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# Datasheet

## 60-SIPT series

*Version 1.1*

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## REVISION HISTORY

Version	Date	Notes	Approver
1.0	29 Aug 2017	Initial version	Jay White
1.1	08 Sept 2017	Updated Max. Current Consumption table/column headings	Andrew Chen

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## 1 SCOPE

This document describes key hardware aspects of the Laird 60-SIPT series system-in-package (SiP) modules providing either SDIO, USB2.0, or PCIe bus interface for WLAN connection and UART/PCM, SDIO/PCM, USB2.0/PCM for Bluetooth® connection. This document is intended to assist device manufacturers and related parties with the integration of this radio into their host devices. Data in this document is drawn from several sources and includes information found in the Marvell 88W8997/88PG823 data sheets issued in April 2016, along with other documents provided from Marvell.

**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-SIPT series SiP modules are an integrated, small form factor 2x2 MIMO 802.11 a/b/g/n/ac WLAN plus *Bluetooth* 4.2 dual mode device that is optimized for low-power mobile devices. The integration of all WLAN and *Bluetooth* functionality in a single package supports low cost and simple implementation along with flexibility for platform-specific customization.

This device is pre-calibrated and integrates the complete transmit/receive RF paths including band pass filter, diplexer, switches, reference crystal oscillator, and power manage units (PMU).

The 60-SIPT series device supports IEEE 802.11 ac (wave 2) 2X2 receive multi-user MIMO (MU-MIMO) spatial stream multiplexing with data rates up to MCS9 (866.7 Mbps). It also supports Bluetooth 2.1 + EDR and Bluetooth 4.2 (Bluetooth Low Energy or BLE). Internal Wi-Fi and BT coexistence scheme provides optimized throughput when Wi-Fi and BT working simultaneously. The device’s low power consumption radio architecture and power manage unit (PMU) proprietary power save technologies allow for extended battery life.

In addition, its dual 802.11 and Bluetooth radio includes full digital MAC and baseband engines that handle all 802.11 CCK/OFDM® 2.4/5GHz, and Bluetooth basic rate and EDR baseband and protocol processing.

Dual embedded low-power CPU cores minimize host loading and maximize flexibility to support customer-specific use cases.

The 60-SIPT series SiP modules include two product SKUs which is have different supported software features. Please check Laird Sales/FAE for further information. Order information is listed in [Table 1](#).



**Table 1: Product ordering information**

Order Model	Description
SU60-SIPT	802.11ac + BT4.2 60 Series hardware combined with Summit Series Enterprise software
ST60-SIPT	802.11ac + BT4.2 60 Series hardware combined with Sterling Series Professional software

### 3 60-SIPT SERIES FEATURES SUMMARY

The Laird 60-SIPT series device features are described in [Table 2](#).

**Table 2: 60-SIPT series features**

Feature	Description
<b>Radio Front End</b>	Integrates the complete transmit/receive RF paths including band pass filter, diplexer, switches, reference crystal oscillator, and power manage unit (PMU). Supports 20/40/80MHz channel bandwidth. WLAN/Bluetooth share one antenna.

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<b>Coexistence</b>	Coexistence arbitration for WLAN, Bluetooth, and LTE operation			
<b>Power Management</b>	Dynamic Voltage Scaling (DVS) and Adaptive Voltage Scaling (AVS) features support the latest Marvell SoC and Processor power control scheme.			
<b>Pre-Calibration</b>	RF system tested and calibrated in production			
<b>Sleep Clock</b>	An external sleep clock of 32.768 KHz is required during power save mode			
<b>Host Interface</b>	<ul style="list-style-type: none"> <li>SDIO 3.0 (4-bit and 1-bit), SDR 12/25/50 mode (up to 100 MHz), USB2.0 or PCIe for WLAN</li> <li>SDIO 3.0, USB 2.0, HS-UART for Bluetooth HCI (compatible with any upper layer Bluetooth stack)</li> <li>PCM digital audio interface for Bluetooth audio application</li> </ul>			
	<b>Strap Value</b>	<b>WLAN</b>	<b>Bluetooth/BLE</b>	<b>ROM Notes</b>
	<b>CONFIG_HOST [2-0]</b>			
	000	SDIO	UART	-
	001	SDIO	SDIO	-
	010	PCIe	USB 2.0	Initial USB 2.0 PHY and COM PHY PCIe portion
	011	PCIe	UART	Initial only COM PHY PCIe portion
	100	USB 2.0	UART	Initial COM PHY USB 2.0
101	USB 2.0	USB 2.0	Initial only USB 2.0 PHY	
<b>Reference Frequency</b>	<ul style="list-style-type: none"> <li>Incorporates a 40 MHz reference frequency source in package</li> <li>An external sleep clock is recommended for minimal current consumption. If no sleep clock input is provided, an internal sleep clock (derived from reference clock) is used. An approximate 50 uA current increase on the 3.3V rail.</li> </ul>			
<b>Advanced WLAN</b>	<ul style="list-style-type: none"> <li>A-MPDU RX (de-aggregation) and TX (aggregation) supports 802.11ac single-MPDU A-MPDU.</li> <li>Multi-BSS/Station</li> <li>Transmit rate adaption, transmit power control</li> <li>Modulation and coding scheme (MCS): 802.11ac—MCS0-9 Nsts=1 and 2. 802.11n—MCS0-15</li> </ul>			
	<ul style="list-style-type: none"> <li>Dynamic frequency selection (radar detection) DFS</li> <li>20/40/80 MHz channel bandwidths support</li> <li>On-chip gain selectable LNA with optimized noise figure and power consumption</li> <li>Internal PA with optimized gain distribution for linearity and noise performance</li> <li>Support wide variety of WLAN encryption: TKIP/WEP/AES</li> </ul>			

Feature	Description
Advanced Bluetooth	<ul style="list-style-type: none"> <li>Bluetooth 4.2 (BDR/EDR/LE), Bluetooth class 1</li> <li>Support data rate: 1 Mbps (GFSK), 2 Mbps (<math>\pi/4</math>-DQPSK), 3 Mbps (8-DPSK)</li> <li>Digital audio interface with PCM/TDM interface for voice application</li> <li>Adaptive Frequency Hopping (AFH) using Package Error Rate (PER)</li> <li>Standard SDIO or UART HCI transport layer</li> <li>WLAN/Bluetooth coexistence protocol support</li> <li>Shared LNA with WLAN/Bluetooth</li> <li>Encryption (AES) support</li> </ul>

## 4 SPECIFICATIONS

Table 3: Specifications

Feature	Description																												
Physical Interface	84-pin LGA package (including 16 thermal ground pad under the package)																												
Wi-Fi Interface	1-bit or 4-bit Secure Digital I/O; PCIe v3.0 Gen1/Gen2 (2.5/5 Gbps); USB 2.0																												
Bluetooth/BLE Interface	Host Controller Interface (HCI) using high speed UART, SDIO, USB 2.0																												
	<table border="1"> <thead> <tr> <th>Strap Value CONFIG_HOST [2-0]</th> <th>WLAN</th> <th>Bluetooth/ BLE</th> <th>ROM Notes</th> </tr> </thead> <tbody> <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>010</td> <td>PCIe</td> <td>USB 2.0</td> <td>Initial USB 2.0 PHY and COM PHY PCIe portion</td> </tr> <tr> <td>011</td> <td>PCIe</td> <td>UART</td> <td>Initial only COM PHY PCIe portion</td> </tr> <tr> <td>100</td> <td>USB 2.0</td> <td>UART</td> <td>Initial COM PHY USB 2.0</td> </tr> <tr> <td>101</td> <td>USB 2.0</td> <td>USB 2.0</td> <td>Initial only USB 2.0 PHY</td> </tr> </tbody> </table>	Strap Value CONFIG_HOST [2-0]	WLAN	Bluetooth/ BLE	ROM Notes	000	SDIO	UART	-	001	SDIO	SDIO	-	010	PCIe	USB 2.0	Initial USB 2.0 PHY and COM PHY PCIe portion	011	PCIe	UART	Initial only COM PHY PCIe portion	100	USB 2.0	UART	Initial COM PHY USB 2.0	101	USB 2.0	USB 2.0	Initial only USB 2.0 PHY
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100	USB 2.0	UART	Initial COM PHY USB 2.0																										
101	USB 2.0	USB 2.0	Initial only USB 2.0 PHY																										
Main Chip	Marvell 88W8997 (WLAN/BT); Marvell 88PG823 (PMU)																												
Input Voltage Requirements	DC 3.3 V $\pm$ 10%																												
I/O Signalling Voltage	DC 3.3 V $\pm$ 10% or DC 1.8 V $\pm$ 10%																												
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	13 mm (length) x 14 mm (width) x 1.87 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																												

Feature	Description
<b>Wi-Fi Standards</b>	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
<b>Bluetooth Standards</b>	Bluetooth version 2.1 with Enhanced Data Rate Bluetooth 4.2 (Bluetooth Low Energy or BLE)
<b>Wi-Fi Data Rates Supported</b>	Support 802.11 ac/a/b/g/n 2X2 MIMO. 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	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
802.11n	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	<b>433.3</b>
	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	<b>866.7</b>

<b>802.11ac/n Spatial Streams</b>	2 (2x2 MIMO)
<b>Bluetooth Data Rates Supported</b>	1, 2, 3 Mbps
<b>Bluetooth Modulation</b>	GFSK@ 1 Mbps Pi/4-DQPSK@ 2 Mbps 8-DPSK@ 3 Mbps
<b>Regulatory Domain Support</b>	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






Feature	Description
<b>2.4 GHz Frequency Bands</b>	<b>ETSI:</b> 2.4 GHz to 2.483 GHz <b>FCC:</b> 2.4 GHz to 2.473 GHz <b>MIC:</b> 2.4 GHz to 2.495 GHz <b>KC:</b> 2.4 GHz to 2.483 GHz
<b>2.4 GHz Operating Channels (Wi-Fi)</b>	<b>ETSI:</b> 13 (3 non-overlapping) <b>FCC:</b> 11 (3 non-overlapping) <b>MIC:</b> 14 (4 non-overlapping) <b>KC:</b> 13 (3 non-overlapping)
<b>5 GHz Frequency Bands</b>	<b>ETSI</b> 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) <b>FCC</b> 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 5.85 GHz (Ch 149/153/157/161/165) <b>MIC (Japan)</b> 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) <b>KC</b> 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)
<b>5 GHz Operating Channels (Wi-Fi)</b>	<b>ETSI:</b> 19 non-overlapping; <b>FCC:</b> 24 non-overlapping <b>MIC:</b> (Japan): 19 non-overlapping; <b>KC:</b> 19 non-overlapping
<b>Transmit Power</b>	<b>802.11a</b> 6 Mbps 18 dBm (63 mW) 54 Mbps 16 dBm (40 mW) <b>802.11b</b> 1 Mbps 18 dBm (63 mW) 11 Mbps 18 dBm (63 mW) <b>802.11g</b> 6 Mbps 18 dBm (63 mW) 54 Mbps 16 dBm (40 mW) <b>802.11n (2.4/5 GHz)</b> 6.5 Mbps (MCS0-5/MCS8-13; HT20) 18 dBm (63 mW) 65 Mbps (MCS6-7/MCS14-15; HT20) 16 dBm (40 mW) 13.5 Mbps (MCS0-5/MCS8-13; HT40) 16 dBm (40 mW) 135 Mbps (MCS6-7/MCS14-15; HT40) 14 dBm (25 mW) <b>802.11ac (5 GHz)</b> 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) 13.5/27 Mbps (MCS0-5; Ntst=1,2; HT40) 16 dBm (40 mW) 180/360 Mbps (MCS6-8; Ntst=1,2; HT40) 14 dBm (25 mW) 200/400 Mbps (MCS9; Ntst=1,2; HT40) 12 dBm (15.8mW) 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) <b>Bluetooth</b> 1 Mbps (1DH5) 10 dBm (12.5 mW)

**Note:** Transmit power on each channel varies per 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

Feature	Description
	2 Mbps 7 dBm (6.3 mW) 3 Mbps 7 dBm (6.3 mW) BLE (1 Mbps) 7 dBm (6.3 mW)
<b>Typical Receiver Sensitivity</b> (PER <= 10%) <i>Note: All values nominal, +/-3 dBm.            Sensitivity on CH13 (WLAN)/CH78            (BT) will degrade up to 4-6dB.</i>	<b>802.11a:</b> 6 Mbps -89 dBm 54 Mbps -74 dBm <b>802.11b:</b> 1 Mbps -95 dBm 11 Mbps -90 dBm (PER<8%) <b>802.11g:</b> 6 Mbps -91 dBm 54 Mbps -75 dBm <b>802.11n (2.4 GHz)</b> 6.5 Mbps (MCS0; HT20) -91 dBm 65 Mbps (MCS7; HT20) -73 dBm 13.5 Mbps (MCS0; HT40) -85 dBm 135 Mbps (MCS7; HT40) -70 dBm <b>802.11n (5 GHz)</b> 6.5 Mbps (MCS0; HT20) -89 dBm 65 Mbps (MCS7; HT20) -70 dBm 13.5Mbps (MCS0; HT40) -86 dBm 135Mbps (MCS7; HT40) -69 dBm <b>802.11ac (5 GHz)</b> 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) -55 dBm <b>Bluetooth:</b> 1 Mbps (1DH5) -95 dBm 2Mbps (2DH5) -94 dBm 3 Mbps (3DH5) -88 dBm BLE -95 dBm
<b>Operating Systems Supported</b>	Linux 3.x to 4.9.x kernel. Android 5.0-5.1.1 (Lollipop) Nov. 2014 supported. Android 6.0-6.01 (Marshmallow) Oct 2015 supported Android 7.0-7.1.1 (Nougat) Aug. 2016 supported

Feature	Description
<b>Security</b>	<p><b>Standards</b>            Wireless Equivalent Privacy (WEP)            Wi-Fi Protected Access (WPA)            IEEE 802.11i (WPA2)</p> <p><b>Encryption</b>            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)</p> <p><b>Dynamic</b>            802.1X Extensible Authentication Protocol Types            EAP-FAST                      PEAP-MSCHAPv2            EAP-TLS                        PEAP-TLS            EAP-TTLS                      LEAP            PEAP-GTC</p>
<b>Compliance</b> <i>Note: These regulatory certifications are pending.</i>	<p><b>ETSI Regulatory Domain</b>            EN 300 328            EN 301 489-1            EN 301 489-17            EN 301 893            EN 60950-1            2011/65/EU (RoHS)</p> <p><b>FCC Regulatory Domain</b>            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</p> <p><b>Industry Canada</b>            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</p>
<b>Certifications</b> <i>Note: These regulatory certifications are pending.</i>	<p><b>Wi-Fi Alliance</b> (Summit version only)            802.11a, 802.11b, 802.11g, 802.11n, 802.11ac            WPA Enterprise            WPA2 Enterprise</p> <p><b>Cisco Compatible Extensions</b> (Version 4) (Summit version only)  <b>Bluetooth® SIG</b> Qualification</p> <div style="display: flex; justify-content: space-around; align-items: center;">    </div>
<b>Warranty</b>	Three Year Warranty

**All specifications are subject to change without notice**

## 5 WLAN FUNCTIONAL DESCRIPTION

### 5.1 Overview

The 60-SIPT series SiP module is designed based on the Marvell 88W8997 802.11ac/a/b/g/n chipset. It is optimized for high speed, reliable, and low-power embedded applications. It's integrated with dual-band WLAN (2.4/5GHz) and Bluetooth 4.2. Its functionality includes:

- 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 (866.7Mbps).

Additional functionality is listed in the following table (Table 4).

**Table 4: WLAN functions**

Feature	Description
<b>WLAN MAC</b>	<ul style="list-style-type: none"> <li>▪ Frame Exchange at the MAC level to deliver data</li> <li>▪ Received frame filtering and validation (Cyclic Redundancy Check (CRC))</li> <li>▪ Generation of MAC header and trailer information (MAC protocol Data Units (MPDUs))</li> <li>▪ Fragmentation of data frames (MAC Service Data Units (MSDUs))</li> <li>▪ Access Mechanism support for fair access to shared wireless medium through (DCF and EDCA)</li> <li>▪ A-MPDU Aggregation/Deaggregation (support 802.11ac single –MPDU A-MPDU)</li> <li>▪ 20/40/80 MHz channel Coexistence</li> <li>▪ RIFS Burst Receive</li> <li>▪ Management Information Base</li> <li>▪ Radio Resource Measurement</li> <li>▪ Quality of Service</li> <li>▪ Block Acknowledgement</li> <li>▪ 802.11ac Downlink MU-MIMO (receive)</li> <li>▪ Dynamic Frequency Selection</li> <li>▪ Beamforming</li> <li>▪ TIM Frame TX and RX</li> <li>▪ Multi-BSS/Station</li> <li>▪ Transmit Rate Adaptation.</li> <li>▪ Transmit Power Control</li> </ul>

Feature	Description
<b>WLAN Base Band</b>	<ul style="list-style-type: none"> <li>▪ 802.11ac 2x2 MU-MIMO (with on-chip Marvell RF radio)</li> <li>▪ Backward compatibility with legacy 802.11 n/a/b/g technology</li> <li>▪ WLAN/Bluetooth LNA sharing</li> <li>▪ PHY rate up to 866.7 Mbps</li> <li>▪ 20 MHz bandwidth/channel, 40 MHz bandwidth/channel, upper/lower 20 MHz packets in 40 MHz channel, 20 MHz duplicate legacy packets in 40 MHz channel operation.</li> <li>▪ 80 MHz bandwidth/channel, 4 positions of 20 MHz packets in 80 MHz channel, upper/lower 40 MHz packets in 80 MHz channel, 20 MHz quadruplicate legacy packets in 80 MHz channel mode operation.</li> <li>▪ Modulation and Coding Scheme (MCS): 802.11ac (MCS0-9. Nsts=1/2); 802.11n (MCS0-15)</li> <li>▪ Dynamic Frequency Selection (DFS) (Radar detection)               <ul style="list-style-type: none"> <li>– Enhanced radar detection for long and short pulse radar</li> <li>– Enhanced AGC scheme for DFS channel</li> <li>– Japan DFS requirements for W53 and W56</li> </ul> </li> <li>▪ 802.11 K Radio Resource Measurement.</li> <li>▪ 802.11ac /802.11n optional MIMO features:               <ul style="list-style-type: none"> <li>20/40/80 MHz Coexistence with middle-packaged detection (GI detection) for enhanced CCA</li> <li>– One spatial stream STBC reception and transmission</li> <li>– LDPC transmission and reception for 802.11ac and 802.11n</li> <li>– 256 QAM (MCS8-9) modulations supported</li> <li>– Short guard interval</li> <li>– RIFS on receive path for 802.11n packets</li> <li>– 802.11n Greenfield TX/RX</li> </ul> </li> <li>▪ Power Save feature</li> </ul>
<b>WLAN Security</b>	<ul style="list-style-type: none"> <li>▪ WLAN Encryption features supported include:               <ul style="list-style-type: none"> <li>– Temporal Key Integrity Protocol (TKIP)/Wired Equivalent Privacy (WEP)</li> <li>– Advanced Encryption Standard (AES)/Counter-Mode/CBC-MAC Protocol (CCMP)</li> <li>– Advanced Encryption Standard (AES)/Cipher-Based Message Authentication Code (CMAC)</li> <li>– Advanced Encryption Standard (AES)/Galois/Counter Mode Protocol (GCMP)</li> <li>– WLAN Authentication and Private Infrastructure (WPAI)</li> </ul> </li> </ul>



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				

## 6 BLUETOOTH FUNCTIONAL DESCRIPTION

The 60-SIPT series includes a fully-integrated Bluetooth baseband/radio. Several features and functions are listed in [Table 5](#).

**Table 5: Bluetooth functions**

Feature	Description
<b>Bluetooth Interface</b>	<ul style="list-style-type: none"> <li>▪ Voice interface:               <ul style="list-style-type: none"> <li>– Hardware support for continual PCM data transmission/reception without processor overhead.</li> <li>– Standard PCM clock rates from 64 kHz to 2.048 MHz with multi-slot handshake and synchronization.</li> <li>– A-law, U-law, and linear voice PCM encoding/decoding.</li> </ul> </li> <li>▪ SDIO interface</li> <li>▪ High-Speed UART interface</li> <li>▪ USB 2.0</li> </ul>
<b>Bluetooth Core functionality</b>	<ul style="list-style-type: none"> <li>▪ Bluetooth 4.2</li> <li>▪ Bluetooth Class 2/Bluetooth class 1</li> <li>▪ WLAN and Bluetooth share same LNA and antenna</li> <li>▪ Digital audio interfaces with PCM/TDM interface for voice application</li> <li>▪ Baseband and radio BDR and EDR package type: 1 Mbps, 2 Mbps, 3 Mbps</li> <li>▪ Fully functional Bluetooth baseband: AFH, forward error correction, header error control, access code correction, CRC, encryption bit stream generation, and whitening.</li> <li>▪ Adaptive Frequency Hopping (AFH) using Packet Error Rate (PER)</li> <li>▪ Interlaced scan for faster connection setup</li> <li>▪ Simultaneous active ACL connection setup</li> <li>▪ Automatic ACL package type selection</li> <li>▪ Full master and slave piconet support</li> <li>▪ Scatter net support</li> <li>▪ SCO/eSCO links with hardware accelerated audio signal processing and hardware supported PPEC algorithm for speech quality improvement</li> <li>▪ All standard SCO/eSCO voice coding</li> <li>▪ All standard pairing, authentication, link key, and encryption operations</li> <li>▪ Encryption (AES) support</li> </ul>
<b>Bluetooth Low Energy (BLE) Core functionality</b>	<ul style="list-style-type: none"> <li>▪ Advertiser, Scanner, Initiator, Master, and Slave roles support (connects to 16 links)</li> <li>▪ WLAN/Bluetooth Coexistence (BCA) protocol support.</li> <li>▪ Shared RF with BDR/EDR</li> <li>▪ Encryption (AES) support.</li> <li>▪ Intelligent Adaptive Frequency Hopping (AFH)</li> <li>▪ LE privacy 1.2</li> <li>▪ LE Secure Connection.</li> <li>▪ LE Data Length Extension</li> <li>▪ LE Advertising Length Extension.</li> <li>▪ 2Mbps LE</li> <li>▪ Direction Finding –connectionless Angle of Departure (AoD)</li> <li>▪ Direction Finding –connectionless Angle of Arrival (AoA)</li> </ul>

## 7 BLOCK DIAGRAM

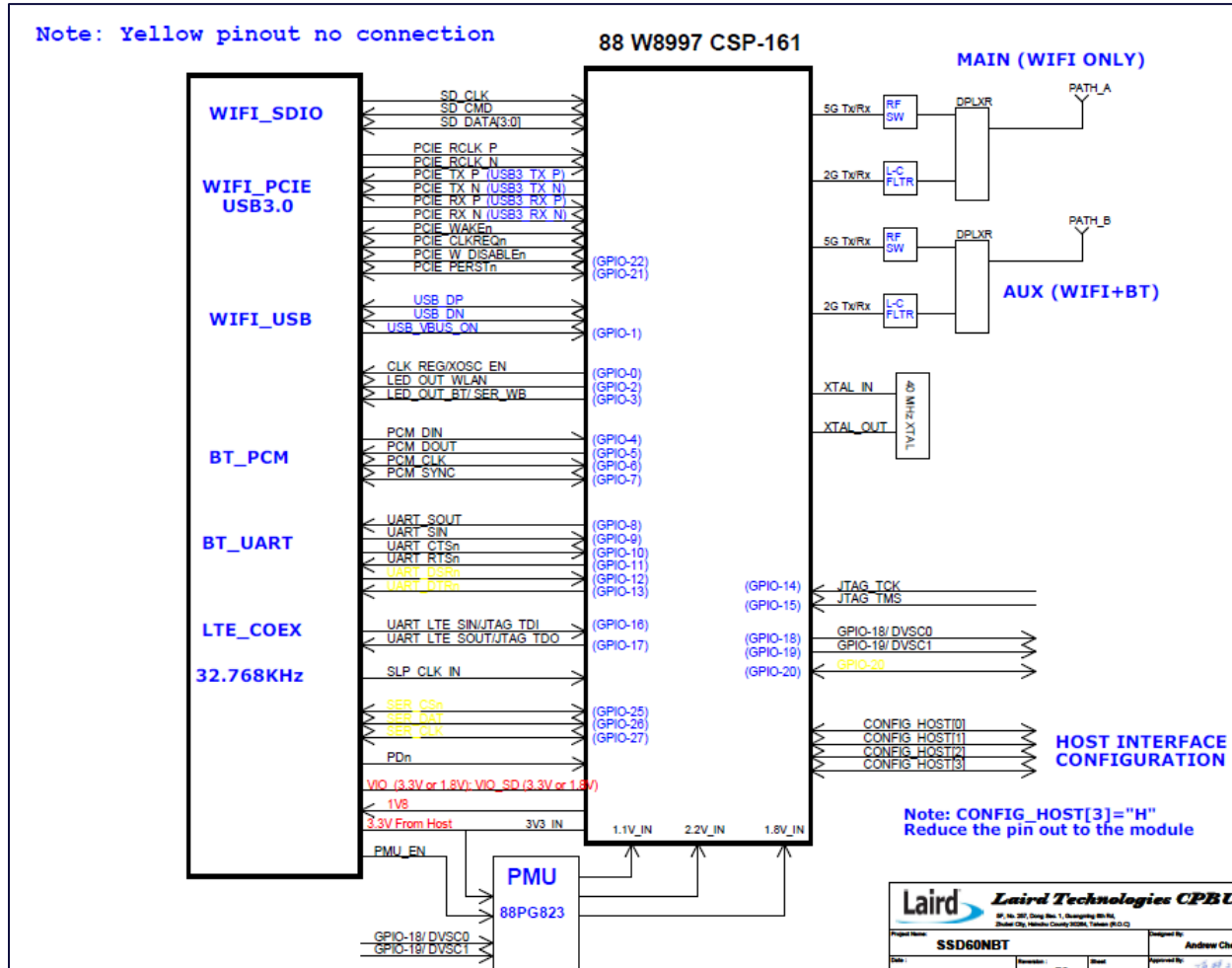


Figure 1: Block diagram

## 8 ELECTRICAL CHARACTERISTICS

### 8.1 Absolute Maximum Ratings

Table 6 summarizes the absolute maximum ratings and Table 7 lists the recommended operating conditions for the 60-SIPT Series. 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 6: Absolute maximum ratings

Symbol (Domain)	Parameter	Max Rating	Unit
VIO_SD	WLAN host SDIO interface I/O supply (for 1.8V system) (for 3.3V system)	2.2 4.0	V

Symbol (Domain)	Parameter	Max Rating	Unit
VIO	I/O configuration power supply (for 1.8V system) (for 3.3V system)	2.2 4.0	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

Table 7: Recommended Operating Conditions

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

## 8.3 DC Electrical Characteristics

Table 8 and Table 9 list the general DC electrical characteristics over recommended operating conditions (unless otherwise specified).

Table 8: General DC electrical characteristics (For 1.8V operation VIO\_SD; VIO)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VIH	High Level Input Voltage	--	1.26		2.2	V
VIL	Low Level Input Voltage	--	-0.4		0.54	V
VHYS	Input Hysteresis	--	100			mV
VOH	Output high Voltage	--	1.4			V
VOL	Output low Voltage	--			0.4	V

Table 9: General DC electrical characteristics (For 3.3V operation VIO\_SD; VIO)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VIH	High Level Input Voltage	--	2.4		3.6	V
VIL	Low Level Input Voltage	--	-0.4		0.9	V
VHYS	Input Hysteresis	--	100			mV
VOH	Output high Voltage	--	2.9			V
VOL	Output low Voltage	--			0.4	V

Table 10: DC electrical characteristics for 1.8V or 3.3V operation on special pads (PCIE\_WAKEn, PCIE\_CLKREQn)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VIH	High Level Input Voltage	--	1.4		3.6	V
VIL	Low Level Input Voltage	--	-0.4		0.8	V

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VHYS	Input Hysteresis	--	150			mV
VOL	Output low Voltage	--			0.4	V

## 8.4 WLAN Radio Receiver Characteristics

Table 11 and Table 12 summarize the WLAN 60-SIPT series receiver characteristics.

Table 11: WLAN receiver characteristics for 2.4 GHz signal chain operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Fr <sub>x</sub>	Receive input frequency range		2.412		2.484	GHz
Sr <sub>f</sub>	Sensitivity					
	CCK, 1 Mbps	See Note <sup>1</sup>		-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 <sup>1</sup>		TBD		dB
	OFDM, 54 Mbps			TBD		
	HT20, MCS0			TBD		
	HT20, MCS7			TBD		

Table 12: WLAN Receiver Characteristics for 5 GHz Dual Chain Operation

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Fr <sub>x</sub>	Receive input frequency range		5.15		5.825	GHz
Sr <sub>f</sub>	Sensitivity					
	OFDM, 6 Mbps	See Note <sup>1</sup>		-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 <sup>1</sup>		TBD		dB
	OFDM, 54 Mbps			TBD		
	HT20, MCS0			TBD		
	HT20, MCS7			TBD		

Note<sup>1</sup>: Performance data are measured under single chain operation.



## 8.5 WLAN Transmitter Characteristics

Table 13: 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 <sup>7</sup>				
	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 °C	-	-2.0	-	+2.0	

Freq.	Mode/Rate (Mbps)	Output Power Per Chain (dBm)	Maximum Current Consumption	
			Single Chain (mA) <sup>8</sup>	Dual Chains (mA) <sup>8</sup>
2412MHz	1 Mbps	18dBm	340	620
	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510
2422MHz	1 Mbps	18dBm	340	620
	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510
2472MHz	1 Mbps	18dBm	340	620
	54 Mbps	16dBm	280	500
	HT20 MCS7	16dBm	280	510

Table 14: 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 <sup>3</sup>				
	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		14		
	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	MCS6-8(Ntst=1,2)		14		
	11ac HT40 EVM compliant	MCS9(Ntst=1,2)		12		

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	11ac HT80 mask compliant	MCS0-5 (Ntst=1,2)		14		
	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 °C	-	-2.0	-	+2.0	dB

Table 15: WLAN current consumption on 5 GHz

Freq.	Mode/Rate [Mbps]	Output Power Per Chain [dBm]	Maximum Current Consumption	
			Single Chain (mA)	Dual Chains (mA)
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

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

## 9 BLUETOOTH RADIO CHARACTERISTICS

Table 16 through Table 17 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 16: Basic rate transmitter performance temperature at 25°C (3.3V)

Test Parameter	Min	Typ	Max	BT Spec.	Unit
Maximum RF Output Power	8	10	11	0 ~ +20	dBm
Frequency Range	2.4	—	2.4835	$2.4 \leq f \leq 2.4835$	GHz
20 dB Bandwidth	—	919.5	—	$\leq 1000$	KHz
$\Delta f_{1avg}$ Maximum Modulation	140	165	175	$140 < \Delta f_{1avg} < 175$	KHz
$\Delta f_{2max}$ Minimum Modulation	—	135	—	$\geq 115$	KHz
$\Delta f_{2avg}/\Delta f_{1avg}$	—	0.9	—	$\geq 0.80$	—

Test Parameter	Min	Typ	Max	BT Spec.	Unit	
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 17: Enhanced data rate transmitter performance 25°C (3.3V)

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

Table 18: Basic rate receiver performance at 3.3V

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 19: Enhanced data rate receiver performance 3.3V

Test Parameter		Min	Typ	Max	Bluetooth Specification	Unit
Sensitivity (BER ≤0.01%)	$\pi/4$ DQPSK	—	-94	-91	≤ -70	dBm
	8 DPSK	—	-88	-85	≤ -70	dBm
Maximum Input (BER ≤0.1%)	$\pi/4$ DQPSK	-20	—	—	≥ -20	dBm
	8 DPSK	-20	—	—	≥ -20	dBm
Co-Channel C/I (BER ≤0.1%)	$\pi/4$ DQPSK	—	10	13	≤ ±13	dB
	8 DPSK	—	16	20	≤ ±20	dB
Adjacent Channel C/I (1MHz)	$\pi/4$ DQPSK	—	-9	0	≤ 0	dB
	8 DPSK	—	-6	5	≤ 5	dB
Second Adjacent Channel C/I (2MHz)	$\pi/4$ DQPSK	—	-47	-30	≤ -30	dB
	8 DPSK	—	-42	-25	≤ -25	dB
Third Adjacent Channel C/I (3MHz)	$\pi/4$ 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

## 10 HOST INTERFACE SPECIFICATIONS

### 10.1 SDIO Specifications

The 60-SIPT series 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.

#### 10.1.1 Default Speed, High-speed Modes

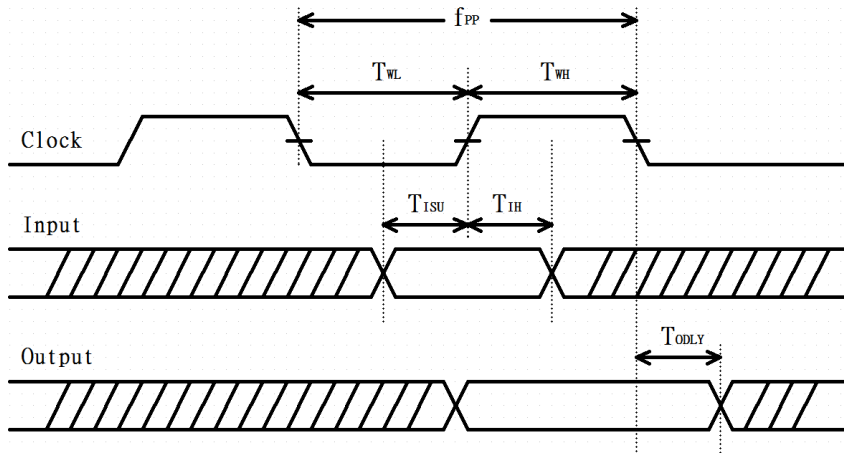


Figure 2: SDIO protocol timing diagram--- default mode (3.3V)

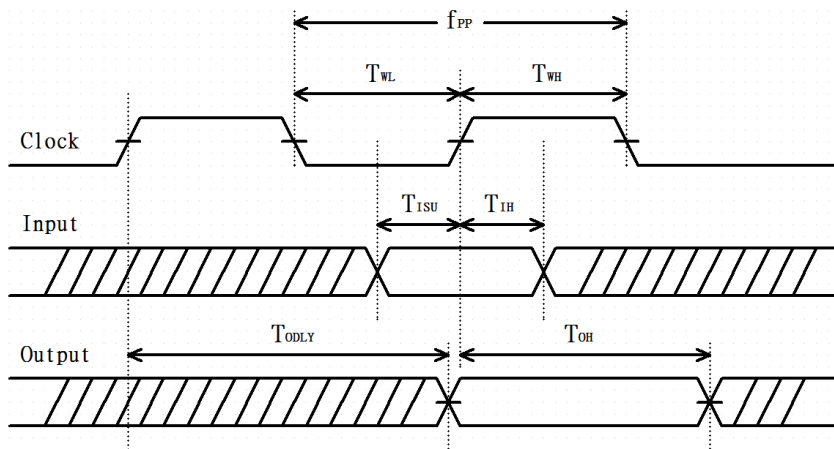


Figure 3: SDIO protocol timing diagram--- High-Speed mode (3.3V)

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

Table 20: SDIO timing requirements

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
f <sub>PP</sub>	Clock Frequency	Default Speed	0	-	25	MHz
		High-Speed	0	-	50	



Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
T <sub>WL</sub>	Clock low time	Default Speed	10	-	-	ns
		High-Speed	7	-	-	
T <sub>WH</sub>	Clock high time	Default Speed	10	-	-	ns
		High-Speed	7	-	-	
T <sub>ISU</sub>	Input Setup time	Default Speed	5	-	-	ns
		High-Speed	6	-	-	
T <sub>IH</sub>	Input Hold time	Default Speed	5	-	-	ns
		High-Speed	2	-	-	
T <sub>ODLY</sub>	Output delay time CL ≤ 40pF (1 card)	Default Speed	-	-	14	ns
		High-Speed	-	-	14	
T <sub>OH</sub>	Output hold time	High-Speed	0	-	-	ns

### 10.1.2 SDR12, SDR25, SDR50 Mode (up to 100MHz) (1.8V)

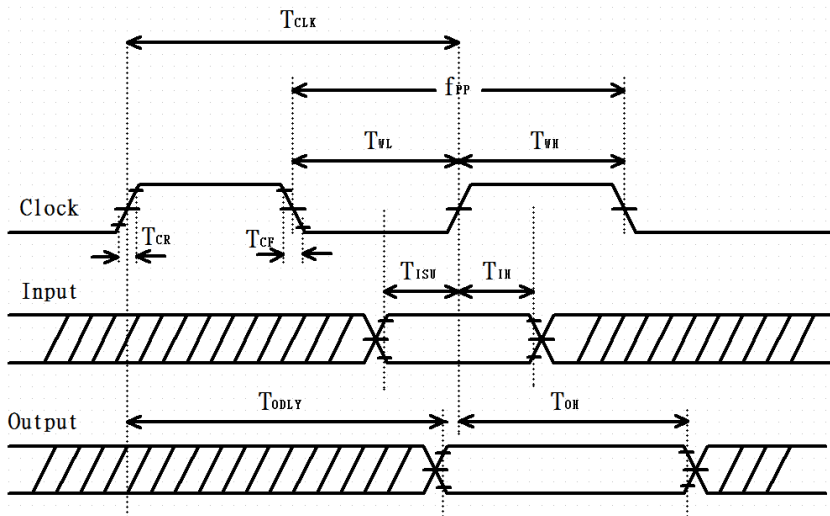


Figure 4: SDIO protocol timing Diagram--- SDR12, SDR25, SDR50 modes (up to 100 MHz) (1.8V)

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

Table 21: SDIO timing requirements--- SDR12, SDR25, SDR50 modes (up to 100 MHz) (1.8V)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
f <sub>PP</sub>	Clock Frequency	SDR12/25/50	25	-	100	MHz
T <sub>ISU</sub>	Input setup time	SDR12/25/50	3	--	-	ns
T <sub>IH</sub>	Input Hold time	SDR12/25/50	0.8	-	-	ns
T <sub>CLK</sub>	Clock Time	SDR12/25/50	10	-	40	ns
T <sub>CR</sub> , T <sub>CF</sub>	Raise time, Fall time	SDR12/25/50	-	-	0.2*T <sub>CLK</sub>	ns
	T <sub>CR</sub> , T <sub>CF</sub> < 2ns (max) at 100MHz C <sub>CARD</sub> =10pF					

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
T <sub>ODLY</sub>	Output delay time C <sub>L</sub> ≤ 30pF	SDR12/25/50	-	-	7.5	ns
T <sub>OH</sub>	Output hold time C <sub>L</sub> = 15pF	SDR12/25/50	1.5	-	-	ns

### 10.1.3 SDR104 Mode (208MHz) (1.8V)

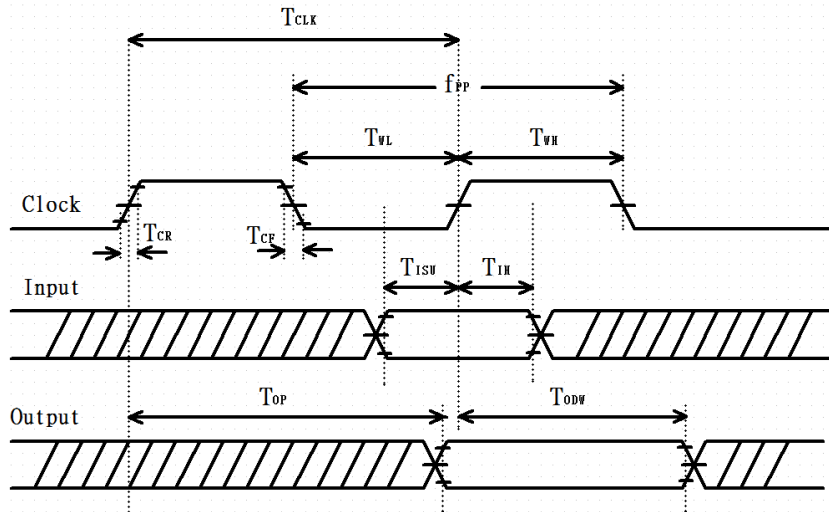


Figure 5: SDIO protocol timing Diagram--- SDR104 modes (up to 208 MHz) (1.8V)

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

Table 22: SDIO timing requirements--- SDR104 modes (up to 208MHz) (1.8V)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
f <sub>FP</sub>	Clock Frequency	SDR104	0	-	208	MHz
T <sub>ISU</sub>	Input setup time	SDR104	1.4	--	-	ns
T <sub>IH</sub>	Input Hold time	SDR104	0.8	-	-	ns
T <sub>CLK</sub>	Clock Time	SDR104	4.8	-	-	ns
T <sub>CR</sub> , T <sub>CF</sub>	Raise time, Fall time T <sub>CR</sub> , T <sub>CF</sub> < 0.96ns (max) at 208MHz C <sub>CARD</sub> = 10pF	SDR104	-	-	0.2 * T <sub>CLK</sub>	ns
T <sub>OP</sub>	Card Output phase	SDR104	0	-	10	ns
T <sub>ODW</sub>	Output timing pf variable data window	SDR12/25/50	2.88	-	-	ns

### 10.1.4 DDR50 Mode (50MHz) (1.8V)

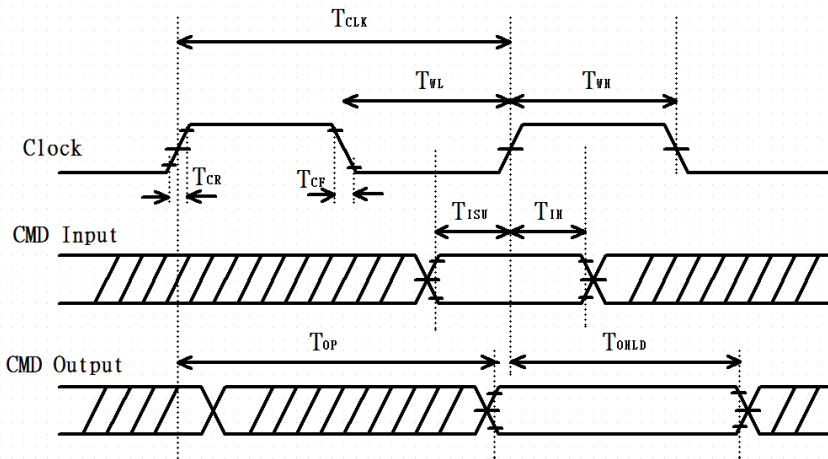


Figure 6: SDIO CMD timing diagram--- DDR50 modes (50 MHz) (1.8V)

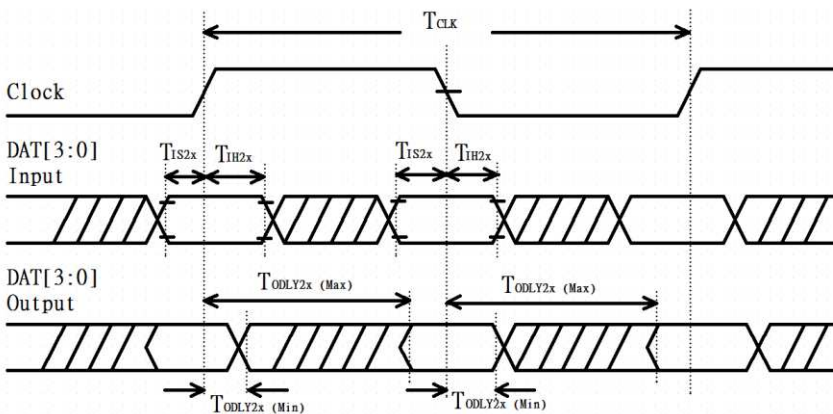


Figure 7: SDIO DAT[3:0] timing Diagram--- DDR50 modes (50 MHz) (1.8V)

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

Table 23: SDIO timing requirements – DDR50 modes (50 MHz)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Clock						
T <sub>CLK</sub>	Clock time 50MHz (max) between rising edge	DDR50	20	--	--	ns
T <sub>CR</sub> , T <sub>CF</sub>	Rise time, fall time T <sub>CR</sub> , T <sub>CF</sub> < 4.00ns (max) at 50MHz. C <sub>CARD</sub> = 10pF	DDR50	--	--	0.2 * T <sub>CLK</sub>	ns
Clock Duty	--	DDR50	45	--	55	%
CMD Input (referenced to clock rising edge)						
T <sub>IS</sub>	Input setup time C <sub>CARD</sub> ≤ 10pF (1 card)	DDR50	6	--	--	ns