Datasheet

ST60-2230C-P/ST60-2230C-PU

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REVISION HISTORY

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1 SCOPE

This document describes key hardware aspects of the ST60-2230C-P/ ST60-2230C-PU M.2 module providing either PCIe bus interface for WLAN connection and UART(ST60-2230C-P)/USB (ST60-2230C-PU) for Bluetooth® (including Low Energy or LE) connection. This document is intended to assist device manufacturers and related parties with the integration of this module into their host devices. Data in this document is drawn from the Marvell 88W8997 datasheet issued in April 25, 2016.

Note that the information in this document is subject to change.

2 INTRODUCTION

2.1 General Description

The ST60-2230C-P/ST60-2230C-PU module is a dual band 2x2 802.11ac WLAN plus Bluetooth 5.1 dual mode adapter; it complies with M.2 2230 E-Key standard. The module provides both simultaneous and independent operation of the following:

- IEEE 802.11ac, 2x2 MIMO spatial stream multiplexing with data rates up to MCS9 (866.7 Mbps)
- Bluetooth (Class 1)
- Bluetooth 5.1 (with Low Energy or LE)
- Bluetooth *Smart Ready* operation
- Three-way coexistence for WLAN and Bluetooth

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Internal coexistence arbitration and a Mobile Wireless System (MWS) serial transport interface provide the functionality for connecting an external Long Term Evolution (LTE).

The module integrates all WLAN and Bluetooth functionality into a single package which supports low-cost and simple implementation along with flexibility for platform-specific customization. In addition, it has low power consumption radio architecture and proprietary power save technologies to extended battery life.

WLAN interface:

- PCIe – Supports PCIe V2.0 Gen 1/Gen 2 rate (2.5/5 Gbps) interface

Bluetooth Interfaces:

- USB 2.0 – ST60-2230C-PU only
- High-Speed UART – ST60-2230C-P only

The ST60-2230C-P/ST60-2230C-PU modules also provide a PCM interface for master or slave mode – with the option of an 8-bit or 16-bit width size. Pins CON[0], CON[1], and CON[2] are used to configure the operation interface.

- ST60-2230C-P – The interfaces are PCIe/UART (WLAN/Bluetooth) with configuration setting to *011*.
- ST60-2230C-PU – The interfaces are PCIe/USB (WLAN/Bluetooth) with configuration setting to *010*.

3 FEATURES SUMMARY

The ST60-2230C-P/ST60-2230C-PU device features are described in Table 1.

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Table 1: ST60-2230C-P/ST60-2230C-PU features

Feature	Description
Radio Front End	Integrates the complete transmit/receive RF paths including band pass filter, diplexer, switches, reference crystal oscillator, and power manage unit (PMU) Supports 20/40/80 MHz channel bandwidth WLAN/Bluetooth share one antenna
Coexistence	Coexistence arbitration for WLAN, Bluetooth, and LTE operation
Power Management	Dynamic Voltage Scaling (DVS) and Adaptive Voltage Scaling (AVS) feature supports the latest Marvell SoC and processor power control scheme.
Pre-Calibration	RF system-tested and calibrated in production.
Sleep Clock	An external sleep clock of 32.768 KHz is required during power save mode.
Host Interface	PCIe V2.0 Gen 1/Gen 2 for WLAN USB 2.0, HS-UART for Bluetooth HCI (compatible with any upper layer Bluetooth stack) PCM digital audio interface for Bluetooth audio application.
Reference Frequency	Incorporates a 40 MHz reference frequency source in package An external sleep clock is recommended for minimal current consumption. If no sleep clock input is provided, an internal sleep clock (derived from the reference clock) is used. An approximate 50 uA current increase on the 3.3V rail.
Advanced WLAN	A-MPDU RX (de-aggregation) and TX (aggregation) supports 802.11ac single-MPDU A-MPDU Multi- BSS/Station Transmit rate adaption, transmit power control Modulation and coding scheme (MCS): – 802.11ac—MCS0-9 Nsts=1 and 2 – 802.11n—MCS0-15 20/40/80 MHz channel bandwidths support On-chip gain selectable LNA with optimized noise figure and power consumption Internal PA with optimized gain distribution for linearity and noise performance Support Wild variety of WLAN encryption: TKIP/WEP/AES
Advanced Bluetooth	Bluetooth 5.1 (BDR/EDR/LE), Bluetooth Class 1 Bluetooth 5 ready Supports the following data rates: 1 Mbps (GFSK), 2 Mbps (π/4-DQPSK), 3 Mbps (8-DPSK) Digital audio interface with PCM/TDM interface for voice application Adaptive Frequency Hopping (AFH) using Package Error Rate (PER) Standard SDIO or UART HCI transport layer WLAN/Bluetooth coexistence protocol support Shared LNA with WLAN/Bluetooth Encryption (AES) support

Strap Value CONFIG_HOST[2-0]	WLAN	Bluetooth/BLE	ROM Notes
010	PCIe	USB 2.0	-
011	PCIe	UART	-

4 SPECIFICATIONS

Table 2: Specifications

Feature	Description
Physical Interface	84-pin LGA package (including 16 thermal ground pad under the package)

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Wi-Fi Interface	1-bit or 4-bit Secure Digital I/O; PCIe v2.0 Gen1/Gen2 (2.5/5 Gbps); USB 2.0
Bluetooth/ BLE Interface	Host Controller Interface (HCI) using High Speed UART, USB 2.0

Strap Value CONFIG_HOST[2-0]	WLAN	Bluetooth/ BLE	ROM Notes
010	PCIe	USB 2.0	-
011	PCIe	UART	-

Main Chip	Marvell 88W8997 (WLAN/BT); Marvell 88PG823 (PMU)
Input Voltage Requirements	DC 3.3 V ±10%
I/O Signalling Voltage	DC 1.8 V ± 10%
Peak Current consumption, **VCC**= 3.3 volts **VIO**= 1.8 volts (At maximum transmit power setting) *(Measured transmit current under 99% duty cycle)* ***Note:*** *Reset refers to the radio are in reset, both Wi-fi and BT reset are asserted.*	**MIMO 2x 2 operations.** **802.11b (with BT in standby) @ 18 dBm 1 Mbps** Transmit: 1050 mA Receive: 520 mA **802.11g (with BT in standby) @ 18 dBm 6 Mbps** Transmit: 980 mA Receive: 520 mA **802.11a (with BT in standby) @ 18 dBm 6 Mbps** Transmit: 1100 mA Receive: 580 mA **802.11n (2.4 GHz/40 MHz) (with BT in standby) @ 16 dBm MCS0** Transmit: 850 mA Receive: 520 mA **802.11n (5.0 GH/40 MHz) (with BT in standby) @ 16 dBm MCS0** Transmit: 900 mA Receive: 600 mA **802.11ac (5.0 GH/80 MHz) (with BT in standby) @ 14 dBm MCS0** Transmit: 850 mA Receive: 600 mA **Bluetooth (with Wi-Fi in standby)** Transmit: 120 mA Receive: 100 mA Reset: **90** mA
Operating Temperature	-30° to 85°C (-22° to 185°F)
Operating Humidity	10 to 90% (non-condensing)
Storage Temperature	-40° to 85°C (-40° to 185°F)
Storage Humidity	10 to 90% (non-condensing)
Maximum Electrostatic Discharge	Conductive 4KV; Air coupled 8KV follow EN61000-4-2
Size	22 mm (length) x 30 mm (width) x 3.3 mm (thickness)
Weight	2.5 g
Wi-Fi Media	Direct Sequence-Spread Spectrum (DSSS) Complementary Code Keying (CCK) Orthogonal Frequency Divisional Multiplexing (OFDM)
Bluetooth Media	Frequency Hopping Spread Spectrum (FHSS)

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Feature	Description
Wi-Fi Media Access Protocol	Carrier sense multiple access with collision avoidance (CSMA/CA) A-MPDU Rx (De-aggregation) and Tx (aggregation) (802.11ac single-MPDU A-MPDU)
Network Architecture Types	Infrastructure and ad-hoc
Wi-Fi Standards	IEEE 802.11a, 802.11b, 802.11d*, 802.11e, 802.11g, 802.11h, 802.11i, 802.11k*, 802.11n, 802.11r, 802.11v*, 802.11ac * Summit version only
Bluetooth Standards	Bluetooth version 2.1 with Enhanced Data Rate Bluetooth 5.1 (Bluetooth Low Energy or BLE)
Wi-Fi Data Rates Supported	Support 802.11 ac/a/b/g/n 2X2 MIMO MIMO/802.11ac 802.11b (DSSS, CCK) 1, 2, 5.5, 11 Mbps 802.11a/g (OFDM) 6, 9, 12, 18, 24, 36, 48, 54 Mbps 802.11n (OFDM, HT20/HT40, MCS 0-15) 802.11ac (OFDM, HT20, MCS0-8; OFDM HT40/HT80, MCS 0-9)
Modulation Table	BPSK, QPSK, CCK, 16-QAM, 64-QAM, and 256-QAM.

802.11ac / 802.11n					20 MHz		40 MHz		80 MHz	
HT MCS Index	**VHT MCS Index**	**Spatial Streams**	**Modulation**	**Coding**	**No SGI**	**SGI**	**No SGI**	**SGI**	**No SGI**	**SGI**
0	0	1	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5
1	1	1	QPSK	1/2	13	14.4	27	30	58.5	65
2	2	1	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5
3	3	1	16-QAM	1/2	26	28.9	54	60	117	130
4	4	1	16-QAM	3/4	39	43.3	81	90	175.5	195
5	5	1	64-QAM	2/3	52	57.8	108	120	234	260
6	6	1	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5
7	7	1	64-QAM	5/6	65	72.2	135	150	292.5	325
	8	1	256-QAM	3/4	78	86.7	162	180	351	390
	9	1	256-QAM	5/6	N/A	N/A	180	200	390	
8	0	2	BPSK	1/2	13	14.4	27	30		**433.3**
									58.5	65
9	1	2	QPSK	1/2	26	28.9	54	60	117	130
10	2	2	QPSK	3/4	39	43.3	81	90	175.5	195
11	3	2	16-QAM	1/2	52	57.8	108	120	234	260
12	4	2	16-QAM	3/4	78	86.7	162	180	351	390
13	5	2	64-QAM	2/3	104	115.6	216	240	468	520
14	6	2	64-QAM	3/4	117	130.3	243	270	526.5	585
15	7	2	64-QAM	5/6	130	144.4	270	300	585	650
	8	2	256-QAM	3/4	156	173.3	324	360	702	180
	9	2	256-QAM	5/6	N/A	N/A	360	400	780	**866.7**

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802.11ac/n Spatial Streams	2 (2x2 MIMO)
Bluetooth Data Rates Supported	1, 2, 3 Mbps

Feature	Description
Bluetooth Modulation	GFSK@ 1 Mbps Pi/4-DQPSK@ 2 Mbps 8-DPSK@ 3 Mbps
Regulatory Domain Support	FCC EU ISED (Canada) MIC (Japan) KC (Korea)
2.4 GHz Frequency Bands	**EU:** 2.4 GHz to 2.483 GHz **FCC:** 2.4 GHz to 2.473 GHz **MIC:** 2.4 GHz to 2.495 GHz **KC:** 2.4 GHz to 2.483 GHz
2.4 GHz Operating Channels	**EU:** 13 (3 non-overlapping) **FCC:** 11 (3 non-overlapping) **(Wi-Fi)** **MIC:** 14 (4 non-overlapping) **KC:** 13 (3 non-overlapping)
5 GHz Frequency Bands	**EU** 5.15 GHz to 5.35 GHz (Ch 36/40/44/48/52/56/60/64) 5.47 GHz to 5.725 GHz (Ch 100/104/108/112/116/120/124/128/132/136/140) 5.725 GHz to 5.825 GHz(Ch 149/153/157/161/165) **FCC** 5.15 GHz to 5.35 GHz (Ch 36/40/44/48/52/56/60/64) 5.47 GHz to 5.725 GHz (Ch 100/104/108/112/116/120/124/128/132/136/140/144) 5.725 GHz to 5.825 GHz(Ch 149/153/157/161/165) **MIC** 5.15 GHz to 5.35 GHz (Ch 36/40/44/48/52/56/60/64) 5.47 GHz to 5.725 GHz (Ch 100/104/108/112/116/120/124/128/132/136/140) **KC** 5.15 GHz to 5.35 GHz (Ch 36/40/44/48/52/56/60/64) 5.47 GHz to 5.725 GHz (Ch 100/104/108/112/116/120/124) 5.725 GHz to 5.825 GHz (Ch 149/153/157/161/165)
5 GHz Operating Channels (Wi-Fi)	**EU:** 24 non-overlapping; **FCC:** 25 non-overlapping **MIC:** 19 non-overlapping; **KC:** 20 non-overlapping

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Transmit Power ***Note:*** *Transmit power on each channel varies according to individual country regulations. All values are nominal with +/-2 dBm tolerance at room temperature.* *Tolerance could be up to +/-2.5 dBm across operating temperature.* ***Note:*** *HT20 – 20 MHz-wide channels*	**802.11a** 6 Mbps 54 Mbps **802.11b** 1 Mbps 11 Mbps **802.11g** 6 Mbps 54 Mbps **802.11n (2.4/5 GHz)** 6.5 Mbps (MCS0-5/MCS8-13;HT20) 65 Mbps (MCS6-7/MCS14-15;HT20) 13.5Mbps(MCS0-5/MCS8-13;HT40) 135Mbps (MCS6-7/MCS14-15;HT40) **802.11ac (5 GHz)** 6.5/13 Mbps (MCS0-6;Ntst=1,2;HT20)	 18 dBm (63 mW) 16 dBm (40 mW) 18 dBm (63 mW) 18 dBm (63 mW) 18 dBm (63 mW) 16 dBm (40 mW) 18 dBm (63 mW) 16 dBm (40 mW) 16 dBm (40 mW) 14 dBm (25 mW) 18 dBm (63 mW)

Feature	Description	
HT40 – 40 Mhz-wide channels *HT80 – 80 MHz-wide channels*	78/156 Mbps (MCS7-8;Ntst=1,2;HT20) 13.5/27Mbps (MCS0-6;Ntst=1,2;HT40) 180/360Mbps (MCS7-9;Ntst=1,2;HT40) 29.3/58.5 Mbps (MCS0-5;Ntst=1,2;HT80) 263.3/526.5 Mbps (MCS6-8;Ntst=1,2;HT80) 390/780 Mbps (MCS9;Ntst=1,2;HT80)	16 dBm (40 mW) 16 dBm (40 mW) 14 dBm (25 mW) 14 dBm (25 mW) 12 dBm (15.8 mW) 10 dBm (10 mW)
	Bluetooth 1 Mbps (1DH5) 2 Mbps 3 Mbps BLE (1 Mbps)	10 dBm (12.5 mW) 7 dBm (6.3 mW) 7 dBm (6.3 mW) 7 dBm (6.3 mW)
Typical Receiver Sensitivity (PER <= 10%) ***Note:*** *All values nominal, +/-3 dBm.* *Sensitivity on CH13 (WLAN)/CH78 (BT) will decade up to 4-6dB.*	**802.11a:** 6 Mbps 54 Mbps **802.11b:** 1 Mbps 11 Mbps **802.11g:** 6 Mbps 54 Mbps **802.11n (2.4 GHz)** 6.5 Mbps (MCS0;HT20)	 -89 dBm -74 dBm -95 dBm -90 dBm (PER<8%) -91 dBm -75 dBm -91 dBm

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65 Mbps (MCS7;HT20)	-73 dBm
13.5Mbps(MCS0;HT40)	-85 dBm
135Mbps (MCS7;HT40)	-70 dBm
802.11n (5 GHz)	
6.5 Mbps (MCS0;HT20)	-89 dBm
65 Mbps (MCS7;HT20)	-70 dBm
13.5Mbps(MCS0;HT40)	-86 dBm
135Mbps (MCS7;HT40)	-69 dBm
802.11ac (5 GHz)	
6.5 Mbps (MCS0;HT20)	-89 dBm
78 Mbps (MCS8;HT20)	-67 dBm
13.5 Mbps (MCS0;HT40)	-86 dBm
180 Mbps (MCS9;HT40)	-63 dBm
29.3 Mbps (MCS0;HT80)	-81 dBm
390/780 Mbps (MCS9;HT80)	-60 dBm
Bluetooth:	
1 Mbps (1DH5)	-95 dBm
2Mbps (2DH5)	-94 dBm
3 Mbps (3DH5)	-88 dBm
BLE	-95 dBm

Operating Systems Supported	Linux Kernel Android

Feature	**Description**
Security	**Standards** Wireless Equivalent Privacy (WEP) Wi-Fi Protected Access (WPA) WPA2-Personal WPA2-Enterprise WPA3-Personal WPA3-Enterprise **Encryption** Wireless Equivalent Privacy (WEP, RC4 Algorithm) Temporal Key Integrity Protocol (TKIP, RC4 Algorithm) Advanced Encryption Standard (AES, Rijndael Algorithm) Encryption Key Provisioning Static (40-bit and 128-bit lengths) Pre-Shared (PSK) **Dynamic** 802.1X Extensible Authentication Protocol Types EAP-FAST, PEAP-MSCHAPv2 EAP-TLS, PEAP-TLS EAP-TTLS, LEAP PEAP-GTC ***Note:*** *EAP types are supplicant software dependent.*

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Compliance	**EU** EN 300 328 EN 300 440 EN 301 489-1 EN 301 489-17 EN 301 893 **FCC** 47 CFR FCC Part 15.247 47 CFR FCC Part 15.407 47 CFR FCC Part 2.1091 FCC Part 15 Subpart B Class B **AS/NZS** AS/NZS 2772.2:2011 AS/NZS 4268:2017 **KC (Korea)**	62311:2008 EN 50665:2017 EN 50385:2017 EU 2015/863 (RoHS 3) **ISED Canada** ICES-003 ANSI C63.4:2014 RSS-247 **MIC** ARIB STD-T66/RCR STD-33 (2.4 GHz) ARIB STD-T71 (5 GHz) **SRRC (China)**
Certifications	*Bluetooth*® SIG Qualification	
Warranty	One Year Warranty	

All specifications are subject to change without notice

5 WLAN Functional Description

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The ST60-2230C-P/ST60-2230C-PU M.2 module is designed based on the 60-SIPT SiP. It is optimized for high-speed, reliable, and low-power embedded applications. It is integrated with dual-band WLAN (2.4 GHz/5 GHz) and Bluetooth 5.1. Its functionality includes the following:

- Improved throughput on the link due to frame aggregation, RIFS (reduced inter-frame spacing), and half-guard intervals.
- Support for STBC (Space Time Block Codes) and LDPC (Low Density Parity Check) codes.
- Improved 11n performance due to features such as 11n frame aggregation (A-MPDU and A-MSDU) and low-overhead host-assisted buffering (RX A-MSDU and RX A-MPDU). These techniques can improve performance and efficiency of applications involving large bulk data transfers such as file transfers or high-resolution video streaming.
- IEEE 802.11 ac, 2X2 MIMO spatial stream multiplexing with data rate up to MCS9 (866.7 Mbps).

Additional functionality is listed in Table 3.

Table 3: WLAN functions

Feature	Description
WLAN MAC	- Frame Exchange at the MAC level to deliver data - Received frame filtering and validation (Cyclic Redundancy Check (CRC)) - Generation of MAC header and trailer information (MAC protocol Data Units (MPDUs)) - Fragmentation of data frames (MAC Service Data Units (MSDUs) - Access Mechanism support for fair access to shared wireless medium through (DCF and EDCA) - A-MPDU Aggregation/Deaggregation (support 802.11ac single –MPDU A-MPDU) - 20/40/80 MHz channel Coexistence - RIFS Burst Receive - Management Information Base - Radio Resource Measurement - Quality of Service - Block Acknowledgement - 802.11ac MIMO - Dynamic Frequency Selection - Beamforming - TIM Frame TX and RX - Multi-BSS/Station - Transmit Rate Adaptation. - Transmit Power Control
Feature	**Description**

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WLAN Base Band	• 802.11ac 2x2 MIMO (with on-chip Marvell RF radio) • Backward compatibility with legacy 802.11 n/a/b/g technology • WLAN/Bluetooth LNA sharing • PHY rate up to 866.7Mbps • 20MHz bandwidth/channel, 40MHz bandwidth/channel, upper/lower 20MHz packets in 40MHz channel, 20MHz duplicate legacy packets in 40MHz channel operation • 80MHz bandwidth/channel, 4 positions of 20MHz packets in 80MHz channel, upper/lower 40MHz packets in 80MHz channel, 20MHz quadruplicate legacy packets in 80MHz channel mode operation • Modulation and Coding Scheme (MCS): 802.11 ac (MCS0-9. Nsts=1/2); 802.11n (MCS0-15) • 802.11 K Radio Resource Measurement • 802.11ac /802.11n optional MIMO features: – 20/40/80 MHz Coexistence with middle-packaged detection (GI detection) for enhanced CCA. – 1 spatial stream STBC reception and transmission – LDPC transmission and reception for 802.11ac and 802.11n – 256 QAM (MCS8-9) modulations supported – Short guard interval – RIFS on receive path for 802.11n packets – 802.11n Greenfield TX/RX • Power Save Feature
WLAN Security	WLAN Encryption features supported include: • Temporal Key Integrity Protocol (TKIP)/Wired Equivalent Privacy (WEP) • Advanced Encryption Standard (AES)/Counter-Mode/CBC-MAC Protocol (CCMP) • Advanced Encryption Standard (AES)/Cipher-Based Message Authentication Code (CMAC) • Advanced Encryption Standard (AES)/Galois/Counter Mode Protocol (GCMP) • WLAN Authentication and Private Infrastructure (WPAI)

Feature	Description

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WLAN Channel

Channel frequency supported.

20 MHz				40 MHz		80 MHz	
Channel	Freq. (MHz)	Channel	Freq. (MHz)	Channel	Freq. (MHz)	Channel	Freq. (MHz)
1	2412	36	5180			42	5210
2	2417	40	5200			58	5290
3	2422	44	5220			74	5370
4	2427	48	5240			90	5410
5	2432	52	5260			106	5530
6	2437	56	5280			122	5610
7	2422	60	5300			138	5690
8	2447	64	5320			155	5775
9	2452	100	5500				
10	2457	104	5520				
11	2462	108		1-5	2422		
				2-6	2427		
				3-7	2432		
				4-8	2437		
				5-9	2422		
				6-10	2447		
				7-11	2452		
				36-40	5190		
				44-48	5230		
				52-56	5270		
				60-64	5310		
				68-72	5350		
				76-80	5390		
				84-88	5430		
				92-96	5470		
				100-104	5510		
				108-112	5550		
				116-120	5590		
				124-128	5630		
				132-136	5670		
				140-144	5710		
			5540	149-153	5755		
12	2467	112	5560				
13	2472	116	5580				
		120	5600				
		124	5620				
		128	5640				
		132	5660				
		136	5680				
		140	5700				
		144	5720				

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	149	5745			
	153	5765			
	157	5785	157-161	5795	
	161	5805			
	165	5825			

6 BLUETOOTH FUNCTIONAL DESCRIPTION

The ST60-2230C-P/ST60-2230C-PU Bluetooth (BT) block is based on the 60-SIPT SiP that already has fully-integrated Bluetooth baseband and radio. Several features and functions are listed in Table 4.

Table 4: Bluetooth functions

Feature	Description
Bluetooth Interface	Voice interface: - Hardware support for continual PCM data transmission/reception without processor overhead. - Standard PCM clock rates from 64 kHz to 2.048 MHz with multi-slot handshake and synchronization. - A-law, U-law, and linear voice PCM encoding/decoding. - High-Speed UART interface – ST60-2230C-P only

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	• USB 2.0 – ST60-2230C-PU only
Bluetooth Low Energy (BLE) Core functionality	• Advertiser, Scanner, Initiator, Master, and Slave roles support (connects up to 16 links) • WLAN/Bluetooth Coexistence (BCA) protocol support • Shared RF with BDR/EDR • Encryption (AES) support • Intelligent Adaptive Frequency Hopping (AFH) LE • privacy 1.2 • LE Secure Connection • LE Data Length Extension • 2 Mbps LE
Bluetooth Core functionality	• Bluetooth 5.1 • Bluetooth Class 1 • WLAN and Bluetooth share same LNA and antenna • Digital audio interfaces with PCM/TDM interface for voice application • Baseband and radio BDR and EDR package type: 1Mbps, 2Mbps, 3Mbps • Fully functional Bluetooth baseband: AFH, forward error correction, header error control, access code correction, CRC, encryption bit stream generation, and whitening • Adaptive Frequency Hopping (AFH) using Packet Error Rate (PER) • Interlaced scan for faster connection setup • Simultaneous active ACL connection setup • Automatic ACL package type selection • Full master and slave piconet support • Scatter net support • SCO/eSCO links with hardware accelerated audio signal processing and hardware supported PPEC algorithm for speech quality improvement • All standard SCO/eSCO voice coding

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- All standard pairing, authentication, link key, and encryption operations
- Encryption (AES) support

7 Block Diagram

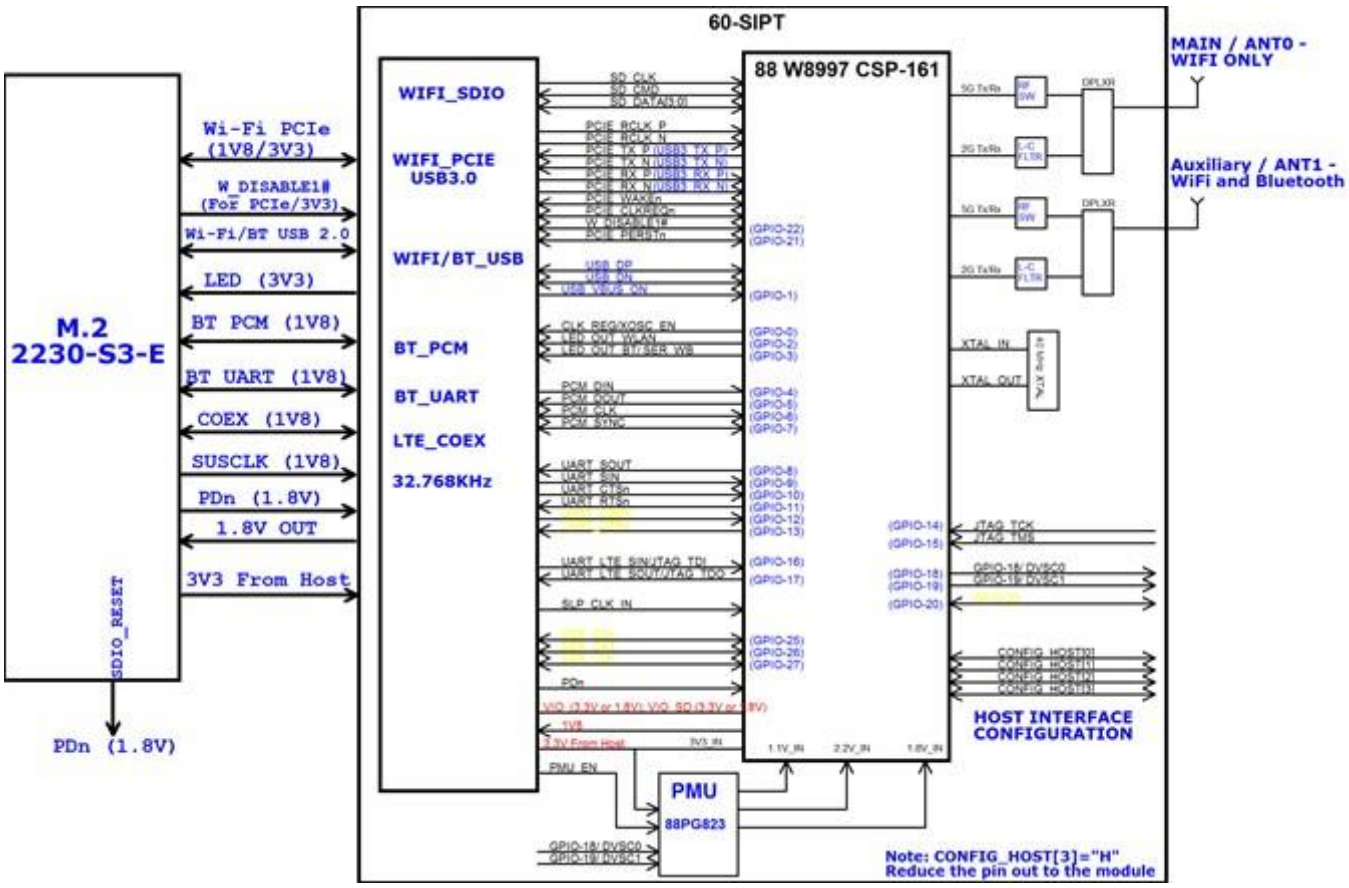

Figure 1: Block Diagram of ST60-2230C-P/ST60-2230C-PU

8 Electrical Characteristics

8.1 Absolute Maximum Ratings

Table 5 summarizes the absolute maximum ratings and Table 6 lists the recommended operating conditions for the ST602230C-P/ST60-2230C-PU. Absolute maximum ratings are those values beyond which damage to the device can occur. Functional operation under these conditions, or at any other condition beyond those indicated in the operational sections of this document, is not recommended.

Note: Maximum rating for signals follows the supply domain of the signals.

Table 5: Absolute maximum ratings

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Symbol (Domain)	Parameter	Max Rating	Unit
VIO	I/O configuration power supply (1.8V system)	2.2	V
3V3	External 3.3V power supply	4.0	V
Storage	Storage Temperature	-40 to +85	°C
ANT0; ANT1	Maximum RF input (reference to 50-Ω input)	+10	dBm
ESD	Electrostatic discharge tolerance	2000	V

8.2

Recommended Operating Conditions

6: Recommended Op Conditions

Symbol (Domain)	Parameter	Min	Typ	Max	Unit
VIO	WLAN and BT GPIO I/O power supply	1.62	1.8	1.98	V
3V3	External 3.3V power supply	2.97	3.30	3.63	V
T-ambient	Ambient temperature	-30	25	85	°C

Table

8.3 DC Electrical Characteristics

Table 7 list the general DC electrical characteristics over recommended operating conditions (unless otherwise specified).

Table 7: General DC electrical characteristics (For 1.8V operation VIO)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VIH	High Level Input Voltage	--	7 x 1V8 0.		1V8+0.4	V
VIL	Low Level Input Voltage	--	-0.4		0.3 x 1V8	V
VHYS	Input Hysteresis	--	100			mV
VOH	Output high Voltage	--	1V8-0.4			V
VOL	Output low Voltage	--			0.4	V

8.4 WLAN Radio Receiver Characteristics

Table 8 and Table 9 summarize the WLAN ST60-2230C-P/ST60-2230C-PU receiver characteristics.

Table 8: WLAN receiver characteristics for 2.4 GHz signal chain operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Frx	Receive input frequency range		2.412		2.484	GHz

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Srf	Sensitivity					
	CCK, 1 Mbps	See Note[3]		-95		dBm
	CCK, 11 Mbps			-90		
	OFDM, 6 Mbps			-91		
	OFDM, 54 Mbps			-75		
	HT20, MCS0			-91		
	HT20, MCS7			-73		
Radj	Adjacent channel rejection					
	OFDM, 6 Mbps	See Note[4]		TBD		dB
	OFDM, 54 Mbps			TBD		
	HT20, MCS0			TBD		
	HT20, MCS7			TBD		

[3]Performance data are measured under signal chain operation.

[4]Performance data are measured under signal chain operation.

Table 9: WLAN receiver characteristics for 5 GHz dual chain operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Frx	Receive input frequency range		5.15		5.825	GHz
Srf	Sensitivity					
	OFDM, 6 Mbps	See Note[1]		-89		dBm
	OFDM, 54 Mbps			-74		
	HT20, MCS0			-89		
	HT20, MCS7			-70		
	HT40, MCS0			-8[2]		
	HT40, MCS7			-69		
Radj	Adjacent channel rejection					
	OFDM, 6 Mbps	See Note[6]		TBD		dB
	OFDM, 54 Mbps			TBD		
	HT20, MCS0			TBD		
	HT20, MCS7			TBD		

[1] Performance data are measured under signal chain operation

[2] Performance data are measured under signal chain operation.

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8.5 WLAN Transmitter Characteristics

Table 10: WLAN transmitter characteristics for 2.4 GHz per chain operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Ftx	Transmit output frequency range		2.412		2.484	GHz
Pout	Output power	See Note[7]				
	11b mask compliant	1-11Mbps		18		dBm
	11g mask compliant	6-36Mbps		18		
	11g EVM compliant	48-54Mbps		16		
	11n HT20 mask compliant	MCS0-5/MCS8-13		18		
	11n HT20 EVM compliant	MCS6-7/MCS14-15		16		
	11n HT40 mask compliant	MCS0-5/MCS8-13		16		
	11n HT40 EVM compliant	MCS6-7/MCS14-15				
ATx	Transmit power accuracy at 25 ℃	-	-			dB

14
+ 2.0

Freq.	Mode/Rate (Mbps)	Output Power Per Chain (dBm)	Max. Current Consumption	
			Single Chain (mA)[8]	Dual Chains (mA)[8]
	1 Mbps	18dBm	340	620
2412 MHz	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510
	Mbps	18dBm	340	620
MHz 54 Mbps		16dBm	280	500
	HT20 MCS7	16dBm	280	510

11: WLAN transmitter characteristics for 5 GHz pe · chain operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	1 Mbps	18dBm	340		620	
2442 MHz	54 Mbps	16dBm	280		500	
	HT20 MCS7	16dBm	280		510	

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Ftx	Transmit output frequency range		5.15		5.925	GHz
Pout	Output power	See Note[3]				
	11a mask compliant	6-36Mbps		18		dBm
	11a EVM compliant	48-54Mbps		16		
	11n HT20 mask compliant	MCS0-5/MCS8-13		18		
	11n HT20 EVM compliant	MCS6-7/MCS14-15		16		
	11n HT40 mask compliant	MCS0-5/MCS8-13		16		
	11n HT40 EVM compliant	MCS6-7/MCS14-15		16		
	11ac HT20 mask compliant	MCS0-6 (Ntst=1,2)		18		
	11ac HT20 EVM compliant	MCS7-8(Ntst=1,2)		16		
	11ac HT40 mask compliant	MCS0-5 (Ntst=1,2)		16		
	11ac HT40 EVM compliant	MCS6-9(Ntst=1,2)		14		
	11ac HT80 mask compliant	MCS0-5 (Ntst=1,2)		14		
Symbol	**Parameter**	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
	11ac HT80 EVM compliant	MCS6-8(Ntst=1,2)		12		
	11ac HT80 EVM compliant	MCS9(Ntst=1,2)		10		
ATx	Transmit power accuracy at 25 ℃	-	-	+ 2.0		dB

Freq.	**Mode/Rate [Mbps]**	**Output Power Per Chain [dBm]**	**Max. Current Consumption**	
			Single Chain (mA)[8]	**Dual Chains (mA)[8]**
5180 MHz	6 Mbps	18 dBm	400	710
	54 Mbps	16 dBm	330	610
	HT20 MCS0	18 dBm	400	720
	HT20 MCS7	16 dBm	360	620
5190 MHz	HT40 MCS7	14 dBm	320	550
5500 MHz	6 Mbps	18 dBm	380	680
	54 Mbps	16 dBm	330	600
	HT20 MCS0	18 dBm	370	690
	HT20 MCS7	16 dBm	320	600
5510 MHz	HT40 MCS7	14 dBm	300	530
5825 MHz	6 Mbps	18 dBm	380	690
	54 Mbps	16 dBm	310	600
	HT20 MCS0	18 dBm	360	710
	HT20 MCS7	16 dBm	340	550

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	HT40 MCS7	14 dBm	300	530
5795 MHz				

[7]Performance data are measured under single chain operation.

Note: Final TX power values on each channel are limited by the regulatory certification test limit.

9 Bluetooth Radio Characteristics

Table 11 through Table 14 describe the basic rate transmitter performance, enhanced data transmitter performance, basic rate receiver performance, enhanced rate receiver performance, and current consumption conditions at 25°C.

Test Parameter	Min	Typ	Max	BT Spec.	Unit
Maximum RF Output Power	8	10	11		dBm
Frequency Range	2.4	—	2.4835		GHz
20 dB Bandwidth	—	919.5	—		KHz
Δf1avg Maximum Modulation	140	165	175	140 < Δf1avg < 175	KHz
Δf2max Minimum Modulation	—	135	—		KHz
Δf2avg/Δf1avg	—	0.9	—		—
Initial Carrier Frequency	—	+/-5	—		KHz
Drift Rate (DH1 package)	—	4	—		KHz/50 µs

Table 11: Basic rate transmitter performance temperature at 25°C (1.8V)

Drift (DH5 packet)		—	7	—		KHz
Adjacent Channel Power	F≥ ± 3MHz	—	–50	—		dBm

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	F = ± 2MHz	—	-46	—		dBm
	F = ± 1MHz	—	-15	—	N/A	dBm
					0 ~ +20	
					2.4 ≤ f ≤ 2.4835	
					≤ 1000	
					≥ 115	
					≥ 0.80	
					≤±75	
					≤ 20	
					≤25	
					≤ 40	
					< –40	
Drift (DH3 packet)		—	8	—	≤ –20	KHz

Table 12: Enhanced data rate transmitter performance 25°C (1.8V)

			4			
			4			
Test Parameter		**Min**	**Typ**	**Max**	**BT Spec.**	**Unit**
Relative Transmit Power		5		9		dBm
Max Carrier Frequency Stability |wo|	2-DH5	—	7	—	≤ ±10	KHz
			1			
	3-DH5	—	1	—		
Max Carrier Frequency Stability |wi|	2-DH5	—		—	≤ ±75	KHz
	3-DH5	—		—		
Max Carrier Frequency Stability |w0+wi|	2-DH5	—		—	≤ ±75	KHz
	3-DH5	—	5	—		
			5			
RMS DEVM	2-DH5	—		—	≤ 20	%

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			4	—		%
	3-DH5	—	4			
Peak DEVM	2-DH5	—		—	≤13	%
					≤ 35	
	3-DH5	—	9	—	≤ 25	%
99% DEVM	2-DH5	—	9 12	—	≤ 30	%
	3-DH5	—	12	—	≤ 20	%
EDR Differential Phase Encoding		—	99	—	≥ 99	%
Adjacent Channel Power	F≥ ± 3MHz	—	TBD	—	< –40	dBm
	F = ± 2MHz	—	TBD	—	≤ –20	dBm

Table 13: Basic rate receiver performance at 1.8V

Test Parameter		Min	Typ	Max	BT Spec.	Unit
Sensitivity (1DH5)	BER ≤ 0.1%	—	–95	-92	≤ –70	dBm
Maximum Input	BER ≤ 0.1%	–20	-10	—	≥ –20	dBm
Carrier-to-Interferer Ratio	Co-Channel	—	10	11	11	
	C/I (± 1 MHz)	—	-4	0	0	
(C/I)	C/I (± 2 MHz)	—	-45	—	–30	dB
	C/I (± 3 MHz)	—	-49	—	–40	dB
Maximum Level of Intermodulation Interferers		–39	-30		≥ –39	dBm

14: Enhanced data rate receiver performance 1.8V

Test Parameter	Min	Typ	Max	Bluetooth Specification	Unit
					dB

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Sensitivity (BER ≤0.01%)	π/4 DQPSK	—	-94	-91	≤ –70	dBm
	8 DPSK	—	-88	-85	≤ –70	dBm
Maximum Input (BER ≤0.1%)	π/4 DQPSK	–20	—	—	≥ –20	dBm
	8 DPSK	–20	—	—	≥ –20	dBm
			10	13	≤ ±13	
			16	20	≤ ±20	
Adjacent Channel C/I (1 MHz)	π/4 DQPSK	—	-9	0	≤ 0	dB
	8 DPSK	—	-6	5	≤5	dB
Second Adjacent Channel C/I (2	π/4 DQPSK	—	-47	–30	≤ –30	dB
Co-Channel C/I (BER ≤0.1%)	π/4 DQPSK	—				dB
	8 DPSK	—				dB
MHz)	8 DPSK	—		–25		dB
Third Adjacent Channel C/I (3 MHz)	π/4 DQPSK	—		–40	–25 –40 –33	dB
	8 DPSK	—		–33		dB
Out-of-band blocking	30-2000MHz		-42	—	—	dBm
	2-2.399GHz		-51	—	—	dBm
	2.484-3GHz		-48	—	—	dBm
	3-12.75GHz		-12.5	—	—	dBm
			-12.4			
			-18			
			-2.6			
		—				
		—				
		—				
		—				

10 PCIE SPECIFICATIONS

The ST60-2230C-P/ST60-2230C-PU PCIe host interface pins are powered from the AVDD18 voltage supply. The PCI Express interface supports a x1 PCI Express interface (one Lane). A Lane consists of an input and an output high-speed differential pair. Also supported is a PCI Express reference clock. Refer to the PCI Express Base Specification for more details on the functional requirements for the PCI Express interface signals.

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10.1 Differential Tx Output Electricals

NOTE: In accordance with PCI Express Base Specification, Revision 2.1 March 4, 2009.

Table 15: PCI Express Tx Output Specifications—2.5 GT/s

Symbol	Parameter	Min	Typ	Max	Units
UI	Unit interval (UI) The specified UI is equivalent to a tolerance of ±300 ppm for each Refclk source. Period does not account for SSC induced variations.	399.88	--	400.12	ps
VTx-DIFF-PP	Differential peak-to-peak Tx voltage swing VTx-DIFFpp = 2*|VTXD+ - VTXD-|	0.8	--	1.2	V
VTx-DIFF-PP-LOW	Low power differential peak-to-peak Tx voltage swing VTx-DIFFpp = 2*|VTXD+ - VTXD-|	0.4	--	1.2	V
VTx-DE-RATIO-3.5dB	Tx de-emphasis level ratio (3.5 dB)	3.0	--	4.0	dB
TTx-EYE	Tx eye including all jitter sources	0.75	--	--	UI
TTx-EYE-MEDIAN-to-MAX-JITTER	Maximum time between jitter median and maximum deviation from median	--	--	0.125	UI
TTx-RISE-FALL	Tx rise/fall time Measured differentially from 20% to 80% of swing.	0.125	--	--	UI
RLTx-DIFF	Tx package plus Si differential return loss	10	--	--	dB
RLTx-CM	Tx package plus Si common mode return loss	6	--	--	dB
VTx-CM-AC-P	Tx AC common mode voltage	--	20	--	mV
ITx-SHORT	Tx short circuit current limit	--	--	90	mA
VTx-DC-CM	Tx DC common mode voltage	0	--	3.6	V
VTx-CM-DC-ACTIVE-IDLE-DELTA	Absolute delta of DC common mode voltage during L0 and electrical idle	0	--	100	mV
VTx-IDLE-DIFF-AC-p	Electrical idle differential peak output voltage	0	--	20	mV
VTx-RCV-DETECT	Voltage change allowed during receiver detection	--	--	600	mV
TTx-IDLE-MIN	Minimum time spent in electrical idle	20	--	--	ns
TTx-IDLE-SET-TO-IDLE	Maximum time to transition to a valid electrical idle after sending an electrical idle ordered set	--	--	8	ns
TTx-IDLE-TO-DIFF-DATA	Maximum time to transition to valid diff signaling after leaving electrical idle	--	--	8	ns
TCROSSLINK	Crosslink random timeout	--	--	1.0	ms
C_{TX}	AC coupling capacitor	75	--	200	nF

Table 16: PCI Express Tx Output Specifications—5 GT/s

Symbol	Parameter	Min	Typ	Max	Units

UI	Unit interval (UI) The specified UI is equivalent to a tolerance of ±300 ppm for each Refclk source. Period does not account for SSC induced variations.	199.94	--	200.06	Ps
VTx-DIFFpp	Differential peak-to-peak Tx voltage swing $V_{Tx\text{-}DIFFpp} = 2*\lvert V_{TXD+} - V_{TXD-}\rvert$	0.8	--	1.2	V
VTx-DIFFpp-LOW	Low power differential peak-to-peak Tx voltage swing $V_{Tx\text{-}DIFFpp} = 2*\lvert V_{TXD+} - V_{TXD-}\rvert$	0.4	--	1.2	V
VTx-DE-RATIO-3.5dB	Tx de-emphasis level ratio (3.5 dB)	3.0	--	4.0	dB
VTx-DE-RATIO-6dB	Tx de-emphasis level ratio (6 dB)	5.5	--	6.5	dB
TMIN-PULSE	Instantaneous lone pulse width Measured relative to rising/falling pulse.	0.9	--	--	UI
TTx-EYE	Tx eye including all jitter sources	0.75	--	--	UI
TTx-HF-DJ-DD	Tx deterministic jitter > 1.5 MHz Deterministic jitter only.	--	--	0.15	UI
TTx-LF-RMS	Tx RMS jitter < 1.5 MHz Total energy measured over a 10 kHz–1.5 MHz range.	--	3.0	--	Ps RMS
TTx-RISE-FALL	Tx rise/fall time Measured differentially from 20% to 80% of swing.	0.15	--	--	UI
RLTx-DIFF	Tx package plus Si differential return loss (0.05–1.25 GHz)	10	--	--	dB
	Tx package plus Si differential return loss (1.25–2.5 GHz)	8	--	--	
RLTx-CM	Tx package plus Si common mode return loss				dB
VTx-CM-AC-PP	Tx AC common mode voltage				mVPP
ITx-SHORT	Tx short circuit current limit				mA
VTx-DC-CM	Tx DC common mode voltage				V
VTx-CM-DC-ACTIVE-IDLE-DELTA	Absolute delta of DC common mode voltage during L0 and electrical idle				mV
VTx-IDLE-DIFF-AC-p	Electrical idle differential peak output voltage $V_{Tx\text{-}IDLE\text{-}DIFF\text{-}DC} = \lvert V_{Tx\text{-}Idle\text{-}D+} - V_{Tx\text{-}Idle\text{-}D-}\rvert \le 20$ mV				mV
VTx-IDLE-DIFF-DC	DC electrical idle differential output voltage $V_{Tx\text{-}IDLE\text{-}DIFF\text{-}DC} = \lvert V_{Tx\text{-}Idle\text{-}D+} - V_{Tx\text{-}Idle\text{-}D-}\rvert \le 5$ mV				mV
VTx-RCV-DETECT	Voltage change allowed during receiver detection				mV
TTx-IDLE-MIN	Minimum time spent in electrical idle				ns
TTx-IDLE-SET-TO-IDLE	Maximum time to transition to a valid electrical idle after sending an electrical idle ordered set		--	8	ns
TTx-IDLE-TO-DIFF-DATA	Maximum time to transition to valid differential signaling after leaving electrical idle	--	--	8	ns
TCROSSLINK	Crosslink random timeout	--	--	1.0	ms
CTx	AC coupling capacitor	75	--	200	nF

10.2 Differential Rx Input Electricals

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NOTE: In accordance with PCI Express Base Specification, Revision 2.1 March 4, 2009.

Table 17: PCI Express Rx Input Specifications—2.5 GT/s

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Symbol	Parameter	Min	Typ	Max	Units
UI	Unit Interval (UI) UI does not account for SSC induced variations.	399.88	--	400.12	ps
VRx-DIFF-PP-CC	Differential Rx peak-to-peak voltage for common Refclk Rx architecture	0.175	--	1.2	V
VRx-DIFF-PP-DC	Differential Rx peak-to-peak voltage for data clocked Rx architecture	0.175	--	1.2	V
TRx-EYE	Rx eye time opening Minimum eye time at Rx pins to yield a 10-12 BER.	0.40	--	--	UI
TRx-EYE-MEDIAN-to-MAX-JITTER	Maximum time delta between median and deviation from median	--	--	0.3	UI
VRx-CM-ACp	AC peak common mode input voltage	--	--	150	mV
RLRx-DIFF	Differential return loss	15	--	--	dB
RLRx-CM	Common mode return loss	0	--	3.6	dB
ZRx-DIFF-DC	differential input impedance	80	100	120	W
ZRx-DC	input impedance	40	50	60	W
ZRx-HIGH-IMP-DC	Powered down DC input impedance	200	--	--	k
VRx-IDLE-DET-DIFF-p-p	Electrical idle detect threshold	65	--	175	mV
TRx-IDLE-DET-DIFF-ENTERTIME	Unexpected electrical idle enter detect threshold integration time	--	--	10	ms
LRx-SKEW	Total skew	--	--	20	ns

18: PCI Express Rx Input Specifications—5 GT/s

Symbol	Parameter	Min	Typ	Max	Units
UI	Unit Interval (UI) UI does not account for SSC induced variations.	199.94	--	200.06	ps
VRx-DIFF-PP-CC	Differential Rx peak-to-peak voltage for common Refclk Rx architecture	0.120	--	1.2	V
VRx-DIFF-PP-DC	Differential Rx peak-to-peak voltage for data clocked Rx architecture	0.100	--	1.2	V
TRx-TJ-CC	Maximum Rx inherent total timing error for common Refclk Rx architecture	--	--	0.40	UI
TRx-TJ-DC	Maximum Rx inherent total timing error for data clocked Rx architecture	--	--	0.34	UI
TRx-DJ-DD-CC	Maximum Rx inherent deterministic timing error for common Refclk Rx architecture	--	--	0.30	UI
TRx-DJ-DD-DC	Maximum Rx inherent deterministic timing error for data clocked Rx architecture	--	--	0.24	UI
TRx-MIN-PULSE	Minimum width pulse at Rx	0.6	--	--	UI

Table

Symbol	Parameter	Min	Typ	Max	Units

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	Measured to account for worst Tj at 10^{-12} BER.				
VRx-CM-ACp	AC peak common mode input voltage	--	--	150	mV
RLRx-DIFF	Differential return loss	15	--	--	dB
RLRx-CM	Common mode return loss	0	--	3.6	dB
ZRx-DIFF-DC	DC differential input impedance	80	100	120	W
ZRx-DC	DC input impedance	40	50	60	W
ZRx-HIGH-IMP-DC	Powered down DC input impedance	200	--	--	k
VRx-IDLE-DET-DIFF-p-p	Electrical idle detect threshold	65	--	175	mV
TRx-IDLE-DET-DIFF-ENTERTIME	Unexpected electrical idle enter detect threshold integration time	--	--	10	ms
LRx-SKEW	Total skew	--	--	20	ns

11 USB SPECIFICATIONS

11.1 USB LS Driver and Receiver Parameters

Notes: Over full range of values specified in the Recommended Operating Conditions unless otherwise specified.

The load is 100Ω differential for these parameters, unless other specified.

Table 15: USB LS Driver and Receiver Specifications

Symbol	Parameter	Min.	Typ.	Max.	Unit
BR	Baud rate		1.5		Mbps
BRPPM	Baud rate tolerance	-15000	-	15000	ppm
Driver Specifications					
VOH	Output signal ended high Defined with 1.425KΩ pull-up resistor to 3.6V	2.8	-	3.6	V
VOL	Output signal ended low Defined with 1.425KΩ pull-up resistor to ground	0.0	-	0.3	V
VCRS	Output signal crossover voltage	1.3		2.0	V
TLR	Data fall time Defined from 10% to 90% for raise time and 90% to 10% for fall time	75.0	-	300.0	ns
TLF	Data risel time Defined from 10% to 90% for raise time and 90% to 10% for fall time	75.0	-	300.0	ns
TLRFM	Rise and fall time matching	80.0	-	125.0	%

TUDJ1	Source jitter total: to next transition *Including frequency tolerance. Timing difference between the differential data signals. *Defined at crossover point of differential signals	-95	-	95	ns

Symbol	Parameter	Min.	Typ.	Max.	Unit
TUDJ2	Source jitter total: for paired transitions *Including frequency tolerance. Timing difference between the differential data signals. *Defined at crossover point of differential signals	-150	-	150	ns
Receiver Specifications					
VIH	Input signal ended high	2.0	-	-	V
VIL	Input signal ended low	-	-	0.8	V
VDI	Differential input sensitivity	0.2	-	-	V

11.2 USB FS Driver and Receiver Parameters

Notes: Over full range of values specified in the Recommended Operating Conditions unless otherwise specified.

The load is 100Ω differential for these parameters, unless other specified.

Table 16: USB FS Driver and Receiver Specifications

Symbol	Parameter	Min.	Typ.	Max.	Unit
BR	Baud rate	-		-	Mbps
BRPPM	Baud rate tolerance	-2500	12.0 -	2500	ppm
Driver Specifications					
VOH	Output signal ended high Defined with 1.425KΩ pull-up resistor to 3.6V	2.8	-	3.6	V
VOL	Output signal ended low Defined with 1.425KΩ pull-up resistor to ground	0.0	-	0.3	V
VCRS	Output signal crossover voltage	1.3		2.0	V
TFR	Output raise time Defined from 10% to 90% for raise time and 90% to 10% for fall time	-4.0	-	20.0	ns
TFL	Output fall time Defined from 10% to 90% for raise time and 90% to 10% for fall time	-4.0	-	20.0	ns

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T_{DJ1}	Source jitter total: to next transition *Including frequency tolerance. Timing difference between the differential data signals. *Defined at crossover point of differential signals	-3.5	-	3.5	ns
T_{DJ2}	Source jitter total: for paired transitions *Including frequency tolerance. Timing difference between the differential data signals. *Defined at crossover point of differential signals	-4.0	-	4.0	ns
T_{FDEOP}	Source jitter for differential transition to SE0 transition. Defined at crossover point of differential signals	-2.0	-	5.0	ns
Receiver Specifications					

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{IH}	Input signal ended high	2.0	-	-	V
V_{IL}	Input signal ended low	-	-	0.8	V
V_{DI}	Differential input sensitivity	0.2	-	-	V
T_{JR1}	Receiver jitter: to next transition Defined at crossover point of differential data signals	-18.5	-	18.5	ns
T_{JR2}	Receiver jitter: for paired transitions Defined at crossover point of differential data signals	-9.0	-	9.0	ns

11.3 USB HS Driver and Receiver Parameters

Notes: Over full range of values specified in the Recommended Operating Conditions unless otherwise specified.

The load is 100Ω differential for these parameters, unless other specified.

Table 17: USB HS Driver and Receiver Specifications

Symbol	Parameter	Min.	Typ.	Max.	Unit
BR	Baud rate	-	480	-	Mbps
BR_{PPM}	Baud rate tolerance	-500	-	500	ppm
Driver Specifications					
V_{HSOH}	Data signal high	360	-	440	mV
V_{HSOL}	Data signal low	-10	-	10	mV
T_{HSR}	Data rise time Defined from 10% to 90% for raise time and 90% to 10% for fall time	500	-	-	ns

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THSF	Data fall time Defined from 10% to 90% for raise time and 90% to 10% for fall time	-500	-	-	ns
Receiver Specifications					
VHSCM	Input signal ended low	-50	-	500	mV

12 PCM INTERFACE SPECIFICATIONS

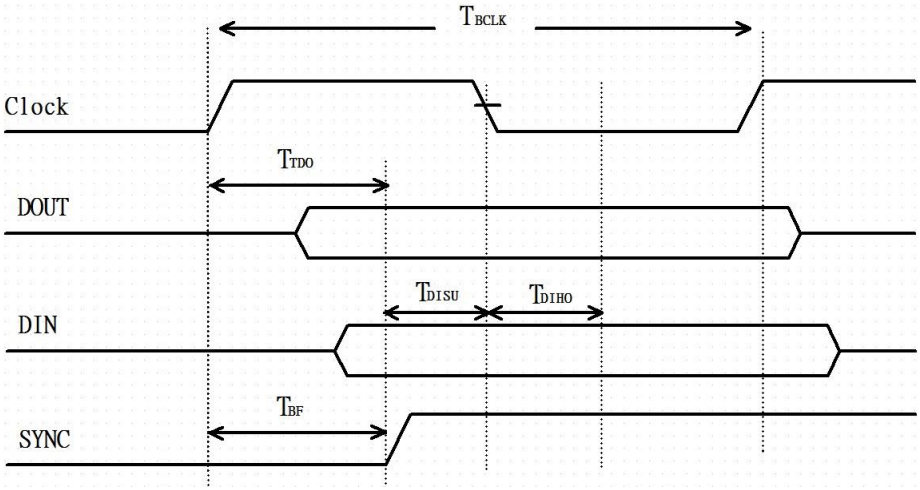

Figure 2: PCM Timing Specification – Master Mode

Table 18:PCM Timing Specification – Master Mode

Symbol	Parameter	Min.	Typ.	Max.	Unit
FBCLK	-	-	2/2.048	-	MHz
Duty CycleBCLK	-	0.4	0.5	0.6	-
TBCLK rise/fall	-	-	3	-	ns
TDO	-	-	-	15	ns
TDISU	-	20	-	-	ns

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TDIHO	-	15	-	-	ns
TBF	-	-	-	15	ns

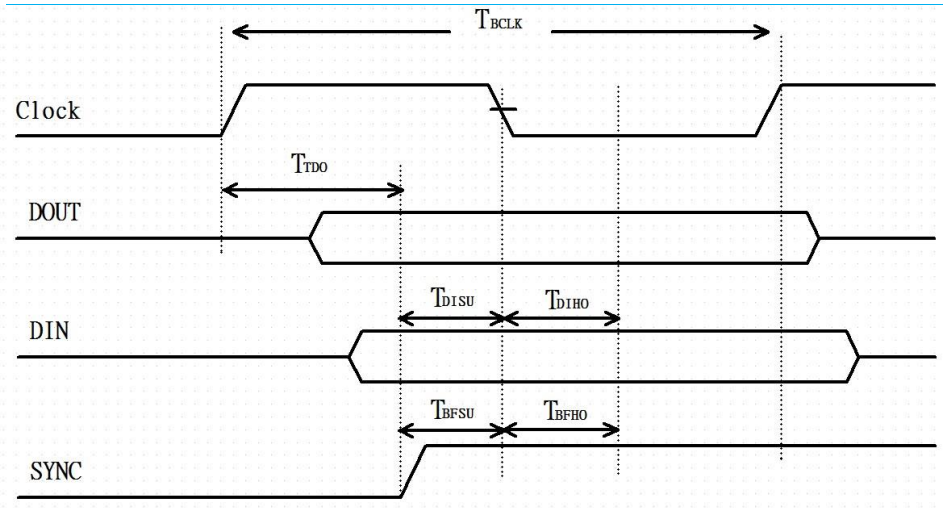

Figure 3: PCM Timing Specification – Slave Mode

Table 19: PCM Timing Specification – Slave Mode

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Symbol	Parameter	Min.	Typ.	Max.	Unit
FBCLK	-	-	2/2.048	-	MHz
Duty CycleBCLK	-	0.4	0.5	0.6	-
TBCLK rise/fall	-	-	3	-	ns
TDO	-	-	-	30	ns
TDISU	-	15	-	-	ns
TDIHO	-	10	-	-	ns
TBFSU	-	15	-	-	ns
TBFHO	-	10	-	-	ns

INITIONS

PIN D

20: Pin definitions

Pin #	Name	Type	Voltage Ref.	Description	If Not Used
1	GND	-	-	Ground	GND
2	3.3V	Power	-	3.3V module power supply	-
3	USB_D+	I/O	3.3V	USB Differential Data-Positive ***ST60-2230C-PU only***	N/C
4	3.3V	Power	-	3.3V module power supply	-
5	USB_D-	I/O	3.3V	USB Differential Data-Negative ***ST60-2230C-PU only***	N/C
6	LED1#	O,PU	3.3V	LED indicator for WLAN with 10mA drive capability	N/C
7	GND	-	-	Ground	GND
8	PCM_CLK	I/O	1.8V	PCM Clock Signal (Optimal) Optimal clock used for some codecs. Output if Master mode; Input if Slave mode.	N/C
9	SDIO CLK	N/C	1.8V	SDIO 4-bit Mode Clock Input	N/C
10	PCM_SYNC	I/O	1.8V	PCM Sync Pulse Signal Output if Master mode; Input if Slave mode.	N/C
11	SDIO CMD	N/C	1.8V	SDIO 4-bit Mode Command/Response	N/C
12	PCM_OUT	O	1.8V	PCM Data	N/C
13	SDIO DATA0	N/C	1.8V	SDIO 4-bit Mode DATA line Bit[0]	N/C
14	PCM_IN	I	1.8V	PCM Data	N/C

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15	SDIO DATA1	N/C	1.8V	SDIO 4-bit Mode DATA line Bit[1]	N/C
16	LED2#	N/C	N/C	N/C	N/C
17	SDIO DATA2	N/C	1.8V	SDIO 4-bit Mode DATA line Bit[2]	N/C
18	GND	-	-	Ground	GND
19	SDIO DATA3	N/C	1.8V	SDIO 4-bit Mode DATA line Bit[3]	N/C
20	UART WAKE#	O	3.3V	Reserved for BT to wakeup Host	N/C
21	SDIO WAKE#	O	1.8V	Reserved for Wake-On-WLAN	N/C

Table

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Pin #	Name	Type	Voltage Ref.	Description	If Not Used
22	UART TXD	O	1.8V	UART Serial Data Output ***ST60-2230C-P only***	N/C
23	SDIO RESET#	N/C	N/C	N/C	N/C
32	UART RXD	I	1.8V	UART Serial Data Input ***ST60-2230C-P only***	N/C
33	GND	-	-	Ground	GND
34	UART RTS	O,WPU	1.8V	UART Request To Send (Active low) ***ST60-2230C-P only***	N/C
35	PERp0	I	1.8V	PCIe Receive Data-Positive	N/C
36	UART CTS	I, PU	1.8V	UART Clear To Send (Active low) ***ST60-2230C-P only***	N/C
37	PERn0	I	1.8V	PCIe Receive Data-Negative	N/C
38	VENDOR DEFINED38	N/C	N/C	N/C	N/C
39	GND	-	-	Ground	GND
40	VENDOR DEFINED40	N/C	N/C	N/C	N/C
41	PETp0	O	1.8V	PCIe Transmit Data-Positive; 0.1µF capacitor included in module	N/C
42	VENDOR DEFINED42	N/C	N/C	N/C	N/C
43	PETn0	O	1.8V	PCIe Transmit Data-Negative; 0.1µF capacitor included in module	N/C
44	COEX3	N/C	1.8V	General purpose I/O pin.	N/C
45	GND	-	-	Ground	GND
46	COEX2	O,PD	1.8V	Serial data to external LTE device/	N/C
47	REFCLKp0	I	1.8V	PCIe Differential Clock input-Positive	N/C
48	COEX1	I,PD	1.8V	Serial data from external LTE device/	N/C
49	REFCLKn0	I	1.8V	PCIe Differential Clock input-Negative	N/C
50	SUSCLK(32KHz)	I,PU	3.3V	Sleep Clock Input An external sleep clock of 32.768KHz with minimum +/250ppm is required for power saving mode	-
51	GND	-	-	Ground	GND
52	PERST0#	I,PD	3.3V	PCIe host indication to reset the device (input) (active low)	N/C
53	CLKREQ0#	I/O	3.3V	PCIe clock request (input/output) (active low)	N/C
54	W_DISABLE2#	N/C	N/C	N/C	N/C
55	PEWAKE0#	I/O	3.3V	PCIe wake signal (input/output) (active low)	N/C
56	W_DISABLE1#	I,PU	3.3V	Reserved	N/C

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57	GND	-	-	Ground	GND
Pin #	**Name**	**Type**	**Voltage Ref.**	**Description**	**If Not Used**
58	I2C DATA (I/O)(0/3.3V)	N/C	N/C	N/C	N/C
59	RESERVED/PETp1	N/C	N/C	N/C	N/C
60	I2C CLK (0/3.3V)	N/C	N/C	N/C	N/C
61	RESERVED/PETn1	N/C	N/C	N/C	N/C
62	ALERT# (0/3.3V)	O	3.3V	N/C	N/C
63	GND	-	-	Ground	GND
64	RESERVED	N/C	N/C	N/C	N/C
65	RESERVED/PERp1	N/C	N/C	N/C	N/C
66	UIM_SWP/PERST1#	N/C	N/C	N/C	N/C
67	RESERVED/PERn1	N/C	N/C	N/C	N/C
68	UIM_POWER_SNK/ CLKREQ1#	N/C	N/C	N/C	N/C
69	GND	-	-	Ground	GND
70	UIM_POWER_SRC/ GPIO1/PEWAKE1#	N/C	N/C	N/C	N/C
71	RESERVED/REFCLKp 1	N/C	N/C	N/C	N/C
72	3.3V	Power	-	3.3V module power supply	-
73	RESERVED/REFCLKn 1	N/C	N/C	N/C	N/C
74	3.3V	Power	-	3.3V module power supply	-
75	GND	-	-	Ground	GND

14 Mechanical Specifications

Module dimensions of ST60-2230C-P/ST60-2230C-PU are 22 mm x 30 mm x 2.66 mm. Detail drawings are shown in Figure 4.

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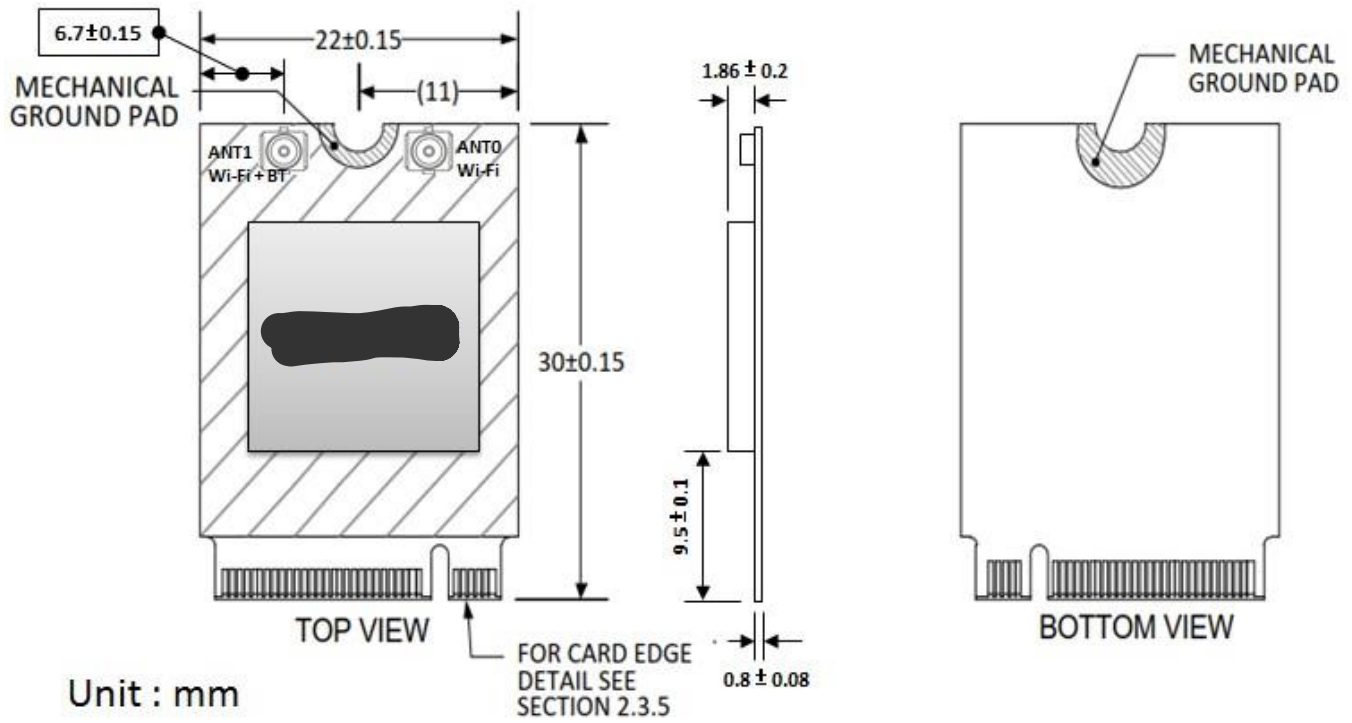

6±0.15

Figure 4: Module dimension of ST60-2230C-P/ST60-2230C-PU

Note: The Wi-Fi MAC address is located on the product label.

The last digit of Wi-Fi MAC address will be assigned to either “0”, “4”, “8”, or “C”.

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The BT MAC address will be the Wi-Fi MAC on the label plus 3.

15 MOUNTING

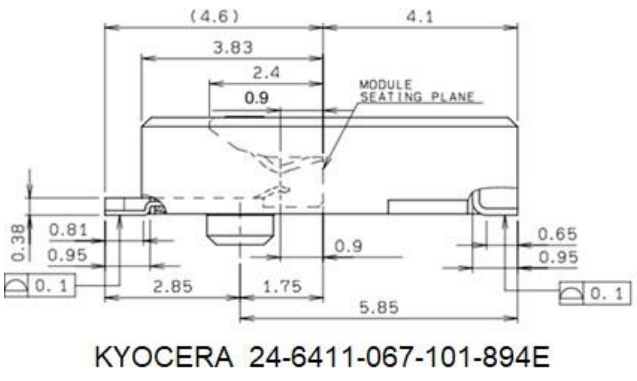
The ST60-2230C-P/ST60-2230C-PU connects to the host via a standard PCI EXPRESS M2 connector. The Kyocera's (www.Kyocera-connector.com) 6411 series provide 1.8 mm, 2.3 mm and 3.2 mm connector heights and JAE's (https://www.jae.com/en/) SM3 series provide 1.2 mm, 2.15 mm, 3.1 mm and 4.1 mm connector heights.

Because the ST60-2230C-P/ST60-2230C-PU is a single-side component module, we recommend the following part numbers which have 2.3 mm and 3.1 mm connector height):

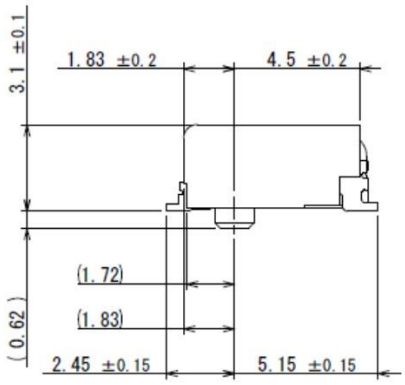
M.2 Key-E Connector	Connector Height
KYOCERA 24-6411-067-101-894E	2.3 mm
JAE SM3ZS067U310AERxxxx	3.1 mm

The stand-off mating to the recommend 2.3 mm connector from EMI STOP (www.EMISTOP.com) is part number **F50M16041525P1D4M** and 3.1mm from JAE (https://www.jae.com/en/) is part number **SM3ZS067U310-NUT1-Rxxxx**.

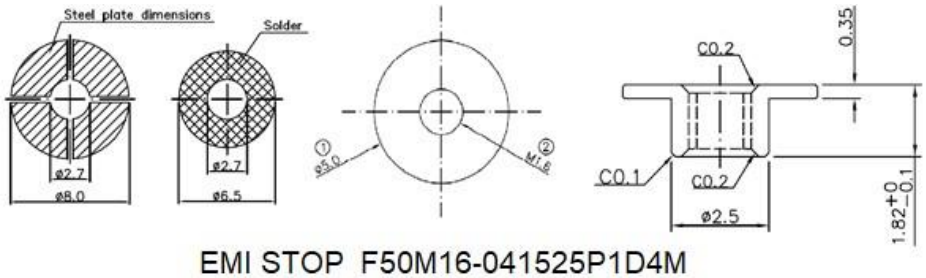
M.2 Key-E Connector	Stand-off
KYOCERA 24-6411-067-101-894E	EMI STOP F50M16-041525P1D4M
JAE SM3ZS067U310AERxxxx	JAE SM3ZS067U310-NUT1-Rxxxx



KYOCERA 24-6411-067-101-894E



JAE SM3ZS067U310AERxxxx



EMI STOP F50M16-041525P1D4M

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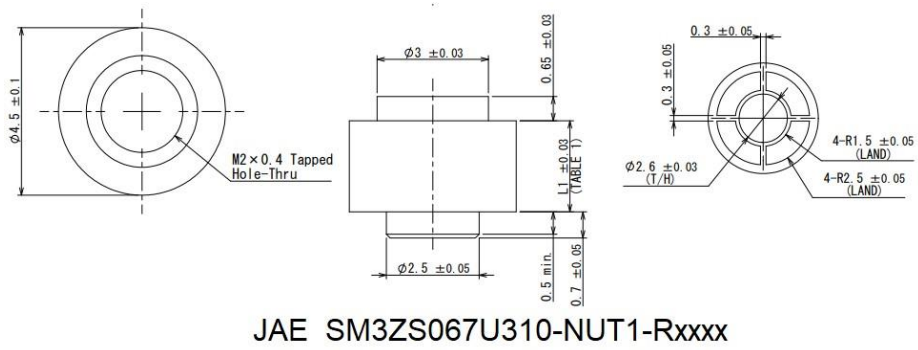

Figure 5: Mounting information of the ST60-2230C-P/ST60-2230C-PU and recommended layout pattern for the stand-off

15.1 Mounting screw

The ST60-2230C modules are secured in their mounting position with a mounting screw. Laird Connectivity recommends the use of the Hama Naka Shoukin Industry Co. FPHM1.6-0.35x3.5(5,0.5)CR3-Zn screw. Contact peggy@hnsco.com.tw for more information.

浜中松琴工業有限公司 **HAMA NAKA SHOUKIN INDUSTRY CO., LTD.**

料號: _____ 規　格: FPHM1.6-0.35x3.5(5,0.5)

材質: AISI-1018 熱處理: Hardening 電鍍: CR3/Zn

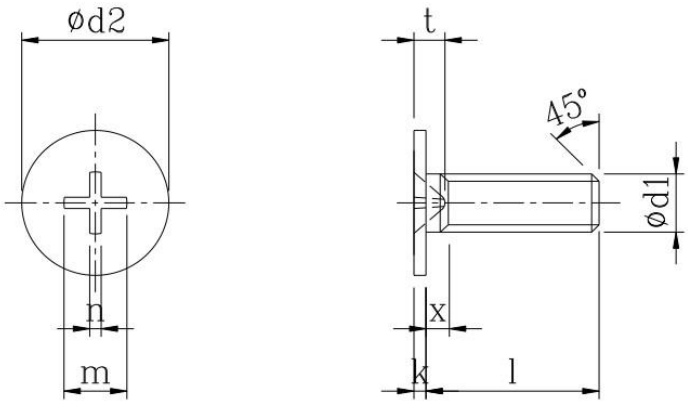

Figure 6: Mechanical drawing of FPH M1.6-0.35x3.5(5,0.5)CR3-Zn

16 RF Layout Design Guidelines / Precautions

The following is a list of RF layout design guidelines and recommendation when installing a radio into your device.

- Do not run antenna cables directly above or directly below the radio.
- Do not place any parts or run any high speed digital lines below the radio.
- If there are other radios or transmitters located on the device (such as a *Bluetooth* radio), place the devices as far apart from each other as possible. Also, make sure there is at least 25 dB isolation between the Bluetooth antenna and the Wi-Fi antenna.
- Ensure that there is the maximum allowable spacing separating the antenna connectors on the radio from the antenna. In addition, do not place antennas directly above or directly below the radio.
- Laird Connectivity recommends the use of a double-shielded cable for the connection between the radio and the antenna elements.
- Be sure to put the capacitor on the power pin as close as possible to reduce the radiation issue.
- Use proper electro-static-discharge (ESD) procedures when installing the radio module.

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- To get maximum throughput when operate at MIMO 2x2, two antennas with at least 25 dB isolation are recommended.
- To avoid negatively impacting Tx power and receiver sensitivity, do not cover the antennas with metallic objects or components.
- Opening/handing/removing must be done on an anti-ESD treated workbench. All workers must be also have undergone anti-ESD treatment.
- The devices should be mounted within one year of the date of delivery.

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17 REGULATORY

17.1 Current Regulatory Certifications

The ST60-2230C holds current certifications in the following countries:

Country/Region	Regulatory ID
USA (FCC)	2AVNR-60SIPT
EU	N/A
Canada (ISED)	26486-602230C
Japan (MIC)	003-170090
Korea (KC)	MSIP-CRM-LAI-60-2230C
Australia	N/A
New Zealand	N/A
China (SRRC)	2017DJ2473

17.2 Certified Antennas

The antennas listed below were tested for use with the ST60-2230C. The OEM can choose a different manufacturer's antenna but must make sure it is of same type and that the gain is less than or equal to the antenna that is approved for use.*

***Note:** Japan (MIC) lists applicable antennas on its certificates. If your antenna is not on the approved list, regardless of whether it is comparative, it must be added to the certificate before it can be used in Japan.

Model	Type	Connector	Maximum Gain				
			2400-2483.5	5150-5250	5250-5350	5470-5725	5725-5850
Laird Connectivity (LSR) 001-0009	Dipole	IPEX U.FL	2.0	2.0	2.0	2.0	2.0
Laird Connectivity NanoBlade-IP04	PCB dipole	IPEX U.FL	2.0	3.9	3.9	4.0	4.0
Laird Connectivity MAF95310 Mini NanoBlade Flex	PCB Dipole	IPEX U.FL	2.79	3.38	3.38	3.38	3.38
Laird Connectivity (LSR) FlexPIFA	PIFA	IPEX U.FL	2.5	3.0	3.0	3.0	3.0
Ethertronics WLAN_1000146	Magnetic dipole	IPEX U.FL	2.5	3.5	3.5	3.5	3.5

Laird Connectivity MIMO FlexPIFA	PIFA	IPEX U.FL	2.0	3.0	3.0	3.0	3.0

17.3 FCC Regulatory

To ensure regulatory compliance, when integrating the ST60-2230C into a host device, it is necessary to meet the documentation requirements set forth by the applicable regulatory agencies. The following sections (FCC, ISED Canada, European Union, and others) outline the information that may be included in the user's guide and external labels for the host devices into which the ST60-2230C is integrated.

17.3.1 Antenna Information

The ST60-2230C family has been designed to operate with the antennas listed below.

Model	Type	Connector	Maximum Gain				
			2400-2483.5	5150-5250	5250-5350	5470-5725	5725-5850
Laird Connectivity (LSR) 001-0009	Dipole	IPEX U.FL	2.0	2.0	2.0	2.0	2.0
Laird Connectivity NanoBlade-IP04	PCB dipole	IPEX U.FL	2.0	3.9	3.9	4.0	4.0
Laird Connectivity MAF95310 Mini NanoBlade Flex	PCB Dipole	IPEX U.FL	2.79	3.38	3.38	3.38	3.38
Laird Connectivity (LSR) FlexPIFA	PIFA	IPEX U.FL	2.5	3.0	3.0	3.0	3.0
Ethertronics WLAN_1000146	Magnetic dipole	IPEX U.FL	2.5	3.5	3.5	3.5	3.5
Laird Connectivity MIMO FlexPIFA	PIFA	IPEX U.FL	2.0	3.0	3.0	3.0	3.0

Note: The OEM is free to choose another vendor's antenna of like type and equal or lesser gain as an antenna appearing in the table and still maintain compliance. Reference FCC Part 15.204(c)(4) for further information on this topic.

17.3.2 FCC Documentation Requirements

Federal Communication Commission Interference Statement

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications.

However, there is no guarantee that interference will not occur in an installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

FCC Caution: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

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

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

FCC Radiation Exposure Statement

This product complies with the US portable RF exposure limit set forth for an uncontrolled environment and is safe for intended operation as described in this manual. Further RF exposure reduction can be achieved if the product is kept as far as possible from the user body or is set to a lower output power if such function is available.

This transmitter must not be co-located or operated in conjunction with any other antenna or transmitter.

This device is intended only for OEM integrators under the following condition:

1. The transmitter module may not be co-located with any other transmitter or antenna,

If the condition above is met, further transmitter testing is not required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this installed module.

IMPORTANT NOTE:

If this condition cannot be met (for example, certain laptop configurations or co-location with another transmitter), then the FCC authorization is no longer considered valid and the FCC ID **cannot** be used on the final product. In these circumstances, the OEM integrator is responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC authorization.

End-Product Labeling

The end product must be labeled in a visible area with the following: ***Contains FCC ID: 2AVNR-60SIPT***

Manual Information to the End User

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

The end user manual shall include all required regulatory information/warning as show in this manual.

17.4 ISED Canada

Model	MIC ID
ST60-2230C	26486-602230C

17.4.1 Antenna Information

This radio transmitter (IC: 26486-602230C) *was approved by* Innovation, Science and Economic Development (ISED) Canada to operate with the antenna types listed below, with the maximum permissible gain indicated. Antenna types not included in this list that have a gain greater than the maximum gain indicated for any type listed are strictly prohibited for use with this device.

Le présent émetteur radio (IC: 26486-602230C) *a été approuvé par Innovation, Sciences et Développement économique Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal. Les types d'antenne non inclus dans cette liste, et dont le gain est supérieur au gain maximal indiqué pour tout type figurant sur la liste, sont strictement interdits pour l'exploitation de l'émetteur.*

Model	Type	Connector	Maximum Gain

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			2400-2483.5	5150-5250	5250-5350	5470-5725	5725-5850
Laird Connectivity (LSR) 001-0009	Dipole	IPEX U.FL	2.0	2.0	2.0	2.0	2.0
Laird Connectivity NanoBlade-IP04	PCB dipole	IPEX U.FL	2.0	3.9	3.9	4.0	4.0
Laird Connectivity MAF95310 Mini NanoBlade Flex	PCB Dipole	IPEX U.FL	2.79	3.38	3.38	3.38	3.38
Laird Connectivity (LSR) FlexPIFA	PIFA	IPEX U.FL	2.5	3.0	3.0	3.0	3.0
Ethertronics WLAN_1000146	Magnetic dipole	IPEX U.FL	2.5	3.5	3.5	3.5	3.5
Laird Connectivity MIMO FlexPIFA	PIFA	IPEX U.FL	2.0	3.0	3.0	3.0	3.0

17.4.2 ISED (Canada) Statement

The end user manual shall include all required regulatory information/warning as shown in this manual.

This device complies with Industry Canada's license-exempt RSSs. Operation is subject to the following two conditions:

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

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

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

Radiation Exposure Statement

The product complies with the Canada portable RF exposure limit set forth for an uncontrolled environment and are safe for intended operation as described in this manual. The minimum separation distance for portable use is limited to 15mm assuming use of antenna with 2 dBi of gain. The further RF exposure reduction can be achieved if the product can be kept as far as possible from the user body or set the device to lower output power if such function is available.

Déclaration d'exposition aux radiations:

Le produit est conforme aux limites d'exposition pour les appareils portables RF pour les Etats-Unis et le Canada établies pour un environnement non contrôlé. La distance de séparation minimale pour l'utilisation portative est limitée à 15mm en supposant l'utilisation de l'antenne avec 2 dBi de gain. Le produit est sûr pour un fonctionnement tel que décrit dans ce manuel. La réduction aux expositions RF peut être augmentée si l'appareil peut être conservé aussi loin que possible du corps de l'utilisateur ou que le dispositif est réglé sur la puissance de sortie la plus faible si une telle fonction est disponible.

This device is intended only for OEM integrators under the following conditions:

1. The transmitter module may not be co-located with any other transmitter or antenna.

If the condition above is met, further transmitter testing is not required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed.

Cet appareil est conçu uniquement pour les intégrateurs OEM dans les conditions suivantes:

1. *Le module émetteur peut ne pas être coïmplanté avec un autre émetteur ou antenne.*

Tant que les 1 condition ci-dessus sont remplies, des essais supplémentaires sur l'émetteur ne seront pas nécessaires. Toutefois, l'intégrateur OEM est toujours responsable des essais sur son produit final pour toutes exigences de conformité supplémentaires requis pour ce module installé.

IMPORTANT NOTE:

If this condition cannot be met (for example, certain laptop configurations or co-location with another transmitter), then the Canada authorization is no longer considered valid and the IC ID **cannot** be used on the final product. In these circumstances, the OEM integrator is responsible for re-evaluating the end product (including the transmitter) and obtaining a separate Canada authorization.

NOTE IMPORTANTE:

Dans le cas où ces conditions ne peuvent être satisfaites (par exemple pour certaines configurations d'ordinateur portable ou de certaines co-localisation avec un autre émetteur), l'autorisation du Canada n'est plus considéré comme valide et l'ID IC ne peut pas être utilisé sur le produit final. Dans ces circonstances, l'intégrateur OEM sera chargé de réévaluer le produit final (y compris l'émetteur) et l'obtention d'une autorisation distincte au Canada.

End-Product Labeling

The final end product must be labeled in a visible area with the following: ***Contains IC: 26486-602230C***

Plaque signalétique du produit final

Le produit final doit être étiqueté dans un endroit visible avec l'inscription suivante: ***Contient des IC: 26486-602230C***

Manual Information to the End User

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

The end user manual shall include all required regulatory information/warning as show in this manual.

Manuel d'information à l'utilisateur final

L'intégrateur OEM doit être conscient de ne pas fournir des informations à l'utilisateur final quant à la façon d'installer ou de supprimer ce module RF dans le manuel de l'utilisateur du produit final qui intègre ce module.
Le manuel de l'utilisateur final doit inclure toutes les informations réglementaires requises et avertissements comme indiqué dans ce manuel.

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