# CC2640R2F
# SimpleLink™ Bluetooth®5.1 Low Energy ワイヤレス MCU

## 1 特長

- マイクロコントローラ
  - 高性能な Arm® Cortex®-M3
  - EEMBC CoreMark® スコア:142
  - クロック速度:最大 48MHz
  - 275KB の不揮発性メモリ、128KB のシステム内蔵のプログラマブル・フラッシュを含む
  - 最大 28KB のシステム SRAM、そのうち 20KB は超低リークの SRAM
  - キャッシュまたはシステム RAM として使用可能な 8KB の SRAM
  - 2 ピンの cJTAG および JTAG デバッグ
  - OTA (Over-The-Air) アップグレードに対応
- 超低消費電力センサ・コントローラ
  - システムの他の部分から自律して動作可能
  - 16 ビット・アーキテクチャ
  - 超低リーク SRAM:2KB (コードおよびデータ用)
- 高効率のコード・サイズ・アーキテクチャ:
  ドライバ、TI-RTOS、および Bluetooth® ソフトウェアを ROM に格納することで、アプリケーションで利用可能なフラッシュが増加
- RoHS 準拠のパッケージ
  - 2.7mm × 2.7mm YFV DSBGA34 (14GPIO)
  - 4mm × 4mm RSM VQFN32 (10GPIO)
  - 5mm × 5mm RHB VQFN32 (15GPIO)
  - 7mm × 7mm RGZ VQFN48 (31GPIO)
- ペリフェラル
  - すべてのデジタル・ペリフェラル・ピンを任意の GPIO に配線可能
  - 4 個の汎用タイマ・モジュール
    (8 個の 16 ビットまたは 4 個の 32 ビット・タイマ、それぞれ PWM)
  - 12 ビット ADC、200k サンプル/秒、8 チャネルのアナログ MUX
  - 連続時間コンパレータ
  - 超低消費電力アナログ・コンパレータ
  - プログラム可能な電流ソース
  - UART、I2C、I2S
  - SSI ×2 (SPI、MICROWIRE、TI)
  - リアルタイム・クロック (RTC)
  - AES-128 セキュリティ・モジュール
  - 真性乱数生成器 (TRNG)
  - 8 つの静電容量式センシング・ボタンのサポート
  - 温度センサ内蔵
- 外部システム
  - オンチップの内蔵 DC/DC コンバータ
  - CC2590 および CC2592 レンジ・エクステンダとのシームレスな統合
  - 必要な外部部品はごくわずか
  - すべての VQFN パッケージで、SimpleLink™ CC2640 および CC2650 デバイスとピン互換
  - 7mm × 7mm VQFN パッケージで、SimpleLink™ CC2642R および CC2652R デバイスとピン互換
  - 4mm × 4mm および 5mm × 5mm VQFN パッケージで、SimpleLink™ CC1350 デバイスとピン互換
- 低消費電力
  - 広い電源電圧範囲
    - 通常動作:1.8～3.8V
    - 外部レギュレータ・モード:1.7～1.95V
  - アクティブ・モード RX:5.9mA
  - アクティブ・モード TX (0dBm):6.1mA
  - アクティブ・モード TX (+5dBm):9.1mA
  - アクティブ・モード MCU:61µA/MHz
  - アクティブ・モード MCU:48.5CoreMark/mA
  - アクティブモード・センサ・コントローラ:
    0.4mA + 8.2µA/MHz
  - スタンバイ:1.1µA (RTC 動作、RAM/CPU 保持)
  - シャットダウン:100nA (外部イベントによるウェークアップ)
- RF 部
  - 2.4GHz RF トランシーバ、Bluetooth® Low Energy 5.1 およびそれ以前の LE 仕様に準拠
  - 非常に優れたレシーバ感度 (BLE で -97dBm)、選択性、およびブロック性能
  - リンク・バジェット:BLE で 102dB
  - 最大 +5dBm のプログラム可能な出力電力
  - シングルエンドまたは差動 RF インターフェイス
  - 国際的な無線周波数規制への準拠を目標としたシステムに最適
    - ETSI EN 300 328 (ヨーロッパ)
    - EN 300 440 Class 2 (ヨーロッパ)
    - FCC CFR47 Part 15 (米国)
    - ARIB STD-T66 (日本)

- 開発ツールとソフトウェア
  - フル機能の開発キット
  - 複数のリファレンス・デザイン
  - SmartRF™ Studio
  - Sensor Controller Studio
  - IAR Embedded Workbench®® for Arm®
  - Code Composer Studio™ 統合開発環境 (IDE)
  - Code Composer Studio™ Cloud IDE

## 2 アプリケーション

- ホーム / ビル・オートメーション
  - ネットワーク接続された家電製品
  - 照明器具
  - スマート・ロック
  - ゲートウェイ
  - セキュリティ・システム
- 産業用
  - ファクトリ・オートメーション
  - アセット・トラッキングおよび管理
  - HMI
  - アクセス制御
- 電子 POS (EPOS)
  - 電子棚札 (ESL)
- 健康と医療
  - 電子温度計
  - SpO2
  - 血糖値測定器と血圧測定器
  - 計量器
  - 補聴器
- スポーツとフィットネス
  - ウェアラブル・フィットネスおよびアクティビティ・モニタ
  - スマート追跡機能
  - 患者モニタ
  - フィットネス機器
- HID
  - ゲーム
  - ポインティング・デバイス (ワイヤレス・キーボードおよびマウス)

## 3 概要

CC2640R2F デバイスは、Bluetooth® 5.1 Low Energy と独自の 2.4GHz アプリケーションをサポートする 2.4GHz ワイヤレス・マイクロコントローラ (MCU) です。このデバイスは、ビルディング・セキュリティ・システム、HVAC、アセット・トラッキング、医療の各市場、および産業用の性能が必要なアプリケーションで、低消費電力のワイヤレス通信と高度なセンシングに最適化されています。このデバイスの主な特長としては、以下に示すものがあります。

- 以下の Bluetooth® 5.1 機能に対応:LE Coded PHY (長距離)、LE 2Mbit PHY (高速)、アドバタイズ拡張機能、複数アドバタイズメント・セット、さらに、Bluetooth® 5.0 とそれ以前の Low Energy 仕様の主な機能の後方互換性およびサポート。
- 強力な Arm® Cortex®-M3 プロセッサ上でアプリケーションを開発するための SimpleLink™ CC2640R2F ソフトウェア開発キット (SDK) に含まれる、認定済みの Bluetooth® 5.1 ソフトウェア・プロトコル・スタック。
- 1.1µA の小さいスタンバイ電流 (全 RAM 保持) によるバッテリ寿命が長いワイヤレス・アプリケーション。
- 高速ウェークアップ機能を備えたプログラマブルな自律型超低消費電力センサ・コントローラ CPU による高度なセンシング。たとえば、このセンサ・コントローラは、1µA のシステム電流で 1Hz の ADC サンプリングが可能です。
- 複数の物理層と RF 規格 (例:RTLS (リアルタイム位置情報システム) 技術) をサポートする柔軟な低消費電力 RF トランシーバ機能を備えた、専用のソフトウェア制御無線コントローラ (Arm® Cortex®-M0)。
- Bluetooth® Low Energy (125kbps の LE Coded PHY で -103 dBm) に対応する優れた無線感度および堅牢 (選択度、ブロッキング) 性能。

CC2640R2F デバイスは、SimpleLink™ マイクロコントローラ (MCU) プラットフォームの一部です。本プラットフォームは、シングル・コア SDK (ソフトウェア開発キット) と豊富なツール・セットを備えた使いやすい共通の開発環境を共有する Wi-Fi®、Bluetooth® Low Energy、Thread、ZigBee®、Sub-1GHz MCU、およびホスト MCU で構成されています。SimpleLink™ プラットフォームは一度で統合を実現でき、製品ラインアップのどのデバイスの組み合わせでも設計に追加できるので、設計要件変更の際もコードの 100% 再利用が可能です。詳細については、SimpleLink™ MCU プラットフォームを参照してください。

**デバイス情報**(1)

| 部品番号 | パッケージ | 本体サイズ (公称) |
|---|---|---|
| CC2640R2FRGZ | VQFN (48) | 7.00mm × 7.00mm |
| CC2640R2FRHB | VQFN (32) | 5.00mm × 5.00mm |
| CC2640R2FRSM | VQFN (32) | 4.00mm × 4.00mm |

**デバイス情報(1) (continued)**

| 部品番号 | パッケージ | 本体サイズ (公称) |
|---|---|---|
| CC2640R2FYFV | DSBGA (34) | 2.70mm × 2.70mm |

(1) 詳細については、セクション 12 を参照してください。

## 4 Functional Block Diagram

図 4-1 shows a block diagram for the CC2640R2F device.

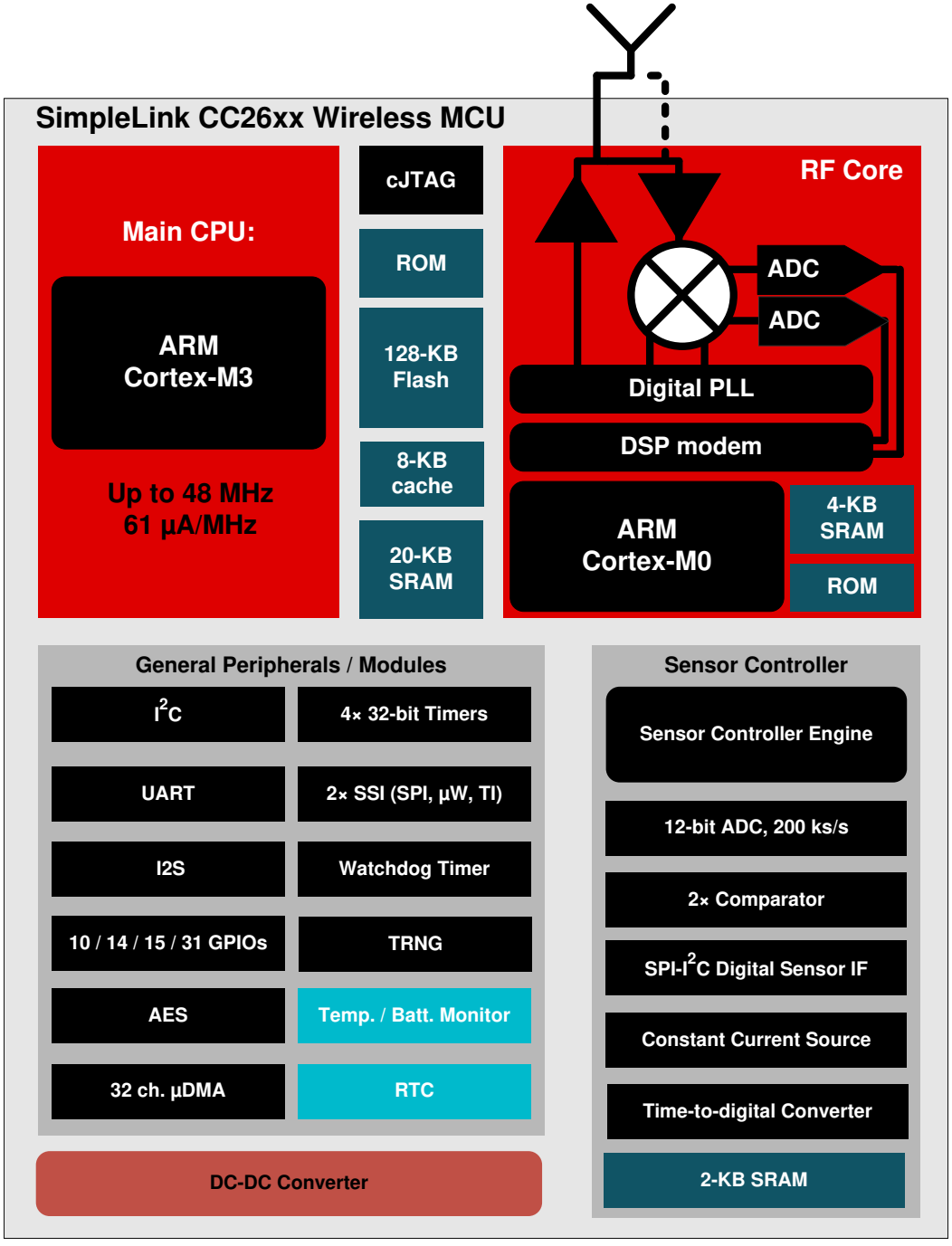




**図 4-1. Block Diagram**

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# 5 Revision History

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

| Changes from Revision B (January 2018) to Revision C (September 2020) | Page |
|---|---|
| • 文書全体にわたって表、図、相互参照の採番方法を更新 | 1 |
| • Changed intermodulation interferer frequencies in セクション 8.12 | 23 |
| • Changed 図 8-20 in セクション 8.29 | 33 |
| • Changed IDLE value for Current in セクション 9.8 | 40 |

# 6 Device Comparison

**表 6-1. Device Family Overview**

| Device | PHY Support | Flash (KB) | RAM (KB) | GPIO | Package(1) |
|---|---|---|---|---|---|
| CC2640R2Fxxx(2) | Bluetooth low energy (Normal, High Speed, Long Range) | 128 | 20 | 31, 15, 14, 10 | RGZ, RHB, YFV, RSM |
| CC2640F128xxx | Bluetooth low energy (Normal) | 128 | 20 | 31, 15, 10 | RGZ, RHB, RSM |
| CC2650F128xxx | Multi-Protocol(3) | 128 | 20 | 31, 15, 10 | RGZ, RHB, RSM |
| CC2630F128xxx | IEEE 802.15.4 (/6LoWPAN) | 128 | 20 | 31, 15, 10 | RGZ, RHB, RSM |
| CC2620F128xxx | IEEE 802.15.4 (RF4CE) | 128 | 20 | 31, 10 | RGZ, RSM |

(1) Package designator replaces the xxx in device name to form a complete device name, RGZ is 7-mm × 7-mm VQFN48, RHB is 5-mm × 5-mm VQFN32, RSM is 4-mm × 4-mm VQFN32, and YFV is 2.7-mm × 2.7-mm DSBGA.
(2) CC2640R2Fxxx devices contain Bluetooth Low Energy Host & Controller libraries in ROM, leaving more of the 128KB Flash memory available for the customer application when used with supported BLE-Stack software protocol stack releases. Actual use of ROM and Flash memory by the protocol stack may vary depending on device software configuration. See www.ti.com for more details.
(3) The CC2650 device supports all PHYs and can be reflashed to run all the supported standards.

## 6.1 Related Products

| | |
|---|---|
| TI's Wireless Connectivity | The wireless connectivity portfolio offers a wide selection of low-power RF solutions suitable for a broad range of applications. The offerings range from fully customized solutions to turn key offerings with pre-certified hardware and software (protocol). |
| TI's SimpleLink™ Sub-1 GHz Wireless MCUs | Long-range, low-power wireless connectivity solutions are offered in a wide range of Sub-1 GHz ISM bands. |
| Companion Products Companion Products | Review products that are frequently purchased or used in conjunction with this product. |
| SimpleLink™ CC2640R2 Wireless MCU LaunchPad™ Development Kit | The CC2640R2 LaunchPad™ development kit brings easy Bluetooth® low energy (BLE) connection to the LaunchPad ecosystem with the SimpleLink ultra-low power CC26xx family of devices. Compared to the CC2650 LaunchPad, the CC2640R2 LaunchPad provides the following:<br>• More free flash memory for the user application in the CC2640R2 wireless MCU<br>• Out-of-the-box support for Bluetooth 4.2 specification<br>• 4× faster Over-the-Air download speed compared to Bluetooth 4.1 |
| SimpleLink™ Bluetooth low energy/Multi-standard SensorTag | The new SensorTag IoT kit invites you to realize your cloud-connected product idea. The new SensorTag now includes 10 low-power MEMS sensors in a tiny red package. And it is expandable with DevPacks to make it easy to add your own sensors or actuators. |
| Reference Designs for CC2640 | TI Designs Reference Design Library is a robust reference design library spanning analog, embedded processor and connectivity. Created by TI experts to help you jump-start your system design, all TI Designs include schematic or block diagrams, BOMs, and design files to speed your time to market. Search and download designs at ti.com/tidesigns. |

# 7 Terminal Configuration and Functions

## 7.1 Pin Diagram – RGZ Package

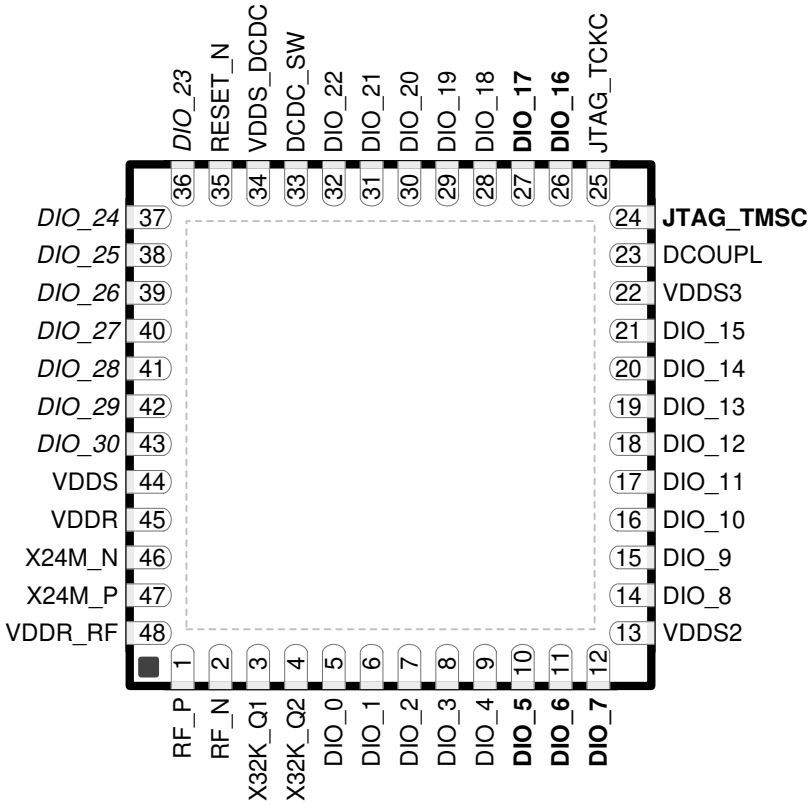



**図 7-1. RGZ Package 48-Pin VQFN (7-mm × 7-mm) Pinout, 0.5-mm Pitch**

I/O pins marked in 図 7-1 in **bold** have high-drive capabilities; they are the following:

- Pin 10, DIO_5
- Pin 11, DIO_6
- Pin 12, DIO_7
- Pin 24, JTAG_TMSC
- Pin 26, DIO_16
- Pin 27, DIO_17

I/O pins marked in 図 7-1 in *italics* have analog capabilities; they are the following:

- Pin 36, DIO_23
- Pin 37, DIO_24
- Pin 38, DIO_25
- Pin 39, DIO_26
- Pin 40, DIO_27
- Pin 41, DIO_28
- Pin 42, DIO_29
- Pin 43, DIO_30

## 7.2 Signal Descriptions – RGZ Package

表 7-1. Signal Descriptions – RGZ Package

| NAME | NO. | TYPE | DESCRIPTION |
|---|---|---|---|
| DCDC_SW | 33 | Power | Output from internal DC/DC(1) |
| DCOUPL | 23 | Power | 1.27-V regulated digital-supply decoupling capacitor(2) |
| DIO_0 | 5 | Digital I/O | GPIO, Sensor Controller |
| DIO_1 | 6 | Digital I/O | GPIO, Sensor Controller |
| DIO_2 | 7 | Digital I/O | GPIO, Sensor Controller |
| DIO_3 | 8 | Digital I/O | GPIO, Sensor Controller |
| DIO_4 | 9 | Digital I/O | GPIO, Sensor Controller |
| DIO_5 | 10 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_6 | 11 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_7 | 12 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_8 | 14 | Digital I/O | GPIO |
| DIO_9 | 15 | Digital I/O | GPIO |
| DIO_10 | 16 | Digital I/O | GPIO |
| DIO_11 | 17 | Digital I/O | GPIO |
| DIO_12 | 18 | Digital I/O | GPIO |
| DIO_13 | 19 | Digital I/O | GPIO |
| DIO_14 | 20 | Digital I/O | GPIO |
| DIO_15 | 21 | Digital I/O | GPIO |
| DIO_16 | 26 | Digital I/O | GPIO, JTAG_TDO, high-drive capability |
| DIO_17 | 27 | Digital I/O | GPIO, JTAG_TDI, high-drive capability |
| DIO_18 | 28 | Digital I/O | GPIO |
| DIO_19 | 29 | Digital I/O | GPIO |
| DIO_20 | 30 | Digital I/O | GPIO |
| DIO_21 | 31 | Digital I/O | GPIO |
| DIO_22 | 32 | Digital I/O | GPIO |
| DIO_23 | 36 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_24 | 37 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_25 | 38 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_26 | 39 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_27 | 40 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_28 | 41 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_29 | 42 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_30 | 43 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| JTAG_TMSC | 24 | Digital I/O | JTAG TMSC, high-drive capability |
| JTAG_TCKC | 25 | Digital I/O | JTAG TCKC(3) |
| RESET_N | 35 | Digital input | Reset, active-low. No internal pullup. |
| RF_P | 1 | RF I/O | Positive RF input signal to LNA during RX<br>Positive RF output signal to PA during TX |
| RF_N | 2 | RF I/O | Negative RF input signal to LNA during RX<br>Negative RF output signal to PA during TX |
| VDDR | 45 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(2) (4) |
| VDDR_RF | 48 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(2) (5) |

**表 7-1. Signal Descriptions – RGZ Package (continued)**

| NAME | NO. | TYPE | DESCRIPTION |
|---|---|---|---|
| VDDS | 44 | Power | 1.8-V to 3.8-V main chip supply(1) |
| VDDS2 | 13 | Power | 1.8-V to 3.8-V DIO supply(1) |
| VDDS3 | 22 | Power | 1.8-V to 3.8-V DIO supply(1) |
| VDDS_DCDC | 34 | Power | 1.8-V to 3.8-V DC/DC supply |
| X32K_Q1 | 3 | Analog I/O | 32-kHz crystal oscillator pin 1 |
| X32K_Q2 | 4 | Analog I/O | 32-kHz crystal oscillator pin 2 |
| X24M_N | 46 | Analog I/O | 24-MHz crystal oscillator pin 1 |
| X24M_P | 47 | Analog I/O | 24-MHz crystal oscillator pin 2 |
| EGP | | Power | Ground – Exposed Ground Pad |

(1) For more details, see the technical reference manual (listed in セクション 11.3).
(2) Do not supply external circuitry from this pin.
(3) For design consideration regarding noise immunity for this pin, see the JTAG Interface chapter in the *CC13x0, CC26x0 SimpleLink™ Wireless MCU Technical Reference Manual*
(4) If internal DC/DC is not used, this pin is supplied internally from the main LDO.
(5) If internal DC/DC is not used, this pin must be connected to VDDR for supply from the main LDO.

## 7.3 Pin Diagram – RHB Package

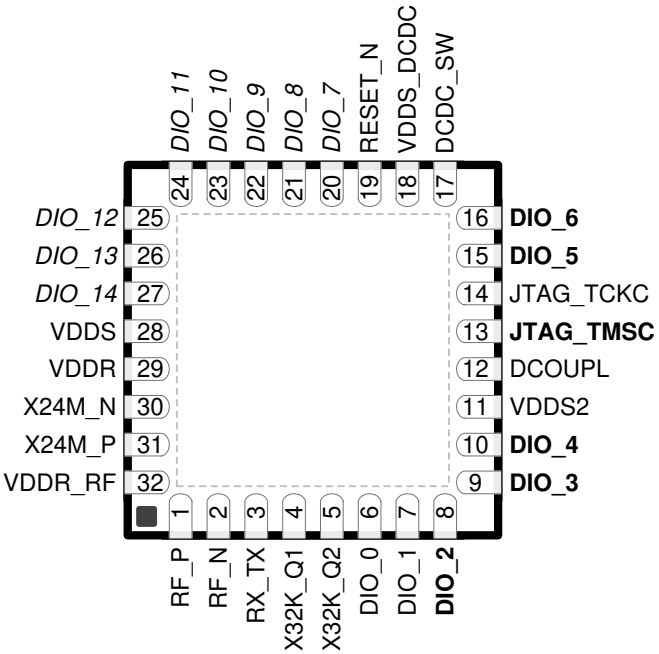



**図 7-2. RHB Package 32-Pin VQFN (5-mm × 5-mm) Pinout, 0.5-mm Pitch**

I/O pins marked in 図 7-2 in **bold** have high-drive capabilities; they are the following:

- Pin 8, DIO_2
- Pin 9, DIO_3
- Pin 10, DIO_4
- Pin 13, JTAG_TMSC
- Pin 15, DIO_5
- Pin 16, DIO_6

I/O pins marked in 図 7-2 in *italics* have analog capabilities; they are the following:

- Pin 20, DIO_7
- Pin 21, DIO_8
- Pin 22, DIO_9
- Pin 23, DIO_10
- Pin 24, DIO_11
- Pin 25, DIO_12
- Pin 26, DIO_13
- Pin 27, DIO_14

## 7.4 Signal Descriptions – RHB Package

表 7-2. Signal Descriptions – RHB Package

| NAME | NO. | TYPE | DESCRIPTION |
|---|---|---|---|
| DCDC_SW | 17 | Power | Output from internal DC/DC(1) |
| DCOUPL | 12 | Power | 1.27-V regulated digital-supply decoupling(2) |
| DIO_0 | 6 | Digital I/O | GPIO, Sensor Controller |
| DIO_1 | 7 | Digital I/O | GPIO, Sensor Controller |
| DIO_2 | 8 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_3 | 9 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_4 | 10 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_5 | 15 | Digital I/O | GPIO, High drive capability, JTAG_TDO |
| DIO_6 | 16 | Digital I/O | GPIO, High drive capability, JTAG_TDI |
| DIO_7 | 20 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_8 | 21 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_9 | 22 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_10 | 23 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_11 | 24 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_12 | 25 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_13 | 26 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_14 | 27 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| JTAG_TMSC | 13 | Digital I/O | JTAG TMSC, high-drive capability |
| JTAG_TCKC | 14 | Digital I/O | JTAG TCKC(3) |
| RESET_N | 19 | Digital input | Reset, active-low. No internal pullup. |
| RF_N | 2 | RF I/O | Negative RF input signal to LNA during RX<br>Negative RF output signal to PA during TX |
| RF_P | 1 | RF I/O | Positive RF input signal to LNA during RX<br>Positive RF output signal to PA during TX |
| RX_TX | 3 | RF I/O | Optional bias pin for the RF LNA |
| VDDR | 29 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(4) (2) |
| VDDR_RF | 32 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(2) (5) |
| VDDS | 28 | Power | 1.8-V to 3.8-V main chip supply(1) |
| VDDS2 | 11 | Power | 1.8-V to 3.8-V GPIO supply(1) |
| VDDS_DCDC | 18 | Power | 1.8-V to 3.8-V DC/DC supply |
| X32K_Q1 | 4 | Analog I/O | 32-kHz crystal oscillator pin 1 |
| X32K_Q2 | 5 | Analog I/O | 32-kHz crystal oscillator pin 2 |
| X24M_N | 30 | Analog I/O | 24-MHz crystal oscillator pin 1 |
| X24M_P | 31 | Analog I/O | 24-MHz crystal oscillator pin 2 |
| EGP | | Power | Ground – Exposed Ground Pad |

(1) See technical reference manual (listed in セクション 11.3) for more details.
(2) Do not supply external circuitry from this pin.
(3) For design consideration regarding noise immunity for this pin, see the JTAG Interface chapter in the *CC13x0, CC26x0 SimpleLink™ Wireless MCU Technical Reference Manual*
(4) If internal DC/DC is not used, this pin is supplied internally from the main LDO.
(5) If internal DC/DC is not used, this pin must be connected to VDDR for supply from the main LDO.

## 7.5 Pin Diagram – YFV (Chip Scale, DSBGA) Package

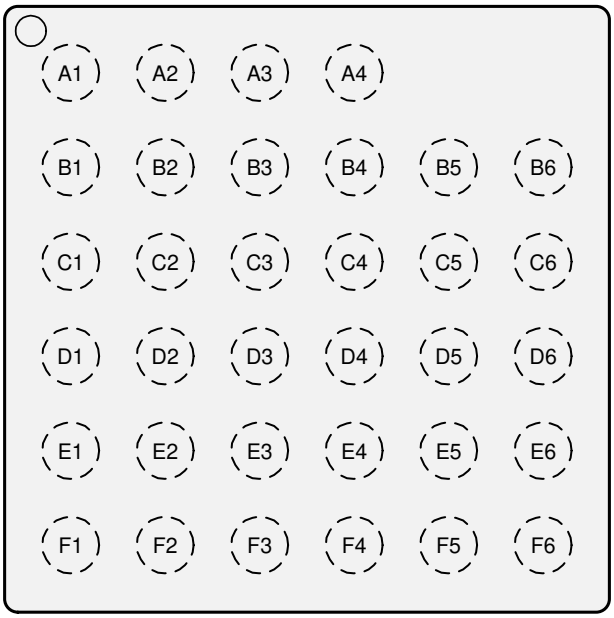



**図 7-3. YFV (2.7-mm × 2.7-mm) Pinout, Top View**

## 7.6 Signal Descriptions – YFV (Chip Scale, DSBGA) Package

**表 7-3. Signal Descriptions – YFV Package**

| NAME | NO. | TYPE | DESCRIPTION |
|---|---|---|---|
| DCDC_SW | D1 | Power | Output from internal DC/DC(1) |
| DCOUPL | F3 | Power | 1.27-V regulated digital-supply decoupling(2) |
| DIO_0 | C5 | Digital I/O | GPIO, Sensor Controller |
| DIO_1 | F6 | Digital I/O | GPIO, Sensor Controller |
| DIO_2 | D5 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_3 | E5 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_4 | F5 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_5 | E3 | Digital I/O | GPIO, High-drive capability, JTAG_TDO |
| DIO_6 | F1 | Digital I/O | GPIO, High-drive capability, JTAG_TDI |
| DIO_7 | D2 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_8 | D3 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_9 | A1 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_10 | C2 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_11 | B2 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_12 | D4 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_13 | B3 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| JTAG_TMSC | E4 | Digital I/O | JTAG TMSC, high-drive capability |
| JTAG_TCKC | F2 | Digital I/O | JTAG TCKC(3) |
| RESET_N | E2 | Digital input | Reset, active-low. No internal pullup. |

**表 7-3. Signal Descriptions – YFV Package (continued)**

| NAME | NO. | TYPE | DESCRIPTION |
|---|---|---|---|
| RF_N | B6 | RF I/O | Negative RF input signal to LNA during RX<br>Negative RF output signal to PA during TX |
| RF_P | B5 | RF I/O | Positive RF input signal to LNA during RX<br>Positive RF output signal to PA during TX |
| VDDR | A3 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(4) (2) |
| VDDR_RF | B4 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(5) (2) |
| VDDS | A2 | Power | 1.8-V to 3.8-V main chip supply(1) |
| VDDS2 | F4 | Power | 1.8-V to 3.8-V GPIO supply(1) |
| VDDS_DCDC | C1 | Power | 1.8-V to 3.8-V DC/DC supply |
| X32K_Q1 | D6 | Analog I/O | 32-kHz crystal oscillator pin 1 |
| X32K_Q2 | E6 | Analog I/O | 32-kHz crystal oscillator pin 2 |
| X24M_N | C3 | Analog I/O | 24-MHz crystal oscillator pin 1 |
| X24M_P | C4 | Analog I/O | 24-MHz crystal oscillator pin 2 |
| GND | A4, B1, C6, E1 | Power | Ground |

(1) For more details, see the technical reference manual (listed in セクション 11.3).
(2) Do not supply external circuitry from this pin.
(3) For design consideration regarding noise immunity for this pin, see the JTAG Interface chapter in the *CC13x0, CC26x0 SimpleLink™ Wireless MCU Technical Reference Manual*
(4) If internal DC/DC is not used, this pin is supplied internally from the main LDO.
(5) If internal DC/DC is not used, this pin must be connected to VDDR for supply from the main LDO.

## 7.7 Pin Diagram – RSM Package

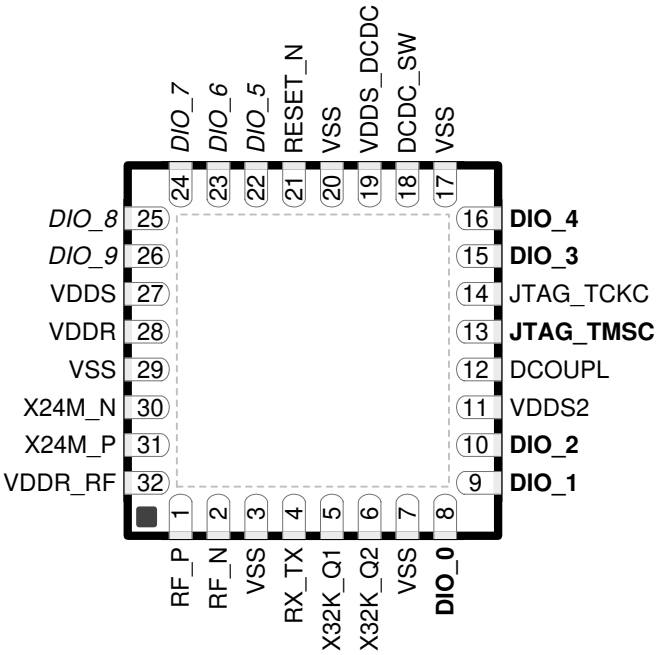



**図 7-4. RSM Package 32-Pin VQFN (4-mm × 4-mm) Pinout, 0.4-mm Pitch**

I/O pins marked in 図 7-4 in **bold** have high-drive capabilities; they are as follows:

- Pin 8, DIO_0
- Pin 9, DIO_1
- Pin 10, DIO_2
- Pin 13, JTAG_TMSC
- Pin 15, DIO_3
- Pin 16, DIO_4

I/O pins marked in 図 7-4 in *italics* have analog capabilities; they are as follows:

- Pin 22, DIO_5
- Pin 23, DIO_6
- Pin 24, DIO_7
- Pin 25, DIO_8
- Pin 26, DIO_9

## 7.8 Signal Descriptions – RSM Package

表 7-4. Signal Descriptions – RSM Package

| NAME | NO. | TYPE | DESCRIPTION |
|---|---|---|---|
| DCDC_SW | 18 | Power | Output from internal DC/DC.(1). Tie to ground for external regulator mode (1.7-V to 1.95-V operation) |
| DCOUPL | 12 | Power | 1.27-V regulated digital-supply decoupling capacitor(2) |
| DIO_0 | 8 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_1 | 9 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_2 | 10 | Digital I/O | GPIO, Sensor Controller, high-drive capability |
| DIO_3 | 15 | Digital I/O | GPIO, High-drive capability, JTAG_TDO |
| DIO_4 | 16 | Digital I/O | GPIO, High-drive capability, JTAG_TDI |
| DIO_5 | 22 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_6 | 23 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_7 | 24 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_8 | 25 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_9 | 26 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| JTAG_TMSC | 13 | Digital I/O | JTAG TMSC |
| JTAG_TCKC | 14 | Digital I/O | JTAG TCKC(3) |
| RESET_N | 21 | Digital Input | Reset, active-low. No internal pullup. |
| RF_N | 2 | RF I/O | Negative RF input signal to LNA during RX<br>Negative RF output signal to PA during TX |
| RF_P | 1 | RF I/O | Positive RF input signal to LNA during RX<br>Positive RF output signal to PA during TX |
| RX_TX | 4 | RF I/O | Optional bias pin for the RF LNA |
| VDDR | 28 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC.(2) (4) |
| VDDR_RF | 32 | Power | 1.7-V to 1.95-V supply, typically connect to output of internal DC/DC(2) (5) |
| VDDS | 27 | Power | 1.8-V to 3.8-V main chip supply(1) |
| VDDS2 | 11 | Power | 1.8-V to 3.8-V GPIO supply(1) |
| VDDS_DCDC | 19 | Power | 1.8-V to 3.8-V DC/DC supply. Tie to ground for external regulator mode (1.7-V to 1.95-V operation). |
| VSS | 3, 7, 17, 20, 29 | Power | Ground |
| X32K_Q1 | 5 | Analog I/O | 32-kHz crystal oscillator pin 1 |
| X32K_Q2 | 6 | Analog I/O | 32-kHz crystal oscillator pin 2 |
| X24M_N | 30 | Analog I/O | 24-MHz crystal oscillator pin 1 |
| X24M_P | 31 | Analog I/O | 24-MHz crystal oscillator pin 2 |
| EGP | | Power | Ground – Exposed Ground Pad |

(1) See technical reference manual (listed in セクション 11.3) for more details.
(2) Do not supply external circuitry from this pin.
(3) For design consideration regarding noise immunity for this pin, see the JTAG Interface chapter in the *CC13x0, CC26x0 SimpleLink™ Wireless MCU Technical Reference Manual*
(4) If internal DC/DC is not used, this pin is supplied internally from the main LDO.
(5) If internal DC/DC is not used, this pin must be connected to VDDR for supply from the main LDO.

# 8 Specifications

## 8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1) (2)

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage (VDDS, VDDS2, and VDDS3) | VDDR supplied by internal DC/DC regulator or internal GLDO. VDDS_DCDC connected to VDDS on PCB | –0.3 | 4.1 | V |
| Supply voltage (VDDS(3) and VDDR) | External regulator mode (VDDS and VDDR pins connected on PCB) | –0.3 | 2.25 | V |
| Voltage on any digital pin(4) (5) | | –0.3 | VDDSx + 0.3, max 4.1 | V |
| Voltage on crystal oscillator pins, X32K_Q1, X32K_Q2, X24M_N and X24M_P | | –0.3 | VDDR + 0.3, max 2.25 | V |
| Voltage on ADC input ($V_{in}$) | Voltage scaling enabled | –0.3 | VDDS | V |
| | Voltage scaling disabled, internal reference | –0.3 | 1.49 | |
| | Voltage scaling disabled, VDDS as reference | –0.3 | VDDS / 2.9 | |
| Input RF level | | | 5 | dBm |
| $T_{stg}$ | Storage temperature | –40 | 150 | °C |

(1) All voltage values are with respect to ground, unless otherwise noted.
(2) 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.
(3) In external regulator mode, VDDS2 and VDDS3 must be at the same potential as VDDS.
(4) Including analog-capable DIO.
(5) Each pin is referenced to a specific VDDSx (VDDS, VDDS2 or VDDS3). For a pin-to-VDDS mapping table, see 表 9-3.

## 8.2 ESD Ratings

| | | | | VALUE | UNIT |
|---|---|---|---|---|---|
| $V_{ESD}$ | Electrostatic discharge<br>RSM, RHB, and RGZ packages | Human body model (HBM), per ANSI/ESDA/JEDEC JS001(1) | All pins | ±2500 | V |
| | | Charged device model (CDM), per JESD22-C101(2) | RF pins | ±500 | |
| | | | Non-RF pins | ±500 | |
| $V_{ESD}$ | Electrostatic discharge<br>YFV package | Human body model (HBM), per ANSI/ESDA/JEDEC JS001(1) | All pins | ±1500 | V |
| | | Charged device model (CDM), per JESD22-C101(2) | RF pins | ±500 | |
| | | | Non-RF pins | ±500 | |

(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.

## 8.3 Recommended Operating Conditions

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

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| Ambient temperature | | | –40 | 85 | °C |
| Operating supply voltage (VDDS and VDDR), external regulator mode | For operation in 1.8-V systems (VDDS and VDDR pins connected on PCB, internal DC/DC cannot be used) | | 1.7 | 1.95 | V |
| Operating supply voltage VDDS | For operation in battery-powered and 3.3-V systems (internal DC/DC can be used to minimize power consumption) | | 1.8 | 3.8 | V |
| Operating supply voltages VDDS2 and VDDS3 | | VDDS < 2.7 V | 1.8 | 3.8 | V |
| Operating supply voltages VDDS2 and VDDS3 | | VDDS ≥ 2.7 V | 1.9 | 3.8 | V |

## 8.4 Power Consumption Summary

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V with internal DC/DC converter, unless otherwise noted.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $I_{core}$ | Core current consumption | Reset. RESET_N pin asserted or VDDS below Power-on-Reset threshold | | 100 | | nA |
| | | Shutdown. No clocks running, no retention | | 150 | | |
| | | Standby. With RTC, CPU, RAM and (partial) register retention. RCOSC_LF | | 1.1 | | µA |
| | | Standby. With RTC, CPU, RAM and (partial) register retention. XOSC_LF | | 1.3 | | |
| | | Standby. With Cache, RTC, CPU, RAM and (partial) register retention. RCOSC_LF | | 2.8 | | |
| | | Standby. With Cache, RTC, CPU, RAM and (partial) register retention. XOSC_LF | | 3.0 | | |
| | | Idle. Supply Systems and RAM powered. | | 650 | | |
| | | Active. Core running CoreMark | | 1.45 mA + 31 µA/MHz | | |
| | | Radio RX (1) | | 5.9 | | mA |
| | | Radio RX(2) | | 6.1 | | |
| | | Radio TX, 0-dBm output power(1) | | 6.1 | | |
| | | Radio TX, 5-dBm output power(2) | | 9.1 | | |
| **Peripheral Current Consumption (Adds to core current $I_{core}$ for each peripheral unit activated)** (3) | | | | | | |
| $I_{peri}$ | Peripheral power domain | Delta current with domain enabled | | 50 | | µA |
| | Serial power domain | Delta current with domain enabled | | 13 | | µA |
| | RF Core | Delta current with power domain enabled, clock enabled, RF core idle | | 237 | | µA |
| | µDMA | Delta current with clock enabled, module idle | | 130 | | µA |
| | Timers | Delta current with clock enabled, module idle | | 113 | | µA |
| | $I^2C$ | Delta current with clock enabled, module idle | | 12 | | µA |
| | I2S | Delta current with clock enabled, module idle | | 36 | | µA |
| | SSI | Delta current with clock enabled, module idle | | 93 | | µA |
| | UART | Delta current with clock enabled, module idle | | 164 | | µA |

(1) Single-ended RF mode is optimized for size and power consumption. Measured on CC2650EM-4XS.

(2) Differential RF mode is optimized for RF performance. Measured on CC2650EM-5XD.
(3) $I_{peri}$ is not supported in Standby or Shutdown.

## 8.5 General Characteristics

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| **FLASH MEMORY** | | | | | |
| Supported flash erase cycles before failure(1) | | 100 | | | k Cycles |
| Maximum number of write operations per row before erase(2) | | | | 83 | write operations |
| Flash retention | 105°C | 11.4 | | | Years at 105°C |
| Flash page/sector erase current | Average delta current | | 12.6 | | mA |
| Flash page/sector size | | | 4 | | KB |
| Flash write current | Average delta current, 4 bytes at a time | | 8.15 | | mA |
| Flash page/sector erase time(3) | | | 8 | | ms |
| Flash write time(3) | 4 bytes at a time | | 8 | | µs |

(1) Aborting flash during erase or program modes is not a safe operation.
(2) Each row is 2048 bits (or 256 Bytes) wide.
(3) This number is dependent on Flash aging and will increase over time and erase cycles.

## 8.6 125-kbps Coded (Bluetooth 5) – RX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Receiver sensitivity | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | –103 | | dBm |
| Receiver saturation | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | >5 | | dBm |
| Frequency error tolerance | Difference between the incoming carrier frequency and the internally generated carrier frequency | –260 | | 310 | kHz |
| Data rate error tolerance | Difference between incoming data rate and the internally generated data rate (37-byte packets) | –260 | | 260 | ppm |
| Data rate error tolerance | Difference between incoming data rate and the internally generated data rate (255-byte packets) | –140 | | 140 | ppm |
| Co-channel rejection (1) | Wanted signal at –79 dBm, modulated interferer in channel, BER = $10^{-3}$ | | –3 | | dB |
| Selectivity, ±1 MHz (1) | Wanted signal at –79 dBm, modulated interferer at ±1 MHz, BER = $10^{-3}$ | | 9 / 5(2) | | dB |
| Selectivity, ±2 MHz (1) | Wanted signal at –79 dBm, modulated interferer at ±2 MHz, Image frequency is at –2 MHz, BER = $10^{-3}$ | | 43 / 32(2) | | dB |
| Selectivity, ±3 MHz (1) | Wanted signal at –79 dBm, modulated interferer at ±3 MHz, BER = $10^{-3}$ | | 47 / 42(2) | | dB |
| Selectivity, ±4 MHz (1) | Wanted signal at –79 dBm, modulated interferer at ±4 MHz, BER = $10^{-3}$ | | 46 / 47(2) | | dB |
| Selectivity, ±6 MHz (1) | Wanted signal at –79 dBm, modulated interferer at ±6 MHz, BER = $10^{-3}$ | | 49 / 46(2) | | dB |
| Alternate channel rejection, ±7 MHz(1) | Wanted signal at –79 dBm, modulated interferer at ≥ ±7 MHz, BER = $10^{-3}$ | | 50 / 47(2) | | dB |
| Selectivity, image frequency(1) | Wanted signal at –79 dBm, modulated interferer at image frequency, BER = $10^{-3}$ | | 32 | | dB |

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Selectivity, image frequency ±1 MHz(1) | Note that Image frequency + 1 MHz is the Co-channel –1 MHz. Wanted signal at –79 dBm, modulated interferer at ±1 MHz from image frequency, BER = $10^{-3}$ | | 5 / 32(2) | | dB |
| Blocker rejection, ±8 MHz and above(1) | Wanted signal at –79 dBm, modulated interferer at ±8 MHz and above, BER = $10^{-3}$ | | >46 | | dB |
| Out-of-band blocking (3) | 30 MHz to 2000 MHz | | –40 | | dBm |
| Out-of-band blocking | 2003 MHz to 2399 MHz | | –19 | | dBm |
| Out-of-band blocking | 2484 MHz to 2997 MHz | | –22 | | dBm |
| Intermodulation | Wanted signal at 2402 MHz, –76 dBm. Two interferers at 2405 and 2408 MHz respectively, at the given power level | | –42 | | dBm |

(1) Numbers given as I/C dB.
(2) X / Y, where X is +N MHz and Y is –N MHz.
(3) Excluding one exception at $F_{wanted}$ / 2, per Bluetooth Specification.

## 8.7 125-kbps Coded (Bluetooth 5) – TX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Output power, highest setting | Differential mode, delivered to a single-ended 50-Ω load through a balun | | 5 | | dBm |
| Output power, highest setting | Measured on CC2650EM-4XS, delivered to a single-ended 50-Ω load | | 2 | | dBm |
| Output power, lowest setting | Delivered to a single-ended 50-Ω load through a balun | | –21 | | dBm |
| Spurious emission conducted measurement(1) | f < 1 GHz, outside restricted bands | | –43 | | dBm |
| | f < 1 GHz, restricted bands ETSI | | –65 | | dBm |
| | f < 1 GHz, restricted bands FCC | | –71 | | dBm |
| | f > 1 GHz, including harmonics | | –46 | | dBm |

(1) Suitable for systems targeting compliance with worldwide radio-frequency regulations ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan).

## 8.8 500-kbps Coded (Bluetooth 5) – RX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Receiver sensitivity | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | –101 | | dBm |
| Receiver saturation | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | >5 | | dBm |
| Frequency error tolerance | Difference between the incoming carrier frequency and the internally generated carrier frequency | –240 | | 240 | kHz |
| Data rate error tolerance | Difference between incoming data rate and the internally generated data rate (37-byte packets) | –500 | | 500 | ppm |
| Data rate error tolerance | Difference between incoming data rate and the internally generated data rate (255-byte packets) | –310 | | 330 | ppm |
| Co-channel rejection (1) | Wanted signal at –72 dBm, modulated interferer in channel, BER = $10^{-3}$ | | –5 | | dB |
| Selectivity, ±1 MHz (1) | Wanted signal at –72 dBm, modulated interferer at ±1 MHz, BER = $10^{-3}$ | | 9 / 5(2) | | dB |

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Selectivity, ±2 MHz (1) | Wanted signal at –72 dBm, modulated interferer at ±2 MHz, Image frequency is at –2 MHz, BER = $10^{-3}$ | | 41 / 31(2) | | dB |
| Selectivity, ±3 MHz (1) | Wanted signal at –72 dBm, modulated interferer at ±3 MHz, BER = $10^{-3}$ | | 44 / 41(2) | | dB |
| Selectivity, ±4 MHz (1) | Wanted signal at –72 dBm, modulated interferer at ±4 MHz, BER = $10^{-3}$ | | 44 / 44(2) | | dB |
| Selectivity, ±6 MHz (1) | Wanted signal at –72 dBm, modulated interferer at ±6 MHz, BER = $10^{-3}$ | | 44 / 44(2) | | dB |
| Alternate channel rejection, ±7 MHz(1) | Wanted signal at –72 dBm, modulated interferer at ≥ ±7 MHz, BER = $10^{-3}$ | | 44 / 44(2) | | dB |
| Selectivity, image frequency(1) | Wanted signal at –72 dBm, modulated interferer at image frequency, BER = $10^{-3}$ | | 31 | | dB |
| Selectivity, image frequency ±1 MHz(1) | Note that Image frequency + 1 MHz is the Co-channel –1 MHz. Wanted signal at –72 dBm, modulated interferer at ±1 MHz from image frequency, BER = $10^{-3}$ | | 5 / 41(2) | | dB |
| Blocker rejection, ±8 MHz and above(1) | Wanted signal at –72 dBm, modulated interferer at ±8 MHz and above, BER = $10^{-3}$ | | 44 | | dB |
| Out-of-band blocking (3) | 30 MHz to 2000 MHz | | –35 | | dBm |
| Out-of-band blocking | 2003 MHz to 2399 MHz | | –19 | | dBm |
| Out-of-band blocking | 2484 MHz to 2997 MHz | | –19 | | dBm |
| Intermodulation | Wanted signal at 2402 MHz, –69 dBm. Two interferers at 2405 and 2408 MHz respectively, at the given power level | | –37 | | dBm |

(1) Numbers given as I/C dB.
(2) X / Y, where X is +N MHz and Y is –N MHz.
(3) Excluding one exception at $F_{wanted}$ / 2, per Bluetooth Specification.

## 8.9 500-kbps Coded (Bluetooth 5) – TX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Output power, highest setting | Differential mode, delivered to a single-ended 50-Ω load through a balun | | 5 | | dBm |
| Output power, highest setting | Measured on CC2650EM-4XS, delivered to a single-ended 50-Ω load | | 2 | | dBm |
| Output power, lowest setting | Delivered to a single-ended 50-Ω load through a balun | | –21 | | dBm |
| Spurious emission conducted measurement(1) | f < 1 GHz, outside restricted bands | | –43 | | dBm |
| | f < 1 GHz, restricted bands ETSI | | –65 | | dBm |
| | f < 1 GHz, restricted bands FCC | | –71 | | dBm |
| | f > 1 GHz, including harmonics | | –46 | | dBm |

(1) Suitable for systems targeting compliance with worldwide radio-frequency regulations ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan).

## 8.10 1-Mbps GFSK (Bluetooth low energy) – RX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Receiver sensitivity | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | –97 | | dBm |
| Receiver sensitivity | Single-ended mode. Measured on CC2650EM-4XS, at the SMA connector, BER = $10^{-3}$ | | –96 | | dBm |
| Receiver saturation | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | 4 | | dBm |
| Receiver saturation | Single-ended mode. Measured on CC2650EM-4XS, at the SMA connector, BER = $10^{-3}$ | | 0 | | dBm |
| Frequency error tolerance | Difference between the incoming carrier frequency and the internally generated carrier frequency | –350 | | 350 | kHz |
| Data rate error tolerance | Difference between incoming data rate and the internally generated data rate | –750 | | 750 | ppm |
| Co-channel rejection(1) | Wanted signal at –67 dBm, modulated interferer in channel, BER = $10^{-3}$ | | –6 | | dB |
| Selectivity, ±1 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±1 MHz, BER = $10^{-3}$ | | 7 / 3(2) | | dB |
| Selectivity, ±2 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±2 MHz, BER = $10^{-3}$ | | 34 / 25(2) | | dB |
| Selectivity, ±3 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±3 MHz, BER = $10^{-3}$ | | 38 / 26(2) | | dB |
| Selectivity, ±4 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±4 MHz, BER = $10^{-3}$ | | 42 / 29(2) | | dB |
| Selectivity, ±5 MHz or more(1) | Wanted signal at –67 dBm, modulated interferer at ≥ ±5 MHz, BER = $10^{-3}$ | | 32 | | dB |
| Selectivity, image frequency(1) | Wanted signal at –67 dBm, modulated interferer at image frequency, BER = $10^{-3}$ | | 25 | | dB |
| Selectivity, image frequency ±1 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±1 MHz from image frequency, BER = $10^{-3}$ | | 3 / 26(2) | | dB |
| Out-of-band blocking (3) | 30 MHz to 2000 MHz | | –20 | | dBm |
| Out-of-band blocking | 2003 MHz to 2399 MHz | | –5 | | dBm |
| Out-of-band blocking | 2484 MHz to 2997 MHz | | –8 | | dBm |
| Out-of-band blocking | 3000 MHz to 12.75 GHz | | –10 | | dBm |
| Intermodulation | Wanted signal at 2402 MHz, –64 dBm. Two interferers at 2405 and 2408 MHz respectively, at the given power level | | –34 | | dBm |
| Spurious emissions, 30 to 1000 MHz | Conducted measurement in a 50-Ω single-ended load. Suitable for systems targeting compliance with EN 300 328, EN 300 440 class 2, FCC CFR47, Part 15 and ARIB STD-T-66 | | –71 | | dBm |
| Spurious emissions, 1 to 12.75 GHz | Conducted measurement in a 50-Ω single-ended load. Suitable for systems targeting compliance with EN 300 328, EN 300 440 class 2, FCC CFR47, Part 15 and ARIB STD-T-66 | | –62 | | dBm |
| RSSI dynamic range | | | 70 | | dB |
| RSSI accuracy | | | ±4 | | dB |

(1) Numbers given as I/C dB.
(2) X / Y, where X is +N MHz and Y is –N MHz.
(3) Excluding one exception at $F_{wanted}$ / 2, per Bluetooth Specification.

## 8.11 1-Mbps GFSK (Bluetooth low energy) – TX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Output power, highest setting | Differential mode, delivered to a single-ended 50-Ω load through a balun | | 5 | | dBm |
| Output power, highest setting | Measured on CC2650EM-4XS, delivered to a single-ended 50-Ω load | | 2 | | dBm |
| Output power, lowest setting | Delivered to a single-ended 50-Ω load through a balun | | –21 | | dBm |
| Spurious emission conducted measurement(1) | f < 1 GHz, outside restricted bands | | –43 | | dBm |
| | f < 1 GHz, restricted bands ETSI | | –65 | | dBm |
| | f < 1 GHz, restricted bands FCC | | –71 | | dBm |
| | f > 1 GHz, including harmonics | | –46 | | dBm |

(1) Suitable for systems targeting compliance with worldwide radio-frequency regulations ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan).

## 8.12 2-Mbps GFSK (Bluetooth 5) – RX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Receiver sensitivity | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | –91 | | dBm |
| Receiver saturation | Differential mode. Measured at the CC2650EM-5XD SMA connector, BER = $10^{-3}$ | | 3 | | dBm |
| Frequency error tolerance | Difference between the incoming carrier frequency and the internally generated carrier frequency | –300 | | 500 | kHz |
| Data rate error tolerance | Difference between incoming data rate and the internally generated data rate | –1000 | | 1000 | ppm |
| Co-channel rejection(1) | Wanted signal at –67 dBm, modulated interferer in channel, BER = $10^{-3}$ | | –7 | | dB |
| Selectivity, ±2 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±2 MHz, Image frequency is at –2 MHz BER = $10^{-3}$ | | 8 / 4(2) | | dB |
| Selectivity, ±4 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±4 MHz, BER = $10^{-3}$ | | 31 / 26(2) | | dB |
| Selectivity, ±6 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ±6 MHz, BER = $10^{-3}$ | | 37 / 38(2) | | dB |
| Alternate channel rejection, ±7 MHz(1) | Wanted signal at –67 dBm, modulated interferer at ≥ ±7 MHz, BER = $10^{-3}$ | | 37 / 36(2) | | dB |
| Selectivity, image frequency(1) | Wanted signal at –67 dBm, modulated interferer at image frequency, BER = $10^{-3}$ | | 4 | | dB |
| Selectivity, image frequency ±2 MHz(1) | Note that Image frequency + 2 MHz is the Co-channel. Wanted signal at –67 dBm, modulated interferer at ±2 MHz from image frequency, BER = $10^{-3}$ | | –7 / 26(2) | | dB |
| Out-of-band blocking(3) | 30 MHz to 2000 MHz | | –33 | | dBm |
| Out-of-band blocking | 2003 MHz to 2399 MHz | | –15 | | dBm |
| Out-of-band blocking | 2484 MHz to 2997 MHz | | –12 | | dBm |
| Out-of-band blocking | 3000 MHz to 12.75 GHz | | –10 | | dBm |
| Intermodulation | Wanted signal at 2402 MHz, –64 dBm. Two interferers at 2408 and 2414 MHz respectively, at the given power level | | –45 | | dBm |

(1) Numbers given as I/C dB.
(2) X / Y, where X is +N MHz and Y is –N MHz.
(3) Excluding one exception at $F_{wanted}$ / 2, per Bluetooth Specification.

## 8.13 2-Mbps GFSK (Bluetooth 5) – TX

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, $f_{RF}$ = 2440 MHz, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Output power, highest setting | Differential mode, delivered to a single-ended 50-Ω load through a balun | | 5 | | dBm |
| Output power, highest setting | Measured on CC2650EM-4XS, delivered to a single-ended 50-Ω load | | 2 | | dBm |
| Output power, lowest setting | Delivered to a single-ended 50-Ω load through a balun | | –21 | | dBm |
| Spurious emission conducted measurement(1) | f < 1 GHz, outside restricted bands | | –43 | | dBm |
| | f < 1 GHz, restricted bands ETSI | | –65 | | dBm |
| | f < 1 GHz, restricted bands FCC | | –71 | | dBm |
| | f > 1 GHz, including harmonics | | –46 | | dBm |

(1) Suitable for systems targeting compliance with worldwide radio-frequency regulations ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan).

## 8.14 24-MHz Crystal Oscillator (XOSC_HF)

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.(1)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| ESR Equivalent series resistance(2) | 6 pF < $C_L$ ≤ 9 pF | | 20 | 60 | Ω |
| ESR Equivalent series resistance(2) | 5 pF < $C_L$ ≤ 6 pF | | | 80 | Ω |
| $L_M$ Motional inductance(2) | Relates to load capacitance ($C_L$ in Farads) | | < 1.6 × $10^{-24}$ / $C_L$ $^2$ | | H |
| $C_L$ Crystal load capacitance(2) (3) | | 5 | | 9 | pF |
| Crystal frequency(2) (4) | | | 24 | | MHz |
| Crystal frequency tolerance(2) (5) | | –40 | | 40 | ppm |
| Start-up time(4) (6) | | | 150 | | µs |

(1) Probing or otherwise stopping the crystal while the DC/DC converter is enabled may cause permanent damage to the device.
(2) The crystal manufacturer's specification must satisfy this requirement
(3) Adjustable load capacitance is integrated into the device. External load capacitors are not required
(4) Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V
(5) Includes initial tolerance of the crystal, drift over temperature, ageing and frequency pulling due to incorrect load capacitance. As per specification.
(6) Kick-started based on a temperature and aging compensated RCOSC_HF using precharge injection.

## 8.15 32.768-kHz Crystal Oscillator (XOSC_LF)

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Crystal frequency(1) | | | 32.768 | | kHz |
| Crystal frequency tolerance, Bluetooth low-energy applications(1) (2) | | –500 | | 500 | ppm |
| ESR Equivalent series resistance(1) | | | 30 | 100 | kΩ |
| $C_L$ Crystal load capacitance(1) | | 6 | | 12 | pF |

(1) The crystal manufacturer's specification must satisfy this requirement
(2) Includes initial tolerance of the crystal, drift over temperature, ageing and frequency pulling due to incorrect load capacitance. As per Bluetooth specification.

## 8.16 48-MHz RC Oscillator (RCOSC_HF)

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Frequency | | | 48 | | MHz |

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Uncalibrated frequency accuracy | | | ±1% | | |
| Calibrated frequency accuracy(1) | | | ±0.25% | | |
| Start-up time | | | 5 | | µs |

(1) Accuracy relative to the calibration source (XOSC_HF).

## 8.17 32-kHz RC Oscillator (RCOSC_LF)

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Calibrated frequency(1) | | | 32.8 | | kHz |
| Temperature coefficient | | | 80 | | ppm/°C |

(1) The frequency accuracy of the Real Time Clock (RTC) is not directly dependent on the frequency accuracy of the 32-kHz RC Oscillator. The RTC can be calibrated to an accuracy within ±500 ppm of 32.768 kHz by measuring the frequency error of RCOSC_LF relative to XOSC_HF and compensating the RTC tick speed. The procedure is explained in *Running Bluetooth® Low Energy on CC2640 Without 32 kHz Crystal*.

## 8.18 ADC Characteristics

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V and voltage scaling enabled, unless otherwise noted.(1)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| | Input voltage range | | 0 | | VDDS | V |
| | Resolution | | | 12 | | Bits |
| | Sample rate | | | | 200 | ksps |
| | Offset | Internal 4.3-V equivalent reference(2) | | 2 | | LSB |
| | Gain error | Internal 4.3-V equivalent reference(2) | | 2.4 | | LSB |
| DNL(3) | Differential nonlinearity | | | >–1 | | LSB |
| INL(4) | Integral nonlinearity | | | ±3 | | LSB |
| ENOB | Effective number of bits | Internal 4.3-V equivalent reference(2), 200 ksps, 9.6-kHz input tone | | 9.8 | | Bits |
| | | VDDS as reference, 200 ksps, 9.6-kHz input tone | | 10 | | |
| | | Internal 1.44-V reference, voltage scaling disabled, 32 samples average, 200 ksps, 300-Hz input tone | | 11.1 | | |
| THD | Total harmonic distortion | Internal 4.3-V equivalent reference(2), 200 ksps, 9.6-kHz input tone | | –65 | | dB |
| | | VDDS as reference, 200 ksps, 9.6-kHz input tone | | –69 | | |
| | | Internal 1.44-V reference, voltage scaling disabled, 32 samples average, 200 ksps, 300-Hz input tone | | –71 | | |
| SINAD, SNDR | Signal-to-noise and Distortion ratio | Internal 4.3-V equivalent reference(2), 200 ksps, 9.6-kHz input tone | | 60 | | dB |
| | | VDDS as reference, 200 ksps, 9.6-kHz input tone | | 63 | | |
| | | Internal 1.44-V reference, voltage scaling disabled, 32 samples average, 200 ksps, 300-Hz input tone | | 69 | | |
| SFDR | Spurious-free dynamic range | Internal 4.3-V equivalent reference(2), 200 ksps, 9.6-kHz input tone | | 67 | | dB |
| | | VDDS as reference, 200 ksps, 9.6-kHz input tone | | 68 | | |
| | | Internal 1.44-V reference, voltage scaling disabled, 32 samples average, 200 ksps, 300-Hz input tone | | 73 | | |
| | Conversion time | Serial conversion, time-to-output, 24-MHz clock | | 50 | | clock-cycles |
| | Current consumption | Internal 4.3-V equivalent reference(2) | | 0.66 | | mA |
| | Current consumption | VDDS as reference | | 0.75 | | mA |

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V and voltage scaling enabled, unless otherwise noted.(1)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Reference voltage | Equivalent fixed internal reference (input voltage scaling enabled). For best accuracy, the ADC conversion should be initiated through the TIRTOS API in order to include the gain/offset compensation factors stored in FCFG1. | | 4.3(2) (5) | | V |
| Reference voltage | Fixed internal reference (input voltage scaling disabled). For best accuracy, the ADC conversion should be initiated through the TIRTOS API in order to include the gain/offset compensation factors stored in FCFG1. This value is derived from the scaled value (4.3 V) as follows: Vref = 4.3 V × 1408 / 4095 | | 1.48 | | V |
| Reference voltage | VDDS as reference (Also known as *RELATIVE*) (input voltage scaling enabled) | | VDDS | | V |
| Reference voltage | VDDS as reference (Also known as *RELATIVE*) (input voltage scaling disabled) | | VDDS / 2.82(5) | | V |
| Input impedance | 200 ksps, voltage scaling enabled. Capacitive input, Input impedance depends on sampling frequency and sampling time | | >1 | | MΩ |

(1) Using IEEE Std 1241™-2010 for terminology and test methods.
(2) Input signal scaled down internally before conversion, as if voltage range was 0 to 4.3 V.
(3) No missing codes. Positive DNL typically varies from +0.3 to +3.5, depending on device (see 図 8-21).
(4) For a typical example, see 図 8-22.
(5) Applied voltage must be within absolute maximum ratings (セクション 8.1) at all times.

## 8.19 Temperature Sensor

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Resolution | | | 4 | | °C |
| Range | | –40 | | 85 | °C |
| Accuracy | | | ±5 | | °C |
| Supply voltage coefficient(1) | | | 3.2 | | °C/V |

(1) Automatically compensated when using supplied driver libraries.

## 8.20 Battery Monitor

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Resolution | | | 50 | | mV |
| Range | | 1.8 | | 3.8 | V |
| Accuracy | | | 13 | | mV |

## 8.21 Continuous Time Comparator

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Input voltage range | | 0 | | VDDS | V |
| External reference voltage | | 0 | | VDDS | V |
| Internal reference voltage | DCOUPL as reference | | 1.27 | | V |
| Offset | | | 3 | | mV |
| Hysteresis | | | <2 | | mV |
| Decision time | Step from –10 mV to 10 mV | | 0.72 | | µs |
| Current consumption when enabled(1) | | | 8.6 | | µA |

(1) Additionally, the bias module must be enabled when running in standby mode.

## 8.22 Low-Power Clocked Comparator

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Input voltage range | | 0 | | VDDS | V |
| Clock frequency | | | 32 | | kHz |
| Internal reference voltage, VDDS / 2 | | | 1.49–1.51 | | V |
| Internal reference voltage, VDDS / 3 | | | 1.01–1.03 | | V |
| Internal reference voltage, VDDS / 4 | | | 0.78–0.79 | | V |
| Internal reference voltage, DCOUPL / 1 | | | 1.25–1.28 | | V |
| Internal reference voltage, DCOUPL / 2 | | | 0.63–0.65 | | V |
| Internal reference voltage, DCOUPL / 3 | | | 0.42–0.44 | | V |
| Internal reference voltage, DCOUPL / 4 | | | 0.33–0.34 | | V |
| Offset | | | <5 | | mV |
| Hysteresis | | | <5 | | mV |
| Decision time | Step from –50 mV to 50 mV | | <1 | | clock-cycle |
| Current consumption when enabled | | | 362 | | nA |

## 8.23 Programmable Current Source

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| Current source programmable output range | | | 0.25–20 | | µA |
| Resolution | | | 0.25 | | µA |
| Current consumption(1) | Including current source at maximum programmable output | | 23 | | µA |

(1) Additionally, the bias module must be enabled when running in standby mode.

## 8.24 Synchronous Serial Interface (SSI)

$T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| S1(1) $t_{clk\_per}$ (SSIClk period) | Device operating as SLAVE | 12 | | 65024 | system clocks |
| S2(1) $t_{clk\_high}$ (SSIClk high time) | Device operating as SLAVE | | 0.5 | | $t_{clk\_per}$ |
| S3(1) $t_{clk\_low}$ (SSIClk low time) | Device operating as SLAVE | | 0.5 | | $t_{clk\_per}$ |
| S1 (TX only)(1) $t_{clk\_per}$ (SSIClk period) | One-way communication to SLAVE - Device operating as MASTER | 4 | | 65024 | system clocks |
| S1 (TX and RX)(1) $t_{clk\_per}$ (SSIClk period) | Normal duplex operation - Device operating as MASTER | 8 | | 65024 | system clocks |
| S2(1) $t_{clk\_high}$ (SSIClk high time) | Device operating as MASTER | | 0.5 | | $t_{clk\_per}$ |
| S3(1) $t_{clk\_low}$ (SSIClk low time) | Device operating as MASTER | | 0.5 | | $t_{clk\_per}$ |

(1) Refer to SSI timing diagrams 図 8-1, 図 8-2, and 図 8-3.

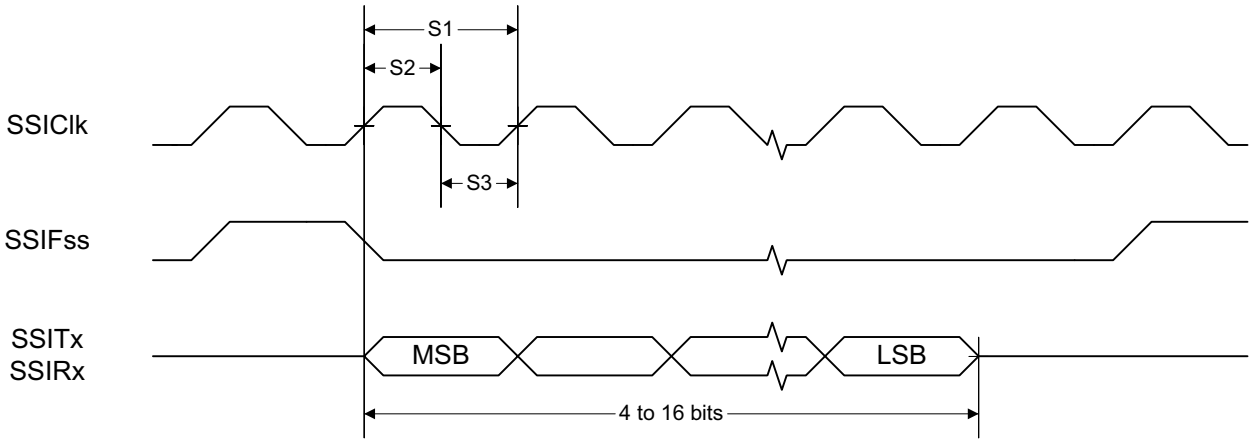



**図 8-1. SSI Timing for TI Frame Format (FRF = 01), Single Transfer Timing Measurement**

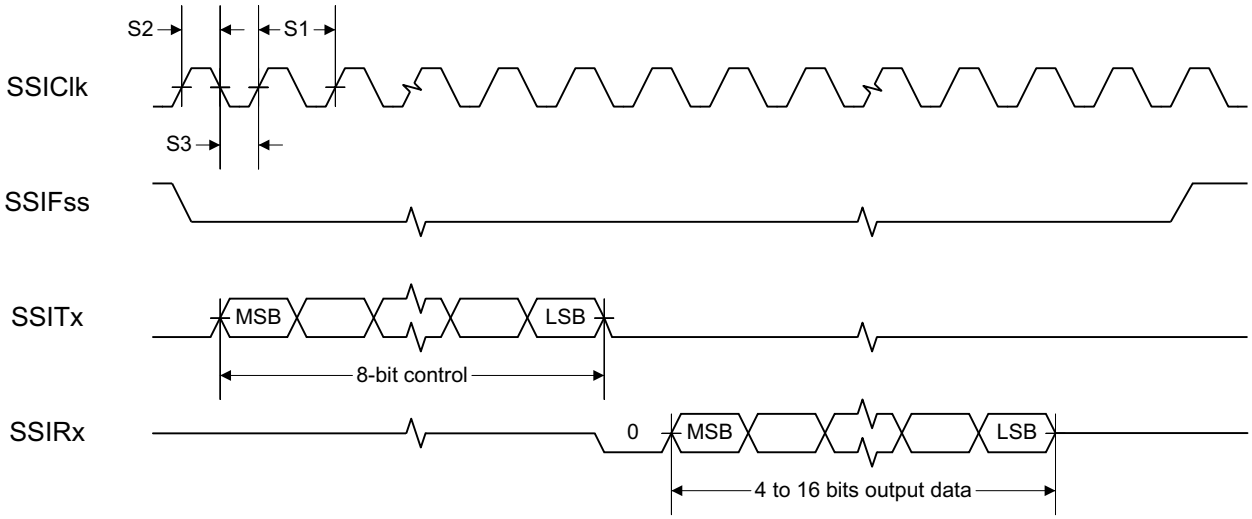



**図 8-2. SSI Timing for MICROWIRE Frame Format (FRF = 10), Single Transfer**

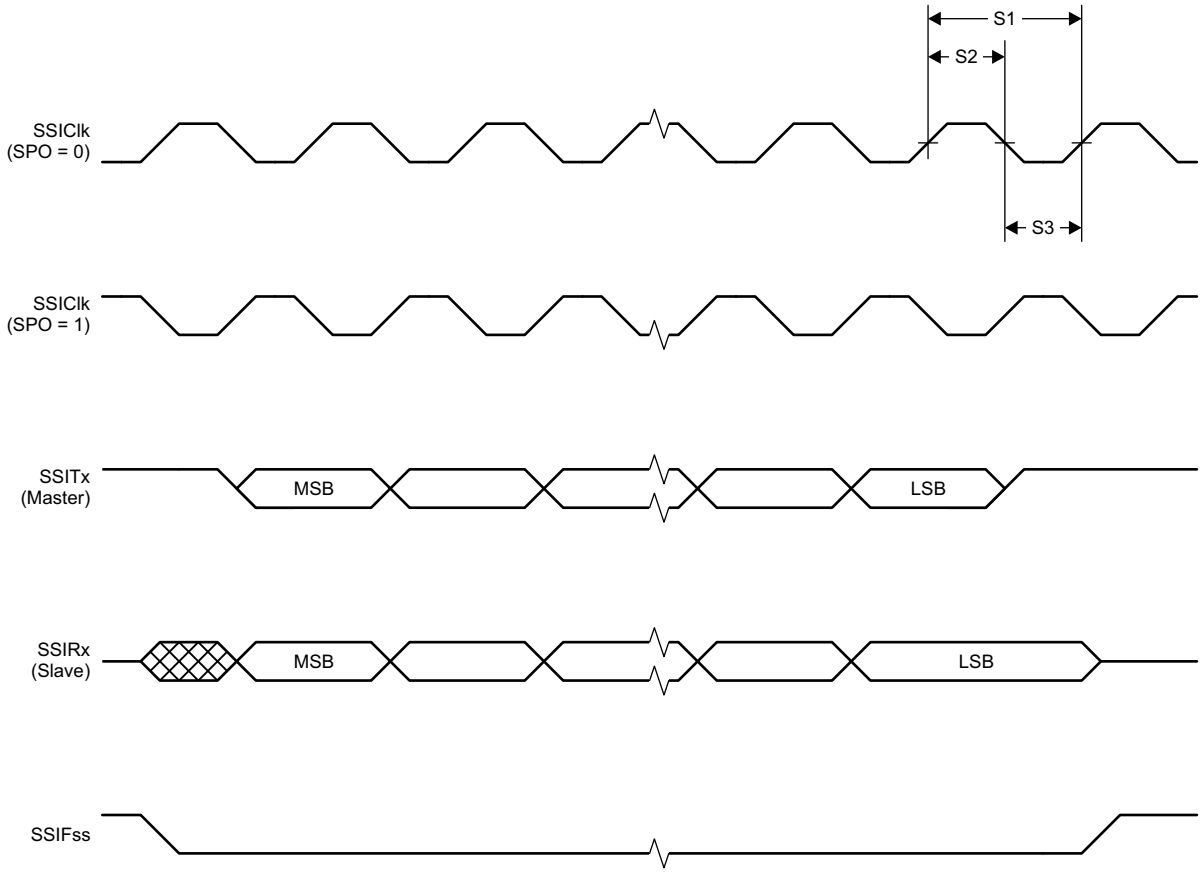



**図 8-3. SSI Timing for SPI Frame Format (FRF = 00), With SPH = 1**

## 8.25 DC Characteristics

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| **$T_A$ = 25°C, $V_{DDS}$ = 1.8 V** | | | | | |
| GPIO VOH at 8-mA load | IOCURR = 2, high-drive GPIOs only | 1.32 | 1.54 | | V |
| GPIO VOL at 8-mA load | IOCURR = 2, high-drive GPIOs only | | 0.26 | 0.32 | V |
| GPIO VOH at 4-mA load | IOCURR = 1 | 1.32 | 1.58 | | V |
| GPIO VOL at 4-mA load | IOCURR = 1 | | 0.21 | 0.32 | V |
| GPIO pullup current | Input mode, pullup enabled, Vpad = 0 V | | 71.7 | | µA |
| GPIO pulldown current | Input mode, pulldown enabled, Vpad = VDDS | | 21.1 | | µA |
| GPIO high/low input transition, no hysteresis | IH = 0, transition between reading 0 and reading 1 | | 0.88 | | V |
| GPIO low-to-high input transition, with hysteresis | IH = 1, transition voltage for input read as 0 → 1 | | 1.07 | | V |
| GPIO high-to-low input transition, with hysteresis | IH = 1, transition voltage for input read as 1 → 0 | | 0.74 | | V |
| GPIO input hysteresis | IH = 1, difference between 0 → 1 and 1 → 0 points | | 0.33 | | V |
| **$T_A$ = 25°C, $V_{DDS}$ = 3.0 V** | | | | | |
| GPIO VOH at 8-mA load | IOCURR = 2, high-drive GPIOs only | | 2.68 | | V |
| GPIO VOL at 8-mA load | IOCURR = 2, high-drive GPIOs only | | 0.33 | | V |
| GPIO VOH at 4-mA load | IOCURR = 1 | | 2.72 | | V |

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| GPIO VOL at 4-mA load | IOCURR = 1 | | 0.28 | | V |

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| | **$T_A$ = 25°C, $V_{DDS}$ = 3.8 V** | | | | |
| GPIO pullup current | Input mode, pullup enabled, Vpad = 0 V | | 277 | | µA |
| GPIO pulldown current | Input mode, pulldown enabled, Vpad = VDDS | | 113 | | µA |
| GPIO high/low input transition, no hysteresis | IH = 0, transition between reading 0 and reading 1 | | 1.67 | | V |
| GPIO low-to-high input transition, with hysteresis | IH = 1, transition voltage for input read as 0 → 1 | | 1.94 | | V |
| GPIO high-to-low input transition, with hysteresis | IH = 1, transition voltage for input read as 1 → 0 | | 1.54 | | V |
| GPIO input hysteresis | IH = 1, difference between 0 → 1 and 1 → 0 points | | 0.4 | | V |
| | **$T_A$ = 25°C** | | | | |
| VIH | Lowest GPIO input voltage reliably interpreted as a «High» | | | 0.8 | VDDS(1) |
| VIL | Highest GPIO input voltage reliably interpreted as a «Low» | 0.2 | | | VDDS(1) |

(1) Each GPIO is referenced to a specific VDDS pin. See the technical reference manual listed in セクション 11.3 for more details.

## 8.26 Thermal Resistance Characteristics

| NAME | DESCRIPTION | RSM (°C/W)(1) (2) | RHB (°C/W)(1) (2) | RGZ (°C/W)(1) (2) | YFV (°C/W)(1) (2) |
|---|---|---|---|---|---|
| $R\theta_{JA}$ | Junction-to-ambient thermal resistance | 36.9 | 32.8 | 29.6 | 76.2 |
| $R\theta_{JC(top)}$ | Junction-to-case (top) thermal resistance | 30.3 | 24.0 | 15.7 | 0.3 |
| $R\theta_{JB}$ | Junction-to-board thermal resistance | 7.6 | 6.8 | 6.2 | 16.3 |
| $Psi_{JT}$ | Junction-to-top characterization parameter | 0.4 | 0.3 | 0.3 | 1.8 |
| $Psi_{JB}$ | Junction-to-board characterization parameter | 7.4 | 6.8 | 6.2 | 16.3 |
| $R\theta_{JC(bot)}$ | Junction-to-case (bottom) thermal resistance | 2.1 | 1.9 | 1.9 | N/A |

(1) °C/W = degrees Celsius per watt.
(2) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC [$R\theta_{JC}$] value, which is based on a JEDEC-defined 1S0P system) and will change based on environment as well as application. For more information, see these EIA/JEDEC standards:

- JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air)*.
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*.
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*.
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*.

For RSM, RHB, and RGZ, power dissipation of 2 W and an ambient temperature of 70°C is assumed. For YFV, power dissipation of 1.3 W and ambient temperature of 25°C is assumed.

## 8.27 Timing Requirements

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| Rising supply-voltage slew rate | | 0 | | 100 | mV/µs |
| Falling supply-voltage slew rate | | 0 | | 20 | mV/µs |
| Falling supply-voltage slew rate, with low-power flash settings(1) | | | | 3 | mV/µs |
| Positive temperature gradient in standby(2) | No limitation for negative temperature gradient, or outside standby mode | | | 5 | °C/s |
| **CONTROL INPUT AC CHARACTERISTICS(3)** | | | | | |
| RESET_N low duration | | 1 | | | µs |

(1) For smaller coin cell batteries, with high worst-case end-of-life equivalent source resistance, a 22-µF VDDS input capacitor (see 図 10-1) must be used to ensure compliance with this slew rate.
(2) Applications using RCOSC_LF as sleep timer must also consider the drift in frequency caused by a change in temperature (see セクション 8.17).

(3) $T_A$ = –40°C to +85°C, $V_{DDS}$ = 1.7 V to 3.8 V, unless otherwise noted.

## 8.28 Switching Characteristics

Measured on the TI CC2650EM-5XD reference design with $T_c$ = 25°C, $V_{DDS}$ = 3.0 V, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|
| **WAKEUP AND TIMING** | | | | | |
| Idle → Active | | | 14 | | µs |
| Standby → Active | | | 151 | | µs |
| Shutdown → Active | | | 1015 | | µs |

## 8.29 Typical Characteristics

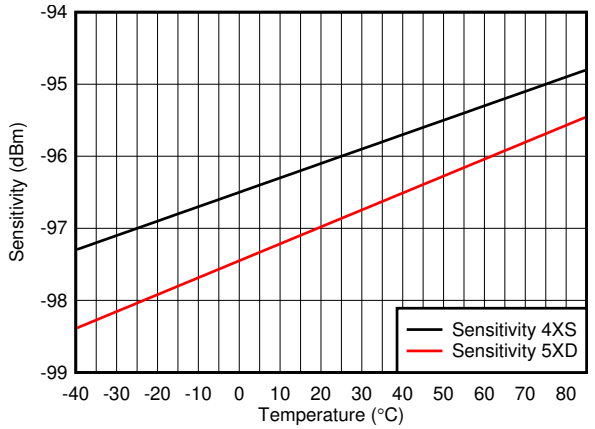



図 8-4. BLE Sensitivity vs Temperature

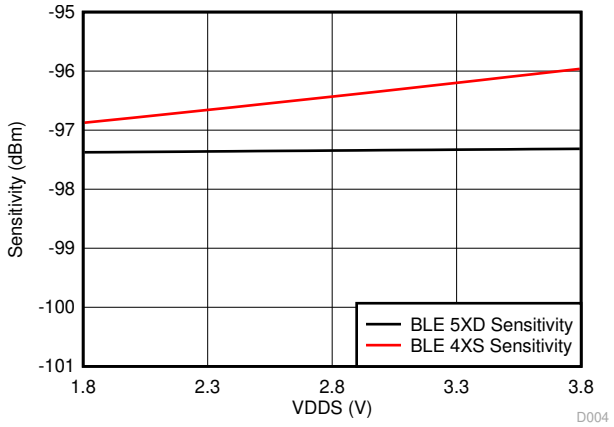



図 8-5. BLE Sensitivity vs Supply Voltage (VDDS)

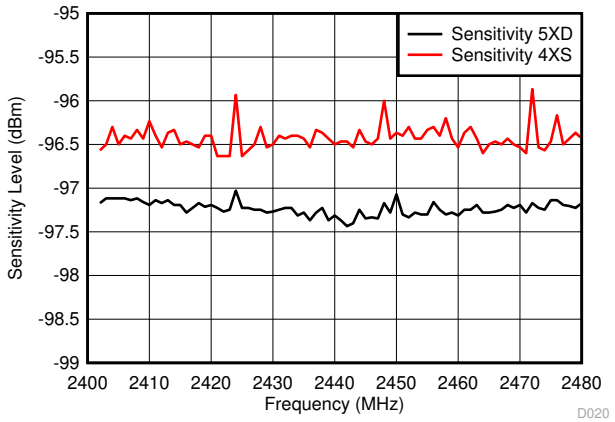



図 8-6. BLE Sensitivity vs Channel Frequency

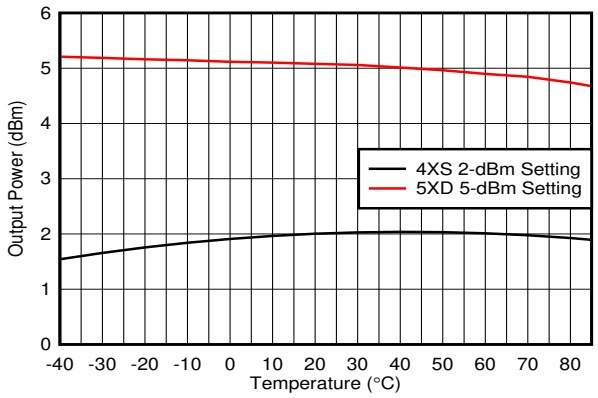



図 8-7. TX Output Power vs Temperature

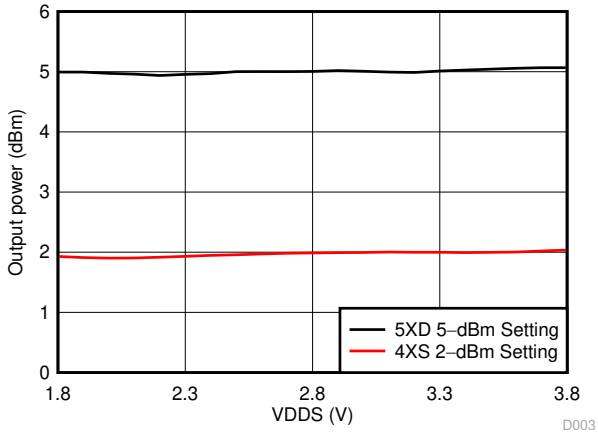



図 8-8. TX Output Power vs Supply Voltage (VDDS)

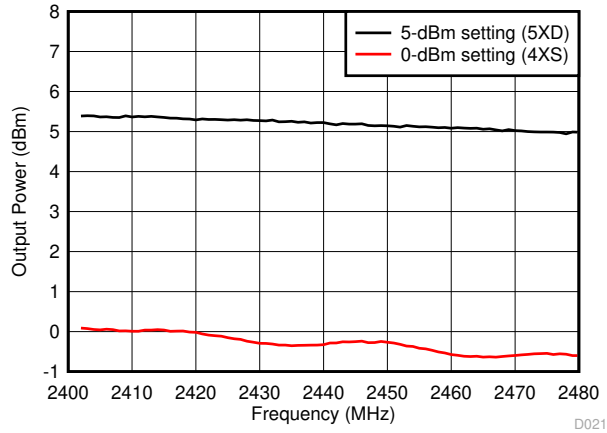



図 8-9. TX Output Power vs Channel Frequency

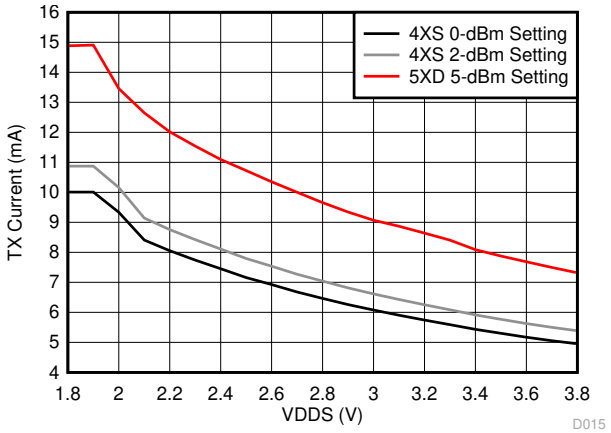



**図 8-10. TX Current Consumption vs Supply Voltage (VDDS)**

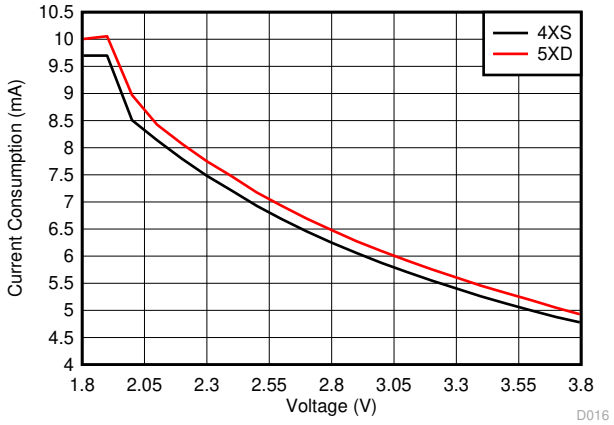



**図 8-11. RX Mode Current vs Supply Voltage (VDDS)**

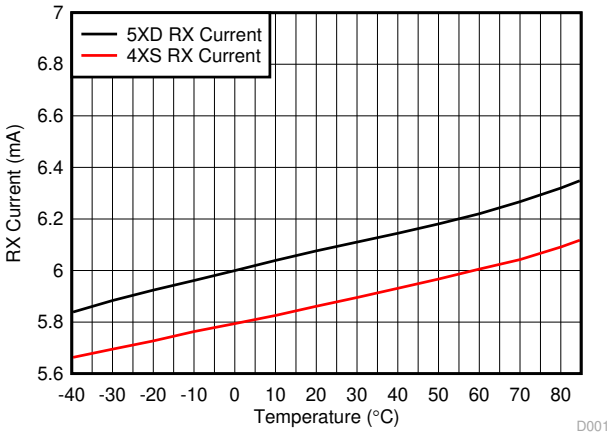



**図 8-12. RX Mode Current Consumption vs Temperature**

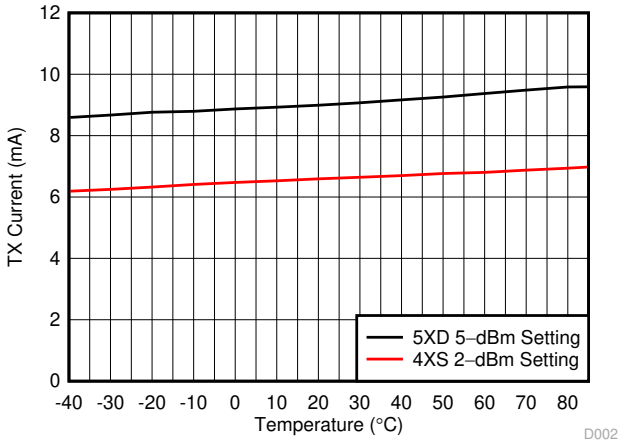



**図 8-13. TX Mode Current Consumption vs Temperature**

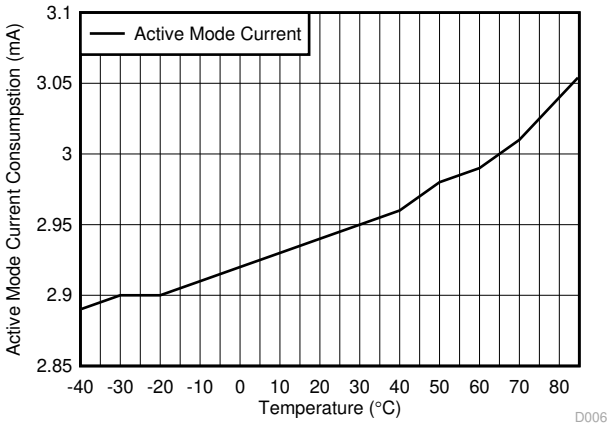



**図 8-14. Active Mode (MCU Running, No Peripherals) Current Consumption vs Temperature**

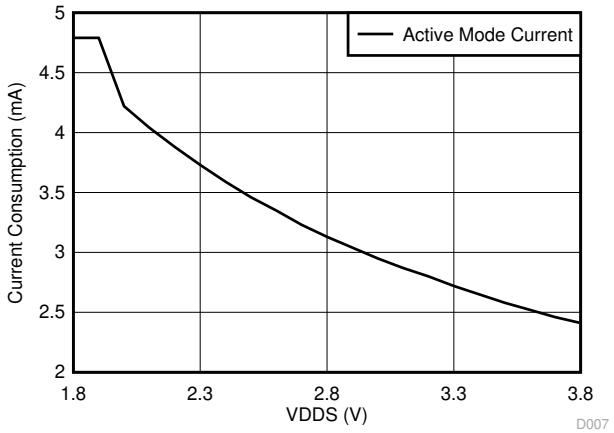



**図 8-15. Active Mode (MCU Running, No Peripherals) Current Consumption vs Supply Voltage (VDDS)**

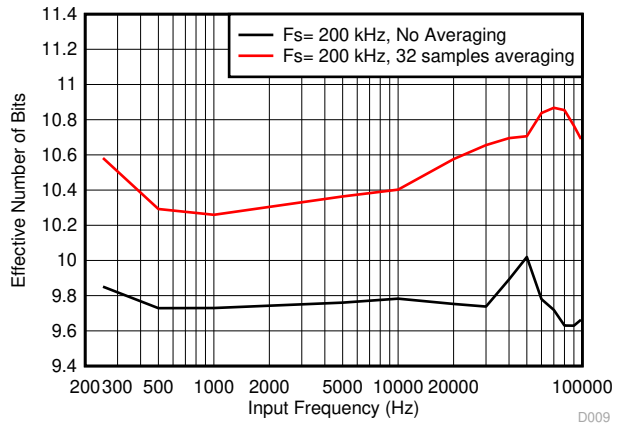



**図 8-16. SoC ADC Effective Number of Bits vs Input Frequency (Internal Reference, Scaling enabled)**

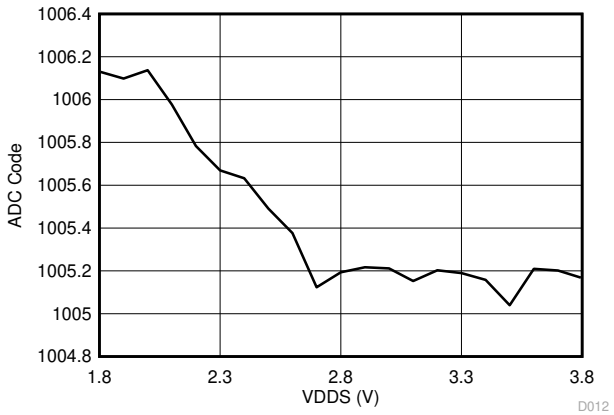



**図 8-17. SoC ADC Output vs Supply Voltage (Fixed Input, Internal Reference)**

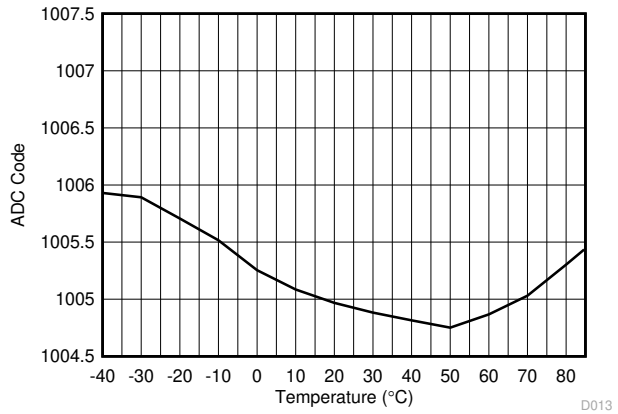



**図 8-18. SoC ADC Output vs Temperature (Fixed Input, Internal Reference)**

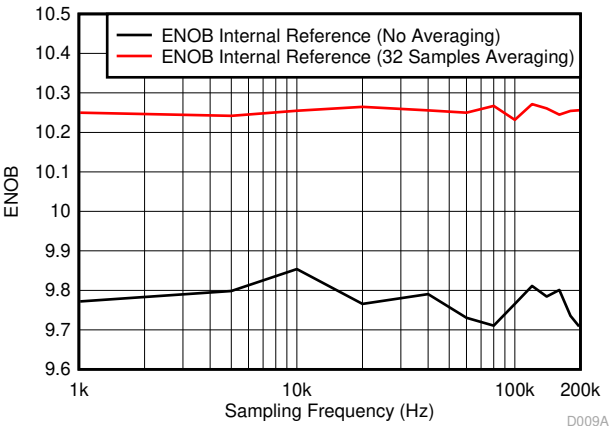



**図 8-19. SoC ADC ENOB vs Sampling Frequency (Scaling enabled, input frequency = FS / 10)**

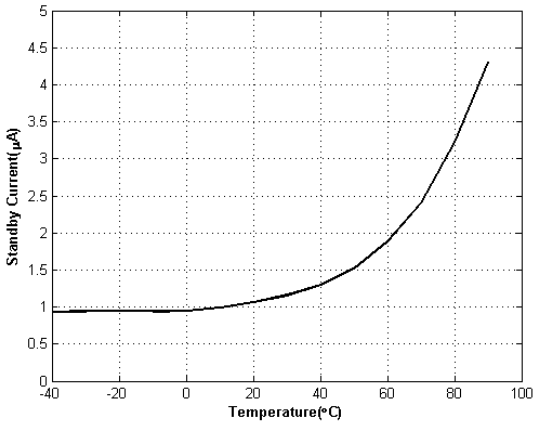



**図 8-20. Standby Mode Supply Current vs Temperature**

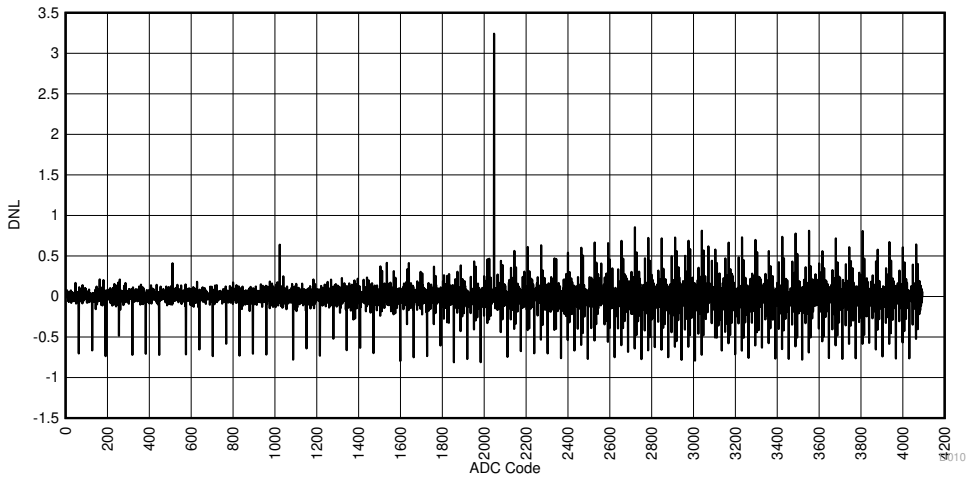



**図 8-21. SoC ADC DNL vs ADC Code (Internal Reference)**

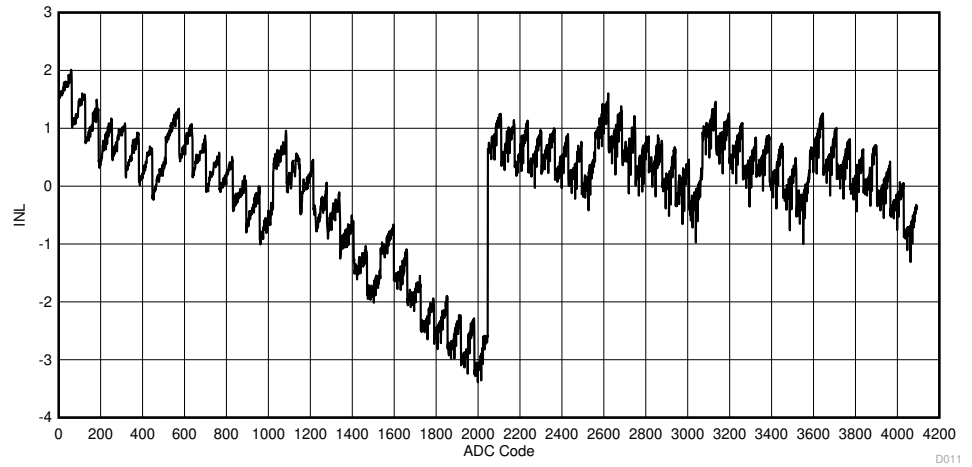


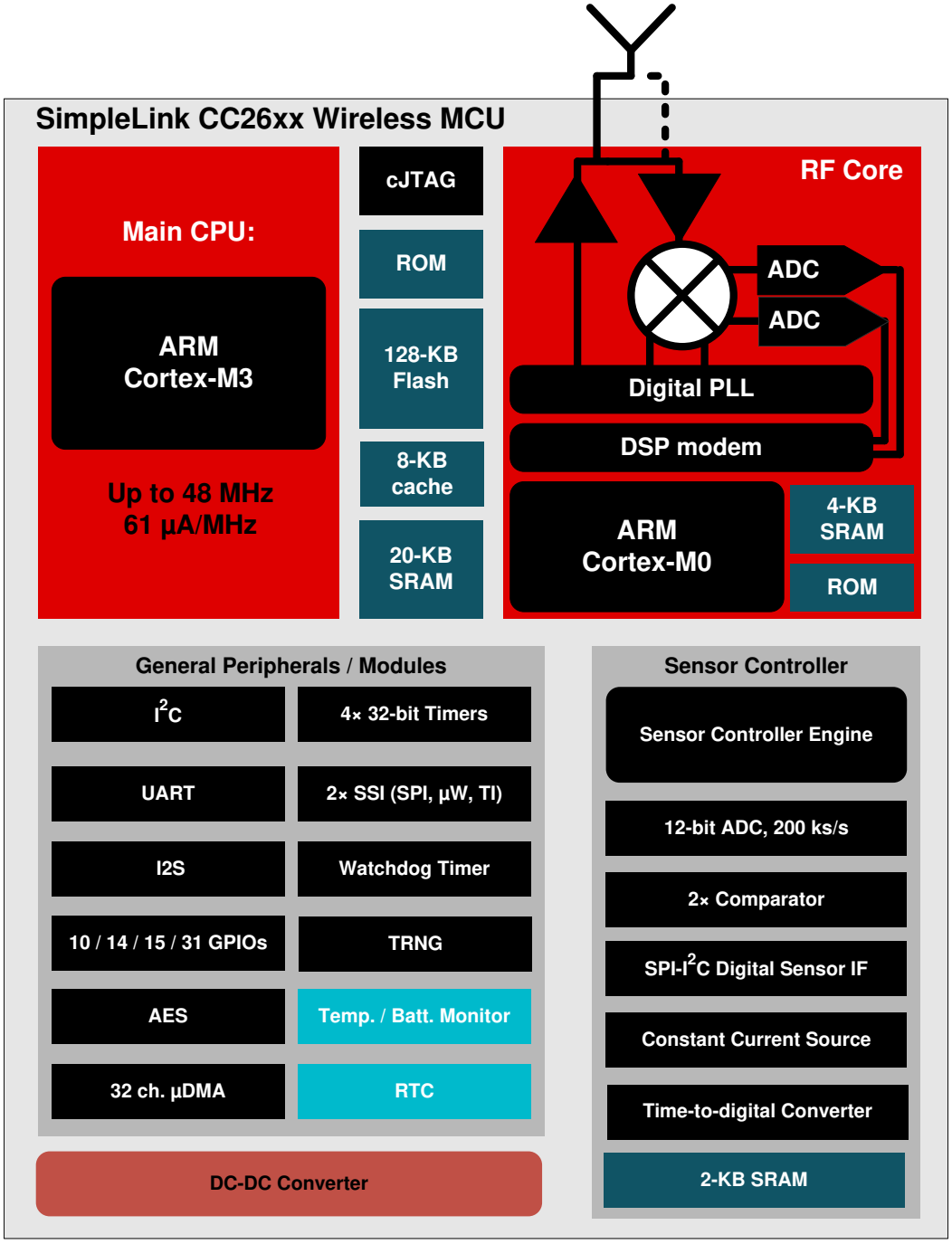

**図 8-22. SoC ADC INL vs ADC Code (Internal Reference)**

# 9 Detailed Description

## 9.1 Overview

The core modules of the CC26xx product family are shown in セクション 9.2.

## 9.2 Functional Block Diagram



## 9.3 Main CPU

The SimpleLink™ CC2640R2F Wireless MCU contains an Arm® Cortex®-M3 (CM3) 32-bit CPU, which runs the application and the higher layers of the protocol stack.

The CM3 processor provides a high-performance, low-cost platform that meets the system requirements of minimal memory implementation, and low-power consumption, while delivering outstanding computational performance and exceptional system response to interrupts.

Arm® Cortex®-M3 features include:

- 32-bit Arm® Cortex®-M3 architecture optimized for small-footprint embedded applications
- Outstanding processing performance combined with fast interrupt handling
- Arm® Thumb®-2 mixed 16- and 32-bit instruction set delivers the high performance expected of a 32-bit Arm® core in a compact memory size usually associated with 8- and 16-bit devices, typically in the range of a few kilobytes of memory for microcontroller-class applications:
  - Single-cycle multiply instruction and hardware divide
  - Atomic bit manipulation (bit-banding), delivering maximum memory use and streamlined peripheral control
  - Unaligned data access, enabling data to be efficiently packed into memory
- Fast code execution permits slower processor clock or increases sleep mode time
- Harvard architecture characterized by separate buses for instruction and data
- Efficient processor core, system, and memories
- Hardware division and fast digital-signal-processing oriented multiply accumulate
- Saturating arithmetic for signal processing
- Deterministic, high-performance interrupt handling for time-critical applications
- Enhanced system debug with extensive breakpoint and trace capabilities
- Serial wire trace reduces the number of pins required for debugging and tracing
- Migration from the ARM7™ processor family for better performance and power efficiency
- Optimized for single-cycle flash memory use
- Ultra-low-power consumption with integrated sleep modes
- 1.25 DMIPS per MHz

## 9.4 RF Core

The RF Core contains an Arm® Cortex®-M0 processor that interfaces the analog RF and base-band circuits, handles data to and from the system side, and assembles the information bits in a given packet structure. The RF core offers a high level, command-based API to the main CPU.

The RF core is capable of autonomously handling the time-critical aspects of the radio protocols (Bluetooth® low energy) thus offloading the main CPU and leaving more resources for the user application.

The RF core has a dedicated 4-KB SRAM block and runs initially from separate ROM memory. The Arm® Cortex®-M0 processor is not programmable by customers.

## 9.5 Sensor Controller

The Sensor Controller contains circuitry that can be selectively enabled in standby mode. The peripherals in this domain may be controlled by the Sensor Controller Engine, which is a proprietary power-optimized CPU. This CPU can read and monitor sensors or perform other tasks autonomously, thereby significantly reducing power consumption and offloading the main CM3 CPU. The GPIOs that can be connected to the Sensor Controller are listed in 表 9-1.

The Sensor Controller is set up using a PC-based configuration tool, called Sensor Controller Studio, and potential use cases may be (but are not limited to):

- Analog sensors using integrated ADC
- Digital sensors using GPIOs, bit-banged $I^2C$, and SPI
- UART communication for sensor reading or debugging
- Capacitive sensing
- Waveform generation
- Pulse counting
- Keyboard scan
- Quadrature decoder for polling rotation sensors
- Oscillator calibration

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Texas Instruments provides application examples for some of these use cases, but not for all of them.

The peripherals in the Sensor Controller include the following:

- The low-power clocked comparator can be used to wake the device from any state in which the comparator is active. A configurable internal reference can be used in conjunction with the comparator. The output of the comparator can also be used to trigger an interrupt or the ADC.
- Capacitive sensing functionality is implemented through the use of a constant current source, a time-to-digital converter, and a comparator. The continuous time comparator in this block can also be used as a higher-accuracy alternative to the low-power clocked comparator. The Sensor Controller will take care of baseline tracking, hysteresis, filtering and other related functions.
- The ADC is a 12-bit, 200-ksamples/s ADC with eight inputs and a built-in voltage reference. The ADC can be triggered by many different sources, including timers, I/O pins, software, the analog comparator, and the RTC.
- The Sensor Controller also includes a SPI–$I^2C$ digital interface.
- The analog modules can be connected to up to eight different GPIOs.

The peripherals in the Sensor Controller can also be controlled from the main application processor.

**表 9-1. GPIOs Connected to the Sensor Controller(1)**

| ANALOG CAPABLE | 7 × 7 RGZ DIO NUMBER | 5 × 5 RHB DIO NUMBER | 2.7 × 2.7 YFV DIO NUMBER | 4 × 4 RSM DIO NUMBER |
|---|---|---|---|---|
| Y | 30 | 14 | | |
| Y | 29 | 13 | 13 | |
| Y | 28 | 12 | 12 | |
| Y | 27 | 11 | 11 | 9 |
| Y | 26 | 9 | 9 | 8 |
| Y | 25 | 10 | 10 | 7 |
| Y | 24 | 8 | 8 | 6 |
| Y | 23 | 7 | 7 | 5 |
| N | 7 | 4 | 4 | 2 |
| N | 6 | 3 | 3 | 1 |
| N | 5 | 2 | 2 | 0 |

**表 9-1. GPIOs Connected to the Sensor Controller(1) (continued)**

| ANALOG CAPABLE | 7 × 7 RGZ DIO NUMBER | 5 × 5 RHB DIO NUMBER | 2.7 × 2.7 YFV DIO NUMBER | 4 × 4 RSM DIO NUMBER |
|---|---|---|---|---|
| N | 4 | 1 | 1 | |
| N | 3 | 0 | 0 | |
| N | 2 | | | |
| N | 1 | | | |
| N | 0 | | | |

(1) Depending on the package size, up to 16 pins can be connected to the Sensor Controller. Up to 8 of these pins can be connected to analog modules.

## 9.6 Memory

The Flash memory provides nonvolatile storage for code and data. The Flash memory is in-system programmable.

The SRAM (static RAM) can be used for both storage of data and execution of code and is split into two 4-KB blocks and two 6-KB blocks. Retention of the RAM contents in standby mode can be enabled or disabled individually for each block to minimize power consumption. In addition, if flash cache is disabled, the 8-KB cache can be used as a general-purpose RAM.

The ROM provides preprogrammed embedded TI-RTOS kernel, Driverlib, and lower layer protocol stack software ( Bluetooth low energy Controller). It also contains a bootloader that can be used to reprogram the device using SPI or UART. For CC2640R2Fxxx devices, the ROM contains Bluetooth 4.2 low energy host- and controller software libraries, leaving more of the flash memory available for the customer application.

## 9.7 Debug

The on-chip debug support is done through a dedicated cJTAG (IEEE 1149.7) or JTAG (IEEE 1149.1) interface.

## 9.8 Power Management

To minimize power consumption, the CC2640R2F device supports a number of power modes and power management features (see 表 9-2).

**表 9-2. Power Modes**

| MODE | SOFTWARE CONFIGURABLE POWER MODES | | | | RESET PIN HELD |
|---|---|---|---|---|---|
| | ACTIVE | IDLE | STANDBY | SHUTDOWN | |
| **CPU** | Active | Off | Off | Off | Off |
| **Flash** | On | Available | Off | Off | Off |
| **SRAM** | On | On | On | Off | Off |
| **Radio** | Available | Available | Off | Off | Off |
| **Supply System** | On | On | Duty Cycled | Off | Off |
| Current | 1.45 mA + 31 µA/MHz | 650 µA | 1 µA | 0.15 µA | 0.1 µA |
| Wake-up Time to CPU Active(1) | – | 14 µs | 151 µs | 1015 µs | 1015 µs |
| Register Retention | Full | Full | Partial | No | No |
| SRAM Retention | Full | Full | Full | No | No |
| High-Speed Clock | XOSC_HF or RCOSC_HF | XOSC_HF or RCOSC_HF | Off | Off | Off |
| Low-Speed Clock | XOSC_LF or RCOSC_LF | XOSC_LF or RCOSC_LF | XOSC_LF or RCOSC_LF | Off | Off |
| Peripherals | Available | Available | Off | Off | Off |
| Sensor Controller | Available | Available | Available | Off | Off |
| Wake up on RTC | Available | Available | Available | Off | Off |
| Wake up on Pin Edge | Available | Available | Available | Available | Off |

**表 9-2. Power Modes (continued)**

| MODE | SOFTWARE CONFIGURABLE POWER MODES | | | | RESET PIN HELD |
|---|---|---|---|---|---|
| | ACTIVE | IDLE | STANDBY | SHUTDOWN | |
| Wake up on Reset Pin | Available | Available | Available | Available | Available |
| Brown Out Detector (BOD) | Active | Active | Duty Cycled | Off | N/A |
| Power On Reset (POR) | Active | Active | Active | Active | N/A |

(1) Not including RTOS overhead

In active mode, the application CM3 CPU is actively executing code. Active mode provides normal operation of the processor and all of the peripherals that are currently enabled. The system clock can be any available clock source (see 表 9-2).

In idle mode, all active peripherals can be clocked, but the Application CPU core and memory are not clocked and no code is executed. Any interrupt event will bring the processor back into active mode.

In standby mode, only the always-on domain (AON) is active. An external wake-up event, RTC event, or sensor-controller event is required to bring the device back to active mode. MCU peripherals with retention do not need to be reconfigured when waking up again, and the CPU continues execution from where it went into standby mode. All GPIOs are latched in standby mode.

In shutdown mode, the device is turned off entirely, including the AON domain and the Sensor Controller. The I/Os are latched with the value they had before entering shutdown mode. A change of state on any I/O pin defined as a *wake-up from Shutdown pin* wakes up the device and functions as a reset trigger. The CPU can differentiate between a reset in this way, a reset-by-reset pin, or a power-on-reset by reading the reset status register. The only state retained in this mode is the latched I/O state and the Flash memory contents.

The Sensor Controller is an autonomous processor that can control the peripherals in the Sensor Controller independently of the main CPU, which means that the main CPU does not have to wake up, for example, to execute an ADC sample or poll a digital sensor over SPI. The main CPU saves both current and wake-up time that would otherwise be wasted. The Sensor Controller Studio enables the user to configure the sensor controller and choose which peripherals are controlled and which conditions wake up the main CPU.

## 9.9 Clock Systems

The CC2640R2F supports two external and two internal clock sources.

A 24-MHz crystal is required as the frequency reference for the radio. This signal is doubled internally to create a 48-MHz clock.

The 32-kHz crystal is optional. *Bluetooth* low energy requires a slow-speed clock with better than ±500 ppm accuracy if the device is to enter any sleep mode while maintaining a connection. The internal 32-kHz RC oscillator can in some use cases be compensated to meet the requirements. The low-speed crystal oscillator is designed for use with a 32-kHz watch-type crystal.

The internal high-speed oscillator (48-MHz) can be used as a clock source for the CPU subsystem.

The internal low-speed oscillator (32.768-kHz) can be used as a reference if the low-power crystal oscillator is not used.

The 32-kHz clock source can be used as external clocking reference through GPIO.

## 9.10 General Peripherals and Modules

The I/O controller controls the digital I/O pins and contains multiplexer circuitry to allow a set of peripherals to be assigned to I/O pins in a flexible manner. All digital I/Os are interrupt and wake-up capable, have a programmable pullup and pulldown function and can generate an interrupt on a negative or positive edge (configurable). When configured as an output, pins can function as either push-pull or open-drain. Five GPIOs have high drive capabilities (marked in **bold** in セクション 7).

The SSIs are synchronous serial interfaces that are compatible with SPI, MICROWIRE, and Texas Instruments synchronous serial interfaces. The SSIs support both SPI master and slave up to 4 MHz.

The UART implements a universal asynchronous receiver/transmitter function. It supports flexible baud-rate generation up to a maximum of 3 Mbps .

Timer 0 is a general-purpose timer module (GPTM), which provides two 16-bit timers. The GPTM can be configured to operate as a single 32-bit timer, dual 16-bit timers or as a PWM module.

Timer 1, Timer 2, and Timer 3 are also GPTMs. Each of these timers is functionally equivalent to Timer 0.

In addition to these four timers, the RF core has its own timer to handle timing for RF protocols; the RF timer can be synchronized to the RTC.

The $I^2C$ interface is used to communicate with devices compatible with the $I^2C$ standard. The $I^2C$ interface is capable of 100-kHz and 400-kHz operation, and can serve as both $I^2C$ master and $I^2C$ slave.

The TRNG module provides a true, nondeterministic noise source for the purpose of generating keys, initialization vectors (IVs), and other random number requirements. The TRNG is built on 24 ring oscillators that create unpredictable output to feed a complex nonlinear combinatorial circuit.

The watchdog timer is used to regain control if the system fails due to a software error after an external device fails to respond as expected. The watchdog timer can generate an interrupt or a reset when a predefined time-out value is reached.

The device includes a direct memory access (µDMA) controller. The µDMA controller provides a way to offload data transfer tasks from the CM3 CPU, allowing for more efficient use of the processor and the available bus bandwidth. The µDMA controller can perform transfer between memory and peripherals. The µDMA controller has dedicated channels for each supported on-chip module and can be programmed to automatically perform transfers between peripherals and memory as the peripheral is ready to transfer more data. Some features of the µDMA controller include the following (this is not an exhaustive list):

- Highly flexible and configurable channel operation of up to 32 channels
- Transfer modes:
  - Memory-to-memory
  - Memory-to-peripheral
  - Peripheral-to-memory
  - Peripheral-to-peripheral
- Data sizes of 8, 16, and 32 bits

The AON domain contains circuitry that is always enabled, except for in Shutdown (where the digital supply is off). This circuitry includes the following:

- The RTC can be used to wake the device from any state where it is active. The RTC contains three compare and one capture registers. With software support, the RTC can be used for clock and calendar operation. The RTC is clocked from the 32-kHz RC oscillator or crystal. The RTC can also be compensated to tick at the correct frequency even when the internal 32-kHz RC oscillator is used instead of a crystal.
- The battery monitor and temperature sensor are accessible by software and give a battery status indication as well as a coarse temperature measure.

## 9.11 Voltage Supply Domains

The CC2640R2F device can interface to two or three different voltage domains depending on the package type. On-chip level converters ensure correct operation as long as the signal voltage on each input/output pin is set with respect to the corresponding supply pin (VDDS, VDDS2 or VDDS3). 表 9-3 lists the pin-to-VDDS mapping.

**表 9-3. Pin Function to VDDS Mapping Table**

| | Package | | | |
|---|---|---|---|---|
| | **VQFN 7 × 7 (RGZ)** | **VQFN 5 × 5 (RHB)** | **VQFN 4 × 4 (RSM)** | **DSBGA (YFV)** |
| **VDDS**(1) | DIO 23–30<br>Reset_N | DIO 7–14<br>Reset_N | DIO 5–9<br>Reset_N | DIO 7–13<br>Reset_N |
| **VDDS2** | DIO 0–11 | DIO 0–6<br>JTAG | DIO 0–4<br>JTAG | DIO 0–6<br>JTAG |
| **VDDS3** | DIO 12–22<br>JTAG | N/A | N/A | N/A |

(1) VDDS_DCDC must be connected to VDDS on the PCB.

## 9.12 System Architecture

Depending on the product configuration, CC26xx can function either as a Wireless Network Processor (WNP—an IC running the wireless protocol stack, with the application running on a separate MCU), or as a System-on-Chip (SoC), with the application and protocol stack running on the Arm® Cortex®-M3 core inside the device.

In the first case, the external host MCU communicates with the device using SPI or UART. In the second case, the application must be written according to the application framework supplied with the wireless protocol stack.

# 10 Application, Implementation, and Layout

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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.

## 10.1 Application Information

Very few external components are required for the operation of the CC2640R2F device. This section provides some general information about the various configuration options when using the CC2640R2F in an application, and then shows two examples of application circuits with schematics and layout. This is only a small selection of the many application circuit examples available as complete reference designs from the product folder on www.ti.com.

図 10-1 shows the various RF front-end configuration options. The RF front end can be used in differential- or single-ended configurations with the options of having internal or external biasing. These options allow for various trade-offs between cost, board space, and RF performance. Differential operation with external bias gives the best performance while single-ended operation with internal bias gives the least amount of external components and the lowest power consumption. Reference designs exist for each of these options.

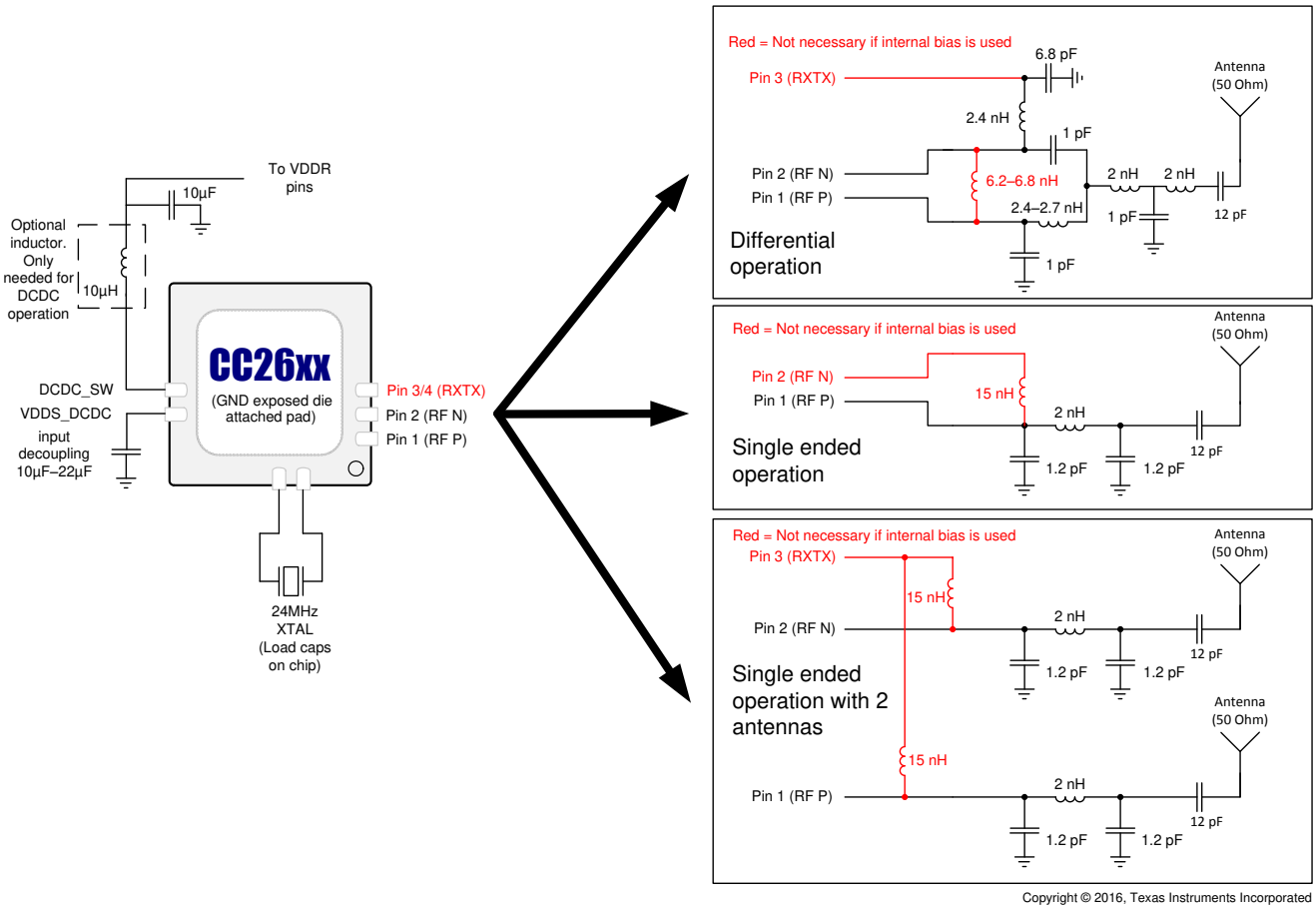




**図 10-1. CC2640R2F Application Circuit**

図 10-2 shows the various supply voltage configuration options. Not all power supply decoupling capacitors or digital I/Os are shown. Exact pin positions will vary between the different package options. For a detailed overview of power supply decoupling and wiring, see the TI reference designs and the CC26xx technical reference manual (セクション 11.3).

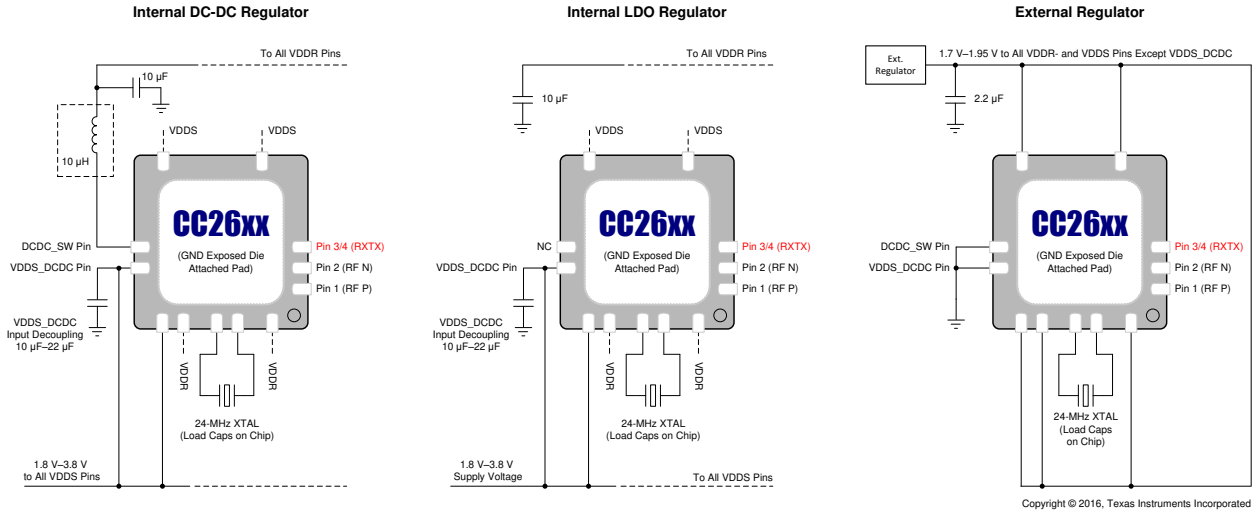


**図 10-2. Supply Voltage Configurations**

## 10.2 5 × 5 External Differential (5XD) Application Circuit

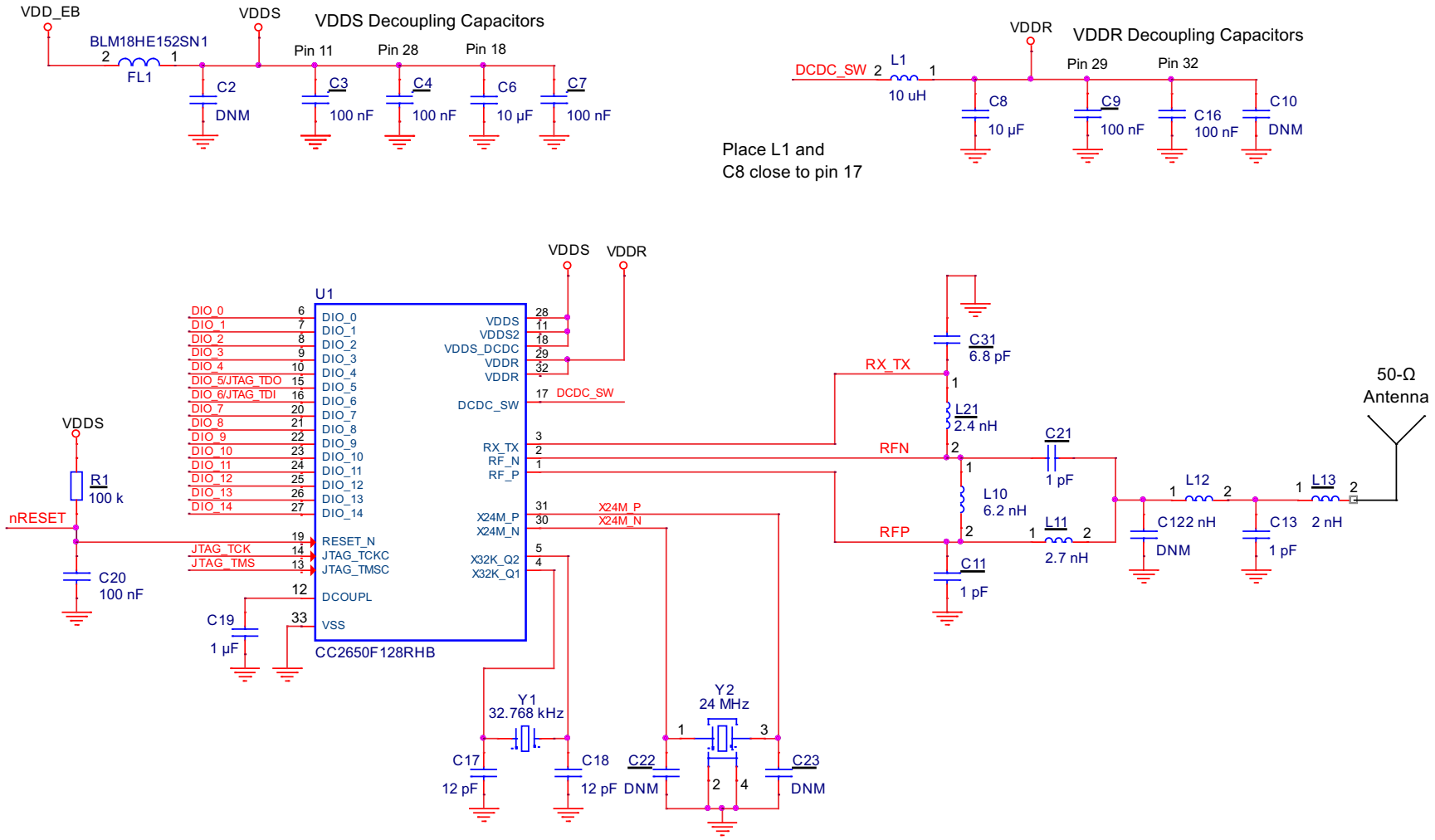




**図 10-3. 5 × 5 External Differential (5XD) Application Circuit**

### 10.2.1 Layout

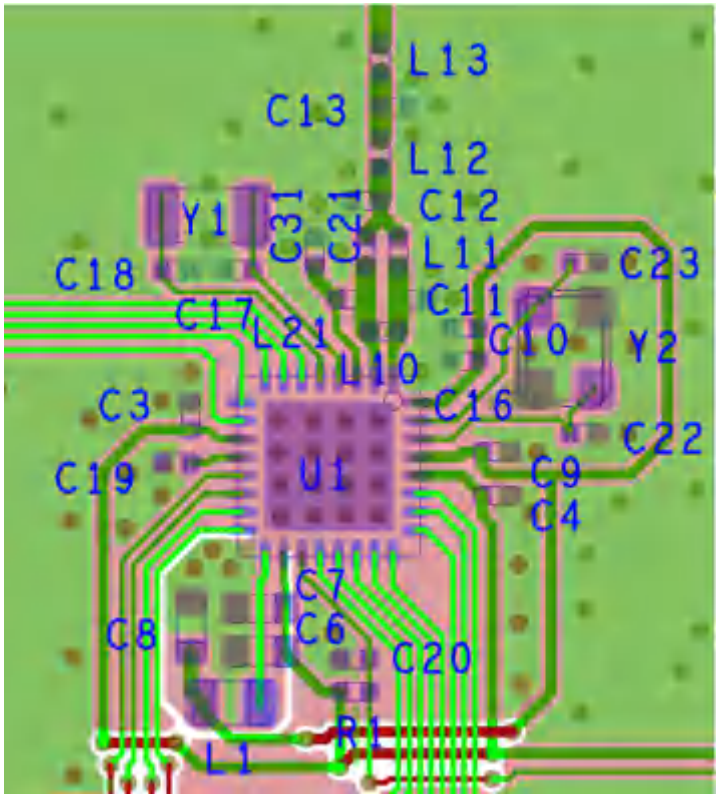


**図 10-4. 5 × 5 External Differential (5XD) Layout**

## 10.3 4 × 4 External Single-ended (4XS) Application Circuit

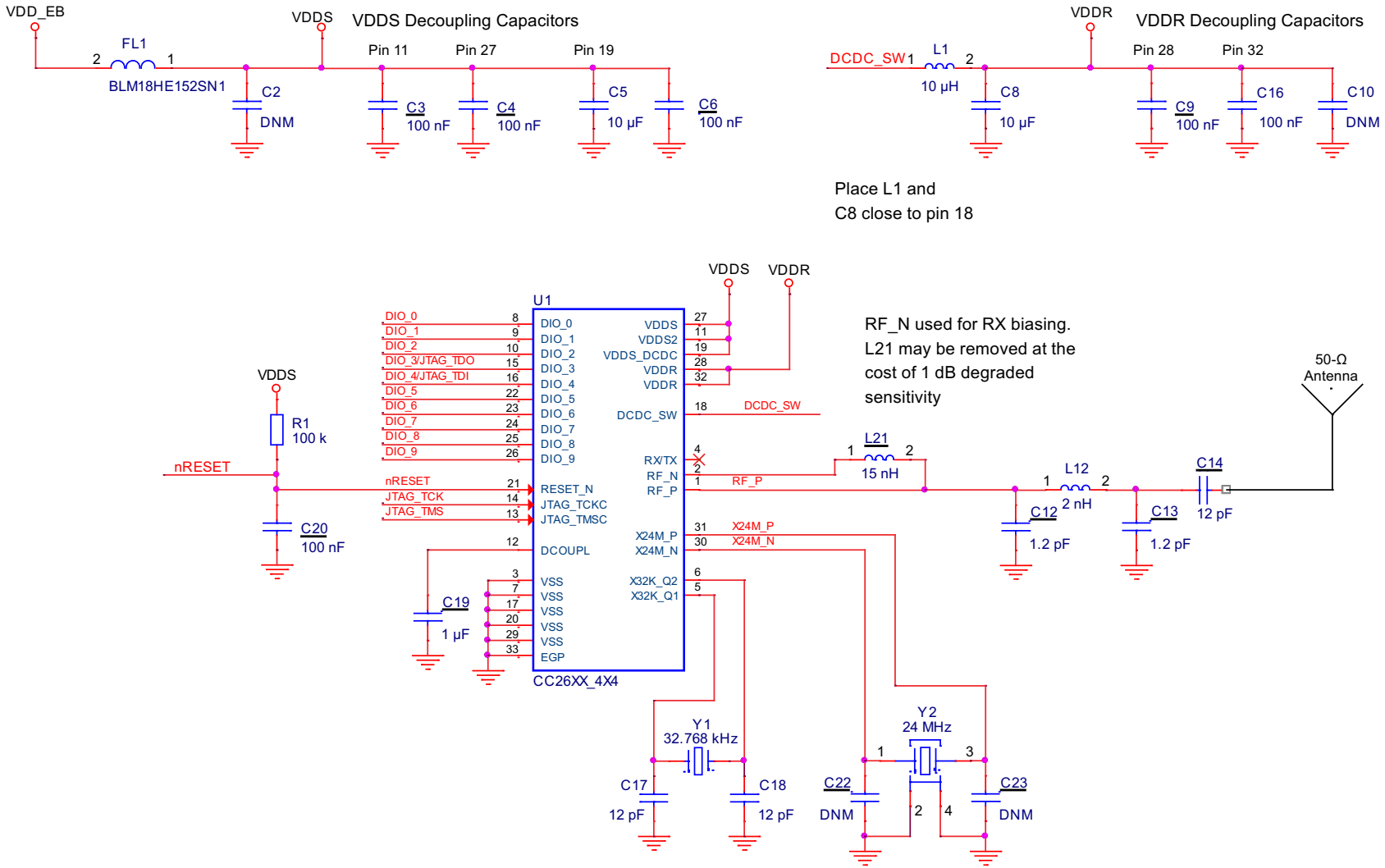




**図 10-5. 4 × 4 External Single-ended (4XS) Application Circuit**

### 10.3.1 Layout

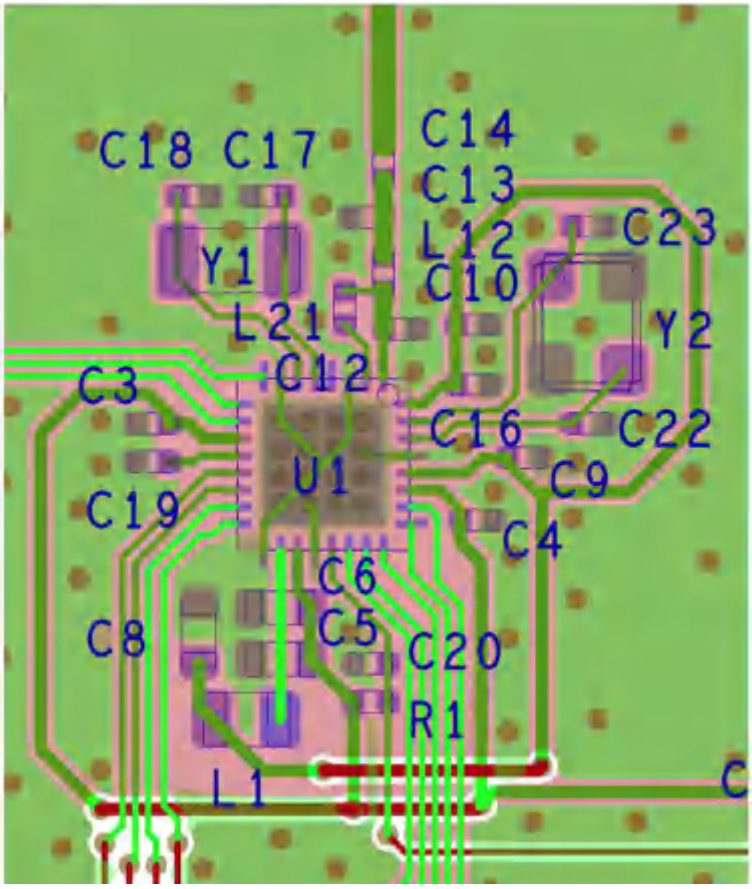


**図 10-6. 4 × 4 External Single-ended (4XS) Layout**

# 11 Device and Documentation Support

## 11.1 Device Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to all pre-production part numbers or date-code markings. Each device has one of three prefixes/identifications: X, P, or null (no prefix) (for example, CC2640R2F is in production; therefore, no prefix/identification is assigned).

Device development evolutionary flow:

**X** Experimental device that is not necessarily representative of the final device's electrical specifications and may not use production assembly flow.

**P** Prototype device that is not necessarily the final silicon die and may not necessarily meet final electrical specifications.

**null** Production version of the silicon die that is fully qualified.

Production devices have been characterized fully, and the quality and reliability of the device have been demonstrated fully. TI's standard warranty applies.

Predictions show that prototype devices (X or P) have a greater failure rate than the standard production devices. Texas Instruments recommends that these devices not be used in any production system because their expected end-use failure rate still is undefined. Only qualified production devices are to be used.

TI device nomenclature also includes a suffix with the device family name. This suffix indicates the package type (for example, ).

For orderable part numbers of the *CC2640R2F* device *RSM, RHB, RGZ, or YFV* package types, see the Package Option Addendum of this document, the TI website (www.ti.com), or contact your TI sales representative.

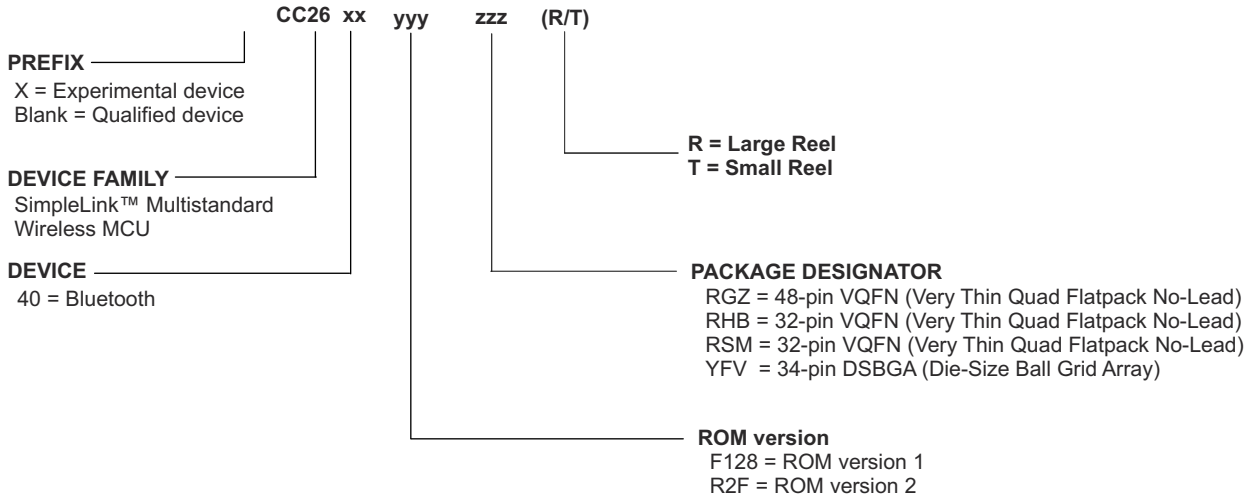


**図 11-1. Device Nomenclature**

## 11.2 Tools and Software

TI offers an extensive line of development tools, including tools to evaluate the performance of the processors, generate code, develop algorithm implementations, and fully integrate and debug software and hardware modules.

The following products support development of the CC2640R2F device applications:

**Software Tools:**

SmartRF Studio 7 is a PC application that helps designers of radio systems to easily evaluate the RF-IC at an early stage in the design process.

- Test functions for sending and receiving radio packets, continuous wave transmit and receive
- Evaluate RF performance on custom boards by wiring it to a supported evaluation board or debugger
- Can also be used without any hardware, but then only to generate, edit and export radio configuration settings
- Can be used in combination with several development kits for Texas Instruments' CCxxxx RF-ICs

Sensor Controller Studio provides a development environment for the CC26xx Sensor Controller. The Sensor Controller is a proprietary, power-optimized CPU in the CC26xx, which can perform simple background tasks autonomously and independent of the System CPU state.

- Allows for Sensor Controller task algorithms to be implemented using a C-like programming language
- Outputs a Sensor Controller Interface driver, which incorporates the generated Sensor Controller machine code and associated definitions
- Allows for rapid development by using the integrated Sensor Controller task testing and debugging functionality. This allows for live visualization of sensor data and algorithm verification.

**IDEs and Compilers:**

Code Composer Studio™ Integrated Development Environment (IDE):

- Integrated development environment with project management tools and editor
- Code Composer Studio (CCS) 7.0 and later has built-in support for the CC26xx device family
- Best support for XDS debuggers; XDS100v3, XDS110 and XDS200
- High integration with TI-RTOS with support for TI-RTOS Object View

IAR Embedded Workbench® for Arm®:

- Integrated development environment with project management tools and editor
- IAR EWARM 7.80.1 and later has built-in support for the CC26xx device family
- Broad debugger support, supporting XDS100v3, XDS200, IAR I-Jet and Segger J-Link
- Integrated development environment with project management tools and editor
- RTOS plugin available for TI-RTOS

For a complete listing of development-support tools for the CC2640R2F platform, visit the Texas Instruments website at www.ti.com. For information on pricing and availability, contact the nearest TI field sales office or authorized distributor.

## 11.3 Documentation Support

To receive notification of documentation updates, navigate to the device product folder on ti.com (CC2640R2F). 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.

The current documentation that describes the CC2640R2F devices, related peripherals, and other technical collateral is listed in the following.

**Technical Reference Manual**

*CC13xx, CC26xx SimpleLink™ Wireless MCU Technical Reference Manual*

## 11.4 Texas Instruments Low-Power RF Website

Texas Instruments' Low-Power RF website has all the latest products, application and design notes, FAQ section, news and events updates. Go to www.ti.com/lprf.

## 11.5 Low-Power RF eNewsletter

The Low-Power RF eNewsletter is up-to-date on new products, news releases, developers' news, and other news and events associated with low-power RF products from TI. The Low-Power RF eNewsletter articles include links to get more online information.

Sign up at: www.ti.com/lprfnewsletter

## 11.6 サポート・リソース

TI E2E™ サポート・フォーラムは、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計で必要な支援を迅速に得ることができます。

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## 11.7 Trademarks

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## 11.8 静電気放電に関する注意事項

この IC は、ESD によって破損する可能性があります。テキサス・インスツルメンツは、IC を取り扱う際には常に適切な注意を払うことを推奨します。正しい ESD 対策をとらないと、デバイスを破損するおそれがあります。

ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

## 11.9 Export Control Notice

Recipient agrees to not knowingly export or re-export, directly or indirectly, any product or technical data (as defined by the U.S., EU, and other Export Administration Regulations) including software, or any controlled product restricted by other applicable national regulations, received from disclosing party under nondisclosure obligations (if any), or any direct product of such technology, to any destination to which such export or re-export

is restricted or prohibited by U.S. or other applicable laws, without obtaining prior authorization from U.S. Department of Commerce and other competent Government authorities to the extent required by those laws.

### 11.10 用語集

TI 用語集　　この用語集には、用語や略語の一覧および定義が記載されています。

# 12 Mechanical, Packaging, and Orderable Information

## 12.1 Packaging 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.

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CC2640R2FRGZR | ACTIVE | VQFN | RGZ | 48 | 2500 | RoHS & Green | NIPDAU \| NIPDAUAG | Level-3-260C-168 HR | -40 to 85 | CC2640 R2F | Samples |
| CC2640R2FRGZT | ACTIVE | VQFN | RGZ | 48 | 250 | RoHS & Green | NIPDAU \| NIPDAUAG | Level-3-260C-168 HR | -40 to 85 | CC2640 R2F | Samples |
| CC2640R2FRHBR | ACTIVE | VQFN | RHB | 32 | 2500 | RoHS & Green | NIPDAU \| NIPDAUAG | Level-3-260C-168 HR | -40 to 85 | CC2640 R2F | Samples |
| CC2640R2FRHBT | ACTIVE | VQFN | RHB | 32 | 250 | RoHS & Green | NIPDAU \| NIPDAUAG | Level-3-260C-168 HR | -40 to 85 | CC2640 R2F | Samples |
| CC2640R2FRSMR | ACTIVE | VQFN | RSM | 32 | 3000 | RoHS & Green | NIPDAU \| NIPDAUAG | Level-3-260C-168 HR | -40 to 85 | CC2640 R2F | Samples |
| CC2640R2FRSMT | ACTIVE | VQFN | RSM | 32 | 250 | RoHS & Green | NIPDAU \| NIPDAUAG | Level-3-260C-168 HR | -40 to 85 | CC2640 R2F | Samples |
| CC2640R2FYFVR | ACTIVE | DSBGA | YFV | 34 | 2500 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | CC2640 | Samples |
| CC2640R2FYFVT | ACTIVE | DSBGA | YFV | 34 | 250 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | CC2640 | 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.



**OTHER QUALIFIED VERSIONS OF CC2640R2F :**

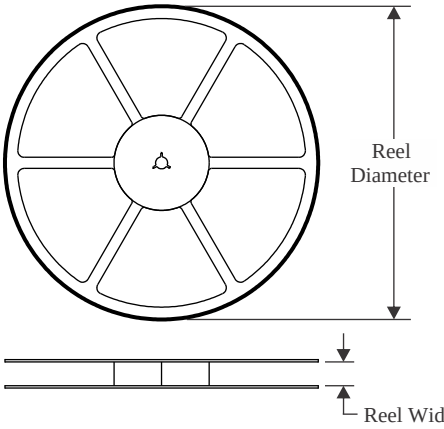
- Automotive : CC2640R2F-Q1

NOTE: Qualified Version Definitions:

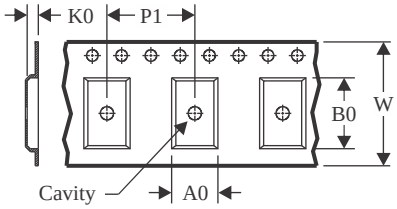
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

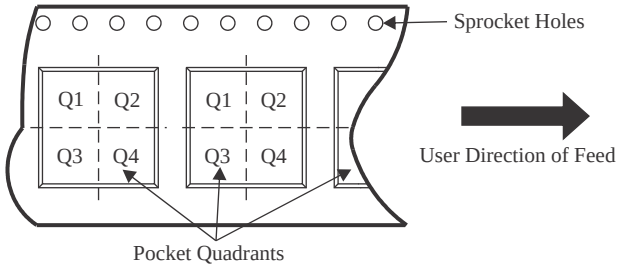



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

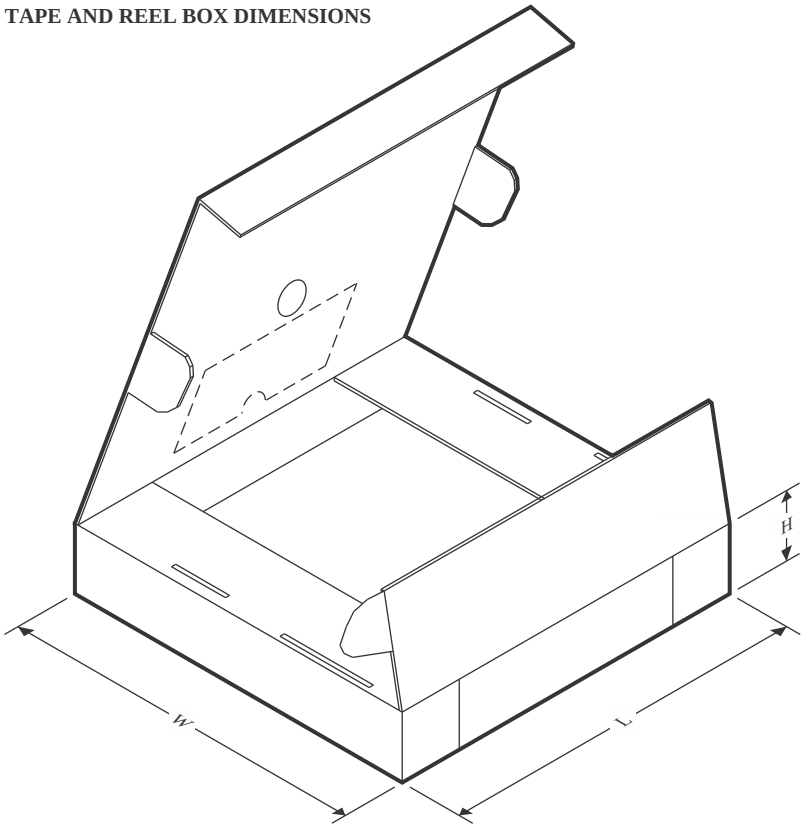
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC2640R2FRGZT | VQFN | RGZ | 48 | 250 | 180.0 | 16.4 | 7.3 | 7.3 | 1.1 | 12.0 | 16.0 | Q2 |
| CC2640R2FRHBR | VQFN | RHB | 32 | 2500 | 330.0 | 12.4 | 5.3 | 5.3 | 1.1 | 8.0 | 12.0 | Q2 |
| CC2640R2FRHBR | VQFN | RHB | 32 | 2500 | 330.0 | 12.4 | 5.3 | 5.3 | 1.1 | 8.0 | 12.0 | Q2 |
| CC2640R2FRHBT | VQFN | RHB | 32 | 250 | 180.0 | 12.4 | 5.3 | 5.3 | 1.1 | 8.0 | 12.0 | Q2 |
| CC2640R2FYFVR | DSBGA | YFV | 34 | 2500 | 180.0 | 8.4 | 2.75 | 2.75 | 0.81 | 4.0 | 8.0 | Q1 |
| CC2640R2FYFVT | DSBGA | YFV | 34 | 250 | 180.0 | 8.4 | 2.75 | 2.75 | 0.81 | 4.0 | 8.0 | Q1 |

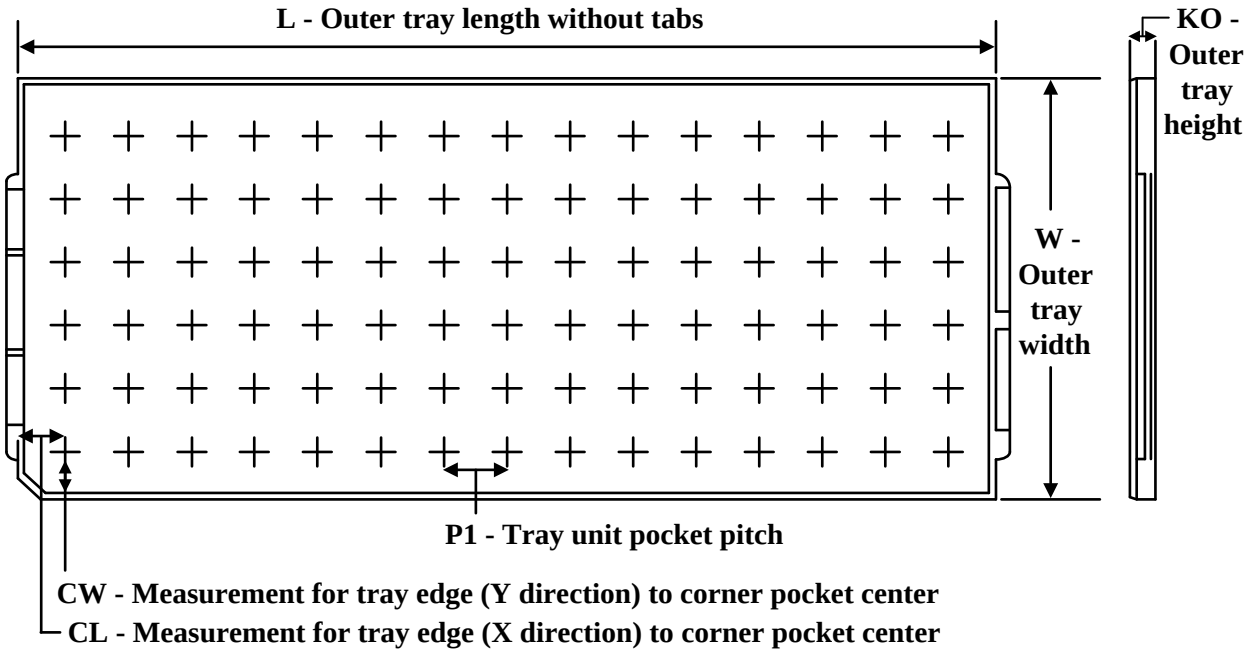
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| CC2640R2FRGZT | VQFN | RGZ | 48 | 250 | 210.0 | 185.0 | 35.0 |
| CC2640R2FRHBR | VQFN | RHB | 32 | 2500 | 367.0 | 367.0 | 35.0 |
| CC2640R2FRHBR | VQFN | RHB | 32 | 2500 | 336.6 | 336.6 | 31.8 |
| CC2640R2FRHBT | VQFN | RHB | 32 | 250 | 210.0 | 185.0 | 35.0 |
| CC2640R2FYFVR | DSBGA | YFV | 34 | 2500 | 182.0 | 182.0 | 20.0 |
| CC2640R2FYFVT | DSBGA | YFV | 34 | 250 | 182.0 | 182.0 | 20.0 |

## TRAY




Chamfer on Tray corner indicates Pin 1 orientation of packed units.

*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (µm) | P1 (mm) | CL (mm) | CW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC2640R2FRHBR | RHB | VQFN | 32 | 2500 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRHBR | RHB | VQFN | 32 | 2500 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRHBT | RHB | VQFN | 32 | 250 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRHBT | RHB | VQFN | 32 | 250 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRSMR | RSM | VQFN | 32 | 3000 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRSMR | RSM | VQFN | 32 | 3000 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRSMT | RSM | VQFN | 32 | 250 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |
| CC2640R2FRSMT | RSM | VQFN | 32 | 250 | 14 x 35 | 150 | 315 | 135.9 | 7620 | 8.8 | 7.9 | 8.15 |

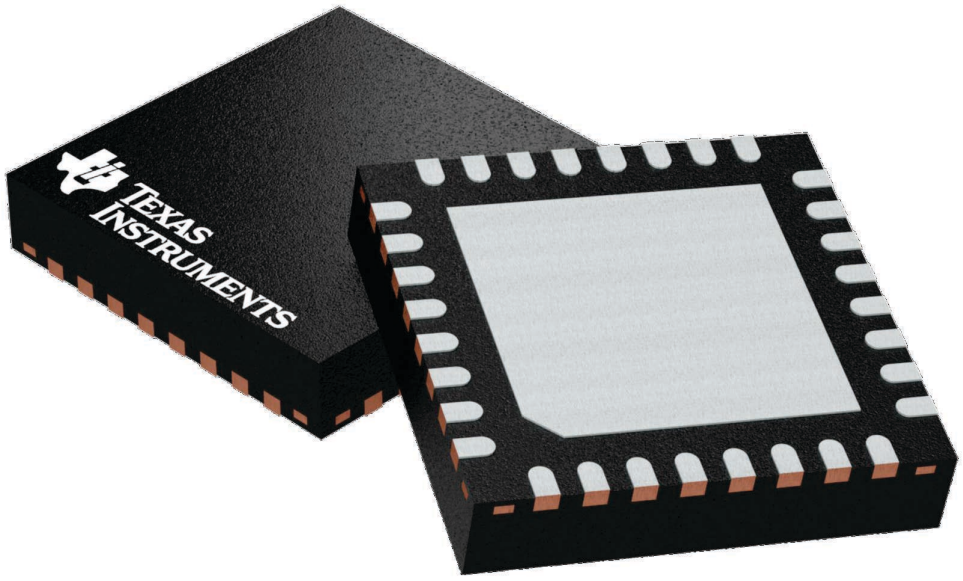
# GENERIC PACKAGE VIEW

## RHB 32

## VQFN - 1 mm max height

**5 x 5, 0.5 mm pitch**

PLASTIC QUAD FLATPACK - NO LEAD




Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

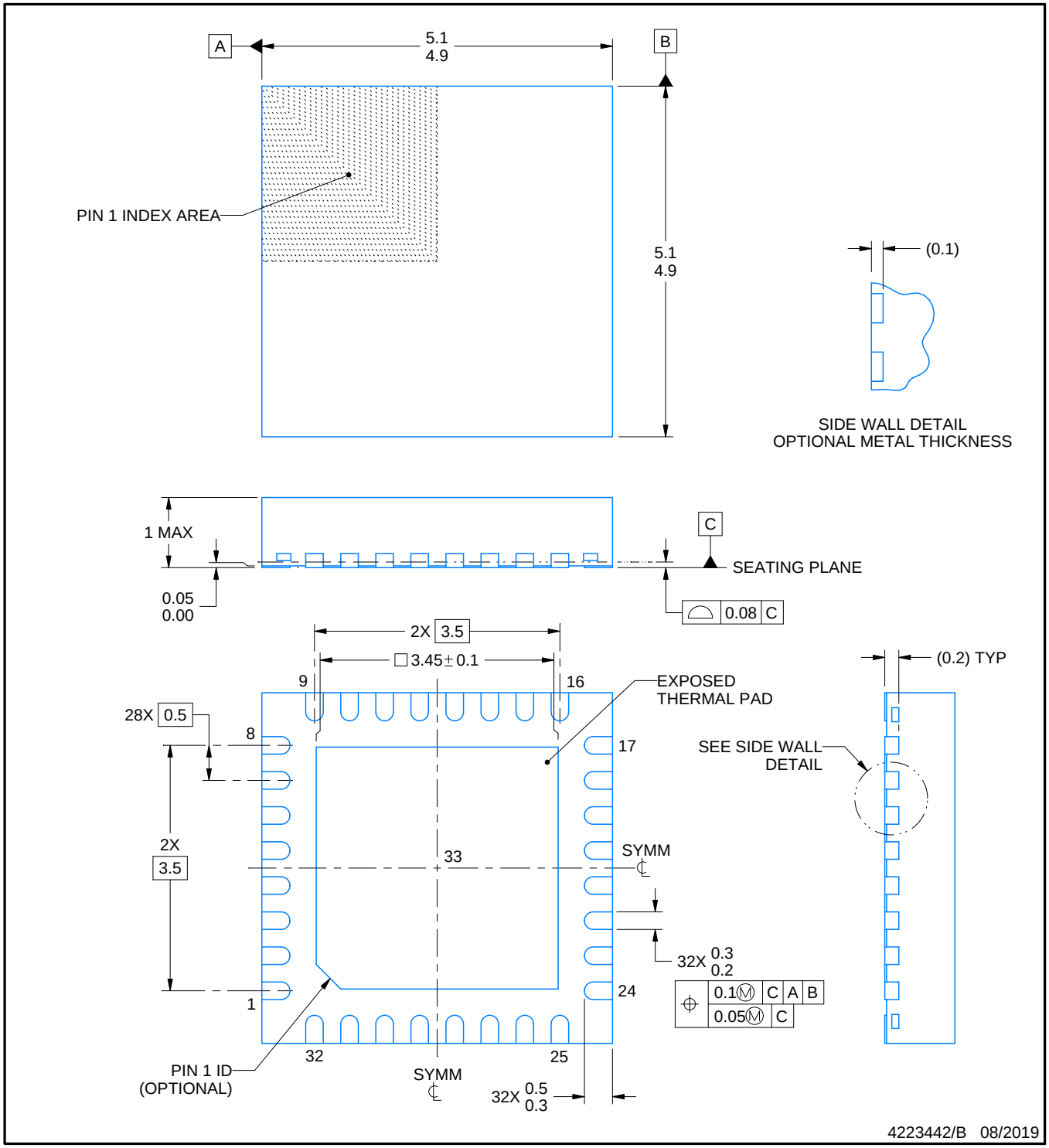
4224745/A

# RHB0032E

# PACKAGE OUTLINE

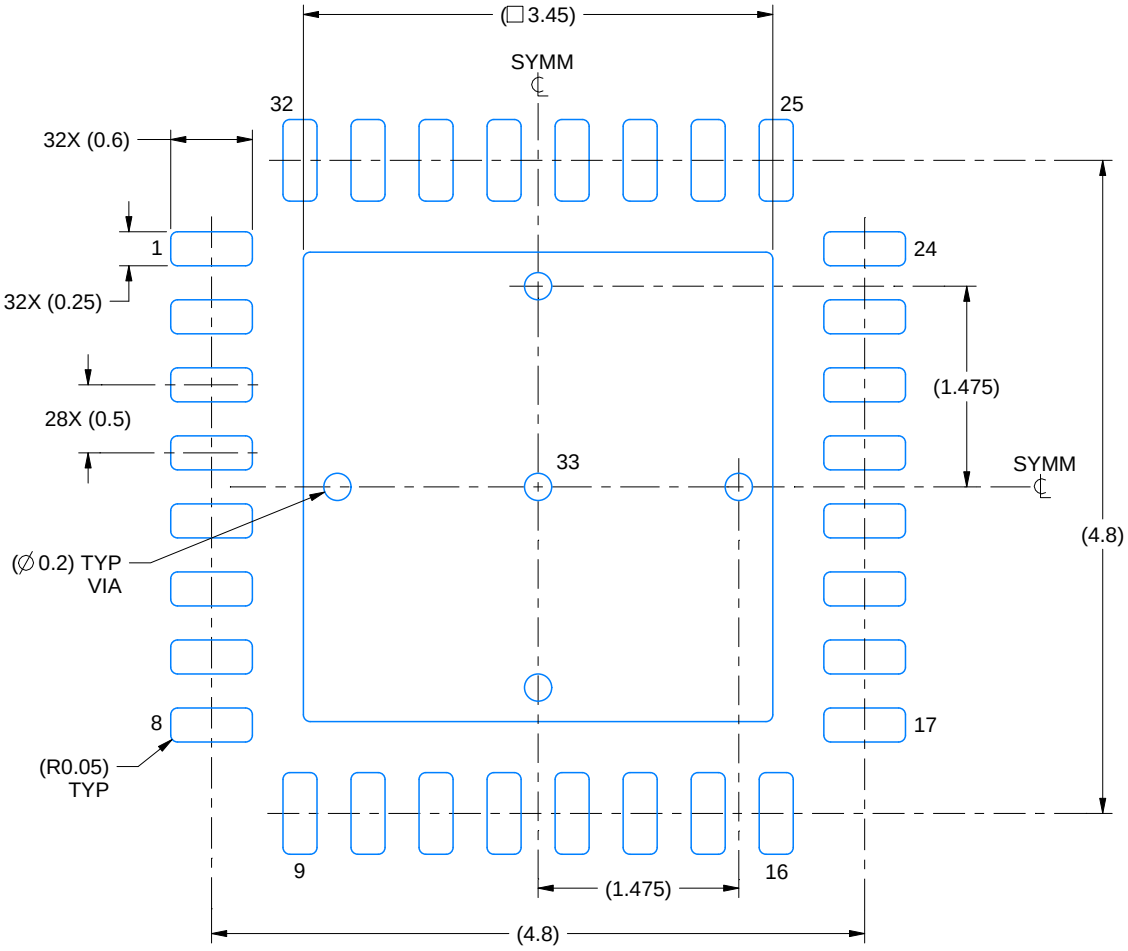
## VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

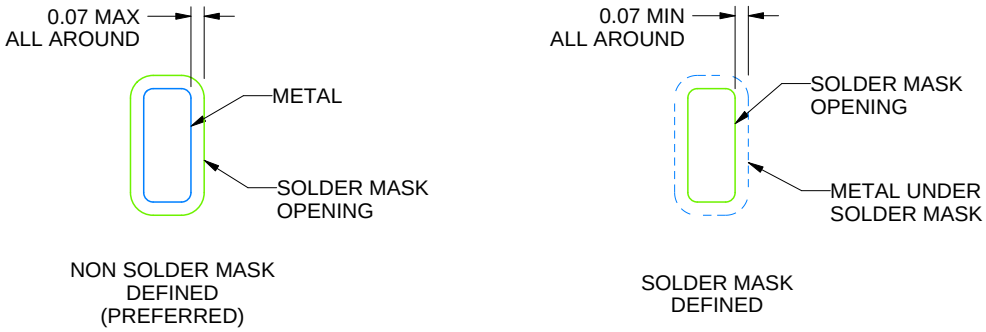



NOTES:

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.




LAND PATTERN EXAMPLE
SCALE:18X




SOLDER MASK DETAILS

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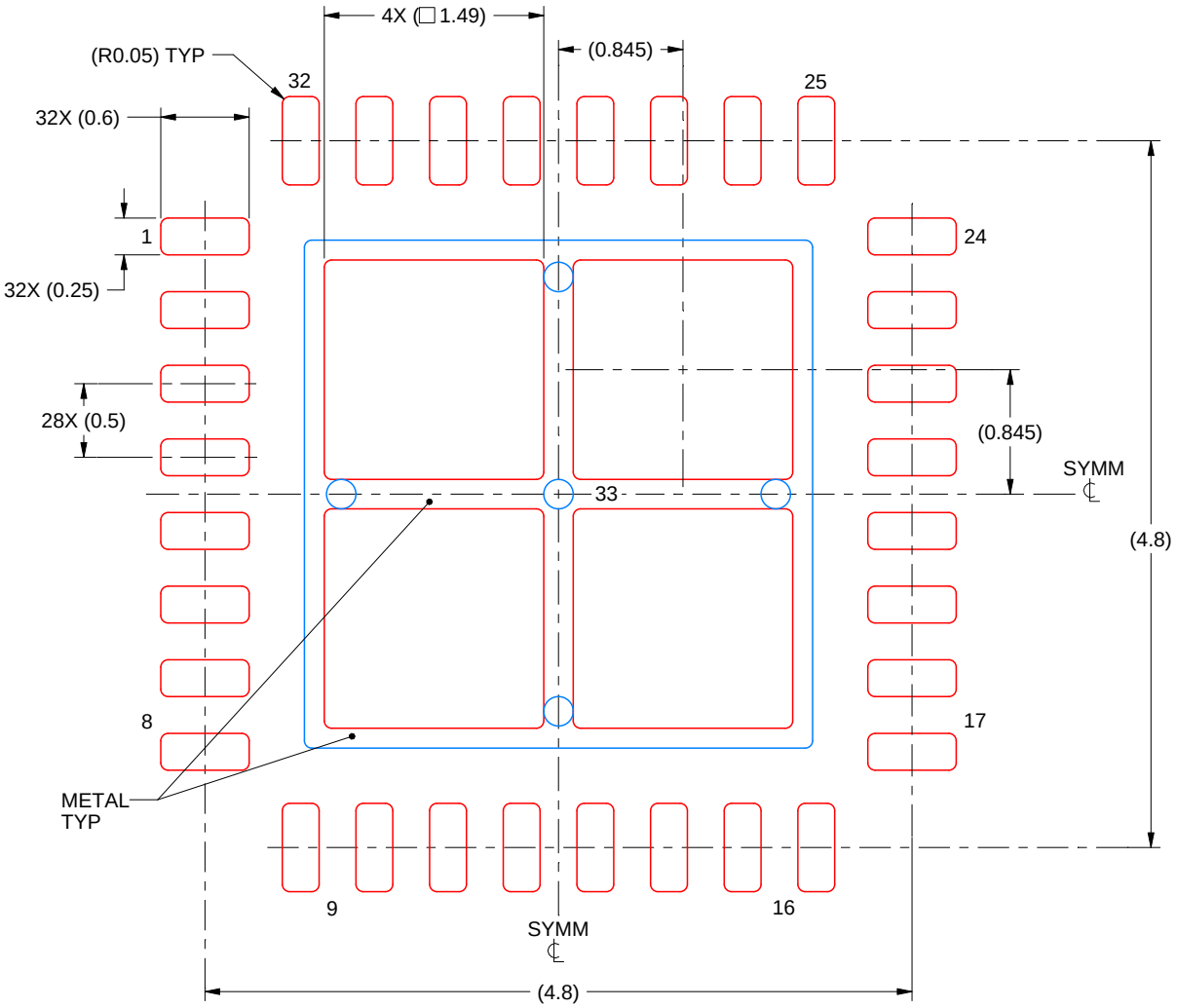
NOTES: (continued)

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.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 33:
75% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:20X

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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.

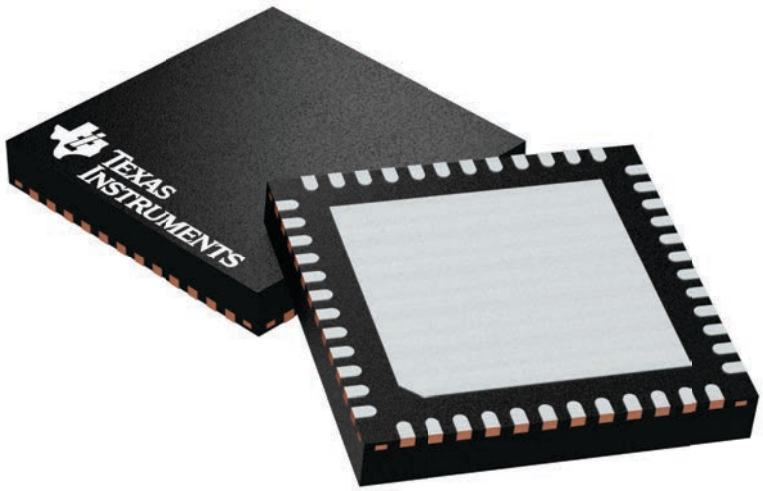
# GENERIC PACKAGE VIEW

## RGZ 48

## VQFN - 1 mm max height

**7 x 7, 0.5 mm pitch**

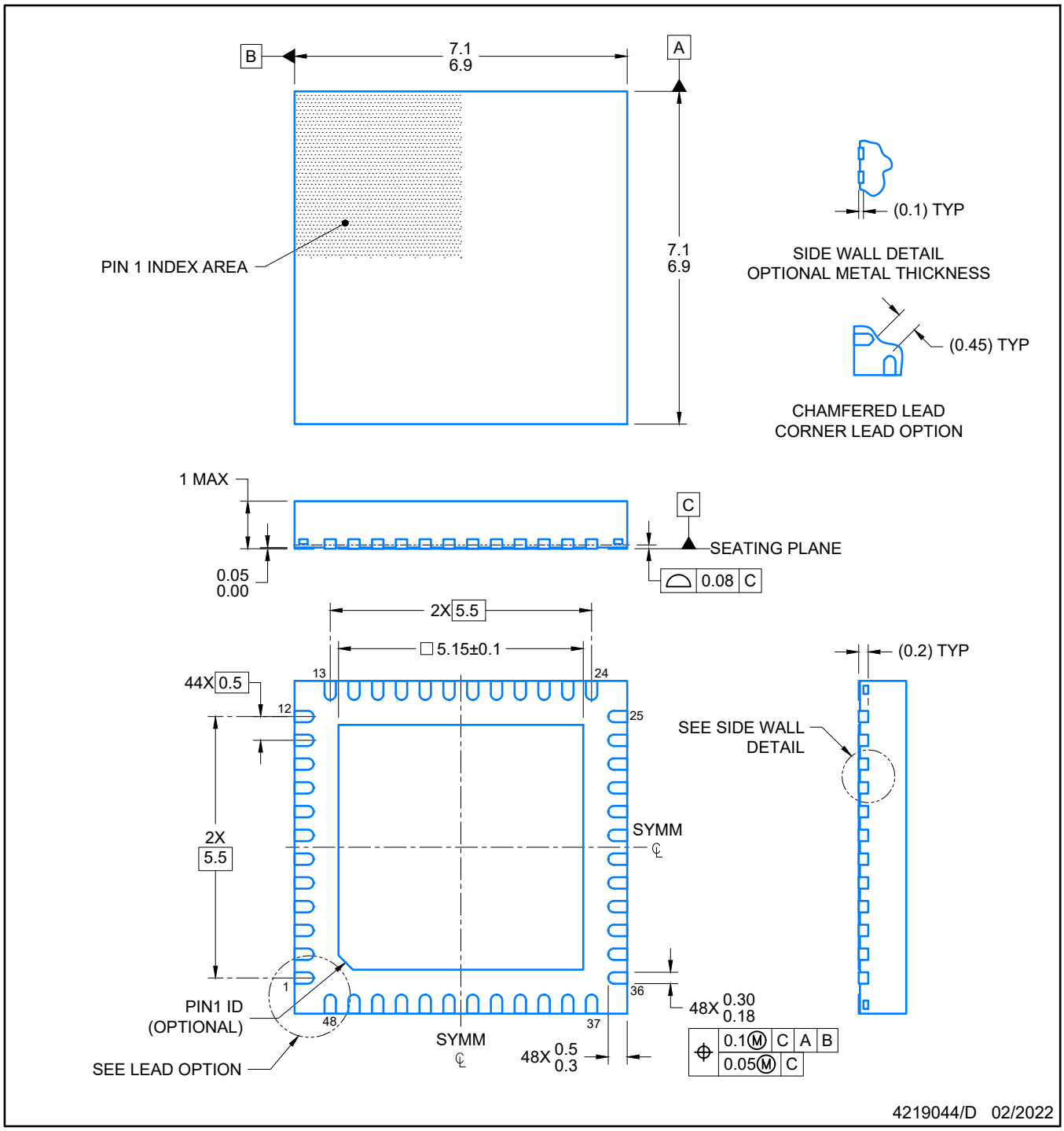
PLASTIC QUADFLAT PACK- NO LEAD




Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

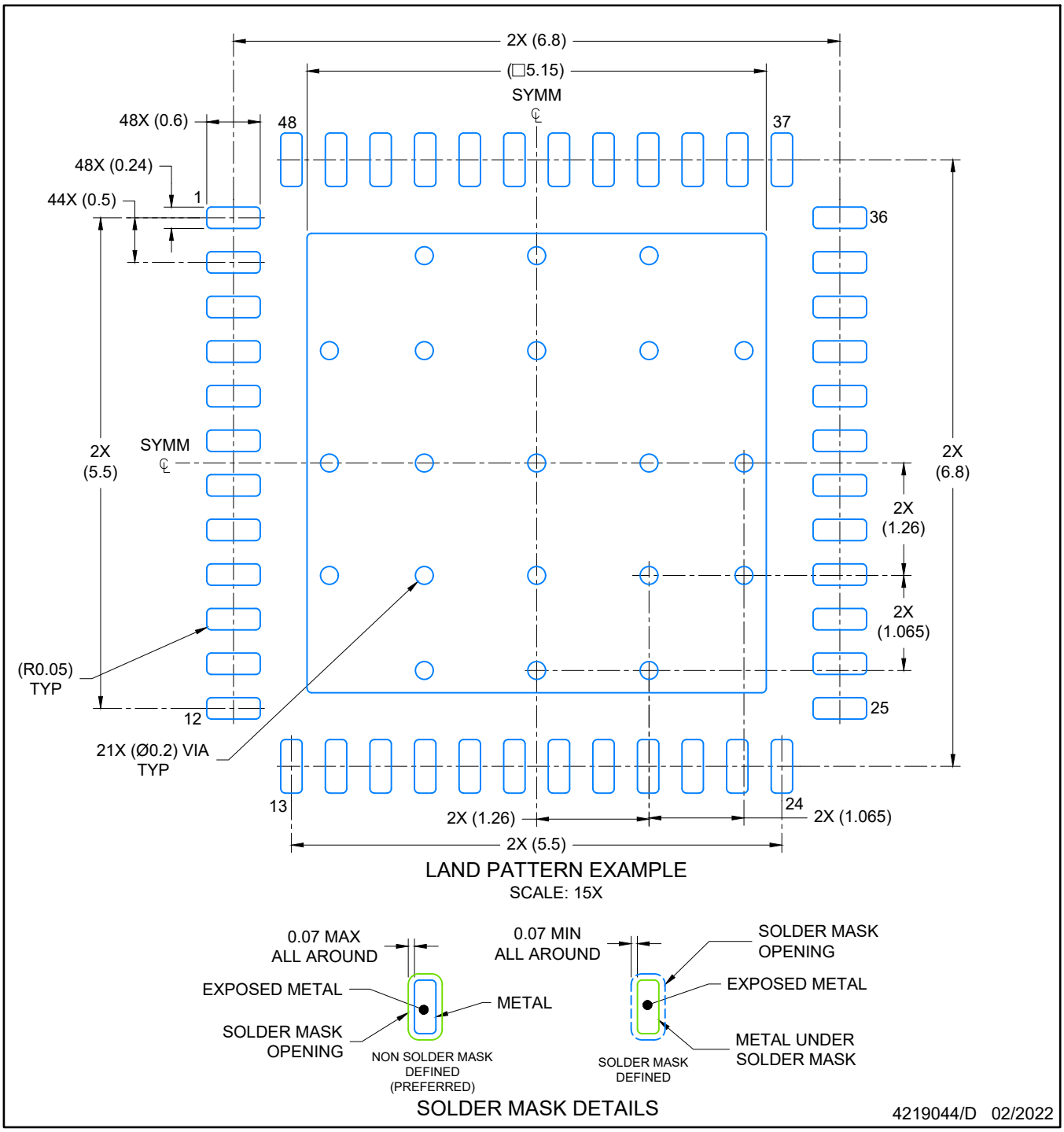
4224671/A

PLASTIC QUADFLAT PACK- NO LEAD



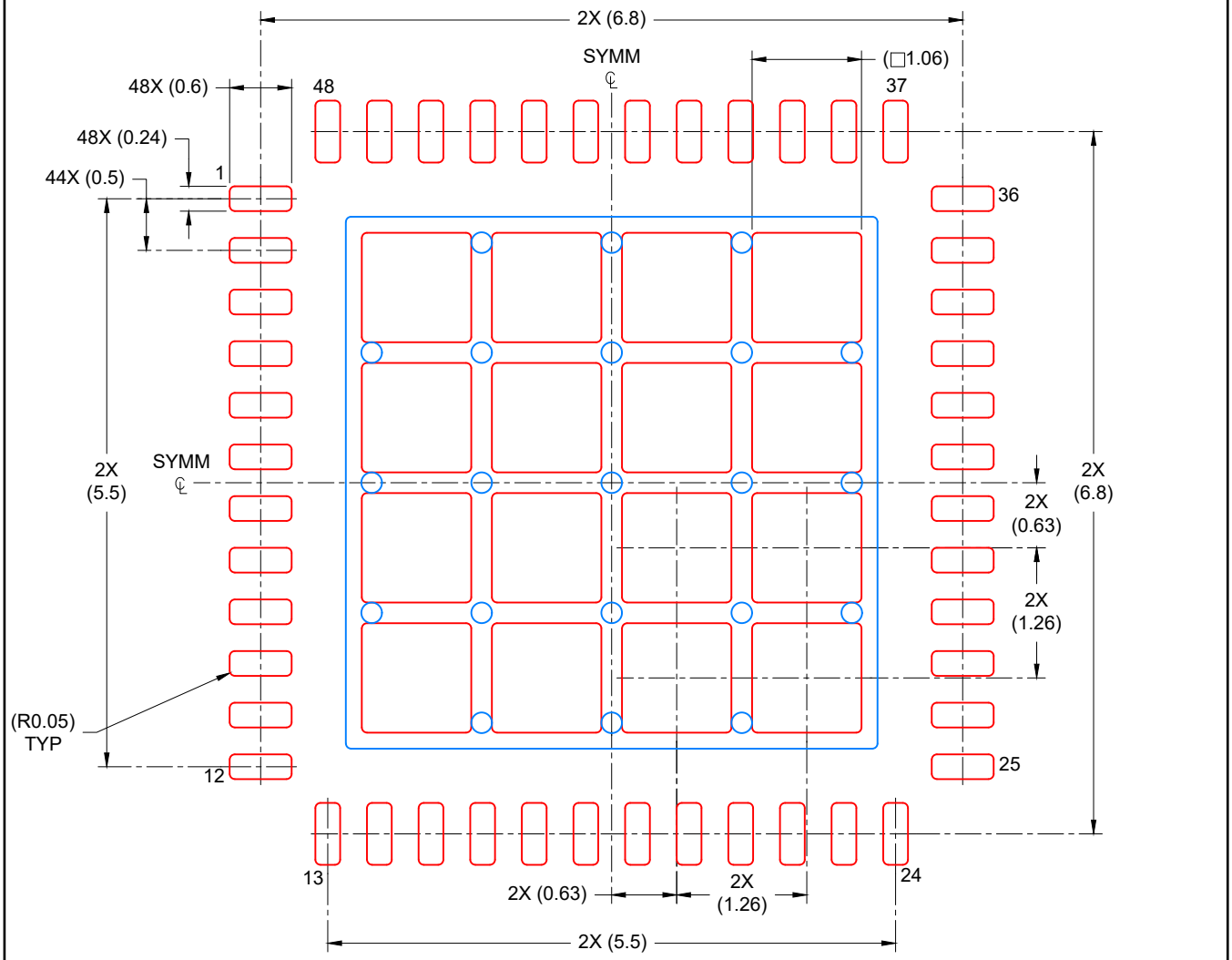

NOTES:

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 optimal thermal and mechanical performance.




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.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

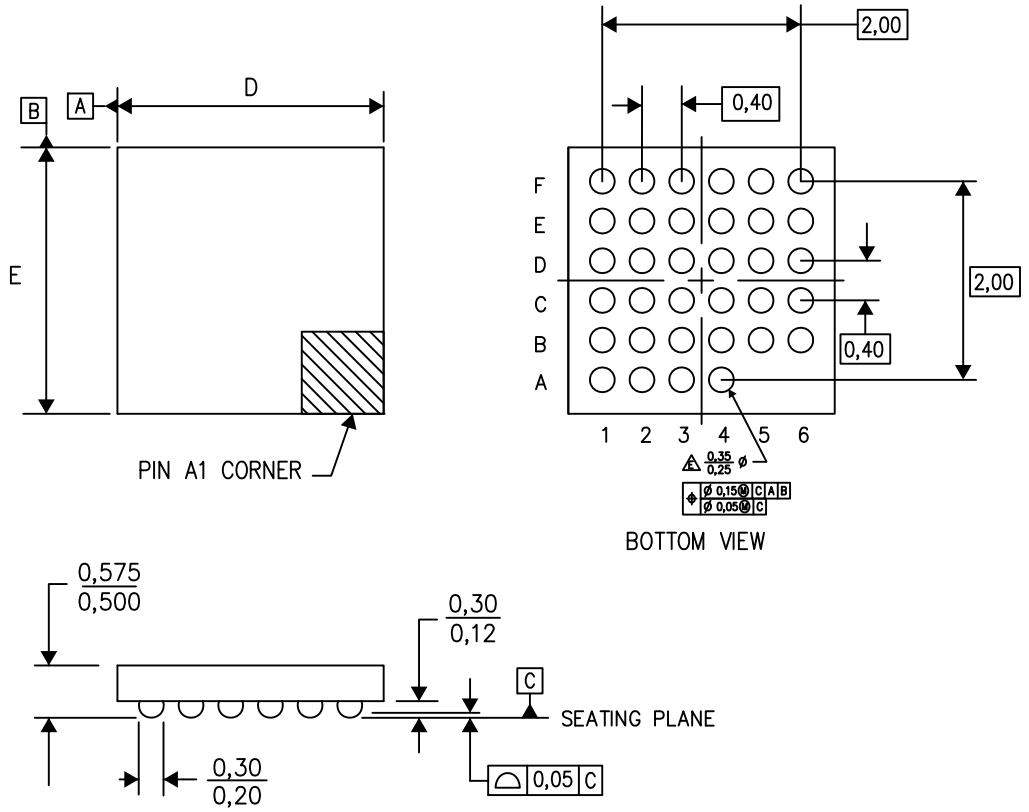
EXPOSED PAD
67% PRINTED COVERAGE BY AREA
SCALE: 15X

4219044/D 02/2022

NOTES: (continued)

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

YFV (R–XBGA–N34) DIE–SIZE BALL GRID ARRAY (WCSP)




D: Max = 2.714 mm, Min =2.654 mm

E: Max = 2.714 mm, Min =2.654 mm

4209189–15/0 11/14

NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. NanoFree™ package configuration.
D. This package contains Pb–free balls.

NanoFree is a trademark of Texas Instruments.

# GENERIC PACKAGE VIEW

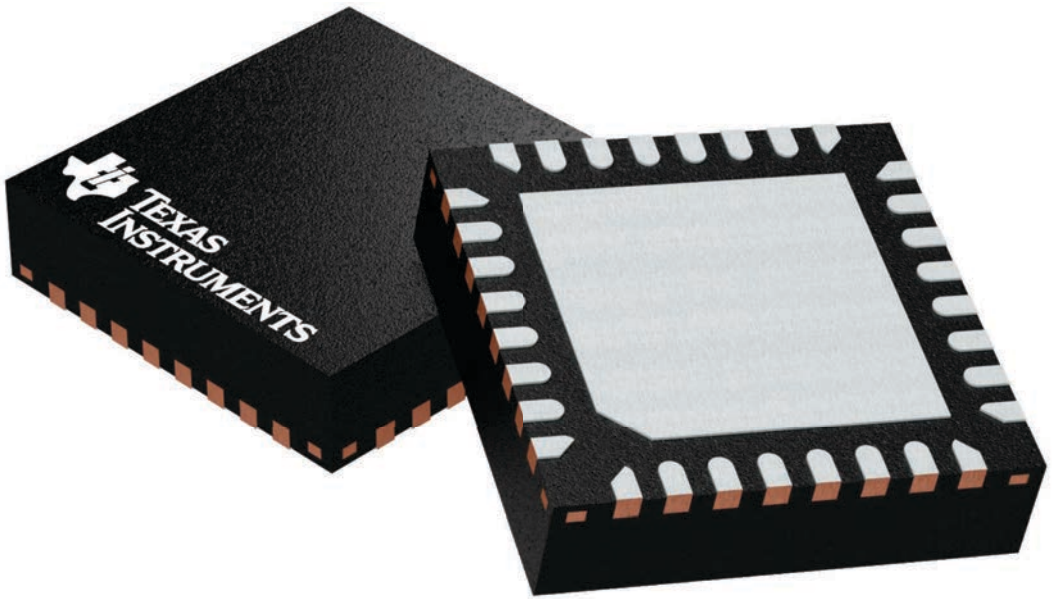
## RSM 32

## VQFN - 1 mm max height

**4 x 4, 0.4 mm pitch**

PLASTIC QUAD FLATPACK - NO LEAD

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



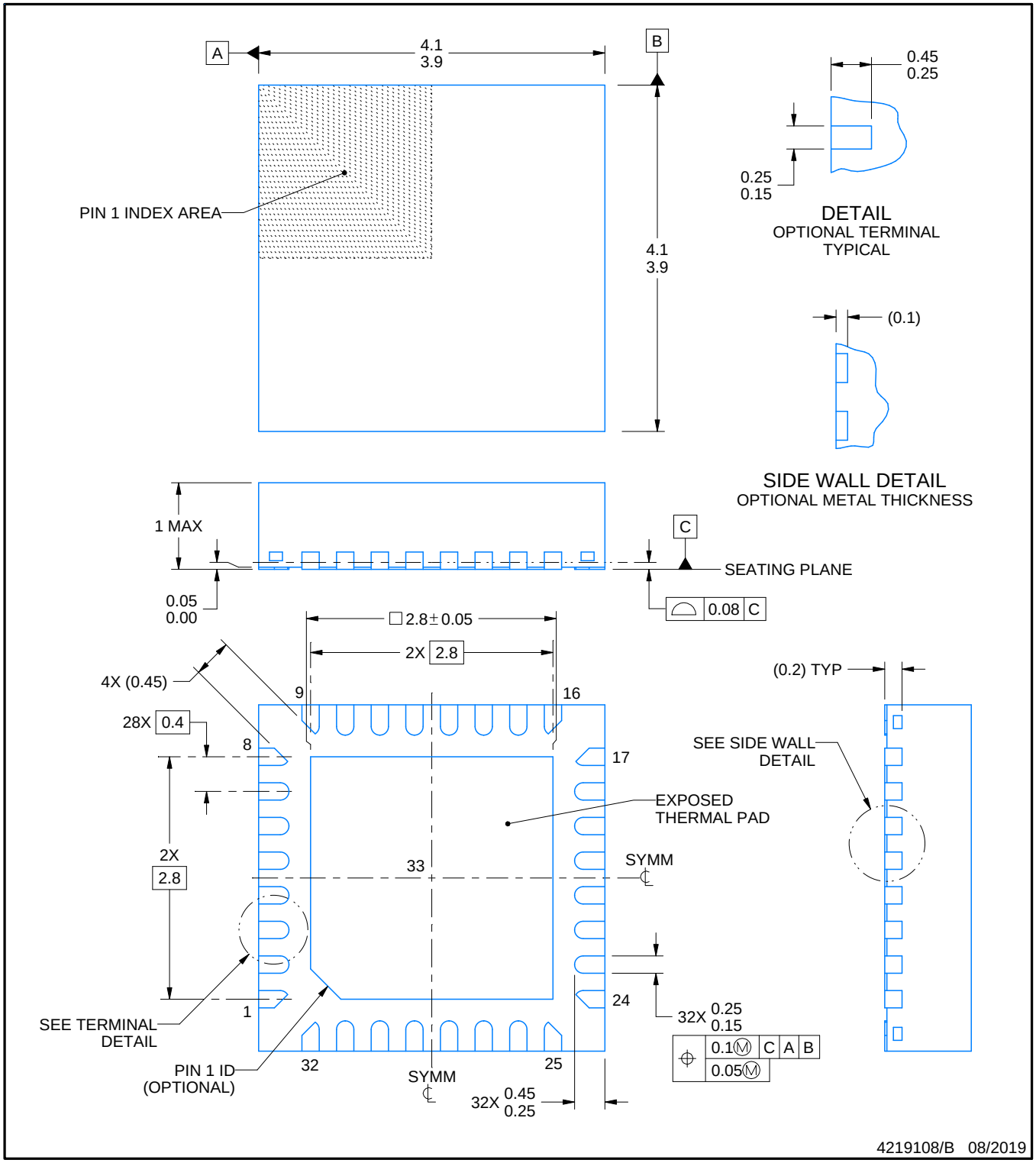

4224982/A

# PACKAGE OUTLINE

## RSM0032B

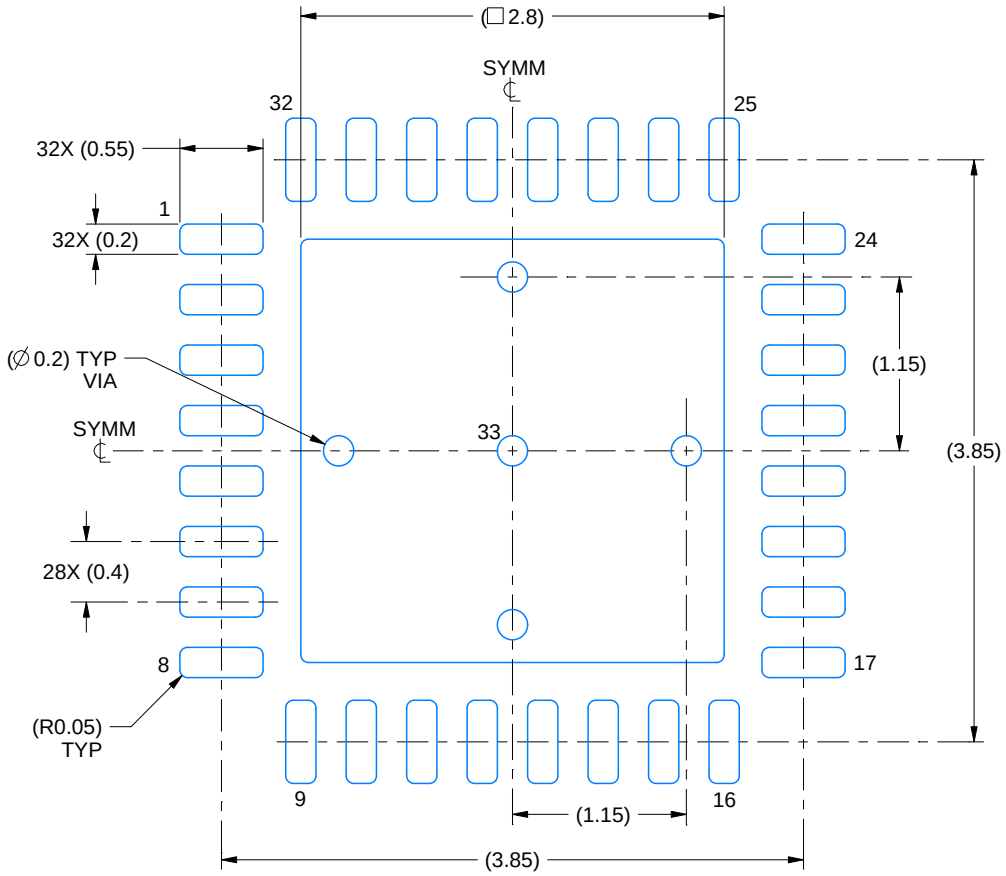
## VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

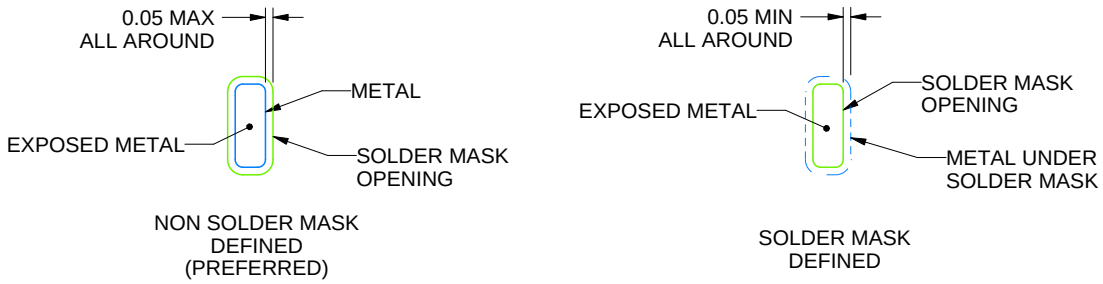



NOTES:

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.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:20X

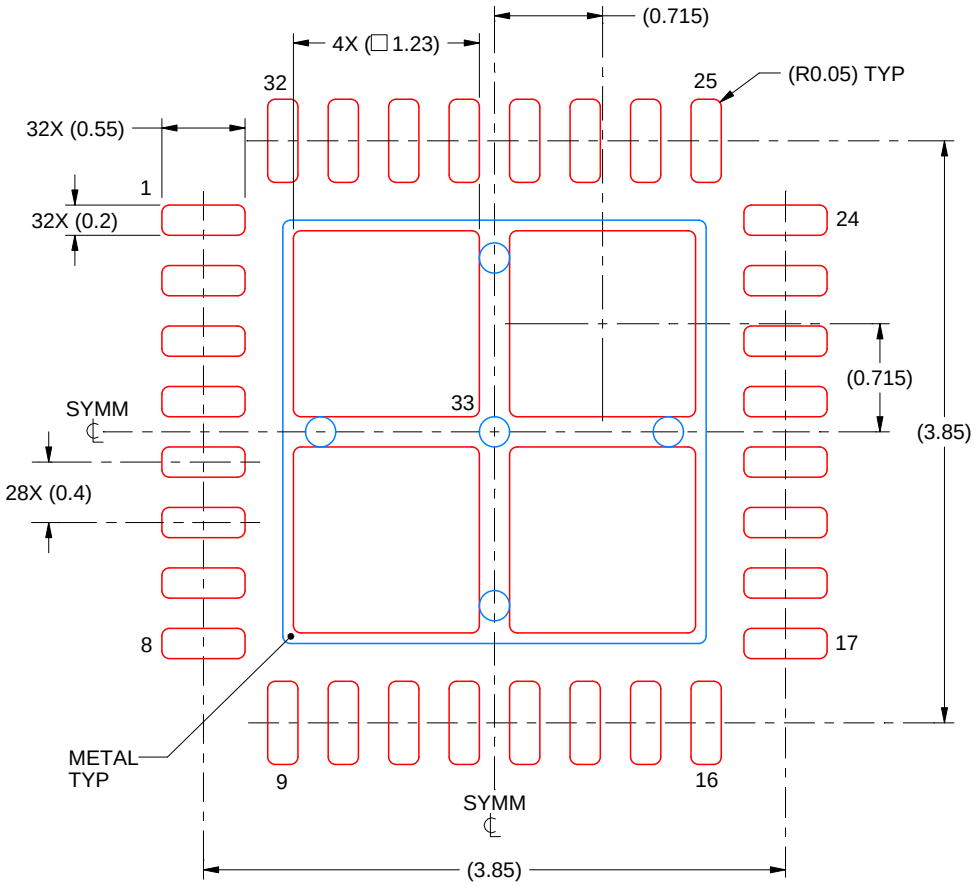



SOLDER MASK DETAILS

4219108/B 08/2019

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.




SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

EXPOSED PAD 33:
77% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:20X

4219108/B 08/2019

NOTES: (continued)

6. 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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