CC2650MODA SimpleLink™ *Bluetooth*® Low EnergyワイヤレスMCUモジュール

1 デバイスの概要

1.1 特長

- マイクロコントローラ
  - パワフルな ARM® Cortex®-M3
  - EEMBC CoreMark®スコア: 142
  - 最大48MHzのクロック速度
  - システム内のプログラマブル・フラッシュ: 128KB
  - キャッシュ用SRAM: 8KB
  - 超低リークSRAM: 20KB
  - 2ピンcJTAGおよびJTAGデバッグ
  - OTA (Over-the-air)アップグレードをサポート
- 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
  - コードおよびデータ用の超低リークSRAM: 2KB
- 効率的なコード・サイズのアーキテクチャ: ドライバ、*Bluetooth*® Low Energyコントローラ、IEEE® 802.15.4 MAC (Medium Access Control)、ブートローダーをROMに配置
- 内蔵アンテナ
- 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つの汎用タイマ・モジュール(8×16ビット、または4×32ビットのタイマ、それぞれがPWM)
  - 12ビットADC、200kサンプル/秒、8チャネルのアナログ・セレクタ
  - 連続時間コンパレータ
  - 超低消費電力のアナログ・コンパレータ
  - プログラマブル電流ソース
  - UART
  - 2×SSI(SPI、MICROWIRE、TI)
  - I^2C
  - I2S
  - リアルタイム・クロック(RTC)
  - AES-128セキュリティ・モジュール
  - TRNG (True Random Number Generator)
  - 15個のGPIO
  - 8個の容量性センシング・ボタンをサポート
  - 組み込みの温度センサ
- 外部システム
  - オンチップ内部DC/DCコンバータ
  - 電源以外の外付け部品が不要
- 低消費電力
  - 広い電源電圧範囲
    - 1.8V～3.8Vで動作
  - アクティブ・モードRX: 6.2mA
  - アクティブ・モードTX (0dBm時): 6.8mA
  - アクティブ・モードTX (+5dBm時): 9.4mA
  - アクティブ・モードMCU: 61µA/MHz
  - アクティブ・モードMCU: 48.5 CoreMark/mA
  - アクティブ・モードのセンサ・コントローラ: 0.4mA + 8.2µA/MHz
  - スタンバイ: 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 (BLE) 5.1 仕様、IEEE 802.15.4 PHY および MAC に準拠
  - CC2650MODA RF-PHY 認定済み (QDID: 88415)
  - 優れたレシーバ感度 (Bluetooth Low Energyで–97dBm、802.15.4で–100dBm)、選択性、およびブロッキング性能
  - 出力パワーを最大+5dBmまでプログラム可能
  - 各国の無線周波数規制への準拠認定済み
    - ETSI RED (欧州)
    - IC (カナダ)
    - FCC (米国)
    - ARIB STD-T66 (日本)
    - JATE (日本)
- ツールおよび開発環境
  - フル機能および低コストの開発キット
  - 異なるRF構成用の複数のリファレンス・デザイン
  - Packet Sniffer PCソフトウェア
  - Sensor Controller Studio
  - SmartRF™Studio
  - SmartRF Flash Programmer 2
  - IAR Embedded Workbench® for ARM
  - Code Composer Studio™

1.2 アプリケーション

- ビルディング・オートメーション
- 医療および保健
- 家電製品
- 産業用
- コンシューマ・エレクトロニクス
- 近接タグ
- アラームとセキュリティ
- リモート・コントロール
- ワイヤレス・センサ・ネットワーク

1.3 概要

SimpleLink™CC2650MODAデバイスは、*Bluetooth*® Low Energyアプリケーションを対象としたワイヤレス・マイクロコントローラ(MCU)モジュールです。CC2650MODAデバイスは、ZigBee®および6LoWPANと、ZigBee RF4CE™リモート・コントロール・アプリケーションも実行できます。

このモジュールの基盤であるSimpleLink CC2650ワイヤレスMCUは、コスト効率が優れ、超低消費電力の2.4GHz RFデバイスであるCC26xxファミリのメンバーです。アクティブ時のRFおよびMCU電流、および低消費電力モードでの消費電流が非常に低いため、バッテリ駆動時間が非常に優れており、小さなコイン型電池や環境発電アプリケーションで動作できます。

CC2650MODAモジュールには32ビットのARM Cortex-M3プロセッサが搭載され、メイン・プロセッサとして48MHzで動作するほか、独自の超低消費電力センサ・コントローラを含む豊富なペリフェラル機能セットも内蔵されています。このセンサ・コントローラは、外部センサとの接続用、またはシステムの他の機能がスリープ・モードの時に、アナログ・データとデジタル・データを自律的に収集するために適しています。このため、CC2650MODAデバイスは、工業用、消費者向け電子機器、医療機器など広範な製品での用途に好適です。

CC2650MODAモジュールは、FCC、IC、ETSI、ARIBの規制に準拠した動作が認定済みです。これらの認定によって、モジュールを自社製品に組み込む時のコストと労力を大幅に削減できます。

Bluetooth Low EnergyコントローラおよびIEEE 802.15.4 MACはROMに組み込まれており、その一部は別のARM® Cortex®-M0プロセッサで実行されます。このアーキテクチャにより、総合的なシステム性能が向上し、消費電力が減少し、より多くのフラッシュ・メモリを利用可能になります。

Bluetooth Low Energyソフトウェア・スタック(BLE-Stack)およびZigBeeソフトウェア・スタック(Z-Stack™)は無料で利用できます。

製品情報(1)

型番	パッケージ	本体サイズ
CC2650MODAMOH	MOH (モジュール)	16.90mm×11.00mm

(1) 詳細については、10を参照してください。

1.4 機能ブロック図

図 1-1 は、CC2650MODAデバイスのブロック図です。

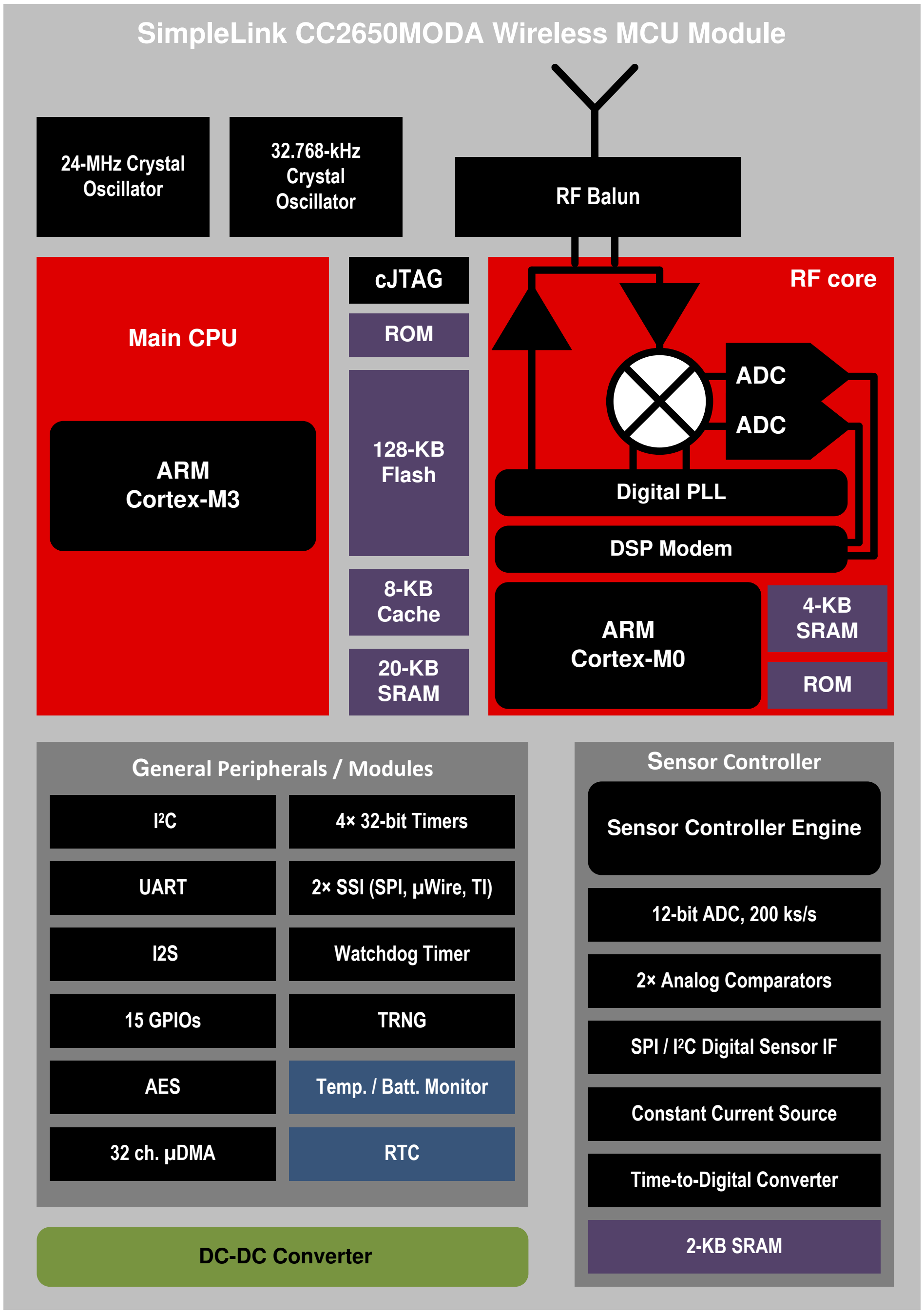

図 1-1. CC2650MODAのブロック図

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2 改訂履歴

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。

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3 Device Comparison

Table 3-1. Device Family Overview

DEVICE	PHY SUPPORT	FLASH (KB)	RAM (KB)	GPIO	PACKAGE
CC2650MODAMOH	Multiprotocol(1)	128	20	15	MOH

(1) The CC2650 device supports all PHYs and can be reflashed to run all the supported standards.

3.1 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 Review products that are frequently purchased or used in conjunction with this product.

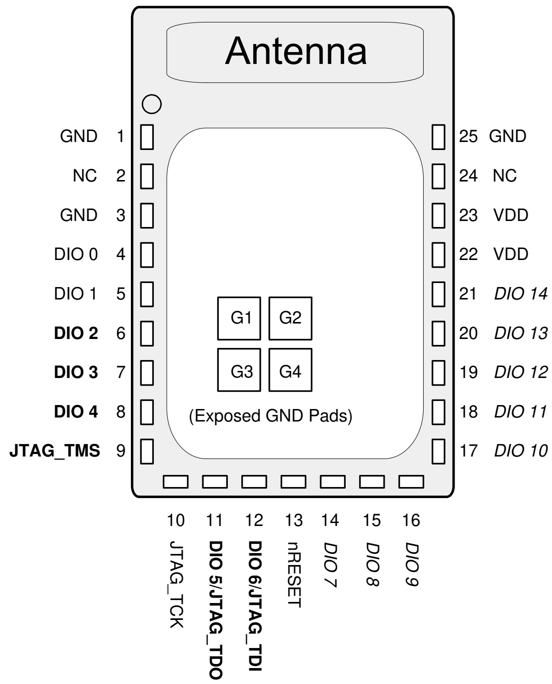
SimpleLink™ CC2650 Wireless MCU LaunchPad™ Development Kit The CC2650 LaunchPad™ development kit brings easy Bluetooth® low energy connectivity to the LaunchPad kit ecosystem with the SimpleLink ultra-low power CC26xx family of devices. This LaunchPad kit also supports development for multi-protocol support for the SimpleLink multi-standard CC2650 wireless MCU and the rest of CC26xx family of products: CC2630 wireless MCU for ZigBee®/6LoWPAN and CC2640 wireless MCU for Bluetooth low energy.

Reference Designs for CC2650MODA 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.

4 Terminal Configuration and Functions

Section 4.1 shows pin assignments for the CC2650MODA device.

4.1 Module Pin Diagram



(1) The following I/O pins marked in **bold** in the pinout have high-drive capabilities:
- DIO 2
- DIO 3
- DIO 4
- JTAG_TMS
- DIO 5/JTAG_TDO
- DIO 6/JTAG_TDI

(2) The following I/O pins marked in *italics* in the pinout have analog capabilities:
- DIO 7
- DIO 8
- DIO 9
- DIO 10
- DIO 11
- DIO 12
- DIO 13
- DIO 14

Figure 4-1. CC2650MODA MOH Package (16.9-mm × 11-mm) Module Pinout

4.2 Pin Functions

Table 4-1 describes the CC2650MODA pins.

Table 4-1. Signal Descriptions – MOH Package

PIN NAME	PIN NO.	PIN TYPE	DESCRIPTION
DIO_0	4	Digital I/O	GPIO, Sensor Controller
DIO_1	5	Digital I/O	GPIO, Sensor Controller
DIO_2	6	Digital I/O	GPIO, Sensor Controller, high-drive capability
DIO_3	7	Digital I/O	GPIO, Sensor Controller, high-drive capability
DIO_4	8	Digital I/O	GPIO, Sensor Controller, high-drive capability
DIO_5/JTAG_TDO	11	Digital I/O	GPIO, high-drive capability, JTAG_TDO
DIO_6/JTAG_TDI	12	Digital I/O	GPIO, high-drive capability, JTAG_TDI
DIO_7	14	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_8	15	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_9	16	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_10	17	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_11	18	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_12	19	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_13	20	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
DIO_14	21	Digital I/O, Analog I/O	GPIO, Sensor Controller, analog
EGP	G1, G2, G3, G4	Power	Ground – Exposed ground pad
GND	1, 3, 25	—	Ground
JTAG_TCK	10	Digital I/O	JTAG TCKC
JTAG_TMS	9	Digital I/O	JTAG TMSC, high-drive capability
NC	2, 24	NC	Not Connected—TI recommends leaving these pins floating
nRESET	13	Digital input	Reset, active low. No internal pullup
VDD	22, 23	Power	1.8-V to 3.8-V main chip supply

5 Specifications

5.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
VDD	Supply voltage		–0.3	4.1	V
	Voltage on any digital pin(3)		–0.3	VDD + 0.3, max 4.1	V
V_{in}	Voltage on ADC input	Voltage scaling enabled	–0.3	VDD	V
		Voltage scaling disabled, internal reference	–0.3	1.49	
		Voltage scaling disabled, VDD as reference	–0.3	VDD / 2.9	
	Input RF level			5	dBm
T_{stg}	Storage temperature		–40	85	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to ground, unless otherwise noted.
(3) Including analog capable DIO.

5.2 ESD Ratings

				VALUE	UNIT
V_{ESD}	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS001(1)	All pins	±1000	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.

5.3 Recommended Operating Conditions

		MIN	MAX	UNIT
Ambient temperature		–40	85	°C
Operating supply voltage (VDD)	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

5.4 Power Consumption Summary

T_c = 25°C, V_{DD} = 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 VDD below Power-on-Reset threshold		100		nA
		Shutdown. No clocks running, no retention		150		nA
		Standby. With RTC, CPU, RAM and (partial) register retention. RCOSC_LF		1		µA
		Standby. With RTC, CPU, RAM and (partial) register retention. XOSC_LF		1.2		µA
		Standby. With Cache, RTC, CPU, RAM and (partial) register retention. RCOSC_LF		2.5		µA
		Standby. With Cache, RTC, CPU, RAM and (partial) register retention. XOSC_LF		2.7		µA
		Idle. Supply systems and RAM powered.		550		µA
		Active. Core running CoreMark		1.45 mA + 31 µA/MHz		
		Radio RX		6.2		mA
		Radio TX, 0-dBm output power		6.8		mA
		Radio TX, 5-dBm output power		9.4		mA
Peripheral Current Consumption (Adds to core current I_{core} for each peripheral unit activated)(1)						
I_{peri}	Peripheral power domain	Delta current with domain enabled		20		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) I_{peri} is not supported in Standby or Shutdown.

5.5 General Characteristics

T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
FLASH MEMORY					
Supported flash erase cycles before failure		100			k Cycles
Flash page/sector erase current	Average delta current		12.6		mA
Flash page/sector erase time(1)			8		ms
Flash page/sector size			4		KB
Flash write current	Average delta current, 4 bytes at a time		8.15		mA
Flash write time(1)	4 bytes at a time		8		µs

(1) This number is dependent on flash aging and will increase over time and erase cycles.

5.6 Antenna

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Polarization			Linear		
Peak Gain	2450 MHz		1.26		dBi
Efficiency	2450 MHz		57%		

5.7 1-Mbps GFSK (Bluetooth low energy) – RX

RF performance is specified in a single ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C, V_{DD} = 3.0 V, f_{RF} = 2440 MHz, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receiver sensitivity	BER = 10^{-3}		–97		dBm
Receiver saturation	BER = 10^{-3}		4		dBm
Frequency error tolerance	Difference between center frequency of the received RF signal and local oscillator frequency.	–350		350	kHz
Data rate error tolerance		–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}		29 / 23(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}		23		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		–8		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 MHz 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 GHz 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

5.8 1-Mbps GFSK (Bluetooth low energy) – TX

RF performance is specified in a single ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C, V_{DD} = 3.0 V, f_{RF} = 2440 MHz, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output power, highest setting			5		dBm
Output power, lowest setting			–21		dBm
Spurious emission conducted measurement(1)	f < 1 GHz, outside restricted bands		–43		dBm
	f < 1 GHz, restricted bands ETSI		–58		dBm
	f < 1 GHz, restricted bands FCC		–57		dBm
	f > 1 GHz, including harmonics		–45		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)

5.9 IEEE 802.15.4 (Offset Q-PSK DSSS, 250 kbps) – RX

RF performance is specified in a single ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receiver sensitivity	PER = 1%		–100		dBm
Receiver saturation	PER = 1%		–7		dBm
Adjacent channel rejection	Wanted signal at –82 dBm, modulated interferer at ±5 MHz, PER = 1%		35		dB
Alternate channel rejection	Wanted signal at –82 dBm, modulated interferer at ±10 MHz, PER = 1%		52		dB
Channel rejection, ±15 MHz or more	Wanted signal at –82 dBm, undesired signal is IEEE 802.15.4 modulated channel, stepped through all channels 2405 to 2480 MHz, PER = 1%		57		dB
Blocking and desensitization, 5 MHz from upper band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		64		dB
Blocking and desensitization, 10 MHz from upper band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		64		dB
Blocking and desensitization, 20 MHz from upper band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		65		dB
Blocking and desensitization, 50 MHz from upper band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		68		dB
Blocking and desensitization, –5 MHz from lower band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		63		dB
Blocking and desensitization, –10 MHz from lower band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		63		dB
Blocking and desensitization, –20 MHz from lower band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		65		dB
Blocking and desensitization, –50 MHz from lower band edge	Wanted signal at –97 dBm (3 dB above the sensitivity level), CW jammer, PER = 1%		67		dB
Spurious emissions, 30 MHz 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 GHz 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
Frequency error tolerance	Difference between center frequency of the received RF signal and local oscillator frequency		>200		ppm
RSSI dynamic range			100		dB
RSSI accuracy			±4		dB

5.10 IEEE 802.15.4 (Offset Q-PSK DSSS, 250 kbps) – TX

RF performance is specified in a single ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output power, highest setting			5		dBm
Output power, lowest setting			–21		dBm
Error vector magnitude	At maximum output power		2%		
Spurious emission conducted measurement(1)	f < 1 GHz, outside restricted bands		–43		dBm
	f < 1 GHz, restricted bands ETSI		–58		
	f < 1 GHz, restricted bands FCC		–57		
	f > 1 GHz, including harmonics		–45		

(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)

5.11 24-MHz Crystal Oscillator (XOSC_HF)(1)

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Crystal frequency			24		MHz
Crystal frequency tolerance(2)		–40		40	ppm
Start-up time(3)			150		µs

(1) Probing or otherwise stopping the XTAL while the DC-DC converter is enabled may cause permanent damage to the device.
(2) Includes initial tolerance of the crystal, drift over temperature, aging and frequency pulling due to incorrect load capacitance. As per Bluetooth and IEEE 802.15.4 specification
(3) Kick-started based on a temperature and aging compensated RCOSC_HF using precharge injection

5.12 32.768-kHz Crystal Oscillator (XOSC_LF)

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Crystal frequency			32.768		kHz
Initial crystal frequency tolerance, Bluetooth low energy applications	T_c = 25°C	–20		20	ppm
Crystal aging		-3		3	ppm/year

5.13 48-MHz RC Oscillator (RCOSC_HF)

T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Frequency			48		MHz
Uncalibrated frequency accuracy			±1%		
Calibrated frequency accuracy(1)			±0.25%		
Start-up time			5		µs

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

5.14 32-kHz RC Oscillator (RCOSC_LF)

T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Calibrated frequency			32.8		kHz
Temperature coefficient			50		ppm/°C

5.15 ADC Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Input voltage range		0		V_{DD}	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
		VDD 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
		VDD 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 and SNDR	Signal-to-noise and distortion ratio	Internal 4.3-V equivalent reference (2), 200 ksps, 9.6-kHz input tone		60		dB
		VDD 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
		VDD as reference, 200 ksps, 9.6-kHz input tone		72		
		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	VDD as reference		0.75		mA
	Reference voltage	Equivalent fixed internal reference (input voltage scaling enabled). For best accuracy, the ADC conversion should be initiated through the TI-RTOS™ API to include the gain or 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 TI-RTOS API to include the gain or offset compensation factors stored in FCFG1. This value is derived from the scaled value (4.3 V) as follows: V_{ref} = 4.3 V × 1408 / 4095		1.48		V
	Reference voltage	VDD as reference (Also known as *RELATIVE*) (input voltage scaling enabled)		VDD		V
	Reference voltage	VDD as reference (Also known as *RELATIVE*) (input voltage scaling disabled)		VDD / 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 Figure 5-24.
(4) For a typical example, see Figure 5-25.
(5) Applied voltage must be within absolute maximum ratings (see Section 5.1) at all times.

5.16 Temperature Sensor

T_c = 25°C, V_{DD} = 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.

5.17 Battery Monitor

T_c = 25°C, V_{DD} = 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

5.18 Continuous Time Comparator

T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage range		0		V_{DD}	V
External reference voltage		0		V_{DD}	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.

5.19 Low-Power Clocked Comparator

T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage range		0		VDD	V
Clock frequency			32		kHz
Internal reference voltage, VDD / 2			1.49–1.51		V
Internal reference voltage, VDD / 3			1.01–1.03		V
Internal reference voltage, VDD / 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			<2		mV
Hysteresis			<5		mV
Decision time	Step from –50 mV to +50 mV		<1		clock-cycle
Current consumption when enabled			362		nA

5.20 Programmable Current Source

T_c = 25°C, V_{DD} = 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.

5.21 DC Characteristics

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
T_A = 25°C, V_{DD} = 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 = VDD		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_{DD} = 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
GPIO VOL at 4-mA load	IOCURR = 1		0.28		V
T_A = 25°C, V_{DD} = 3.8 V					
GPIO pullup current	Input mode, pullup enabled, Vpad = 0 V		277		µA
GPIO pulldown current	Input mode, pulldown enabled, Vpad = VDD		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	VDD
VIL	Highest GPIO input voltage reliably interpreted as a «Low»	0.2			VDD

5.22 Thermal Resistance Characteristics for MOH Package

NAME	DESCRIPTION	°C/W (1) (2)	AIR FLOW (m/s) (3)
$R\Theta_{JC}$	Junction-to-case	20.0	
$R\Theta_{JB}$	Junction-to-board	15.3	
$R\Theta_{JA}$	Junction-to-free air	29.6	0
$R\Theta_{JMA}$	Junction-to-moving air	25.0	1
Psi_{JT}	Junction-to-package top	8.8	0
Psi_{JB}	Junction-to-board	14.8	0

(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*

Power dissipation of 2 W and an ambient temperature of 70ºC is assumed.
(3) m/s = meters per second.

5.23 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
SYNCHRONOUS SERIAL INTERFACE (SSI) (4)						
S1 (SLAVE) (5)	t_{clk_per}	SSIClk period	12		65024	System clocks
S2 (5)	t_{clk_high}	SSIClk high time		0.5		t_{clk_per}
S3 (5)	t_{clk_low}	SSIClk low time		0.5		t_{clk_per}

(1) For smaller coin cell batteries, with high worst-case end-of-life equivalent source resistance, a 22-µF VDD input capacitor (see Section 7.1.1) 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 Section 5.14).
(3) T_A = –40°C to +85°C, V_{DD} = 1.7 V to 3.8 V, unless otherwise noted.
(4) T_c = 25°C, V_{DD} = 3.0 V, unless otherwise noted. Device operating as slave. For SSI master operation, see Section 5.24.
(5) Refer to the SSI timing diagrams Figure 5-1, Figure 5-2, and Figure 5-3.

5.24 Switching Characteristics

Measured on the TI CC2650EM-5XD reference design with T_c = 25°C, V_{DD} = 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

Switching Characteristics *(continued)*

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SYNCHRONOUS SERIAL INTERFACE (SSI) (1)					
S1 (TX only)(2) t_{clk_per} (SSIClk period)	One-way communication to SLAVE	4		65024	System clocks
S1 (TX and RX)(2) t_{clk_per} (SSIClk period)	Normal duplex operation	8		65024	System clocks
S2(2) t_{clk_high} (SSIClk high time)			0.5		t_{clk_per}
S3(2) t_{clk_low} (SSIClk low time)			0.5		t_{clk_per}

(1) Device operating as master. For SSI slave operation, see Section 5.23.
(2) Refer to SSI timing diagrams Figure 5-1, Figure 5-2, and Figure 5-3.

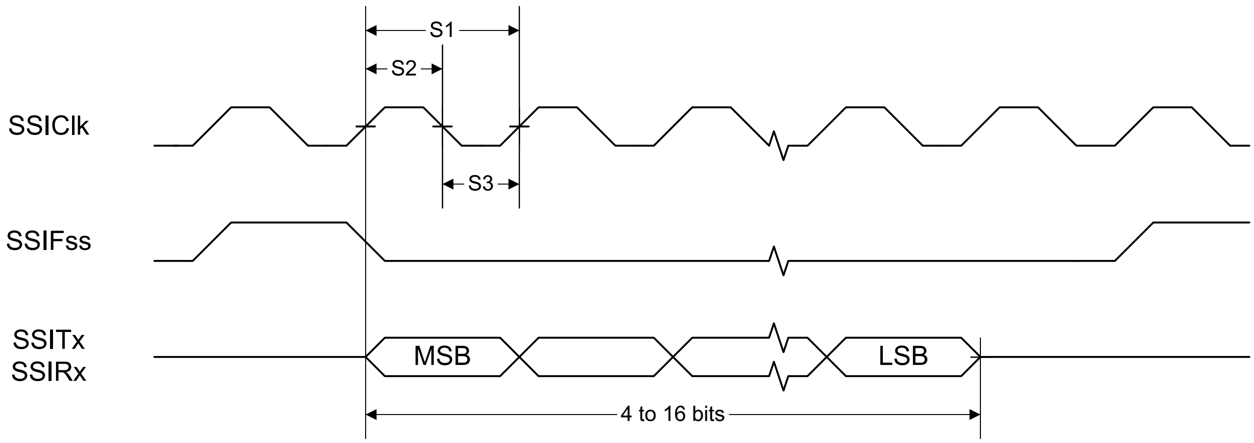


Figure 5-1. SSI Timing for TI Frame Format (FRF = 01), Single Transfer Timing Measurement

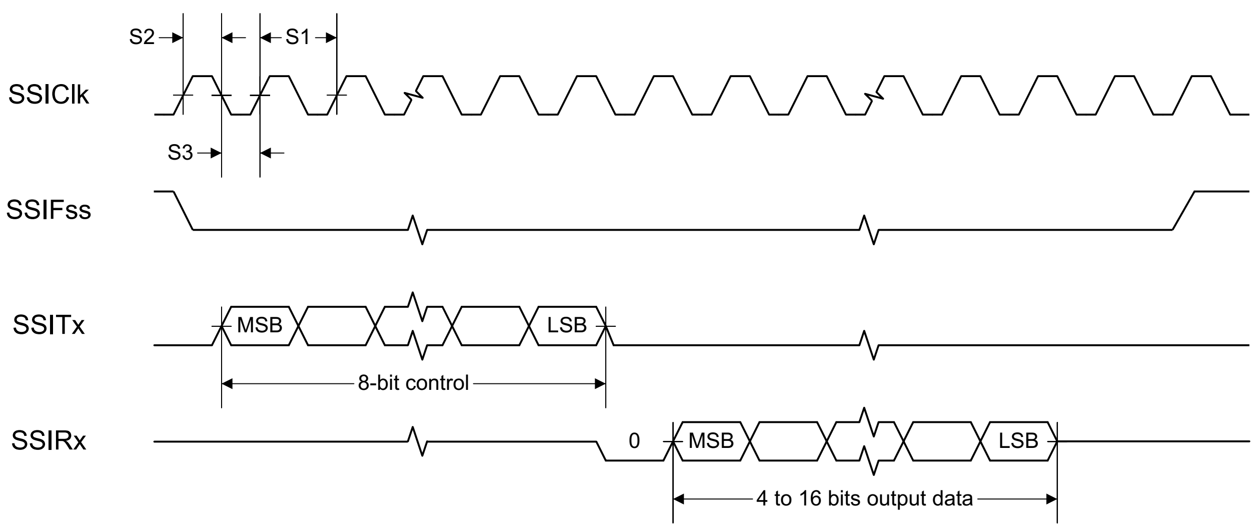


Figure 5-2. SSI Timing for MICROWIRE Frame Format (FRF = 10), Single Transfer

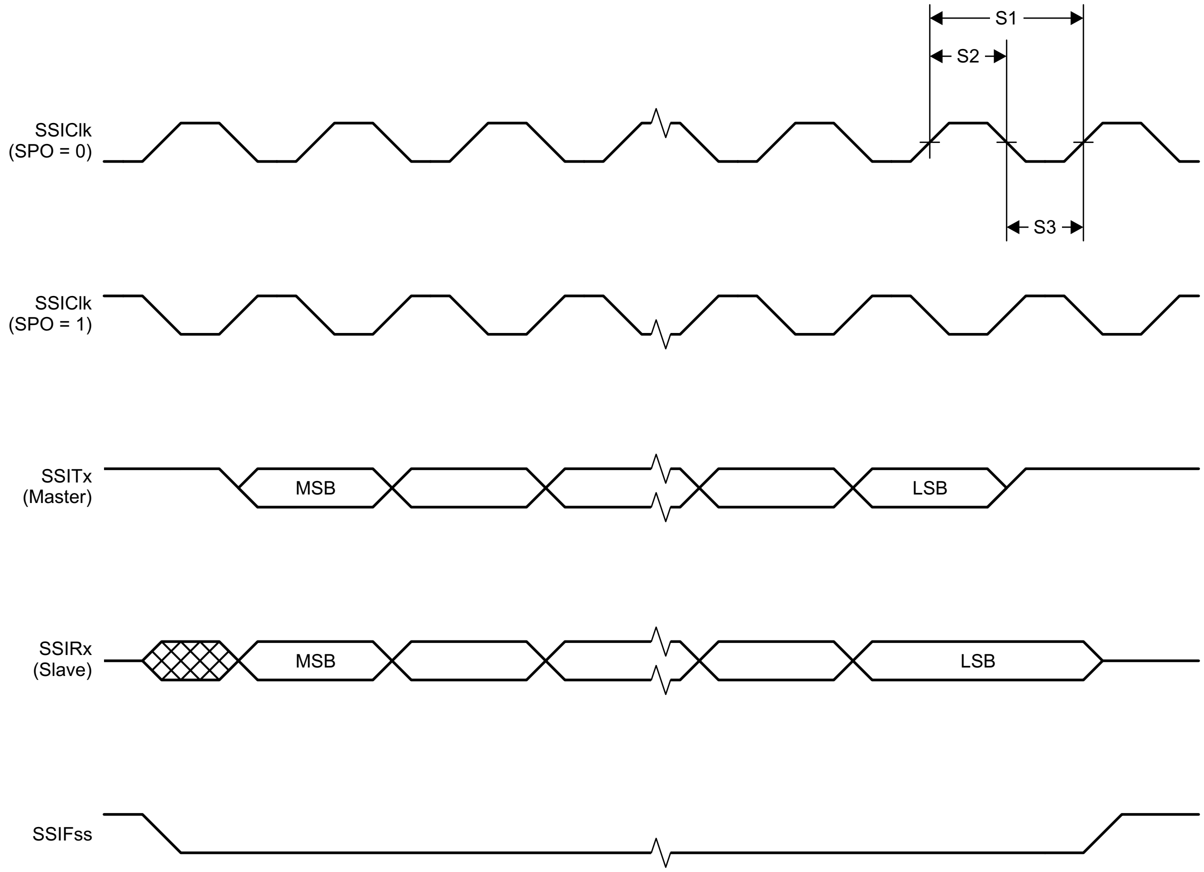


Figure 5-3. SSI Timing for SPI Frame Format (FRF = 00), With SPH = 1

5.25 Typical Characteristics

This section contains typical performance plots measured on the CC2650F128RHB device. They are published in the CC2650 data sheet, and the plots relevant for the CC2650MODA device are repeated here. RF performance is specified in a single-ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C and V_{DD} = 3.0 V, unless otherwise noted.

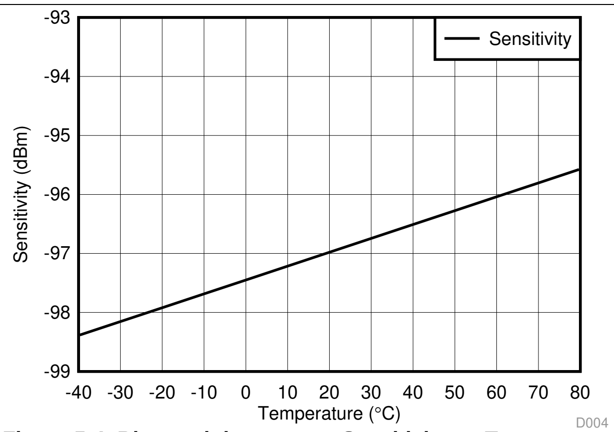


Figure 5-4. Bluetooth low energy Sensitivity vs Temperature

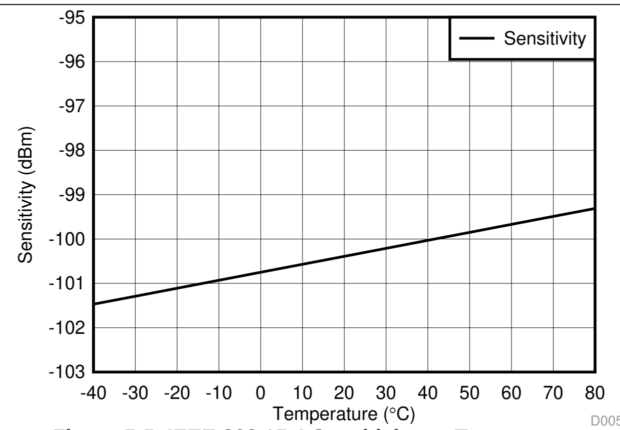


Figure 5-5. IEEE 802.15.4 Sensitivity vs Temperature

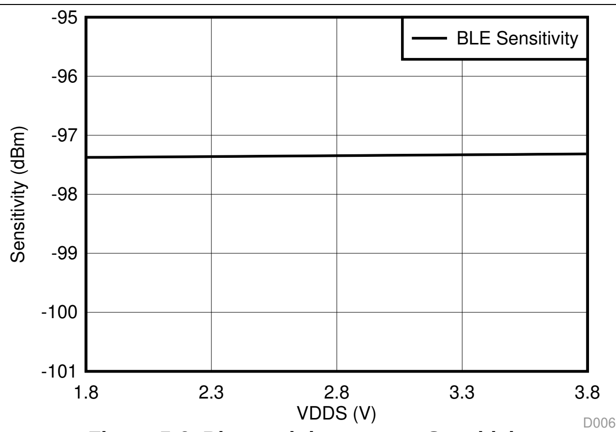


Figure 5-6. Bluetooth low energy Sensitivity vs Supply Voltage (VDD)

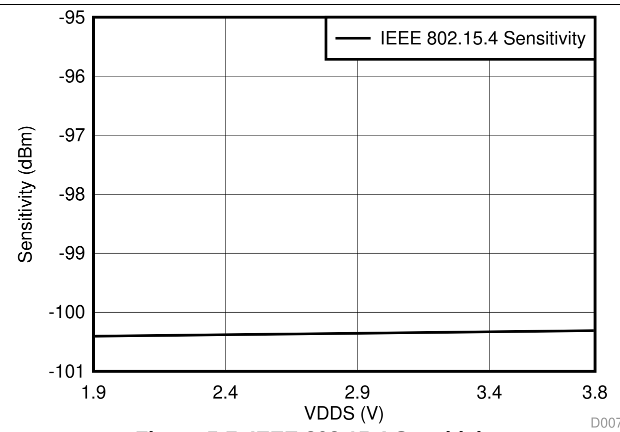


Figure 5-7. IEEE 802.15.4 Sensitivity vs Supply Voltage (VDD)

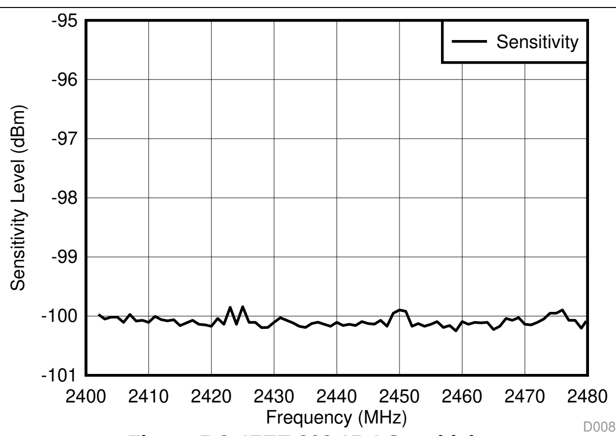


Figure 5-8. IEEE 802.15.4 Sensitivity vs Channel Frequency

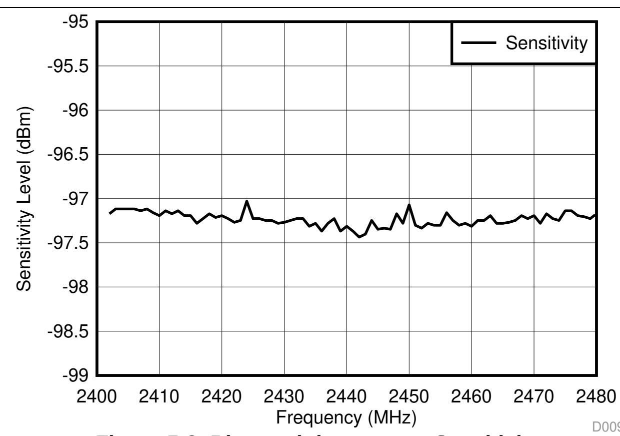


Figure 5-9. Bluetooth low energy Sensitivity vs Channel Frequency

Typical Characteristics *(continued)*

This section contains typical performance plots measured on the CC2650F128RHB device. They are published in the CC2650 data sheet, and the plots relevant for the CC2650MODA device are repeated here. RF performance is specified in a single-ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C and V_{DD} = 3.0 V, unless otherwise noted.

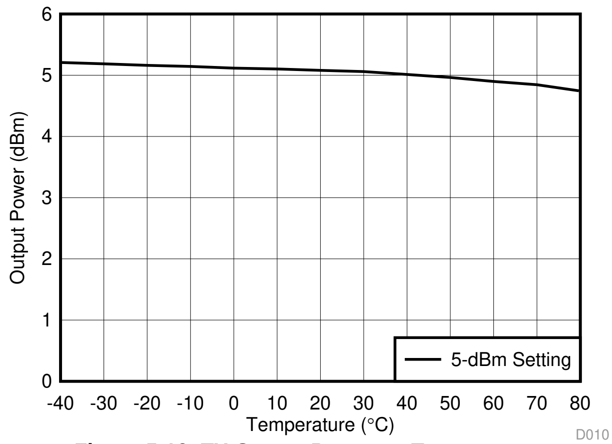


Figure 5-10. TX Output Power vs Temperature

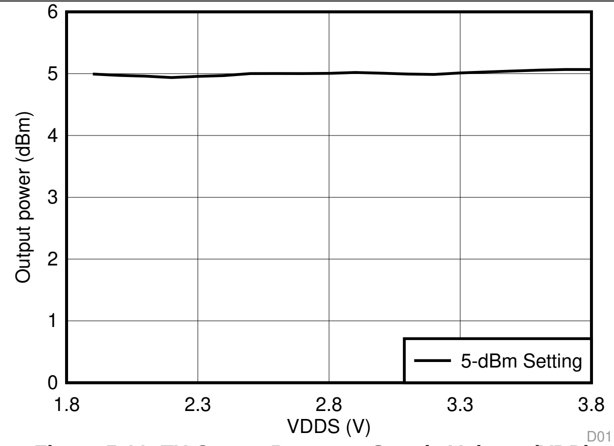


Figure 5-11. TX Output Power vs Supply Voltage (VDD)

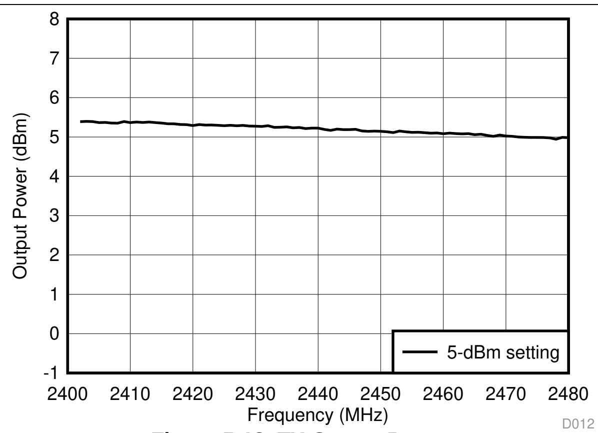


Figure 5-12. TX Output Power vs Channel Frequency

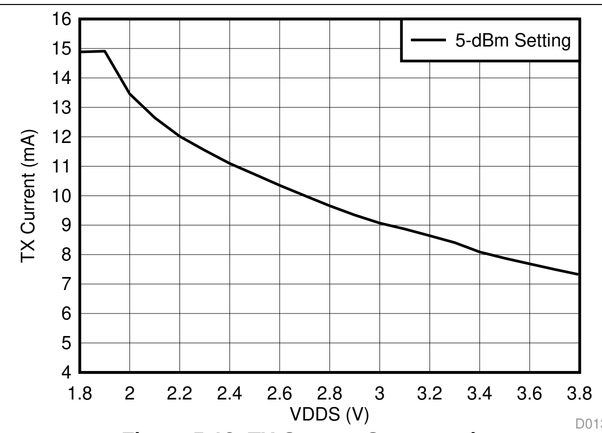


Figure 5-13. TX Current Consumption vs Supply Voltage (VDD)

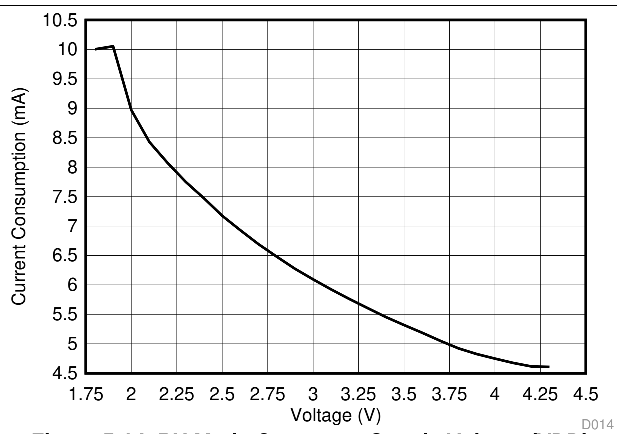


Figure 5-14. RX Mode Current vs Supply Voltage (VDD)

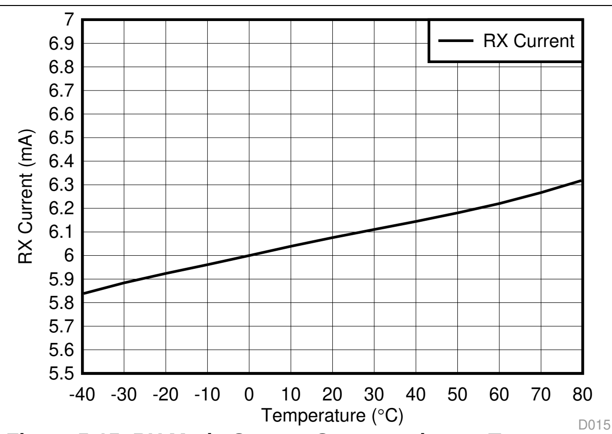


Figure 5-15. RX Mode Current Consumption vs Temperature

Typical Characteristics *(continued)*

This section contains typical performance plots measured on the CC2650F128RHB device. They are published in the CC2650 data sheet, and the plots relevant for the CC2650MODA device are repeated here. RF performance is specified in a single-ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C and V_{DD} = 3.0 V, unless otherwise noted.

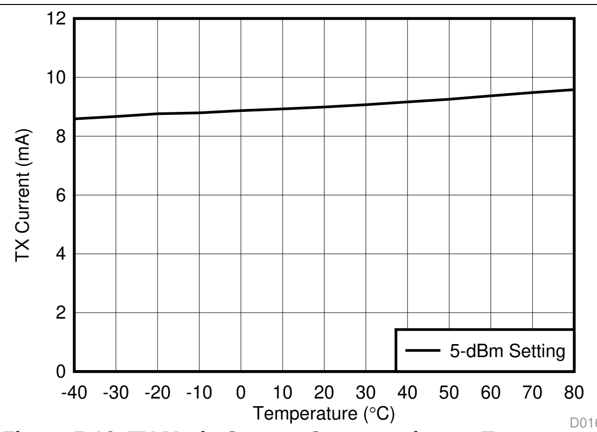


Figure 5-16. TX Mode Current Consumption vs Temperature

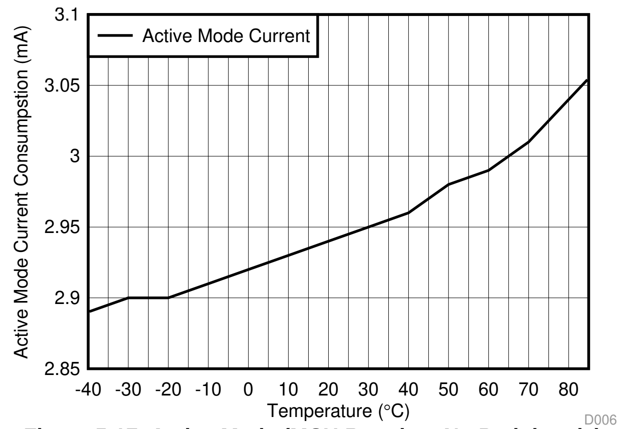


Figure 5-17. Active Mode (MCU Running, No Peripherals) Current Consumption vs Temperature

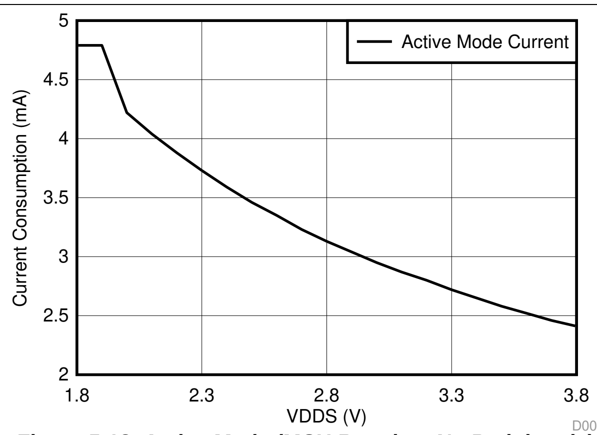


Figure 5-18. Active Mode (MCU Running, No Peripherals) Current Consumption vs Supply Voltage (VDD)

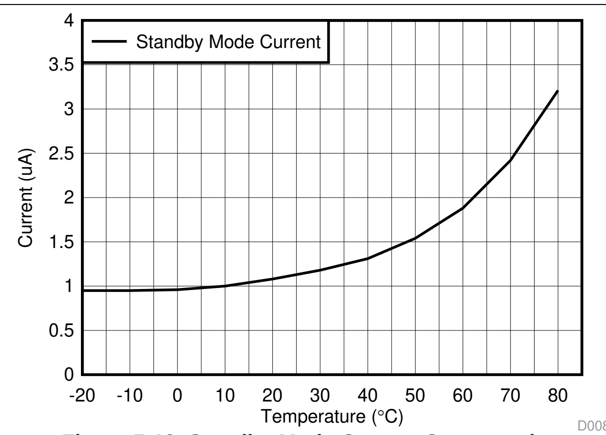


Figure 5-19. Standby Mode Current Consumption With RCOSC RTC vs Temperature

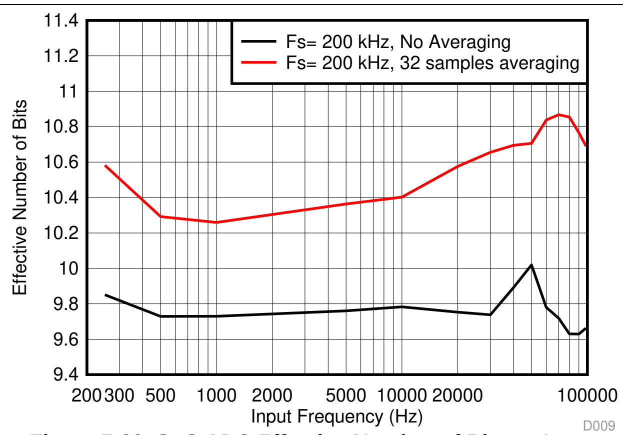


Figure 5-20. SoC ADC Effective Number of Bits vs Input Frequency (Internal Reference)

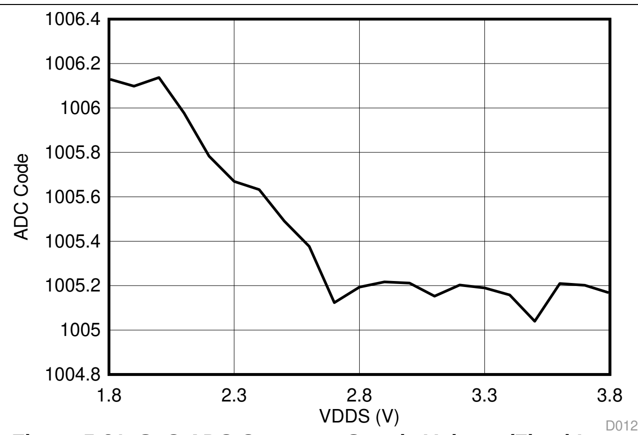


Figure 5-21. SoC ADC Output vs Supply Voltage (Fixed Input, Internal Reference)

Typical Characteristics *(continued)*

This section contains typical performance plots measured on the CC2650F128RHB device. They are published in the CC2650 data sheet, and the plots relevant for the CC2650MODA device are repeated here. RF performance is specified in a single-ended 50-Ω reference plane at the antenna feeding point with T_c = 25°C and V_{DD} = 3.0 V, unless otherwise noted.

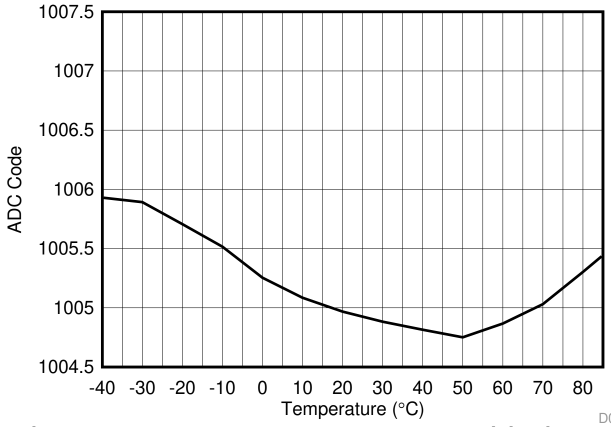


Figure 5-22. SoC ADC Output vs Temperature (Fixed Input, Internal Reference)

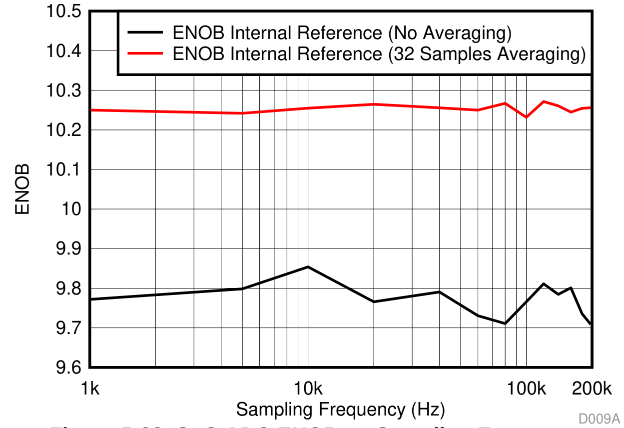


Figure 5-23. SoC ADC ENOB vs Sampling Frequency (Input Frequency = FS / 10)

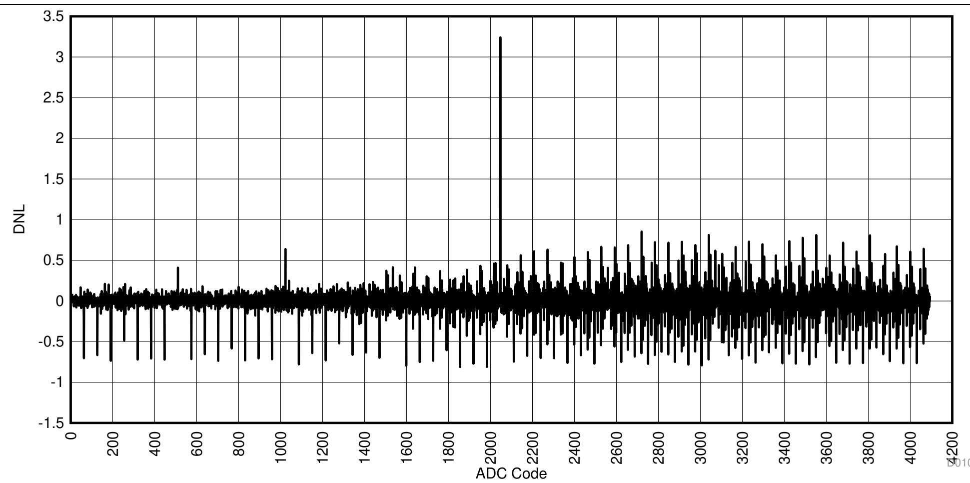


Figure 5-24. SoC ADC DNL vs ADC Code (Internal Reference)

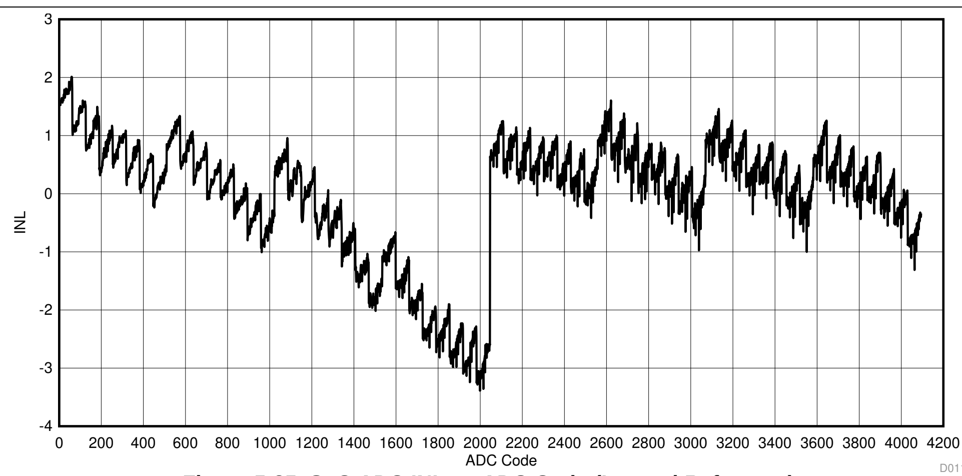


Figure 5-25. SoC ADC INL vs ADC Code (Internal Reference)

6 Detailed Description

6.1 Overview

Figure 6-1 shows the core modules of the CC2650MODA device.

6.2 Functional Block Diagram

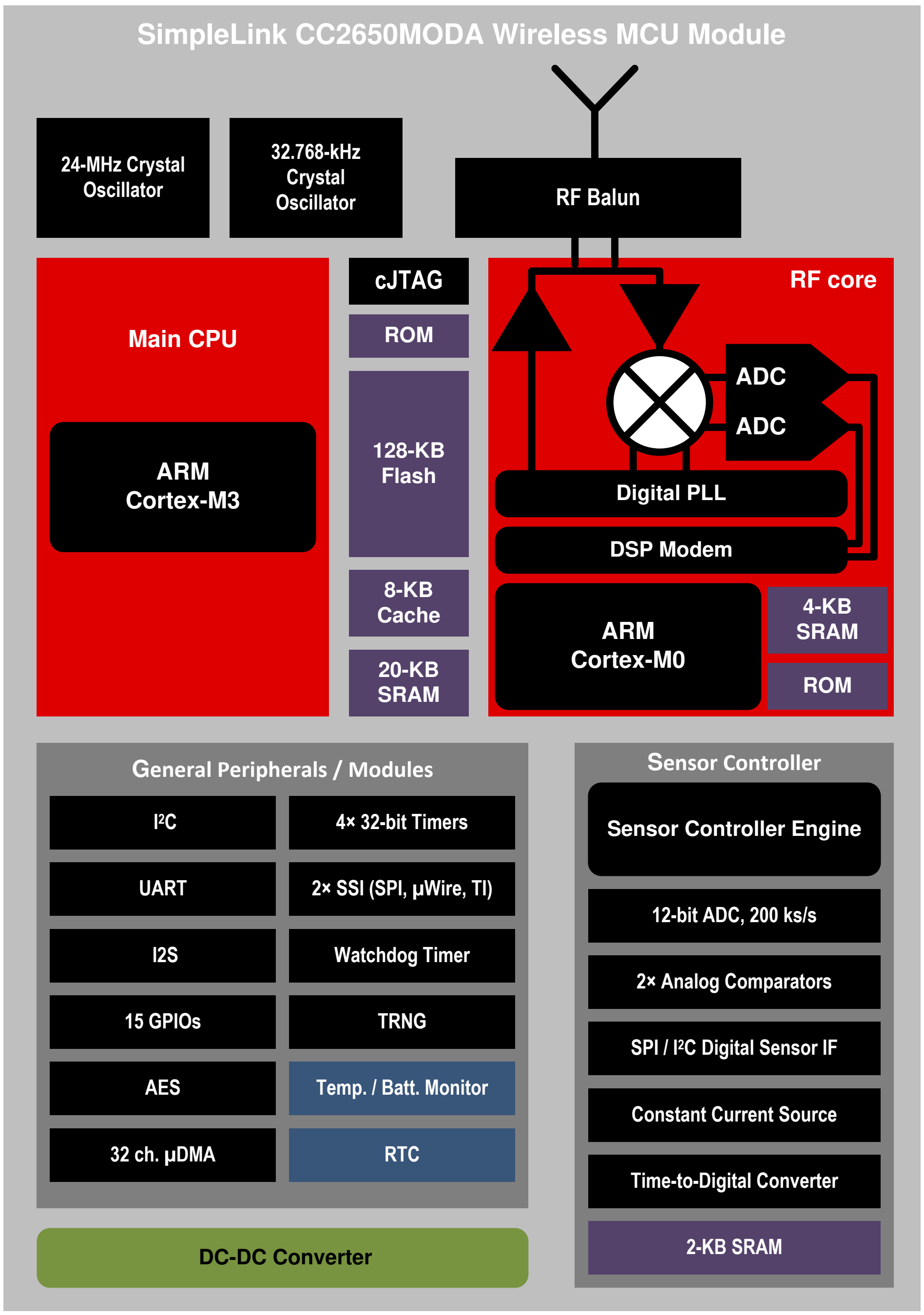


Figure 6-1. CC2650MODA Functional Block Diagram

6.3 Main CPU

The SimpleLink CC2650MODA wireless MCU contains an ARM Cortex-M3 32-bit CPU, which runs the application and the higher layers of the protocol stack.

The Cortex-M3 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.

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

6.4 RF Core

The RF core contains an ARM Cortex-M0 processor that interfaces the analog RF and base-band circuitries, 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 can autonomously handle the time-critical aspects of the radio protocols (802.15.4 RF4CE and ZigBee, 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.

6.5 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 Cortex-M3 CPU.

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

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

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 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.

Table 6-1 lists the GPIOs that are connected to the Sensor Controller.

Table 6-1. GPIOs Connected to the Sensor Controller(1)

ANALOG CAPABLE	16.9 × 11 MOH DIO NUMBER
Y	14
Y	13
Y	12
Y	11
Y	9
Y	10
Y	8
Y	7
N	4
N	3
N	2
N	1
N	0

(1) Up to 13 pins can be connected to the Sensor Controller. Up to eight of these pins can be connected to analog modules

6.6 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 8KB of cache can be used as a general-purpose RAM.

The ROM provides preprogrammed embedded TI-RTOS kernel, Driverlib and lower layer protocol stack software (802.15.4 MAC and Bluetooth low energy Controller). The ROM also contains a bootloader that can be used to reprogram the device using SPI or UART.

6.7 Debug

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

6.8 Power Management

To minimize power consumption, the CC2650MODA device supports a number of power modes and power-management features (see Table 6-2).

Table 6-2. 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	550 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
Wake up on reset pin	Available	Available	Available	Available	Available
Brown Out Detector (BOD)	Active	Active	Duty Cycled (2)	Off	N/A
Power On Reset (POR)	Active	Active	Active	Active	N/A

(1) Not including RTOS overhead
(2) The Brown Out Detector is disabled between recharge periods in STANDBY. Lowering the supply voltage below the BOD threshold between two recharge periods while in STANDBY may cause the BOD to lock the device upon wake-up until a Reset or POR releases it. To avoid this, TI recommends that STANDBY mode is avoided if there is a risk that the supply voltage (VDD) may drop below the specified operating voltage range. For the same reason, it is also good practice to ensure that a power cycling operation, such as a battery replacement, triggers a Power-on-reset by ensuring that the VDD decoupling network is fully depleted before applying supply voltage again (for example, inserting new batteries).

In active mode, the application Cortex-M3 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 Table 6-2).

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 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 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.

6.9 Clock Systems

The CC2650MODA device 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.

6.10 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 Section 4).

The SSIs are synchronous serial interfaces that are compatible with SPI, MICROWIRE, and TI's 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 Cortex-M3 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, and peripheral-to-peripheral
- Data sizes of 8, 16, and 32 bits

The AON domain contains circuitry that is always enabled, except in Shutdown mode (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.

6.11 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.

6.12 Certification

The CC2650MODA module is certified to the standards listed in Table 6-3 (with IDs where applicable).

Table 6-3. CC2650MODA List of Certifications

REGULATORY BODY	SPECIFICATION	ID (IF APPLICABLE)
FCC (USA)	Part 15C:2015 + MPE FCC 1.1307 RF Exposure (Bluetooth)	FCC ID: ZAT26M1
	Part 15C:2015 + MPE FCC 1.1307 RF Exposure (802.15.4)	
IC (Canada)	RSS-102 (MPE) and RSS-247 (Bluetooth)	ID: 451H-26M1
	RSS-102 (MPE) and RSS-247 (IEEE 802.15.4)	
ETSI/CE (Europe)	EN 300 328 V2.1.1 (Bluetooth)	
	EN 300 328 V2.1.1 (802.15.4)	
	EN 62479:2010 (MPE)	
	Draft EN 301 489-1 V2.2.0 (2017-03)	
	Draft EN 301 489-1 V3.2.0 (2017-03)	
	EN 55024:2010 + A1:2015	
	EN 55032:2015 + AC:2016-07	
	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/A2:2013	
Japan MIC	ARIB STD-T66	No: 201-160413/00
	JATE	D 16 0093 201/00

6.12.1 Regulatory Information Europe

Hereby, Texas Instruments Inc. declares that the radio equipment type CC2650MODA is in compliance with Directive 2014/53/EU.

The full text of the EU Declaration of Conformity (DoC) is available on the CC2650MODA technical documents page. The compliance has been verified in the operating frequency band of 2400 MHz to 2483.5 MHz. Developers and integrators that incorporate the CC2650MODA RF Module in any end products are responsible for obtaining applicable regulatory approvals for such end product.

NOTE

The CC2650MODA has been tested in the 2400-GHz to 2483.5-GHz ISM frequency band at 3.3 V with a maximum peak power of 5.056-dBm EIRP across the temperature range –40°C to +85°C and tolerance.

6.12.2 Federal Communications Commission Statement

You are cautioned that changes or modifications not expressly approved by the part responsible for compliance could void the user's authority to operate the equipment.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference and
2. This device must accept any interference received, including interference that may cause undesired operation of the device.

FCC RF Radiation Exposure Statement:

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. End users must follow the specific operating instructions for satisfying RF exposure limits. This transmitter must not be colocated or operating with any other antenna or transmitter.

6.12.3 Canada, Industry Canada (IC)

This device complies with Industry Canada licence-exempt RSS standards.

Operation is subject to the following two conditions:

1. This device may not cause interference, and
2. This device must accept any interference, including interference that may cause undesired operation of the device

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence

L'exploitation est autorisée aux deux conditions suivantes:

1. l'appareil ne doit pas produire de brouillage, et
2. l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC RF Radiation Exposure Statement:

To comply with IC RF exposure requirements, this device and its antenna must not be co-located or operating in conjunction with any other antenna or transmitter.

Pour se conformer aux exigences de conformité RF canadienne l'exposition, cet appareil et son antenne ne doivent pas étre co-localisés ou fonctionnant en conjonction avec une autre antenne ou transmetteur.

6.12.4 Japan (JATE ID)

JATE ID is D 16 0093 201

For units already sold and marked with JATE ID: D 16 0086 201, please publicize to users that the JATE ID: D 16 0086 201 should be read as D 16 0093 201 (for example, clients web page, by software update, or similar).

6.13 End Product Labeling

This module is designed to comply with the FCC statement, FCC ID: ZAT26M1. The host system using this module must display a visible label indicating the following text:

"Contains FCC ID: ZAT26M1"

This module is designed to comply with the IC statement, IC: 451H-26M1. The host system using this module must display a visible label indicating the following text:

"Contains IC: 451H-26M1"

6.14 Manual Information to the End User

The OEM integrator must be aware not to provide information to the end user regarding how to install or remove this RF module in the user's manual of the end product that integrates this module.

NOTE

Operation outside of test conditions as documented in this datasheet is not supported and may void TI's warranty. Should the user choose to configure the CC2650MODA to operate outside of the test conditions, the device must be operated inside a protected and controlled environment, such as an RF shielded chamber and user must ensure compliance with regulatory requirements.

The end user's manual must include all required regulatory information and warnings as shown in this document.

6.15 Module Marking

Figure 6-2 shows the marking for the SimpleLink™ CC2650MODA module.

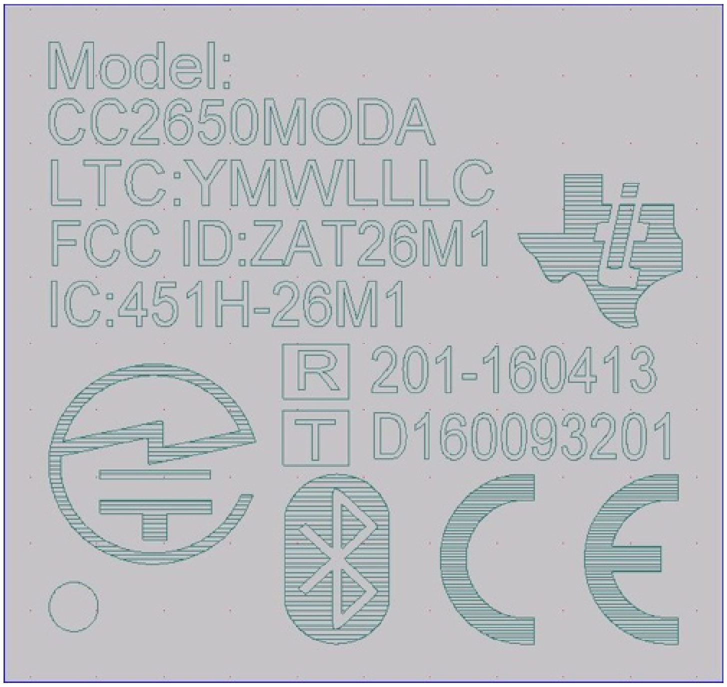


Figure 6-2. SimpleLink CC2650MODA Module Marking

Table 6-4. Module Descriptions

MARKING	DESCRIPTION
CC2650MODA	Model
YMWLLLC	LTC (lot trace code): • Y = Year • M = Month • WLLLLC = Reserved for internal use
ZAT26M1	FCC ID: single modular FCC grant ID
451H-26M1	IC: single modular IC grant ID
	MIC compliance mark
R 201-160413	JATE ID: Japan module grant ID
T D160093201	ARIB STD-T66 ID: Japan modular grant ID
	Bluetooth compliance mark
CE	CE compliance mark

7 Application, Implementation, and Layout

NOTE

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.

NOTE

TI does not recommend the use of conformal coating or similar material on the module. This coating can lead to localized stress on the solder connections inside the module and impact the module reliability. Use caution during the module assembly process to the final PCB to avoid the presence of foreign material inside the module.

7.1 Application Information

7.1.1 Typical Application Circuit

No external components are required for the operation of the CC2650MODA device. Figure 7-1 shows the application circuit.

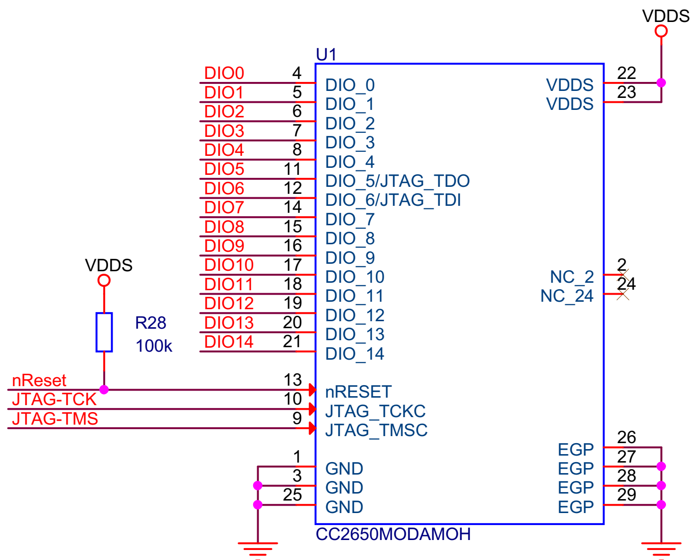


Figure 7-1. CC2650MODA Application Circuit

7.2 Layout

7.2.1 Layout Guidelines

Use the following guidelines to lay out the CC2650MODA device:

- The module must be placed close to the edge of the PCB.
- TI recommends leaving copper clearance on all PCB layers underneath the antenna area, as shown in Figure 7-2 and Figure 7-3.
- TI recommends using a generous amount of ground vias to stitch together the ground planes on different layers. Several ground vias should be placed close to the exposed ground pads of the module.
- No external decoupling is required.
- The reset line should have an external pullup resistor unless the line is actively driven. Placement of this component is not critical.
- TI recommends leaving a clearance in the top-side copper plane underneath the RF test pads.

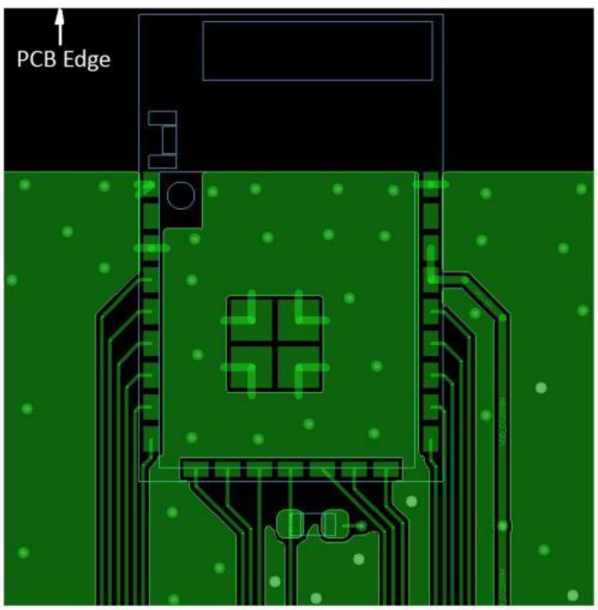


Figure 7-2. Top Layer

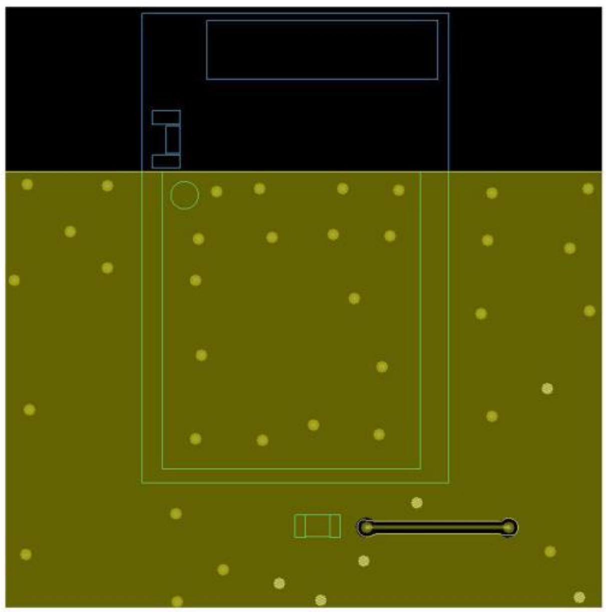


Figure 7-3. Bottom Layer

8 Environmental Requirements and Specifications

8.1 PCB Bending

The PCB follows IPC-A-600J for PCB twist and warpage < 0.75% or 7.5 mil per inch.

8.2 Handling Environment

8.2.1 Terminals

The product is mounted with motherboard through land-grid array (LGA). To prevent poor soldering, do not make skin contact with the LGA portion.

8.2.2 Falling

The mounted components will be damaged if the product falls or is dropped. Such damage may cause the product to malfunction.

8.3 Storage Condition

8.3.1 Moisture Barrier Bag Before Opened

A moisture barrier bag must be stored in a temperature of less than 30°C with humidity under 85% RH. The calculated shelf life for the dry-packed product will be 12 months from the date the bag is sealed.

8.3.2 Moisture Barrier Bag Open

Humidity indicator cards must be blue, < 30%.

8.4 Baking Conditions

Products require baking before mounting if:

- Humidity indicator cards read > 30%
- Temp < 30°C, humidity < 70% RH, over 96 hours

Baking condition: 90°C, 12 to 24 hours

Baking times: 1 time

8.5 Soldering and Reflow Condition

- Heating method: Conventional convection or IR convection
- Temperature measurement: Thermocouple d = 0.1 mm to 0.2 mm CA (K) or CC (T) at soldering portion or equivalent method
- Solder paste composition: Sn/3.0 Ag/0.5 Cu
- Allowable reflow soldering times: 2 times based on the reflow soldering profile (see Figure 8-1)
- Temperature profile: Reflow soldering will be done according to the temperature profile (see Figure 8-1)

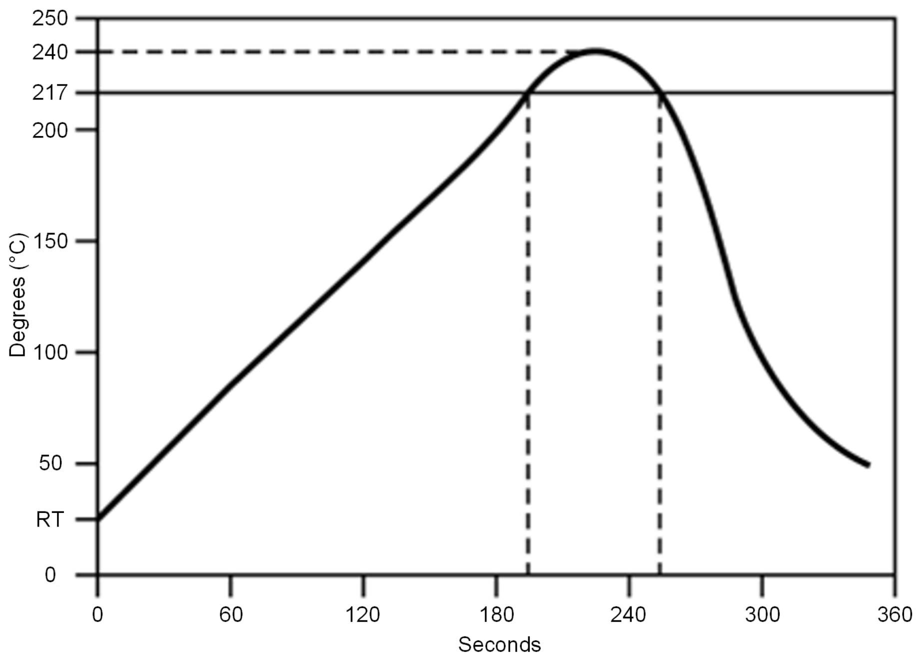


Figure 8-1. Temperature Profile for Evaluation of Solder Heat Resistance of a Component (at Solder Joint)

Table 8-1. Temperature Profile

Profile Elements	Convection or IR(1)
Peak temperature range	235 to 240°C typical (260°C maximum)
Pre-heat / soaking (150 to 200°C)	60 to 120 seconds
Time above melting point	60 to 90 seconds
Time with 5°C to peak	30 seconds maximum
Ramp up	< 3°C / second
Ramp down	< -6°C / second

(1) For details, refer to the solder paste manufacturer's recommendation.

NOTE

TI does not recommend the use of conformal coating or similar material on the SimpleLink™ module. This coating can lead to localized stress on the solder connections inside the module and impact the module reliability. Use caution during the module assembly process to the final PCB to avoid the presence of foreign material inside the module.

9 デバイスおよびドキュメントのサポート

9.1 デバイスの項目表記

製品開発サイクルの段階を示すために、TIではすべての型番や日付コードに接頭辞を割り当てます。各デバイスには、接頭辞/識別子としてX、P、空白(接頭辞なし)の3つのいずれかが割り当てられています (例: CC2650MODAは量産中です。このため、接頭辞/識別子は割り当てられていません)。

デバイス開発の段階は次のとおりです。

X 実験的デバイス。最終デバイスの電気的特性を必ずしも表さず、量産アセンブリ・フローを使用しない可能性があります。

P プロトタイプ・デバイス。最終的なシリコン・ダイとは限らず、最終的な電気的特性を満たさない可能性があります。

空白 認定済みのシリコン・ダイの量産バージョン。

量産デバイスの特性は完全に明確化されており、デバイスの品質と信頼性が十分に示されています。TIの標準保証が適用されます。

プロトタイプ・デバイス(XまたはP)の方が標準的な量産デバイスに比べて故障率が大きいと予測されます。これらのデバイスは予測される最終使用時の故障率が未定義であるため、テキサス・インスツルメンツではそれらのデバイスを量産システムで使用しないよう推奨しています。認定された量産デバイスのみを使用する必要があります。

TIデバイスの項目表記には、デバイス・ファミリ名の接尾辞も含まれます。この接尾辞はパッケージ・タイプを示します(例: MOH)。

MOHパッケージ・タイプのCC2650MODAデバイスの注文可能な部品番号については、このデータシートの末尾にあるパッケージ注文情報や、TIのWebサイト(www.ti.com)を参照するか、TIの販売担当者にお問い合わせください。

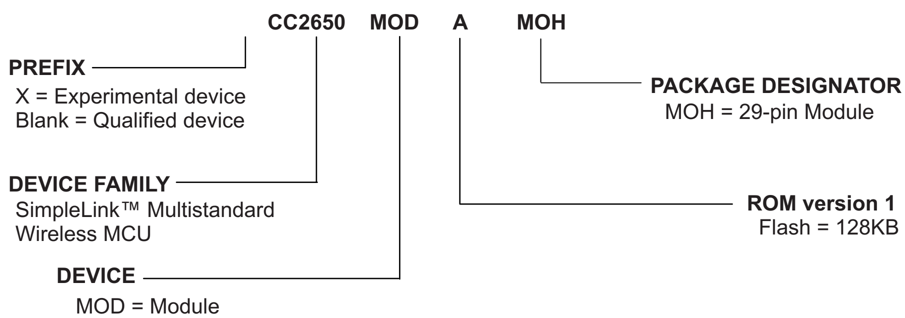


図 9-1. デバイスの項目表記

9.2 ツールとソフトウェア

TIは広範な開発ツールを提供しており、プロセッサの性能評価、コード生成、アルゴリズム実装の開発、ソフトウェアおよびハードウェア・モジュールの完全な統合とデバッグなどの用途に利用できます。

以下の製品は、CC2650MODAデバイスのアプリケーションの開発をサポートしています。

ソフトウェア・ツール

SmartRF Studio 7:

SmartRF Studio は、無線システムの設計者が設計プロセスの初期段階で RF-IC を簡単に評価するため役立つ、PC 用アプリケーションです。

- 無線パケットの送受信や、連続波形の送受信のテスト機能
- RFをサポート対象の評価ボードかデバッガに接続することで、カスタム・ボード上でRF性能を評価
- 無線構成設定の生成、編集、エクスポートをする場合は、ハードウェアがなくても使用可能
- TI製のCCxxxx RF-IC用のいくつかの開発キットと組み合わせて使用可能

Sensor Controller Studio:

Sensor Controller Studioは、CC26xx Sensor Controller用の開発環境です。Sensor ControllerはCC26xxに搭載されている独自の電力最適化CPUで、単純なバックグラウンド・タスクを自律的に実行し、システムCPUの状態に依存しません。

- Sensor Controller タスク・アルゴリズムを、Cライクのプログラミング言語を用いて実行可能
- Sensor Controller インターフェイス・ドライバを出力 (生成された Sensor Controller マシン・コードと関連する定義を含む)
- 統合された Sensor Controller タスク・テストとデバッグ機能を用いた迅速な開発が可能。これにより、センサ・データおよびアルゴリズム検証のライブでの可視化が可能になります。

IDEとコンパイラ

Code Composer Studio:

- プロジェクト管理ツールとエディタの付属した統合開発環境
- Code Composer Studio (CCS) 6.1およびそれ以降にはCC26xxデバイス・ファミリのサポートが組み込み済み
- XDSデバッガ、XDS100v3、XDS110、XDS200を最大限にサポート
- TI-RTOSとの高度な統合、TI-RTOS Object Viewのサポート

IAR Embedded Workbench for ARM

- プロジェクト管理ツールとエディタの付属した統合開発環境
- IAR EWARM 7.30.3およびそれ以降にはCC26xxデバイス・ファミリのサポートが組み込み済み
- 幅広いデバッガ・サポート。対象: XDS100v3、XDS200、IAR I-Jet、およびSegger J-Link
- プロジェクト管理ツールとエディタの付属した統合開発環境
- TI-RTOS用にRTOSプラグインが利用可能

CC2650MODAプラットフォーム用開発サポート・ツールの全リストは、テキサス・インスツルメンツWebサイトwww.ti.comに掲載されています。価格と在庫状況については、お近くのフィールド・セールス・オフィスまたは認可代理店にお問い合わせください。

9.3 ドキュメントのサポート

ドキュメントの更新についての通知を受け取るには、ti.comのデバイス製品フォルダを開いてください。右上の「アラートを受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

CC2650MODAデバイスについては、以下のドキュメントに記載されています。これらのドキュメントのコピーは、www.ti.comで入手できます。

準拠宣言

『CC2650MODA EU準拠宣言(DoC)』

正誤表

『CC2630およびCC2650 SimpleLink™ワイヤレスMCU正誤表』

テクニカル・リファレンス・マニュアル

『CC13x0、CC26x0 SimpleLink™ワイヤレスMCU』

アプリケーション・レポート

『CC2650モジュールでのスタンドアロンBluetooth® Low Energyアプリケーションの実行』

『How to Qualify Your Bluetooth(R) Low Energy Product』(英語)

ユーザーズ・ガイド

『CC2650モジュール BoosterPack™使い始めガイド』

ホワイト・ペーパー

『最適なTI Bluetooth®ソリューションの選択』

その他の資料

『認定済みワイヤレス・モジュールによるRF設計の課題の効率化』

9.4 テキサス・インスツルメンツのローパワーRF Webサイト

TIのローパワーRF Webサイトには、最新製品、アプリケーション・ノートおよびデザイン・ノート、FAQ、最新のニュースおよびイベント情報が記載されています。「ワイヤレス・コネクティビティ: TIのSimpleLink™サブ1GHzワイヤレスMCU」を参照してください。

9.5 ローパワーRF eニュースレター

ローパワーRF eニュースレターは、新製品、ニュース・リリース、開発者ニュース、TIのローパワーRFに関連したその他のニュースおよびイベント情報の最新版です。ローパワーRF eニュースレターの記事には、さらなるオンライン情報を得るためのリンクが含まれています。

www.ti.com/lprfnewsletterで、サインアップしてください。

9.6 コミュニティ・リソース

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community The TI engineer-to-engineer (E2E) community was created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

テキサス・インスツルメンツの組み込みプロセッサ**Wiki** テキサス・インスツルメンツの組み込みプロセッサを使用し始める開発者を支援し、これらのデバイスを取り巻くハードウェアとソフトウェアに関する一般知識の強化とイノベーションの促進を図るために、開設されました。

ローパワー**RF**オンライン・コミュニティ TI E2Eサポート・コミュニティのワイヤレス・コネクティビティ・セクション

- フォーラム、ビデオ、ブログ
- RF設計サポート
- E2Eインタラクション

こちらから参加しましょう。

ローパワー**RF**デベロッパ・ネットワーク テキサス・インスツルメンツは、ローパワーRF開発パートナーの広範なネットワークを立ち上げ、顧客のアプリケーション開発のスピードアップを支援します。このネットワークは、ハードウェア・モジュール製品および設計サービスを提供する推奨企業、RFコンサルタント、および独立の設計業者で構成されています。

- RF回路、ローパワーRFおよびZigBee設計サービス
- ローパワーRFおよびZigBeeモジュール・ソリューションと開発ツール
- RF認定サービスおよびRF回路の製造

モジュール、エンジニアリング・サービス、または開発ツールに関する支援が必要な場合は:

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9.9 静電気放電に関する注意事項

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9.11 Glossary

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

10 メカニカル、パッケージ、および注文情報

10.1 パッケージ情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

10.2 PACKAGE OPTION ADDENDUM

10.2.1 PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4) (5)
CC2650MODAMOHR	ACTIVE	QFM	MOH	29	1200	Green (RoHS & no Sb/Br)	ENIG	3, 250°C	–40 to 85	CC2650MODA

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PRE_PROD Unannounced device, not in production, not available for mass market, nor on the web, samples not available.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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

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

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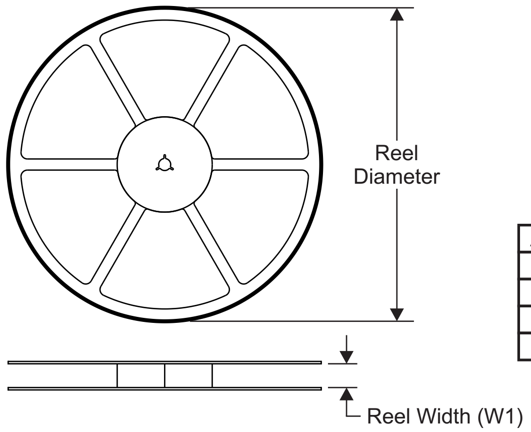
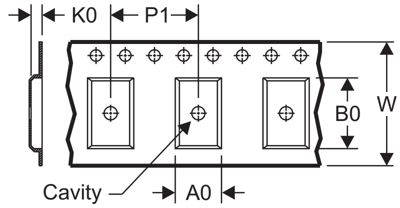
10.3 PACKAGE MATERIALS INFORMATION

10.3.1 TAPE AND REEL INFORMATION

REEL DIMENSIONS

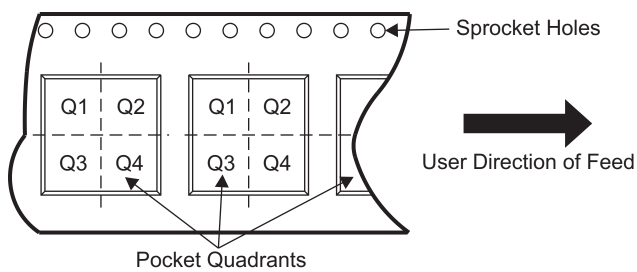


TAPE DIMENSIONS



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

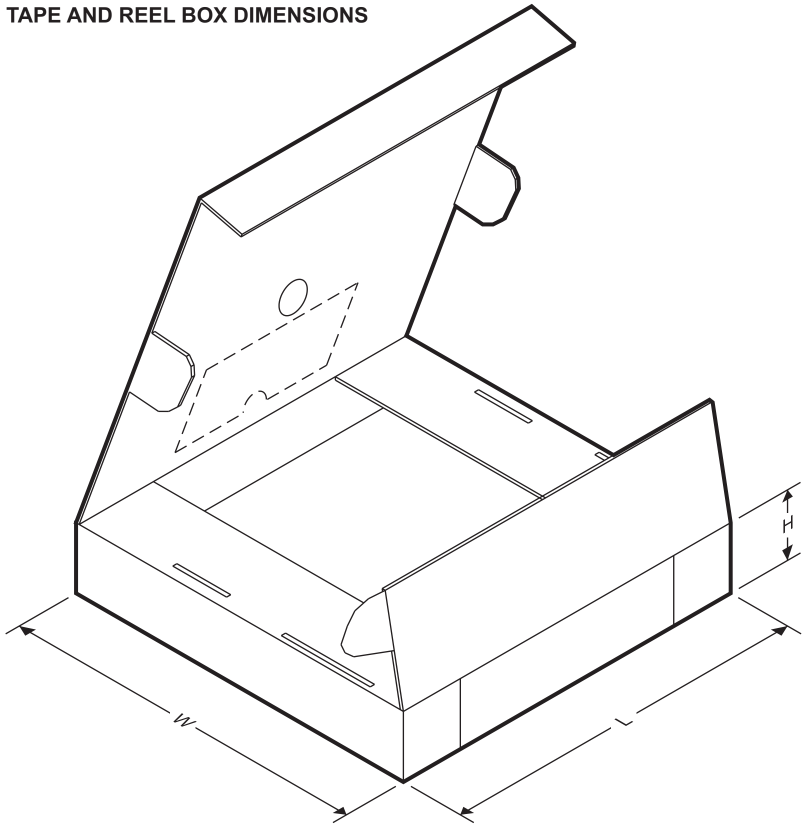
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



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
CC2650MODAMOHR	QFM	MOH	29	1200	330	32.5	11.4	17.4	2.9	16	32	Q1

TAPE AND REEL BOX DIMENSIONS



Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CC2650MODAMOHR	QFM	MOH	29	1200	352	348	56

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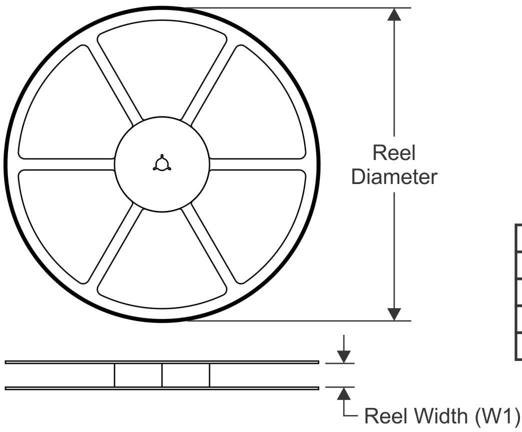
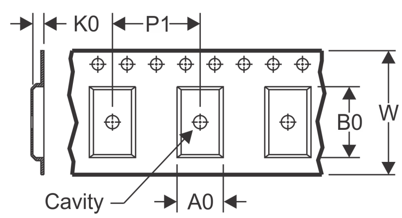
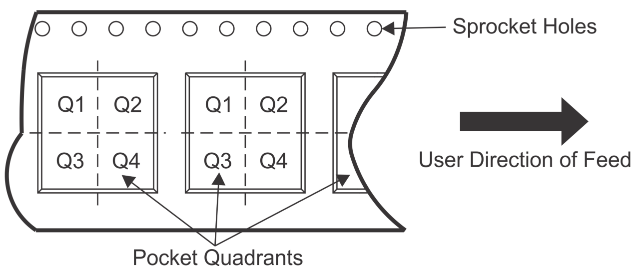
TAPE AND REEL INFORMATION





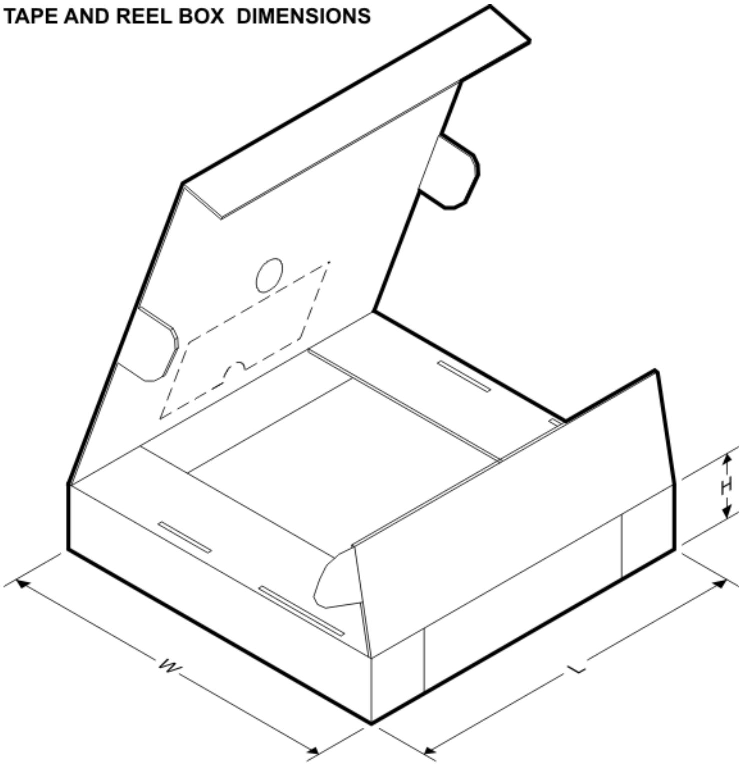
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers



*All dimensions are nominal

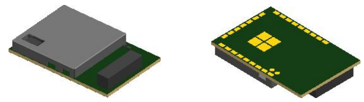
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
CC2650MODAMOHR	QFM	MOH	29	1200	330.0	32.4	11.4	17.4	2.9	16.0	32.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

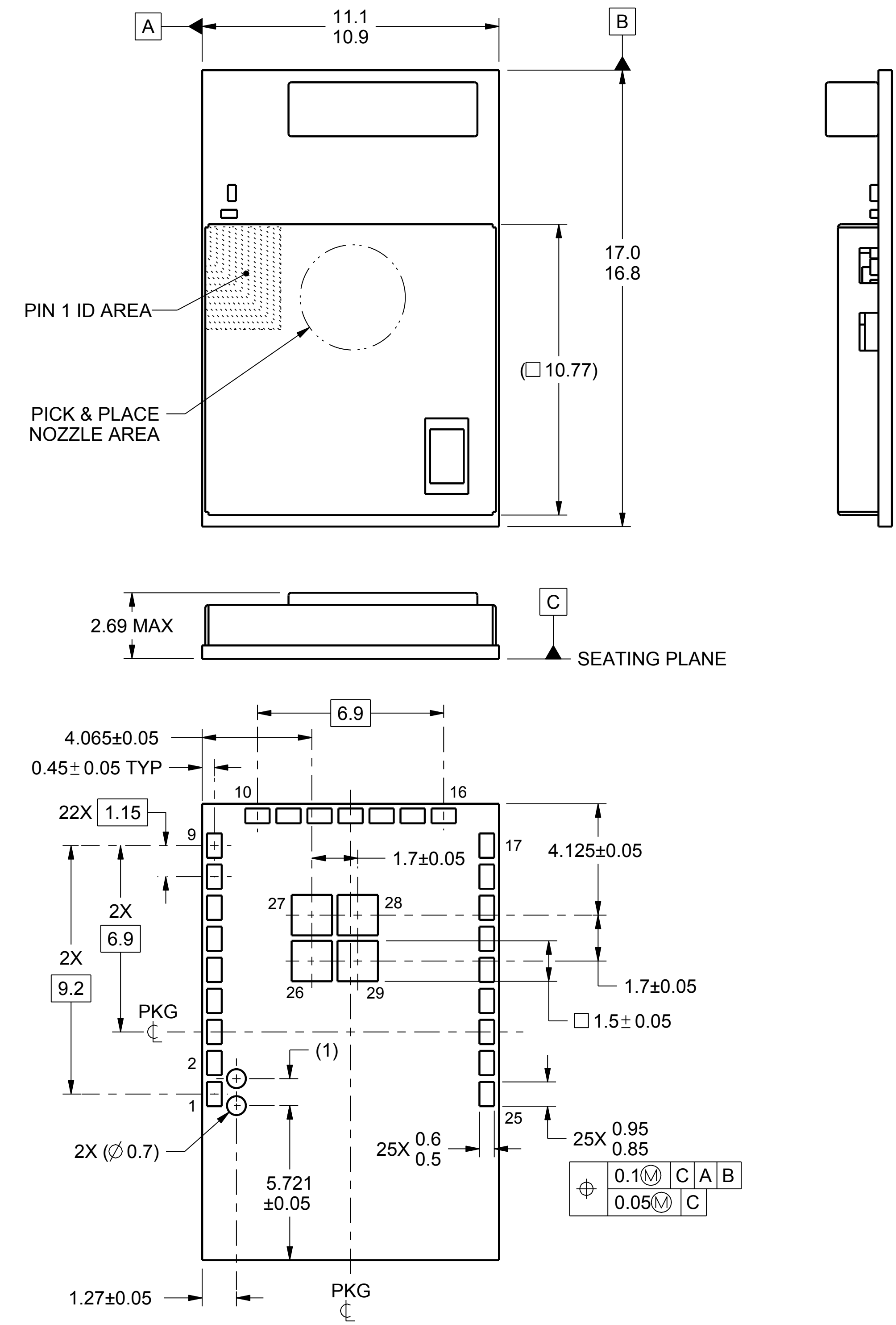
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CC2650MODAMOHR	QFM	MOH	29	1200	383.0	353.0	58.0



PACKAGE OUTLINE

QFM - 2.69 mm max height

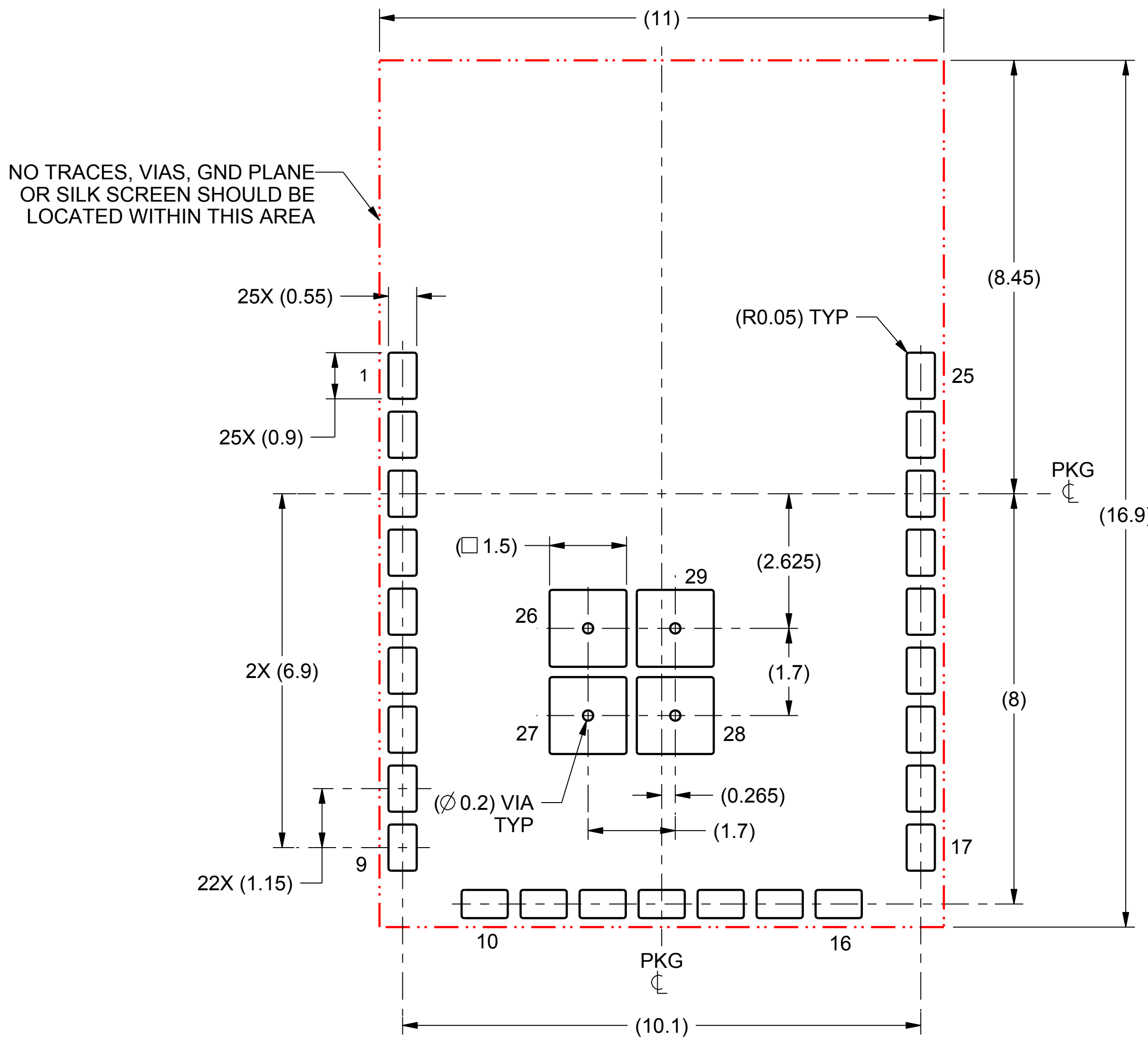
QUAD FLAT MODULE



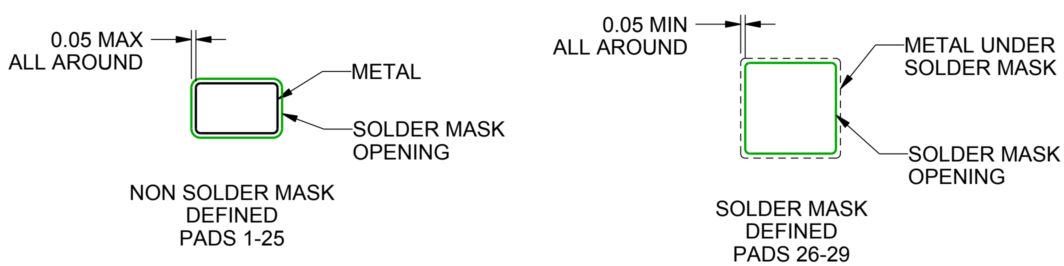
4222814/A 04/2016

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.



LAND PATTERN EXAMPLE
SCALE:7X

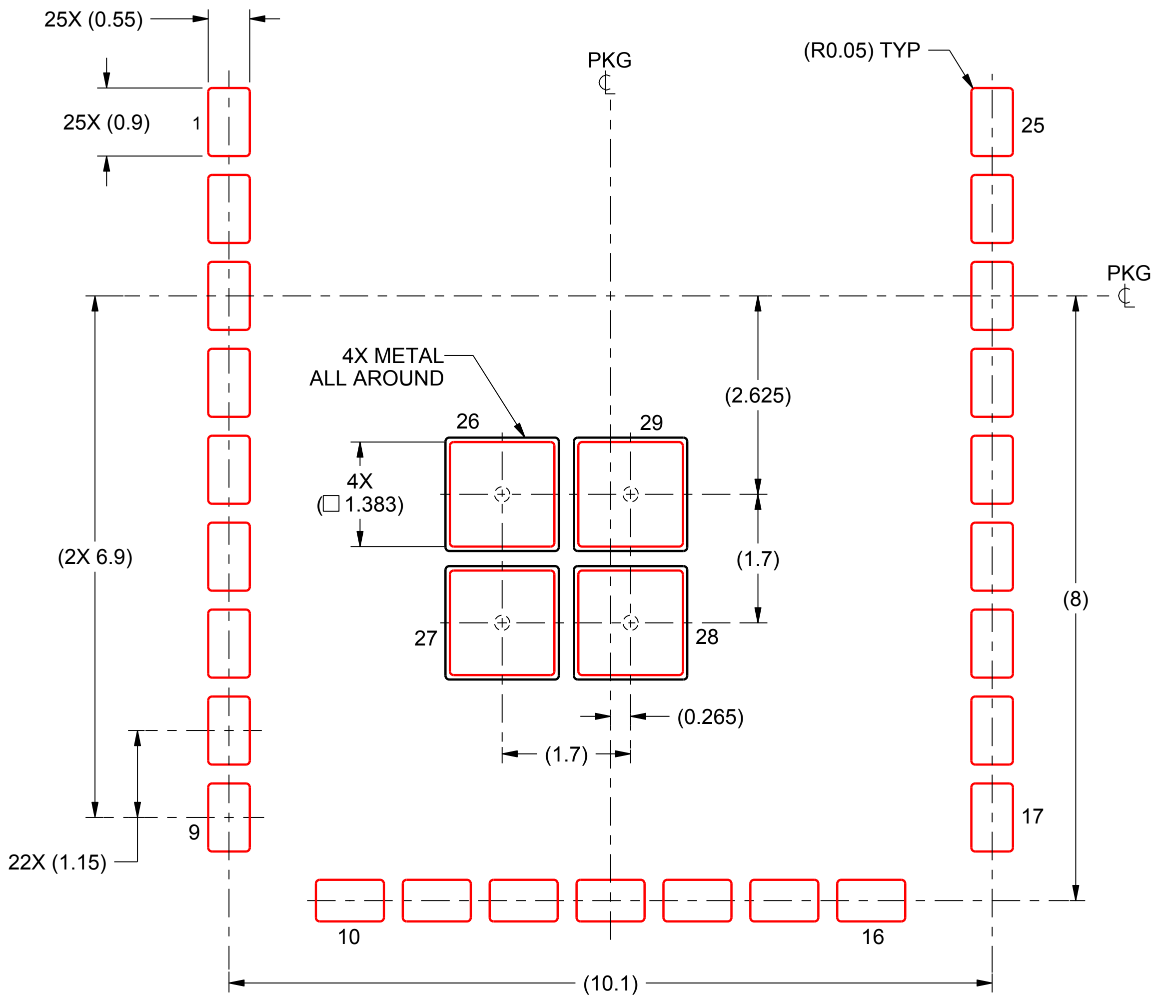


SOLDER MASK DETAILS

4222814/A 04/2016

NOTES: (continued)

3. 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).



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

PRINTED SOLDER COVERAGE BY AREA
PADS 26-29: 85%
SCALE:10X

4222814/A 04/2016

NOTES: (continued)

4. 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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