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CYW4339

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

General Description

The Cypress® CYW4339 single-chip device provides the highest level of integration for Internet of Things and handheld wireless system with integrated single-stream IEEE 802.11ac MAC/baseband/radio and Bluetooth 4.1. 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 up to 433.3 Mbps. In addition, all the rates specified in 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, LNAs, and antenna diversity are also supported.

For the WLAN section, several alternative host interface options are included: an SDIO v3.0 interface that can operate in 4b or 1b and a PCIe Gen1 interface (3.0 compliant). For the Bluetooth section, host interface options of a high-speed 4-wire UART and USB 2.0 full-speed (12 Mbps) are provided.

Using advanced design techniques and process technology to reduce active and idle power, the CYW4339 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 CYW4339 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, GPS, and WiMAX) is provided via an external interface. As a result, enhanced overall quality for simultaneous voice, video, and data transmission is achieved.

Cypress Part Numbering Scheme

Cypress is converting the acquired IoT part numbers from Cypress to the Cypress part numbering scheme. Due to this conversion, there is no change in form, fit, or function as a result of offering the device with Cypress part number marking. The table provides Cypress ordering part number that matches an existing IoT part number.

Table 1. Mapping Table for Part Number between Broadcom and Cypress

Broadcom Part Number	Cypress Part Number
BCM4339	CYW4339
BCM4339XKUBG	CYW4339XKUBG
BCM4339NKFFBG	CYW4339NKFFBG
BCM4339XKWBG	CYW4339XKWBG

Features

IEEE 802.11x Key Features

- IEEE 802.11ac compliant.
- 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.
- Tx and Rx low-density parity check (LDPC) support for improved range and power efficiency.
- Supports Rx space-time block coding (STBC)
- Supports IEEE 802.11ac/n beamforming.
- On-chip power amplifiers and low-noise amplifiers for both bands.
- Support for optional front-end modules (FEM) with external PAs and LNAs
- 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 nPLL 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, GPS, or WiMAX
- Supports standard SDIO v3.0 (including DDR50 mode at 50 MHz and SDR104 mode at 208 MHz, 4-bit and 1-bit) host interfaces.
- Backward compatible with SDIO v2.0 host interfaces.
- PCIe mode (FCBGA package only) 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, 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 768 KB SRAM and 640 KB ROM.
- OneDriver™ software architecture for easy migration from existing embedded WLAN and Bluetooth devices as well as future devices.

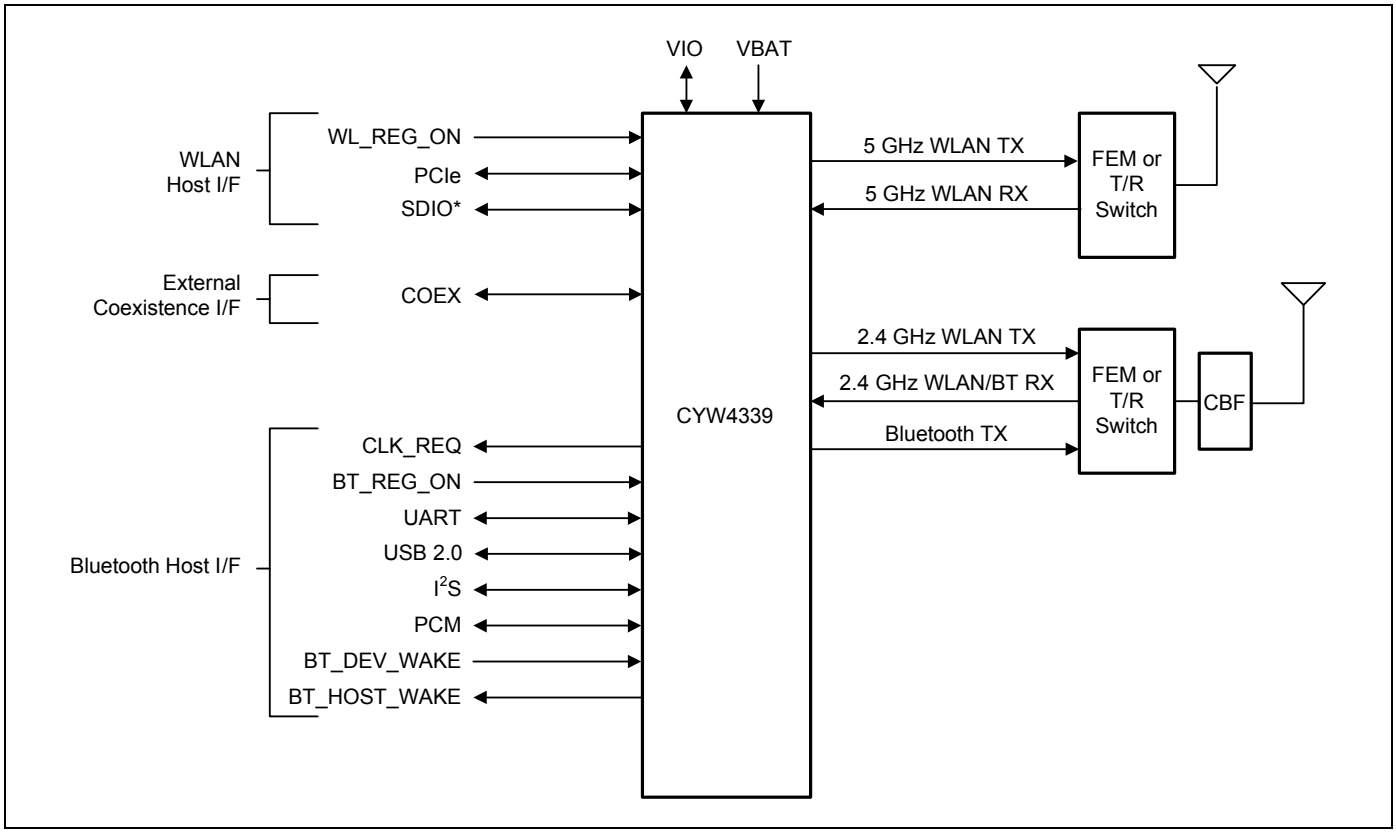
Bluetooth Key Features

- 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 USB or high-speed UART interface and PCM for audio data.
- USB 2.0 full-speed (12 Mbps) supported (FCFBGA and WLCSP packages).
- 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.
- Supports serial flash interfaces.

General Features

- Supports battery voltage range from 3.0V to 5.25V supplies with internal switching regulator.
- Programmable dynamic power management
- OTP: 502 bytes of user-accessible memory
- GPIOs: 12 on FCFBGA, nine on WLBGA, and 16 on WLCSP
- Package options:
  - 160 ball FCFBGA (8 mm x 8 mm, 0.4 mm pitch)
  - 145 ball WLBGA (4.87 mm × 5.413 mm, 0.4 mm pitch)
  - 286 bump WLCSP (4.87 mm × 5.413 mm, 0.2 mm pitch)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, CCX 4.0, CCX 5.0)
  - Reference WLAN subsystem provides Wi-Fi Protected Setup (WPS)
- Worldwide regulatory support: Global products supported with worldwide homologated design.

Figure 1: Functional Block Diagram



Contents

1. Overview

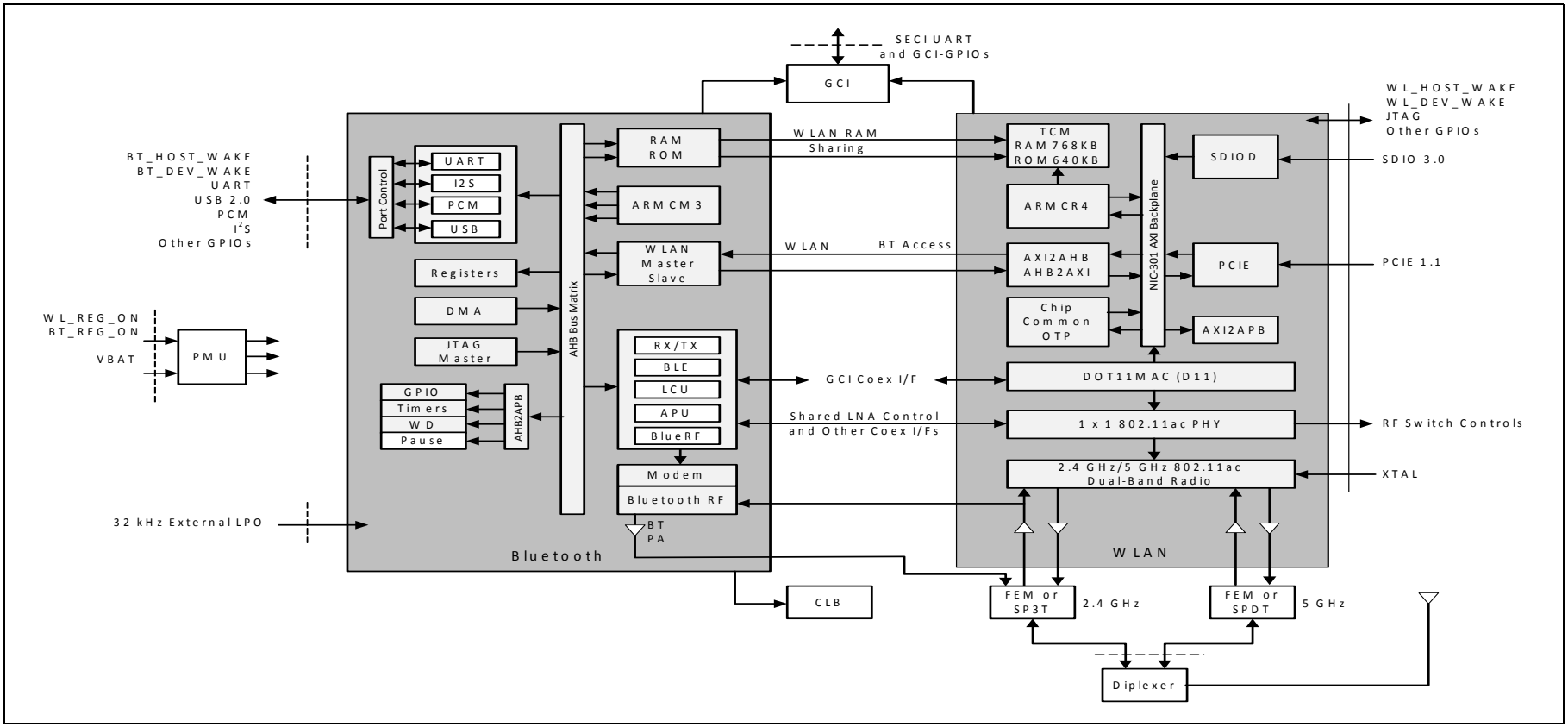
1.1 Overview

The Cypress CYW4339 single-chip device provides the highest level of integration for IoT applications or handheld wireless system, with integrated IEEE 802.11 a/b/g/n/ac MAC/baseband/radio, Bluetooth 4.1 + enhanced data rate (EDR).

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.

The following figure shows the interconnect of all the major physical blocks in the CYW4339 and their associated external interfaces, which are described in greater detail in the following sections.

Figure 1. CYW4339 Block Diagram



1.2 Features

The CYW4339 supports the following features:

- IEEE 802.11a/b/g/n/ac dual-band radio with virtual-simultaneous dual-band operation
- Bluetooth v4.1 + EDR with integrated Class 1 PA
- Concurrent Bluetooth, and WLAN operation
- On-chip WLAN driver execution capable of supporting IEEE 802.11 functionality
- WLAN host interface options:
  - SDIO v3.0 (1-bit/4-bit)—up to 208 MHz clock rate in SDR104 mode
- BT host digital interface (which can be used concurrently with the above interfaces):
  - UART (up to 4 Mbps)
- BT supports full-speed USB version 1.1 for FCBGA package.
- ECI—enhanced coexistence support, ability to coordinate BT SCO transmissions around WLAN receptions
- I^2S/PCM for BT audio
- HCI high-speed UART (H4, H4+, H5) transport support
- Wideband speech support (16 bits linear data, MSB first, left justified at 4K samples/s for transparent air coding, both through I^2S and PCM interface)
- Bluetooth SmartAudio® technology improves voice and music quality to headsets
- Bluetooth low-power inquiry and page scan
- Bluetooth Low Energy (BLE) support
- Bluetooth Packet Loss Concealment (PLC)
- Bluetooth Wide Band Speech (WBS)
- Audio rate-matching algorithms
- Multiple simultaneous A2DP audio streams

1.3 Standards Compliance

The CYW4339 supports the following standards:

- Bluetooth 2.1 + EDR
- Bluetooth 3.0
- Bluetooth 4.1 (Bluetooth Low Energy)
- IEEE802.11ac single-stream mandatory and optional requirements for 20 MHz, 40 MHz, 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 (HW Accelerator)
  - CKIP (SW Support)
- Proprietary Protocols:
  - CCXv2
  - CCXv3
  - CCXv4
  - CCXv5
- IEEE 802.15.2 Coexistence Compliance—on silicon solution compliant with IEEE 3 wire requirements

The CYW4339 will support 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

2. Power Supplies and Power Management

2.1 Power Supply Topology

One buck regulator, multiple LDO regulators, and a power management unit (PMU) are integrated into the CYW4339. 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 maximum) and VIO supply (1.8V to 3.3V) can be used, with all additional voltages being provided by the regulators in the CYW4339.

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 and on based on the dynamic demands of the digital baseband.

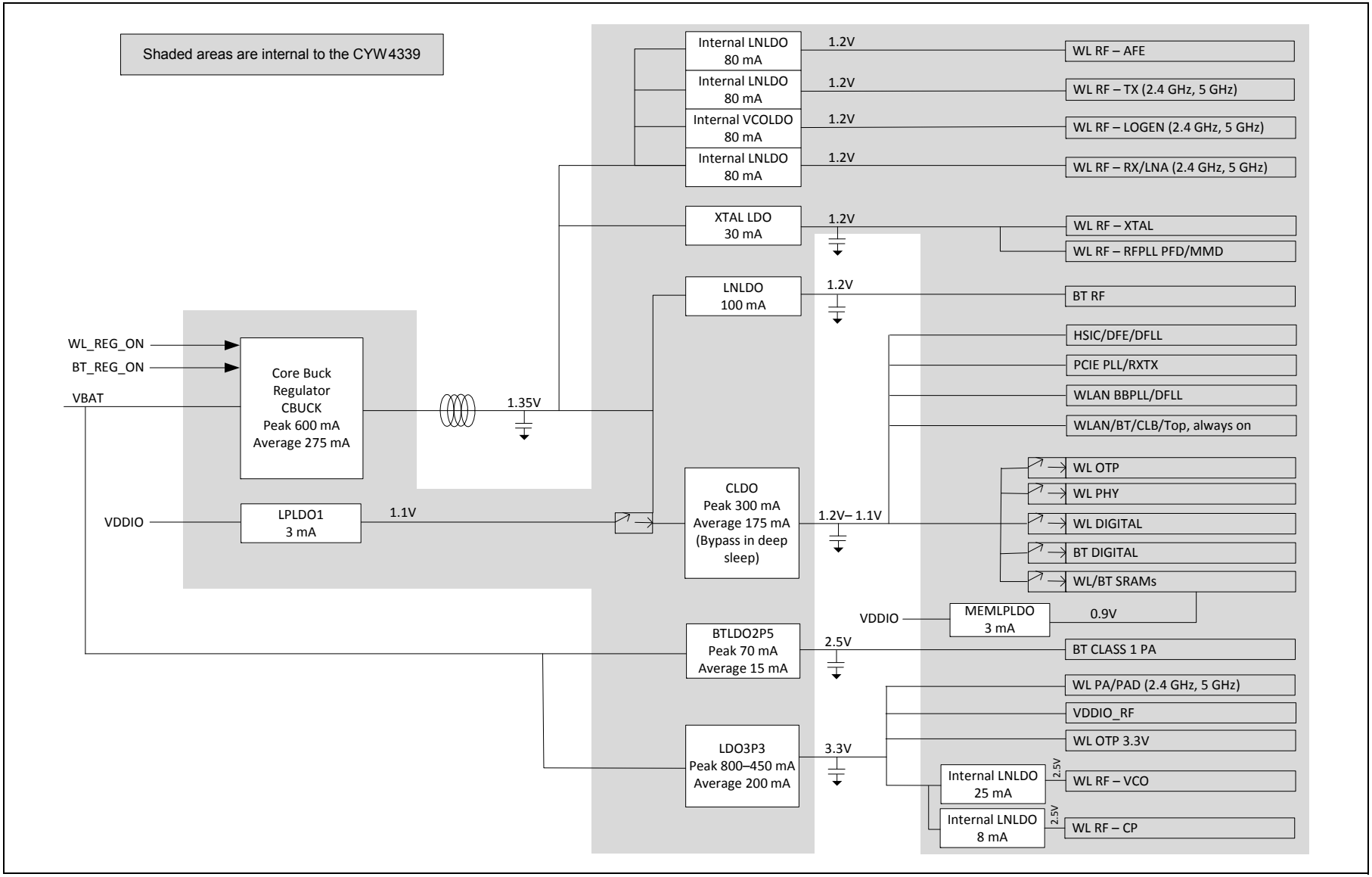
The CYW4339 allows for an extremely low power-consumption mode by completely shutting down the CBUCK, CLDO, and LNLDO regulators. When in this state, LPLDO1 and LPLDO2 (which are low-power linear regulators that are supplied by the system VIO supply) provide the CYW4339 with all the voltages it requires, further reducing leakage currents.

2.2 PMU Features

- VBAT to 1.35V (275 mA nominal, 600 mA maximum) Core-Buck (CBUCK) switching regulator
- VBAT to 3.3V (200 mA nominal, 450 mA maximum) LDO3P3
- VBAT to 2.5V (15 mA nominal, 70 mA maximum) BTLDO2P5
- 1.35V to 1.2V (100 mA nominal, 150 mA maximum) LNLDO
- 1.35V to 1.2V (175 mA nominal, 300 mA maximum) CLDO with bypass mode for deep-sleep
- Additional internal LDOs (not externally accessible)

The following figure shows the regulators and a typical power topology.

Figure 2. Typical Power Topology for CYW4339



2.3 WLAN Power Management

The CYW4339 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 CYW4339 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 CYW4339 includes an advanced WLAN power management unit (PMU) sequencer. The PMU sequencer provides significant power savings by putting the CYW4339 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 the 32.768 kHz LPO clock frequency) in the PMU sequencer are used to turn on and 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 CYW4339 WLAN power states are described as follows:

- Active mode—All WLAN blocks in the CYW4339 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 CYW4339 remains powered up in an IDLE state. All main clocks (PLL, crystal oscillator or TCXO) are shut down to reduce active power consumption 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 SDIO bus, logic states in the digital core are restored to their pre-deep-sleep settings to avoid lengthy HW reinitialization.
- Power-down mode—The CYW4339 is effectively powered off by shutting down all internal regulators. The chip is brought out of this mode by external logic reenabling the internal regulators.

2.4 PMU Sequencing

The PMU sequencer is responsible for minimizing system power consumption. It enables and disables various system resources 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.

Resource requests may come 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, and transition_off) and has a timer that contains 0 when the resource is enabled or disabled and a nonzero 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 go immediately from disabled to enabled. Similarly, a time_off value of 0 indicates that the resource can go 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 Resource Pending bit for the resource and inverts the Resource State 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.

2.5 Power-Off Shutdown

The CYW4339 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 CYW4339 is not needed in the system, VDDIO_RF and VDDC are shut down while VDDIO remains powered. This allows the CYW4339 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 shut-down state, the provided VDDIO remains applied to the CYW4339, 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 CYW4339 to be fully integrated in an embedded device and take full advantage of the lowest power-savings modes.

When the CYW4339 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.

2.6 Power-Up/Power-Down/Reset Circuits

The CYW4339 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 Power-Up Sequence and Timing on page 119.

Table 1. Power-Up/Power-Down/Reset Control Signals

Signal	Description
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 CYW4339 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 kΩ 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 CYW4339 regulators. If BT_REG_ON and WL_REG_ON are low, the regulators will be disabled. This pin has an internal 200 kΩ pull-down resistor that is enabled by default. It can be disabled through programming.

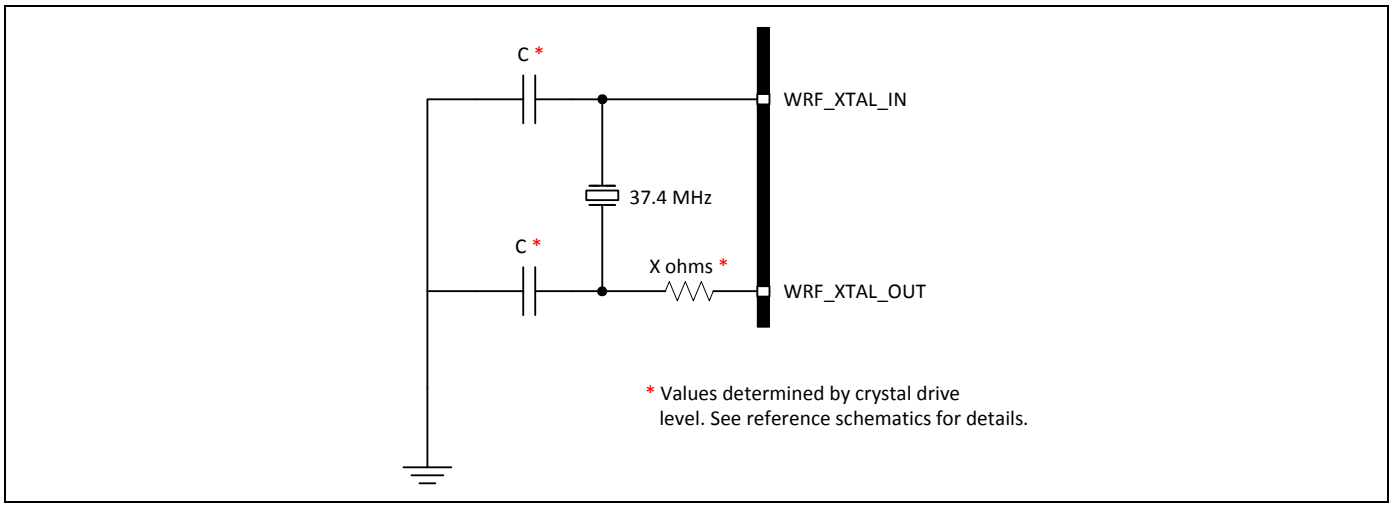
3. Frequency References

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.

3.1 Crystal Interface and Clock Generation

The CYW4339 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 3. Consult the reference schematics for the latest configuration and recommended components.

Figure 3. Recommended Oscillator Configuration



A fractional-N synthesizer in the CYW4339 generates the radio frequencies, clocks, and data/packet timing, enabling the CYW4339 to operate using a wide selection of frequency references.

For SDIO applications, the recommended default frequency reference is a 37.4 MHz crystal. The signal characteristics for the crystal interface are listed in Table 2.

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 Cypress for details.

3.2 External Frequency Reference

As an alternative to a crystal, an external precision frequency reference can be used. The recommended default frequency is 37.4 MHz. This must meet the phase noise requirements listed in Table 2.

If used, the external clock should be connected to the WRF_XTAL_IN pin through an external 1000 pF coupling capacitor, as shown in Figure 4. The internal clock buffer connected to this pin will be turned off when the CYW4339 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_BUCK_VDD1P5 pin.

Figure 4. Recommended Circuit to Use with an External Reference Clock

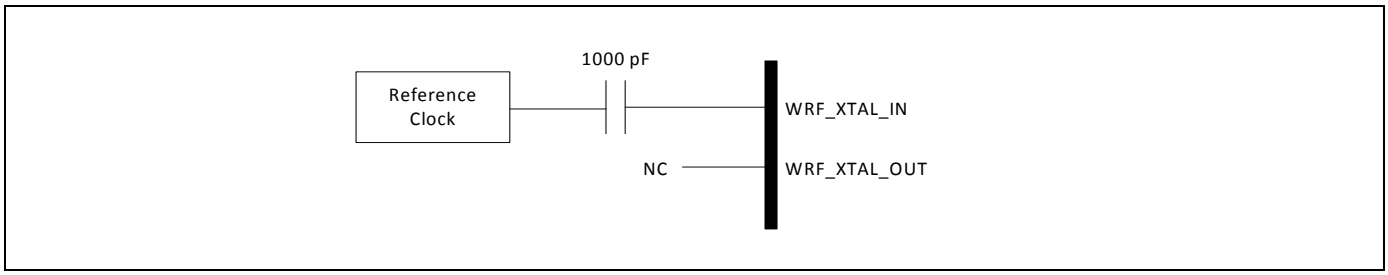


Table 2. Crystal Oscillator and External Clock—Requirements and Performance

Parameter	Conditions/Notes	Crystal[1]			External Frequency Reference[2 3]			
		Min.	Typ.	Max.	Min.	Typ.	Max.	Units
Frequency	2.4 GHz and 5 GHz bands, IEEE 802.11ac operation	35	37.4	38.4	–	37.4	–	MHz
Frequency	5 GHz band, IEEE 802.11n operation only	19	37.4	38.4	35	37.4	38.4	MHz
Frequency	2.4 GHz band IEEE 802.11n operation, and both bands legacy 802.11a/b/g operation only	Ranges between 19 MHz and 38.4 MHz[4]						
Frequency tolerance over the lifetime of the equipment, including temperature[5]	Without trimming	–20	–	20	–20	–	20	ppm
Crystal load capacitance	–	–	12	–	–	–	–	pF
ESR	–	–	–	60	–	–	–	Ω
Drive level	External crystal must be able to tolerate this drive level.	200	–	–	–	–	–	µW
Input impedance (WRF_XTAL_IN)	Resistive	–	–	–	30k	100k	–	Ω
	Capacitive	–	–	7.5	–	–	7.5	pF
WRF_XTAL_IN input low level	DC-coupled digital signal	–	–	–	0	–	0.2	V
WRF_XTAL_IN input high level	DC-coupled digital signal	–	–	–	1.0	–	1.26	V
WRF_XTAL_IN input voltage (see Figure 4)	AC-coupled analog signal	–	–	–	1000	–	1200	mV_{p-p}
Duty cycle	37.4 MHz clock	–	–	–	40	50	60	%
Phase noise[6] (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[6] (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

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

Parameter	Conditions/Notes	Crystal[1]			External Frequency Reference[2 3]			
		Min.	Typ.	Max.	Min.	Typ.	Max.	Units
Phase noise[6] (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[6] (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[6] (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

1. (Crystal) Use WRF_XTAL_IN and WRF_XTAL_OUT.

2. See External Frequency Reference for alternative connection methods.

3. For a clock reference other than 37.4 MHz, 20 × log10(f/37.4) dB should be added to the limits, where f = the reference clock frequency in MHz.

4. The frequency step size is approximately 80 Hz.

5. It is the responsibility of the equipment designer to select oscillator components that comply with these specifications.

6. Assumes that external clock has a flat phase-noise response above 100 kHz.

3.3 Frequency Selection

Any frequency within the ranges specified for the crystal and TCXO reference may be used. These include not only the standard mobile platform reference frequencies of 19.2, 19.8, 24, 26, 33.6, 37.4, and 38.4 MHz, but also other frequencies in this range with an approximate resolution of 80 Hz. The CYW4339 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 Cypress for details.

The reference frequency for the CYW4339 may be set in the following ways:

- Set the xtalfreq=xxxxx parameter in the nvram.txt file (used to load the driver) to correctly match the crystal frequency.
- Autodetect 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 CYW4339 automatically detects the reference frequency and programs itself to the correct reference frequency. In order for automatic frequency detection to work correctly, the CYW4339 must have a valid and stable 32.768 kHz LPO clock that meets the requirements listed in Table 3 and is present during power-on reset.

3.4 External 32.768 kHz Low-Power Oscillator

The CYW4339 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 ± 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

Parameter	LPO Clock	Units
Nominal input frequency	32.768	kHz
Frequency accuracy	±200	ppm
Duty cycle	30–70	%
Input signal amplitude	200–1800	mV, p-p
Signal type	Square-wave or sine-wave	–
Input impedance[1]	>100k <5	Ω pF
Clock jitter (during initial start-up)	<10,000	ppm

1. When power is applied or switched off.

4. Bluetooth Subsystem Overview

The Cypress CYW4339 is a Bluetooth 4.1 + EDR-compliant, baseband processor/2.4 GHz transceiver. 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 Wi-Fi system.

The CYW4339 is the optimal solution for any Bluetooth voice and/or data application. The Bluetooth subsystem presents a standard Host Controller Interface (HCI) via a high-speed UART and PCM for audio. The CYW4339 incorporates all Bluetooth 4.1 features including Secure Simple Pairing, Sniff Subrating, and Encryption Pause and Resume.

The CYW4339 Bluetooth radio transceiver provides enhanced radio performance to meet the most stringent mobile phone temperature applications and the tightest integration into handsets and portable devices. It is fully compatible with any of the standard TCXO frequencies and 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.

4.1 Features

Major Bluetooth features of the CYW4339 include:

- Supports key features of upcoming Bluetooth standards
- Fully supports Bluetooth Core Specification version 4.1 + (Enhanced Data Rate) 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 Bluetooth 4.1 packet types
- Supports maximum Bluetooth data rates over HCI UART
- BT supports full-speed USB version 1.1 in the FCBGA package
- 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 Cypress 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)
- 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

- TCXO input and autodetection of all standard handset clock frequencies. Also supports a low-power crystal, which can be used during power save mode for better timing accuracy.

4.2 Bluetooth Radio

The CYW4339 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.

4.2.1 Transmit

The CYW4339 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 performs signal filtering, I/Q upconversion, output power amplification, and RF filtering. The transmitter path also incorporates π/4-DQPSK and 8-DPSK modulations for 2 Mbps and 3 Mbps EDR support, respectively. 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.

4.2.2 Digital Modulator

The digital modulator performs the data modulation and filtering required for the GFSK, π/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.

4.2.3 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.

4.2.4 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 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.

4.2.5 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 CYW4339 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.

4.2.6 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.

4.2.7 Receiver Signal Strength Indicator

The radio portion of the CYW4339 provides a Receiver Signal Strength Indicator (RSSI) signal to the baseband, so that the controller can determine whether the transmitter should increase or decrease its output power.

4.2.8 Local Oscillator Generation

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 CYW4339 uses an internal RF and IF loop filter.

4.2.9 Calibration

The CYW4339 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 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.

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:

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

5.1 Bluetooth 4.1 Features

The BBC supports all Bluetooth 4.1 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.

5.2 Bluetooth Low Energy

The CYW4339 supports the Bluetooth Low Energy operating mode.

5.3 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

5.4 Test Mode Support

The CYW4339 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 CYW4339 also supports enhanced testing features to simplify RF debugging, 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
  - Eight-bit fixed pattern or PRBS-9
  - Enables modulated signal measurements with standard RF test equipment

5.5 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 CYW4339 are:

- RF Power Management
- Host Controller Power Management
- BBC Power Management

5.5.1 RF Power Management

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

5.5.2 Host Controller Power Management

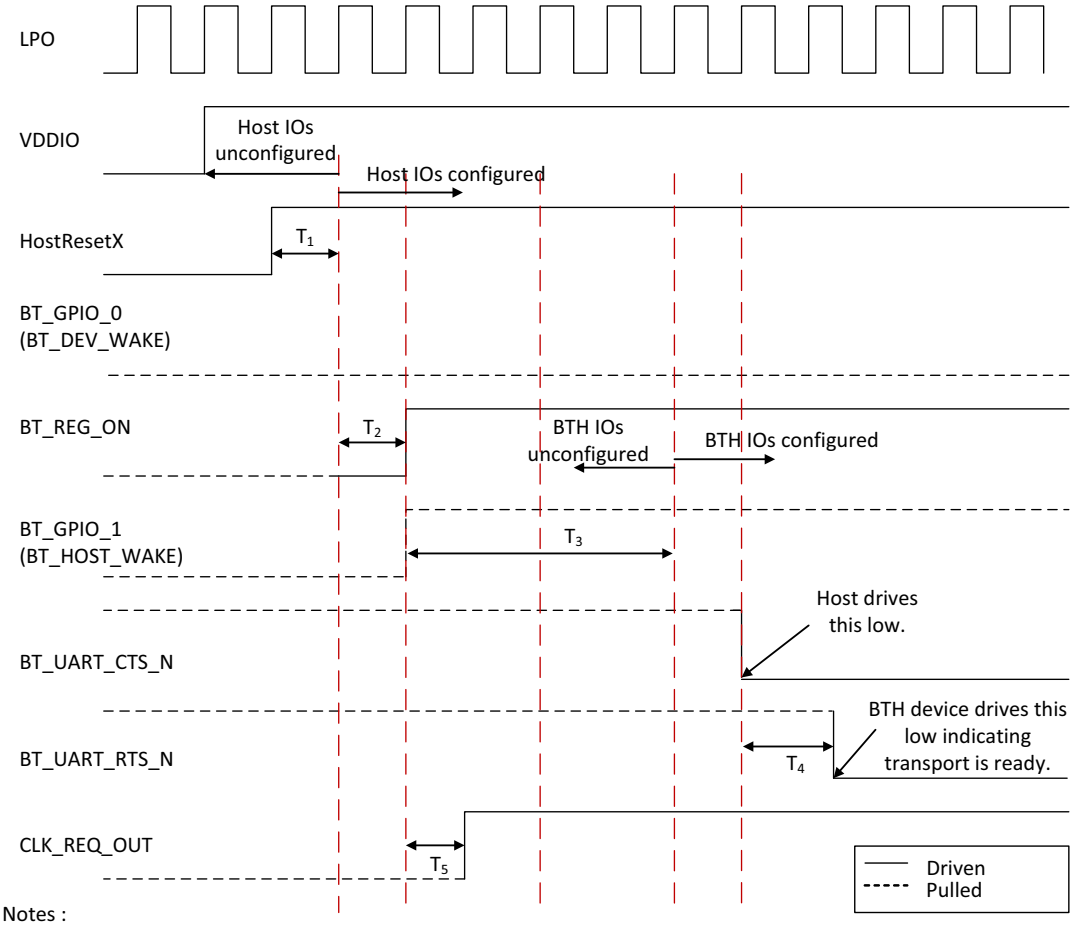
When running in UART mode, the CYW4339 may be configured so that dedicated signals are used for power management handshaking between the CYW4339 and the host. The basic power saving functions supported by those handshaking signals include the standard Bluetooth defined power savings modes and standby modes of operation.

Table 4 describes the power-control handshake signals used with the UART interface.

Table 4. Power Control Pin Description

Signal	Mapped to Pin	Type	Description
BT_DEV_WAKE	BT_GPIO_0	I	Bluetooth device wake-up: Signal from the host to the CYW4339 indicating that the host requires attention. • Asserted: The Bluetooth device must wake-up or remain awake. • Deasserted: The Bluetooth device may sleep when sleep criteria are met. The polarity of this signal is software configurable and can be asserted high or low.
BT_HOST_WAKE	BT_GPIO_1	O	Host wake up. Signal from the CYW4339 to the host indicating that the CYW4339 requires attention. • Asserted: host device must wake-up or remain awake. • Deasserted: host device may sleep when sleep criteria are met. The polarity of this signal is software configurable and can be asserted high or low.
CLK_REQ	BT_CLK_REQ_OUT WL_CLK_REQ_OUT	O	The CYW4339 asserts CLK_REQ when either the Bluetooth or WLAN block wants the host to turn on the reference clock. The CLK_REQ polarity is active-high. Add an external 100 kΩ pull-down resistor to ensure the signal is deasserted when the CYW4339 powers up or resets when VDDIO is present.
Note: Pad function Control Register is set to 0 for these pins. See DC Characteristics for more details.			

Figure 5. Startup Signaling Sequence



Notes :

- T_1 is the time for the host to settle its IOs after a reset.
- T_2 is the time for the host to drive BT_REG_ON high after the host IOs are configured.
- T_3 is the time for the BTH device to settle its IOs after a reset and the reference clock settling time has elapsed.
- T_4 is the time for the BTH device to drive BT_UART_RTS_N low after the host drives BT_UART_CTS_N low. This assumes the BTH device has completed initialization.
- T_5 is the time for the BTH device to drive CLK_REQ_OUT high after BT_REG_ON goes high. The CLK_REQ_OUT pin is used in designs that have an external reference clock source from the host. It is irrelevant on clock-based designs where the BTH device generates its own reference clock from an external crystal connected to its oscillator circuit.
- The timing diagram assumes that VBAT is present.

5.5.3 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 CYW4339 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 CYW4339 is not needed in the system, the RF and core supplies are shut down while the I/O remains powered. This allows the CYW4339 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 shut-down state, provided VDDIO remains applied to the CYW4339, 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 CYW4339 to be fully integrated in an embedded device to take full advantage of the lowest power-saving modes.

Two CYW4339 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 CYW4339 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.

5.5.4 Wideband Speech

The CYW4339 provides support for wideband speech (WBS) using on-chip SmartAudio technology. The CYW4339 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.

5.5.5 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 bitstream. 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 bitstream and decode it as usual (frame repeat).

These techniques cause distortion and popping in the audio stream. The CYW4339 uses a proprietary waveform extension algorithm to provide dramatic improvement in the audio quality. Figure 6 and Figure 7 show audio waveforms with and without Packet Loss Concealment. Cypress PLC and bit-error correction (BEC) algorithms also support wideband speech.

Figure 6. CVSD Decoder Output Waveform Without PLC

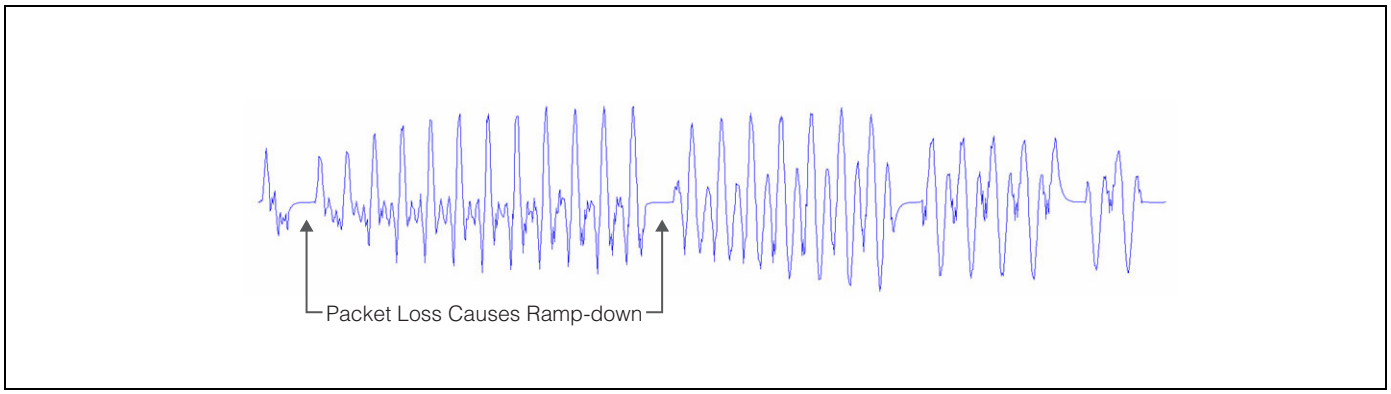
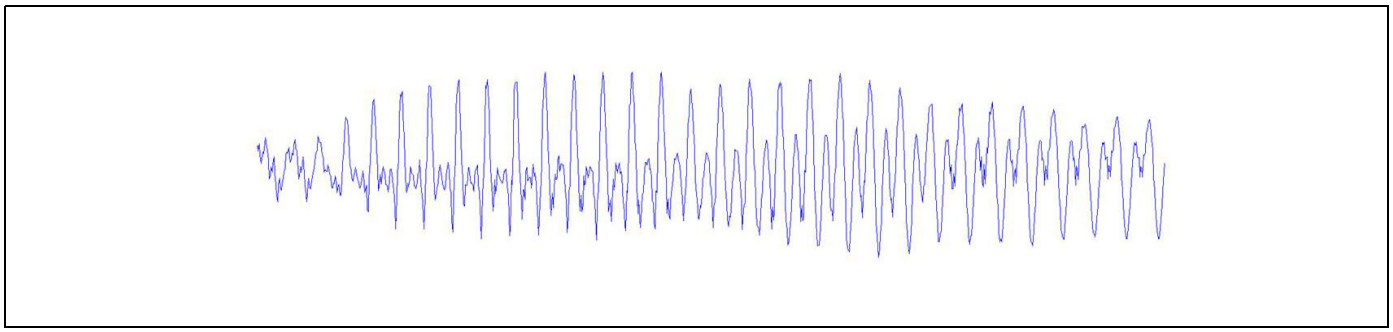


Figure 7. CVSD Decoder Output Waveform After Applying PLC



5.5.6 Audio Rate-Matching Algorithms

The CYW4339 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.

5.5.7 Codec Encoding

The CYW4339 can support SBC and mSBC encoding and decoding for wideband speech.

5.5.8 Multiple Simultaneous A2DP Audio Streams

The CYW4339 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.

5.5.9 Burst Buffer Operation

The CYW4339 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.

5.6 Adaptive Frequency Hopping

The CYW4339 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.