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Data Sheet

BCM20732

Single-Chip Bluetooth Low-Energy Only SoC

GENERAL DESCRIPTION

The Broadcom® BCM20732 is a Bluetooth Low-Energy (BLE)-only SoC. The BCM20732 radio has been designed to provide low power, low cost, and robust communications for applications operating in the globally available 2.4 GHz unlicensed Industrial, Scientific, and Medical (ISM) band.

The single-chip BLE SoC is a monolithic component implemented in a standard digital CMOS process and requires minimal external components to make a fully compliant Bluetooth device. The BCM20732 is available in a 32-pin, 5 mm × 5 mm 32-QFN package.

FEATURES

- Bluetooth Low-Energy (BLE)-compliant
- Infrared modulator
- IR learning
- Supports Adaptive Frequency Hopping
- Excellent receiver sensitivity
- 10-bit auxiliary ADC with nine analog channels
- On-chip support for serial peripheral interface (master and slave modes)
- Broadcom Serial Control (BSC) interface (compatible with NXP I^2C slaves)
- Programmable output power control
- Integrated ARM Cortex-M3 based microprocessor core
- On-chip power-on reset (POR)
- Support for EEPROM and serial flash interfaces
- Integrated Low DropOut (LDO) regulator
- On-chip, software controlled power management unit
- 32-pin 32-QFN (5 mm × 5 mm) package
- RoHS compliant

APPLICATIONS

The following profiles are supported in ROM:

- Battery status
- Blood pressure monitor
- Find me
- Heart rate monitor
- Proximity
- Thermometer
- Weight scale
- Time

Additional profiles that can be supported from RAM include:

- Blood glucose monitor
- Temperature alarm
- Location

Full qualification and use of these profiles may require firmware updates from Broadcom. Some profiles are under development/approval at Bluetooth SIG and conformity with the final approved version is pending. Contact your supplier for updates and the latest list of profiles.

20732-DS111-R

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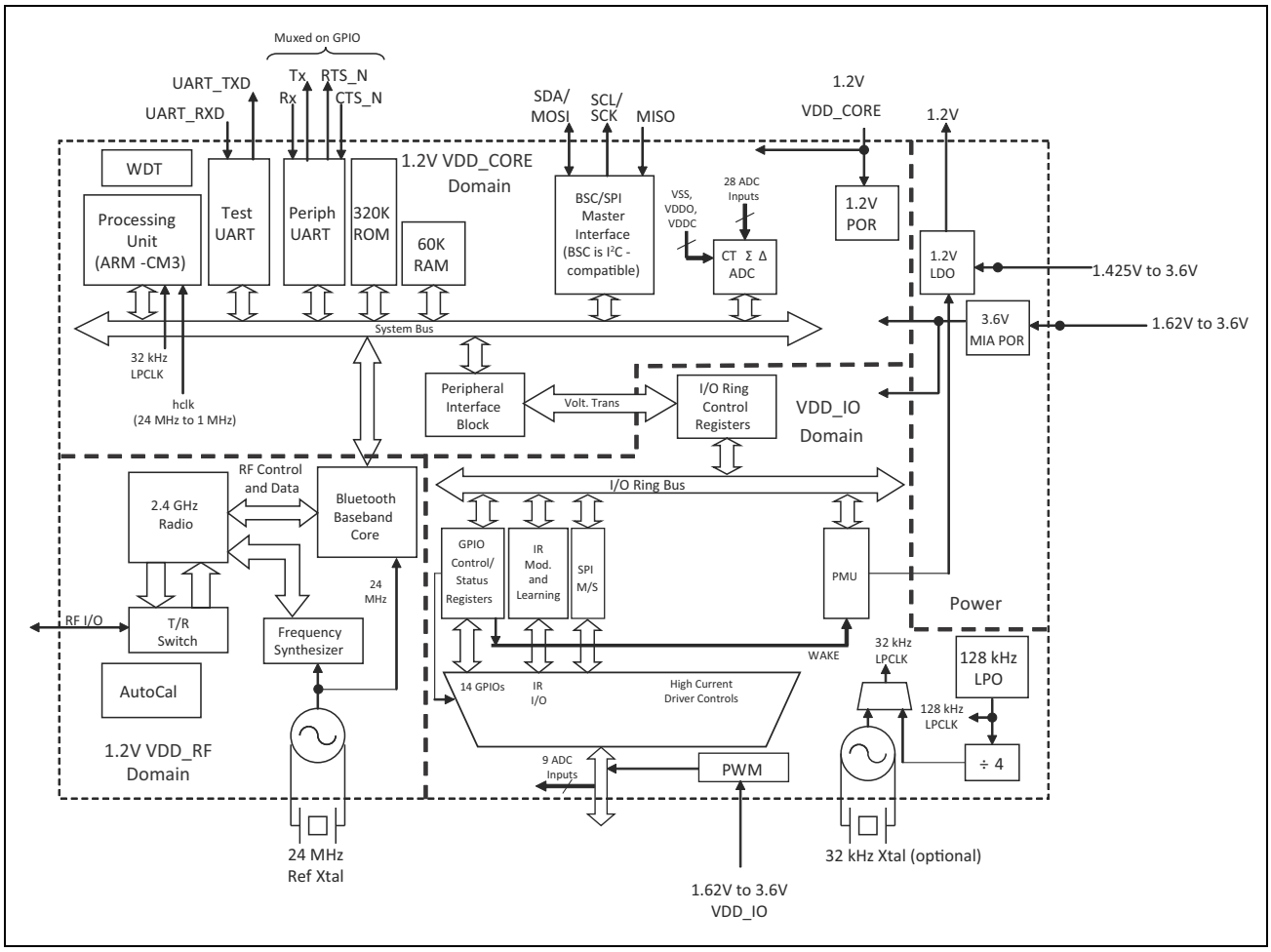
February 16, 2016

Figure 1: Functional Block Diagram



Revision History

Revision	*Date*	*Change Description*
20732-DS111-R	02/16/16	**Added:** • "ESD Test Models" on page 38
20732-DS110-R	04/21/15	**Updated:** • Table 15: "Receiver RF Specifications," on page 33
20732-DS109-R	11/24/14	**Updated:** • Table 5: "Reference Crystal Electrical Specifications," on page 20
20732-DS108-R	06/05/14	**Updated:** • "UART Interface" on page 19.
20732-DS107-R	3/26/2014	**Updated:** • Figure 14: "32-Pin 5x5 mm QFN Package," on page 38 **Added:** • Table 20: "32-pin 5x5 mm QFN Package Dimensions (Footprint: 0.80)," on page 39
20732-DS106-R	12/12/13	**Updated:** • Table 16: "Transmitter RF Specifications," on page 36
20732-DS105-R	10/03/13	**Updated:** • Table 14: "Current Consumption," on page 34.
20732-DS104-R	9/17/13	**Updated:** • Table 14: "Current Consumption," on page 34: RX/Tx maximum current values.
20732-DS103-R	7/10/13	**Updated:** • "Bluetooth Low Energy Features" on page 10. • "Microprocessor Unit" on page 15. • Table 9: "Maximum Electrical Rating," on page 31 • Table 21: "Ordering Information," on page 42.
20732-DS102-R	9/17/12	**Updated:** • 'Preliminary Data Sheet' to 'Data Sheet'. • 'HIDOFF mode' to 'HIDOFF (Deep Sleep) mode'.
20732-DS101-R	2/24/12	**Updated:** • Document title changed. • "Bluetooth Low Energy Features" on page 11. • Table 8: "GPIO Pin Descriptions," on page 28. • Table 15: "Receiver RF Specifications," on page 35. • Table 16: "Transmitter RF Specifications," on page 36. • "SPI Timing" on page 38.
20732-DS100-R	6/27/11	Initial release

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About This Document

Purpose and Audience

This data sheet provides a description of the major blocks, interfaces, pin assignments, and specifications of the BCM20732 single-chip Bluetooth low energy (BLE) SoC. This is a required document for designers responsible for adding the BCM20732 BLE SoC to wireless input device applications including heart-rate monitors, blood-pressure monitors, proximity sensors, temperature sensors, and battery monitors.

Acronyms and Abbreviations

In most cases, acronyms and abbreviations are defined on first use. Acronyms and abbreviations in this document are also defined in Appendix A: “Acronyms and Abbreviations,” on page 44.

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

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Section 1: Functional Description

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 data routing for all connections. It also buffers data that passes through it, handles data flow control, schedules 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 TX/RX data reliability and security before sending over the air:

- Receive Functions: symbol timing recovery, data deframing, forward error correction (FEC), header error control (HEC), cyclic redundancy check (CRC), data decryption, and data dewhitening.
- Transmit Functions: data framing, FEC generation, HEC generation, CRC generation, link key generation, data encryption, and data whitening.

Frequency Hopping Generator

The frequency hopping sequence generator selects the correct hopping channel number depending on the link controller state, Bluetooth clock, and device address.

E0 Encryption

The encryption key and the encryption engine are implemented using dedicated hardware to reduce software complexity and provide minimal processor intervention.

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, which takes software commands, and other controllers that are activated or configured by the Command Controller to perform the link control tasks. Each task performs a different Bluetooth link controller state. STANDBY and CONNECTION are the two major states. In addition, there are five substates: page, page scan, inquiry, and inquiry scan.

Adaptive Frequency Hopping

The BCM20732 gathers link quality statistics on a channel-by-channel basis to facilitate channel assessment and channel map selection. The link quality is determined by using both RF and baseband signal processing to provide a more accurate frequency hop map.

Bluetooth Low Energy Profiles

The BCM20732 supports Bluetooth low-energy, including the following profiles that are supported[1] in ROM:

- Battery status
- Blood pressure monitor
- Find me
- Heart rate monitor
- Proximity
- Thermometer
- Weight scale
- Time

The following additional profiles can be supported[1] from RAM:

- Blood glucose monitor
- Temperature alarm
- Location
- Custom profile

Test Mode Support

The BCM20732 fully supports Bluetooth Test mode, as described in the Bluetooth low energy specification.

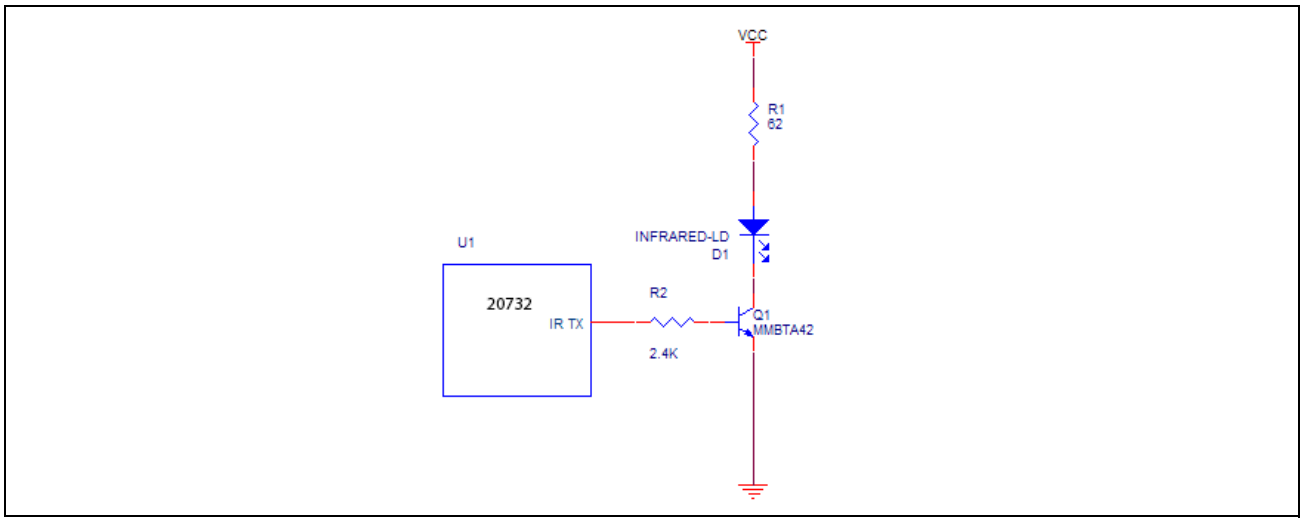
Infrared Modulator

The BCM20732 includes hardware support for infrared TX. The hardware can transmit both modulated and unmodulated waveforms. For modulated waveforms, hardware inserts the desired carrier frequency into all IR transmissions. IR TX can be sourced from firmware-supplied descriptors, a programmable bit, or the peripheral UART transmitter.

If descriptors are used, they include IR on/off state and the duration between 1 and 32,767 µsec. The BCM20732 IR TX firmware driver inserts this information in a hardware FIFO and makes sure that all descriptors are played out without a glitch due to underrun (see Figure 2 on page 12).

1. Full qualification and use of these profiles may require firmware updates from Broadcom. Some of these profiles are under development/approval at the Bluetooth SIG and conformity with the final approved version is pending. Contact your supplier for updates and the latest list of profiles.

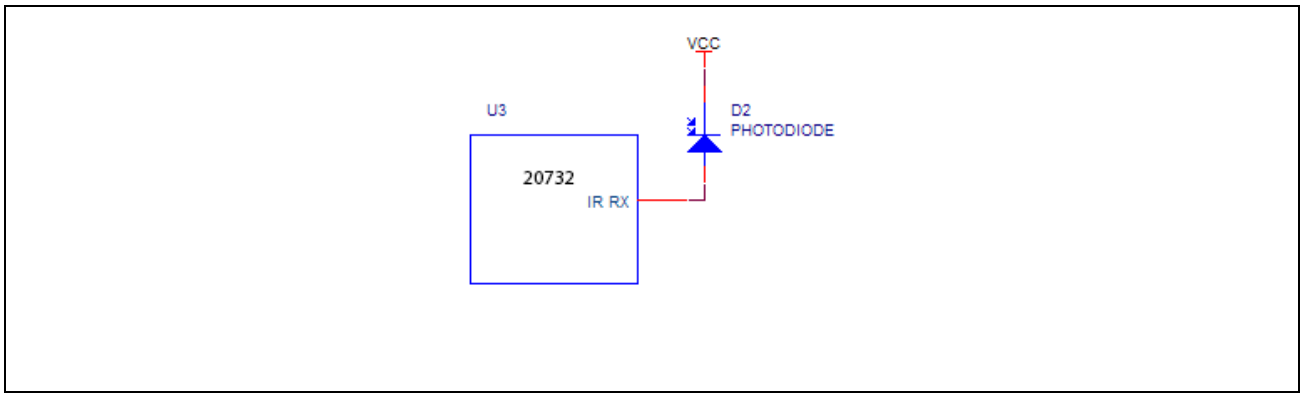
Figure 2: Infrared TX



Infrared Learning

The BCM20732 includes hardware support for infrared learning. The hardware can detect both modulated and unmodulated signals. For modulated signals, the BCM20732 can detect carrier frequencies between 10 kHz–500 kHz and the duration that the signal is present or absent. The BCM20732 firmware driver supports further analysis and compression of learned signal. The learned signal can then be played back through the BCM20732 IR TX subsystem (see Figure 3).

Figure 3: Infrared RX



ADC Port

The BCM20732 contains a 16-bit ADC (effective number of bits is 10).

Additionally:

- There are nine analog input channels in the 32-pin package
- The following GPIOs can be used as ADC inputs:
  - P0
  - P1
  - P8/P33 (select only one)
  - P11
  - P12
  - P13/P28 (select only one)
  - P14/P38 (select only one)
  - P15
  - P32
- The conversion time is 10 µs.
- There is a built-in reference with supply- or bandgap-based reference modes.
- The maximum conversion rate is 187 kHz.
- There is a rail-to-rail input swing.

The ADC consists of an analog ADC core that performs the actual analog-to-digital conversion and digital hardware that processes the output of the ADC core into valid ADC output samples. Directed by the firmware, the digital hardware also controls the input multiplexers that select the ADC input signal V_{inp} and the ADC reference signals V_{ref}.

The ADC input range is selectable by firmware control:

- When an input range of 0–3.6V is used, the input impedance is 3 MΩ.
- When an input range of 0–2.4V is used, the input impedance is 1.84 MΩ.
- When an input range of 0–1.2V is used, the input impedance is 680 kΩ.

ADC modes are defined in Table 1.

Table 1: ADC Modes

Mode	*ENOB (Typical)*	*Maximum Sampling Rate (kHz)*	*Latency[a] (µs)*
0	13	5.859	171
1	12.6	11.7	85
2	12	46.875	21
3	11.5	93.75	11
4	10	187	5

a. Settling time after switching channels.

Serial Peripheral Interface

The BCM20732 has two independent SPI interfaces. One is a master-only interface and the other can be either a master or a slave. Each interface has a 16-byte transmit buffer and a 16-byte receive buffer. To support more flexibility for user applications, the BCM20732 has optional I/O ports that can be configured individually and separately for each functional pin as shown in Table 2, Table 3, and Table 4. The BCM20732 acts as a SPI master device that supports 1.8V or 3.3V SPI slaves. The BCM20732 can also act as an SPI slave device that supports a 1.8V or 3.3V SPI master.

Table 2: BCM20732 First SPI Set (Master Mode)

Pin Name	*SPI_CLK*	*SPI_MOSI*	*SPI_MISO*	*SPI_CS*[a]
Configured Pin Name	SCL	SDA	P24	–
	–	–	P26	–
	–	–	P32	–

a. Any GPIO can be used as SPI_CS when SPI is in master mode.

Table 3: BCM20732 Second SPI Set (Master Mode)

Pin Name	*SPI_CLK*	*SPI_MOSI*	*SPI_MISO*	*SPI_CS*[a]
Configured Pin Name	P3	P0	P1	–
	–	P4	P25	–
	P24	P27	–	–

a. Any GPIO can be used as SPI_CS when SPI is in master mode.

Table 4: BCM20732 Second SPI Set (Slave Mode)

Pin Name	*SPI_CLK*	*SPI_MOSI*	*SPI_MISO*	*SPI_CS*
Configured Pin Name	P3	P0	P1	P2
	–	P27	–	–
	P24	P33	P25	P26
	–	–	–	P32

Microprocessor Unit

The BCM20732 microprocessor unit (µPU) executes software from the link control (LC) layer up to the application layer components. The microprocessor is based on an ARM Cortex-M3, 32-bit RISC processor with embedded ICE-RT debug and JTAG interface units. The µPU has 320 KB of ROM for program storage and boot-up, 60 KB of RAM for scratch-pad data, and patch RAM code. The SoC has a total storage of 380 KB, including RAM and ROM.

The internal boot ROM provides power-on reset flexibility, which enables the same device to be used in different HID applications with an external serial EEPROM or with an external serial flash memory. At power-up, the lowest layer of the 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 and feature additions. The device can also support the integration of user applications.

EEPROM Interface

The BCM20732 provides a Broadcom Serial Control (BSC) master interface. BSC is programmed by the CPU to generate four types of bus transfers: read-only, write-only, combined read/write, and combined write/read. BSC supports both low-speed and fast mode devices. BSC is compatible with an NXP I^2C slave device, except that master arbitration (multiple I^2C masters contending for the bus) is not supported.

The EEPROM can contain customer application configuration information including application code, configuration data, patches, pairing information, BD_ADDR, baud rate, SDP service record, and file system information used for code.

Native support for the Microchip 24LC128, Microchip 24AA128, and the STMicroelectronics M24128-BR is included.

Serial Flash Interface

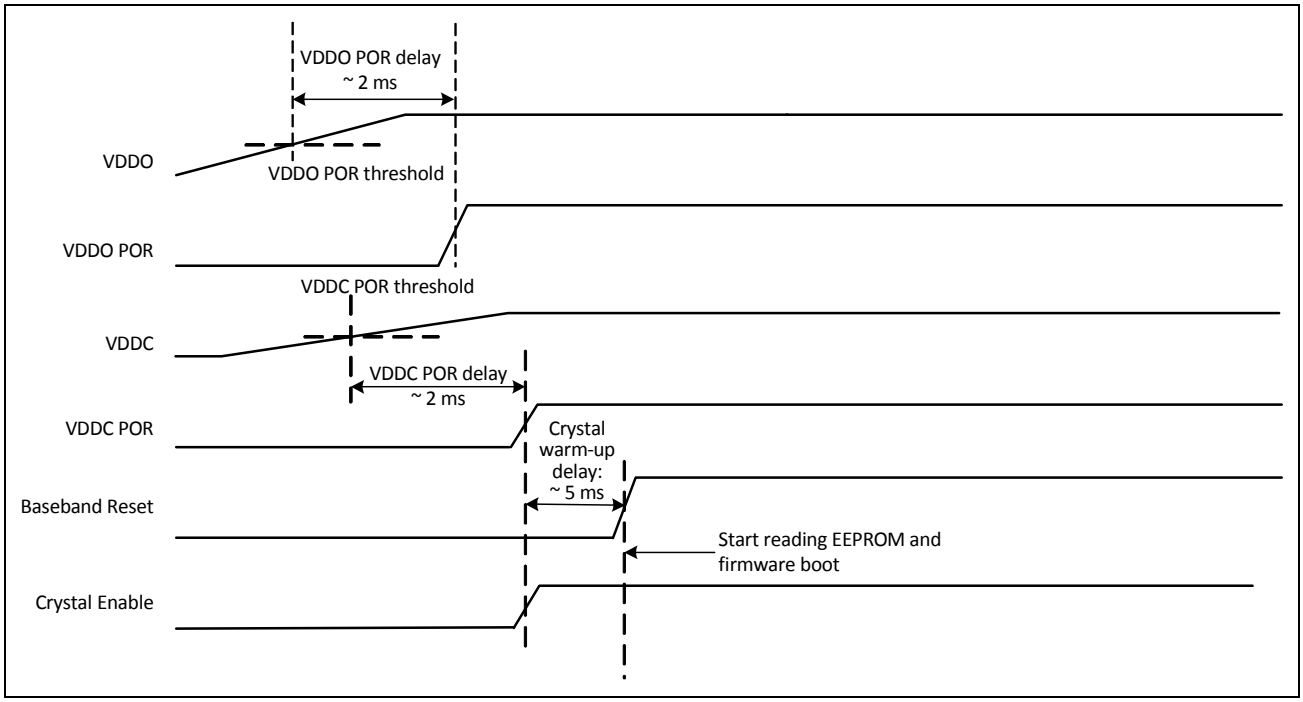
The BCM20732 includes an SPI master controller that can be used to access serial flash memory. The SPI master contains an AHB slave interface, transmit and receive FIFOs, and the SPI core PHY logic.

Devices natively supported include the following:

- Atmel AT25BCM512B
- MXIC MX25V512ZUI-20G

Internal Reset

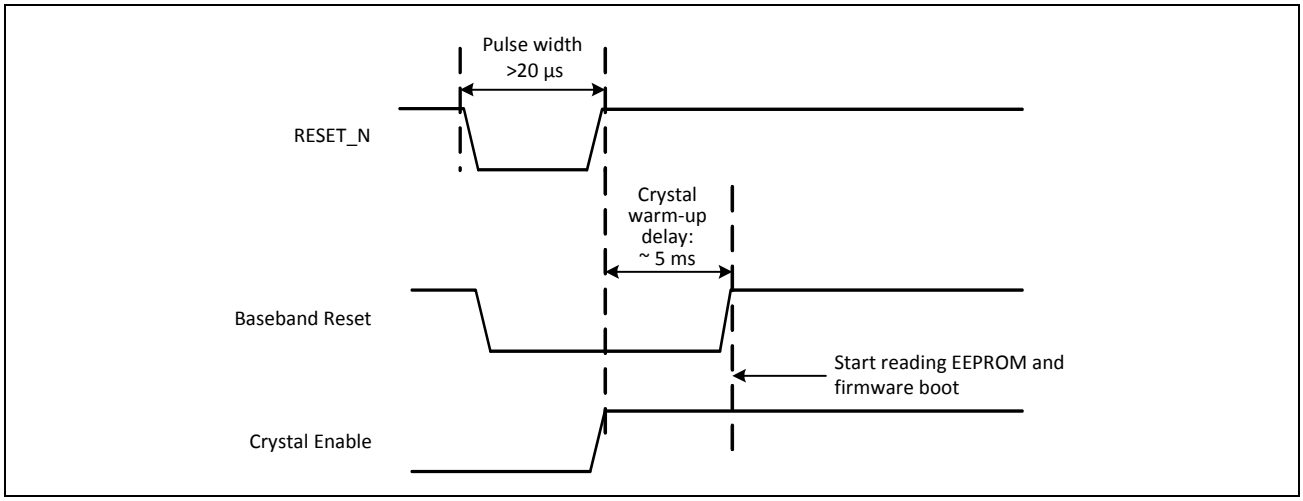
Figure 4: Internal Reset Timing



External Reset

The BCM20732 has an integrated power-on reset circuit that completely resets all circuits to a known power-on state. An external active low reset signal, RESET_N, can be used to put the BCM20732 in the reset state. The RESET_N pin has an internal pull-up resistor and, in most applications, it does not require that anything be connected to it. RESET_N should only be released after the VDDO supply voltage level has been stabilized.

Figure 5: External Reset Timing



Integrated Radio Transceiver

The BCM20732 has an integrated radio transceiver that is optimized for 2.4 GHz Bluetooth wireless 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 band. It is fully compliant with Bluetooth Radio Specification 4.0 and meets or exceeds the requirements to provide the highest communication link quality of service.

Transmitter Path

The BCM20732 features a fully integrated transmitter. The baseband transmit data is GFSK modulated in the 2.4 GHz ISM band.

Digital Modulator

The digital modulator performs the data modulation and filtering required for the GFSK signal. The fully digital modulator minimizes any frequency drift or anomalies in the modulation characteristics of the transmitted signal.

Power Amplifier

The BCM20732 has an integrated power amplifier (PA) that can transmit up to +4 dBm for class 2 operation.

Receiver Path

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, which has built-in out-of-band attenuation, enables the BCM20732 to be used in most applications without off-chip filtering.

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 BCM20732 provides a receiver signal strength indicator (RSSI) to the baseband. This enables the controller to 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

The local oscillator (LO) provides fast frequency hopping (1600 hops/second) across the 79 maximum available channels. The BCM20732 uses an internal loop filter.

Calibration

The BCM20732 radio transceiver features a self-contained automated calibration scheme. No user interaction is required during normal operation or during manufacturing to provide optimal performance. Calibration compensates for filter, matching network, and amplifier gain and phase characteristics to yield radio performance within 2% of what is optimal. Calibration takes process and temperature variations into account, and it takes place transparently during normal operation and hop setting times.

Internal LDO Regulator

The BCM20732 has an integrated 1.2V LDO regulator that provides power to the digital and RF circuits. The 1.2V LDO regulator operates from a 1.425V to 3.63V input supply with a 30 mA maximum load current.

Note: Always place the decoupling capacitors near the pins as closely together as possible.

Peripheral Transport Unit

Broadcom Serial Communications Interface

The BCM20732 provides a 2-pin master BSC interface, which can be used to retrieve configuration information from an external EEPROM or to communicate with peripherals such as track-ball or touch-pad modules, and motion tracking ICs used in mouse devices. The BSC interface is compatible with I^2C slave devices. The BSC does not support multimaster capability or flexible wait-state insertion by either master or slave devices.

The following transfer clock rates are supported by the BSC:

- 100 kHz
- 400 kHz
- 800 kHz (not a standard I^2C-compatible speed.)
- 1 MHz (Compatibility with high-speed I^2C-compatible devices is not guaranteed.)

The following transfer types are supported by the BSC:

- Read (Up to 16 bytes can be read.)
- Write (Up to 16 bytes can be written.)
- Read-then-Write (Up to 16 bytes can be read and up to 16 bytes can be written.)
- Write-then-Read (Up to 16 bytes can be written and up to 16 bytes can be read.)

Hardware controls the transfers, requiring minimal firmware setup and supervision.

The clock pin (SCL) and data pin (SDA) are both open-drain I/O pins. Pull-up resistors external to the BCM20732 are required on both the SCL and SDA pins for proper operation.

UART Interface

The UART is a standard 2-wire interface (RX and TX) and has adjustable baud rates from 9600 bps to 115.2 Kbaud. The baud rate can be selected via a vendor-specific UART HCI command. The interface supports the Bluetooth 3.0 UART HCI (H4) specification. The default baud rate for H4 is 115.2 Kbaud.

Both high and low baud rates can be supported by running the UART clock at 24 MHz.

The BCM20732 UART operates correctly with the host UART as long as the combined baud rate error of the two devices is within ±5 percent

Clock Frequencies

The BCM20732 is set with a crystal frequency of 24 MHz.

Crystal Oscillator

The crystal oscillator requires a crystal with an accuracy of ±20 ppm as defined by the Bluetooth specification. Two external load capacitors in the range of 5 pF to 30 pF (see Figure 6) are required to work with the crystal oscillator. The selection of the load capacitors is crystal-dependent.

Figure 6: Recommended Oscillator Configuration—12 pF Load Crystal

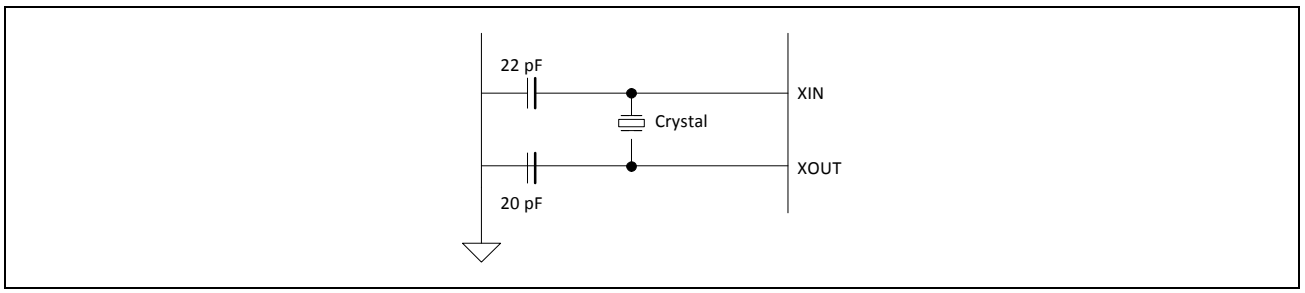


Table 5 shows the recommended crystal specifications.

Table 5: Reference Crystal Electrical Specifications

Parameter	*Conditions*	*Minimum*	*Typical*	*Maximum*	*Unit*
Nominal frequency	–	–	24.000	–	MHz
Oscillation mode	–	Fundamental			–
Frequency tolerance	@25°C	–	±10	–	ppm
Tolerance stability over temp	@0°C to +70°C	–	±10	–	ppm
Equivalent series resistance	–	–	–	60	Ω
Load capacitance	–	–	12	–	pF
Operating temperature range	–	0	–	+70	°C
Storage temperature range	–	–40	–	+125	°C
Drive level	–	–	–	200	µW
Aging	–	–	–	±10	ppm/year
Shunt capacitance	–	–	–	2	pF

Peripheral Block

The BCM20732 peripheral blocks all run from a single 128 kHz low-power RC oscillator. The oscillator can be turned on at the request of any of the peripherals. If the peripheral is not enabled, it shall not assert its clock request line.

The keyboard scanner is a special case, in that it may drop its clock request line even when enabled, and then reassert the clock request line if a keypress is detected.

32 kHz Crystal Oscillator

Figure 7 shows the 32 kHz crystal (XTAL) oscillator with external components and Table 6 on page 21 lists the oscillator's characteristics. It is a standard Pierce oscillator using a comparator with hysteresis on the output to create a single-ended digital output. The hysteresis was added to eliminate any chatter when the input is around the threshold of the comparator and is ~100 mV. This circuit can be operated with a 32 kHz or 32.768 kHz crystal oscillator or be driven with a clock input at similar frequency. The default component values are: R1 = 10 MΩ, C1 = C2 = ~10 pF. The values of C1 and C2 are used to fine-tune the oscillator.

Figure 7: 32 kHz Oscillator Block Diagram

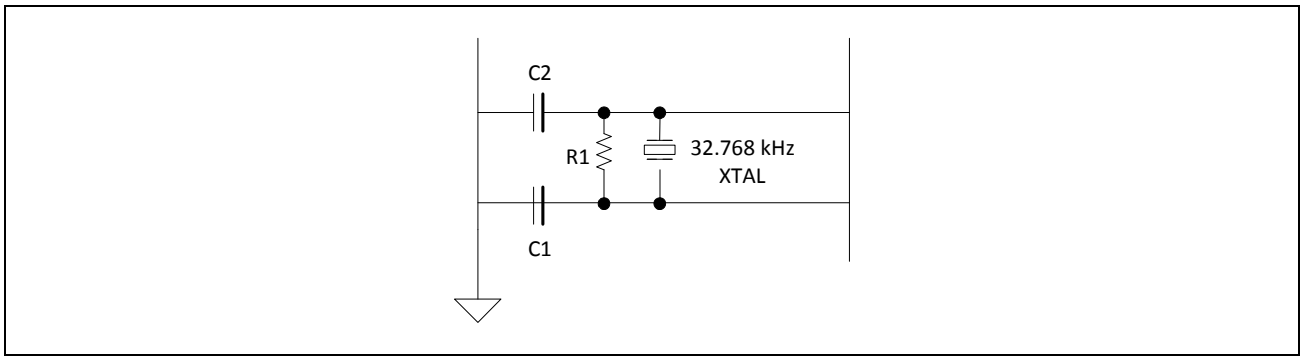


Table 6: XTAL Oscillator Characteristics

Parameter	Symbol	Conditions	Minimum	Typical	Maximum	Unit
Output frequency	F_{oscout}	–	–	32.768	–	kHz
Frequency tolerance	–	Crystal dependent	–	100	–	ppm
Start-up time	$T_{startup}$	–	–	–	500	ms
XTAL drive level	P_{drv}	For crystal selection	0.5	–	–	µW
XTAL series resistance	R_{series}	For crystal selection	–	–	70	kΩ
XTAL shunt capacitance	C_{shunt}	For crystal selection	–	–	1.3	pF

GPIO Port

The BCM20732 has 14 general-purpose I/Os (GPIOs) in the 32-pin package. All GPIOs support programmable pull-up and pull-down resistors, and all support a 2 mA drive strength except P26, P27, and P28, which provide a 16 mA drive strength at 3.3V supply.

The following GPIOs are available:

- P0–P4
- P8/P33 (Dual bonded, only one of two is available.)
- P11/P27 (Dual bonded, only one of two is available.)
- P12/P26 (Dual bonded, only one of two is available.)
- P13/P28 (Dual bonded, only one of two is available.)
- P14/P38 (Dual bonded, only one of two is available.)
- P15
- P24
- P25
- P32

For a description of all GPIOs, see Table 8: “GPIO Pin Descriptions,” on page 26.

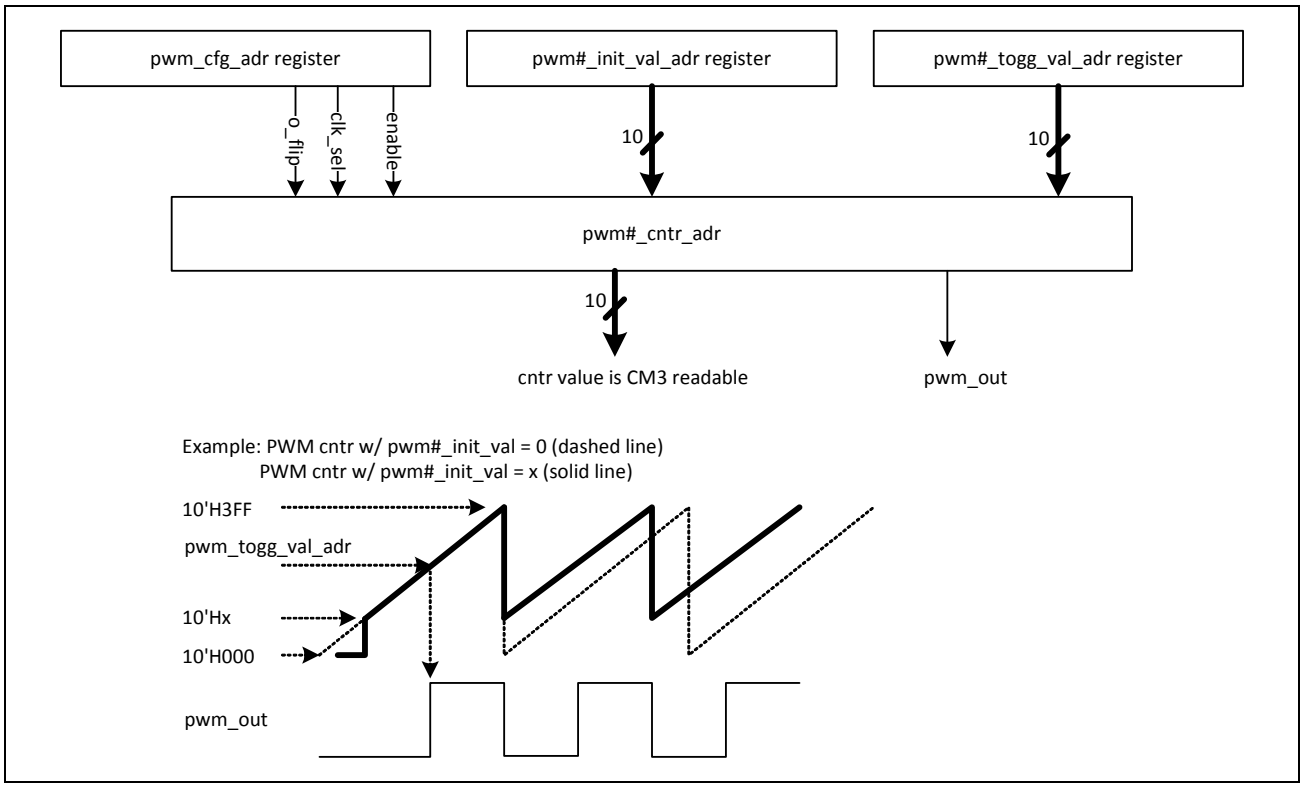
PWM

The BCM20732 has four internal PWM channels. The PWM module is described as follows:

- PWM0–3
- The following GPIOs can be mapped as PWMs:
  - P26
  - P27
  - P14/P28 (Dual bonded, only one of two is available.)
  - P13
- Each of the PWM channels, PWM0–3, contains the following registers:
  - 10-bit initial value register (read/write)
  - 10-bit toggle register (read/write)
  - 10-bit PWM counter value register (read)
- The PWM configuration register is shared among PWM0–3 (read/write). The 12-bit register is used:
  - To configure each PWM channel.
  - To select the clock of each PWM channel.
  - To change the phase of each PWM channel.

Figure 8 shows the structure of one PWM channel.

Figure 8: PWM Channel Block Diagram



Power Management Unit

The power management unit (PMU) provides power management features that can be invoked by software through power management registers or packet-handling in the baseband core.

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, which then processes the power-down functions accordingly.

Host Controller Power Management

Power is automatically managed by the firmware based on input device activity. As a power-saving task, the firmware controls the disabling of the on-chip regulator when in deep sleep mode.

BBC Power Management

There are several low-power operations for the BBC:

- Physical layer packet handling turns RF on and off dynamically within packet TX and RX.
- Bluetooth-specified low-power connection mode. While in these low-power connection modes, the BCM20732 runs on the low power oscillator (LPO) and wakes up after a predefined time period.

The BCM20732 automatically adjusts its power dissipation based on user activity. The following power modes are supported:

- Active mode
- Idle mode
- Sleep mode
- HIDOFF (Deep Sleep) mode

The BCM20732 transitions to the next lower state after a programmable period of user inactivity. Busy mode is immediately entered when user activity resumes.

In HIDOFF (Deep Sleep) mode, the BCM20732 baseband and core are powered off by disabling power to LDOOUT. The VDDO domain remains powered up and will turn the remainder of the chip on when it detects user events. This mode minimizes chip power consumption and is intended for long periods of inactivity.

Section 2: Pin Assignments

Pin Descriptions

Table 7: Pin Descriptions

Pin Number	Pin Name	I/O	Power Domain	Description
Radio I/O				
6	RF	I/O	VDD_RF	RF antenna port
RF Power Supplies				
4	VDDIF	I	VDD_RF	IFPLL power supply
5	VDDFE	I	VDD_RF	RF front-end supply
7	VDDVCO	I	VDD_RF	VCO, LOGEN supply
8	VDDPLL	I	VDD_RF	RFPLL and crystal oscillator supply
Power Supplies				
11	VDDC	I	VDDC	Baseband core supply
28	VDDO	I	VDDO	I/O pad and core supply
14	VDDM	I	VDDM	I/O pad supply
Clock Generator and Crystal Interface				
9	XTALI	I	VDD_RF	Crystal oscillator input. See page 19 for options.
10	XTALO	O	VDD_RF	Crystal oscillator output.
1	XTALI32K	I	VDDO	LPO input is used. Alternative Function: • P11 • P27
32	XTALO32K	O	VDDO	LPO output. Alternative Function: • P12 • P26
Core				
18	RESET_N	I/O PU	VDDO	Active-low system reset with open-drain output & internal pull-up resistor
17	TMC	I	VDDO	Test mode control High: test mode Connect to GND if not used.
UART				
12	UART_RXD	I	VDDM	UART serial input – Serial data input for the HCI UART interface. Leave unconnected if not used. Alternative function: • GPIO3

Table 7: Pin Descriptions (Cont.)

Pin Number	Pin Name	I/O	Power Domain	Description
13	UART_TXD	O, PU	VDDM	UART serial output – Serial data output for the HCI UART interface. Leave unconnected if not used. Alternative Function: • GPIO2
BSC				
15	SDA	I/O, PU	VDDM	Data signal for an external I^2C device. Alternative function: • SPI_1: MOSI (master only) • GPIO0 • CTS
16	SCL	I/O, PU	VDDM	Clock signal for an external I^2C device. Alternative function: • SPI_1: SPI_CLK (master only) • GPIO1 • RTS
LDO Regulator Power Supplies				
2	LDOIN	I	N/A	Battery input supply for the LDO
3	LDOOUT	O	N/A	LDO output

Table 8: GPIO Pin Descriptions[a]

Pin Number	Pin Name	Default Direction	After POR State	Power Domain	Alternate Function Description
19	P0	Input	Input floating	VDDO	• GPIO: P0 • A/D converter input • Peripheral UART: puart_tx • SPI_2: MOSI (master and slave) • IR_RX • 60Hz_main • Not available during TMC=1
20	P1	Input	Input floating	VDDO	• GPIO: P1 • A/D converter input • Peripheral UART: puart_rts • SPI_2: MISO (master and slave) • IR_TX
21	P3	Input	Input floating	VDDO	• GPIO: P3 • Peripheral UART: puart_cts • SPI_2: SPI_CLK (master and slave)
22	P2	Input	Input floating	VDDO	• GPIO: P2 • Peripheral UART: puart_rx • SPI_2: SPI_CS (slave only) • SPI_2: SPI_MOSI (master only)
23	P4	Input	Input floating	VDDO	• GPIO: P4 • Peripheral UART: puart_rx • SPI_2: MOSI (master and slave) • IR_TX
24	P8	Input	Input floating	VDDO	• GPIO: P8 • A/D converter input • External T/R switch control: ~tx_pd
	P33	Input	Input floating	VDDO	• GPIO: P33 • A/D converter input • SPI_2: MOSI (slave only) • Auxiliary clock output: ACLK1 • Peripheral UART: puart_rx
1	P11	Input	Input floating	VDDO	• GPIO: P11 • A/D converter input • XTALI32K
	P27 PWM1	Input	Input floating	VDDO	• GPIO: P27 • SPI_2: MOSI (master and slave) Current: 16 mA

Table 8: GPIO Pin Descriptions[a] (Cont.)

Pin Number	Pin Name	Default Direction	After POR State	Power Domain	Alternate Function Description
32	P12	Input	Input floating	VDDO	• GPIO: P12 • A/D converter input • XTALO32K
	P26 PWM0	Input	Input floating	VDDO	• GPIO: P26 • SPI_2: SPI_CS (slave only) • SPI_1: MISO (master only) Current: 16 mA
29	P13 PWM3	Input	Input floating	VDDO	• GPIO: P13 • A/D converter input
	P28 PWM2	Input	Input floating	VDDO	• GPIO: P28 • A/D converter input • LED1 • IR_TX Current: 16 mA
30	P14 PWM2	Input	Input floating	VDDO	• GPIO: P14 • A/D converter input
	P38	Input	Input floating	VDDO	• GPIO: P38 • A/D converter input • SPI_2: MOSI (master and slave) • IR_TX
31	P15	Input	Input floating	VDDO	• GPIO: P15 • A/D converter input • IR_RX • 60 Hz_main
27	P24	Input	Input floating	VDDO	• GPIO: P24 • SPI_2: SPI_CLK (master and slave) • SPI_1: MISO (master only) • Peripheral UART: puart_tx
26	P25	Input	Input floating	VDDO	• GPIO: P25 • SPI_2: MISO (master and slave) • Peripheral UART: puart_rx

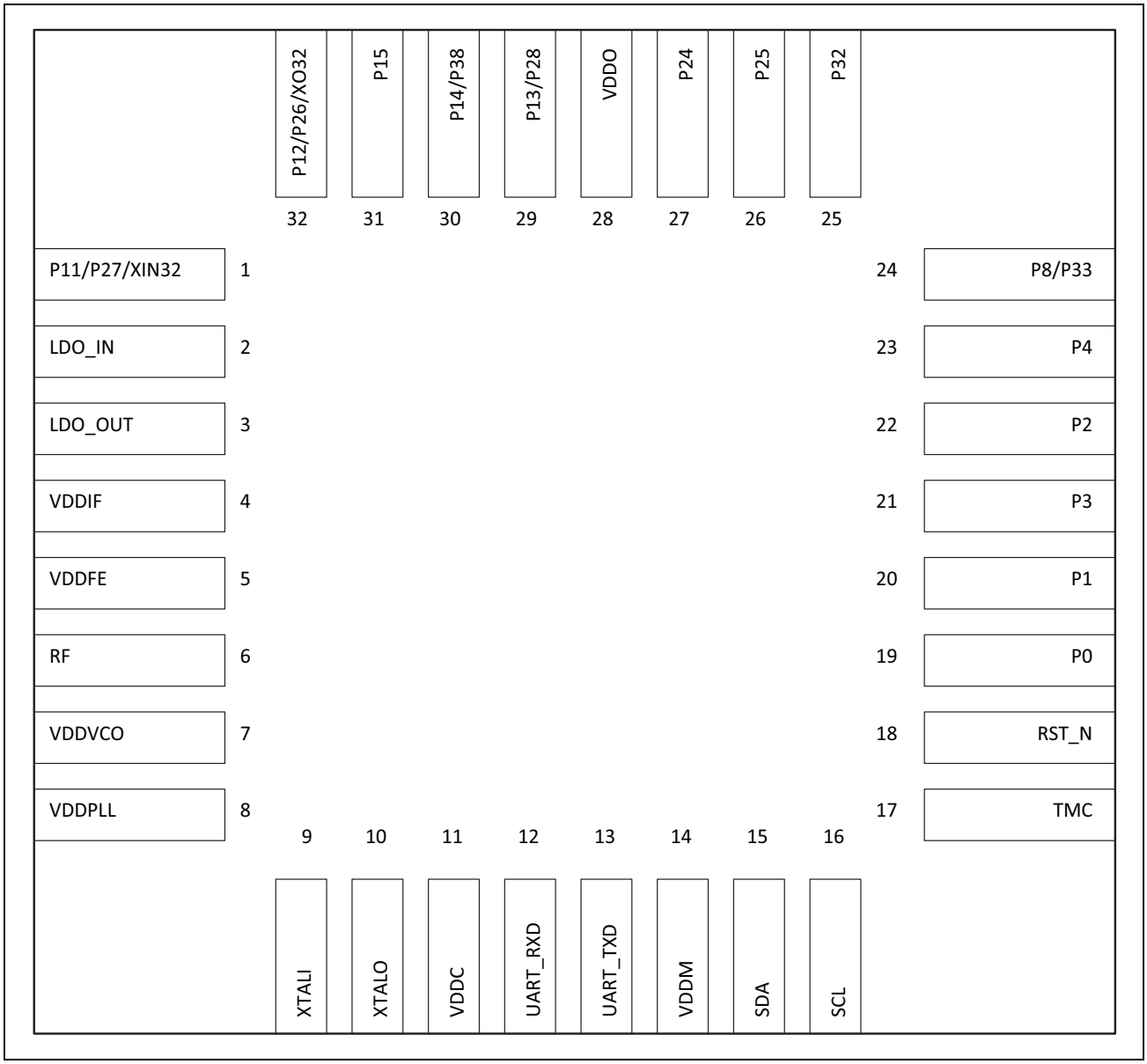
Table 8: GPIO Pin Descriptions[a] (Cont.)

Pin Number	Pin Name	Default Direction	After POR State	Power Domain	Alternate Function Description
25	P32	Input	Input floating	VDDO	• GPIO: P32 • A/D converter input • SPI_2: SPI_CS (slave only) • SPI_1: MISO (master only) • Auxiliary clock output: ACLK0 • Peripheral UART: puart_tx

a. During power-on reset, all inputs are disabled.

Ball Maps

Figure 9: 32-pin QFN Ball Map



Section 3: Specifications

Electrical Characteristics

Table 9 shows the maximum electrical rating for voltages referenced to VDD pin.

Table 9: Maximum Electrical Rating

Rating	*Symbol*	*Value*	*Unit*
DC supply voltage for RF domain	–	1.4	V
DC supply voltage for core domain	–	1.4	V
DC supply voltage for VDDM domain (UART/I^2C)	–	3.8	V
DC supply voltage for VDDO domain	–	3.8	V
DC supply voltage for VR3V	–	3.8	V
DC supply voltage for VDDFE	–	1.4	V
Voltage on input or output pin	–	V_{SS} – 0.3 to V_{DD} + 0.3	V
Operating ambient temperature range	Topr	–30 to +85	°C
Storage temperature range	Tstg	–40 to +125	°C

Table 10 shows the power supply characteristics for the range T_J = 0 to 125°C.

Table 10: Power Supply

Parameter	*Minimum*[a]	*Typical*	*Maximum*[a]	*Unit*
DC supply voltage for RF	1.14	1.2	1.26	V
DC supply voltage for Core	1.14	1.2	1.26	V
DC supply voltage for VDDM (UART/I^2C)	1.62	–	3.63	V
DC supply voltage for VDDO	1.62	–	3.63	V
DC supply voltage for LDOIN	1.425	–	3.63	V
DC supply voltage for VDDFE	1.14	1.2[b]	1.26	V

a. Overall performance degrades beyond minimum and maximum supply voltages.
b. 1.2V for Class 2 output with internal VREG.

Table 11 shows the digital level characteristics for (VSS = 0V).

Table 11: LDO Regulator Electrical Specifications

Parameter	Conditions	Min.	Typ.	Max.	Unit
Input voltage range	–	1.425	–	3.63	V
Default output voltage	–	–	1.2	–	V
Output voltage	Range	0.8	–	1.4	V
	Step size	–	40 or 80	–	mV
	Accuracy at any step	–5	–	+5	%
Load current	–	–	–	30	mA
Line regulation	Vin from 1.425 to 3.63V, I_{load} = 30 mA	–0.2	–	0.2	$\%V_O/V$
Load regulation	I_{load} from 1 µA to 30 mA, Vin = 3.3V, Bonding R = 0.3Ω	–	0.1	0.2	$\%V_O/mA$
Quiescent current	No load @Vin = 3.3V *Current limit enabled	–	6	–	µA
Power-down current	Vin = 3.3V, worst@70°C	–	5	200	nA

Table 12 shows the specifications for the ADC characteristics.

Table 12: ADC Specifications

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Number of Input channels	–	–	–	9	–	–
Channel switching rate	f_{ch}	–	–	–	133.33	kch/s
Input signal range	V_{inp}	–	0	–	3.63	V
Reference settling time	–	Changing refsel	7.5	–	–	µs
Input resistance	R_{inp}	Effective, single ended	–	500	–	kΩ
Input capacitance	C_{inp}	–	–	–	5	pF
Conversion rate	f_C	–	5.859	–	187	kHz
Conversion time	T_C	–	5.35	–	170.7	µs
Resolution	R	–	–	16	–	bits
Effective number of bits	–	In specified performance range	–	See Table 1 on page 13	–	–
Absolute voltage measurement error	–	Using on-chip ADC firmware driver	–	±2	–	%
Current	I	$I_{avdd1p2} + I_{avdd3p3}$	–	–	1	mA
Power	P	–	–	1.5	–	mW
Leakage current	$I_{leakage}$	T = 25°C	–	–	100	nA
Power-up time	$T_{powerup}$	–	–	–	200	µs
Integral nonlinearity[3]	INL	In guaranteed performance range	–1	–	1	LSB[a]
Differential nonlinearity[a]	DNL	In guaranteed performance range	–1	–	1	LSB[a]

a. LSBs are expressed at the 10-bit level.

Table 13 shows the specifications for the digital voltage levels.

Table 13: Digital Levels[a]

Characteristics	Symbol	Min	Typ	Max	Unit
Input low voltage	V_{IL}	–	–	0.4	V
Input high voltage	V_{IH}	0.75 × VDDO	–	–	V
Input low voltage (VDDO = 1.62V)	V_{IL}	–	–	0.4	V
Input high voltage (VDDO = 1.62V)	V_{IH}	1.2	–	–	V
Output low voltage[b]	V_{OL}	–	–	0.4	V
Output high voltage[b]	V_{OH}	VDDO – 0.4	–	–	V
Input capacitance (VDDMEM domain)	C_{IN}	–	0.12	–	pF

a. This table is also applicable to VDDMEM domain.
b. At the specified drive current for the pad.

Table 14 shows the specifications for current consumption.

Table 14: Current Consumption [a]

Operational Mode	Conditions	Min	Typ	Max	Unit
Receive	Receiver and baseband are both operating, 100% ON.	–	9.8	–	mA
Transmit	Transmitter and baseband are both operating, 100% ON.	–	9.1	–	mA
Sleep	Internal LPO is in use.	–	12.0	–	µA
	–	–	0.65	–	

a. Currents measured between power terminals (Vdd) using 90% efficient DC-DC converter at 3V.

RF Specifications

Table 15: Receiver RF Specifications

Parameter	Mode and Conditions	Min	Typ	Max	Unit
Receiver Section[a]					
Frequency range	–	2402	–	2480	MHz
RX sensitivity (standard)	0.1%BER, 1Mbps, dirty transmitter OFF	–	–93	–	dBm
RX sensitivity (low current)		–	–90	–	dBm
Input IP3	–	–16	–	–	dBm
Maximum input	–	–10	–	–	dBm
Interference Performance[a,b]					
C/I cochannel	0.1%BER	–	–	21	dB
C/I 1 MHz adjacent channel	0.1%BER	–	–	15	dB
C/I 2 MHz adjacent channel	0.1%BER	–	–	–17	dB
C/I ≥ 3 MHz adjacent channel	0.1%BER	–	–	–27	dB
C/I image channel	0.1%BER	–	–	–9.0	dB
C/I 1 MHz adjacent to image channel	0.1%BER	–	–	–15	dB
Out-of-Band Blocking Performance (CW)[a,b]					
30 MHz to 2000 MHz	0.1%BER[c]	–	–30.0	–	dBm
2003 MHz to 2399 MHz	0.1%BER[d]	–	–35	–	dBm
2484 MHz to 2997 MHz	0.1%BER[d]	–	–35	–	dBm
3000 MHz to 12.75 GHz	0.1%BER[e]	–	–30.0	–	dBm
Spurious Emissions					
30 MHz to 1 GHz	–	–	–	–57.0	dBm
1 GHz to 12.75 GHz	–	–	–	–55.0	dBm

a. 30.8% PER.
b. Desired signal is 3 dB above the reference sensitivity level (defined as –70 dBm).
c. Measurement resolution is 10 MHz.
d. Measurement resolution is 3 MHz.
e. Measurement resolution is 25 MHz.

Table 16: Transmitter RF Specifications

Parameter	*Minimum*	*Typical*	*Maximum*	*Unit*
Transmitter Section				
Frequency range	2402	–	2480	MHz
Output power adjustment range	–20	–	4	dBm
Default output power	–	4.0	–	dBm
Output power variation	–	2.0	–	dB
Adjacent Channel Power				
|M – N| = 2	–	–	–20	dBm
|M – N| ≥ 3	–	–	–30	dBm
Out-of-Band Spurious Emission				
30 MHz to 1 GHz	–	–	–36.0	dBm
1 GHz to 12.75 GHz	–	–	–30.0	dBm
1.8 GHz to 1.9 GHz	–	–	–47.0	dBm
5.15 GHz to 5.3 GHz	–	–	–47.0	dBm
LO Performance				
Initial carrier frequency tolerance	–	–	±150	kHz
Frequency Drift				
Frequency drift	–	–	±50	kHz
Drift rate	–	–	20	kHz/50 µs
Frequency Deviation				
Average deviation in payload (sequence used is 00001111)	225	–	275	kHz
Maximum deviation in payload (sequence used is 10101010)	185	–	–	kHz
Channel spacing	–	2	–	MHz

Timing and AC Characteristics

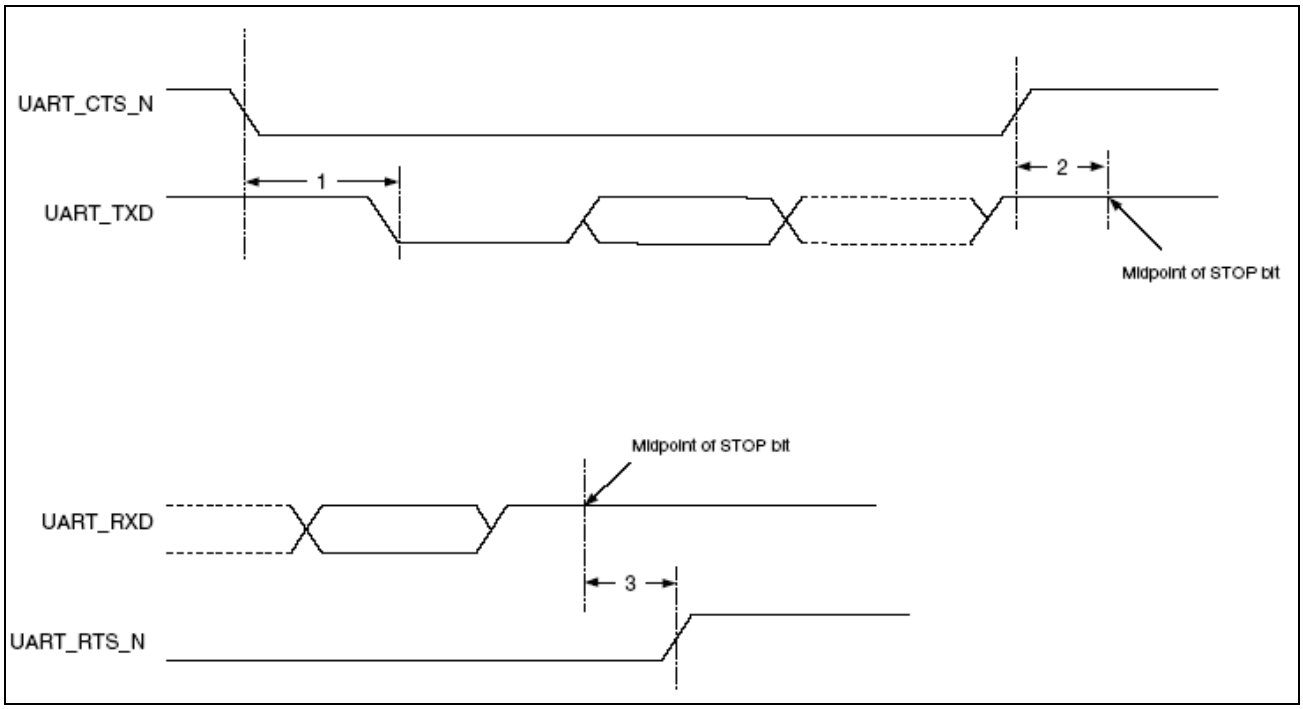
In this section, use the numbers listed in the **Reference** column of each table to interpret the following timing diagrams.

UART Timing

Table 17: UART Timing Specifications

Reference	*Characteristics*	*Min*	*Max*	*Unit*
1	Delay time, UART_CTS_N low to UART_TXD valid	–	24	Baud out cycles
2	Setup time, UART_CTS_N high before midpoint of stop bit	–	10	ns
3	Delay time, midpoint of stop bit to UART_RTS_N high	–	2	Baud out cycles

Figure 10: UART Timing



SPI Timing

The SPI interface supports clock speeds up to 12 MHz with VDDIO ≥ 2.2V. The supported clock speed is 6 MHz when 2.2V > VDDIO ≥ 1.62V.

Table 18: SPI Interface Timing Specifications

Reference	*Characteristics*	*Min*	*Typ*	*Max*
1	Time from CSN asserted to first clock edge	1 SCK	100	∞
2	Master setup time	–	½ SCK	–
3	Master hold time	½ SCK	–	–
4	Slave setup time	–	½ SCK	–
5	Slave hold time	½ SCK	–	–
6	Time from last clock edge to CSN deasserted	1 SCK	10 SCK	100

Figure 11 and Figure 12 on page 37 show the timing requirements when operating in SPI Mode 0 and 2, and SPI Mode 1 and 3, respectively.

Figure 11: SPI Timing – Mode 0 and 2

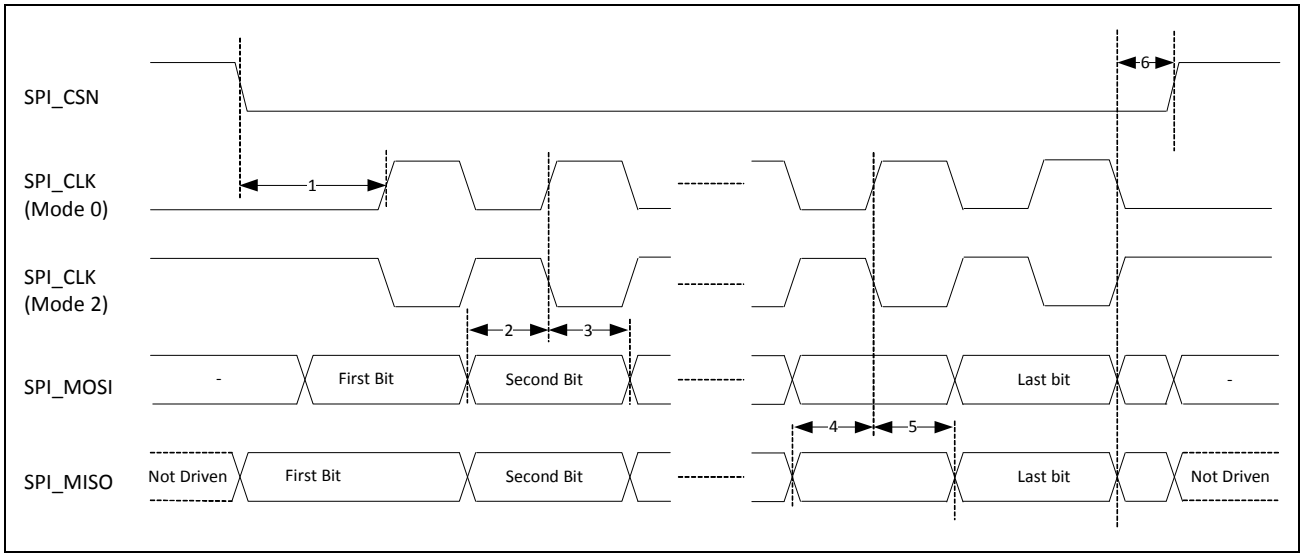
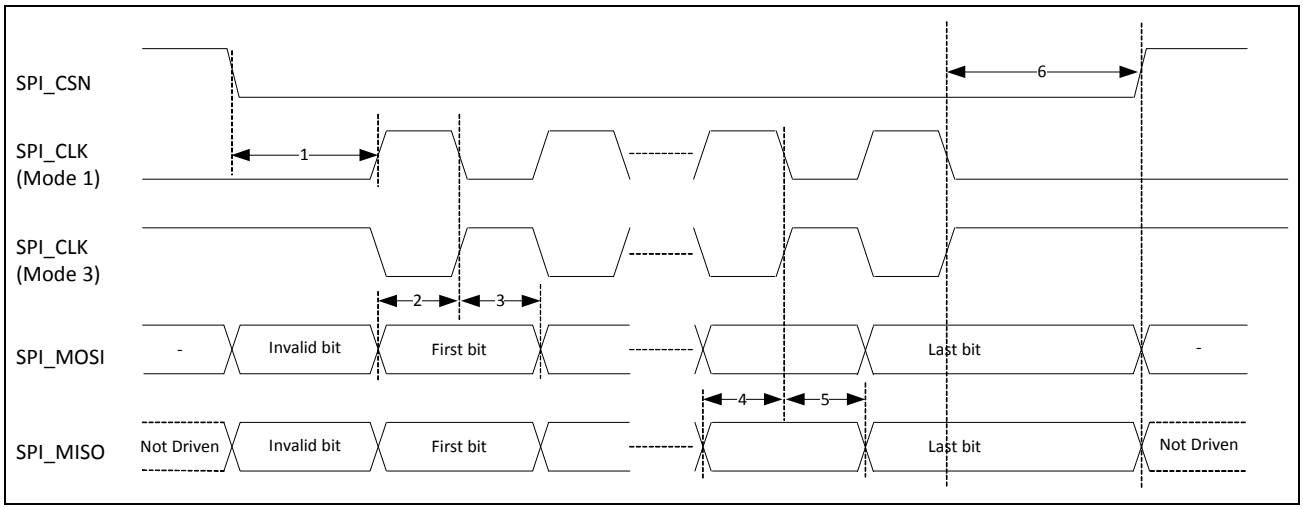


Figure 12: SPI Timing – Mode 1 and 3



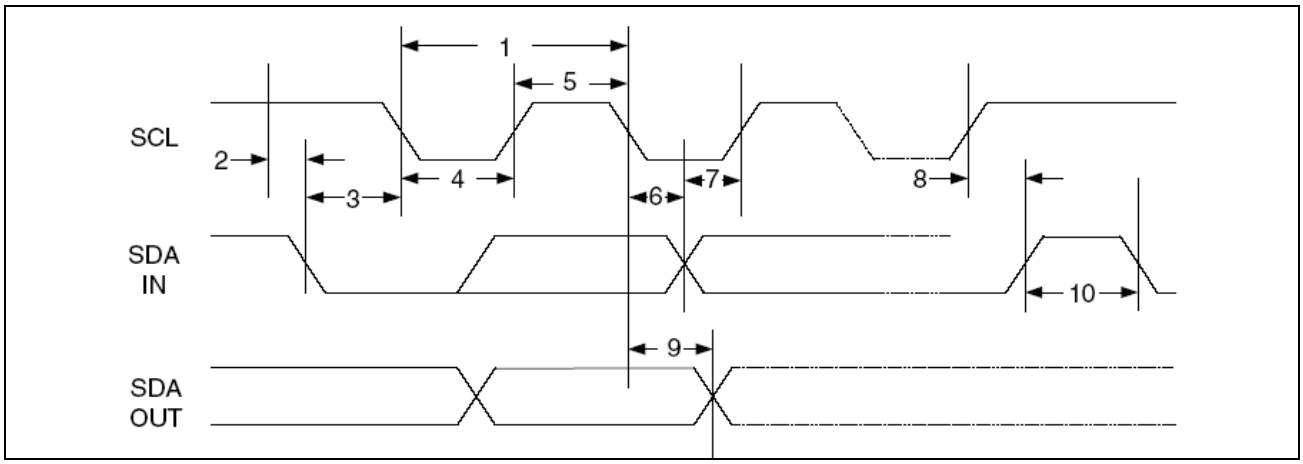
BSC Interface Timing

Table 19: BSC Interface Timing Specifications

Reference	*Characteristics*	*Min*	*Max*	*Unit*
1	Clock frequency	–	100	kHz
			400	
			800	
			1000	
2	START condition setup time	650	–	ns
3	START condition hold time	280	–	ns
4	Clock low time	650	–	ns
5	Clock high time	280	–	ns
6	Data input hold time[a]	0	–	ns
7	Data input setup time	100	–	ns
8	STOP condition setup time	280	–	ns
9	Output valid from clock	–	400	ns
10	Bus free time[b]	650	–	ns

a. As a transmitter, 300 ns of delay is provided to bridge the undefined region of the falling edge of SCL to avoid unintended generation of START or STOP conditions.
b. Time that the cbus must be free before a new transaction can start.

Figure 13: BSC Interface Timing Diagram



ESD Test Models

ESD can have serious detrimental effects on all semiconductor ICs and the system that contains them. Standards are developed to enhance the quality and reliability of ICs by ensuring all devices employed have undergone proper ESD design and testing, thereby minimizing the detrimental effects of ESD. Three major test methods are widely used in the industry today to describe uniform methods for assessing ESD immunity at Component level, Human Body Model (HBM), Machine Model (MM), and Charged Device Model (CDM). The following standards were used to test this device:

Human-Body Model (HBM) – ANSI/ESDA/JEDEC JS-001-2012

The HBM has been developed to simulate the action of a human body discharging an accumulated static charge through a device to ground, and employs a series RC network consisting of a 100 pF capacitor and a 1500Ω (Ohm) resistor. Both positive and negative polarities are used for this test. Although, a 100 ms delay is allowable per specification, the minimum delay used for testing was set to 300 ms between each pulse.

Machine Model (MM) – JEDEC JESD22-A115C

The MM has been developed to simulate the rapid discharge from a charged conductive object, such as a metallic tool or fixture. The most common application would be rapid discharge from charged board assembly or the charged cables of automated testers. This model consists of a 200 pF capacitor discharged directly into a component with no series resistor (0Ω). One positive and one negative polarity pulses are applied. The minimum delay between pulses is 500 ms.

Charged-Device Model (CDM) - JEDEC JESD22-C101E

CDM simulates charging/discharging events that occur in production equipment and processes. The potential for a CDM ESD events occurs when there is metal-to-metal contact in manufacturing. CDM addresses the possibility that a charge may reside on the lead frame or package (e.g., from shipping) and discharge through a pin that subsequently is grounded, causing damage to sensitive devices in the path. Discharge current is limited only by the parasitic impedance and capacitance of the device. CDM testing consists of charging package to a specified voltage, then discharging the voltage through relevant package leads. One positive and one negative polarity pulse is applied. The minimum delay between pulses is 200 ms.

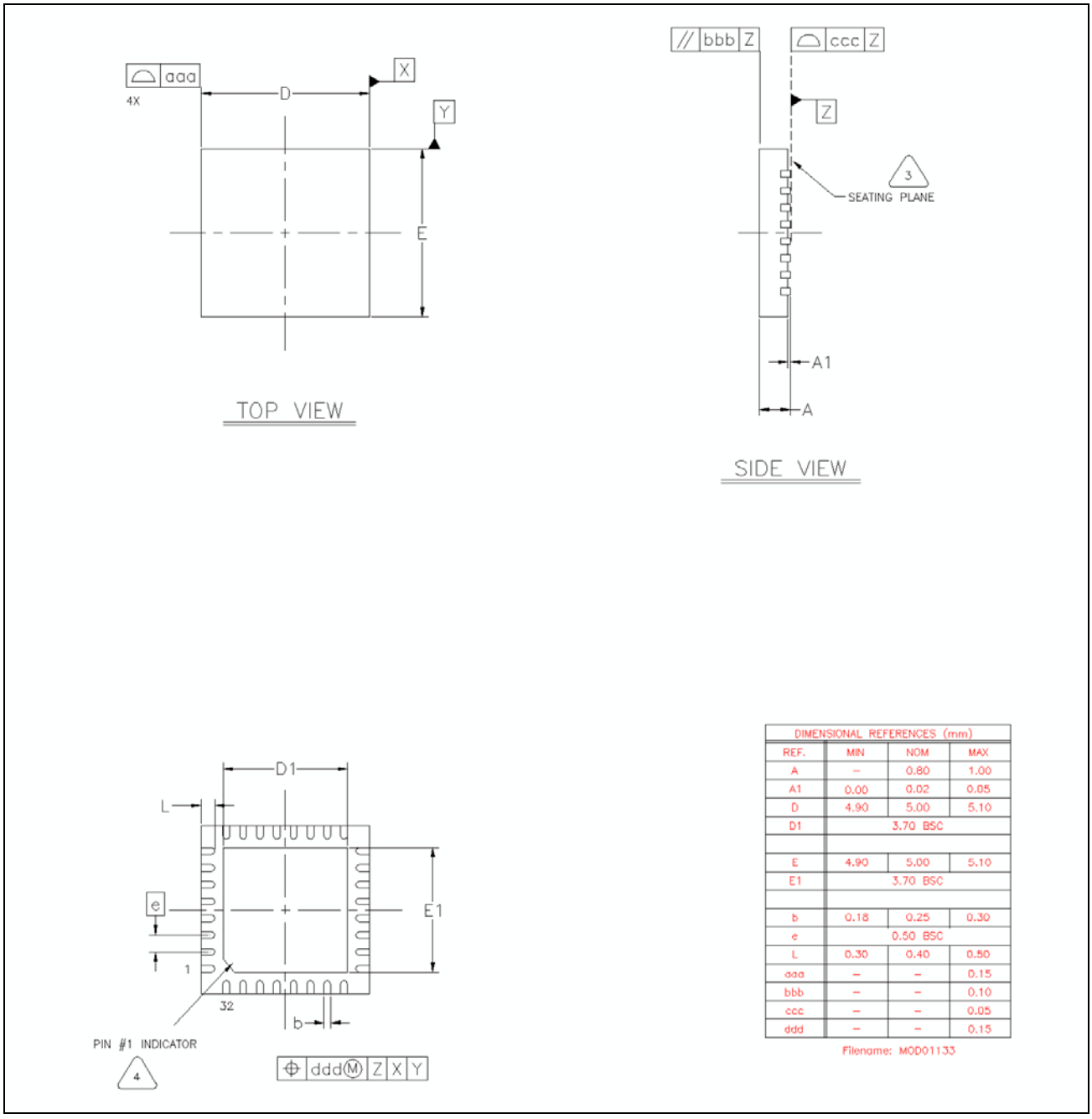
Results Summary

ESD Test Voltage Level Results:

- HBM +/– 2KV PASS
- CDM +/– 500V PASS
- MM +/– 150V PASS

Section 4: Mechanical Information

Figure 14: 32-Pin 5x5 mm QFN Package



DIMENSIONAL REFERENCES (mm)			
REF.	MIN	NOM	MAX
A	–	0.80	1.00
A1	0.00	0.02	0.05
D	4.90	5.00	5.10
D1		3.70 BSC	
E	4.90	5.00	5.10
E1		3.70 BSC	
b	0.18	0.25	0.30
e		0.50 BSC	
L	0.30	0.40	0.50
aaa	–	–	0.15
bbb	–	–	0.10
ccc	–	–	0.05
ddd	–	–	0.15

Filename: MOD01133

Table 20 provides dimensions and additional details on the 32-pin 5x5 mm QFN package.

Table 20: 32-pin 5x5 mm QFN Package Dimensions (Footprint: 0.80)

S/N	SYM	Dimension	Comments/Specifications			
1	A	0.900 ±0.100	**Overall Height**			
			General tolerance:	Distance:	±0.100	
				Angle:		
2	A1	0.020 ±TBD	**Standoff**			
			Matte finish on package body surface, except ejection and pin 1 marking.			Ra 0.3 ~ 1.2 µm
3	D	5.000 ±0.100	**Package Length**			
			Frame base metal thickness			0.203 base
4	E	5.000 ±0.100	**Package Width**			
			All molded body sharp corner radii; unless otherwise specified.			R0.200 (maximum)
5	L	0.400 ±0.075	**Foot Length**			
			Drawing does not include plastic or metal protrusion of cutting burr.			
6	T	0.203 Ref.	**Frame Thickness**			
			Compliant to JEDEC standard: MO-220.			
7	b	0.250 ±0.050	Lead Width			
8	e	0.500 Base	Lead Pitch			

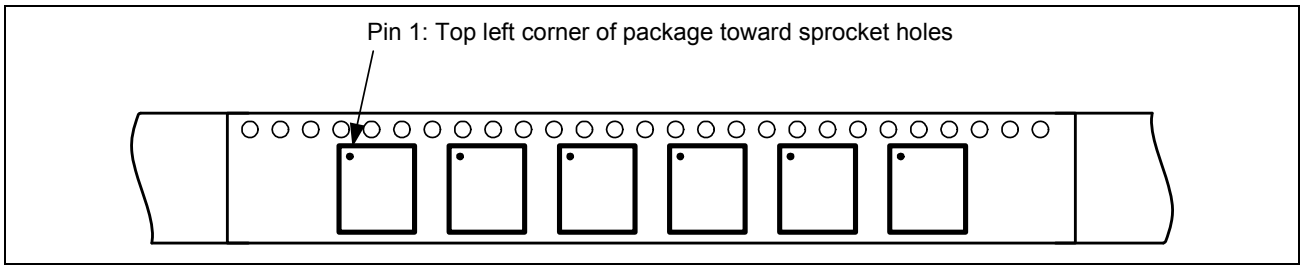
Tape Reel and Packaging Specifications

Table 21: BCM20732 5 × 5 × 1 mm QFN, 32-Pin Tape Reel Specifications

Parameter	*Value*
Quantity per reel	2500 pieces
Reel diameter	13 inches
Hub diameter	7 inches
Tape width	12 mm
Tape pitch	8 mm

The top left corner of the BCM20732 package is situated near the sprocket holes, as shown in Figure 15.

Figure 15: Pin 1 Orientation



Section 5: Ordering Information

Table 22: Ordering Information

Part Number	*Package*	*Ambient Operating Temperature*
BCM20732A0KML2G	32-pin QFN	–30°C to +85°C

Appendix A: Acronyms and Abbreviations

The following list of acronyms and abbreviations may appear in this document.

Term	*Description*
ADC	analog-to-digital converter
AFH	adaptive frequency hopping
AHB	advanced high-performance bus
APB	advanced peripheral bus
APU	audio processing unit
ARM7TDMI-S	Acorn RISC Machine 7 Thumb instruction, Debugger, Multiplier, Ice, Synthesizable
BSC	Broadcom Serial Control
BTC	Bluetooth controller
COEX	coexistence
DFU	device firmware update
DMA	direct memory access
EBI	external bus interface
HCI	Host Control Interface
HV	high voltage
IDC	initial digital calibration
IF	intermediate frequency
IRQ	interrupt request
JTAG	Joint Test Action Group
LCU	link control unit
LDO	low drop-out
LHL	lean high land
LPO	low power oscillator
LV	LogicVision
MIA	multiple interface agent
PCM	pulse code modulation
PLL	phase locked loop
PMU	power management unit
POR	power-on reset
PWM	pulse width modulation
QD	quadrature decoder
RAM	random access memory
RF	radio frequency
ROM	read-only memory
RX/TX	receive, transmit
SPI	serial peripheral interface

Term	*Description*
SW	software
UART	universal asynchronous receiver/transmitter
UPI	µ-processor interface
WD	watchdog

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