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Datasheet

60-2230C

Version 1.2

REVISION HISTORY

Version	Date	Notes	Approver
1.0	29 Aug 2017	Initial version	Jay White
1.1	06 Sept 2017	Updated module size to 22 mm (length) x 30 mm (width) x 3.3 mm (thickness) Updated *Figure 8: Module dimension of 60-2230C.* Changed *6.7±0.15* to *6±0.15*. Changed pin definitions for pins 54 and 56	Jay White
1.2	08 Sept 2017	Updated Max. Current Consumption table/column headings	Andrew Chen

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CONTENTS

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1. SCOPE

This document describes key hardware aspects of the Laird 60-2230C M.2 module providing either SDIO or USB2.0 bus interface for WLAN connection and UART/SDIO/USB2.0 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. Please contact Laird to obtain the most recent version of this document.

2. INTRODUCTION

2.1. General Description

The 60-2230C module is a dual band 2x2 802.11ac WLAN plus Bluetooth 4.2 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 (Wave 2), 2x2 receive Multi-User MIMO spatial stream multiplexing with data rates up to MCS9 (866.7 Mbps)
- Bluetooth (Class 1 and Class 2)
- Bluetooth 4.2 (with Low Energy or LE)
- Bluetooth 5 Ready
- 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.

On the DFS engine, the module supports 802.11h Dynamic Frequency Selection to detect the presence of radar signals; support is extended to 80 MHz mode under the 802.11ac channelization modes. In addition, the E-DFS (Enhanced DFS) scheme is designed to increase pulse detection rates for shorter (0.5 us, 0.8 us, 1 us), in-band DFS pulses. The scheme is designed to minimize the false-alarm rate for out-of-band DFS pulse.

There are two interfaces for WLAN function:

- SDIO 3.0 – Supports both 1-bit SDIO and 4-bit SDIO transfer modes at full clock range up to 208 MHz
- USB 2.0

In addition, there are three interfaces for Bluetooth function:

- SDIO
- USB 2.0
- High-Speed UART

The 60-2230C module also provides 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 configuration pins (operation mode). Currently, the default mode for the SDIO/UART (WLAN/Bluetooth) interface is *000*.

3. FEATURES SUMMARY

The Laird 60-2230C device features are described in Table 1.

Table 1: 60-2230C of features

<table>
<tr><th>Feature</th><th>Description</th></tr>
<tr><td>Radio Front End</td><td>▪ 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</td></tr>
<tr><td>Coexistence</td><td>Coexistence arbitration for WLAN, Bluetooth, and LTE operation</td></tr>
<tr><td>Power Management</td><td>Dynamic Voltage Scaling (DVS) and Adaptive Voltage Scaling (AVS) feature supports the latest Marvell SoC and processor power control scheme.</td></tr>
<tr><td>Pre-Calibration</td><td>RF system-tested and calibrated in production.</td></tr>
<tr><td>Sleep Clock</td><td>An external sleep clock of 32.768 KHz is required during power save mode.</td></tr>
<tr><td>Host Interface</td><td>▪ SDIO 3.0 (4-bit and 1-bit), SDR 12/25/50 mode (up to 100MHz), USB 2.0 or PCIe for WLAN
▪ SDIO 3.0, USB 2.0, HS-UART for Bluetooth HCI (compatible with any upper layer Bluetooth stack)
▪ PCM digital audio interface for Bluetooth audio application.
<table>
<tr><th>Strap Value CONFIG_HOST[2-0]</th><th>WLAN</th><th>Bluetooth/ BLE</th><th>ROM Notes</th></tr>
<tr><td>000</td><td>SDIO</td><td>UART</td><td>-</td></tr>
<tr><td>001</td><td>SDIO</td><td>SDIO</td><td>-</td></tr>
<tr><td>100</td><td>USB 2.0</td><td>UART</td><td>Initial USB 2.0 PHY and COM PHY PCIe USB 3.0</td></tr>
<tr><td>101</td><td>USB 2.0</td><td>USB 2.0</td><td>Initial USB 2.0 PHY only</td></tr>
</table></td></tr>
<tr><td>Reference Frequency</td><td>▪ 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.</td></tr>
<tr><td>Advanced WLAN</td><td>▪ 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
▪ Dynamic frequency selection (DFS) – Radar detection
▪ 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</td></tr>
</table>

Feature	Description
Advanced Bluetooth	▪ Bluetooth 4.2 (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

4. SPECIFICATIONS

Table 2: Specifications

<table>
<tr><th>Feature</th><th>Description</th></tr>
<tr><td>Physical Interface</td><td>84-pin LGA package (including 16 thermal ground pad under the package)</td></tr>
<tr><td>Wi-Fi Interface</td><td>1-bit or 4-bit Secure Digital I/O; PCIe v3.0 Gen1/Gen2 (2.5/5 Gbps); USB 2.0</td></tr>
<tr><td>Bluetooth/
BLE Interface</td><td>Host Controller Interface (HCI) using High Speed UART, SDIO, USB 2.0
<table>
<tr><th>Strap Value CONFIG_HOST[2-0]</th><th>WLAN</th><th>Bluetooth /BLE</th><th>ROM Notes</th></tr>
<tr><td>000</td><td>SDIO</td><td>UART</td><td>-</td></tr>
<tr><td>001</td><td>SDIO</td><td>SDIO</td><td>-</td></tr>
<tr><td>100</td><td>USB 2.0</td><td>UART</td><td>Initial USB 2.0 PHY and COM PHY PCIe USB 3.0</td></tr>
<tr><td>101</td><td>USB 2.0</td><td>USB 2.0</td><td>Initial USB 2.0 PHY only</td></tr>
</table></td></tr>
<tr><td>Main Chip</td><td>Marvell 88W8997 (WLAN/BT); Marvell 88PG823 (PMU)</td></tr>
<tr><td>Input Voltage Requirements</td><td>DC 3.3 V ±10%</td></tr>
<tr><td>I/O Signalling Voltage</td><td>DC 3.3 V ± 10% or DC 1.8 V ± 10%</td></tr>
<tr><td>Peak Current consumption, VCC=VIO = 3.3 volts (At maximum transmit power setting)

Note: Reset refers to the radio are in reset, both Wi-fi and BT reset are asserted.</td><td>MIMO 2x 2 operations.
802.11b (with BT in standby) @ 18 dBm 1 Mbps
Transmit: XX mA Receive: XX mA
802.11g (with BT in standby) @ 18 dBm 6 Mbps
Transmit: XX mA Receive: XX mA
802.11a (with BT in standby) @ 18 dBm 6 Mbps
Transmit: XX mA Receive: XX mA
802.11n (2.4 GHz/40MHz) (with BT in standby) @ 16 dBm MCS0
Transmit: XX mA Receive: XX mA
802.11n (5.0 GH/40MHz) (with BT in standby) @ 16 dBm MCS0
Transmit: XX mA Receive: XX mA
802.11ac (5.0 GH/80MHz) (with BT in standby) @ 14 dBm MCS0
Transmit: XX mA Receive: XX mA
Bluetooth (with Wi-Fi in standby)
Transmit: XX mA Receive: XX mA
Reset:
XXX mA</td></tr>
<tr><td>Operating Temperature</td><td>-30° to 85°C (-22° to 185°F)</td></tr>
</table>

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Feature	Description
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	TBD 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)
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, 802.11s*, 802.11v*, 802.11ac * Summit version only
Bluetooth Standards	Bluetooth version 2.1 with Enhanced Data Rate Bluetooth 4.2 (Bluetooth Low Energy or BLE) Bluetooth 5 (coming soon)
Wi-Fi Data Rates Supported	Support 802.11 ac/a/b/g/n 2X2 MIMO MU-MIMO/802.11ac Wave 2 802.11b (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)

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Feature	Description
Modulation Table	BPSK, QPSK, CCK, 16-QAM, 64-QAM, and 256-QAM.

802.11ac / 802.11n	HT MCS Index	VHT MCS Index	Spatial Streams	Modulation	Coding	20 MHz		40 MHz		80 MHz	
						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	**433.3**
	8	0	2	BPSK	1/2	13	14.4	27	30	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**

802.11ac/n Spatial Streams	2 (2x2 MIMO)
Bluetooth Data Rates Supported	1, 2, 3 Mbps
Bluetooth Modulation	GFSK@ 1 Mbps Pi/4-DQPSK@ 2 Mbps 8-DPSK@ 3 Mbps
Regulatory Domain Support	FCC (Americas, Parts of Asia, and Middle East) ETSI (Europe, Middle East, Africa, and Parts of Asia) IC (Industry Canada) MIC (Japan) (formerly TELEC) – Option KC (Korea) (formerly KCC) – Option
2.4 GHz Frequency Bands	**ETSI:** 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 (Wi-Fi)	**ETSI:** 13 (3 non-overlapping) **FCC:** 11 (3 non-overlapping) **MIC:** 14 (4 non-overlapping) **KC:** 13 (3 non-overlapping)

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Feature	Description
5 GHz Frequency Bands	**ETSI** 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) **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 (Japan)** 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) **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)
5 GHz Operating Channels (Wi-Fi)	**ETSI:** 19 non-overlapping; **FCC:** 24 non-overlapping **MIC (Japan):** 19 non-overlapping; **KC:** 19 non-overlapping
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* *HT40 – 40 Mhz-wide channels* *HT80 – 80 MHz-wide channels*	**802.11a** 6 Mbps — 18 dBm (63 mW) 54 Mbps — 16 dBm (40 mW) **802.11b** 1 Mbps — 18 dBm (63 mW) 11 Mbps — 18 dBm (63 mW) **802.11g** 6 Mbps — 18 dBm (63 mW) 54 Mbps — 16 dBm (40 mW) **802.11n (2.4/5 GHz)** 6.5 Mbps (MCS0-5/MCS8-13;HT20) — 18 dBm (63 mW) 65 Mbps (MCS6-7/MCS14-15;HT20) — 16 dBm (40 mW) 13.5Mbps(MCS0-5/MCS8-13;HT40) — 16 dBm (40 mW) 135Mbps (MCS6-7/MCS14-15;HT40) — 14 dBm (25 mW) **802.11ac (5 GHz)** 6.5/13 Mbps (MCS0-6;Ntst=1,2;HT20) — 18 dBm (63 mW) 78/156 Mbps (MCS7-8;Ntst=1,2;HT20) — 16 dBm (40 mW) 13.5/27Mbps (MCS0-6;Ntst=1,2;HT40) — 16 dBm (40 mW) 180/360Mbps (MCS7-9;Ntst=1,2;HT40) — 14 dBm (25 mW) 29.3/58.5 Mbps (MCS0-5;Ntst=1,2;HT80) — 14 dBm (25 mW) 263.3/526.5 Mbps (MCS6-8;Ntst=1,2;HT80) — 12 dBm (15.8 mW) 390/780 Mbps (MCS9;Ntst=1,2;HT80) — 10 dBm (10 mW) **Bluetooth** 1 Mbps (1DH5) — 10 dBm (12.5 mW) 2 Mbps — 7 dBm (6.3 mW) 3 Mbps — 7 dBm (6.3 mW) BLE (1 Mbps) — 7 dBm (6.3 mW)

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Feature	Description		
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	-89 dBm	
	54 Mbps	-74 dBm	
	802.11b:		
	1 Mbps	-95 dBm	
	11 Mbps	-90 dBm	(PER<8%)
	802.11g:		
	6 Mbps	-91 dBm	
	54 Mbps	-75 dBm	
	802.11n (2.4 GHz)		
	6.5 Mbps (MCS0;HT20)	-91 dBm	
	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 3x or newer Android 5x and newer		

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Feature	Description
Security	**Standards** Wireless Equivalent Privacy (WEP) Wi-Fi Protected Access (WPA) IEEE 802.11i (WPA2) **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.
Compliance ***Note:*** *All regulatory certifications are currently pending.*	**ETSI Regulatory Domain** EN 300 328 EN 301 489-1 EN 301 489-17 EN 301 893 EN 60950-1 EU 2002/95/EC (RoHS) **FCC Regulatory Domain** FCC 15.247 DTS – 802.11b/g (Wi-Fi) – 2.4 GHz FCC 15.407 UNII – 802.11a (Wi-Fi) – 5 GHz FCC 15.247 DSS – BT 2.1 **Industry Canada** RSS-247 – 802.11a/b/g/n (Wi-Fi) – 2.4 GHz, 5.8 GHz, 5.2 GHz, and 5.4 GHz RSS-247 – BT 2.1
Certifications	**Wi-Fi Alliance** (Summit version only) 802.11a, 802.11b, 802.11g , 802.11n, 802.11ac WPA Enterprise WPA2 Enterprise **Cisco Compatible Extensions** (Version 4) (Summit version only) ***Bluetooth*® SIG Qualification**
Warranty	Three Year Warranty
All specifications are subject to change without notice	

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5. WLAN Functional Description

The 60-2230C M2 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 4.2. 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 (Wave 2), 2X2 receive Multi-User MIMIO (MU-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 Downlink MU-MIMO (receive) ▪ Dynamic Frequency Selection ▪ Beamforming ▪ TIM Frame TX and RX ▪ Multi-BSS/Station ▪ Transmit Rate Adaptation. ▪ Transmit Power Control

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Feature	Description
WLAN Base Band	▪ 802.11ac 2x2 MU-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) ▪ Dynamic Frequency Selection (DFS) (Radar detection) – Enhanced radar detection for long and short pulse radar – Enhanced AGC scheme for DFS channel – Japan DFS requirements for W53 and W56 ▪ 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)

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Feature	Description
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	1-5	2422	42	5210
2	2417	40	5200	2-6	2427	58	5290
3	2422	44	5220	3-7	2432	74	5370
4	2427	48	5240	4-8	2437	90	5410
5	2432	52	5260	5-9	2422	106	5530
6	2437	56	5280	6-10	2447	122	5610
7	2422	60	5300	7-11	2452	138	5690
8	2447	64	5320	36-40	5190	155	5775
9	2452	100	5500	44-48	5230		
10	2457	104	5520	52-56	5270		
11	2462	108	5540	60-64	5310		
12	2467	112	5560	68-72	5350		
13	2472	116	5580	76-80	5390		
		120	5600	84-88	5430		
		124	5620	92-96	5470		
		128	5640	100-104	5510		
		132	5660	108-112	5550		
		136	5680	116-120	5590		
		140	5700	124-128	5630		
		144	5720	132-136	5670		
		149	5745	140-144	5710		
		153	5765	149-153	5755		
		157	5785	157-161	5795		
		161	5805				
		165	5825				

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6. Bluetooth Functional Description

The 60-2230C 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. ▪ SDIO interface ▪ High-Speed UART interface ▪ USB 2.0
Bluetooth Core functionality	▪ Bluetooth 4.2 ▪ Bluetooth Class 2/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 ▪ All standard pairing, authentication, link key, and encryption operations ▪ Encryption (AES) support
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 ▪ LE Advertising Length Extension ▪ 2 Mbps LE ▪ Direction Finding – Connectionless Angle of Departure (AoD) ▪ Direction Finding – Connectionless Angle of Arrival (AoA)

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8. BLOCK DIAGRAM

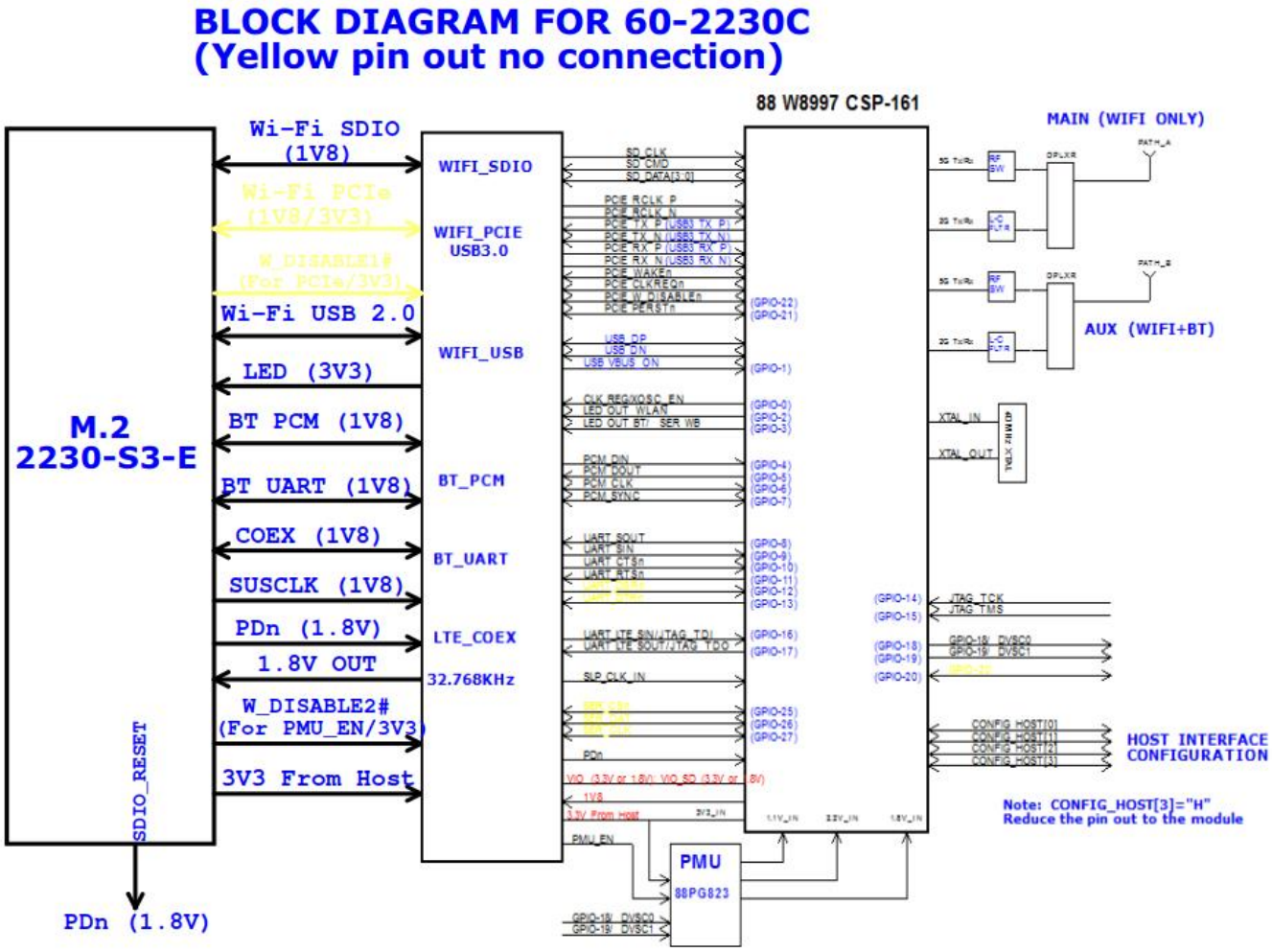

Figure 1: 60-2230C

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9. Electrical Characteristics

9.1. Absolute Maximum Ratings

Table 5 summarizes the absolute maximum ratings and Table 6 lists the recommended operating conditions for the 60-2230C. 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

Symbol (Domain)	Parameter	Max Rating	Unit
VIO_SD	WLAN host SDIO interface I/O supply (1.8V system)	2.2	V
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

9.2. Recommended Operating Conditions

Table 6: Recommended Operating Conditions

Symbol (Domain)	Parameter	Min	Typ	Max	Unit
VIO_SD	WLAN host interface I/O supply	1.62	1.8	1.98	V
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

9.3. 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_SD;VIO)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VIH	High Level Input Voltage	--	0.7 x 1V8		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

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9.4. WLAN Radio Receiver Characteristics

Table 8 and Table 9 summarize the WLAN 60-2230C 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
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[5]		-89		dBm
	OFDM, 54 Mbps			-74		
	HT20, MCS0			-89		
	HT20, MCS7			-70		
	HT40, MCS0			-86		
	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		

[5]Performance data are measured under signal chain operation

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

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9.5. 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		14		
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]
2412 MHz	1 Mbps	18dBm	340	620
	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510
2442 MHz	1 Mbps	18dBm	340	620
	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510
2472 MHz	1 Mbps	18dBm	340	620
	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510

Table 11: WLAN transmitter characteristics for 5 GHz per chain operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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
5795 MHz	HT40 MCS7	14 dBm	300	530

[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.

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10. 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.

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

Test Parameter		Min	Typ	Max	BT Spec.	Unit
Maximum RF Output Power		8	10	11	0 ~ +20	dBm
Frequency Range		2.4	—	2.4835	2.4 ≤ f ≤ 2.4835	GHz
20 dB Bandwidth		—	919.5	—	≤ 1000	KHz
Δf1avg Maximum Modulation		140	165	175	140 < Δf1avg < 175	KHz
Δf2max Minimum Modulation		—	135	—	≥ 115	KHz
Δf2avg/Δf1avg		—	0.9	—	≥ 0.80	—
Initial Carrier Frequency		—	+/-5	—	≤±75	KHz
Drift Rate (DH1 package)		—	4	—	≤ 20	KHz/50 µs
Drift (DH3 packet)		—	8	—	≤25	KHz
Drift (DH5 packet)		—	7	—	≤ 40	KHz
Adjacent Channel Power	F≥ ± 3MHz	—	–50	—	< –40	dBm
	F = ± 2MHz	—	-46	—	≤ –20	dBm
	F = ± 1MHz	—	-15	—	N/A	dBm

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

Test Parameter		Min	Typ	Max	BT Spec.	Unit
Relative Transmit Power		5	7	9		dBm
Max Carrier Frequency Stability |wo|	2-DH5	—	1	—	≤ ±10	KHz
	3-DH5	—	1	—		
Max Carrier Frequency Stability |wi|	2-DH5	—	4	—	≤ ±75	KHz
	3-DH5	—	4	—		
Max Carrier Frequency Stability |w0+wi|	2-DH5	—	5	—	≤ ±75	KHz
	3-DH5	—	5	—		
RMS DEVM	2-DH5	—	4	—	≤ 20	%
	3-DH5	—	4	—	≤13	%
Peak DEVM	2-DH5	—	9	—	≤ 35	%
	3-DH5	—	9	—	≤ 25	%
99% DEVM	2-DH5	—	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

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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 (C/I)	Co-Channel	—	10	11	11	
	C/I (± 1 MHz)	—	-4	0	0	dB
	C/I (± 2 MHz)	—	-45	—	–30	dB
	C/I (± 3 MHz)	—	-49	—	–40	dB
Maximum Level of Intermodulation Interferers		–39	-30	-	≥ –39	dBm

Table 14: Enhanced data rate receiver performance 1.8V

Test Parameter		Min	Typ	Max	Bluetooth Specification	Unit
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
Co-Channel C/I (BER ≤0.1%)	π/4 DQPSK	—	10	13	≤ ±13	dB
	8 DPSK	—	16	20	≤ ±20	dB
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 MHz)	π/4 DQPSK	—	-47	–30	≤ –30	dB
	8 DPSK	—	-42	–25	≤ –25	dB
Third Adjacent Channel C/I (3 MHz)	π/4 DQPSK	—	-51	–40	≤ –40	dB
	8 DPSK	—	-48	–33	≤ –33	dB
Out-of-band blocking	30-2000MHz	—	-12.5	—	—	dBm
	2-2.399GHz	—	-12.4	—	—	dBm
	2.484-3GHz	—	-18	—	—	dBm
	3-12.75GHz	—	-2.6	—	—	dBm

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11. SDIO TIMING REQUIREMENTS

The 60-2230C SDIO host interface pins are powered from the VIO_SD voltage supply. The SDIO electrical specifications are identical for the 1-bit SDIO and 4-bit SDIO modes.

11.1. SDR12, SDR25, SDR50 Mode (up to 100MHz) (1.8V)

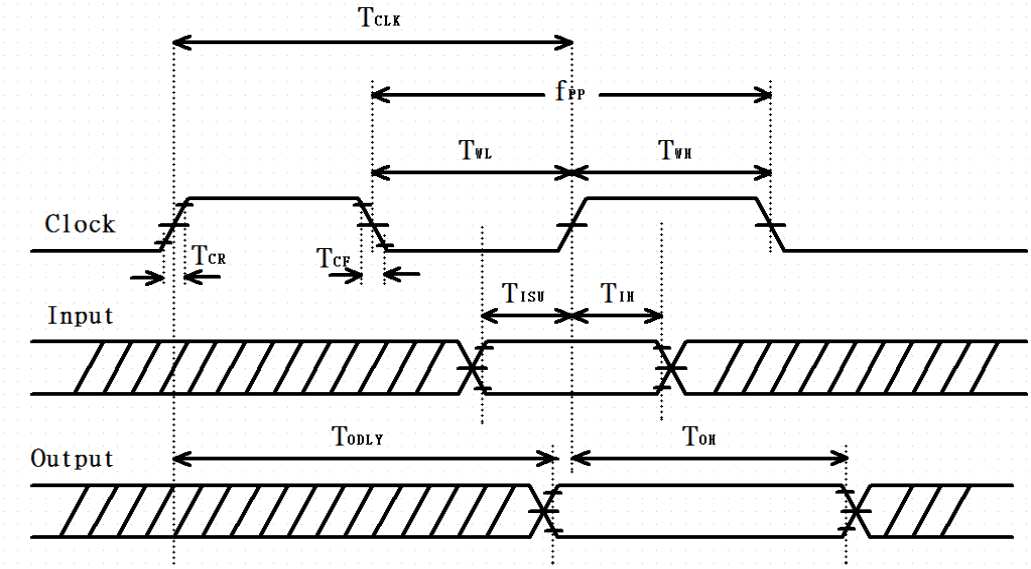

Figure 2:SDIO protocol timing Diagram--- SDR12, SDR25, SDR50 modes (up to 100 MHz) (1.8V)

Table 16: SDIO timing requirements--- SDR12, SDR25, SDR50 modes (up to 100 MHz) (1.8V)

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
fPP	Clock Frequency	SDR12/25/50	25	-	100	MHz
TISU	Input setup time	SDR12/25/50	3	--	-	ns
TIH	Input Hold time	SDR12/25/50	0.8	-	-	ns
TCLK	Clock Time	SDR12/25/50	10	-	40	ns
TCR,TCF	Raise time, Fall time TCR,TCF <2ns (max) at 100 MHz CCARD=10pF	SDR12/25/50	-	-	0.2*TCLK	ns
TODLY	Output delay time CL≦30pF	SDR12/25/50	-	-	7.5	ns
TOH	Output hold time CL=15pF	SDR12/25/50	1.5	-	-	ns

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11.2. SDR104 Mode (208MHz) (1.8V)

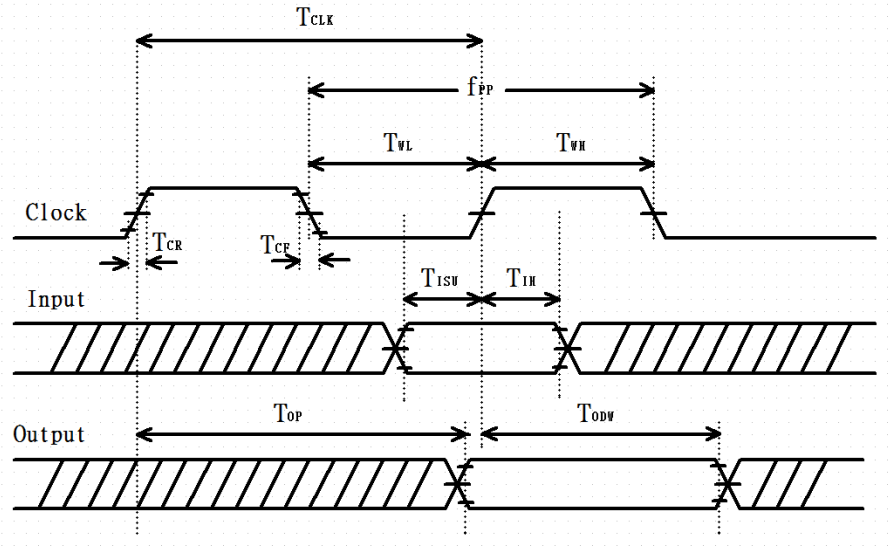

Figure 3: SDIO protocol timing Diagram--- SDR104 modes (up to 208 MHz) (1.8V)

Table 17: SDIO timing requirements--- SDR104 modes (up to 208MHz) (1.8V)

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
fPP	Clock Frequency	SDR104	0	-	208	MHz
TISU	Input setup time	SDR104	1.4	--	-	ns
TIH	Input Hold time	SDR104	0.8	-	-	ns
TCLK	Clock Time	SDR104	4.8	-	-	ns
TCR,TCF	Raise time, Fall time TCR,TCF <0.96ns (max) at 208 MHz CCARD=10 pF	SDR104	-	-	0.2*TCLK	ns
TOP	Card Output phase	SDR104	0	-	10	ns
TODW	Output timing pf variable data window	SDR12/25/50	2.88	-	-	ns

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11.3. DDR50 Mode (50MHz) (1.8V)

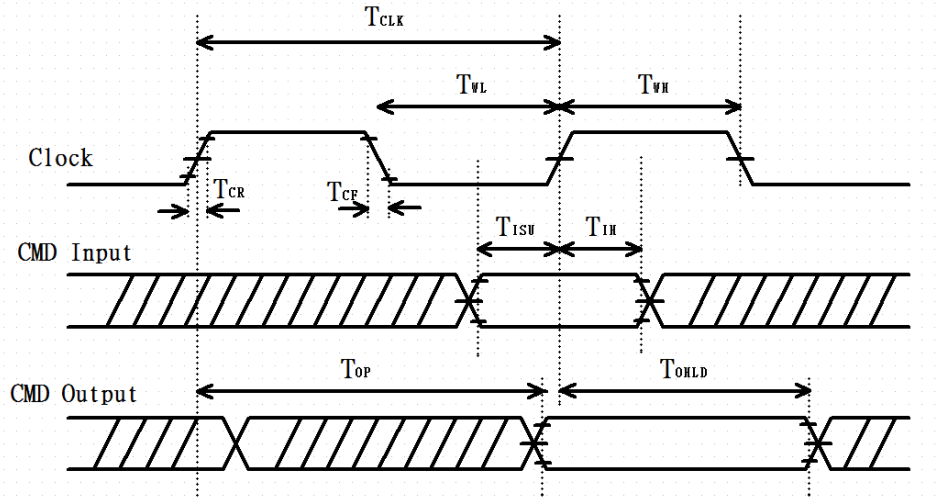

Figure 4: SDIO CMD timing Diagram--- DDR50 modes (50 MHz) (1.8V)

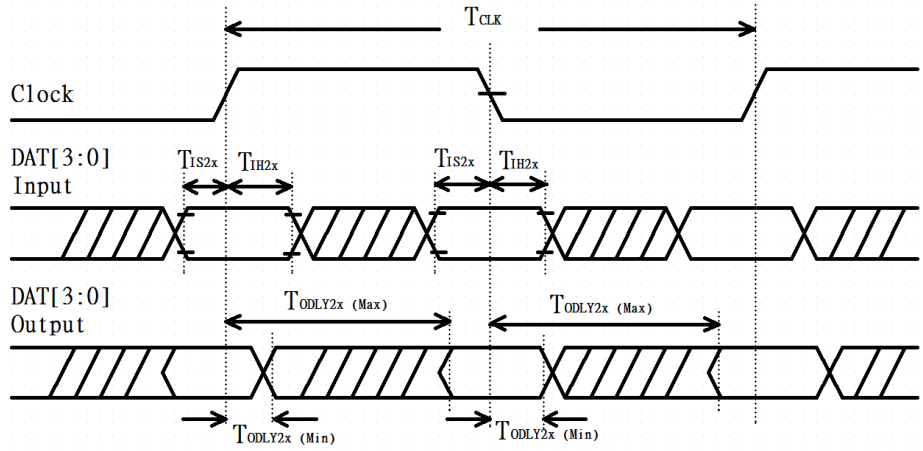

Figure 5: SDIO DAT[3:0] timing Diagram--- DDR50 modes (50 MHz) (1.8V)

Note: In DDR50 mode, DAT[3:0] lines are samples on both edges pF the clock (not applicable for CMD line)

Table 18: SDIO timing requirements--- DDR50 modes (50MHz)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Clock						
T_{CLK}	Clock time 50MHz (max) between rising edge	DDR50	20	--	--	ns
T_{CR}, T_{CF}	Rise time, fall time T_{CR}, T_{CF} <4.00ns (max) at 50MHz. C_{CARD}=10pF	DDR50	--	--	0.2*T_{CLK}	ns
Clock Duty	--	DDR50	45	--	55	%
CMD Input (referenced to clock rising edge)						
T_{IS}	Input setup time	DDR50	6	--	--	ns