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# WL18x7MOD WiLink™ 8 Dual-Band Industrial Module – Wi-Fi®, Bluetooth®, and Bluetooth Low Energy (BLE)

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## 1 Device Overview

### 1.1 Features

- **General**

- Integrates RF, Power Amplifiers (PAs), Clock, RF Switches, Filters, Passives, and Power Management
- Quick Hardware Design With TI Module Collateral and Reference Designs
- Operating Temperature: –40°C to 85°C Industrial Temperature Grade
- Small Form Factor: 13.3 × 13.4 × 2 mm
- 100-Pin MOC Package
- FCC, IC, ETSI/CE, and TELEC Certified With Chip Antennas

- **Wi-Fi**

- WLAN Baseband Processor and RF Transceiver Support of IEEE Std 802.11a, 802.11b, 802.11g, and 802.11n
- 20- and 40-MHz SISO and 20-MHz 2 × 2 MIMO at 2.4 GHz for High Throughput: 80 Mbps (TCP), 100 Mbps (UDP)
- 2.4-GHz MRC Support for Extended Range and 5-GHz Diversity Capable
- Fully Calibrated: Production Calibration Not Required
- 4-Bit SDIO Host Interface Support
- Wi-Fi Direct Concurrent Operation (Multichannel, Multirole)

- **Bluetooth and BLE (WL1837MOD Only)**

- *Bluetooth* 4.1 Compliance and CSA2 Support
- Host Controller Interface (HCI) Transport for *Bluetooth* Over UART
- Dedicated Audio Processor Support of SBC Encoding + A2DP
- Dual-Mode *Bluetooth* and BLE
- TI's *Bluetooth* and LE Certified Stack

- **Key Benefits**

- Reduces Design Overhead
- Differentiated Use-Cases by Configuring WiLink 8 Simultaneously in Two Roles (STA and AP) to Connect Directly With Other Wi-Fi Devices on Different RF Channel (Wi-Fi Networks)
- Best-in-Class Wi-Fi With High-Performance Audio and Video Streaming Reference Applications With Up to 1.4X the Range Versus a Single Antenna
- Different Provisioning Methods for In-Home Devices Connectivity to Wi-Fi in One Step
- Lowest Wi-Fi Power Consumption in Connected Idle (< 800 μA)
- Configurable Wake on WLAN Filters to Only Wake Up the System
- Wi-Fi-*Bluetooth* Single Antenna Coexistence

### 1.2 Applications

- Internet of Things
- Multimedia
- Home Electronics
- Home Appliances and White Goods
- Industrial and Home Automation
- Smart Gateway and Metering
- Video Conferencing
- Video Camera and Security



### 1.3 Description

The certified WiLink 8 module from TI offers high throughput and extended range along with Wi-Fi and *Bluetooth* coexistence (WL1837MOD only) in a power-optimized design. The WL18x7MOD is a Wi-Fi, dual-band, 2.4- and 5-GHz module solution with two antennas supporting Industrial temperature grade. The device is FCC, IC, ETSI/CE, and TELEC certified for AP (with DFS support) and client. TI offers drivers for high-level operating systems, such as Linux®, Android™, WinCE, and RTOS.

#### Device Information

ORDER NUMBER	PACKAGE	BODY SIZE
WL1807MOD	MOC (100)	13.3 mm x 13.4 mm x 2 mm
WL1837MOD	MOC (100)	13.3 mm x 13.4 mm x 2 mm

### 1.4 Functional Block Diagram

Figure 1-1 shows a functional block diagram of the WL1837MOD variant.

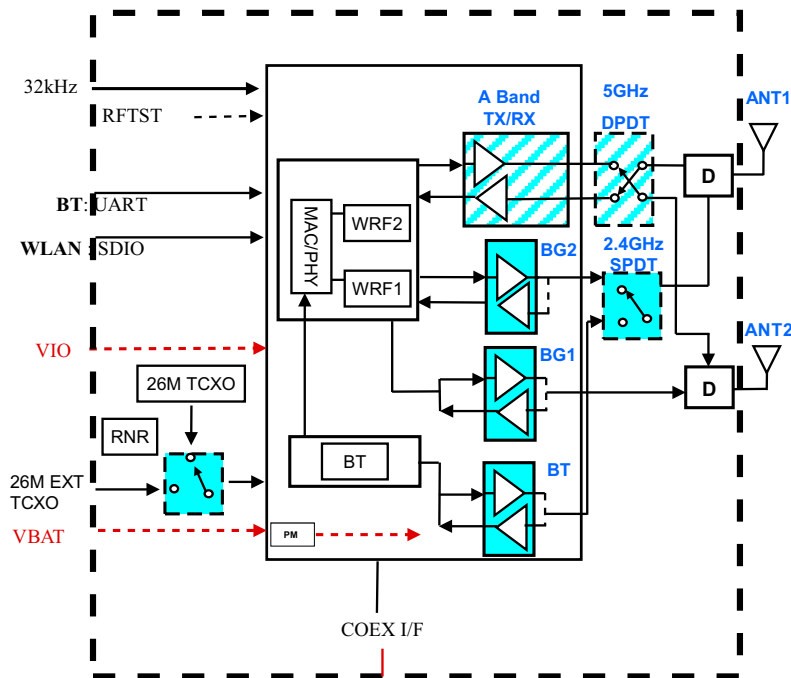


Figure 1-1. WL1837MOD Functional Block Diagram

## Table of Contents

<b>1 Device Overview</b> .....	<b><a href="#">1</a></b>	5.12 Timing and Switching Characteristics .....	<a href="#">21</a>
1.1 Features .....	<a href="#">1</a>	<b>6 Detailed Description</b> .....	<b><a href="#">29</a></b>
1.2 Applications .....	<a href="#">1</a>	6.1 WLAN .....	<a href="#">30</a>
1.3 Description .....	<a href="#">2</a>	6.2 <i>Bluetooth</i> .....	<a href="#">30</a>
1.4 Functional Block Diagram .....	<a href="#">2</a>	6.3 BLE .....	<a href="#">31</a>
<b>2 Revision History</b> .....	<b><a href="#">3</a></b>	6.4 WiLink 8 Module Markings .....	<a href="#">31</a>
<b>3 Device Comparison</b> .....	<b><a href="#">4</a></b>	6.5 Test Grades .....	<a href="#">32</a>
<b>4 Terminal Configuration and Functions</b> .....	<b><a href="#">5</a></b>	<b>7 Applications and Implementation</b> .....	<b><a href="#">33</a></b>
4.1 Pin Description .....	<a href="#">7</a>	7.1 Application Information .....	<a href="#">33</a>
<b>5 Specifications</b> .....	<b><a href="#">10</a></b>	<b>8 Device and Documentation Support</b> .....	<b><a href="#">39</a></b>
5.1 Absolute Maximum Ratings .....	<a href="#">10</a>	8.1 Device Support .....	<a href="#">39</a>
5.2 Handling Ratings .....	<a href="#">10</a>	8.2 Related Links .....	<a href="#">39</a>
5.3 Power-On Hours (POH) .....	<a href="#">11</a>	8.3 Community Resources .....	<a href="#">39</a>
5.4 Recommended Operating Conditions .....	<a href="#">11</a>	8.4 Trademarks .....	<a href="#">39</a>
5.5 External Digital Slow Clock Requirements .....	<a href="#">11</a>	8.5 Electrostatic Discharge Caution .....	<a href="#">40</a>
5.6 Thermal Characteristics .....	<a href="#">12</a>	8.6 Glossary .....	<a href="#">40</a>
5.7 WLAN Performance .....	<a href="#">13</a>	<b>9 Mechanical Packaging and Orderable Information</b> .....	<b><a href="#">41</a></b>
5.8 <i>Bluetooth</i> Performance .....	<a href="#">17</a>	9.1 TI Module Mechanical Outline .....	<a href="#">41</a>
5.9 <i>Bluetooth</i> LE Performance .....	<a href="#">19</a>	9.2 Tape and Reel Information .....	<a href="#">42</a>
5.10 <i>Bluetooth</i> -BR/EDR Dynamic Currents .....	<a href="#">20</a>	9.3 Packaging Information .....	<a href="#">44</a>
5.11 <i>Bluetooth</i> LE Currents .....	<a href="#">21</a>		

## 2 Revision History

Changes from Revision C (November 2014) to Revision D	Page
• Changed document status from product preview to production data .....	<a href="#">1</a>
• Added correct corner pin marking where appropriate throughout document .....	<a href="#">1</a>
• Added "Compliance" to Bluetooth 4.1 and CSA2 Support in <a href="#">Section 1.1, Features</a> .....	<a href="#">1</a>
• Changed "Bluetopia + LE Certified Stack Provided by TI" <a href="#">Section 1.1, Features</a> .....	<a href="#">1</a>
• Added definitions of SISO and MIMO in <a href="#">Table 3-1</a> .....	<a href="#">4</a>
• Changed names of pins 18 and 32 and description of pin 64 .....	<a href="#">7</a>
• Changed WL_SDIO_CMD_1V8 (pin 6) description from WLAN SDIO command in .....	<a href="#">8</a>
• Added specification measurement statement, reference to Level Shifting WL18xx I/Os Application Report, and FCC authorization statement in <a href="#">Section 5, Specifications</a> .....	<a href="#">10</a>
• Added TYP values for VBAT, VIO. ....	<a href="#">11</a>
• Changed <a href="#">Section 5.6, Thermal Characteristics</a> .....	<a href="#">12</a>
• Changed values in <a href="#">Section 5.7.1, WLAN 2.4-GHz Receiver Characteristics</a> through <a href="#">Section 5.7.4, WLAN 5-GHz Transmitter Power</a> .....	<a href="#">13</a>
• Changed BR RF output power from 12.7 dBm typical .....	<a href="#">18</a>
• Changed <i>Bluetooth</i> LE RF transmitter output power from 10.0 dBm typical (VBAT ≥ 3V) and 7.2 dBm (VBAT ≤ 3V) in <a href="#">Section 5.9.2, Bluetooth LE Transmitter Characteristics</a> .....	<a href="#">20</a>
• Changed BR power from 12.7 dBm in <a href="#">Section 5.10, Bluetooth-BLE Dynamic Currents</a> .....	<a href="#">20</a>
• Changed output power at which current is measured from 7.2 dBm in <a href="#">Section 5.11, Bluetooth LE Currents</a> .....	<a href="#">21</a>
• Changed values in <a href="#">Table 6-1</a> .....	<a href="#">29</a>
• Changed test grade marking in <a href="#">Section 7.1.6.2, WiLink 8 Module Markings</a> .....	<a href="#">31</a>
• Added single modular TELEC grant ID .....	<a href="#">31</a>
• Changed schematic in <a href="#">Figure 7-1</a> .....	<a href="#">33</a>
• Added <a href="#">Section 9.2, Tape and Reel Information</a> .....	<a href="#">42</a>

### 3 Device Comparison

The TI WiLink 8 module offers two footprint-compatible dual-band 2.4- and 5-GHz industrial temperature grade variants providing stand-alone Wi-Fi and *Bluetooth* combo connectivity. [Table 3-1](#) compares the features of the module variants.

**Table 3-1. TI WiLink 8 Module Variants**

DEVICE	WLAN 2.4-GHZ SISO <sup>(1)</sup>	WLAN 2.4-GHZ MIMO <sup>(1)</sup>	WLAN 2.4-GHZ MRC <sup>(2)</sup>	BLUETOOTH	WLAN 5-GHZ SISO <sup>(1)</sup>
WL1837MOD	√	√	√	√	√
WL1807MOD	√	√	√		√

(1) SISO: single input, single output; MIMO: multiple input, multiple output.

(2) MRC: maximum ratio combining; supported at 2.4-GHz only.

## 4 Terminal Configuration and Functions

Figure 4-1 shows the pin assignments for the 100-pin MOC package.

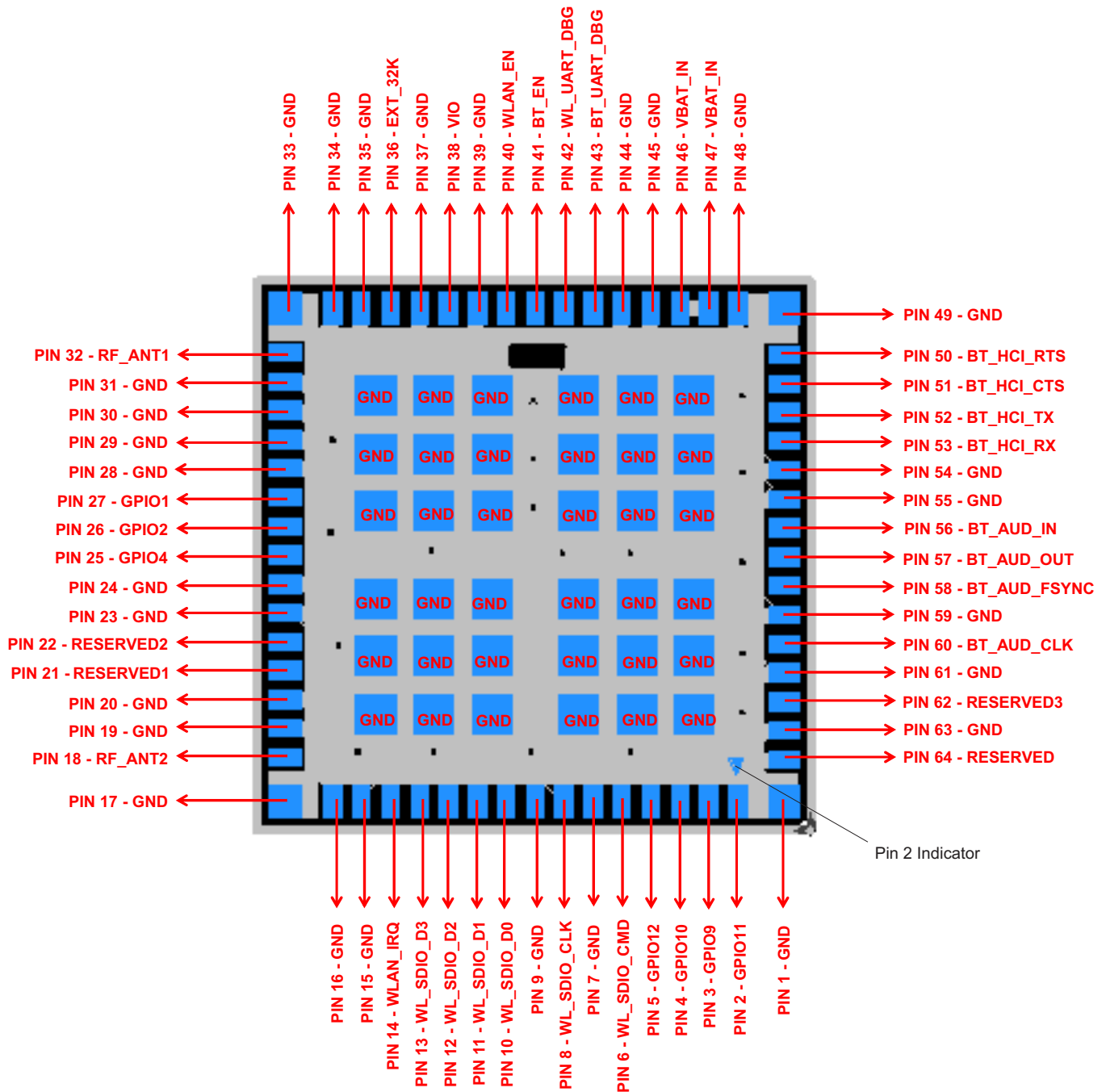
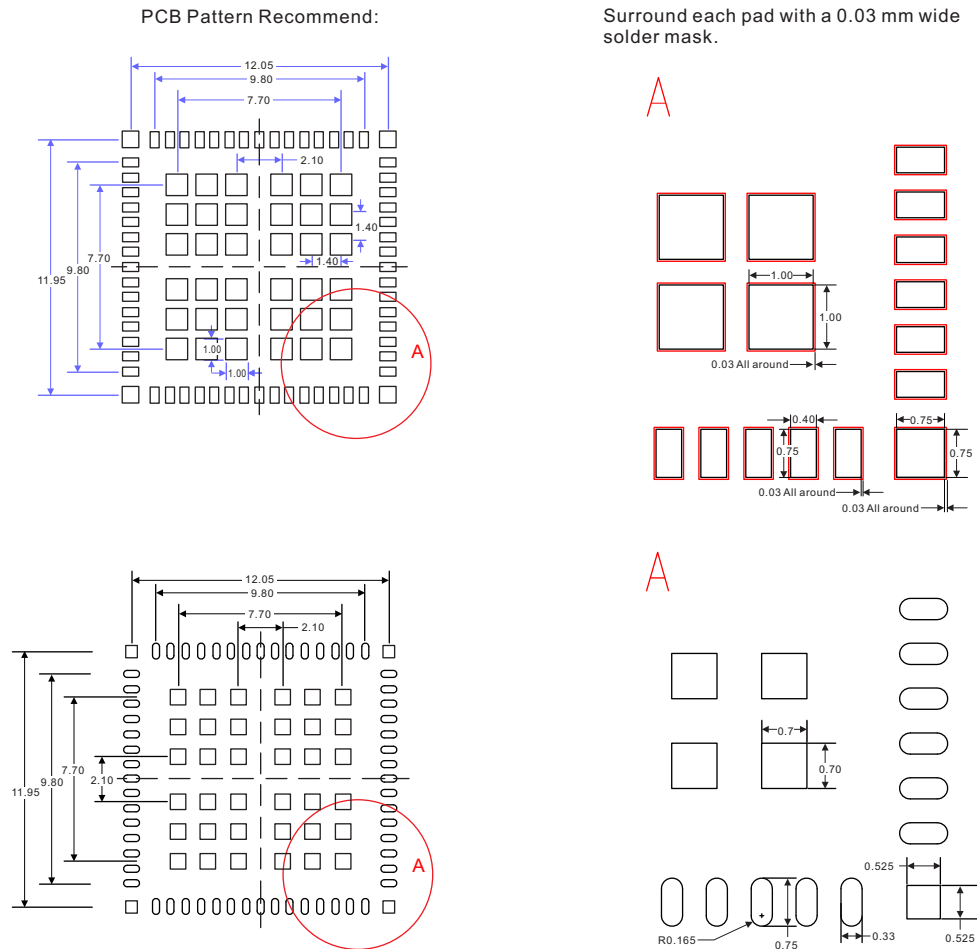


Figure 4-1. 100-Pin MOC Package (Bottom View)

Figure 4-2 shows the recommended PCB pattern and the outline of the 100-pin MOC package.



- NOTE: 1. Module size: 13.4 x 13.3 mm  
 2. Signal pad size: 0.75 x 0.40 mm  
 3. 4 x corner ground size: 0.75 x 0.75 mm  
 4. Central ground pin size: 1.00 x 1.00 mm Pitch: 0.7 mm  
 5. Pitch: 0.7 mm

**Figure 4-2. Recommended PCB Pattern and Outline of 100-Pin MOC Package**

## 4.1 Pin Description

Table 4-1 describes the module pins.

**Table 4-1. Pin Description**

PIN NAME	PIN	TYPE/ DIR	SHUTDOWN STATE(1)	AFTER POWER UP(1)	VOLTAGE LEVEL	CONNECTIVITY(2)		DESCRIPTION
						1807	1837	
<b>Clocks and Reset Signals</b>								
WL_SDIO_CLK_1V8	8	I	Hi-Z	Hi-Z	1.8 V	v	v	WLAN SDIO clock. Must be driven by the host.
EXT_32K	36	ANA			–	v	v	Input sleep clock: 32.768 kHz
WLAN_EN	40	I	PD	PD	1.8 V	v	v	Mode setting: high = enable
BT_EN	41	I	PD	PD	1.8 V	x	v	Mode setting: high = enable. If <i>Bluetooth</i> is not used, connect to ground.
<b>Power-Management Signals</b>								
VIO_IN	38	POW	PD	PD	1.8 V	v	v	Connect to 1.8-V external VIO
VBAT_IN	46	POW			VBAT	v	v	Power supply input, 2.9 to 4.8 V
VBAT_IN	47	POW			VBAT	v	v	Power supply input, 2.9 to 4.8 V
<b>TI Reserved</b>								
GPIO11	2	I/O	PD	PD	1.8 V	v	v	Reserved for future use. NC if not used.
GPIO9	3	I/O	PD	PD	1.8 V	v	v	Reserved for future use. NC if not used.
GPIO10	4	I/O	PU	PU	1.8 V	v	v	Reserved for future use. NC if not used.
GPIO12	5	I/O	PU	PU	1.8 V	v	v	Reserved for future use. NC if not used.
RESERVED1	21	I	PD	PD	1.8 V	x	x	Reserved for future use. NC if not used.
RESERVED2	22	I	PD	PD	1.8 V	x	x	Reserved for future use. NC if not used.
GPIO4	25	I/O	PD	PD	1.8 V	v	v	Reserved for future use. NC if not used.
RESERVED3	62	O	PD	PD	1.8 V	x	x	Reserved for future use. NC if not used. Option: External TCXO.
RESERVED	64	GND			–	v	v	Reserved for future use. Connect to ground if not used.

Table 4-1. Pin Description (continued)

PIN NAME	PIN	TYPE/ DIR	SHUTDOWN STATE(1)	AFTER POWER UP(1)	VOLTAGE LEVEL	CONNECTIVITY(2)		DESCRIPTION
						1807	1837	
<b>WLAN Functional Block: Int Signals</b>								
WL_SDIO_CMD_1V8	6	I/O	Hi-Z	Hi-Z	1.8 V	v	v	WLAN SDIO command(3)
WL_SDIO_D0_1V8	10	I/O	Hi-Z	Hi-Z	1.8 V	v	v	WLAN SDIO data bit 0(3)
WL_SDIO_D1_1V8	11	I/O	Hi-Z	Hi-Z	1.8 V	v	v	WLAN SDIO data bit 1(3)
WL_SDIO_D2_1V8	12	I/O	Hi-Z	Hi-Z	1.8 V	v	v	WLAN SDIO data bit 2(3)
WL_SDIO_D3_1V8	13	I/O	Hi-Z	PU	1.8 V	v	v	WLAN SDIO data bit 3. Changes state to PU at WL_EN or BT_EN assertion for card detects. Later disabled by software during initialization. (1)
WL_IRQ_1V8	14	O	PD	0	1.8 V	v	v	SDIO available, interrupt out. Active high. (For WL_RS232_TX/RX pullup is at power up.) Set to rising edge (active high) on power up. The Wi-Fi interrupt line can be configured by the driver according to the IRQ configuration (polarity/level/edge).
RF_ANT2	18	ANA			–	v	v	5G ANT diversity TX/RX , 2.4G Secondary antenna MRC/MIMO only
GPIO2	26	I/O	PD	PD	1.8 V	v	v	WL_RS232_RX (when WLAN_IRQ = 1 at power up)
GPIO1	27	I/O	PD	PD	1.8 V	v	v	WL_RS232_TX (when WLAN_IRQ = 1 at power up)
RF_ANT1	32	ANA			–	v	v	5G main ANT TX/RX, 2.4G WLAN main antenna SISO, <i>Bluetooth</i>
WL_UART_DBG	42	O	PU	PU	1.8 V	v	v	Option: WLAN logger

**Table 4-1. Pin Description (continued)**

PIN NAME	PIN	TYPE/ DIR	SHUTDOWN STATE(1)	AFTER POWER UP(1)	VOLTAGE LEVEL	CONNECTIVITY(2)		DESCRIPTION
						1807	1837	
<b>Bluetooth Functional Block: Int Signals</b>								
BT_UART_DBG	43	O	PU	PU	1.8 V	x	v	Option: <i>Bluetooth</i> logger
BT_HCI_RTS_1V8	50	O	PU	PU	1.8 V	x	v	UART RTS to host. NC if not used.
BT_HCI_CTS_1V8	51	I	PU	PU	1.8 V	x	v	UART CTS from host. NC if not used.
BT_HCI_TX_1V8	52	O	PU	PU	1.8 V	x	v	UART TX to host. NC if not used.
BT_HCI_RX_1V8	53	I	PU	PU	1.8 V	x	v	UART RX from host. NC if not used.
BT_AUD_IN	56	I	PD	PD	1.8 V	x	v	<i>Bluetooth</i> PCM/I2S bus. Data in. NC if not used.
BT_AUD_OUT	57	O	PD	PD	1.8 V	x	v	<i>Bluetooth</i> PCM/I2S bus. Data out. NC if not used.
BT_AUD_FSYNC	58	I/O	PD	PD	1.8 V	x	v	<i>Bluetooth</i> PCM/I2S bus. Frame sync. NC if not used.
BT_AUD_CLK	60	I/O	PD	PD	1.8 V	x	v	<i>Bluetooth</i> PCM/I2S bus. NC if not used.
<b>Ground Pins</b>								
GND	1, 7, 9, 15, 16, 17, 19, 20, 23, 24, 28, 29, 30, 31, 33, 34, 35, 37, 39, 44, 45, 48, 49, 54, 55, 59, 61, 63, G1-G36	GND			–	v	v	

(1) PU = pullup; PD = pulldown.

(2) v = connect; x = no connect.

(3) Host must provide PU using a 10-K resistor for all non-CLK SDIO signals.

## 5 Specifications

All specifications are measured at the module pins using the TI WL1837MODCOM8I evaluation board. All measurements are performed with VBAT = 3.7 V, VIO = 1.8 V, 25°C for typical values with matched RF antennas, unless otherwise indicated.

### NOTE

For level shifting I/Os with the TI WL18x7MOD, see *Level Shifting WL18xx I/Os Application Report* ([SWRA448](#)).

### NOTE

This device as presently configured has been granted US Federal Communications Commission (FCC) equipment authorization (reference number Z64-WL18DBMOD). Please note that any modifications to the device software or configuration, including but not limited to the init file(s), can cause device performance to vary beyond the scope of the currently referenced FCC authorization. Accordingly, if any user modifications are sought to be made to the device software or configuration, the user may be required to independently seek fresh FCC and other regulatory authorizations as relevant prior to distributing or marketing the devices or products incorporating the same.

### 5.1 Absolute Maximum Ratings<sup>(1)</sup>

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

PARAMETER	VALUE	UNIT
VBAT	4.8 <sup>(2)</sup>	V
VIO	–0.5 to 2.1	V
Input voltage to analog pins	–0.5 to 2.1	V
Input voltage limits (CLK_IN)	–0.5 to VDD_IO	V
Input voltage to all other pins	–0.5 to (VDD_IO + 0.5 V)	V
Operating ambient temperature range	–40 to 85 <sup>(3)</sup>	°C

- 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 “operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- 4.8 V cumulative to 2.33 years, including charging dips and peaks
- Operating free-air temperature range at which the device can operate reliably for 15K cumulative active TX power-on hours (assuming a maximum junction temperature of (T<sub>j</sub>) of 125°C). [Section 5.3, Power-On Hours \(POH\)](#), describes the correlation between T<sub>j</sub> and PoH. In the WL18xx system, a control mechanism automatically ensures T<sub>j</sub> < 125°C. Whenever T<sub>j</sub> approaches the threshold, this mechanism controls the transmitter patterns.

### 5.2 Handling Ratings

		MIN	MAX	UNIT
T <sub>stg</sub>	Storage temperature range	–40	+85	°C
ESD stress voltage <sup>(1)</sup>	Human body model (HBM) <sup>(2)</sup>	–1000	+1000	V
	Charged device model (CDM) <sup>(3)</sup>	–250	+250	

- ESD measures device sensitivity and immunity to damage caused by electrostatic discharges into the device.
- The level listed is the passing level per ANSI/ESDA/JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process, and manufacturing with less than 500-V HBM is possible, if necessary precautions are taken. Pins listed as 1000 V can actually have higher performance.
- The level listed is the passing level per EIA-JEDEC JESD22-C101E. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process, and manufacturing with less than 250-V CDM is possible, if necessary precautions are taken. Pins listed as 250 V can actually have higher performance.

### 5.3 Power-On Hours (POH)

OPERATING JUNCTION TEMPERATURE (°C)	POH
125	15,000
120	20,000
115	27,000
110	37,000
105	50,000

### 5.4 Recommended Operating Conditions

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

			MIN	TYP	MAX	UNIT
V <sub>BAT</sub> <sup>(1)</sup>	DC supply range for all modes		2.9	3.7	4.8	V
V <sub>IO</sub>	1.8-V I/O ring power supply voltage		1.62	1.8	1.95	V
V <sub>IH</sub>	I/O high-level input voltage		0.65 x V <sub>DD_IO</sub>	V <sub>DD_IO</sub>		V
V <sub>IL</sub>	I/O low-level input voltage		0	0.35 x V <sub>DD_IO</sub>		V
V <sub>IH_EN</sub>	Enable inputs high-level input voltage		1.365	V <sub>DD_IO</sub>		V
V <sub>IL_EN</sub>	Enable inputs low-level input voltage		0	0.4		V
V <sub>OH</sub>	High-level output voltage	@ 4 mA	V <sub>DD_IO</sub> -0.45	V <sub>DD_IO</sub>		V
V <sub>OL</sub>	Low-level output voltage	@ 4 mA	0	0.45		V
T <sub>r</sub> , T <sub>f</sub>	Input transitions time T <sub>r</sub> , T <sub>f</sub> from 10% to 90% (digital I/O) <sup>(2)</sup>		1		10	ns
T <sub>r</sub>	Output rise time from 10% to 90% (digital pins) <sup>(2)</sup>	C <sub>L</sub> < 25 pF			5.3	ns
T <sub>f</sub>	Output fall time from 10% to 90% (digital pins) <sup>(2)</sup>	C <sub>L</sub> < 25 pF			4.9	ns
	Ambient operating temperature		-40		85	°C
Maximum power dissipation	WLAN operation				2.8	W
	Bluetooth operation				0.2	

(1) 4.8 V is applicable only for 2.33 years (30% of the time). Otherwise, maximum V<sub>BAT</sub> must not exceed 4.3 V.

(2) Applies to all digital lines except SDIO, UART, I2C, PCM and slow clock lines

### 5.5 External Digital Slow Clock Requirements

The supported digital slow clock is 32.768 kHz digital (square wave). All core functions share a single input.

PARAMETER	CONDITION	SYMBOL	MIN	TYP	MAX	UNIT
Input slow clock frequency				32768		Hz
Input slow clock accuracy (Initial + temp + aging)	WLAN, Bluetooth				±250	ppm
Input transition time T <sub>r</sub> , T <sub>f</sub> (10% to 90%)		T <sub>r</sub> , T <sub>f</sub>			200	ns
Frequency input duty cycle			15	50	85	%
Input voltage limits	Square wave, DC-coupled	V <sub>IH</sub>	0.65 x V <sub>DD_IO</sub>		V <sub>DD_IO</sub>	V <sub>peak</sub>
		V <sub>IL</sub>	0		0.35 x V <sub>DD_IO</sub>	
Input impedance			1			MΩ
Input capacitance					5	pF

## 5.6 Thermal Characteristics

AIR FLOW		
NAME	DESCRIPTION	MOC(100) (°C/W) <sup>(1)</sup>
$\theta_{JA}$	Junction to free air <sup>(2)</sup>	16.6
$\phi_{JB}$	Junction to board	6.06
$\phi_{JC}$	Junction to case <sup>(3)</sup>	5.13

- (1) °C/W = degrees Celsius per watt
- (2) According to the JEDEC EIA/JESD 51 document
- (3) Modeled using the JEDEC 2s2p thermal test board with 36 thermal vias

## 5.7 WLAN Performance

All RF and performance numbers are aligned to the module pin.

### 5.7.1 WLAN 2.4-GHz Receiver Characteristics

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

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Operation frequency range		2412		2484	MHz
Sensitivity: 20-MHz bandwidth. At < 10% PER limit	1 Mbps DSSS		-95.0		dBm
	2 Mbps DSSS		-92.0		
	5.5 Mbps CCK		-89.2		
	11 Mbps CCK		-86.3		
	6 Mbps OFDM		-91.0		
	9 Mbps OFDM		-89.0		
	12 Mbps OFDM		-88.0		
	18 Mbps OFDM		-85.5		
	24 Mbps OFDM		-82.5		
	36 Mbps OFDM		-79.0		
	48 Mbps OFDM		-74.0		
	54 Mbps OFDM		-72.5		
	MCS0 MM 4K		-89.3		
	MCS1 MM 4K		-86.5		
	MCS2 MM 4K		-84.5		
	MCS3 MM 4K		-81.5		
	MCS4 MM 4K		-78.0		
	MCS5 MM 4K		-73.5		
	MCS6 MM 4K		-71.5		
	MCS7 MM 4K		-70.0		
MCS0 MM 4K 40 MHz		-86.0			
MCS7 MM 4K 40 MHz		-66.3			
MCS0 MM 4K MRC		-91.0			
MCS7 MM 4K MRC		-73.0			
MCS13 MM 4K		-70.0			
MCS14 MM 4K		-69.0			
MCS15 MM 4K		-68.3			
Maximum input level	OFDM	-20.0	-10.0		dBm
	CCK	-10.0	-6.0		dBm
	DSSS	-4.0	-1.0		dBm
Adjacent channel rejection: Sensitivity level +3 dB for OFDM; Sensitivity level +6 dB for 11b	2 Mbps DSSS	42.0			dB
	11 Mbps CCK	38.0			dB
	54 Mbps OFDM	2.0			dB
RX leakage			-70		dBm
PER floor			1.0		%
RSSI accuracy				±3	dB

### 5.7.2 WLAN 2.4-GHz Transmitter Power

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

PARAMETER	CONDITION <sup>(1)</sup>	MIN	TYP	MAX	UNIT
<b>RF_IO2_BG_WL pin 2.4-GHz SISO</b>					
RMS output power compliant with IEEE mask or EVM <sup>(2)</sup>	1 Mbps DSSS		16.0		dBm
	2 Mbps DSSS		16.0		
	5.5 Mbps CCK		16.0		
	11 Mbps CCK		16.0		
	6 Mbps OFDM		16.5		
	9 Mbps OFDM		16.5		
	12 Mbps OFDM		16.5		
	18 Mbps OFDM		16.5		
	24 Mbps OFDM		16.5		
	36 Mbps OFDM		15.2		
	48 Mbps OFDM		14.3		
	54 Mbps OFDM		13.5		
	MCS0 MM		16.0		
	MCS1 MM		16.0		
	MCS2 MM		16.0		
	MCS3 MM		16.0		
	MCS4 MM		15.2		
	MCS5 MM		14.3		
	MCS6 MM		13.5		
	MCS7 MM		12.6		
MCS0 MM 40 MHz		14.0			
MCS7 MM 40 MHz		11.8			
<b>RF_ANT1 + RF ANT2</b>					
RMS output power compliant with IEEE mask or EVM <sup>(2)</sup>	MCS12		16.5		dBm
	MCS13		16.5		
	MCS14		14.0		
	MCS15		13.0		
Operation frequency range		2412		2484	MHz
Return loss			-10.0		dB
Reference input impedance			50.0		Ω

(1) Maximum transmitter power (TP) degradation of up to 30% is expected, starting from 80°C ambient temperature on MIMO operation

(2) Regulatory constraints limit TI module output power to the following:

- Channel 14 is used only in Japan; to keep the channel spectral shaping requirement, the power is limited:14.5 dBm.
- Channels 1, 11 @ OFDM legacy and HT 20-MHz rates: 12 dBm
- Channels 1, 11 @ HT 40-MHz rates: 10 dBm
- Channel 7 @ HT 40-MHz lower rates: 10 dBm
- Channel 5 @ HT 40-MHz upper rates: 10 dBm
- All 11B rates are limited to 16 dBm to comply with the ETSI PSD 10 dBm/MHz limit.
- All OFDM rates are limited to 16.5 dBm to comply with the ETSI EIRP 20 dBm limit.
- For further clarification regarding power limitation, see the [INI Guide](#).

### 5.7.3 WLAN 5-GHz Receiver Characteristics

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

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Operation frequency range		4910.0		5825.0	MHz
Sensitivity: 20-MHz bandwidth. At < 10% PER limit	6 Mbps OFDM 1K		-92.5		dBm
	9 Mbps OFDM 1K		-90.5		
	12 Mbps OFDM 1K		-90.0		
	18 Mbps OFDM 1K		-87.5		
	24 Mbps OFDM 1K		-84.5		
	36 Mbps OFDM 1K		-81.0		
	48 Mbps OFDM 1K		-76.5		
	54 Mbps OFDM 1K		-74.6		
	MCS0 MM 4K		-91.4		
	MCS1 MM 4K		-88.0		
	MCS2 MM 4K		-86.0		
	MCS3 MM 4K		-83.0		
	MCS4 MM 4K		-79.8		
	MCS5 MM 4K		-75.5		
	MCS6 MM 4K		-74.0		
	MCS7 MM 4K		-72.4		
MCS0 MM 4K 40 MHz		-88.5			
MCS7 MM 4K 40 MHz		-69.3			
Maximum input level	OFDM	-30.0	-15.0		dBm
Adjacent channel rejection sensitivity +3 dB	OFDM54	2.0			dBm
RX LO leakage			-52.0		dBm
PER floor			1.0	2.0	%
RSSI accuracy			±3		dB

### 5.7.4 WLAN 5-GHz Transmitter Power

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

PARAMETER	CONDITION <sup>(1)</sup>	MIN	TYP	MAX	UNIT
<b>RF_ANT1 or RF_ANT2</b>					
Operation frequency range		4920		5825	MHz
RMS output power complies with IEEE mask and EVM requirements <sup>(2)</sup>	6 Mbps OFDM		18.0		
	9 Mbps OFDM		18.0		
	12 Mbps OFDM		18.0		
	18 Mbps OFDM		18.0		
	24 Mbps OFDM		17.4		
	36 Mbps OFDM		16.5		
	48 Mbps OFDM		15.8		
	54 Mbps OFDM		14.5		
	MCS0 MM		18.0		
	MCS1 MM 4K		18.0		
	MCS2 MM 4K		18.0		
	MCS3 MM 4K		18.0		
	MCS4 MM 4K		16.5		
	MCS5 MM 4K		15.8		
	MCS6 MM 4K		14.5		
	MCS7 MM 4K		13.0		
	MCS0 MM 40 MHz		16.5		
	MCS7 MM 40 MHz		12.0		
Output power resolution			0.125		dB
Return loss			-10.0		dB
Reference input impedance			50.0		Ω

(1) Maximum TP degradation of up to 30% is expected, starting from 80°C ambient temperature on 5-GHz TX operation.

(2) For further clarification regarding power limitation, see the [INI Guide](#).

### 5.7.5 WLAN Currents

	SPECIFICATION ITEMS	TYP (AVG) – 25°C	UNITS
Receiver	Low-power mode (LPM) 2.4-GHz RX SISO20 single chain	49	mA
	2.4 GHz RX search SISO20	58	mA
	2.4-GHz RX search MIMO20	74	mA
	2.4-GHz RX search SISO40	63	mA
	2.4-GHz RX 20 M SISO 11 CCK	60	mA
	2.4-GHz RX 20 M SISO 6 OFDM	61	mA
	2.4-GHz RX 20 M SISO MCS7	69	mA
	2.4-GHz RX 20 M MRC 1 DSSS	74	mA
	2.4-GHz RX 20 M MRC 6 OFDM	81	mA
	2.4-GHz RX 20 M MRC 54 OFDM	85	mA
	2.4-GHz RX 40 MHz MCS7	81	mA
	5-GHz RX 20 MHz OFDM6	68	mA
	5-GHz RX 20 MHz MCS7	77	mA
	5-GHz RX 40 MHz MCS7	85	mA

	SPECIFICATION ITEMS	TYP (AVG) – 25°C	UNITS
Transmitter <sup>(1)</sup>	2.4-GHz TX 20 M SISO 6 OFDM	285	mA
	2.4-GHz TX 20 M SISO 11 CCK	283	mA
	2.4-GHz TX 20 M SISO 54 OFDM	247	mA
	2.4-GHz TX 20 M SISO MCS7	238	mA
	2.4-GHz TX 20 M MIMO MCS15	510	mA
	2.4-GHz TX 40 M SISO MCS7	243	mA
	5-GHz TX 20 M SISO 6 OFDM	366	mA
	5-GHz TX 20 M SISO 54 OFDM	329	mA
	5-GHz TX 20 M SISO MCS7	324	mA
	5-GHz TX 40 M SISO MCS7	332	mA

(1) Numbers reflect the typical current consumption at maximum output power per rate.

## 5.8 Bluetooth Performance

All RF and performance numbers are aligned to the module pin.

### 5.8.1 Bluetooth BR, EDR Receiver Characteristics—In-Band Signals

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

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Bluetooth BR, EDR operation frequency range		2402		2480	MHz
Bluetooth BR, EDR channel spacing			1		MHz
Bluetooth BR, EDR input impedance			50		Ω
Bluetooth BR, EDR sensitivity <sup>(1)</sup> dirty TX on	BR, BER = 0.1%		–92.2		dBm
	EDR2, BER = 0.01%		–91.7		dBm
	EDR3, BER = 0.01%		–84.7		dBm
Bluetooth EDR BER floor at sensitivity + 10 dB Dirty TX off (for 1,600,000 bits)	EDR2	1e-6			
	EDR3	1e-6			
Bluetooth BR, EDR maximum usable input power	BR, BER = 0.1%	–5.0			dBm
	EDR2, BER = 0.1%	–15.0			dBm
	EDR3, BER = 0.1%	–15.0			dBm
Bluetooth BR intermodulation	Level of interferers for n = 3, 4, and 5	–36.0	–30.0		dBm

(1) Sensitivity degradation up to –3 dB may occur due to fast clock harmonics with dirty TX on.

PARAMETER	CONDITION		MIN	TYP	MAX	UNIT
Bluetooth BR, EDR C/I performance Numbers show wanted signal-to-interfering-signal ratio. Smaller numbers indicate better C/I performances (Image frequency = -1 MHz)	BR, co-channel				10	dB
	EDR, co-channel	EDR2			12	dB
		EDR3			20	dB
	BR, adjacent ±1 MHz				-3.0	dB
	EDR, adjacent ±1 MHz, (image)	EDR2			-3.0	dB
		EDR3			2.0	dB
	BR, adjacent +2 MHz				-33.0	dB
	EDR, adjacent +2 MHz	EDR2			-33.0	dB
		EDR3			-28.0	dB
	BR, adjacent -2 MHz				-20.0	dB
	EDR, adjacent -2 MHz	EDR2			-20.0	dB
		EDR3			-13.0	dB
BR, adjacent ≥ ±3  MHz				-42.0	dB	
EDR, adjacent ≥ ±3  MHz	EDR2			-42.0	dB	
	EDR3			-36.0	dB	
Bluetooth BR, EDR RF return loss				-10.0		dB

### 5.8.2 Bluetooth Transmitter, BR

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

PARAMETER	MIN	TYP	MAX	UNIT
BR RF output power <sup>(1)</sup>	VBAT ≥ 3 V	11.7		dBm
	VBAT < 3 V	7.2		dBm
BR gain control range		30.0		dB
BR power control step		5.0		dB
BR adjacent channel power  M-N  = 2		-43.0		dBm
BR adjacent channel power  M-N  > 2		-48.0		dBm

(1) Values reflect maximum power. Reduced power is available using a vendor-specific (VS) command.

### 5.8.3 Bluetooth Transmitter, EDR

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

PARAMETER	MIN	TYP	MAX	UNIT
EDR output power <sup>(1)</sup>	VBAT ≥ 3 V	7.2		dBm
	VBAT < 3 V	5.2		
EDR relative power				dB
EDR gain control range		30		dB
EDR power control step		5		dB
EDR adjacent channel power  M-N  = 1		-36		dBc
EDR adjacent channel power  M-N  = 2		-30		dBm
EDR adjacent channel power  M-N  > 2		-42		dBm

(1) Values reflect default maximum power. Max power can be changed using a VS command.

### 5.8.4 Bluetooth Modulation, BR

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

CHARACTERISTICS	CONDITION <sup>(1)</sup>		MIN	TYP	MAX	UNIT
BR –20 dB bandwidth				925	995	kHz
BR modulation characteristics	$\Delta f_{1avg}$	Mod data = 4 1s, 4 0s: 111100001111...	145	160	170	kHz
	$\Delta f_{2max} \geq$ limit for at least 99.9% of all $\Delta f_{2max}$	Mod data = 1010101...	120	130		kHz
	$\Delta f_{2avg}$ , $\Delta f_{1avg}$		85	88		%
BR carrier frequency drift	One slot packet		–25		25	kHz
	Three and five slot packet		–35		35	kHz
BR drift rate	$f_{k+5} - f_k$ , $k = 0 \dots \text{max}$				15	kHz/50 $\mu$ s
BR initial carrier frequency tolerance <sup>(2)</sup>	$f_0 - f_{TX}$		$\pm 75$		$\pm 75$	kHz

(1) Performance values reflect maximum power.

(2) Numbers include XTAL frequency drift over temperature and aging.

### 5.8.5 Bluetooth Modulation, EDR

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

PARAMETER <sup>(1)</sup>	CONDITION	MIN	TYP	MAX	UNIT
EDR carrier frequency stability		–5		5	kHz
EDR initial carrier frequency tolerance <sup>(2)</sup>		$\pm 75$		$\pm 75$	kHz
EDR RMS DEVM	EDR2		4	15	%
	EDR3		4	10	%
EDR 99% DEVM	EDR2			30	%
	EDR3			20	%
EDR peak DEVM	EDR2		9	25	%
	EDR3		9	18	%

(1) Performance values reflect maximum power.

(2) Numbers include XTAL frequency drift over temperature and aging.

## 5.9 Bluetooth LE Performance

All RF and performance numbers are aligned to the module pin.

### 5.9.1 Bluetooth LE Receiver Characteristics – In-Band Signals

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

PARAMETER	CONDITION <sup>(1)</sup>	MIN	TYP	MAX	UNIT
Bluetooth LE operation frequency range		2402		2480	MHz
Bluetooth LE channel spacing			2		MHz
Bluetooth LE input impedance			50		$\Omega$
Bluetooth LE sensitivity <sup>(2)</sup> Dirty TX on			–92.2		dBm
Bluetooth LE maximum usable input power		–5			dBm
Bluetooth LE intermodulation characteristics	Level of interferers. For $n = 3, 4, 5$	–36	–30		dBm

(1) BER of 0.1% corresponds to PER of 30.8% for a minimum of 1500 transmitted packets, according to the Bluetooth LE test specification.

(2) Sensitivity degradation of up to –3 dB can occur due to fast clock harmonics.

PARAMETER	CONDITION <sup>(1)</sup>	MIN	TYP	MAX	UNIT
Bluetooth LE C/I performance. Note: Numbers show wanted signal-to-interfering-signal ratio. Smaller numbers indicate better C/I performance.	LE, co-channel			12	dB
	LE, adjacent $\pm 1$ MHz			0	
	LE, adjacent +2 MHz			-38	
	LE, adjacent -2 MHz			-15	
Image = -1 MHz	LE, adjacent $\geq  \pm 3 $ MHz			-40	

### 5.9.2 Bluetooth LE Transmitter Characteristics

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

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Bluetooth LE RF output power <sup>(1)(2)</sup>	VBAT $\geq 3$ V		7.0		dBm
	VBAT < 3 V		7.0		dBm
Bluetooth LE adjacent channel power  M-N  = 2			-51.0		dBm
Bluetooth LE adjacent channel power  M-N  > 2			-54.0		dBm

- (1) To reduce the maximum BLE power, use a VS command. The optional extra margin is offered to compensate for design losses, such as trace and filter losses, and to achieve the maximum allowed output power at system level.  
 (2) BLE power is restricted to comply with the ETSI 10-dBm EIRP limit requirement.

### 5.9.3 Bluetooth LE Modulation Characteristics

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

CHARACTERISTICS	CONDITION <sup>(1)</sup>		MIN	TYP	MAX	UNIT
Bluetooth LE modulation characteristics	$\Delta f1_{avg}$	Mod data = 4 1s, 4 0s: 111100001111...	240	250	260	kHz
	$\Delta f2_{max} \geq$ limit for at least 99.9% of all $\Delta f2_{max}$	Mod data = 1010101...	195	215		kHz
	$\Delta f2_{avg}, \Delta f1_{avg}$		85	90		%
Bluetooth LE carrier frequency drift	f0 - fn , n = 2,3 .... K		-25		25	kHz
Bluetooth LE drift rate	f1 - f0  and  fn - fn-1 , n = 6,7 .... K				15	kHz/50 $\mu$ s
LE initial carrier frequency tolerance <sup>(2)</sup>	fn - fTX		$\pm 75$		$\pm 75$	kHz

- (1) Performance values reflect maximum power.  
 (2) Numbers include XTAL frequency drift over temperature and aging.

### 5.10 Bluetooth-BR/EDR Dynamic Currents

Current is measured at output power as follows:

- BR at 11.7 dBm
- EDR at 7.2 dBm

USE CASE <sup>(1) (2)</sup>	TYP	UNIT
BR voice HV3 + sniff	11.6	mA
EDR voice 2-EV3 no retransmission + sniff	5.9	mA
Sniff 1 attempt 1.28 s	178.0	$\mu$ A
EDR A2DP EDR2 (master). SBC high quality - 345 Kbs	10.4	mA
EDR A2DP EDR2 (master). MP3 high quality - 192 Kbs	7.5	mA
Full throughput ACL RX: RX-2DH5 <sup>(3)(4)</sup>	18.0	mA
Full throughput BR ACL TX: TX-DH5 <sup>(4)</sup>	50.0	mA

- (1) The role of Bluetooth in all scenarios except A2DP is slave.  
 (2) CL1P5 PA is connected to VBAT, 3.7 V.  
 (3) ACL RX has the same current in all modulations.  
 (4) Full throughput assumes data transfer in one direction.

USE CASE <sup>(1) (2)</sup>	TYP	UNIT
Full throughput EDR ACL TX: TX-2DH5 <sup>(4)</sup>	33.0	mA
Page scan or inquiry scan (scan interval is 1.28 s or 11.25 ms, respectively)	253.0	μA
Page scan and inquiry scan (scan interval is 1.28 s and 2.56 s, respectively)	332.0	μA

### 5.11 Bluetooth LE Currents

All current measured at output power of 6.5 dBm

USE CASE <sup>(1)</sup>	TYP	UNIT
Advertising, not connectable <sup>(2)</sup>	131	μA
Advertising, discoverable <sup>(2)</sup>	143	μA
Scanning <sup>(3)</sup>	266	μA
Connected, master role, 1.28-s connect interval <sup>(4)</sup>	124	μA
Connected, slave role, 1.28-s connect interval <sup>(4)</sup>	132	μA

- (1) CL1p% PA is connected to VBAT, 3.7 V.
- (2) Advertising in all three channels, 1.28-s advertising interval, 15 bytes advertise data
- (3) Listening to a single frequency per window, 1.28-s scan interval, 11.25-ms scan window
- (4) Zero slave connection latency, empty TX and RX LL packets

### 5.12 Timing and Switching Characteristics

#### 5.12.1 Power Management

##### 5.12.1.1 Block Diagram – Internal DC2DCs

The device incorporates three internal DC2DCs (switched-mode power supplies) to provide efficient internal supplies, derived from V<sub>BAT</sub>.

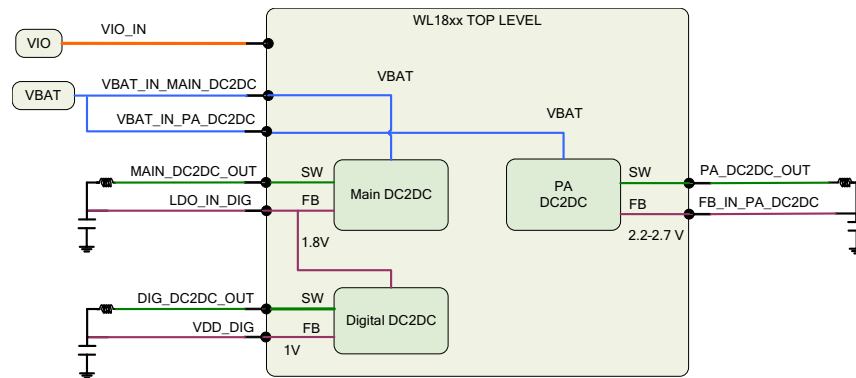


Figure 5-1. Internal DC2DCs

#### 5.12.2 Power-Up and Shut-Down States

The correct power-up and shut-down sequences must be followed to avoid damage to the device.

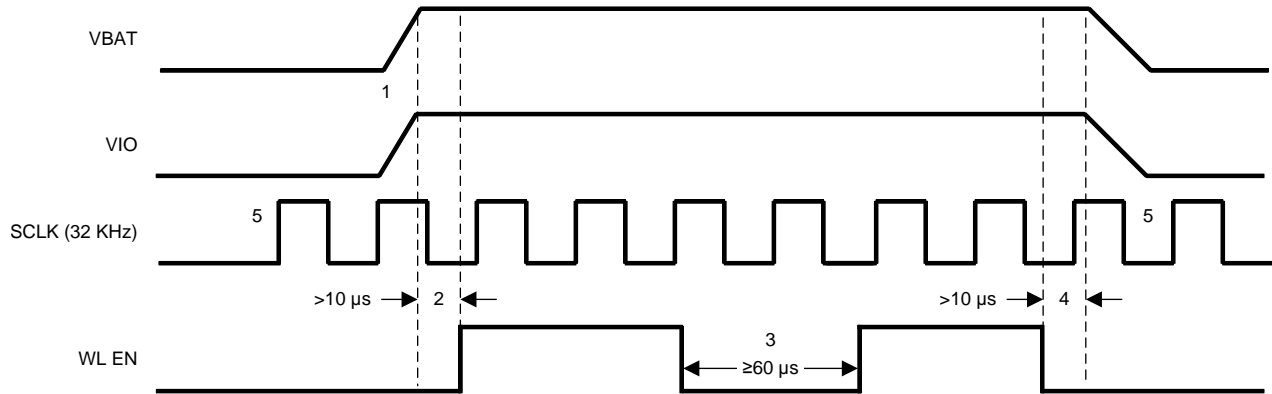
While V<sub>BAT</sub> or V<sub>IO</sub> or both are deasserted, no signals should be driven to the device. The only exception is the slow clock that is a fail-safe I/O.

While V<sub>BAT</sub>, V<sub>IO</sub>, and slow clock are fed to the device, but WL\_EN is deasserted (low), the device is in SHUTDOWN state. In SHUTDOWN state all functional blocks, internal DC2DCs, clocks, and LDOs are disabled.

To perform the correct power-up sequence, assert (high) WL\_EN. The internal DC2DCs, LDOs, and clock start to ramp and stabilize. Stable slow clock, V<sub>IO</sub>, and V<sub>BAT</sub> are prerequisites to the assertion of one of the enable signals.

To perform the correct shut-down sequence, deassert (low) WL\_EN while all the supplies to the device (V<sub>BAT</sub>, V<sub>IO</sub>, and slow clock) are still stable and available. The supplies to the chip (V<sub>BAT</sub> and V<sub>IO</sub>) can be deasserted only after both enable signals are deasserted (low).

Figure 5-2 shows the general power scheme for the module, including the powerdown sequence.



- NOTE:
1. Either V<sub>BAT</sub> or V<sub>IO</sub> can come up first.
  2. V<sub>BAT</sub> and V<sub>IO</sub> supplies and slow clock (SCLK), must be stable prior to EN being asserted and at all times when the EN is active.
  3. At least 60 μs is required between two successive device enables. The device is assumed to be in shutdown state during that period, meaning all enables to the device are LOW for that minimum duration.
  4. EN must be deasserted at least 10 μs before V<sub>BAT</sub> or V<sub>IO</sub> supply can be lowered. (Order of supply turn off after EN shutdown is immaterial)
  5. SCLK - Fail safe I/O

Figure 5-2. Power-Up System

### 5.12.3 Chip Top-level Power-Up Sequence

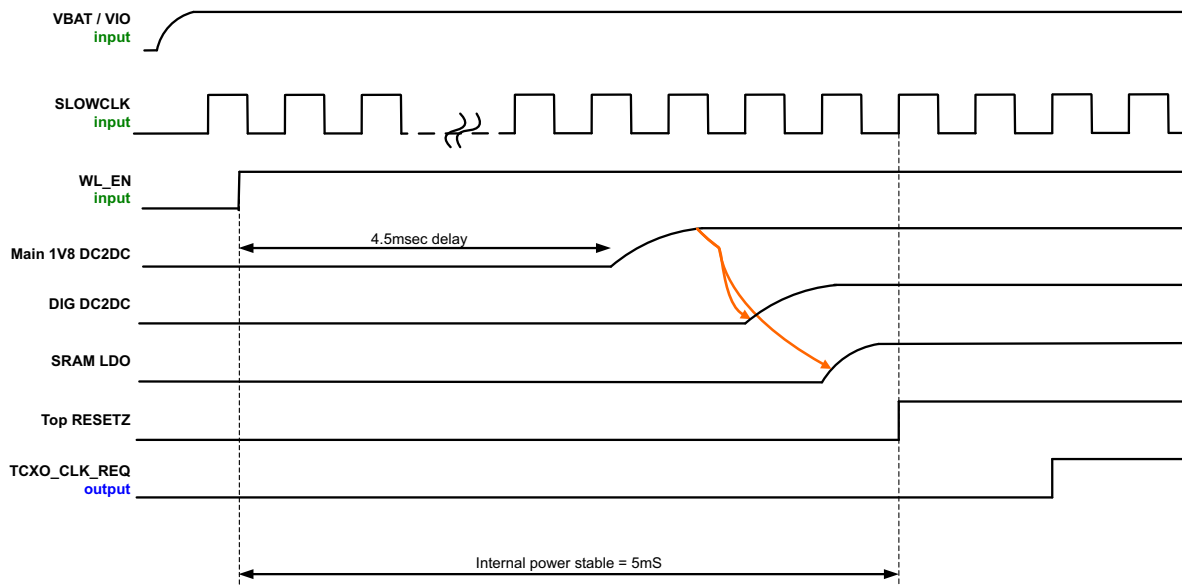


Figure 5-3. Chip Top-Level Power-Up Sequence

### 5.12.4 WLAN Power-Up Sequence

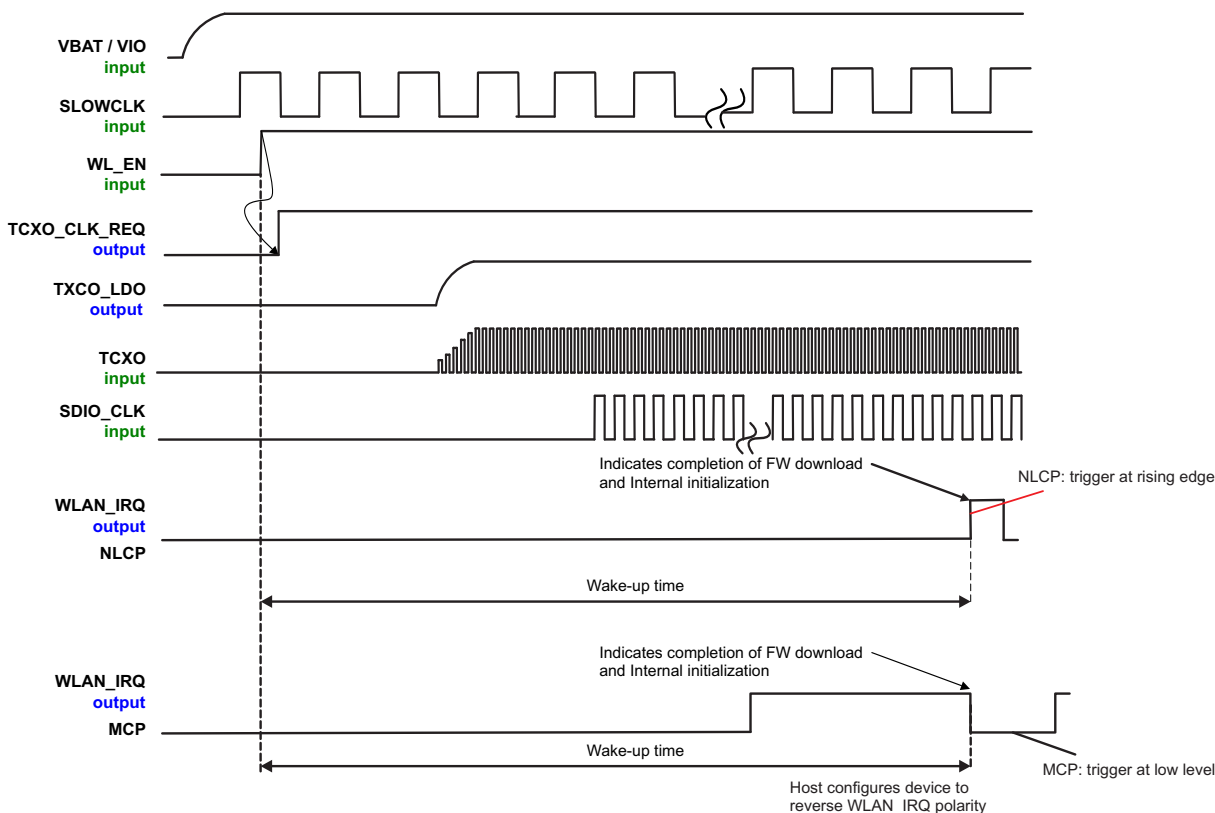


Figure 5-4. WLAN Power-Up Sequence

### 5.12.5 Bluetooth-BLE Power-Up Sequence

Figure 5-5 shows the Bluetooth-BLE power-up sequence.

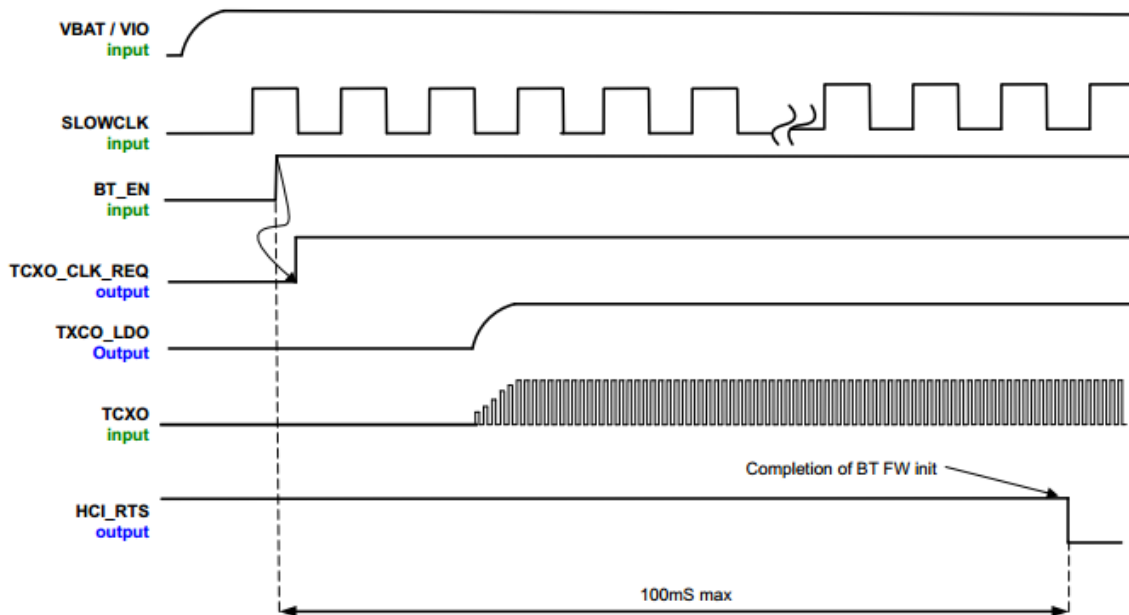


Figure 5-5. Bluetooth/BLE Power-Up Sequence

### 5.12.6 WLAN SDIO Transport Layer

The SDIO is the host interface for WLAN. The interface between the host and the WL18xx module uses an SDIO interface and supports a maximum clock rate of 50 MHz.

The device SDIO also supports the following features of the SDIO V3 specification:

- 4-bit data bus
- Synchronous and asynchronous in-band interrupt
- Default and high-speed (HS, 50 MHz) timing
- Sleep and wake commands

#### 5.12.6.1 SDIO Timing Specifications

Figure 5-6 and Figure 5-7 show the SDIO switching characteristics over recommended operating conditions and with the default rate for input and output.

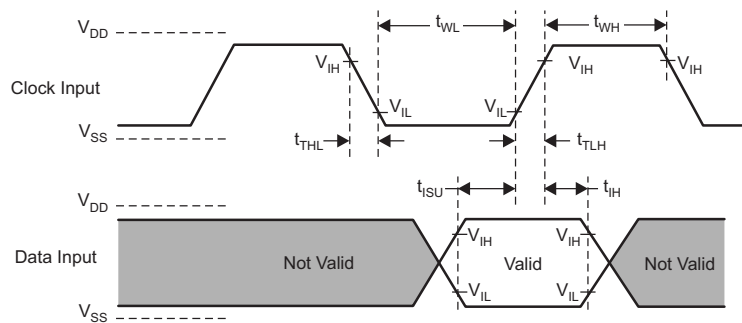


Figure 5-6. SDIO Default Input Timing

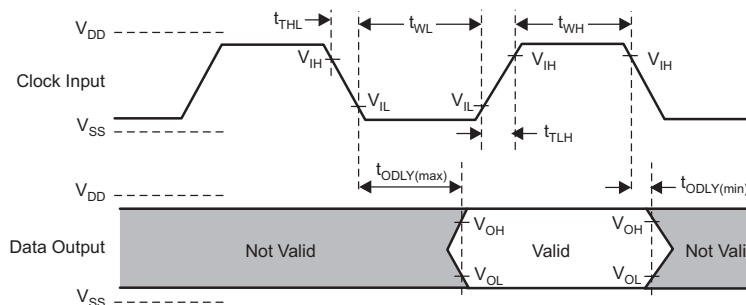


Figure 5-7. SDIO Default Output Timing

Table 5-1 lists the SDIO default timing characteristics.

Table 5-1. SDIO Default Timing Characteristics<sup>(1)</sup>

PARAMETER <sup>(2)</sup>		MIN	MAX	UNIT
$f_{\text{clock}}$	Clock frequency, CLK	0.0	26.0	MHz
DC	Low, high duty cycle	40.0	60.0	%
$t_{\text{TLH}}$	Rise time, CLK		10.0	ns
$t_{\text{THL}}$	Fall time, CLK		10.0	ns
$t_{\text{ISU}}$	Setup time, input valid before CLK $\uparrow$	3.0		ns
$t_{\text{IH}}$	Hold time, input valid after CLK $\uparrow$	2.0		ns
$t_{\text{ODLY}}$	Delay time, CLK $\downarrow$ to output valid	7.0	10.0	ns
$C_i$	Capacitive load on outputs		15.0	pF

(1) To change the data out clock edge from the falling edge (default) to the rising edge, set the configuration bit.

(2) Parameter values reflect maximum clock frequency.

5.12.6.2 SDIO Switching Characteristics – High Rate

Figure 5-8 and Figure 5-9 show the parameters for maximum clock frequency.

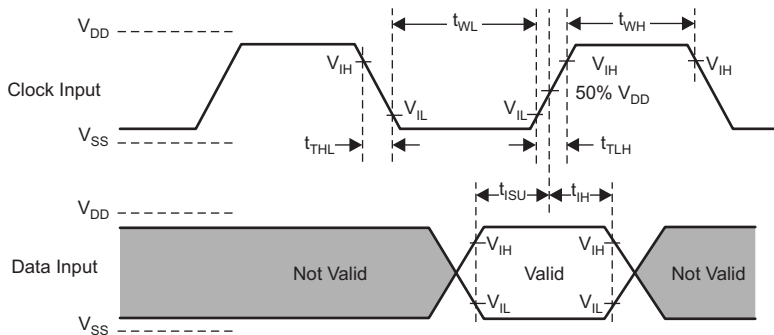


Figure 5-8. SDIO HS Input Timing

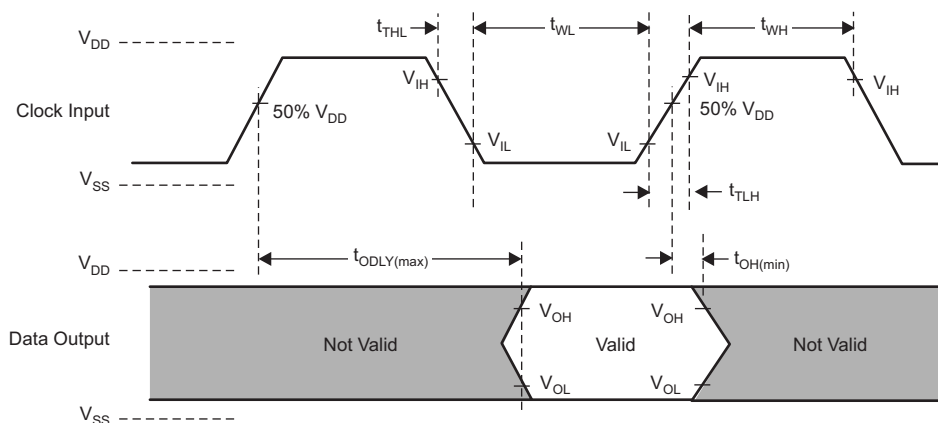


Figure 5-9. SDIO HS Output Timing

Table 5-2 lists the SDIO high-rate timing characteristics.

Table 5-2. SDIO HS Timing Characteristics

PARAMETER		MIN	MAX	UNIT
$f_{clock}$	Clock frequency, CLK	0.0	52.0	MHz
DC	Low, high duty cycle	40.0	60.0	%
$t_{TLH}$	Rise time, CLK		3.0	ns
$t_{THL}$	Fall time, CLK		3.0	ns
$t_{SU}$	Setup time, input valid before CLK $\uparrow$	3.0		ns
$t_{H}$	Hold time, input valid after CLK $\uparrow$	2.0		ns
$t_{ODLY}$	Delay time, CLK $\uparrow$ to output valid	7.0	10.0	ns
$C_I$	Capacitive load on outputs		10.0	pF

5.12.7 HCI UART Shared Transport Layers for All Functional Blocks (Except WLAN)

The device incorporates a UART module dedicated to the *Bluetooth* shared-transport, host controller interface (HCI) transport layer. The HCI interface transports commands, events, and ACL between the *Bluetooth* device and its host using HCI data packets acting as a shared transport for all functional blocks except WLAN.

WLAN	SHARED HCI FOR ALL FUNCTIONAL BLOCKS EXCEPT WLAN	BLUETOOTH VOICE-AUDIO
WLAN HS SDIO	Over UART	<i>Bluetooth</i> PCM

The HCI UART supports most baud rates (including all PC rates) for all fast-clock frequencies up to a maximum of 4 Mbps. After power up, the baud rate is set for 115.2 kbps, regardless of the fast-clock frequency. The baud rate can then be changed using a VS command. The device responds with a Command Complete Event (still at 115.2 kbps), after which the baud rate change occurs.

HCI hardware includes the following features:

- Receiver detection of break, idle, framing, FIFO overflow, and parity error conditions
- Receiver-transmitter underflow detection
- CTS, RTS hardware flow control
- 4 wire (H4)

Table 5-3 lists the UART default settings.

**Table 5-3. UART Default Setting**

PARAMETER	VALUE
Bit rate	115.2 kbps
Data length	8 bits
Stop bit	1
Parity	None

**5.12.7.1 UART 4-Wire Interface – H4**

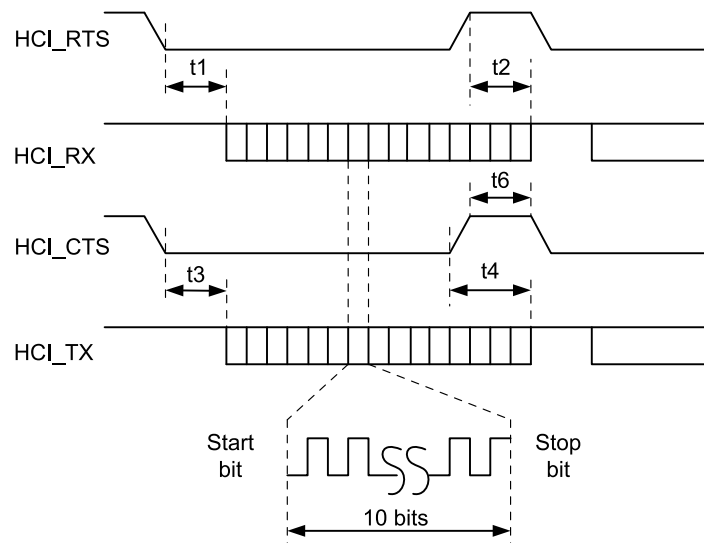
The interface includes four signals:

- TXD
- RXD
- CTS
- RTS

Flow control between the host and the device is byte-wise by hardware.

When the UART RX buffer of the device passes the flow-control threshold, the buffer sets the UART\_RTS signal high to stop transmission from the host. When the UART\_CTS signal is set high, the device stops transmitting on the interface. If HCI\_CTS is set high in the middle of transmitting a byte, the device finishes transmitting the byte and stops the transmission.

Figure 5-10 shows the UART timing.



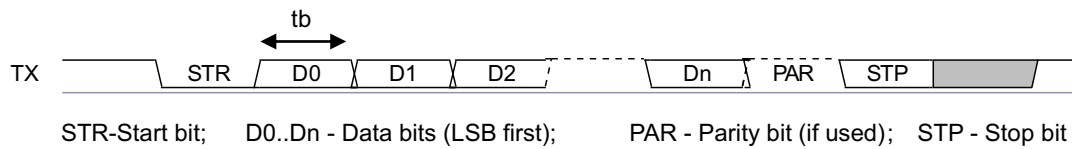
**Figure 5-10. UART Timing Diagram**

Table 5-4 lists the UART timing characteristics.

**Table 5-4. UART Timing Characteristics**

PARAMETER	CONDITION	SYMBOL	MIN	TYP	MAX	UNIT
Baud rate			37.5		4364	Kbps
Baud rate accuracy per byte	Receive-transmit		-2.5		+1.5	%
Baud rate accuracy per bit	Receive-transmit		-12.5		+12.5	%
CTS low to TX_DATA on		t3	0.0	2.0		µs
CTS high to TX_DATA off	Hardware flow control	t4			1.0	Byte
CTS high pulse width		t6	1.0			Bit
RTS low to RX_DATA on		t1	0.0	2.0		µs
RTS high to RX_DATA off	Interrupt set to 1/4 FIFO	t2			16.0	Bytes

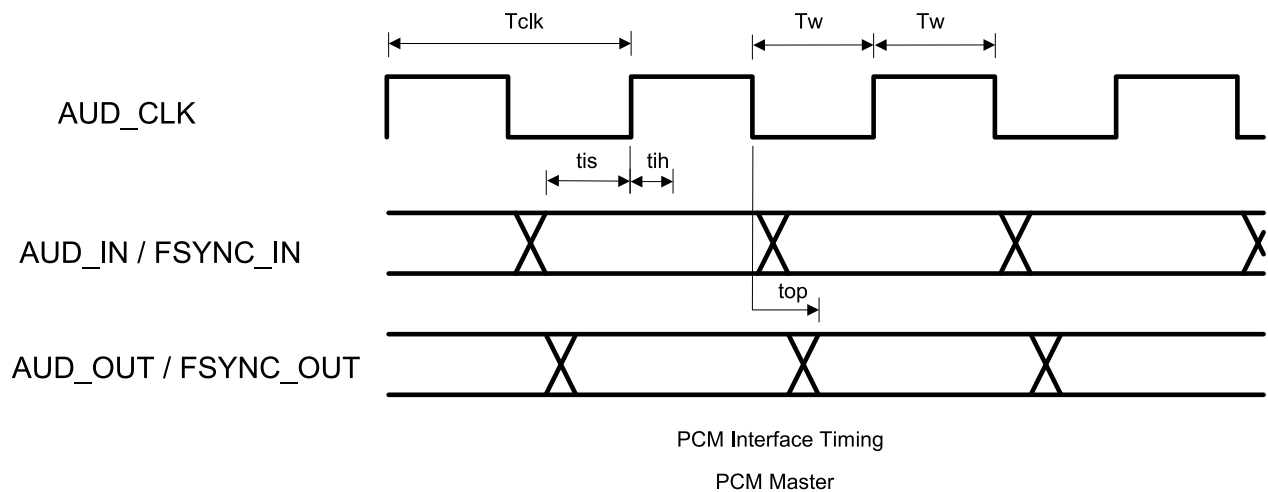
Figure 5-11 shows the UART data frame.



**Figure 5-11. UART Data Frame**

**5.12.8 Bluetooth Codec-PCM (Audio) Timing Specifications**

Figure 5-12 shows the Bluetooth codec-PCM (audio) timing diagram.



**Figure 5-12. Bluetooth Codec-PCM (Audio) Master Timing Diagram**

Table 5-5 lists the *Bluetooth* codec-PCM master timing characteristics.

**Table 5-5. *Bluetooth* Codec-PCM Master Timing Characteristics**

PARAMETER	SYMBOL	MIN	MAX	UNIT
Cycle time	$T_{clk}$	162.76 (6.144 MHz)	15625 (64 kHz)	ns
High or low pulse width	$T_s$	35% of $T_{clk}$ min		
AUD_IN setup time	$t_{is}$	10.6		
AUD_IN hold time	$t_{ih}$	0		
AUD_OUT propagation time	$t_{op}$	0	15	
FSYNC_OUT propagation time	$t_{op}$	0	15	
Capacitive loading on outputs	$C_l$		40	pF

Table 5-6 lists the *Bluetooth* codec-PCM slave timing characteristics.

**Table 5-6. *Bluetooth* Codec-PCM Slave Timing Characteristics**

PARAMETER	SYMBOL	MIN	MAX	UNIT
Cycle time	$T_{clk}$	81.38 (12.266 MHz)		ns
High or low pulse width	$T_w$	35% of $T_{clk}$ min		
AUD_IN setup time	$t_{is}$	5		
AUD_IN hold time	$t_{ih}$	0		
AUD_FSYNC setup time	$t_{is}$	5		
AUD_FSYNC hold time	$t_{ih}$	0		
AUD_OUT propagation time	$t_{op}$	0	19	
Capacitive loading on outputs	$C_l$		40	pF

## 6 Detailed Description

The WiLink 8 module is a self-contained connectivity solution based on WiLink 8 connectivity. As the eighth-generation connectivity combo chip from TI, the WiLink 8 module is based on proven technology.

Table 6-1 through Table 6-3 list performance parameters along with shutdown and sleep currents.

**Table 6-1. WLAN Performance Parameters**

WLAN <sup>(1)</sup>	SPECIFICATION (TYP)	CONDITIONS
Maximum TX power, 5 GHz (OFDM6)	18 dBm	6 Mbps OFDM
Maximum TX power, 2.4 GHz (1DSSS)	16.5 dBm	1 Mbps DSSS
Minimum sensitivity, 5 GHz (OFDM6)	-92.5dBm	6 Mbps OFDM
Minimum sensitivity, 2.4GHz (1DSSS)	-95 dBm	1 Mbps DSSS
Sleep current	160 $\mu$ A	Leakage, firmware retained
Connected IDLE	750 $\mu$ A	No traffic IDLE connect
RX search	58 mA	2.4GHz SISO 20
RX current (SISO20)	69 mA	MCS7, 2.4 GHz
RX current (SISO20)	77 mA	MCS7, 5 GHz
TX current (SISO20)	238 mA	MCS7, 2.4 GHz
TX current (SISO20)	324 mA	MCS7, 5 GHz
Maximum peak current consumption during calibration <sup>(2)</sup>	850 mA	

(1) System design power scheme must comply with both peak and average TX bursts.

(2) Peak current VBAT can hit 850 mA during device calibration.

- At wakeup, the WiLink 8 module performs the entire calibration sequence at the center of the 2.4-GHz band.
- Once a link is established, calibration is performed periodically (every 5 minutes) on the specific channel tuned.
- The maximum VBAT value is based on peak calibration consumption with a 30% margin.

**Table 6-2. Bluetooth Performance Parameters**

BLUETOOTH	SPECIFICATION (TYP)	CONDITIONS
Maximum TX power	11.7 dBm	GFSK
Minimum sensitivity	-92.2 dBm	GFSK
Sniff	178 $\mu$ A	1 attempt, 1.28 s (+4 dBm)
Page or inquiry	253 $\mu$ A	1.28-s interrupt, 11.25-ms scan window (+4 dBm)
A2DP	7.5 mA	MP3 high quality 192 kbps (+4 dBm)

**Table 6-3. Shutdown and Sleep Currents**

PARAMETER	POWER SUPPLY CURRENT	TYP	UNIT
Shutdown mode All functions shut down	VBAT	10	$\mu$ A
	VIO	2	$\mu$ A
WLAN sleep mode	VBAT	160	$\mu$ A
Bluetooth sleep mode	VBAT	110	$\mu$ A

Figure 6-1 shows a high-level view of the WL1837MOD variant.

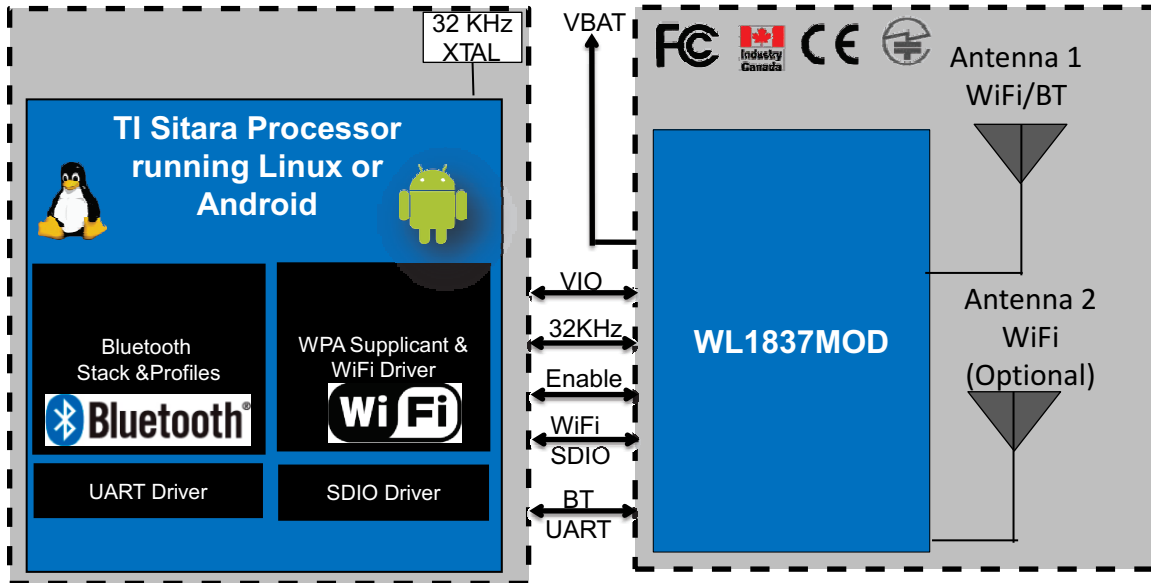


Figure 6-1. WL1837MOD High-Level System Diagram

## 6.1 WLAN

The device supports the following WLAN features:

- Integrated 2.4-GHz power amplifiers (PAs) for a complete WLAN solution
- Baseband processor: IEEE Std 802.11a, 802.11b/g, and IEEE Std 802.11n data rates with 20- or 40-MHz SISO and 20-MHz MIMO
- Fully calibrated system (production calibration not required)
- Medium access controller (MAC)
  - Embedded ARM® central processing unit (CPU)
  - Hardware-based encryption-decryption using 64-, 128-, and 256-bit WEP, TKIP, or AES keys
  - Requirements for Wi-Fi-protected access (WPA and WPA2.0) and IEEE Std 802.11i (includes hardware-accelerated Advanced Encryption Standard [AES])
- New advanced coexistence scheme with *Bluetooth* and BLE
- 2.4- and 5-GHz radio
  - Internal LNA and PA
  - IEEE Std 802.11a, 802.11b, 802.11g, and 802.11n
- 4-bit SDIO host interface, including high speed (HS) and V3 modes

## 6.2 Bluetooth

The device supports the following *Bluetooth* features:

- *Bluetooth* 4.1 as well as CSA2
- Concurrent operation and built-in coexisting and prioritization handling of *Bluetooth*, BLE, audio processing, and WLAN
- Dedicated audio processor supporting on-chip SBC encoding + A2DP
  - Assisted A2DP (A3DP): SBC encoding implemented internally
  - Assisted WB-speech (AWBS): modified SBC codec implemented internally

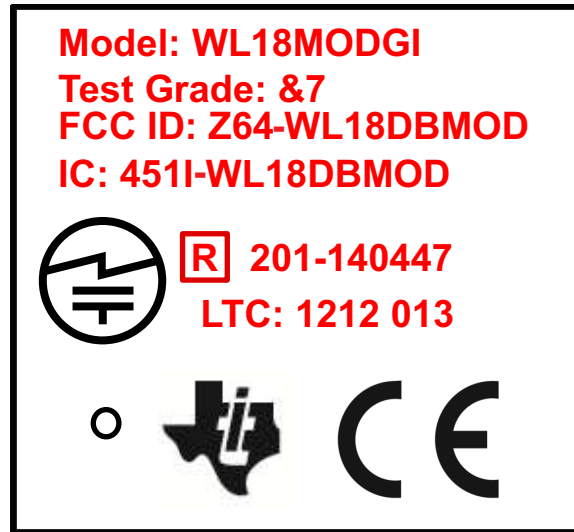
### 6.3 BLE

The device supports the following BLE features:

- *Bluetooth* 4.0 BLE dual-mode standard
- All roles and role combinations, mandatory as well as optional
- Up to 10 BLE connections
- Independent LE buffering allowing many multiple connections with no affect on BR-EDR performance

### 6.4 WiLink 8 Module Markings


Figure 6-2 shows the markings for the TI WiLink 8 module.



**Figure 6-2. WiLink 8 Module Markings**

Table 6-4 describes the WiLink 8 module markings.

**Table 6-4. Description of WiLink 8 Module Markings**

MARKING	DESCRIPTION
WL18 MODGI	Model
&7	Test grade (for more information, see <a href="#">Section 6.5, Test Grades</a> )
Z64-WL18DBMOD	FCC ID: single modular FCC grant ID
451I-WL18DBMOD	IC: single modular IC grant ID
201-140447	R: single modular TELEC grant ID
YYWWSSF	LTC (lot trace code): <ul style="list-style-type: none"> <li>• YY = year (for example, 12 = 2012)</li> <li>• WW = week</li> <li>• SS = serial number (01 to 99) matching manufacturer lot number</li> <li>• F = Reserved for internal use</li> </ul>
	TELEC compliance mark
CE	CE compliance mark

## 6.5 Test Grades

To minimize delivery time, TI may ship the device ordered or an equivalent device currently available that contains at least the functions of the part ordered. From all aspects, this device will behave exactly the same as the part ordered. For example, if a customer orders device WL1807MOD, the part shipped can be marked with a test grade of 37, 07 (see [Table 6-5](#)).

**Table 6-5. Test Grade Markings**

MARK	WLAN 2.4 and 5 GHz	BLUETOOTH
07	Tested	–
37	Tested	Tested

## 7 Applications and Implementation

### 7.1 Application Information

#### 7.1.1 Typical Application – WL1837MOD Reference Design

Figure 7-1 shows the TI WL1837MOD reference design.

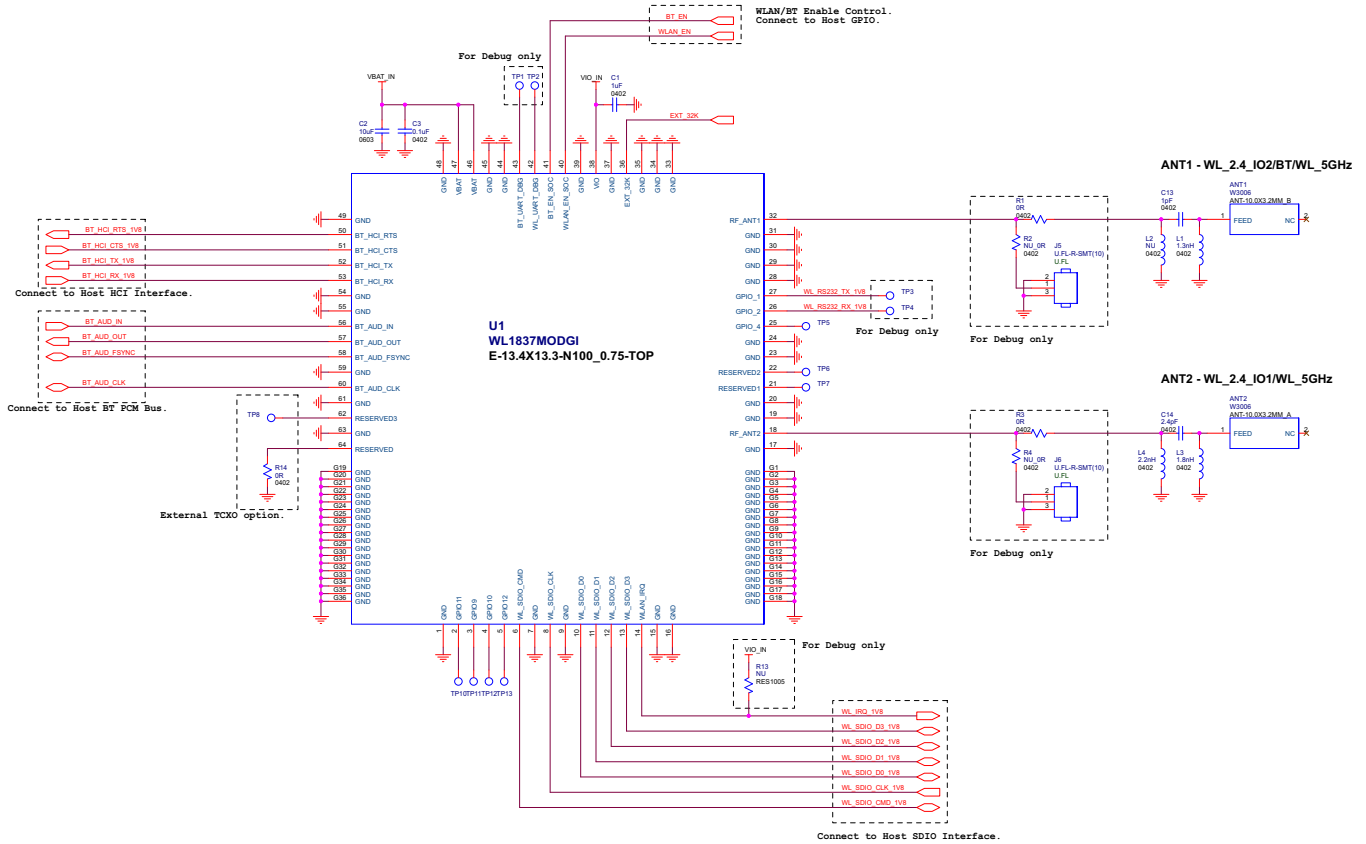


Figure 7-1. TI Module Reference Schematics

Table 7-1 lists the bill materials (BOM).

**Table 7-1. Bill of Materials**

ITEM	DESCRIPTION	PART NO.	PACKAGE	REFERENCE	QTY	MFR
1	WL1837 Wi-Fi/Bluetooth Module	WL1837MODGI	13.4 × 13.3 × 2.0 mm	U1	1	TI
2	XOSC 3225/32.768 KHZ/1.8 V/±50 ppm	7XZ3200005	3.2 × 2.5 × 1.0 mm	OSC1	1	TXC
3	ANT/Chip/2.4 GHz and 5 GHz <sup>(1)</sup>	W3006	10.0 × 3.2 × 1.5 mm	ANT1, ANT2	2	Pulse
4	Mini-RF Header Receptacle	U.FL-R-SMT-1 (10)	3.0 × 2.6 × 1.25 mm	J5, J6	2	Hirose
5	Inductor 0402/1.3 nH/±0.1 nH/SMD	LQP15MN1N3B02	0402	L1	1	Murata
6	Inductor 0402/1.8 nH/±0.1 nH/SMD	LQP15MN1N8B02	0402	L3	1	Murata
7	Inductor 0402/2.2 nH/±0.1 nH/SMD	LQP15MN2N2B02	0402	L4	1	Murata
8	Capacitor 0402/1 pF/50 V/C0G/±0.1 pF	GJM1555C1H1R0BB01	0402	C13	1	Murata
9	Capacitor 0402/2.4 pF/50 V/C0G/±0.1 pF	GJM1555C1H2R4BB01	0402	C14	1	Murata
10	Capacitor 0402/0.1 μF/10 V/X7R/±10%	0402B104K100CT	0402	C3	1	Walsin
11	Capacitor 0402/1 μF/6.3 V/X5R/±10%/HF	GRM155R60J105KE19D	0402	C1	1	Murata
12	Capacitor 0603/10 μF/6.3 V/X5R/±20%	C1608X5R0J106M	0603	C2	1	TDK
13	Resistor 0402/0R/±5%	WR04X000 PTL	0402	R1, R3	2	Walsin

(1) For more information see [productfinder.pulseeng.com/product/W3006](http://productfinder.pulseeng.com/product/W3006).

### 7.1.2 Design Recommendations

This section describes the layout recommendations for the (X)WL1837 module, RF trace, and antenna.

Table 7-2 summarizes the layout recommendations.

**Table 7-2. Layout Recommendations Summary**

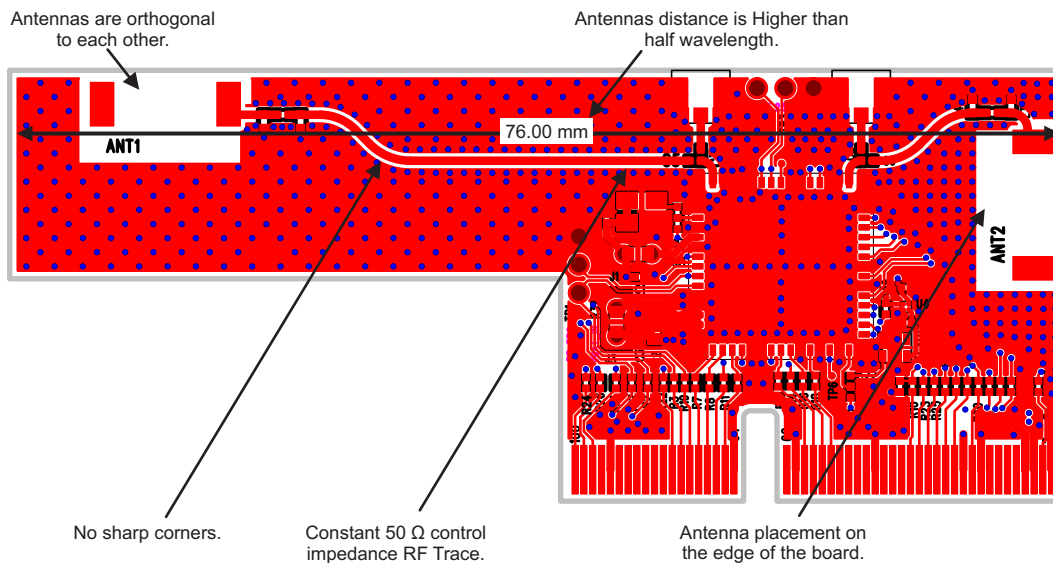
ITEM	DESCRIPTION
	<b>Thermal</b>
1	The proximity of ground vias must be close to the pad.
2	Signal traces must not be run underneath the module on the layer where the module is mounted.
3	Have a complete ground pour in layer 2 for thermal dissipation.
4	Have a solid ground plane and ground vias under the module for stable system and thermal dissipation.
5	Increase the ground pour in the first layer and have all of the traces from the first layer on the inner layers, if possible.
6	Signal traces can be run on a third layer under the solid ground layer, which is below the module mounting layer.
	<b>RF Trace and Antenna Routing</b>
7	The RF trace antenna feed must be as short as possible beyond the ground reference. At this point, the trace starts to radiate.
8	The RF trace bends must be gradual with an approximate maximum bend of 45 degrees with trace mitered. RF traces must not have sharp corners.
9	RF traces must have via stitching on the ground plane beside the RF trace on both sides.
10	RF traces must have constant impedance (microstrip transmission line).
11	For best results, the RF trace ground layer must be the ground layer immediately below the RF trace. The ground layer must be solid.
12	There must be no traces or ground under the antenna section.
13	RF traces must be as short as possible. The antenna, RF traces, and modules must be on the edge of the PCB product. The proximity of the antenna to the enclosure and the enclosure material must also be considered.
	<b>Supply and IF</b>
14	The power trace for VBAT must be at least 40-mil wide.
15	The 1.8-V trace must be at least 18-mil wide.
16	Make VBAT traces as wide as possible to ensure reduced inductance and trace resistance.

**Table 7-2. Layout Recommendations Summary (continued)**

ITEM	DESCRIPTION
17	If possible, shield VBAT traces with ground above, below, and beside the traces.
18	SDIO signals traces (CLK, CMD, D0, D1, D2, and D3) must be routed in parallel to each other and as short as possible (less than 12 cm). In addition, every trace length must be the same as the others. There should be enough space between traces – greater than 1.5 times the trace width or ground – to ensure signal quality, especially for the SDIO_CLK trace. Remember to keep these traces away from the other digital or analog signal traces. TI recommends adding ground shielding around these buses.
19	SDIO and digital clock signals are a source of noise. Keep the traces of these signals as short as possible. If possible, maintain a clearance around them.

### 7.1.3 RF Trace and Antenna Layout Recommendations

Figure 7-2 shows the location of the antenna on the WL1837MODCOM8I board as well as the RF trace routing from the (X)WL1837 module (TI reference design). The Pulse multilayer antennas are mounted on the board with a specific layout and matching circuit for the radiation test conducted in FCC, CE, and IC certifications.



**Figure 7-2. Location of Antenna and RF Trace Routing on the WL1837MODCOM8I Board**

Follow these RF trace routing recommendations:

- RF traces must have 50-Ω impedance.
- RF traces must not have sharp corners.
- RF traces must have via stitching on the ground plane beside the RF trace on both sides.
- RF traces must be as short as possible. The antenna, RF traces, and module must be on the edge of the PCB product in consideration of the product enclosure material and proximity.

### 7.1.4 Module Layout Recommendations

Figure 7-3 and Figure 7-4 show layer 1 and layer 2 of the TI module layout.

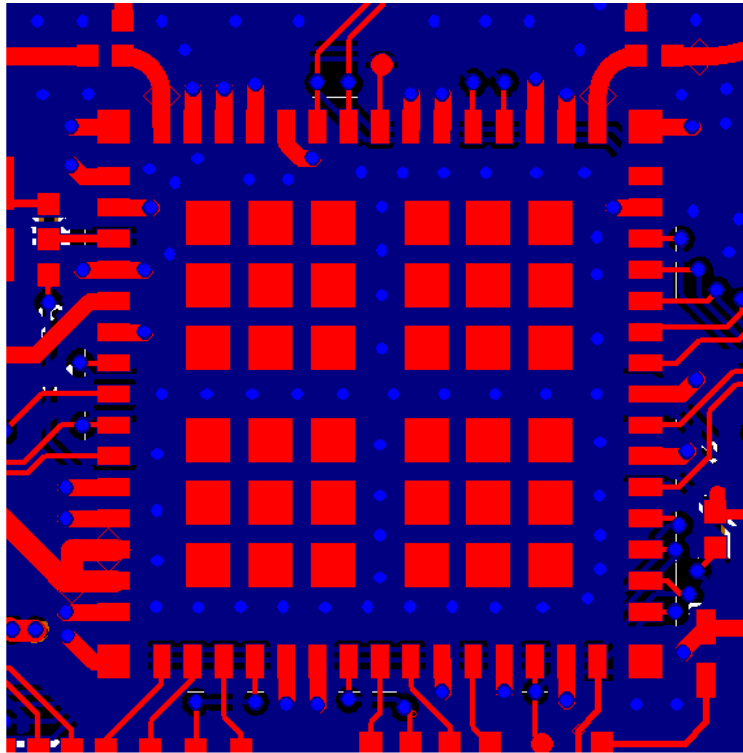


Figure 7-3. TI Module Layout: Layer 1

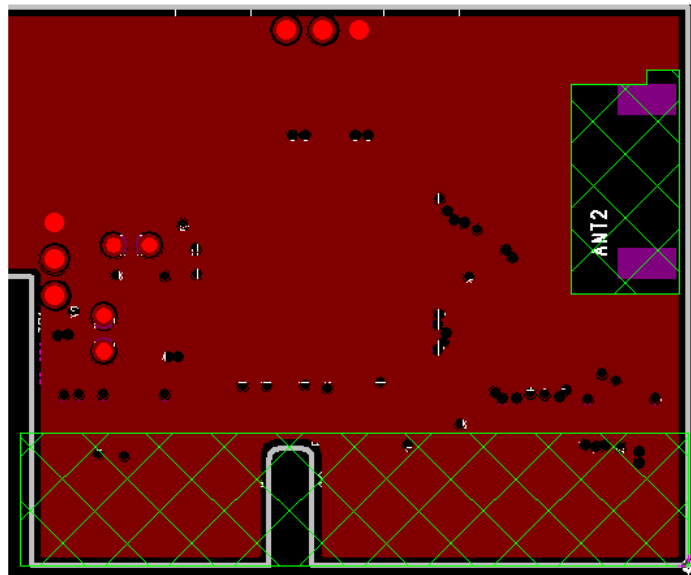


Figure 7-4. TI Module Layout: Layer 2 (Solid GND)

Follow these module layout recommendations:

- Ensure a solid ground plane and ground vias under the module for stable system and thermal dissipation.
- Do not run signal traces underneath the module on a layer where the module is mounted.
- Signal traces can be run on a third layer under the solid ground layer and beneath the module mounting.
- Run the host interfaces with ground on the adjacent layer to improve the return path.
- TI recommends routing the signals as short as possible to the host.

### 7.1.5 Thermal Board Recommendations

The TI module uses  $\mu$ vias for layers 1 through 6 with full copper filling, providing heat flow all the way to the module ground pads.

TI recommends using one big ground pad under the module with vias all the way to connect the pad to all ground layers (see [Figure 7-5](#)).

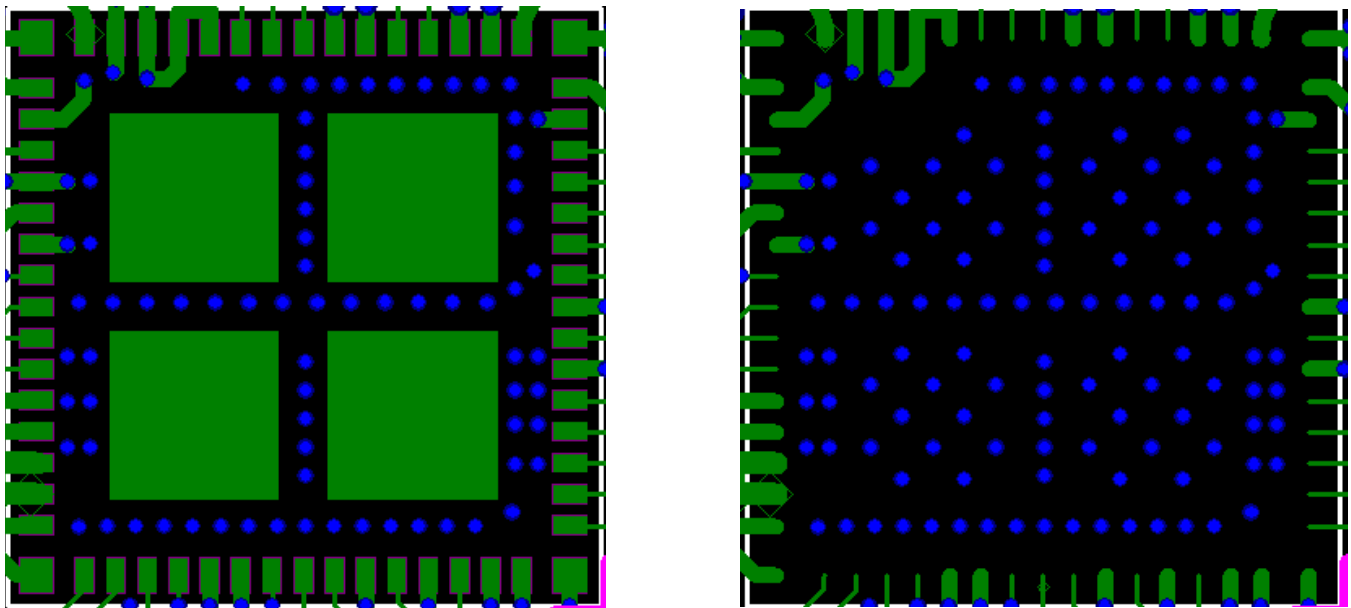
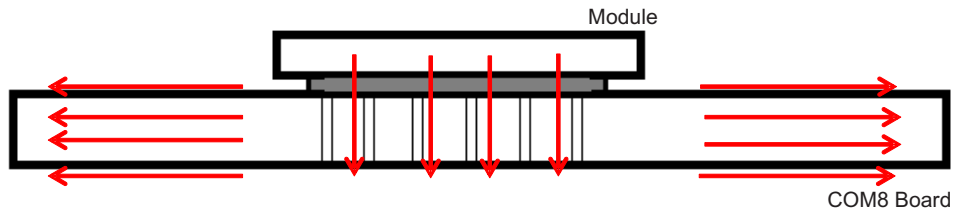


Figure 7-5. Block of Ground Pads on Bottom Side of Package

Figure 7-6 shows via array patterns, which are applied wherever possible to connect all of the layers to the TI module central or main ground pads.



Figure 7-6. Via Array Patterns

## 7.1.6 Baking and SMT Recommendations

### 7.1.6.1 Baking Recommendations

Follow these baking guidelines for the WiLink 8 module:

- Follow MSL level 3 to perform the baking process.
- After the bag is open, devices subjected to reflow solder or other high temperature processes must be mounted within 168 hours of factory conditions (< 30°C/60% RH) or stored at <10% RH.
- if the Humidity Indicator Card reads >10%, devices require baking before being mounted.
- If baking is required, bake devices for 8 hours at 125 °C.

### 7.1.6.2 SMT Recommendations

Figure 7-7 shows the recommended reflow profile for the WiLink 8 module.

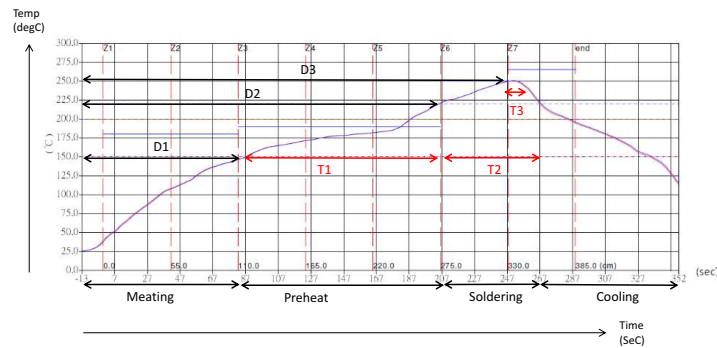


Figure 7-7. Reflow Profile for the WiLink 8 Module

Table 7-3 lists the temperature values for the profile shown in Figure 7-7.

Table 7-3. Temperature Values for Reflow Profile

ITEM	TEMPERATURE (°C)	TIME (s)
Preheat	D1 to approximately D2: 140 to 200	T1: 80 to approximately 120
Soldering	D2: 220	T2: 60 ±10
Peak temperature	D3: 250 max	T3: 10

## 8 Device and Documentation Support

### 8.1 Device Support

#### 8.1.1 Development Support

For a complete listing of development-support tools, visit the Texas Instruments [WL18xx Wiki](#). For information on pricing and availability, contact the nearest TI field sales office or authorized distributor.

#### 8.1.2 Device Support Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers. These prefixes represent evolutionary stages of product development from engineering prototypes through fully qualified production devices.

- X Experimental, preproduction, sample or prototype device. Device may not meet all product qualification conditions and may not fully comply with TI specifications. Experimental/Prototype devices are shipped against the following disclaimer: "This product is still in development and is intended for internal evaluation purposes." Notwithstanding any provision to the contrary, TI makes no warranty expressed, implied, or statutory, including any implied warranty of merchantability of fitness for a specific purpose, of this device.
- null Device is qualified and released to production. TI's standard warranty applies to production devices.

### 8.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 8-1. Related Links**

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
WL1807MOD	<a href="#">Click here</a>	<a href="#">Click here</a>	<a href="#">Click here</a>	<a href="#">Click here</a>	<a href="#">Click here</a>
WL1837MOD	<a href="#">Click here</a>	<a href="#">Click here</a>	<a href="#">Click here</a>	<a href="#">Click here</a>	<a href="#">Click here</a>

### 8.3 Community Resources

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](#)** *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](http://e2e.ti.com), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**[TI Embedded Processors Wiki](#)** *Texas Instruments Embedded Processors Wiki*. Established to help developers get started with Embedded Processors from Texas Instruments and to foster innovation and growth of general knowledge about the hardware and software surrounding these devices.

### 8.4 Trademarks

WiLink, E2E are trademarks of Texas Instruments.  
 ARM is a registered trademark of ARM Physical IP, Inc.  
*Bluetooth* is a registered trademark of Bluetooth SIG, Inc..  
 Android is a trademark of Google, Inc.  
 Linux is a registered trademark of Linus Torvalds.  
 Wi-Fi is a registered trademark of Wi-Fi Alliance.  
 All other trademarks are the property of their respective owners.

## 8.5 Electrostatic Discharge Caution



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

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

## 8.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 9 Mechanical Packaging and Orderable Information

### 9.1 TI Module Mechanical Outline

Figure 9-1 shows the mechanical outline for the device.

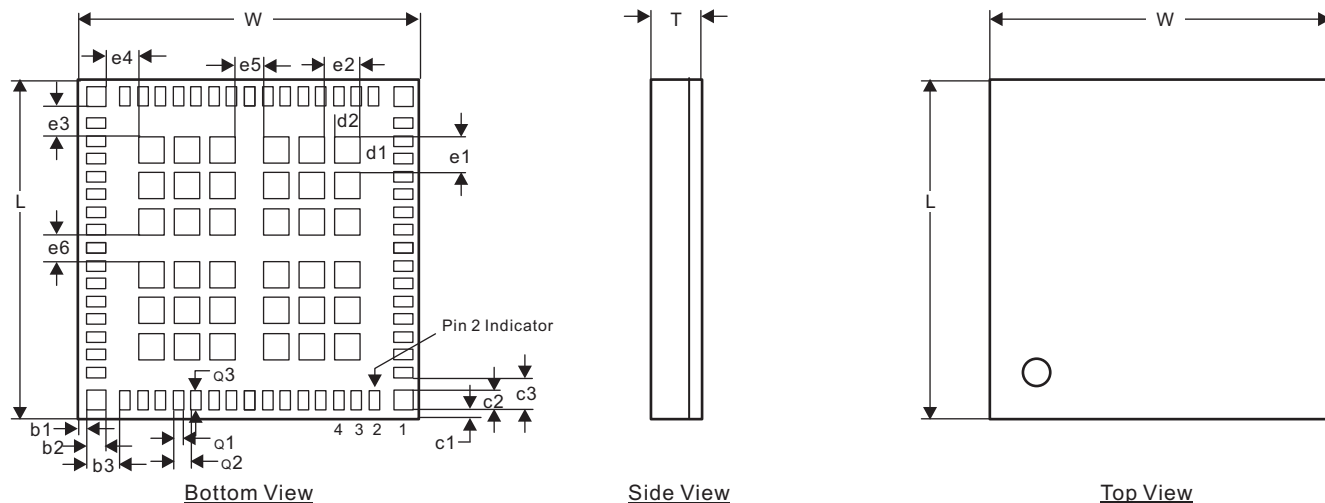


Figure 9-1. TI Module Mechanical Outline

Table 9-1 lists the dimensions for the mechanical outline of the device.

**NOTE**

The TI module weighs 684 g ( $\pm 5$  g).

Table 9-1. Dimensions for TI Module Mechanical Outline

MARKING	MIN (mm)	NOM (mm)	MAX (mm)	MARKING	MIN (mm)	NOM (mm)	MAX (mm)
L (body size)	13.20	13.30	13.40	c2	0.65	0.75	0.85
W (body size)	13.30	13.40	13.50	c3	1.15	1.25	1.35
T (thickness)	1.90		2.00	d1	0.90	1.00	1.10
a1	0.30	0.40	0.50	d2	0.90	1.00	1.10
a2	0.60	0.70	0.80	e1	1.30	1.40	1.50
a3	0.65	0.75	0.85	e2	1.30	1.40	1.50
b1	0.20	0.30	0.40	e3	1.15	1.25	1.35
b2	0.65	0.75	0.85	e4	1.20	1.30	1.40
b3	1.20	1.30	1.40	e5	1.00	1.10	1.20
c1	0.20	0.30	0.40	e6	1.00	1.10	1.20

## 9.2 Tape and Reel Information

Emboss taping specification for MOC 100 pin.

### 9.2.1 Tape and Reel Specification

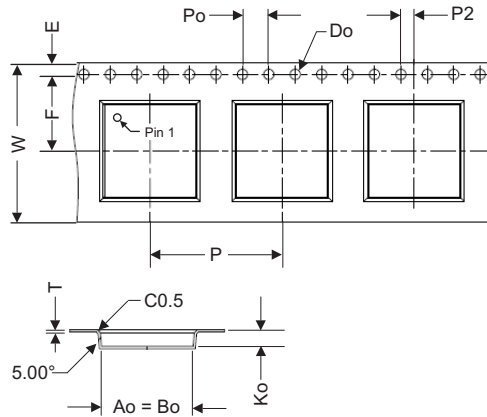


Figure 9-2. Tape Specification

Table 9-2. Dimensions for Tape Specification

ITEM	W	E	F	P	Po	P2	Do	T	Ao	Bo	Ko
<b>DIMENSION (mm)</b>	24.00 (±0.30)	1.75 (±0.10)	11.50 (±0.10)	20.00 (±0.10)	4.00 (±0.10)	2.00 (±0.10)	2.00 (±0.10)	0.35 (±0.05)	13.80 (±0.10)	13.80 (±0.10)	2.50 (±0.10)

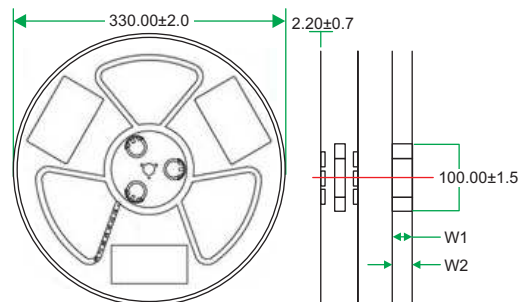


Figure 9-3. Reel Specification

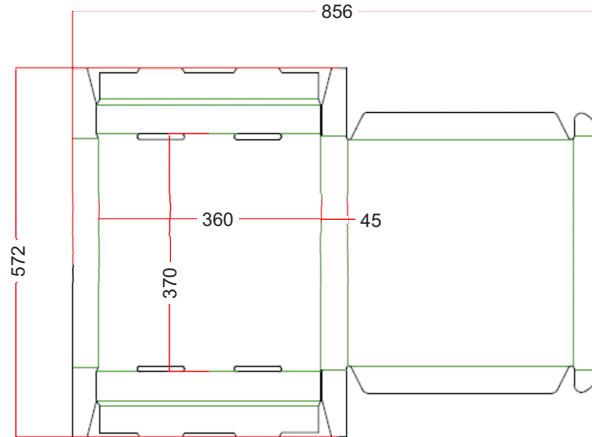
Table 9-3. Dimensions for Reel Specification

ITEM	W1	W2
<b>DIMENSION (mm)</b>	24.4 (+1.5, -0.5)	30.4 (maximum)

### 9.2.2 Packing Specification

#### 9.2.2.1 Reel Box

The reel is packed in a moisture barrier bag fastened by heat-sealing. Each moisture-barrier bag is packed into a reel box, as shown in [Figure 9-4](#).



**Figure 9-4. Reel Box**

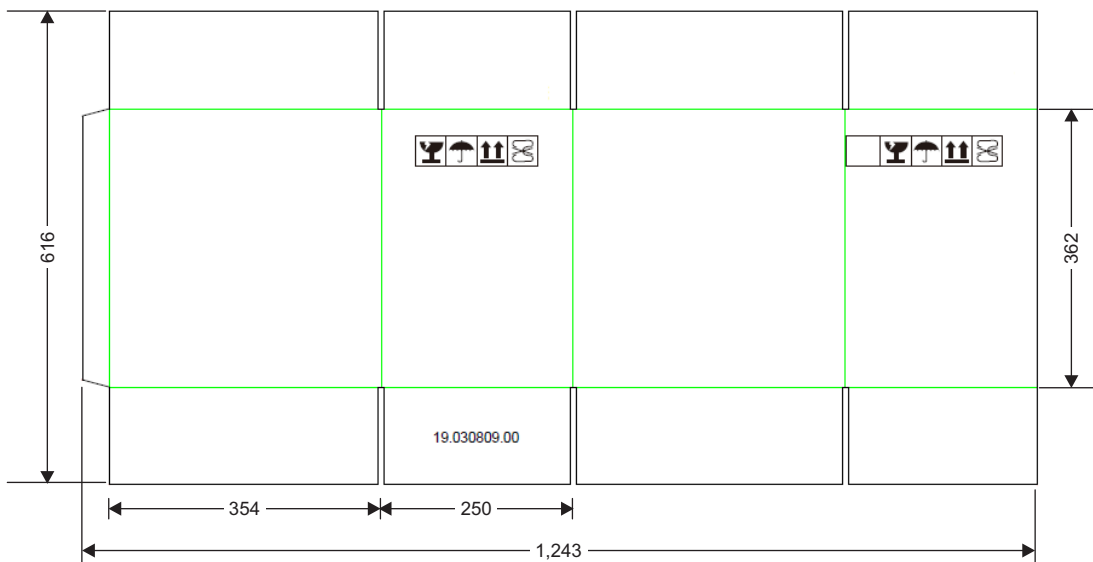
The reel box is made of corrugated fiberboard.

**9.2.2.2 Shipping Box**

Figure 9-5 shows a typical shipping box. If the shipping box has excess space, filler (such as cushion) is added.

**NOTE**

The size of the shipping box may vary depending on the number of reel boxes packed.



**Figure 9-5. Shipping Box**

The shipping box is made of corrugated fiberboard.

### **9.3 Packaging Information**

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
WL1807MODGIMOCR	ACTIVE			100	1200	TBD	Call TI	Call TI	-40 to 85		<a href="#">Samples</a>
WL1807MODGIMOCT	ACTIVE			100	250	TBD	Call TI	Call TI	-40 to 85		<a href="#">Samples</a>
WL1837MODGIMOCR	ACTIVE			100	1200	TBD	Call TI	Call TI	-40 to 85		<a href="#">Samples</a>
WL1837MODGIMOCT	ACTIVE			100	250	TBD	Call TI	Call TI	-40 to 85		<a href="#">Samples</a>
XWL1837MODGIMOC	ACTIVE			100	1	TBD	Call TI	Call TI	-40 to 85		<a href="#">Samples</a>

(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.

**OBSELETE:** 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.

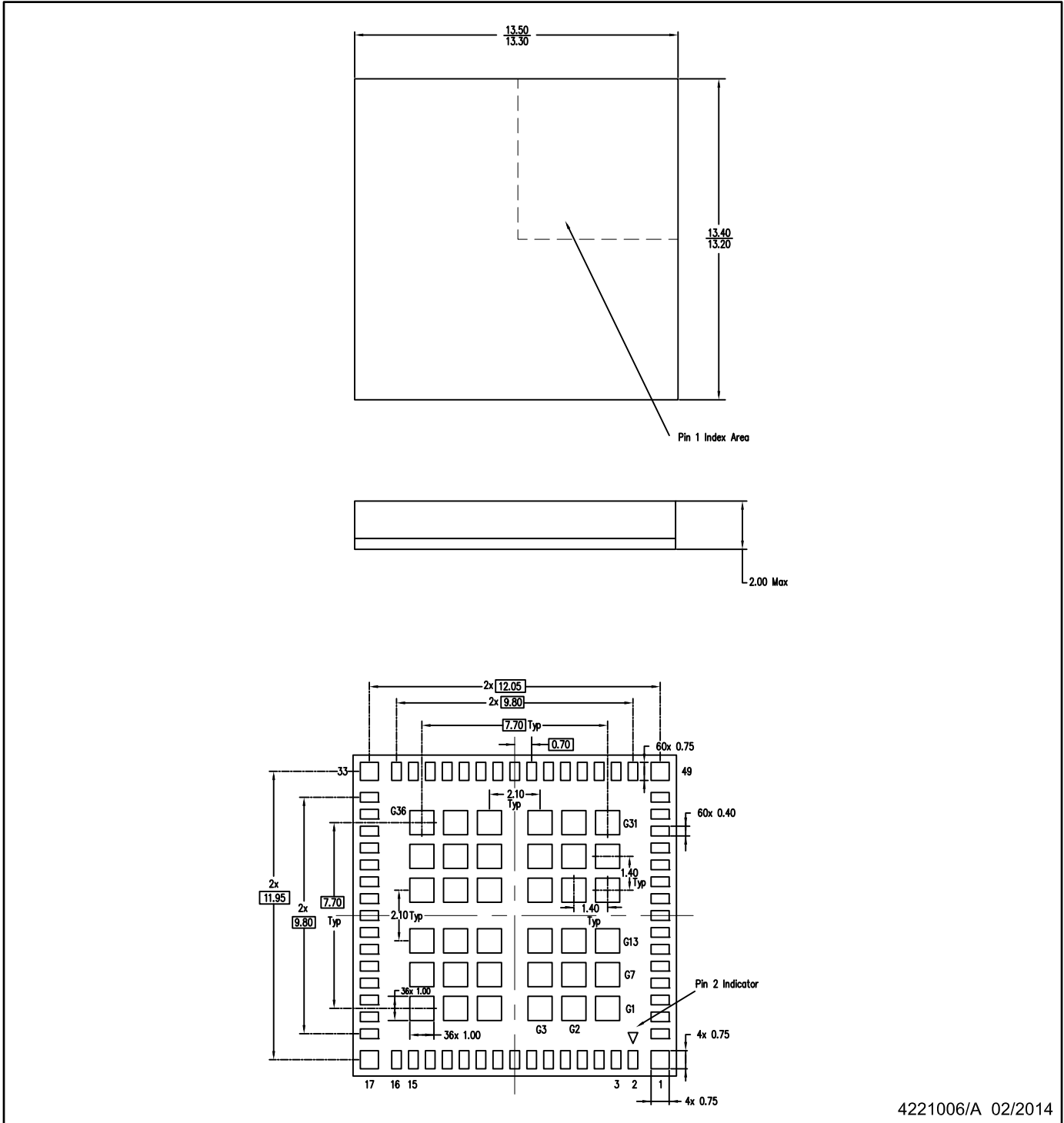
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

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

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NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

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