SimpleLink™ 2.4 GHz *Bluetooth*® Low Energy Wireless Network Processor

Check for Samples: CC2541S

FEATURES

- RF
  - 2.4-GHz *Bluetooth* low energy Compliant Wireless Network Processor
  - Excellent Link Budget, Enabling Long-Range Applications Without External Front End
  - Programmable Output Power up to 0 dBm
  - Excellent Receiver Sensitivity (–94 dBm at 1 Mbps), Selectivity, and Blocking Performance
  - 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)
- Layout
  - Few External Components
  - Reference Design Provided
  - 6-mm × 6-mm QFN-40 Package
  - Pin-Compatible With CC2540, CC2541 (when these are used as a wireless network processor)
- Low Power
  - Active-Mode RX Down to: 17.9 mA
  - Active-Mode TX (0 dBm): 18.2 mA
  - Power Mode 1 (4-µs Wake-Up): 270 µA
  - Power Mode 2 (Sleep Timer On): 1 µA
  - Power Mode 3 (External Interrupts): 0.5 µA
  - Wide Supply-Voltage Range (2 V–3.6 V)
- TPS62730 Compatible Low Power in Active Mode
  - RX Down to: 14.7 mA (3-V supply)
  - TX (0 dBm): 14.3 mA (3-V supply)
- Wireless Network Processor (WNP) Features
  - SimpleLink™ Provides Easy Integration with Host MCUs such as MSP430
  - CC2541S Runs Entire *Bluetooth* Low Energy Stack up to GATT
  - CC2541S is Based on Flash Memory, Making it Possible to Upgrade the Software, Even in the Field
  - Software is Configurable to Support both Central and Peripheral Roles
  - Both UART and SPI Interfaces Supported
- Development Tools
  - CC2541S Booster Pack with MSP430 LaunchPad Value Line Development Kit
  - PC-Based Configurator GUI Tool
  - Open-source Flash Loader Tool for Linux

SOFTWARE FEATURES

- *Bluetooth* v4.0 Compliant Protocol Stack for Single-Mode BLE Solution
  - Complete Power-Optimized Stack, Including Controller and Host
    - GAP – Central, Peripheral, Observer, or Broadcaster (Including Combination Roles)
    - ATT / GATT – Client and Server
    - SMP – AES-128 Encryption and Decryption
    - L2CAP
  - MSP430 Sample Peripheral Application Available
  - Configuration
    - Network Processor Interface for Applications Running on an External Microcontroller
  - BTool – Windows PC Application for Evaluation, Development, and Test

APPLICATIONS

- 2.4-GHz *Bluetooth* low energy Systems
- Sports and Leisure Equipment
- Mobile Phone Accessories
- Consumer Electronics

PRODUCT PREVIEW

CC2541S WITH TPS62730

- **TPS62730 is a 2-MHz Step-Down Converter With Bypass Mode**
- **Extends Battery Lifetime by up to 20%**
- **Reduced Current in All Active Modes**
- **30-nA Bypass Mode Current to Support Low-Power Modes**
- **RF Performance Unchanged**
- **Small Package Allows for Small Solution Size**
- **CC2541S Controllable**

DESCRIPTION

The CC2541S is a power-optimized Wireless Network Processor (WNP) solution for *Bluetooth* low energy (*Bluetooth* Smart) applications. It features easy integration with various host MCUs, since the majority of the *Bluetooth* low energy software stack resides inside the CC2541S. The CC2541S combines the excellent performance of a leading RF transceiver with TI’s robust *Bluetooth* low energy software stack. The CC2541S is highly suited for systems where ultra low power consumption is required. It can be combined with the TPS62730 RF-friendly step-down DC/DC converter for even lower current consumption.

The CC2541S is pin-compatible with the CC2540 and CC2541 when these are used in a Wireless Network Processor configuration. The CC2541S radio is identical to the radio in CC2541, but CC2541S does not contain MCU peripherals and cannot run SoC software written for CC2540 or CC2541.

The CC2541S comes pre-programmed with a bootloader. Prior to operation, the appropriate WNP image must be loaded into the device. An image can also be loaded into CC2541S through the host MCU, allowing the *Bluetooth* low energy stack inside CC2541S to be upgraded in the field.

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)

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

		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 pins, excluding pins 25 and 26, according to human-body model, JEDEC STD 22, method A114		2	kV
	All pins, according to human-body model, JEDEC STD 22, method A114		1	kV
	According to charged-device model, JEDEC STD 22, method C101		500	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

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

	MIN	NOM	MAX	UNIT
Operating ambient temperature range, T_A	–40		85	°C
Operating supply voltage	2		3.6	V

ELECTRICAL CHARACTERISTICS

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C and VDD = 3 V,
1 Mbps, GFSK, 250-kHz deviation, *Bluetooth* low energy mode, and 0.1% BER

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{core}	Core current consumption	RX mode, standard mode, no peripherals active, low MCU activity		17.9		mA
		RX mode, high-gain mode, no peripherals active, low MCU activity		20.2		mA
		TX mode, –20 dBm output power, no peripherals active, low MCU activity		16.8		mA
		TX mode, 0 dBm output power, no peripherals active, low MCU activity		18.2		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		270		µA
		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		µA
		Power mode 3. Digital regulator off; no clocks; POR active; RAM and register retention		0.5		µA
		Low MCU activity: 32-MHz XOSC running. No radio or peripherals. Limited flash access, no RAM access.		6.7		mA
I_{peri}	Peripheral current consumption (Adds to core current I_{core} for each peripheral unit activated)	Timer 2. Timer running, 32-MHz XOSC used		90		µA
		Sleep timer, including 32.753-kHz RCOSC		0.6		µA
		ADC, when converting		1.2		mA

PRODUCT PREVIEW

GENERAL CHARACTERISTICS

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C and VDD = 3 V

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		120		μs
Active → TX or RX	Crystal ESR = 16 Ω. Initially running on 16-MHz RCOSC, with 32-MHz XOSC OFF		500		μs
	With 32-MHz XOSC initially on		180		μs
RX/TX turnaround			130		μs
	BLE mode		150		
RADIO PART					
RF frequency range	Programmable in 1-MHz steps	2379		2496	MHz
Data rate and modulation format	1 Mbps, GFSK, 250-kHz deviation				

RF RECEIVE SECTION

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C, VDD = 3 V, f_c = 2440 MHz

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
1 Mbps, GFSK, 250-kHz Deviation, *Bluetooth* low energy Mode, 0.1% BER					
Receiver sensitivity(1)(2)	High-gain mode		–94		dBm
	Standard mode		–88		
Saturation(2)	BER < 0.1%		5		dBm
Co-channel rejection(2)	Wanted signal –67 dBm		–6		dB
In-band blocking rejection(2)	±1 MHz offset, 0.1% BER, wanted signal –67 dBm		–2		dB
	±2 MHz offset, 0.1% BER, wanted signal –67 dBm		26		
	±3 MHz offset, 0.1% BER, wanted signal –67 dBm		34		
	>6 MHz offset, 0.1% BER, wanted signal –67 dBm		33		
Out-of-band blocking rejection(2)	Minimum interferer level < 2 GHz (Wanted signal –67 dBm)		–21		dBm
	Minimum interferer level [2 GHz, 3 GHz] (Wanted signal –67 dBm)		–25		
	Minimum interferer level > 3 GHz (Wanted signal –67 dBm)		–7		
Intermodulation(2)	Minimum interferer level		–36		dBm
Frequency error tolerance(3)	Including both initial tolerance and drift. Sensitivity better than -67dBm, 250 byte payload. BER 0.1%	–250		250	kHz
Symbol rate error tolerance(4)	Maximum packet length. Sensitivity better than –67 dBm, 250 byte payload. BER 0.1%	–80		80	ppm
ALL RATES/FORMATS					
Spurious emission in RX. Conducted measurement	f < 1 GHz		–67		dBm
Spurious emission in RX. Conducted measurement	f > 1 GHz		–57		dBm

(1) The receiver sensitivity setting is programmable using a TI BLE stack vendor-specific API command. The default value is standard mode.
(2) Results based on standard-gain mode.
(3) Difference between center frequency of the received RF signal and local oscillator frequency
(4) Difference between incoming symbol rate and the internally generated symbol rate

RF TRANSMIT SECTION

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C, VDD = 3 V and f_c = 2440 MHz

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output power	Delivered to a single-ended 50-Ω load through a balun using maximum recommended output power setting		0		dBm
	Delivered to a single-ended 50-Ω load through a balun using minimum recommended output power setting		–20		
Programmable output power range	Delivered to a single-ended 50-Ω load through a balun using minimum recommended output power setting		20		dB
Spurious emission conducted measurement	f < 1 GHz		–52		dBm
	f > 1 GHz		–48		dBm
	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)				
Optimum load impedance	Differential impedance as seen from the RF port (RF_P and RF_N) toward the antenna		70 +j30		Ω

Designs with antenna connectors that require conducted ETSI compliance at 64 MHz should insert an LC resonator in front of the antenna connector. Use a 1.6-nH inductor in parallel with a 1.8-pF capacitor. Connect both from the signal trace to a good RF ground.

CURRENT CONSUMPTION WITH TPS62730

Measured on Texas Instruments CC2541S TPA62730 EM reference design with T_A = 25°C, VDD = 3 V and f_c = 2440 MHz, **1 Mbsp, GFSK, 250-kHz deviation, Bluetooth™ low energy Mode, 1% BER**(1)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Current consumption	RX mode, standard mode, no peripherals active, low MCU activity, MCU at 1 MHz		14.7		mA
	RX mode, high-gain mode, no peripherals active, low MCU activity, MCU at 1 MHz		16.7		
	TX mode, –20 dBm output power, no peripherals active, low MCU activity, MCU at 1 MHz		13.1		
	TX mode, 0 dBm output power, no peripherals active, low MCU activity, MCU at 1 MHz		14.3		

(1) 0.1% BER maps to 30.8% PER

32-MHz CRYSTAL OSCILLATOR

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C and VDD = 3 V

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			0.25		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]

PRODUCT PREVIEW

32.768-kHz CRYSTAL OSCILLATOR

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C and VDD = 3 V

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	kΩ
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 CC2541S EM reference design with T_A = 25°C and VDD = 3 V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Calibrated frequency(1)			32.753		kHz
Frequency accuracy after calibration			±0.2%		
Temperature coefficient(2)			0.4		%/°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 SLEEPCMD.OSC32K_CALDIS is set to 0.

16-MHz RC OSCILLATOR

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C and VDD = 3 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Frequency(1)			16		MHz
Uncalibrated frequency accuracy			±18%		
Calibrated frequency accuracy			±0.6%		
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 SLEEPCMD.OSC_PD is set to 0.

RSSI CHARACTERISTICS

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C and VDD = 3 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Useful RSSI range(1)	Standard mode		64		dB
	High-gain mode		64		
RSSI offset(1)	Standard mode		98		dBm
	High-gain mode		107		
Absolute uncalibrated accuracy(1)			±3		dB
Step size (LSB value)			1		dB

(1) Assuming CC2541S EM reference design. Other RF designs give an offset from the reported value.

FREQUENCY SYNTHESIZER CHARACTERISTICS

Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C, VDD = 3 V and f_c = 2440 MHz

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Phase noise, unmodulated carrier	At ±1-MHz offset from carrier		–109		dBc/Hz
	At ±3-MHz offset from carrier		–112		
	At ±5-MHz offset from carrier		–119		

CONTROL INPUT AC CHARACTERISTICS

T_A = –40°C to 85°C, VDD = 2 V to 3.6 V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
System clock, f_{SYSCLK} t_{SYSCLK} = 1/ f_{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
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 do 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

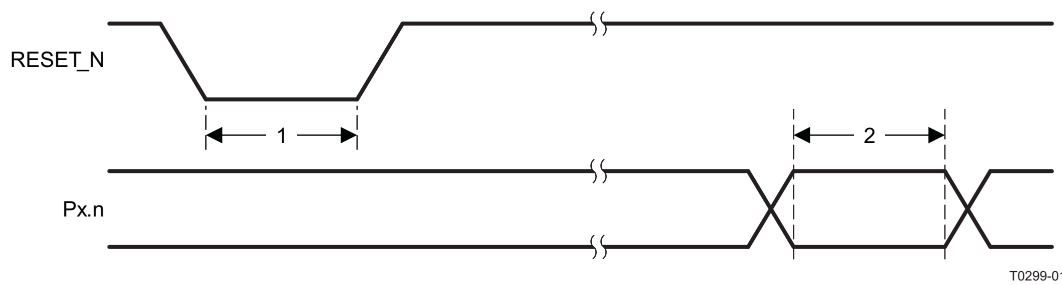


Figure 1. Control Input AC Characteristics

PRODUCT PREVIEW

SPI AC CHARACTERISTICS

T_A = –40°C to 85°C, VDD = 2 V to 3.6 V

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

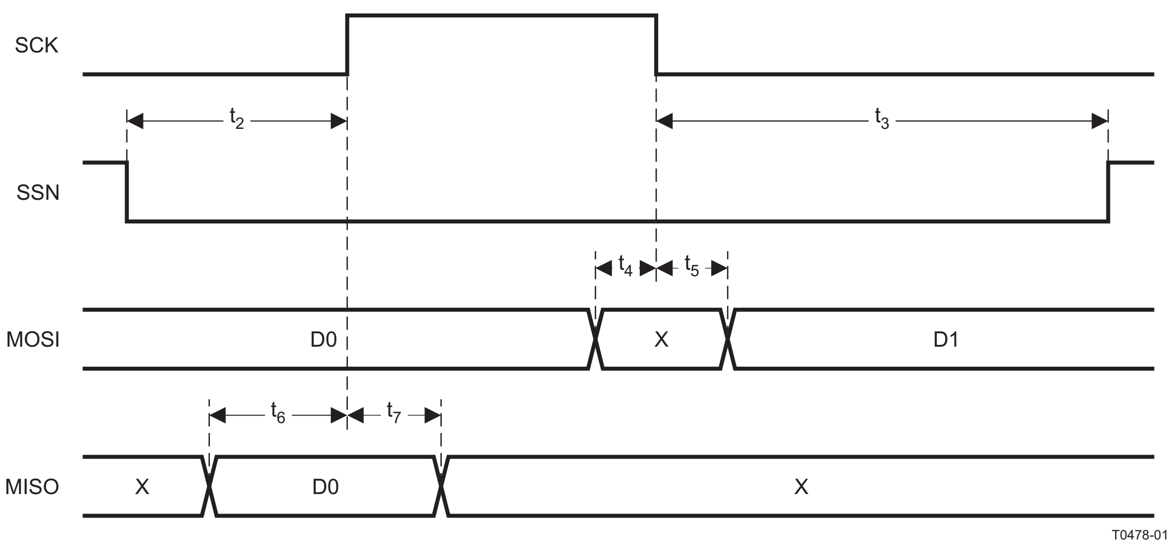


Figure 2. SPI Master AC Characteristics

PRODUCT PREVIEW

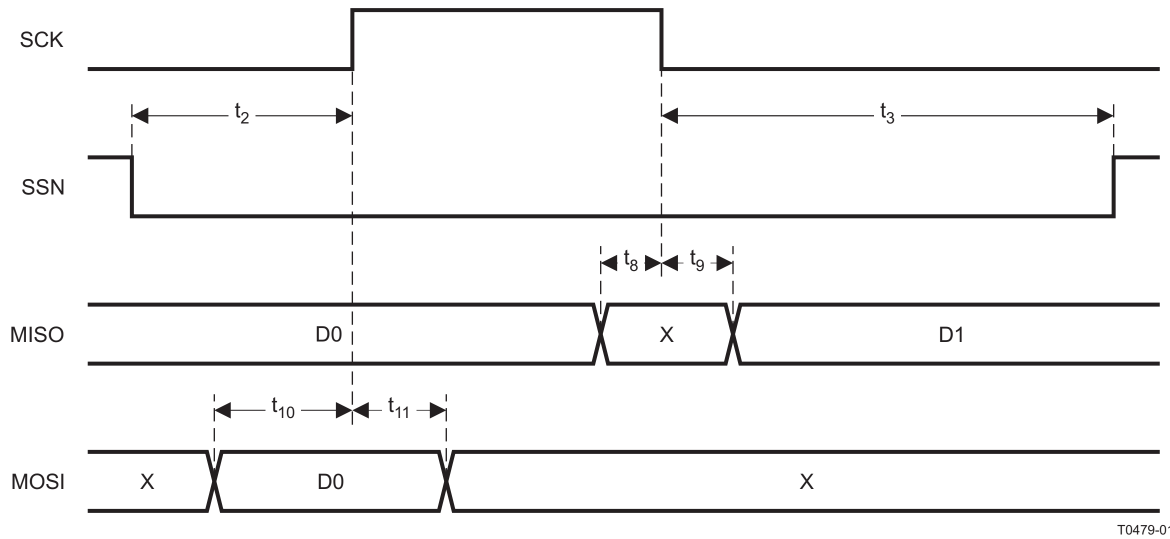


Figure 3. SPI Slave AC Characteristics

DC CHARACTERISTICS

T_A = 25°C, VDD = 3 V

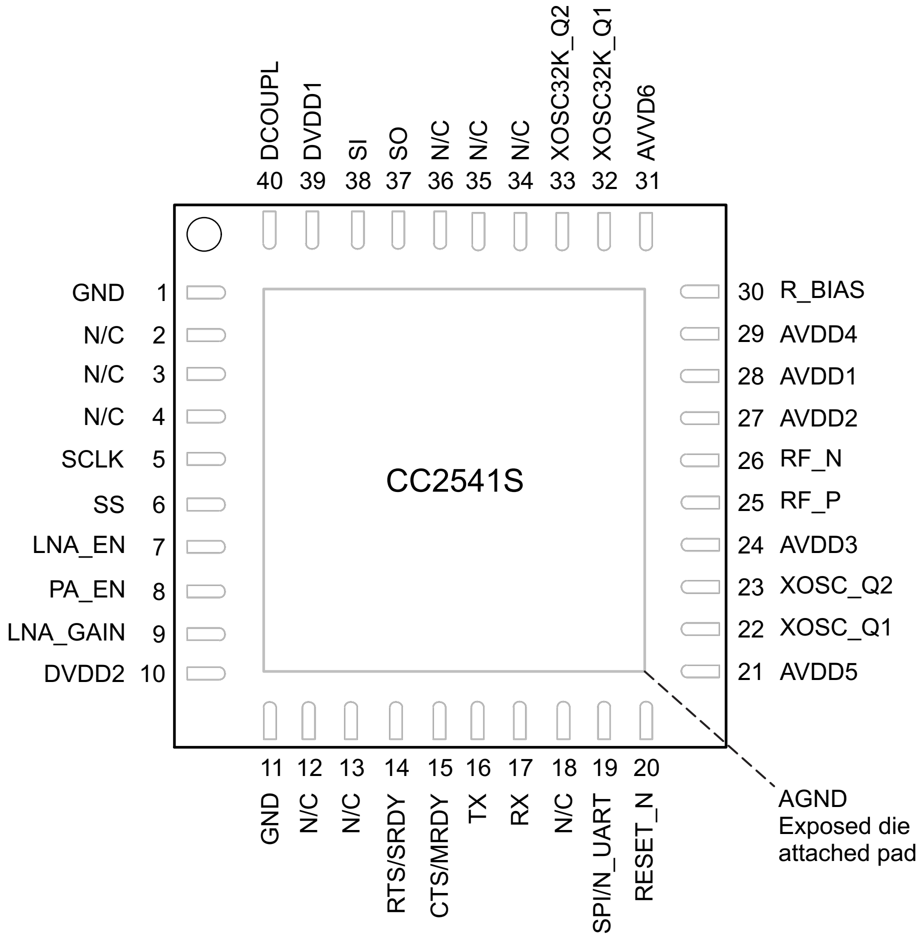
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Logic-0 input voltage				0.5	V
Logic-1 input voltage		2.4			V
Logic-0 input current	Input equals 0 V	–50		50	nA
Logic-1 input current	Input equals VDD	–50		50	nA
I/O-pin pullup and pulldown resistors			20		kΩ
Logic-0 output voltage, 4- mA pins	Output load 4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

PRODUCT PREVIEW

DEVICE INFORMATION

PIN DESCRIPTIONS

The CC2541S pinout is shown in Figure 4 and a short description of the pins follows.



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

Figure 4. Pinout Top View

PRODUCT PREVIEW

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
CTS/MRDY	15	Digital I/O	Clear to Send/ Maser Ready
DCOUPL	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	1,11	Ground pin	Connect to GND
GND	—	Ground	The ground pad must be connected to a solid ground plane.
LNA_EN	7	Digital I/O	Enables range extender LNA
LNA_GAIN	9	Digital I/O	LNA gain control
NC	2,3,4 12,13, 18,34 35,36	Unused pins	Not connected. Leave unconnected
PA_EN	8	Digital I/O	Enables range extender PA
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
RTS/SRDY	14	Digital I/O	Ready to Send/ Slave Ready
RX	17	Digital I	UART input
SCLK	5	Digital I	SPI Clock Input
SI	38	Digital I	SPI Slave In
SO	37	Digital O	SPI Slave Out
SPI/N_UART	19	Digital I/O	SPI or UART select
SS	6	Digital I	SPI Slave select
TX	16	Digital O	UART output
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
XOSC32K_Q1	32	Analog I/O	32.768 kHz XOSC
XOSC32K_Q2	33	Analog I/O	32.768 kHz XOSC

BLOCK DIAGRAM

A block diagram of the CC2541S is shown in Figure 5. The modules can be roughly divided into one of three categories: CPU-related modules; modules related to power, test, and clock distribution; and radio-related modules. In the following subsections, a short description of each module is given.

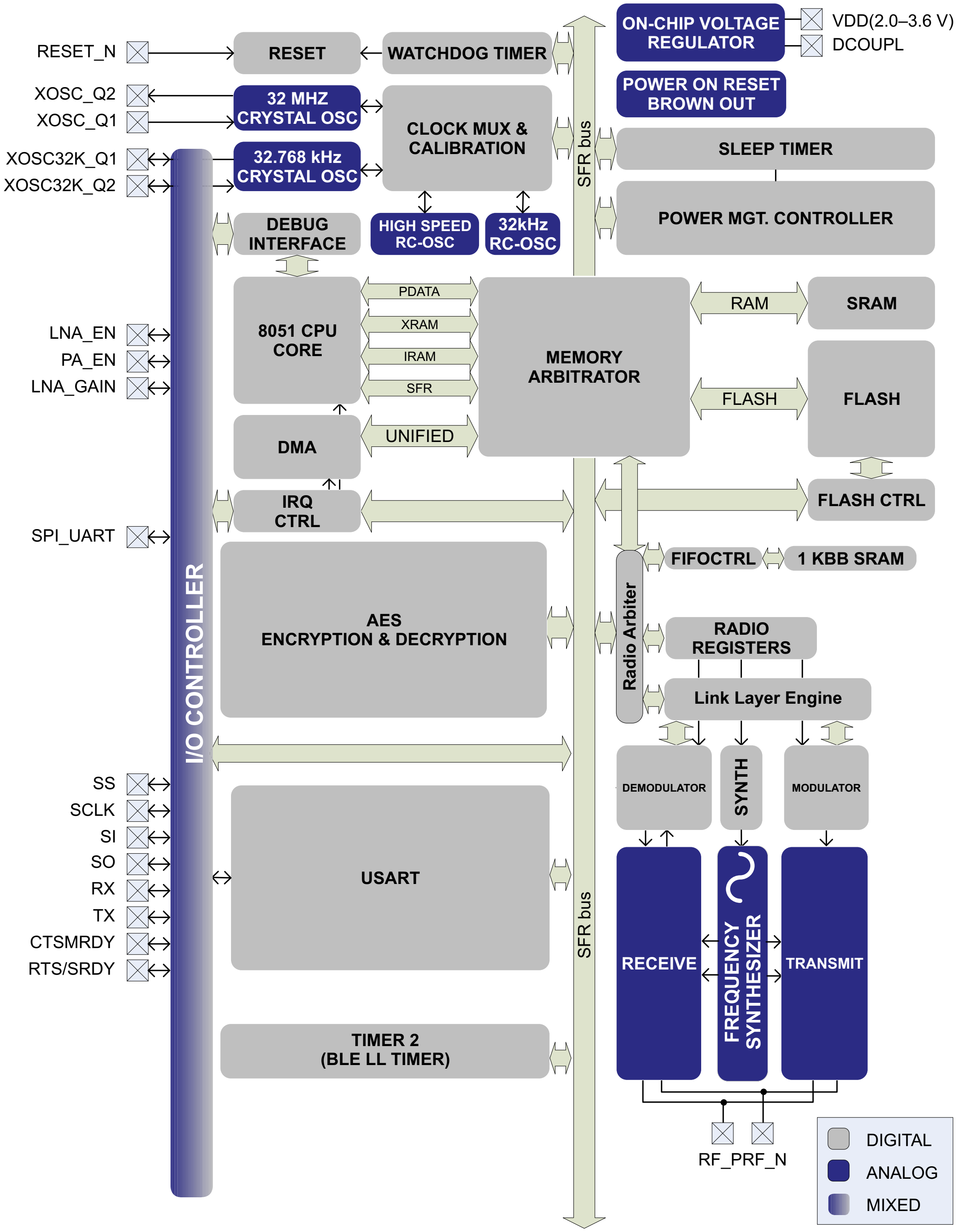


Figure 5. CC2541S Block Diagram

TYPICAL CHARACTERISTICS

RX CURRENT vs TEMPERATURE

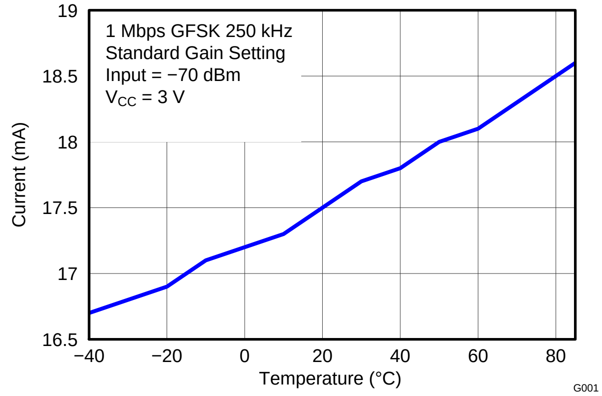


Figure 6.

TX CURRENT vs TEMPERATURE

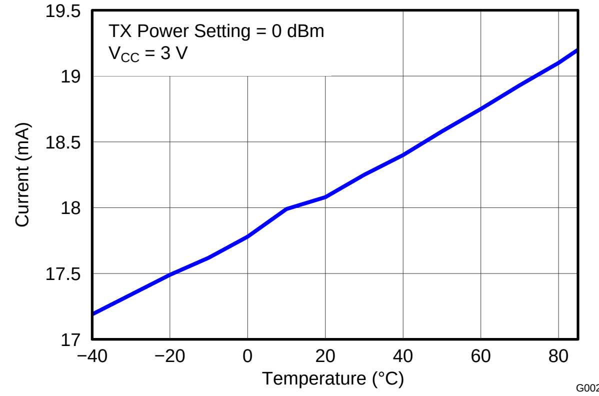


Figure 7.

RX SENSITIVITY vs TEMPERATURE

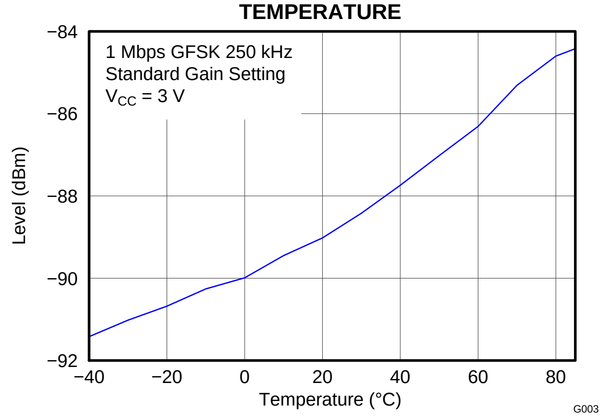


Figure 8.

TX POWER vs TEMPERATURE

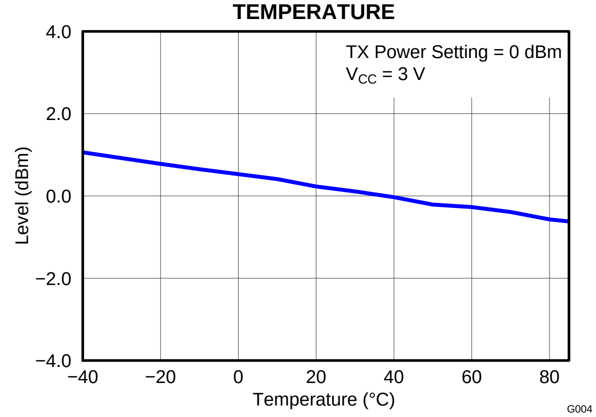


Figure 9.

RX CURRENT vs SUPPLY VOLTAGE

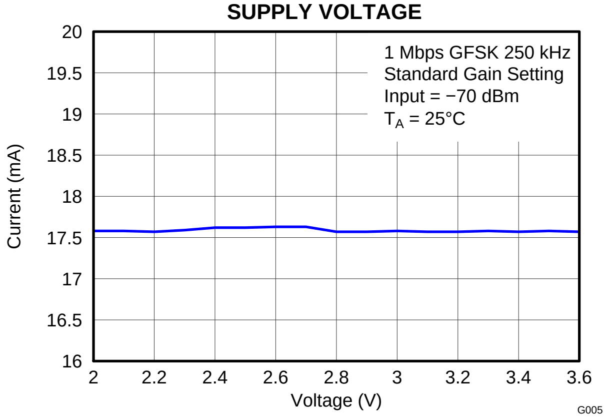


Figure 10.

TX CURRENT vs SUPPLY VOLTAGE

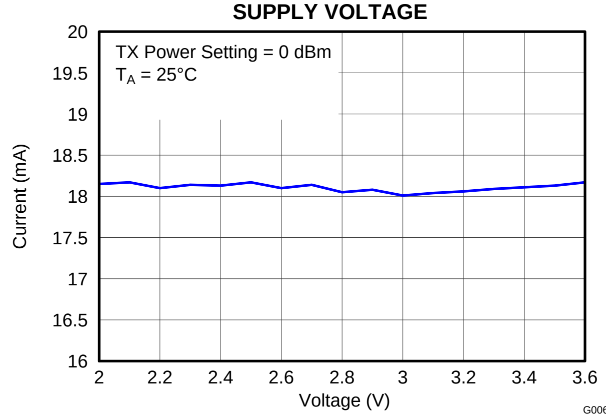


Figure 11.

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS (continued)

RX SENSITIVITY vs SUPPLY VOLTAGE

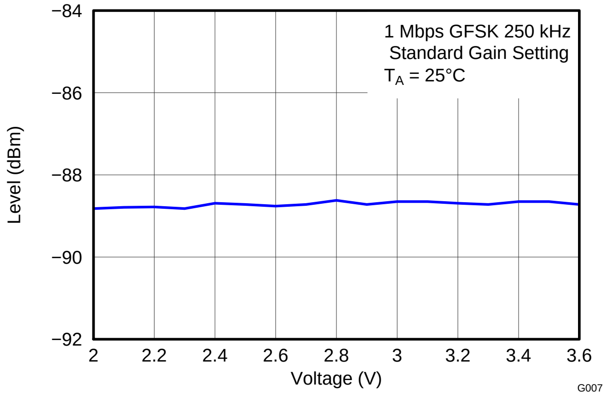


Figure 12.

TX POWER vs SUPPLY VOLTAGE

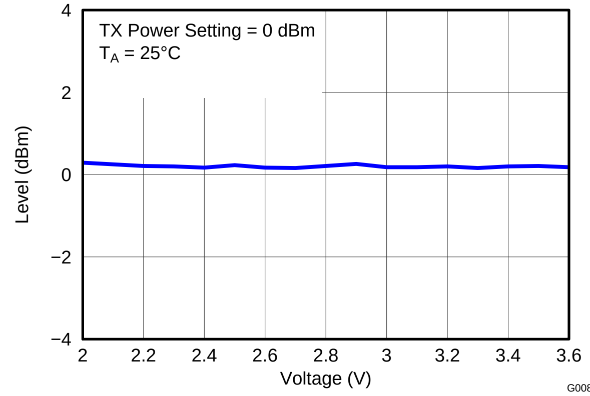


Figure 13.

RX SENSITIVITY vs FREQUENCY

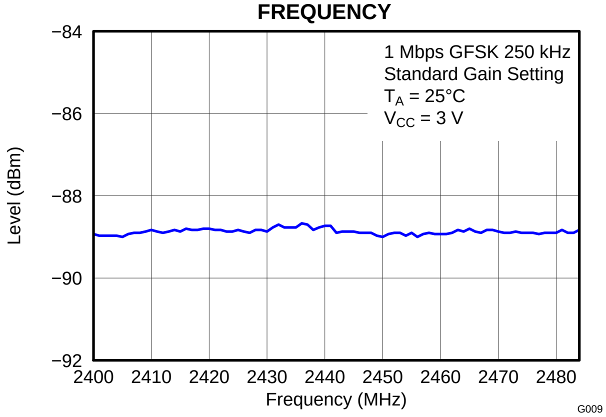


Figure 14.

TX POWER vs FREQUENCY

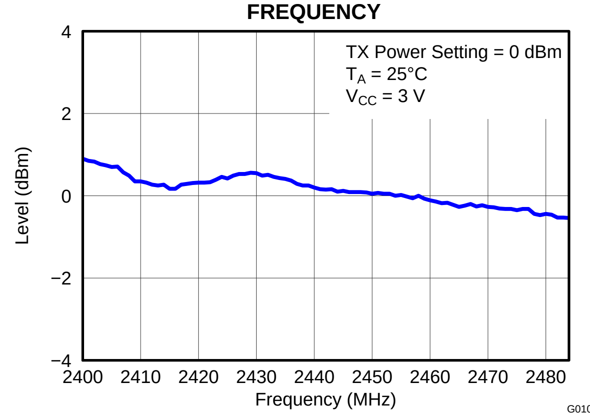


Figure 15.

Table 1. Output Power(1)(2)

TXPOWER Setting	Typical Output Power (dBm)
0xE1	0
0xD1	–2
0xC1	–4
0xB1	–6
0xA1	–8
0x91	–10
0x81	–12
0x71	–14
0x61	–16
0x51	–18
0x41	–20

(1) Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C, VDD = 3 V and f_c = 2440 MHz. See SWRU191 for recommended register settings.
(2) 1 Mbsp, GFSK, 250-kHz deviation, *Bluetooth*™ low energy mode, 1% BER

PRODUCT PREVIEW

Table 2. Output Power and Current Consumption

Typical Output Power (dBm)	Typical Current Consumption (mA)[1]	Typical Current Consumption With TPS62730 (mA)[2]
0	18.2	14.3
–20	16.8	13.1

(1) Measured on Texas Instruments CC2541S EM reference design with T_A = 25°C, VDD = 3 V and f_c = 2440 MHz.
(2) Measured on Texas Instruments CC2541S TPS62730 EM reference design with T_A = 25°C, VDD = 3 V and f_c = 2440 MHz.

TYPICAL CURRENT SAVINGS WHEN USING TPS62730

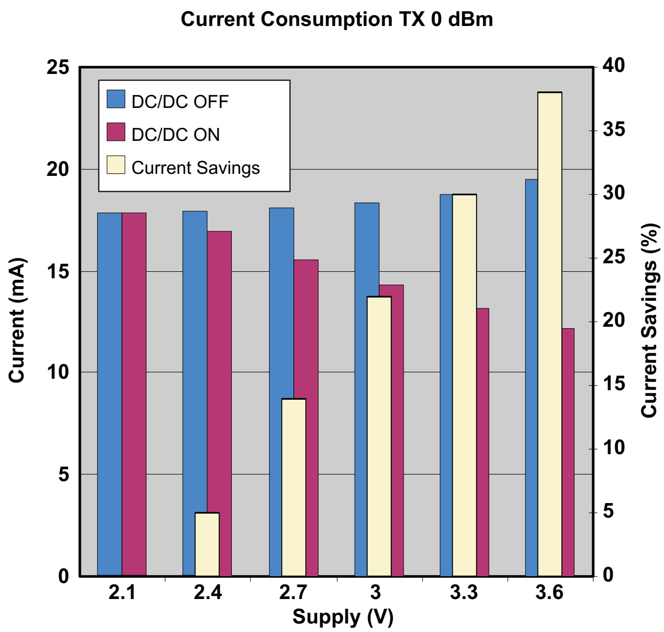


Figure 16. Current Savings in TX at Room Temperature

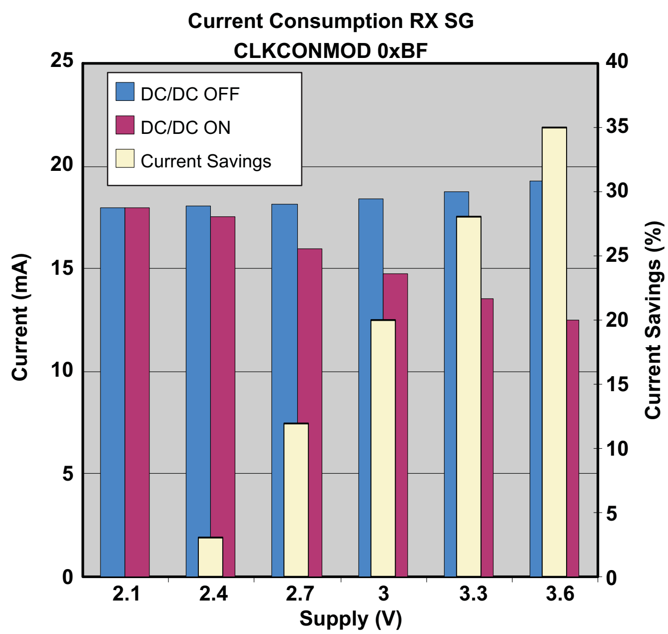


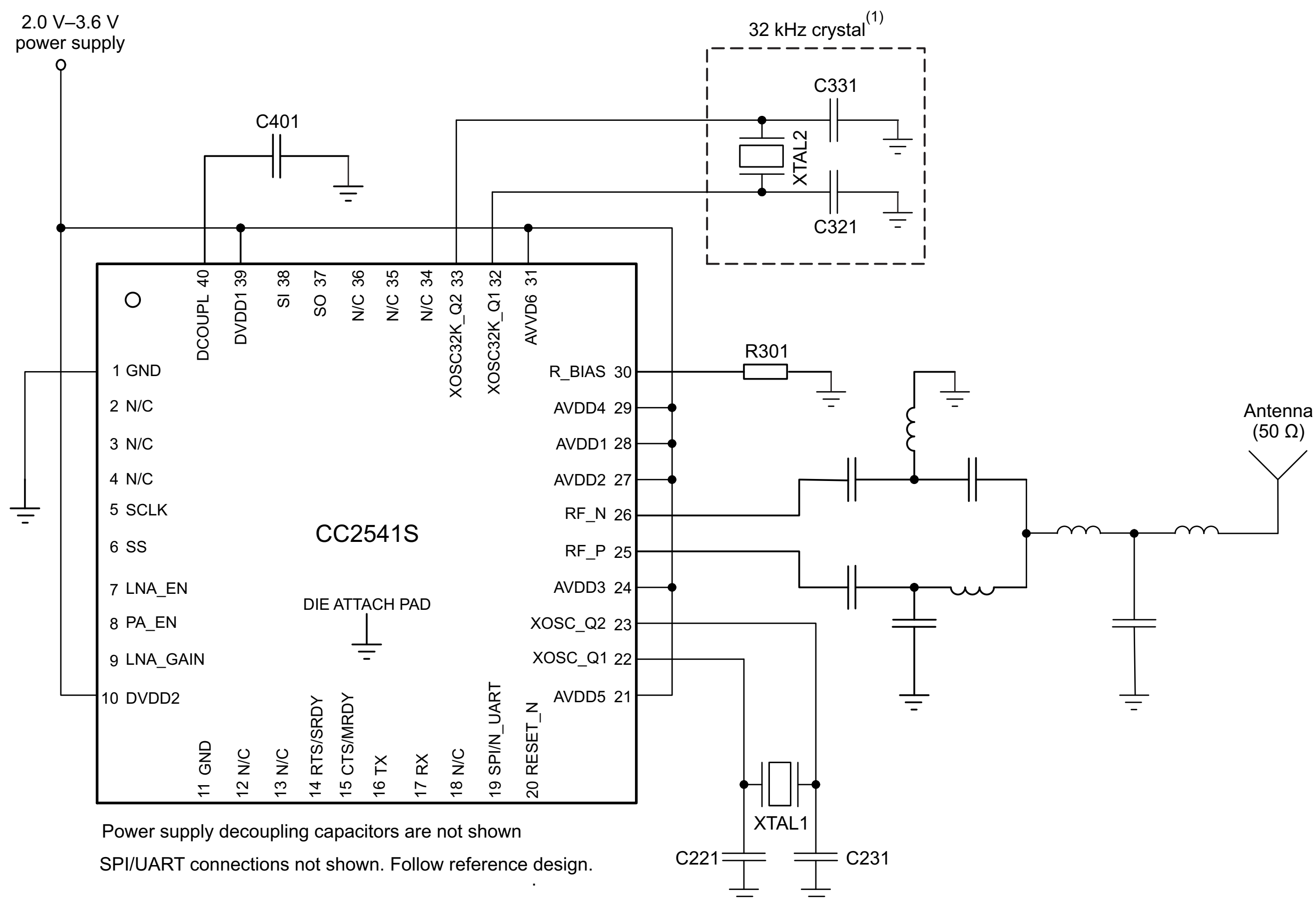
Figure 17. Current Savings in RX at Room Temperature

PRODUCT PREVIEW

The application note (SWRA365) has information regarding the CC2541S and TPS62730 combo board and the current savings that can be achieved using the combo board.

APPLICATION INFORMATION

Few external components are required for the operation of the CC2541S. A typical application circuit is shown in Figure 18.



(1) 32-kHz crystal is mandatory when running the BLE protocol stack in low-power modes, except if the link layer is in the standby state (Vol. 6 Part B Section 1.1 in [1]).

NOTE: Different antenna alternatives will be provided as reference designs.

Figure 18. CC2541S Application Circuit

Table 3. Overview of External Components (Excluding Supply Decoupling Capacitors)

Component	Description	Value
C401	Decoupling capacitor for the internal 1.8-V digital voltage regulator	1 µF
R301	Precision resistor ±1%, 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. See reference design, CC2541SEM, for recommended balun.

Crystal

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

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

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:

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

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. *Bluetooth*® Core Technical Specification document, version 4.0
   http://www.bluetooth.com/SiteCollectionDocuments/Core_V40.zip
2. Current Savings in CC254x Using the TPS62730 (SWRA365).

Additional Information

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PRODUCT PREVIEW

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)	Samples
CC2541SRHAR	PREVIEW	VQFN	RHA	40		Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-3-260C-168 HR		CC2541S	
CC2541SRHAT	PREVIEW	VQFN	RHA	40		Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-3-260C-168 HR		CC2541S	

(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) 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 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.

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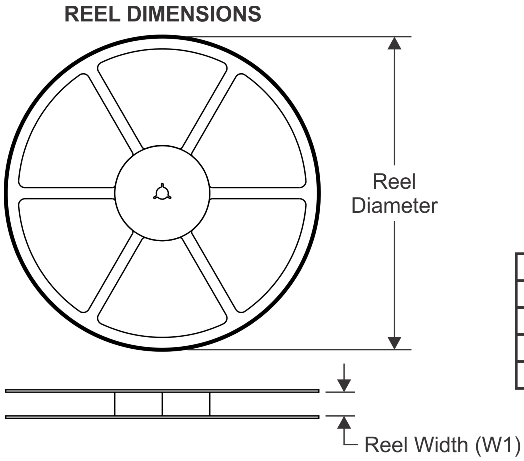
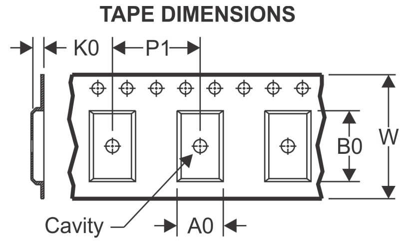
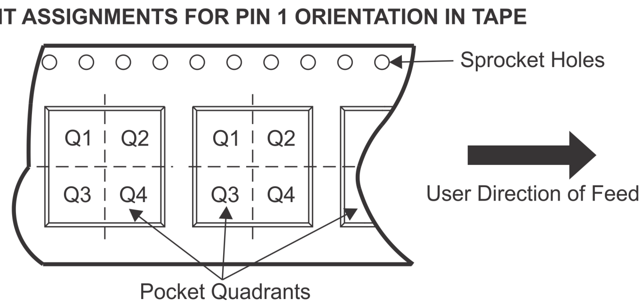
TAPE AND REEL INFORMATION





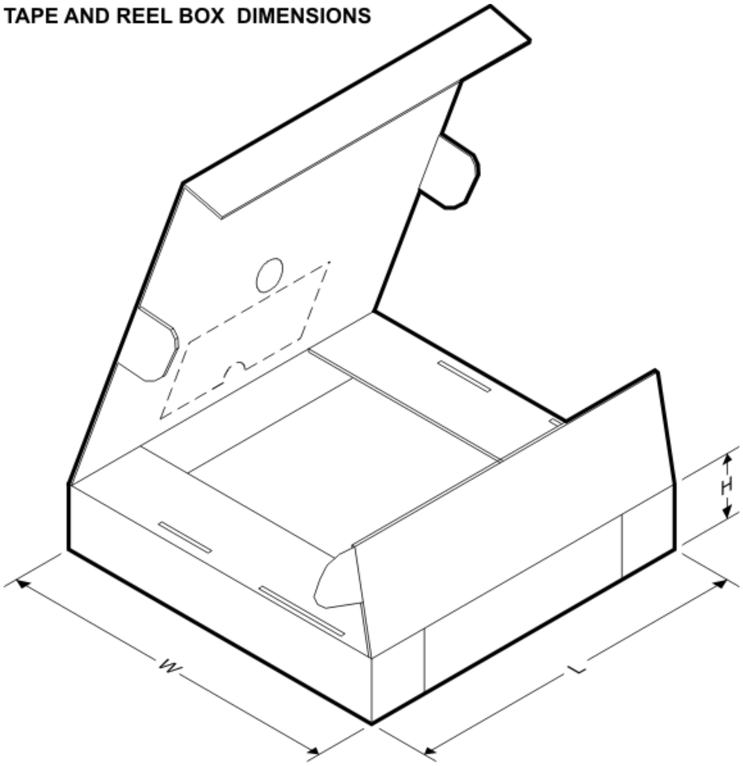
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers



*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
CC2541SRHAR	VQFN	RHA	40	0	330.0	16.4	6.3	6.3	1.5	12.0	16.0	Q2
CC2541SRHAT	VQFN	RHA	40	0	330.0	16.4	6.3	6.3	1.5	12.0	16.0	Q2

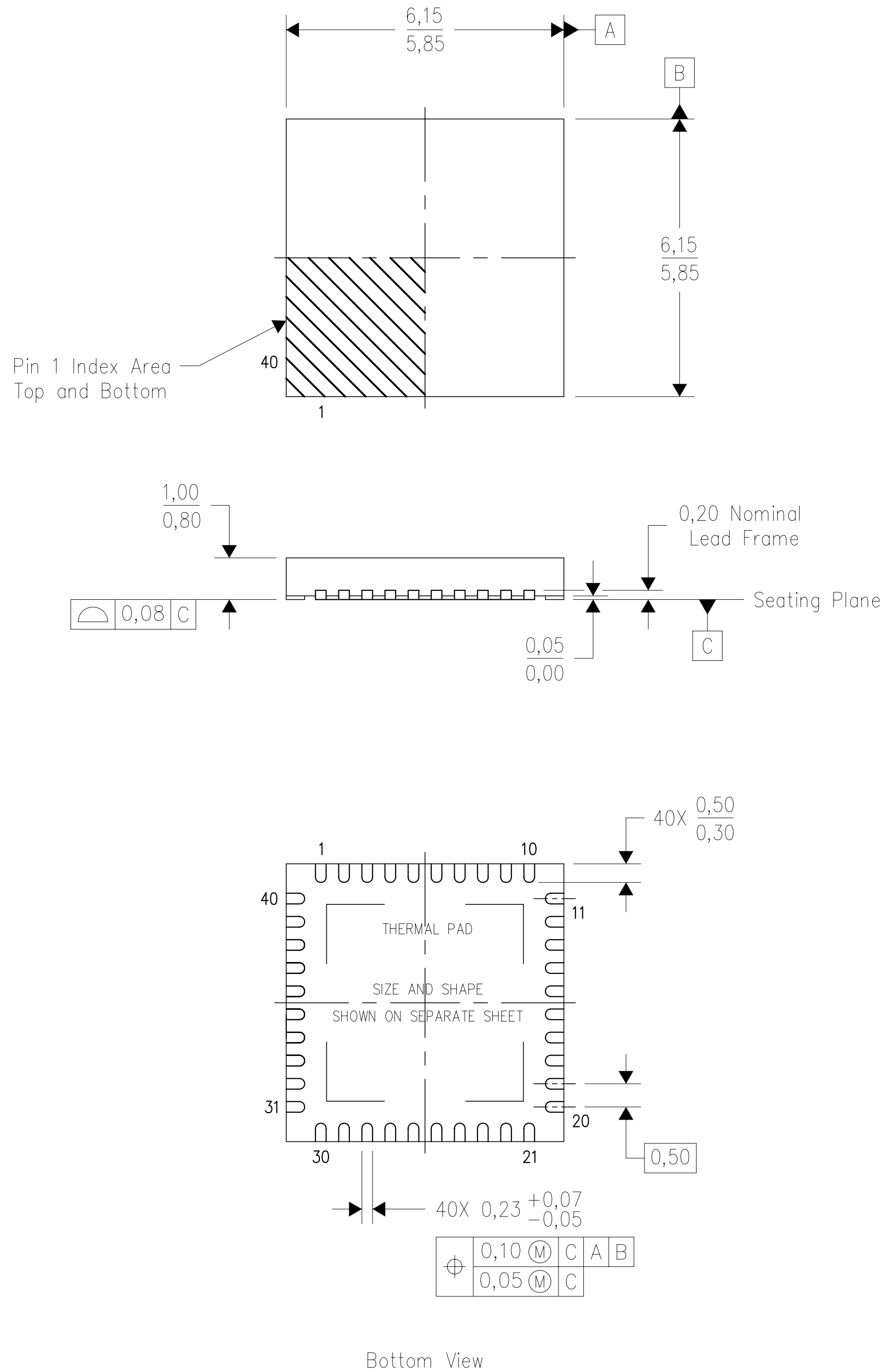
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CC2541SRHAR	VQFN	RHA	40	0	336.6	336.6	28.6
CC2541SRHAT	VQFN	RHA	40	0	336.6	336.6	28.6

RHA (S-PVQFN-N40) PLASTIC QUAD FLATPACK NO-LEAD



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NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M−1994.
- B. This drawing is subject to change without notice.
- C. QFN (Quad Flatpack No−Lead) Package configuration.
- D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
- E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
- F. Package complies to JEDEC MO−220 variation VJJD−2.