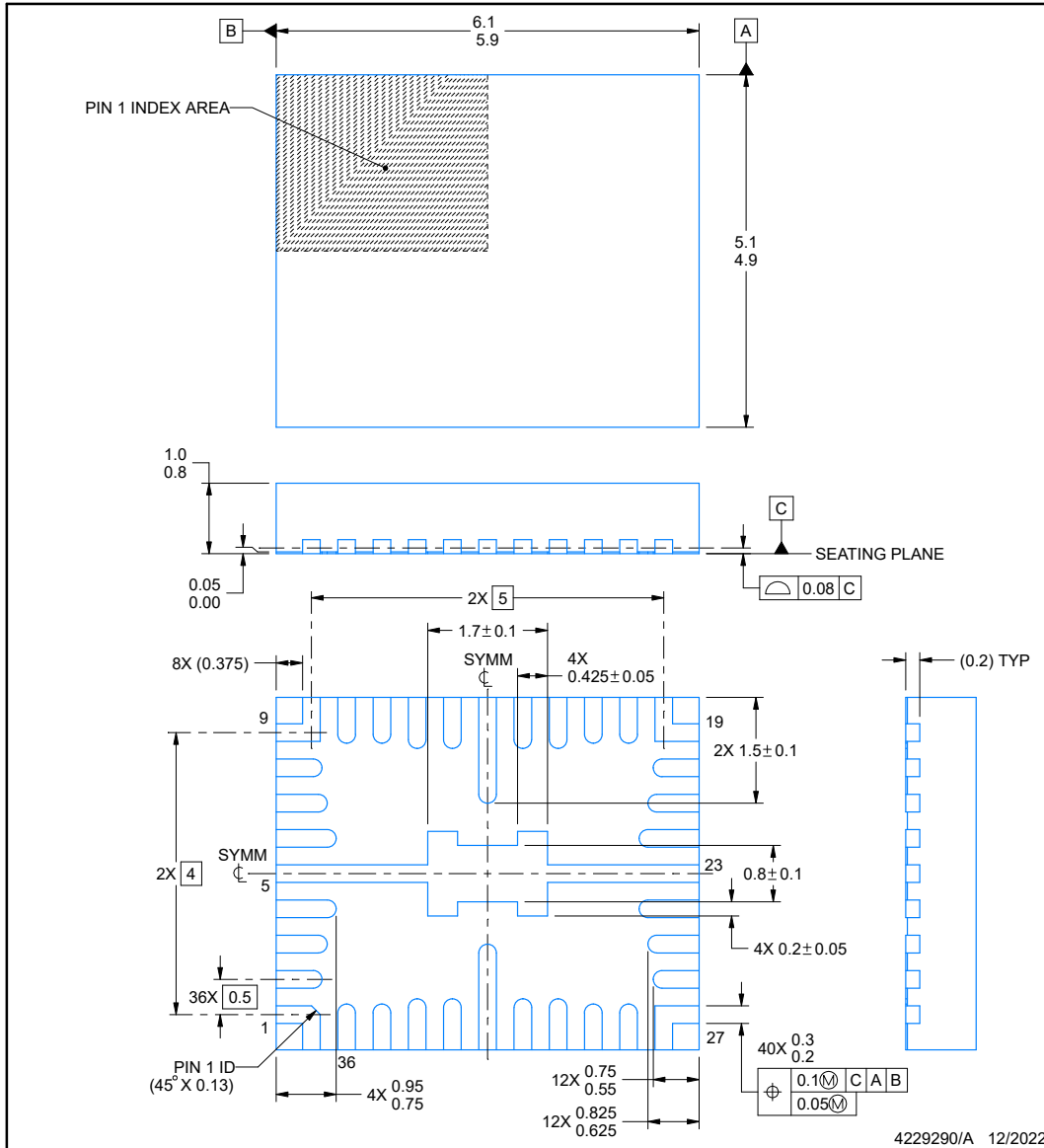
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS65224RAHRQ1	VQFN-HR	RAH	36	3000	367.0	367.0	35.0



RAH0036A

PACKAGE OUTLINE
VQFN-HR - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES:

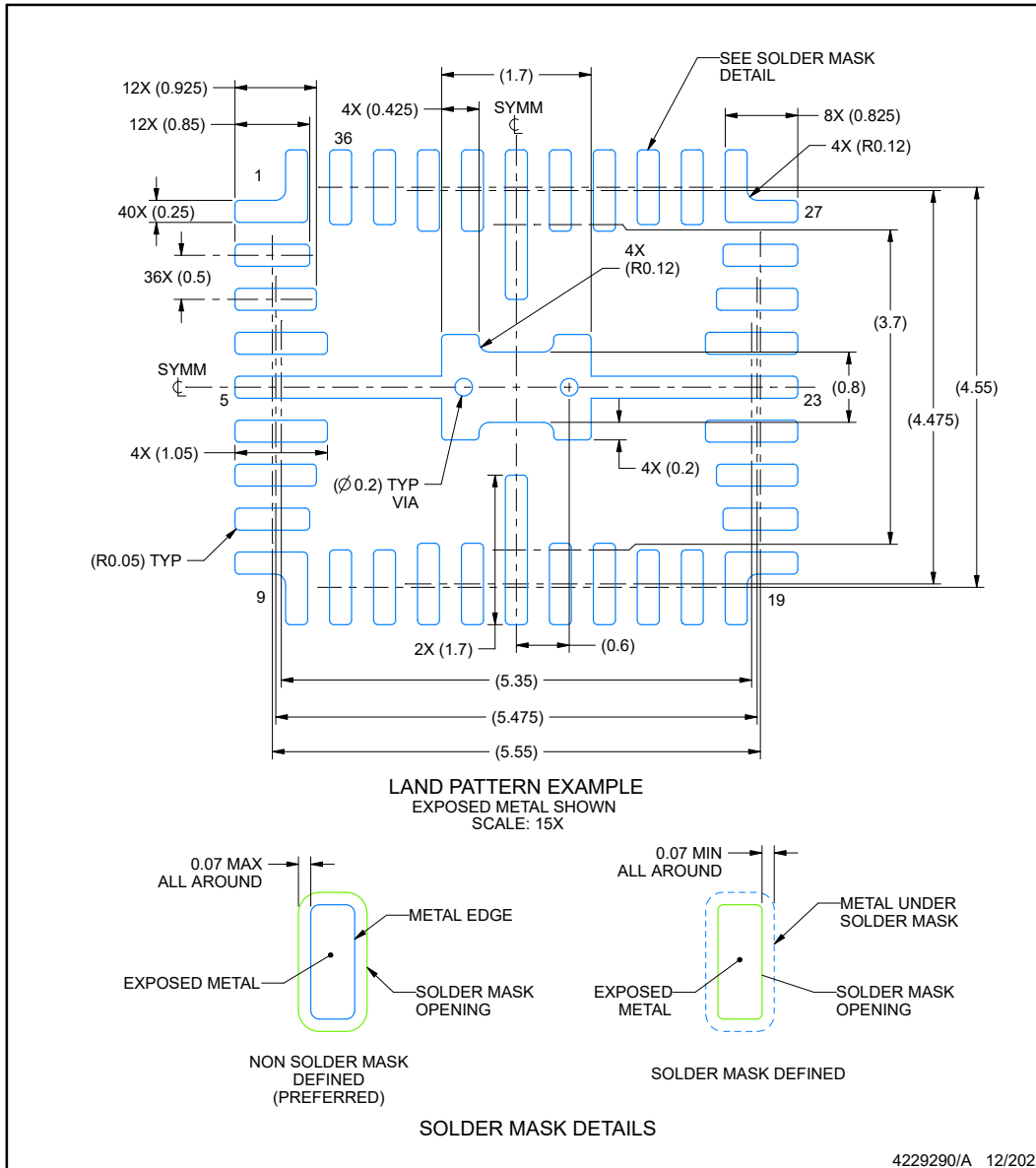
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

RAH0036A

VQFN-HR - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

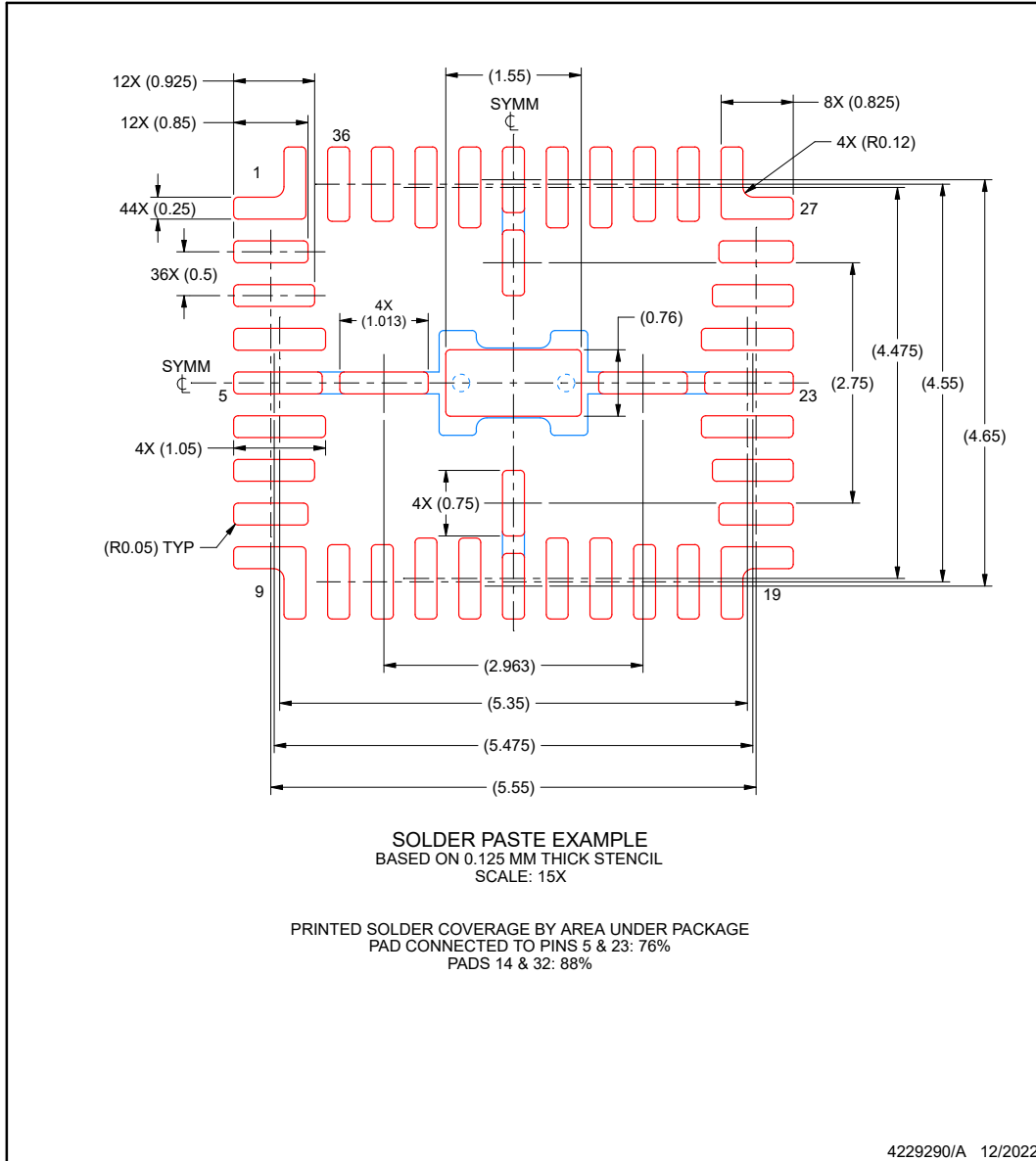
- 4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slva271).
- 5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RAH0036A

VQFN-HR - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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
TPS6522430RAHRQ1	ACTIVE	VQFN-HR	RAH	36	3000	RoHS & Green	SN	Level-2-260C-1 YEAR	-40 to 125	TPS6522 430Q1	Samples

(1) The marketing status values are defined as follows:

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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

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
TPS6522430RAHRQ1	VQFN-HR	RAH	36	3000	330.0	12.4	5.3	6.3	1.15	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS6522430RAHRQ1	VQFN-HR	RAH	36	3000	367.0	367.0	35.0

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