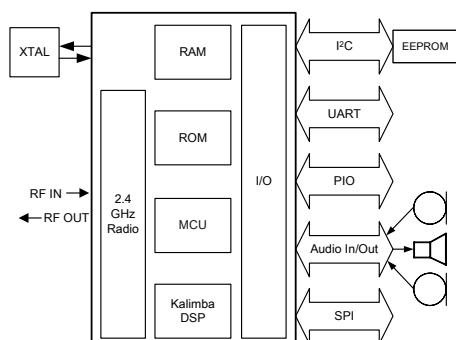


Features

- Single-chip Bluetooth mono headset solution with advanced echo and noise cancellation
- Low-power consumption: over 7 hours of talk-time from a 120mAh battery
- Built-in high-performance 5th Generation CVC (CVC v5.0) single and dual microphone echo and noise cancellation
- Advanced Multipoint support: allows a headset (HFP) connection to 2 phones for voice
- Packet Loss Concealment and Bit Error Concealment to improve audio quality in the presence of air interference
- Programmable Audio Prompts
- Secure Simple Pairing and Proximity Pairing (headset initiated pairing)
- Best-in-class Bluetooth radio with 7.5dBm transmit power and -91dBm receive sensitivity
- 64MIPS Kalimba DSP coprocessor
- Configurable mono headset software
- HFP v1.5 and HSP v1.1 support
- Integrated 1.5V and 1.8V linear regulators
- Integrated switch-mode regulator
- Integrated 150mA lithium battery charger
- Integrated high-quality codec with 95dB SNR DAC
- 68-lead 8 x 8 x 0.9mm, 0.4mm pitch QFN package (pin-for-pin compatible with BlueVox DSP QFN)
- Green (RoHS compliant and no antimony or halogenated flame retardants)
- A complete BC6150 QFN mono headset solution development kit, including example design, is available. Order code DK-BC-6150-1A

General Description

BC6150 QFN is a low-cost fully featured ROM chip solution for mono headsets. It features advanced single-microphone and dual-microphone CVC v5.0 echo and noise cancellation. BC6150 QFN includes a Bluetooth radio, baseband, Kalimba DSP, DAC / ADC, switch-mode power supply and battery charger in a compact 8 x 8 x 0.9mm QFN package for low-cost designs.



BlueCore® BC6150™ QFN

BC6150 QFN Mono Headset Solution Fully Qualified Single-chip Bluetooth® v2.1 + EDR System

Production Information

BC6150A08

Issue 2

Applications

- Mono headset solution with advanced echo and noise cancellation

BC6150 QFN also includes state-of-the-art CVC v5.0 single and dual-microphone echo and noise reduction including significant near end audio enhancements. Dual-microphone CVC v5.0 achieves over 30dB dynamic noise suppression, allowing the headset user to be heard more clearly.

BC6150 QFN supports the latest Bluetooth v2.1 + EDR specification which includes Secure Simple Pairing. This greatly simplifies the pairing process, making it easier to use a Bluetooth headset.

The device incorporates auto-calibration and BIST routines to simplify development, type approval and production test.

BC6150 QFN contains the Kalimba DSP coprocessor for supporting enhanced audio applications.

BC6150 QFN is designed to reduce the number of external components required, which minimises production costs.

Document History

Revision	Date	Change Reason
1	27 AUG 09	Original publication of this document.
2	13 NOV 09	Production Information added. SPI interface information updated. If you have any comments about this document, email comments@csr.com giving the number, title and section with your feedback.

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The status of this Data Sheet is **Production Information**.

CSR Product Data Sheets progress according to the following format:

Advance Information

Information for designers concerning CSR product in development. All values specified are the target values of the design. Minimum and maximum values specified are only given as guidance to the final specification limits and must not be considered as the final values.

All detailed specifications including pinouts and electrical specifications may be changed by CSR without notice.

Pre-production Information

Pinout and mechanical dimension specifications finalised. All values specified are the target values of the design. Minimum and maximum values specified are only given as guidance to the final specification limits and must not be considered as the final values.

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Production Information

Final Data Sheet including the guaranteed minimum and maximum limits for the electrical specifications.

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Contents

1	Device Details	8
2	Functional Block Diagram	9
3	Package Information	10
3.1	Pinout Diagram	10
3.2	Device Terminal Functions	11
3.3	Package Dimensions	15
3.4	PCB Design and Assembly Considerations	16
3.5	Typical Solder Reflow Profile	16
4	Bluetooth Modem	17
4.1	RF Ports	17
4.1.1	RF_N and RF_P	17
4.2	RF Receiver	17
4.2.1	Low Noise Amplifier	17
4.2.2	RSSI Analogue to Digital Converter	17
4.3	RF Transmitter	18
4.3.1	IQ Modulator	18
4.3.2	Power Amplifier	18
4.4	Bluetooth Radio Synthesiser	18
4.5	Baseband	18
4.5.1	Burst Mode Controller	18
4.5.2	Physical Layer Hardware Engine	18
4.6	Basic Rate Modem	18
4.7	Enhanced Data Rate Modem	18
5	Clock Generation	20
5.1	Clock Architecture	20
5.2	Input Frequencies and PS Key Settings	20
5.3	External Reference Clock	20
5.3.1	Input: XTAL_IN	20
5.3.2	XTAL_IN Impedance in External Mode	21
5.3.3	Clock Start-up Delay	21
5.3.4	Clock Timing Accuracy	21
5.4	Crystal Oscillator: XTAL_IN and XTAL_OUT	22
5.4.1	Load Capacitance	23
5.4.2	Frequency Trim	23
5.4.3	Transconductance Driver Model	24
5.4.4	Negative Resistance Model	24
5.4.5	Crystal PS Key Settings	25
6	Bluetooth Stack Microcontroller	26
6.1	Programmable I/O Ports, PIO and AIO	26
7	Kalimba DSP	27
8	Memory Interface and Management	28
8.1	Memory Management Unit	28
8.2	System RAM	28
8.3	Kalimba DSP RAM	28
8.4	Internal ROM	28
9	Serial Interfaces	29
9.1	UART Interface	29
9.1.1	UART Configuration While Reset is Active	31
9.2	Programming and Debug Interface	31
9.2.1	Instruction Cycle	31

9.2.2	Multi-slave Operation	31
9.3	I ² C Interface	31
10	Audio Interface	33
10.1	Audio Input and Output	33
10.2	Mono Audio Codec Interface	33
10.2.1	Mono Audio Codec Block Diagram	34
10.2.2	ADC	34
10.2.3	ADC Digital Gain	34
10.2.4	ADC Analogue Gain	35
10.2.5	DAC	35
10.2.6	DAC Digital Gain	35
10.2.7	DAC Analogue Gain	36
10.2.8	Microphone Input	36
10.2.9	Output Stage	39
10.2.10	Side Tone	40
10.2.11	Integrated Digital Filter	40
11	Power Control and Regulation	42
11.1	Power Sequencing	42
11.2	External Voltage Source	42
11.3	Switch-mode Regulator	43
11.4	Low-voltage Linear Regulator	43
11.5	Low-voltage Audio Linear Regulator	43
11.6	Voltage Regulator Enable Pins	44
11.7	Battery Charger	44
11.8	LED Drivers	44
11.9	Reset, RST#	45
11.9.1	Digital Pin States on Reset	46
11.9.2	Status after Reset	46
12	Example Application Schematic	47
13	Electrical Characteristics	48
13.1	ESD Precautions	48
13.2	Absolute Maximum Ratings	48
13.3	Recommended Operating Conditions	48
13.4	Input/Output Terminal Characteristics	49
13.4.1	Low-voltage Linear Regulator	49
13.4.2	Low-voltage Linear Audio Regulator	50
13.4.3	Switch-mode Regulator	51
13.4.4	Battery Charger	52
13.4.5	Reset	53
13.4.6	Regulator Enable	53
13.4.7	Digital Terminals	54
13.4.8	Mono Codec: Analogue to Digital Converter	55
13.4.9	Mono Codec: Digital to Analogue Converter	56
13.4.10	Clocks	57
13.4.11	LED Driver Pads	57
13.4.12	Auxiliary ADC	58
14	Power Consumption	59
15	CSR Green Semiconductor Products and RoHS Compliance	61
15.1	RoHS Statement	61
15.1.1	List of Restricted Materials	61
16	BC6150 QFN Software Stack	62
16.1	BC6150 QFN Mono Headset Solution Development Kit	62
16.2	BC6150 QFN Mono Headset Solution	62

16.3	Advanced Multipoint Support	62
16.4	Programmable Audio Prompts	63
16.5	Proximity Pairing	63
16.5.1	Proximity Pairing Configuration	63
17	Ordering Information	64
17.1	BC6150 QFN Mono Headset Solution Development Kit Ordering Information	64
18	Tape and Reel Information	65
18.1	Tape Orientation	65
18.2	Tape Dimensions	65
18.3	Reel Information	66
18.4	Moisture Sensitivity Level	66
19	Document References	67
	Terms and Definitions	68

List of Figures

Figure 2.1	Functional Block Diagram	9
Figure 3.1	Device Pinout	10
Figure 3.2	Package Dimensions	15
Figure 4.1	Simplified Circuit RF_N and RF_P	17
Figure 4.2	BDR and EDR Packet Structure	19
Figure 5.1	Clock Architecture	20
Figure 5.2	TCXO Clock Accuracy	22
Figure 5.3	Crystal Driver Circuit	22
Figure 5.4	Crystal Equivalent Circuit	23
Figure 7.1	Kalimba DSP Interface to Internal Functions	27
Figure 9.1	Universal Asynchronous Receiver	29
Figure 9.2	Break Signal	30
Figure 9.3	Example EEPROM Connection	32
Figure 10.1	BC6150 QFN Audio Interface	33
Figure 10.2	Mono Codec Audio Input and Output Stages	34
Figure 10.3	ADC Analogue Amplifier Block Diagram	35
Figure 10.4	Microphone Biasing	36
Figure 10.5	Speaker Output	40
Figure 11.1	Voltage Regulator Configuration	42
Figure 11.2	LED Equivalent Circuit	45
Figure 12.1	Example Application Schematic	47
Figure 16.1	Programmable Audio Prompts in External I ² C EEPROM	63
Figure 18.1	BC6150 QFN Tape Orientation	65
Figure 18.2	Reel Dimensions	66

List of Tables

Table 4.1	Data Rate Schemes	19
Table 5.1	External Clock Specifications	21
Table 5.2	Crystal Specification	23
Table 9.1	Possible UART Settings	29
Table 9.2	Standard Baud Rates	30
Table 9.3	Instruction Cycle for a SPI Transaction	31
Table 10.1	ADC Digital Gain Rate Selection	34
Table 10.2	DAC Digital Gain Rate Selection	35
Table 10.3	DAC Analogue Gain Rate Selection	36
Table 10.4	Voltage Output Steps	38

Table 10.5	Current Output Steps	39
Table 11.1	BC6150 QFN Voltage Regulator Enable Pins	44
Table 11.2	BC6150 QFN Digital Pin States on Reset	46

List of Equations

Equation 5.1	Load Capacitance	23
Equation 5.2	Trim Capacitance	23
Equation 5.3	Frequency Trim	24
Equation 5.4	Pullability	24
Equation 5.5	Transconductance Required for Oscillation	24
Equation 5.6	Equivalent Negative Resistance	25
Equation 9.1	Baud Rate	30
Equation 10.1	IIR Filter Transfer Function, $H(z)$	41
Equation 10.2	IIR Filter plus DC Blocking Transfer Function, $H_{DC}(z)$	41
Equation 11.1	LED Current	45
Equation 11.2	LED PAD Voltage	45

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1 Device Details

Radio

- Common TX/RX terminal simplifies external matching; eliminates external antenna switch
- BIST minimises production test time
- Bluetooth v2.1 + EDR specification compliant

Transmitter

- 7.5dBm RF transmit power with level control from a 6-bit DAC over a typical 30dB dynamic range
- Class 2 and Class 3 support without the need for an external power amplifier or TX/RX switch

Receiver

- Receiver sensitivity of -91dBm
- Integrated channel filters
- Digital demodulator for improved sensitivity and co-channel rejection
- Real-time digitised RSSI available on HCI interface
- Fast AGC for enhanced dynamic range

Synthesiser

- Fully integrated synthesiser requires no external VCO, varactor diode, resonator or loop filter
- Compatible with crystals 16MHz to 26MHz or an external clock 12MHz to 52MHz

Kalimba DSP

- Very low power Kalimba DSP coprocessor, 64MIPS, 24-bit fixed point core
- Single-cycle MAC; 24 x 24-bit multiply and 56-bit accumulator
- 32-bit instruction word, dual 24-bit data memory
- 6K x 32-bit program RAM, 8K x 24-bit + 8K x 24-bit data RAM
- 64 x 32-bit program memory cache when executing from ROM

Audio Codec

- 16-bit internal codec
- ADC and DAC for stereo audio
- Integrated amplifiers for driving 16Ω speakers; no need for external components
- Support for single-ended speaker termination and line output
- Integrated low-noise microphone bias

Physical Interfaces

- Synchronous serial interface for system debugging
- I²C compatible interface to external EEPROM containing device configuration data (PS Keys)
- UART interface with data rates up to 3Mbits/s
- Bidirectional serial programmable audio interface supporting PCM, I²S and SPDIF formats
- 2 LED drivers with faders

Baseband and Software

- Internal ROM
- 48KB of internal RAM, allows full-speed data transfer, mixed voice/data and full piconet support
- Logic for forward error correction, header error control, access code correlation, CRC, demodulation, encryption bit stream generation, whitening and transmit pulse shaping
- Transcoders for A-law, μ -law and linear voice from host and A-law, μ -law and CVSD voice over air
- Configurable mono headset ROM software to set-up headset features and user interface
- Support for HFP v1.5 (including three-way calling) and HSP v1.1
- Support for Bluetooth v2.1 + EDR specification Secure Simple Pairing
- Proximity Pairing (headset initiated pairing)
- Advanced Multipoint support, allowing the headset to connect to 2 mobile phones or 1 mobile phone and a VoIP dongle
- Programmable audio prompts
- Packet Loss Concealment and Bit Error Concealment to improve audio quality in the presence of air interference
- DSP based single-microphone CVC v5.0 echo and noise cancellation is included in the BC6150 QFN for effective noise cancellation under all conditions
- A high-performance dual-microphone noise cancellation is available using CVC v5.0 is available in BC6150 QFN providing over 30dB of dynamic noise suppression

Auxiliary Features

- Crystal oscillator with built-in digital trimming
- Power management includes digital shutdown and wake-up commands with an integrated low-power oscillator for ultra-low power Park/Sniff/Hold mode
- Clock request output to control external clock
- On-chip regulators: 1.5V output from 1.7V to 1.95V input
- On-chip high-efficiency switched-mode regulator: 1.8V output from 2.5V to 4.4V input
- Power-on-reset cell detects low-supply voltage
- 10-bit ADC available to applications
- On-chip 150mA charger for lithium ion/polymer batteries

Package Option

- QFN 68-lead, 8 x 8 x 0.9mm, 0.4mm pitch

2 Functional Block Diagram

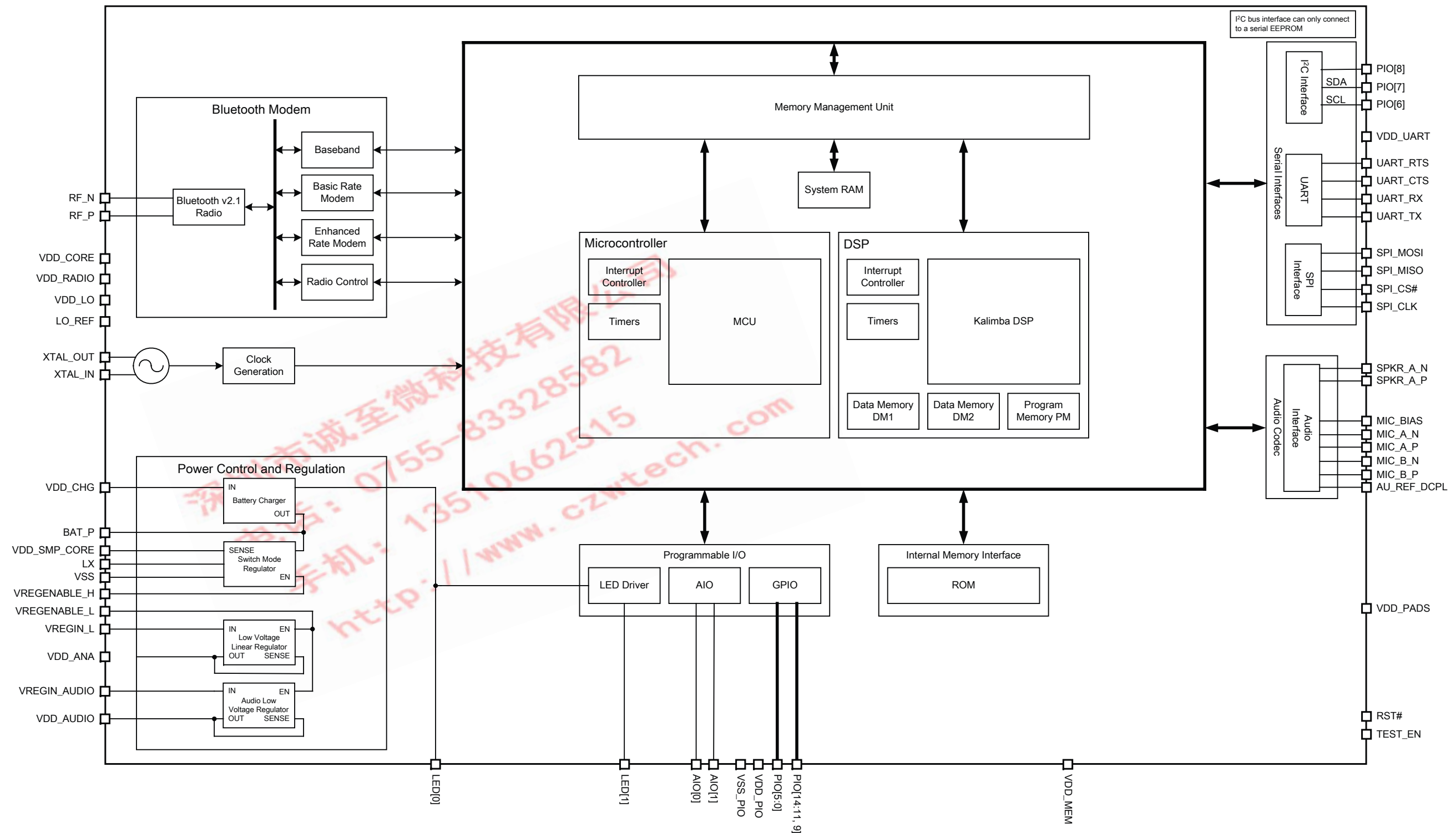
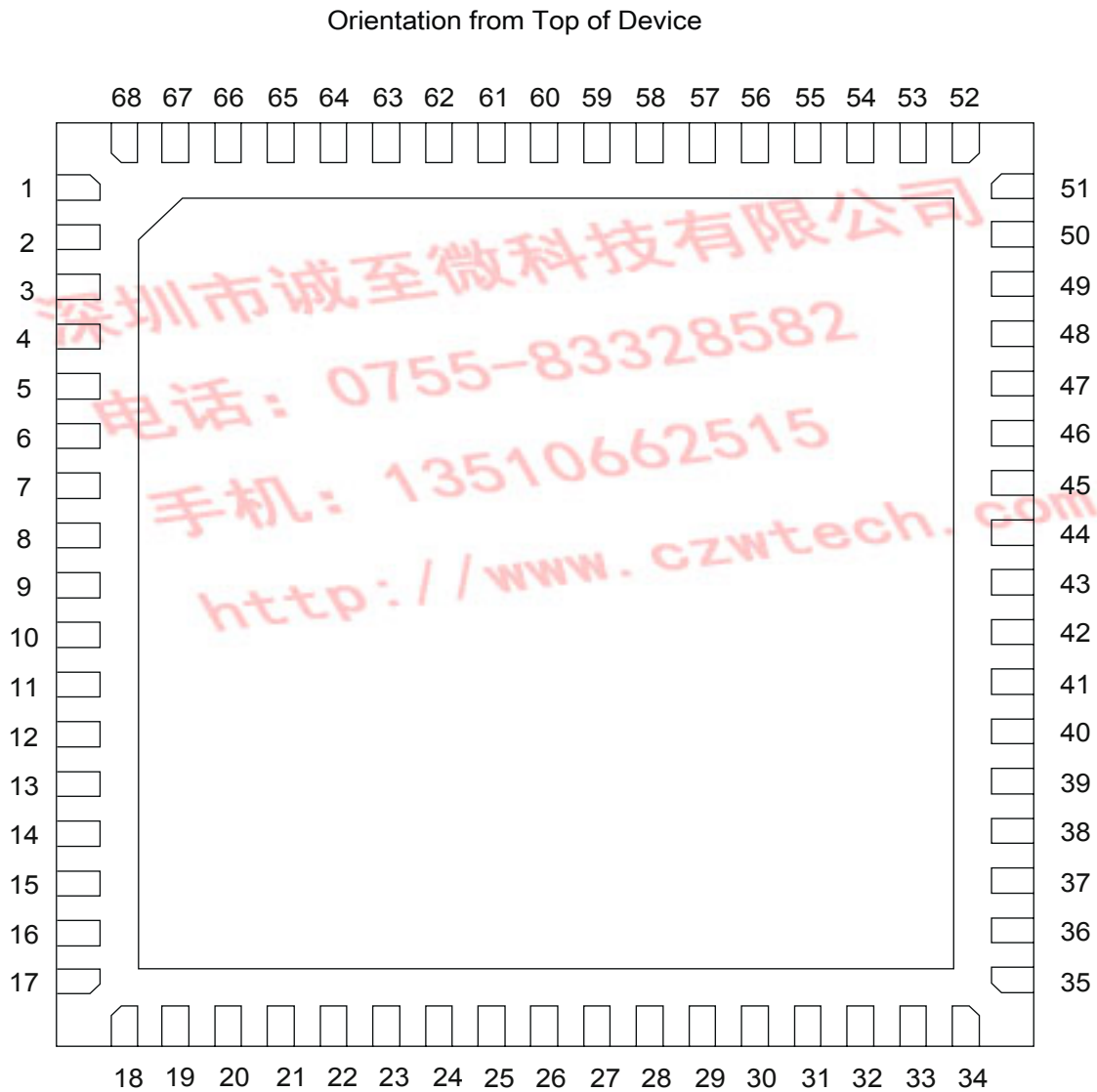


Figure 2.1: Functional Block Diagram

3 Package Information

3.1 Pinout Diagram



G-TW-0000901.4.2

BC6150 QFN Data Sheet

Figure 3.1: Device Pinout

3.2 Device Terminal Functions

Bluetooth Radio	Lead	Pad Type	Supply Domain	Description
RF_N	65	RF	VDD_RADIO	Transmitter output/switched receiver
RF_P	64	RF		Complement of RF_N

Synthesiser and Oscillator	Lead	Pad Type	Supply Domain	Description
XTAL_IN	3	Analogue	VDD_ANA	For crystal or external clock input
XTAL_OUT	4			Drive for crystal
LO_REF	5			Reference voltage to decouple the synthesiser

SPI Interface	Lead	Pad Type	Supply Domain	Description
SPI_MOSI	28	Input, with weak internal pull-down	VDD_PADS	SPI data input
SPI_CS#	30	Bidirectional with weak internal pull-down		Chip select for SPI, active low
SPI_CLK	29	Bidirectional with weak internal pull-down		SPI clock
SPI_MISO	31	Bidirectional with weak internal pull-down		SPI data output

UART Interface	Lead	Pad Type	Supply Domain	Description
UART_TX	9	Output, tri-state, with weak internal pull-down	VDD_UART	UART data output, active high
UART_RX	10	Bidirectional with weak internal pull-down		UART data input, active high
UART_RTS	12	Bidirectional CMOS output, tri-state, with weak internal pull-up		UART request to send active low
UART_CTS	11	CMOS input with weak internal pull-down		UART clear to send active low

PIO Port	Lead	Pad Type	Supply Domain	Description
PIO[14]	20	Bidirectional with programmable strength internal pull-up/down	VDD_PADS	Programmable input/output line
PIO[13]	19			
PIO[12]	18			
PIO[11]	15			
PIO[9]	14			
PIO[8]	21			
PIO[7]	22			
PIO[6]	23			
PIO[5]	24			
PIO[4]	25			
PIO[3]	58	Bidirectional with programmable strength internal pull-up/down	VDD_PIO	Programmable input/output line
PIO[2]	59			
PIO[1]	60			
PIO[0]	61			
AIO[1]	6	Bidirectional	VDD_ANA	Programmable input/output line
AIO[0]	7			

Audio	Lead	Pad Type	Supply Domain	Description
SPKR_A_N	56	Analogue	VDD_AUDIO	Speaker output, negative, channel A
SPKR_A_P	57	Analogue	VDD_AUDIO	Speaker output, positive, channel A
MIC_A_N	52	Analogue	VDD_AUDIO	Microphone input, negative, channel A
MIC_A_P	51	Analogue	VDD_AUDIO	Microphone input, positive, channel A
MIC_B_N	50	Analogue	VDD_AUDIO	Microphone input, negative, channel B
MIC_B_P	48	Analogue	VDD_AUDIO	Microphone input, positive, channel B
MIC_BIAS	45	Analogue	VDD_AUDIO, BAT_P	Microphone bias
AU_REF_DCPL	55	Analogue	VDD_AUDIO	Decoupling of audio reference, for high-quality audio

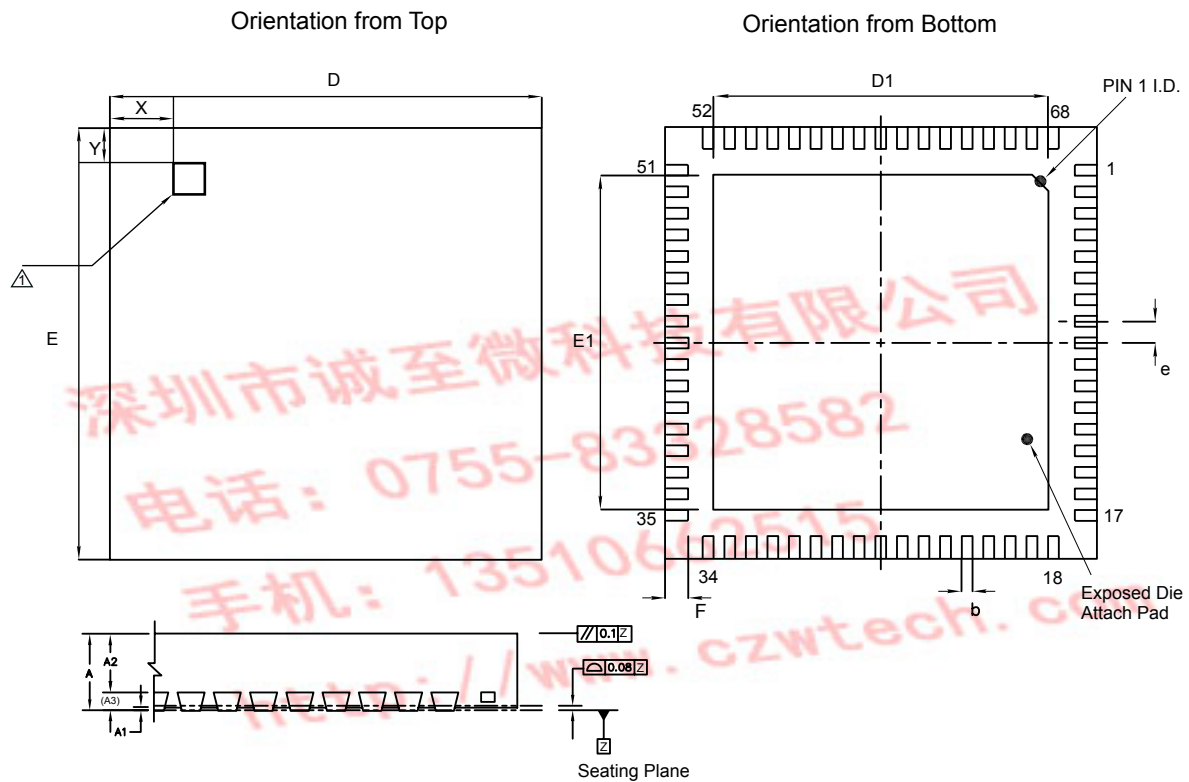
LED Drivers	Lead	Pad Type	Supply Domain	Description
LED[1]	33	Open drain output	Open drain	LED driver
LED[0]	32			LED driver

Test and Debug	Lead	Pad Type	Supply Domain	Description
RST#	26	Input with weak internal pull-up	VDD_PADS	Reset if low. Input debounced so must be low for >5ms to cause a reset
TEST_EN	27	Input with strong internal pull-down		For test purposes only, leave unconnected

Power Supplies Control	Lead	Description
VREGENABLE_L	68	Low-voltage linear regulator and low-voltage audio linear regulator enable, active high
VREGIN_L	1	Input to internal low-voltage regulator
VREGENABLE_H	35	Switch-mode regulator enable, active high
VREGIN_AUDIO	46	Input to internal audio low-voltage linear regulator
VDD_AUDIO	47	Positive supply for audio
LX	37	Switch-mode regulator output
VDD_ANA	2	Positive supply output for analogue circuitry and 1.5V regulated output, from internal low-voltage regulator
VDD_PIO	62	Positive supply for digital input/output ports PIO[3:0]
VDD_PADS	16	Positive supply for all other digital Input/Output ports including PIO[14:11,9:4]
VDD_CORE	17, 34	Positive supply for internal digital circuitry
VDD_RADIO	63, 66	Positive supply for RF circuitry
VDD_UART	13	Positive supply for UART ports
VDD_LO	67	Positive supply for local oscillator circuitry
BAT_P	38	Lithium ion/polymer battery positive terminal. Battery charger output and input to switch-mode regulator
VDD_CHG	39	Lithium ion/polymer battery charger input
VDD_SMP_CORE	36	Positive supply for switch-mode control circuitry
VSS	Exposed Pad	Ground connections

Unconnected Leads (N/Cs)	Description
8, 40, 41, 42, 43, 44, 49, 53, 54	Leave unconnected

3.3 Package Dimensions




Description	68-lead Quad Flat No-lead Package			
Size	8 x 8 x 0.9mm			
Pitch	0.4mm			
Dimension	Minimum	Typical	Maximum	Notes
A	0.80	0.85	0.90	 Top-side polarity mark. The dimensions of the square polarity mark are 0.75 x 0.75mm. Coplanarity applies to leads, corner leads and die attach pad.
A1	0.00	0.035	0.05	
A2	-	0.65	0.67	
A3	-	0.203	-	
b	0.15	0.20	0.25	
D	7.90	8.00	8.05	
E	7.90	8.00	8.05	
e	-	0.40	-	
D1	6.10	6.20	6.30	
E1	6.10	6.20	6.30	
F	0.35	0.40	0.45	
X	-	1.00	-	
Y	-	0.85	-	
JEDEC	MO-220			
Unit	mm			

Figure 3.2: Package Dimensions

3.4 PCB Design and Assembly Considerations

This section lists recommendations to achieve maximum board-level reliability of the 8 x 8 x 0.9mm QFN 68-lead package:

- NSMD lands (lands smaller than the solder mask aperture) are preferred, because of the greater accuracy of the metal definition process compared to the solder mask process. With solder mask defined pads, the overlap of the solder mask on the land creates a step in the solder at the land interface, which can cause stress concentration and act as a point for crack initiation.
- CSR recommends that the PCB land pattern to be in accordance with IPC standard IPC-7351.
- Solder paste must be used during the assembly process.

3.5 Typical Solder Reflow Profile

See *Typical Solder Reflow Profile for Lead-free Devices* for information.

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4 Bluetooth Modem

4.1 RF Ports

4.1.1 RF_N and RF_P

RF_N and RF_P form a complementary balanced pair and are available for both transmit and receive. On transmit their outputs are combined using an external balun into the single-ended output required for the antenna. Similarly, on receive their input signals are combined internally.

Both terminals present similar complex impedances that may require matching networks between them and the balun. Viewed from the chip, the outputs can each be modelled as an ideal current source in parallel with a lossy capacitor. An equivalent series inductance can represent the package parasitics.

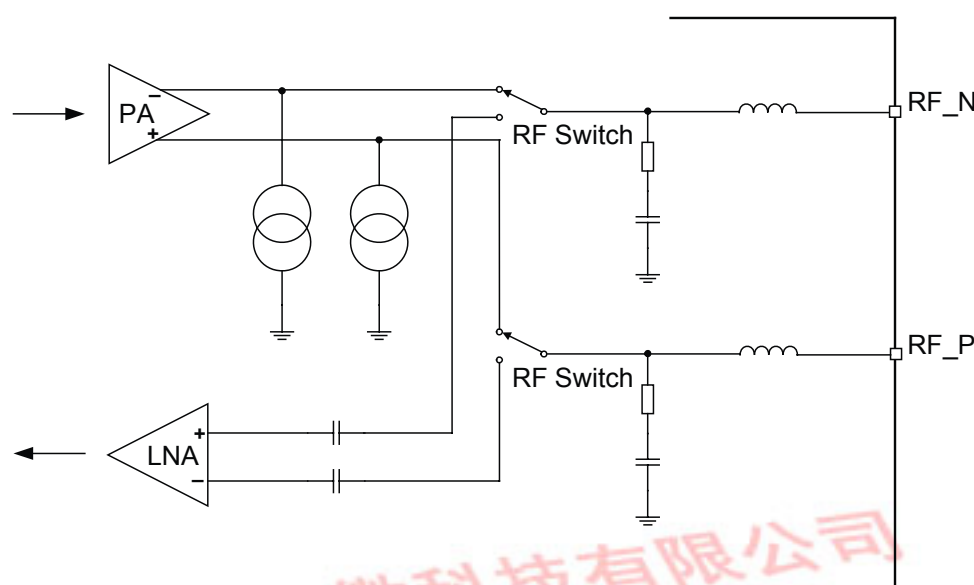


Figure 4.1: Simplified Circuit RF_N and RF_P

RF_N and RF_P require an external DC bias. The DC level must be set at VDD_RADIO.

4.2 RF Receiver

The receiver features a near-zero IF architecture that allows the channel filters to be integrated onto the die. Sufficient out-of-band blocking specification at the LNA input allows the receiver to be used in close proximity to GSM and W-CDMA cellular phone transmitters without being desensitised. The use of a digital FSK discriminator means that no discriminator tank is needed and its excellent performance in the presence of noise allows BC6150 QFN to exceed the Bluetooth requirements for co-channel and adjacent channel rejection.

For EDR, the demodulator contains an ADC which digitises the IF received signal. This information is then passed to the EDR modem.

4.2.1 Low Noise Amplifier

The LNA operates in differential mode and takes its input from the shared RF port.

4.2.2 RSSI Analogue to Digital Converter

The ADC implements fast AGC. The ADC samples the RSSI voltage on a slot-by-slot basis. The front-end LNA gain is changed according to the measured RSSI value, keeping the first mixer input signal within a limited range. This improves the dynamic range of the receiver, improving performance in interference limited environments.

4.3 RF Transmitter

4.3.1 IQ Modulator

The transmitter features a direct IQ modulator to minimise frequency drift during a transmit timeslot, which results in a controlled modulation index. Digital baseband transmit circuitry provides the required spectral shaping.

4.3.2 Power Amplifier

The internal PA has a maximum output power that allows BC6150 QFN to be used in Class 2 and Class 3 radios without an external RF PA.

4.4 Bluetooth Radio Synthesiser

The Bluetooth radio synthesiser is fully integrated onto the die with no requirement for an external VCO screening can, varactor tuning diodes, LC resonators or loop filter. The synthesiser is guaranteed to lock in sufficient time across the guaranteed temperature range to meet the Bluetooth v2.1 + EDR specification.

4.5 Baseband

4.5.1 Burst Mode Controller

During transmission the BMC constructs a packet from header information previously loaded into memory-mapped registers by the software and payload data/voice taken from the appropriate ring buffer in the RAM. During reception, the BMC stores the packet header in memory-mapped registers and the payload data in the appropriate ring buffer in RAM. This architecture minimises the intervention required by the processor during transmission and reception.

4.5.2 Physical Layer Hardware Engine

Dedicated logic performs the following:

- Forward error correction
- Header error control
- Cyclic redundancy check
- Encryption
- Data whitening
- Access code correlation
- Audio transcoding

Firmware performs the following voice data translations and operations:

- A-law/ μ -law/linear voice data (from host)
- A-law/ μ -law/CVSD (over the air)
- Voice interpolation for lost packets
- Rate mismatch correction

The hardware supports all optional and mandatory features of Bluetooth v2.1 + EDR specification including AFH and eSCO.

4.6 Basic Rate Modem

The basic rate modem satisfies the basic data rate requirements of the Bluetooth v2.1 + EDR specification. The basic rate was the standard data rate available on the Bluetooth v1.2 specification and below, it is based on GFSK modulation scheme.

Including the basic rate modem allows BC6150 QFN compatibility with earlier Bluetooth products.

The basic rate modem uses the RF ports, receiver, transmitter and synthesiser, alongside the baseband components described in Section 4.5.

4.7 Enhanced Data Rate Modem

The EDR modem satisfies the requirements of the Bluetooth v2.1 + EDR specification. EDR has been introduced to provide 2x and 3x data rates with minimal disruption to higher layers of the Bluetooth stack. BC6150 QFN supports both the basic and enhanced data rates and is compliant with the Bluetooth v2.1 + EDR specification.

At the baseband level, EDR uses the same 1.6kHz slot rate and the 1MHz symbol rate defined for the basic data rate. EDR differs in that each symbol in the payload portion of a packet represents 2 or 3 bits. This is achieved using 2 new distinct modulation schemes. Table 4.1 and Figure 4.2 summarise these. Link Establishment and Management are unchanged and still use GFSK for both the header and payload portions of these packets.

The enhanced data rate modem uses the RF ports, receiver, transmitter and synthesiser, with the baseband components described in Section 4.5.

Data Rate Scheme	Bits Per Symbol	Modulation
Basic Rate	1	GFSK
EDR	2	$\pi/4$ DQPSK
EDR	3	8DPSK (optional)

Table 4.1: Data Rate Schemes

Basic Rate

Access Code	Header	Payload
-------------	--------	---------

Enhanced Data Rate

Access Code	Header	Guard	Sync	Payload	Trailer
-------------	--------	-------	------	---------	---------

$\pi/4$ DQPSK or 8DPSK

G-TW-0000244.2.3

Figure 4.2: BDR and EDR Packet Structure

5 Clock Generation

BC6150 QFN requires a Bluetooth reference clock frequency of 12MHz to 52MHz from either an externally connected crystal or from an external TCXO source.

All BC6150 QFN internal digital clocks are generated using a phase locked loop, which is locked to the frequency of either the external 12MHz to 52MHz reference clock source or an internally generated watchdog clock frequency of 1kHz.

The Bluetooth operation determines the use of the watchdog clock in low-power modes.

5.1 Clock Architecture

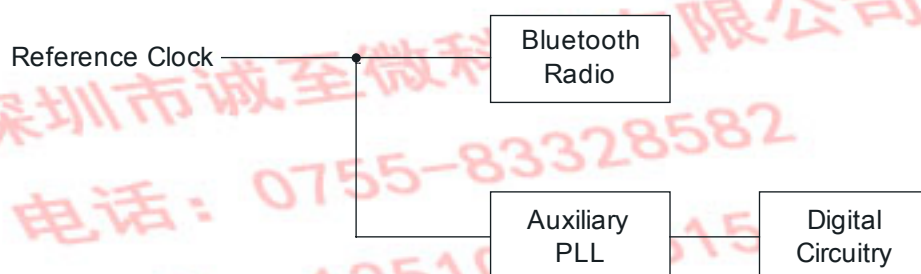


Figure 5.1: Clock Architecture

5.2 Input Frequencies and PS Key Settings

BC6150 QFN is configured to operate with a chosen reference frequency. Configuration is by setting the PSKEY_ANA_FREQ for all frequencies with an integer multiple of 250kHz. The input frequency default setting for BC6150 QFN is 26MHz depending on the software build. Full details are in the software release note for the specific build from www.csrsupport.com.

5.3 External Reference Clock

5.3.1 Input: XTAL_IN

The external reference clock is applied to the BC6150 QFN XTAL_IN input. BC6150 QFN is configured to accept the external reference clock at XTAL_IN by connecting XTAL_OUT to ground.

The external clock can be either a digital level square wave or sinusoidal, and this may be directly coupled to XTAL_IN without the need for additional components. A digital level reference clock gives superior noise immunity, as the high slew rate clock edges have lower voltage to phase conversion. If peaks of the reference clock are either below VSS or above VDD_ANA, it must be driven through a DC blocking capacitor (approximately 33pF) connected to XTAL_IN.

The external reference clock signal should meet the specifications in Table 5.1.

G-TW-0000189.3.3

			Min	Typ	Max	Unit
Frequency ^(a)			12	26	52	MHz
Duty cycle			20:80	50:50	80:20	-
Edge jitter (at zero crossing)			-	-	15	ps rms
Signal level	AC coupled sinusoid		0.4	-	VDD_ANA ^(b)	V pk-pk
	DC coupled digital	V _{IL}	-	VSS ^(c)	-	V
		V _{IH}	-	VDD_ANA ^(b) (c)	-	V

Table 5.1: External Clock Specifications

^(a) The frequency should be an integer multiple of 250kHz except for the CDMA/3G frequencies

^(b) VDD_ANA is 1.50V nominal

^(c) If driven via a DC blocking capacitor max amplitude is reduced to 750mV pk-pk for non 50:50 duty cycle

5.3.2 XTAL_IN Impedance in External Mode

The impedance of XTAL_IN does not change significantly between operating modes, typically 10fF. When transitioning from deep sleep to an active state a spike of up to 1pC may be measured. For this reason CSR recommends that a buffered clock input is used.

5.3.3 Clock Start-up Delay

BC6150 QFN hardware incorporates an automatic 5ms delay after the assertion of the system clock request signal before running firmware, see Figure 5.2. This is suitable for most applications using an external clock source. However, there may be scenarios where the clock cannot be guaranteed to either exist or be stable after this period. Under these conditions, BC6150 QFN firmware provides a software function that extends the system clock request signal by a period stored in PSKEY_CLOCK_STARTUP_DELAY. This value is set in milliseconds from 1ms to 31ms. Zero is the default entry for 5ms delay.

This PS Key allows the designer to optimise a system where clock latencies may be longer than 5ms while still keeping the current consumption of BC6150 QFN as low as possible. BC6150 QFN consumes about 2mA of current for the duration of PSKEY_CLOCK_STARTUP_DELAY before activating the firmware.

5.3.4 Clock Timing Accuracy

As Figure 5.2 shows, the 250ppm timing accuracy on the external clock is required 2ms after the firmware begins to run. This is to guarantee that the firmware can maintain timing accuracy in accordance with the Bluetooth v2.1 + EDR specification. Radio activity may occur after 6ms after the firmware starts. Therefore, at this point the timing accuracy of the external clock source must be within ± 20 ppm.

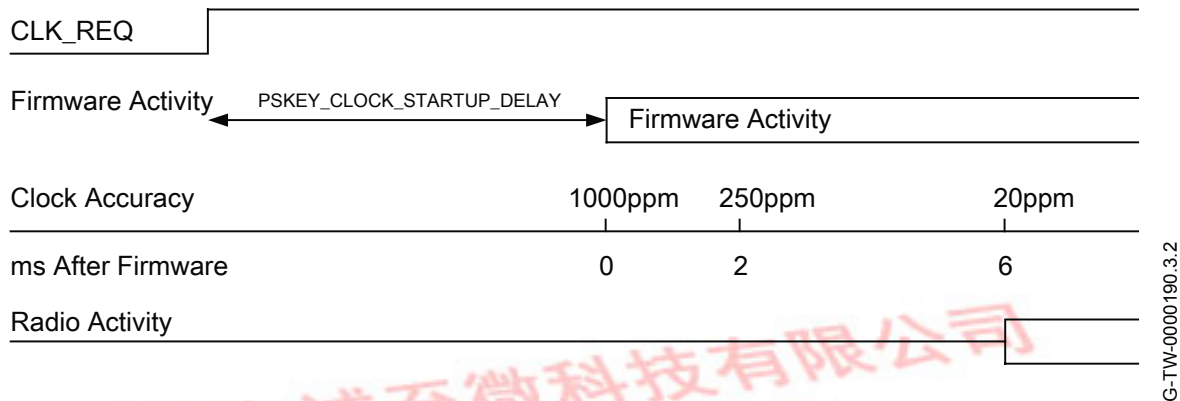


Figure 5.2: TCXO Clock Accuracy

5.4 Crystal Oscillator: XTAL_IN and XTAL_OUT

BC6150 QFN contains a crystal driver circuit. This operates with an external crystal and capacitors to form a Pierce oscillator. The external crystal is connected to pins XTAL_IN, XTAL_OUT.

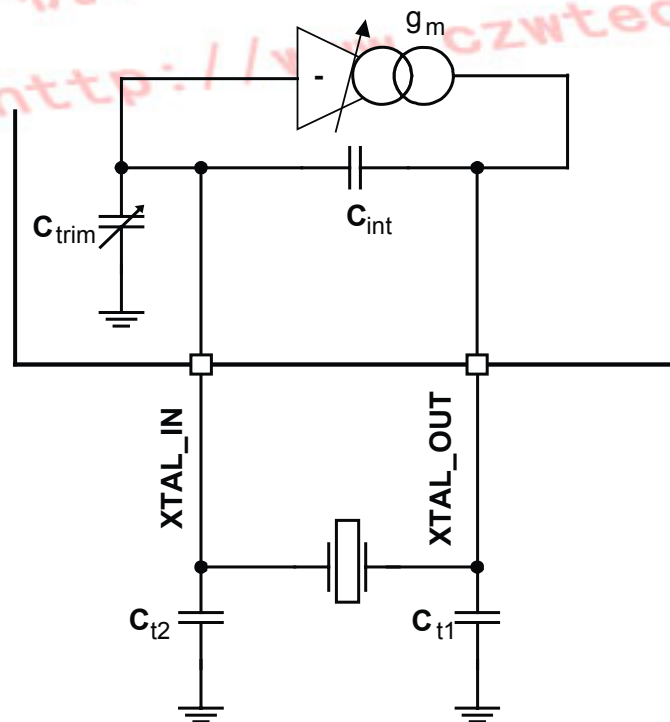
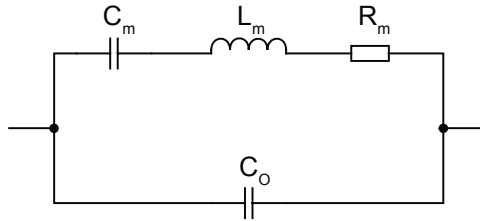


Figure 5.3: Crystal Driver Circuit

Figure 5.4 shows an electrical equivalent circuit for a crystal. The crystal appears inductive near its resonant frequency. It forms a resonant circuit with its load capacitors.



G-TW-0000245.4.4

Figure 5.4: Crystal Equivalent Circuit

The resonant frequency may be trimmed with the crystal load capacitance. BC6150 QFN contains variable internal capacitors to provide a fine trim.

Parameter	Min	Typ	Max	Unit
Frequency	16	26	26	MHz
Initial Tolerance	-	±25	-	ppm
Pullability	-	±20	-	ppm/pF

Table 5.2: Crystal Specification

The BC6150 QFN driver circuit is a transconductance amplifier. A voltage at XTAL_IN generates a current at XTAL_OUT. The value of transconductance is variable and may be set for optimum performance.

5.4.1 Load Capacitance

For resonance at the correct frequency the crystal should be loaded with its specified load capacitance, which is defined for the crystal. This is the total capacitance across the crystal viewed from its terminals. BC6150 QFN provides some of this load with the capacitors C_{trim} and C_{int} . The remainder should be from the external capacitors labelled C_{t1} and C_{t2} . C_{t1} should be three times the value of C_{t2} for best noise performance. This maximises the signal swing and slew rate at XTAL_IN (to which all on-chip clocks are referred).

Crystal load capacitance, C_l is calculated with Equation 5.1:

$$C_l = C_{int} + \frac{(C_{t2} + C_{trim}) C_{t1}}{C_{t2} + C_{trim} + C_{t1}}$$

Equation 5.1: Load Capacitance

Note:

$C_{trim} = 3.4\text{pF}$ nominal (mid-range setting)

$C_{int} = 1.5\text{pF}$

C_{int} does not include the crystal internal self capacitance; it is the driver self capacitance.

5.4.2 Frequency Trim

BC6150 QFN enables frequency adjustments to be made. This feature is typically used to remove initial tolerance frequency errors associated with the crystal. Frequency trim is achieved by adjusting the crystal load capacitance with an on-chip trim capacitor, C_{trim} . The value of C_{trim} is set by a 6-bit word in PSKEY_ANA_FTRIM. Its value is calculated as follows:

$$C_{trim} = 125\text{fF} \times \text{PSKEY_ANA_FTRIM}$$

Equation 5.2: Trim Capacitance

The C_{trim} capacitor is connected between XTAL_IN and ground. When viewed from the crystal terminals, the combination of the tank capacitors and the trim capacitor presents a load across the terminals of the crystal which varies in steps of typically 125fF for each least significant bit increment of PSKEY_ANA_FTRIM.

Equation 5.3 describes the frequency trim.

$$\frac{\Delta(F_x)}{F_x} = \text{pullability} \times 0.110 \times \left(\frac{C_{t1}}{C_{t1} + C_{t2} + C_{trim}} \right) (\text{ppm/LSB})$$

Equation 5.3: Frequency Trim

Note:

F_x = crystal frequency

Pullability is a crystal parameter with units of ppm/pF

Total trim range is 0 to 63

If not specified, the pullability of a crystal may be calculated from its motional capacitance with Equation 5.4.

$$\frac{\partial(F_x)}{\partial(C_1)} = F_x \cdot \frac{C_m}{2(C_1 + C_0)^2}$$

Equation 5.4: Pullability

Note:

C_0 = Crystal self capacitance (shunt capacitance)

C_m = Crystal motional capacitance (series branch capacitance in crystal model), see Figure 5.4

It is a Bluetooth requirement that the frequency is always within $\pm 20\text{ppm}$. The trim range should be sufficient to pull the crystal within $\pm 5\text{ppm}$ of the exact frequency. This leaves a margin of $\pm 15\text{ppm}$ for frequency drift with ageing and temperature. A crystal with an ageing and temperature drift specification of better than $\pm 15\text{ppm}$ is required.

5.4.3 Transconductance Driver Model

The crystal and its load capacitors should be viewed as a transimpedance element, whereby a current applied to one terminal generates a voltage at the other. The transconductance amplifier in BC6150 QFN uses the voltage at its input, XTAL_IN, to generate a current at its output, XTAL_OUT. Therefore, the circuit oscillates if the transconductance, transimpedance product is greater than unity. For sufficient oscillation amplitude, the product should be greater than three. The transconductance required for oscillation is defined by the relationship shown in Equation 5.5.

$$g_m > 3 \frac{(2\pi F_x)^2 R_m ((C_0 + C_{int})(C_{t1} + C_{t2} + C_{trim}) + C_{t1} (C_{t2} + C_{trim}))}{C_{t1} (C_{t2} + C_{trim})}$$

Equation 5.5: Transconductance Required for Oscillation

BC6150 QFN guarantees a transconductance value of at least 2mA/V at maximum drive level.

Note:

More drive strength is required for higher frequency crystals, higher loss crystals (larger R_m) or higher capacitance loading

Optimum drive level is attained when the level at XTAL_IN is approximately 1V pk-pk. The drive level is determined by the crystal driver transconductance.

5.4.4 Negative Resistance Model

An alternative representation of the crystal and its load capacitors is a frequency dependent resistive element. The driver amplifier may be considered as a circuit that provides negative resistance. For oscillation, the value of the negative resistance must be greater than that of the crystal circuit equivalent resistance. Although the BC6150 QFN crystal driver circuit is based on a transimpedance amplifier, an equivalent negative resistance can be calculated for it using Equation 5.6.

$$R_{neg} > \frac{C_{t1}(C_{t2} + C_{trim})}{g_m(2\pi F_x)^2(C_0 + C_{int})((C_{t1} + C_{t2} + C_{trim}) + C_{t1}(C_{t2} + C_{trim}))^2}$$

Equation 5.6: Equivalent Negative Resistance

This formula shows the negative resistance of the BC6150 QFN driver as a function of its drive strength.

The value of the driver negative resistance may be easily measured by placing an additional resistance in series with the crystal. The maximum value of this resistor (oscillation occurs) is the equivalent negative resistance of the oscillator.

5.4.5 Crystal PS Key Settings

The BC6150 QFN firmware automatically controls the drive level on the crystal circuit to achieve optimum input swing. PSKEY_XTAL_TARGET_AMPLITUDE is used by the firmware to servo the required amplitude of crystal oscillation. Refer to the software build release note for a detailed description.

BC6150 QFN should be configured to operate with the chosen reference frequency.

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6 Bluetooth Stack Microcontroller

A 16-bit RISC MCU is used for low power consumption and efficient use of memory.

The MCU, interrupt controller and event timer run the Bluetooth software stack and control the Bluetooth radio and host interfaces.

6.1 Programmable I/O Ports, PIO and AIO

BC6150 QFN contains 14 lines of programmable bidirectional I/O.

BC6150 QFN has 2 general-purpose analogue interface pins, AIO[1:0], used to access internal circuitry and control signals. Auxiliary functions available on the analogue interface include a 10-bit ADC.

Note:

The PIO and AIO configuration is dependent on the BC6150 QFN mono headset solution.

PIO[14:11,9:4] are powered from VDD_PADS and PIO[3:0] are powered from VDD_PIO. AIO[1:0] are powered from VDD_ANA.

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7 Kalimba DSP

The Kalimba DSP is an open platform Kalimba DSP allowing signal processing functions to be performed on over-air data or codec data in order to enhance audio applications. Figure 7.1 shows the Kalimba DSP interfaces to other functional blocks within BC6150 QFN.

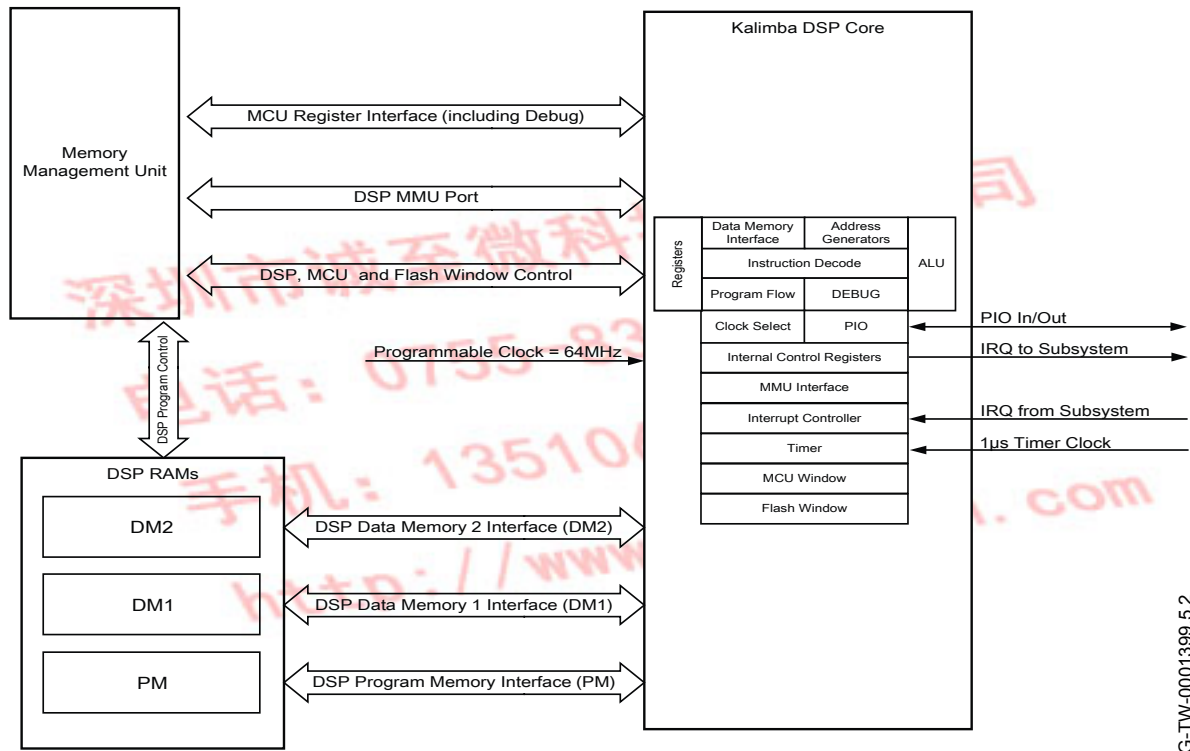


Figure 7.1: Kalimba DSP Interface to Internal Functions

The key features of the DSP include:

- 64MIPS performance, 24-bit fixed point DSP core
- Single cycle MAC of 24 x 24-bit multiply and 56-bit accumulate
- 32-bit instruction word
- Separate program memory and dual data memory, allowing an ALU operation and up to two memory accesses in a single cycle
- Zero overhead looping
- Zero overhead circular buffer indexing
- Single cycle barrel shifter with up to 56-bit input and 24-bit output
- Multiple cycle divide (performed in the background)
- Bit reversed addressing
- Orthogonal instruction set
- Low overhead interrupt

8 Memory Interface and Management

8.1 Memory Management Unit

The MMU provides a number of dynamically allocated ring buffers that hold the data that is in transit between the host, the air or the Kalimba DSP. The dynamic allocation of memory ensures efficient use of the available RAM and is performed by a hardware MMU to minimise the overheads on the processor during data/voice transfers.

8.2 System RAM

48KB of on-chip RAM supports the RISC MCU and is shared between the ring buffers used to hold voice/data for each active connection and the general-purpose memory required by the Bluetooth stack.

8.3 Kalimba DSP RAM

Additional on-chip RAM is provided to support the Kalimba DSP:

- 8K x 24-bit for data memory 1 (DM1)
- 8K x 24-bit for data memory 2 (DM2)
- 6K x 32-bit for program memory (PM)

Note:

The Kalimba DSP can also execute directly from internal ROM, using a 64-instruction on-chip cache.

8.4 Internal ROM

Internal ROM is provided for system firmware implementation.

9 Serial Interfaces

9.1 UART Interface

BC6150 QFN has a standard UART serial interface that provides a simple mechanism for communicating using RS232 protocol.

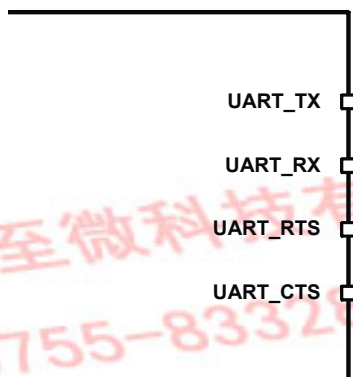


Figure 9.1: Universal Asynchronous Receiver

Figure 9.1 shows the 4 signals that implement the UART function. When BC6150 QFN is connected to another digital device, UART_RX and UART_TX transfer data between the 2 devices. The remaining 2 signals, UART_CTS and UART_RTS, can implement RS232 hardware flow control where both are active low indicators.

UART configuration parameters, such as baud rate and packet format, are set using BC6150 QFN firmware.

Note:

To communicate with the UART at its maximum data rate using a standard PC, an accelerated serial port adapter card is required for the PC.

Parameter		Possible Values
Baud rate	Minimum	1200 baud ($\leq 2\%$ Error)
		9600 baud ($\leq 1\%$ Error)
	Maximum	4Mbaud ($\leq 1\%$ Error)
Flow control		RTS/CTS or None
Parity		None, Odd or Even
Number of stop bits		1 or 2
Bits per byte		8

Table 9.1: Possible UART Settings

The UART interface can reset BC6150 QFN on reception of a break signal. A break is identified by a continuous logic low (0V) on the UART_RX terminal, as shown in Figure 9.2. If t_{BRK} is longer than the value, defined by PSKEY_HOSTIO_UART_RESET_TIMEOUT a reset occurs. This feature allows a host to initialise the system to a known state. Also, BC6150 QFN can emit a break character that may be used to wake the host.

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G-TW-0000250.3.2

Figure 9.2: Break Signal

Table 9.2 shows a list of commonly used baud rates and their associated values for PSKEY_UART_BAUDRATE. There is no requirement to use these standard values. Any baud rate within the supported range can be set in the PS Key according to the formula in Equation 9.1.

$$\text{Baud Rate} = \frac{\text{PSKEY_UART_BAUDRATE}}{0.004096}$$

Equation 9.1: Baud Rate

Baud Rate	Persistent Store Value		Error
	Hex	Dec	
1200	0x0005	5	1.73%
2400	0x000a	10	1.73%
4800	0x0014	20	1.73%
9600	0x0027	39	-0.82%
19200	0x004f	79	0.45%
38400	0x009d	157	-0.18%
57600	0x00ec	236	0.03%
76800	0x013b	315	0.14%
115200	0x01d8	472	0.03%
230400	0x03b0	944	0.03%
460800	0x075f	1887	-0.02%
921600	0x0ebf	3775	0.00%
1382400	0x161e	5662	-0.01%
1843200	0x1d7e	7550	0.00%
2764800	0x2c3d	11325	0.00%
3686400	0x3afb	15099	0.00%

Table 9.2: Standard Baud Rates

9.1.1 UART Configuration While Reset is Active

The UART interface is tristate while BC6150 QFN is being held in reset. This allows the user to daisy chain devices onto the physical UART bus. The constraint on this method is that any devices connected to this bus must tristate when BC6150 QFN reset is de-asserted and the firmware begins to run.

9.2 Programming and Debug Interface

BC6150 QFN uses a 16-bit data and 16-bit address programming and debug interface. Transactions can occur when the internal processor is running or is stopped.

Data may be written or read one word at a time, or the auto-increment feature is available for block access.

9.2.1 Instruction Cycle

The BC6150 QFN is the slave and receives commands on SPI_MOSI and outputs data on SPI_MISO. Table 9.3 shows the instruction cycle for a SPI transaction.

1	Reset the SPI interface	Hold SPI_CS# high for two SPI_CLK cycles
2	Write the command word	Take SPI_CS# low and clock in the 8-bit command
3	Write the address	Clock in the 16-bit address word
4	Write or read data words	Clock in or out 16-bit data word(s)
5	Termination	Take SPI_CS# high

Table 9.3: Instruction Cycle for a SPI Transaction

With the exception of reset, SPI_CS# must be held low during the transaction. Data on SPI_MOSI is clocked into the BC6150 QFN on the rising edge of the clock line SPI_CLK. When reading, BC6150 QFN replies to the master on SPI_MISO with the data changing on the falling edge of the SPI_CLK. The master provides the clock on SPI_CLK. The transaction is terminated by taking SPI_CS# high.

Sending a command word and the address of a register for every time it is to be read or written is a significant overhead, especially when large amounts of data are to be transferred. To overcome this BC6150 QFN offers increased data transfer efficiency via an auto increment operation. To invoke auto increment, SPI_CS# is kept low, which auto increments the address, while providing an extra 16 clock cycles for each extra word to be written or read.

9.2.2 Multi-slave Operation

BC6150 QFN should not be connected in a multi-slave arrangement by simple parallel connection of slave MISO lines. When BC6150 QFN is deselected (SPI_CS# = 1), the SPI_MISO line does not float. Instead, BC6150 QFN outputs 0 if the processor is running or 1 if it is stopped.

9.3 I²C Interface

PIO[8:6] is available to form a master I²C interface. The interface is formed using software to drive these lines.

Note:

The program memory for the BC6150 QFN is internal ROM so the I²C interface can only connect to a serial EEPROM, Figure 9.3 shows an example. The EEPROM stores PS Keys and configuration information.

EEPROM Supply in Figure 9.3 is 1.8V.

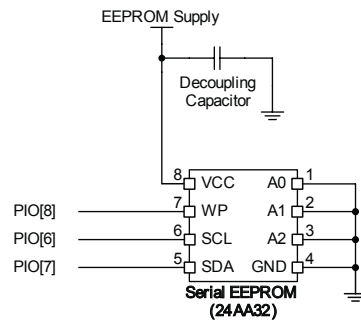


Figure 9.3: Example EEPROM Connection

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10 Audio Interface

The BC6150 QFN audio interface circuit consists of:

- Mono audio codec
- 2 audio inputs and single audio output

The codec supports all requirements of the BC6150 QFN mono headset solution and Figure 10.1 shows the functional blocks of the BC6150 QFN audio interface.

The ADC contains 2 independent channels and the DAC a single channel. The sample rate of the ADC or DAC are independent but controlled by the BC6150 QFN solution.

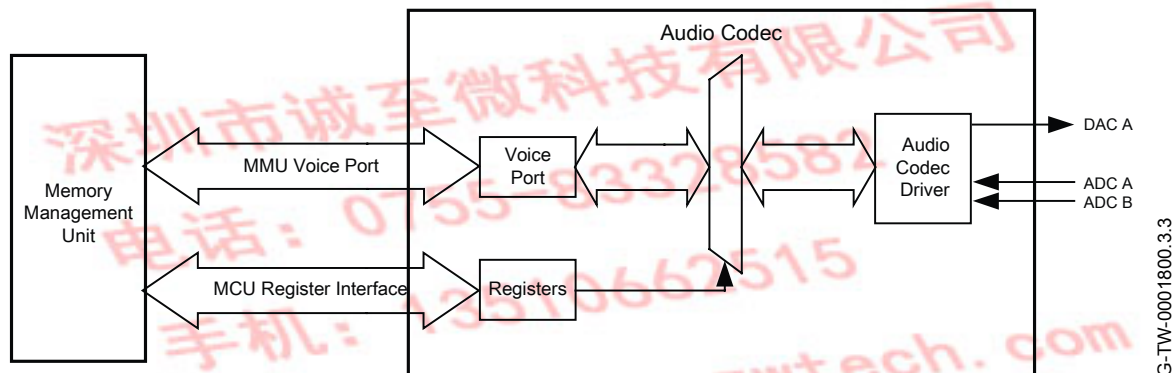


Figure 10.1: BC6150 QFN Audio Interface

10.1 Audio Input and Output

The audio input circuitry consists:

- 2 independent channels of microphone input
- Each microphone input is configurable to be either single-ended or fully differential
- Each input has an analogue and digital programmable gain stage for optimisation of different microphones

The audio output circuitry consists of a single differential class A-B output stage.

10.2 Mono Audio Codec Interface

The main features of the interface are:

- Dual mono analogue input for voice band and audio band
- Mono analogue output for voice band and audio band

10.2.1 Mono Audio Codec Block Diagram

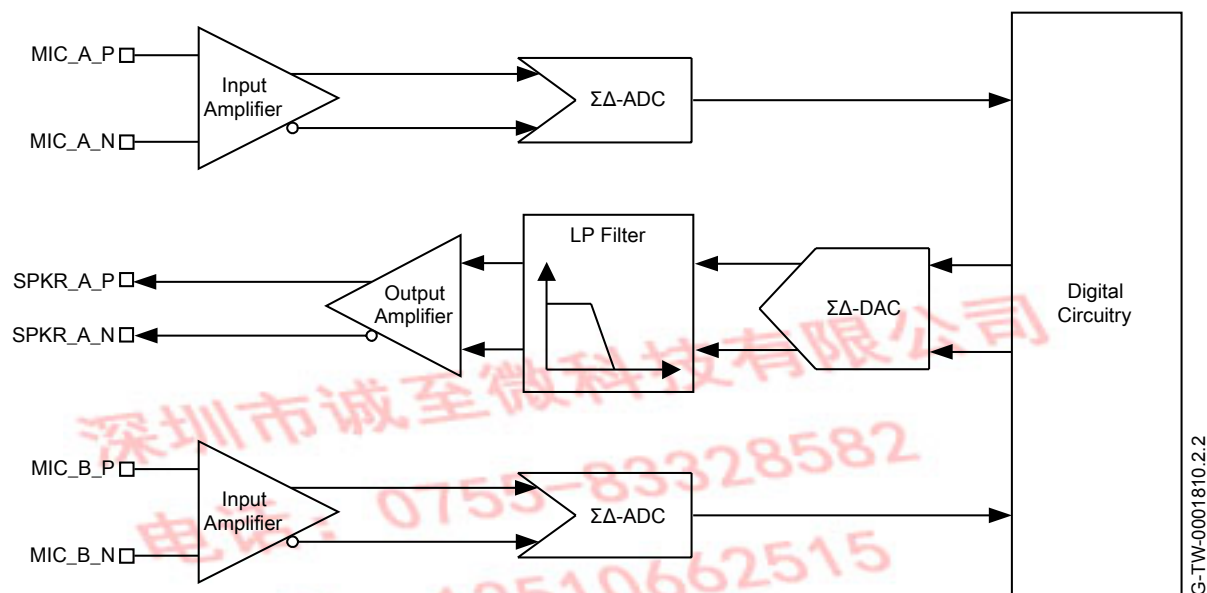


Figure 10.2: Mono Codec Audio Input and Output Stages

The mono audio codec uses a fully differential architecture in the analogue signal path, which results in low noise-sensitivity and good power supply rejection while effectively doubling the signal amplitude. It operates from a single power-supply of 1.5V and uses a minimum of external components.

10.2.2 ADC

The ADC consists of:

- 2 second-order Sigma-Delta converters allowing 2 separate channels that are identical in functionality, as Figure 10.2 shows.
- 2 gain stages for each channel, 1 of which is an analogue gain stage and the other is a digital gain stage.

10.2.3 ADC Digital Gain

The digital gain stage has a programmable selection value in the range of 0 to 15 with the associated ADC gain settings summarised in Table 10.1. There is also a high resolution digital gain mode that allows the gain to be changed in 1/32dB steps. Contact CSR for more information.

Gain Selection Value	ADC Digital Gain Setting (dB)	Gain Selection Value	ADC Digital Gain Setting (dB)
0	0	8	-24
1	3.5	9	-20.5
2	6	10	-18
3	9.5	11	-14.5
4	12	12	-12
5	15.5	13	-8.5
6	18	14	-6
7	21.5	15	-2.5

Table 10.1: ADC Digital Gain Rate Selection

10.2.4 ADC Analogue Gain

Figure 10.3 shows the equivalent block diagram for the ADC analogue amplifier. It is a two-stage amplifier:

- The first stage amplifier has a 24dB gain for the microphone.
- The second stage has a programmable gain with 7 individual 3dB steps. By combining the 24dB gain selection of the microphone input with the 7 individual 3dB gain steps, the overall range of the analogue amplifier is approximately -3dB to 42dB in 3dB steps. The BC6150 QFN controls all the gain control of the ADC.

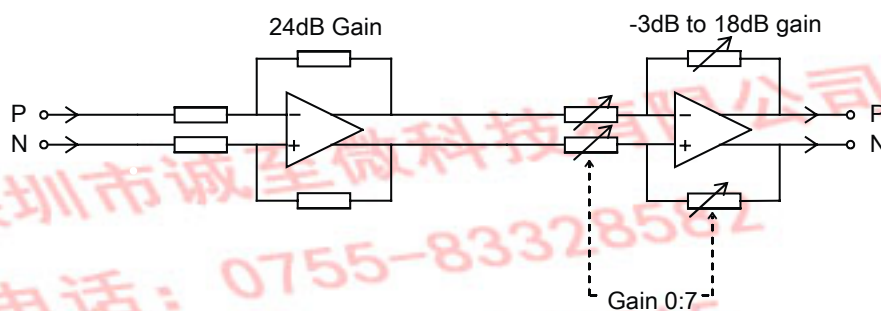


Figure 10.3: ADC Analogue Amplifier Block Diagram

10.2.5 DAC

The DAC consists of:

- 2 second-order Sigma-Delta converters allowing 2 separate channels that are identical in functionality, as Figure 10.2 shows.
- 2 gain stages for each channel, 1 of which is an analogue gain stage and the other is a digital gain stage.

10.2.6 DAC Digital Gain

The digital gain stage has a programmable selection value in the range of 0 to 15 with associated DAC gain settings, summarised in Table 10.2. There is also a high resolution digital gain mode that allows the gain to be changed in 1/32dB steps. Contact CSR for more information.

The overall gain control of the DAC is controlled by the BC6150 QFN. Its setting is a combined function of the digital and analogue amplifier settings.

Digital Gain Selection Value	DAC Digital Gain Setting (dB)	Digital Gain Selection Value	DAC Digital Gain Setting (dB)
0	0	8	-24
1	3.5	9	-20.5
2	6	10	-18
3	9.5	11	-14.5
4	12	12	-12
5	15.5	13	-8.5
6	18	14	-6
7	21.5	15	-2.5

Table 10.2: DAC Digital Gain Rate Selection

10.2.7 DAC Analogue Gain

As Table 10.3 shows the DAC analogue gain stage consists of 8 gain selection values that represent seven 3dB steps.

The BC6150 QFN controls the overall gain control of the DAC. Its setting is a combined function of the digital and analogue amplifier settings.

Analogue Gain Selection Value	DAC Analogue Gain Setting (dB)	Analogue Gain Selection Value	DAC Analogue Gain Setting (dB)
7	3	3	-9
6	0	2	-12
5	-3	1	-15
4	-6	0	-18

Table 10.3: DAC Analogue Gain Rate Selection

10.2.8 Microphone Input

Figure 10.4 shows recommended biasing for each microphone. The microphone bias, MIC_BIAS, derives its power from the BAT_P and requires a 1μF capacitor on its output.

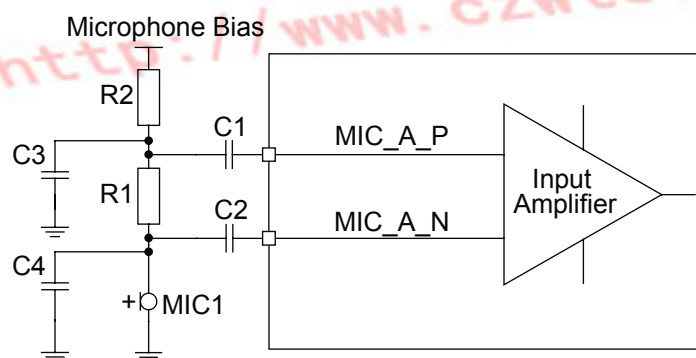


Figure 10.4: Microphone Biasing

Note:

Figure 10.4 shows a single channel only.

The MIC_BIAS is like any voltage regulator and requires a minimum load to maintain regulation. The MIC_BIAS maintains regulation within the limits 0.200mA to 1.230mA. If the microphone sits below these limits, then the microphone output must be pre-loaded with a large value resistor to ground.

The audio input is intended for use in the range from 1μA @ 94dB SPL to about 10μA @ 94dB SPL. With biasing resistors R1 and R2 equal to 1kΩ, this requires microphones with sensitivity between about -40dBV and -60dBV.

The input impedance at MIC_A_N, MIC_A_P, MIC_B_N and MIC_B_P is typically 6.0kΩ.

C1 and C2 should be 150nF if bass roll-off is required to limit wind noise on the microphone.

R1 sets the microphone load impedance and is normally in the range of 1kΩ to 2kΩ.

R2, C3 and C4 improve the supply rejection by decoupling supply noise from the microphone. Values should be selected as required. R2 may be connected to a convenient supply, in which case the bias network is permanently enabled, or to the MIC_BIAS output (which is ground referenced and provides good rejection of the supply), which may be configured to provide bias only when the microphone is required.

Table 10.4 shows the 4-bit programmable output voltage that the microphone bias provides, and Table 10.5 shows the 4-bit programmable output current.

The characteristics of the microphone bias include:

- Power supply:
 - BC6150 QFN microphone supply is BAT_P
 - Minimum input voltage = Output voltage + drop-out voltage
 - Maximum input voltage is 4.4V
 - Typically the microphone bias is between 2V and 2.5V, or as specified by the microphone vendor
- Drop-out voltage:
 - 300mV minimum
 - Guaranteed for configuration of voltage or current output shown in Table 10.4 and Table 10.5
- Output voltage:
 - 4-bit programmable between 1.7V to 3.6V
 - Tolerance 90 to 110%
- Output current:
 - 4-bit programmable from 200 μ A to 1.230mA
 - Maximum current guaranteed to be >1mA
- Load capacitance:
 - Unconditionally stable for 1 μ F \pm 20% and 2.2 μ F \pm 20% pure C

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Output Step	VOL_SET[3:0]	Min	Typ	Max	Units
0	0000	-	1.71	-	V
1	0001	-	1.76	-	V
2	0010	-	1.82	-	V
3	0011	-	1.87	-	V
4	0100	-	1.95	-	V
5	0101	-	2.02	-	V
6	0110	-	2.10	-	V
7	0111	-	2.18	-	V
8	1000	-	2.32	-	V
9	1001	-	2.43	-	V
10	1010	-	2.56	-	V
11	1011	-	2.69	-	V
12	1100	-	2.90	-	V
13	1101	-	3.08	-	V
14	1110	-	3.33	-	V
15	1111	-	3.57	-	V

Table 10.4: Voltage Output Steps

Output Step	CUR_SET[3:0]	Typ	Units
0	0000	0.200	mA
1	0001	0.280	mA
2	0010	0.340	mA
3	0011	0.420	mA
4	0100	0.480	mA
5	0101	0.530	mA
6	0110	0.610	mA
7	0111	0.670	mA
8	1000	0.750	mA
9	1001	0.810	mA
10	1010	0.860	mA
11	1011	0.950	mA
12	1100	1.000	mA
13	1101	1.090	mA
14	1110	1.140	mA
15	1111	1.230	mA

Table 10.5: Current Output Steps

Note:

For BAT_P, the PSRR at 100Hz to 22kHz, with >300mV supply headroom, decoupling capacitor of 1.1μF, is typically 58.9dB and worst case 53.4dB.

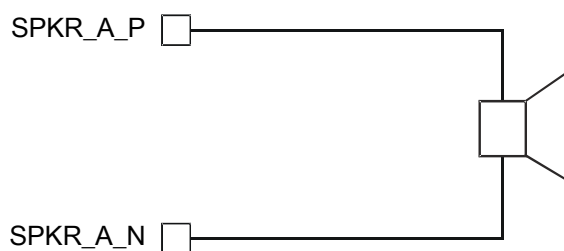
For VDD_AUDIO, the PSRR at 100Hz to 22kHz, decoupling capacitor of 1.1μF, is typically 88dB and worst case 60dB.

10.2.9 Output Stage

The output stage digital circuitry converts the signal from 16-bit per sample, linear PCM of variable sampling frequency to bit stream, which is fed into the analogue output circuitry.

The output stage circuit comprises a DAC with gain setting and class AB output stage amplifier. The output is available as a differential signal between SPKR_A_N and SPKR_A_P, as Figure 10.5 shows.

The output stage is capable of driving a speaker directly when its impedance is at least 8Ω and an external regulator is used, but this will be at a reduced output swing.



G-TW-0001451.3.2

Figure 10.5: Speaker Output

A 3-bit programmable resistive divider controls the analogue gain of the output stage, which sets the gain in steps of approximately 3dB.

10.2.10 Side Tone

In some applications it is necessary to implement side tone. This involves feeding an attenuated version of the microphone signal to the earpiece. The BC6150 QFN codec contains side tone circuitry to do this. The side tone hardware is configured through the following PS Keys:

- PSKEY_SIDE_TONE_ENABLE
- PSKEY_SIDE_TONE_GAIN
- PSKEY_SIDE_TONE_AFTER_ADC
- PSKEY_SIDE_TONE_AFTER_DAC

10.2.11 Integrated Digital Filter

BC6150 QFN has a programmable digital filter integrated into the ADC channel of the codec. The filter is a 2 stage, second order IIR and is used for functions such as custom wind noise rejection. The filter also has optional DC blocking.

The filter has 10 configuration words used as follows:

- 1 for gain value
- 8 for coefficient values
- 1 for enabling and disabling the DC blocking

The gain and coefficients are all 12-bit 2's complement signed integer with the format `XX.XXXXXXXXXX`

Note:

The position of the binary point is between bit[10] and bit[9], where bit[11] is the most significant bit.

For example:

`01.1111111111` = most positive number, close to 2

`01.0000000000` = 1

`00.0000000000` = 0

`11.0000000000` = -1

`10.0000000000` = -2, most negative number

Equation 10.1 shows the equation for the IIR filter. Equation 10.2 shows the equation for when the DC blocking is enabled.

The filter can be configured, enabled and disabled from the VM via the `CodecSetIIRFilterA` and `CodecSetIIRFilterB` traps. This requires firmware support. The configuration function takes 10 variables in the order shown below:

0 : Gain

1 : b_{01}

2 : b_{02}

3 : a_{01}

4 : a_{02}

5 : b_{11}

6 : b_{12}

7 : a_{11}

8 : a_{12}

9 : DC Block (1 = enable, 0 = disable)

$$\text{Filter, } H(z) = \text{Gain} \times \frac{(1 + b_{01} z^{-1} + b_{02} z^{-2})}{(1 + a_{01} z^{-1} + a_{02} z^{-2})} \times \frac{(1 + b_{11} z^{-1} + b_{12} z^{-2})}{(1 + a_{11} z^{-1} + a_{12} z^{-2})}$$

Equation 10.1: IIR Filter Transfer Function, $H(z)$

$$\text{Filter with DC Blocking, } H_{\text{DC}}(z) = H(z) \times (1 - z^{-1})$$

Equation 10.2: IIR Filter plus DC Blocking Transfer Function, $H_{\text{DC}}(z)$

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11 Power Control and Regulation

BC6150 QFN contains 3 regulators:

- 1 switch-mode regulator used to generate a 1.8V rail for the chip I/Os
- 2 low-voltage regulators which run in parallel to supply the 1.5V core supplies from the 1.8V rail.

Various configurations for power control and regulation with the BC6150 QFN are available:

- Powered from the switch-mode regulator and the low-voltage regulators in series, as Figure 11.1 shows.
- Powered directly from an external 1.8V rail, bypassing the switch-mode regulator.
- Powered from an external 1.5V rail omitting all regulators.

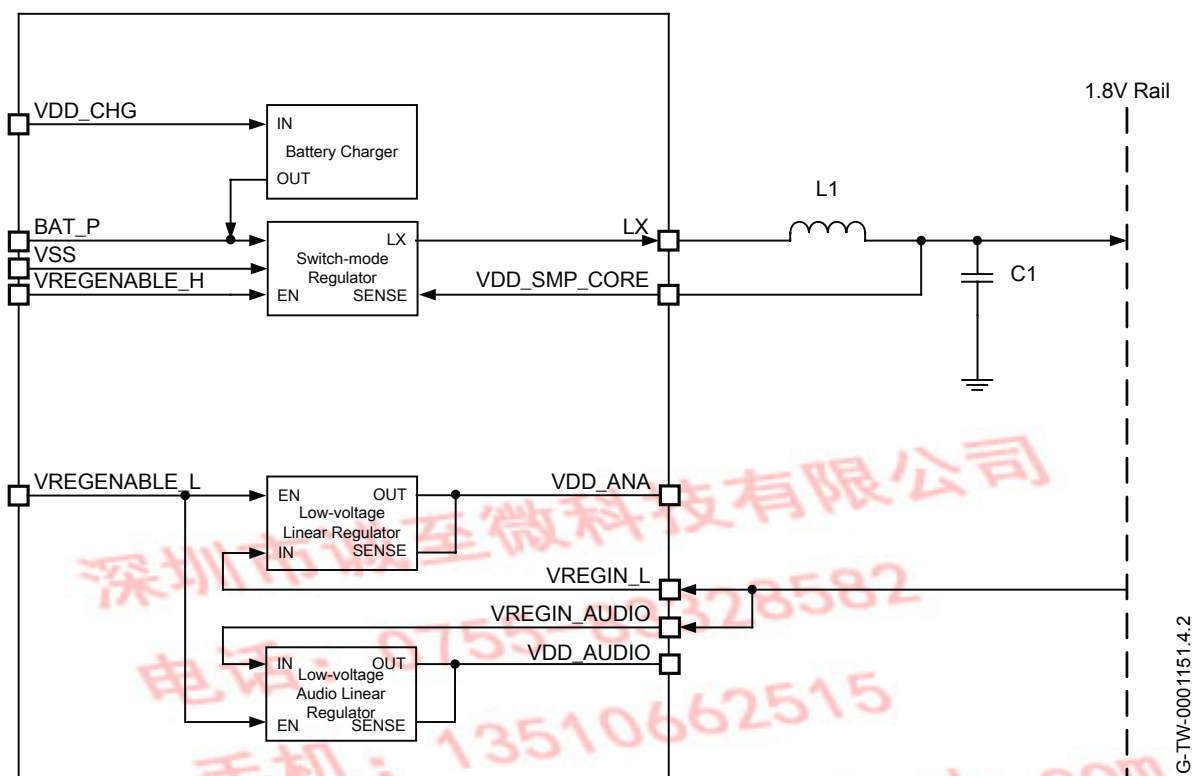


Figure 11.1: Voltage Regulator Configuration

11.1 Power Sequencing

The 1.50V supply rails are VDD_ANA, VDD_LO, VDD_RADIO, VDD_AUDIO and VDD_CORE. CSR recommends that these supply rails are all powered at the same time.

The digital I/O supply rails are VDD_PIO, VDD_PADS and VDD_UART.

The sequence of powering the 1.50V supply rails relative to the digital I/O supply rails is not important. If the digital I/O supply rails are powered before the 1.50V supply rails, all digital I/Os will have a weak pull-down irrespective of the reset state.

VDD_ANA, VDD_LO, VDD_RADIO and VDD_AUDIO can connect directly to a 1.50V supply.

A simple RC filter is recommended for VDD_CORE to reduce transients fed back onto the power supply rails.

The digital I/O supply rails are connected either together or independently to an appropriate voltage rail. Decoupling of the digital I/O supply rails is recommended.

11.2 External Voltage Source

If any of the supply rails for BC6150 QFN are supplied from an external voltage source, rather than one of the internal voltage regulators, CSR recommends that VDD_LO, VDD_RADIO and VDD_AUDIO should have less than 10mV rms noise levels between 0 and 10MHz. Also avoid single tone frequencies.

The transient response of any external regulator used should match or be better than the internal regulator available on BC6150 QFN. For more information, refer to regulator characteristics in Section 13. It is essential that the power rail recovers quickly at the start of a packet, where the power consumption jumps to high levels.

11.3 Switch-mode Regulator

CSR recommends the on-chip switch-mode regulator to power the 1.8V supply rail.

An external LC filter circuit of a low-resistance series inductor, L1 (22 μ H), followed by a low ESR shunt capacitor, C1 (4.7 μ F), is required between the LX terminal and the 1.8V supply rail. A connection between the 1.8V supply rail and the VDD_SMP_CORE pin is required.

A 2.2 μ F decoupling capacitor is required between BAT_P and VSS.

To maintain high-efficiency power conversion and low supply ripple, it is essential that the series resistance of tracks between the BAT_P and VSS terminals, the filter and decoupling components, and the external voltage source are minimised.

The switch-mode regulator is enabled by either:

- VREGENABLE_H pin
- BC6150 QFN device firmware
- BC6150 QFN battery charger

The switch-mode regulator switches into a low-power pulse skipping mode when the device is sent into deep sleep mode, or in reset.

When the switch-mode regulator is not required the terminals BAT_P and LX must be grounded or left unconnected.

11.4 Low-voltage Linear Regulator

The low-voltage linear regulator is available to power a 1.5V supply rail. Its output is connected internally to VDD_ANA, and can be connected externally to the other 1.5V power inputs.

If the low-voltage linear regulator is used, connect a smoothing circuit using a low ESR 2.2 μ F capacitor and a 2.2 Ω resistor to ground to the output of the low-voltage linear regulator, VDD_ANA. Alternatively use a 2.2 μ F capacitor with an ESR of at least 2 Ω .

The low-voltage linear regulator is enabled by either:

- VREGENABLE_L pin
- BC6150 QFN device firmware
- BC6150 QFN battery charger

The low-voltage linear regulator switches into a low power mode when the device is in deep sleep mode, or in reset.

When the low-voltage linear regulator is not used, either leave the terminal VREGIN_L unconnected, or tie it to VDD_ANA.

11.5 Low-voltage Audio Linear Regulator

The low-voltage audio linear regulator is available to power a 1.5V audio supply rail. Its output is connected internally to VDD_AUDIO, and can be connected externally to the other 1.5V audio power inputs.

If the low-voltage audio linear regulator is used, connect a smoothing circuit using a low ESR 2.2 μ F capacitor and a 2.2 Ω resistor to ground to the output of the low-voltage audio linear regulator, VDD_AUDIO. Alternatively use a 2.2 μ F capacitor with an ESR of at least 2 Ω .

The low-voltage audio linear regulator is enabled by either:

- VREGENABLE_L pin
- BC6150 QFN device firmware

The low-voltage audio linear regulator switches into a low-power mode when no audio cells are enabled, or when the chip is in reset.

When this regulator is not used, either leave the terminal VREGIN_AUDIO unconnected or tie it to VDD_AUDIO.

11.6 Voltage Regulator Enable Pins

The voltage regulator enable pins, VREGENABLE_H and VREGENABLE_L, are used to enable the BC6150 QFN device if the on-chip regulators are being used. Table 11.1 shows the enable pin responsible for each voltage regulator.

Enable Pin	Regulator
VREGENABLE_H	Switch-mode Regulator
VREGENABLE_L	Low-voltage Linear Regulator and Low-voltage Audio Linear Regulator

Table 11.1: BC6150 QFN Voltage Regulator Enable Pins

The voltage regulator enable pins are active high, with weak pull-downs.

BC6150 QFN boots-up when the voltage regulator enable pins are pulled high, enabling the appropriate regulators. The firmware then latches the regulators on and the voltage regulator enable pins may then be released.

The status of the VREGENABLE_H pin is available to firmware through an internal connection. VREGENABLE_H also works as an input line.

11.7 Battery Charger

The battery charger is a constant current / constant voltage charger circuit, and is suitable for lithium ion/polymer batteries only. It shares a connection to the battery terminal, BAT_P, with the switch-mode regulator. However it may be used in conjunction with either of the high-voltage regulators on the device.

The constant current level can be varied to allow charging of different capacity batteries.

The charger enters various states of operation as it charges a battery, as listed below. A full operational description is in *BlueCore5 Charger Description and Calibration Procedure Application Note*.

- Off : entered when charger disconnected.
- Trickle charge: entered when battery is below 2.9V. The battery is charged at a nominal 4.5mA. This mode is for the safe charge of deeply discharged cells.
- Fast charge constant current: entered when battery is above 2.9V. The charger enters the main fast charge mode. This mode charges the battery at the selected constant current, I_{chgset} .
- Fast charge constant voltage: entered when battery has reached a selected voltage, V_{float} . The charger switches mode to maintain the cell voltage at the V_{float} voltage by adjusting the charge current.
- Standby: this is the state when the battery is fully charged and no charging takes place. The battery voltage is continuously monitored and if it drops by more than 150mV below the V_{float} voltage the charger will re-enter the fast charge constant current mode to keep the battery fully charged.

When a voltage is applied to the charger input terminal VDD_CHG, and the battery is not fully charged, the charger operates and an LED connected to the terminal LED[0] illuminates. By default, until the firmware is running, the LED pulses at a low-duty cycle to minimise current consumption.

The battery charger circuitry auto-detects the presence of a power source, allowing the firmware to detect, using an internal status bit, when the charger is powered. Therefore when the charger supply is not connected to VDD_CHG, the terminal must be left open-circuit. The VDD_CHG pin when not connected must be allowed to float and not pulled to a power rail. When the battery charger is not enabled this pin may float to a low undefined voltage. Any DC connection increases current consumption of the device. Capacitive components may be connected such as diodes, FETs and ESD protection.

The battery charger is designed to operate with a permanently connected battery. If the application enables the charger input to be connected while the battery is disconnected, then the BAT_P pin voltage may become unstable. This in turn may cause damage to the internal switch-mode regulator. Connecting a 470µF capacitor to BAT_P limits these oscillations so preventing damage.

11.8 LED Drivers

BC6150 QFN includes 2 pads dedicated to driving LED indicators. Both terminals can be controlled by firmware, while LED[0] can also be set by the battery charger.

The terminals are open-drain outputs, so the LED must be connected from a positive supply rail to the pad in series with a current limiting resistor.

CSR recommends that the LED pad, LED[0] or LED[1] pins, operate with a pad voltage below 0.5V. In this case, the pad is like a resistor, R_{ON} . The resistance together with the external series resistor sets the current, I_{LED} , in the LED. The current is also dependent on the external voltage, VDD, as Figure 11.2 shows.

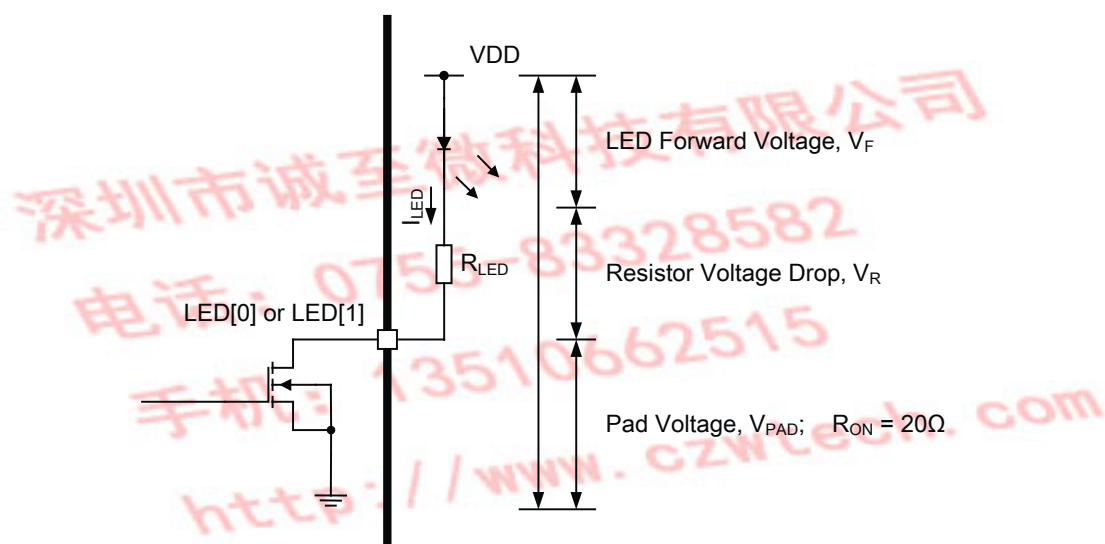


Figure 11.2: LED Equivalent Circuit

From Figure 11.2 it is possible to derive Equation 11.1 to calculate I_{LED} . If a known value of current is required through the LED to give a specific luminous intensity, then the value of R_{LED} can be calculated.

$$I_{LED} = \frac{VDD - V_F}{R_{LED} + R_{ON}}$$

Equation 11.1: LED Current

For the LED[0] or LED[1] pad to act as resistance, the external series resistor, R_{LED} , needs to be such that the voltage drop across it, V_R , keeps V_{PAD} below 0.5V. Equation 11.2 also applies.

$$VDD = V_F + V_R + V_{PAD}$$

Equation 11.2: LED PAD Voltage

Note:

The LED current adds to the overall current, so conservative selection of the LEDs will extend battery life.

11.9 Reset, RST#

BC6150 QFN can be reset from several sources:

- RST# pin
- Power-on reset
- UART break character
- Software configured watchdog timer

The RST# pin is an active low reset and is internally filtered using the internal low frequency clock oscillator. A reset is performed between 1.5 and 4.0ms following RST# being active. CSR recommends that RST# be applied for a period greater than 5ms.

The power-on reset typically occurs when the VDD_CORE supply falls below 1.25V and is released when VDD_CORE rises above typically 1.30V. At reset the digital I/O pins are set to inputs for bidirectional pins and outputs are tristate. Following a reset, BC6150 QFN assumes the maximum XTAL_IN frequency, which ensures that the internal clocks run at a safe (low) frequency until BC6150 QFN is configured for the actual XTAL_IN frequency. If no clock is present at XTAL_IN, the oscillator in BC6150 QFN free runs, again at a safe frequency.

11.9.1 Digital Pin States on Reset

Table 11.2 shows the pin states of BC6150 QFN on reset.

Pin Name / Group	I/O Type	No Core Voltage Reset	Full Chip Reset
UART_RX	Digital input with PD	PD	PD
UART_CTS	Digital input with PD	PD	PD
UART_TX	Digital bidirectional with PU	PU	PU
UART_RTS	Digital bidirectional with PU	PU	PU
SPI_MOSI	Digital input with PD	PD	PD
SPI_CLK	Digital input with PD	PD	PD
SPI_CS#	Digital input with PU	PU	PU
SPI_MISO	Digital tristate output with PD	PD	PD
RST#	Digital input with PU	PU	PU
TEST_EN	Digital input with PD	PD	PD
PIO[14:11,9:0]	Digital bidirectional with PU/ PD	PD	PD

Table 11.2: BC6150 QFN Digital Pin States on Reset

Note:

PU = pull-up

PD = pull-down

Pull-up and pull-down default to weak values unless specified otherwise

11.9.2 Status after Reset

The status of BC6150 QFN after a reset is:

- Warm reset: data rate and RAM data remain available
- Cold reset: data rate and RAM data not available

BC6150 QFN Data Sheet



Figure 12.1: Example Application Schematic

13 Electrical Characteristics

13.1 ESD Precautions

BC6150 QFN is classified as a JESD22-A114 class 2, JESD22-A115 class A product. Apply ESD static handling precautions during manufacturing.

13.2 Absolute Maximum Ratings

Rating		Min	Max	Unit
Storage temperature		-40	105	°C
Core supply voltage	VDD_ANA, VDD_LO, VDD_RADIO, VDD_AUDIO and VDD_CORE	-0.4	1.65	V
I/O voltage	VDD_PIO, VDD_PADS and VDD_UART	-0.4	3.6	V
Supply voltage	VREGIN_L	-0.4	2.7	V
	VREGIN_AUDIO	-0.4	2.7	V
	VREGENABLE_H and VREGENABLE_L	-0.4	4.9	V
	BAT_P	-0.4	4.4	V
	LED[1:0]	-0.4	4.4	V
	VDD_CHG	-0.4	6.5	V
Other terminal voltages		VSS - 0.4	VDD + 0.4	V

13.3 Recommended Operating Conditions

Operating Condition		Min	Typ	Max	Unit
Operating temperature range		-20	20	70	°C
Core supply voltage	VDD_ANA, VDD_LO, VDD_RADIO, VDD_AUDIO and VDD_CORE	1.42	1.50	1.57	V
I/O supply voltage	VDD_PIO, VDD_PADS and VDD_UART	1.7	3.3	3.6	V

Note:

For radio performance over temperature refer to *BC6150 QFN Performance Specification*.

BC6150 QFN operates up to the maximum supply voltage given in the Absolute Maximum Ratings, but RF performance is not guaranteed above 4.2V.

13.4 Input/Output Terminal Characteristics

Note:

For all I/O terminal characteristics:

- VDD_ANA, VDD_LO, VDD_RADIO, VDD_AUDIO and VDD_CORE at 1.50V unless shown otherwise.
- VDD_PIO, VDD_PADS and VDD_UART at 3.3V unless shown otherwise.
- Current drawn into a pin is defined as positive; current supplied out of a pin is defined as negative.

13.4.1 Low-voltage Linear Regulator

Normal Operation	Min	Typ	Max	Unit
Input voltage	1.70	1.80	1.95	V
Output voltage ($I_{load} = 70mA$ / $VREGIN_L = 1.7V$)	1.42	1.50	1.57	V
Temperature coefficient	-300	0	300	ppm/°C
Output noise ^{(a) (b)}	-	-	1	mV rms
Load regulation ($100\mu A < I_{load} < 90mA$), ΔV_{out}	-	-	5	mV
Load regulation ($100\mu A < I_{load} < 115mA$), ΔV_{out}	-	-	25	mV
Settling time ^{(a) (c)}	-	-	50	μs
Output current	-	-	115	mA
Minimum load current	5	-	100	μA
Quiescent current (excluding load, $I_{load} < 1mA$)	50	90	150	μA
Low-power Mode ^(d)				
Quiescent current (excluding load, $I_{load} < 100\mu A$)	5	8	15	μA

^(a) Regulator output connected to 47nF pure and 4.7 μ F 2.2 Ω ESR capacitors

^(b) Frequency range 100Hz to 100kHz

^(c) 1mA to 115mA pulsed load

^(d) The regulator is in low power mode when the chip is in deep sleep mode, or in reset

13.4.2 Low-voltage Linear Audio Regulator

Normal Operation	Min	Typ	Max	Unit
Input voltage	1.70	1.80	1.95	V
Output voltage ($I_{load} = 70\text{mA}$ / $V_{REGIN_AUDIO} = 1.7\text{V}$)	1.42	1.50	1.57	V
Temperature coefficient	-300	0	300	ppm/°C
Output noise ^{(a) (b)}	-	-	1	mV rms
Load regulation ($100\mu\text{A} < I_{load} < 70\text{mA}$), ΔV_{out}	-	-	5	mV
Settling time ^{(a) (c)}	-	-	50	μs
Output current	-	-	70	mA
Minimum load current	5	-	100	μA
Quiescent current (excluding load, $I_{load} < 1\text{mA}$)	25	30	50	μA
Low-power Mode ^(d)				
Quiescent current (excluding load, $I_{load} < 100\mu\text{A}$)	5	8	15	μA

^(a) Regulator output connected to 47nF pure and 4.7 μF 2.2 Ω ESR capacitors

^(b) Frequency range 100Hz to 100kHz

^(c) 1mA to 70mA pulsed load

^(d) The regulator is in low power mode when the chip is in deep sleep mode, or in reset

13.4.3 Switch-mode Regulator

Switch-mode Regulator	Min	Typ	Max	Unit
Input voltage	2.5	-	4.4	V
Output voltage ($I_{load} = 70mA$)	1.70	1.80	1.90	V
Temperature coefficient	-250	-	250	ppm/°C
Normal Operation				
Output ripple	-	-	10	mV rms
Transient settling time ^(a)	-	-	50	μs
Maximum load current	200	-	-	mA
Conversion efficiency ($I_{load} = 70mA$)	-	90	-	%
Switching frequency ^(b)	-	1.333	-	MHz
Start-up current limit ^(c)	30	50	80	mA
Low-power Mode ^(d)				
Output ripple	-	-	1	mV rms
Transient settling time ^(e)	-	-	700	μs
Maximum load current	5	-	-	mA
Minimum load current	1	-	-	μA
Conversion efficiency ($I_{load} = 1mA$)	-	80	-	%
Switching frequency ^(f)	50	-	150	kHz

^(a) For step changes in load of 30 to 80mA and 80 to 30mA

^(b) Locked to crystal frequency

^(c) Current is limited on start-up to prevent excessive stored energy in the filter inductor

^(d) The regulator is in low power mode when the chip is in deep sleep mode, or in reset

^(e) 100μA to 1mA pulsed load

^(f) Defines minimum period between pulses. Pulses are skipped at low current loads

Note:

The external inductor used with the switch-mode regulator must have an ESR in the range 0.3Ω to 0.7Ω:

- Low ESR < 0.3Ω causes instability.
- High ESR > 0.7Ω derates the maximum current.

13.4.4 Battery Charger

Battery Charger	Min	Typ	Max	Unit
Input voltage	4.5	-	6.5	V

Charging Mode (BAT_P rising to 4.2V)		Min	Typ	Max	Unit
Supply current ^(a)		-	4.5	6	mA
Battery trickle charge current ^(b)		-	4	-	mA
Maximum battery fast charge current (I-CTRL = 15) ^{(c) (d)}	Headroom ^(e) > 0.7V	-	140	-	mA
	Headroom = 0.3V	-	120	-	mA
Minimum battery fast charge current (I-CTRL = 0) ^{(c) (d)}	Headroom > 0.7V	-	40	-	mA
	Headroom = 0.3V	-	35	-	mA
Fast charge step size (I-CTRL = 0 to 15)	Spread $\pm 17\%$	-	6.3	-	mA
Trickle charge voltage threshold		-	2.9	-	V
Float voltage (with correct trim value set), V _{FLOAT} ^(f)		4.17	4.2	4.23	V
Float voltage trim step size ^(f)		-	50	-	mV
Battery charge termination current, % of fast charge current		5	10	20	%

^(a) Current into VDD_CHG does not include current delivered to battery ($I_{VDD_CHG} - I_{BAT_P}$)

^(b) BAT_P < trickle charge voltage threshold

^(c) Charge current can be set in 16 equally spaced steps

^(d) Trickle charge threshold < BAT_P < Float voltage

^(e) Where headroom = VDD_CHG - BAT_P

^(f) Float voltage can be adjusted in 15 steps. Trim setting is determined in production test and must be loaded into the battery charger by firmware during boot-up sequence

Standby Mode (BAT_P falling from 4.2V)	Min	Typ	Max	Unit
Supply current ^(a)	-	1.5	2	mA
Battery current	-	-5	-	μ A
Battery recharge hysteresis ^(b)	100	-	200	mV

^(a) Current into VDD_CHG; does not include current delivered to battery ($I_{VDD_CHG} - I_{BAT_P}$)

^(b) Hysteresis of (V_{FLOAT} - BAT_P) for charging to restart

Shutdown Mode (VDD_CHG too low or disabled by firmware)		Min	Typ	Max	Unit
Supply current		-	1.5	2	mA
Battery current		-1	-	0	μA
VDD_CHG under-voltage threshold	VDD_CHG rising	-	3.90	-	V
	VDD_CHG falling	-	3.70	-	V
VDD_CHG - BAT_P lockout threshold	VDD_CHG rising	-	0.22	-	V
	VDD_CHG falling	-	0.17	-	V

13.4.5 Reset

Power-on Reset	Min	Typ	Max	Unit
VDD_CORE falling threshold	1.13	1.25	1.30	V
VDD_CORE rising threshold	1.20	1.30	1.35	V
Hysteresis	0.05	0.10	0.15	V

13.4.6 Regulator Enable

Switching Threshold	Min	Typ	Max	Unit
VREGENABLE_H				
Rising threshold	0.50	-	0.95	V
Falling threshold	0.35	-	0.80	V
Hysteresis	0.14	-	0.28	V
VREGENABLE_L				
Rising threshold	0.50	-	0.95	V
Falling threshold	0.35	-	0.80	V
Hysteresis	0.14	-	0.28	V

13.4.7 Digital Terminals

Supply Voltage Levels		Min	Typ	Max	Unit
VDD _{PRE}	Pre-driver supply voltage	1.4	1.5	1.6	V
VDD I/O supply voltage (post-driver)	Full spec.	3.0	3.3	3.6	V
	Reduced spec.	1.7	-	3.0	V

Input Voltage Levels		Min	Typ	Max	Unit
V _{IL} input logic level low		-0.3	-	0.25 x VDD	V
V _{IH} input logic level high		0.625 x VDD	-	VDD + 0.3	V
V _{SCHMITT} Schmitt voltage		0.25 x VDD	-	0.625 x VDD	V

Output Voltage Levels		Min	Typ	Max	Unit
V _{OL} output logic level low, I _{OL} = 4.0mA		0	-	0.125	V
V _{OH} output logic level high, I _{OH} = -4.0mA		0.75 x VDD	-	VDD	V

Input and Tristate Currents		Min	Typ	Max	Unit
I _i input leakage current at V _{in} = VDD or 0V		-100	0	100	nA
I _{oz} tristate output leakage current at V _o = VDD or 0V		-100	0	100	nA
With strong pull-up		-100	-40	-10	μA
With strong pull-down		10	40	100	μA
With weak pull-up		-5	-1.0	-0.2	μA
With weak pull-down		-0.2	1.0	5.0	μA
C _i input capacitance		1.0	-	5.0	pF

Resistive Strength		Min	Typ	Max	Unit
R _{puw} weak pull-up strength at VDD - 0.2V		0.5	-	2	MΩ
R _{pdw} weak pull-down strength at 0.2V		0.5	-	2	MΩ
R _{pus} strong pull-up strength at VDD - 0.2V		10	-	50	kΩ
R _{pds} strong pull-down strength at 0.2V		10	-	50	kΩ

13.4.8 Mono Codec: Analogue to Digital Converter

Analogue to Digital Converter						
Parameter	Conditions		Min	Typ	Max	Unit
Resolution	-		-	-	16	Bits
Input sample rate, F _{sample}	-		8	-	32	kHz
Signal to Noise Ratio, SNR ^(a)	f _{in} = 1kHz B/W = 20Hz→20kHz A-Weighted THD+N < 1% 150mV _{pk-pk} input	F _{sample}				
		8kHz	-	79	-	dB
		11.025kHz	-	77	-	dB
		16kHz	-	76	-	dB
		22.050kHz	-	76	-	dB
		32kHz	-	75	-	dB
Digital gain	Digital gain resolution = 1/32dB		-24	-	21.5	dB
Analogue gain	Analogue gain resolution = 3dB		-3	-	42	dB
Input full scale at maximum gain (differential)			-	4	-	mV rms
Input full scale at minimum gain (differential)			-	800	-	mV rms
3dB bandwidth			-	20	-	kHz
Microphone mode input impedance			-	6.0	-	kΩ
THD+N (microphone input) @ 30mV rms input			-	0.04	-	%

^(a) Improved SNR performance can be achieved at the expense of current consumption. See Optimising BlueCore5-Multimedia ADC Performance Application Note for details.

13.4.9 Mono Codec: Digital to Analogue Converter

Digital to Analogue Converter						
Parameter	Conditions		Min	Typ	Max	Unit
Resolution	-		-	-	16	Bits
Output Sample Rate, F_{sample}	-		8	-	32	kHz
Signal to Noise Ratio, SNR	$f_{\text{in}} = 1\text{kHz}$ B/W = 20Hz→20kHz A-Weighted THD+N < 0.01% 0dBFS signal Load = 100kΩ	F_{sample}				
		8kHz	-	95	-	dB
		11.025kHz	-	95	-	dB
		16kHz	-	95	-	dB
		22.050kHz	-	95	-	dB
		32kHz	-	95	-	dB
Digital Gain	Digital Gain Resolution = 1/32dB		-24	-	21.5	dB
Analogue Gain	Analogue Gain Resolution = 3dB		0	-	-21	dB
Output voltage full-scale swing (differential)			-	750	-	mV rms
Allowed Load	Resistive		16(8)	-	OC	Ω
	Capacitive		-	-	500	pF
THD+N 100kΩ load			-	-	0.01	%
THD+N 16Ω load			-	-	0.1	%
SNR (Load = 16Ω, 0dBFS input relative to digital silence)			-	95	-	dB

13.4.10 Clocks

Clock Source	Min	Typ	Max	Unit
Crystal Oscillator				
Crystal frequency ^(a)	16	26	26	MHz
Digital trim range ^(b)	5.0	6.2	8.0	pF
Trim step size ^(b)	-	0.1	-	pF
Transconductance	2.0	-	-	mS
Negative resistance ^(c)	870	1500	2400	Ω
External Clock				
Input frequency ^(d)	12	26	52	MHz
Clock input level ^(e)	0.4	-	VDD_ANA	V pk-pk
Edge jitter (allowable jitter), at zero crossing	-	-	15	ps rms
XTAL_IN input impedance	-	≥ 10	-	k Ω
XTAL_IN input capacitance	-	≤ 4	-	pF

^(a) Integer multiple of 250kHz

^(b) Difference between the internal capacitance at minimum and maximum settings of the internal digital trim

^(c) XTAL frequency = 16MHz; XTAL C_0 = 0.75pF; XTAL load capacitance = 8.5pF.

^(d) Clock input can be any frequency between 12MHz to 52MHz in steps of 250kHz plus CDMA/3G TCXO frequencies of 14.40, 15.36, 16.2, 16.8, 19.2, 19.44, 19.68, 19.8 and 38.4MHz.

^(e) Clock input can be either sinusoidal or square wave. If the peaks of the signal are below VSS or above VDD_ANA. A DC blocking capacitor is required between the signal and XTAL_IN.

13.4.11 LED Driver Pads

LED Driver Pads		Min	Typ	Max	Unit
Off current		-	1	2	μ A
On resistance	$V_{PAD} < 0.5V$	-	20	33	Ω
On resistance, pad enabled by battery charger	$V_{PAD} < 0.5V$	-	20	50	Ω

13.4.12 Auxiliary ADC

Auxiliary ADC		Min	Typ	Max	Unit
Resolution		-	-	10	Bits
Input voltage range ^(a)		0	-	VDD_ANA	V
Accuracy (Guaranteed monotonic)	INL	-1	-	1	LSB
	DNL	0	-	1	LSB
Offset		-1	-	1	LSB
Gain error		-0.8	-	0.8	%
Input bandwidth		-	100	-	kHz
Conversion time		-	2.5	-	μs
Sample rate ^(b)		-	-	700	Samples/s

^(a) LSB size = VDD_ANA/1023

^(b) The auxiliary ADC is accessed through a VM function. The sample rate given is achieved as part of this function.

14 Power Consumption

DUT Role	Connection		Packet Type	Packet Size	Average Current	Unit
Slave	SCO		HV3	30	10.86	mA
Slave	eSCO		EV3	30	12.51	mA
Slave	eSCO		2EV3	60	8.75	mA
Slave	eSCO		2EV3	30	12.29	mA
Slave	SCO	1-mic CVC	HV3	30	13.48	mA
Slave	eSCO	1-mic CVC	2EV3	60	11.34	mA
Slave	eSCO	1-mic CVC	2EV3	30	14.88	mA
Slave	SCO	2-mic CVC	HV3	30	17.65	mA
Slave	eSCO	2-mic CVC	2EV3	60	15.52	mA
Slave	eSCO	2-mic CVC	2EV3	30	19.06	mA
Slave	ACL	Sniff = 100ms	-	-	0.78	mA
Slave	ACL	Sniff = 500ms	-	-	0.33	mA
Slave	ACL	Sniff = 1280ms	-	-	0.25	mA
Master	SCO		HV3	30	11.04	mA
Master	eSCO		EV3	30	11.41	mA
Master	eSCO		2EV3	60	8.24	mA
Master	eSCO		2EV3	30	10.84	mA
Master	SCO	1-mic CVC	HV3	30	13.67	mA
Master	eSCO	1-mic CVC	2EV3	60	10.85	mA
Master	eSCO	1-mic CVC	2EV3	30	13.46	mA
Master	SCO	2-mic CVC	HV3	30	17.84	mA
Master	eSCO	2-mic CVC	2EV3	60	15.03	mA
Master	eSCO	2-mic CVC	2EV3	30	17.65	mA
Master	ACL	Sniff = 100ms	-	-	0.97	mA
Master	ACL	Sniff = 500ms	-	-	0.33	mA
Master	ACL	Sniff = 1280ms	-	-	0.25	mA

Note:

Current consumption values are taken with:

- BAT_P pin for switch-mode regulator = 3.7V
- RF TX power set to 0dBm
- No RF retransmissions in case of eSCO
- Microphones and speakers disconnected, with internal microphone bias circuit set to minimum current level
- Audio gateway transmits silence when SCO/eSCO channel is open
- LEDs disconnected

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15 CSR Green Semiconductor Products and RoHS Compliance

15.1 RoHS Statement

BC6150 QFN where explicitly stated in this Data Sheet meets the requirements of Directive 2002/95/EC of the European Parliament and of the Council on the *Restriction of Hazardous Substance* (RoHS).

15.1.1 List of Restricted Materials

BC6150 QFN is compliant with RoHS in relation to the following substances:

- Cadmium
- Lead
- Mercury
- Hexavalent chromium
- Polybrominated Biphenyl
- Polybrominated Diphenyl Ether

In addition, the following substances are not intentionally added to BC6150 QFN devices:

- Halogenated flame retardant
- Antimony (Sb) and Compounds, including Antimony Trioxide flame retardant
- Polybrominated Diphenyl and Biphenyl Oxides
- Tetrabromobisphenol-A bis (2,3-dibromopropylether)
- Asbestos or Asbestos compounds
- Azo compounds
- Organic tin compounds
- Mirex
- Polychlorinated naphthalenes
- Polychlorinated terphenyls
- Polychlorinated biphenyls
- Polychlorinated/Short chain chlorinated paraffins
- Polyvinyl Chloride (PVC) and PVC blends
- Formaldehyde
- Arsenic and compounds (except as a semiconductor dopant)
- Beryllium and its compounds
- Ethylene Glycol Monomethyl Ether or its acetate
- Ethylene Glycol Monoethyl Ether or its acetate
- Halogenated dioxins and furans
- Persistent Organic Pollutants (POP), including Perfluorooctane sulphonates
- Red phosphorous
- Ozone Depleting Chemicals (Class I and II): Chlorofluorocarbons (CFC) and Halons
- Radioactive substances

For further information, see CSR's *Environmental Compliance Statement for CSR Green Semiconductor Products*.

16 BC6150 QFN Software Stack

BC6150 QFN is supplied with Bluetooth v2.1 + EDR specification compliant stack firmware, which runs on the internal RISC MCU.

The BC6150 QFN software architecture allows Bluetooth processing and the application program to be shared in different ways between the internal RISC MCU and an external host processor, if any. The upper layers of the Bluetooth stack, above the HCI, can be run either on-chip or on the host processor.

16.1 BC6150 QFN Mono Headset Solution Development Kit

CSR's BC6150 QFN mono headset solution development kit for BC6150 QFN, order code DK-BC-6150-1A, includes a headset demonstrator board, form-factor representative example design, music and voice dongle and necessary interface adapters and cables. In conjunction with the BlueVox Configurator tool and other supporting utilities the development kit provides the best environment for designing a mono headset solution with BC6150 QFN.

16.2 BC6150 QFN Mono Headset Solution

- The CSR mono headset ROM software supports HFP v1.5 and HSP v1.1. Advanced features in these specifications are supported, including three-way calling.
- Bluetooth v2.1 + EDR specification is supported in the ROM software including Secure Simple Pairing, greatly simplifying the pairing process.
- Proximity Pairing (headset initiated pairing) for greatly simplifying the out-of-box pairing process, for more information see Section 16.5.
- For connection to more than one mobile phone Advanced Multipoint is supported. This allows a user to take calls from a work and personal phone or a work phone and a VoIP dongle for Skype users. Advanced Multipoint support allows a headset (HFP) connection to 2 phones for voice. This is supported with a minimal impact on power consumption and can be easily configured.
- BC6150 QFN includes CVC v5.0 1-microphone algorithm for echo and noise reduction including significant near end audio enhancements. This algorithm is particularly effective for the removal of static noise that would otherwise be transmitted to the far-end user and also in improving the intelligibility of speech to the near-end user despite static background noise. It is enabled in the ROM part and no license key is required. The algorithm is configured for different headset plastics using the Parameter Manager tool.
- For superior noise suppression, including dynamic noise, the CVC v5.0 2-microphone algorithm can be enabled. This provides 30dB noise suppression and is effective at cancelling both dynamic and static noise. This software is also configured using the Parameter Manager tool. For more information see www.csrsupport.com/cvc
- Most of the CSR mono headset ROM software features can be configured on the BC6150 QFN using the BlueVox Configurator tool available from www.csrsupport.com/MonoHeadsetSolutions. The tool can be used to read and write headset configurations directly to the EEPROM or alternatively to a PSR file. Configurable headset features include:
 - Bluetooth v2.1 + EDR specification features
 - Reconnection policies, e.g. reconnect on power on
 - Audio features, including default volumes
 - Button events: configuring button presses and durations for certain events, e.g. double press on PIO[1] for Last Number Redial
 - LED indications for states, e.g. headset connected, and events, e.g. power on
 - Indication tones for events and ringtones
 - HFP v1.5 supported features
 - Battery divider ratios and thresholds, e.g. thresholds for battery low indication, full battery etc.
 - Advanced Multipoint settings
- The BC6150 QFN mono headset solution has undergone extensive interoperability testing to ensure that it works with the majority of phones on the market

16.3 Advanced Multipoint Support

Advanced Multipoint allows the connection of 2 devices to BC6150 QFN at the same time. For example, this could be either 2 phones connected to a BC6150 QFN headset, or a phone and a VoIP dongle connected to a headset.

The BC6150 QFN mono headset solution:

- Supports a maximum of 2 connections (either HFP or HSP)
- Allows multiple calls to be handled from both devices at the same time
- During a call from 1 device, all headset buttons work as in the standard use case with one device connected
- During multiple calls (1 on each device), all headset buttons work as in the standard use case for a single AG with multiple calls in progress (three-way calling)
- This implementation is easy to use with negligible effect on power consumption

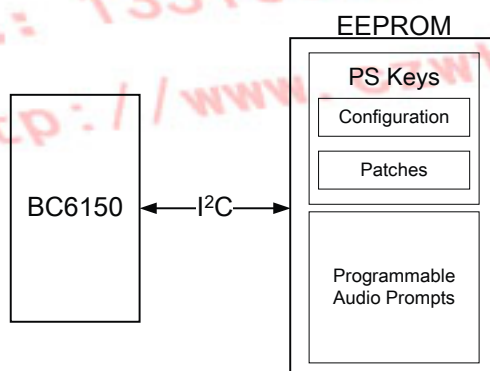
16.4 Programmable Audio Prompts

Figure 16.1 shows that users can configure and load pre-programmed audio prompts from an external EEPROM. The prompts provide a mechanism for higher quality audio indications to replace standard tone indications. In this way, a programmable audio prompt can be assigned to any user event in place of a standard tone.

Programmable audio prompts can contain either voice prompts to indicate that events have occurred or they can provide user defined higher quality ring tones / indications, e.g. custom power on/off tones. The prompts are stored in the same EEPROM as used for standard PS Keys, see Section 9.3. A larger EEPROM is required for programmable audio prompts. EEPROMs up to 512Kb are supported for use in this way. An EEPROM of 512Kb allows approximately 15 seconds of audio to be stored.

The content of the programmable audio prompts can be generated from standard WAV audio files using the BlueVOX Configurator tool. The tool also allows the user to configure which prompts are assigned to which user events.

Section 9.3 describes the I²C interface to the external EEPROM.



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Figure 16.1: Programmable Audio Prompts in External I²C EEPROM

16.5 Proximity Pairing

Proximity Pairing is headset initiated pairing and it simplifies the out-of-box pairing process. Proximity Pairing allows the headset to find the closest discoverable phone. The headset then initiates the pairing activity and the user simply has to accept the incoming pairing invitation on the phone.

This means that the phone-user does not have to hunt through phone menus in order to pair with the new headset.

Depending on the phone UI:

- For a Bluetooth v2.0 phone the headset pairing is with a PIN code
- For a Bluetooth v2.1 phone the headset pairing is without a PIN code

Proximity Pairing is based on finding and pairing with the closest phone. In order to do this, the headset finds the loudest phone by carrying out RSSI power threshold measurements. The loudest phone is the one with the largest RSSI power threshold measurement, and is defined as the closest device, the headset then attempts to pair with and connect to this device.

16.5.1 Proximity Pairing Configuration

Proximity Pairing is configurable using the BlueVox Configurator tool available from www.csrsupport.com/MonoHeadsetSolutions.

17 Ordering Information

Device	Package			Order Number
	Type	Size	Shipment Method	
BC6150 QFN Mono Headset Solution	QFN 68-lead (Pb free)	8 x 8 x 0.9mm, 0.4mm pitch	Tape and Reel	BC6150A08-IQQF-R

Note:

BC6150 QFN is a ROM-based device where the product code has the form BC6150Axx. xx is the specific ROM-variant, 08 is the ROM-variant for BC6150 QFN Mono Headset Solution.

Minimum order quantity is 2kpcs taped and reeled.

Supply chain: CSR's manufacturing policy is to multisource volume products. For further details, contact your local sales account manager or representative.

To contact a CSR representative, email sales@csr.com or go to www.csr.com/contacts.

17.1 BC6150 QFN Mono Headset Solution Development Kit Ordering Information

Description	Order Number
BC6150 QFN Mono Headset Solution Development Kit, including headset example design	DK-BC-6150-1A

18 Tape and Reel Information

For tape and reel packing and labelling see *IC Packing and Labelling Specification*.

18.1 Tape Orientation

Figure 18.1 shows the BC6150 QFN packing tape orientation.

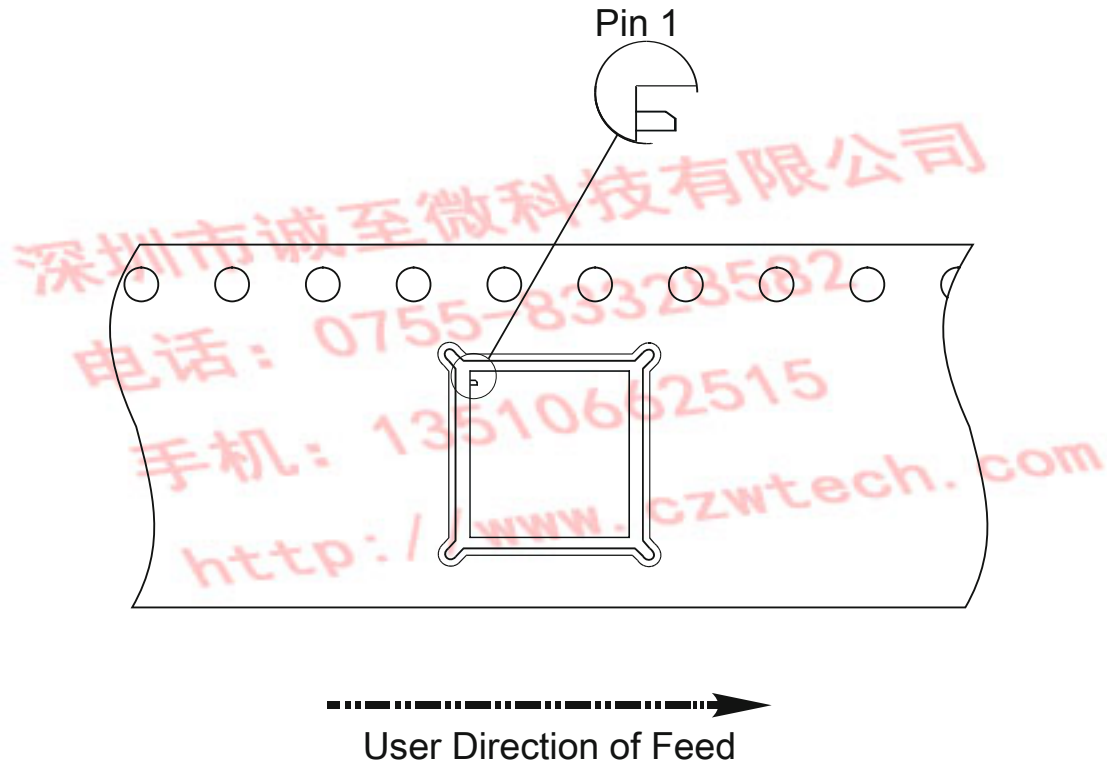
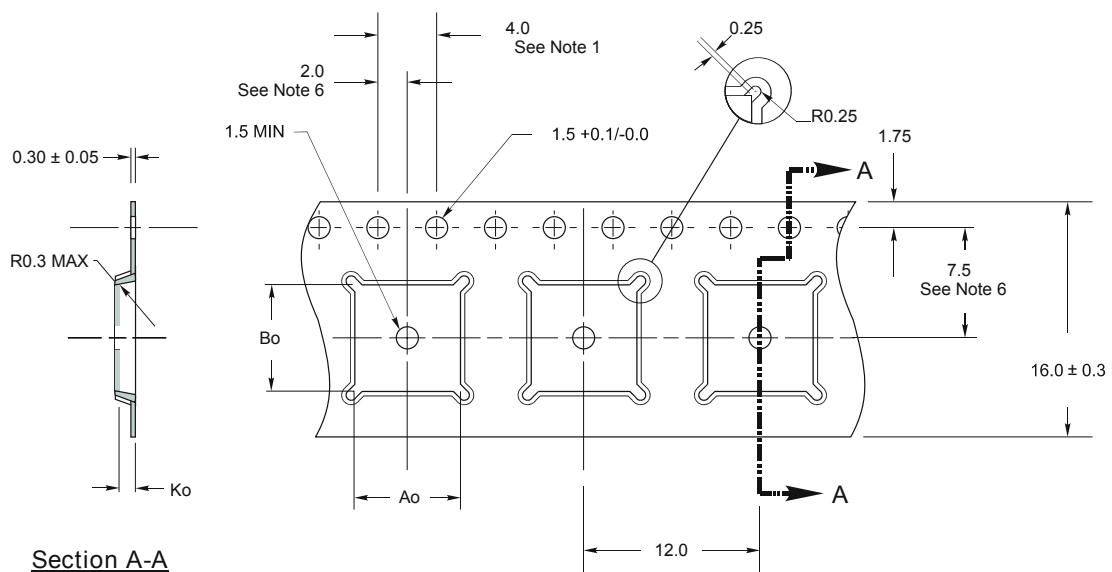


Figure 18.1: BC6150 QFN Tape Orientation

18.2 Tape Dimensions



G-TW-0002812.2.2

G-TW-0002811.3.2

A ₀	B ₀	K ₀	Unit	Notes
8.30	8.30	1.10	mm	<ol style="list-style-type: none"> 10 sprocket hole pitch cumulative tolerance ± 0.2 Camber not to exceed 1mm in 100mm Material: PS + C A₀ and B₀ measured as indicated K₀ measured from a plane on the inside bottom of the pocket to the top surface of the carrier Pocket position relative to sprocket hole measured as true position of pocket, not pocket hole

18.3 Reel Information

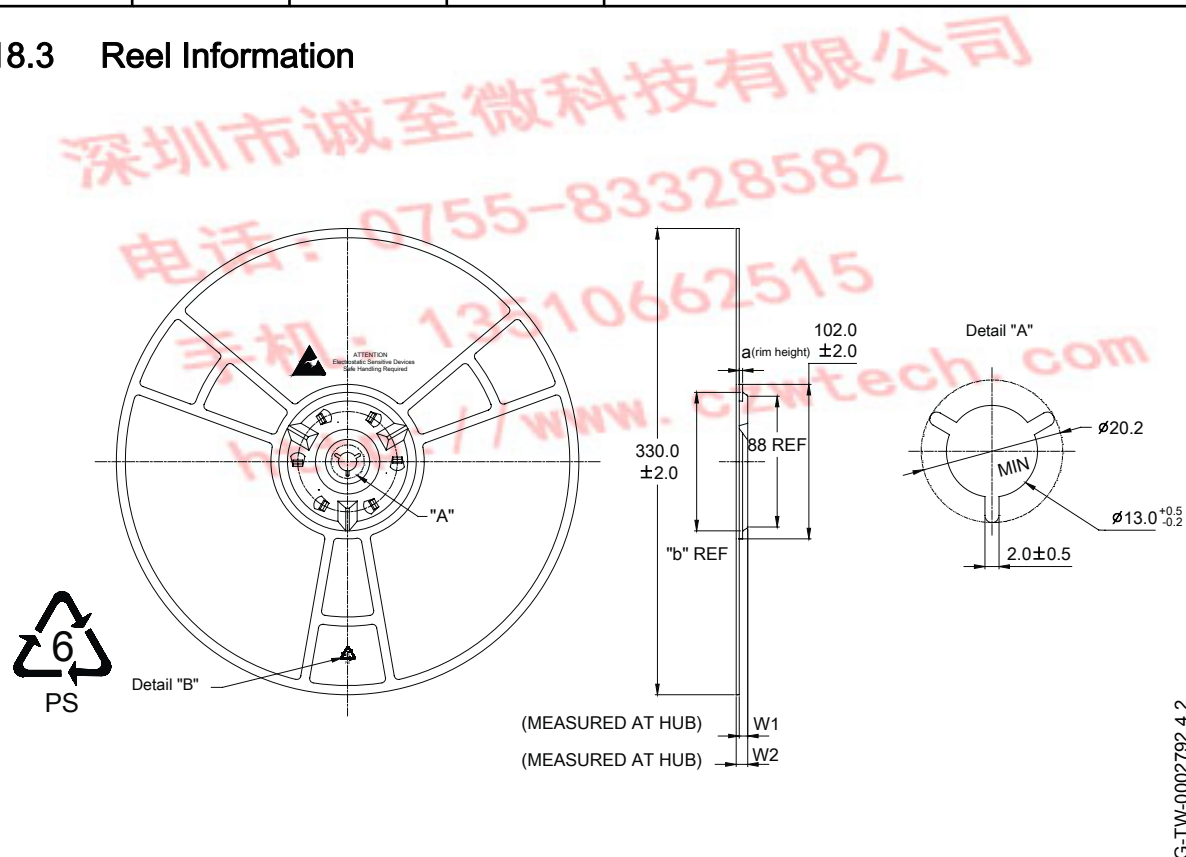


Figure 18.2: Reel Dimensions

Package Type	Nominal Hub Width (Tape Width)	a	b	W1	W2 Max	Units
8 x 8 x 0.9mm QFN	16	4.5	98.0	16.4 (3.0/-0.2)	19.1	mm

18.4 Moisture Sensitivity Level

BC6150 QFN is qualified to moisture sensitivity level MSL3 in accordance with JEDEC J-STD-020.

19 Document References

Document	Reference, Date
<i>BlueCore5 Charger Description and Calibration Procedure Application Note</i>	CS-113282-ANP, 2007
<i>BlueCore5-Multimedia External Recommendations for ESD Protection</i>	CS-114058-ANP, 2007
<i>Bluetooth and IEEE 802.11 b/g Co-existence Solutions Overview</i>	bcore-an-066P, 2005
<i>BC6150 QFN Performance Specification</i>	CS-128747-SPP, 2009
<i>Core Specification of the Bluetooth System</i>	v2.1 + EDR, 2007
<i>IC Packing and Labelling Specification</i>	CS-112584-SPP, 2007
<i>Moisture / Reflow Sensitivity Classification for Nonhermitic Solid State Surface Mount Devices</i>	IPC / JEDEC J-STD-020
<i>Optimising BlueCore5-Multimedia ADC Performance Application Note</i>	CS-120059-AN, 2008
<i>Selection of I²C EEPROMS for Use with BlueCore</i>	bcore-an-008P, 2003
<i>Test Suite Structure (TSS) and Test Purposes (TP) System Specification 1.2/2.0/2.0 + EDR/ 2.1/2.1 + EDR</i>	RF.TS/2.1.E.0, 2006
<i>Typical Solder Reflow Profile for Lead-free Devices</i>	CS-116434-ANP, 2007

Terms and Definitions

Term	Definition
8DPSK	8-phase Differential Phase Shift Keying
$\pi/4$ DQPSK	$\pi/4$ rotated Differential Quaternary Phase Shift Keying
μ -law	Audio companding standard (G.711)
A-law	Audio companding standard (G.711)
AC	Alternating Current
ACL	Asynchronous Connection-oriented
ADC	Analogue to Digital Converter
AFH	Adaptive Frequency Hopping
AG	Audio Gateway
AGC	Automatic Gain Control
AIO	Analogue Input/Output
ALU	Arithmetic logic unit
BIST	Built-In Self-Test
BlueCore®	Group term for CSR's range of Bluetooth wireless technology ICs
Bluetooth®	Set of technologies providing audio and data transfer over short-range radio connections
BMC	Burst Mode Controller
CFC	Chlorofluorocarbon
codec	Coder decoder
CRC	Cyclic Redundancy Check
CSR	Cambridge Silicon Radio
CTS	Clear to Send
CVC	Clear Voice Capture
CVSD	Continuous Variable Slope Delta Modulation
DAC	Digital to Analogue Converter
DC	Direct Current
DNL	Differential Non Linearity (ADC accuracy parameter)
DSP	Digital Signal Processor
DUT	Device Under Test
e.g.	<i>exempli gratia</i> , for example
EDR	Enhanced Data Rate
EEPROM	Electrically Erasable Programmable Read Only Memory
eSCO	Extended SCO
ESD	Electrostatic Discharge
ESR	Equivalent Series Resistance
FET	Field Effect Transistor
FSK	Frequency Shift Keying
GFSK	Gaussian Frequency Shift Keying
GSM	Global System for Mobile communications
HCI	Host Controller Interface
HFP	Hands-Free Profile
HSP	HeadSet Profile

Term	Definition
I ² C	Inter-Integrated Circuit Interface
I ² S	Inter-Integrated Circuit Sound
I/O	Input/Output
IF	Intermediate Frequency
IIR	Infinite Impulse Response (filter)
INL	Integral Non Linearity (ADC accuracy parameter)
IQ	In-Phase and Quadrature
JEDEC	Joint Electron Device Engineering Council (now the JEDEC Solid State Technology Association)
Kalimba	An open platform DSP co-processor, enabling support of enhanced audio applications, such as echo and noise suppression, and file compression / decompression
Kb	Kilobit
LC	An inductor (L) and capacitor (C) network
LED	Light-Emitting Diode
LNA	Low Noise Amplifier
LSB	Least-Significant Bit (or Byte)
MAC	Medium Access Control
MAC	Multiplier and Accumulator
MCU	MicroController Unit
MIPS	Million Instructions Per Second
MISO	Master In Slave Out
MMU	Memory Management Unit
NSMD	Non Solder Mask Defined
PA	Power Amplifier
PC	Personal Computer
PCM	Pulse Code Modulation
PIN	Personal Identification Number
PIO	Programmable Input/Output
plc	Public Limited Company
POP	Persistent Organic Pollutants
ppm	parts per million
PS Key	Persistent Store Key
PSRR	Power Supply Rejection Ratio
PVC	Poly Vinyl Chloride
RAM	Random Access Memory
RC	Resistor Capacitor
RF	Radio Frequency
RISC	Reduced Instruction Set Computer
RoHS	Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (2002/95/EC)
ROM	Read Only Memory
RSSI	Received Signal Strength Indication
RTS	Request To Send
RX	Receive or Receiver
SCO	Synchronous Connection-Oriented

Term	Definition
SIG	(Bluetooth) Special Interest Group
SNR	Signal-to-Noise Ratio
S/PDIF	Sony/Philips Digital InterFace (also IEC 958 type II, part of IEC-60958). An interface designed to transfer stereo digital audio signals between various devices and stereo components with minimal loss.
SPI	Serial Peripheral Interface
SPL	Sound Pressure Level
TCXO	Temperature Compensated crystal Oscillator
TX	Transmit or Transmitter
UART	Universal Asynchronous Receiver Transmitter
UI	User Interface
VCO	Voltage Controlled Oscillator
VM	Virtual Machine
VoIP	Voice over Internet Protocol
W-CDMA	Wideband Code Division Multiple Access