



BK32881 Bluetooth Audio SoC

1-MIC and Stereo Headsets

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Disclaimer: Descriptions of specific implementations are for illustrative purpose only, actual hardware implementation may differ.

Revision History

Rev.	Date	Remark
1.0	10/22/2020	Initial release
1.1	11/03/2020	Update with BLE current consumption
1.2	12/29/2020	Updated VCC3SYS voltage range from 3.8 V to 3.5 V
1.3	01/27/2021	- Updated Bluetooth spec support to 5.2 - Minor corrections
1.4	06/17/2021	- Removed features: ANC, keyword spotting, voice command and microphone array - Updated Figure 1 Block Diagram of BK32881 - Updated Section 3 Pin Definition - Added the number of interfaces in Section 4 Functional Description - Updated the battery voltage range in Section 4.1 Power Management - Updated the description of sample rates of ADC and DAC in Section 4.3 Audio Peripherals - Updated the description of I2C clock rate in Section 4.10 I2C Interface and UART Interface - Updated the SPI clock rate in Section 4.11 SPI Interface - Removed SDIO from Section 4.14 USB Interface - Updated the minimum sample rate of I2S in Section 4.15 I2S Interface and SPDIF Interface - Updated the maximum data rate of QSPI in Section 4.16 QSPI Interface - Removed TRNG from Section 4.17 Code Encryption and System Security - Updated Section 5.1 Absolute Maximum Ratings - Updated Section 5.2 Recommended Operating Conditions - Removed the original section USB LDO in Section 5 Electrical Characteristics - Updated typical value of ADC SNR to 100 dB in Section 5.10 Audio Characteristics - Updated part number in Section 8 Ordering Information
1.5	07/30/2021	- Removed line in Figure 1 Block Diagram of BK32881 - Removed signal LIN1L (pin P2) from Figure 2 and Table 1



Rev.	Date	Remark
		in Section 3 Pin Definition Added TRNG to Section 4.17 Code Encryption and System Security
1.6	09/13/2021	Added signal TXEN (pin P9) to Figure 2 and Table 1 in Section 3 Pin Definition
1.7	04/15/2022	Updated BR/LE 1 Mbps sensitivity in Section 5.9 RF Characteristics
1.8	04/26/2022	Corrected VCC3SYS voltage in Section 5.3 System LDO
1.9	07/13/2022	- Added description of MCU and DSP as well as RAM size and Flash size to Section 2 Features - Added Section 4.4 MCU - Added main features of DSP to Section 4.5 DSP



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1. General Description

The BK32881 is a dual mode Bluetooth 5.2 system on chip solution.

The 64-bit SIMD and high precision floating point digital signal processor provides clear voice communication and high performance music quality. Flexible and abundant peripherals make it ideal for different Bluetooth audio applications, such as true wireless stereo headsets and audio enhanced speakers.

2. Features

- BA22 32-bit RISC MCU at up to 200 MHz
- High performance CEVA-X2 DSP at up to 300 MHz
- 896 KB RAM: 128 KB MCU RAM + 640 KB DSP RAM + 128 KB share RAM
- SiP Flash: 1 MB or 2 MB
- Touch and pressure sensor
- Bond conduction
- 24 bits audio quality
- 8 kHz to 384 kHz audio sample rate
- Acoustic echo cancellation
- Code encryption and system security
- Bluetooth 5.2 classic and Low Energy

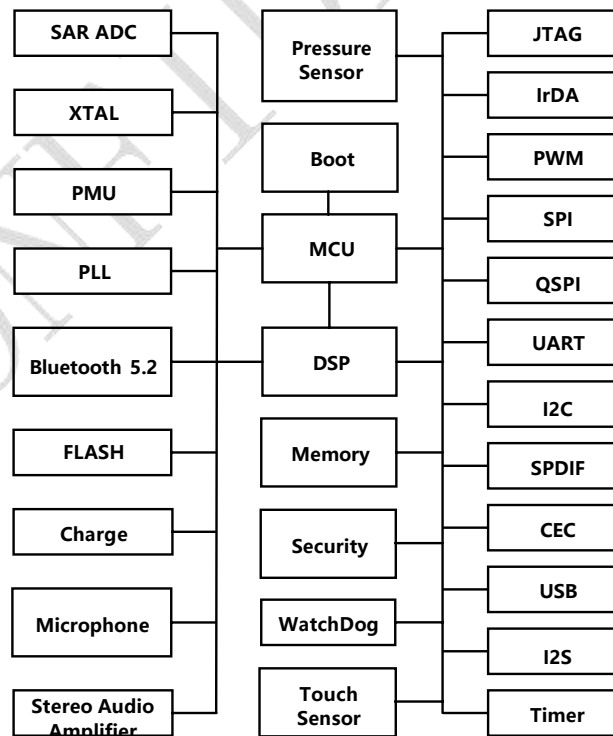


Figure 1 Block Diagram of BK32881

3. Pin Definition

The BK32881 uses a 40-pin 4x5 mm² QFN package.

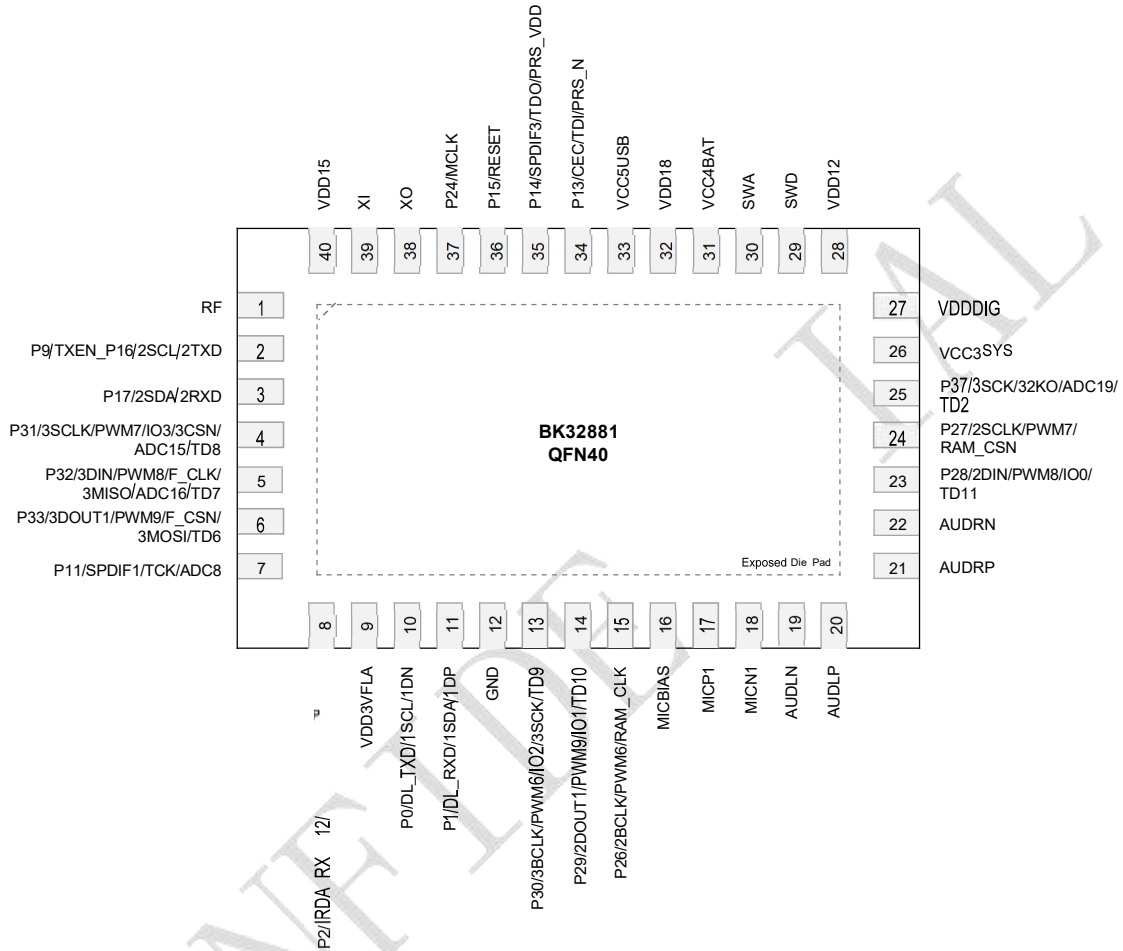


Figure 2 BK32881 QFN40 Pin Assignments

Table 1 Pin Description of BK32881

Pin #	Name	I/O	Type	Description
1	RF	-	RF	2.4 GHz RF signal port
2	P9/TXEN_P16/2SCL/2TXD	I/O	Digital	- GPIO9 - TXEN is high when transmitting - GPIO16 - I2C2: SCL - UART2: TXD



Pin #	Name	I/O	Type	Description
3	P17/2SDA/2RXD	I/O	Digital	- GPIO17 - I2C2: SDA - UART2: RXD
4	P31/3SCLK/PWM7/ IO3/3CSN/ADC15/TD8	I/O	Digital/Analog	- GPIO31 - I2S3: SCLK - PWM7 - QSPI: IO3 - SPI3: CSN - ADC15 - Touch sensor: TD8
5	P32/3DIN/PWM8/ F_CLK/3MISO/ADC16/ TD7	I/O	Digital/Analog	- GPIO32 - I2S3: DIN - PWM8 - QSPI: Flash CLK - SPI3: MISO - ADC16 - Touch sensor: TD7
6	P33/3DOUT1/PWM9/ F_CSN/3MOSI/TD6	I/O	Digital/Analog	- GPIO33 - I2S3: DOUT1 - PWM9 - QSPI: Flash CSN - SPI3: MOSI - Touch sensor: TD6
7	P11*/SPDIF1/TCK/ ADC8	I/O	Digital/Analog	- GPIO11 - Sony/Philips Digital Interface 1 input - JTAG: TCK - ADC8
8	P2/IRDA_RX_P12*/SPD IF2/TMS/PRS_P	I/O	Digital/Analog	- GPIO2 - IrDA RX - GPIO12 - Sony/Philips Digital Interface 2 input - JTAG: TMS - Pressure sensor: Positive input



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V1.9

Pin #	Name	I/O	Type	Description
9	VDD3VFLA	-	Analog output	Flash voltage output, can be shut down in idle state, connected to VCC3SYS
10	P0/DL_TXD/1SCL/1DN	I/O	Digital/Analog	- GPIO0 - UART1: Download TXD - I2C1: SCL - USB1: Data minus
11	P1/DL_RXD/1SDA/1DP	I/O	Digital/Analog	- GPIO1 - UART1: Download RXD - I2C1: SDA - USB1: Data plus
12	GND	-	GND	Ground
13	P30/3BCLK/PWM6/ IO2/3SCK/TD9	I/O	Digital/Analog	- GPIO30 - I2S3: BCLK - PWM6 - QSPI: IO2 - SPI3: SCK - Touch sensor: TD9
14	P29/2DOUT1/PWM9/ IO1/TD10	I/O	Digital/Analog	- GPIO29 - I2S2: DOUT1 - PWM9 - QSPI: IO1 - Touch sensor: TD10
15	P26/2BCLK/PWM6/ RAM_CLK	I/O	Digital	- GPIO26 - I2S2: BCLK - PWM6 - QSPI: RAM CLK
16	MICBIAS	-	Analog output	Microphone bias output
17	MICP1	-	Analog input	Microphone 1 positive input
18	MICN1	-	Analog input	Microphone 1 negative input
19	AUDLN	-	Analog output	Audio left channel negative output
20	AUDLP	-	Analog output	Audio left channel positive output
21	AUDRP	-	Analog output	Audio right channel positive output



Bluetooth Smart Audio SoC

V1.9

Pin #	Name	I/O	Type	Description
22	AUDRN	-	Analog output	Audio right channel negative output
23	P28/2DIN/PWM8/IO0/ TD11	I/O	Digital/Analog	- GPIO28 - I2S2: DIN - PWM8 - QSPI: IO0 - Touch sensor: TD11
24	P27/2SCLK/PWM7/ RAM_CSN	I/O	Digital	- GPIO27 - I2S2: SCLK - PWM7 - QSPI: RAM CSN
25	P37/3SCK/32KO/ ADC19/TD2	I/O	Digital/Analog	- GPIO37 - SPI3: SCK 32 kHz output - ADC19 - Touch sensor: TD2
26	VCC3SYS	-	Analog output	System LDO output
27	VDDDIG	-	Analog output	Digital LDO output
28	VDD12	-	Analog output	Digital LDO output
29	SWD	-	BUCK output	Digital BUCK switch output
30	SWA	-	BUCK output	Analog BUCK switch output
31	VCC4BAT	-	Power	Battery input, up to 4.2 V
32	VDD18	-	Analog output	Analog LDO output
33	VCC5USB	-	Power/Digital/ Analog	USB 5.0 V input or DLP or 3.3 V Reset input
34	P13*/CEC/TDI/PRS_N	I/O	Digital/Analog	- GPIO13 - HDMI CEC - JTAG: TDI - Pressure sensor: Negative input
35	P14*/SPDIF3/TDO/ PRS_VDD	I/O	Digital/Analog	- GPIO14 - Sony/Philips Digital Interface 3 input - JTAG: TDO - Pressure sensor: VDD, connected to VCC3SYS



Pin #	Name	I/O	Type	Description
36	P15*/RESET	I/O	Digital/Analog	- GPIO15 - Reset input, active-low
37	P24/MCLK	I/O	Digital	- GPIO24 - I2S: MCLK
38	XO	-	Analog output	26 MHz crystal output
39	XI	-	Analog input	26 MHz crystal input
40	VDD15	-	Analog output	Bluetooth radio LDO output
Die pad	GND_SLUG	-	GND	Ground

* **Note:** LEDs cannot be connected to P11 ~ P15.

4. Functional Description

4.1. Power Management

The BK32881 can be powered directly from a 2.8 V to 4.2 V external battery via the VCC4BAT pin or it can be powered from a 4.75 V to 5.5 V USB power supply via the VCC5USB pin. The VCC5USB can be also used to charge battery with internal charge control circuit.

4.2. Bluetooth

The BK32881 integrates dual mode Bluetooth 5.2 inside. Both the classic and BLE has their own independent clock and synchronization logic, that support simultaneously classic and BLE link much more efficient and stable.

4.3. Audio Peripherals

The BK32881 comes with a rich set of audio peripherals to enhance the Bluetooth listening experience. The chip includes a 24 bits analog-to-digital converter (ADC) and two 24 bits digital-to-analog converters (DAC), together with amplifier and bias. The DAC is capable of driving 16 Ω speakers with up to 30 pF of load capacitance.

The sample rates of ADC and DAC are typically 8 kHz, 44.1 kHz and 48 kHz, and can be set to any 8x or 12x integer from 8 kHz to 384 kHz.

The PDM does the 8:1 CIC decimation that the PCM sample rate can be up to 384 kHz when the PDM clock frequency is 3.072 MHz.

4.4. MCU

The BK32881 integrates a compact yet powerful BA22 32-bit processor for deeply embedded applications. The BA22 is a Harvard-style processor able to run at relatively high clock frequencies, with a surprisingly small silicon footprint. The BA22 uses separate instruction and data buses, and it has a pipeline depth of 5 stages. The processor connects to the system via AMBA® AHB™. It is also equipped with dedicated Quick Memory (QMEM) interfaces to tightly-coupled memories, which offer fast and deterministic access to code and data. The BA22 includes general-purpose registers (GPRs), a tick timer (TTimer), a programmable interrupt controller (PIC), an advanced power management unit (PMU), and a debug unit (DBGU).

The BA22 supports the following features:

- 2.93 CoreMark/MHz
- Single-cycle execution on most instructions
- Fast interrupt response
- Hardware multiply, multiply-accumulate, DSP instructions acceleration, and floating-point units

4.5. DSP

The BK32881 includes a low power digital signal processor, which is good at audio processing such as acoustic echo cancellation.

The DSP supports high precision floating point and 64 SIMD. As a high performance DSP, it includes the following main features:

- 4.5 CoreMark/MHz, 300 MHz
- Dual 32×32 MAC operations per cycle
- Quad 16×16 MAC operations per cycle
- 64-bit SIMD fixed-point operations
- 256 KB IRAM + 384 KB DRAM or 128 KB ICache + 512 KB DRAM

- Parallel DSP with two SPUs (Scalar Processing Units)
- Flexible data plane processing with 8/16/32/64-bit native C data types support
- Up to two IEEE single-precision floating-point units operating in parallel

4.6. DMA

The DMA is used to transfer content between memory mapped device and the data memory. Total fifteen DMA channels can work simultaneously.

DMA can access I2S, audio ADC and DAC, PSRAM, SPI and UART interface.

4.7. GPIO

The BK32881 GPIOs can be configured as either input or output, and the output drive capability can be programmed from 5 mA to 32 mA. The GPIO voltage is constantly defined by VCC3SYS. Most of them have peripheral mode or connected with analog function. The GPIO0 and GPIO1 pair is also used for UART download.

All GPIO pins can wake up the internal MCU from standby mode and deep sleep mode. Any level change on the set GPIO will trigger the wake up procedure.

4.8. Timers

There are two sets of timers, three 32-bit timers for each set. One set (fast) uses 26 MHz clock as the main clock, and another set (slow) uses low power clock as main clock.

4.9. PWM Output

There are PWM timers to provide PWM output on GPIO. All the timers run with the same frequency, which can be either 26 MHz clock or low power clock.

All PWM timers have 32-bit resolution.

4.10. I2C Interface and UART Interface

There are two I2C interfaces and two UART interfaces for debug or external MCU control of the BK32881.

The I2C clock rate can be from 22 to 3072 divided frequency from 26 MHz clock.

The UART clock rate can be from 3.2 kHz to 6.5 MHz.

4.11. SPI Interface

There is a high speed full duplex SPI interface, which can be used as an interface for an external memory or LCD controller.

The SPI clock rate is from 50.98 kHz to 26 MHz when acts as master, and can be 26 MHz maximum as slave.

4.12. General Purpose SAR ADC

The general purpose SAR ADC has 12-bit resolution with a programmable sample rate. The ADC reference voltage range can be either IO voltage or internal constant bias voltage.

4.13. Touch

The touch sensor supports multi-channel scan that it can detect capacitance change immediately.

4.14. USB Interface

The USB interface supports both host and device mode with full speed.

4.15. I2S Interface and SPDIF Interface

The two I2S interfaces support both master and slave mode with sample rate from 8 kHz to 384 kHz.

There is an I2S DPLL dedicated for I2S and audio ADC/DAC, that it can output master clock for external device.

The SPDIF interface has CEC output and SPDIF input that it can work directly with analog input with internal amplifier and slicer.

4.16. QSPI Interface

The QSPI is designed for FLASH and RAM extension. The data IO are time shared by FLASH and RAM, while dedicated clock and select signals are separately used by FLASH and RAM. The QSPI can work up to 50 MHz, and FLASH clock and RAM clock can be set differently.

4.17. Code Encryption and System Security

There are a True Random Number Generator (TRNG) and one time NVM for code encryption and system security. Each unit can have different password for code encryption, where hardware will do the decryption automatically.

The download and debug interface can be closed permanently by the user to keep system security.

5. Electrical Characteristics

5.1. Absolute Maximum Ratings

Parameter	Description	MIN	MAX	Unit
VCC4BAT	Battery regulator supply voltage	-0.3	4.35	V
VCC5USB	USB power supply voltage	-0.3	5.5	V
P _{RX}	RX input power		10	dBm
T _{STR}	Storage temperature range	-40	150	°C

5.2. Recommended Operating Conditions

Parameter	Description	MIN	TYP	MAX	Unit
VCC4BAT	Battery regulator supply voltage	2.8	3.6	4.2	V
VCC5USB	USB power supply voltage	4.75	5.0	5.5	V
VDD15	BT radio LDO output voltage	1.3	1.35	1.55	V
VDD3VFLA	Power supply of Flash	2.8	3.0	3.6	V
VCC3SYS	System LDO output voltage	2.8	3.0	3.6	V
VDDDIG	Digital Core LDO output voltage	0.4	0.8	1.0	V
MICBIAS	Microphone bias output voltage	1.8		2.4	V
T _{OPR}	Operating temperature range	-20		85	°C

5.3. System LDO

Parameter	Description	MIN	TYP	MAX	Unit
VCC4BAT	Battery input voltage	2.8		4.2	V
VCC3SYS	LDO output voltage	2.8	3.0	3.6	V
Load Current	Load current			200	mA

5.4. Battery Charge

Parameter	Description	MIN	TYP	MAX	Unit
VCC5USB	Charger input voltage	4.75	5	5.5	V
I _{trickle}	Charge current at trickle mode as		10		%



Parameter	Description	MIN	TYP	MAX	Unit
	percent of fast charge mode				
I_fast	Charge current at fast charge mode	5		220	mA
V_end (Calibrated)	VBAT voltage when charge ends		4.2		V

5.5. Analog LDO/BUCK

The system can choose the analog BUCK or LDO as the power supply of RF and Audio part.

Parameter	Description	MIN	TYP	MAX	Unit
Analog LDO					
VDD18	Analog LDO output voltage	1.3	1.5	1.9	V
Load Current	Load current			150	mA
Analog BUCK					
VDD18	Analog BUCK output voltage	1.3	1.5	1.9	V
Load Current	Load current			150	mA
Switching frequency	BUCK modulation frequency	0.5	1	4	MHz

5.6. Digital LDO/BUCK

The system can also choose the digital BUCK or LDO as the power supply for the Digital part.

Parameter	Description	MIN	TYP	MAX	Unit
Digital LDO					
VDD12	Digital LDO output voltage	0.9	1.0	1.2	V
Load Current	Load current			40	mA
Digital BUCK					
VDD12	Digital BUCK output voltage	0.9	1.0	1.2	V
Load Current	Load current			40	mA
Switching frequency	BUCK modulation frequency	0.5	1	4	MHz

5.7. Crystal and Reference Clock

Parameter	Description	MIN	TYP	MAX	Unit
Frequency	Crystal and reference frequency		26		MHz
Tolerance	Crystal and reference frequency tolerance	-10		+10	ppm
XI Pin	Input voltage range for reference clock input	-0.3		1.2	V

5.8. Typical Power Consumption

State	Description	MIN	TYP	MAX	Unit
Shutdown	Software sets device into shutdown mode, wake up from GPIO		0.9		uA
Standby	Software sets device into standby mode, wake up from GPIO and RTC timer		20		uA
Idle-Sniff	Idle state at Sniff mode		0.2		mA
Active (A2DP)	2DH5		5		mA
Active (HFP)	HV1		6		mA
BLE RX			12		mA
BLE TX	0 dBm		15		mA
BLE TX	4 dBm		19		mA
BLE TX	10 dBm		28		mA

5.9. RF Characteristics

Parameter	Condition	MIN	TYP	MAX	Unit
Operating frequency		2402		2480	MHz
RXSENS-BR 1Mbps	BER = 0.001		-92		dBm
RXSENS-EDR 2Mbps	BER = 0.0001		-94		dBm
RXSENS-EDR 3Mbps	BER = 0.0001		-86		dBm
RXSENS-BLE 1Mbps	PER = 30.8%		-96		dBm
Maximum received signal	BER = 0.001	0			dBm
Maximum RF transmit			10		dBm



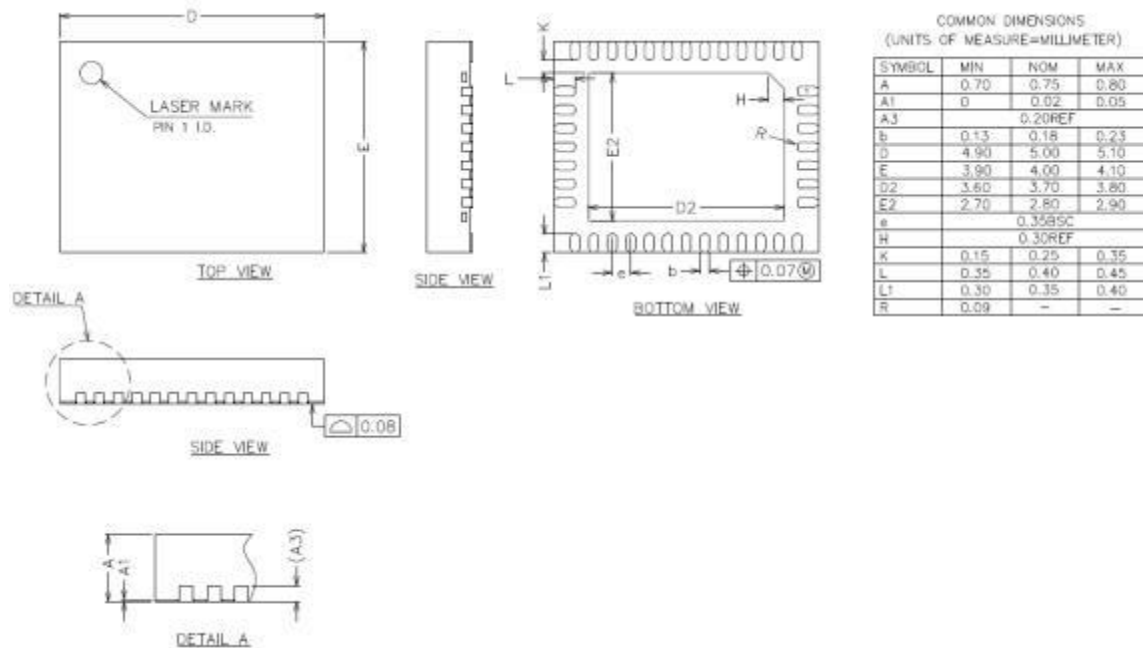
Parameter	Condition	MIN	TYP	MAX	Unit
power					
RF Power Control Range		30			dB
Carrier Drift	BLE	-50	5	50	kHz
Drift Rate	BLE	-20	2.5	20	kHz/ 50us
Δf_{1avg}	BLE	225	255	275	kHz
Δf_2 99.9%	BLE	185	250		kHz
$\Delta f_{2avg}/\Delta f_{1avg}$	BLE	0.8	1.1		

5.10. Audio Characteristics

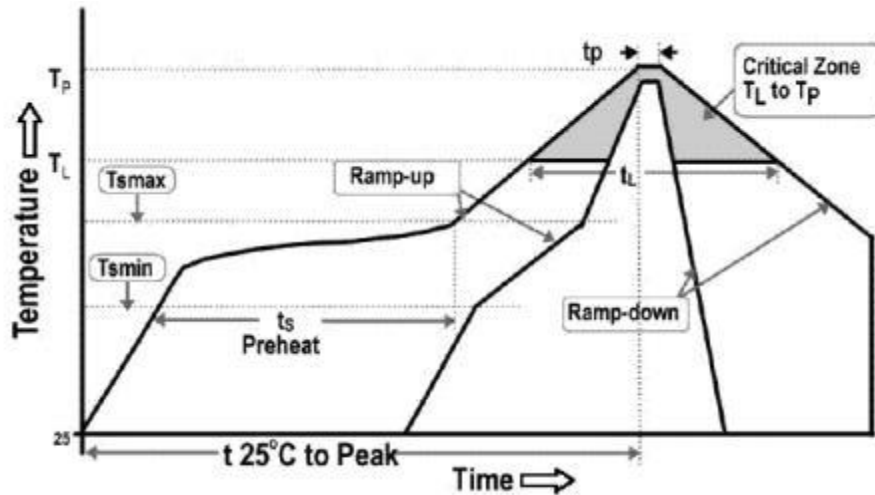
Parameter	Condition	MIN	TYP	MAX	Unit
DAC Diff. Output Amplitude	600 Ohm loading			1.1	Vrms
	16 Ohm loading			0.9	Vrms
DAC Diff. Output THD	1.1Vrms @600 Ohm loading		80		dB
	0.8 Vrms @16 Ohm loading		75		dB
DAC Output SNR	1 kHz sine wave		104		dB
DAC Sample Rate		8		384	kHz
Audio Output Gain		-34		6	dB
Audio Output Gain Step			1		dB
Audio Output Channel Separation	Full differential		90		dB
Microphone Gain		0		36	dB
Microphone Gain Step			2		dB
Microphone Reference	MICREF	1.8		2.4	V
Audio Input Channel Separation			80		dB
ADC Sample Rate		8		384	kHz
ADC SNR	1 kHz sine wave		100		dB

6. Package Information

Figure 3 QFN 4x5 40-Pin Package



7. Solder Reflow Profile



Profile Feature		Specification
Average Ramp-Up Rate (Tsmax to Tp)		3°C/second max.
Pre_heat	Temperature Min (Tsmmin)	150°C
	Temperature Max (Tsmmax)	200°C
	Time (ts)	60-180 seconds
Time Maintained above	Temperature (TL)	217°C
	Time (tL)	60-150 seconds
Peak/Classification Temperature (Tp)		260°C
Time within 5°C of Actual Peak Temperature (tp)		20-40 seconds
Ramp-Down Rate		6°C/second max.
Time 25°C to Peak Temperature		8 minutes max.

RoHS Compliant

The product does not contain lead, mercury, cadmium, hexavalent chromium, PBB&PBDE content in accordance with directive 2002/95/EC(RoHS).

ESD Sensitivity

Integrated circuits are ESD sensitive and can be damaged by static electricity. Proper ESD techniques should be used when handling these devices.



8. Ordering Information

Part Number	Package	Packing	MOQ ^a (ea)
BK32881QN40CP1	QFN 4 mm x 5 mm 40-pin	Tape Reel	3 k
BK32881QN40EP2	QFN 4 mm x 5 mm 40-pin	Tape Reel	3 k

a. MOQ: Minimum Order Quantity

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Appendix 1: RF Port Impedance

Frequency	Real (Ohm)	Imag (Ohm)
2.400 GHz	23.931	20.436
2.405 GHz	24.033	20.358
2.410 GHz	24.039	20.255
2.415 GHz	24.157	20.189
2.420 GHz	24.225	20.154
2.425 GHz	24.389	20.072
2.430 GHz	24.457	20.106
2.435 GHz	24.62	20.096
2.440 GHz	24.775	20.049
2.445 GHz	24.968	20.132
2.450 GHz	25.174	20.168
2.455 GHz	25.36	20.271
2.460 GHz	25.63	20.338
2.465 GHz	25.826	20.449
2.470 GHz	26.02	20.601
2.475 GHz	26.214	20.671
2.480 GHz	26.406	20.75

Note: The RF Port Impedance will be 50 Ohm by adding a parallel about 1 pF capacitor.