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## Single-Chip 5G WiFi IEEE 802.11ac MAC/Baseband/ Radio with Integrated Bluetooth 4.1 and FM Receiver

### GENERAL DESCRIPTION

The Broadcom<sup>®</sup> BCM43455 single-chip device provides the highest level of integration for a mobile or handheld wireless system with integrated single-stream IEEE 802.11ac MAC/baseband/radio, Bluetooth 4.1, and FM receiver.

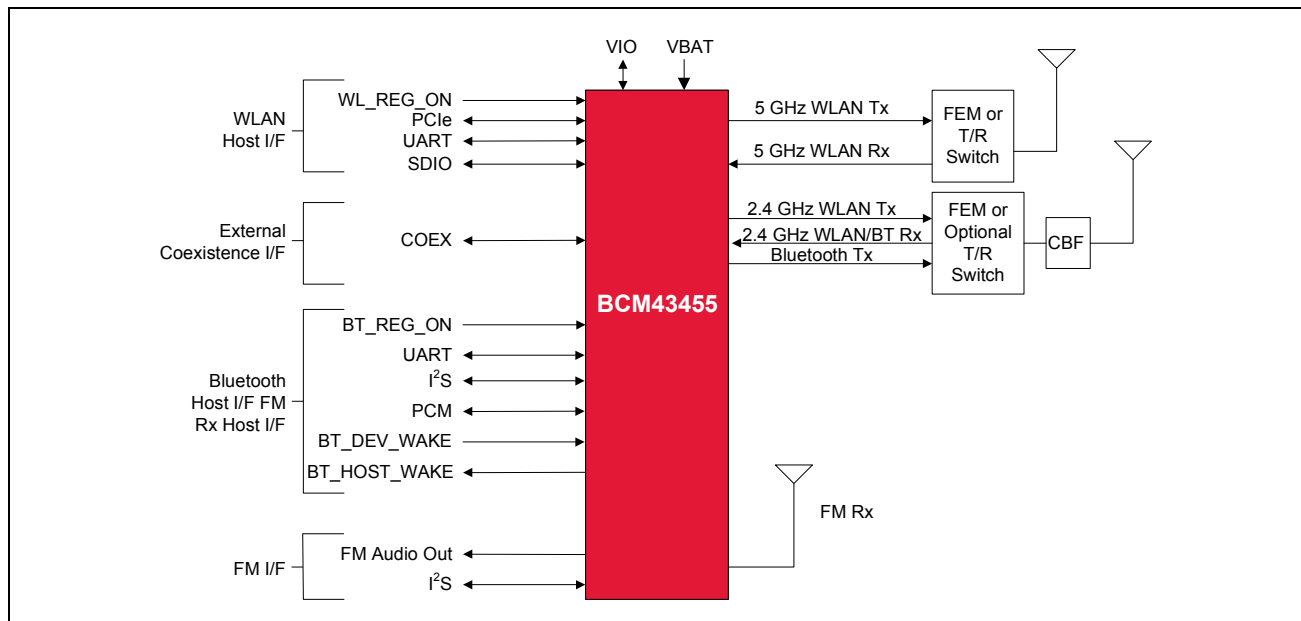
In IEEE 802.11ac mode, the WLAN operation supports rates of MCS0–MCS9 (up to 256 QAM) in 20 MHz, 40 MHz, and 80 MHz channels for data rates of up to 433.3 Mbps. All rates specified in the IEEE 802.11a/b/g/n are supported. Included on-chip are 2.4 GHz and 5 GHz transmit amplifiers and receive low-noise amplifiers. Optional external PAs and LNAs are also supported.

The WLAN section supports the following host interface options: an SDIO v3.0 interface that can operate in 4b or 1b mode, a high-speed 4-wire UART, and a PCIe Gen1 (3.0 compliant) interface. The Bluetooth section supports a high-speed 4-wire UART interface.

Using advanced design techniques and process technology to reduce active and idle power, the BCM43455 is designed to address the needs of mobile devices that require minimal power consumption and compact size. It includes a power management unit which simplifies the system power topology and allows for direct operation from a mobile platform battery while maximizing battery life.

The BCM43455 implements highly sophisticated enhanced collaborative coexistence hardware mechanisms and algorithms, which ensure that WLAN and Bluetooth collaboration is optimized for maximum performance. In addition, coexistence support for external radios (such as LTE cellular and GPS) is provided via an external interface. As a result, enhanced overall quality for simultaneous voice, video, and data transmission on a handheld system is achieved.

Figure 1: Functional Block Diagram



## FEATURES

### IEEE 802.11x Key Features

- IEEE 802.11ac compliant.
- Support for TurboQAM<sup>®</sup> (MCS0–MCS8 86 Mbps and MCS0–MCS9 96 Mbps) HT20, 20 MHz channel bandwidth.
- Single-stream spatial multiplexing up to 433.3 Mbps data rate.
- Supports 20, 40, and 80 MHz channels with optional SGI (256 QAM modulation).
- Full IEEE 802.11a/b/g/n legacy compatibility with enhanced performance.
- Supports explicit IEEE 802.11ac transmit beamforming.
- TX and RX low-density parity check (LDPC) support for improved range and power efficiency.
- On-chip power amplifiers and low-noise amplifiers for both bands.
- Support for optional front-end modules (FEM) with external PAs and LNAs.
- Supports optional integrated T/R switch for 2.4 GHz band.
- Supports RF front-end architecture with a single dual-band antenna shared between Bluetooth and WLAN for lowest system cost.
- Shared Bluetooth and WLAN receive signal path eliminates the need for an external power splitter while maintaining excellent sensitivity for both Bluetooth and WLAN.
- Internal fractional-n PLL allows support for a wide range of reference clock frequencies.
- Supports IEEE 802.15.2 external coexistence interface to optimize bandwidth utilization with other co-located wireless technologies such as LTE or GPS.
- Supports standard SDIO v3.0 (including DDR50 mode at 50 MHz and SDR104 mode at 208 MHz, 4-bit and 1-bit) interfaces.

### Bluetooth Key Features

- Complies with Bluetooth Core Specification Version 4.1 with provisions for supporting future specifications.
- Bluetooth Class 1 or Class 2 transmitter operation.
- Supports extended synchronous connections (eSCO), for enhanced voice quality by allowing for retransmission of dropped packets.
- Adaptive frequency hopping (AFH) for reducing radio frequency interference.
- Interface support, host controller interface (HCI) using a high-speed UART interface and PCM for audio data.
- FM unit supports HCI for communication.
- FM receiver: 65 MHz to 108 MHz FM bands; supports the European radio data systems (RDS) and the North American radio broadcast data system (RBDS) standards.
- Low power consumption improves battery life of handheld devices.
- Supports multiple simultaneous Advanced Audio Distribution Profiles (A2DP) for stereo sound.
- Automatic frequency detection for standard crystal and TCXO values.

### General Features

- Supports battery voltage range from 3.0V to 5.25V supplies with internal switching regulator.
- Programmable dynamic power management
- 6 Kbit OTP for storing board parameters.
- GPIOs: 15
- 140-ball WLPGA package (4.47 mm × 5.27 mm, 0.4 mm pitch).
-

## FEATURES

### IEEE 802.11x Key Features (Cont.)

- Backward compatible with SDIO v2.0 host interfaces.
- PCIe mode complies with PCI Express base specification revision 3.0 compliant Gen1 interface for ×1 lane and power management base specification.
- Integrated ARMCR4 processor with tightly coupled memory for complete WLAN subsystem functionality and minimizing the need to wake-up the applications processor for standard WLAN functions. This allows for further minimization of power consumption, while maintaining the ability to field upgrade with future features. On-chip memory includes 800 KB SRAM and 704 KB ROM.
- OneDriver™ software architecture for easy migration from existing embedded WLAN and Bluetooth devices as well as future devices.

### General Features (Cont.)

- Security:
  - WPA and WPA2 (Personal) support for powerful encryption and authentication
  - AES and TKIP in hardware for faster data encryption and IEEE 802.11i compatibility
  - Reference WLAN subsystem provides Cisco Compatible Extensions (CCX, CCX 2.0, CCX 3.0, and CCX 4.0)
  - Reference WLAN subsystem provides Wi-Fi Protected Setup (WPS)
- Worldwide regulatory support: Global products supported with worldwide homologated design.

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## Revision History

<b>Revision</b>	<b>Date</b>	<b>Change Description</b>
43455-DS109-R	11/05/15	<b>Updated:</b> <ul style="list-style-type: none"><li>• <a href="#">Table 17: “WLBGA Pin List by Pin Number,” on page 81.</a></li><li>• <a href="#">Table 18: “WLBGA Pin List by Pin Name,” on page 83.</a></li><li>• <a href="#">Table 19: “Signal Descriptions,” on page 85.</a></li></ul>
43455-DS108-R	09/25/15	<b>Updated:</b> <ul style="list-style-type: none"><li>• <a href="#">Figure 55: “140-Ball WLBGA Package Mechanical Information,” on page 24: nominal height (A) is 0.55 mm.</a></li></ul>
43455-DS107-R	07/29/15	<b>Updated:</b> <ul style="list-style-type: none"><li>• <a href="#">Figure 56: “140-Balls WLBGA Keep-out Areas for PCB Layout —Top View with Balls Facing Down,” on page 169</a></li></ul>
43455-DS106-R	07/09/15	<b>Updated:</b> <ul style="list-style-type: none"><li>• <a href="#">Table 22: “WLBGA Signal Descriptions,” on page 97.</a></li><li>• <a href="#">Table 26: “I/O States,” on page 106.</a></li><li>• <a href="#">Table 37: “WLAN 2.4 GHz Receiver Performance Specifications,” on page 125.</a></li><li>• <a href="#">Table 39: “WLAN 5 GHz Receiver Performance Specifications,” on page 130.</a></li><li>• <a href="#">Figure 56: “140-Balls WLBGA Keep-out Areas for PCB Layout—Top View with Balls Facing Down,” on page 168.</a></li></ul>
43455-DS105-R	04/06/15	<b>Updated:</b> <ul style="list-style-type: none"><li>• <a href="#">Table 36: “WLAN 2.4 GHz Transmitter Performance Specifications,” on page 122.</a></li><li>• <a href="#">Table 38: “WLAN 5 GHz Transmitter Performance Specifications,” on page 128.</a></li></ul>

<b>Revision</b>	<b>Date</b>	<b>Change Description</b>
43455-DS104-R	03/31/15	<p><b>Updated:</b></p> <ul style="list-style-type: none"> <li>• “JTAG/SWD Interface” on page 73.</li> <li>• Table 22: “WLBGA Signal Descriptions,” on page 97: WLAN GPIO interface and JTAG interface.</li> <li>• Table 29: “ESD Specifications,” on page 110.</li> <li>• Table 31: “Bluetooth Receiver RF Specifications,” on page 113.</li> <li>• Table 32: “Bluetooth Transmitter RF Specifications,” on page 116.</li> <li>• Table 33: “Local Oscillator Performance,” on page 118.</li> <li>• Table 34: “BLE RF Specifications,” on page 118.</li> <li>• Table 36: “2.4 GHz Band General RF Specifications,” on page 125.</li> <li>• Table 37: “WLAN 2.4 GHz Receiver Performance Specifications,” on page 125.</li> <li>• Table 38: “WLAN 2.4 GHz Transmitter Performance Specifications,” on page 129.</li> <li>• Table 40: “WLAN 5 GHz Transmitter Performance Specifications,” on page 135.</li> <li>• “Transmitter Spurious Emissions Specifications” on page 137.</li> <li>• Section 18: “Internal Regulator Electrical Specifications,” on page 141.</li> <li>• Table 53: “2.4 GHz Mode WLAN Power Consumption,” on page 147.</li> <li>• Table 54: “5 GHz Mode WLAN Power Consumption,” on page 148.</li> <li>• Table 55: “Bluetooth and BLE Current Consumption,” on page 149.</li> </ul> <p><b>Added:</b></p> <ul style="list-style-type: none"> <li>• “SWD Timing” on page 161.</li> </ul>

<b>Revision</b>	<b>Date</b>	<b>Change Description</b>
43455-DS103-R	02/04/15	<p><b>Updated:</b></p> <ul style="list-style-type: none"> <li>• “External Coexistence Interface” on page 72.</li> <li>• Table 31: “Bluetooth Receiver RF Specifications,” on page 113.</li> <li>• Table 32: “Bluetooth Transmitter RF Specifications,” on page 116.</li> <li>• Table 33: “Local Oscillator Performance,” on page 118.</li> <li>• Table 34: “BLE RF Specifications,” on page 118.</li> <li>• Table 35: “FM Receiver Specifications,” on page 119.</li> <li>• Table 37: “WLAN 2.4 GHz Receiver Performance Specifications,” on page 125.</li> <li>• Table 38: “WLAN 2.4 GHz Transmitter Performance Specifications,” on page 128.</li> <li>• Table 39: “WLAN 5 GHz Receiver Performance Specifications,” on page 129.</li> <li>• Table 40: “WLAN 5 GHz Transmitter Performance Specifications,” on page 133.</li> <li>• Table 42: “2.4 GHz Band, 20 MHz Channel Spacing TX Spurious Emissions Specifications,” on page 135.</li> <li>• Table 43: “5 GHz Band, 20 MHz Channel Spacing TX Spurious Emissions Specifications,” on page 136.</li> <li>• Table 44: “5 GHz Band, 40 MHz Channel Spacing TX Spurious Emissions Specifications,” on page 137.</li> <li>• Table 45: “5 GHz Band, 80 MHz Channel Spacing TX Spurious Emissions Specifications,” on page 138.</li> <li>• Table 46: “2G and 5G General Receiver Spurious Emissions,” on page 139.</li> <li>• Table 53: “2.4 GHz Mode WLAN Power Consumption,” on page 146.</li> <li>• Table 54: “5 GHz Mode WLAN Power Consumption,” on page 147.</li> </ul>
43455-DS102-R	11/20/14	<p><b>Updated:</b></p> <ul style="list-style-type: none"> <li>• Table 26: “ESD Specifications,” on page 104.</li> </ul>
43455-DS101-R	11/06/14	<p><b>Updated:</b></p> <ul style="list-style-type: none"> <li>• Figure 3: “Typical Power Topology (Page 1 of 2),” on page 22 and Figure 4: “Typical Power Topology (Page 2 of 2),” on page 23.</li> <li>• Figure 38: “Port Locations for Bluetooth Testing,” on page 109.</li> <li>• Figure 39: “Port Locations for WLAN Testing,” on page 121.</li> </ul>
43455-DS100-R	10/27/14	Initial release.

# Table of Contents

<b>About This Document</b> .....	17
Purpose and Audience .....	17
Acronyms and Abbreviations .....	17
Document Conventions .....	17
References .....	17
<b>Technical Support</b> .....	18
<b>Section 1: BCM43455 Overview</b> .....	<b>19</b>
<b>Overview</b> .....	19
<b>Standards Compliance</b> .....	21
<b>Mobile Phone Usage Model</b> .....	22
<b>Section 2: Power Supplies and Power Management</b> .....	<b>23</b>
<b>Power Supply Topology</b> .....	23
<b>BCM43455 PMU Features</b> .....	23
<b>WLAN Power Management</b> .....	26
<b>PMU Sequencing</b> .....	26
<b>Power-Off Shutdown</b> .....	27
<b>Power-Up/Power-Down/Reset Circuits</b> .....	28
<b>Section 3: Frequency References</b> .....	<b>29</b>
<b>Crystal Interface and Clock Generation</b> .....	29
<b>External Frequency Reference</b> .....	30
<b>Frequency Selection</b> .....	32
<b>External 32.768 kHz Low-Power Oscillator</b> .....	33
<b>Section 4: Bluetooth and FM Subsystem Overview</b> .....	<b>34</b>
<b>Features</b> .....	34
<b>Bluetooth Radio</b> .....	36
Transmit .....	36
Digital Modulator .....	36
Digital Demodulator and Bit Synchronizer .....	36
Power Amplifier .....	36
Receiver .....	37
Digital Demodulator and Bit Synchronizer .....	37
Receiver Signal Strength Indicator .....	37
Local Oscillator Generation .....	37
Calibration .....	37
<b>Section 5: Bluetooth Baseband Core</b> .....	<b>38</b>
<b>Bluetooth 4.0 Features</b> .....	38



<b>Bluetooth 4.1 Features</b> .....	39
<b>Bluetooth Low Energy</b> .....	39
<b>Link Control Layer</b> .....	39
<b>Test Mode Support</b> .....	40
<b>Bluetooth Power Management Unit</b> .....	40
RF Power Management .....	40
Host Controller Power Management .....	40
BBC Power Management.....	43
Wideband Speech.....	43
Packet Loss Concealment .....	43
Audio Rate-Matching Algorithms.....	44
Codec Encoding.....	44
Multiple Simultaneous A2DP Audio Stream.....	44
FM Over Bluetooth .....	44
Burst Buffer Operation .....	44
<b>Adaptive Frequency Hopping</b> .....	45
<b>Advanced Bluetooth/WLAN Coexistence</b> .....	45
<b>Fast Connection (Interlaced Page and Inquiry Scans)</b> .....	45
<b>Section 6: Microprocessor and Memory Unit for Bluetooth</b> .....	<b>46</b>
RAM, ROM, and Patch Memory .....	46
Reset.....	46
<b>Section 7: Bluetooth Peripheral Transport Unit</b> .....	<b>47</b>
<b>SPI Interface</b> .....	47
<b>SPI/UART Transport Detection</b> .....	47
<b>PCM Interface</b> .....	48
Slot Mapping .....	48
Frame Synchronization .....	48
Data Formatting.....	48
Wideband Speech Support .....	49
Multiplexed Bluetooth Over PCM .....	49
Burst PCM Mode .....	49
PCM Interface Timing.....	50
Short Frame Sync, Master Mode .....	50
Short Frame Sync, Slave Mode .....	51
Long Frame Sync, Master Mode.....	52
Long Frame Sync, Slave Mode.....	53
Short Frame Sync, Burst Mode.....	54
Long Frame Sync, Burst Mode .....	55

UART Interface.....	56
I <sup>2</sup> S Interface.....	57
I <sup>2</sup> S Timing.....	58
<b>Section 8: FM Receiver Subsystem .....</b>	<b>60</b>
FM Radio .....	60
Digital FM Audio Interfaces .....	60
FM Over Bluetooth .....	60
eSCO.....	60
Wideband Speech Link .....	61
A2DP .....	61
Autotune and Search Algorithms .....	61
Audio Features .....	62
RDS/RBDS.....	64
<b>Section 9: WLAN Global Functions .....</b>	<b>65</b>
WLAN CPU and Memory Subsystem.....	65
One-Time Programmable Memory .....	65
GPIO Interface.....	65
External Coexistence Interface .....	66
UART Interface.....	67
JTAG/SWD Interface.....	67
<b>Section 10: WLAN Host Interfaces.....</b>	<b>68</b>
SDIO v3.0 .....	68
SDIO Pins.....	69
PCI Express Interface.....	70
Transaction Layer Interface.....	71
Data Link Layer .....	71
Physical Layer .....	71
Logical Subblock .....	71
Scrambler/Descrambler.....	71
8B/10B Encoder/Decoder.....	72
Elastic FIFO.....	72
Electrical Subblock.....	72
Configuration Space.....	72
<b>Section 11: Wireless LAN MAC and PHY .....</b>	<b>73</b>
IEEE 802.11ac MAC .....	73
PSM.....	74
WEP .....	75
TXE .....	75

RXE.....	75
IFS.....	75
TSF.....	76
NAV.....	76
MAC-PHY Interface.....	76
IEEE 802.11ac PHY.....	76
<b>Section 12: WLAN Radio Subsystem .....</b>	<b>78</b>
Receiver Path.....	78
Transmit Path.....	78
Calibration.....	78
<b>Section 13: Ball Map and Pin Descriptions .....</b>	<b>80</b>
Ball Map.....	80
Pin List by Pin Number .....	81
Pin List by Pin Name .....	83
Pin Descriptions .....	85
WLAN GPIO Signals and Strapping Options .....	91
Multiplexed Bluetooth GPIO Signals .....	92
I/O States .....	94
<b>Section 14: DC Characteristics .....</b>	<b>97</b>
Absolute Maximum Ratings .....	97
Environmental Ratings .....	98
Electrostatic Discharge Specifications .....	98
Recommended Operating Conditions and DC Characteristics .....	99
<b>Section 15: Bluetooth RF Specifications .....</b>	<b>100</b>
<b>Section 16: FM Receiver Specifications .....</b>	<b>107</b>
<b>Section 17: WLAN RF Specifications .....</b>	<b>112</b>
Introduction.....	112
2.4 GHz Band General RF Specifications.....	113
WLAN 2.4 GHz Receiver Performance Specifications .....	113
WLAN 2.4 GHz Transmitter Performance Specifications .....	117
WLAN 5 GHz Receiver Performance Specifications .....	118
WLAN 5 GHz Transmitter Performance Specifications .....	124
General Spurious Emissions Specifications .....	125
Transmitter Spurious Emissions Specifications .....	125
2.4 GHz Band Spurious Emissions .....	126
20 MHz Channel Spacing .....	126
5 GHz Band Spurious Emissions .....	127

20 MHz Channel Spacing .....	127
40 MHz Channel Spacing .....	128
80 MHz Channel Spacing .....	129
Receiver Spurious Emissions Specifications .....	129
<b>Section 18: Internal Regulator Electrical Specifications .....</b>	<b>130</b>
Core Buck Switching Regulator .....	130
3.3V LDO (LDO3P3) .....	131
2.5V LDO (BTLDO2P5) .....	132
CLDO .....	133
LNLDO .....	134
PCIe LDO .....	135
<b>Section 19: System Power Consumption.....</b>	<b>136</b>
WLAN Current Consumption.....	136
2.4 GHz Mode .....	136
5 GHz Mode .....	137
Bluetooth Current Consumption.....	138
<b>Section 20: Interface Timing and AC Characteristics .....</b>	<b>139</b>
SDIO Timing.....	139
SDIO Default Mode Timing .....	139
SDIO High-Speed Mode Timing.....	141
SDIO Bus Timing Specifications in SDR Modes .....	142
Clock Timing .....	142
Card Input Timing.....	143
Card Output Timing.....	144
SDIO Bus Timing Specifications in DDR50 Mode.....	146
Data Timing.....	147
PCI Express Interface Parameters .....	148
JTAG Timing .....	150
SWD Timing .....	150
<b>Section 21: Power-Up Sequence and Timing .....</b>	<b>151</b>
Sequencing of Reset and Regulator Control Signals .....	151
Description of Control Signals.....	151
Control Signal Timing Diagrams.....	152
<b>Section 22: Package Information .....</b>	<b>154</b>
Package Thermal Characteristics .....	154
Junction Temperature Estimation and $PSI_{JT}$ Versus $THETA_{JC}$ .....	154
Environmental Characteristics.....	154

**Section 23: Mechanical Information ..... 155**  
**Section 24: Ordering Information ..... 157**

## List of Figures

Figure 1: Functional Block Diagram.....	1
Figure 2: BCM43455 Block Diagram .....	20
Figure 3: Typical Power Topology (Page 1 of 2).....	24
Figure 4: Typical Power Topology (Page 2 of 2).....	25
Figure 5: Recommended Oscillator Configuration .....	29
Figure 6: Recommended Circuit to Use With an External Reference Clock .....	30
Figure 7: Startup Signaling Sequence Prior to Software Download .....	42
Figure 8: CVSD Decoder Output Waveform Without PLC .....	44
Figure 9: CVSD Decoder Output Waveform After Applying PLC.....	44
Figure 10: Functional Multiplex Data Diagram .....	49
Figure 11: PCM Timing Diagram (Short Frame Sync, Master Mode).....	50
Figure 12: PCM Timing Diagram (Short Frame Sync, Slave Mode).....	51
Figure 13: PCM Timing Diagram (Long Frame Sync, Master Mode).....	52
Figure 14: PCM Timing Diagram (Long Frame Sync, Slave Mode).....	53
Figure 15: PCM Burst Mode Timing (Receive Only, Short Frame Sync).....	54
Figure 16: PCM Burst Mode Timing (Receive Only, Long Frame Sync) .....	55
Figure 17: UART Timing .....	57
Figure 18: I <sup>2</sup> S Transmitter Timing.....	59
Figure 19: I <sup>2</sup> S Receiver Timing.....	59
Figure 20: Audio SNR for Blend, Switch, and FME Modes.....	62
Figure 21: Stereo Separation for Blend, Switch, and FME Modes .....	63
Figure 22: Example Soft Mute Characteristic .....	63
Figure 23: Broadcom GCI or BT-SIG WCI-2 LTE Coexistence Interface .....	66
Figure 24: 3-Wire LTE Coexistence Interface.....	66
Figure 25: Signal Connections to SDIO Host (SD 4-Bit Mode).....	69
Figure 26: Signal Connections to SDIO Host (SD 1-Bit Mode).....	69
Figure 27: PCI Express Layer Model .....	70
Figure 28: WLAN MAC Architecture .....	73
Figure 29: WLAN PHY Block Diagram.....	77
Figure 30: Radio Functional Block Diagram .....	79
Figure 31: 140-Ball WLBGA Map—Bottom View (Balls Facing Up) .....	80
Figure 32: Port Locations for Bluetooth Testing.....	100
Figure 33: Port Locations for WLAN Testing .....	112
Figure 34: SDIO Bus Timing (Default Mode) .....	139
Figure 35: SDIO Bus Timing (High-Speed Mode).....	141

---

Figure 36: SDIO Clock Timing (SDR Modes) .....	142
Figure 37: SDIO Bus Input Timing (SDR Modes) .....	143
Figure 38: SDIO Bus Output Timing (SDR Modes up to 100 MHz) .....	144
Figure 39: SDIO Bus Output Timing (SDR Modes 100 MHz to 208 MHz).....	144
Figure 40: $\Delta t_{OP}$ Consideration for Variable Data Window (SDR 104 Mode) .....	145
Figure 41: SDIO Clock Timing (DDR50 Mode) .....	146
Figure 42: SDIO Data Timing (DDR50 Mode) .....	147
Figure 43: SWD Read and Write Timing.....	150
Figure 44: WLAN = ON, Bluetooth = ON .....	152
Figure 45: WLAN = OFF, Bluetooth = OFF.....	152
Figure 46: WLAN = ON, Bluetooth = OFF .....	153
Figure 47: WLAN = OFF, Bluetooth = ON .....	153
Figure 48: 140-Ball WLBGA Package Mechanical Information .....	155
Figure 49: 140-Balls WLBGA Keep-out Areas for PCB Layout—Top View with Balls Facing Down .....	156

## List of Tables

Table 1: Power-Up/Power-Down/Reset Control Signals.....	28
Table 2: Crystal Oscillator and External Clock—Requirements and Performance .....	30
Table 3: External 32.768 kHz Sleep Clock Specifications .....	33
Table 4: Power Control Pin Description .....	41
Table 5: SPI-to-UART Signal Mapping .....	47
Table 6: PCM Interface Timing Specifications (Short Frame Sync, Master Mode).....	50
Table 7: PCM Interface Timing Specifications (Short Frame Sync, Slave Mode).....	51
Table 8: PCM Interface Timing Specifications (Long Frame Sync, Master Mode) .....	52
Table 9: PCM Interface Timing Specifications (Long Frame Sync, Slave Mode) .....	53
Table 10: PCM Burst Mode (Receive Only, Short Frame Sync).....	54
Table 11: PCM Burst Mode (Receive Only, Long Frame Sync) .....	55
Table 12: Example of Common Baud Rates.....	56
Table 13: UART Timing Specifications .....	57
Table 14: Timing for I <sup>2</sup> S Transmitters and Receivers .....	58
Table 15: 3-Wire External Coexistence Interface .....	66
Table 16: SDIO Pin Description .....	69
Table 17: WLBGA Pin List by Pin Number .....	81
Table 18: WLBGA Pin List by Pin Name.....	83
Table 19: Signal Descriptions .....	85
Table 20: Strapping Options .....	91
Table 21: GPIO Multiplexing Matrix .....	92
Table 22: Multiplexed GPIO Signals .....	93
Table 23: I/O States .....	94
Table 24: Absolute Maximum Ratings .....	97
Table 25: Environmental Ratings .....	98
Table 26: ESD Specifications .....	98
Table 27: Recommended Operating Conditions and DC Characteristics.....	99
Table 28: Bluetooth Receiver RF Specifications.....	101
Table 29: Bluetooth Transmitter RF Specifications.....	104
Table 30: Local Oscillator Performance.....	106
Table 31: BLE RF Specifications .....	106
Table 32: FM Receiver Specifications .....	107
Table 33: 2.4 GHz Band General RF Specifications.....	113
Table 34: WLAN 2.4 GHz Receiver Performance Specifications .....	113
Table 35: WLAN 2.4 GHz Transmitter Performance Specifications .....	117



Table 36: WLAN 5 GHz Receiver Performance Specifications .....	118
Table 37: WLAN 5 GHz Transmitter Performance Specifications .....	124
Table 38: Recommended Spectrum Analyzer Settings .....	125
Table 39: 2.4 GHz Band, 20 MHz Channel Spacing TX Spurious Emissions Specifications .....	126
Table 40: 5 GHz Band, 20 MHz Channel Spacing TX Spurious Emissions Specifications .....	127
Table 41: 5 GHz Band, 40 MHz Channel Spacing TX Spurious Emissions Specifications .....	128
Table 42: 5 GHz Band, 80 MHz Channel Spacing TX Spurious Emissions Specifications .....	129
Table 43: 2G and 5G General Receiver Spurious Emissions .....	129
Table 44: Core Buck Switching Regulator (CBUCK) Specifications .....	130
Table 45: LDO3P3 Specifications .....	131
Table 46: BTLDO2P5 Specifications .....	132
Table 47: CLDO Specifications .....	133
Table 48: LNLDO Specifications .....	134
Table 49: PCIe LDO Specifications .....	135
Table 50: 2.4 GHz Mode WLAN Power Consumption .....	136
Table 51: 5 GHz Mode WLAN Power Consumption .....	137
Table 52: Bluetooth and BLE Current Consumption .....	138
Table 53: SDIO Bus Timing Parameters (Default Mode) .....	139
Table 54: SDIO Bus Timing Parameters (High-Speed Mode) .....	141
Table 55: SDIO Bus Clock Timing Parameters (SDR Modes) .....	142
Table 56: SDIO Bus Input Timing Parameters (SDR Modes) .....	143
Table 57: SDIO Bus Output Timing Parameters (SDR Modes up to 100 MHz) .....	144
Table 58: SDIO Bus Output Timing Parameters (SDR Modes 100 MHz to 208 MHz) .....	145
Table 59: SDIO Bus Clock Timing Parameters (DDR50 Mode) .....	146
Table 60: SDIO Bus Timing Parameters (DDR50 Mode) .....	147
Table 61: PCI Express Interface Parameters .....	148
Table 62: JTAG Timing Characteristics .....	150
Table 63: SWD Read and Write Timing Parameters .....	150
Table 64: Package Thermal Characteristics .....	154
Table 65: Part Ordering Information .....	157

## About This Document

### Purpose and Audience

This data sheet provides details on the functional, operational, and electrical characteristics for the Broadcom® BCM43455. It is intended for hardware design, application, and OEM engineers.

### Acronyms and Abbreviations

In most cases, acronyms and abbreviations are defined on first use.

For a comprehensive list of acronyms and other terms used in Broadcom documents, go to: <http://www.broadcom.com/press/glossary.php>.

### Document Conventions

The following conventions may be used in this document:

<b>Convention</b>	<b>Description</b>
<b>Bold</b>	User input and actions: for example, type <b>exit</b> , click <b>OK</b> , press <b>ALT+C</b>
Monospace	Code: <code>#include &lt;iostream&gt;</code> HTML: <code>&lt;td rowspan = 3&gt;</code> Command line commands and parameters: <code>wl [-l] &lt;command&gt;</code>
< >	Placeholders for <i>required</i> elements: enter your <code>&lt;username&gt;</code> or <code>wl &lt;command&gt;</code>
[ ]	Indicates <i>optional</i> command-line parameters: <code>wl [-l]</code> Indicates bit and byte ranges (inclusive): <code>[0:3]</code> or <code>[7:0]</code>

### References

The references in this section may be used in conjunction with this document.



**Note:** Broadcom provides customer access to technical documentation and software through its Customer Support Portal (CSP) and Downloads & Support site (see [Technical Support](#)).

For Broadcom documents, replace the “xx” in the document number with the largest number available in the repository to ensure that you have the most current version of the document.

<b>Document (or Item) Name</b>	<b>Number</b>	<b>Source</b>
[1] <i>Bluetooth MWS Coexistence 2-wire Transport Interface Specification</i>	–	<a href="http://www.bluetooth.com">www.bluetooth.com</a>
[2] <i>PCI Bus Local Bus Specification, Revision 2.3</i>	–	<a href="http://www.pcisig.com">www.pcisig.com</a>
[3] <i>PCIe Base Specification Version 1.1</i>	–	<a href="http://www.pcisig.com">www.pcisig.com</a>

## Technical Support

Broadcom provides customer access to a wide range of information, including technical documentation, schematic diagrams, product bill of materials, PCB layout information, and software updates through its customer support portal (<https://support.broadcom.com>). For a CSP account, contact your Sales or Engineering support representative.

In addition, Broadcom provides other product support through its Downloads & Support site (<http://www.broadcom.com/support/>).

# Section 1: BCM43455 Overview

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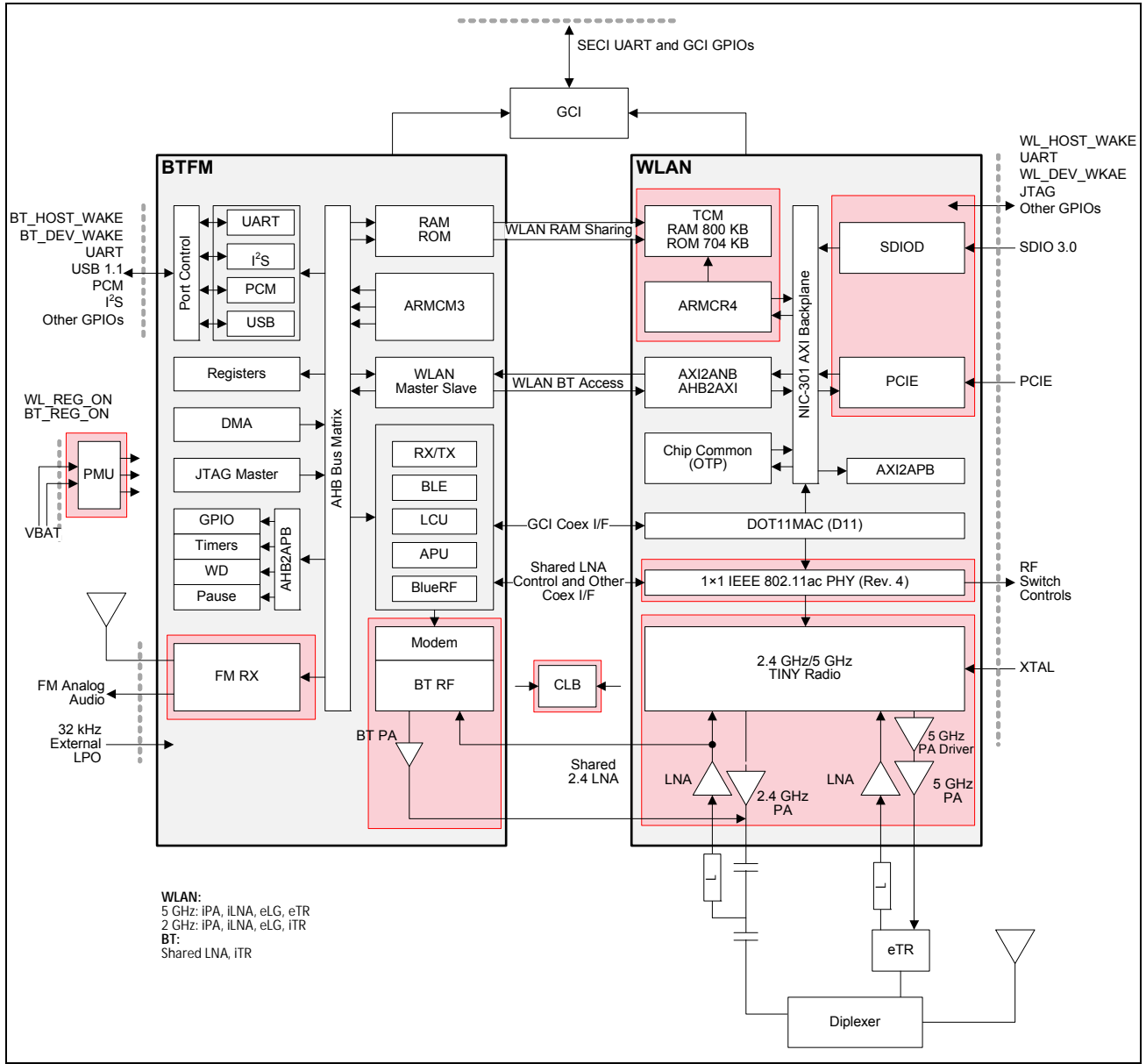
## Overview

The Broadcom BCM43455 single-chip device provides the highest level of integration for a mobile or handheld wireless system, with integrated IEEE 802.11 a/b/g/n/ac MAC/baseband/radio, Bluetooth 4.1 + EDR (enhanced data rate), and FM receiver. It provides a small form-factor solution with minimal external components to drive down cost for mass volumes and allows for handheld device flexibility in size, form, and function.

Comprehensive power management circuitry and software ensure the system can meet the needs of highly mobile devices that require minimal power consumption and reliable operation.

[Figure 2 on page 20](#) shows the interconnect of all the major physical blocks in the BCM43455 and their associated external interfaces, which are described in greater detail in the following sections.

Figure 2: BCM43455 Block Diagram



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## Standards Compliance

The BCM43455 supports the following standards:

- Bluetooth 2.1 + EDR
- Bluetooth 3.0
- Bluetooth 4.1 (Bluetooth Low Energy)
- IEEE 802.11ac single-stream mandatory and optional requirements for 20, 40, and 80 MHz channels
- IEEE 802.11n (Handheld Device Class, Section 11)
- IEEE 802.11a
- IEEE 802.11b
- IEEE 802.11g
- IEEE 802.11d
- IEEE 802.11h
- IEEE 802.11i
- Security:
  - WEP
  - WPA Personal
  - WPA2 Personal
  - WMM
  - WMM-PS (U-APSD)
  - WMM-SA
  - AES (hardware accelerator)
  - TKIP (hardware accelerator)
  - CKIP (software support)
- Proprietary protocols:
  - CCXv2
  - CCXv3
  - CCXv4
  - CCXv5
  - WFAEC
- IEEE 802.15.2 Coexistence Compliance (on-silicon solution compliant with IEEE 3-wire requirements)

The BCM43455 supports the following future drafts/standards:

- IEEE 802.11r (fast roaming between APs)
- IEEE 802.11w (secure management frames)

- IEEE 802.11 Extensions:
  - IEEE 802.11e QoS Enhancements (as per the WMM specification is already supported)
  - IEEE 802.11h 5 GHz Extensions
  - IEEE 802.11i MAC Enhancements
  - IEEE 802.11k Radio Resource Measurement

---

## Mobile Phone Usage Model

The BCM43455 incorporates a number of unique features to simplify integration into mobile phone platforms. Its flexible PCM and UART interfaces enable it to transparently connect with the existing circuits. In addition, the TCXO and LPO inputs allow the use of existing handset features to further minimize the size, power, and cost of the complete system.

- The PCM interface provides multiple modes of operation to support both master and slave as well as hybrid interfacing to single or multiple external codec devices.
- The UART interface supports hardware flow control with tight integration to power control sideband signaling to support the lowest power operation.
- The crystal oscillator interface accommodates any of the typical reference frequencies used by cell phones.
- FM digital interfaces can use either I<sup>2</sup>S or PCM.
- The highly linear design of the radio transceiver ensures that the device has the lowest spurious emissions output regardless of the state of operation. It has been fully characterized in the global cellular bands.
- The transceiver design has excellent blocking and intermodulation performance in the presence of a cellular transmission (LTE, GSM, GPRS, CDMA, WCDMA, or iDEN).

The BCM43455 is designed to directly interface with new and existing handset designs.

## Section 2: Power Supplies and Power Management

### Power Supply Topology

One Buck regulator, multiple LDO regulators, and a power management unit (PMU) are integrated into the BCM43455. All regulators are programmable via the PMU. These blocks simplify power supply design for Bluetooth, and WLAN functions in embedded designs.

A single VBAT (3.0V to 5.25V DC max.) and VIO supply (1.8V to 3.3V) can be used, with all additional voltages being provided by the regulators in the BCM43455.

Two control signals, BT\_REG\_ON and WL\_REG\_ON, are used to power-up the regulators and take the respective section out of reset. The CBUCK CLDO and LNLDO power-up when any of the reset signals are deasserted. All regulators are powered down only when both BT\_REG\_ON and WL\_REG\_ON are deasserted. The CLDO and LNLDO may be turned off/on based on the dynamic demands of the digital baseband.

The BCM43455 allows for an extremely low power-consumption mode by completely shutting down the CBUCK, CLDO, and LNLDO regulators. When in this state, the LPLDO1 (which is the low-power linear regulator that is supplied by the system VIO supply) provides the BCM43455 with all required voltage, further reducing leakage currents.

### BCM43455 PMU Features

- VBAT to 1.35Vout (170 mA nominal, 600 mA maximum) Core-Buck (CBUCK) switching regulator
- VBAT to 3.3Vout (200 mA nominal, 450 mA–850 mA maximum) LDO3P3
- VBAT to 2.5Vout (15 mA nominal, 70 mA maximum) BTLDO2P5
- 1.35V to 1.2Vout (100 mA nominal, 150 mA maximum) LNLDO
- 1.35V to 1.2Vout (80 mA nominal, 200 mA maximum) CLDO with bypass mode for deep-sleep
- 1.35V to 1.2Vout (35 mA nominal, 55 mA maximum) LDO for PCIE
- Additional internal LDOs (not externally accessible)
- PMU internal timer auto-calibration by the crystal clock for precise wake-up timing from extremely low power-consumption mode.



Figure 3 and Figure 4 on page 25 show the regulators and a typical power topology.

Figure 3: Typical Power Topology (Page 1 of 2)

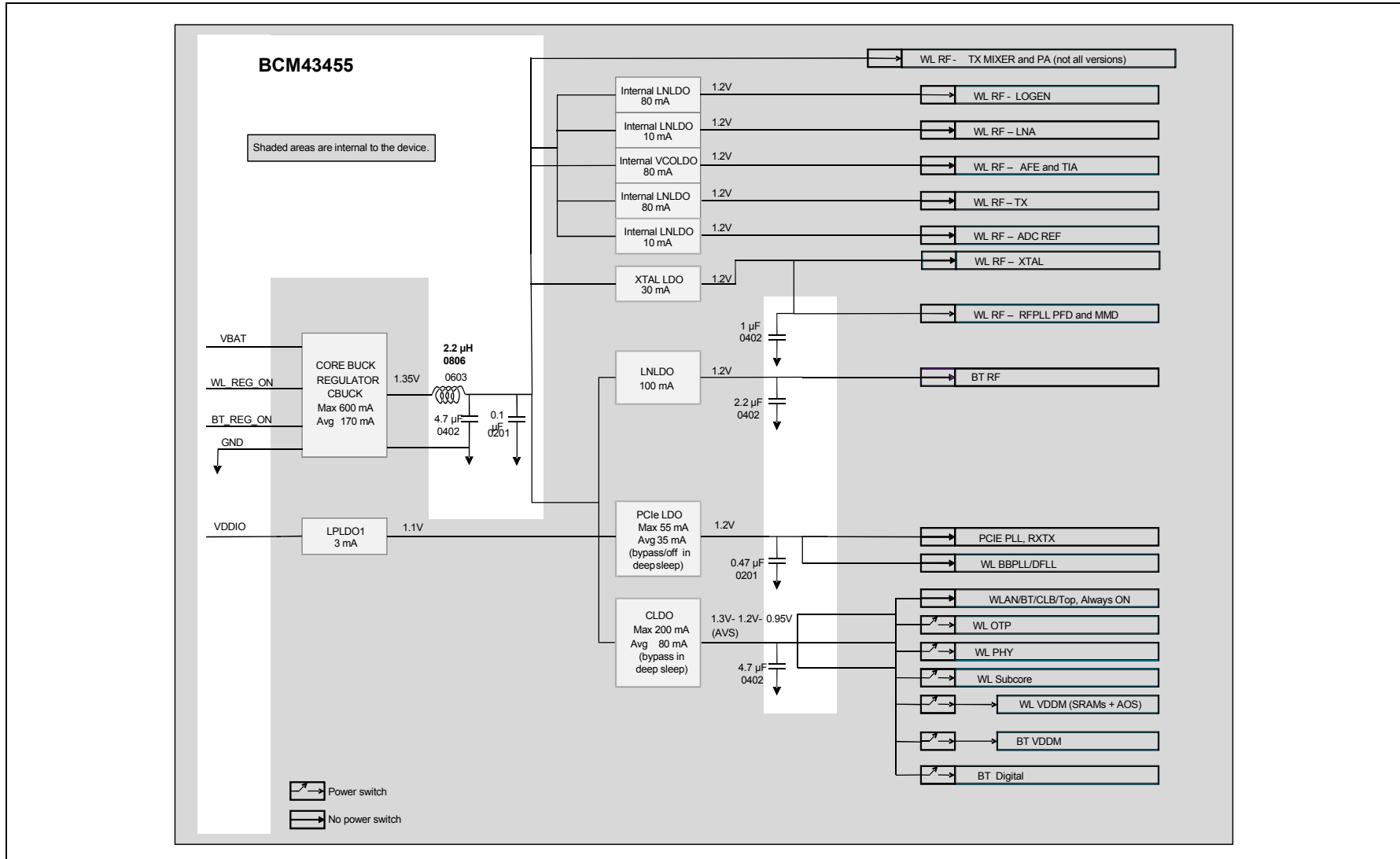
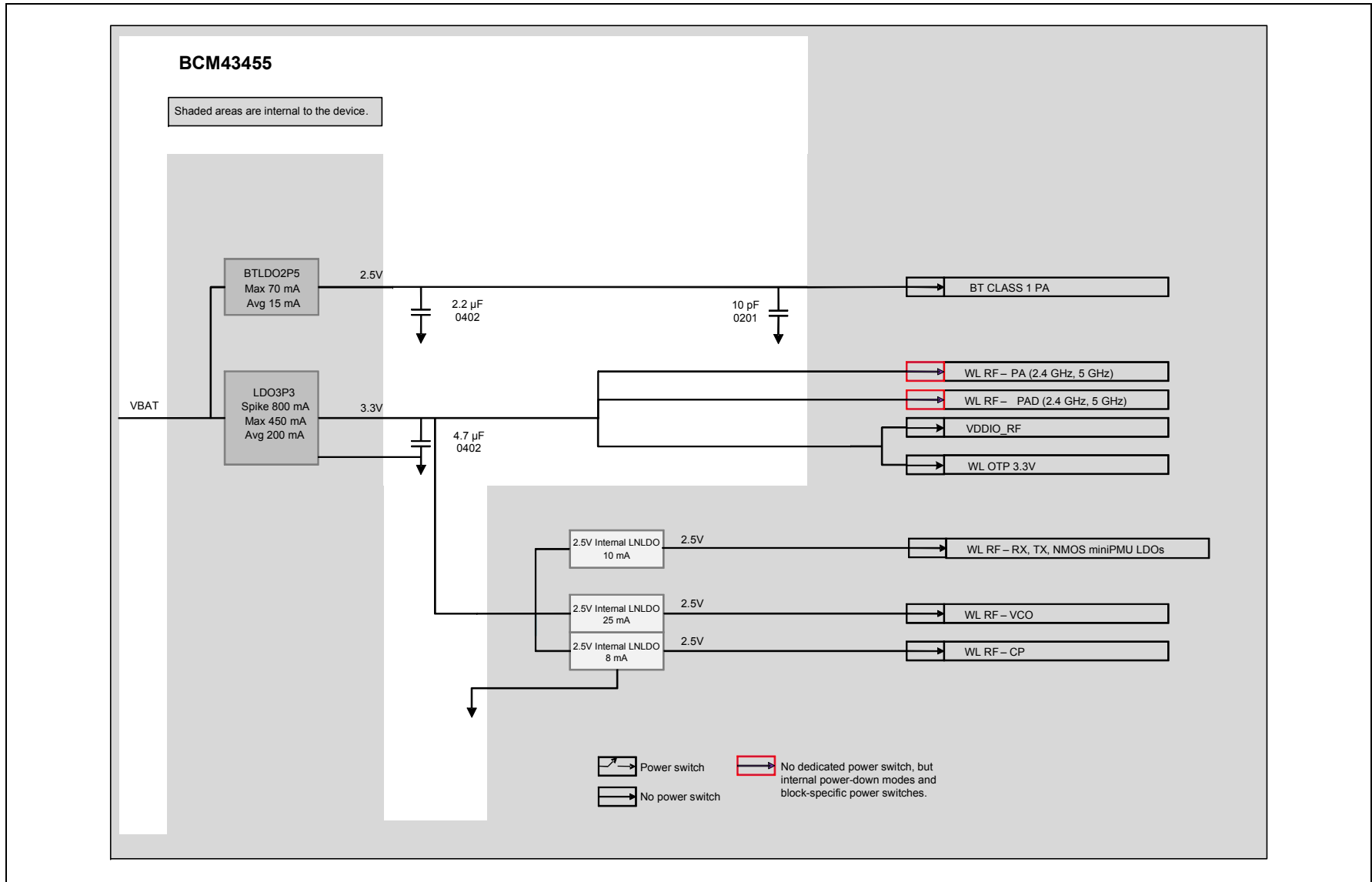


Figure 4: Typical Power Topology (Page 2 of 2)



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## WLAN Power Management

The BCM43455 has been designed with the stringent power consumption requirements of mobile devices in mind. All areas of the chip design are optimized to minimize power consumption. Silicon processes and cell libraries were chosen to reduce leakage current and supply voltages. Additionally, the BCM43455 integrated RAM is a high Vt memory with dynamic clock control. The dominant supply current consumed by the RAM is leakage current only. Additionally, the BCM43455 includes an advanced WLAN power management unit (PMU) sequencer. The PMU sequencer provides significant power savings by putting the BCM43455 into various power management states appropriate to the current environment and activities that are being performed. The power management unit enables and disables internal regulators, switches, and other blocks based on a computation of the required resources and a table that describes the relationship between resources and the time needed to enable and disable them. Power-up sequences are fully programmable. Configurable, free-running counters (running at 32.768 kHz LPO clock) in the PMU sequencer are used to turn on/turn off individual regulators and power switches. Clock speeds are dynamically changed (or gated altogether) for the current mode. Slower clock speeds are used wherever possible.

The BCM43455 WLAN power states are described as follows:

- Active mode—All WLAN blocks in the BCM43455 are powered up and fully functional with active carrier sensing and frame transmission and receiving. All required regulators are enabled and put in the most efficient mode based on the load current. Clock speeds are dynamically adjusted by the PMU sequencer.
- Doze mode—The radio, analog domains, and most of the linear regulators are powered down. The rest of the BCM43455 remains powered up in an IDLE state. All main clocks (PLL, crystal oscillator or TCXO) are shut down to reduce active power to the minimum. The 32.768 kHz LPO clock is available only for the PMU sequencer. This condition is necessary to allow the PMU sequencer to wake-up the chip and transition to Active mode. In Doze mode, the primary power consumed is due to leakage current.
- Deep-sleep mode—Most of the chip including both analog and digital domains and most of the regulators are powered off. Logic states in the digital core are saved and preserved into a retention memory in the always-ON domain before the digital core is powered off. Upon a wake-up event triggered by the PMU timers, an external interrupt or a host resume through the PCIe bus, logic states in the digital core are restored to their pre-deep-sleep settings to avoid lengthy HW reinitialization.
- Power-down mode—The BCM43455 is effectively powered off by shutting down all internal regulators. The chip is brought out of this mode by external logic re-enabling the internal regulators.

---

## PMU Sequencing

The PMU sequencer is used to minimize system power consumption. It enables and disables various system resources based on a computation of required resources and a table that describes the relationship between resources and the time required to enable and disable them.

Resource requests may derive from several sources: clock requests from cores, the minimum resources defined in the *ResourceMin* register, and the resources requested by any active resource request timers. The PMU sequencer maps clock requests into a set of resources required to produce the requested clocks.

Each resource is in one of four states:

- enabled
- disabled
- transition\_on
- transition\_off

The timer contains 0 when the resource is enabled or disabled and a non-zero value in the transition states. The timer is loaded with the time\_on or time\_off value of the resource when the PMU determines that the resource must be enabled or disabled. That timer decrements on each 32.768 kHz PMU clock. When it reaches 0, the state changes from transition\_off to disabled or transition\_on to enabled. If the time\_on value is 0, the resource can transition immediately from disabled to enabled. Similarly, a time\_off value of 0 indicates that the resource can transition immediately from enabled to disabled. The terms *enable sequence* and *disable sequence* refer to either the immediate transition or the timer load-decrement sequence.

During each clock cycle, the PMU sequencer performs the following actions:

- Computes the required resource set based on requests and the resource dependency table.
- Decrements all timers whose values are non zero. If a timer reaches 0, the PMU clears the ResourcePending bit for the resource and inverts the ResourceState bit.
- Compares the request with the current resource status and determines which resources must be enabled or disabled.
- Initiates a disable sequence for each resource that is enabled, no longer being requested, and has no powered up dependents.
- Initiates an enable sequence for each resource that is disabled, is being requested, and has all of its dependencies enabled.

---

## Power-Off Shutdown

The BCM43455 provides a low-power shutdown feature that allows the device to be turned off while the host, and any other devices in the system, remain operational. When the BCM43455 is not needed in the system, VDDIO\_RF and VDDC are shut down while VDDIO remains powered. This allows the BCM43455 to be effectively off while keeping the I/O pins powered so that they do not draw extra current from any other devices connected to the I/O.

During a low-power shutdown state, provided VDDIO remains applied to the BCM43455, all outputs are tristated, and most inputs signals are disabled. Input voltages must remain within the limits defined for normal operation. This is done to prevent current paths or create loading on any digital signals in the system, and enables the BCM43455 to be fully integrated in an embedded device and take full advantage of the lowest power-savings modes.

When the BCM43455 is powered on from this state, it is the same as a normal power-up and the device does not retain any information about its state from before it was powered down.

---

## Power-Up/Power-Down/Reset Circuits

The BCM43455 has two signals (see [Table 1](#)) that enable or disable the Bluetooth and WLAN circuits and the internal regulator blocks, allowing the host to control power consumption. For timing diagrams of these signals and the required power-up sequences, see [Section 21: “Power-Up Sequence and Timing,” on page 151](#).

**Table 1: Power-Up/Power-Down/Reset Control Signals**

<b>Signal</b>	<b>Description</b>
WL_REG_ON	This signal is used by the PMU (with BT_REG_ON) to power-up the WLAN section. It is also OR-gated with the BT_REG_ON input to control the internal BCM43455 regulators. When this pin is high, the regulators are enabled and the WLAN section is out of reset. When this pin is low, the WLAN section is in reset. If BT_REG_ON and WL_REG_ON are both low, the regulators are disabled. This pin has an internal 200 k $\Omega$ pull-down resistor that is enabled by default. It can be disabled through programming.
BT_REG_ON	This signal is used by the PMU (with WL_REG_ON) to decide whether or not to power down the internal BCM43455 regulators. If BT_REG_ON and WL_REG_ON are low, the regulators will be disabled. This pin has an internal 200 k $\Omega$ pull-down resistor that is enabled by default. It can be disabled through programming.

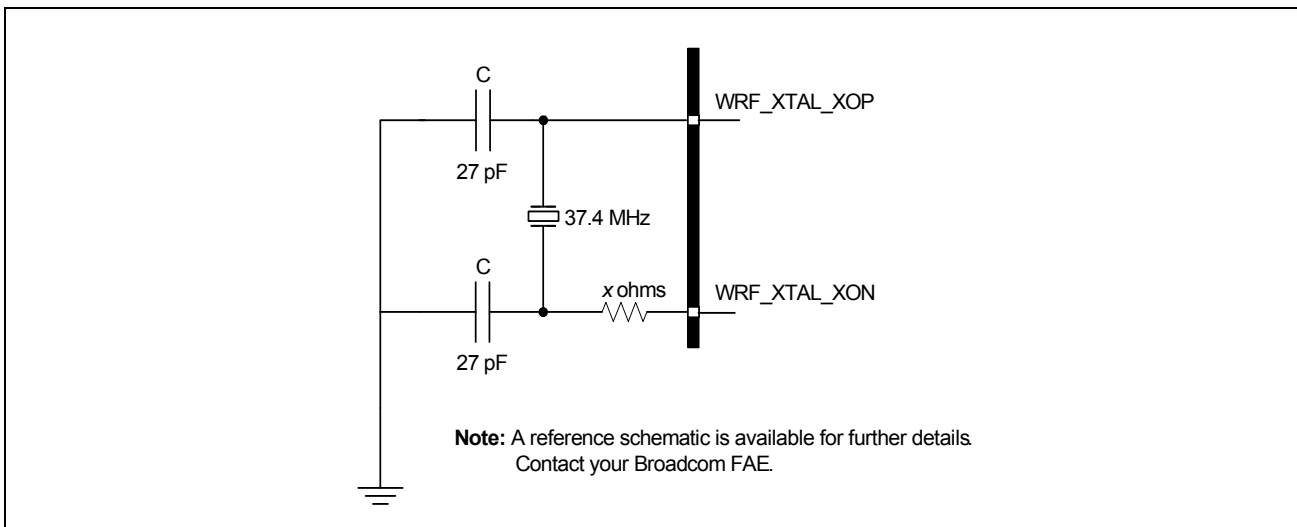
## Section 3: Frequency References

An external crystal is used for generating all radio frequencies and normal operation clocking. As an alternative, an external frequency reference may be used. In addition, a low-power oscillator (LPO) is provided for lower power mode timing.

### Crystal Interface and Clock Generation

The BCM43455 can use an external crystal to provide a frequency reference. The recommended configuration for the crystal oscillator including all external components is shown in [Figure 5](#). Consult the reference schematics for the latest configuration.

**Figure 5: Recommended Oscillator Configuration**



A fractional-N synthesizer in the BCM43455 generates the radio frequencies, clocks, and data/packet timing, enabling it to operate using a wide selection of frequency references.

The recommended default frequency reference is a 37.4 MHz crystal. The signal characteristics for the crystal interface are listed in [Table 2 on page 30](#).



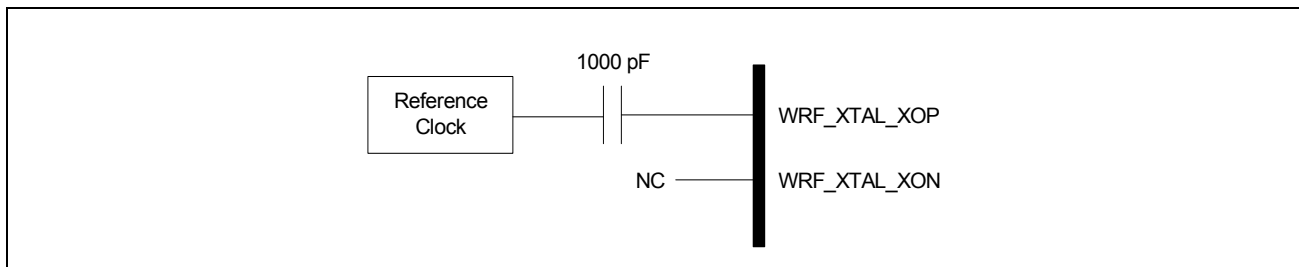
**Note:** Although the fractional-N synthesizer can support alternative reference frequencies, frequencies other than the default require support to be added in the driver, plus additional extensive system testing. Contact Broadcom for further details.

## External Frequency Reference

As an alternative to a crystal, an external precision frequency reference can be used, provided that it meets the Phase Noise requirements listed in [Table 2](#).

If used, the external clock should be connected to the WRF\_XTAL\_XOP pin through an external 1000 pF coupling capacitor, as shown in [Figure 6](#). The internal clock buffer connected to this pin will be turned OFF when the BCM43455 goes into sleep mode. When the clock buffer turns ON and OFF there will be a small impedance variation. Power must be supplied to the WRF\_XTAL\_VDD1P35 pin.

**Figure 6: Recommended Circuit to Use With an External Reference Clock**



**Table 2: Crystal Oscillator and External Clock—Requirements and Performance**

Parameter	Conditions/Notes	Crystal <sup>a</sup>			External Frequency Reference <sup>b c</sup>			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Frequency	2.4G and 5G bands, IEEE 802.11ac operation	35	–	52	–	52	–	MHz
Frequency	5G Band, IEEE 802.11n operation only	19	–	52	35	–	52	MHz
	2.4G band IEEE 802.11n operation, and both bands legacy IEEE 802.11a/b/g operation only	Between 19 MHz and 52 MHz <sup>d, e</sup>						
Frequency tolerance over the lifetime of the equipment, including temperature <sup>f</sup>	Without trimming	–20	–	20	–20	–	20	ppm
Crystal load capacitance	–	–	16	–	–	–	–	pF
ESR	–	–	–	60	–	–	–	Ω
Drive level	External crystal must be able to tolerate this drive level.	200	–	–	–	–	–	μW
Input impedance (WRF_XTAL_XOP)	Resistive	–	–	–	30k	100k	–	Ω
	Capacitive	–	–	7.5	–	–	7.5	pF
WRF_XTAL_XOP Input low level	DC-coupled digital signal	–	–	–	0	–	0.2	V

**Table 2: Crystal Oscillator and External Clock—Requirements and Performance (Cont.)**

Parameter	Conditions/Notes	Crystal <sup>a</sup>			External Frequency Reference <sup>b c</sup>			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
WRF_XTAL_XOP Input high level	DC-coupled digital signal	–	–	–	1.0	–	1.26	V
WRF_XTAL_XOP input voltage (see <a href="#">Figure 6 on page 30</a> )	IEEE 802.11a/b/g operation only	–	–	–	400	–	1200	mV <sub>p-p</sub>
WRF_XTAL_XOP input voltage (see <a href="#">Figure 6 on page 30</a> )	IEEE 802.11n/ac AC-coupled analog input	–	–	–	1	–	–	V <sub>p-p</sub>
Duty cycle	37.4 MHz clock	–	–	–	40	50	60	%
Phase Noise <sup>g</sup> (IEEE 802.11b/g)	37.4 MHz clock at 10 kHz offset	–	–	–	–	–	–129	dBc/Hz
	37.4 MHz clock at 100 kHz offset	–	–	–	–	–	–136	dBc/Hz
Phase Noise <sup>g</sup> (IEEE 802.11a)	37.4 MHz clock at 10 kHz offset	–	–	–	–	–	–137	dBc/Hz
	37.4 MHz clock at 100 kHz offset	–	–	–	–	–	–144	dBc/Hz
Phase Noise <sup>g</sup> (IEEE 802.11n, 2.4 GHz)	37.4 MHz clock at 10 kHz offset	–	–	–	–	–	–134	dBc/Hz
	37.4 MHz clock at 100 kHz offset	–	–	–	–	–	–141	dBc/Hz
Phase Noise <sup>g</sup> (IEEE 802.11n, 5 GHz)	37.4 MHz clock at 10 kHz offset	–	–	–	–	–	–142	dBc/Hz
	37.4 MHz clock at 100 kHz offset	–	–	–	–	–	–149	dBc/Hz
Phase Noise <sup>g</sup> (IEEE 802.11ac, 5 GHz)	37.4 MHz clock at 10 kHz offset	–	–	–	–	–	–148	dBc/Hz
	37.4 MHz clock at 100 kHz offset	–	–	–	–	–	–155	dBc/Hz

- (Crystal) Use WRF\_XTAL\_XON and WRF\_XTAL\_XOP.
- See [“External Frequency Reference” on page 30](#) for alternative connection methods.
- For a clock reference other than 37.4 MHz,  $20 \times \log_{10}(f/37.4)$  dB should be added to the limits, where  $f$  = the reference clock frequency in MHz.
- BT\_TM6 should be tied low for a 52 MHz clock reference. For other frequencies, BT\_TM6 should be tied high. Note that 52 MHz is not an auto-detected frequency using the LPO clock.
- The frequency step size is approximately 80 Hz resolution.
- It is the responsibility of the equipment designer to select oscillator components that comply with these specifications.
- Assumes that external clock has a flat phase noise response above 100 kHz.



---

## Frequency Selection

Any frequency within the ranges specified for the crystal and TCXO reference may be used. These include not only the standard handset reference frequencies of 19.2, 19.8, 24, 26, 33.6, 37.4, 38.4, and 52 MHz, but also other frequencies in this range, with approximately 80 Hz resolution. The BCM43455 must have the reference frequency set correctly in order for any of the UART or PCM interfaces to function correctly, since all bit timing is derived from the reference frequency.



**Note:** The fractional-N synthesizer can support many reference frequencies. However, frequencies other than the default require support to be added in the driver plus additional, extensive system testing. Contact Broadcom for further details.

The reference frequency for the BCM43455 may be set in the following ways:

- Set the `xtalfreq=xxxxx` parameter in the `nvr.am.txt` file (used to load the driver) to correctly match the crystal frequency.
- Auto-detect any of the standard handset reference frequencies using an external LPO clock.

For applications such as handsets and portable smart communication devices, where the reference frequency is one of the standard frequencies commonly used, the BCM43455 automatically detects the reference frequency and programs itself to the correct reference frequency. In order for auto frequency detection to work correctly, the BCM43455 must have a valid and stable 32.768 kHz LPO clock that meets the requirements listed in [Table 3 on page 33](#) and is present during power-on reset.

## External 32.768 kHz Low-Power Oscillator

The BCM43455 uses a secondary low frequency clock for low-power-mode timing. Either the internal low-precision LPO or an external 32.768 kHz precision oscillator is required. The internal LPO frequency range is approximately 33 kHz  $\pm$  30% over process, voltage, and temperature, which is adequate for some applications. However, one trade-off caused by this wide LPO tolerance is a small current consumption increase during power save mode that is incurred by the need to wake-up earlier to avoid missing beacons.

Whenever possible, the preferred approach is to use a precision external 32.768 kHz clock that meets the requirements listed in [Table 3](#).

**Table 3: External 32.768 kHz Sleep Clock Specifications**

<b>Parameter</b>	<b>LPO Clock</b>	<b>Units</b>
Nominal input frequency	32.768	kHz
Frequency accuracy	$\pm$ 200	ppm
Duty cycle	30–70	%
Input signal amplitude	200–3300	mV, p-p
Signal type	Square-wave or sine-wave	–
Input impedance <sup>a</sup>	>100k	$\Omega$
	<5	pF
Clock jitter (during initial start-up)	<10,000	ppm

a. When power is applied or switched off.

## Section 4: Bluetooth and FM Subsystem Overview

The BCM43455 is a Bluetooth 4.1 + EDR-compliant, baseband processor with 2.4 GHz transceiver with an integrated FM/RDS/RBDS receiver. It features the highest level of integration and eliminates all critical external components, thus minimizing the footprint, power consumption, and system cost of a Bluetooth plus FM radio solution.

The BCM43455 is the optimal solution for any Bluetooth voice and/or data application that also requires an FM radio receiver. The Bluetooth subsystem presents a standard host controller interface (HCI) via a high-speed UART and PCM for audio. The FM subsystem supports the HCI control interface, analog output, as well as I<sup>2</sup>S and PCM interfaces. The BCM43455 incorporates all Bluetooth 4.1 features including secure simple pairing, sniff subrating, and encryption pause and resume.

The BCM43455 Bluetooth radio transceiver provides enhanced radio performance to meet the most stringent mobile phone temperature applications and the tightest integration into mobile handsets and portable devices. It provides full radio compatibility to operate simultaneously with GPS, WLAN, and cellular radios.

The Bluetooth transmitter also features a Class 1 power amplifier with Class 2 capability.

---

### Features

Primary BCM43455 Bluetooth features include:

- Supports key features of upcoming Bluetooth standards
- Fully supports Bluetooth Core Specification version 4.1 + EDR features:
  - Adaptive frequency hopping (AFH)
  - Quality of service (QoS)
  - Extended synchronous connections (eSCO)—voice connections
  - Fast connect (interlaced page and inquiry scans)
  - Secure simple pairing (SSP)
  - Sniff subrating (SSR)
  - Encryption pause resume (EPR)
  - Extended inquiry response (EIR)
  - Link supervision timeout (LST)
- UART baud rates up to 4 Mbps
- Supports all Bluetooth 4.1 + HS packet types
- Supports maximum Bluetooth data rates over HCI UART
- Multipoint operation with up to seven active slaves
  - Maximum of seven simultaneous active ACL links
  - Maximum of three simultaneous active SCO and eSCO connections with scatternet support

- Trigger Broadcom fast connect (TBFC)
- Narrowband and wideband packet loss concealment
- Scatternet operation with up to four active piconets with background scan and support for scatter mode
- High-speed HCI UART transport support with low-power out-of-band BT\_DEV\_WAKE and BT\_HOST\_WAKE signaling (see [“Host Controller Power Management” on page 40](#))
- Channel quality driven data rate and packet type selection
- Standard Bluetooth test modes
- Extended radio and production test mode features
- Full support for power savings modes
  - Bluetooth clock request
  - Bluetooth standard sniff
  - Deep-sleep modes and software regulator shutdown
- Supports a low-power crystal, which can be used during power save mode for better timing accuracy.

**Major FM radio features include:**

- 65 MHz to 108 MHz FM bands supported (US, Europe, and Japan)
- FM subsystem control using the Bluetooth HCI interface
- FM subsystem operates from reference clock inputs.
- Improved audio interface capabilities with full-featured bidirectional PCM and I<sup>2</sup>S
- I<sup>2</sup>S can be master or slave.

**FM receiver-specific features include:**

- Excellent FM radio performance with 1  $\mu$ V sensitivity for 26 dB (S + N)  $\div$  N
- Signal-dependent stereo/mono blending
- Signal dependent soft mute
- Auto search and tuning modes
- Audio silence detection
- RSSI, IF frequency, status indicators
- RDS and RBDS demodulator and decoder with filter and buffering functions
- Automatic frequency jump

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## Bluetooth Radio

The BCM43455 has an integrated radio transceiver that has been optimized for use in 2.4 GHz Bluetooth wireless systems. It has been designed to provide low-power, low-cost, robust communications for applications operating in the globally available 2.4 GHz unlicensed ISM band. It is fully compliant with the Bluetooth Radio Specification and EDR specification and meets or exceeds the requirements to provide the highest communication link quality of service.

## Transmit

The BCM43455 features a fully integrated zero-IF transmitter. The baseband transmit data is GFSK-modulated in the modem block and upconverted to the 2.4 GHz ISM band in the transmitter path. The transmitter path consists of signal filtering, I/Q upconversion, output power amplifier, and RF filtering. The transmitter path also incorporates  $\pi/4$ -DQPSK for 2 Mbps and 8-DPSK for 3 Mbps to support EDR. The transmitter section is compatible to the Bluetooth Low Energy specification. The transmitter PA bias can also be adjusted to provide Bluetooth class 1 or class 2 operation.

## Digital Modulator

The digital modulator performs the data modulation and filtering required for the GFSK,  $\pi/4$ -DQPSK, and 8-DPSK signal. The fully digital modulator minimizes any frequency drift or anomalies in the modulation characteristics of the transmitted signal and is much more stable than direct VCO modulation schemes.

## Digital Demodulator and Bit Synchronizer

The digital demodulator and bit synchronizer take the low-IF received signal and perform an optimal frequency tracking and bit-synchronization algorithm.

## Power Amplifier

The fully integrated PA supports Class 1 or Class 2 output using a highly linearized, temperature-compensated design. This provides greater flexibility in front-end matching and filtering. Due to the linear nature of the PA combined with some integrated filtering, external filtering is required to meet the Bluetooth and regulatory harmonic and spurious requirements. For integrated mobile handset applications in which Bluetooth is integrated next to the cellular radio, external filtering can be applied to achieve near thermal noise levels for spurious and radiated noise emissions. The transmitter features a sophisticated on-chip transmit signal strength indicator (TSSI) block to keep the absolute output power variation within a tight range across process, voltage, and temperature.

## Receiver

The receiver path uses a low-IF scheme to downconvert the received signal for demodulation in the digital demodulator and bit synchronizer. The receiver path provides a high degree of linearity, an extended dynamic range, and high-order on-chip channel filtering to ensure reliable operation in the noisy 2.4 GHz ISM band. The front-end topology with built-in out-of-band attenuation enables the BCM43455 to be used in most applications with minimal off-chip filtering. For integrated handset operation, in which the Bluetooth function is integrated close to the cellular transmitter, external filtering is required to eliminate the desensitization of the receiver by the cellular transmit signal.

## Digital Demodulator and Bit Synchronizer

The digital demodulator and bit synchronizer take the low-IF received signal and perform an optimal frequency tracking and bit synchronization algorithm.

## Receiver Signal Strength Indicator

The radio portion of the BCM43455 provides a receiver signal strength indicator (RSSI) signal to the baseband, so that the controller can take part in a Bluetooth power-controlled link by providing a metric of its own receiver signal strength to determine whether the transmitter should increase or decrease its output power.

## Local Oscillator Generation

A local oscillator (LO) generation provides fast frequency hopping (1600 hops/second) across the 79 maximum available channels. The LO generation subblock employs an architecture for high immunity to LO pulling during PA operation. The BCM43455 uses an internal RF and IF loop filter.

## Calibration

The BCM43455 radio transceiver features an automated calibration scheme that is fully self contained in the radio. No user interaction is required during normal operation or during manufacturing to provide the optimal performance. Calibration optimizes the performance of all the major blocks within the radio to within 2% of optimal conditions, including gain and phase characteristics of filters, matching between key components, and key gain blocks. This takes into account process variation and temperature variation. Calibration occurs transparently during normal operation during the settling time of the hops and calibrates for temperature variations as the device cools and heats during normal operation in its environment.

## Section 5: Bluetooth Baseband Core

The Bluetooth Baseband Core (BBC) implements all of the time critical functions required for high-performance Bluetooth operation. The BBC manages the buffering, segmentation, and routing of data for all connections. It also buffers data that passes through it, handles data flow control, schedules SCO/ACL TX/RX transactions, monitors Bluetooth slot usage, optimally segments and packages data into baseband packets, manages connection status indicators, and composes and decodes HCI packets. In addition to these functions, it independently handles HCI event types, and HCI command types.

The following transmit and receive functions are also implemented in the BBC hardware to increase reliability and security of the TX/RX data before sending over the air:

- Symbol timing recovery, data deframing, forward error correction (FEC), header error control (HEC), cyclic redundancy check (CRC), data decryption, and data dewatering in the receiver.
- Data framing, FEC generation, HEC generation, CRC generation, key generation, data encryption, and data whitening in the transmitter.

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### Bluetooth 4.0 Features

The BBC supports all Bluetooth 4.0 features, with the following benefits:

- Dual-mode Bluetooth Low Energy (BT and BLE operation)
- Extended Inquiry Response (EIR): Shortens the time to retrieve the device name, specific profile, and operating mode.
- Encryption Pause Resume (EPR): Enables the use of Bluetooth technology in a much more secure environment.
- Sniff Subrating (SSR): Optimizes power consumption for low duty cycle asymmetric data flow, which subsequently extends battery life.
- Secure Simple Pairing (SSP): Reduces the number of steps for connecting two devices, with minimal or no user interaction required.
- Link Supervision Time Out (LSTO): Additional commands added to HCI and Link Management Protocol (LMP) for improved link time-out supervision.
- QoS enhancements: Changes to data traffic control, which results in better link performance. Audio, human interface device (HID), bulk traffic, SCO, and enhanced SCO (eSCO) are improved with the erroneous data (ED) and packet boundary flag (PBF) enhancements.

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## Bluetooth 4.1 Features

The BBC supports all Bluetooth 4.1 features, with the following benefits:

- Dual-mode classic Bluetooth and classic low energy (BT and BLE) operation
- Low-energy physical layer
- Low-energy link layer
- Enhancements to HCI for low energy
- Low-energy direct test mode
- 128 AES-CCM secure connection for both BT and BLE



**Note:** The BCM43455 is compatible with the Bluetooth Low Energy operating mode, which provides a dramatic reduction in the power consumption of the Bluetooth radio and baseband. The primary application for this mode is to provide support for low data rate devices, such as sensors and remote controls.

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## Bluetooth Low Energy

The BCM43455 supports the Bluetooth Low Energy operating mode.

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## Link Control Layer

The link control layer is part of the Bluetooth link control functions that are implemented in dedicated logic in the link control unit (LCU). This layer consists of the command controller that takes commands from the software, and other controllers that are activated or configured by the command controller, to perform the link control tasks. Each task performs a different state in the Bluetooth Link Controller.

- Major states:
  - Standby
  - Connection
- Substates:
  - Page
  - Page Scan
  - Inquiry
  - Inquiry Scan
  - Sniff



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## Test Mode Support

The BCM43455 fully supports Bluetooth Test mode as described in Part I:1 of the *Specification of the Bluetooth System Version 3.0*. This includes the transmitter tests, normal and delayed loopback tests, and reduced hopping sequence.

In addition to the standard Bluetooth Test Mode, the BCM43455 also supports enhanced testing features to simplify RF debugging and qualification and type-approval testing. These features include:

- Fixed frequency carrier wave (unmodulated) transmission
  - Simplifies some type-approval measurements (Japan)
  - Aids in transmitter performance analysis
- Fixed frequency constant receiver mode
  - Receiver output directed to I/O pin
  - Allows for direct BER measurements using standard RF test equipment
  - Facilitates spurious emissions testing for receive mode
- Fixed frequency constant transmission
  - 8-bit fixed pattern or PRBS-9
  - Enables modulated signal measurements with standard RF test equipment

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## Bluetooth Power Management Unit

The Bluetooth Power Management Unit (PMU) provides power management features that can be invoked by either software through power management registers or packet handling in the baseband core.

The power management functions provided by the BCM43455 are:

- [RF Power Management](#)
- [Host Controller Power Management](#)
- [“BBC Power Management” on page 43](#)
- [“FM Over Bluetooth” on page 44](#)

## RF Power Management

The BBC generates power-down control signals for the transmit path, receive path, PLL, and power amplifier to the 2.4 GHz transceiver. The transceiver then processes the power-down functions accordingly.

## Host Controller Power Management

When running in UART mode, the BCM43455 may be configured so that dedicated signals are used for power management hand-shaking between the BCM43455 and the host. The basic power saving functions supported by those hand-shaking signals include the standard Bluetooth defined power savings modes and standby modes of operation. [Table 4 on page 41](#) describes the power-control handshake signals used with the UART interface.



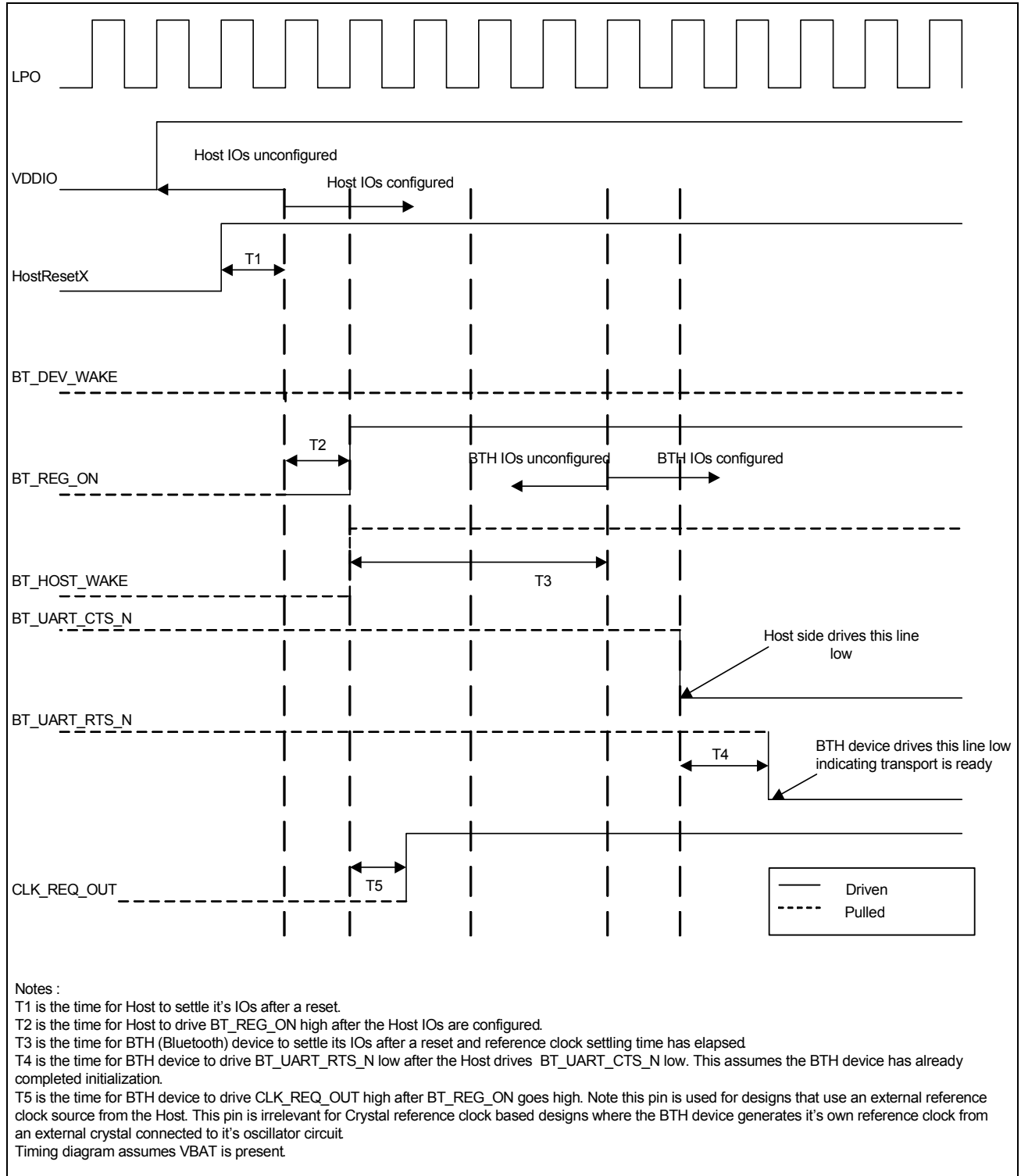
**Note:** Pad function Control Register is set to 0 for these pins. See “DC Characteristics” on page 97 for more details.

**Table 4: Power Control Pin Description**

<b>Signal</b>	<b>Mapped to Pin</b>	<b>Type</b>	<b>Description</b>
BT_DEV_WAKE	BT_GPIO_0	I	<p>Bluetooth device wake-up: Signal from the host to the BCM43455 indicating that the host requires attention.</p> <ul style="list-style-type: none"> <li>• Asserted: The Bluetooth device must wake-up or remain awake.</li> <li>• Deasserted: The Bluetooth device may sleep when sleep criteria are met.</li> </ul> <p>The polarity of this signal is software configurable and can be asserted high or low.</p>
BT_HOST_WAKE	BT_GPIO_1	O	<p>Host wake-up. Signal from the BCM43455 to the host indicating that the BCM43455 requires attention.</p> <ul style="list-style-type: none"> <li>• Asserted: host device must wake-up or remain awake.</li> <li>• Deasserted: host device may sleep when sleep criteria are met.</li> </ul> <p>The polarity of this signal is software configurable and can be asserted high or low.</p>
BT_CLK_REQ	BT_CLK_REQ_OUT WL_CLK_REQ_OUT	O	<p>The BCM43455 asserts BT_CLK_REQ when Bluetooth or WLAN wants the host to turn on the reference clock. The BT_CLK_REQ polarity is active-high. Add an external 100 kΩ pull-down resistor to ensure the signal is deasserted when the BCM43455 powers up or resets when VDDIO is present.</p>

Figure 7 shows the startup signaling sequence prior to software download.

**Figure 7: Startup Signaling Sequence Prior to Software Download**



## BBC Power Management

The following are low-power operations for the BBC:

- Physical layer packet-handling turns the RF on and off dynamically within transmit/receive packets.
- Bluetooth-specified low-power connection modes: sniff, hold, and park. While in these modes, the BCM43455 runs on the low-power oscillator and wakes up after a predefined time period.
- A low-power shutdown feature allows the device to be turned off while the host and any other devices in the system remain operational. When the BCM43455 is not needed in the system, the RF and core supplies are shut down while the I/O remains powered. This allows the BCM43455 to effectively be off while keeping the I/O pins powered so they do not draw extra current from any other devices connected to the I/O.

During the low-power shutdown state, provided VDDIO remains applied to the BCM43455, all outputs are tristated, and most input signals are disabled. Input voltages must remain within the limits defined for normal operation. This is done to prevent current paths or create loading on any digital signals in the system and enables the BCM43455 to be fully integrated in an embedded device to take full advantage of the lowest power-saving modes.

Two BCM43455 input signals are designed to be high-impedance inputs that do not load the driving signal even if the chip does not have VDDIO power supplied to it: the frequency reference input (WRF\_TCXO\_IN) and the 32.768 kHz input (LPO). When the BCM43455 is powered on from this state, it is the same as a normal power-up, and the device does not contain any information about its state from the time before it was powered down.

## Wideband Speech

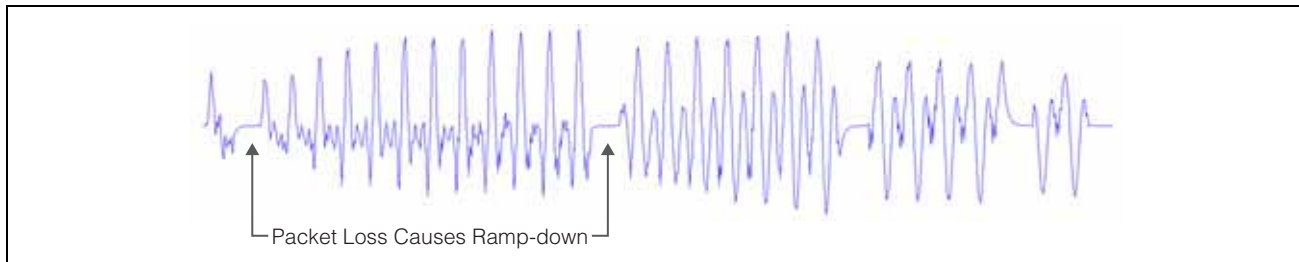
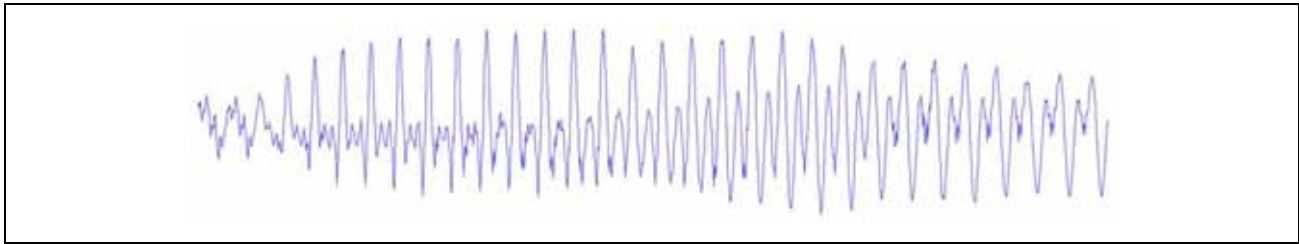
The BCM43455 provides support for wideband speech (WBS) using on-chip Broadcom SmartAudio® technology. The BCM43455 can perform subband-codec (SBC), as well as mSBC, encoding and decoding of linear 16 bits at 16 kHz (256 Kbps rate) transferred over the PCM bus.

## Packet Loss Concealment

Packet Loss Concealment (PLC) improves apparent audio quality for systems with marginal link performance. Bluetooth messages are sent in packets. When a packet is lost, it creates a gap in the received audio bit-stream. Packet loss can be mitigated in several ways:

- Fill in zeros.
- Ramp down the output audio signal toward zero (this is the method used in current Bluetooth headsets).
- Repeat the last frame (or packet) of the received bit-stream and decode it as usual (frame repeat).

These techniques cause distortion and popping in the audio stream. The BCM43455 uses a proprietary waveform extension algorithm to provide dramatic improvement in the audio quality. [Figure 8](#) and [Figure 9 on page 44](#) show audio waveforms with and without Packet Loss Concealment. Broadcom PLC/BEC algorithms also support wideband speech.

**Figure 8: CVSD Decoder Output Waveform Without PLC****Figure 9: CVSD Decoder Output Waveform After Applying PLC**

## Audio Rate-Matching Algorithms

The BCM43455 has an enhanced rate-matching algorithm that uses interpolation algorithms to reduce audio stream jitter that may be present when the rate of audio data coming from the host is not the same as the Bluetooth audio data rates.

## Codec Encoding

The BCM43455 can support SBC and mSBC encoding and decoding for wideband speech.

## Multiple Simultaneous A2DP Audio Stream

The BCM43455 has the ability to take a single audio stream and output it to multiple Bluetooth devices simultaneously. This allows a user to share his or her music (or any audio stream) with a friend.

## FM Over Bluetooth

FM Over Bluetooth enables the BCM43455 to stream data from FM over Bluetooth without requiring the host to be awake. This can significantly extend battery life for usage cases where someone is listening to FM radio on a Bluetooth headset.

## Burst Buffer Operation

The BCM43455 has a data buffer that can buffer data being sent over the HCI and audio transports, then send the data at an increased rate. This mode of operation allows the host to sleep for the maximum amount of time, dramatically reducing system current consumption.

## **Adaptive Frequency Hopping**

The BCM43455 gathers link quality statistics on a channel by channel basis to facilitate channel assessment and channel map selection. The link quality is determined using both RF and baseband signal processing to provide a more accurate frequency-hop map.

## **Advanced Bluetooth/WLAN Coexistence**

The BCM43455 includes advanced coexistence technologies that are only possible with a Bluetooth/WLAN integrated die solution. These coexistence technologies are targeted at small form-factor platforms, such as cell phones and media players, including applications such as VoWLAN + SCO and Video-over-WLAN + High Fidelity BT Stereo.

Support is provided for platforms that share a single antenna between Bluetooth and WLAN. Dual-antenna applications are also supported. The BCM43455 radio architecture allows for lossless simultaneous Bluetooth and WLAN reception for shared antenna applications. This is possible only via an integrated solution (shared LNA and joint AGC algorithm). It has superior performance versus implementations that need to arbitrate between Bluetooth and WLAN reception.

The BCM43455 integrated solution enables MAC-layer signaling (firmware) and a greater degree of sharing via an enhanced coexistence interface. Information is exchanged between the Bluetooth and WLAN cores without host processor involvement.

The BCM43455 also supports Transmit Power Control on the STA together with standard Bluetooth TPC to limit mutual interference and receiver desensitization. Preemption mechanisms are utilized to prevent AP transmissions from colliding with Bluetooth frames. Improved channel classification techniques have been implemented in Bluetooth for faster and more accurate detection and elimination of interferers (including non-WLAN 2.4 GHz interference).

The Bluetooth AFH classification is also enhanced by the WLAN core's channel information.

## **Fast Connection (Interlaced Page and Inquiry Scans)**

The BCM43455 supports page scan and inquiry scan modes that significantly reduce the average inquiry response and connection times. These scanning modes are compatible with the Bluetooth version 2.1 page and inquiry procedures.

## Section 6: Microprocessor and Memory Unit for Bluetooth

The Bluetooth microprocessor core is based on the ARM Cortex-M3 32-bit RISC processor with embedded ICE-RT debug and JTAG interface units. It runs software from the link control (LC) layer, up to the host controller interface (HCI).

The ARM core is paired with a memory unit that contains 845 KB of ROM memory for program storage and boot ROM, 270 KB of RAM for data scratchpad and patch RAM code. The internal ROM allows for flexibility during power-on reset to enable the same device to be used in various configurations. At power-up, the lower-layer protocol stack is executed from the internal ROM memory.

External patches may be applied to the ROM-based firmware to provide flexibility for bug fixes or features additions. These patches may be downloaded from the host to the BCM43455 through the UART transports. The mechanism for downloading via UART is identical to the proven interface of the BCM4329 and BCM4330 devices.

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### RAM, ROM, and Patch Memory

The BCM43455 Bluetooth core has 270 KB of internal RAM which is mapped between general purpose scratch pad memory and patch memory and 845 KB of ROM used for the lower-layer protocol stack, test mode software, and boot ROM. The patch memory capability enables the addition of code changes for purposes of feature additions and bug fixes to the ROM memory.

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### Reset

The BCM43455 has an integrated power-on reset circuit that resets all circuits to a known power-on state. The BT power-on reset (POR) circuit is out of reset after BT\_REG\_ON goes High. If BT\_REG\_ON is low, then the POR circuit is held in reset.

## Section 7: Bluetooth Peripheral Transport Unit

### SPI Interface

The BCM43455 supports a slave SPI HCI transport with an input clock range of up to 16 MHz. Higher clock rates can be possible. The physical interface between the SPI master and the BCM43455 consists of the four SPI signals (SPI\_CSB, SPI\_CLK, SPI\_SI, and SPI\_SO) and one interrupt signal (SPI\_INT). The SPI signals are muxed onto the UART signals (see [Table 5](#)). The BCM43455 can be configured to accept active-low or active-high polarity on the SPI\_CSB chip select signal. It can also be configured to drive an active-low or active-high SPI\_INT interrupt signal. Bit ordering on the SPI\_SI and SPI\_SO data lines can be configured as either little-endian or big-endian. Additionally, proprietary sleep mode and half-duplex handshaking is implemented between the SPI master and the BCM43455. The SPI\_INT is required to negotiate the start of a transaction. The SPI interface does not require flow control in the middle of a payload. The FIFO is large enough to handle the largest packet size. Only the SPI master can stop the flow of bytes on the data lines, since it controls SPI\_CSB and SPI\_CLK. Flow control should be implemented in the higher layer protocols.

**Table 5: SPI-to-UART Signal Mapping**

<b>SPI Signals</b>	<b>UART Signals</b>
SPI_CLK	BT_UART_CTS_N
SPI_CSB	BT_UART_RTS_N
SPI_MISO	BT_UART_RXD
SPI_MOSI	BT_UART_TXD
SPI_INT	BT_HOST_WAKE

### SPI/UART Transport Detection

The BT\_HOST\_WAKE (BT\_GPIO1) pin is also used for BT transport detection. The transport detection occurs during the power-up sequence. It selects either UART or SPI transport operation based on the following pin state:

- If the BT\_HOST\_WAKE (BT\_GPIO1) pin is pulled low by an external pull-down during power-up, it selects the SPI transport interface.
- If the BT\_HOST\_WAKE (BT\_GPIO1) pin is not pulled low externally during power-up, then the default internal pull-up is detected as a high and it selects the UART transport interface.



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## PCM Interface

The BCM43455 supports two independent PCM interfaces that share the pins with the I2S interfaces. The PCM Interface on the BCM43455 can connect to linear PCM Codec devices in master or slave mode. In master mode, the BCM43455 generates the PCM\_CLK and PCM\_SYNC signals, and in slave mode, these signals are provided by another master on the PCM interface and are inputs to the BCM43455.

The configuration of the PCM interface may be adjusted by the host through the use of vendor-specific HCI commands.

## Slot Mapping

The BCM43455 supports up to three simultaneous full-duplex SCO or eSCO channels through the PCM interface. These three channels are time-multiplexed onto the single PCM interface by using a time-slotting scheme where the 8 kHz or 16 kHz audio sample interval is divided into as many as 16 slots. The number of slots is dependent on the selected interface rate of 128 kHz, 512 kHz, or 1024 kHz. The corresponding number of slots for these interface rate is 1, 2, 4, 8, and 16, respectively. Transmit and receive PCM data from an SCO channel is always mapped to the same slot. The PCM data output driver tristates its output on unused slots to allow other devices to share the same PCM interface signals. The data output driver tristates its output after the falling edge of the PCM clock during the last bit of the slot.

## Frame Synchronization

The BCM43455 supports both short- and long-frame synchronization in both master and slave modes. In short-frame synchronization mode, the frame synchronization signal is an active-high pulse at the audio frame rate that is a single-bit period in width and is synchronized to the rising edge of the bit clock. The PCM slave looks for a high on the falling edge of the bit clock and expects the first bit of the first slot to start at the next rising edge of the clock. In long-frame synchronization mode, the frame synchronization signal is again an active-high pulse at the audio frame rate; however, the duration is three bit periods and the pulse starts coincident with the first bit of the first slot.

## Data Formatting

The BCM43455 may be configured to generate and accept several different data formats. For conventional narrowband speech mode, the BCM43455 uses 13 of the 16 bits in each PCM frame. The location and order of these 13 bits can be configured to support various data formats on the PCM interface. The remaining three bits are ignored on the input and may be filled with 0s, 1s, a sign bit, or a programmed value on the output. The default format is 13-bit 2's complement data, left justified, and clocked MSB first.

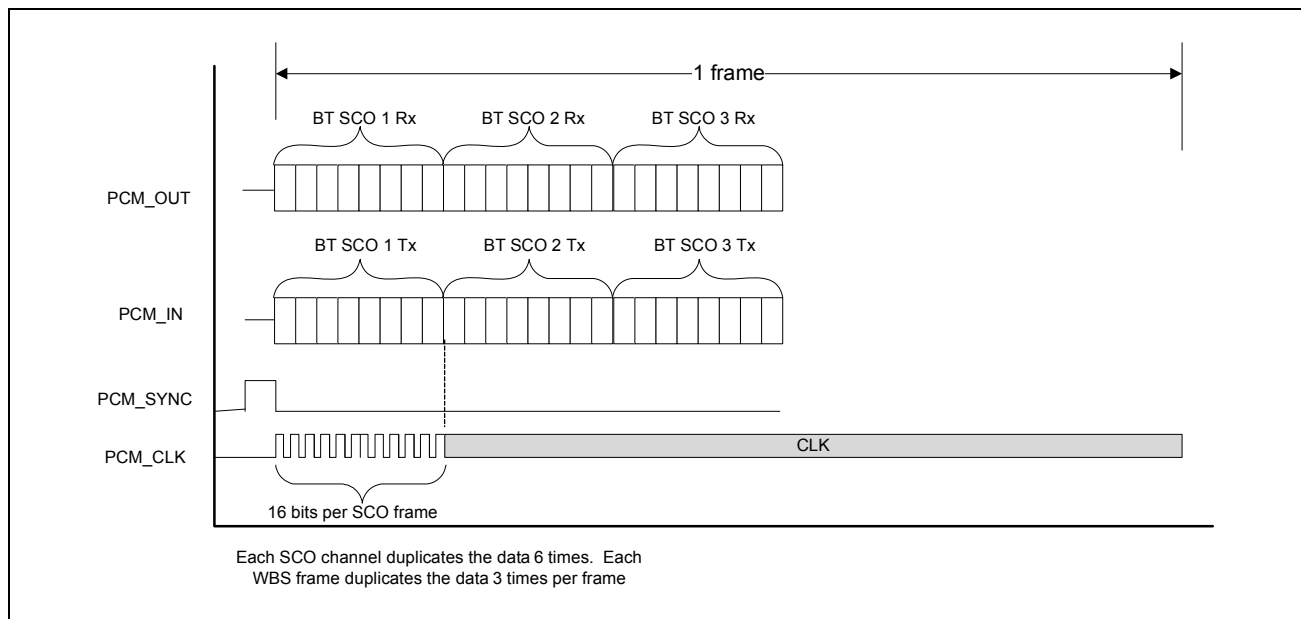
## Wideband Speech Support

When the host encodes Wideband Speech (WBS) packets in transparent mode, the encoded packets are transferred over the PCM bus for an eSCO voice connection. In this mode, the PCM bus is typically configured in master mode for a 4 kHz sync rate with 16-bit samples, resulting in a 64 Kbps bit rate. The BCM43455 also supports slave transparent mode using a proprietary rate-matching scheme. In SBC-code mode, linear 16-bit data at 16 kHz (256 Kbps rate) is transferred over the PCM bus.

## Multiplexed Bluetooth Over PCM

Bluetooth supports multiple audio streams within the Bluetooth channel and both 16 kHz and 8 kHz streams can be multiplexed. This mode of operation is only supported when the Bluetooth host is the master. Figure 10 shows the operation of the multiplexed transport with three simultaneous SCO connections. To accommodate additional SCO channels, the transport clock speed is increased. To change between modes of operation, the transport must be halted and restarted in the new configuration.

Figure 10: Functional Multiplex Data Diagram



## Burst PCM Mode

In this mode of operation, the PCM bus runs at a significantly higher rate of operation to allow the host to duty cycle its operation and save current. In this mode of operation, the PCM bus can operate at a rate of up to 24 MHz. This mode of operation is initiated with an HCI command from the host.

# PCM Interface Timing

## Short Frame Sync, Master Mode

Figure 11: PCM Timing Diagram (Short Frame Sync, Master Mode)

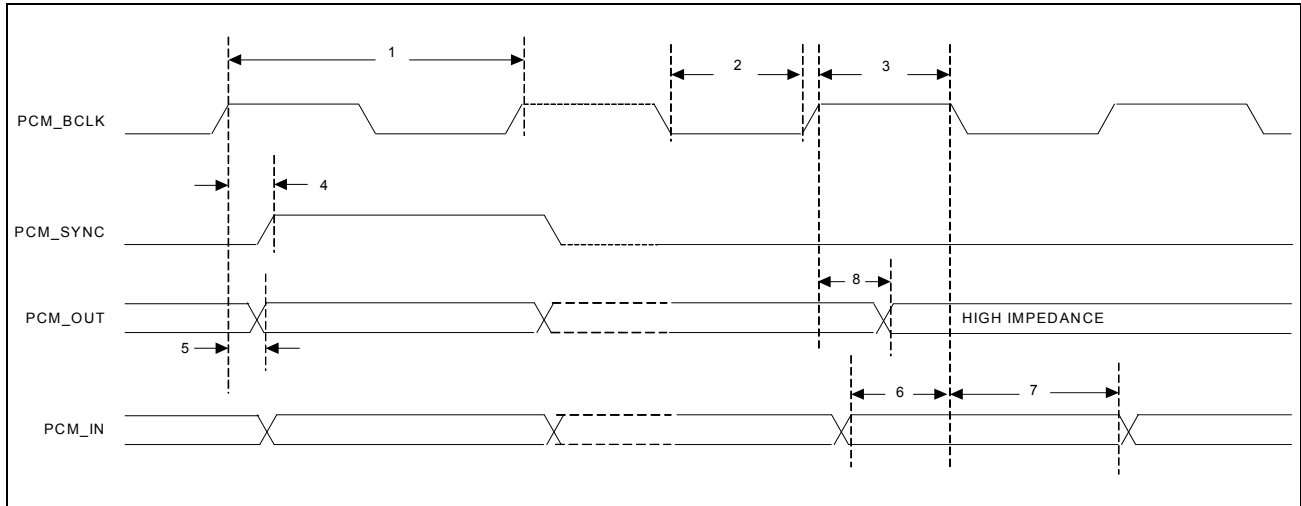


Table 6: PCM Interface Timing Specifications (Short Frame Sync, Master Mode)

Reference	Characteristics	Minimum	Typical	Maximum	Unit
1	PCM bit clock frequency	–	–	12	MHz
2	PCM bit clock LOW	41	–	–	ns
3	PCM bit clock HIGH	41	–	–	ns
4	PCM_SYNC delay	0	–	25	ns
5	PCM_OUT delay	0	–	25	ns
6	PCM_IN setup	8	–	–	ns
7	PCM_IN hold	8	–	–	ns
8	Delay from rising edge of PCM_BCLK during last bit period to PCM_OUT becoming high impedance	0	–	25	ns

## Short Frame Sync, Slave Mode

Figure 12: PCM Timing Diagram (Short Frame Sync, Slave Mode)

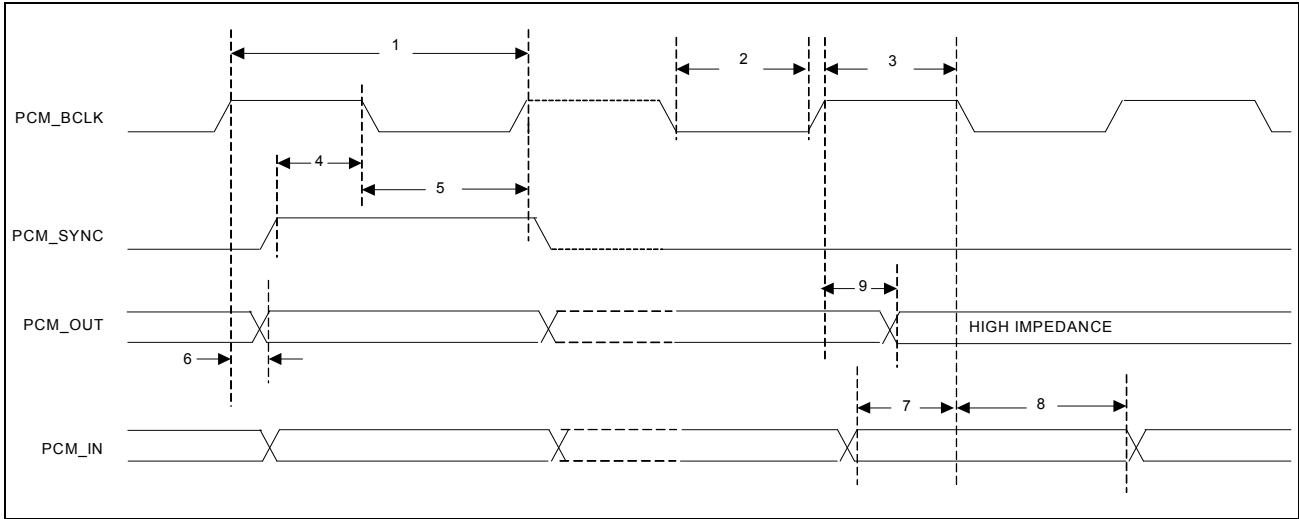


Table 7: PCM Interface Timing Specifications (Short Frame Sync, Slave Mode)

Reference	Characteristics	Minimum	Typical	Maximum	Unit
1	PCM bit clock frequency	–	–	12	MHz
2	PCM bit clock LOW	41	–	–	ns
3	PCM bit clock HIGH	41	–	–	ns
4	PCM_SYNC setup	8	–	–	ns
5	PCM_SYNC hold	8	–	–	ns
6	PCM_OUT delay	0	–	25	ns
7	PCM_IN setup	8	–	–	ns
8	PCM_IN hold	8	–	–	ns
9	Delay from rising edge of PCM_BCLK during last bit period to PCM_OUT becoming high impedance	0	–	25	ns

## Long Frame Sync, Master Mode

Figure 13: PCM Timing Diagram (Long Frame Sync, Master Mode)

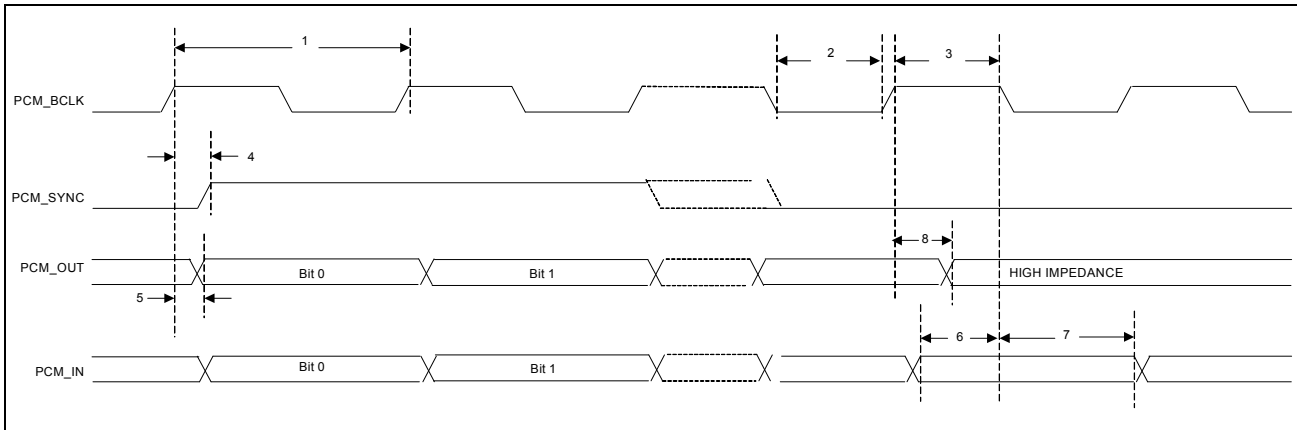


Table 8: PCM Interface Timing Specifications (Long Frame Sync, Master Mode)

Reference	Characteristics	Minimum	Typical	Maximum	Unit
1	PCM bit clock frequency	–	–	12	MHz
2	PCM bit clock LOW	41	–	–	ns
3	PCM bit clock HIGH	41	–	–	ns
4	PCM_SYNC delay	0	–	25	ns
5	PCM_OUT delay	0	–	25	ns
6	PCM_IN setup	8	–	–	ns
7	PCM_IN hold	8	–	–	ns
8	Delay from rising edge of PCM_BCLK during last bit period to PCM_OUT becoming high impedance	0	–	25	ns

## Long Frame Sync, Slave Mode

Figure 14: PCM Timing Diagram (Long Frame Sync, Slave Mode)

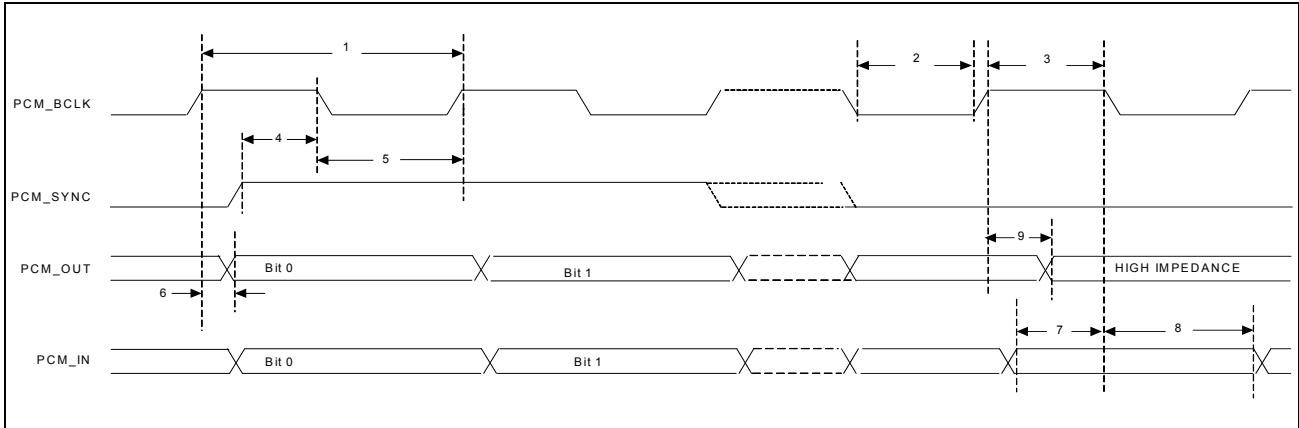


Table 9: PCM Interface Timing Specifications (Long Frame Sync, Slave Mode)

Reference	Characteristics	Minimum	Typical	Maximum	Unit
1	PCM bit clock frequency	–	–	12	MHz
2	PCM bit clock LOW	41	–	–	ns
3	PCM bit clock HIGH	41	–	–	ns
4	PCM_SYNC setup	8	–	–	ns
5	PCM_SYNC hold	8	–	–	ns
6	PCM_OUT delay	0	–	25	ns
7	PCM_IN setup	8	–	–	ns
8	PCM_IN hold	8	–	–	ns
9	Delay from rising edge of PCM_BCLK during last bit period to PCM_OUT becoming high impedance	0	–	25	ns

## Short Frame Sync, Burst Mode

Figure 15: PCM Burst Mode Timing (Receive Only, Short Frame Sync)

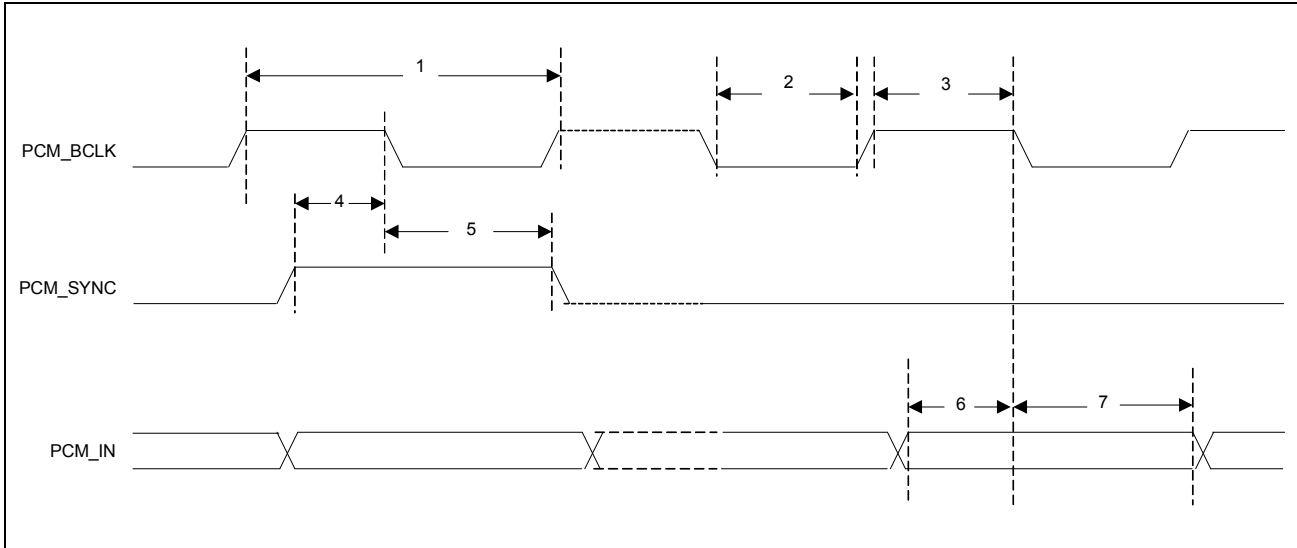


Table 10: PCM Burst Mode (Receive Only, Short Frame Sync)

Reference	Characteristics	Minimum	Typical	Maximum	Unit
1	PCM bit clock frequency	–	–	24	MHz
2	PCM bit clock LOW	20.8	–	–	ns
3	PCM bit clock HIGH	20.8	–	–	ns
4	PCM_SYNC setup	8	–	–	ns
5	PCM_SYNC hold	8	–	–	ns
6	PCM_IN setup	8	–	–	ns
7	PCM_IN hold	8	–	–	ns

## Long Frame Sync, Burst Mode

Figure 16: PCM Burst Mode Timing (Receive Only, Long Frame Sync)

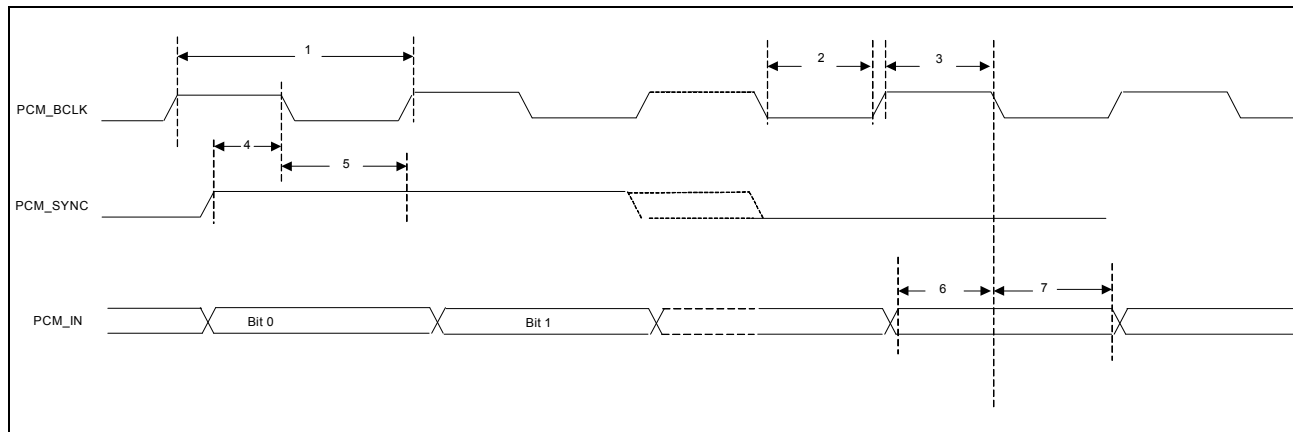


Table 11: PCM Burst Mode (Receive Only, Long Frame Sync)

Reference	Characteristics	Minimum	Typical	Maximum	Unit
1	PCM bit clock frequency	–	–	24	MHz
2	PCM bit clock LOW	20.8	–	–	ns
3	PCM bit clock HIGH	20.8	–	–	ns
4	PCM_SYNC setup	8	–	–	ns
5	PCM_SYNC hold	8	–	–	ns
6	PCM_IN setup	8	–	–	ns
7	PCM_IN hold	8	–	–	ns



## UART Interface

The UART is a standard 4-wire interface (RX, TX, RTS, and CTS) with adjustable baud rates from 9600 bps to 4.0 Mbps. The interface features an automatic baud rate detection capability that returns a baud rate selection. Alternatively, the baud rate may be selected through a vendor-specific UART HCI command.

UART has a 1040-byte receive FIFO and a 1040-byte transmit FIFO to support EDR. Access to the FIFOs is conducted through the AHB interface through either DMA or the CPU. The UART supports the Bluetooth 4.1 UART HCI specification: H4, a custom Extended H4, and H5. The default baud rate is 115.2 Kbaud.

The UART supports the 3-wire H5 UART transport, as described in the Bluetooth specification (*Three-wire UART Transport Layer*). Compared to H4, the H5 UART transport reduces the number of signal lines required by eliminating the CTS and RTS signals.

The BCM43455 UART can perform XON/XOFF flow control and includes hardware support for the Serial Line Input Protocol (SLIP). It can also perform wake-on activity. For example, activity on the RX or CTS inputs can wake the chip from a sleep state.

Normally, the UART baud rate is set by a configuration record downloaded after device reset, or by automatic baud rate detection, and the host does not need to adjust the baud rate. Support for changing the baud rate during normal HCI UART operation is included through a vendor-specific command that allows the host to adjust the contents of the baud rate registers. The BCM43455 UARTs operate correctly with the host UART as long as the combined baud rate error of the two devices is within  $\pm 2\%$ .

**Table 12: Example of Common Baud Rates**

<b>Desired Rate</b>	<b>Actual Rate</b>	<b>Error (%)</b>
4000000	4000000	0.00
3692000	3692308	0.01
3000000	3000000	0.00
2000000	2000000	0.00
1500000	1500000	0.00
1444444	1454544	0.70
921600	923077	0.16
460800	461538	0.16
230400	230796	0.17
115200	115385	0.16
57600	57692	0.16
38400	38400	0.00
28800	28846	0.16
19200	19200	0.00
14400	14423	0.16
9600	9600	0.00

Figure 17: UART Timing

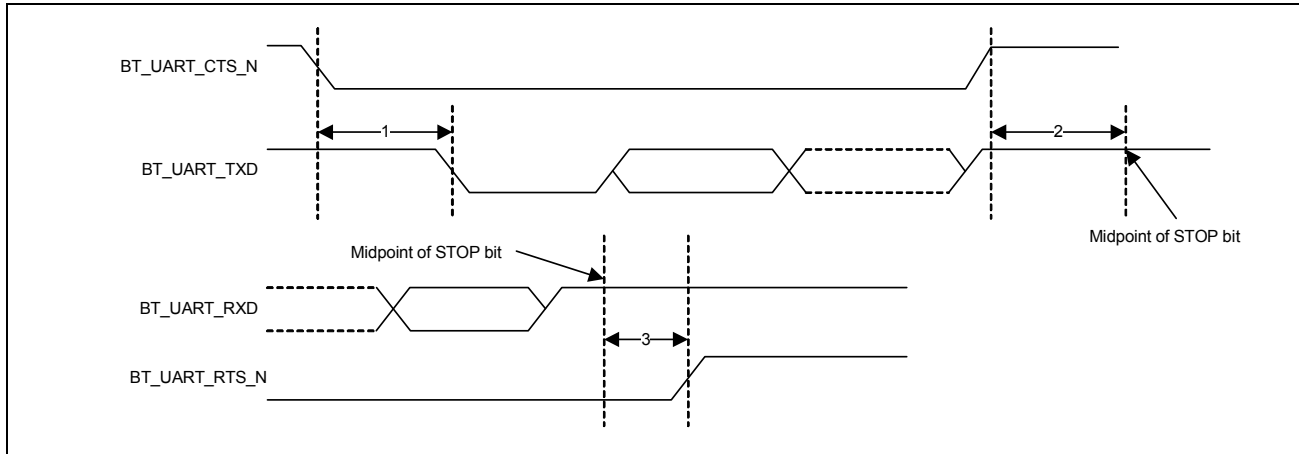


Table 13: UART Timing Specifications

Ref	Characteristics	Min.	Typ.	Max.	Unit
1	Delay time, BT_UART_CTS_N low to BT_UART_TXD valid	–	–	1.5	Bit periods
2	Setup time, BT_UART_CTS_N high before midpoint of stop bit	–	–	0.5	Bit periods
3	Delay time, midpoint of stop bit to BT_UART_RTS_N high	–	–	0.5	Bit periods

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

The BCM43455 supports an I<sup>2</sup>S digital audio port for Bluetooth audio. The I<sup>2</sup>S signals are:

- I<sup>2</sup>S clock: I<sup>2</sup>S SCK
- I<sup>2</sup>S Word Select: I<sup>2</sup>S WS
- I<sup>2</sup>S Data Out: I<sup>2</sup>S SDO
- I<sup>2</sup>S Data In: I<sup>2</sup>S SDI

I<sup>2</sup>S SCK and I<sup>2</sup>S WS become outputs in master mode and inputs in slave mode, while I<sup>2</sup>S SDO always stays as an output. The channel word length is 16 bits and the data is justified so that the MSB of the left-channel data is aligned with the MSB of the I<sup>2</sup>S bus, per the I<sup>2</sup>S specification. The MSB of each data word is transmitted one bit clock cycle after the I<sup>2</sup>S WS transition, synchronous with the falling edge of bit clock. Left-channel data is transmitted when I<sup>2</sup>S WS is low, and right-channel data is transmitted when I<sup>2</sup>S WS is high. Data bits sent by the BCM43455 are synchronized with the falling edge of I2S\_SCK and should be sampled by the receiver on the rising edge of I2S\_SSCK.

The clock rate in master mode is either of the following:

$$48 \text{ kHz} \times 32 \text{ bits per frame} = 1.536 \text{ MHz}$$

$$48 \text{ kHz} \times 50 \text{ bits per frame} = 2.400 \text{ MHz}$$

The master clock is generated from the input reference clock using a N/M clock divider. In the slave mode, any clock rate is supported to a maximum of 3.072 MHz.

## I<sup>2</sup>S Timing



**Note:** Timing values specified in Table 14 are relative to high and low threshold levels.

**Table 14: Timing for I<sup>2</sup>S Transmitters and Receivers**

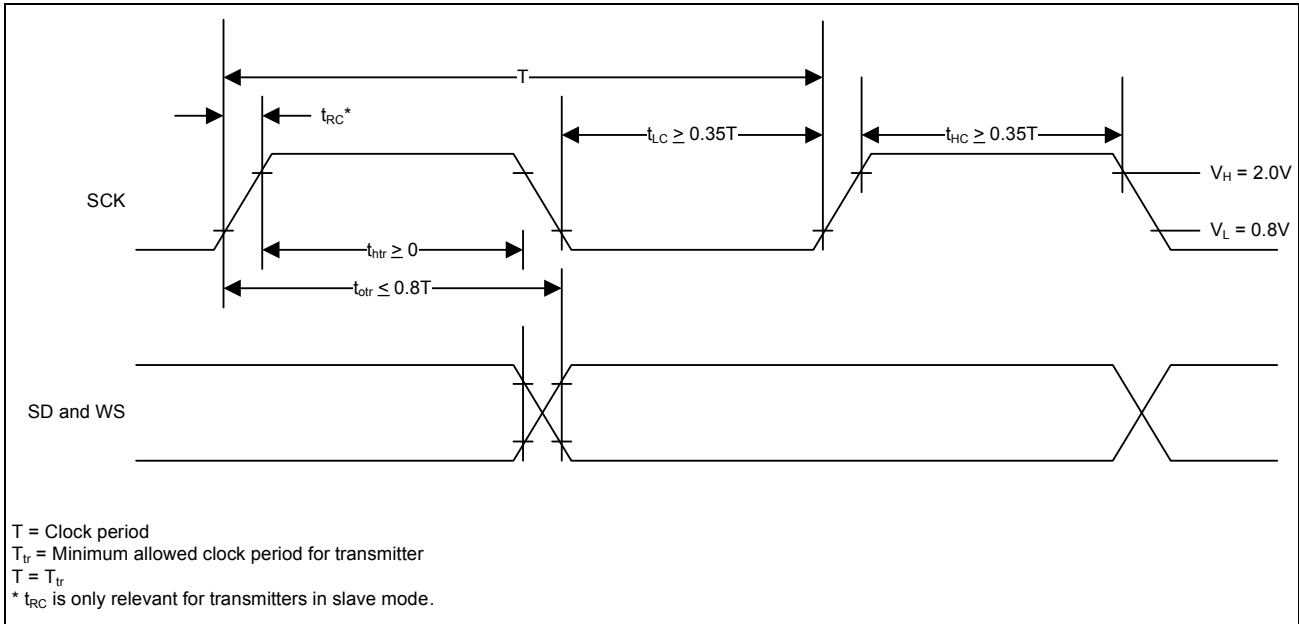
	<i>Transmitter</i>				<i>Receiver</i>				<i>Notes</i>
	<i>Lower Limit</i>		<i>Upper Limit</i>		<i>Lower Limit</i>		<i>Upper Limit</i>		
	<i>Min.</i>	<i>Max.</i>	<i>Min.</i>	<i>Max.</i>	<i>Min.</i>	<i>Max.</i>	<i>Min.</i>	<i>Max.</i>	
Clock Period T	T <sub>tr</sub>	–	–	–	T <sub>r</sub>	–	–	–	a
<b>Master Mode: Clock generated by transmitter or receiver</b>									
HIGH t <sub>HC</sub>	0.35T <sub>tr</sub>	–	–	–	0.35T <sub>tr</sub>	–	–	–	b
LOW t <sub>LC</sub>	0.35T <sub>tr</sub>	–	–	–	0.35T <sub>tr</sub>	–	–	–	b
<b>Slave Mode: Clock accepted by transmitter or receiver</b>									
HIGH t <sub>HC</sub>	–	0.35T <sub>tr</sub>	–	–	–	0.35T <sub>tr</sub>	–	–	c
LOW t <sub>LC</sub>	–	0.35T <sub>tr</sub>	–	–	–	0.35T <sub>tr</sub>	–	–	c
Rise time t <sub>RC</sub>	–	–	0.15T <sub>tr</sub>	–	–	–	–	–	d
<b>Transmitter</b>									
Delay t <sub>dtr</sub>	–	–	–	0.8T	–	–	–	–	e
Hold time t <sub>htr</sub>	0	–	–	–	–	–	–	–	d
<b>Receiver</b>									
Setup time t <sub>sr</sub>	–	–	–	–	–	0.2T <sub>r</sub>	–	–	f
Hold time t <sub>hr</sub>	–	–	–	–	–	0	–	–	f

- The system clock period T must be greater than T<sub>tr</sub> and T<sub>r</sub> because both the transmitter and receiver have to be able to handle the data transfer rate.
- At all data rates in master mode, the transmitter or receiver generates a clock signal with a fixed mark/space ratio. For this reason, t<sub>HC</sub> and t<sub>LC</sub> are specified with respect to T.
- In slave mode, the transmitter and receiver need a clock signal with minimum HIGH and LOW periods so that they can detect the signal. So long as the minimum periods are greater than 0.35T<sub>r</sub>, any clock that meets the requirements can be used.
- Because the delay (t<sub>dtr</sub>) and the maximum transmitter speed (defined by T<sub>tr</sub>) are related, a fast transmitter driven by a slow clock edge can result in t<sub>dtr</sub> not exceeding t<sub>RC</sub> which means t<sub>htr</sub> becomes zero or negative. Therefore, the transmitter has to guarantee that t<sub>htr</sub> is greater than or equal to zero, so long as the clock rise-time t<sub>RC</sub> is not more than t<sub>RCmax</sub>, where t<sub>RCmax</sub> is not less than 0.15T<sub>tr</sub>.
- To allow data to be clocked out on a falling edge, the delay is specified with respect to the rising edge of the clock signal and T, always giving the receiver sufficient setup time.
- The data setup and hold time must not be less than the specified receiver setup and hold time.

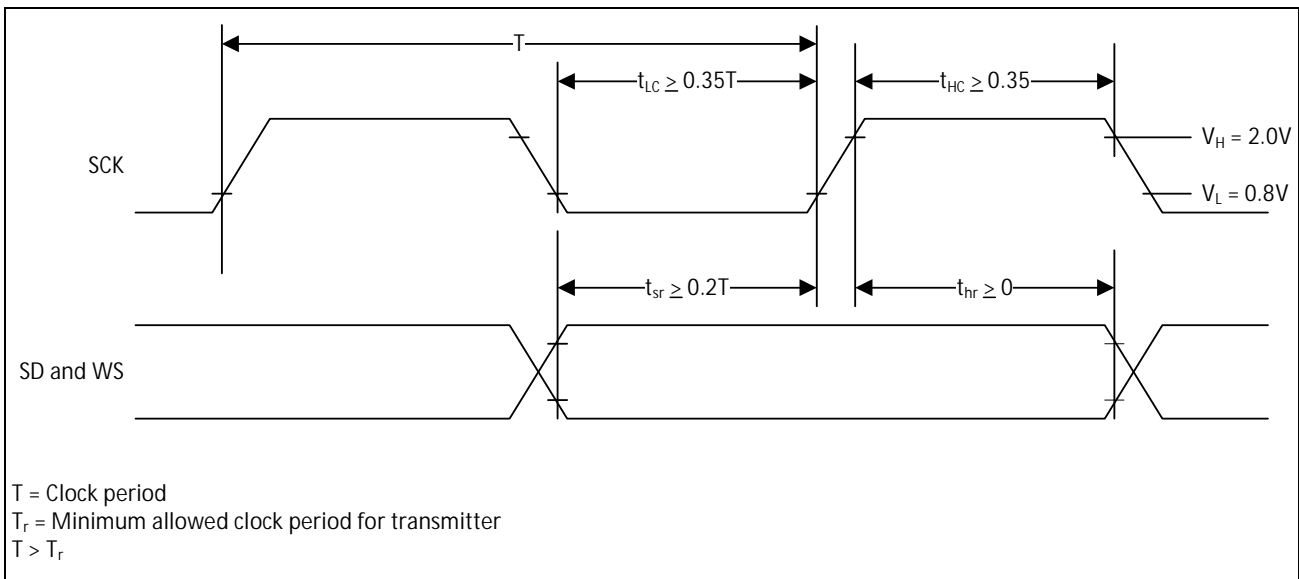


**Note:** The time periods specified in Figure 18 and Figure 19 are defined by the transmitter speed. The receiver specifications must match transmitter performance.

**Figure 18: I<sup>2</sup>S Transmitter Timing**



**Figure 19: I<sup>2</sup>S Receiver Timing**



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## Section 8: FM Receiver Subsystem

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### FM Radio

The BCM43455 includes a completely integrated FM radio receiver with RDS/RBDS covering all FM bands from 65 MHz to 108 MHz. The receiver is controlled through commands on the HCI. FM received audio is available in analog form or in digital form through I<sup>2</sup>S or PCM. The FM radio operates from the external clock reference.

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### Digital FM Audio Interfaces

The FM audio can be transmitted via the shared PCM and I<sup>2</sup>S pins, and the sampling rate is programmable. The BCM43455 supports a three-wire PCM or I<sup>2</sup>S audio interface in either master or slave configuration. The master or slave configuration is selected using vendor specific commands over the HCI interface. In addition, multiple sampling rates are supported, derived from either the FM or Bluetooth clocks. In master mode, the clock rate is either of the following:

- 48 kHz x 32 bits per frame = 1.536 MHz
- 48 kHz x 50 bits per frame = 2.400 MHz

In slave mode, any clock rate is supported up to a maximum of 3.072 MHz.

---

### FM Over Bluetooth

The BCM43455 can output received FM audio onto Bluetooth using one of following three links: eSCO, WBS, and A2DP. In all of the above modes, once the link has been set up, the host processor can enter sleep mode while the BCM43455 continues to stream FM audio to the remote Bluetooth device, allowing the system current consumption to be minimized.

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### eSCO

In this use case, the stereo FM audio is downsampled to 8 kHz and a mono or stereo stream is then sent through the Bluetooth eSCO link to a remote Bluetooth device, typically a headset. Two Bluetooth voice connections must be used to transport stereo.

## Wideband Speech Link

In this case, the stereo FM audio is downsampled to 16 kHz and a mono or stereo stream is then sent through the Bluetooth wideband speech link to a remote Bluetooth device, typically a headset. Two Bluetooth voice connections must be used to transport stereo.

## A2DP

In this case, the stereo FM audio is encoded by the on-chip SBC encoder and transported as an A2DP link to a remote Bluetooth device. Sampling rates of 48 kHz, 44.1 kHz, and 32 kHz joint stereo are supported. An A2DP “lite” stack is implemented in the BCM43455 to support this use case, which eliminates the need to route the SBC-encoded audio back to the host to create the A2DP packets.

## Autotune and Search Algorithms

The BCM43455 supports a number of FM search and tune functions that allows the host to implement many convenient user functions, which are accessed through the Broadcom FM stack.

- Tune to Play—Allows the FM receiver to be programmed to a specific frequency.
- Search for SNR > Threshold—Checks the power level of the available channel and the estimated SNR of the channel to help achieve precise control of the expected sound quality for the selected FM channel. Specifically, the host can adjust its SNR requirements to retrieve a signal with a specific sound quality, or adjust this to return the weakest channels.
- Alternate Frequency Jump—Allows the FM receiver to automatically jump to an alternate FM channel that carries the same information, but has a better SNR. For example, when traveling, a user may pass through a region where a number of channels carry the same station. When the user passes from one area to the next, the FM receiver can automatically switch to another channel with a stronger signal to spare the user from having to manually change the channel to continue listening to the same station.

# Audio Features

A number of features are implemented in the BCM43455 to provide the best possible audio experience for the user.

- Mono/Stereo Blend, Switch, or FME—The BCM43455 provides automatic control of the stereo or mono settings based on the FM signal carrier-to-noise ratio (C/N). This feature is used to maintain the best possible audio SNR based on the FM channel condition. Three modes of operation are supported:
  - Blend: In this mode, fine control of stereo separation is used to achieve optimal audio quality over a wide range of input C/N. The amount of separation is fully programmable. In [Figure 20](#), the separation is programmed to maintain a minimum 50 dB SNR across the blend range.
  - Extended blend: In this mode, stereo separation is maximized across a wide range of input CNR. Broadcom static suppression typically gives a static-free user experience to within 3 dB of ultimate sensitivity.
  - Switch: In this mode, the audio switches from full stereo to full mono at a predetermined level to maintain optimal audio quality. The stereo-to-mono switch point and the mono-to-stereo switch points are fully programmable to provide the desired amount of audio SNR. In [Figure 21 on page 63](#), the switch point is programmed to switch to mono to maintain a 40 dB SNR.
  - FM enhancement (FME): In this mode, advanced digital signal processing in the FM receiver greatly enhances the stereo separation of the received audio. Traditional FM receivers deliver a full stereo signal at a high carrier-to-noise ratio (CNR) and gradually blend into mono as the CNR drops. The Broadcom stereo extension allows full stereo separation to within 2 dB of the FM receiver sensitivity threshold. The same signal processing delays the onset of pops at the FM sensitivity threshold and reduces the ambient background noise by more than 20 dB in the low CNR region near sensitivity. The result is a low-noise full stereo signal at input RF levels lower than previously achievable.

**Figure 20: Audio SNR for Blend, Switch, and FME Modes**

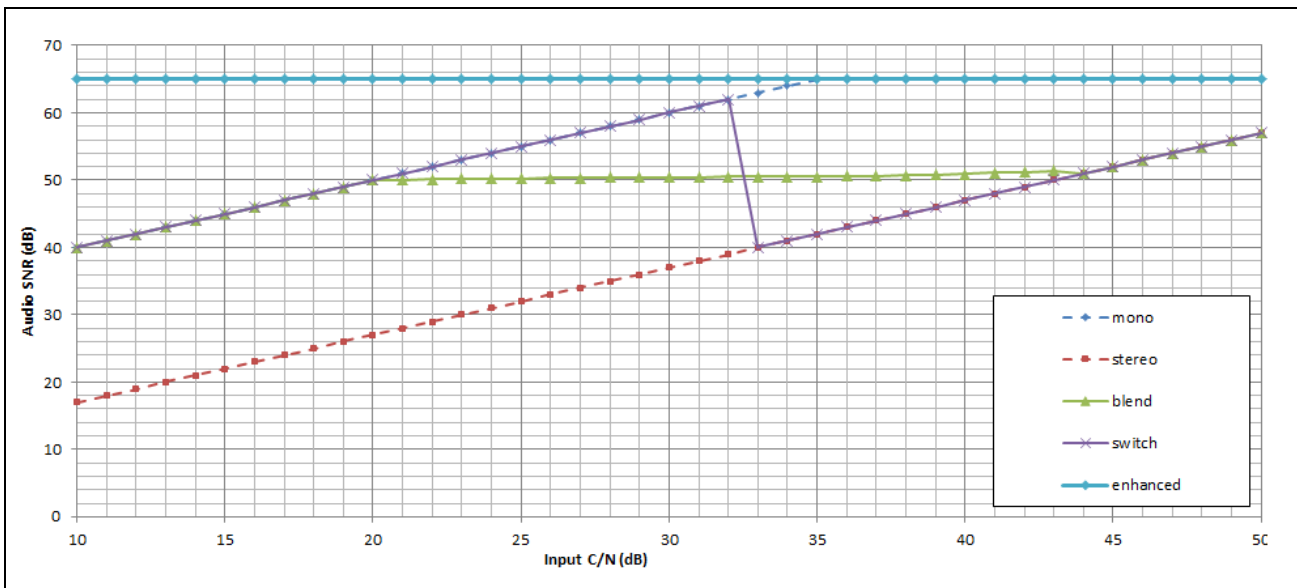
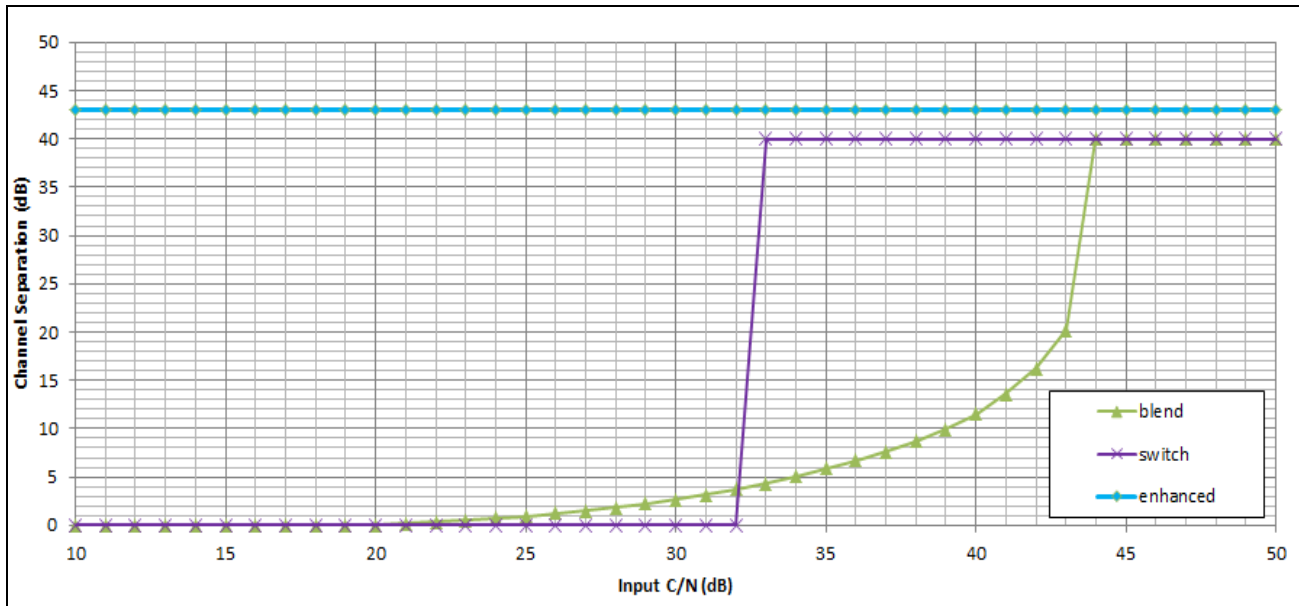
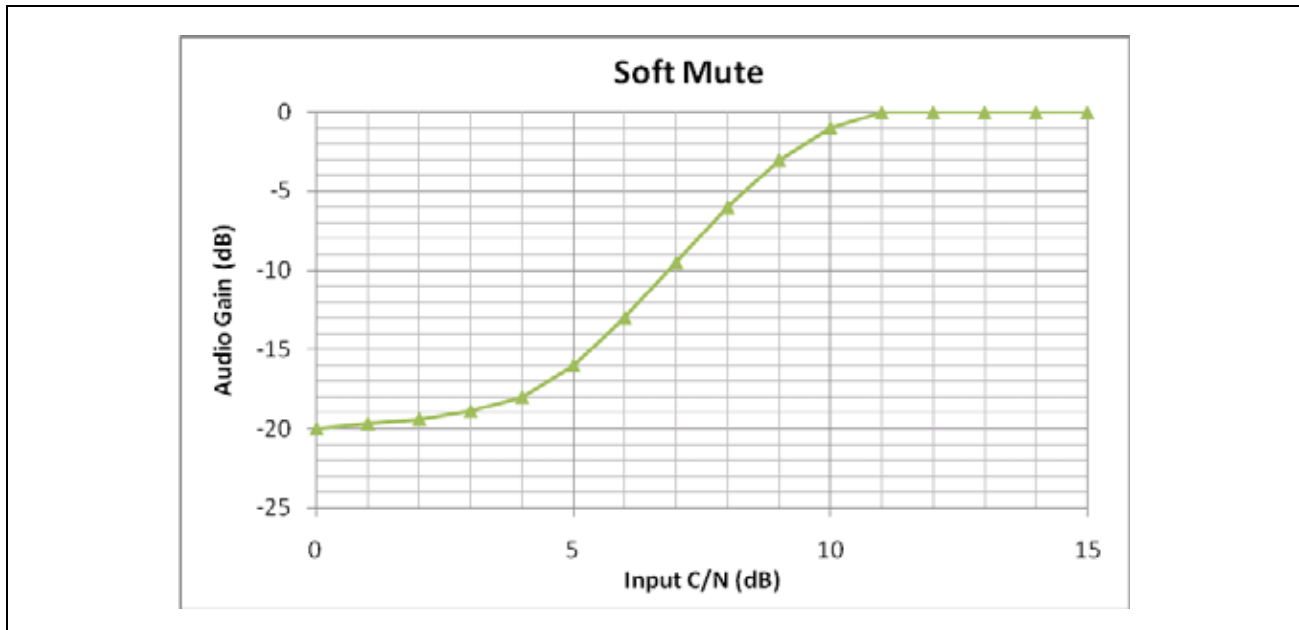


Figure 21: Stereo Separation for Blend, Switch, and FME Modes



- Soft Mute—Improves the user experience by dynamically muting the output audio proportionate to the FM signal C/N. This prevents the user from being assaulted with a blast of static. The mute characteristic is fully programmable to accommodate fine tuning of the output signal level. An example mute characteristic is shown in Figure 22.

Figure 22: Example Soft Mute Characteristic





- High Cut—A programmable high-cut filter is provided to reduce the amount of high-frequency noise caused by static in the output audio signal. Like the soft mute circuit, it is fully programmable to allow for any amount of high cut based on the FM signal C/N.
- Audio Pause Detect—The FM receiver monitors the magnitude of the audio signal and notifies the host through an interrupt when the magnitude of the signal has fallen below the threshold set for a programmable period. This feature can be used to provide alternate frequency jumps during periods of silence to minimize disturbances to the listener. Filtering techniques are used within the audio pause detection block to provide more robust presence-to-silence detection and silence-to-presence detection.
- Automatic Antenna Tuning—The BCM43455 has an on-chip automatic antenna tuning network. When used with a single off-chip inductor, the on-chip circuitry automatically chooses an optimal on-chip matching component to obtain the highest signal strength for the desired frequency. The high-Q nature of this matching network simultaneously provides out-of-band blocking protection as well as a reduction of radiated spurious emissions from the FM antenna. It is designed to accommodate a wide range of external wire antennas.

---

## RDS/RBDS

The BCM43455 integrates a RDS/RBDS modem and codec, the decoder includes programmable filtering and buffering functions, and the encoder includes the option to encode messages to PS or RT frame format with programmable scrolling in PS mode. The RDS/RBDS data can be read out in receive mode or delivered in transmit mode through either the HCI interface.

In addition, the RDS/RBDS functionality supports the following:

### Receive

- Block decoding, error correction and synchronization
- Flywheel synchronization feature, allowing the host to set parameters for acquisition, maintenance, and loss of sync. (It is possible to set up the BCM43455 such that synchronization is achieved when a minimum of two good blocks (error free) are decoded in sequence. The number of good blocks required for sync is programmable.)
- Storage capability up to 126 blocks of RDS data
- Full or partial block B match detect and interrupt to host
- Audio pause detection with programmable parameters
- Program identification (PI) code detection and interrupt to host
- Automatic frequency jump
- Block E filtering
- Soft mute
- Signal dependent mono/stereo blend
- Programmable pre-emphasis

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## Section 9: WLAN Global Functions

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### WLAN CPU and Memory Subsystem

The BCM43455 WLAN section includes an integrated ARM Cortex-R4 32-bit processor with internal RAM and ROM. The ARM Cortex-R4 is a low-power processor that features low gate count, low interrupt latency, and low-cost debug capabilities. It is intended for deeply embedded applications that require fast interrupt response features. Delivering more than 30% performance gain over ARM7TDMI, the ARM Cortex-R4 implements the ARM v7-R architecture with support for the Thumb-2 instruction set.

At 0.19  $\mu\text{W}/\text{MHz}$ , the Cortex-R4 is the most power efficient general-purpose microprocessor available, outperforming 8- and 16-bit devices on MIPS/ $\mu\text{W}$ . It supports integrated sleep modes.

Using multiple technologies to reduce cost, the ARM Cortex-R4 offers improved memory utilization, reduced pin overhead, and reduced silicon area. It supports independent buses for Code and Data access (ICode/DCode and System buses), and extensive debug features including real time trace of program execution.

On-chip memory for the CPU includes 800 KB SRAM and 704 KB ROM.

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### One-Time Programmable Memory

Various hardware configuration parameters may be stored in an internal 6144-bit (768 bytes) One-Time Programmable (OTP) memory, which is read by the system software after device reset. In addition, customer-specific parameters, including the system vendor ID and the MAC address can be stored, depending on the specific board design.

The initial state of all bits in an unprogrammed OTP device is 0. After any bit is programmed to a 1, it cannot be reprogrammed to 0. The entire OTP array can be programmed in a single write cycle using a utility provided with the Broadcom WLAN manufacturing test tools. Alternatively, multiple write cycles can be used to selectively program specific bytes, but only bits which are still in the 0 state can be altered during each programming cycle.

Prior to OTP programming, all values should be verified using the appropriate editable nvram.txt file, which is provided with the reference board design package.

---

### GPIO Interface

The following number of general-purpose I/O (GPIO) pins are available on the WLAN section of the BCM43455 that can be used to connect to various external devices:

- WLPGA package – 15 GPIOs

Upon power-up and reset, these pins become tristated. Subsequently, they can be programmed to be either input or output pins via the GPIO control register. In addition, the GPIO pins can be assigned to various other functions.

# External Coexistence Interface

An external handshake interface is available to enable signaling between the device and an external co-located wireless device, such as GPS or LTE to manage wireless medium sharing for optimum performance.

Figure 23 shows the WCI-2 LTE coexistence interface. See Table 13: “UART Timing Specifications,” on page 57 for UART baud rate.

**Figure 23: Broadcom GCI or BT-SIG WCI-2 LTE Coexistence Interface**

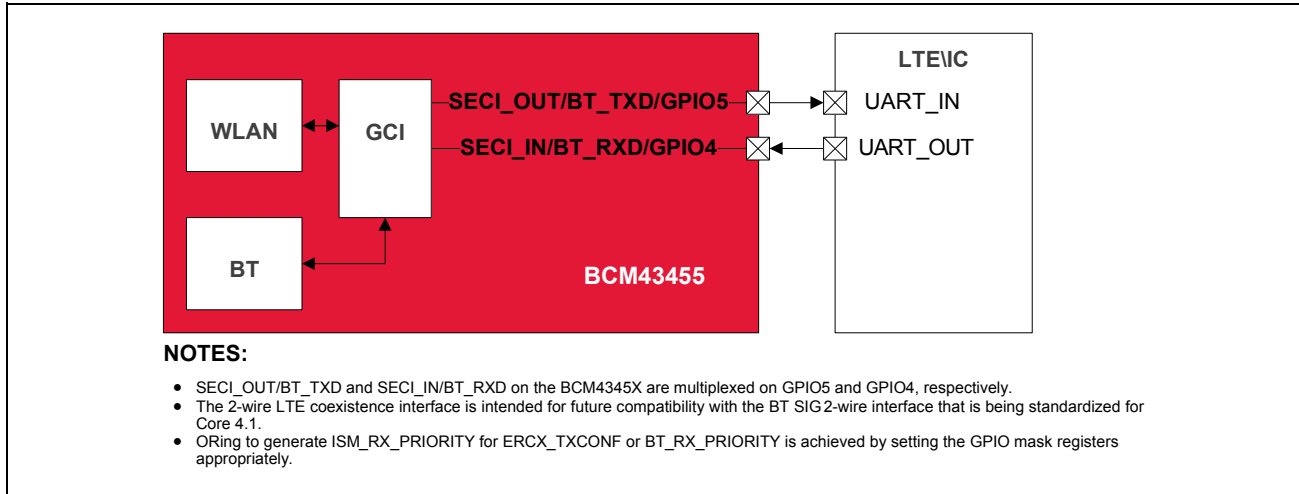
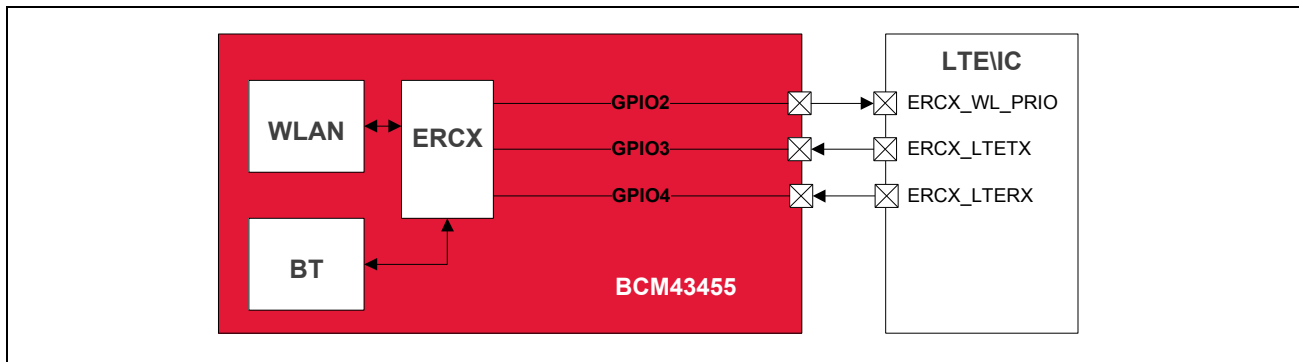


Figure 24 and Table 15 on page 66 define an alternate 3-wire LTE coexistence interface.

**Figure 24: 3-Wire LTE Coexistence Interface**



**Table 15: 3-Wire External Coexistence Interface**

GPIO Name	Coexistence Signal	Type	Comment
GPIO_2	ERCX_WL_PRIO	Output	Notify LTE of request to sleep
GPIO_3	ERCX_LTE_TX	Input	Notify WLAN RX of requirement to sleep
GPIO_4	ERCX_LTE_RX	Input	Notify WLAN TX to reduce TX power

## UART Interface

A high-speed 4-wire CTS/RTS UART interface can be enabled by software as an alternate function on GPIO pins. Provided primarily for debugging during development, this UART enables the BCM43455 to operate as RS-232 data termination equipment (DTE) for exchanging and managing data with other serial devices. It is compatible with the industry standard 16550 UART, and provides a FIFO size of 64 × 8 in each direction.

## JTAG/SWD Interface

The BCM43455 supports IEEE 1149.1 JTAG boundary scan and reduced pin-count Serial Wire Debug (SWD) mode to access the chip's internal blocks and backplane for system bring-up and debugging. This interface allows Broadcom engineers to assist customers with proprietary debug and characterization test tools. It is highly recommended that customers provide access to at least the SWD pins on all PCB designs by using either test points or a header.

The SWD interface uses two of the JTAG signals: TMS for bidirectional data (SWDIO) and TCK for the clock (SWCLK). The debug access port (DAP) embedded in the ARM processor supports both SWD and JTAG interfaces and can be switched from one to the other through a specific sequence on the TMS/SWD lines. In addition to the ARM debug interface, an internal JTAG master on the DAP allows access to test access points (TAPs) in the BCM43455 for hardware debugging.

## Section 10: WLAN Host Interfaces

### SDIO v3.0

All three package options of the BCM43455 WLAN section provide support for SDIO version 3.0, including the new UHS-I modes:

- DS: Default speed (DS) up to 25 MHz, including 1- and 4-bit modes (3.3V signaling).
- HS: High speed up to 50 MHz (3.3V signaling).
- SDR12: SDR up to 25 MHz (1.8V signaling).
- SDR25: SDR up to 50 MHz (1.8V signaling).
- SDR50: SDR up to 100 MHz (1.8V signaling).
- SDR104: SDR up to 208 MHz (1.8V signaling)
- DDR50: DDR up to 50 MHz (1.8V signaling).



**Note:** The BCM43455 is backward compatible with SDIO v2.0 host interfaces.

The SDIO interface also has the ability to map the interrupt signal on to a GPIO pin for applications requiring an interrupt different from the one provided by the SDIO interface. The ability to force control of the gated clocks from within the device is also provided. SDIO mode is enabled by strapping options. See [Table 20 on page 91](#) for strapping options.

The following three functions are supported:

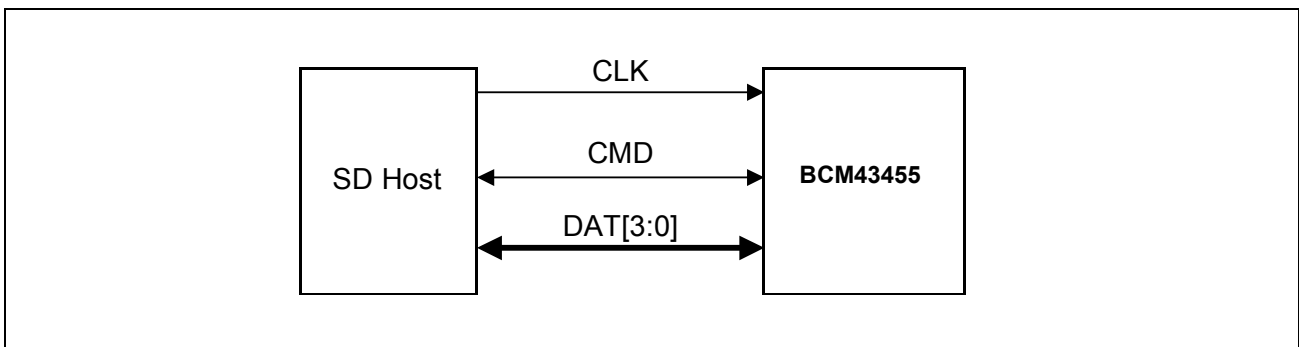
- Function 0 Standard SDIO function (Max BlockSize/ByteCount = 32B)
- Function 1 Backplane Function to access the internal system-on-chip (SoC) address space (Max BlockSize/ByteCount = 64B)
- Function 2 WLAN Function for efficient WLAN packet transfer through DMA (Max BlockSize/ByteCount = 512B).

## SDIO Pins

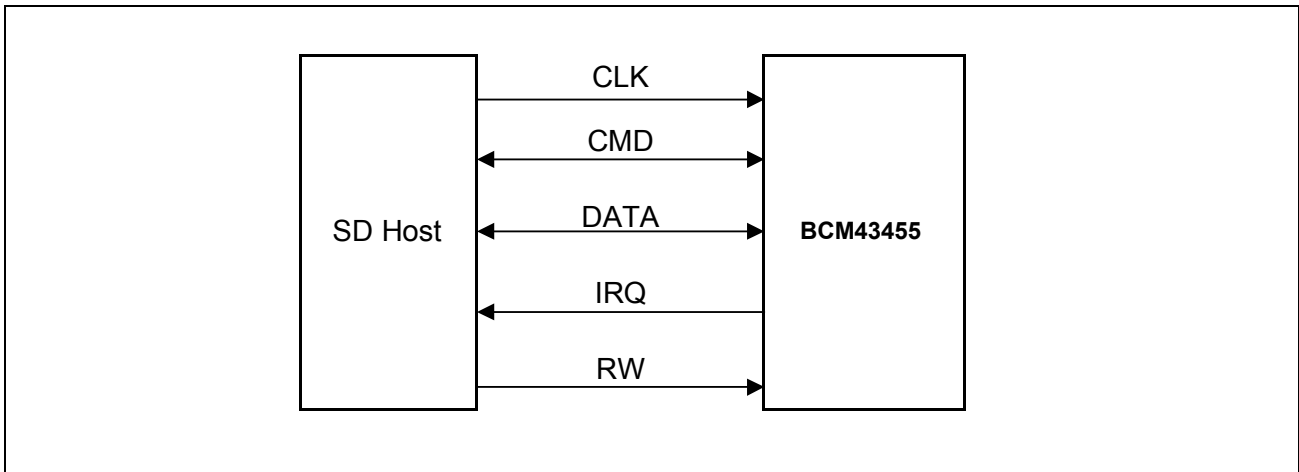
**Table 16: SDIO Pin Description**

<i>SD 4-Bit Mode</i>		<i>SD 1-Bit Mode</i>	
DATA0	Data line 0	DATA	Data line
DATA1	Data line 1 or Interrupt	IRQ	Interrupt
DATA2	Data line 2 or Read Wait	RW	Read Wait
DATA3	Data line 3	N/C	Not used
CLK	Clock	CLK	Clock
CMD	Command line	CMD	Command line

**Figure 25: Signal Connections to SDIO Host (SD 4-Bit Mode)**



**Figure 26: Signal Connections to SDIO Host (SD 1-Bit Mode)**



**Note:** Per Section 6 of the SDIO specification, pull-ups in the 10 kΩ to 100 kΩ range are required on the four DATA lines and the CMD line. This requirement must be met during all operating states either through the use of external pull-up resistors or through proper programming of the SDIO host's internal pull-ups.

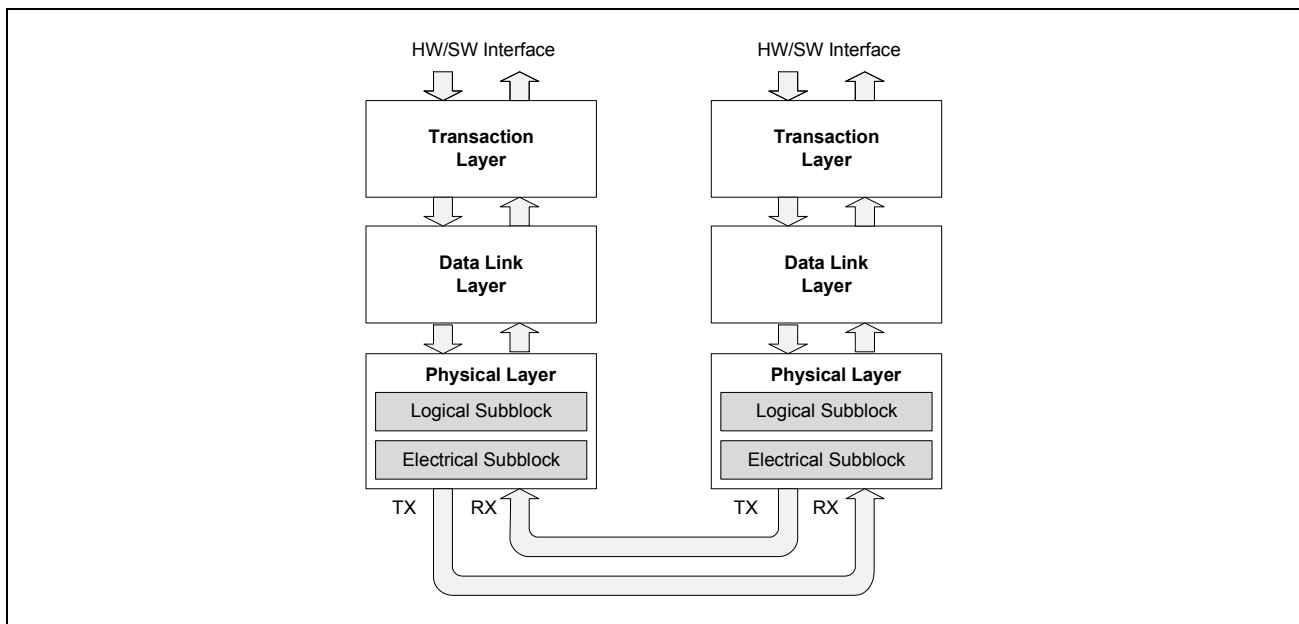
# PCI Express Interface

The PCI Express (PCIe) core on the BCM43455 is a high-performance serial I/O interconnect that is protocol compliant and electrically compatible with the *PCI Express Base Specification v2.0*. This core contains all the necessary blocks, including logical and electrical functional subblocks to perform PCIe functionality and maintain high-speed links, using existing PCI system configuration software implementations without modification.

Organization of the PCIe core is in logical layers: Transaction Layer, Data Link Layer, and Physical Layer, as shown in [Figure 27](#). A configuration or link management block is provided for enumerating the PCIe configuration space and supporting generation and reception of System Management Messages by communicating with PCIe layers.

Each layer is partitioned into dedicated transmit and receive units that allow point-to-point communication between the host and BCM43455 device. The transmit side processes outbound packets while the receive side processes inbound packets. Packets are formed and generated in the Transaction and Data Link Layer for transmission onto the high-speed links and onto the receiving device. A header is added at the beginning to indicate the packet type and any other optional fields.

**Figure 27: PCI Express Layer Model**



## Transaction Layer Interface

The PCIe core employs a packet-based protocol to transfer data between the host and BCM43455 device, delivering new levels of performance and features. The upper layer of the PCIe is the Transaction Layer. The Transaction layer is primarily responsible for assembly and disassembly of Transaction Layer Packets (TLPs). TLP structure contains header, data payload, and End-to-End CRC (ECRC) fields, which are used to communicate transactions, such as read and write requests and other events.

A pipelined full split-transaction protocol is implemented in this layer to maximize efficient communication between devices with credit-based flow control of TLP, which eliminates wasted link bandwidth due to retries.

## Data Link Layer

The data link layer serves as an intermediate stage between the transaction layer and the physical layer. Its primary responsibility is to provide reliable, efficient mechanism for the exchange of TLPs between two directly connected components on the link. Services provided by the data link layer include data exchange, initialization, error detection and correction, and retry services.

Data Link Layer Packets (DLLPs) are generated and consumed by the data link layer. DLLPs are the mechanism used to transfer link management information between data link layers of the two directly connected components on the link, including TLP acknowledgment, power management, and flow control.

## Physical Layer

The physical layer of the PCIe provides a handshake mechanism between the data link layer and the high-speed signaling used for Link data interchange. This layer is divided into the logical and electrical functional subblocks. Both subblocks have dedicated transmit and receive units that allow for point-to-point communication between the host and BCM43455 device. The transmit section prepares outgoing information passed from the data link layer for transmission, and the receiver section identifies and prepares received information before passing it to the data link layer. This process involves link initialization, configuration, scrambler, and data conversion into a specific format.

## Logical Subblock

The logical sub block primary functions are to prepare outgoing data from the data link layer for transmission and identify received data before passing it to the data link layer.

## Scrambler/Descrambler

This PCIe PHY component generates pseudo-random sequence for scrambling of data bytes and the idle sequence. On the transmit side, scrambling is applied to characters prior to the 8b/10b encoding. On the receive side, descrambling is applied to characters after 8b/10b decoding. Scrambling may be disabled in polling and recovery for testing and debugging purposes.



## 8B/10B Encoder/Decoder

The PCIe core on the BCM43455 uses an 8b/10b encoder/decoder scheme to provide DC balancing, synchronizing clock and data recovery, and error detection. The transmission code is specified in the ANSI X3.230-1994, clause 11 and in IEEE 802.3z, 36.2.4.

Using this scheme, 8-bit data characters are treated as 3 bits and 5 bits mapped onto a 4-bit code group and a 6-bit code group, respectively. The control bit in conjunction with the data character is used to identify when to encode one of the twelve Special Symbols included in the 8b/10b transmission code. These code groups are concatenated to form a 10-bit symbol, which is then transmitted serially. Special Symbols are used for link management, frame TLPs, and DLLPs, allowing these packets to be quickly identified and easily distinguished.

## Elastic FIFO

An elastic FIFO is implemented in the receiver side to compensate for the differences between the transmit clock domain and the receive clock domain, with worst case clock frequency specified at 600 ppm tolerance. As a result, the transmit and receive clocks can shift one clock every 1666 clocks. In addition, the FIFO adaptively adjusts the elastic level based on the relative frequency difference of the write and read clock. This technique reduces the elastic FIFO size and the average receiver latency by half.

## Electrical Subblock

The high-speed signals utilize the Common Mode Logic (CML) signaling interface with on-chip termination and de-emphasis for best-in-class signal integrity. A de-emphasis technique is employed to reduce the effects of Intersymbol Interference (ISI) due to the interconnect by optimizing voltage and timing margins for worst case channel loss. This results in a maximally open “eye” at the detection point, thereby allowing the receiver to receive data with acceptable Bit-Error Rate (BER).

To further minimize ISI, multiple bits of the same polarity that are output in succession are de-emphasized. Subsequent same bits are reduced by a factor of 3.5 dB in power. This amount is specified by PCIe to allow for maximum interoperability while minimizing the complexity of controlling the de-emphasis values. The high-speed interface requires AC coupling on the transmit side to eliminate the DC common mode voltage from the receiver. The range of AC capacitance allowed is 75 nF to 200 nF.

## Configuration Space

The PCIe function in the BCM43455 implements the configuration space as defined in the *PCI Express Base Specification v2.0*.

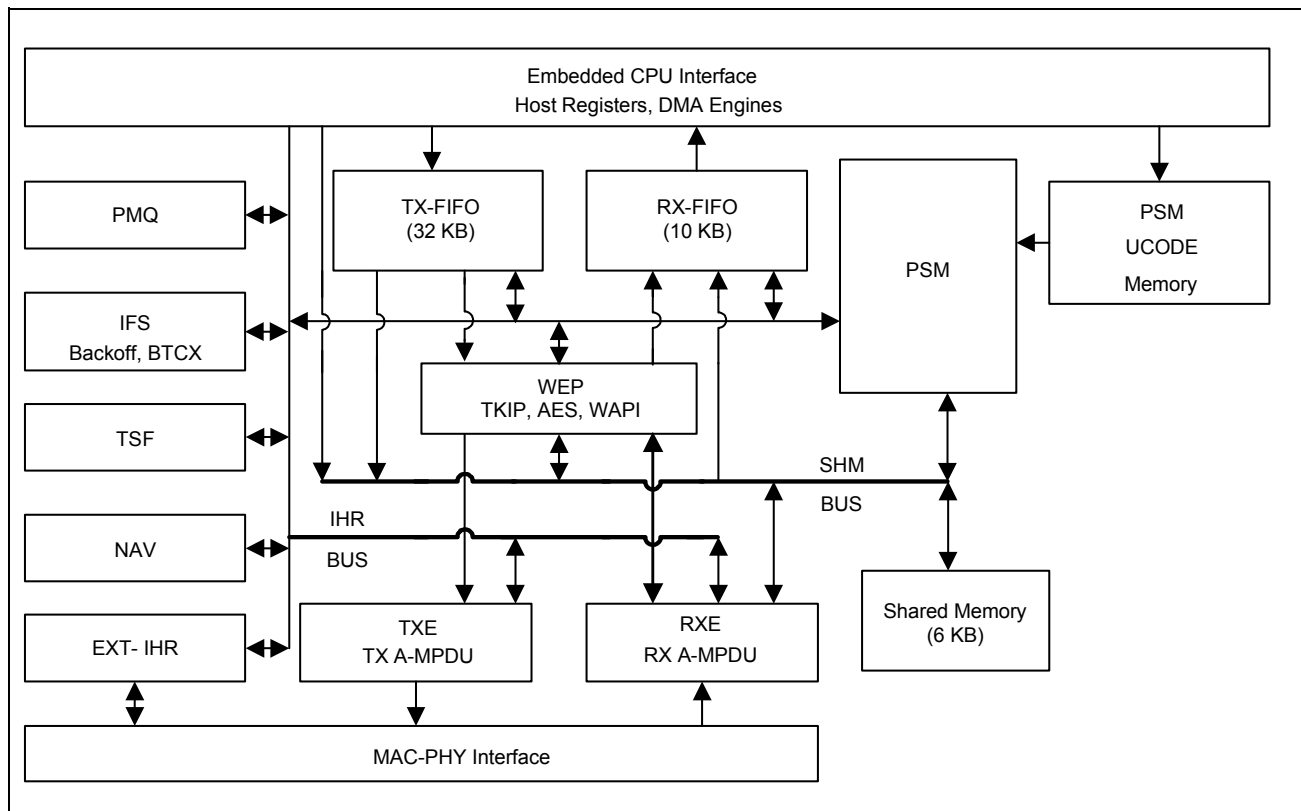
# Section 11: Wireless LAN MAC and PHY

## IEEE 802.11ac MAC

The BCM43455 WLAN MAC is designed to support high-throughput operation with low-power consumption. It does so without compromising the Bluetooth coexistence policies, thereby enabling optimal performance over both networks. In addition, several power saving modes have been implemented that allow the MAC to consume very little power while maintaining network-wide timing synchronization. The architecture diagram of the MAC is shown in [Figure 28](#).

The following sections provide an overview of the important modules in the MAC.

**Figure 28: WLAN MAC Architecture**



The BCM43455 WLAN media access controller (MAC) supports features specified in the IEEE 802.11 base standard, and amended by IEEE 802.11n. The key MAC features include:

- Enhanced MAC for supporting IEEE 802.11ac features
- Transmission and reception of aggregated MPDUs (A-MPDU) for high throughput (HT)
- Support for power management schemes, including WMM power-save, power-save multi-poll (PSMP) and multiphase PSMP operation
- Support for immediate ACK and Block-ACK policies
- Interframe space timing support, including RIFS
- Support for RTS/CTS and CTS-to-self frame sequences for protecting frame exchanges
- Back-off counters in hardware for supporting multiple priorities as specified in the WMM specification
- Timing synchronization function (TSF), network allocation vector (NAV) maintenance, and target beacon transmission time (TBTT) generation in hardware
- Hardware offload for AES-CCMP, legacy WPA TKIP, legacy WEP ciphers, WAPI, and support for key management
- Support for coexistence with Bluetooth and other external radios
- Programmable independent basic service set (IBSS) or infrastructure basic service set functionality
- Statistics counters for MIB support

## PSM

The programmable state machine (PSM) is a microcoded engine, which provides most of the low-level control to the hardware, to implement the IEEE 802.11 specification. It is a microcontroller that is highly optimized for flow control operations, which are predominant in implementations of communication protocols. The instruction set and fundamental operations are simple and general, which allows algorithms to be optimized until very late in the design process. It also allows for changes to the algorithms to track evolving IEEE 802.11 specifications.

The PSM fetches instructions from the microcode memory. It uses the shared memory to obtain operands for instructions, as a data store, and to exchange data between both the host and the MAC data pipeline (via the SHM bus). The PSM also uses a scratchpad memory (similar to a register bank) to store frequently accessed and temporary variables.

The PSM exercises fine-grained control over the hardware engines, by programming internal hardware registers (IHR). These IHRs are co-located with the hardware functions they control, and are accessed by the PSM via the IHR bus.

The PSM fetches instructions from the microcode memory using an address determined by the program counter, instruction literal, or a program stack. For ALU operations the operands are obtained from shared memory, scratchpad, IHRs, or instruction literals, and the results are written into the shared memory, scratchpad, or IHRs.

There are two basic branch instructions: conditional branches and ALU based branches. To better support the many decision points in the IEEE 802.11 algorithms, branches can depend on either a readily available signals from the hardware modules (branch condition signals are available to the PSM without polling the IHRs), or on the results of ALU operations.

## WEP

The wired equivalent privacy (WEP) engine encapsulates all the hardware accelerators to perform the encryption and decryption, and MIC computation and verification. The accelerators implement the following cipher algorithms: legacy WEP, WPA TKIP, WPA2 AES-CCMP.

The PSM determines, based on the frame type and association information, the appropriate cipher algorithm to be used. It supplies the keys to the hardware engines from an on-chip key table. The WEP interfaces with the TXE to encrypt and compute the MIC on transmit frames, and the RXE to decrypt and verify the MIC on receive frames.

## TXE

The transmit engine (TXE) constitutes the transmit data path of the MAC. It coordinates the DMA engines to store the transmit frames in the TXFIFO. It interfaces with WEP module to encrypt frames, and transfers the frames across the MAC-PHY interface at the appropriate time determined by the channel access mechanisms.

The data received from the DMA engines are stored in transmit FIFOs. The MAC supports multiple logical queues to support traffic streams that have different QoS priority requirements. The PSM uses the channel access information from the IFS module to schedule a queue from which the next frame is transmitted. Once the frame is scheduled, the TXE hardware transmits the frame based on a precise timing trigger received from the IFS module.

The TXE module also contains the hardware that allows the rapid assembly of MPDUs into an A-MPDU for transmission. The hardware module aggregates the encrypted MPDUs by adding appropriate headers and pad delimiters as needed.

## RXE

The receive engine (RXE) constitutes the receive data path of the MAC. It interfaces with the DMA engine to drain the received frames from the RXFIFO. It transfers bytes across the MAC-PHY interface and interfaces with the WEP module to decrypt frames. The decrypted data is stored in the RXFIFO.

The RXE module contains programmable filters that are programmed by the PSM to accept or filter frames based on several criteria such as receiver address, BSSID, and certain frame types.

The RXE module also contains the hardware required to detect A-MPDUs, parse the headers of the containers, and disaggregate them into component MPDUS.

## IFS

The IFS module contains the timers required to determine interframe space timing including RIFS timing. It also contains multiple backoff engines required to support prioritized access to the medium as specified by WMM.

The interframe spacing timers are triggered by the cessation of channel activity on the medium, as indicated by the PHY. These timers provide precise timing to the TXE to begin frame transmission. The TXE uses this information to send response frames or perform transmit frame-bursting (RIFS or SIFS separated, as within a TXOP).

The backoff engines (for each access category) monitor channel activity, in each slot duration, to determine whether to continue or pause the backoff counters. When the backoff counters reach 0, the TXE gets notified, so that it may commence frame transmission. In the event of multiple backoff counters decrementing to 0 at the same time, the hardware resolves the conflict based on policies provided by the PSM.

The IFS module also incorporates hardware that allows the MAC to enter a low-power state when operating under the IEEE power save mode. In this mode, the MAC is in a suspended state with its clock turned off. A sleep timer, whose count value is initialized by the PSM, runs on a slow clock and determines the duration over which the MAC remains in this suspended state. Once the timer expires the MAC is restored to its functional state. The PSM updates the TSF timer based on the sleep duration ensuring that the TSF is synchronized to the network.

The IFS module also contains the PTA hardware that assists the PSM in Bluetooth coexistence functions.

## TSF

The timing synchronization function (TSF) module maintains the TSF timer of the MAC. It also maintains the target beacon transmission time (TBTT). The TSF timer hardware, under the control of the PSM, is capable of adopting timestamps received from beacon and probe response frames in order to maintain synchronization with the network.

The TSF module also generates trigger signals for events that are specified as offsets from the TSF timer, such as uplink and downlink transmission times used in PSMP.

## NAV

The network allocation vector (NAV) timer module is responsible for maintaining the NAV information conveyed through the duration field of MAC frames. This ensures that the MAC complies with the protection mechanisms specified in the standard.

The hardware, under the control of the PSM, maintains the NAV timer and updates the timer appropriately based on received frames. This timing information is provided to the IFS module, which uses it as a virtual carrier-sense indication.

## MAC-PHY Interface

The MAC-PHY interface consists of a data path interface to exchange RX/TX data from/to the PHY. In addition, there is an programming interface, which can be controlled either by the host or the PSM to configure and control the PHY.

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## IEEE 802.11ac PHY

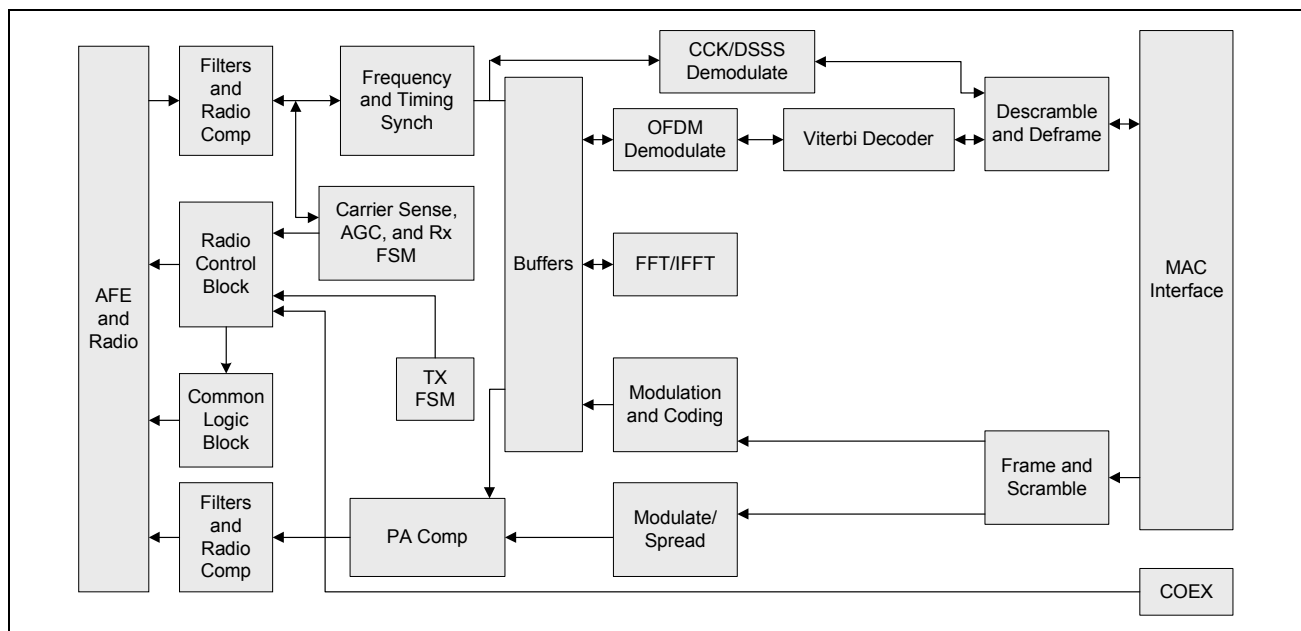
The BCM43455 WLAN Digital PHY is designed to comply with IEEE 802.11ac and IEEE 802.11a/b/g/n single-stream specifications to provide wireless LAN connectivity supporting data rates from 1 Mbps to 433.3 Mbps for low-power, high-performance handheld applications.

The PHY has been designed to work in the presence of interference, radio nonlinearity, and various other impairments. It incorporates optimized implementations of the filters, FFT and Viterbi decoder algorithms. Efficient algorithms have been designed to achieve maximum throughput and reliability, including algorithms for carrier sense/rejection, frequency/phase/timing acquisition and tracking, channel estimation and tracking. The PHY receiver also contains a robust IEEE 802.11b demodulator. The PHY carrier sense has been tuned to provide high throughput for IEEE 802.11g/11b hybrid networks with Bluetooth coexistence. It has also been designed for shared single antenna systems between WL and BT to support simultaneous RX-RX.

The key PHY features include:

- Programmable data rates from MCS0–MCS9 in 20, 40, and 80 MHz channels, as specified in IEEE 802.11ac.
- Supports Optional Short GI and Green Field modes in TX and RX.
- TX and RX LDPC for improved range and power efficiency.
- All scrambling, encoding, forward error correction, and modulation in the transmit direction and inverse operations in the receive direction.
- Supports IEEE 802.11h/k for worldwide operation.
- Advanced algorithms for low power, enhanced sensitivity, range, and reliability.
- Algorithms to improve performance in presence of Bluetooth.
- Automatic gain control scheme for blocking and non blocking application scenario for cellular applications.
- Closed loop transmit power control.
- Digital RF chip calibration algorithms to handle CMOS RF chip non-idealities.
- On-the-fly channel frequency and transmit power selection.
- Supports per-packet RX antenna diversity.
- Available per-packet channel quality and signal strength measurements.
- Designed to meet FCC and other worldwide regulatory requirements.

**Figure 29: WLAN PHY Block Diagram**



## Section 12: WLAN Radio Subsystem

The BCM43455 includes an integrated dual-band WLAN RF transceiver that has been optimized for use in 2.4 GHz and 5 GHz Wireless LAN systems. It has been designed to provide low-power, low-cost, and robust communications for applications operating in the globally available 2.4 GHz unlicensed ISM or 5 GHz U-NII bands. The transmit and receive sections include all on-chip filtering, mixing, and gain control functions.

Ten RF control signals are available to drive external RF switches and support optional external power amplifiers and low-noise amplifiers for each band. See the reference board schematics for further details.

A block diagram of the radio subsystem is shown in [Figure 30 on page 79](#). Note that integrated on-chip baluns (not shown) convert the fully differential transmit and receive paths to single-ended signal pins.

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### Receiver Path

The BCM43455 has a wide dynamic range, direct conversion receiver that employs high order on-chip channel filtering to ensure reliable operation in the noisy 2.4 GHz ISM band or the entire 5 GHz U-NII band. An on-chip low-noise amplifier (LNA) in the 2.4 GHz path is shared between the Bluetooth and WLAN receivers, while the 5 GHz receive path has a dedicated on-chip LNA. Control signals are available that can support the use of optional LNAs for each band, which can increase the receive sensitivity by several dB.

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### Transmit Path

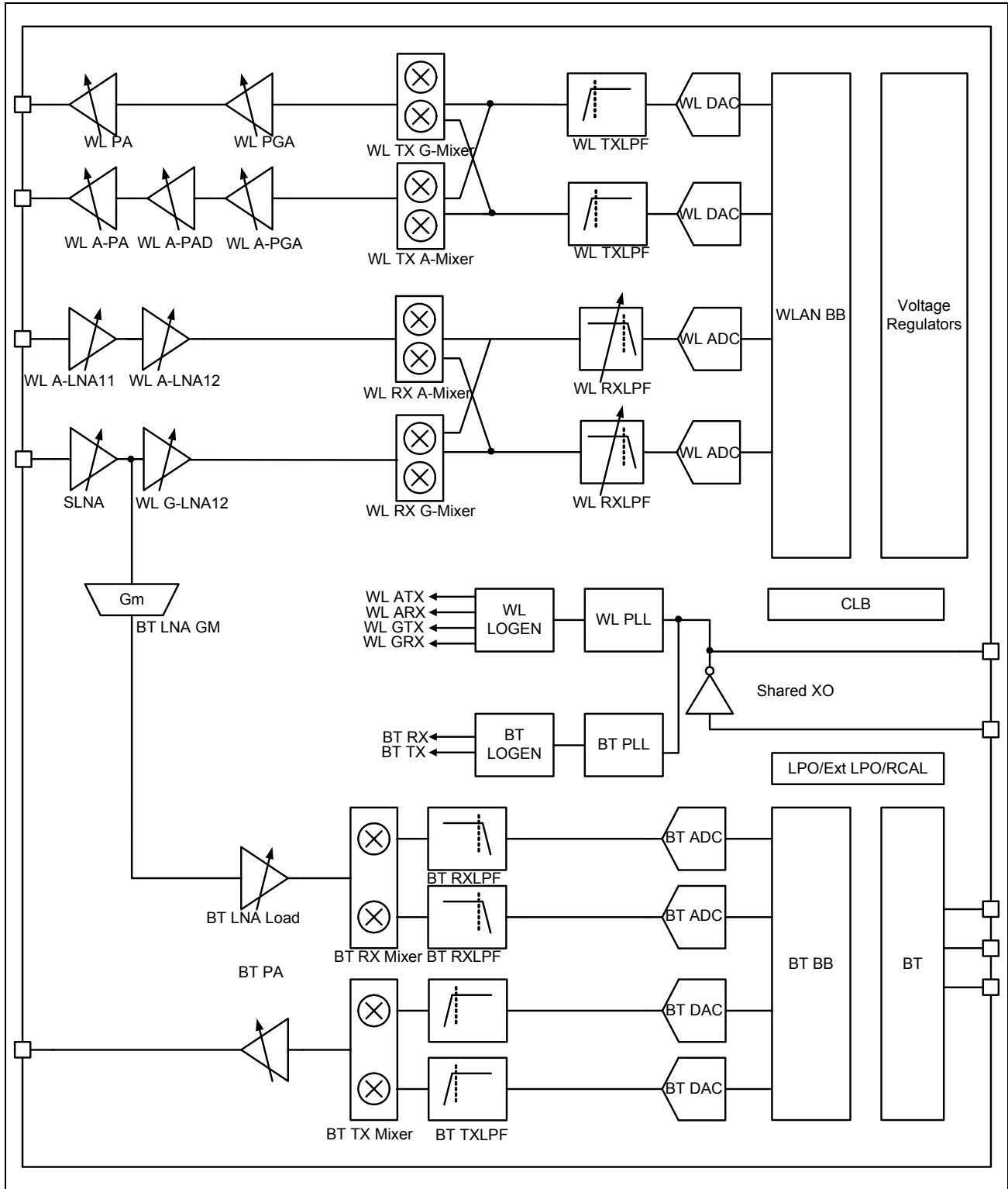
Baseband data is modulated and upconverted to the 2.4 GHz ISM or 5-GHz U-NII bands, respectively. Linear on-chip power amplifiers are included, which are capable of delivering high output powers while meeting IEEE 802.11ac and IEEE 802.11a/b/g/n specifications without the need for external PAs. When using the internal PAs, closed-loop output power control is completely integrated. As an option, external PAs can be used for even higher output power, in which case the closed-loop output power control is provided by means of a-band and g-band TSSI inputs from external power detectors.

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### Calibration

The BCM43455 features dynamic and automatic on-chip calibration to continually compensate for temperature and process variations across components. These calibration routines are performed periodically in the course of normal radio operation. Examples of some of the automatic calibration algorithms are baseband filter calibration for optimum transmit and receive performance, and LOFT calibration for carrier leakage reduction. In addition, I/Q Calibration, R Calibration, and VCO Calibration are performed on-chip. No per-board calibration is required in manufacturing test, which helps to minimize the test time and cost in large volume production.

Figure 30: Radio Functional Block Diagram





# Section 13: Ball Map and Pin Descriptions

## Ball Map

Figure 31: 140-Ball WLBGA Map—Bottom View (Balls Facing Up)

	11	10	9	8	7	6	5	4	3	2	1	
A		PCIE_TDN	PCIE_RDN	PCIE_RDP	SDIO_CLK	SDIO_DATA_3	LDO_VDDBAT5V	VOUT_3P3	LDO_VDD1P5	SR_VDDBAT5V	SR_PVSS	A
B	PCIE_REFCLKP	PCIE_TDP	PCIE_RTX_AVDD1P2	PCIE_CLKREQ_L	SDIO_DATA_1	SDIO_DATA_2	VOUT_BTLD02P5	VOUT_LNLD0	VOUT_CLDO	VOUT_PCIELDO	SR_VLX	B
C	PCIE_REFCLKN	PCIE_PLL_AVDD1P2	PCIE_VSS	VDDC	SDIO_DATA_0	SDIO_CMD	VSSC	WL_REG_ON	BT_REG_ON	PMU_AVSS	GPIO_0	C
D	GPIO_13	GPIO_14	NC1	PERST_L	PCI_PME_L	VDDIO_SD	VDDIO	GPIO_2	GPIO_1	GPIO_3	GPIO_6	D
E	NC2	AVSS_BBP_LL	AVDD_BBP_LL	NC3	VDDIO_RF	RF_SWCTRL_8	JTAG_SEL	GPIO_4	GPIO_5	VDDC	GPIO_7	E
F	RF_SWCTRL_0	RF_SWCTRL_1	VSSC	VDDC	RF_SWCTRL_4	RF_SWCTRL_7	VSSC	GPIO_9	GPIO_10	BT_VDDC	LPO_IN	F
G	WRF_XTAL_XON	WRF_XTAL_GND1P2	RF_SWCTRL_2	RF_SWCTRL_3	RF_SWCTRL_5	RF_SWCTRL_6	GPIO_8	BT_VDDO	BT_PCM_SYNC	VSSC	BT_PCM_IN	G
H	WRF_XTAL_XOP	WRF_XTAL_VDD1P35	WRF_XTAL_VDD1P2	WRF_SYNTH_VDD3P3		BT_GPIO_3	BT_GPIO_4	NC	BT_PCM_OUT	BT_I2S_DO	BT_PCM_CLK	H
J	WRF_PMU_VDD1P35	WRF_SYNTH_VDD1P2	WRF_SYNTH_GND	WRF_VCO_GND	BT_GPIO_2	BT_UART_CTS_N	VDDC	BT_VDDC	BT_I2S_WS	BT_I2S_DI	BT_I2S_CLK	J
K	WRF_RX5G_GND	WRF_AFE_VDD1P35	WRF_GENERAL_GND	WRF_EXT_TSSIA	GPIO_15	GPIO_16	VSSC	BT_GPIO_5	BT_UARTRTS_N	BT_UARTTXD	BT_UARTRXD	K
L	WRF_RFIN_5G	WRF_GENERAL2_GND	WRF_AFE_GND	WRF_GPAIO_OUT	BT_LNAVD1P2	BT_IFVSS	BT_PLLVSS	BT_CLKREQ	BT_HOST_WAKE	VSSC	BT_VDDC	L
M	WRF_PAOUT_5G	WRF_PA_GND3P3	WRF_TXMIX_VDD	WRF_RX2G_GND	BT_LNAVSS	BT_PAVSS	BT_PLLVD1P2	FM_PLLVSS	FM_RFVSS	FM_PLLVD1P2	BT_DEV_WAKE	M
N	WRF_PA_VDD3P3		WRF_PAOUT_2G	WRF_RFIN_2G	BT_RF	BT_PAVDD2P5	BT_IFVDD1P2	FM_RFIN	FM_RFVDD1P2	FM_AOUT2	FM_AOUT1	N
	11	10	9	8	7	6	5	4	3	2	1	

## Pin List by Pin Number

Table 17 lists BCM43455 pins by pin number. For a list of BCM43455 pins by pin name, see [Table 18 on page 83](#).

**Table 17: WLBGA Pin List by Pin Number**

Ball	Name
A1	SR_PVSS
A2	SR_VDDBAT5V
A3	LDO_VDD1P5
A4	VOUT_3P3
A5	LDO_VDDBAT5V
A6	SDIO_DATA_3
A7	SDIO_CLK
A8	PCIE_RDP
A9	PCIE_RDN
A10	PCIE_TDN
A11	–
B1	SR_VLX
B2	VOUT_PCIELDO
B3	VOUT_CLDO
B4	VOUT_LNLDO
B5	VOUT_BTLDO2P5
B6	SDIO_DATA_2
B7	SDIO_DATA_1
B8	PCIE_CLKREQ_L
B9	PCIE_RXTX_AVDD1P2
B10	PCIE_TDP
B11	PCIE_REFCLKP
C1	GPIO_0
C2	PMU_AVSS
C3	BT_REG_ON
C4	WL_REG_ON
C5	VSSC
C6	SDIO_CMD
C7	SDIO_DATA_0
C8	VDDC
C9	PCIE_VSS
C10	PCIE_PLL_AVDD1P2
C11	PCIE_REFCLKN

**Table 17: WLBGA Pin List by Pin Number (Cont.)**

Ball	Name
D1	GPIO_6
D2	GPIO_3
D3	GPIO_1
D4	GPIO_2
D5	VDDIO
D6	VDDIO_SD
D7	PCI_PME_L
D8	PERST_L
D9	NC1
D10	GPIO_14
D11	GPIO_13
E1	GPIO_7
E2	VDDC
E3	GPIO_5
E4	GPIO_4
E5	JTAG_SEL
E6	RF_SW_CTRL_8
E7	VDDIO_RF
E8	NC3
E9	AVDD_BBPLL
E10	AVSS_BBPLL
E11	NC2
F1	LPO_IN
F2	BT_VDDC
F3	GPIO_10
F4	GPIO_9
F5	VSSC
F6	RF_SW_CTRL_7
F7	RF_SW_CTRL_4
F8	VDDC
F9	VSSC
F10	RF_SW_CTRL_1
F11	RF_SW_CTRL_0

**Table 17: WLBGA Pin List by Pin Number (Cont.)**

<b>Ball</b>	<b>Name</b>
G1	BT_PCM_IN
G2	VSSC
G3	BT_PCM_SYNC
G4	BT_VDDO
G5	GPIO_8
G6	RF_SW_CTRL_6
G7	RF_SW_CTRL_5
G8	RF_SW_CTRL_3
G9	RF_SW_CTRL_2
G10	WRF_XTAL_GND1P2
G11	WRF_XTAL_XON
H1	BT_PCM_CLK
H2	BT_I2S_DO
H3	BT_PCM_OUT
H4	NC
H5	BT_GPIO_4
H6	BT_GPIO_3
H7	–
H8	WRF_SYNTH_VDD3P3
H9	WRF_XTAL_VDD1P2
H10	WRF_XTAL_VDD1P35
H11	WRF_XTAL_XOP
J1	BT_I2S_CLK
J2	BT_I2S_DI
J3	BT_I2S_WS
J4	BT_VDDC
J5	VDDC
J6	BT_UART_CTS_N
J7	BT_GPIO_2
J8	WRF_VCO_GND
J9	WRF_SYNTH_GND
J10	WRF_SYNTH_VDD1P2
J11	WRF_PMU_VDD1P35
K1	BT_UART_RXD
K2	BT_UART_TXD
K3	BT_UART_RTS_N
K4	BT_GPIO_5
K5	VSSC
K6	GPIO_16

**Table 17: WLBGA Pin List by Pin Number (Cont.)**

<b>Ball</b>	<b>Name</b>
K7	GPIO_15
K8	WRF_EXT_TSSIA
K9	WRF_GENERAL_GND
K10	WRF_AFE_VDD1P35
K11	WRF_RX5G_GND
L1	BT_VDDC
L2	VSSC
L3	BT_HOST_WAKE
L4	BT_CLK_REQ
L5	BT_PLLVSS
L6	BT_IFVSS
L7	BT_LNAVDD1P2
L8	WRF_GPAIO_OUT
L9	WRF_AFE_GND
L10	WRF_GENERAL2_GND
L11	WRF_RFIN_5G
M1	BT_DEV_WAKE
M2	FM_PLLVDD1P2
M3	FM_RFVSS
M4	FM_PLLVSS
M5	BT_PLLVDD1P2
M6	BT_PAVSS
M7	BT_LNAVSS
M8	WRF_RX2G_GND
M9	WRF_TXMIX_VDD
M10	WRF_PA_GND3P3
M11	WRF_PAOUT_5G
N1	FM_AOUT1
N2	FM_AOUT2
N3	FM_RFVDD1P2
N4	FM_RFIN
N5	BT_IFVDD1P2
N6	BT_PAVDD2P5
N7	BT_RF
N8	WRF_RFIN_2G
N9	WRF_PAOUT_2G
N10	–
N11	WRF_PA_VDD3P3

## Pin List by Pin Name

Table 18 lists BCM43455 pins by pin name. For a list of BCM43455 pins by pin number, see Table 17 on page 81.

**Table 18: WLBGA Pin List by Pin Name**

Name	Ball
AVDD_BBPLL	E9
AVSS_BBPLL	E10
BT_CLK_REQ	L4
BT_DEV_WAKE	M1
BT_GPIO_2	J7
BT_GPIO_3	H6
BT_GPIO_4	H5
BT_GPIO_5	K4
BT_HOST_WAKE	L3
BT_I2S_CLK	J1
BT_I2S_DI	J2
BT_I2S_DO	H2
BT_I2S_WS	J3
BT_IFVDD1P2	N5
BT_IFVSS	L6
BT_LNAVDD1P2	L7
BT_LNAVSS	M7
BT_PAVDD2P5	N6
BT_PAVSS	M6
BT_PCM_CLK	H1
BT_PCM_IN	G1
BT_PCM_OUT	H3
BT_PCM_SYNC	G3
BT_PLLVDD1P2	M5
BT_PLLVSS	L5
BT_REG_ON	C3
BT_RF	N7
BT_UART_CTS_N	J6
BT_UART_RTS_N	K3
BT_UART_RXD	K1
BT_UART_TXD	K2
BT_VDDC	F2
BT_VDDC	J4

**Table 18: WLBGA Pin List by Pin Name (Cont.)**

Name	Ball
BT_VDDC	L1
BT_VDDO	G4
FM_AOUT1	N1
FM_AOUT2	N2
FM_PLLVDD1P2	M2
FM_PLLVSS	M4
FM_RFIN	N4
FM_RFVDD1P2	N3
FM_RFVSS	M3
GPIO_0	C1
GPIO_1	D3
GPIO_2	D4
GPIO_3	D2
GPIO_4	E4
GPIO_5	E3
GPIO_6	D1
GPIO_7	E1
GPIO_8	G5
GPIO_9	F4
GPIO_10	F3
GPIO_13	D11
GPIO_14	D10
GPIO_15	K7
GPIO_16	K6
JTAG_SEL	E5
LDO_VDD1P5	A3
LDO_VDDBAT5V	A5
LPO_IN	F1
NC	H4
NC1	D9
NC2	E11
NC3	E8
PCIE_CLKREQ_L	B8

**Table 18: WLPGA Pin List by Pin Name (Cont.)**

<b>Name</b>	<b>Ball</b>
PCIE_PLL_AVDD1P2	C10
PCIE_RDN	A9
PCIE_RDP	A8
PCIE_REFCLKN	C11
PCIE_REFCLKP	B11
PCIE_RXTX_AVDD1P2	B9
PCIE_TDN	A10
PCIE_TDP	B10
PCIE_VSS	C9
PCI_PME_L	D7
PERST_L	D8
PMU_AVSS	C2
RF_SW_CTRL_0	F11
RF_SW_CTRL_1	F10
RF_SW_CTRL_2	G9
RF_SW_CTRL_3	G8
RF_SW_CTRL_4	F7
RF_SW_CTRL_5	G7
RF_SW_CTRL_6	G6
RF_SW_CTRL_7	F6
RF_SW_CTRL_8	E6
SDIO_CLK	A7
SDIO_CMD	C6
SDIO_DATA_0	C7
SDIO_DATA_1	B7
SDIO_DATA_2	B6
SDIO_DATA_3	A6
SR_PVSS	A1
SR_VDDBAT5V	A2
SR_VLX	B1
VDDC	C8
VDDC	E2
VDDC	F8
VDDC	J5
VDDIO	D5
VDDIO_RF	E7
VDDIO_SD	D6
VOUT_3P3	A4
VOUT_BTLD02P5	B5

**Table 18: WLPGA Pin List by Pin Name (Cont.)**

<b>Name</b>	<b>Ball</b>
VOUT_CLDO	B3
VOUT_LNLDO	B4
VOUT_PCIELDO	B2
VSSC	C5
VSSC	F5
VSSC	F9
VSSC	G2
VSSC	K5
VSSC	L2
WL_REG_ON	C4
WRF_AFE_GND	L9
WRF_AFE_VDD1P35	K10
WRF_EXT_TSSIA	K8
WRF_GENERAL2_GND	L10
WRF_GENERAL_GND	K9
WRF_GPAIO_OUT	L8
WRF_PAOUT_2G	N9
WRF_PAOUT_5G	M11
WRF_PA_GND3P3	M10
WRF_PA_VDD3P3	N11
WRF_PMU_VDD1P35	J11
WRF_RFIN_2G	N8
WRF_RFIN_5G	L11
WRF_RX2G_GND	M8
WRF_RX5G_GND	K11
WRF_SYNTG_GND	J9
WRF_SYNTG_VDD1P2	J10
WRF_SYNTG_VDD3P3	H8
WRF_TXMIX_VDD	M9
WRF_VCO_GND	J8
WRF_XTAL_GND1P2	G10
WRF_XTAL_VDD1P2	H9
WRF_XTAL_VDD1P35	H10
WRF_XTAL_XON	G11
WRF_XTAL_XOP	H11
–	A11
–	H7
–	N10

## Pin Descriptions

The signal name, type, and description of each pin in the BCM43455 is listed in [Table 19](#). The symbols shown under Type indicate pin directions (I/O = bidirectional, I = input, O = output) and the internal pull-up/pull-down characteristics (PU = weak internal pull-up resistor and PD = weak internal pull-down resistor), if any.

**Table 19: Signal Descriptions**

<b>Signal Name</b>	<b>WLBGA Ball</b>	<b>Type</b>	<b>Description</b>
<b>WLAN and Bluetooth Receive RF Signal Interface</b>			
WRF_RFIN_2G	N8	I	2.4 GHz Bluetooth and WLAN receiver shared input.
WRF_RFIN_5G	L11	I	5 GHz WLAN receiver input.
WRF_PAOUT_2G	N9	O	2.4 GHz WLAN PA output.
WRF_PAOUT_5G	M11	O	5 GHz WLAN PA output.
WRF_EXT_TSSIA	K8	I	5 GHz TSSI input from an optional external power amplifier/power detector.
WRF_GPAIO_OUT	L8	I/O	GPIO or 2.4 GHz TSSI input from an optional external power amplifier/power detector.
<b>RF Switch Control Lines</b>			
RF_SW_CTRL_0	F11	O	Programmable RF switch control lines. The control lines are programmable via the driver and NVRAM file.
RF_SW_CTRL_1	F10	O	
RF_SW_CTRL_2	G9	O	
RF_SW_CTRL_3	G8	O	
RF_SW_CTRL_4	F7	O	
RF_SW_CTRL_5	G7	O	
RF_SW_CTRL_6	G6	O	
RF_SW_CTRL_7	F6	O	
RF_SW_CTRL_8	E6	O	
<b>WLAN PCI Express Interface</b>			
PCIE_CLKREQ_L	B8	OD	PCIe clock request signal which indicates when the REFCLK to the PCIe interface can be gated. 1 = the clock can be gated. 0 = the clock is required.
PERST_L	D8	I (PU)	PCIe System Reset. This input is the PCIe reset as defined in the <i>PCIe Base Specification Version 1.1</i> .
PCIE_RDN	A9	I	Receiver differential pair (×1 lane).
PCIE_RDP	A8	I	
PCIE_REFCLKN	C11	I	PCIe differential clock inputs (negative and positive), 100 MHz differential.
PCIE_REFCLKP	B11	I	
PCIE_TDN	A10	O	Transmitter differential pair (×1 lane).
PCIE_TDP	B10	O	

**Table 19: Signal Descriptions (Cont.)**

<b>Signal Name</b>	<b>WLBGA Ball</b>	<b>Type</b>	<b>Description</b>
PCI_PME_L	D7	OD	PCI power management event output. Used to request a change in the device or system power state. The assertion and deassertion of this signal is asynchronous to the PCIe reference clock. This signal has an open-drain output structure, as per the <i>PCI Bus Local Bus Specification, Revision 2.3</i> .

**WLAN SDIO Bus Interface**

**Note:** These signals can also have alternate functionality depending on package and host interface mode.

SDIO_CLK	A7	I	SDIO clock input.
SDIO_CMD	C6	I/O	SDIO command line.
SDIO_DATA_0	C7	I/O	SDIO data line 0.
SDIO_DATA_1	B7	I/O	SDIO data line 1.
SDIO_DATA_2	B6	I/O	SDIO data line 2.
SDIO_DATA_3	A6	I/O	SDIO data line 3.

**WLAN GPIO Interface**

**Note:** The GPIO signals can be multiplexed via software and the JTAG\_SEL pin to behave as various specific functions.

GPIO_0	C1	I/O	
GPIO_1	D3	I/O	
GPIO_2	D4	I/O	
GPIO_3	D2	I/O	
GPIO_4	E4	I/O	Programmable GPIO pins:
GPIO_5	E3	I/O	GPIO_2 is TCK/SWCLK if
GPIO_6	D1	I/O	JTAG_SEL = 1
GPIO_7	E1	I/O	GPIO_3 is TMS/SWDIO if
GPIO_8	G5	I/O	JTAG_SEL = 1
GPIO_9	F4	I/O	GPIO_4 is TDIO if JTAG_SEL = 1
GPIO_10	F3	I/O	GPIO_5 is TDO if JTAG_SEL = 1
GPIO_13	D11	I/O	GPIO_6 is TRST_L if JTAG_SEL = 1
GPIO_14	D10	I/O	
GPIO_15	K7	I/O	
GPIO_16	K6	I/O	

**Table 19: Signal Descriptions (Cont.)**

<b>Signal Name</b>	<b>WLPGA Ball</b>	<b>Type</b>	<b>Description</b>
<b>JTAG/SWD Interface</b>			
JTAG_SEL	E5	I/O	JTAG select. This pin must be connected to ground if the JTAG/SWD interface is not used. It must be high to select SWD OR JTAG. When JTAG_SEL = 1: <ul style="list-style-type: none"> <li>• GPIO_2 is TCK/SWCLK</li> <li>• GPIO_3 is TMS/SWDIO</li> <li>• GPIO_4 is TDIO</li> <li>• GPIO_5 is TDO</li> <li>• GPIO_6 is TRST_L</li> </ul>
<b>Clocks</b>			
WRF_XTAL_XOP	H11	I	XTAL oscillator input.
WRF_XTAL_XON	G11	O	XTAL oscillator output.
LPO_IN	F1	I	External sleep clock input (32.768 kHz).
BT_CLK_REQ	L4	O	Reference clock request (shared by BT and WLAN).
<b>Bluetooth/FM Transceiver</b>			
BT_RF	N7	O	Bluetooth PA output.
FM_RFIN	N4	I	FM radio antenna port.
FM_AOUT1	N1	O	FM DAC output 1.
FM_AOUT2	N2	O	FM DAC output 2.
<b>Bluetooth PCM</b>			
BT_PCM_CLK	H1	I/O	PCM or SLIMbus clock; can be master (output) or slave (input).
BT_PCM_IN	G1	I	PCM data input or SLIMbus transport sensing.
BT_PCM_OUT	H3	O	PCM data output.
BT_PCM_SYNC	G3	I/O	PCM sync; can be master (output) or slave (input), or SLIMbus data.
<b>Bluetooth UART</b>			
BT_UART_CTS_N	J6	I	UART clear-to-send. Active-low clear-to-send signal for the HCI UART interface.
BT_UART_RTS_N	K3	O	UART request-to-send. Active-low request-to-send signal for the HCI UART interface. BT LED control pin.
BT_UART_RXD	K1	I	UART serial input. Serial data input for the HCI UART interface. BT RF disable pin 2.
BT_UART_TXD	K2	O	UART serial output. Serial data output for the HCI UART interface.



**Table 19: Signal Descriptions (Cont.)**

<b>Signal Name</b>	<b>WLBGA Ball</b>	<b>Type</b>	<b>Description</b>
<b>Bluetooth/FM I2S</b>			
BT_I2S_CLK	J1	I/O	I <sup>2</sup> S clock, can be master (output) or slave (input).
BT_I2S_DI	J2	I/O	I <sup>2</sup> S data input.
BT_I2S_DO	H2	I/O	I <sup>2</sup> S data output.
BT_I2S_WS	J3	I/O	I <sup>2</sup> S WS; can be master (output) or slave (input).
<b>Bluetooth GPIO</b>			
BT_GPIO_2	J7	I/O	Bluetooth general-purpose I/O.
BT_GPIO_3	H6	I/O	Bluetooth general-purpose I/O.
BT_GPIO_4	H5	I/O	Bluetooth general-purpose I/O.
BT_GPIO_5	K4	I/O	Bluetooth general-purpose I/O.
<b>Miscellaneous</b>			
WL_REG_ON	C4	I	Used by PMU to power-up or power down the internal BCM43455 regulators used by the WLAN section. Also, when deasserted, this pin holds the WLAN section in reset. This pin has an internal 200 k $\Omega$ pull-down resistor that is enabled by default. It can be disabled through programming.
BT_REG_ON	C3	I	Used by PMU to power-up or power down the internal BCM43455 regulators used by the Bluetooth/FM section. Also, when deasserted, this pin holds the Bluetooth/FM section in reset. This pin has an internal 200 k $\Omega$ pull-down resistor that is enabled by default. It can be disabled through programming.
BT_DEV_WAKE	M1	I/O	Bluetooth DEV_WAKE.
BT_HOST_WAKE	L3	I/O	Bluetooth HOST_WAKE.
<b>Integrated Voltage Regulators</b>			
SR_VDDBAT5V	A2	I	VBAT.
SR_VLX	B1	O	CBUCK switching regulator output. Refer to <a href="#">Table 44 on page 130</a> for details of the inductor and capacitor required on this output.
LDO_VDD1P5	A3	I	LNLDO input.
LDO_VDDBAT5V	A5	I	LDO VBAT.
WRF_XTAL_VDD1P35	H10	I	XTAL LDO input (1.35V).
WRF_XTAL_VDD1P2	H9	O	XTAL LDO output (1.2V).
VOUT_LNLDO	B4	O	Output of LNLDO.
VOUT_CLDO	B3	O	Output of core LDO.
VOUT_BTLDO2P5	B5	O	Output of BT LDO.

**Table 19: Signal Descriptions (Cont.)**

<b>Signal Name</b>	<b>WLPGA Ball</b>	<b>Type</b>	<b>Description</b>
VOUT_3P3	A4	O	LDO 3.3V output.
<b>Bluetooth Supplies</b>			
BT_PAVDD2P5	N6	PWR	Bluetooth PA power supply.
BT_LNAVDD1P2	L7	PWR	Bluetooth LNA power supply.
BT_IFVDD1P2	N5	PWR	Bluetooth IF block power supply.
BT_PLLVDD1P2	M5	PWR	Bluetooth RF PLL power supply.
<b>FM Transceiver Supplies</b>			
FM_RFVDD1P2	N3	PWR	FM RF power supply.
FM_PLLVDD1P2	M2	PWR	FM PLL power supply.
<b>WLAN Supplies</b>			
WRF_SYNTH_VDD3P3	H8	PWR	Synthesizer VDD 3.3V supply.
WRF_PA_VDD3P3	N11	PWR	2 GHz and 5 GHz PA 3.3V VBAT supply.
WRF_PMU_VDD1P35	J11	PWR	PMU 1.35V supply.
WRF_TXMIX_VDD	M9	PWR	3.3V supply for the TX Mix.
WRF_SYNTH_VDD1P2	J10	PWR	1.2V supply for the synthesizer.
WRF_AFE_VDD1P35	K10	PWR	1.35V supply for the AFE.
<b>Miscellaneous Supplies</b>			
VDDC	C8, E2, F8, J5	PWR	1.2V core supply for the WLAN.
VDDIO	D5	PWR	1.8V–3.3V VDDIO supply for the WLAN. Must be directly connected to PMU_VDDO and BT_VDDO on the PCB.
BT_VDDC	F2, J4, L1	PWR	1.2V core supply for the BT.
BT_VDDO	G4	PWR	1.8V–3.3V VDDIO supply for the BT. Must be directly connected to PMU_VDDO and VDDIO on the PCB.
VDDIO_SD	D6	PWR	1.8V–3.3V supply for the SDIO pads.
VDDIO_RF	E7	PWR	IO supply for the RF switch control pads (3.3V).
AVDD_BBPLL	E9	PWR	1.2V supply for the baseband PLL.
PCIE_PLL_AVDD1P2	C10	PWR	1.2V supply for the PCIe PLL.
VOUT_PCIELDO	B2	PWR	1.2V supply for the PCIe.
PCIE_RXTX_AVDD1P2	B9	PWR	1.2V supply for the PCIe TX/RX.
<b>Ground</b>			
WRF_VCO_GND	J8	GND	VCO/LOGEN ground.
WRF_AFE_GND	L9	GND	AFE ground.
WRF_XTAL_GND1P2	G10	GND	XTAL ground.
WRF_RX2G_GND	M8	GND	RX 2 GHz ground.
WRF_RX5G_GND	K11	GND	RX 5 GHz ground.
WRF_PA_GND3P3	M10	GND	PA ground.
WRF_GENERAL_GND	K9	GND	General ground.

**Table 19: Signal Descriptions (Cont.)**

<b>Signal Name</b>	<b>WLBGA Ball</b>	<b>Type</b>	<b>Description</b>
WRF_GENERAL2_GND	L10	GND	General ground.
WRF_SYNTG_GND	J9	GND	Ground.
VSSC	C5, F5, F9, G2, K5, L2	GND	Core ground for WLAN and BT.
SR_PVSS	A1	GND	Power ground.
PMU_AVSS	C2	GND	Quiet ground.
BT_PAVSS	M6	GND	Bluetooth PA ground.
BT_LNAVSS	M7	GND	Bluetooth LNA ground.
BT_IFVSS	L6	GND	Bluetooth IF block ground.
BT_PLLVSS	L5	GND	Bluetooth PLL ground.
FM_PLLVSS	M4	GND	FM PLL ground.
FM_RFVSS	M3	GND	FM RF ground.
AVSS_BBPLL	E10	GND	Baseband PLL ground.
PCIE_VSS	C9	GND	PCIe ground.
<b>No Connect</b>			
NC1	D9	–	No connect.
NC2	E11		
NC3	E8		
NC	H4	–	No connect.
<b>Depopulated Pins</b>			
–	A11, H7, N10	–	–

## WLAN GPIO Signals and Strapping Options

This section describes WLAN GPIO signals and strapping options. The pins are sampled at power-on reset (POR) to determine the various operating modes. Sampling occurs a few milliseconds after an internal POR or deassertion of the external POR. After the POR, each pin assumes the GPIO or alternative function specified in the signal descriptions table. Each strapping option pin has an internal pull-up (PU) or pull-down (PD) resistor that determines the default mode. To change the mode, connect an external PU resistor to VDDIO or a PD resistor to GND, using a 10 kΩ resistor or less.



**Note:** Refer to the reference board schematics for more information.

**Table 20: Strapping Options**

<i>Pin Name</i>	<i>Strap</i>	<i>WLBGA Ball</i>	<i>Default Internal Pull During Strap</i>	<i>Description</i>
GPIO_7	sdio_padvddio	E1	1	Default pull = 1.  SDIO interface voltage. 1 = 1.8V, 0 = 3.3V. Default is 1.8V.
GPIO_16	host_iface_sdio	K6	0	Default is PCIe. Pull high during POR to select SDIO.

## Multiplexed Bluetooth GPIO Signals

The Bluetooth GPIO pins (BT\_GPIO\_0 to BT\_GPIO\_7) are multiplexed pins and can be programmed to be used as GPIOs or for other Bluetooth interface signals such as I<sup>2</sup>S. The specific function for a given BT\_GPIO\_X pin is chosen by programming the Pad Function Control register for that specific pin. [Table 21](#) shows the possible options for each BT\_GPIO\_X pin. Note that each BT\_GPIO\_X pin's Pad Function Control register setting is independent (BT\_GPIO\_5 can be set to pad function 7 at the same time that BT\_GPIO\_3 is set to pad function 0). When the Pad Function Control register is set to 0, the BT\_GPIOs do not have specific functions assigned to them and behave as generic GPIOs. The A\_GPIO\_X pins described below are multiplexed behind the BCM43455's PCM and I<sup>2</sup>S interface pins.

**Table 21: GPIO Multiplexing Matrix**

Pin Name	Pad Function Control Register Setting								
	0	1	2	3	4	5	6	7	15
BT_UART_CTS_N	UART_CTS_N	-	-	-	-	-	-	A_GPIO[1]	-
BT_UART_RTS_N	UART_RTS_N	-	-	-	-	-	-	A_GPIO[0]	-
BT_UART_RXD	UART_RXD	-	-	-	-	-	-	GPIO[5]	-
BT_UART_TXD	UART_TXD	-	-	-	-	-	-	GPIO[4]	-
BT_PCM_IN	A_GPIO[3]	PCM_IN	PCM_IN	HCLK	-	-	-	I2S_SSDI/MSDI	SF_MISO
BT_PCM_OUT	A_GPIO[2]	PCM_OUT	PCM_OUT	LINK_IND	-	I2S_MSDO	-	I2S_SSDO	SF_MOSI
BT_PCM_SYNC	A_GPIO[1]	PCM_SYNC	PCM_SYNC	HCLK	-	I2S_MWS	-	I2S_SWS	SF_SPI_CSN
BT_PCM_CLK	A_GPIO[0]	PCM_CLK	PCM_CLK	-	-	I2S_MSCK	-	I2S_SSCK	SF_SPI_CLK
BT_I2S_DO	A_GPIO[5]	PCM_OUT	-	-	I2S_SSDO	I2S_MSDO	-	STATUS	-
BT_I2S_DI	A_GPIO[6]	PCM_IN	-	HCLK	I2S_SSDI/MSDI	-	-	TX_CON_FX	-
BT_I2S_WS	GPIO[7]	PCM_SYNC	-	LINK_IND	-	I2S_MWS	-	I2S_SWS	-
BT_I2S_CLK	GPIO[6]	PCM_CLK	-	-	INT_LPO	I2S_MSCK	-	I2S_SSCK	-
BT_GPIO_5	GPIO[5]	HCLK	-	I2S_MSCK	I2S_SSCK	-	-	CLK_REQ	-
BT_GPIO_4	GPIO[4]	LINK_IND	-	I2S_MSDO	I2S_SSDO	-	-	-	-
BT_GPIO_3	GPIO[3]	-	-	I2S_MWS	I2S_SWS	-	-	-	-
BT_GPIO_2	GPIO[2]	-	-	-	I2S_SSDI/MSDI	-	-	-	-
BT_CLK_REQ	WL/BT_CLK_REQ	-	-	-	-	-	-	A_GPIO[7]	-

The multiplexed GPIO signals are described in [Table 22](#).

**Table 22: Multiplexed GPIO Signals**

<b>Pin Name</b>	<b>Type</b>	<b>Description</b>
UART_CTS_N	I	Host UART clear to send.
UART_RTS_N	O	Device UART request to send.
UART_RXD	I	Device UART receive data.
UART_TXD	O	Host UART transmit data.
PCM_IN	I	PCM data input.
PCM_OUT	O	PCM data output.
PCM_SYNC	I/O	PCM sync signal, can be master (output) or slave (input).
PCM_CLK	I/O	PCM clock, can be master (output) or slave (input).
GPIO[7:0]	I/O	General-purpose I/O.
A_GPIO[7:0]	I/O	A group general-purpose I/O.
I2S_MSDO	O	I <sup>2</sup> S master data output.
I2S_MWS	O	I <sup>2</sup> S master word select.
I2S_MSCK	O	I <sup>2</sup> S master clock.
I2S_SSCK	I	I <sup>2</sup> S slave clock.
I2S_SSDO	O	I <sup>2</sup> S slave data output.
I2S_SWS	I	I <sup>2</sup> S slave word select.
I2S_SSDI/MSDI	I	I <sup>2</sup> S slave/master data input.
STATUS	O	Signals Bluetooth priority status.
TX_CON_FX	I	WLAN-BT coexist. Transmission confirmation; permission for BT to transmit.
RF_ACTIVE	O	WLAN-BT coexist. Asserted (logic high) during local BT RX and TX slots.
LINK_IND	O	BT receiver/transmitter link indicator.
CLK_REQ	O	WLAN/BT clock request output.
SF_SPI_CLK	O	SFlash SCLK: serial clock (output from master).
SF_MISO	I	SFlash MISO; SOMI: master input, slave output (output from slave).
SF_MOSI	O	SFlash MOSI; SIMO: master output, slave input (output from master).
SF_SPI_CSN	O	SFlash SS: slave select (active low, output from master).

## I/O States

The following notations are used in [Table 23](#):

- I: Input signal
- O: Output signal
- I/O: Input/Output signal
- PU = Pulled up
- PD = Pulled down
- NoPull = Neither pulled up nor pulled down

**Table 23: I/O States**

Name	I/O	Keeper <sup>a</sup>	Active Mode	Low Power State/Sleep (All Power Present)	Power-down <sup>b</sup> (BT_REG_ON and WL_REG_ON Held Low)	Out-of-Reset; Before SW Download (BT_REG_ON High; WL_REG_ON High)	(WL_REG_ON High and BT_REG_ON = 0) and VDDIOs Are Present	Power Rail
WL_REG_ON	I	N	Input; PD (pull-down can be disabled)	Input; PD (pull-down can be disabled)	Input; PD (of 200K)	Input; PD (of 200K)	Input; PD (of 200K)	–
BT_REG_ON	I	N	Input; PD (pull down can be disabled)	Input; PD (pull down can be disabled)	Input; PD (of 200K)	Input; PD (of 200K)	Input; PD (of 200K)	–
BT_CLK_REQ	I/O	Y	Open drain or push-pull (programmable). Active high.	Open drain or push-pull (programmable). Active high.	High-Z, NoPull	Open drain. Active high	Open drain. Active high.	BT_VDDO
BT_HOST_WAKE	I/O	Y	Input/Output; PU, PD, NoPull (programmable)	Input/Output; PU, PD, NoPull (programmable)	High-Z, NoPull	Input, PU	Input, PD	BT_VDDO
BT_DEV_WAKE	I/O	Y	Input/Output; PU, PD, NoPull (programmable)	Input; PU, PD, NoPull (programmable)	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_GPIO_2, BT_GPIO_3	I/O	Y	Input/Output; PU, PD, NoPull (programmable)	Input/Output; PU, PD, NoPull (programmable)	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_GPIO_4, BT_GPIO_5	I/O	Y	Input/Output; PU, PD, NoPull (programmable)	Input/Output; PU, PD, NoPull (programmable)	High-Z, NoPull	Input, PU	Input, PU	BT_VDDO
BT_UART_CTS_N	I	Y	Input; NoPull	Input; NoPull	High-Z, NoPull	Input; PU	Input; PU	BT_VDDO
BT_UART_RTS_N	O	Y	Output; NoPull	Output; NoPull	High-Z, NoPull	Input; PU	Input; PU	BT_VDDO
BT_UART_RXD	I	Y	Input; PU	Input; NoPull	High-Z, NoPull	Input; PU	Input; PU	BT_VDDO
BT_UART_TXD	O	Y	Output; NoPull	Output; NoPull	High-Z, NoPull	Input; PU	Input; PU	BT_VDDO
SDIO_DATA[0:3]	I/O	N	Input/Output; PU (SDIO Mode)	Input; PU (SDIO Mode)	High-Z, NoPull	Input; PU (SDIO Mode)	Input; PU (SDIO Mode)	WL_VDDIO

**Table 23: I/O States (Cont.)**

<b>Name</b>	<b>I/O</b>	<b>Keeper<sup>a</sup></b>	<b>Active Mode</b>	<b>Low Power State/Sleep (All Power Present)</b>	<b>Power-down<sup>b</sup> (BT_REG_ON and WL_REG_ON Held Low)</b>	<b>Out-of-Reset; Before SW Download (BT_REG_ON High; WL_REG_ON High)</b>	<b>(WL_REG_ON High and BT_REG_ON = 0) and VDDIOs Are Present</b>	<b>Power Rail</b>
SDIO_CMD	I/O	N	Input/Output; PU (SDIO Mode)	Input; PU (SDIO Mode)	High-Z, NoPull	Input; PU (SDIO Mode)	Input; PU (SDIO Mode)	WL_VDDIO
SDIO_CLK	I	N	Input; NoPull	Input; noPull	High-Z, NoPull	Input; noPull	Input; noPull	WL_VDDIO
BT_PCM_CLK	I/O	Y	Input; NoPull <sup>c</sup>	Input; NoPull <sup>c</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_PCM_IN	I/O	Y	Input; NoPull <sup>c</sup>	Input; NoPull <sup>c</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_PCM_OUT	I/O	Y	Input; NoPull <sup>c</sup>	Input; NoPull <sup>c</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_PCM_SYNC	I/O	Y	Input; NoPull <sup>c</sup>	Input; NoPull <sup>c</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_I2S_WS	I/O	Y	Input; NoPull <sup>d</sup>	Input; NoPull <sup>d</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_I2S_CLK	I/O	Y	Input; NoPull <sup>d</sup>	Input; NoPull <sup>d</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_I2S_DI	I/O	Y	Input; NoPull <sup>d</sup>	Input; NoPull <sup>d</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
BT_I2S_DO	I/O	Y	Input; NoPull <sup>d</sup>	Input; NoPull <sup>d</sup>	High-Z, NoPull	Input, PD	Input, PD	BT_VDDO
GPIO_0	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: PD])	Input/Output; PU, PD, NoPull (programmable [Default: PD])	High-Z, NoPull	Input; PD	Input; PD	WL_VDDIO
GPIO_1	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_2	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_3	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: PD])	Input/Output; PU, PD, NoPull (programmable [Default: PD])	High-Z, NoPull	Input; PD	Input; PD	WL_VDDIO
GPIO_4	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_5	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: PD])	Input/Output; PU, PD, NoPull (programmable [Default: PD])	High-Z, NoPull	Input; PD	Input; PD	WL_VDDIO
GPIO_6	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_7	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO



**Table 23: I/O States (Cont.)**

<b>Name</b>	<b>I/O</b>	<b>Keeper<sup>a</sup></b>	<b>Active Mode</b>	<b>Low Power State/Sleep (All Power Present)</b>	<b>Power-down<sup>b</sup> (BT_REG_ON and WL_REG_ON Held Low)</b>	<b>Out-of-Reset; Before SW Download (BT_REG_ON High; WL_REG_ON High)</b>	<b>(WL_REG_ON High and BT_REG_ON = 0) and VDDIOs Are Present</b>	<b>Power Rail</b>
GPIO_8	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: PD]) <sup>e</sup>	Input/Output; PU, PD, NoPull (programmable [Default: PD]) <sup>e</sup>	High-Z, NoPull	Input; PD <sup>e</sup>	Input; PD <sup>e</sup>	WL_VDDIO
GPIO_9	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: PD])	Input/Output; PU, PD, NoPull (programmable [Default: PD])	High-Z, NoPull	Input; PD	Input; PD	WL_VDDIO
GPIO_10	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_13	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_14	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_15	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
GPIO_16	I/O	Y	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	Input/Output; PU, PD, NoPull (programmable [Default: NoPull])	High-Z, NoPull	Input; NoPull	Input; NoPull	WL_VDDIO
RF_SW_CTRL [0:8]	I/O	Y	Output; NoPull	Output; NoPull	High-Z	Output; NoPull	Output; NoPull	VDDIO_RF

- a. Keeper column: N = pad has no keeper. Y = pad has a keeper. Keeper is always active except in power-down state. If there is no keeper, and it is an input and there is NoPull, then the pad should be driven to prevent leakage due to floating pad (SDIO\_CLK, for example).
- b. In the power-down state (xx\_REG\_ON=0): High-Z; NoPull => the pad is disabled because power is not supplied.
- c. Depending on whether the PCM interface is enabled and the configuration of PCM is in master or slave mode, it can be either output or input.
- d. Depending on whether the I<sup>2</sup>S interface is enabled and the configuration of I<sup>2</sup>S is in master or slave mode, it can be either output or input.
- e. NoPull when in SDIO mode.

## Section 14: DC Characteristics



**Note:** Values in this data sheet are design goals and are subject to change based on the results of device characterization.

### Absolute Maximum Ratings



**Caution!** The absolute maximum ratings in [Table 24](#) indicate levels where permanent damage to the device can occur, even if these limits are exceeded for only a brief duration. Functional operation is not guaranteed under these conditions. Operation at absolute maximum conditions for extended periods can adversely affect long-term reliability of the device.

**Table 24: Absolute Maximum Ratings**

<b>Rating</b>	<b>Symbol</b>	<b>Value</b>	<b>Unit</b>
DC supply for the VBAT and PA driver supply	VBAT	-0.5 to +6.0	V
DC supply voltage for digital I/O	VDDIO	-0.5 to 3.9	V
DC supply voltage for RF switch I/Os	VDDIO_RF	-0.5 to 3.9	V
DC input supply voltage for CLDO and LNLDO	–	-0.5 to 1.575	V
DC supply voltage for RF analog	VDDRF	-0.5 to 1.32	V
DC supply voltage for core	VDDC	-0.5 to 1.32	V
WRF_TCXO_VDD	–	-0.5 to 3.63	V
Maximum undershoot voltage for I/O <sup>a</sup>	V <sub>undershoot</sub>	-0.5	V
Maximum overshoot voltage for I/O <sup>a</sup>	V <sub>overshoot</sub>	VDDIO + 0.5	V
Maximum junction temperature	T <sub>j</sub>	125	°C

a. Duration not to exceed 25% of the duty cycle.

## Environmental Ratings

The environmental ratings are shown in [Table 25](#).

**Table 25: Environmental Ratings**

<b>Characteristic</b>	<b>Value</b>	<b>Units</b>	<b>Conditions/Comments</b>
Ambient Temperature ( $T_A$ )	-30 to +85	°C	Functional operation <sup>a</sup>
Storage Temperature	-40 to +125	°C	–
Relative Humidity	Less than 60	%	Storage
	Less than 85	%	Operation

- a. Functionality is guaranteed across this ambient temperature range. Optimal RF performance specified in the data sheet, however, is guaranteed only for -20°C to 75°C.

## Electrostatic Discharge Specifications

Extreme caution must be exercised to prevent electrostatic discharge (ESD) damage. Proper use of wrist and heel grounding straps to discharge static electricity is required when handling these devices. Always store unused material in its antistatic packaging.

**Table 26: ESD Specifications**

<b>Pin Type</b>	<b>Symbol</b>	<b>Condition</b>	<b>Minimum ESD Rating</b>	<b>Unit</b>
ESD Handling Reference: NQY00083, Section 3.4, Group D9, Table B	ESD_HAND_HBM	Human body model contact discharge per JEDEC EID/JESD22-A114	1	kV
CDM	ESD_HAND_CDM	Charged device model contact discharge per JEDEC EIA/JESD22-C101	250	V

## Recommended Operating Conditions and DC Characteristics



**Caution!** Functional operation is not guaranteed outside of the limits shown in [Table 27](#). Operation outside these limits for extended periods can adversely affect long-term reliability of the device.



**Note:** For DC absolute maximum rating (AMR), see [Table 24 on page 97](#).

**Table 27: Recommended Operating Conditions and DC Characteristics**

Parameter	Symbol	Value			Unit
		Minimum	Typical	Maximum	
DC supply voltage for VBAT	VBAT	3.0 <sup>a</sup>	–	5.25 <sup>b</sup>	V
DC supply voltage for core	VDD	1.14	1.2	1.26	V
DC supply voltage for RF blocks in chip	VDDRF	1.14	1.2	1.26	V
DC supply voltage for TCXO input buffer	WRF_TCXO_VDD	1.62	1.8	1.98	V
DC supply voltage for digital I/O	VDDIO	1.62	–	3.63	V
DC supply voltage for RF switch I/Os	VDDIO_RF	3.13	3.3	3.46	V
External TSSI input	TSSI	0.15	–	0.95	V
Internal POR threshold	Vth_POR	0.4	–	0.7	V
<b>Other Digital I/O Pins</b>					
For VDDIO = 1.8V:					
Input high voltage	VIH	0.65 × VDDIO	–	–	V
Input low voltage	VIL	–	–	0.35 × VDDIO	V
Output high voltage @ 2 mA	VOH	VDDIO – 0.45	–	–	V
Output low voltage @ 2 mA	VOL	–	–	0.45	V
For VDDIO = 3.3V:					
Input high voltage	VIH	2.00	–	–	V
Input low voltage	VIL	–	–	0.80	V
Output high voltage @ 2 mA	VOH	VDDIO – 0.4	–	–	V
Output low Voltage @ 2 mA	VOL	–	–	0.40	V
<b>RF Switch Control Output Pins<sup>c</sup></b>					
For VDDIO_RF = 3.3V:					
Output high voltage @ 2 mA	VOH	VDDIO – 0.4	–	–	V
Output low voltage @ 2 mA	VOL	–	–	0.40	V
Output capacitance	C <sub>OUT</sub>	–	–	5	pF

a. The BCM43455 is functional across this range of voltages. Optimal RF performance specified in the data sheet, however, is guaranteed only for 3.2V < VBAT < 4.8V.

b. The maximum continuous voltage is 5.25V.

c. Programmable 2 mA to 16 mA drive strength. Default is 10 mA.

# Section 15: Bluetooth RF Specifications

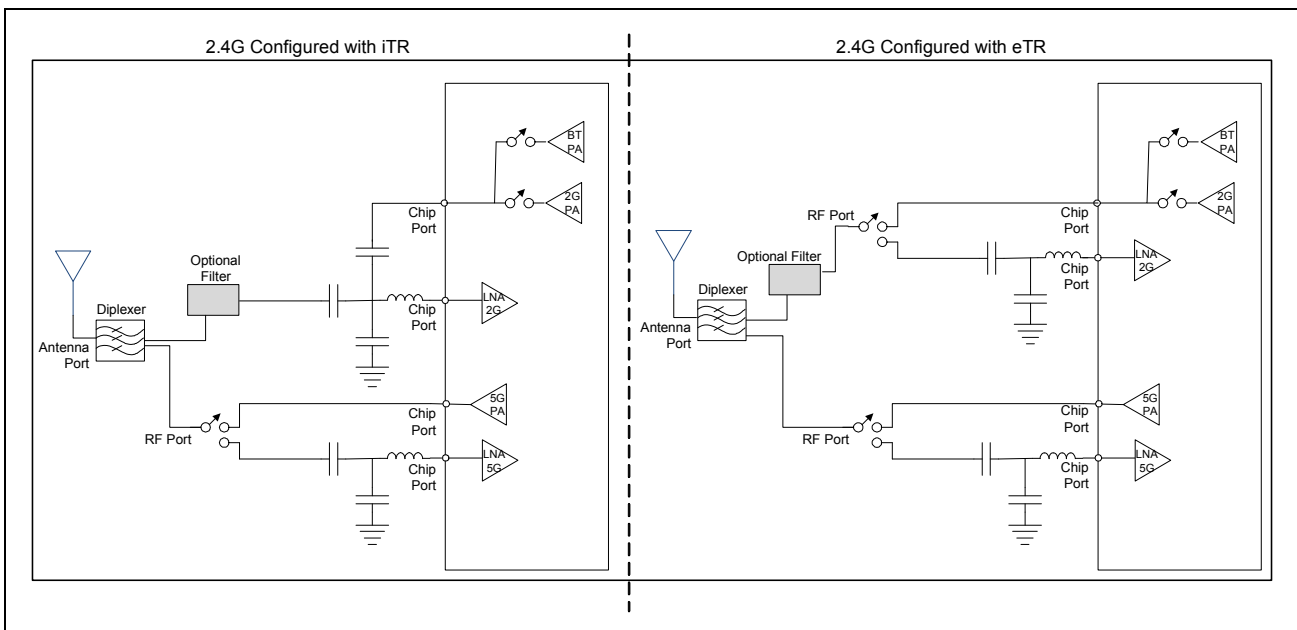


**Note:** Values in this data sheet are design goals and are subject to change based on device characterization results.

Unless otherwise stated, limit values apply for the conditions specified in [Table 25: “Environmental Ratings,”](#) on page 98 and [Table 27: “Recommended Operating Conditions and DC Characteristics,”](#) on page 99. Typical values apply for the following conditions:

- VBAT = 3.6V
- Ambient temperature +25°C

**Figure 32: Port Locations for Bluetooth Testing**



**Note:** All Bluetooth specifications are measured at the chip port, unless otherwise defined.



**Note:** The specifications in [Table 28 on page 101](#) are measured at the chip port input, unless otherwise defined.

**Table 28: Bluetooth Receiver RF Specifications**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>General</b>					
Frequency range	–	2402	–	2480	MHz
RX sensitivity <sup>a</sup>	GFSK, 0.1% BER, 1 Mbps	–	–93.5	–	dBm
	$\pi/4$ -DQPSK, 0.01% BER, 2 Mbps	–	–95.5	–	dBm
	8-DPSK, 0.01% BER, 3 Mbps	–	–89.5	–	dBm
Input IP3	–	–16	–	–	dBm
Maximum input at RF port	–	–	–	–20	dBm
<b>RX LO Leakage</b>					
2.4 GHz band	–	–	–	–90	dBm
<b>Interference Performance<sup>b</sup></b>					
C/I co-channel	GFSK, 0.1% BER	–	–	11	dB
C/I 1 MHz adjacent channel	GFSK, 0.1% BER	–	–	0	dB
C/I 2 MHz adjacent channel	GFSK, 0.1% BER	–	–	–30	dB
C/I $\geq$ 3 MHz adjacent channel	GFSK, 0.1% BER	–	–	–40	dB
C/I image channel	GFSK, 0.1% BER	–	–	–9	dB
C/I 1-MHz adjacent to image channel	GFSK, 0.1% BER	–	–	–20	dB
C/I co-channel	$\pi/4$ -DQPSK, 0.1% BER	–	–	13	dB
C/I 1 MHz adjacent channel	$\pi/4$ -DQPSK, 0.1% BER	–	–	0	dB
C/I 2 MHz adjacent channel	$\pi/4$ -DQPSK, 0.1% BER	–	–	–30	dB
C/I $\geq$ 3 MHz adjacent channel	$\pi/4$ -DQPSK, 0.1% BER	–	–	–40	dB
C/I image channel	$\pi/4$ -DQPSK, 0.1% BER	–	–	–7	dB
C/I 1 MHz adjacent to image channel	$\pi/4$ -DQPSK, 0.1% BER	–	–	–20	dB
C/I co-channel	8-DPSK, 0.1% BER	–	–	21	dB
C/I 1 MHz adjacent channel	8-DPSK, 0.1% BER	–	–	5	dB
C/I 2 MHz adjacent channel	8-DPSK, 0.1% BER	–	–	–25	dB
C/I $\geq$ 3 MHz adjacent channel	8-DPSK, 0.1% BER	–	–	–33	dB
C/I Image channel	8-DPSK, 0.1% BER	–	–	0	dB
C/I 1 MHz adjacent to image channel	8-DPSK, 0.1% BER	–	–	–13	dB

**Table 28: Bluetooth Receiver RF Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>Out-of-Band Blocking Performance (CW)</b>					
30–2000 MHz	0.1% BER	–	–10	–	dBm
2000–2399 MHz	0.1% BER	–	–27	–	dBm
2498–3000 MHz	0.1% BER	–	–27	–	dBm
3000 MHz–12.75 GHz	0.1% BER	–	–10	–	dBm
<b>Out-of-Band Blocking Performance, Modulated Interferer</b>					
<b>GFSK (1 Mbps) <sup>c</sup></b>					
698–716 MHz	WCDMA	–	–14	–	dBm
776–849 MHz	WCDMA	–	–14	–	dBm
824–849 MHz	GSM850	–	–14	–	dBm
824–849 MHz	WCDMA	–	–14	–	dBm
880–915 MHz	E-GSM	–	–13	–	dBm
880–915 MHz	WCDMA	–	–13	–	dBm
1710–1785 MHz	GSM1800	–	–18	–	dBm
1710–1785 MHz	WCDMA	–	–17	–	dBm
1850–1910 MHz	GSM1900	–	–20	–	dBm
1850–1910 MHz	WCDMA	–	–19	–	dBm
1880–1920 MHz	TD-SCDMA	–	–20	–	dBm
1920–1980 MHz	WCDMA	–	–20	–	dBm
2010–2025 MHz	TD-SCDMA	–	–20	–	dBm
2500–2570 MHz	WCDMA	–	–23	–	dBm
2500–2570 MHz <sup>d</sup>	Band 7	–	–25	–	dBm
2300–2400 MHz <sup>e</sup>	Band 40	–	–35.2	–	dBm
2570–2620 MHz <sup>f</sup>	Band 38	–	–21	–	dBm
2545–2575 MHz <sup>g</sup>	XGP Band	–	–22	–	dBm
<b><math>\pi/4</math>-DPSK (2 Mbps) <sup>c</sup></b>					
698–716 MHz	WCDMA	–	–10	–	dBm
776–794 MHz	WCDMA	–	–10	–	dBm
824–849 MHz	GSM850	–	–11	–	dBm
824–849 MHz	WCDMA	–	–11	–	dBm
880–915 MHz	E-GSM	–	–10	–	dBm
880–915 MHz	WCDMA	–	–10	–	dBm
1710–1785 MHz	GSM1800	–	–16	–	dBm
1710–1785 MHz	WCDMA	–	–16	–	dBm
1850–1910 MHz	GSM1900	–	–17	–	dBm
1850–1910 MHz	WCDMA	–	–16	–	dBm
1880–1920 MHz	TD-SCDMA	–	–18	–	dBm

**Table 28: Bluetooth Receiver RF Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
1920–1980 MHz	WCDMA	–	–17	–	dBm
2010–2025 MHz	TD-SCDMA	–	–19	–	dBm
2500–2570 MHz	WCDMA	–	–23	–	dBm
2500–2570 MHz <sup>d</sup>	Band 7	–	–24.4	–	dBm
2300–2400 MHz <sup>e</sup>	Band 40	–	–36.5	–	dBm
2570–2620 MHz <sup>f</sup>	Band 38	–	–21	–	dBm
2545–2575 MHz <sup>g</sup>	XGP Band	–	–22	–	dBm
<b>8-DPSK (3 Mbps)<sup>c</sup></b>					
698-716 MHz	WCDMA	–	–13	–	dBm
776-794 MHz	WCDMA	–	–13	–	dBm
824-849 MHz	GSM850	–	–13	–	dBm
824-849 MHz	WCDMA	–	–14	–	dBm
880-915 MHz	E-GSM	–	–13	–	dBm
880-915 MHz	WCDMA	–	–13	–	dBm
1710-1785 MHz	GSM1800	–	–18	–	dBm
1710-1785 MHz	WCDMA	–	–17	–	dBm
1850-1910 MHz	GSM1900	–	–19	–	dBm
1850-1910 MHz	WCDMA	–	–19	–	dBm
1880-1920 MHz	TD-SCDMA	–	–19	–	dBm
1920-1980 MHz	WCDMA	–	–19	–	dBm
2010-2025 MHz	TD-SCDMA	–	–20	–	dBm
2500-2570 MHz	WCDMA	–	–23	–	dBm
2500–2570 MHz <sup>d</sup>	Band 7	–	–24.7	–	dBm
2300–2400 MHz <sup>e</sup>	Band 40	–	–36.7	–	dBm
2570–2620 MHz <sup>f</sup>	Band 38	–	–21	–	dBm
2545–2575 MHz <sup>g</sup>	XGP Band	–	–22	–	dBm



**Table 28: Bluetooth Receiver RF Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>Spurious Emissions</b>					
30 MHz–1 GHz		–	–95	–62	dBm
1–12.75 GHz		–	–70	–47	dBm
851–894 MHz		–	–147	–	dBm/Hz
925–960 MHz		–	–147	–	dBm/Hz
1805–1880 MHz		–	–147	–	dBm/Hz
1930–1990 MHz		–	–147	–	dBm/Hz
2110–2170 MHz		–	–147	–	dBm/Hz

- a. Dirty TX is off.
- b. The maximum value represents the actual Bluetooth specification required for Bluetooth qualification as defined in the version 4.1 specification.
- c. 3 dB receiver desense.
- d. 2560 MHz performance is used.
- e. 2360 MHz performance is used.
- f. 2580 MHz performance is used.
- g. 2555 MHz performance is used.

**Table 29: Bluetooth Transmitter RF Specifications**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>Note:</b> The specifications in this table are measured at the Bluetooth chip port output, unless otherwise defined.					
<b>General</b>					
Frequency range		2402	–	2480	MHz
Basic rate (GFSK) TX power at Bluetooth		–	12	–	dBm
QPSK TX Power at Bluetooth		–	8	–	dBm
8PSK TX Power at Bluetooth		–	8	–	dBm
Power control step	–	2	4	8	dB
<b>Note:</b> Output power is with TCA and TSSI enabled.					
<b>GFSK In-Band Spurious Emissions</b>					
–20 dBc BW	–	–	0.93	1	MHz
<b>EDR In-Band Spurious Emissions</b>					
1.0 MHz <  M – N  < 1.5 MHz	M – N = the frequency range for which the spurious emission is measured relative to the transmit center frequency.	–	–38	–26	dBc
1.5 MHz <  M – N  < 2.5 MHz		–	–31	–20	dBm
M – N  ≥ 2.5 MHz <sup>a</sup>		–	–43	–40	dBm

**Table 29: Bluetooth Transmitter RF Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>Out-of-Band Spurious Emissions</b>					
30 MHz to 1 GHz	–	–	–	–36 <sup>b, c</sup>	dBm
1 GHz to 12.75 GHz	–	–	–	–30 <sup>b, d, e</sup>	dBm
1.8 GHz to 1.9 GHz	–	–	–	–47	dBm
5.15 GHz to 5.3 GHz	–	–	–	–47	dBm
<b>GPS Band Spurious Emissions</b>					
Spurious emissions	–	–	–103	–	dBm
<b>Out-of-Band Noise Floor<sup>f</sup></b>					
65–108 MHz	FM RX	–	–147	–	dBm/Hz
776–794 MHz	CDMA2000	–	–146	–	dBm/Hz
869–960 MHz	cdmaOne, GSM850	–	–146	–	dBm/Hz
925–960 MHz	E-GSM	–	–146	–	dBm/Hz
1570–1580 MHz	GPS	–	–146	–	dBm/Hz
1805–1880 MHz	GSM1800	–	–144	–	dBm/Hz
1930–1990 MHz	GSM1900, cdmaOne, WCDMA	–	–143	–	dBm/Hz
2110–2170 MHz	WCDMA	–	–137	–	dBm/Hz
2500–2570 MHz	Band 7	–	–130	–	dBm/Hz
2300–2400 MHz	Band 40	–	–130	–	dBm/Hz
2570–2620 MHz	Band 38	–	–132	–	dBm/Hz
2545–2575 MHz	XGP Band	–	–135	–	dBm/Hz

a. The typical number is measured at  $\pm 3$  MHz offset.

b. The maximum value represents the value required for Bluetooth qualification as defined in the v4.1 specification.

c. The spurious emissions during Idle mode are the same as specified in [Table 29 on page 104](#).

d. Specified at the Bluetooth Antenna port.

e. Meets this specification using a front-end band-pass filter.

f. Transmitted power in cellular and FM bands at the antenna port. See [Figure 32 on page 100](#) for location of the port.

**Table 30: Local Oscillator Performance**

<b>Parameter</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>LO Performance</b>				
Lock time	–	72	–	μs
Initial carrier frequency tolerance	–	±25	±75	kHz
<b>Frequency Drift</b>				
DH1 packet	–	±8	±25	kHz
DH3 packet	–	±8	±40	kHz
DH5 packet	–	±8	±40	kHz
Drift rate	–	5	20	kHz/50 μs
<b>Frequency Deviation</b>				
00001111 sequence in payload <sup>a</sup>	140	155	175	kHz
10101010 sequence in payload <sup>b</sup>	115	140	–	kHz
Channel spacing	–	1	–	MHz

a. This pattern represents an average deviation in payload.

b. Pattern represents the maximum deviation in payload for 99.9% of all frequency deviations.

**Table 31: BLE RF Specifications**

<b>Parameter</b>	<b>Conditions</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Frequency range	–	2402	–	2480	MHz
RX sense <sup>a</sup>	GFSK, 0.1% BER, 1 Mbps	–	–96.5	–	dBm
TX power <sup>b</sup>	–	–	8.5	–	dBm
Mod Char: delta F1 average	–	225	255	275	kHz
Mod Char: delta F2 max. <sup>c</sup>	–	230	–	–	%
Mod Char: ratio	–	0.8	1	–	%

a. Dirty TX is Off.

b. The BLE TX power cannot exceed 10 dBm EIRP specification limit. The front-end losses and antenna gain/loss must be factored in so as not to exceed the limit.

c. At least 99.9% of all delta F2 max. frequency values recorded over 10 packets must be greater than 185 kHz.

## Section 16: FM Receiver Specifications

Unless otherwise stated, limit values apply for the conditions specified in [Table 25: “Environmental Ratings,” on page 98](#) and [Table 27: “Recommended Operating Conditions and DC Characteristics,” on page 99](#). Typical values apply for the following conditions:

- VBAT = 3.6V
- Ambient temperature +25°C

**Table 32: FM Receiver Specifications**

<b>Parameter</b>	<b>Conditions<sup>a</sup></b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Units</b>
<b>RF Parameters</b>					
Operating frequency <sup>b</sup>	Frequencies inclusive	65	–	108	MHz
Sensitivity <sup>c</sup>	FM only SNR $\geq$ 26 dB	–	–1	–	dB $\mu$ V EMF
		–	0.9	–	$\mu$ V EMF
		–	–7	–	dB $\mu$ V
Receiver adjacent channel selectivity <sup>c, d</sup>	Measured for 30 dB SNR at the audio output with best tune. Signal of interest: 23 dB $\mu$ V EMF (14.1 $\mu$ V EMF),	–	51	–	dB
		–	62	–	dB
		–	–	–	–
Intermediate signal plus noise-to-noise ratio (S+N)/N <sup>c</sup>	Vin = 20 dB $\mu$ V EMF (10 $\mu$ V EMF)	45	53	–	dB
Intermodulation performance <sup>c, d</sup>	Blocker level increased until desired at 30 dB SNR Wanted Signal: 33 dB $\mu$ V EMF (45 $\mu$ V EMF) Modulated Interferer: At $f_{\text{Wanted}}$ $\pm$ 400 kHz and $\pm$ 4 MHz CW Interferer: At $f_{\text{Wanted}} \pm$ 800 kHz and $\pm$ 8 MHz	–	55	–	dBc
AM suppression, mono <sup>c</sup>	Vin = 23 dB $\mu$ V EMF (14.1 $\mu$ V EMF) AM at 400 Hz with m = 0.3 No A-weighted or any other filtering applied.	40	–	–	dB
<b>RDS</b>					
RDS Sensitivity <sup>e, f</sup>	RDS deviation = 1.2 kHz	–	16	–	dB $\mu$ V EMF
		–	6.3	–	$\mu$ V EMF
		–	10	–	dB $\mu$ V
	RDS deviation = 2 kHz	–	12	–	dB $\mu$ V EMF
		–	4	–	$\mu$ V EMF
		–	6	–	dB $\mu$ V

**Table 32: FM Receiver Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions<sup>a</sup></b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Units</b>
RDS selectivity <sup>f</sup>	Wanted Signal: 33 dB $\mu$ V EMF (45 $\mu$ V EMF), 2 kHz RDS deviation with best tune Interferer: $\Delta f = 40$ kHz, $f_{mod} = 1$ kHz				
	$\pm 200$ kHz	–	49	–	dB
	$\pm 300$ kHz	–	52	–	dB
	$\pm 400$ kHz	–	52	–	dB
RF input impedance	–	1.5	–	–	k $\Omega$
Antenna tuning capacitor	–	2.5	–	30	pF
Maximum input level <sup>c</sup>	SNR > 26 dB	–	–	113	dB $\mu$ V EMF
		–	–	446	mV EMF
		–	–	107	dB $\mu$ V
RF conducted emissions	Local oscillator breakthrough measured on the reference port	–	–	–55	dBm
	869–894 MHz, 925–960 MHz, 1805–1880 MHz, 1930–1990 MHz. GPS	–	–	–90	dBm
RF blocking levels at the FM antenna input 40 dB SNR (assumes a 50 $\Omega$ at the radio input and excludes spurs)	GSM850, E-GSM (std), BW = 0.2 MHz, 824–849 MHz 880–915 MHz	–	5	–	dBm
	GSM850, E-GSM (edge), BW = 0.2 MHz, 824–849 MHz 880–915 MHz	–	–4	–	dBm
	GSM DCS 1800, PCS 1900 (std/edge), BW = 0.2 MHz, 1710–1785 MHz 1850–1910 MHz	–	12	–	dBm
	WCDMA: II(I), III (IV, X), BW = 5 MHz, 1850–1980 MHz (1920–1980 MHz), 1710–1785 MHz (1710–1755 MHz, 1710–1770 MHz)	–	12	–	dBm

**Table 32: FM Receiver Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions<sup>a</sup></b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Units</b>
–	WCDMA: V(VI), VIII, XII, XIII, XIV, BW = 5 MHz, 824–849 MHz (830–840 MHz), 880–915 MHz	–	1	–	dBm
–	CDMA2000, cdmaOne, BW = 1.25 MHz, 824–849 MHz, 887–925 MHz, 776–794 MHz	–	–3	–	dBm
–	CDMA2000, cdmaOne, BW = 1.25 MHz, 1850–1910 MHz, 1750–1780 MHz, 1920–1980 MHz	–	12	–	dBm
–	Bluetooth, BW = 1 MHz, 2402–2480 MHz	–	11	–	dBm
–	IEEE 802.11g/b, BW = 20 MHz, 2400–2483.5 MHz	–	11	–	dBm
–	IEEE 802.11a, BW = 20 MHz, 4915–5825 MHz	–	6	–	dBm
2500–2570 MHz	Band 7	–	11	–	dBm
2300–2400 MHz	Band 40	–	11	–	dBm
2570–2620 MHz	Band 38	–	11	–	dBm
2545–2575 MHz	XGP Band	–	11	–	dBm
<b>Tuning</b>					
Frequency step	–	10	–	–	kHz
Settling time	Single-frequency switch in any direction to a frequency within the bands 88–108 MHz or 76–90 MHz. Time measured to within 5 kHz of the final frequency.	–	150	–	µs
Search time	Total time for an automatic search to sweep from 88–108 MHz or 76–90 MHz (and reverse direction) assuming no channels are found.	–	–	8	sec
<b>General Audio</b>					
Audio output level <sup>g</sup>	–	–14.5	–	–12.5	dBFS
Maximum audio output level <sup>h</sup>	–	–	–	0	dBFS
Audio DAC output level <sup>g</sup>	–	72	–	88	mVrms
Maximum DAC audio output level <sup>h</sup>	–	–	333	–	mVrms
Audio DAC output level difference <sup>i</sup>	–	–1	–	1	dB

**Table 32: FM Receiver Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions<sup>a</sup></b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Units</b>
Left and right AC mute	FM input signal fully muted with DAC enabled	60	–	–	dB
Left and right hard mute	FM input signal fully muted with DAC disabled	80	–	–	dB
Soft mute attenuation and start level	Muting is performed dynamically proportional to the FM wanted input signal C/N. The muting characteristic is fully programmable. Refer to “ <a href="#">Audio Features</a> ” on page 62 for further details.	–	–	–	–
Maximum signal plus noise-to-noise ratio (S + N)/N, mono <sup>i</sup>	–	–	68	–	dB
Maximum signal plus noise-to-noise ratio (S + N) ÷ N, stereo <sup>g</sup>	–	–	64	–	dB
Total harmonic distortion, mono	Vin = 66 dBμV EMF (2 mV EMF), Δf = 75 kHz, fmod = 400 Hz	–	–	1.5	%
	Δf = 75 kHz, fmod = 1 kHz	–	–	–60	%
	Δf = 75 kHz, fmod = 3 kHz	–	–	0.8	%
	Δf = 100 kHz, fmod = 1 kHz	–	–	1.0	%
Total harmonic distortion, stereo	Vin = 66 dBμV EMF (2 mV EMF) Δf = 67.5 kHz, fmod = 1 kHz, Δf Pilot = 7.5 kHz, L = R	–	–	1.5	%
Audio spurious products <sup>i</sup>	Range from 300 Hz to 15 kHz, with respect to 1 kHz tone	–	–	–60	dBc
Audio bandwidth, upper (–3 dB point)	Vin = 66 dBμV EMF (2 mV EMF) Δf = 8 kHz, for 50 μs	15	–	–	kHz
Audio bandwidth, lower (–3 dB point)	–	–	–	20	Hz
Audio in-band ripple	100 Hz to 13 kHz, Vin = 66 dBμV EMF (2 mV EMF) Δf = 8 kHz, for 50 μs	–0.5	–	0.5	dB
De-emphasis time constant tolerance	With respect to 50 and 75 μs	–	–	±5	%
RSSI range	With 1 dB resolution and ± 5 dB accuracy at room temp	3	–	83	dBμV EMF
		1.41	–	1.41E + 04	μV EMF
		–3	–	77	dBμV
<b>Stereo Decoder</b>					
Stereo channel separation	Forced Stereo mode Vin = 66 dBμV EMF (2 mV EMF), Δf = 67.5 kHz, fmod = 1 kHz, Δf Pilot = 6.75 kHz R = 0, L = 1	–	48	–	dB

**Table 32: FM Receiver Specifications (Cont.)**

<b>Parameter</b>	<b>Conditions<sup>a</sup></b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Units</b>
Mono stereo blend and switching	Blending and switching is dynamically proportional to the FM wanted input signal C/N. The blending and switching characteristics are fully programmable. Refer to “Audio Features” on page 62 for further details.	–	–	–	–
Pilot suppression	$V_{in} = 66 \text{ dB}\mu\text{V EMF (2 mV EMF)}$ , $\Delta f = 75 \text{ kHz}$ , $f_{mod} = 1 \text{ kHz}$	46	–	–	dB
<b>Pause detection</b>					
Audio level at which a pause is detected	Relative to 1 kHz tone, $\Delta f = 22.5 \text{ kHz}$	–	–	–	–
	Four values in 3 dB steps	–21	–	–12	dB
Audio pause duration	Four values	20	–	40	ms

- Following conditions are applied to all relevant tests unless otherwise indicated: Pre-emphasis and de-emphasis of 50  $\mu\text{s}$ , R = L for mono, DAC Load  $\geq 20 \text{ k}\Omega$ , BAF = 300 Hz to 15 kHz, and A-weighted filtering applied.
- Contact Broadcom regarding applications that operate between 65 and 76 MHz.
- Wanted Signal:  $\Delta f = 22.5 \text{ kHz}$ , and  $f_{mod} = 1 \text{ kHz}$ .
- Interferer:  $\Delta f = 22.5 \text{ kHz}$ , and  $f_{mod} = 1 \text{ kHz}$ .
- RDS sensitivity numbers are for 87.5–108 MHz only.
- $V_{in} = \Delta f = 32 \text{ kHz}$ ,  $f_{mod} = 1 \text{ kHz}$ ,  $\Delta f \text{ Pilot} = 7.5 \text{ kHz}$ , and 95% of blocks decoded with no errors after correction
- $V_{in} = 66 \text{ dB}\mu\text{V EMF (2 mV EMF)}$ ,  $\Delta f = 22.5 \text{ kHz}$ ,  $f_{mod} = 1 \text{ kHz}$ , and  $\Delta f \text{ Pilot} = 6.75 \text{ kHz}$ .
- $V_{in} = 66 \text{ dB}\mu\text{V EMF (2 mV EMF)}$ ,  $\Delta f = 100 \text{ kHz}$ ,  $f_{mod} = 1 \text{ kHz}$ , and  $\Delta f \text{ Pilot} = 6.75 \text{ kHz}$ .
- $V_{in} = 66 \text{ dB}\mu\text{V EMF (2 mV EMF)}$ ,  $\Delta f = 22.5 \text{ kHz}$ , and  $f_{mod} = 1 \text{ kHz}$ .



# Section 17: WLAN RF Specifications

## Introduction

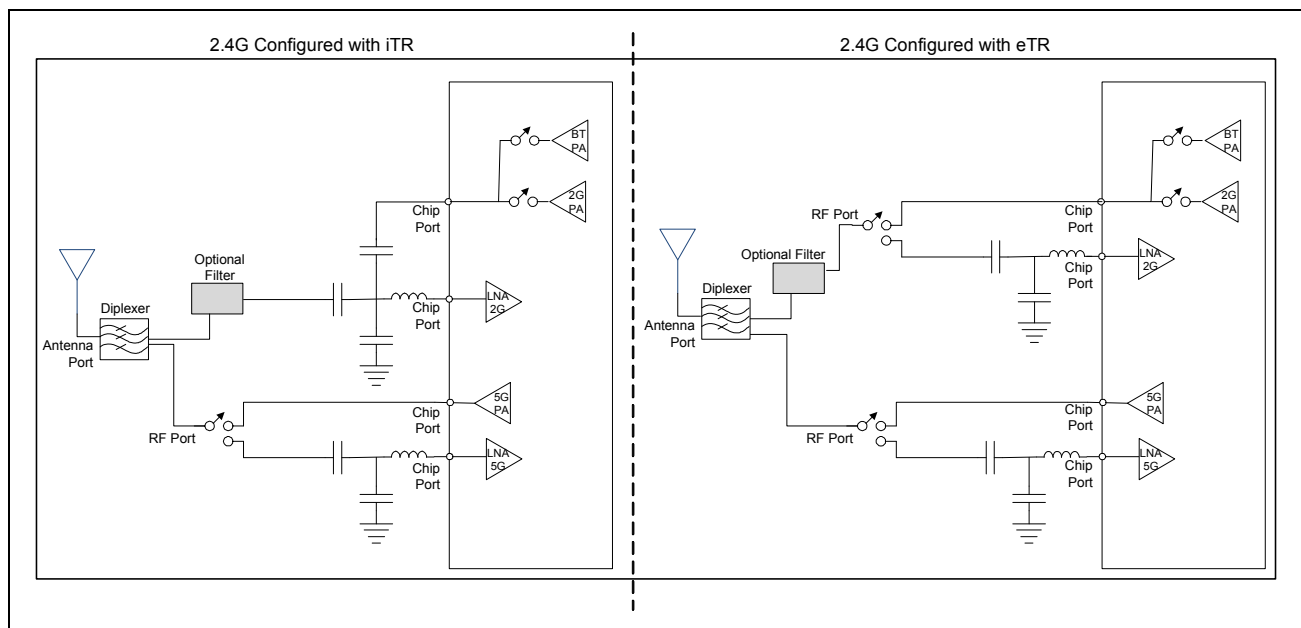
The BCM43455 includes an integrated dual-band direct conversion radio that supports the 2.4 GHz and the 5 GHz bands. This section describes the RF characteristics of the 2.4 GHz and 5 GHz radio.

**Note:** Values in this section of the data sheet are design goals and are subject to change based on device characterization results.

Unless otherwise stated, limit values apply for the conditions specified in [Table 25: “Environmental Ratings,” on page 98](#) and [Table 27: “Recommended Operating Conditions and DC Characteristics,” on page 99](#). Typical values apply for the following conditions:

- VBAT = 3.6V
- Ambient temperature +25°C

**Figure 33: Port Locations for WLAN Testing**



**Note:** Unless otherwise defined, all WLAN specifications are provided at the chip port.

## 2.4 GHz Band General RF Specifications

**Table 33: 2.4 GHz Band General RF Specifications**

<i>Item</i>	<i>Condition</i>	<i>Minimum</i>	<i>Typical</i>	<i>Maximum</i>	<i>Unit</i>
TX/RX switch time	Including TX ramp down	–	–	5	μs
RX/TX switch time	Including TX ramp up	–	–	2	μs
Power-up and power-down ramp time	DSSS/CCK modulations	–	–	<2	μs

## WLAN 2.4 GHz Receiver Performance Specifications



**Note:** The specifications shown in the following table are provided at the chip port, unless otherwise defined.

**Table 34: WLAN 2.4 GHz Receiver Performance Specifications**

<i>Parameter</i>	<i>Condition/Notes</i>	<i>Minimum</i>	<i>Typical</i>	<i>Maximum</i>	<i>Unit</i>
Frequency range	–	2400	–	2500	MHz
RX sensitivity IEEE 802.11b (8% PER for 1024 octet PSDU)	1 Mbps DSSS	–	–98.7	–	dBm
	2 Mbps DSSS	–	–96.0	–	dBm
	5.5 Mbps DSSS	–	–94.4	–	dBm
	11 Mbps DSSS	–	–90.7	–	dBm
RX sensitivity IEEE 802.11g (10% PER for 1024 octet PSDU)	6 Mbps OFDM	–	–95.3	–	dBm
	9 Mbps OFDM	–	–94.3	–	dBm
	12 Mbps OFDM	–	–93.5	–	dBm
	18 Mbps OFDM	–	–90.9	–	dBm
	24 Mbps OFDM	–	–87.7	–	dBm
	36 Mbps OFDM	–	–84.4	–	dBm
	48 Mbps OFDM	–	–79.6	–	dBm
RX sensitivity IEEE 802.11n (10% PER for 4096 octet PSDU) <sup>a</sup> Defined for default parameters: 800 ns GI and non-STBC.	20 MHz channel spacing for all MCS rates				
	MCS0	–	–94.8	–	dBm
	MCS1	–	–92.3	–	dBm
	MCS2	–	–89.8	–	dBm
	MCS3	–	–86.4	–	dBm
	MCS4	–	–83.3	–	dBm
	MCS5	–	–78.6	–	dBm
	MCS6	–	–76.7	–	dBm
MCS7	–	–74.7	–	dBm	

**Table 34: WLAN 2.4 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
RX sensitivity IEEE 802.11ac (10% PER for 4096 octet PSDU) <sup>b</sup> Defined for default parameters: 800 ns GI and non-STBC	20 MHz channel spacing for all MCS rates				
	MCS0	–	–95.0	–	dBm
	MCS1	–	–92.3	–	dBm
	MCS2	–	–90.1	–	dBm
	MCS3	–	–87.0	–	dBm
	MCS4	–	–83.6	–	dBm
	MCS5	–	–78.7	–	dBm
	MCS6	–	–76.8	–	dBm
	MCS7	–	–75.9	–	dBm
	MCS8	–	–71.5	–	dBm
RX sensitivity IEEE 802.11ac with LDPC (10% PER for 4096 octet PSDU) at RF port. Defined for default parameters: 800 ns GI, LDPC coding, and non-STBC.	20 MHz channel spacing for all MCS rates				
	MCS7	–	–77.8	–	dBm
	MCS8	–	–74.0	–	dBm
	MCS9	–	–72.0	–	dBm

**Table 34: WLAN 2.4 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Blocking level for 3 dB RX sensitivity degradation (without external filtering) <sup>c</sup>	<b>776–794 MHz (CDMA2000):</b>				
	Blocker frequency = 794 MHz	–	–16	–	dBm
	<b>824–849 MHz<sup>d</sup> (cdmaOne):</b>				
	Blocker frequency = 849 MHz	–	–11	–	dBm
	<b>824–849 MHz (GSM850):</b>				
	Blocker frequency = 849 MHz	–	–11	–	dBm
	<b>880–915 MHz (E-GSM):</b>				
	Blocker frequency = 915 MHz	–	–11	–	dBm
	<b>1710–1785 MHz (GSM1800):</b>				
	Blocker frequency = 1785 MHz	–	–12	–	dBm
	<b>1850–1910 MHz (GSM1900):</b>				
	Blocker frequency = 1910 MHz	–	–13	–	dBm
	<b>1850–1910 MHz (cdmaOne):</b>				
	Blocker frequency = 1910 MHz	–	–5	–	dBm
	<b>1850–1910 MHz (WCDMA):</b>				
	Blocker frequency = 1910 MHz	–	–19	–	dBm
	<b>1920–1980 MHz (WCDMA):</b>				
	Blocker frequency = 1980 MHz	–	–19	–	dBm
	<b>2300–2400 MHz (LTE band 40)</b>				
Blocker frequency = 2300 MHz	–	–29	–	dBm	
Blocker frequency = 2365 MHz	–	–35	–	dBm	
<b>2500–2570 MHz (LTE band 7):</b>					
Blocker frequency = 2505 MHz	–	–39	–	dBm	
Blocker frequency = 2565 MHz	–	–35	–	dBm	
<b>2570–2620 MHz (LTE band 38):</b>					
Blocker frequency = 2575 MHz	–	–35	–	dBm	
<b>2496-2690 MHz (LTE band 41):</b>					
Blocker frequency = 2501 MHz	–	–42	–	dBm	
Blocker frequency = 2685 MHz	–	–17	–	dBm	
<b>2545–2575 MHz (XGP Band):</b>					
Blocker frequency = 2550 MHz	–	–33	–	dBm	
In-band static CW jammer immunity (fc – 8 MHz < f <sub>cw</sub> < + 8 MHz)	RX PER < 1%, 54 Mbps OFDM, 1000 octet PSDU for: (RxSens + 23 dB < Rxlevel < max. input level)	–80	–	–	dBm
Input In-Band IP3	Maximum LNA gain	–	–10	–	dBm
	Minimum LNA gain	–	15	–	dBm

**Table 34: WLAN 2.4 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Maximum Receive Level @ 2.4 GHz	@ 1, 2 Mbps (8% PER, 1024 octets)	-3.5	-	-	dBm
	@ 5.5, 11 Mbps (8% PER, 1024 octets)	-9.5	-	-	dBm
	@ 6–54 Mbps (10% PER, 1024 octets)	-9.5	-	-	dBm
	@ MCS0–MCS7 rates (10% PER, 4095 octets)	-9.5	-	-	dBm
	@ MCS8–MCS9 rates (10% PER, 4095 octets)	-11.5	-	-	dBm
Adjacent channel rejection-DSSS (Difference between interfering and desired signal at 8% PER for 1024 octet PSDU with desired signal level as specified in Condition/Notes)	<b>Desired and interfering signal 30 MHz apart</b>				
	1 Mbps DSSS -74 dBm	35	-	-	dB
	2 Mbps DSSS -74 dBm	35	-	-	dB
	<b>Desired and interfering signal 25 MHz apart</b>				
	5.5 Mbps DSSS -70 dBm	35	-	-	dB
	11 Mbps DSSS -70 dBm	35	-	-	dB
Adjacent channel rejection-OFDM (Difference between interfering and desired signal (25 MHz apart) at 10% PER for 1024 octet PSDU with desired signal level as specified in Condition/Notes)	6 Mbps OFDM -79 dBm	16	-	-	dB
	9 Mbps OFDM -78 dBm	15	-	-	dB
	12 Mbps OFDM -76 dBm	13	-	-	dB
	18 Mbps OFDM -74 dBm	11	-	-	dB
	24 Mbps OFDM -71 dBm	8	-	-	dB
	36 Mbps OFDM -67 dBm	4	-	-	dB
	48 Mbps OFDM -63 dBm	0	-	-	dB
54 Mbps OFDM -62 dBm	-1	-	-	dB	
Adjacent channel rejection MCS0–MCS9 (Difference between interfering and desired signal (25 MHz apart) at 10% PER for 4096 octet PSDU with desired signal level as specified in Condition/Notes)	MCS0 -79 dBm	16	-	-	dB
	MCS1 -76 dBm	13	-	-	dB
	MCS2 -74 dBm	11	-	-	dB
	MCS3 -71 dBm	8	-	-	dB
	MCS4 -67 dBm	4	-	-	dB
	MCS5 -63 dBm	0	-	-	dB
	MCS6 -62 dBm	-1	-	-	dB
	MCS7 -61 dBm	-2	-	-	dB
	MCS8 -59 dBm	-4	-	-	dB
MCS9 -57 dBm	-6	-	-	dB	
Maximum receiver gain	-	-	70	-	dB
Gain control step	-	-	3	-	dB
RSSI accuracy <sup>e</sup>	Range -95 <sup>f</sup> dBm to -30 dBm	-5	-	5	dB
	Range above -30 dBm	-8	-	8	dB
Return loss	Z <sub>0</sub> = 50Ω, across the dynamic range	10	11.5	13	dB
Receiver cascaded noise figure	At maximum gain	-	4	-	dB

- Sensitivity degradations for alternate settings in MCS modes. SGI: 2 dB drop.
- Sensitivity degradations for alternate settings in MCS modes. SGI: 2 dB drop.
- The cellular standard listed for each band indicates the type of modulation used to generate the interfering signal in that band for the purpose of this test. It is not intended to indicate any specific usage of each band in any specific country.
- The blocking levels are valid for channels 1 to 11. (For higher channels, the performance may be lower due to third harmonic signals ( $3 \times 824$  MHz) falling within band.)
- The minimum and maximum values shown have a 95% confidence level.
- 95 dBm with calibration at time of manufacture, -92 dBm without calibration.

## WLAN 2.4 GHz Transmitter Performance Specifications



**Note:** Unless otherwise noted, the values shown in the following table are provided at the WLAN chip port output.

**Table 35: WLAN 2.4 GHz Transmitter Performance Specifications**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Frequency range	–	2400	–	2500	MHz
Transmitted power in cellular and FM bands (at +21 dBm, 100% duty cycle, 1 Mbps CCK) <sup>a</sup>	776-794 MHz (CDMA2000)	–	-164	–	dBm/Hz
	869-960 MHz (cdmaOne, GSM850)	–	-163	–	dBm/Hz
	1450-1495 (DAB)	–	-153.6	–	dBm/Hz
	1570-1580 MHz (GPS)	–	-151.2	–	dBm/Hz
	1592-1610 MHz (GLONASS)	–	-150.4	–	dBm/Hz
	1710-1800 (DSC-1800-Uplink)	–	-145	–	dBm/Hz
	1805-1880 MHz (GSM 1800)	–	-139	–	dBm/Hz
	1850-1910 MHz (GSM 1900)	–	-139	–	dBm/Hz
	1910-1930 MHz (TDSCDMA, LTE)	–	-140	–	dBm/Hz
	1930-1990 MHz (GSM1900, cdmaOne, WCDMA)	–	-128	–	dBm/Hz
	2010-2075 MHz (TDSCDMA)	–	-131	–	dBm/Hz
	2110-2170 MHz (WCDMA)	–	-125	–	dBm/Hz
	2305-2370 (LTE band 40)	–	-95	–	dBm/Hz
	2370-2400 (LTE band 40)	–	-80	–	dBm/Hz
	2496-2530 (LTE band 41)	–	-90	–	dBm/Hz
2530-2560 (LTE band 41)	–	-110	–	dBm/Hz	
2570-2690 (LTE band 41)	–	-116	–	dBm/Hz	
5000-5900 (WLAN 5G)	–	-155	–	dBm/Hz	

**Table 35: WLAN 2.4 GHz Transmitter Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>	
<b>EVM Does Not Exceed</b>						
TX power at the chip port for highest power level setting at 25°C and VBAT = 3.6V with spectral mask and EVM compliance	802.11b (DSSS/CCK)	-9 dB	-	21.5	-	dBm
	OFDM, BPSK	-8 dB	-	20	-	dBm
	OFDM, 64QAM	-25 dB	-	19	-	dBm
	MCS7	-27 dB	-	19	-	dBm
	MCS8	-30 dB	-	17	-	dBm
Phase noise	37.4 MHz crystal, integrated from 10 kHz to 10 MHz	-	0.45	-	Degrees	
TX power control dynamic range	-	10	-	-	dB	
Closed-loop TX power variation at highest power level setting	Across full temperature and voltage range. Applies to 10 dBm to 20 dBm output power range.	-	-	±1.5	dB	
Carrier suppression	-	15	-	-	dBc	
Gain control step	-	-	0.25	-	dB	
Return loss at Chip port TX $Z_0 = 50\Omega$	-	-	6	-	dB	

a. The cellular standards listed indicate only typical usages of that band in some countries. Other standards may also be used within those bands.

## WLAN 5 GHz Receiver Performance Specifications



**Note:** Unless otherwise noted, the values shown in the following table are provided at the chip port input.

**Table 36: WLAN 5 GHz Receiver Performance Specifications**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Frequency range	-	4900	-	5845	MHz
RX sensitivity <sup>a</sup> IEEE 802.11a (10% PER for 1000 octet PSDU)	6 Mbps OFDM	-	-94.5	-	dBm
	9 Mbps OFDM	-	-93.5	-	dBm
	12 Mbps OFDM	-	-92.7	-	dBm
	18 Mbps OFDM	-	-90.1	-	dBm
	24 Mbps OFDM	-	-86.9	-	dBm
	36 Mbps OFDM	-	-83.6	-	dBm
	48 Mbps OFDM	-	-78.6	-	dBm
54 Mbps OFDM	-	-77.4	-	dBm	

**Table 36: WLAN 5 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
RX sensitivity <sup>a</sup>	20 MHz channel spacing for all MCS rates				
IEEE 802.11n (10% PER for 4096 octet PSDU) Defined for default parameters: 800 ns GI and non-STBC.	MCS0	–	–94.0	–	dBm
	MCS1	–	–91.5	–	dBm
	MCS2	–	–89.0	–	dBm
	MCS3	–	–85.6	–	dBm
	MCS4	–	–82.5	–	dBm
	MCS5	–	–77.8	–	dBm
	MCS6	–	–75.9	–	dBm
	MCS7	–	–73.9	–	dBm
RX sensitivity <sup>a</sup>	40 MHz channel spacing for all MCS rates				
IEEE 802.11n (10% PER for 4096 octet PSDU) Defined for default parameters: 800 ns GI and non-STBC.	MCS0	–	–92.0	–	dBm
	MCS1	–	–89.0	–	dBm
	MCS2	–	–86.5	–	dBm
	MCS3	–	–83.2	–	dBm
	MCS4	–	–79.9	–	dBm
	MCS5	–	–75.3	–	dBm
	MCS6	–	–73.8	–	dBm
	MCS7	–	–72.2	–	dBm
RX sensitivity <sup>a</sup>	20 MHz channel spacing for all MCS rates				
IEEE 802.11ac (10% PER for 4096 octet PSDU) Defined for default parameters: 800 ns GI and non-STBC.	MCS0	–	–94.2	–	dBm
	MCS1	–	–91.5	–	dBm
	MCS2	–	–89.3	–	dBm
	MCS3	–	–86.2	–	dBm
	MCS4	–	–82.8	–	dBm
	MCS5	–	–77.9	–	dBm
	MCS6	–	–76.0	–	dBm
	MCS7	–	–75.1	–	dBm
	MCS8	–	–70.7	–	dBm
RX sensitivity <sup>a</sup>	40 MHz channel spacing for all MCS rates				
IEEE 802.11ac (10% PER for 4096 octet PSDU) Defined for default parameters: 800 ns GI and non-STBC.	MCS0	–	–92.3	–	dBm
	MCS1	–	–89.3	–	dBm
	MCS2	–	–86.9	–	dBm
	MCS3	–	–83.6	–	dBm
	MCS4	–	–80.2	–	dBm
	MCS5	–	–75.6	–	dBm
	MCS6	–	–74.0	–	dBm
	MCS7	–	–72.6	–	dBm
	MCS8	–	–68.3	–	dBm
	MCS9	–	–66.7	–	dBm



**Table 36: WLAN 5 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
RX sensitivity <sup>a</sup>	80 MHz channel spacing for all MCS rates				
IEEE 802.11ac (10% PER for 4096 octet PSDU)	MCS0	–	–89.0	–	dBm
Defined for default parameters: 800 ns GI and non-STBC.	MCS1	–	–86.0	–	dBm
	MCS2	–	–83.3	–	dBm
	MCS3	–	–80.1	–	dBm
	MCS4	–	–76.8	–	dBm
	MCS5	–	–72.2	–	dBm
	MCS6	–	–70.9	–	dBm
	MCS7	–	–69.2	–	dBm
	MCS8	–	–65.2	–	dBm
	MCS9	–	–63.6	–	dBm
	RX sensitivity <sup>a</sup>	MCS7 20 MHz	–	–76.8	–
IEEE 802.11ac 20/40/80 MHz channel spacing with LDPC (10% PER for 4096 octet PSDU) at RF port.	MCS8 20 MHz	–	–72.9	–	dBm
	MCS9 20 MHz	–	–70.7	–	dBm
	MCS7 40 MHz	–	–74.8	–	dBm
Defined for default parameters: 800 ns GI, LDPC coding and non-STBC.	MCS8 40 MHz	–	–70.9	–	dBm
	MCS9 40 MHz	–	–68.9	–	dBm
	MCS7 80 MHz	–	–71.5	–	dBm
	MCS8 80 MHz	–	–67.6	–	dBm
	MCS9 80 MHz	–	–65.5	–	dBm

**Table 36: WLAN 5 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Blocking level for 3 dB RX sensitivity degradation (without external filtering) <sup>b</sup>	<b>776–794 MHz (CDMA2000):</b>				
	Blocker frequency = 794 MHz	–	–21	–	dBm
	<b>824–849 MHz<sup>c</sup> (cdmaOne):</b>				
	Blocker frequency = 849 MHz	–	–20	–	dBm
	<b>824–849 MHz (GSM850):</b>				
	Blocker frequency = 849 MHz	–	–10	–	dBm
	<b>880–915 MHz (E-GSM):</b>				
	Blocker frequency = 915 MHz	–	–12	–	dBm
	<b>1710–1785 MHz (GSM1800):</b>				
	Blocker frequency = 1785 MHz	–	–13	–	dBm
	<b>1850–1910 MHz (GSM1900):</b>				
	Blocker frequency = 1910 MHz	–	–13	–	dBm
	<b>1850–1910 MHz (cdmaOne):</b>				
	Blocker frequency = 1910 MHz	–	–18	–	dBm
	<b>1850–1910 MHz (WCDMA):</b>				
	Blocker frequency = 1910 MHz	–	–20	–	dBm
	<b>1920–1980 MHz (WCDMA):</b>				
Blocker frequency = 1980 MHz	–	–20	–	dBm	
<b>2300–2400 MHz (LTE band 40)</b>					
Blocker frequency = 2395 MHz	–	–19	–	dBm	
<b>2500–2570 MHz (LTE band 7):</b>					
Blocker frequency = 2565 MHz	–	–16	–	dBm	
<b>2570–2620 MHz (LTE band 38):</b>					
Blocker frequency = 2615 MHz	–	–16	–	dBm	
<b>2496-2690 MHz (LTE band 41):</b>					
Blocker frequency = 2685 MHz	–	–16	–	dBm	
<b>2545–2575 MHz (XGP Band):</b>					
Blocker frequency = 2570 MHz	–	–18	–	dBm	

**Table 36: WLAN 5 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Input In-Band IP3	Maximum LNA gain	–	–11	–	dBm
	Minimum LNA gain	–	5	–	dBm
Maximum receive level @ 5.24 GHz	@ 6, 9, 12 Mbps	–9.5	–	–	dBm
	@ 18, 24, 36, 48, 54 Mbps	–14.5	–	–	dBm
Adjacent channel rejection (Difference between interfering and desired signal (20 MHz apart) at 10% PER for 1000 octet PSDU with desired signal level as specified in Condition/Notes)	6 Mbps OFDM	–79 dBm	16	–	dB
	9 Mbps OFDM	–78 dBm	15	–	dB
	12 Mbps OFDM	–76 dBm	13	–	dB
	18 Mbps OFDM	–74 dBm	11	–	dB
	24 Mbps OFDM	–71 dBm	8	–	dB
	36 Mbps OFDM	–67 dBm	4	–	dB
	48 Mbps OFDM	–63 dBm	0	–	dB
	54 Mbps OFDM	–62 dBm	–1	–	dB
	65 Mbps OFDM	–61 dBm	–2	–	dB
Alternate adjacent channel rejection (Difference between interfering and desired signal (40 MHz apart) at 10% PER for 1000 <sup>d</sup> octet PSDU with desired signal level as specified in Condition/Notes)	6 Mbps OFDM	–78.5 dBm	32	–	dB
	9 Mbps OFDM	–77.5 dBm	31	–	dB
	12 Mbps OFDM	–75.5 dBm	29	–	dB
	18 Mbps OFDM	–73.5 dBm	27	–	dB
	24 Mbps OFDM	–70.5 dBm	24	–	dB
	36 Mbps OFDM	–66.5 dBm	20	–	dB
	48 Mbps OFDM	–62.5 dBm	16	–	dB
	54 Mbps OFDM	–61.5 dBm	15	–	dB
65 Mbps OFDM	–60.5 dBm	14	–	dB	
Maximum receiver gain	–	–	65	–	dB
Gain control step	–	–	3	–	dB

**Table 36: WLAN 5 GHz Receiver Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
RSSI accuracy <sup>e</sup>	Range -98 dBm to -30 dBm	-5	-	5	dB
	Range above -30 dBm	-8	-	8	dB
Return loss	Z <sub>o</sub> = 50Ω, across the dynamic range	10	-	13	dB
Receiver cascaded noise figure	At maximum gain	-	4	-	dB

- a. For PCIE derate 5G RX sensitivity by 1.5 dB
- b. The cellular standard listed for each band indicates the type of modulation used to generate the interfering signal in that band for the purpose of this test. It is not intended to indicate any specific usage of each band in any specific country.
- c. The blocking levels are valid for channels 1 to 11. (For higher channels, the performance may be lower due to third harmonic signals (3 × 824 MHz) falling within band.)
- d. For 65 Mbps, the size is 4096.
- e. The minimum and maximum values shown have a 95% confidence level.

## WLAN 5 GHz Transmitter Performance Specifications



**Note:** Unless otherwise noted, the values shown in the following table are provided at the WLAN chip port output.

**Table 37: WLAN 5 GHz Transmitter Performance Specifications**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Frequency range	–	4900	–	5845	MHz
Transmitted power in cellular and FM bands (at +18.5 dBm, 100% duty cycle, 6 Mbps OFDM) <sup>a</sup>	776–794 MHz (CDMA2000)	–	–164	–	dBm/Hz
	869–960 MHz (cdmaOne, GSM850)	–	–166	–	dBm/Hz
	1450–1495 (DAB)	–	–166	–	dBm/Hz
	1570–1580 MHz (GPS)	–	–166	–	dBm/Hz
	1592–1610 MHz (GLONASS)	–	–165.5	–	dBm/Hz
	1710–1800(DSC-1800-Uplink)	–	–135	–	dBm/Hz
	1805–1880 MHz (GSM 1800)	–	–165	–	dBm/Hz
	1850–1910 MHz (GSM 1900)	–	–165	–	dBm/Hz
	1910–1930 MHz (TDSCDMA, LTE)	–	–165	–	dBm/Hz
	1930–1990 MHz (GSM1900, cdmaOne, WCDMA)	–	–165	–	dBm/Hz
	2010–2075 MHz (TDSCDMA)	–	–164.5	–	dBm/Hz
	2110–2170 MHz (WCDMA)	–	–164	–	dBm/Hz
	2305–2370 (LTE band 40)	–	–160	–	dBm/Hz
	2370–2400 (LTE band 40)	–	–163	–	dBm/Hz
	2400–2500 (WLAN 2G)	–	–160	–	dBm/Hz
	2496–2530 (LTE band 41)	–	–161.5	–	dBm/Hz
2530–2560 (LTE band 41)	–	–161.5	–	dBm/Hz	
2570–2690 (LTE band 41)	–	–161	–	dBm/Hz	
<b>EVM Does Not Exceed</b>					
TX power at the chip port for highest power level setting at 25°C and VBAT = 3.6V with spectral mask and EVM compliance	OFDM, BPSK	–8 dB	–	21.5	dBm
	OFDM, 64QAM	–25 dB	–	19	dBm
	MCS7	–27 dB	–	19	dBm
	MCS9	–32 dB	–	17	dBm

**Table 37: WLAN 5 GHz Transmitter Performance Specifications (Cont.)**

<b>Parameter</b>	<b>Condition/Notes</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
Phase noise	37.4 MHz Crystal, Integrated from 10 kHz to 10 MHz	–	0.5	–	Degrees
TX power control dynamic range	–	10	–	–	dB
Closed loop TX power variation at highest power level setting	Across full-temperature and voltage range. Applies across 10 to 20 dBm output power range.	–	–	±2.0	dB
Carrier suppression	–	15	–	–	dBc
Gain control step	–	–	0.25	–	dB
Return loss	$Z_o = 50\Omega$	–	6	–	dB

a. The cellular standards listed indicate only typical usages of that band in some countries. Other standards may also be used within those bands.

## General Spurious Emissions Specifications

This section provides the TX and RX spurious emissions specifications for both the WLAN 2.4 GHz and 5 GHz bands. The recommended spectrum analyzer settings for the spurious emissions specifications are provided in [Table 38](#).

**Table 38: Recommended Spectrum Analyzer Settings**

<b>Parameter</b>	<b>Setting</b>
Resolution Bandwidth (RBW):	1 MHz
Video Bandwidth (VBW):	1 MHz
Sweep:	Auto
Span:	100 MHz
Detector:	Maximum Peak
Trace:	Maximum Hold
Modulation:	OFDM (Orthogonal Frequency-division Multiplexing)

## Transmitter Spurious Emissions Specifications

The TX spurious emissions specifications in this subsection are based on the following definitions:

- AFE = VCO/16 for 2G channels
- AFE = VCO/18 for 5G 20 MHz channels
- AFE = VCO/9 for 5G 40 MHz channels
- AFE = VCO/6 for 5G 80 MHz channels
- LO = Channel frequency

## 2.4 GHz Band Spurious Emissions

### 20 MHz Channel Spacing



**Note:** Possible AFE combinations are as follows. The AFE=VCO/16 specifications for channel 2442 are listed in [Table 39](#).

**Table 39: 2.4 GHz Band, 20 MHz Channel Spacing TX Spurious Emissions Specifications<sup>a</sup>**

Spurious Frequency	Power (dBm)	Frequency (Fch; MHz) Channel 2442	
		Typical (dBm)	Maximum (dBm)
HD2	21	-22.78	–
HD3	21	-19.54	–
HD4	21	-41.79	–
HD5	21	-61.78	–
VCO – LO	21	-55.13	–
VCO + LO	21	-63.40	–
VCO	21	-48.56	–
LO + AFE	21	-59.2	–
LO-AFE	21	-59.3	–
LO + AFE × 2	21	-68.2	–
LO – AFE × 2	21	-67.4	–
LO + XTAL × 2	21	-56.2	–
LO – XTAL × 2	21	-56.3	–
LO + XTAL × 4	21	-57.5	–
LO – XTAL × 4	21	-56.7	–
LO + XTAL × 8	21	-59.1	–
LO – XTAL × 8	21	-67.2	–

a. VCO = 1.5 × Fch, where Fch is the center frequency of the channel.

## 5 GHz Band Spurious Emissions

### 20 MHz Channel Spacing



**Note:** Possible AFE combinations are as follows. The AFE=VCO/18 specifications for channels 5180, 5500, and 5825 are listed in [Table 40](#).

**Table 40: 5 GHz Band, 20 MHz Channel Spacing TX Spurious Emissions Specifications**

Spurious Frequency	Power (dBm)	CH5180 <sup>a</sup>		CH5500 <sup>a</sup>		CH5825 <sup>a</sup>	
		Typ. (dBm)	Max. (dBm)	Typ. (dBm)	Max. (dBm)	Typ. (dBm)	Max. (dBm)
HD2	19	-29.33	–	-32.56	–	-33.14	–
HD3	19	-39.71	–	-38.93	–	-39.87	–
VCO	19	-49.03	–	-48.35	–	-46.70	–
VCO × 2	19	-55.64	–	-60.40	–	-64.77	–
LO + VCO	19	-63.94	–	-62.80	–	-62.16	–
LO – VCO	19	-81.58	–	-72.56	–	-70.58	–
LO – AFE	19	-62.1	–	-63.3	–	-60.4	–
LO + AFE	19	-57.8	–	-59.6	–	-60.6	–
LO – XTAL × 4	19	-60.1	–	-60.1	–	-58.7	–
LO + XTAL × 4	19	-57.2	–	-57.4	–	-58.2	–
LO – XTAL × 6	19	-63.4	–	-59.3	–	-61.1	–
LO + XTAL × 6	19	-60.2	–	-58.9	–	-60.8	–
LO – XTAL × 8	19	-66.1	–	-67.3	–	-63.8	–
LO + XTAL × 8	19	-64.2	–	-63.8	–	-65.8	–
AFE × 12	19	–	–	–	–	–	–

a.  $VCO = (2/3) \times F_{ch}$ , where  $F_{ch}$  is the center frequency of the channel.



## 40 MHz Channel Spacing



**Note:** Possible AFE combinations are as follows. The AFE=VCO/9 specifications for channels 5190, 5510, and 5795 are listed in [Table 41](#).

**Table 41: 5 GHz Band, 40 MHz Channel Spacing TX Spurious Emissions Specifications**

Spurious Frequency	Power (dBm)	CH5190m <sup>a</sup>		CH5510m <sup>a</sup>		CH5795m <sup>a</sup>	
		Typ. (dBm)	Max. (dBm)	Typ. (dBm)	Max. (dBm)	Typ. (dBm)	Max. (dBm)
HD2	19	-33.43	-	-35.53	-	-36.49	-
HD3	19	-41.81	-	-42.13	-	-42.33	-
VCO	19	-48.36	-	-47.65	-	-46.93	-
VCO × 2	19	-55.87	-	-59.26	-	-64.45	-
LO + VCO	19	-65.58	-	-64.96	-	-	-
LO - VCO	19	-	-	-	-	-	-
LO - AFE	19	-65.3	-	-67.2	-	-65.2	-
LO + AFE	19	-63.2	-	-64.3	-	-67.3	-
LO - XTAL × 4	19	-59.3	-	-59.7	-	-59.6	-
LO + XTAL × 4	19	-58.3	-	-57.4	-	-57.9	-
LO - XTAL × 6	19	-64.1	-	-63.4	-	-63.2	-
LO + XTAL × 6	19	-61.5	-	-59.4	-	-61.2	-
LO - XTAL × 8	19	-66.3	-	-67.1	-	-64.3	-
LO + XTAL × 8	19	-63.8	-	-64.7	-	-61.2	-
AFE × 12	19	-65.2	-	-66.3	-	-65.4	-

a.  $VCO = (2/3) \times F_{ch}$ , where  $F_{ch}$  is the center frequency of the channel.

## 80 MHz Channel Spacing



**Note:** Possible AFE combinations are as follows. The AFE=VCO/6 specifications for channels 5210, 5530, and 5775 are listed in [Table 42](#).

**Table 42: 5 GHz Band, 80 MHz Channel Spacing TX Spurious Emissions Specifications**

Spurious Frequency	Power (dBm)	CH5210q <sup>a</sup>		CH5530q <sup>a</sup>		CH5775q <sup>a</sup>	
		Typ. (dBm)	Max. (dBm)	Typ. (dBm)	Max. (dBm)	Typ. (dBm)	Max. (dBm)
HD2	19	-36.28	–	-39.59	–	-41.02	–
HD3	19	-45.00	–	-44.82	–	-46.10	–
VCO	19	-48.00	–	-47.34	–	-46.01	–
VCO × 2	19	-57.04	–	-62.82	–	-66.84	–
LO + VCO	19	-66.66	–	-66.11	–	-66.40	–
LO – VCO	19	–	–	–	–	–	–
LO – AFE	19	-68.5	–	-67.8	–	-66.9	–
LO + AFE	19	-63.8	–	-66.3	–	-68.6	–
LO – XTAL × 4	19	–	–	–	–	–	–
LO + XTAL × 4	19	–	–	–	–	–	–
LO – XTAL × 6	19	–	–	–	–	–	–
LO + XTAL × 6	19	–	–	–	–	–	–
LO – XTAL × 8	19	–	–	–	–	–	–
LO + XTAL × 8	19	–	–	–	–	–	–
AFE × 12	19	–	–	–	–	–	–

a.  $VCO = (2/3) \times F_{ch}$ , where  $F_{ch}$  is the center frequency of the channel.

## Receiver Spurious Emissions Specifications

**Table 43: 2G and 5G General Receiver Spurious Emissions**

Band	Frequency Range	Typical	Maximum	Unit
2G	2.4 GHz < f < 2.5 GHz	-92	–	dBm
	3.6 GHz < f < 3.8 GHz	-75.16	–	dBm
5G	5150 MHz < f < 5850 MHz	-70.4	–	dBm
	3.45 GHz < f < 3.9 GHz	-59.2	–	dBm

# Section 18: Internal Regulator Electrical Specifications

## Core Buck Switching Regulator



**Note:** Values in this data sheet are design goals and are subject to change based on device characterization results.

**Note:** Functional operation is not guaranteed outside of the specification limits provided in this section.

**Table 44: Core Buck Switching Regulator (CLOCK) Specifications**

Specification	Notes	Min.	Typ.	Max.	Unit
Input supply voltage (DC)	DC voltage range inclusive of disturbances.	3.0	3.6	5.25 <sup>a</sup>	V
PWM mode switching frequency	CCM, Load > 100 mA VBAT = 3.6V	–	4	–	MHz
PWM output current	–	–	–	600	mA
Output current limit	–	–	1400	–	mA
Output voltage range	Programmable, 30 mV steps. Default = 1.35V	1.2	1.35	1.5	V
PWM output voltage DC accuracy	Includes load and line regulation. Forced PWM mode.	–4	–	4	%
PWM ripple voltage, static	Measure with 20 MHz bandwidth limit. Static Load. Max. Ripple based on VBAT = 3.6V, Vout = 1.35V, Fsw = 4 MHz, 2.2 μH inductor L > 1.05 μH, Cap + Board total-ESR < 20 mΩ, Cout > 1.9 μF, ESL < 200 pH	–	7	20	mVpp
PWM mode peak efficiency	Peak Efficiency at 200 mA load	78	86	–	%
PFM mode efficiency	10 mA load current	70	80	–	%
Start-up time from power down	VIO already ON and steady. Time from REG_ON rising edge to CLDO reaching 1.2V.	–	400	500	μs
External inductor	0806 size, 2.2 μH, DCR=0.11Ω, ACR=1.18Ω @ 4 MHz	–	2.2	–	μH
External output capacitor	Ceramic, X5R, 0402, ESR < 30 mΩ at 4 MHz, 4.7 μF ±20%, 6.3V	2.0	4.7	10 <sup>b</sup>	μF
External input capacitor	For SR_VDDBATP5V pin, ceramic, X5R, 0603, ESR < 30 mΩ at 4 MHz, ±4.7μF ±20%, 6.3V	0.67 <sup>b</sup>	4.7	–	μF
Input supply voltage ramp-up time	0 to 4.3V	40	–	–	μs

a. The maximum continuous voltage is 5.25V. Voltages up to 6.0V for up to 10 seconds, cumulative duration, over the lifetime of the device are allowed. Voltages as high as 5.0V for up to 250 seconds, cumulative duration, over the lifetime of the device are allowed.

b. Total capacitance includes those connected at the far end of the active load.

## 3.3V LDO (LDO3P3)

**Table 45: LDO3P3 Specifications**

Specification	Notes	Min.	Typ.	Max.	Units
Input supply voltage, $V_{in}$	Min. = $V_o + 0.2V = 3.5V$ dropout voltage requirement must be met under maximum load for performance specifications.	3.0	3.6	5.25 <sup>a</sup>	V
Output current	–	0.001	–	450	mA
Nominal output voltage, $V_o$	Default = 3.3V	–	3.3	–	V
Dropout voltage	At max. load.	–	–	200	mV
Output voltage DC accuracy	Includes line/load regulation.	–5	–	+5	%
Quiescent current	No load	–	–	100	$\mu A$
Line regulation	$V_{in}$ from ( $V_o + 0.2V$ ) to 5.25V, max. load	–	–	3.5	mV/V
Load regulation	load from 1 mA to 450 mA	–	–	0.3	mV/mA
PSRR	$V_{in} \geq V_o + 0.2V$ , $V_o = 3.3V$ , $C_o = 4.7 \mu F$ , Max. load, 100 Hz to 100 kHz	20	–	–	dB
LDO turn-on time	Chip already powered up.	–	160	250	$\mu s$
External output capacitor, $C_o$	Ceramic, X5R, 0402, (ESR: 5 m $\Omega$ –240 m $\Omega$ ), $\pm 10\%$ , 10V	1.0 <sup>b</sup>	4.7	10	$\mu F$
External input capacitor	For SR_VDDBATA5V pin (shared with Bandgap) Ceramic, X5R, 0402, (ESR: 30m-200 m $\Omega$ ), $\pm 10\%$ , 10V. Not needed if sharing VBAT capacitor 4.7 $\mu F$ with SR_VDDBATP5V.	–	4.7	–	$\mu F$

- The maximum continuous voltage is 5.25V. Voltages up to 6.0V for up to 10 seconds, cumulative duration, over the lifetime of the device are allowed. Voltages as high as 5.0V for up to 250 seconds, cumulative duration, over the lifetime of the device are allowed.
- Minimum capacitor value refers to the residual capacitor value after taking into account the part-to-part tolerance, DC-bias, temperature, and aging.

## 2.5V LDO (BTLDO2P5)

**Table 46: BTLDO2P5 Specifications**

Specification	Notes	Min.	Typ.	Max.	Units
Input supply voltage	Min. = 2.5V + 0.2V = 2.7V. Dropout voltage requirement must be met under maximum load for performance specifications.	3.0	3.6	5.25 <sup>a</sup>	V
Nominal output voltage	Default = 2.5V.	–	2.5	–	V
Output voltage programmability	Range	2.2	2.5	2.8	V
	Accuracy at any step (including line/load regulation), load > 0.1 mA.	–5	–	5	%
Dropout voltage	At maximum load.	–	–	200	mV
Output current	–	0.1	–	70	mA
Quiescent current	No load.	–	8	16	μA
	Maximum load at 70 mA.	–	660	700	μA
Leakage current	Power-down mode.	–	1.5	5	μA
Line regulation	$V_{in}$ from ( $V_o + 0.2V$ ) to 5.25V, maximum load.	–	–	3.5	mV/V
Load regulation	Load from 1 mA to 70 mA, $V_{in} = 3.6V$ .	–	–	0.3	mV/mA
PSRR	$V_{in} \geq V_o + 0.2V$ , $V_o = 2.5V$ , $C_o = 2.2 \mu F$ , 20 maximum load, 100 Hz to 100 kHz.	–	–	–	dB
LDO turn-on time	Chip already powered up.	–	–	150	μs
In-rush current	$V_{in} = V_o + 0.15V$ to 5.25V, $C_o = 2.2 \mu F$ , No load.	–	–	250	mA
External output capacitor, $C_o$	Ceramic, X5R, 0402, (ESR: 5m–240 mΩ), ±10%, 10V	0.7 <sup>b</sup>	2.2	2.64	μF
External input capacitor	For SR_VDDBATA5V pin (shared with Bandgap) ceramic, X5R, 0402, (ESR: 30–200 mΩ), ±10%, 10V. Not needed if sharing VBAT 4.7 μF capacitor with SR_VDDBATP5V.	–	4.7	–	μF

- a. The maximum continuous voltage is 5.25V. Voltages up to 6.0V for up to 10 seconds, cumulative duration, over the lifetime of the device are allowed. Voltages as high as 5.0V for up to 250 seconds, cumulative duration, over the lifetime of the device are allowed.
- b. The minimum value refers to the residual capacitor value after taking into account part-to-part tolerance, DC-bias, temperature, and aging.

## CLDO

**Table 47: CLDO Specifications**

Specification	Notes	Min.	Typ.	Max.	Units
Input supply voltage, $V_{in}$	Min. = $1.2 + 0.15V = 1.35V$ dropout voltage requirement must be met under maximum load.	1.3	1.35	1.5	V
Output current	–	0.2	–	200	mA
Output voltage, $V_o$	Programmable in 10 mV steps. Default = 1.2.V	0.95	1.2	1.26	V
Dropout voltage	At max. load	–	–	150	mV
Output voltage DC accuracy	Includes line/load regulation	–4	–	+4	%
Quiescent current	No load	–	13	–	$\mu A$
	200 mA load	–	1.24	–	mA
Line Regulation	$V_{in}$ from ( $V_o + 0.15V$ ) to 1.5V, maximum load	–	–	5	mV/V
Load Regulation	Load from 1 mA to 300 mA	–	0.02	0.05	mV/mA
Leakage Current	Power down	–	5	20	$\mu A$
	Bypass mode	–	1	3	$\mu A$
PSRR	@1 kHz, $V_{in} \geq 1.35V$ , $C_o = 4.7 \mu F$	20	–	–	dB
Start-up Time of PMU	VIO up and steady. Time from the REG_ON rising edge to the CLDO reaching 1.2V.	–	–	700	$\mu s$
LDO Turn-on Time	LDO turn-on time when rest of the chip is up	–	140	180	$\mu s$
External Output Capacitor, $C_o$	Total ESR: 5 m $\Omega$ –240 m $\Omega$	1.1 <sup>a</sup>	2.2	–	$\mu F$
External Input Capacitor	Only use an external input capacitor at the VDD_LDO pin if it is not supplied from CBUCK output.	–	1	2.2	$\mu F$

- a. Minimum capacitor value refers to the residual capacitor value after taking into account the part-to-part tolerance, DC-bias, temperature, and aging.

## LNLDO

**Table 48: LNLDO Specifications**

Specification	Notes	Min.	Typ.	Max.	Units
Input supply voltage, $V_{in}$	Min. $V_{IN} = V_O + 0.15V = 1.35V$ (where $V_O = 1.2V$ ) dropout voltage requirement must be met under maximum load.	1.3	1.35	1.5	V
Output Current	–	0.1	–	150	mA
Output Voltage, $V_O$	Programmable in 25 mV steps. Default = 1.2V	1.1	1.2	1.275	V
Dropout Voltage	At maximum load	–	–	150	mV
Output Voltage DC Accuracy	Includes line/load regulation	–4	–	+4	%
Quiescent current	No load	–	44	–	$\mu A$
	Max. load	–	970	990	$\mu A$
Line Regulation	$V_{in}$ from ( $V_O + 0.1V$ ) to 1.5V, 150 mA load	–	–	5	mV/V
Load Regulation	Load from 1 mA to 150 mA	–	0.02	0.05	mV/mA
Leakage Current	Power-down	–	–	10	$\mu A$
Output Noise	@30 kHz, 60–150 mA load $C_O = 2.2 \mu F$	–	–	60	nV/rt Hz
	@100 kHz, 60–150 mA load $C_O = 2.2 \mu F$	–	–	35	nV/rt Hz
PSRR	@ 1kHz, Input > 1.35V, $C_O = 2.2 \mu F$ , $V_O = 1.2V$	20	–	–	dB
LDO Turn-on Time	LDO turn-on time when rest of chip is up	–	140	180	$\mu s$
External Output Capacitor, $C_O$	Total ESR (trace/capacitor): 5 m $\Omega$ –240 m $\Omega$	0.5 <sup>a</sup>	2.2	4.7	$\mu F$
External Input Capacitor	Only use an external input capacitor at the VDD_LDO pin if it is not supplied from CBUCK output. Total ESR (trace/capacitor): 30 m $\Omega$ –200 m $\Omega$	–	1	2.2	$\mu F$

- a. Minimum capacitor value refers to the residual capacitor value after taking into account the part-to-part tolerance, DC-bias, temperature, and aging.

## PCIe LDO

**Table 49: PCIe LDO Specifications**

Specification	Notes	Min.	Typ.	Max.	Units
Input supply voltage, $V_{in}$	Min. $V_{IN} = V_O + 0.15V = 1.35V$ (where $V_O = 1.2V$ ) dropout voltage requirement must be met under maximum load.	1.3	1.35	1.5	V
Output Current	Peak load=80 mA. Average load=35 mA	0.1	–	55	mA
Output Voltage, $V_O$	Programmable in 25 mV steps. Default = 1.2V	1.1	1.2	1.275	V
Dropout Voltage	At maximum load	–	–	150	mV
Output Voltage DC Accuracy	Includes line/load regulation	–4	–	+4	%
Quiescent current	No load	–	10	12	$\mu A$
	55 mA load	–	550	570	$\mu A$
Line Regulation	$V_{IN}$ from ( $V_O + 0.1V$ ) to 1.5V, 150 mA load	–	–	5	mV/V
Load Regulation	Load from 1 mA to 150 mA	–	0.02	0.05	mV/mA
Leakage Current	Power-down	–	5	20	$\mu A$
	Bypass mode	–	0.02	1.5	$\mu A$
Output Noise	@30 kHz, 60–150 mA load $C_o = 2.2 \mu F$	–	–	60	nV/rt Hz
	@100 kHz, 60–150 mA load $C_o = 2.2 \mu F$	–	–	35	nV/rt Hz
PSRR	@ 1kHz, Input > 1.35V, $C_o = 2.2 \mu F$ , $V_O = 1.2V$	20	–	–	dB
LDO Turn-on Time	LDO turn-on time when balance of chip is up	–	140	180	$\mu s$
External Output Capacitor, $C_o$	Total ESR (trace/capacitor): 5 m $\Omega$ –240 m $\Omega$	0.27 <sup>a</sup>	0.47	–	$\mu F$
External Input Capacitor	Only use an external input capacitor at the VDD_LDO pin if it is not supplied from CBUCK output. Total ESR (trace/capacitor): 30 m $\Omega$ –200 m $\Omega$	–	1	2.2	$\mu F$

- a. Minimum capacitor value refers to the residual capacitor value after taking into account the part-to-part tolerance, DC-bias, temperature, and aging.



# Section 19: System Power Consumption



**Note:** Values in this data sheet are design goals and are subject to change based on the results of device characterization.

**Note:** Unless otherwise stated, these values apply for the conditions specified in [Table 27: “Recommended Operating Conditions and DC Characteristics,” on page 99.](#)

## WLAN Current Consumption

The tables in this subsection show the typical, total current consumed by the BCM43455. All values shown are with the Bluetooth core in reset mode with Bluetooth off.

### 2.4 GHz Mode

**Table 50: 2.4 GHz Mode WLAN Power Consumption**

Mode	$V_{BAT} = 3.6V, V_{DDIO} = 1.8V, T_A 25^{\circ}C$	
	$V_{BAT}, mA$	$V_{IO}, \mu A^a$
<b>Sleep Modes</b>		
Radio off <sup>b</sup>	0.006	5
Sleep <sup>c</sup>	0.020	200
IEEE Power Save: DTIM = 1, single RX <sup>d</sup>	1.25	200
IEEE Power Save: DTIM = 3, single RX	0.45	200
<b>Active RX Modes</b>		
Continuous RX mode: MCS7, HT20, 1SS <sup>e, f</sup>	55	60
CRS: HT20 <sup>g</sup>	50	60

**Table 50: 2.4 GHz Mode WLAN Power Consumption (Cont.)**

Mode	$V_{BAT} = 3.6V, V_{DDIO} = 1.8V, T_A 25^{\circ}C$	
	$V_{BAT}, mA$	$V_{IO}, \mu A^a$
<b>Active TX Modes – Internal PA</b>		
Continuous TX mode: 1 Mbps @ 21.5 dBm <sup>h</sup>	400	60
Continuous TX mode: MCS7, HT20, 1SS, 1 TX @ 19 dBm <sup>h</sup>	350	60

- VIO is specified with all pins idle (not switching) and not driving any loads.
- WL\_REG\_ON and BT\_REG\_ON are both low. All supplies are present.
- Idle, not associated, or inter-beacon.
- Beacon Interval = 102.4 ms. Beacon duration = 1 ms @ 1 Mbps. Average current over 3× DTIM intervals.
- Duty cycle is 100%. Carrier sense (CS) detect/packet receive.
- Measured using packet engine test mode.
- Carrier sense (CCA) when no carrier present.
- Duty cycle is 100%.

## 5 GHz Mode

**Table 51: 5 GHz Mode WLAN Power Consumption**

Mode	$V_{BAT} = 3.6V, V_{DDIO} = 1.8V, T_A 25^{\circ}C$	
	$V_{BAT}, mA$	$V_{IO}, \mu A^a$
<b>Sleep Modes</b>		
Radio off <sup>b</sup>	0.006	5
Sleep <sup>c</sup>	0.025	200
IEEE Power Save: DTIM = 1, single RX <sup>d</sup>	1.1	200
IEEE Power Save: DTIM = 3, single RX	0.4	200
<b>Active RX Modes</b>		
Continuous RX mode: MCS7, HT20, 1SS <sup>e, f</sup>	74	60
Continuous RX mode: MCS7, HT40, 1SS <sup>e, f</sup>	82	60
Continuous RX mode: MCS9, HT40, 1SS <sup>e, f</sup>	86	60
Continuous RX mode: MCS9, HT80, 1SS <sup>e, f</sup>	117	60
CRS: HT20 <sup>g</sup>	70	60
CRS: HT40 <sup>g</sup>	79	60
CRS: HT80 <sup>g</sup>	100	60
<b>Active TX Modes – Internal PA</b>		
Continuous TX mode: MCS7, HT20, 1SS, 1 TX @ 19 dBm <sup>h</sup>	330	60
Continuous TX mode: MCS7, HT40, 1SS, 1 TX @ 19 dBm <sup>h</sup>	340	60
Continuous TX mode: MCS9, HT40, 1SS, 1 TX @ 16 dBm <sup>h</sup>	270	60
Continuous TX mode: MCS9, HT80, 1SS, 1 TX @ 16 dBm <sup>h</sup>	270	60

- a.  $V_{IO}$  is specified with all pins idle (not switching) and not driving any loads.
- b. WL\_REG\_ON and BT\_REG\_ON are both low. All supplies present.
- c. Idle, not associated, or inter-beacon.
- d. Beacon Interval = 102.4 ms. Beacon duration = 1ms @ 1Mbps. Average current over 3x DTIM intervals.
- e. Duty cycle is 100%. Carrier sense (CS) detect/packet receive.
- f. Measured using packet engine test mode.
- g. Carrier sense (CCA) when no carrier present.
- h. Duty cycle is 100%.

## Bluetooth Current Consumption

The Bluetooth and BLE current consumption measurements are shown in [Table 52](#).



**Note:** The WLAN core is in reset (WLAN\_REG\_ON = low) for all measurements provided in [Table 52](#).

**Note:** The BT current consumption numbers are measured based on GFSK TX output power = 10 dBm.

**Table 52: Bluetooth and BLE Current Consumption**

<i>Operating Mode</i>	<i>VBAT</i>	<i>VDDIO</i>	<i>Units</i>
Sleep	6	295	$\mu$ A
Standard 1.28s Inquiry Scan	153	294	$\mu$ A
500 ms Sniff Master	216	291	$\mu$ A
DM1/DH1 Master	23.9	0.155	mA
DM3/DH3 Master	29.1	0.164	mA
DM5/DH5 Master	29.8	0.166	mA
3DH5/3DH1 Master	24.8	0.210	mA
SCO HV3 Master	11.5	0.166	mA
BLE Scan <sup>a</sup>	179	296	$\mu$ A
BLE Adv—Unconnectable 1.00 sec	69	295	$\mu$ A
BLE Connected 1 sec	1960	146	$\mu$ A

- a. No devices present. A 1.28 second interval with a scan window of 11.25 ms.

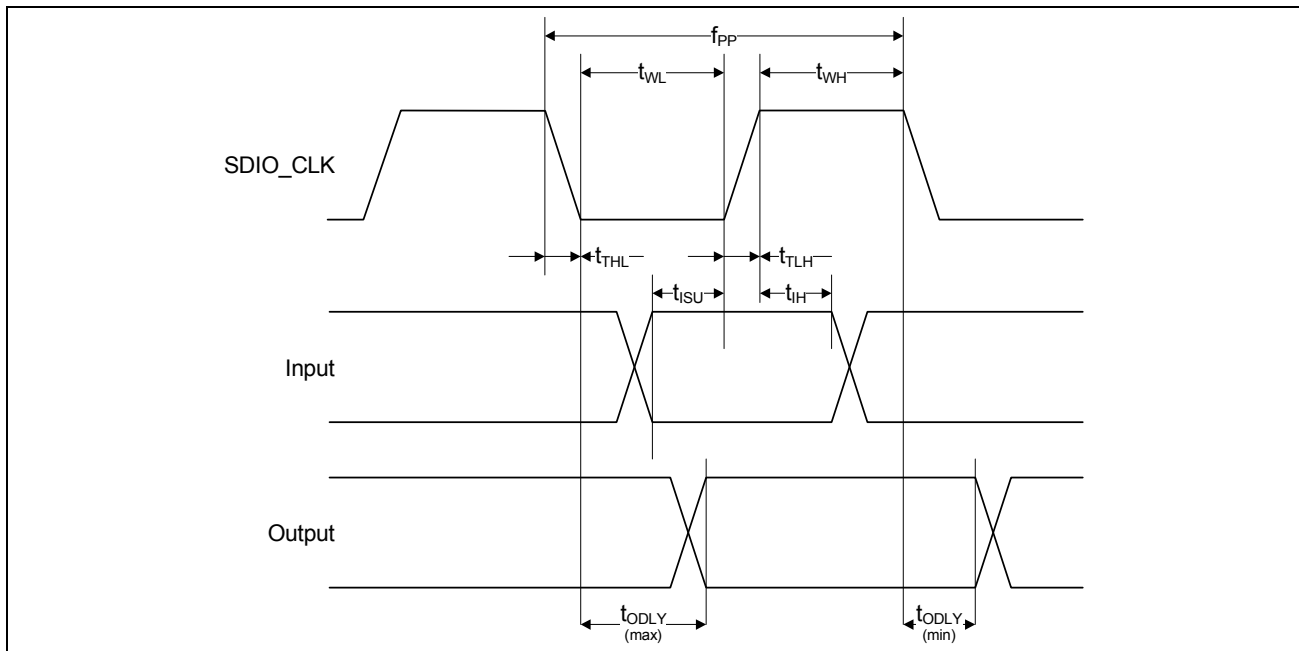
# Section 20: Interface Timing and AC Characteristics

## SDIO Timing

### SDIO Default Mode Timing

SDIO default mode timing is shown by the combination of [Figure 34](#) and [Table 53](#).

**Figure 34: SDIO Bus Timing (Default Mode)**



**Table 53: SDIO Bus Timing<sup>a</sup> Parameters (Default Mode)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
<b>SDIO CLK (All values are referred to minimum <math>V_{IH}</math> and maximum <math>V_{IL}</math><sup>b</sup>)</b>					
Frequency – Data Transfer mode	$f_{PP}$	0	–	25	MHz
Frequency – Identification mode	$f_{OD}$	0	–	400	kHz
Clock low time	$t_{WL}$	10	–	–	ns
Clock high time	$t_{WH}$	10	–	–	ns
Clock rise time	$t_{TLH}$	–	–	10	ns
Clock low time	$t_{THL}$	–	–	10	ns

**Table 53: SDIO Bus Timing<sup>a</sup> Parameters (Default Mode) (Cont.)**

<b>Parameter</b>	<b>Symbol</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
<b>Inputs: CMD, DAT (referenced to CLK)</b>					
Input setup time	tISU	5	–	–	ns
Input hold time	tIH	5	–	–	ns
<b>Outputs: CMD, DAT (referenced to CLK)</b>					
Output delay time – Data Transfer mode	tODLY	0	–	14	ns
Output delay time – Identification mode	tODLY	0	–	50	ns

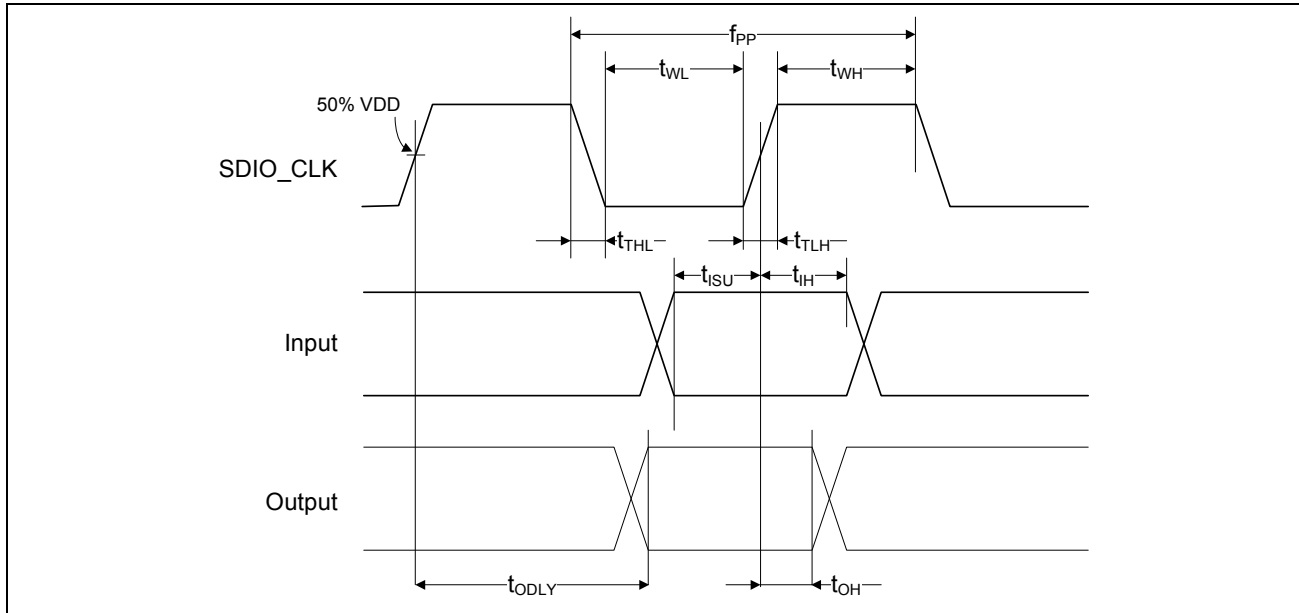
a. Timing is based on  $CL \leq 40$  pF load on CMD and Data.

b. Min (Vih) =  $0.7 \times VDDIO$  and max (Vil) =  $0.2 \times VDDIO$ .

## SDIO High-Speed Mode Timing

SDIO high-speed mode timing is shown by the combination of [Figure 35](#) and [Table 54](#).

**Figure 35: SDIO Bus Timing (High-Speed Mode)**



**Table 54: SDIO Bus Timing<sup>a</sup> Parameters (High-Speed Mode)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
<b>SDIO CLK (all values are referred to minimum <math>V_{IH}</math> and maximum <math>V_{IL}^b</math>)</b>					
Frequency – Data Transfer Mode	f <sub>PP</sub>	0	–	50	MHz
Frequency – Identification Mode	f <sub>OD</sub>	0	–	400	kHz
Clock low time	t <sub>WL</sub>	7	–	–	ns
Clock high time	t <sub>WH</sub>	7	–	–	ns
Clock rise time	t <sub>TLH</sub>	–	–	3	ns
Clock low time	t <sub>THL</sub>	–	–	3	ns
<b>Inputs: CMD, DAT (referenced to CLK)</b>					
Input setup Time	t <sub>ISU</sub>	6	–	–	ns
Input hold Time	t <sub>IH</sub>	2	–	–	ns
<b>Outputs: CMD, DAT (referenced to CLK)</b>					
Output delay time – Data Transfer Mode	t <sub>ODLY</sub>	–	–	14	ns
Output hold time	t <sub>OH</sub>	2.5	–	–	ns
Total system capacitance (each line)	CL	–	–	40	pF

- a. Timing is based on  $CL \leq 40$  pF load on CMD and Data.
- b. Min ( $V_{ih}$ ) =  $0.7 \times V_{DDIO}$  and max ( $V_{il}$ ) =  $0.2 \times V_{DDIO}$ .

## SDIO Bus Timing Specifications in SDR Modes

### Clock Timing

Figure 36: SDIO Clock Timing (SDR Modes)

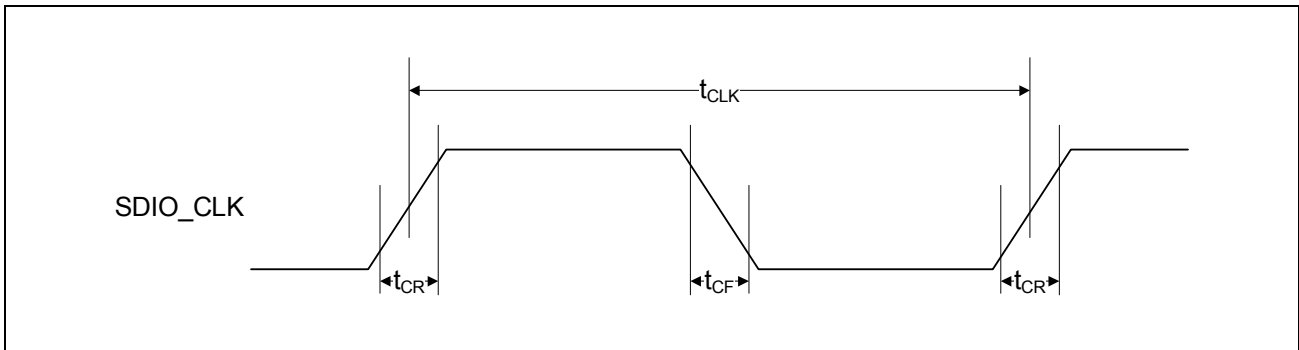


Table 55: SDIO Bus Clock Timing Parameters (SDR Modes)

Parameter	Symbol	Minimum	Maximum	Unit	Comments
–	$t_{CLK}$	40	–	ns	SDR12 mode
		20	–	ns	SDR25 mode
		10	–	ns	SDR50 mode
		4.8	–	ns	SDR104 mode
–	$t_{CR}, t_{CF}$	–	$0.2 \times t_{CLK}$	ns	$t_{CR}, t_{CF} < 2.00$ ns (max) @ 100 MHz, $C_{CARD} = 10$ pF $t_{CR}, t_{CF} < 0.96$ ns (max) @ 208 MHz, $C_{CARD} = 10$ pF
Clock duty cycle	–	30	70	%	–

## Card Input Timing

Figure 37: SDIO Bus Input Timing (SDR Modes)

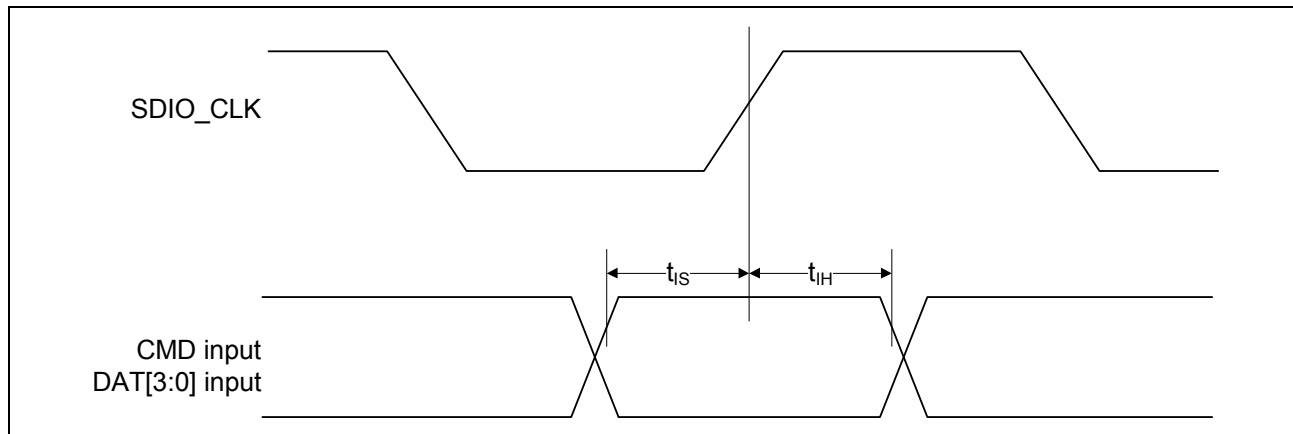


Table 56: SDIO Bus Input Timing Parameters (SDR Modes)

Symbol	Minimum	Maximum	Unit	Comments
<b>SDR104 Mode</b>				
$t_{IS}$	1.4	–	ns	$C_{CARD} = 10 \text{ pF}$ , $V_{CT} = 0.975\text{V}$
$t_{IH}$	0.8	–	ns	$C_{CARD} = 5 \text{ pF}$ , $V_{CT} = 0.975\text{V}$
<b>SDR50 Mode</b>				
$t_{IS}$	3.00	–	ns	$C_{CARD} = 10 \text{ pF}$ , $V_{CT} = 0.975\text{V}$
$t_{IH}$	0.8	–	ns	$C_{CARD} = 5 \text{ pF}$ , $V_{CT} = 0.975\text{V}$



## Card Output Timing

Figure 38: SDIO Bus Output Timing (SDR Modes up to 100 MHz)

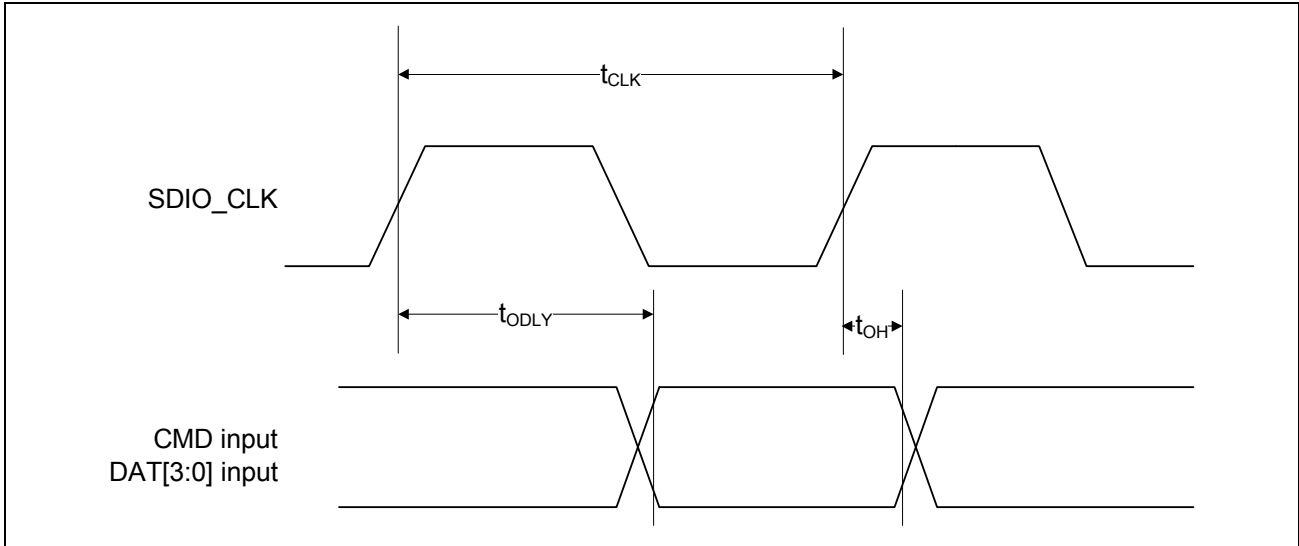
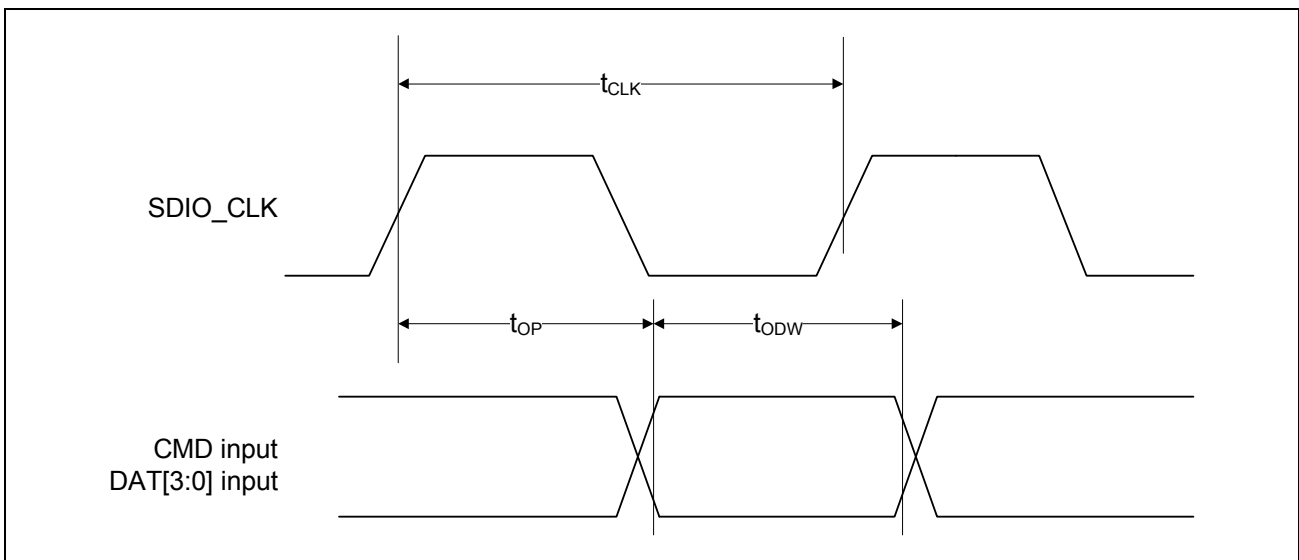


Table 57: SDIO Bus Output Timing Parameters (SDR Modes up to 100 MHz)

Symbol	Minimum	Maximum	Unit	Comments
$t_{ODLY}$	–	7.5	ns	$t_{CLK} \geq 10$ ns $C_L = 30$ pF using driver type B for SDR50
$t_{ODLY}$	–	14.0	ns	$t_{CLK} \geq 20$ ns $C_L = 40$ pF using for SDR12, SDR25
$t_{OH}$	1.5	–	ns	Hold time at the $t_{ODLY}$ (min) $C_L = 15$ pF

Figure 39: SDIO Bus Output Timing (SDR Modes 100 MHz to 208 MHz)

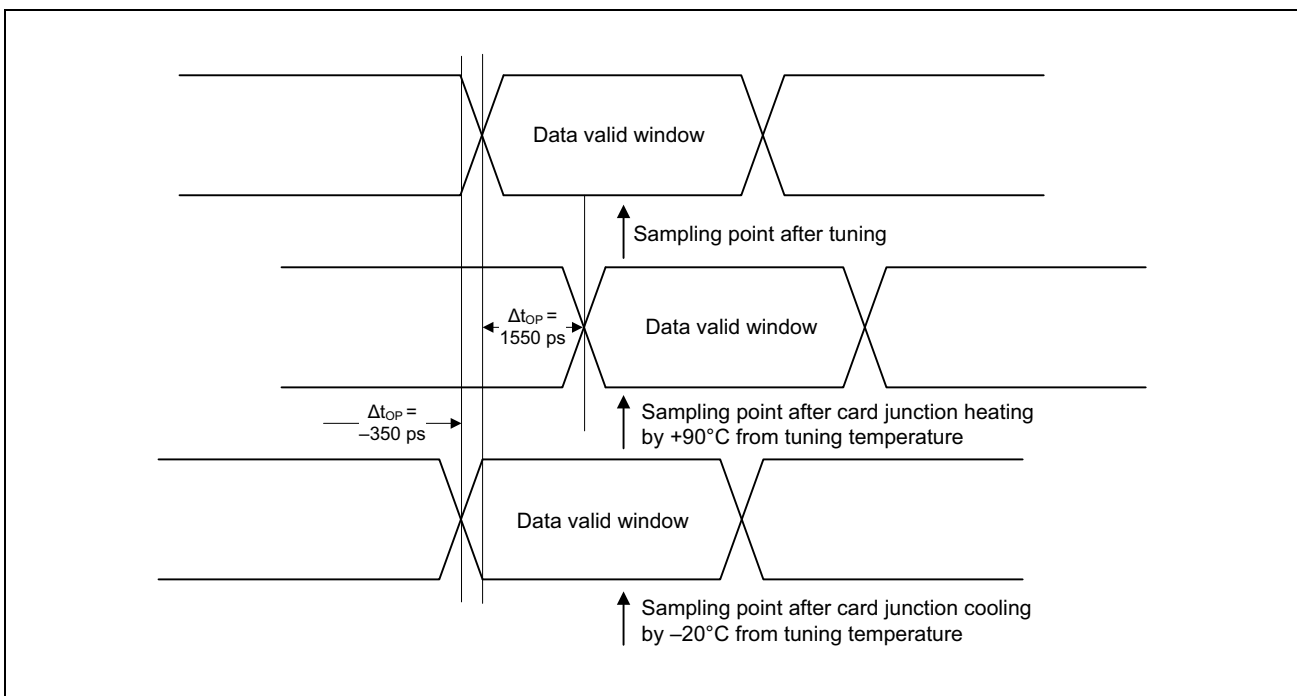


**Table 58: SDIO Bus Output Timing Parameters (SDR Modes 100 MHz to 208 MHz)**

Symbol	Minimum	Maximum	Unit	Comments
$t_{OP}$	0	2	UI	Card output phase
$\Delta t_{OP}$	-350	+1550	ps	Delay variation due to temp change after tuning
$t_{ODW}$	0.60	-	UI	$t_{ODW} = 2.88 \text{ ns @ 208 MHz}$

- $\Delta t_{OP} = +1550 \text{ ps}$  for junction temperature of  $\Delta t_{OP} = 90^\circ\text{C}$  during operation.
- $\Delta t_{OP} = -350 \text{ ps}$  for junction temperature of  $\Delta t_{OP} = -20^\circ\text{C}$  during operation.
- $\Delta t_{OP} = +2600 \text{ ps}$  for junction temperature of  $\Delta t_{OP} = -20^\circ\text{C}$  to  $+125^\circ\text{C}$  during operation.

**Figure 40:  $\Delta t_{OP}$  Consideration for Variable Data Window (SDR 104 Mode)**



## SDIO Bus Timing Specifications in DDR50 Mode

Figure 41: SDIO Clock Timing (DDR50 Mode)

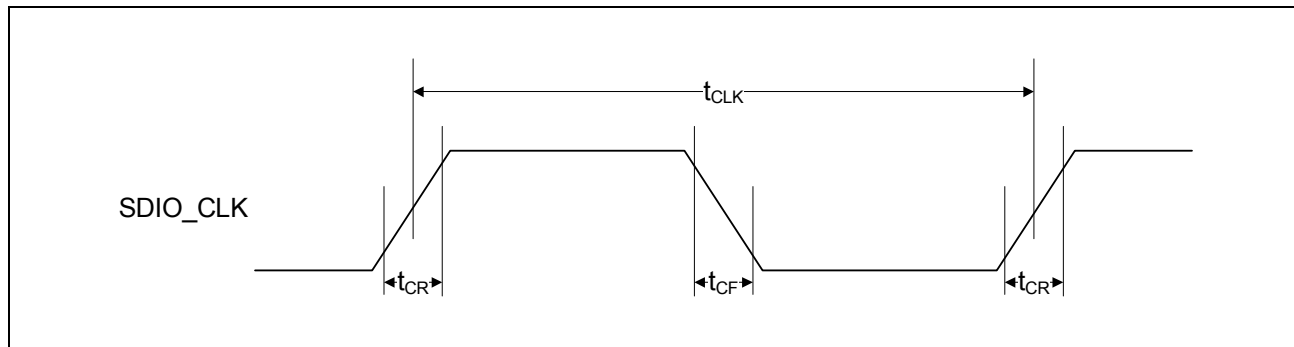


Table 59: SDIO Bus Clock Timing Parameters (DDR50 Mode)

Parameter	Symbol	Minimum	Maximum	Unit	Comments
–	$t_{CLK}$	20	–	ns	DDR50 mode
–	$t_{CR}, t_{CF}$	–	$0.2 \times t_{CLK}$	ns	$t_{CR}, t_{CF} < 4.00$ ns (max) @50 MHz, $C_{CARD} = 10$ pF
Clock duty cycle	–	45	55	%	–

## Data Timing

Figure 42: SDIO Data Timing (DDR50 Mode)

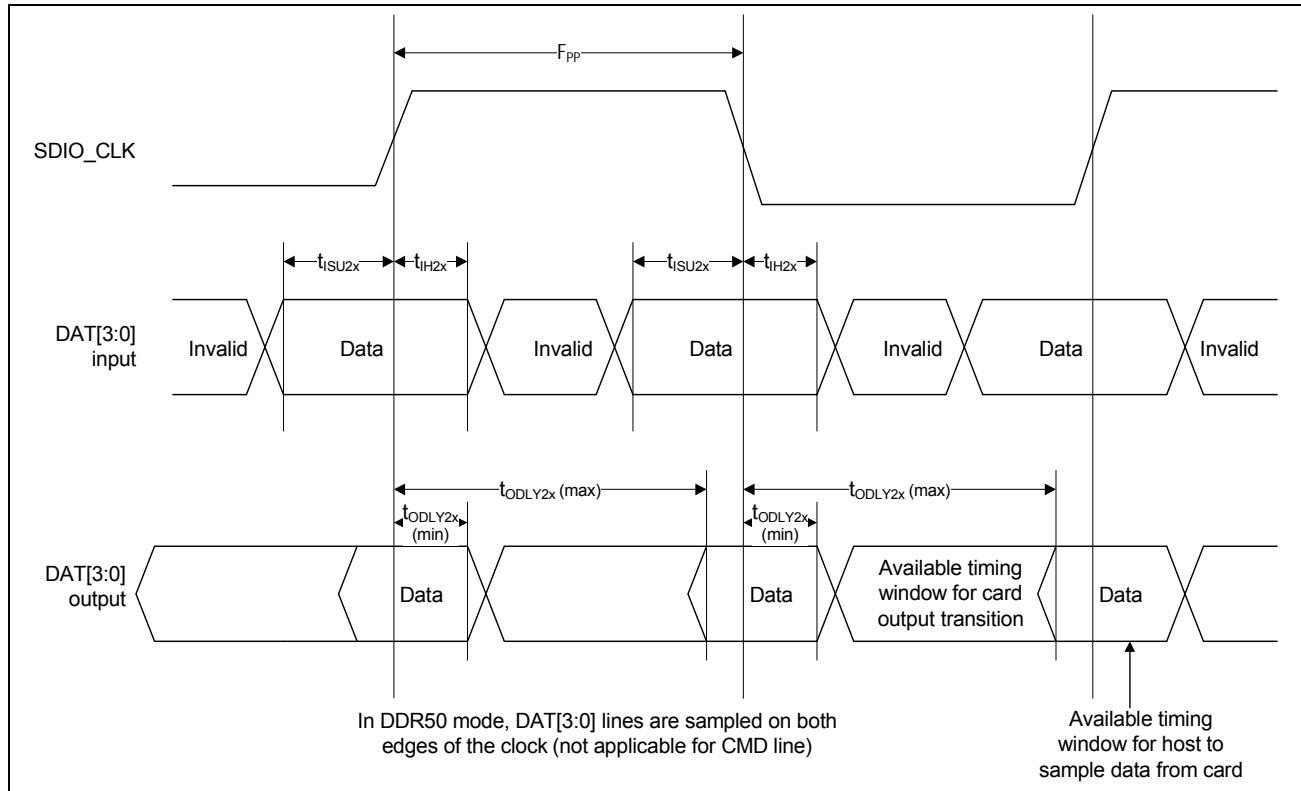


Table 60: SDIO Bus Timing Parameters (DDR50 Mode)

Parameter	Symbol	Minimum	Maximum	Unit	Comments
<b>Input CMD</b>					
Input setup time	$t_{ISU}$	6	–	ns	$C_{CARD} < 10 \text{ pF}$ (1 Card)
Input hold time	$t_{IH}$	0.8	–	ns	$C_{CARD} < 10 \text{ pF}$ (1 Card)
<b>Output CMD</b>					
Output delay time	$t_{ODLY}$	–	13.7	ns	$C_{CARD} < 30 \text{ pF}$ (1 Card)
Output hold time	$t_{OH}$	1.5	–	ns	$C_{CARD} < 15 \text{ pF}$ (1 Card)
<b>Input DAT</b>					
Input setup time	$t_{ISU2x}$	3	–	ns	$C_{CARD} < 10 \text{ pF}$ (1 Card)
Input hold time	$t_{IH2x}$	0.8	–	ns	$C_{CARD} < 10 \text{ pF}$ (1 Card)
<b>Output DAT</b>					
Output delay time	$t_{ODLY2x}$	–	7.5	ns	$C_{CARD} < 25 \text{ pF}$ (1 Card)
Output hold time	$t_{ODLY2x}$	1.5	–	ns	$C_{CARD} < 15 \text{ pF}$ (1 Card)

## PCI Express Interface Parameters

Table 61: PCI Express Interface Parameters

Parameter	Symbol	Comments	Minimum	Typical	Maximum	Unit
<b>General</b>						
Baud rate	BPS	–	–	5	–	Gbaud
Reference clock amplitude	Vref	LVPECL, AC coupled	1	–	–	V
<b>Receiver</b>						
Differential termination	ZRX-DIFF-DC	Differential termination	80	100	120	$\Omega$
DC impedance	ZRX-DC	DC common-mode impedance	40	50	60	$\Omega$
Powered down termination (POS)	ZRX-HIGH-IMP-DC-POS	Power-down or RESET high impedance	100k	–	–	$\Omega$
Powered down termination (NEG)	ZRX-HIGH-IMP-DC-NEG	Power-down or RESET high impedance	1k	–	–	$\Omega$
Input voltage	VRX-DIFFp-p	AC coupled, differential p-p	175	–	–	mV
Jitter tolerance	TRX-EYE	Minimum receiver eye width	0.4	–	–	UI
Differential return loss	RLRX-DIFF	Differential return loss	10	–	–	dB
Common-mode return loss	RLRX-CM	Common-mode return loss	6	–	–	dB
Unexpected electrical idle enter detect threshold integration time	TRX-IDEL-DET-DIFF-ENTERTIME	An unexpected electrical idle must be recognized no longer than this time to signal an unexpected idle condition.	–	–	10	ms
Signal detect threshold	VRX-IDLE-DET-DIFFp-p	Electrical idle detect threshold	65	–	175	mV
<b>Transmitter</b>						
Output voltage	VTX-DIFFp-p	Differential p-p, programmable in 16 steps	0.8	–	1200	mV
Output voltage rise time	VTX-RISE	20% to 80%	0.125 (2.5 GT/s) 0.15 (5 GT/s)	–	–	UI
Output voltage fall time	VTX-FALL	80% to 20%	0.125 (2.5 GT/s) 0.15 (5 GT/s)	–	–	UI

**Table 61: PCI Express Interface Parameters (Cont.)**

<b>Parameter</b>	<b>Symbol</b>	<b>Comments</b>	<b>Minimum</b>	<b>Typical</b>	<b>Maximum</b>	<b>Unit</b>
RX detection voltage swing	VTX-RCV-DETECT	The amount of voltage change allowed during receiver detection.	–	–	600	mV
TX AC peak common-mode voltage (5 GT/s)	VTX-CM-AC-PP	TX AC common mode voltage (5 GT/s)	–	–	100	mV
TX AC peak common-mode voltage (2.5 GT/s)	VTX-CM-AC-P	TX AC common mode voltage (2.5 GT/s)	–	–	20	mV
Absolute delta of DC common-mode voltage during L0 and electrical idle	VTX-CM-DC-ACTIVE-IDLE-DELTA	Absolute delta of DC common-mode voltage during L0 and electrical idle.	0	–	100	mV
Absolute delta of DC common-mode voltage between D+ and D-	VTX-CM-DC-LINE-DELTA	DC offset between D+ and D-	0	–	25	mV
Electrical idle differential peak output voltage	VTX-IDLE-DIFF-AC-p	Peak-to-peak voltage	0	–	20	mV
TX short circuit current	ITX-SHORT	Current limit when TX output is shorted to ground.	–	–	90	mA
DC differential TX termination	ZTX-DIFF-DC	Low impedance defined during signaling (parameter is captured for 5.0 GHz by RLTX-DIFF)	80	–	120	Ω
Differential return loss	RLTX-DIFF	Differential return loss	10 (min.) for 0.05: 1.25 GHz 8 (min.) for 1.25: 2.5 GHz	–	–	dB
Common-mode return loss	RLTX-CM	Common-mode return loss	6	–	–	dB
TX eye width	TTX-EYE	Minimum TX eye width	0.75	–	–	UI

# JTAG Timing

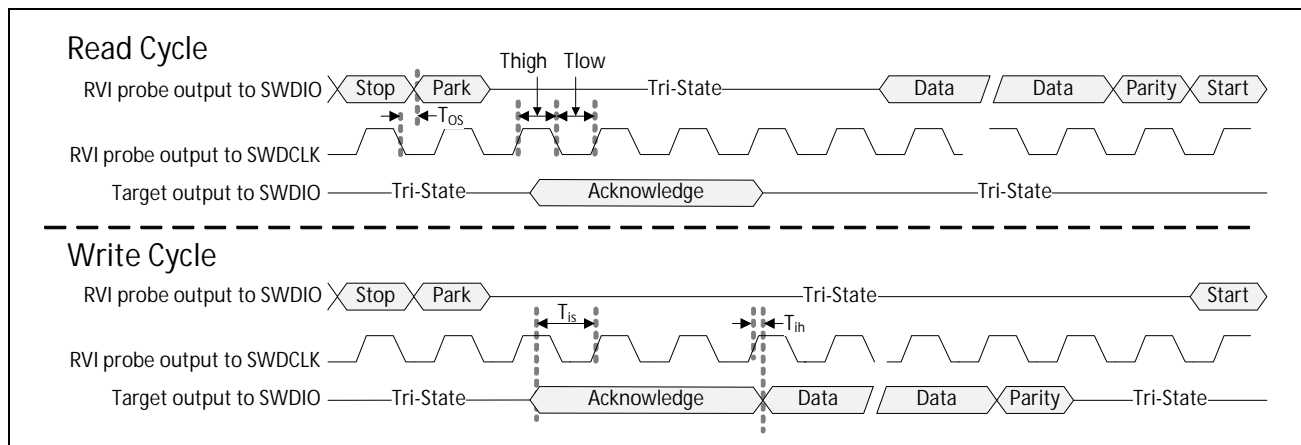
**Table 62: JTAG Timing Characteristics**

Signal Name	Period	Output Maximum	Output Minimum	Setup	Hold
TCK	125 ns	–	–	–	–
TDI	–	–	–	20 ns	0 ns
TMS	–	–	–	20 ns	0 ns
TDO	–	100 ns	0 ns	–	–
JTAG_TRST	250 ns	–	–	–	–

# SWD Timing

The probe outputs data to SWDIO on the falling edge of SWDCLK and captures data from SWDIO on the rising edge of SWDCLK. The target outputs data to SWDIO on the rising edge of SWDCLK and captures data from SWDIO on the rising edge of SWDCLK. SWD timing is defined through the combination of [Figure 43](#) and [Table 63](#).

**Figure 43: SWD Read and Write Timing**



**Table 63: SWD Read and Write Timing Parameters**

Parameter	Description	Min.	Max.	Units
$T_{cyc}$	SWDCLK cycle time	125	–	ns
$T_{high}$	SWDCLK high period	50	–	ns
$T_{low}$	SWDCLK low period	50	–	ns
$T_{os}$	SWDIO output skew to the falling edge of SWDCLK	–5	5	ns
$T_{is}$	Input setup time between SWDIO and the rising edge of SWDCLK	20	–	ns
$T_{ih}$	Input hold time between SWDIO and the rising edge of SWDCLK	0	100	ns

# Section 21: Power-Up Sequence and Timing

## Sequencing of Reset and Regulator Control Signals

The BCM43455 has two signals that allow the host to control power consumption by enabling or disabling the Bluetooth, WLAN, and internal regulator blocks. These signals are described below. Additionally, diagrams are provided to indicate proper sequencing of the signals for various operational states (see [Figure 44](#), [Figure 45 on page 152](#), and [Figure 46 on page 153](#) and [Figure 47 on page 153](#)). The timing values indicated are minimum required values; longer delays are also acceptable.

### Description of Control Signals

- **WL\_REG\_ON:** Used by the PMU to power-up the WLAN section. It is also OR-gated with the BT\_REG\_ON input to control the internal BCM43455 regulators. When this pin is high, the regulators are enabled and the WLAN section is out of reset. When this pin is low the WLAN section is in reset. If both the BT\_REG\_ON and WL\_REG\_ON pins are low, the regulators are disabled.
- **BT\_REG\_ON:** Used by the PMU (OR-gated with WL\_REG\_ON) to power-up the internal BCM43455 regulators. If both the BT\_REG\_ON and WL\_REG\_ON pins are low, the regulators are disabled. When this pin is low and WL\_REG\_ON is high, the BT section is in reset.



**Note:** For both the WL\_REG\_ON and BT\_REG\_ON pins, there should be at least a 10 ms time delay between consecutive toggles (where both signals have been driven low). This is to allow time for the CBUCK regulator to discharge. If this delay is not followed, then there may be a VDDIO in-rush current on the order of 36 mA during the next PMU cold start.

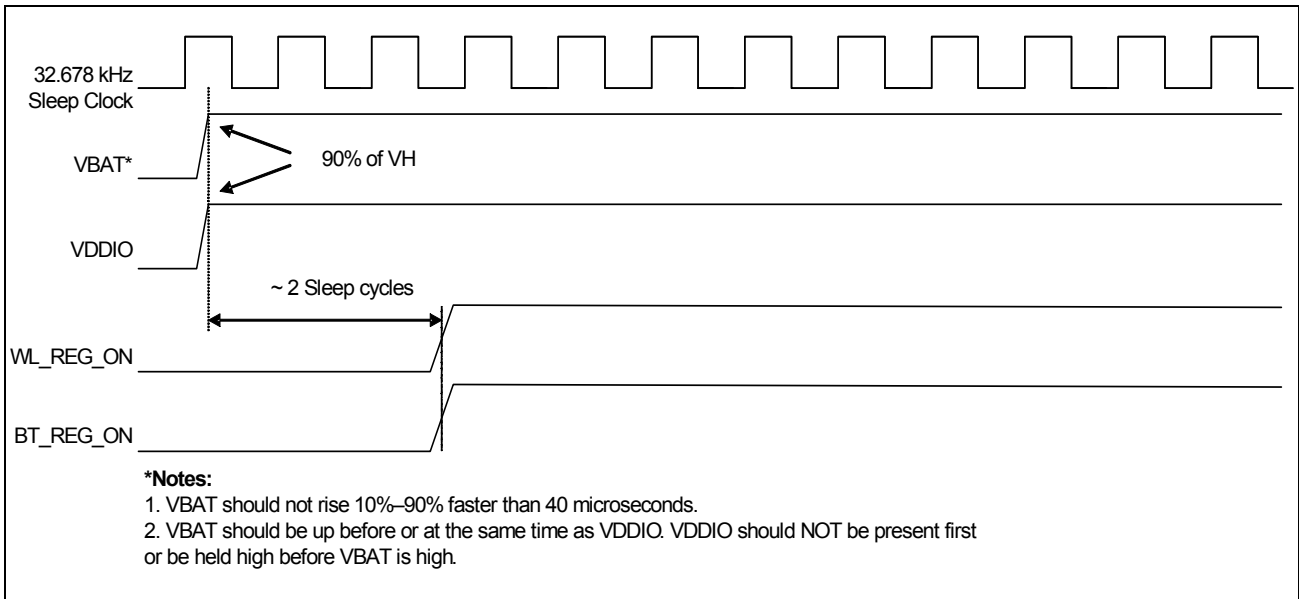
**Note:** The BCM43455 has an internal power-on reset (POR) circuit. The device will be held in reset for a maximum of 110 ms after VDDC and VDDIO have both passed the POR threshold. Wait at least 150 ms after VDDC and VDDIO are available before initiating PCIe accesses.

**Note:** VBAT should not rise 10%–90% faster than 40 microseconds. VBAT should be up before or at the same time as VDDIO. VDDIO should NOT be present first or be held high before VBAT is high.

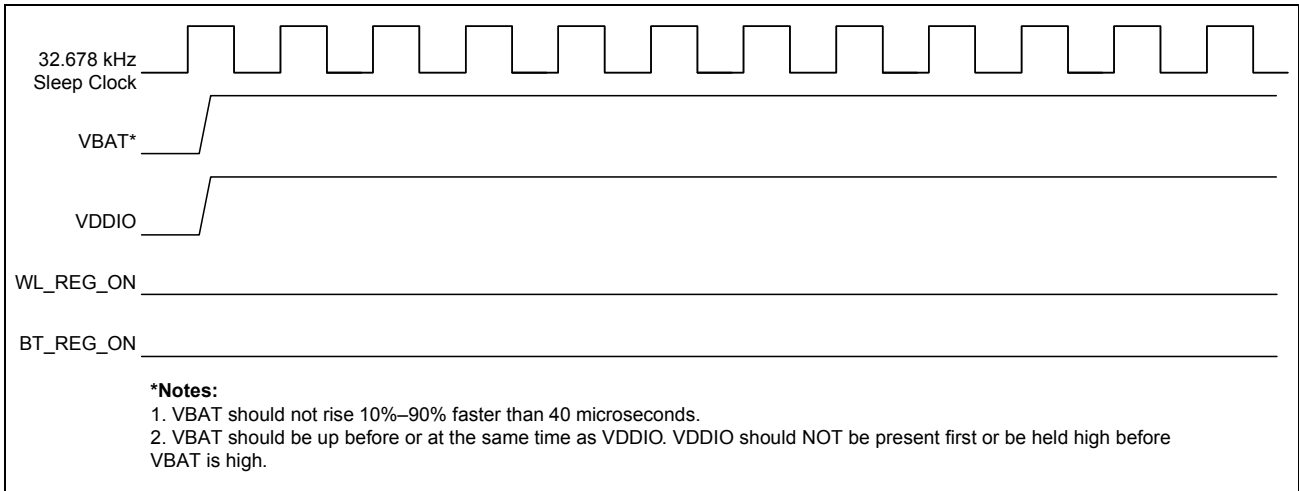


# Control Signal Timing Diagrams

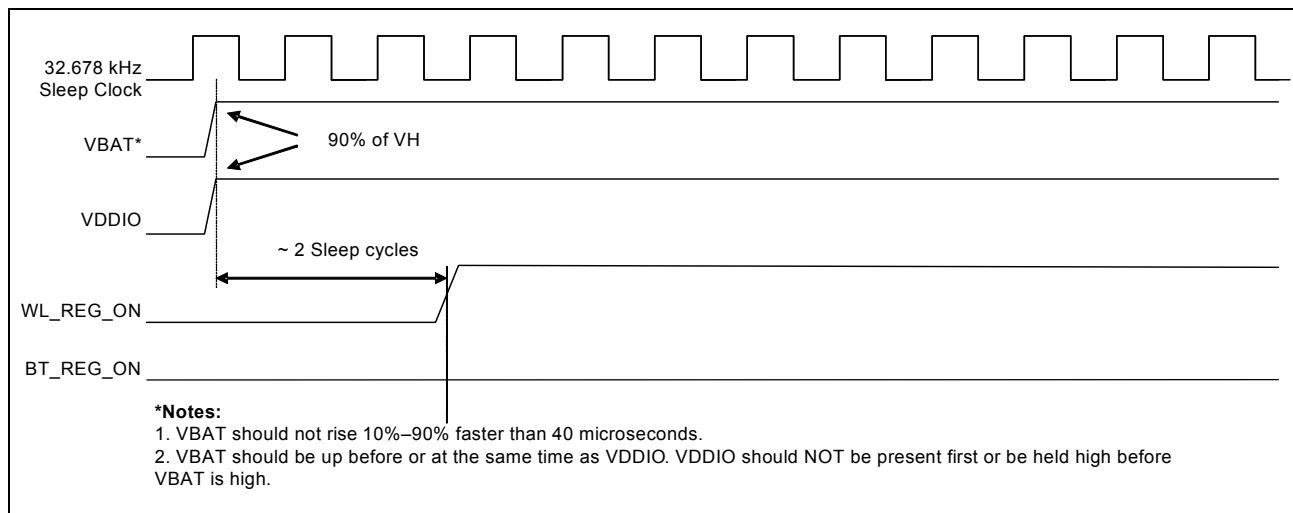
**Figure 44: WLAN = ON, Bluetooth = ON**



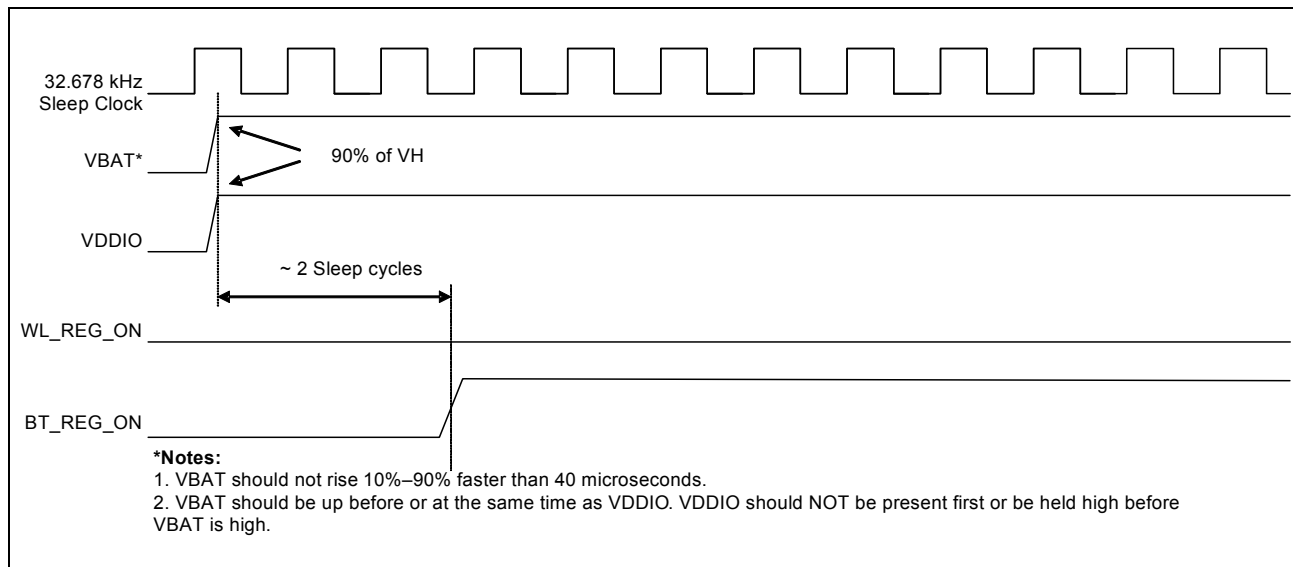
**Figure 45: WLAN = OFF, Bluetooth = OFF**



**Figure 46: WLAN = ON, Bluetooth = OFF**



**Figure 47: WLAN = OFF, Bluetooth = ON**



## Section 22: Package Information

### Package Thermal Characteristics

**Table 64: Package Thermal Characteristics<sup>a</sup>**

Characteristic	WLBGA
$\theta_{JA}$ (°C/W) (value in still air)	38.73
$\theta_{JB}$ (°C/W)	1.97
$\theta_{JC}$ (°C/W)	3.16
$\Psi_{JT}$ (°C/W)	9.3
$\Psi_{JB}$ (°C/W)	16.21
Maximum Junction Temperature $T_j$ (°C)	123.6
Maximum Power Dissipation (W)	1.38

a. No heat sink,  $T_A = 70^\circ\text{C}$ . This is an estimate, based on a 4-layer PCB that conforms to EIA/JESD51-7 (101.6 mm × 101.6 mm × 1.6 mm) and  $P = 1.119\text{W}$  continuous dissipation.

### Junction Temperature Estimation and $\Psi_{JT}$ Versus $\theta_{JC}$

Package thermal characterization parameter  $\Psi_{JT}$  yields a better estimation of actual junction temperature ( $T_J$ ) versus using the junction-to-case thermal resistance parameter  $\theta_{JC}$ . The reason for this is that  $\theta_{JC}$  assumes that all the power is dissipated through the top surface of the package case. In actual applications, some of the power is dissipated through the bottom and sides of the package.  $\Psi_{JT}$  takes into account power dissipated through the top, bottom, and sides of the package. The equation for calculating the device junction temperature is:

$$T_J = T_T + P \times \Psi_{JT}$$

Where:

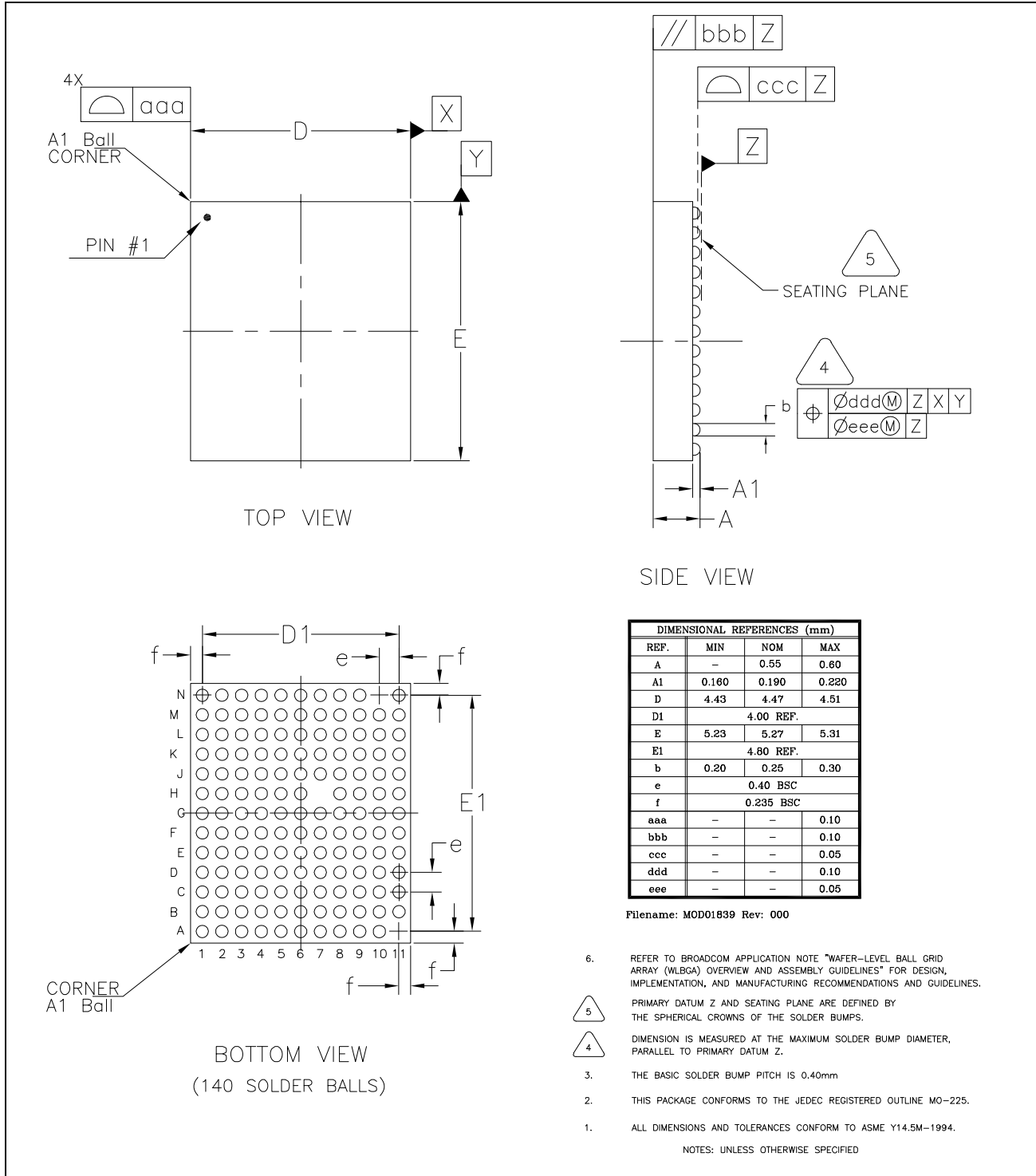
- $T_J$  = Junction temperature at steady-state condition (°C)
- $T_T$  = Package case top center temperature at steady-state condition (°C)
- $P$  = Device power dissipation (Watts)
- $\Psi_{JT}$  = Package thermal characteristics; no airflow (°C/W)

### Environmental Characteristics

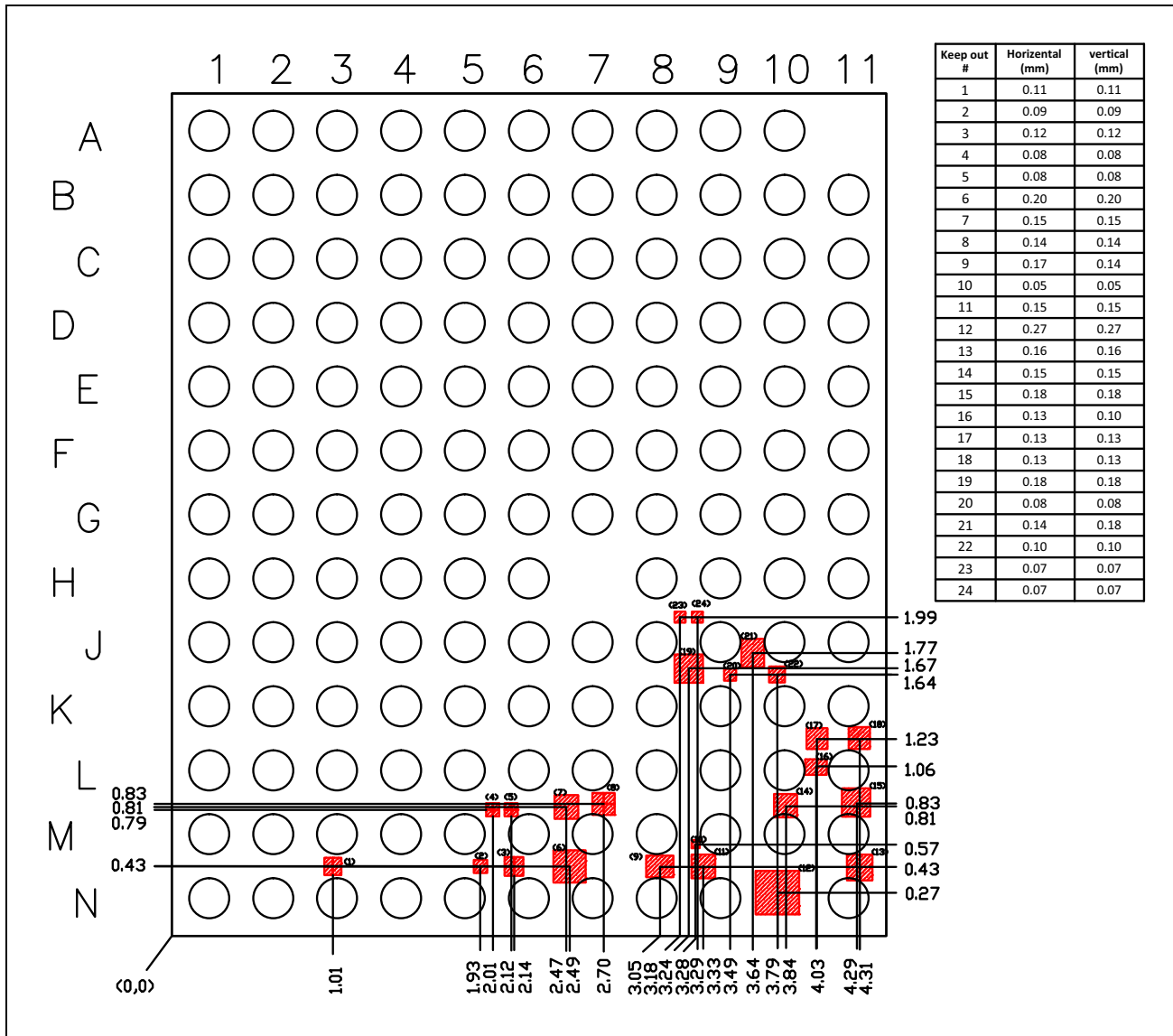
For environmental characteristics data, see [Table 25: "Environmental Ratings,"](#) on page 98.

# Section 23: Mechanical Information

Figure 48: 140-Ball WLBGA Package Mechanical Information



**Figure 49: 140-Balls WLBGA Keep-out Areas for PCB Layout—Top View with Balls Facing Down**



**Note:** No top-layer metal is allowed in keep-out areas.



**Note:** A DXF file for the WLBGA keep-out area is available for importation into a layout program. Contact your Broadcom FAE for more information.

## Section 24: Ordering Information

*Table 65: Part Ordering Information*

<b>Part Number</b>	<b>Package</b>	<b>Description</b>	<b>Operating Ambient Temperature</b>
BCM43455XKUBG	140-ball WLBGA (4.47 mm × 5.27 mm, 0.4 mm pitch)	Dual-band 2.4 GHz and 5 GHz WLAN+ BT 4.1 + FMRX	–30°C to +85°C
BCM43455HKUBG	140-ball WLBGA (4.47 mm × 5.27 mm, 0.4 mm pitch)	Dual-band 2.4 GHz and 5 GHz WLAN + BT 4.1 + FMRX, BSP	–30°C to +85°C

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