TEXAS INSTRUMENTS

LM5137F-Q1
SNVSCV0 – SEPTEMBER 2024

LM5137F-Q1 Automotive, 4V to 80V, 100% Duty Cycle Capable, Dual-Channel Synchronous Buck Controller Family for Functional Safety Applications

1 Features

- AEC-Q100 qualified for automotive applications:
  - Device temperature grade 1: –40°C to 125°C ambient operating temperature
- Functional Safety-Compliant targeted
  - Developed for functional safety applications
    - Three orderable part numbers for Capable, ASIL B, and ASIL D options
  - Documentation available to aid ISO 26262 system design up to ASIL D will be available upon production release
  - Systematic capability up to ASIL D targeted
  - Hardware integrity up to ASIL D targeted
- Versatile dual synchronous buck DC/DC controller
  - 1% accurate, fixed 3.3V, 5V, 12V, or adjustable outputs from 0.8V to 60V
  - Current monitor output for each channel
  - Charge-pump gate drivers for 100% duty cycle
  - No-load sleep current of 12.7µA (typical)
  - Internal hiccup-mode overcurrent protection
- Two interleaved synchronous buck channels
  - Dual channel or single-output multiphase
  - Stackable up to four phases
- Designed for ultra-low EMI requirements
  - Dual Random Spread Spectrum (DRSS)
  - Switching frequency from 100kHz to 2.5MHz
- VQFN-36 package with wettable flanks
- Create a custom design using the LM5137F-Q1 with WEBENCH® Power Designer

2 Applications

- Automotive electronic systems
- Infotainment systems, instrument clusters, ADAS
- High-voltage battery-operated systems

3 Description

The LM5137F-Q1 is an 80V dual-channel buck controller offered frrom a family with three options for functional safety: Capable, ASIL B, or ASIL D. The device uses an interleaved, stackable, peak current-mode architecture for easy loop compensation, fast transient response, excellent load and line regulation, and accurate current sharing with paralleled phases for high output current. A high-side switch minimum on-time of 15ns facilitates large step-down ratios, enabling the direct conversion from 12V, 24V or 48V automotive inputs to low-voltage rails for reduced system design cost and complexity. The LM5137F-Q1 continues operating during input voltage dips as low as 4V, at 100% duty cycle if needed.

Package Information

PART NUMBER	PACKAGE[1]	PACKAGE SIZE[2]
LM5137F-Q1	RHA (VQFN, 36)	6.0mm × 6.0mm

(1) For more information, see Section 7.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.

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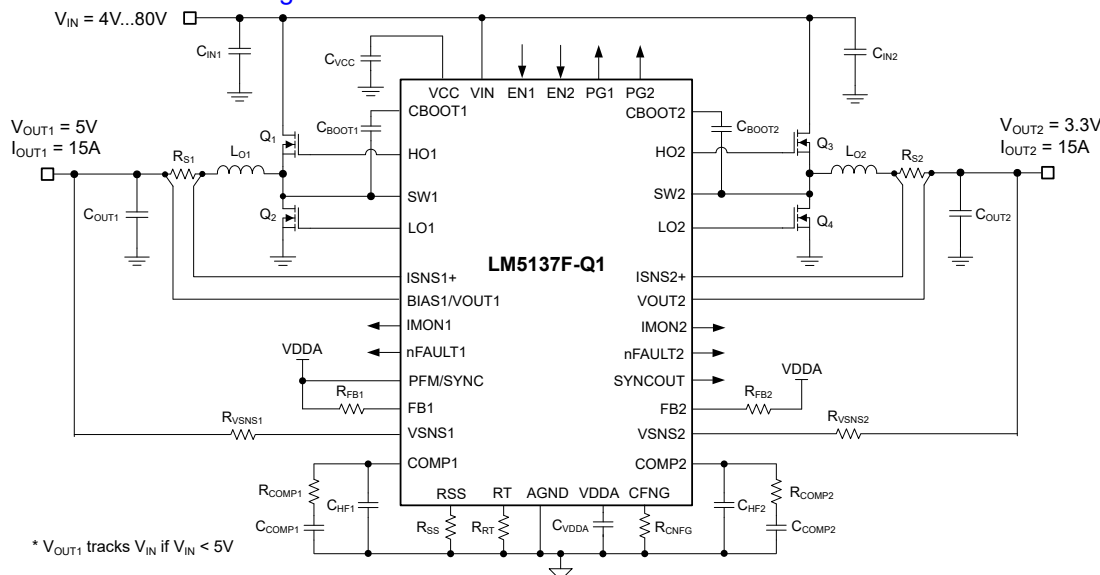
LM5137F-Q1 Dual-Output Buck Switching Regulator – Simplified Schematic

Several features are included to simplify compliance with CISPR 25 and automotive EMI requirements. Adaptively timed, high-current MOSFET gate drivers minimize body diode conduction during switching transitions, reducing switching losses and improving thermal and EMI performance at high input voltage and high switching frequency. To reduce input capacitor ripple current and EMI filter size, 180° interleaved operation is provided for two outputs. A 90° out-of-phase clock output works well for cascaded, multi-channel or multiphase power stages. Resistor-adjustable switching frequency as high as 2.2MHz can be synchronized to an external clock source up to 2.5MHz to eliminate beat frequencies in noise-sensitive applications.

The 12.7µA no-load quiescent current with the output voltage in regulation extends operating run-time in battery-powered automotive systems. Additional features of the LM5137F-Q1 include 150°C maximum junction temperature operation, user-selectable PFM mode for lower current consumption at light-load conditions, configurable soft-start functions, open-drain PG and FAULT flags for fault reporting and output monitoring, independent enable inputs, monotonic start-up into prebiased loads, integrated VCC bias supply regulator powered from VIN or BIAS1/VOUT1, hiccup-mode overload protection, and thermal shutdown protection with automatic recovery. Current is sensed using the inductor DCR for highest efficiency or an optional shunt resistor for high accuracy.

The LM5137F-Q1 controller is qualified to AEC-Q100 grade 1 for automotive applications and comes in a 6mm × 6mm thermally-enhanced, 36-pin VQFN package with additional pin clearance for increased reliability and wettable flank pins to facilitate optical inspection during manufacturing. The wide input voltage range, low quiescent current consumption, high-temperature operation, cycle-by-cycle current limit, low EMI signature, and small design size provide an excellent point-of-load regulator solution for functional safety (FuSa) applications requiring enhanced robustness and durability.

ADVANCE INFORMATION

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4 Device Comparison Table

Table 4-1. Orderable Part Numbers

GENERIC PART NUMBER	ORDERABLE PART NUMBER	FUNCTIONAL SAFETY CLASSIFICATION[1]	PRODUCT DATA SHEET
LM5137-Q1	LM5137QRHARQ1	Functional safety-capable	Available here
LM5137F-Q1	LM5137FBQRHARQ1	ASIL B functional safety-compliant	Request the full data sheet here
	LM5137FDQRHARQ1	ASIL D functional safety-compliant	

(1)   Refer to the functional safety homepage to understand the different functional safety classifications (in terms of the development process, analysis report, and diagnostics description).

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Submit Document Feedback   3
Product Folder Links: *LM5137F-Q1*

ADVANCE INFORMATION

5 Device and Documentation Support

5.1 Device Support

5.1.1 Third-Party Products Disclaimer

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5.1.2 Development Support

With an input operating voltage as low as 3.5V and up to 100V as specified in Table 5-1, the LM(2)514x-Q1 family of automotive synchronous buck controllers from TI provides flexibility, scalability and optimized design size for a variety of applications.

With the LM5137F-Q1 and LM25137F-Q1 now available to aid in functional safety system design up to ASIL D, the controller family enables DC/DC designs with high density, low EMI, and increased system reliability. All controllers are rated for a maximum operating junction temperature of 150°C and have AEC-Q100 grade 1 qualification.

Table 5-1. Automotive Synchronous Buck DC/DC Controller Family

DC/DC CONTROLLER	SINGLE or DUAL	V_{IN} RANGE	CONTROL METHOD	GATE DRIVE VOLTAGE	SYNC OUTPUT	PROGRAMMABLE SPREAD SPECTRUM
LM5137-Q1	Dual	4V to 80V	Peak current mode	5V	90° phase shift	DRSS (5% or 10%)
LM25137-Q1	Dual	4V to 42V	Peak current mode	5V	90° phase shift	DRSS (5% or 10%)
LM5141-Q1	Single	3.8V to 65V	Peak current mode	5V	N/A	Triangular
LM25141-Q1	Single	3.8V to 42V	Peak current mode	5V	N/A	Triangular
LM5143A-Q1	Dual	3.5V to 65V	Peak current mode	5V	90° phase shift	Triangular
LM25143-Q1	Dual	3.5V to 42V	Peak current mode	5V	90° phase shift	Triangular
LM5145-Q1	Single	5.5V to 75V	Voltage mode	7.5V	180° phase shift	N/A
LM5146-Q1	Single	5.5V to 100V	Voltage mode	7.5V	180° phase shift	N/A
LM5148-Q1	Single	3.5V to 80V	Peak current mode	5V	180° phase shift	DRSS
LM25148-Q1	Single	3.5V to 42V	Peak current mode	5V	180° phase shift	DRSS
LM5149-Q1	Single	3.5V to 80V	Peak current mode	5V	180° phase shift	DRSS
LM25149-Q1	Single	3.5V to 42V	Peak current mode	5V	180° phase shift	DRSS

For development support, see the following:

- LM(2)5137-Q1 DC/DC controller *Quickstart Calculator* and PSPICE simulation models
- LM25137-Q1 EVM PCB layout files
- For TI's WEBENCH design environments, visit the WEBENCH® Design Center
- For TI's reference design library, visit TI Designs
- TI Designs:
  - *Automotive Wide V_{IN} Front-end Reference Design for Digital Cockpit Processing Units*

5.1.2.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LM5137F-Q1 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage (V_{IN}), output voltage (V_{OUT}), and output current (I_{OUT}) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer gives a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:
- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

5.2 Documentation Support

5.2.1 Related Documentation

For related documentation, see the following:
- User's guides:
  – Texas Instruments, *LM25137-Q1 Synchronous Buck Controller EVM*
  – Texas Instruments, *LM5143-Q1 Synchronous Buck Controller EVM*
  – Texas Instruments, *LM5141-Q1 Synchronous Buck Controller EVM*
  – Texas Instruments, *LM5146-Q1 EVM User's Guide*
  – Texas Instruments, *LM5145EVM-HD-20A High Density Evaluation Module*
- Application reports:
  – Texas Instruments, *LM5143-Q1 4-phase Buck Regulator Design for Automotive ADAS Applications*
  – Texas Instruments, *AN-2162 Simple Success With Conducted EMI From DCDC Converters*
  – Texas Instruments, *Maintaining Output Voltage Regulation During Automotive Cold-Crank with LM5140-Q1 Dual Synchronous Buck Controller*
- Analog design journal:
  – Texas Instruments, *Reduce Buck Converter EMI and Voltage Stress by Minimizing Inductive Parasitics*
- White papers:
  – Texas Instruments, *An Overview of Conducted EMI Specifications for Power Supplies*
  – Texas Instruments, *An Overview of Radiated EMI Specifications for Power Supplies*
  – Texas Instruments, *Valuing Wide V_{IN}, Low EMI Synchronous Buck Circuits for Cost-driven, Demanding Applications*

5.2.1.1 PCB Layout Resources

- Application reports:
  – Texas Instruments, *AN-1149 Layout Guidelines for Switching Power Supplies*
  – Texas Instruments, *Low Radiated EMI Layout Made SIMPLE with LM4360x and LM4600x*
- Application brief:
  – Texas Instruments, *Improve High-current DC/DC Regulator Performance for Free with Optimized Power Stage Layout*
- Seminar:
  – Texas Instruments, *Constructing Your Power Supply – Layout Considerations*

5.2.1.2 Thermal Design Resources

- Application reports:
  – Texas Instruments, *AN-2020 Thermal Design by Insight, Not Hindsight*
  – Texas Instruments, *AN-1520 A Guide to Board Layout for Best Thermal Resistance for Exposed Pad Packages*
  – Texas Instruments, *Semiconductor and IC Package Thermal Metrics*
  – Texas Instruments, *Thermal Design Made Simple with LM43603 and LM43602*
  – Texas Instruments, *PowerPAD™Thermally Enhanced Package*
  – Texas Instruments, *PowerPAD Made Easy*
  – Texas Instruments, *Using New Thermal Metrics*

ADVANCE INFORMATION

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5.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on 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.

5.4 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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5.6 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.

5.7 Glossary

TI Glossary   This glossary lists and explains terms, acronyms, and definitions.
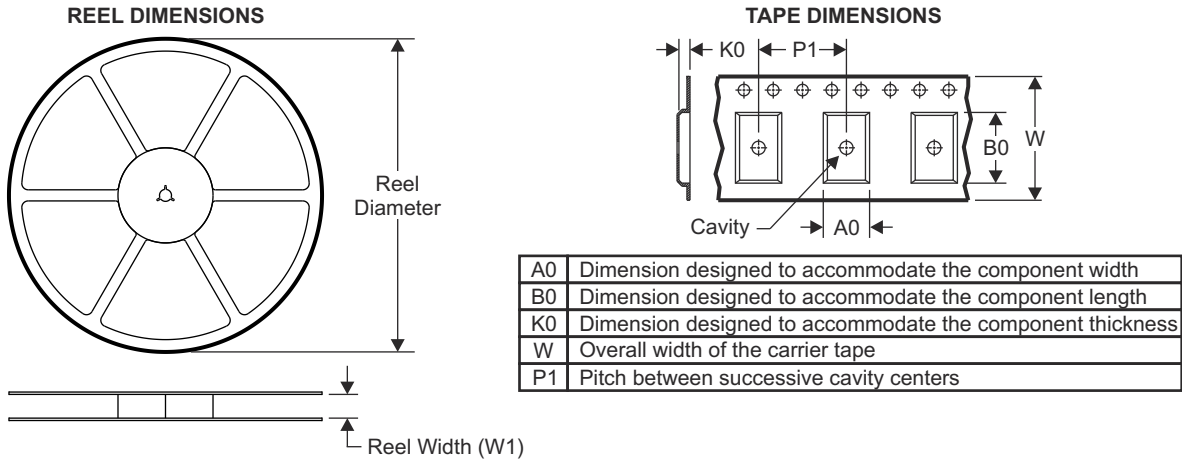
6 Revision History

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

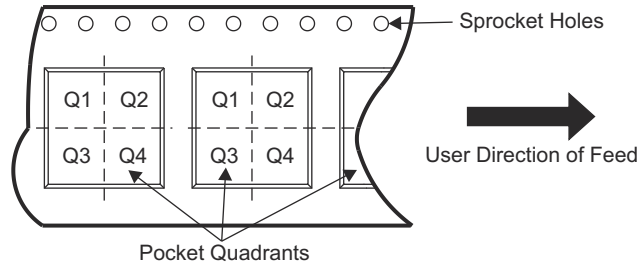| DATE	REVISION	NOTES
September 2024	*	Initial Release

7 Mechanical, Packaging, and Orderable Information

The following pages show 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.

7.1 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

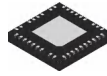| Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
P5137FDQRHARQ1	VQFN	RHA	36	2500	330.0	16.4	6.3	6.3	1.1	12.0	16.0	Q1

ADVANCE INFORMATION

TAPE AND REEL BOX DIMENSIONS

ADVANCE INFORMATION

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
P5137FDQRHARQ1	VQFN	RHA	36	2500	367.0	367.0	35.0

PACKAGE OUTLINE

RHA0036D

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

PIN 1 INDEX AREA

6.1
5.9

6.1
5.9

0.1 MIN

(0.13)

SECTION A-A
TYPICAL

1.0
0.8

0.05
0.00

2X 4.5

2X 1

C

SEATING PLANE

0.08 C

EXPOSED
THERMAL PAD

PKG ℄

10

17

(0.2) TYP

(0.16) TYP

9

18

2X 4.5

PKG ℄

37

A   A

2X 1

4X 0.32
0.22

0.1 Ⓜ C A B
0.05 Ⓜ C
PINS 3, 24, 29 & 34

1

28X 0.5

PIN 1 ID

36

27

26

32X 0.3
0.2

0.1 Ⓜ C A B
0.05 Ⓜ C

4X (0.17)
PINS 3, 24, 29 & 34

36X 0.5
0.3

□ 3.3±0.1

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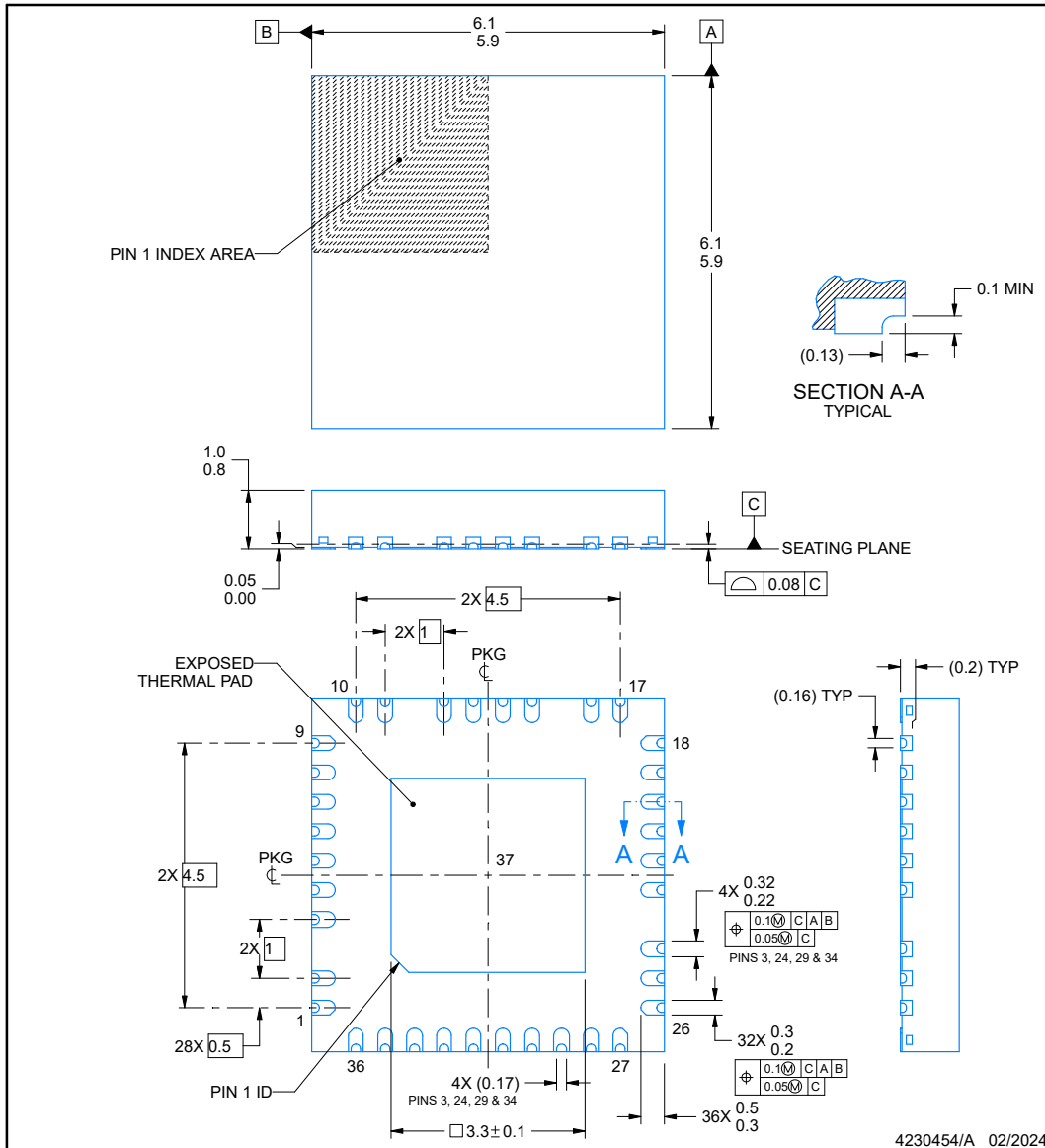
NOTES:

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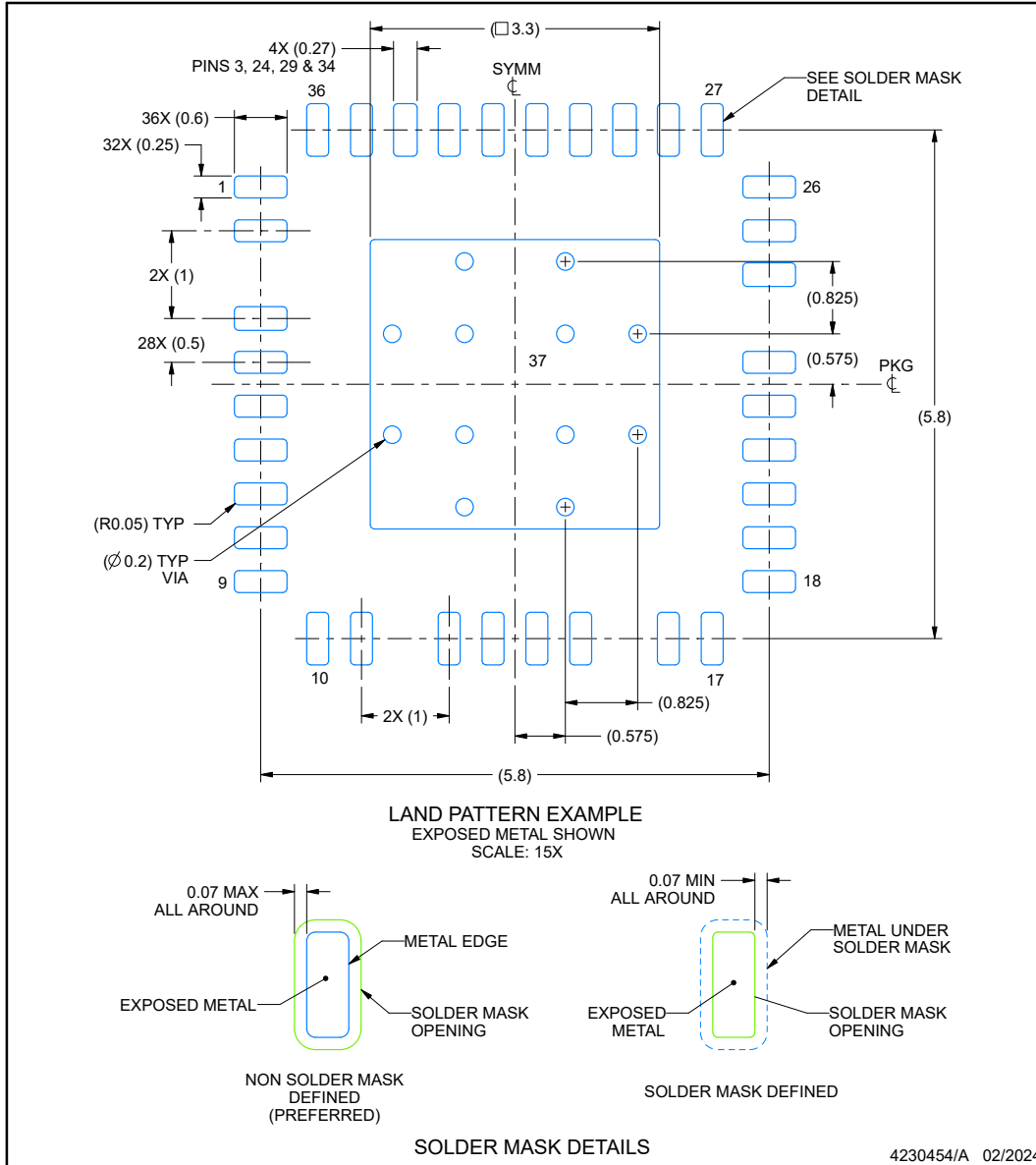
ADVANCE INFORMATION

EXAMPLE BOARD LAYOUT

RHA0036D

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

ADVANCE INFORMATION

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

0.07 MAX
ALL AROUND

METAL EDGE

EXPOSED METAL

SOLDER MASK
OPENING

NON SOLDER MASK
DEFINED
(PREFERRED)

0.07 MIN
ALL AROUND

METAL UNDER
SOLDER MASK

EXPOSED
METAL

SOLDER MASK
OPENING

SOLDER MASK DEFINED

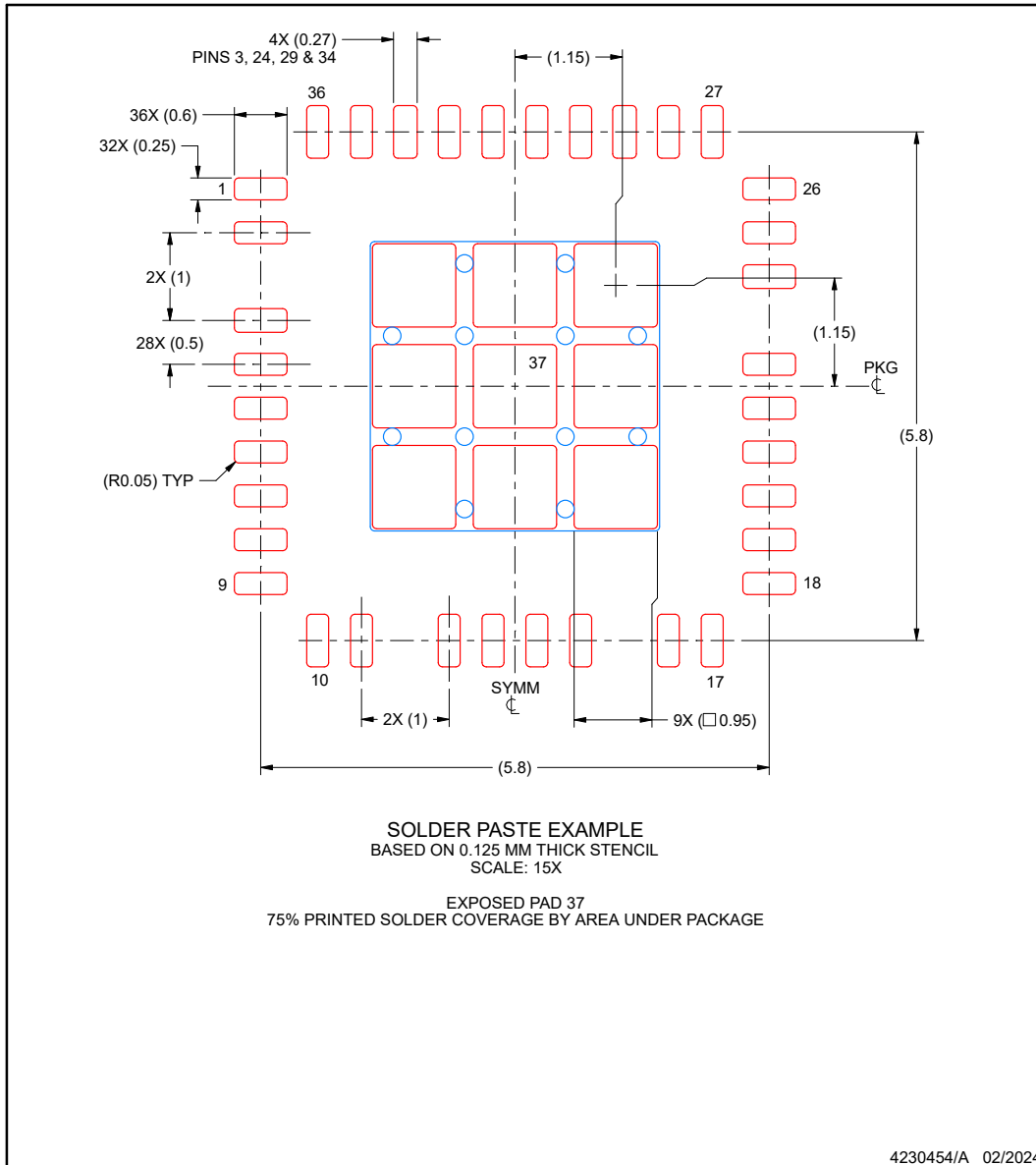SOLDER MASK DETAILS

4230454/A 02/2024

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/slua271).
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.

Product Folder Links: LM5137F-Q1

EXAMPLE STENCIL DESIGN

RHA0036D   **VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD

SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 15X

EXPOSED PAD 37
75% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

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NOTES: (continued)

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

Product Folder Links: *LM5137F-Q1*

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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
P5137FDQRHARQ1	ACTIVE	VQFN	RHA	36	2500	TBD	Call TI	Call TI	-40 to 150		Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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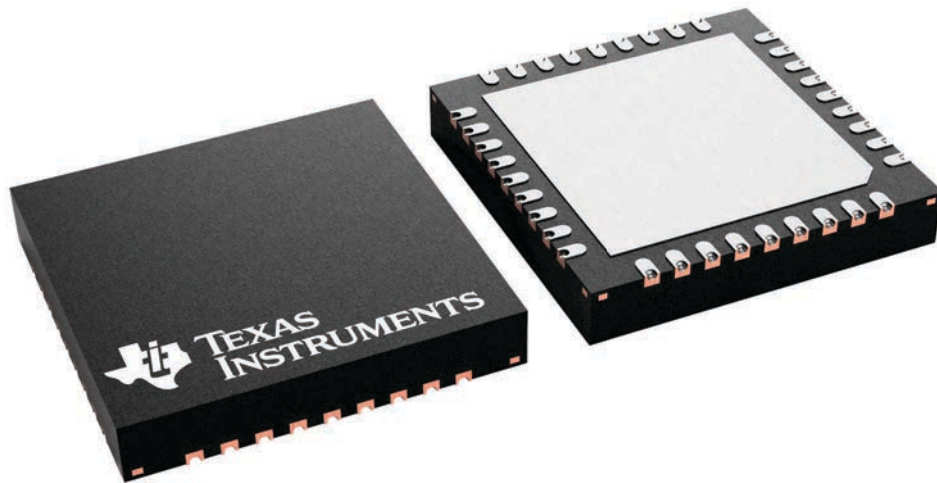This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

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