

## MAX32665–MAX32668

# Low-Power Arm Cortex-M4 with FPU-Based Microcontroller with Bluetooth 5 for Wearables

## General Description

DARWIN is a new breed of low-power microcontrollers built to thrive in the rapidly evolving Internet of Things (IoT). They are smart, with the biggest memories in their class and a massively scalable memory architecture. They run forever, thanks to wearable-grade power technology. They are durable enough to withstand the most advanced cyberattacks. DARWIN microcontrollers are designed to run any application imaginable—in places where you would not dream of sending other microcontrollers.

Generation UB microcontrollers are designed to handle the increasingly complex applications demanded by today's advanced battery-powered devices and wirelessly connected devices, while providing robust hardware security and Bluetooth® 5 Low Energy (BLE) radio connectivity.

The MAX32665-MAX32668 UB class microcontrollers are advanced systems-on-chips featuring an Arm® Cortex®-M4 with FPU CPU for efficient computation of complex functions and algorithms with integrated power management. It also includes the newest generation Bluetooth 5 Low Energy radio with support for long range (4x) and high throughput (2Mbps) and Maxim's best-in-class hardware security suite trust protection unit (TPU). The devices offer large on-board memory with 1MB flash and up to 560KB SRAM that can be configured as 448KB SRAM with error correction coding (ECC). Split flash banks of 512KB each support seamless over the air upgrades, adding an additional degree of reliability. Memory scalability of data (SRAM) and code (Flash) space is supported by two SPI execute-in-place (SPIX) interfaces.

Multiple high-speed interfaces are supported including HS-USB, secure digital interface (SD, SDIO, MMC, SD-HC, and microSD™), SPI, UART, and I<sup>2</sup>C serial interfaces, and an audio subsystem supporting PDM, PCM, I<sup>2</sup>S, and TDM interfaces. An 8-input, 10-bit ADC is available to monitor analog inputs from external sensors and meters. The devices are available in 109-bump WLP (0.35mm pitch) and 121-bump CTBGA (0.65mm pitch).

## Applications

- Connected Home
- Industrial Sensors
- Payment/Fitness/Medical Wearables
- Telemedicine
- Gaming Devices
- Hearables

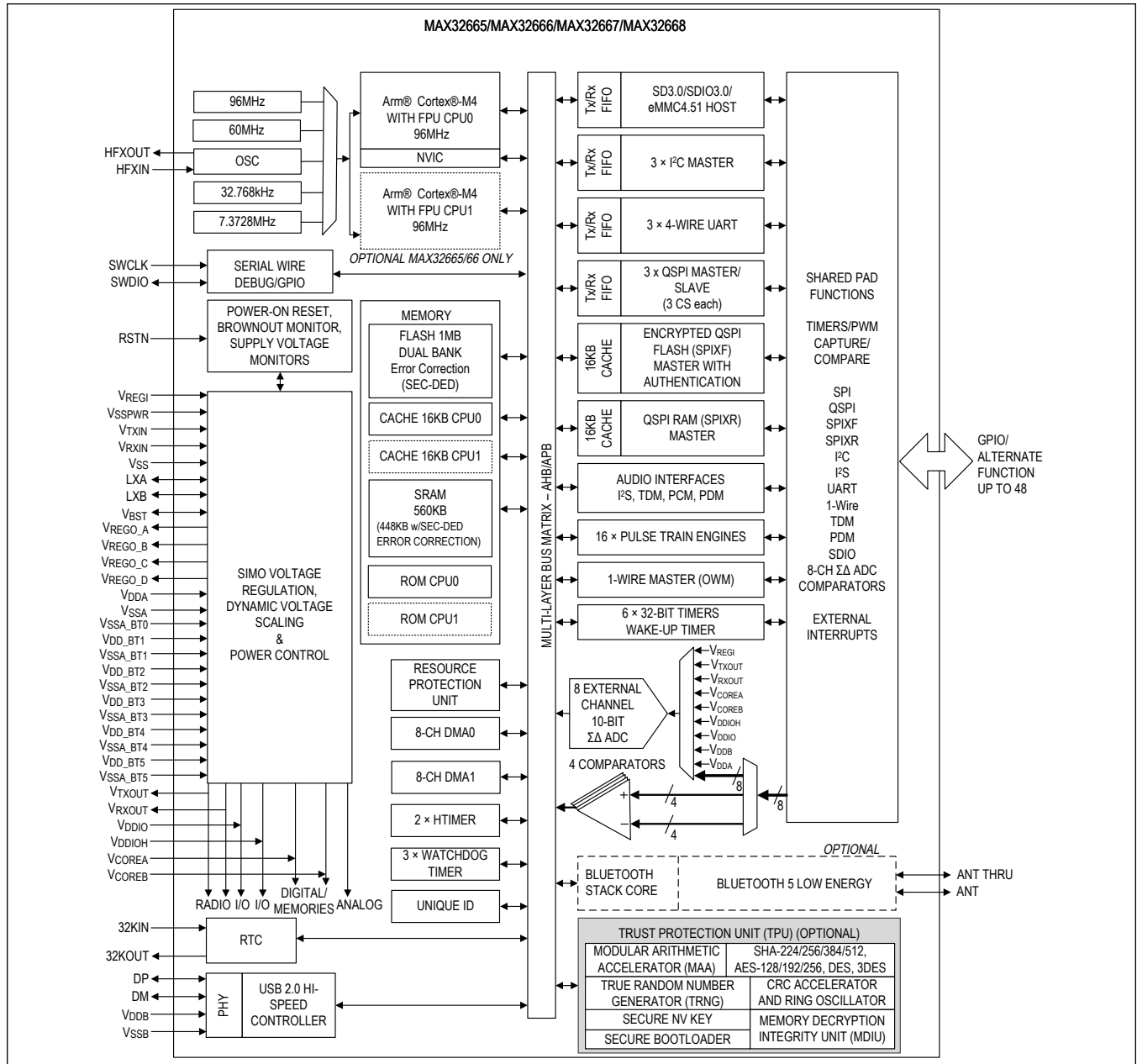
## Benefits and Features

- High-Efficiency Microcontroller and Audio DSP for Wearable and Hearable Devices
  - Arm Cortex-M4 with FPU Up to 96MHz
  - Optional Second Arm Cortex-M4 with FPU Optimized for Data Processing
  - Low-Power 7.3728MHz System Clock Option
  - 1MB Flash, Organized into Dual Banks 2 x 512KB
  - 560KB (448KB ECC) SRAM; 3 x 16KB Cache
  - Optional Error Correction Code (ECC-SEC-DED) for Cache, SRAM, and Internal Flash
- Bluetooth 5 Low Energy Radio
  - 1Mbps and 2Mbps Data Throughput
  - Long Range (125kbps and 500kbps)
  - Advertising Extension
  - Rx Sensitivity: -95dbm; Tx Power Up to +4.5dbm
  - On-Chip Matching with Single-Ended Antenna Port
- Power Management Maximizes Operating Time for Battery Applications
  - Integrated SIMO SMPS for Coin-Cell Operation
  - Dynamic Voltage Scaling Minimizes Active Core Power Consumption
  - 27.3µA/MHz at 3.3V Executing from Cache
  - Selectable SRAM Retention in Low Power Modes with RTC Enabled
- Multiple Peripherals for System Control
  - Three QSPI Master/Slave with Three Chip Selects Each, Three 4-Wire UARTs, Three I<sup>2</sup>C Master/Slave, up to 50 GPIO
  - QSPI (SPIXF) with Real-Time Flash Decryption
  - QSPI (SPIXR) RAM Interface Provides SRAM Expansion
  - 8-Input, 10-Bit Delta-Sigma ADC 7.8ksps
  - USB 2.0 HS Engine with Internal Transceiver
  - PDM Interface Supports Two Digital Microphones
  - I<sup>2</sup>S with TDM, Six 32-Bit Timers, Two High-Speed Timers, 1-Wire Master, Sixteen Pulse Trains (PWM)
  - Secure Digital Interface Supports SD3.0/SDIO3.0/eMMC4.51
- Secure Valuable IP/Data with Hardware Security
  - Trust Protection Unit (TPU) with MAA Supports Fast ECDSA and Modular Arithmetic
  - AES128/192/256, DES, 3DES, Hardware Accelerator
  - TRNG Seed Generator, SHA-2 Accelerator
  - Secure Bootloader

[Ordering Information](#) appears at end of data sheet.



Simplified Block Diagram



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## Absolute Maximum Ratings

V <sub>COREA</sub> .....	-0.3V to +1.21V	DM, DP (with respect to V <sub>SSB</sub> ).....	-0.3V to +3.6V
V <sub>COREB</sub> .....	-0.3V to +1.21V	V <sub>DDIO</sub> Combined Pins (sink).....	100mA
V <sub>DDA</sub> .....	-0.3V to +1.98V	V <sub>DDIOH</sub> Combined Pins (sink).....	100mA
V <sub>DDIO</sub> .....	-0.3V to +1.98V	V <sub>SSA</sub> .....	100mA
V <sub>DDIOH</sub> .....	-0.3V to +3.6V	V <sub>SS</sub> .....	100mA
V <sub>REGI</sub> .....	-0.3V to +3.6V	V <sub>SSPWR</sub> .....	100mA
V <sub>TXIN</sub> .....	-0.3V to +1.9V	V <sub>SSA_BT[1:5]</sub> .....	100mA
V <sub>RXIN</sub> .....	-0.3V to +1.9V	Output Current (sink) by Any GPIO Pin.....	25mA
V <sub>DDA_BT[1:5]</sub> .....	-0.3V to +1V	Output Current (source) by Any GPIO Pin.....	-25mA
RSTN, GPIO (V <sub>DDIO</sub> ).....	-0.3V to V <sub>DDIO</sub> + 0.5V	Continuous Package Power Dissipation CTBGA (multilayer board) T <sub>A</sub> = +70°C (derate 31.0mW/°C above +70°C).....	1692mW
GPIO (V <sub>DDIOH</sub> ).....	-0.3V to V <sub>DDIOH</sub> + 0.5V	Operating Temperature Range.....	-40°C to +105°C
32KIN, 32KOUT.....	-0.3V to V <sub>DDA</sub> + 0.2V	Storage Temperature Range.....	-65°C to +150°C
HFXIN, HFXOUT.....	-0.3V to V <sub>DDA</sub> + 0.2V	Soldering Temperature.....	+260°C
AIN[7:0].....	-0.3V to +3.6V		
V <sub>DDB</sub> (with respect to V <sub>SSB</sub> ).....	-0.3V to +3.6V		

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Package Information

### 109 WLP

Package Code	W1093A4+1
Outline Number	<a href="#">21-100301</a>
Land Pattern Number	Refer to <a href="#">Application Note 1891</a>
<b>Thermal Resistance, Four-Layer Board:</b>	
Junction to Ambient ( $\theta_{JA}$ )	38.05°C/W
Junction to Case ( $\theta_{JC}$ )	N/A

### 121 CTBGA

Package Code	X12188+6C
Outline Number	<a href="#">21-0680</a>
Land Pattern Number	<a href="#">90-0451</a>
<b>Thermal Resistance, Four-Layer Board:</b>	
Junction to Ambient ( $\theta_{JA}$ )	32.5°C/W
Junction to Case ( $\theta_{JC}$ )	8.8°C/W

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maximintegrated.com/thermal-tutorial](http://www.maximintegrated.com/thermal-tutorial).

## Electrical Characteristics

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>POWER SUPPLIES</b>						
Core Input Supply Voltage A	$V_{\text{COREA}}$		$V_{\text{COREA}}$ $V_{\text{RST}}$	1.1	1.21	V
Core Input Supply Voltage B	$V_{\text{COREB}}$		$V_{\text{COREB}}$ $V_{\text{RST}}$	1.1	1.21	V
Input Supply Voltage, Analog	$V_{\text{DDA}}$		1.71	1.8	1.89	V
Input Supply Voltage, TXIN	$V_{\text{TXIN}}$	Bluetooth Transmitter Supply	1.1	1.3	1.9	V
Input Supply Voltage, RXIN	$V_{\text{RXIN}}$	Bluetooth Receiver Supply	1.1	1.3	1.9	V
Input Supply Voltage, Battery	$V_{\text{REGI}}$		2.0	2.7	3.6	V
	$V_{\text{REGI\_POR}}$		2.4			
Input Supply Voltage, GPIO	$V_{\text{DDIO}}$		1.71	1.8	1.89	V
Input Supply Voltage, GPIO (High)	$V_{\text{DDIOH}}$		1.71	1.8	3.6	V
Power-Fail Reset Voltage	$V_{\text{RST}}$	Monitors $V_{\text{COREA}}$	0.72	0.77		V
		Monitors $V_{\text{COREB}}$	0.72	0.77		
		Monitors $V_{\text{DDA}}$	1.60	1.65	1.69	
		Monitors $V_{\text{ddb}}$	2.81	2.91		
		Monitors $V_{\text{DDIO}}$	1.60	1.65	1.69	
		Monitors $V_{\text{DDIOH}}$	1.60	1.65	1.69	
		Monitors $V_{\text{REGI}}$	1.94		2.08	
		Monitors $V_{\text{TXOUT}}$		0.773		
		Monitors $V_{\text{RXOUT}}$		0.773		
Power-On Reset Voltage	$V_{\text{POR}}$	Monitors $V_{\text{COREA}}$		0.63		V
$V_{\text{REGI}}$ Current, Active Mode	$I_{\text{REGI\_ACT}}$	Total current into $V_{\text{REGI}}$ pins, $f_{\text{SYS\_CLK}} = 96\text{MHz}$ , $V_{\text{REGI}} = 3.3\text{V}$ , CPU0 in Active mode, executing While(1) from cache, inputs tied to $V_{\text{SS}}$ , $V_{\text{DDIO}}$ , or $V_{\text{DDIOH}}$ , outputs source/sink 0mA		3.3		mA
	$I_{\text{REGI\_SLOPE}}$	This parameter is the slope of a line which includes the point $I_{\text{REGI\_ACT}}$ and a non-zero y-intercept. $V_{\text{REGI}} = 3.3\text{V}$ , $f_{\text{SYS\_CLK}}$ is changed only. DVS off. CPU0 in Active mode, executing While(1) from cache, inputs tied to $V_{\text{SS}}$ , $V_{\text{DDIO}}$ , or $V_{\text{DDIOH}}$ , outputs source/sink 0mA.		27.3		$\mu\text{A/MHz}$



**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{\text{REGI}}$ Current, Sleep Mode	$I_{\text{REGI\_SLP}}$	Total current into $V_{\text{REGI}}$ pins, $f_{\text{SYS\_CLK}} = 96\text{MHz}$ , $V_{\text{REGI}} = 3.3\text{V}$ , CPU0 in Sleep mode, inputs tied to $V_{\text{SS}}$ , $V_{\text{DDIO}}$ , or $V_{\text{DDIOH}}$ , outputs source/sink 0mA		2.1		mA
$V_{\text{REGI}}$ Current, Backup Mode	$I_{\text{REGI\_BK}}$	Total current into $V_{\text{REGI}}$ pins, $V_{\text{REGI}} = 3.3\text{V}$ , inputs tied to $V_{\text{SS}}$ , $V_{\text{DDIO}}$ , or $V_{\text{DDIOH}}$ , outputs source/sink 0mA	RTC enabled, full memory retention	8.6		$\mu\text{A}$
			RTC enabled, no memory retention	1.6		
			RTC disabled, no memory retention	1.2		
			RTC disabled, full memory retention	8.4		
			RTC disabled, 32KB ECC memory retention	6.3		
			RTC disabled, 64KB ECC memory retention	6.3		
$V_{\text{REGI}}$ Fixed Current, DeepSleep Mode	$I_{\text{REGI\_FDSL}}$	Standby state with full retention		10.0		$\mu\text{A}$
$V_{\text{REGO\_X}}$ Output Current	$V_{\text{REGO\_X\_IOU\_T}}$	Output current for each of the $V_{\text{REGO\_X}}$ outputs		5	50	mA
$V_{\text{REGO\_X}}$ Output Current Combined	$V_{\text{REGO\_X\_IOU\_T\_TOT}}$	All four $V_{\text{REGO\_X}}$ outputs combined		15	100	mA
$V_{\text{REGO\_X}}$ Output Voltage Range	$V_{\text{REGO\_X\_RANGE}}$	$V_{\text{REGI}} \geq V_{\text{REGO\_X}} + 200\text{mV}$	0.5	1.0	1.85	V
$V_{\text{REGO\_X}}$ Efficiency	$V_{\text{REGO\_X\_EFF}}$	$V_{\text{REGI}} = 2.7\text{V}$ , $V_{\text{REGO\_X}} = 1.1\text{V}$ , load = 30mA		90		%
<b>CLOCKS</b>						
System Clock Frequency	$f_{\text{SYS\_CLK}}$		8		96,000	kHz
System Clock Period	$t_{\text{SYS\_CLK}}$			$1/f_{\text{SYS\_CLK}}$		ns
High-Speed Oscillator Frequency	$f_{\text{HSCLK}}$	Factory default, user adjustable 50MHz–96MHz	92.5	96	99.6	MHz
Low-Power Oscillator Frequency	$f_{\text{LPCLK}}$			60		MHz
RF Oscillator Frequency	$f_{\text{RFCLK}}$	32MHz crystal, $C_L = 12\text{pF}$ , $\text{ESR} \leq 50\Omega$ , $C_0 \leq 7\text{pF}$ , temperature stability $\pm 20\text{ppm}$ , initial tolerance $\pm 20\text{ppm}$		32		MHz

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
HFXIN, HFXOUT Input Capacitance	$C_{\text{HFX\_PIN}}$			6		pF
7MHz Oscillator Frequency	$f_{7\text{MCLK}}$			7.3728		MHz
RTC Input Frequency	$f_{32\text{KIN}}$	32kHz watch crystal, $C_L = 6\text{pF}$ , $\text{ESR} < 90\text{k}\Omega$ , $C_0 \leq 2\text{pF}$		32.768		kHz
RTC Operating Current	$I_{\text{RTC\_BDSLP}}$	Backup or DeepSleep mode		0.39		$\mu\text{A}$
RTC Power-Up Time	$t_{\text{RTC\_ON}}$			250		ms
Nano-ring Oscillator Frequency	$f_{\text{NANO}}$			8		kHz
<b>GENERAL-PURPOSE I/O</b>						
Input Low Voltage for All GPIO	$V_{\text{IL\_VDDIO}}$	$V_{\text{DDIO}}$ selected as I/O supply			$0.3 \times V_{\text{DDIO}}$	V
	$V_{\text{IL\_VDDIOH}}$	$V_{\text{DDIOH}}$ selected as I/O supply			$0.3 \times V_{\text{DDIOH}}$	
Input Low Voltage for RSTN	$V_{\text{IL\_RSTN}}$			$0.5 \times V_{\text{COREA}}$		V
Input High Voltage for All GPIO	$V_{\text{IH\_VDDIO}}$	$V_{\text{DDIO}}$ selected as I/O supply	$0.7 \times V_{\text{DDIO}}$			V
	$V_{\text{IH\_VDDIOH}}$	$V_{\text{DDIOH}}$ selected as I/O supply	$0.7 \times V_{\text{DDIOH}}$			
Input High Voltage for RSTN	$V_{\text{IH\_RSTN}}$			$0.5 \times V_{\text{COREA}}$		V

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Low Voltage for All GPIO	$V_{OL\_VDDIO}$	$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 00$ , $I_{OL} = 1\text{mA}$		0.2	0.4	V
		$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 01$ , $I_{OL} = 2\text{mA}$		0.2	0.4	
		$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 10$ , $I_{OL} = 4\text{mA}$		0.2	0.4	
		$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 11$ , $I_{OL} = 8\text{mA}$		0.2	0.4	
	$V_{OL\_VDDIOH}$	$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 00$ , $I_{OL} = 1\text{mA}$		0.2	0.4	
		$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 01$ , $I_{OL} = 2\text{mA}$		0.2	0.4	
		$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 10$ , $I_{OL} = 4\text{mA}$		0.2	0.4	
		$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 11$ , $I_{OL} = 8\text{mA}$		0.2	0.4	
Combined $I_{OL}$ , All GPIO	$I_{OL\_TOTAL}$				48	mA

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output High Voltage for All GPIO	$V_{OH\_VDDIO}$	$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 00$ , $I_{OL} = -1\text{mA}$	$V_{DDIO} - 0.4$			V
		$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 01$ , $I_{OL} = -2\text{mA}$	$V_{DDIO} - 0.4$			
		$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 10$ , $I_{OL} = -4\text{mA}$	$V_{DDIO} - 0.4$			
		$V_{DDIO}$ selected as I/O supply, $V_{DDIO} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 11$ , $I_{OL} = -8\text{mA}$	$V_{DDIO} - 0.4$			
	$V_{OH\_VDDIOH}$	$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 00$ , $I_{OL} = -1\text{mA}$	$V_{DDIOH} - 0.4$			
		$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 01$ , $I_{OL} = -2\text{mA}$	$V_{DDIOH} - 0.4$			
		$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 10$ , $I_{OL} = -8\text{mA}$	$V_{DDIOH} - 0.4$			
		$V_{DDIOH}$ selected as I/O supply, $V_{DDIOH} = 1.71\text{V}$ , $\text{GPIO}_n\text{DS\_SEL}[1:0] = 11$ , $I_{OL} = -8\text{mA}$	$V_{DDIOH} - 0.4$			
Combined $I_{OH}$ , All GPIO	$I_{OH\_TOTAL}$				-48	mA
Input Hysteresis (Schmitt)	$V_{IHYS}$			300		mV
Input Leakage Current Low	$I_{IL}$	$V_{DDIO} = 1.89\text{V}$ , $V_{DDIOH} = 3.6\text{V}$ , $V_{DDIOH}$ selected as I/O supply, $V_{IN} = 0\text{V}$ , internal pullup disabled	-100		+100	nA
Input Leakage Current High	$I_{IH}$	$V_{DDIO} = 1.89\text{V}$ , $V_{DDIOH} = 3.6\text{V}$ , $V_{DDIOH}$ selected as I/O supply, $V_{IN} = 3.6\text{V}$ , internal pulldown disabled	-100		+100	nA
	$I_{OFF}$	$V_{DDIO} = 0\text{V}$ , $V_{DDIOH} = 0\text{V}$ , $V_{DDIO}$ selected as I/O supply, $V_{IN} < 1.89\text{V}$	-1		+1	$\mu\text{A}$
	$I_{IH3V}$	$V_{DDIO} = V_{DDIOH} = 1.71\text{V}$ , $V_{DDIO}$ selected as I/O supply, $V_{IN} = 3.6\text{V}$	-2		+2	
Input Pullup Resistor RSTN	$R_{PU\_R}$	P1M = 1		1		M $\Omega$
		P1M = 0		25		k $\Omega$
Input Pullup/Pulldown Resistor for All GPIO	$R_{PU1}$	Normal resistance		25		k $\Omega$
	$R_{PU2}$	Highest resistance		1		M $\Omega$

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>BLUETOOTH RADIO / POWER</b>						
Bluetooth Supply Voltage LNA/Mixer	$V_{DDA\_BT1}$	Internal LDO disabled.	0.855	0.9	0.945	V
Bluetooth Supply Voltage Power Amplifier	$V_{DDA\_BT2}$	Internal LDO disabled.	0.9		1.2	V
Bluetooth Supply Voltage FRAC_N Divider	$V_{DDA\_BT3}$	Internal LDO disabled.	0.855	0.9	0.945	V
Bluetooth Supply Voltage Receiver Baseband	$V_{DDA\_BT4}$	Internal LDO disabled.	0.855	0.9	0.945	V
Bluetooth Supply Voltage Voltage-Controlled Oscillator	$V_{DDA\_BT5}$	Internal LDO disabled.	0.855	0.9	0.945	V
<b>BLUETOOTH RADIO / FREQUENCY</b>						
Operating Frequency		1MHz channel spacing	2360		2500	MHz
PLL Programming Resolution	PLL_RES			1		MHz
Frequency Deviation at 1MBPS	$\Delta f_{1\text{MHz}}$			$\pm 170$		kHz
Frequency Deviation at BLE 1MBPS	$\Delta f_{\text{BLE}1\text{MHz}}$			$\pm 250$		kHz
Frequency Deviation at 2MBPS	$\Delta f_{2\text{MHz}}$			$\pm 320$		kHz
Frequency Deviation at BLE 2MBPS	$\Delta f_{\text{BLE}2\text{MHz}}$			$\pm 500$		kHz
<b>BLUETOOTH RADIO / CURRENT CONSUMPTION (SIMO enabled, <math>V_{\text{REGI}} = 3.3\text{V}</math>. Low power oscillator enabled, <math>f_{\text{SYS\_CLK}} = 60\text{MHz}</math>, BLE stack running on dedicated hardware. Measured at the <math>V_{\text{REGI}}</math> device pin, <math>V_{\text{REGO\_B}} = 0.9\text{V}</math>. CPU0 in Deep Sleep mode.)</b>						
Tx Run Current	$I_{\text{TX\_}+4.5\text{DBM}}$	$P_{\text{RF}} = +4.5\text{dBm}$		6.00		mA
	$I_{\text{TX\_}0\text{DBM}}$	$P_{\text{RF}} = 0\text{dBm}$		4.30		
	$I_{\text{TX\_}-10\text{DBM}}$	$P_{\text{RF}} = -10\text{dBm}$		3.22		
	$I_{\text{TX\_}-12\text{DBM}}$	$P_{\text{RF}} = -12\text{dBm}$		3.05		
	$I_{\text{TX\_}-16\text{DBM}}$	$P_{\text{RF}} = -16\text{dBm}$		2.85		
	$I_{\text{TX\_}-20\text{DBM}}$	$P_{\text{RF}} = -20\text{dBm}$		2.80		
Tx Startup Current	$I_{\text{START\_TX}}$			1.40		mA
Rx Run Current	$I_{\text{RX\_}1\text{M}}$	$f_{\text{RX}} = 1\text{Mbps}$		3.20		mA
	$I_{\text{RX\_}2\text{M}}$	$f_{\text{RX}} = 2\text{Mbps}$		3.30		
Rx Startup Current	$I_{\text{START\_RX}}$			1.40		mA

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>BLUETOOTH RADIO / TRANSMITTER</b>						
Maximum Output Power	$P_{RF}$			+4.5		dBm
RF Power Accuracy	$P_{RF\_ACC}$			$\pm 1$		dB
First Adjacent Channel Transmit Power $\pm 2\text{MHz}$	$P_{RF1\_1}$	2Mbps BLE		-31.7		dBc
Second Adjacent Channel Transmit Power $\pm 4\text{MHz}$	$P_{RF2\_1}$	2Mbps BLE		-49.1		dBc
<b>BLUETOOTH RADIO / RECEIVER</b>						
Maximum Received Signal Strength at < 0.1% PER	$P_{RX\_MAX}$			0		dBm
Receiver Sensitivity, Ideal Transmitter	$P_{SENS\_IT}$	1Mbps BLE		-95		dBm
		2Mbps BLE		-92		
Receiver Sensitivity, Dirty Transmitter	$P_{SENS\_DT}$	1Mbps BLE		-94		dBm
		2Mbps BLE		-91		
Receiver Sensitivity, Long Range Coded	$P_{SENS\_LR}$	125kbps BLE		-103		dBm
		500kbps BLE		-101		
C/I Cochannel	$C/I_{1\text{MHz}}$	1Mbps BLE		8		dB
	$C/I_{2\text{MHz}}$	2Mbps BLE		8		
Adjacent Interference	$C/I_{+1\_1}$	+1MHz offset, 1Mbps BLE		-1		dBm
	$C/I_{-1\_1}$	-1MHz offset, 1Mbps BLE		-2		
	$C/I_{+2\_1}$	+2MHz offset, 1Mbps BLE		-30.7		
	$C/I_{-2\_1}$	-2MHz offset, 1Mbps BLE		-32.3		
	$C/I_{+2\_2}$	+2MHz offset, 2Mbps BLE		-1.7		
	$C/I_{-2\_2}$	-2MHz offset, 2Mbps BLE		-3		
	$C/I_{+4\_2}$	+4MHz offset, 2Mbps BLE		-25.3		
$C/I_{-4\_2}$	-4MHz offset, 2Mbps BLE		-26.3			
Adjacent Interference, (3+n) MHz Offset [n = 0, 1, 2, ...]	$C/I_{3+\text{MHz}}$	1Mbps BLE		-34.8		dB
Adjacent Interference, (6+2n) MHz Offset [n = 0, 1, 2, ...]	$C/I_{6+\text{MHz}}$	2Mbps BLE		-34.8		dB
Intermodulation Performance, 1Mbps BLE with 3MHz, 4MHz, 5MHz Offset	$P_{IMD\_1\text{MBPS}}$	1Mbps BLE		-37.1		dBm

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Intermodulation Performance, 2Mbps BLE with 6MHz, 8MHz, 10MHz Offset	$P_{IMD\_2MBPS}$	2Mbps BLE			-36.4		dBm
Received Signal Strength Indicator Accuracy	$RSSI_{ACC}$				+/- 3		dB
Received Signal Strength Indicator Range	$RSSI_{RANGE}$				-95 to -50		dB
<b>ADC (DELTA-SIGMA)</b>							
Resolution					10		Bits
ADC Clock Rate	$f_{ACLK}$			0.1		8	MHz
ADC Clock Period	$t_{ACLK}$				$1/f_{ACLK}$		$\mu\text{s}$
Input Voltage Range	$V_{AIN}$	$AIN[7:0]$ , ADC_DIVSEL = [00], ADC_CH_SEL = [7:0]	REF_SEL = 0, INPUT_SCALE = 0	$V_{SSA} + 0.05$		$V_{BG}$	V
		$AIN[7:0]$ , ADC_DIVSEL = [01], ADC_CH_SEL = [7:0]	REF_SCALE = 0, INPUT_SCALE = 0	$V_{SSA} + 0.05$		$2 \times V_{BG}$	
		$AIN[7:0]$ , ADC_DIVSEL = [10], ADC_CH_SEL = [7:0]	REF_SCALE = 0, INPUT_SCALE = 0, $V_{DDIOH}$ selected as the I/O supply	$V_{SSA} + 0.05$		$V_{DDIOH}$	
		$AIN[7:0]$ , ADC_DIVSEL = [11], ADC_CH_SEL = [7:0]	REF_SEL = 0, INPUT_SCALE = 0, $V_{DDIOH}$ selected as the I/O supply	$V_{SSA} + 0.05$		$V_{DDIOH}$	
Input Impedance	$R_{AIN}$				30		k $\Omega$
Analog Input Capacitance	$C_{AIN}$	Fixed capacitance to $V_{SSA}$			1		pF
		Dynamically switched capacitance			250		fF
Integral Nonlinearity	INL	Measured at $25^\circ\text{C}$ , Insignificant temperature drift due to architecture				$\pm 2$	LSb
Differential Nonlinearity	DNL	Measured at $25^\circ\text{C}$ , Insignificant temperature drift due to architecture				$\pm 1$	LSb
Offset Error	$V_{OS}$				$\pm 1$		LSb

**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ADC Active Current	$I_{\text{ADC}}$	ADC active, reference buffer enabled, input buffer disabled		210		$\mu\text{A}$
ADC Setup Time	$t_{\text{ADC\_SU}}$	Any power-up of ADC clock or ADC bias to CpuAdcStart			10	$\mu\text{s}$
ADC Output Latency	$t_{\text{ADC}}$			1067		$t_{\text{ACLK}}$
ADC Sample Rate	$f_{\text{ADC}}$				7.8	ksps
ADC Input Leakage	$I_{\text{ADC\_LEAK}}$	ADC inactive or channel not selected		0.16		nA
Full-Scale Voltage	$V_{\text{FS}}$	ADC code = 0x3FF		1.2		V
Bandgap Temperature Coefficient	$V_{\text{TEMPCO}}$	Box method		30		ppm
<b>COMPARATORS</b>						
Input Offset Voltage	$V_{\text{OFFSET}}$			+/-1		mV
Input Hysteresis	$V_{\text{HYST}}$	AINCOMPHYST[1:0] = 00		$\pm 23$		mV
		AINCOMPHYST[1:0] = 01		$\pm 50$		
		AINCOMPHYST[1:0] = 10		$\pm 2$		
		AINCOMPHYST[1:0] = 11		$\pm 7$		
Input Voltage Range	$V_{\text{IN\_CMP}}$	Common-mode range	0.6		1.35	V
<b>FLASH MEMORY</b>						
Flash Erase Time	$t_{\text{M\_ERASE}}$	Mass erase		20		ms
	$t_{\text{P\_ERASE}}$	Page erase		20		
Flash Programming Time per Word	$t_{\text{PROG}}$	32-bit programming mode, $f_{\text{FLC\_CLK}} = 1\text{MHz}$		42		$\mu\text{s}$
Flash Endurance			10			kcycles
Data Retention	$t_{\text{RET}}$	$T_A = +85^\circ\text{C}$	10			years
<b>USB</b>						
USB Transceiver Supply Voltage	$V_{\text{DDB}}$		3.0	3.3	3.6	V
Pin Capacitance (DP, DM)	$C_{\text{IN\_USB}}$	Pin to $V_{\text{SSB}}$		8		pF
Driver Output Resistance	$R_{\text{DRV}}$	Steady state drive		$44 \pm 10\%$		$\Omega$
<b>USB / FULL SPEED</b>						
Single-Ended Input High Voltage (DP, DM)	$V_{\text{IH\_USB}}$		2.1			V
Single-Ended Input Low Voltage (DP, DM)	$V_{\text{IL\_USB}}$				0.5	V
Output High Voltage (DP, DM)	$V_{\text{OH\_USB}}$	$R_L = 1.5\text{k}\Omega$ from DP and DM to $V_{\text{SSB}}$ , $I_{\text{OH}} = -4\text{mA}$	2.8		$V_{\text{DDB}}$	V



**Electrical Characteristics (continued)**

(Limits are 100% tested at  $T_A = +25^\circ\text{C}$  and  $T_A = +105^\circ\text{C}$ . Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization. Specifications marked GBD are guaranteed by design and not production tested. Specifications to the minimum operating temperature are guaranteed by design and are not production tested. GPIO are only tested at  $T_A = +105^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Low Voltage (DP, DM)	$V_{OL\_USB}$	$R_L = 1.5\text{k}\Omega$ from DP to $V_{DDB}$ , $I_{OL} = 4\text{mA}$	$V_{SS}$		0.3	V
Differential Input Sensitivity	$V_{DI}$	DP to DM ; system requirement, not tested	0.2			V
Common-Mode Voltage Range	$V_{CM}$	Includes $V_{DI}$ range; system requirement, not tested	0.8		2.5	V
Transition Time (Rise/Fall) DP, DM	$t_{RF}$	$C_L = 50\text{pF}$	4		20	ns
Pullup Resistor on Upstream Ports	$R_{PU}$		1.05	1.5	1.95	$\text{k}\Omega$
<b>USB / HI-SPEED</b>						
Hi-Speed Data Signaling Common-Mode Voltage Range	$V_{HSCM}$		-50		+500	mV
Hi-Speed Squelch Detection Threshold	$V_{HSSQ}$	Squelch detected		100		mV
		No squelch detected		200		
Hi-Speed Idle Level Output Voltage	$V_{HSOI}$		-10		+10	mV
Hi-Speed Low-Level Output Voltage	$V_{HSOL}$		-10		+10	mV
Hi-Speed High-Level Output Voltage	$V_{HSOH}$			400 $\pm$ 40		mV
Chirp-J Output Voltage (Differential)	$V_{CHIRPJ}$			900 $\pm$ 200		mV
Chirp-K Output Voltage (Differential)	$V_{CHIRPK}$			-700 $\pm$ 200		mV

**Electrical Characteristics—SPI**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>MASTER MODE</b>						
SPI Master Operating Frequency	$f_{MCK}$	$f_{SYS\_CLK} = 96\text{MHz}$ , $f_{MCK(\text{MAX})} = f_{SYS\_CLK}/2$			48	MHz
SPI Master SCK Period	$t_{MCK}$			$1/f_{MCK}$		ns
SCK Output Pulse-Width High/Low	$t_{MCH}$ , $t_{MCL}$		$t_{MCK}/2$			ns
MOSI Output Hold Time After SCK Sample Edge	$t_{MOH}$		$t_{MCK}/2$			ns
MOSI Output Valid to Sample Edge	$t_{MOV}$		$t_{MCK}/2$			ns

**Electrical Characteristics—SPI (continued)**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
MOSI Output Hold Time After SCK Low Idle	$t_{MLH}$			$t_{MCK}/2$		ns
MISO Input Valid to SCK Sample Edge Setup	$t_{MIS}$			5		ns
MISO Input to SCK Sample Edge Hold	$t_{MIH}$			$t_{MCK}/2$		ns
<b>SLAVE MODE</b>						
SPI Slave Operating Frequency	$f_{SCK}$				48	MHz
SPI Slave SCK Period	$t_{SCK}$			$1/f_{SCK}$		ns
SCK Input Pulse-Width High/Low	$t_{SCH}, t_{SCL}$			$t_{SCK}/2$		
SSx Active to First Shift Edge	$t_{SSE}$			10		ns
MOSI Input to SCK Sample Edge Rise/Fall Setup	$t_{SIS}$			5		ns
MOSI Input from SCK Sample Edge Transition Hold	$t_{SIH}$			1		ns
MISO Output Valid After SCLK Shift Edge Transition	$t_{SOV}$			5		ns
SCK Inactive to SSx Inactive	$t_{SSD}$			10		ns
SSx Inactive Time	$t_{SSH}$			$1/f_{SCK}$		$\mu$ s
MISO Hold Time After SSx Deassertion	$t_{SLH}$			10		ns

**Electrical Characteristics—I<sup>2</sup>C**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>STANDARD MODE</b>						
Output Fall Time	$t_{OF}$	Standard mode, from $V_{IH(MIN)}$ to $V_{IL(MAX)}$		150		ns
SCL Clock Frequency	$f_{SCL}$		0		100	kHz
Low Period SCL Clock	$t_{LOW}$		4.7			$\mu$ s
High Time SCL Clock	$t_{HIGH}$		4.0			$\mu$ s
Setup Time for Repeated Start Condition	$t_{SU;STA}$		4.7			$\mu$ s

**Electrical Characteristics—I<sup>2</sup>C (continued)**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Hold Time for Repeated Start Condition	t <sub>HD;STA</sub>		4.0			μs
Data Setup Time	t <sub>SU;DAT</sub>			300		ns
Data Hold Time	t <sub>HD;DAT</sub>			10		ns
Rise Time for SDA and SCL	t <sub>R</sub>			800		ns
Fall Time for SDA and SCL	t <sub>F</sub>			200		ns
Setup Time for a Stop Condition	t <sub>SU;STO</sub>		4.0			μs
Bus Free Time Between a Stop and Start Condition	t <sub>BUS</sub>		4.7			μs
Data Valid Time	t <sub>VD;DAT</sub>		3.45			μs
Data Valid Acknowledge Time	t <sub>VD;ACK</sub>		3.45			μs
<b>FAST MODE</b>						
Output Fall Time	t <sub>OF</sub>	From V <sub>IH(MIN)</sub> to V <sub>IL(MAX)</sub>		150		ns
Pulse Width Suppressed by Input Filter	t <sub>SP</sub>			75		ns
SCL Clock Frequency	f <sub>SCL</sub>		0		400	kHz
Low Period SCL Clock	t <sub>LOW</sub>		1.3			μs
High Time SCL Clock	t <sub>HIGH</sub>		0.6			μs
Setup Time for Repeated Start Condition	t <sub>SU;STA</sub>		0.6			μs
Hold Time for Repeated Start Condition	t <sub>HD;STA</sub>		0.6			μs
Data Setup Time	t <sub>SU;DAT</sub>			125		ns
Data Hold Time	t <sub>HD;DAT</sub>			10		ns
Rise Time for SDA and SCL	t <sub>R</sub>			30		ns
Fall Time for SDA and SCL	t <sub>F</sub>			30		ns
Setup Time for a Stop Condition	t <sub>SU;STO</sub>		0.6			μs
Bus Free Time Between a Stop and Start Condition	t <sub>BUS</sub>		1.3			μs
Data Valid Time	t <sub>VD;DAT</sub>		0.9			μs
Data Valid Acknowledge Time	t <sub>VD;ACK</sub>		0.9			μs

**Electrical Characteristics—I<sup>2</sup>C (continued)**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>FAST MODE PLUS</b>						
Output Fall Time	$t_{OF}$	From $V_{IH(MIN)}$ to $V_{IL(MAX)}$		80		ns
Pulse Width Suppressed by Input Filter	$t_{SP}$			75		ns
SCL Clock Frequency	$f_{SCL}$		0		1000	kHz
Low Period SCL Clock	$t_{LOW}$		0.5			$\mu$ s
High Time SCL clock	$t_{HIGH}$		0.26			$\mu$ s
Setup Time for Repeated Start Condition	$t_{SU;STA}$		0.26			$\mu$ s
Hold Time for Repeated Start Condition	$t_{HD;STA}$		0.26			$\mu$ s
Data Setup Time	$t_{SU;DAT}$			50		ns
Data Hold Time	$t_{HD;DAT}$			10		ns
Rise Time for SDA and SCL	$t_R$			50		ns
Fall Time for SDA and SCL	$t_F$			30		ns
Setup Time for a Stop Condition	$t_{SU;STO}$		0.26			$\mu$ s
Bus Free Time Between a Stop and Start Condition	$t_{BUS}$		0.5			$\mu$ s
Data Valid Time	$t_{VD;DAT}$		0.45			$\mu$ s
Data Valid Acknowledge Time	$t_{VD;ACK}$		0.45			$\mu$ s

**Electrical Characteristics—SD/SDIO/SDHC/MMC**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Clock Frequency in Data Transfer Mode	$f_{SDHC\_CLK}$		0		$f_{HSCLK}/2$	MHz
Clock Period	$t_{CLK}$			$1/f_{SDHC\_CLK}$		ns
Clock Low Time	$t_{WCL}$			7		ns
Clock High Time	$t_{WCH}$			7		ns
Input Setup Time	$t_{ISU}$			5		ns
Input Hold Time	$t_{IHLD}$			1		ns
Output Valid Time	$t_{OVLDT}$			5		ns
Output Hold Time	$t_{OHLD}$			6		ns

**Electrical Characteristics—One Wire Master**

(Timing specifications are guaranteed by design and not production tested.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Write 0 Low Time	$t_{W0L}$	Standard		60		$\mu\text{s}$
		Overdrive		8		
Write 1 Low Time	$t_{W1L}$	Standard		6		$\mu\text{s}$
		Standard, long line mode		8		
		Overdrive		1		
Presence Detect Sample	$t_{MSP}$	Standard		70		$\mu\text{s}$
		Standard, Long Line mode		85		
		Overdrive		9		
Read Data Value	$t_{MSR}$	Standard		15		$\mu\text{s}$
		Standard, Long Line mode		24		
		Overdrive		3		
Recovery Time	$t_{RECO}$	Standard		10		$\mu\text{s}$
		Standard, Long Line mode		20		
		Overdrive		4		
Reset Time High	$t_{RSTH}$	Standard		480		$\mu\text{s}$
		Overdrive		58		
Reset Time Low	$t_{RSTL}$	Standard		600		$\mu\text{s}$
		Overdrive		70		
Time Slot	$t_{SLOT}$	Standard		70		$\mu\text{s}$
		Overdrive		12		

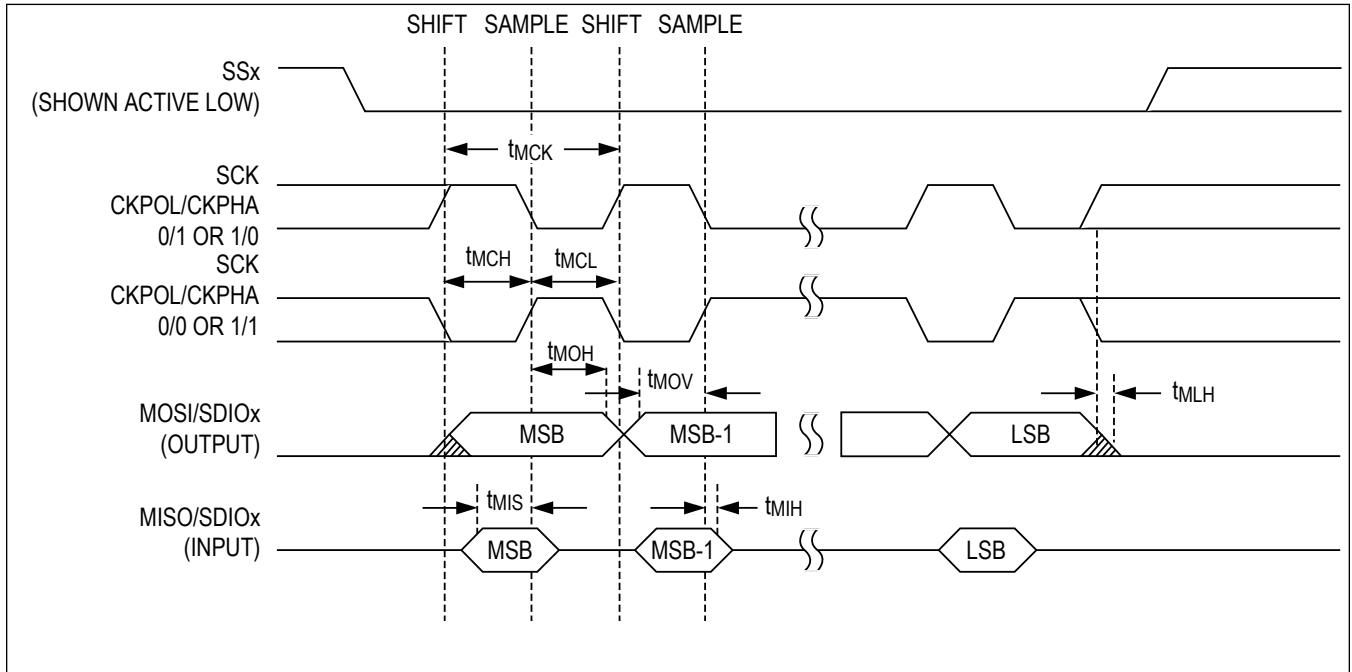


Figure 1. SPI Master Mode Timing Diagram

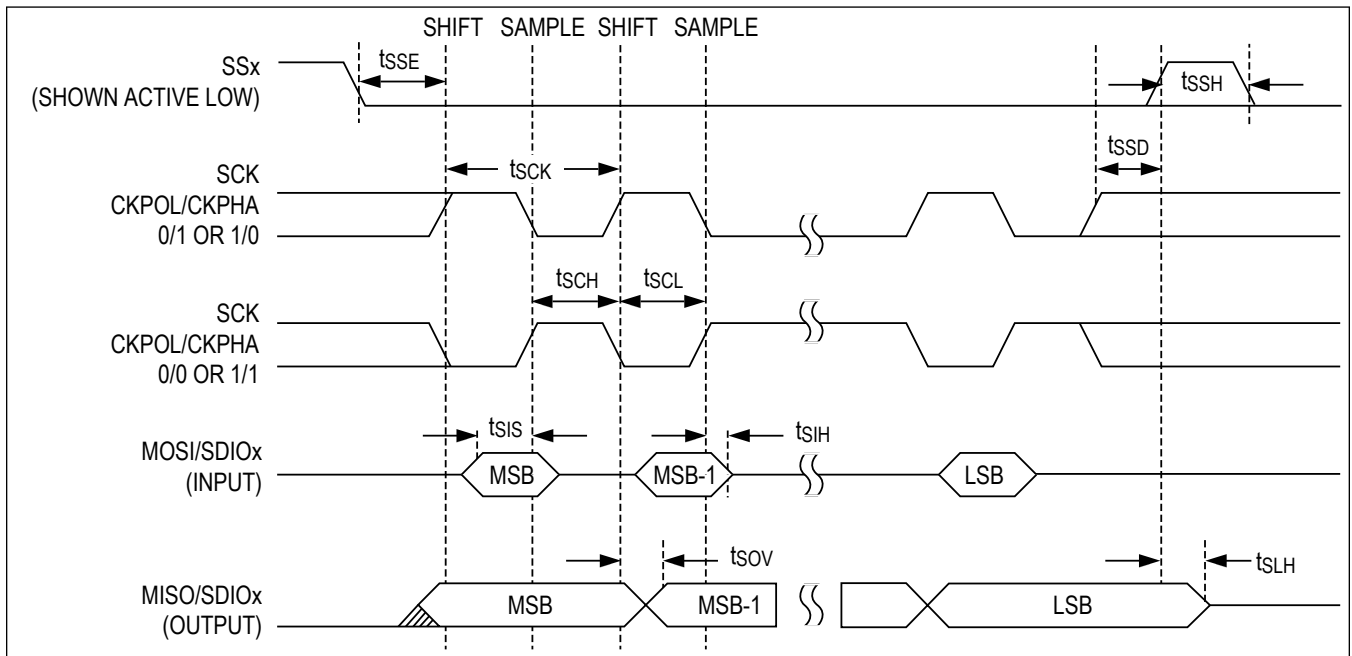


Figure 2. SPI Slave Mode Timing Diagram

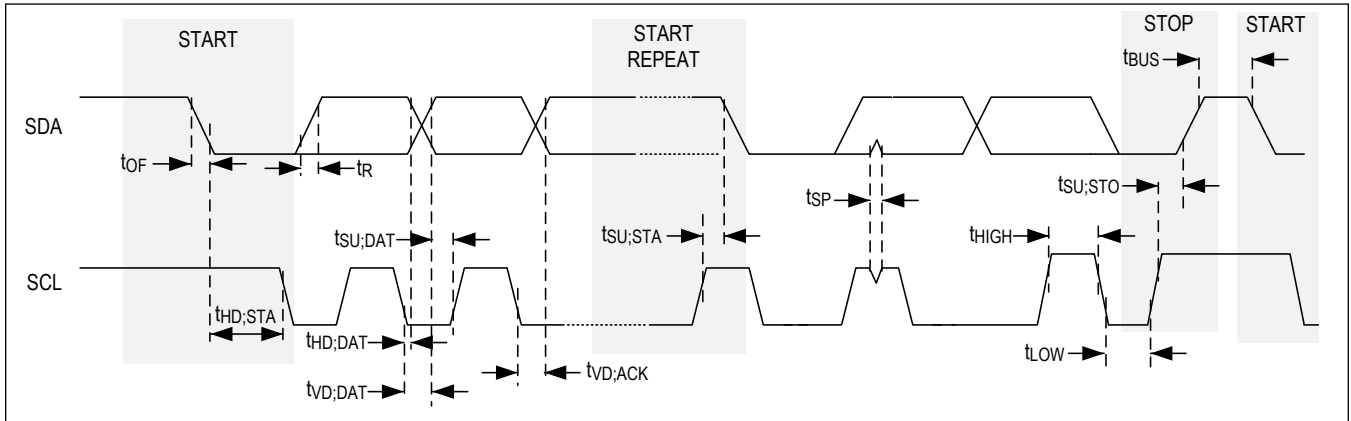


Figure 3. I<sup>2</sup>C Timing Diagram

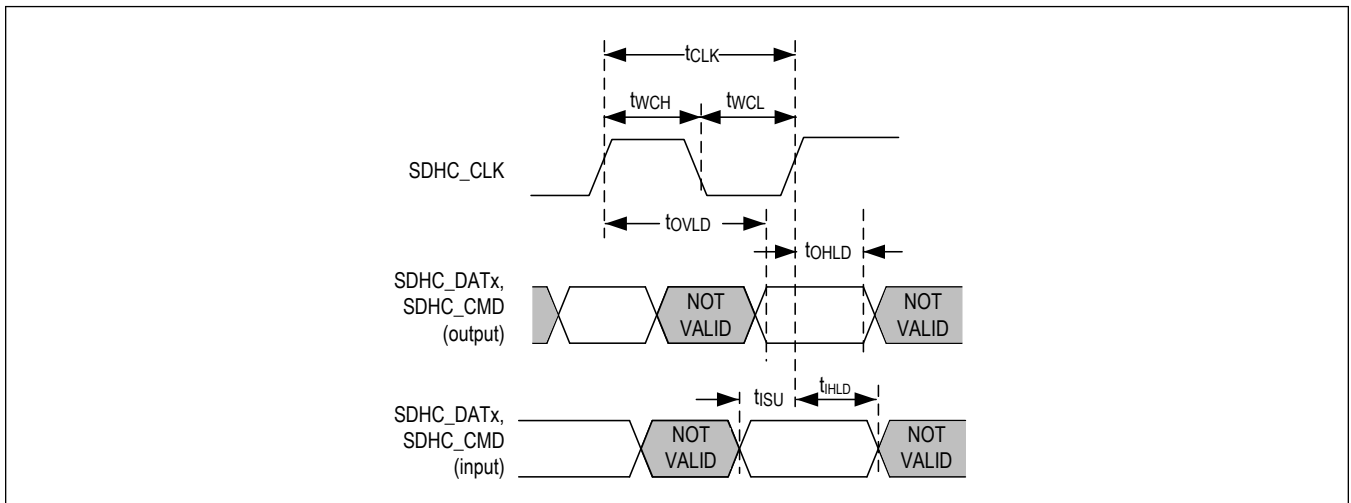


Figure 4. SD/SDIO/SDHC/MMC Timing Diagram

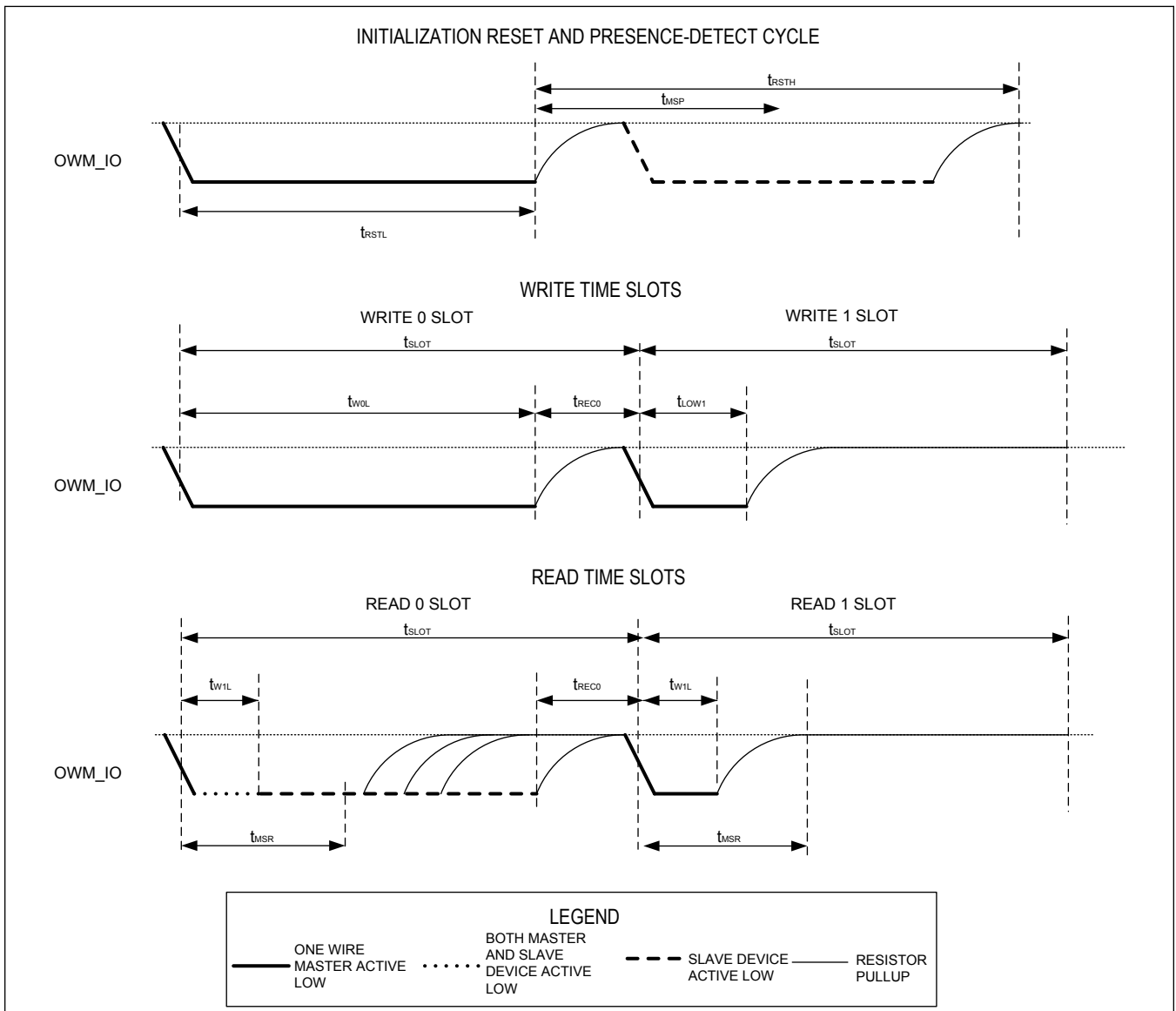
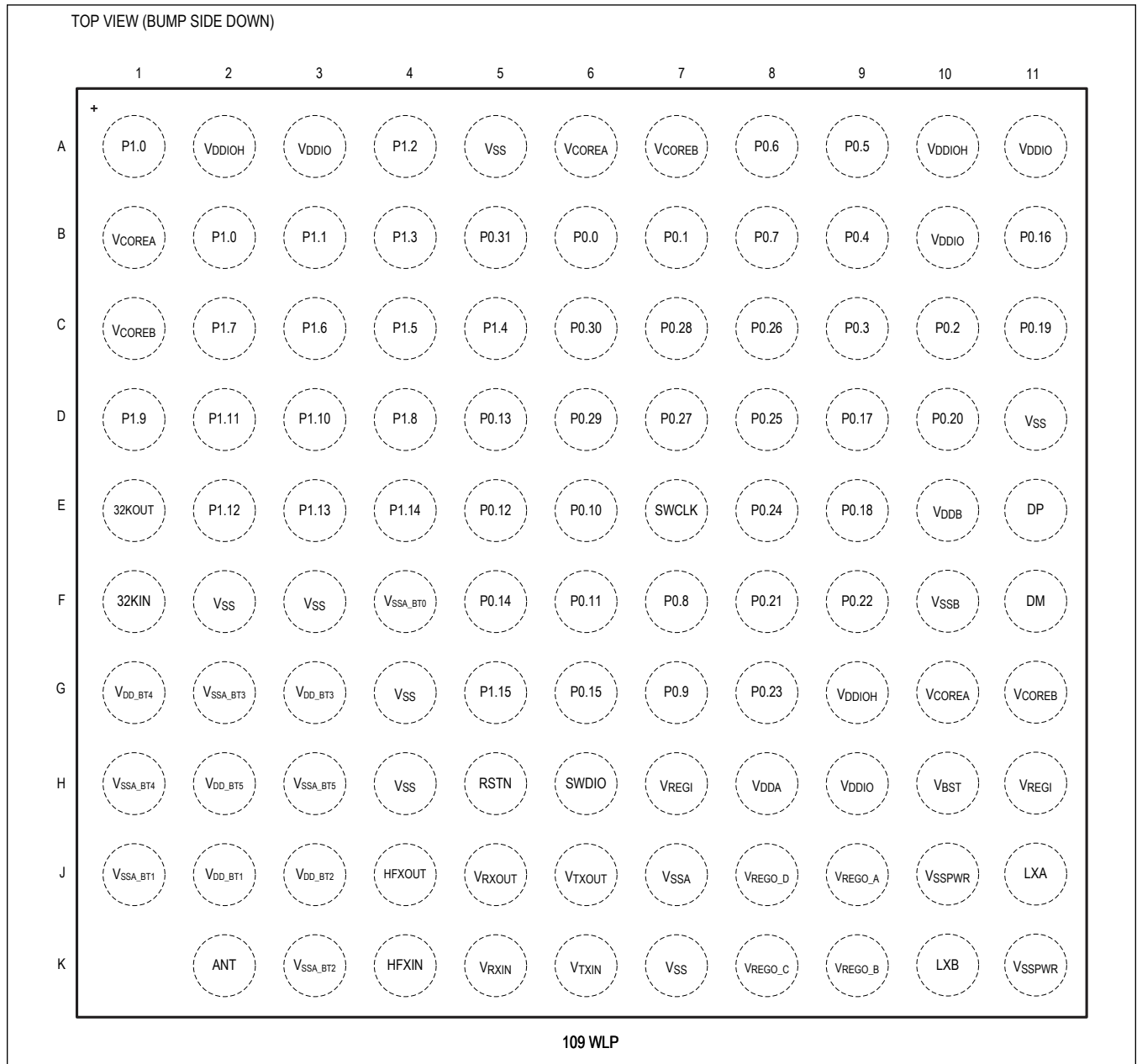


Figure 5. One-Wire Master Data Timing Diagram

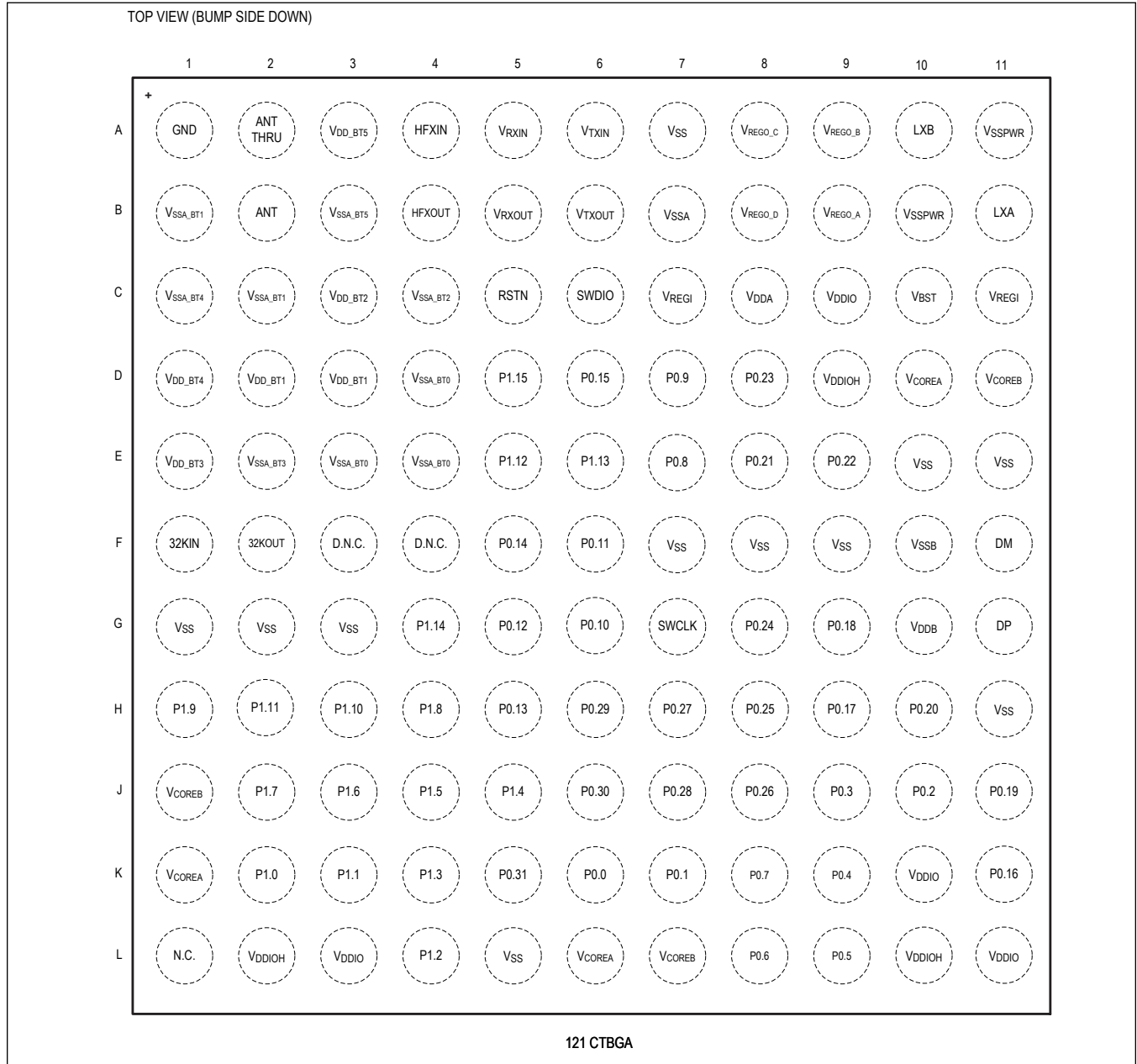


Pin Configurations

109 WLP



121 CTBGA



Pin Description

PIN		NAME	FUNCTION
109 WLP	121 CTBGA		
<b>POWER (See <a href="#">Applications Information</a> for bypass capacitor recommendations.)</b>			
H7, H11	C7, C11	VREGI	Battery Power Supply. Bypass this pin to V <sub>SS</sub> with 2 x 47µF capacitors placed as close as possible to the VREGI and VSSPWR pins. If power to the device is cycled, the voltage applied to this device pin must reach VREGI_POR.

## Pin Description (continued)

PIN		NAME	FUNCTION
109 WLP	121 CTBGA		
J10, K11	A11, B10	VSSPWR	Ground for the SIMO SMPS
A5, D11, F2, F3, G4, H4, K7	A7, E10, E11, F7, F8, F9, G1, G2, G3, H11, L5	VSS	Digital Ground
—	A1	GND	This device pin is not connected internally to the die. Connect this device pin to the ground plane of the circuit board. Do not connect any other signal to this pin.
K6	A6	V <sub>TXIN</sub>	Radio Transmitter Supply Voltage
K5	A5	V <sub>RXIN</sub>	Radio Receiver Supply Voltage
J11	B11	LXA	Switching Inductor Input A. Connect a 2.2μH inductor between LXA and LXB.
K10	A10	LXB	Switching Inductor Input B. Connect a 2.2μH inductor between LXA and LXB.
H10	C10	V <sub>BST</sub>	The boosted supply voltage for the gate drive of high-side switches. Bypass V <sub>BST</sub> to LXB with a 3.3nF capacitor.
J9	B9	V <sub>REGO_A</sub>	Buck Converter A Voltage Output. Bypass V <sub>REGO_A</sub> with a 22μF capacitor to V <sub>SS</sub> placed as close as possible to the V <sub>DDA</sub> device pin.
K9	A9	V <sub>REGO_B</sub>	Buck Converter B Voltage Output. Bypass V <sub>REGO_B</sub> with a 22μF capacitor to V <sub>SS</sub> placed as close as possible to the closest V <sub>COREB</sub> device pin.
K8	A8	V <sub>REGO_C</sub>	Buck Converter C Voltage Output. Bypass V <sub>REGO_C</sub> with a 22μF capacitor to V <sub>SS</sub> placed as close as possible to the closest V <sub>COREA</sub> device pin.
J8	B8	V <sub>REGO_D</sub>	Buck Converter D Voltage Output. Bypass V <sub>REGO_D</sub> with a 22μF capacitor to V <sub>SS</sub> placed as close as possible to the V <sub>RXIN</sub> and V <sub>TXIN</sub> device pins.
H8	C8	V <sub>DDA</sub>	1.8V Analog/Digital Power Supply
J7	B7	V <sub>SSA</sub>	Analog Ground
J6	B6	V <sub>TXOUT</sub>	Radio Transmitter Supply Voltage Output. Bypass this pin to V <sub>SS</sub> with a 1.0μF capacitor placed as close as possible to the package.
J5	B5	V <sub>RXOUT</sub>	Radio Receiver Supply Voltage Output. Bypass this pin to V <sub>SS</sub> with a 1.0μF capacitor placed as close as possible to the package.
A3, A11, B10, H9,	C9, L3, L11, K10	V <sub>DDIO</sub>	GPIO Supply Voltage. Bypass this pin to V <sub>SS</sub> with a 1.0μF capacitor placed as close as possible to the package.
A2, A10, G9	D9, L2, L10	V <sub>DDIOH</sub>	GPIO Supply Voltage, High. V <sub>DDIOH</sub> ≥ V <sub>DDIO</sub> . Bypass this pin to V <sub>SS</sub> with a 1.0μF capacitor placed as close as possible to the package.
A6, B1, G10	D10, K1, L6	V <sub>COREA</sub>	Digital Core Supply Voltage A
A7, C1, G11	D11, J1, L7	V <sub>COREB</sub>	Digital Core Supply Voltage B
E10	G10	V <sub>DDB</sub>	USB Transceiver Supply Voltage. Bypass this pin to V <sub>SSB</sub> with a 1.0μF capacitor as close as possible to the package.
F10	F10	V <sub>SSB</sub>	USB Transceiver Ground
J2	D2, D3	V <sub>DD_BT1</sub>	0.9V Analog Power Supply for the Bluetooth Radio Low Noise Amplifier and Mixer
J3	C3	V <sub>DD_BT2</sub>	1.1V Power Supply for the Bluetooth Radio Power Amplifier
G3	E1	V <sub>DD_BT3</sub>	0.9V Power Supply for the Bluetooth Radio FRAC-N Divider
G1	D1	V <sub>DD_BT4</sub>	0.9V Power Supply for the Bluetooth Radio Receiver Baseband
H2	A3	V <sub>DD_BT5</sub>	0.9V Power Supply for the Bluetooth Radio Voltage-Controlled Oscillator
F4	D4, E3, E4	V <sub>SSA_BT0</sub>	Bluetooth Radio Analog Ground 0

## Pin Description (continued)

PIN		NAME	FUNCTION
109 WLP	121 CTBGA		
J1	B1, C2	VSSA_BT1	Bluetooth Radio Analog Ground 1
K3	C4	VSSA_BT2	Bluetooth Radio Analog Ground 2
G2	E2	VSSA_BT3	Bluetooth Radio Analog Ground 3
H1	C1	VSSA_BT4	Bluetooth Radio Analog Ground 4
H3	B3	VSSA_BT5	Bluetooth Radio Analog Ground 5
<b>CLOCK</b>			
E1	F2	32KOUT	32kHz Crystal Oscillator Output
F1	F1	32KIN	32kHz Crystal Oscillator Input. Connect a 32kHz crystal between 32KIN and 32KOUT for RTC operation. Optionally, this pin can be configured as the input for an external CMOS-level clock source.
J4	B4	HFXOUT	32MHz Crystal Oscillator Output
K4	A4	HFXIN	32MHz Crystal Oscillator Input. Connect a 32MHz crystal between HFXIN and HFXOUT for Bluetooth operation. Optionally, this pin can be configured as the input for an external CMOS-level clock source.
<b>USB</b>			
E11	G11	DP	USB DP Signal. This bidirectional pin carries the positive differential data or single-ended data. This pin is weakly pulled high internally when the USB is disabled.
F11	F11	DM	USB DM Signal. This bidirectional pin carries the negative differential data or single-ended data. This pin is weakly pulled high internally when the USB is disabled.
<b>TEST</b>			
E7	G7	SWCLK	Serial Wire Debug Clock/TCK/GPIO. When TTAP_ENABLE = 1, this pin becomes the JTAG Test Clock (TCK). This pin can also be configured as a GPIO.
H6	C6	SWDIO	Serial Wire Debug I/O/TMS/GPIO. When TTAP_ENABLE = 1, this pin becomes the JTAG Mode Select (TMS). This spin can also be configured as a GPIO.
<b>RESET</b>			
H5	C5	RSTN	Active-Low, External System Reset Input. The device remains in reset while this pin is in its active state. When the pin transitions to its inactive state, the device performs a POR reset (resetting all logic on all supplies except for real-time clock circuitry) and begins execution. This pin has an internal pullup to the V <sub>DDIO</sub> supply.
<b>GPIO AND ALTERNATE FUNCTION (See <a href="#">Applications Information</a> for GPIO and Alternate Function Matrices.)</b>			
B6	K6	P0.0	General-Purpose I/O, Port 0
B7	K7	P0.1	General-Purpose I/O, Port 0
C10	J10	P0.2	General-Purpose I/O, Port 0
C9	J9	P0.3	General-Purpose I/O, Port 0
B9	K9	P0.4	General-Purpose I/O, Port 0
A9	L9	P0.5	General-Purpose I/O, Port 0
A8	L8	P0.6	General-Purpose I/O, Port 0
B8	K8	P0.7	General-Purpose I/O, Port 0
F7	E7	P0.8	General-Purpose I/O, Port 0

## Pin Description (continued)

PIN		NAME	FUNCTION
109 WLP	121 CTBGA		
G7	D7	P0.9	General-Purpose I/O, Port 0
E6	G6	P0.10	General-Purpose I/O, Port 0
F6	F6	P0.11	General-Purpose I/O, Port 0
E5	G5	P0.12	General-Purpose I/O, Port 0
D5	H5	P0.13	General-Purpose I/O, Port 0
F5	F5	P0.14	General-Purpose I/O, Port 0
G6	D6	P0.15	General-Purpose I/O, Port 0
B11	K11	P0.16	General-Purpose I/O, Port 0
D9	H9	P0.17	General-Purpose I/O, Port 0
E9	G9	P0.18	General-Purpose I/O, Port 0
C11	J11	P0.19	General-Purpose I/O, Port 0
D10	H10	P0.20	General-Purpose I/O, Port 0
F8	E8	P0.21	General-Purpose I/O, Port 0
F9	E9	P0.22	General-Purpose I/O, Port 0
G8	D8	P0.23	General-Purpose I/O, Port 0
E8	G8	P0.24	General-Purpose I/O, Port 0
D8	H8	P0.25	General-Purpose I/O, Port 0
C8	J8	P0.26	General-Purpose I/O, Port 0
D7	H7	P0.27	General-Purpose I/O, Port 0
C7	J7	P0.28	General-Purpose I/O, Port 0
D6	H6	P0.29	General-Purpose I/O, Port 0
C6	J6	P0.30	General-Purpose I/O, Port 0
B5	K5	P0.31	General-Purpose I/O, Port 0
A1, B2	K2	P1.0	General-Purpose I/O, Port 1
B3	K3	P1.1	General-Purpose I/O, Port 1
A4	L4	P1.2	General-Purpose I/O, Port 1
B4	K4	P1.3	General-Purpose I/O, Port 1
C5	J5	P1.4	General-Purpose I/O, Port 1
C4	J4	P1.5	General-Purpose I/O, Port 1
C3	J3	P1.6	General-Purpose I/O, Port 1
C2	J2	P1.7	General-Purpose I/O, Port 1
D4	H4	P1.8	General-Purpose I/O, Port 1
D1	H1	P1.9	General-Purpose I/O, Port 1
D3	H3	P1.10	General-Purpose I/O, Port 1
D2	H2	P1.11	General-Purpose I/O, Port 1
E2	E5	P1.12	General-Purpose I/O, Port 1
E3	E6	P1.13	General-Purpose I/O, Port 1
E4	G4	P1.14	General-Purpose I/O, Port 1

## Pin Description (continued)

PIN		NAME	FUNCTION
109 WLP	121 CTBGA		
G5	D5	P1.15	General-Purpose I/O, Port 1
<b>ANTENNA OUTPUT</b>			
K2	B2	ANT	Antenna for Bluetooth radio. Attach the single-ended unbalanced Bluetooth radio antenna.
—	A2	ANT THRU	The single-ended unbalanced Bluetooth radio antenna circuit board trace uses this pin as a pass-through. Do not connect any other signal to this pin.
<b>NO CONNECT</b>			
—	F3, F4	D.N.C.	Do Not Connect. Internally connected. Do not make any electrical connection to this pin, including power supply grounds.
—	L1	N.C.	No Connection. Not internally connected.

## Detailed Description

### MAX32665–MAX32668

The MAX32665–MAX32668 are Arm Cortex-M4 with FPU-based microcontrollers with 1MB flash and up to 560KB SRAM that can be configured as 448KB SRAM with error correction coding (ECC). They are ideal for wearable medical fitness applications. Optionally available is a second Arm Cortex-M4 with FPU (MAX32665/MAX32666 only).

The architecture includes a Bluetooth 5 Low Energy radio. The devices feature five powerful and flexible power modes. The flash memory is split into two banks of 512KB to provide flexibility when programming over-the-air. A built-in single inductor multiple output (SIMO) switch mode power supply allows the device to be optionally self-powered by a primary lithium cell. The devices have an ECC with single error correction double error detection (SEC-DED) for flash, and SRAM providing extremely reliable code execution. Dedicated hardware runs the Bluetooth 5 Low Energy stack freeing the CPUs for data processing tasks. Built-in dynamic clock gating and firmware-controlled power gating allows the user to optimize power for the specific application. Multiple SPI, UART, and I<sup>2</sup>C serial interfaces, 1-Wire Master, and USB 2.0 High-Speed Device interface allow for interconnection to a wide variety of external sensors. An audio subsystem supporting PDM, PCM, I<sup>2</sup>S, and TDM. An 8-input, 10-bit ADC is available to monitor analog input from external sensors and meters.

The MAX32665/MAX32666 feature a second Arm Cortex-M4 with FPU with supporting ROM and cache. This feature supports extended data processing capabilities such as audio processing for wireless Bluetooth applications. See the Ordering Information for device feature detail.

The MAX32666/MAX32668 incorporate a trust protection unit (TPU) with encryption and advanced security features. These features include a modular arithmetic accelerator (MAA) for fast ECDSA, a hardware AES engine, a hardware TRNG entropy generator, a SHA-2 accelerator and a secure bootloader.

All devices are available in a 109-bump WLP with 0.35mm pitch and a 121-bump CTBGA with 0.65mm pitch packages.

### Arm Cortex-M4 with FPU Processor

The Arm Cortex-M4 with FPU processors CPU0 and CPU1 are ideal for the emerging category of wearable medical and wellness applications. The architecture combines high-efficiency signal processing functionality with low power, low cost, and ease of use.

The Arm Cortex-M4 with FPU DSP supports single instruction multiple data (SIMD) path DSP extensions, providing:

- Four parallel 8-bit add/sub
- Floating point single precision
- Two parallel 16-bit add/sub
- Two parallel MACs
- 32- or 64-bit accumulate
- Signed, unsigned, data with or without saturation

### Memory

#### Internal Flash Memory

1MB of internal flash memory provides nonvolatile storage of program and data memory. It is supported by ECC with SEC-DED.

Flash can be expanded through the SPIXF flash serial interface backed by 16KB of cache. The SPIXF flash interface can address an additional 128MB.

#### Internal SRAM

The internal 560KB SRAM provides low-power retention of application information in all power modes. The SRAM can be configured as 448KB with ECC SEC-DED). The SRAM can be divided into granular banks that create a flexible SRAM retention architecture. This data-retention feature is optional and configurable. This granularity allows the application to

minimize its power consumption by retaining the most essential data only. SRAM can be expanded through the SPIXR SRAM serial interface supported by 16KB of cache. The SPIXR SRAM interface can address an additional 512MB.

### Secure Digital Interface

The secure digital interface (SDI) provides high-speed, high-density data storage capability for media files and large long-term data logs. This interface supports eMMC, SD, SDHC, and SDXC memory devices at transfer rates up to 24MB/s. The 7-pin interface (4 data, 1 clock, 1 command, 1 write-protect) supports the following specifications:

- SD Host Controller Standard Specification Version 3.00
- SDIO Card Specification Version 3.0
- SD Memory Card Specification Version 3.01
- SD Memory Card Security Specification Version 1.01
- MMC Specification Version 4.51

## Bluetooth 5

### Bluetooth 5 Low Energy Radio

Bluetooth 5 Low Energy is the latest version of the Bluetooth wireless communication standard. It is used for wireless headphones and other audio hardware, as well as for communication between various smart home and Internet of Things (IoT) devices. Devices operate in the unlicensed 2.4GHz ISM (Industrial, Scientific, Medical) band. A frequency-hopping transceiver is used to combat interference and fading. The system operates in the 2.4GHz ISM band at 2400MHz–2483.5MHz. It uses 40 RF channels. These RF channels have center frequencies  $2402 + k \times 2\text{MHz}$ , where  $k = 0, \dots, 39$ . The Bluetooth stack runs on dedicated hardware so that CPU0 and CPU1 can be freed to run application code. The features of the radio include the following:

- Higher transmit power up to +4.5dbm
- 1Mbps, 2Mbps, and Long Range coded (125kbps and 500kbps)
- Increased broadcast capability
  - Advertising packet up to 255 bytes
- On-chip matching network to the antenna
- Provides hardware on-the-fly encryption and decryption for lower power consumption
- Low transmit current of 4.30mA at 0dbm at 3.3V
- Low receive current of 3.20mA at 3.3V
- Supports mesh networking
- Supports high-quality audio streaming (isochronous)

### Bluetooth 5 Software Stack

A Bluetooth 5 software stack is available for application developers to quickly add support to devices. The Arm Cordio®-B50 software stack is provided in library form and provides application developers access to Bluetooth without validation and development of a software stack. The Cordio-B50 software stack interfaces to the Bluetooth link layer running on dedicated hardware. The dedicated hardware for the stack enables the ultimate in power management for IoT applications. Cordio-B50 features the following:

- C library for linking directly into an application development tool
- Change PHY Support
  - Host selects the PHY it needs to use at any given time enabling long range or higher bandwidth only when required
    - LE 1M
    - LE Coded S = 2
    - LE Coded S = 8
    - LE 2M
- Bluetooth 5 advertising extension support for enabling next generation Bluetooth beacons
  - Larger packets and advertising channel offloading
  - Packets up to 255 octets long



- Advertising packet chaining
- Advertising sets
- Periodic advertising
- High-duty cycle non-connectable advertising
- Sample applications using standard profiles built on the Cordio-B50 software framework

### Comparators

The eight AIN[7:0] inputs can be configured as four pairs and deployed as four independent comparators with the following features:

- Comparison events can trigger interrupts
- Events can wake the CPU from Sleep, DeepSleep, or Backup operating modes
- Can be active in all power modes

### Dynamic Voltage Scaling Controller

The Dynamic Voltage Scaling (DVS) Controller works using the fixed high-speed oscillator and the  $V_{COREA}$  supply voltage to optimally operate the Arm core at the lowest practical voltage. The ability to adaptively adjust the voltage provides a significant reduction in dynamic power consumption.

The DVS Controller provides the following features:

- Controls DVS monitoring and adjustment functions
- Continuous monitoring with programmable monitor sample period
- Controlled transition to a programmable operating point
- Independent high and low operating limits for safe, bounded operation
- Independent high, center, and low operating range delay line delay monitors
- Programmable adjustment rate – when an adjustment is required
- Single clock operation
- APB interface provides IP control and status access
- Interrupt capability during error

### Clocking Scheme

The high-frequency oscillator operates at a maximum frequency of 96MHz.

Optionally, five other oscillators can be selected depending upon power needs:

- 60MHz low-power oscillator ( $f_{LPCLK}$ )
- 8kHz nano-ring oscillator ( $f_{NANO}$ )
- 32.768kHz RTC oscillator (external crystal required)
- 7.3728MHz oscillator ( $f_{MCLK}$ )
- 32MHz RF oscillator (external crystal required) ( $f_{RFLK}$ )

This clock is the primary clock source for the digital logic and peripherals. Select the 7.3728MHz internal oscillator to optimize active power consumption. Using the 7.3727MHz oscillator allows UART communications to meet a 2% baud rate tolerance. Wake-up is possible from either the 7.3728MHz internal oscillator or the high-frequency oscillator. The device exits power-on reset using the the 60MHz oscillator.

An external 32.768kHz timebase is required when using the RTC.

The audio interface can be clocked by one of three sources:

- 96MHz high-speed oscillator
- 32MHz RF oscillator
- External clock applied to device pin P0.23 up to 100MHz.

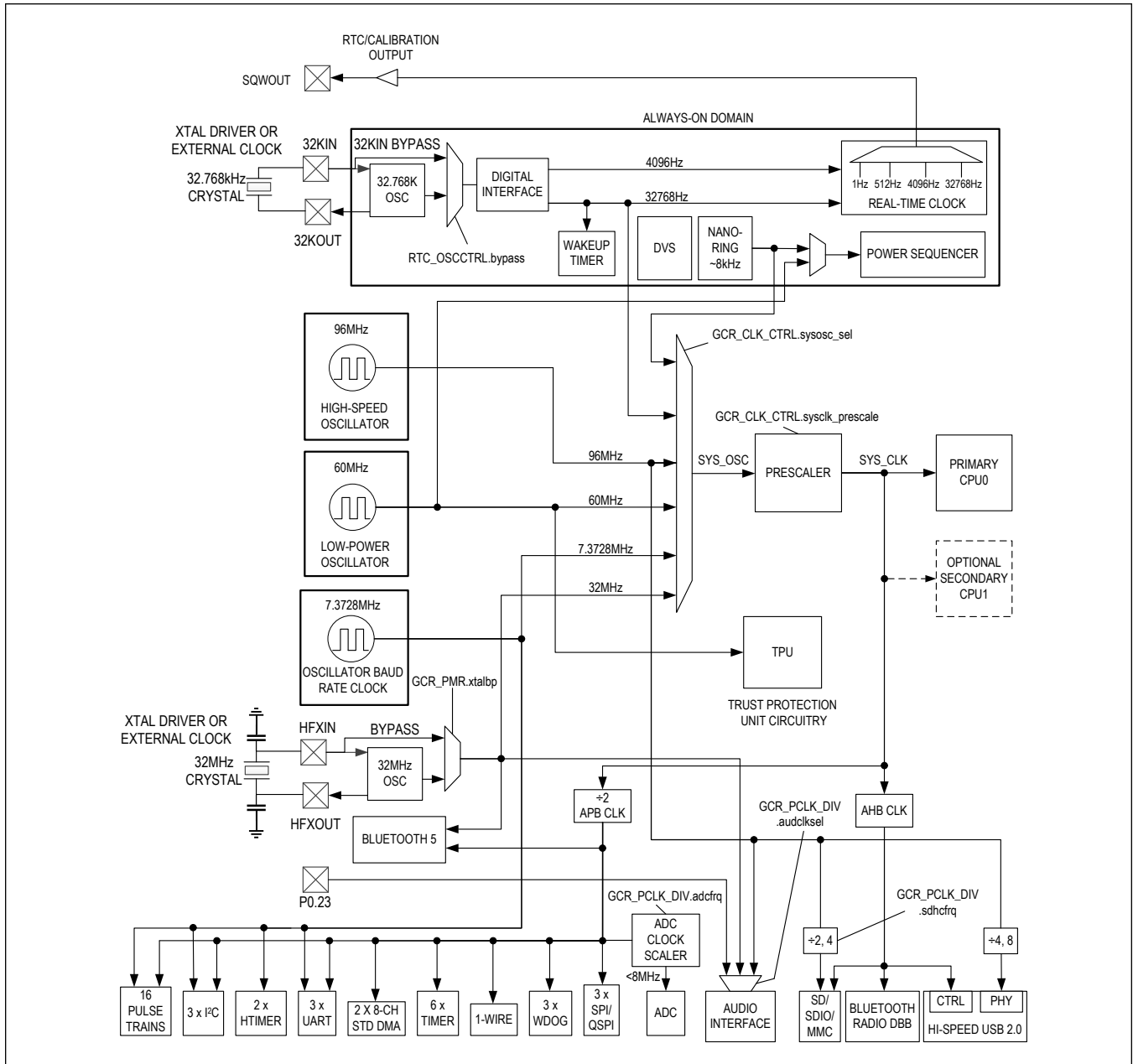


Figure 6. Clocking Scheme Diagram

**General-Purpose I/O and Special Function Pins**

Most general-purpose I/O (GPIO) pins share both a firmware-controlled I/O function and one or more alternate functions associated with peripheral modules. Pins can be individually enabled for GPIO or peripheral special function use. Configuring a pin as a special function usually supersedes its use as a firmware-controlled I/O. Although this multiplexing between peripheral and GPIO functions is usually static, it can also be done dynamically. The electrical characteristics of a GPIO pin are identical whether the pin is configured as an I/O or special function, except where explicitly noted in the [Electrical Characteristics](#) tables.

In GPIO mode, pins are logically divided into ports of 32 pins. Each pin of a port has an interrupt function that can be

independently enabled, and configured as a level- or edge-sensitive interrupt. All GPIOs of a given port share the same interrupt vector.

When configured as GPIO, the following features are provided. The features can be independently enabled or disabled on a per-pin basis.

- Configurable as input, output, bidirectional, or high impedance
- Optional internal pullup resistor or internal pulldown resistor when configured as input
- Exit from low-power modes on rising or falling edge
- Selectable standard- or high-drive modes

The MAX32665–MAX32668 provide up to 50 GPIO pins.

### Analog-to-Digital Converter

The 10-bit delta-sigma ADC provides an integrated reference generator and a single-ended input multiplexer. The multiplexer selects an input channel from one of the eight external analog input signals (AIN0–AIN7) or the internal power supply inputs.

The reference for the ADC can be:

- Internal 1.22V bandgap
- $V_{DDA}$  analog supply

An optional feature allows samples captured by the ADC to be automatically compared against user-programmable high and low limits. Up to four channel limit pairs can be configured in this way. The comparison allows the ADC to trigger an interrupt (and potentially wake the CPU from a low-power sleep mode) when a captured sample goes outside the preprogrammed limit range. Since this comparison is performed directly by the sample limit monitors, it can be performed even while the CPU is in Sleep or DeepSleep mode. The eight AIN[7:0] inputs can be configured a four pairs and deployed as four independent comparators.

The ADC measures the following voltages:

- AIN[7:0] up to 3.3V
- $V_{REG1}$
- $V_{TXOUT}$
- $V_{RXOUT}$
- $V_{COREA}$
- $V_{COREB}$
- $V_{DDIOH}$
- $V_{DDIO}$
- $V_{DDB}$
- $V_{DDA}$

### Single-Inductor Multiple-Output Switch-Mode Power Supply (SIMO SMPS)

The SIMO SMPS built into the device provides a monolithic power supply architecture for operation from a single lithium cell. The SIMO provides four buck regulator outputs that are voltage programmable. This architecture optimizes power consumption efficiency of the device and minimizes the bill of materials for the circuit design since only a single inductor/capacitor pair is required.

## Power Management

### Power Management Unit

The power management unit (PMU) provides high-performance operation while minimizing power consumption. It exercises intelligent, precise control of power distribution to the CPUs and peripheral circuitry.

The PMU provides the following features:

- User-configurable system clock

- Automatic enabling and disabling of crystal oscillators based on power mode
- Multiple power domains
- Fast wake-up of powered-down peripherals when activity detected

### Active Mode

In this mode, the CPU is executing application code and all digital and analog peripherals are available on demand. Dynamic clocking disables peripherals not in use, providing the optimal mix of high performance and low power consumption.

### Sleep Mode

This mode consumes less power, but wakes faster because the clocks can optionally be enabled.

The device status is as follows:

- CPU is asleep
- Peripherals are on
- Standard DMA blocks are available for optional use

### DeepSleep Mode

This mode corresponds to the Arm Cortex-M4 with FPU DeepSleep mode. In this mode, CPU and critical peripheral configuration settings and all volatile memory is preserved.

The device status is a follows:

- CPU is off. System state and all SRAM is retained.
- The GPIO pins retain their state.
- The transition from DeepSleep to Active mode is faster than the transition from Backup mode because system initialization is not required.
- The system oscillators are all disabled to provide additional power savings over Sleep mode:
  - 96MHz high-speed oscillator
  - 60MHz low-power oscillator
  - 7.3728MHz oscillator system clock shuts down.

### Backup Mode

This mode places the CPUs in a static, low-power state that supports a fast wake-up to Active mode feature.

The device status is as follows:

- CPU is off. System state is not retained.
- Either 32KB, 64KB, or all the SRAM can be retained.
- The RTC can be enabled.

### Wake-up Sources

The sources of wakeup from the Sleep, DeepSleep, and Backup operating modes can be summarized in Table 1.

**Table 1. Wake-up Sources**

OPERATING MODE	WAKE-UP SOURCE
Sleep	Interrupts (RTC, GPIO, USB, comparators, all peripherals), RSTN assertion, wake-up timer
DeepSleep	Interrupts (RTC, GPIO, USB, comparators), RSTN assertion, wake-up timer
Backup	Interrupts (RTC, GPIO, USB, comparators), RSTN assertion, wake-up timer

## Real-Time Clock

A real-time clock (RTC) keeps the time of day in absolute seconds. The 32-bit seconds register can count up to approximately 136 years and be translated to calendar format by application software.

The RTC provides a time-of-day alarm that can be programmed to any future value between 1 second and 12 days. When configured for long intervals, the time-of-day alarm can be used as a power-saving timer, allowing the device to remain in an extremely low-power mode, but still awaken periodically to perform assigned tasks. A second independent 32-bit 1/4096 subsecond alarm can be programmed with a tick resolution of 244µs. Both can be configured as recurring alarms. When enabled, either alarm can cause an interrupt or wake the device from most low power modes.

The time base is generated by a 32.768kHz crystal or an external clock source that must meet the electrical/timing requirements in the *Electrical Characteristics* table.

The RTC calibration feature provides the ability for user software to compensate for minor variations in the RTC oscillator, crystal, temperature, and board layout. Enabling the SQWOUT alternate function outputs a timing signal derived from the RTC. External hardware can measure the frequency and adjust the RTC frequency in increments of ±127ppm with 1ppm resolution. Under most circumstances, the oscillator does not require any calibration.

## CRC Module

A cyclic redundancy check (CRC) hardware module provides fast calculations and data integrity checks by application software. The CRC module supports the following polynomials:

- CRC-16-CCITT
- CRC-32 ( $X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$ )

## Programmable Timers

### 32-Bit Timer/Counter/PWM (TMR)

General-purpose, 32-bit timers provide timing, capture/compare, or generation of pulse-width modulated (PWM) signals with minimal software interaction.

The timer provides the following features:

- 32-bit up/down autoreload
- Programmable prescaler
- PWM output generation
- Capture, compare, and capture/compare capability
- External pin multiplexed with GPIO for timer input, clock gating, or capture
- Timer output pin
- Timer interrupt

The MAX32665–MAX32668 provides six instances of the general-purpose 32-bit timer (TMR0, TMR1, TMR2, TMR3, TMR4, and TMR5).

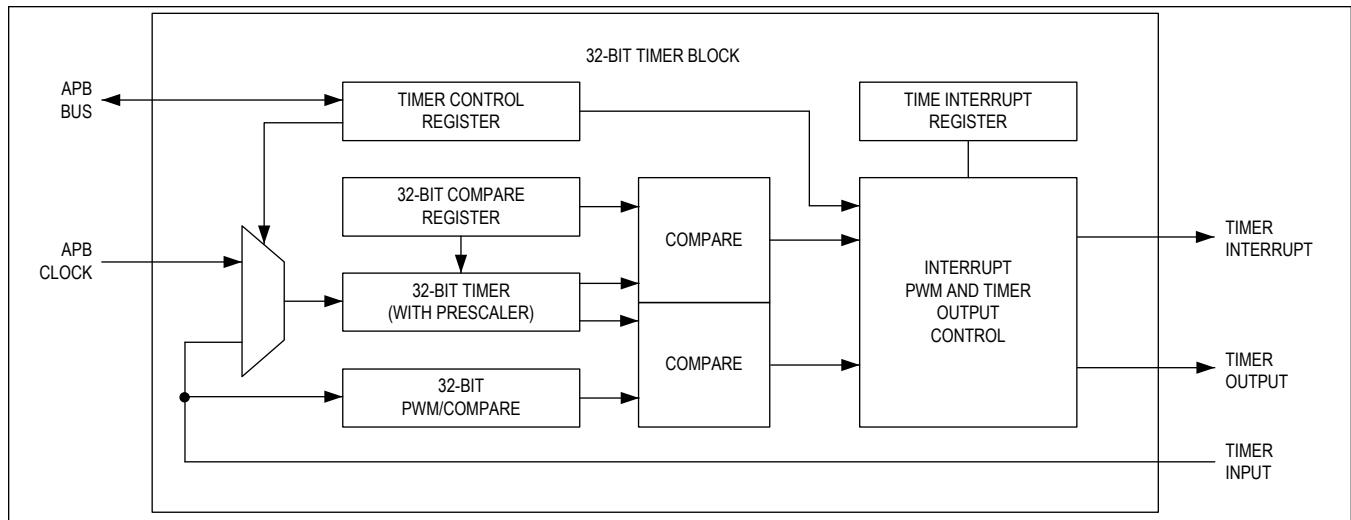


Figure 7. 32-Bit Timer

### Watchdog Timer (WDT)

Microcontrollers are often used in harsh environments where electrical noise and electromagnetic interference (EMI) are abundant. Without proper safeguards, these hazards can disturb device operation and corrupt program execution. One of the most effective countermeasures is the watchdog timer (WDT), which detects runaway code or system unresponsiveness.

The WDT is a 32-bit, free-running counter with a configurable prescaler. When enabled, the WDT must be periodically reset by the application software. Failure to reset the WDT within the user-configurable timeout period indicates that the application software is not operating correctly and results in a WDT timeout. A WDT timeout can trigger an interrupt, system reset, or both. Either response forces the instruction pointer to a known good location before resuming instruction execution.

The MAX32665-MAX32668 provide three instances of the WDT (WDT0, WDT1, WDT2). All three WDTs are identical and independent of each other. Each has a dedicated reset bit, reset and/or interrupt enable bits, and status flags. They all share the same timebase, which is a scaled of the version system clock, but have independent prescale values.

### Pulse Train Engine (PT)

Multiple, independent pulse train generators can provide either a square wave or a repeating pattern from 2 to 32 bits in length. Any single pulse train generator or any desired group of pulse train generators can be synchronized at the bit level allowing for multibit patterns. Each pulse train generator is independently configurable.

The pulse train generators provide the following features:

- Independently enabled
- Safe enable and disable for pulse trains without bit banding
- Multiple pin configurations allow for flexible layout
- Pulse trains can be started/synchronized independently or as a group
- Frequency of each enabled pulse train generator is also set separately, based on a divide down (divide by 2, divide by 4, divide by 8, and so on) of the input pulse train module clock
- Input pulse train module clock can be optionally configured to be independent from the system AHB clock
- Multiple repetition options
  - Single shot (nonrepeating pattern of 2 to 32 bits)
  - Pattern repeats user-configurable number of times or indefinitely
  - Termination of one pulse train loop count can restart one or more other pulse trains

The pulse train engine feature is an alternate function associated with a GPIO pin. In most cases, enabling the pulse train

engine function supersedes the GPIO function.

The MAX32665-MAX32668 provide up to 16 instances of the pulse train engine peripheral (PT[15:0]).

### HTIMER

The HTIMER is a 44-bit timer that is driven by the 7.3728MHz source clock resulting in a tick resolution of 135.63ns. It is programmable to provide interrupts at count comparison.

The MAX32665–MAX32668 provide two instances of the HTIMER.

## Serial Peripherals

### USB Controller

The integrated USB slave controller is compliant with the High-Speed (480Mb/s) USB 2.0 specification. The integrated USB physical interface (PHY) reduces board space and system cost. An integrated voltage regulator enables smart switching between the main supply and  $V_{DDB}$  when connected to a USB host controller. The USB controller supports DMA for the endpoint buffers. A total of 11 endpoint buffers are supported with configurable selection of IN or OUT in addition to endpoint 0.

### Audio Interface

The audio interface allows the device to communicate with external audio devices using standard I<sup>2</sup>S pulse-coded modulation (PCM) and pulse density modulation (PDM) audio interfaces in a slave-only configuration. This allows audio algorithms to be run such as dynamic speaker management (DSM) or ambient noise cancellation (ANC).

I<sup>2</sup>S PCM mode features the following:

- Single 4-wire I<sup>2</sup>S PCM interface allowing transmit and receive of audio data and is intended to connect to speaker driver devices
- Four transmit channels and eight receive channels are supported to allow 4-channel DSM
- Support four PDM receive channels at the same time as PCM support
- Sample rates from 8kHz to 192kHz
- 

PDM mode features the following:

- Up to four PDM transmit channels at 3.072MHz
- Up to six PDM receive channels at 3.072MHz
- Interpolation and decimation filtering to save MIPS in the DSP

### I<sup>2</sup>C Interface

The I<sup>2</sup>C interface is a bidirectional, two-wire serial bus that provides a medium-speed communications network. It can operate as a one-to-one, one-to-many, or many-to-many communications medium. The I<sup>2</sup>C master/slave interface to a wide variety of I<sup>2</sup>C-compatible peripherals. These engines support standard mode, fast mode, and fast mode plus I<sup>2</sup>C speeds. It provides the following features:

- Master or slave mode operation
- Supports standard 7-bit addressing or 10-bit addressing
- RESTART condition
- Interactive receive mode
- Tx FIFO preloading
- Support for clock stretching to allow slower slave devices to operate on higher speed buses
- Multiple transfer rates
  - Standard mode: 100kbps
  - Fast mode: 400kbps
  - Fast mode plus: 1000kbps
  - High-speed mode: 3400kbps

- Internal filter to reject noise spikes
- Receiver FIFO depth of 8 bytes
- Transmitter FIFO depth of 8 bytes

The MAX32665–MAX32668 provide three instances of the I<sup>2</sup>C interface (I2C0, I2C1, I2C2).

### Serial Peripheral Interface

The serial peripheral interface (SPI) is a highly configurable, flexible, and efficient synchronous interface between multiple SPI devices on a single bus. The bus uses a single clock signal and multiple data signals, and one or more slave select lines to address only the intended target device. The SPI operates independently and requires minimal processor overhead.

The provided SPI peripherals can operate in either slave or master mode and provide the following features:

- SPI modes 0, 1, 2, 3 for single-bit communication
- 3- or 4-wire mode for single-bit slave device communication
- Full-duplex operation in single-bit, 4-wire mode
- Dual and quad data modes supported
- Multiple slave select lines on some instances
- Multimaster mode fault detection
- Programmable interface timing
- Programmable SCK frequency and duty cycle
- 32-byte transmit and receive FIFOs
- Slave select assertion and deassertion timing with respect to leading/trailing SCK edge

The MAX32665–MAX32668 provide three instances of the SPI interface (SPI0, SPI1, SPI2).

**Table 2. SPI Configuration Options**

INSTANCE	DATA	SLAVE SELECT LINES		MAXIMUM FREQUENCY (MASTER MODE) (MHz)	MAXIMUM FREQUENCY (SLAVE MODE) (MHz)
		109 WLP	121 CTBGA		
SPI0	3-wire, 4-wire, dual, or quad data support	3	3	48	48
SPI1	3-wire, 4-wire, dual, or quad data support	3	3	48	48
SPI2	3-wire, 4-wire, dual, or quad data support	3	3	48	48

### SPI Execute in Place (SPIX) Master

There are two SPI execute in place (SPIX) master interfaces. One is dedicated for SRAM (SPIXR) and one is dedicated for flash (SPIXF) with dedicated slave selects. This allows the CPU to transparently execute instructions stored in an external SPI memory device. Instructions fetched through the SPI master are cached just like instructions fetched from internal program memory. The SPI SRAM master provides write-through capability. These two SPI execute in place master interfaces can also be used to access large amounts of external static data that would otherwise reside in internal data memory.

### UART

The universal asynchronous receiver-transmitter (UART) interface supports full-duplex asynchronous communication with optional hardware flow control (HFC) modes to prevent data overruns. If HFC mode is enabled on a given port, the system uses two extra pins to implement the industry standard request to send (RTS) and clear to send (CTS) flow control signaling. Each UART is individually programmable.

The UART supports the following features:



- Baud rate generation with  $\pm 2\%$  optionally utilizing the 7.3727MHz relaxation oscillator
- 2-wire interface or 4-wire interface with flow control
- 32-byte send/receive FIFO
- Full-duplex operation for asynchronous data transfers
- Interrupts available for frame error, parity error, CTS, Rx FIFO overrun and FIFO full/partially full conditions
- Automatic parity and frame error detection
- Independent baud-rate generator
- Programmable 9th bit parity support
- Multidrop support
- Start/stop bit support
- Hardware flow control using RTS/CTS
- Maximum baud rate 4000kB
- Two DMA channels can be connected (read and write FIFOs)
- Programmable word size (5 bits to 8 bits)

The MAX32665–MAX32668 provide three instances of the UART peripheral (UART0, UART1, and UART2).

**Table 3. UART Configuration Options**

INSTANCE	FLOW CONTROL		MAXIMUM BAUD RATE (kb)
	109 WLP	121 CTBGA	
UART0	YES	YES	4000
UART1	YES	YES	4000
UART2	YES	YES	4000

### 1-Wire Master (OWM)

Maxim's 1-wire bus consists of one signal that carries data and also supplies power to the slave devices and a ground return. The bus master communicates serially with one or more slave devices through the bidirectional, multidrop 1-Wire bus. The single contact serial interface is ideal for communication networks requiring minimal interconnection.

The provided 1-Wire master supports the following features:

- Single contact for control and operation
- Unique factory identifier for any 1-Wire device
- Multiple device capability on a single line

The OWM supports both standard (15.6 kbps) and overdrive (110 kbps) speeds.

### Standard DMA Controller

The standard DMA controller allows automatic one-way data transfer between two entities. These entities can be either memories or peripherals. The transfers are done without using CPU resources. The following transfer modes are supported:

- 8-channel
- Peripheral to data memory
- Data memory to peripheral
- Data memory to data memory
- Event support

All DMA transactions consist of an AHB burst read into the DMA FIFO followed immediately by an AHB burst write from the FIFO.

The MAX32665–MAX32668 provide two instances of the standard DMA controller.

### Trusted Protection Unit (TPU)

**True Random Number Generator (TRNG)**

Random numbers are a vital part of a secure application, providing random numbers that can be used for cryptographic seeds or strong encryption keys to ensure data privacy.

Software can use random numbers to trigger asynchronous events that result in nondeterministic behavior. This is helpful in thwarting replay attacks or key search approaches. An effective true random number generator (TRNG) must be continuously updated by a high-entropy source.

The provided TRNG is continuously driven by a physically-unpredictable entropy source. It generates a 128-bit true random number in 128 system clock cycles.

The TRNG can support the system-level validation of many security standards such as FIPS 140-2, PCI-PED, and Common Criteria. Contact Maxim for details of compliance with specific standards.

**MAA**

The provided high-speed, hardware-based modulo arithmetic accelerator (MAA) performs mathematical computations that support strong cryptographic algorithms. These include:

- 2048-bit DSA
- 4096-bit RSA
- Elliptic curve public key infrastructure

**AES**

The dedicated hardware-based AES engine supports the following algorithms:

- AES-128
- AES-192
- AES-256

The AES keys are automatically generated by the engine and stored in dedicated flash to protect against tampering. Key generation and storage is transparent to the user.

**SHA-2**

SHA-2 is a cryptographic hash function. It authenticates user data and verifies its integrity. It is used for digital signatures.

The device provides a hardware SHA-2 engine for fast computation of digests supporting:

- SHA-224
- SHA-256
- SHA-384
- SHA-512

**Memory Decryption Integrity Unit (MDIU)**

The external SPI flash can optionally be encrypted for additional security. Data can be transparently encrypted when it is loaded and decrypted on the fly. Encryption keys are stored in the always-on domain and preserved as long as  $V_{COREA}$  is present.

**Secure Bootloader**

The secure bootloader provides a secure, authenticated communication channel with a system host. The secure communication protocol (SCP) allows the programming of internal and external memory.

The secure bootloader provides the following features:

- Life cycle management
- Trusted boot authentication through ECDSA P-256, RSA 2048, and RSA 4096
- Preprogrammed Maxim manufacturer root key (MRK)
- Programmable customer root key (CRK)
- Support for 2048- or 4096-bit RSA digital signature

## Applications Information

### Bypass Capacitors

The proper use of bypass capacitors reduces noise generated by the IC into the ground plane. The [Pin Description](#) indicates which pins should be connected to bypass capacitors and the appropriate ground plane.

It is recommended that one instance of a bypass capacitor should be connected to each pin/ball of the IC package. For example, if the [Pin Description](#) shows 4 device pins associated with voltage supply A, a separate capacitor should be connected to each pin for a total of 4 capacitors.

Place capacitors as close as possible to their corresponding device pins. Pins that recommend more than one value of capacitor per pin should place them in parallel with the lowest value capacitor first, closest to the pin.

### Transmitted Spurious Emissions

Various local regulatory agencies can impose limits on transmitted spurious emissions. At maximum output power of +4.5dbm, compliance with local regulations can require either an antenna with at least 6 dB rejection at the 7.2GHz third harmonic or the use of a lowpass filter network between the device RF port and antenna. The MAX32665–MAX32668 are designed with an on-chip matching network providing a 50Ω impedance at the ANT device pin. Filter design must match this impedance for best efficiency.

### GPIO and Alternate Function Matrix

**Table 4. GPIO and Alternate Function Matrix**

GPIO	ALTERNATE FUNCTION 1	ALTERNATE FUNCTION 2	ALTERNATE FUNCTION 3	ALTERNATE FUNCTION 4	GPIOOUT_ENABLE	TTAP_ENABLE
P0.0	SPIXF_SS0		UART2_CTS	TMR0		
P0.1	SPIXF_MOSI/ SDIO0		UART2_TX	TMR1		
P0.2	SPIXF_MISO/ SDIO1		UART2_RX	TMR2		
P0.3	SPIXF_SCK		UART2_RTS	TMR3		
P0.4	SPIXF_SDIO2		OWM_IO	TMR4		
P0.5	SPIXF_SDIO3		OWM_PE	TMR5		
P0.6	I2C0_SCL		SWDIO2	TMR0		
P0.7	I2C0_SDA		SWCLK2	TMR1		
P0.8	SPIXR_SS0	QSPI0_SS0	UART0_CTS	TMR2		
P0.9	SPIXR_MOSI/ SDIO0	QSPI0_MOSI/ SDIO0	UART0_TX	TMR3		
P0.10	SPIXR_MISO/ SDIO1	QSPI0_MISO/ SDIO1	UART0_RX	TMR4		
P0.11	SPIXR_SCK	QSPI0_SCK	UART0_RTS	TMR5		
P0.12	SPIXR_SDIO2	QSPI0_SDIO2	OWM_IO	TMR0		
P0.13	SPIXR_SDIO3	QSPI0_SDIO3	OWM_PE	TMR1		
P0.14	I2C1_SCL	QSPI0_SS1		TMR2		
P0.15	I2C1_SDA	QSPI0_SS2		TMR3		
P0.16	AIN0/AIN0P	QSPI1_SS0	OWM_IO	TMR4		
P0.17	AIN1/AIN0N	QSPI1_MOSI/ SDIO0	OWM_PE	TMR5		

**Table 4. GPIO and Alternate Function Matrix (continued)**

GPIO	ALTERNATE FUNCTION 1	ALTERNATE FUNCTION 2	ALTERNATE FUNCTION 3	ALTERNATE FUNCTION 4	GPIOOUT_ENABLE	TTAP_ENABLE
P0.18	AIN2/AIN1P	QSPI1_MISO/ SDIO1		TMR0	PDOWN (active low)	
P0.19	AIN3/AIN1N	QSPI1_SCK		TMR1	SQWOUT	
P0.20	AIN4/AIN2P	QSPI1_SDIO2	UART1_RX	TMR2		
P0.21	AIN5/AIN2N	QSPI1_SDIO3	UART1_TX	TMR3		
P0.22	AIN6/AIN3P	QSPI1_SS1	UART1_CTS	TMR4		
P0.23	AIN7/AIN3N	QSPI1_SS2	UART1_RTS	TMR5		
P0.24	PCM_LRCLK	QSPI2_SS0	OWM_IO	TMR0		
P0.25	PCM_DOUT	QSPI2_MOSI/ SDIO0	OWM_PE	TMR1		
P0.26	PCM_DIN	QSPI2_MISO/ SDIO1		TMR2	PDOWN (active low)	
P0.27	PCM_BCLK	QSPI2_SCK		TMR3	SQWOUT	
P0.28	PDM_DATA2	QSPI2_SDIO2	UART2_RX	TMR4		
P0.29	PDM_DATA3	QSPI2_SDIO3	UART2_TX	TMR5		
P0.30	PDM_RX_CLK	QSPI2_SS1	UART2_CTS	TMR0		
P0.31	PDM_MCLK	QSPI2_SS2	UART2_RTS	TMR1		
P1.0	SDHC_DAT3		SDMA_TMS	PT0		
P1.1	SDHC_CMD		SDMA_TDO	PT1		
P1.2	SDHC_DAT0		SDMA_TDI	PT2		
P1.3	SDHC_CLK		SDMA_TCK	PT3		
P1.4	SDHC_DAT1		UART0_RX	PT4		
P1.5	SDHC_DAT2		UART0_TX	PT5		
P1.6	SDHC_WP		UART0_CTS	PT6		
P1.7	SDHC_CDN		UART0_RTS	PT7		
P1.8	QSPI0_SS0			PT8		
P1.9	QSPI0_MOSI/ SDIO0			PT9		
P1.10	QSPI0_MISO/ SDIO1			PT10		
P1.11	QSPI0_SCK			PT11		
P1.12	QSPI0_SDIO2		UART1_RX	PT12		
P1.13	QSPI0_SDIO3		UART1_TX	PT13		
P1.14	I2C2_SCL		UART1_CTS	PT14		JTAG TDI
P1.15	I2C2_SDA		UART1_RTS	PT15		JTAG TDO
SWDIO	GPIO					
SWCLK	GPIO					

## Ordering Information

PART	BLE	Arm CORTEX-M4 CPU	SRAM SIZE	ECC	SECURITY/TPU	SECURE BOOTLOADER	PIN-PACKAGE
MAX32665GWPBT+*	Yes	Dual	560KB	Yes	No	No	109 WLP
MAX32665GWPBT+T*	Yes	Dual	560KB	Yes	No	No	109 WLP
MAX32665GXMBT+*	Yes	Dual	560KB	Yes	No	No	121 CTBGA
MAX32665GXMBT+T*	Yes	Dual	560KB	Yes	No	No	121 CTBGA
MAX32666GWP+	No	Dual	560KB	Yes	Yes	No	109 WLP
MAX32666GWP+T	No	Dual	560KB	Yes	Yes	No	109 WLP
MAX32666GWPBT+	Yes	Dual	560KB	Yes	Yes	No	109 WLP
MAX32666GWPBT+T	Yes	Dual	560KB	Yes	Yes	No	109 WLP
MAX32666GXMBT+	Yes	Dual	560KB	Yes	Yes	No	121 CTBGA
MAX32666GXMBT+T	Yes	Dual	560KB	Yes	Yes	No	121 CTBGA
MAX32666GWPBL+*	Yes	Dual	560KB	Yes	Yes	Yes	109 WLP
MAX32666GWPBL+T*	Yes	Dual	560KB	Yes	Yes	Yes	109 WLP
MAX32666GXMBL+*	Yes	Dual	560KB	Yes	Yes	Yes	121 CTBGA
MAX32666GXMBL+T*	Yes	Dual	560KB	Yes	Yes	Yes	121 CTBGA
MAX32667GWPBT+*	Yes	Single	192KB	No	No	No	109 WLP
MAX32667GWPBT+T*	Yes	Single	192KB	No	No	No	109 WLP
MAX32667GXMBT+*	Yes	Single	192KB	No	No	No	121 CTBGA
MAX32667GXMBT+T*	Yes	Single	192KB	No	No	No	121 CTBGA
MAX32668GWPBT+*	Yes	Single	192KB	No	Yes	No	109 WLP
MAX32668GWPBT+T*	Yes	Single	192KB	No	Yes	No	109 WLP
MAX32668GXMBT+*	Yes	Single	192KB	No	Yes	No	121 CTBGA
MAX32668GXMBT+T*	Yes	Single	192KB	No	Yes	No	121 CTBGA
MAX32668GWPBL+*	Yes	Single	192KB	No	Yes	Yes	109 WLP
MAX32668GWPBL+T*	Yes	Single	192KB	No	Yes	Yes	109 WLP
MAX32668GXMBL+*	Yes	Single	192KB	No	Yes	Yes	121 CTBGA
MAX32668GXMBL+T*	Yes	Single	192KB	No	Yes	Yes	121 CTBGA

+Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel. Full reel.

\*Future product—contact factory for availability.

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/18	Initial release	—
1	4/19	Updated <i>Benefits and Features</i> , <i>Electrical Characteristics</i> table, <i>Pin Description</i> , <i>Bluetooth 5 Low Energy Radio</i> , <i>Bluetooth 5 Software Stack</i> , and <i>Ordering Information</i> sections	1, 4, 7–9, 21, 25, 26, 37
2	8/19	Updated <i>General Description</i> , <i>Electrical Characteristics</i> table, <i>Detailed Description</i> , <i>DeepSleep Mode</i> , <i>Backup Mode</i> , <i>I<sup>2</sup>C Interface</i> sections, and Table 4	1, 4, 5, 8, 24, 29, 35, 36
2.1		Corrected typos in <i>Electrical Characteristics</i> table	4
3	2/20	Updated <i>Benefits and Features</i> , <i>Simplified Block Diagram</i> , <i>Electrical Characteristics</i> table, <i>Pin Description</i> , <i>Detailed Description</i> , <i>Bluetooth 5 Low Energy Radio</i> , <i>Bluetooth 5 Software Stack</i> , <i>Clocking Scheme</i> , Figure 6, <i>DeepSleep Mode</i> , <i>Backup Mode</i> , <i>Audio Interface</i> , <i>I<sup>2</sup>C Interface</i> , <i>Bypass Capacitors</i> , <i>Transmitted Spurious Emissions</i> , Table 4, and <i>Ordering Information</i>	1, 2, 10–17, 26–34, 36, 39, 43–45
4	4/20	Updated <i>Absolute Maximum Ratings</i> $V_{DDB}$ and DM, DP signal descriptions, $V_{REGI}$ <i>Current</i> , <i>Backup Mode</i> and $V_{REGI}$ <i>Fixed Current DeepSleep Mode Electrical Characteristics</i> table specs, <i>Parameter</i> descriptions for USB in the <i>Electrical Characteristics</i> table, the RSTN pin description in the <i>Pin Descriptions</i> table, <i>Programmable Timers Detailed Description</i> , updated the <i>Ordering Information</i> table	7, 9, 16, 28, 37, 45, 46

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

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