

An Optimized System-on-Chip Solution for 2.4-GHz IEEE 802.15.4 Remote Control Applications

Check for Samples: [CC2533](#)

FEATURES

- **RF/Layout**
 - 2.4-GHz IEEE 802.15.4 Compliant RF Transceiver
 - Excellent Receiver Sensitivity and Robustness to Interference
 - Programmable Output Power Up to 4.5 dBm
 - Boost-Mode TX at 7 dBm
 - Very Few External Components
 - Only a Single Crystal Needed for Asynchronous Networks
 - Space-Saving 6-mm × 6-mm QFN40 Package
 - Suitable for Systems Targeting Compliance With Worldwide Radio-Frequency Regulations: ETSI EN 300 328 and EN 300 440 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T-66 (Japan)
 - Pin- and Software-Compatible With the CC2530Fxxx Series
- **Low Power**
 - Active-Mode RX (CPU Idle): 25 mA
 - Active Mode TX at 0 dBm (CPU Idle): 28.5 mA
 - Power Mode 1 (4 μ s Wake-Up): 0.2 mA
 - Power Mode 2 (Sleep Timer Running): 1 μ A
 - Power Mode 3 (External Interrupts): 0.5 μ A
 - Wide Supply-Voltage Range (2 V–3.6 V)
- **Microcontroller**
 - High-Performance and Low-Power 8051 Microcontroller Core With Code Prefetch
 - 64- or 96-KB In-System-Programmable Flash
 - 4- or 6-KB RAM With Retention in All Power Modes
 - Hardware Debug Support
- **Peripherals**
 - Powerful Five-Channel DMA
 - IEEE 802.15.4 MAC Timer, General-Purpose Timers (One 16-Bit, Two 8-Bit)
 - IR Generation Circuitry
 - 32-kHz Sleep Timer With Capture
 - CSMA/CA Hardware Support
 - Accurate Digital RSSI/LQI Support
 - Battery Monitor Comparator
 - Random Number Generation
 - AES Security Coprocessor
 - Two Powerful USARTs With Support for UART and SPI
 - I²C Interface
 - 23 General-Purpose I/O Pins
 - Watchdog Timer
- **Development Tools**
 - CC2533 Remote Control Development Kit for RF4CE
 - CC2533 Development Kit
 - CC2533EMK Evaluation Modules
 - SmartRF™ Software
 - Packet Sniffer
 - IAR Embedded Workbench™ Available

APPLICATIONS

- ZigBee™ RF4CE Remote Control Target and Device
- 2.4-GHz IEEE 802.15.4 Systems Based on TIMAC or SimpliciTI™ Network Protocol
- Consumer Electronics
- Electronic Shelf Labeling



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ZigBee is a trademark of ZigBee Alliance.

DESCRIPTION

The CC2533 is an optimized system-on-chip (SoC) solution for IEEE 802.15.4 based remote-control systems. It enables single-chip remote controls to be built with low bill-of-material cost when used as a flexible SoC. It also provides a simple path to adding RF4CE capability to a device or target when used in the wireless network processor configuration of the RemoTI™ RF4CE stack. Robust network nodes can be built with very low total bill-of-material costs.

The CC2533 combines the excellent performance of a leading RF transceiver with a single-cycle 8051 compliant CPU, up to 96-KB in-system programmable flash memory, up to 6-KB RAM, and many other powerful features. The CC2533 has efficient power modes with RAM and register retention below 1 μ A, making it highly suited for low-duty-cycle systems where ultralow power consumption is required. Short transition times between operating modes further ensure low energy consumption.

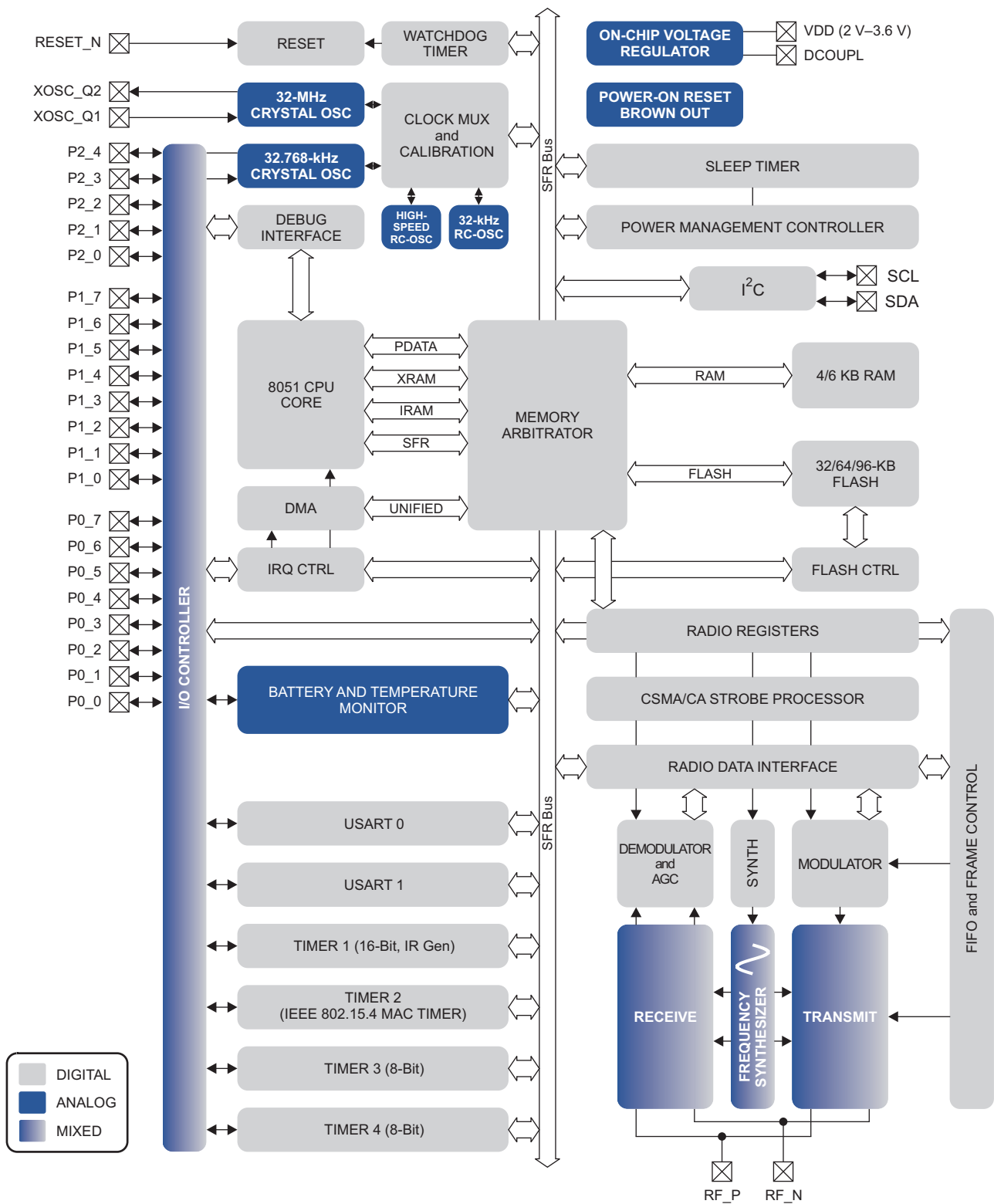
Combined with the golden-unit-status RemoTI stack from Texas Instruments, the CC2533 provides a robust and complete ZigBee RF4CE remote-control solution. It is also ideal for implementing the target side of a remote-control system in a network processor configuration with an SPI/UART/I²C interface. The CC2533 comes complete with reference designs and example software that implement a remote control system to ensure efficient design-in.

The CC2533 exists in three memory-size configurations:

CC2533F32 – 32-KB Flash, 4-KB RAM

CC2533F64 – 64-KB Flash, 4-KB RAM

CC2533F96 – 96-KB Flash, 6-KB RAM



B0301-04



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

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

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

		MIN	MAX	UNIT
Supply voltage	All supply pins must have the same voltage	–0.3	3.9	V
Voltage on any digital pin		–0.3	VDD + 0.3, ≤ 3.9	V
Input RF level			10	dBm
Storage temperature range		–40	125	°C
ESD ⁽²⁾	All pads, according to human-body model, JEDEC STD 22, method A114		2	kV
	According to charged-device model, JEDEC STD 22, method C101		500	V
	All pads excluding RF pads, according to machine model, JEDEC STD 22, method A115		200	V

- (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) CAUTION: ESD-sensitive device. Precautions should be used when handling the device in order to prevent permanent damage.

RECOMMENDED OPERATING CONDITIONS

	MIN	MAX	UNIT
Operating ambient temperature range, T _A	–40	125	°C
Operating supply voltage	2	3.6	V

ELECTRICAL CHARACTERISTICS

Measured on Texas Instruments CC2533 EM reference design with T_A = 25°C and VDD = 3 V, unless otherwise noted.

Boldface limits apply over the entire operating range, T_A = –40°C to 125°C, VDD = 2 V to 3.6 V, and f_c = 2394 MHz to 2507 MHz.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I _{core} Core current consumption	Digital regulator on. 16-MHz RCOSC running. No radio, crystals, or peripherals active. Medium CPU activity: normal flash access ⁽¹⁾ , no RAM access		3.6		mA
	32-MHz XOSC running. No radio or peripherals active. Medium CPU activity: normal flash access ⁽¹⁾ , no RAM access		6.6	7.7	mA
	32-MHz XOSC running, radio in RX mode, –50-dBm input power, no peripherals active, CPU idle		21.6		mA
	32-MHz XOSC running, radio in RX mode at –100-dBm input power (waiting for signal), no peripherals active, CPU idle		25.1	29.8	mA
	32-MHz XOSC running, radio in TX mode, 0-dBm output power, no peripherals active, CPU idle		28.5		mA
	32-MHz XOSC running, radio in TX mode, 4.5-dBm output power, no peripherals active, CPU idle		32.3	40.6	mA
	32-MHz XOSC running, radio in boost mode TX, 7-dBm output power, no peripherals active, CPU idle		38.8		mA
	Power mode 1. Digital regulator on; 16-MHz RCOSC and 32-MHz crystal oscillator off; 32.768-kHz XOSC, POR, BOD, and sleep timer active; RAM and register retention		0.2	0.3	mA
	Power mode 2. Digital regulator off; 16-MHz RCOSC and 32-MHz crystal oscillator off; 32.768-kHz XOSC, POR, and sleep timer active; RAM and register retention		1	1.5	μA
	Power mode 3. Digital regulator off; no clocks; POR active; RAM and register retention		0.4	0.7	μA
	During reset with supply voltage of 1.2 V		54		μA

(1) Normal flash access means that the code used exceeds the cache storage, so cache misses happen frequently.

ELECTRICAL CHARACTERISTICS (continued)

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$, unless otherwise noted. **Boldface** limits apply over the entire operating range, $T_A = -40^\circ\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V , and $f_c = 2394\text{ MHz}$ to 2507 MHz .

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{peri}	Peripheral Current Consumption (Adds to core current I_{core} for each peripheral unit activated)					
	Timer 1	Timer running, 32-MHz XOSC used		90		μA
	Timer 2	Timer running, 32-MHz XOSC used		90		μA
	Timer 3	Timer running, 32-MHz XOSC used		60		μA
	Timer 4	Timer running, 32-MHz XOSC used		70		μA
	Sleep timer	Including 32.753-kHz RCOSC		0.6		μA
	Battery monitor	When comparing		93		μA
	Flash	Erase		0.2		mA
		Burst-write peak current		6		mA

GENERAL CHARACTERISTICS

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
WAKE-UP AND TIMING					
Power mode 1 → active	Digital regulator on, 16-MHz RCOSC and 32-MHz crystal oscillator off. Start-up of 16-MHz RCOSC		4		μs
Power mode 2 or 3 → active	Digital regulator off, 16-MHz RCOSC and 32-MHz crystal oscillator off. Start-up of regulator and 16-MHz RCOSC		0.1		ms
Active → TX or RX	Initially running on 16-MHz RCOSC, with 32-MHz XOSC OFF		0.6		ms
	With 32-MHz XOSC initially on			192	μs
RX/TX and TX/RX turnaround				192	μs
RADIO PART					
RF frequency range	Programmable in 1-MHz steps, 5 MHz between channels for compliance with [1]	2394		2507	MHz
Radio baud rate	As defined by [1]		250		kbps
Radio chip rate	As defined by [1]		2		MChip/s
Flash page size			1		KB
Flash erase cycles				20	K Cycles

RF RECEIVE SECTION

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$, $V_{DD} = 3\text{ V}$, and $f_c = 2440\text{ MHz}$, unless otherwise noted.

Boldface limits apply over the entire operating range, $T_A = -40^\circ\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V , and $f_c = 2394\text{ MHz}$ to 2507 MHz .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receiver sensitivity	PER = 1%, as specified by [1] [1] requires -85 dBm		-97	-93 -89	dBm
Saturation (maximum input level)	PER = 1%, as specified by [1] [1] requires -20 dBm		10		dBm
Adjacent-channel rejection, 5-MHz channel spacing	Wanted signal -82 dBm, adjacent modulated channel at 5 MHz, PER = 1%, as specified by [1]. [1] requires 0 dB		49		dB
Adjacent-channel rejection, -5-MHz channel spacing	Wanted signal -82 dBm, adjacent modulated channel at -5 MHz, PER = 1%, as specified by [1]. [1] requires 0 dB		49		dB
Alternate-channel rejection, 10-MHz channel spacing	Wanted signal -82 dBm, adjacent modulated channel at 10 MHz, PER = 1%, as specified by [1] [1] requires 30 dB		57		dB
Alternate-channel rejection, -10-MHz channel spacing	Wanted signal -82 dBm, adjacent modulated channel at -10 MHz, PER = 1%, as specified by [1] [1] requires 30 dB		57		dB
Channel rejection $\geq 20\text{ MHz}$ $\leq -20\text{ MHz}$	Wanted signal at -82 dBm. Undesired signal is an IEEE 802.15.4 modulated channel, stepped through all channels from 2405 to 2480 MHz. Signal level for PER = 1%.		57 57		dB
Co-channel rejection	Wanted signal at -82 dBm. Undesired signal is 802.15.4 modulated at the same frequency as the desired signal. Signal level for PER = 1%.		-2		dB
Blocking/desensitization -250 MHz from band edge -100 MHz from band edge -50 MHz from band edge 50 MHz from band edge 100 MHz from band edge 250 MHz from band edge	Measured according to ETSI EN 300 440-1 V1.6.1 (2010-04) blocking/desensitization. Wanted signal 3 dB above sensitivity limit, interferer at 10 $\times$, 20 $\times$ and 50 $\times$ bandwidth from receiver channel band edge. Limit > -45dBm for class-2 receiver.		-37 -35 -40 -38 -33 -32		dBm
Spurious emission. Only largest spurious emission stated within each band. 30 MHz–1000 MHz 1 GHz–12.75 GHz	Conducted measurement with a 50- Ω single-ended load. Suitable for systems targeting compliance with EN 300 328, EN 300 440, FCC CFR47 Part 15, and ARIB STD-T-66.		< -80 -57		dBm
Frequency error tolerance ⁽¹⁾	[1] requires minimum 80 ppm		± 150		ppm
Symbol rate error tolerance ⁽²⁾	[1] requires minimum 80 ppm		± 1000		ppm

(1) Difference between center frequency of the received RF signal and local oscillator frequency.

(2) Difference between incoming symbol rate and the internally generated symbol rate

RF TRANSMIT SECTION

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$, $V_{DD} = 3\text{ V}$ and $f_c = 2440\text{ MHz}$, unless otherwise noted.

Boldface limits apply over the entire operating range, $T_A = -40^\circ\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V , and $f_c = 2394\text{ MHz}$ to 2507 MHz .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Nominal output power	Delivered to a single-ended 50- Ω load through a balun using 4.5 dBm output-power setting [1] requires minimum -3 dBm	1 -3	4.5	7 8	dBm
Boost mode	Delivered to a single-ended 50- Ω load through a balun using boost mode TX settings		7		dBm
Programmable output-power range			27		dB
Spurious emissions	4.5 dBm output power setting ⁽¹⁾ 25 MHz–1000 MHz (outside restricted bands) ⁽²⁾⁽²⁾ 25 MHz–2400 MHz (within FCC restricted bands) ⁽²⁾ 25 MHz–1000 MHz (within ETSI restricted bands) ⁽²⁾ 1800–1900 MHz (ETSI restricted band) ⁽²⁾ 5150–5300 MHz (ETSI restricted band) ⁽²⁾ At $2 \times f_c$ and $3 \times f_c$ (FCC restricted band) ⁽²⁾ At $2 \times f_c$ and $3 \times f_c$ (ETSI EN 300-440 and EN 300-328) ^{(3) (2)} 1 GHz–12.75 GHz (outside restricted bands) ⁽²⁾ At 2483.5 MHz and above (FCC restricted band) ⁽²⁾ $f_c = 2480\text{ MHz}$ ^{(4) (2)}		-60 -60 -60 -56 -54 -48 -39 -60 -45		dBm
Error vector magnitude (EVM)	Measured as defined by [1] using 4.5 dBm output-power setting [1] requires maximum 35%.		3%		
Optimum load impedance	Differential impedance as seen from the RF port (RF_P and RF_N) towards the antenna		69 + j29		Ω

(1) Texas Instruments CC2533 EM reference design is suitable for systems targeting compliance with EN 300 328, EN 300 440, FCC CFR47 Part 15, and ARIB STD-T-66.

(2) Measurement conducted according to stated regulations. Only largest spurious emission stated within each band.

(3) Margins for passing conducted requirements at the third harmonic can be improved by using a simple band-pass filter connected between matching network and RF connector (1.8 pF in parallel with 1.6 nH); this filter must be connected to a good RF ground.

(4) Margins for passing FCC requirements at 2483.5 MHz and above when transmitting at 2480 MHz can be improved by using a lower output-power setting or having less than 100% duty cycle.

32-MHz CRYSTAL OSCILLATOR

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Crystal frequency			32		MHz
Crystal frequency accuracy requirement ⁽¹⁾		–40		40	ppm
ESR Equivalent series resistance		6		60	Ω
C_0 Crystal shunt capacitance		1		7	pF
C_L Crystal load capacitance		10		16	pF
Start-up time			0.3		ms
Power-down guard time	The crystal oscillator must be in power down for a guard time before it is used again. This requirement is valid for all modes of operation. The need for power-down guard time can vary with crystal type and load.	3			ms

(1) Including aging and temperature dependency, as specified by [1]

32.768-kHz CRYSTAL OSCILLATOR

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Crystal frequency			32.768		kHz
Crystal frequency accuracy requirement ⁽¹⁾		–40		40	ppm
ESR Equivalent series resistance			40	130	k Ω
C_0 Crystal shunt capacitance			0.9	2	pF
C_L Crystal load capacitance			12	16	pF
Start-up time			0.4		s

(1) Including aging and temperature dependency, as specified by [1]

32-kHz RC OSCILLATOR

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Calibrated frequency ⁽¹⁾			32.753		kHz
Frequency accuracy after calibration			$\pm 0.2\%$		
Temperature coefficient ⁽²⁾			0.4		%/ $^\circ\text{C}$
Supply-voltage coefficient ⁽³⁾			3		%/V
Calibration time ⁽⁴⁾			2		ms

(1) The calibrated 32-kHz RC oscillator frequency is the 32-MHz XTAL frequency divided by 977.

(2) Frequency drift when temperature changes after calibration

(3) Frequency drift when supply voltage changes after calibration

(4) When the 32-kHz RC oscillator is enabled, it is calibrated when a switch from the 16-MHz RC oscillator to the 32-MHz crystal oscillator is performed while SLEEP_CMD.OSC32K_CALDIS is 0.

16-MHz RC OSCILLATOR

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Frequency ⁽¹⁾			16		MHz
Uncalibrated frequency accuracy			±18%		
Calibrated frequency accuracy			±0.6%	±1%	
Start-up time				10	μs
Initial calibration time ⁽²⁾			50		μs

(1) The calibrated 16-MHz RC oscillator frequency is the 32-MHz XTAL frequency divided by 2.

(2) When the 16-MHz RC oscillator is enabled, it is calibrated when a switch from the 16-MHz RC oscillator to the 32-MHz crystal oscillator is performed while SLEEP_CMD.OSC_PD is set to 0.

RSSI/CCA CHARACTERISTICS

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
RSSI range			100		dB
Absolute uncalibrated RSSI/CCA accuracy			±4		dB
RSSI/CCA offset			73		dB
Step size (LSB value)			1		dB

FREQUENCY ESTIMATION CHARACTERISTICS

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
FREQUENCY range			±250		kHz
FREQUENCY accuracy			±40		kHz
FREQUENCY offset			20		kHz
Step size (LSB value)			7.8		kHz

FREQUENCY SYNTHESIZER CHARACTERISTICS

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$, $V_{DD} = 3\text{ V}$, and $f_c = 2440\text{ MHz}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Phase noise, unmodulated carrier	At ±1-MHz offset from carrier		–110		dBc/Hz
	At ±2-MHz offset from carrier		–117		
	At ±5-MHz offset from carrier		–122		

BATTERY MONITOR CHARACTERISTICS

Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$ and $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Settling time				2	μs
Step size	For voltages up to 2.5 V		24		mV
	For voltages above 2.5 V		169		mV
Calibrated accuracy	Across 1.95 V to 2.5 V, with single-point calibration at 1.95 V		2	20	mV
	Across 2.5 V to 3.6 V, with single-point calibration at 1.95 V		10	55	mV

CONTROL INPUT AC CHARACTERISTICS

$T_A = -40^\circ\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
System clock, f_{SYSCLK} $t_{\text{SYSCLK}} = 1/f_{\text{SYSCLK}}$	The undivided system clock is 32 MHz when crystal oscillator is used. The undivided system clock is 16 MHz when calibrated 16-MHz RC oscillator is used.	16		32	MHz

CONTROL INPUT AC CHARACTERISTICS (continued)

$T_A = -40^{\circ}\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
RESET_N low duration	See item 1, Figure 1 . This is the shortest pulse that is recognized as a complete reset-pin request. Note that shorter pulses may be recognized but might not lead to complete reset of all modules within the chip.	1			μs
Interrupt pulse duration	See item 2, Figure 1 . This is the shortest pulse that is recognized as an interrupt request.	20			ns

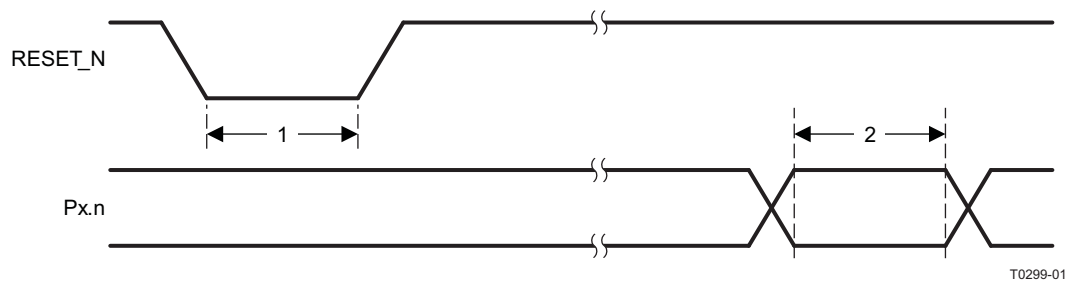
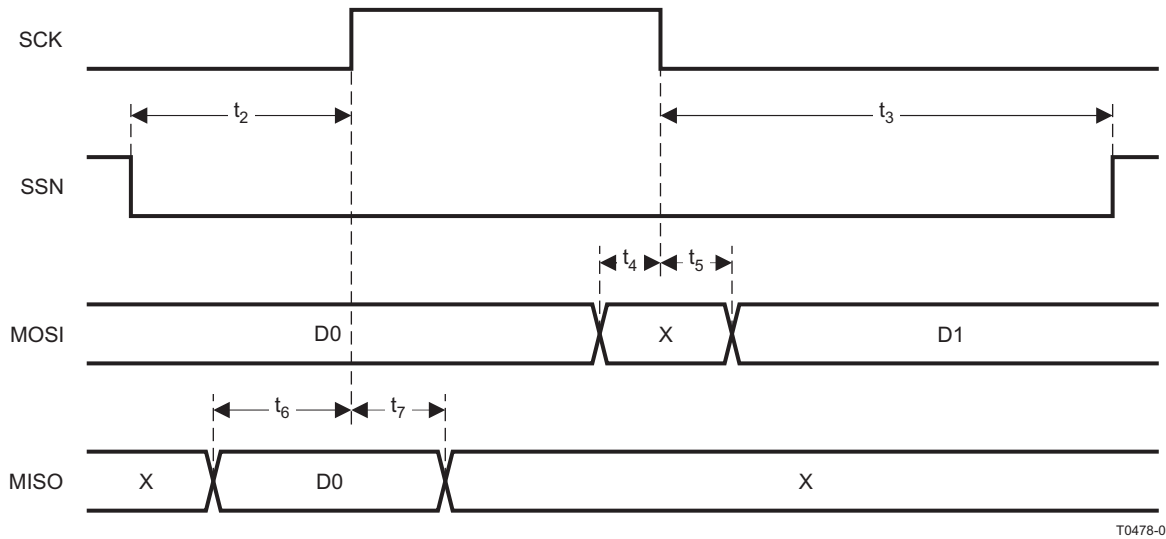


Figure 1. Control Input AC Characteristics

SPI AC CHARACTERISTICS

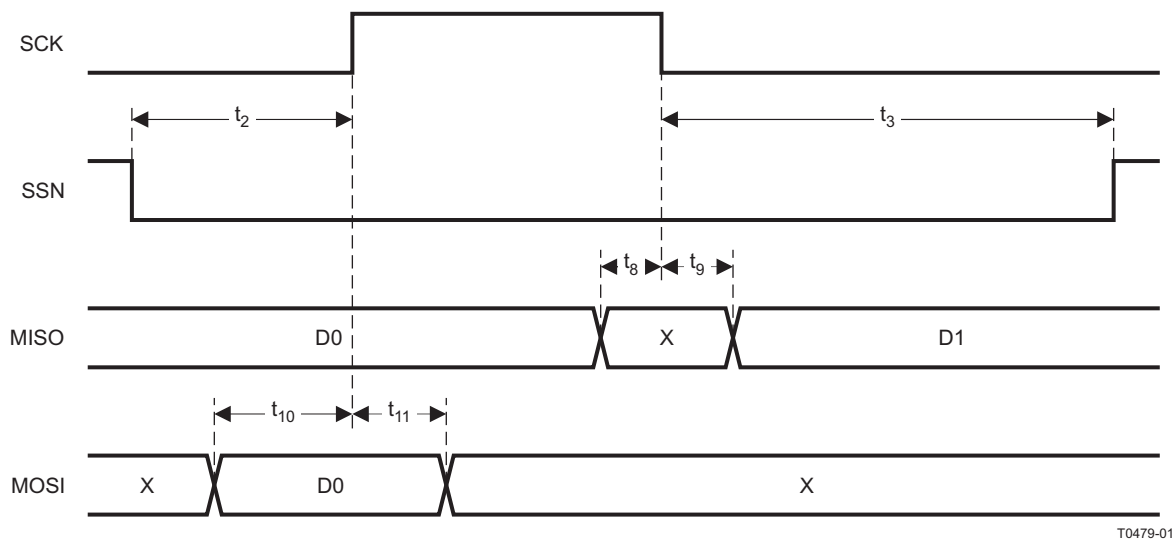
 $T_A = -40^{\circ}\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SCK period	Master, RX and TX	250			ns
SCK duty cycle	Master		50%		
t_2 SSN low to SCK	Master	63			ns
t_3 SCK to SSN high	Master	63			ns
t_4 MOSI early out	Master, load = 10 pF			7	ns
t_5 MOSI late out	Master, load = 10 pF			10	ns
t_6 MISO setup	Master	90			ns
t_7 MISO hold	Master	10			ns
t_1 SCK period	Slave, RX and TX	250			ns
SCK duty cycle	Slave		50%		ns
t_2 SSN low to SCK	Slave	63			ns
t_3 SCK to SSN high	Slave	63			ns
t_8 MISO early out	Slave, load = 10 pF			0	ns
t_9 MISO late out	Slave, load = 10 pF			95	ns
t_{10} MOSI setup	Slave	35			ns
t_{11} MOSI hold	Slave	10			ns
Operating frequency	Master, TX only			8	MHz
	Master, RX and TX			4	
	Slave, RX only			8	
	Slave, RX and TX			4	



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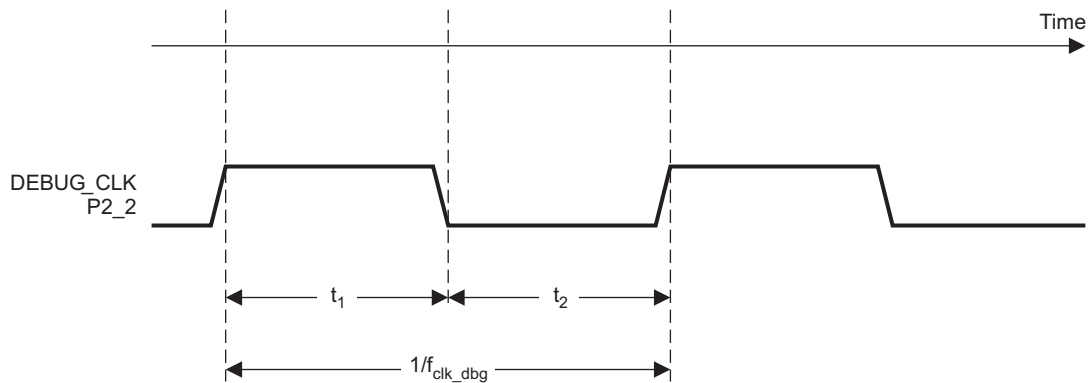
Figure 2. SPI Master AC Characteristics

**Figure 3. SPI Slave AC Characteristics**

DEBUG INTERFACE AC CHARACTERISTICS

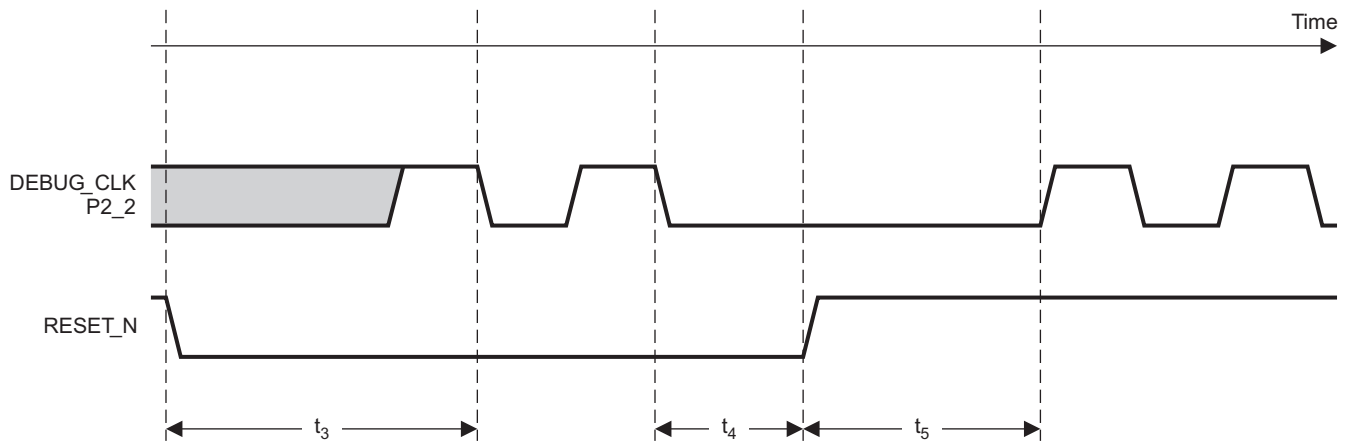
$T_A = -40^\circ\text{C}$ to 125°C , $V_{DD} = 2\text{ V}$ to 3.6 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_{\text{clk_dbg}}$ Debug clock frequency (see Figure 4)				12	MHz
t_1 Allowed high pulse on clock (see Figure 4)		35			ns
t_2 Allowed low pulse on clock (see Figure 4)		35			ns
t_3 RESET_N low to first falling edge on debug clock (see Figure 5)		167			ns
t_4 Falling edge on clock to RESET_N high (see Figure 5)		83			ns
t_5 RESET_N high to first debug command (see Figure 5)		83			ns
t_6 Debug data setup (see Figure 6)		2			ns
t_7 Debug data hold (see Figure 6)		4			ns
t_8 Clock-to-data delay (see Figure 6)	Load = 10 pF			30	ns



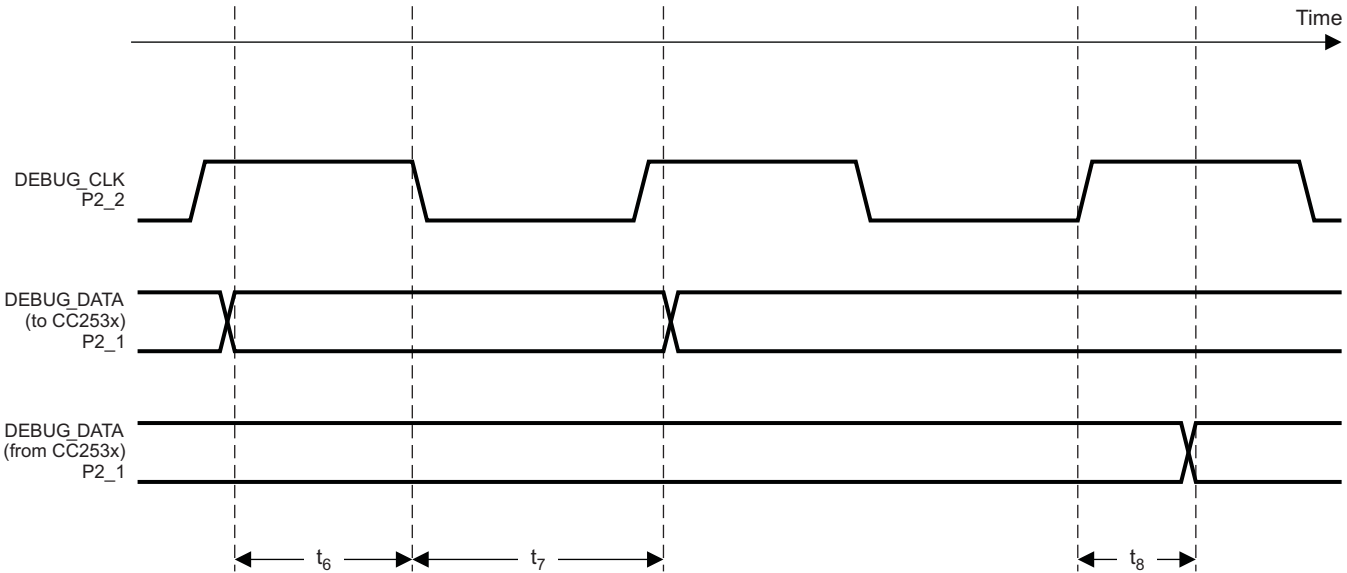
T0436-01

Figure 4. Debug Clock – Basic Timing



T0437-01

Figure 5. Data Setup and Hold Timing



T0438-01

Figure 6. Debug Enable Timing

TIMER INPUT AC CHARACTERISTICS

T_A = -40°C to 125°C, VDD = 2 V to 3.6 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input capture pulse duration	Synchronizers determine the shortest input pulse that can be recognized. The synchronizers operate at the current system clock rate (16 MHz or 32 MHz).	1.5			t _{SYSCLK}

DC CHARACTERISTICS

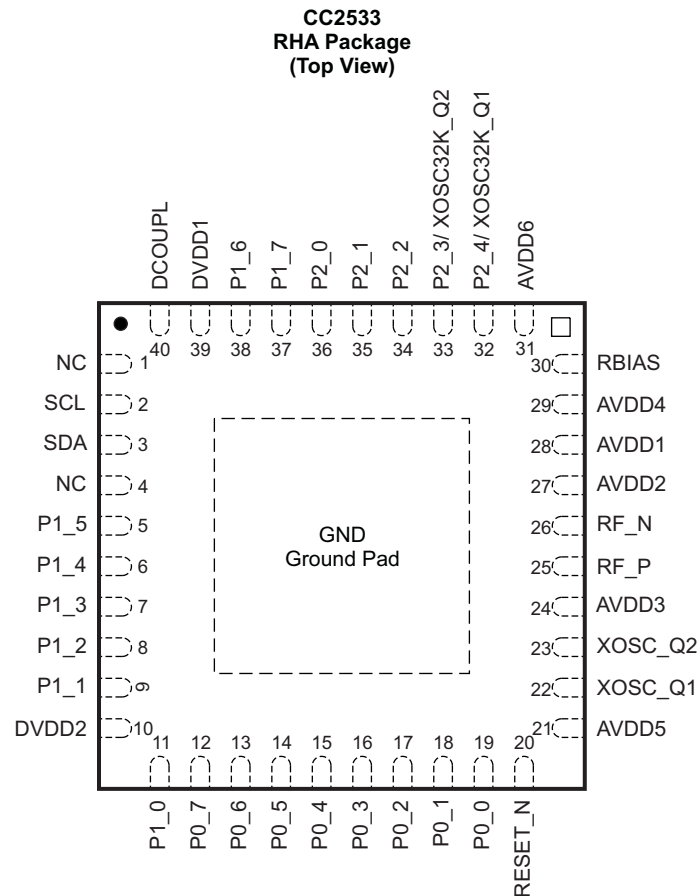
$T_A = 25^\circ\text{C}$, $V_{DD} = 3\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Logic-0 input voltage				0.5	V
Logic-1 input voltage		2.5			V
Logic-0 input current	Input equals 0 V	–50		50	nA
Logic-1 input current	Input equals V_{DD}	–50		50	nA
I/O-pin pullup and pulldown resistors			20		k Ω
Logic-0 output voltage, 4-mA pins	Output load 4 mA			0.5	V
Logic-1 output voltage, 4-mA pins	Output load 4 mA	2.4			V
Logic-0 output voltage, 20-mA pins	Output load 20 mA			0.5	V
Logic-1 output voltage, 20-mA pins	Output load 20 mA	2.4			V

DEVICE INFORMATION

PIN DESCRIPTIONS

The CC2533 pinout is shown in [Figure 7](#) and a short description of the pins follows.



P0076-04

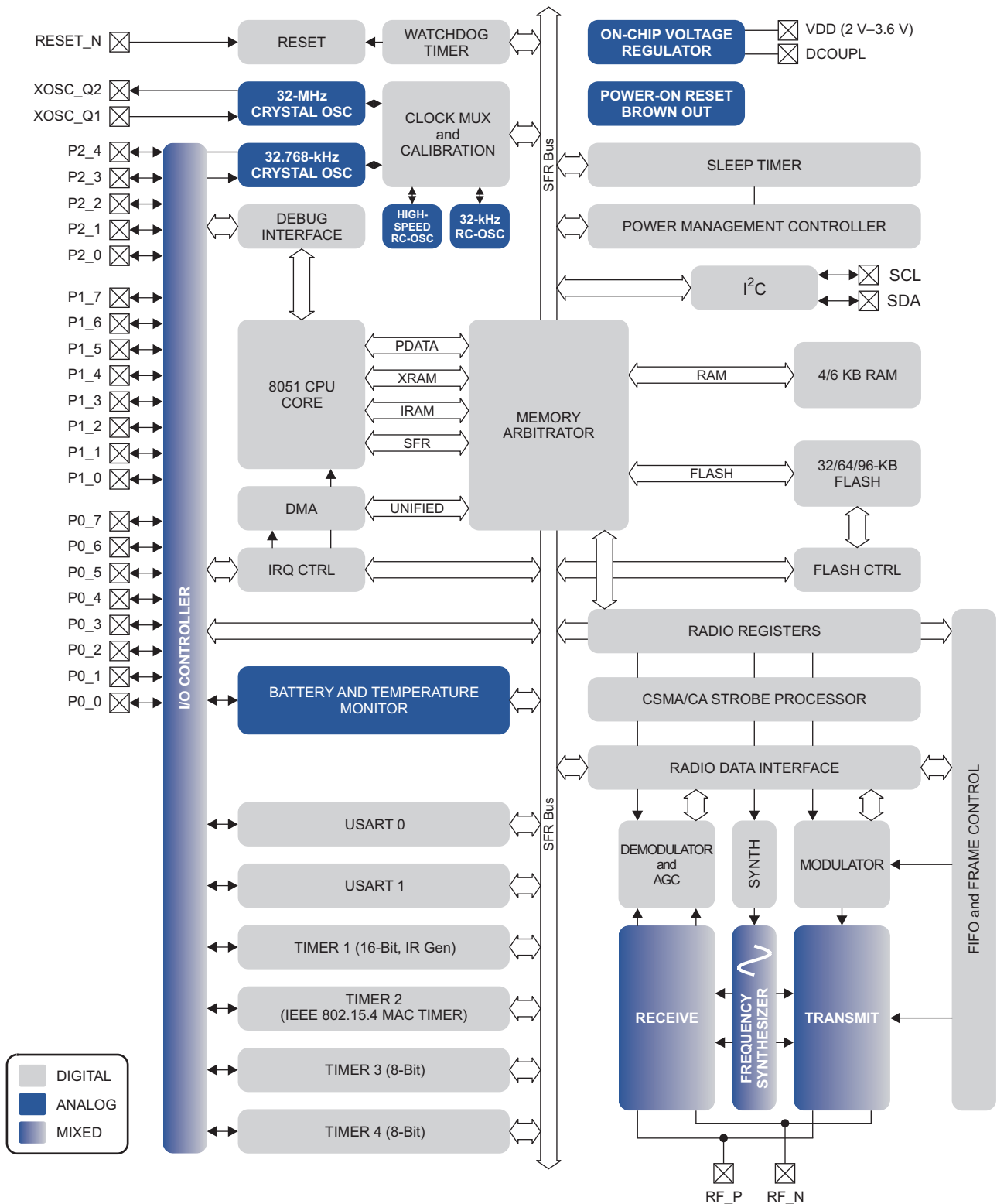
NOTE: The exposed ground pad must be connected to a solid ground plane, as this is the ground connection for the chip.

Figure 7. Pinout Top View

Table 1. Pin Descriptions

PIN NAME	PIN	PIN TYPE	DESCRIPTION
AVDD1	28	Power (analog)	2-V–3.6-V analog power-supply connection
AVDD2	27	Power (analog)	2-V–3.6-V analog power-supply connection
AVDD3	24	Power (analog)	2-V–3.6-V analog power-supply connection
AVDD4	29	Power (analog)	2-V–3.6-V analog power-supply connection
AVDD5	21	Power (analog)	2-V–3.6-V analog power-supply connection
AVDD6	31	Power (analog)	2-V–3.6-V analog power-supply connection
DCOUPPL	40	Power (digital)	1.8-V digital power-supply decoupling. Do not use for supplying external circuits.
DVDD1	39	Power (digital)	2-V–3.6-V digital power-supply connection
DVDD2	10	Power (digital)	2-V–3.6-V digital power-supply connection
GND	—	Ground	The ground pad must be connected to a solid ground plane.
NC	1, 4	Unused pins	No connect
P0_0	19	Digital I/O	Port 0.0
P0_1	18	Digital I/O	Port 0.1
P0_2	17	Digital I/O	Port 0.2
P0_3	16	Digital I/O	Port 0.3
P0_4	15	Digital I/O	Port 0.4
P0_5	14	Digital I/O	Port 0.5
P0_6	13	Digital I/O	Port 0.6
P0_7	12	Digital I/O	Port 0.7
P1_0	11	Digital I/O	Port 1.0 – 20-mA drive capability
P1_1	9	Digital I/O	Port 1.1 – 20-mA drive capability
P1_2	8	Digital I/O	Port 1.2
P1_3	7	Digital I/O	Port 1.3
P1_4	6	Digital I/O	Port 1.4
P1_5	5	Digital I/O	Port 1.5
P1_6	38	Digital I/O	Port 1.6
P1_7	37	Digital I/O	Port 1.7
P2_0	36	Digital I/O	Port 2.0
P2_1	35	Digital I/O	Port 2.1
P2_2	34	Digital I/O	Port 2.2
P2_3/ XOSC32K_Q2	33	Digital I/O, analog I/O	Port 2.3/32.768 kHz XOSC
P2_4/ XOSC32K_Q1	32	Digital I/O, analog I/O	Port 2.4/32.768 kHz XOSC
RBIAS	30	Analog I/O	External precision bias resistor for reference current
RESET_N	20	Digital input	Reset, active-low
RF_N	26	RF I/O	Negative RF input signal to LNA during RX Negative RF output signal from PA during TX
RF_P	25	RF I/O	Positive RF input signal to LNA during RX Positive RF output signal from PA during TX
SCL	2	I ² C clock or digital I/O	Can be used as I ² C clock pin or digital I/O. Leave floating if not used.
SDA	3	I ² C clock or digital I/O	Can be used as I ² C data pin or digital I/O. Leave floating if not used.
XOSC_Q1	22	Analog I/O	32-MHz crystal oscillator pin 1 or external clock input
XOSC_Q2	23	Analog I/O	32-MHz crystal oscillator pin 2

CIRCUIT DESCRIPTION



B0301-04

Figure 8. CC2533 Block Diagram

A block diagram of the CC2533 is shown in [Figure 8](#). The modules can be roughly divided into one of three categories: CPU- and memory-related modules; modules related to peripherals, clocks, and power management; and radio-related modules. In the following subsections, a short description of each module that appears in [Figure 8](#) is given.

For more details about the modules and their usage, see the corresponding chapters in the CC253x User's Guide ([SWRU191](#)).

CPU and Memory

The **8051 CPU** core used in the CC253x device family is a single-cycle 8051-compatible core. It has three different memory-access buses (SFR, DATA, and CODE/XDATA) with single-cycle access to SFR, DATA, and the main SRAM. It also includes a debug interface and an 18-input extended interrupt unit.

The **interrupt controller** services a total of 18 interrupt sources, divided into six interrupt groups, each of which is associated with one of four interrupt priorities. Any interrupt service request is serviced also when the device is in idle mode by going back to active mode. Some interrupts can also wake up the device from sleep mode (power modes 1–3).

The **memory arbiter** is at the heart of the system, as it connects the CPU and DMA controller with the physical memories and all peripherals through the SFR bus. The memory arbiter has four memory access points, access of which can map to one of three physical memories: an 8-KB SRAM, flash memory, and XREG/SFR registers. It is responsible for performing arbitration and sequencing between simultaneous memory accesses to the same physical memory.

The **4- or 6-KB SRAM** maps to the DATA memory space and to parts of the XDATA memory spaces. The 6-KB SRAM is an ultralow-power SRAM that retains its contents even in the lowest power modes (PM2/3). This is an important feature for low-power applications.

The **64- or 96-KB flash block** provides in-circuit programmable non-volatile program memory for the device, and maps into the CODE and XDATA memory spaces. In addition to holding program code and constants, the non-volatile memory allows the application to save data that must be preserved such that it is available after restarting the device. Using this feature, one can, e.g., use saved network-specific data to avoid the need for a full start-up and network find-and-join process.

Clocks and Power Management

The digital core and peripherals are powered by a 1.8-V low-dropout **voltage regulator**. It provides **power management** functionality that enables low-power operation for long battery life using different power modes. Five different **reset** sources exist to reset the device.

Peripherals

The CC2533 includes many different peripherals that allow the application designer to develop advanced applications.

The **debug interface** implements a proprietary two-wire serial interface that is used for in-circuit debugging. Through this debug interface, it is possible to perform an erasure of the entire flash memory, control which oscillators are enabled, stop and start execution of the user program, execute supplied instructions on the 8051 core, set code breakpoints, and single-step through instructions in the code. Using these techniques, it is possible to perform in-circuit debugging and external flash programming elegantly.

The device contains flash memory for storage of program code. The flash memory is programmable from the user software and through the debug interface. The **flash controller** handles writing and erasing the embedded flash memory. The flash controller allows page-wise erasure and 4-bytewise programming.

The **I/O controller** is responsible for all general-purpose I/O pins. The CPU can configure whether peripheral modules control certain pins or whether they are under software control, and if so, whether each pin is configured as an input or output and if a pullup or pulldown resistor in the pad is connected. CPU interrupts can be enabled on each pin individually. Each peripheral that connects to the I/O pins can choose between two different I/O pin locations to ensure flexibility in various applications.

A versatile five-channel **DMA controller** is available in the system, accesses memory using the XDATA memory space, and thus has access to all physical memories. Each channel (trigger, priority, transfer mode, addressing mode, source and destination pointers, and transfer count) is configured with DMA descriptors anywhere in memory. Many of the hardware peripherals (AES core, flash controller, USARTs, timers, ADC interface) achieve highly efficient operation by using the DMA controller for data transfers between SFR or XREG addresses and flash/SRAM.

Timer 1 is a 16-bit timer with timer/counter/PWM functionality. It has a programmable prescaler, a 16-bit period value, and five individually programmable counter/capture channels, each with a 16-bit compare value. Each of the counter/capture channels can be used as a PWM output or to capture the timing of edges on input signals. It can also be configured in **IR Generation Mode**, where it counts Timer 3 periods and the output is ANDed with the output of Timer 3 to generate modulated consumer IR signals with minimal CPU interaction.

Timer 2 (the MAC Timer) is specially designed for supporting an IEEE 802.15.4 MAC or other time-slotted protocol in software. The timer has a configurable timer period and a 24-bit overflow counter that can be used to keep track of the number of periods that have transpired. A 40-bit capture register is also used to record the exact time at which a start-of-frame delimiter is received/transmitted or the exact time at which transmission ends, as well as two 16-bit output compare registers and two 24-bit overflow compare registers that can send various command strobes (start RX, start TX, etc.) at specific times to the radio modules.

Timer 3 and Timer 4 are 8-bit timers with timer/counter/PWM functionality. They have a programmable prescaler, an 8-bit period value, and one programmable counter channel with an 8-bit compare value. Each of the counter channels can be used as a PWM output.

The **sleep timer** is an ultralow-power timer that counts 32-kHz crystal oscillator or 32-kHz RC oscillator periods. The sleep timer runs continuously in all operating modes except power mode 3 (PM3). Typical applications of this timer are as a real-time counter or as a wake-up timer to come out of power mode 1 (PM1) or 2 (PM2).

The **battery monitor** comparator enables simple voltage monitoring in the devices that do not include an ADC. It is designed such that it is accurate in the voltage areas around 2 V, with lower resolution at higher voltages.

The **random-number generator** uses a 16-bit LFSR to generate pseudorandom numbers, which can be read by the CPU or used directly by the command strobe processor. It can be seeded with random data from noise in the radio ADC.

The **AES encryption/decryption core** allows the user to encrypt and decrypt data using the AES algorithm with 128-bit keys. The core is able to support the security operations required by IEEE 802.15.4 MAC security, the ZigBee network layer, and the application layer.

A built-in **watchdog timer** allows the CC2533 to reset itself in case the firmware hangs. When enabled by software, the watchdog timer must be cleared periodically; otherwise, it resets the device when it times out. It can alternatively be configured for use as a general 32-kHz timer.

USART 0 and USART 1 are each configurable as either a SPI master/slave or a UART. They provide double buffering on both RX and TX, as well as hardware flow control, and are thus well suited to high-throughput full-duplex applications. Each has its own high-precision baud-rate generator, thus leaving the ordinary timers free for other uses.

The **I²C** module provides a digital peripheral connection with two pins and supports both master and slave operation.

Radio

The CC2533 features an IEEE 802.15.4-compliant radio transceiver. The RF core controls the analog radio modules. In addition, it provides an interface between the MCU and the radio which makes it possible to issue commands, read status, and automate and sequence radio events. The radio also includes a packet-filtering and address-recognition module.

TYPICAL CHARACTERISTICS

**OUTPUT POWER
vs
FREQUENCY**

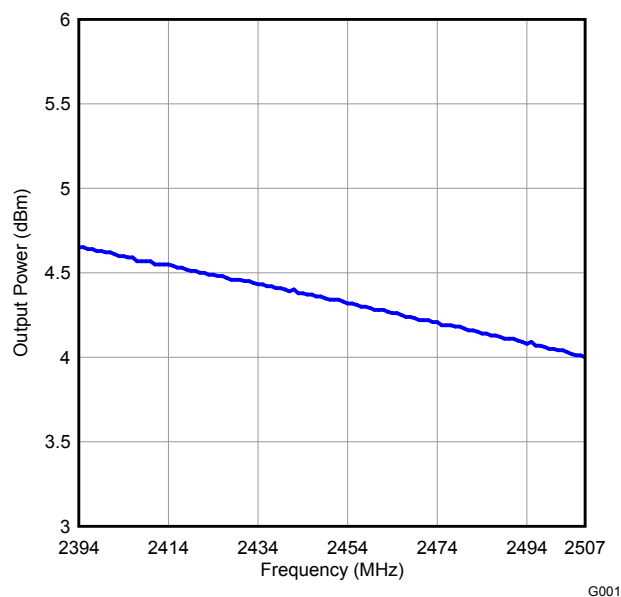


Figure 9.

**OUTPUT POWER
vs
TEMPERATURE**

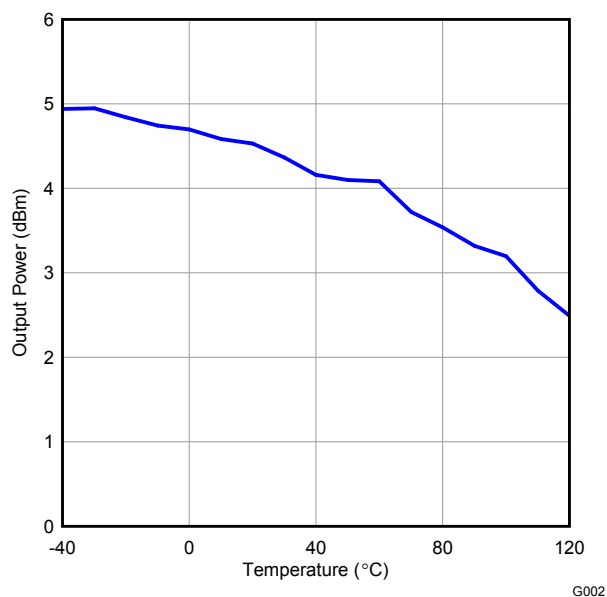


Figure 10.

**SENSITIVITY
vs
FREQUENCY**

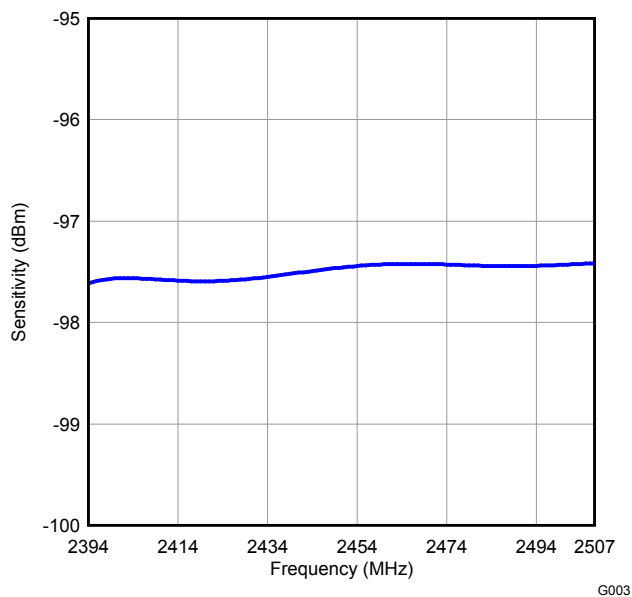


Figure 11.

**SENSITIVITY
vs
TEMPERATURE**

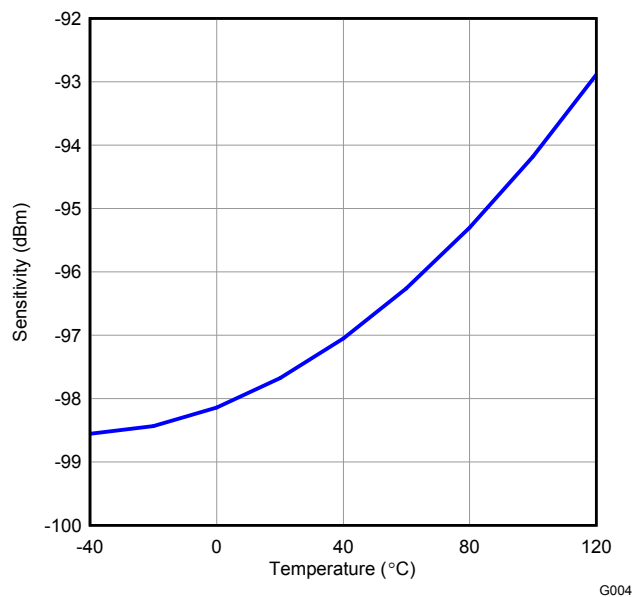


Figure 12.

TYPICAL CHARACTERISTICS (continued)

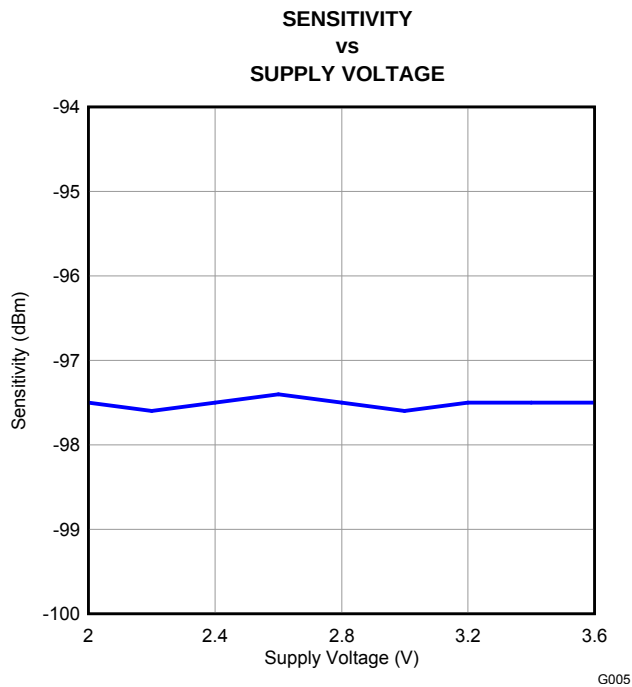


Figure 13.

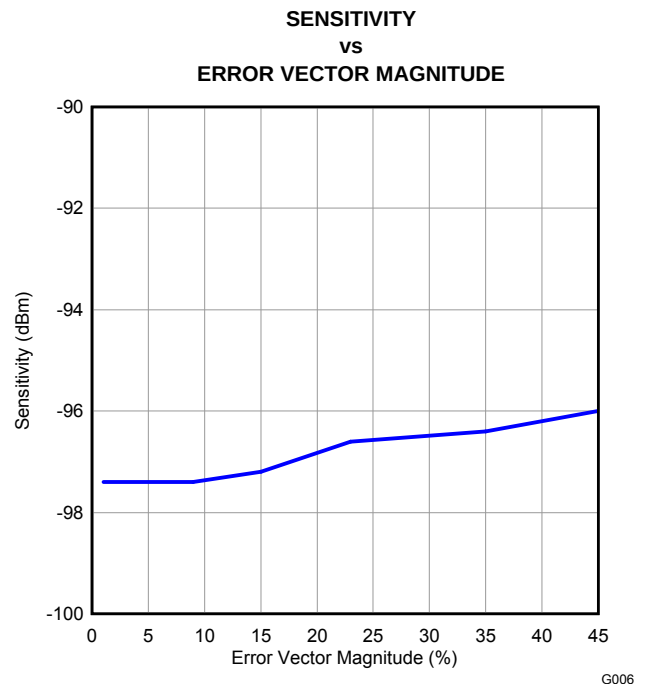


Figure 14.

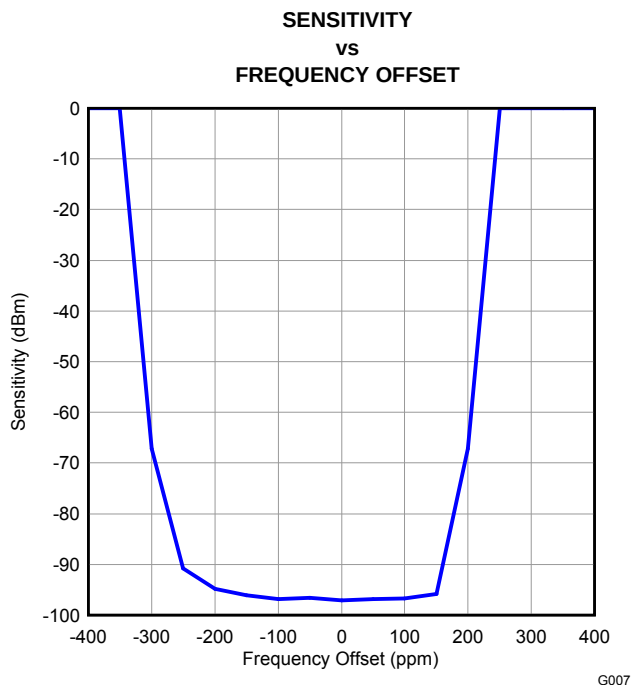


Figure 15.

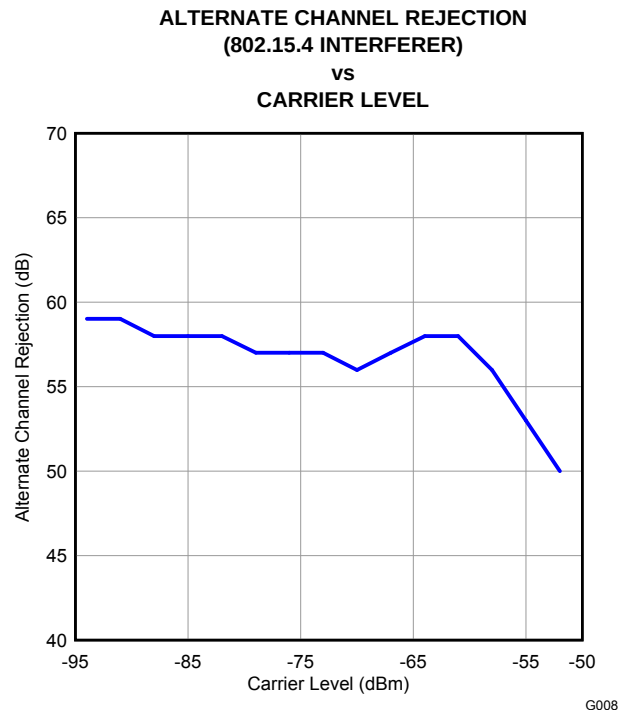


Figure 16.

TYPICAL CHARACTERISTICS (continued)

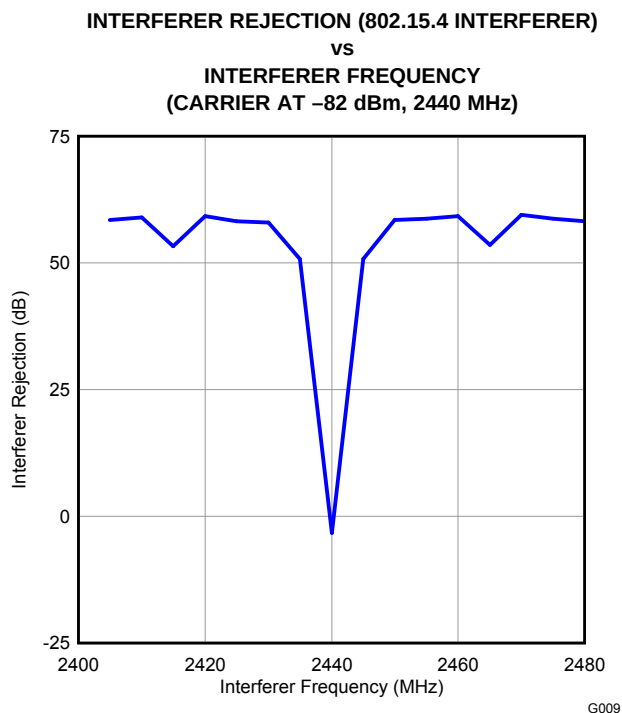


Figure 17.

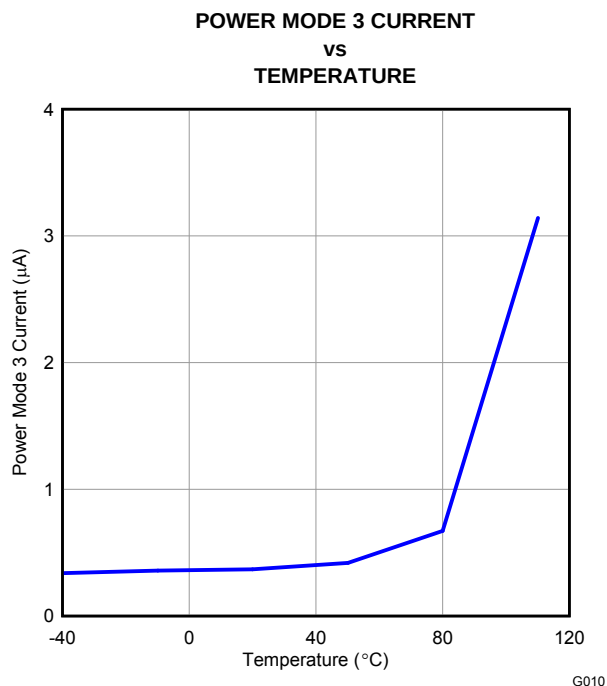


Figure 18.

Recommended RF Settings

This section contains a summary of the register settings that must be updated from their default value to have optimal performance. The following settings should be set for both RX and TX. Although not all settings are necessary for both RX and TX, it is recommended for simplicity (allowing one set of settings to be written at the initialization of the code).

Table 2. Recommended RF Register Settings

Register Name	Value
FRMCTRL0	0x43
FRMCTRL1	0x00
TXFILTCFG	0x09
FSCAL1	0x00
IVCTRL	0x0F
FSCTRL	0x55

Boost-Mode TX Settings

This section contains the register settings for boost-mode TX. Note that it is recommended to add two additional components (a capacitor and an inductor) adjacent to the capacitor C253 in [Figure 19](#) in order to reduce third-harmonic spurious emission to simplify passing regulations. There are three *do not mount* pads on the EM reference design. Two of these should be used to mount the additional components. The capacitor (0.9 pF) should be mounted to the pad on the chip side of C253 (to the left of C253 in [Figure 19](#)). The inductor (4.3 nH) should be mounted between C253 and the antenna on the pad closest to C253 (to the right of C253 in [Figure 19](#)). Using this filter lowers the output power 0.12 dB when using boost-mode TX and 0.4 dB at regular full power.

Table 3. Boost Mode TX Register Settings

Register Name	Value
FRMCTRL0	0x43
FRMCTRL1	0x00
TXFILTCFG	0x09
FSCAL1	0x00
IVCTRL	0x0F
FSCTRL	0xF5
TXCTRL	0x74
TXPOWER	0xFD

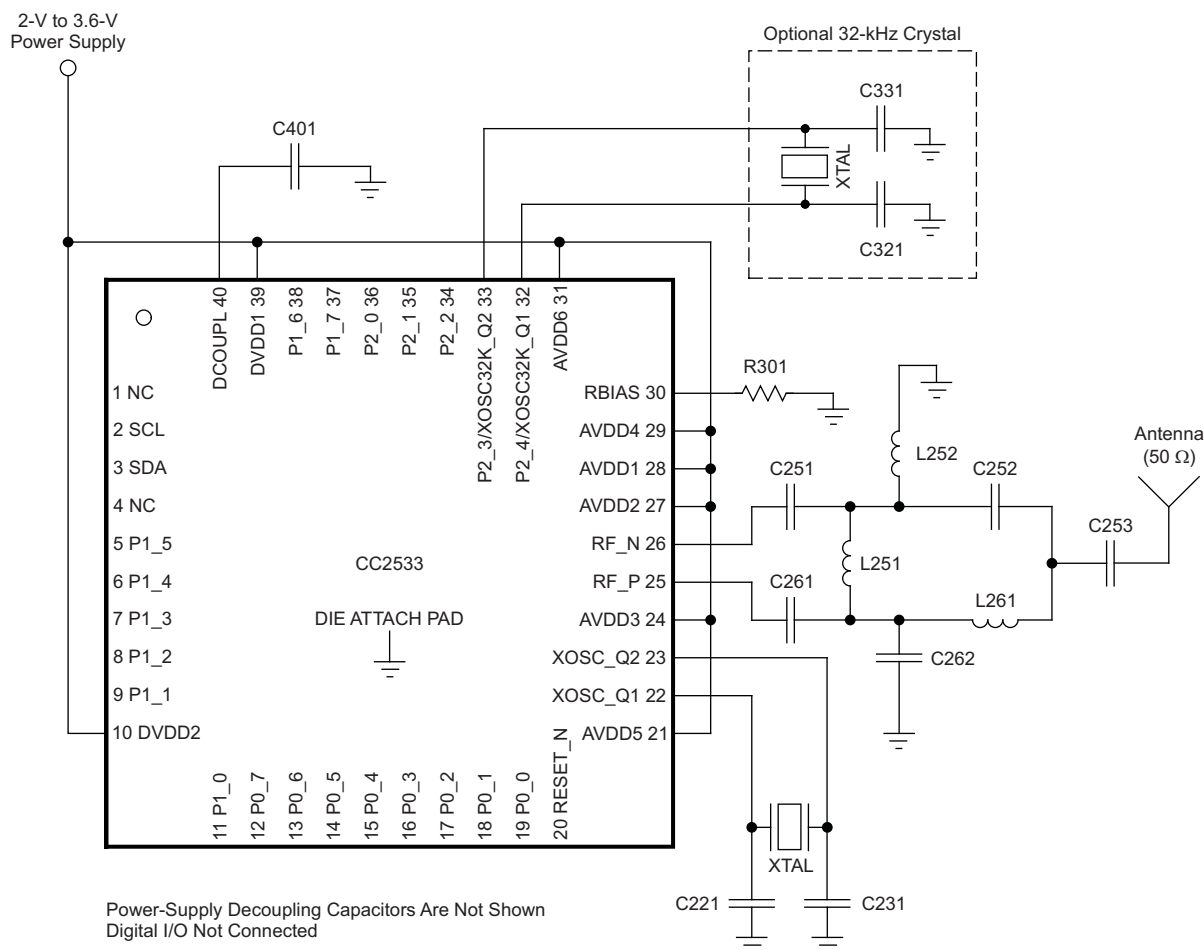
Table 4. Recommended Output Power Settings⁽¹⁾

TXPOWER Register Setting	Typical Output Power (dBm)	Typical Current Consumption (mA)
Boost mode TX	7	38.8
0xEC	4.5	32.3
0xDC	3	30.4
0xCC	1.7	29.6
0xBC	0.3	28.5
0xAC	–1	27.9
0x9C	–2.8	26.7
0x8C	–4.1	26.3
0x7C	–5.9	25.8
0x6C	–7.7	25.5
0x5C	–9.9	25.3
0x4C	–12.4	25.1
0x3C	–14.9	25.0
0x2C	–16.6	24.9
0x1C	–18.7	24.9
0x0C	–20.4	23.3

(1) Measured on Texas Instruments CC2533 EM reference design with $T_A = 25^\circ\text{C}$, $V_{DD} = 3\text{ V}$ and $f_c = 2440\text{ MHz}$, unless otherwise noted. See [Table 2](#) for recommended register settings.

APPLICATION INFORMATION

Few external components are required for the operation of the CC2533. A typical application circuit is shown in Figure 19. Typical values and description of external components are shown in Table 5.



S0383-02

Figure 19. CC2533 Application Circuit

Table 5. Overview of External Components (Excluding Supply Decoupling Capacitors)

Component	Description	Value
C221	32-MHz xtal loading capacitor	27 pF
C231	32-MHz xtal loading capacitor	27 pF
C251	Part of the RF matching network	18 pF
C252	Part of the RF matching network	1 pF
C253	Part of the RF matching network	2.2 pF
C261	Part of the RF matching network	18 pF
C262	Part of the RF matching network	1 pF
C321	32-kHz xtal loading capacitor	15 pF
C331	32-kHz xtal loading capacitor	15 pF
C401	Decoupling capacitor for the internal digital regulator	1 μ F
L252	Part of the RF matching network	2 nH

Table 5. Overview of External Components (Excluding Supply Decoupling Capacitors) (continued)

Component	Description	Value
L261	Part of the RF matching network	2 nH
R301	Resistor used for internal biasing	56 kΩ

Input/Output Matching

When using an unbalanced antenna such as a monopole, a balun should be used to optimize performance. The balun can be implemented using low-cost discrete inductors and capacitors. The recommended balun shown consists of C262, L261, C252, and L252.

If a balanced antenna such as a folded dipole is used, the balun can be omitted.

Crystal

An external 32-MHz crystal, XTAL1, with two loading capacitors (C221 and C231) is used for the 32-MHz crystal oscillator. See the [32-MHz Crystal Oscillator](#) section for details. The load capacitance seen by the 32-MHz crystal is given by:

$$C_L = \frac{1}{\frac{1}{C_{221}} + \frac{1}{C_{231}}} + C_{\text{parasitic}} \quad (1)$$

XTAL2 is an optional 32.768-kHz crystal, with two loading capacitors (C321 and C331) used for the 32.768-kHz crystal oscillator. The 32.768-kHz crystal oscillator is used in applications where both very low sleep-current consumption and accurate wake-up times are needed. The load capacitance seen by the 32.768-kHz crystal is given by:

$$C_L = \frac{1}{\frac{1}{C_{321}} + \frac{1}{C_{331}}} + C_{\text{parasitic}} \quad (2)$$

A series resistor may be used to comply with the ESR requirement.

On-Chip 1.8-V Voltage-Regulator Decoupling

The 1.8-V on-chip voltage regulator supplies the 1.8-V digital logic. This regulator requires a decoupling capacitor (C401) for stable operation.

Power-Supply Decoupling and Filtering

Proper power-supply decoupling must be used for optimum performance. The placement and size of the decoupling capacitors and the power supply filtering are very important to achieve the best performance in an application. TI provides a compact reference design that should be followed very closely.

REFERENCES

1. IEEE Std. 802.15.4-2006: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)
<http://standards.ieee.org/getieee802/download/802.15.4-2006.pdf>
2. CC253x User's Guide – CC253x System-on-Chip Solution for 2.4 GHz IEEE 802.15.4 and ZigBee Applications ([SWRU191](#))

ADDITIONAL INFORMATION

Texas Instruments offers a wide selection of cost-effective, low-power RF solutions for proprietary and standard-based wireless applications for use in industrial and consumer applications. Our selection includes RF transceivers, RF transmitters, RF front ends, and System-on-Chips as well as various software solutions for the sub-1-GHz and 2.4-GHz frequency bands.

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- RF design help
- E2E interaction

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- Low-power RF and ZigBee module solutions and development tools
- RF certification services and RF circuit manufacturing

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
CC2533F32RHAR	ACTIVE	VQFN	RHA	40	2500	RoHS & Green	NIPDAU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	CC2533 F32	Samples
CC2533F32RHAT	ACTIVE	VQFN	RHA	40	250	RoHS & Green	NIPDAU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	CC2533 F32	Samples
CC2533F64RHAR	ACTIVE	VQFN	RHA	40	2500	RoHS & Green	NIPDAU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	CC2533 F64	Samples
CC2533F64RHAT	ACTIVE	VQFN	RHA	40	250	RoHS & Green	NIPDAU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	CC2533 F64	Samples
CC2533F96RHAR	ACTIVE	VQFN	RHA	40	2500	RoHS & Green	NIPDAU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	CC2533 F96	Samples
CC2533F96RHAT	ACTIVE	VQFN	RHA	40	250	RoHS & Green	NIPDAU NIPDAUAG	Level-3-260C-168 HR	-40 to 125	CC2533 F96	Samples

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

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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

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TAPE AND REEL INFORMATION


*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
CC2533F32RHAR	VQFN	RHA	40	2500	330.0	16.4	6.3	6.3	1.1	12.0	16.0	Q2
CC2533F32RHAT	VQFN	RHA	40	250	180.0	16.4	6.3	6.3	1.1	12.0	16.0	Q2
CC2533F64RHAR	VQFN	RHA	40	2500	330.0	16.4	6.3	6.3	1.1	12.0	16.0	Q2
CC2533F64RHAT	VQFN	RHA	40	250	180.0	16.4	6.3	6.3	1.1	12.0	16.0	Q2
CC2533F96RHAR	VQFN	RHA	40	2500	330.0	16.4	6.3	6.3	1.1	12.0	16.0	Q2
CC2533F96RHAT	VQFN	RHA	40	250	180.0	16.4	6.3	6.3	1.1	12.0	16.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CC2533F32RHAR	VQFN	RHA	40	2500	367.0	367.0	38.0
CC2533F32RHAT	VQFN	RHA	40	250	210.0	185.0	35.0
CC2533F64RHAR	VQFN	RHA	40	2500	367.0	367.0	38.0
CC2533F64RHAT	VQFN	RHA	40	250	210.0	185.0	35.0
CC2533F96RHAR	VQFN	RHA	40	2500	367.0	367.0	38.0
CC2533F96RHAT	VQFN	RHA	40	250	210.0	185.0	35.0

GENERIC PACKAGE VIEW

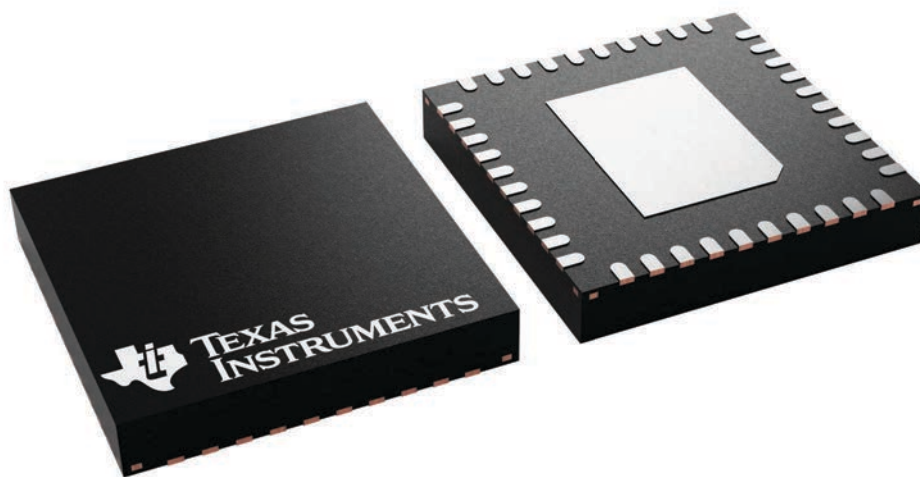
RHA 40

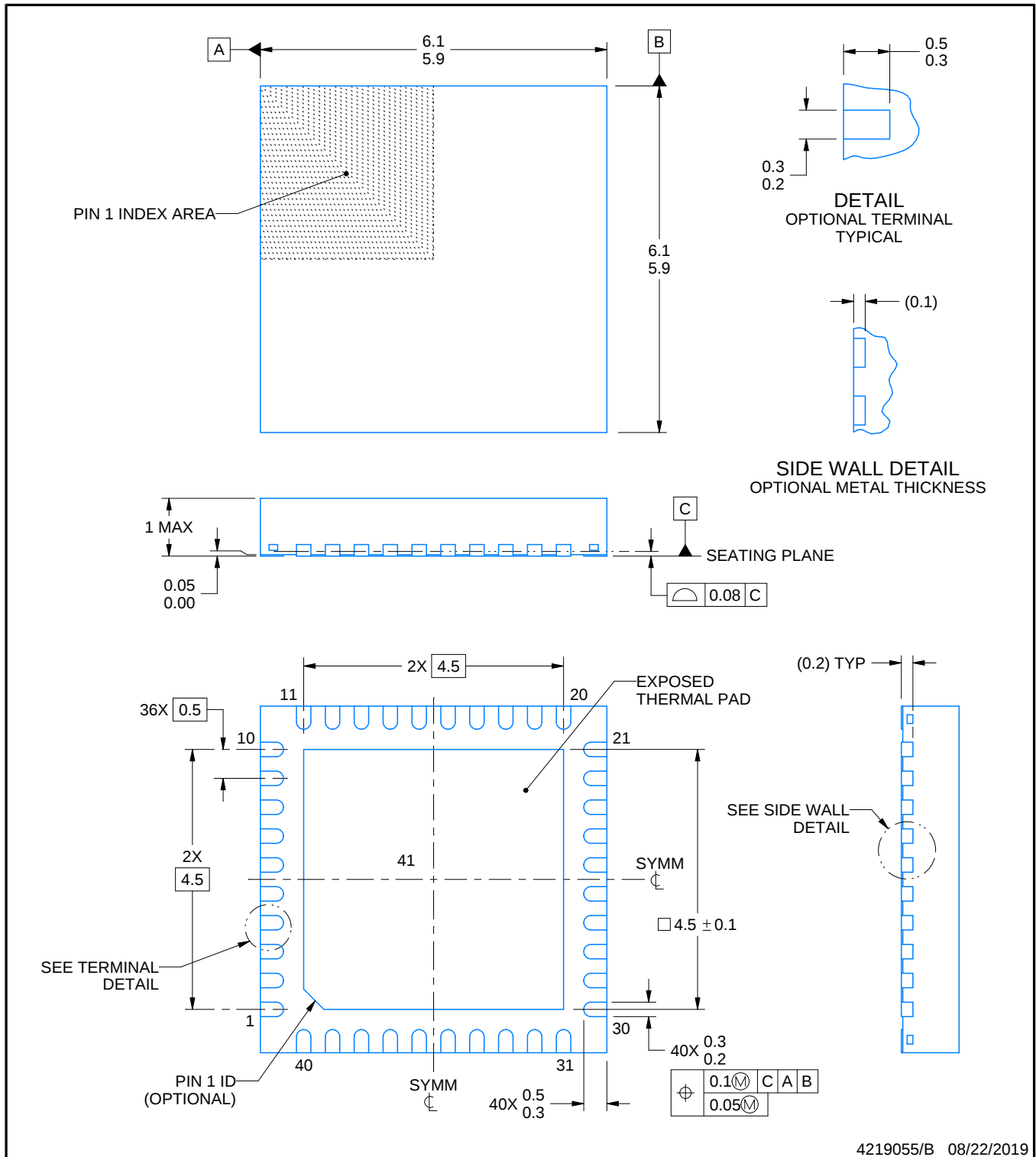
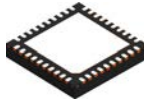
VQFN - 1 mm max height

6 x 6, 0.5 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.





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NOTES:

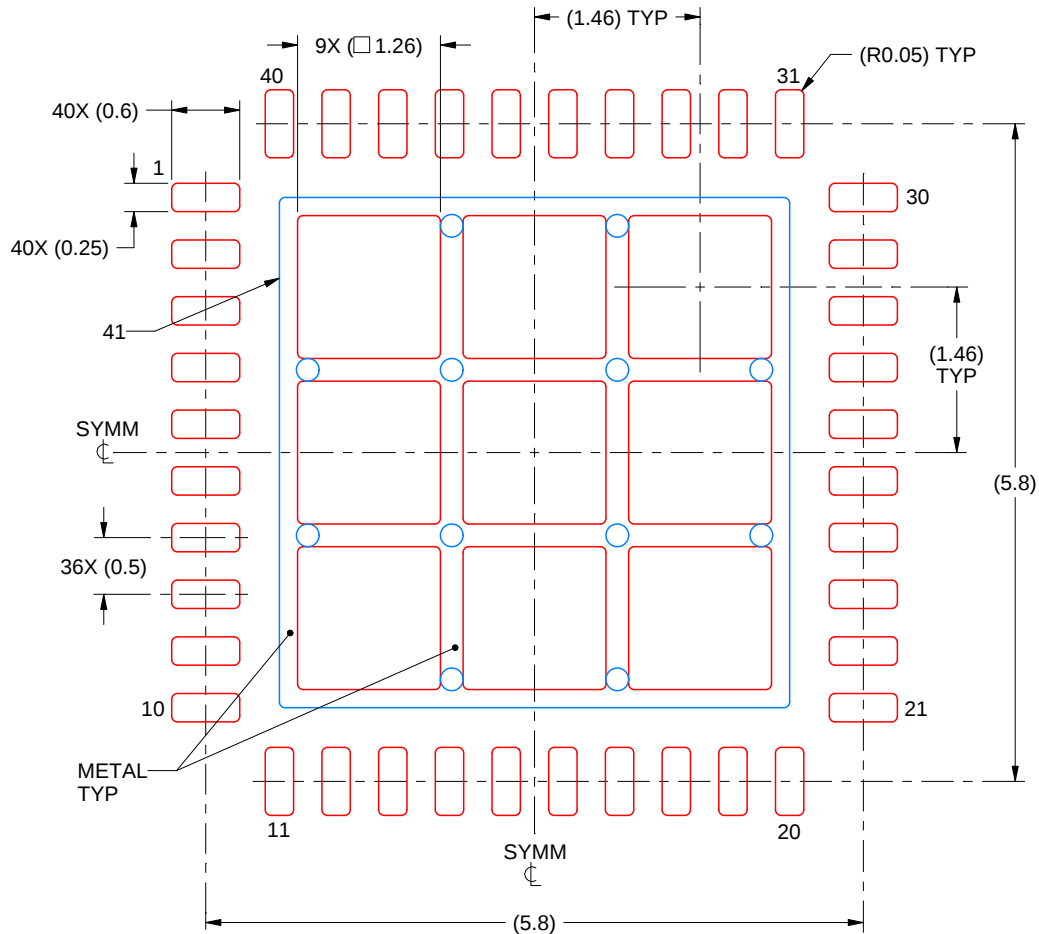
- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE STENCIL DESIGN

RHA0040H

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 41:
70% PRINTED SOLDER COVERAGE BY AREA
SCALE:15X

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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.

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