



## **ATS3015 Datasheet**

**Actions® ATS3015™ QFN32**

**Bluetooth Audio Solution**

**Low Power Solution for  
Portable & Wireless  
Audio Applications  
Headphone and Earphone**

**RISC32 core Single-chip  
Bluetooth 5.2**

*Version: V1.4*

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2021-8-3

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## Revision History

| Date      | Revision | Description                                               |
|-----------|----------|-----------------------------------------------------------|
| 2020-4-27 | V1.0     | Initial version                                           |
| 2020-6-2  | V1.1     | Add performance parameters of BLE mode.                   |
| 2020-8-25 | V1.2     | Change the company name to "Actions Technology Co., Ltd." |
| 2020-10-9 | V1.3     | Modify the description of SARADC.                         |
| 2021-8-3  | V1.4     | Upgrade Bluetooth version to BT5.2                        |

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# 1 Introduction

## 1.1 Overview

Actions' ATS3015 is a highly integrated single-chip Bluetooth Audio solution. Targeting at Bluetooth headsets and earphones market, ATS3015 satisfies the market requirements with high performance, low cost and low power consumptions.

ATS3015 adopts RISC32 core architecture. Large capacity RAM is embedded to meet different Bluetooth applications. ATS3015 supports decoding Bluetooth A2DP audio and loading sound effects simultaneously, supports Bluetooth handfree calls with microphone AEC and noise reduction.

ATS3015 integrates Bluetooth controller support BT5.2 and compliant with BT4.2/4.2 LE/4.0 Bluetooth specification, and supports dual mode (BR/EDR + Low Energy Controllers). The links in BR/EDR and LE can be active simultaneously.

ATS3015 take special methods at power optimization, especially for various applications scenarios, including sniff, Bluetooth idle, Bluetooth playing and call modes. Embedded PMU supports power optimization and provide long battery life. The competitive advantages of ATS3015 are high music and call qualities with low power and BOM, which lays the foundation for our goal at high-end market. Above all, ATS3015 provides a true "ALL-IN-ONE" solution, making it the ideal choice for highly integrated and optimized Bluetooth audio products.

## 1.2 Key Features

### System

- 200MHz 32bit RISC processor Core
- Internal 188K RAM for data and program
- Internal ROM for firmware implementation
- Internal 4M bits SPI serial Flash for custom defined software
- Support 24MHz OSC with on-chip PLL
- Operating voltage: I/O 3.3V, Core 1.2V
- Fully configurable PEQ, up to 14 segments
- Support for echo cancellation and noise reduction
- Support for wind noise reduction
- Support for packet loss concealment
- Support for voice prompt

### Bluetooth

- Support Bluetooth5.2, compatible with Bluetooth4.2/4.2 LE/4.0/2.1 + EDR system
- Max transmitting output power: 10dBm
- Bluetooth receiving sensitivity:  
-95dBm@GFSK, -95dBm@ $\pi/4$  DQPSK,  
-86dBm@8DPSK modulation
- Compatible with AVRCP Profile V1.6
- Compatible with A2DP Profile V1.3
- Compatible with HFP Profile V1.7
- TWS two earphones can switch between master and slave at will
- Support for SBC & AAC Bluetooth audio transmission format
- Support for mSBC broadband speech coding
- Supports all packet types in basic rate and enhanced data rate
- Supports SCO/eSCO link
- Supports Secure Simple Pairing
- Supports Low Power Mode ( Sniff / Sniff Sub-rating / Hold / Park )
- Bluetooth Dual Mode support: Simultaneous LE and BR / EDR
- Supports multiple Low Energy states
- Fast AGC control to improve receiving dynamic range
- Supports AFH to dynamically detect channel quality to improve transmission quality
- Supports Power/Enhanced Power Control
- LE Data Packet Length Extension
- Extended Scanner Filter Policies
- LE 2M PHY
- LE Extended Advertising
- LE Periodic Advertising
- Channel Selection Algorithm #2

### Audio

- Build in mono 16-bit input sigma-delta ADC, SNR>85dB, THD+N<-81dB
- ADC supports sample rate 8k/12k/11.025k/16k/22.05k/24k/32k/44.1k/48kHz
- Supports mono input analog microphone
- Supports two digital microphones
- Supports stereo single-ended line in
- Build in stereo 20-bit input sigma-delta DAC, SNR>98dB, THD+N<-84dB
- DAC supports sample rate 8k/12k/11.025k/16k/22.05k/24k/32k/44.1k/48k/96kHz
- Build in stereo 18mW PA for headphone
- Support I2S TX with master mode, sampling rate from 8KHz to 96KHz
- Support I2S RX , sampling rate from 8KHz to 48KHz

### Power Management

- Supports Li-Ion battery and 5V power supply
- Supports 5V power supply plugged in reset
- Integrated linear battery charger up to 300mA charging current, which supports CC/CV mode, does not support charging battery directly
- Integrated Low precision A/D converters for battery voltage monitor, temperature monitor and wire-controller
- Energy saving with dynamic power management
- Integrated DC-DC buck converters, which can be switch to LDO mode
- Supports DC5V insertion detection
- Supports DC5V pull out detection
- Low Power Consumption:  
A2DP TWS: 6mA(Min)@Vbat = 3.8V  
HFP TWS: 8.3mA@Vbat=3.8V  
Typical Sniff Current: 300 $\mu$ A@500ms  
Deep sleep: <1 $\mu$ A@Vbat = 3.8V

### Physical Interfaces

- Support 10 GPIO
- Support 10-bits SARADC
- Support 5 PWM for lamp controller
- Serial Interface: SPI\*2, UART\*2, I2C\*2

### Package

- QFN-32 (4\*4\*0.75mm, Pitch 0.4mm)



### 1.3 Application Diagram

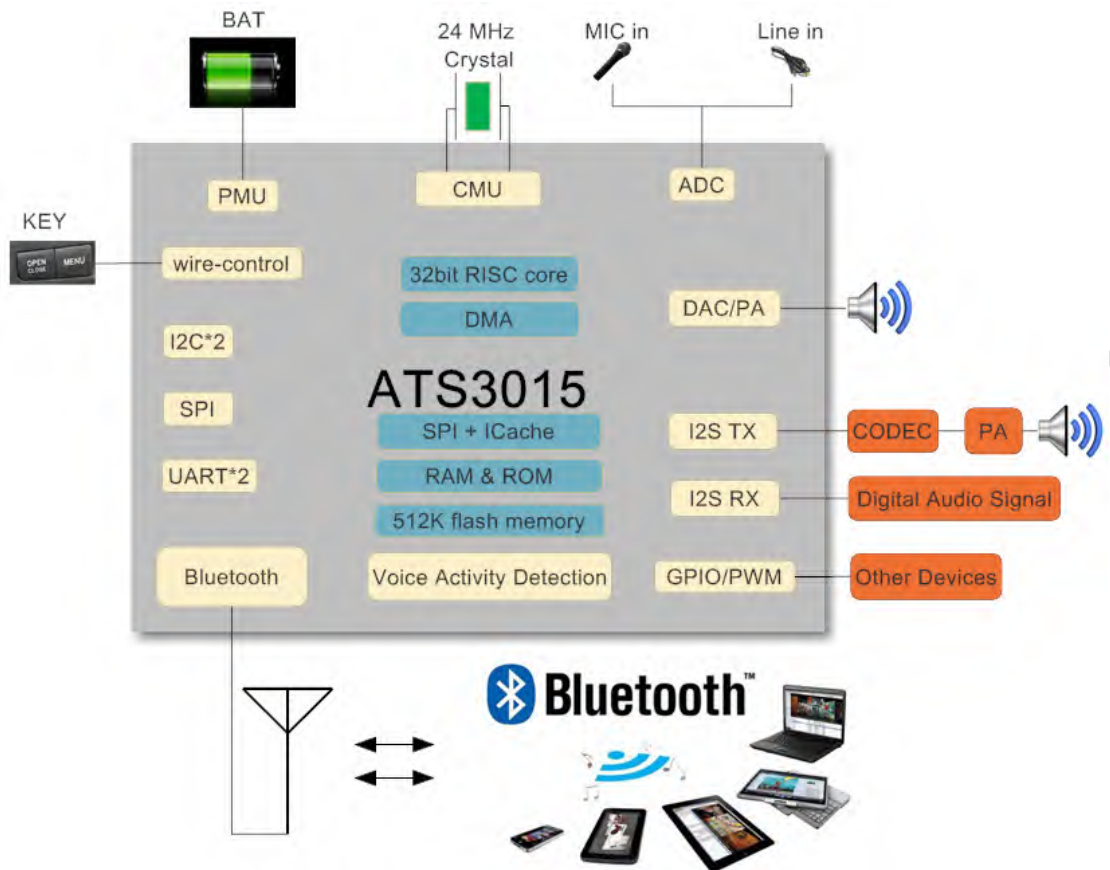
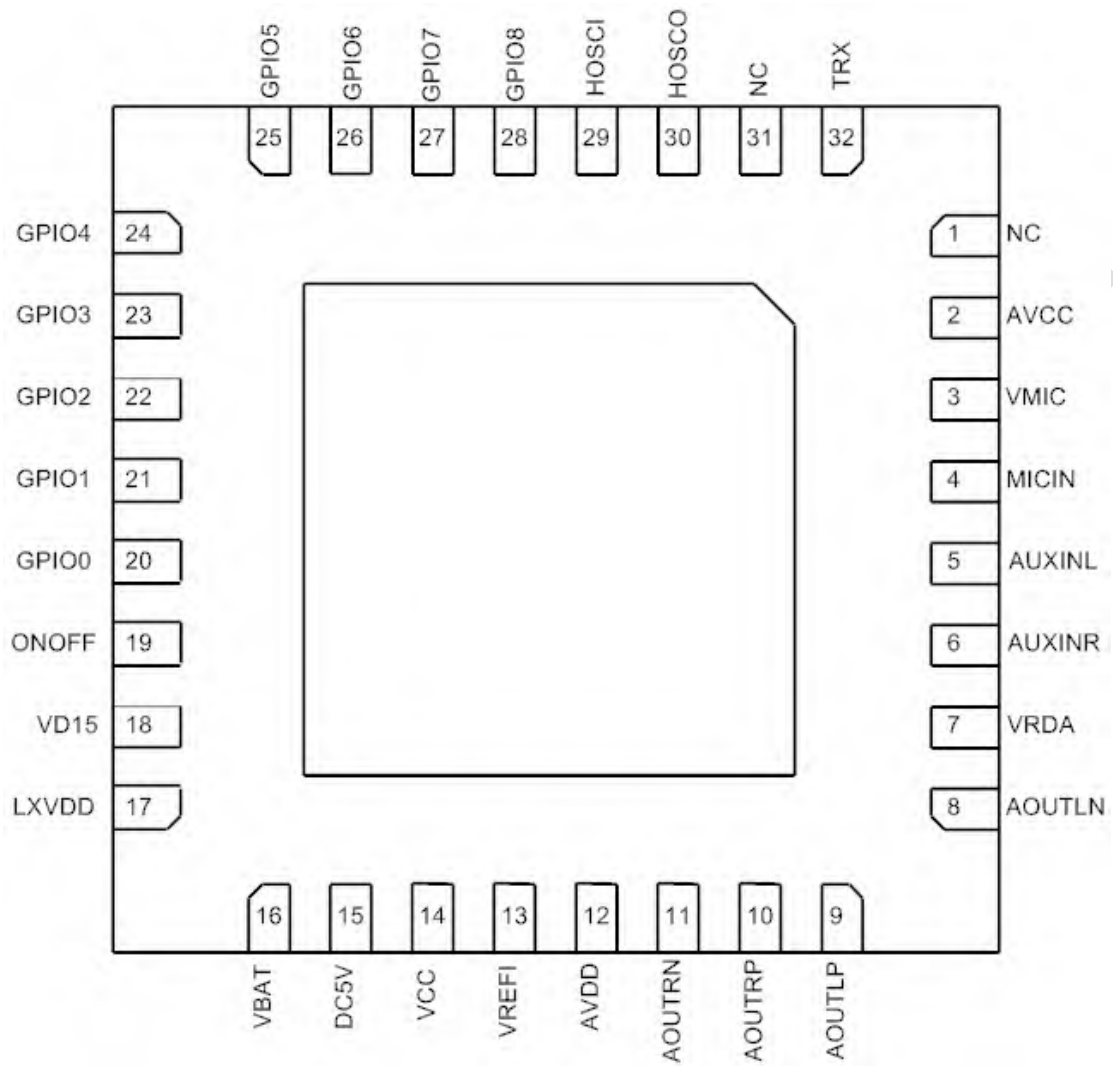


Figure 1-1 ATS3015 Application Diagram

## 1.4 Pin Assignment and Descriptions

### 1.4.1 Pin Assignment



## 1.4.2 Pin Description

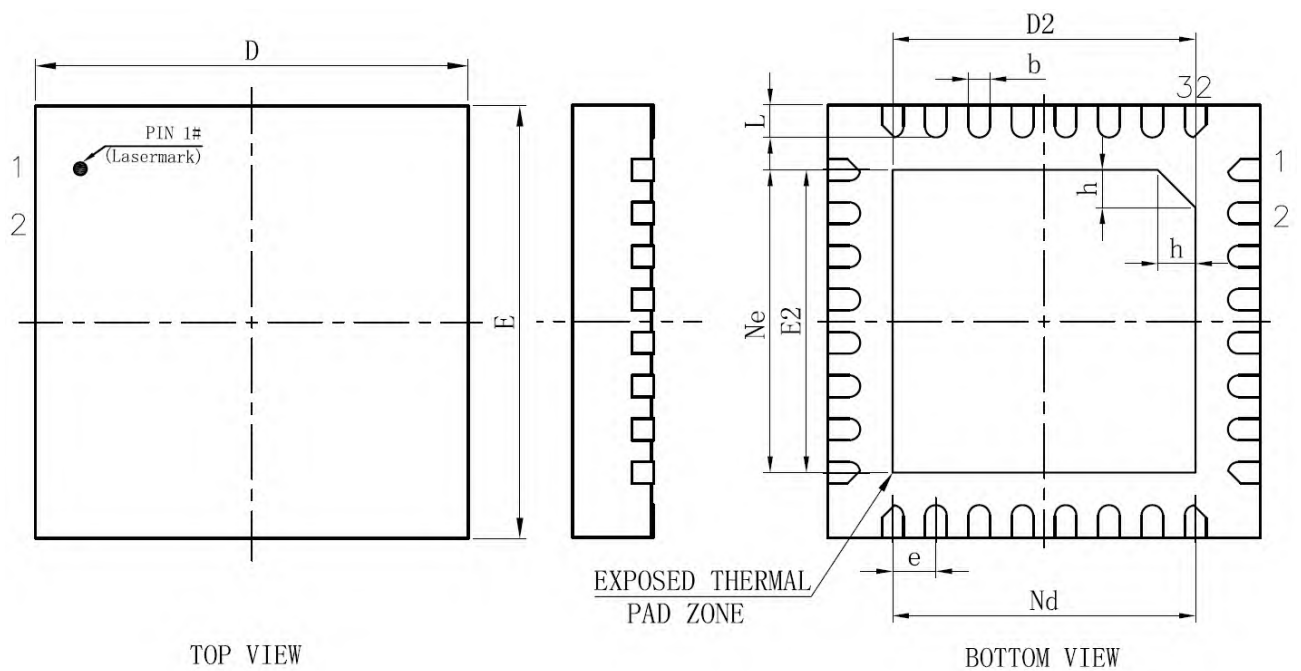
| Pin No. | Pin Name | Function Multiplex                                                      | IO Type | PAD Drive Level | GPIO Initial State | Description                            |
|---------|----------|-------------------------------------------------------------------------|---------|-----------------|--------------------|----------------------------------------|
| 1       | NC       |                                                                         |         |                 |                    |                                        |
| 2       | AVCC     |                                                                         | PWR     |                 |                    | 2.95v voltage                          |
| 3       | VMIC     | GPIO9<br>PWM3<br>SIRQ<br>I2C0_SDA<br>DMIC_CLK<br>UART0_RX<br>I2C1_SDA   | DIO     | 2/4/8/10 mA     | Z                  | VMIC(MIC power) or General purpose I/O |
| 4       | MICIN    | DMIC_DAT                                                                | AI/DIO  |                 |                    | Microphone input                       |
| 5       | AUXINL   |                                                                         | AIO     |                 |                    | Left channel of AUX input              |
| 6       | AUXINR   |                                                                         | AIO     |                 |                    | Right channel of AUX input             |
| 7       | VRDA     |                                                                         | PWR     |                 |                    | AUDIO power                            |
| 8       | AOUTLN   |                                                                         | AIO     |                 |                    | Left channel of AUDIO Analog output    |
| 9       | AOUTLP   |                                                                         | AIO     |                 |                    |                                        |
| 10      | AOUTRP   |                                                                         | AIO     |                 |                    | Right channel of AUDIO Analog output   |
| 11      | AOUTRN   |                                                                         | AIO     |                 |                    |                                        |
| 12      | AVDD     |                                                                         | PWR     |                 |                    | 1.2v voltage                           |
| 13      | VREFI    |                                                                         | PWR     |                 |                    | Reference Voltage input                |
| 14      | VCC      |                                                                         | PWR     |                 |                    | Digital power pin                      |
| 15      | DC5V     |                                                                         | PWR     |                 |                    | 5.0V Voltage                           |
| 16      | VBAT     |                                                                         | PWR     |                 |                    | Battery Voltage input.                 |
| 17      | LXVDD    |                                                                         | PWR     |                 |                    | LXVDD                                  |
| 18      | VD15     |                                                                         | PWR     |                 |                    | 1.5v voltage                           |
| 19      | ONOFF    |                                                                         | PWR     |                 |                    | ON/OFF reset signal                    |
| 20      | GPIO0    | SARADC<br>UART0_TX<br>UART1_TX<br>I2C1_SDA<br>SDC_CLK                   | DIO     | 2/4/8/10 mA     | Z                  | General purpose I/O                    |
| 21      | GPIO1    | PWM0<br>UART0_TX<br>I2C0_SCL                                            | DIO     | 2/4/8/10 mA     | Z                  | General purpose I/O                    |
| 22      | GPIO2    | PWM1<br>UART0_RX<br>I2C0_SDA<br>DMIC_CLK                                | DIO     | 2/4/8/10 mA     | Z                  | General purpose I/O                    |
| 23      | GPIO3    | PWM2<br>UART0_CTS<br>UART0_TX<br>I2STX_MCLK<br>I2SRX_MCLK<br>I2C1_SCL   | DIO     | 2/4/8/10 mA     | Z                  | General purpose I/O                    |
| 24      | GPIO4    | PWM3<br>UART0_RTS<br>UART0_TX<br>UART1_RX<br>I2STX_LRCLK<br>I2SRX_LRCLK | DIO     | 2/4/8/10 mA     | Z                  | General purpose I/O                    |

|    |       |                                                                   |     |                |   |                       |
|----|-------|-------------------------------------------------------------------|-----|----------------|---|-----------------------|
| 25 | GPIO5 | PWM4<br>SPI1_CLK<br>UART1_CTS<br>I2STX_BCLK<br>I2SRX_BCLK         | DIO | 2/4/8/10<br>mA | Z | General purpose I/O   |
| 26 | GPIO6 | PWM0<br>SIRQ<br>UART1_RTS<br>SPI1_SS<br>I2STX_DOUT<br>I2SRX_DIN   | DIO | 2/4/8/10<br>mA | Z | General purpose I/O   |
| 27 | GPIO7 | PWM1<br>I2C0_SCL<br>DMIC_DAT<br>DMIC12_DAT<br>SPI1_MOSI           | DIO | 2/4/8/10<br>mA | Z | General purpose I/O   |
| 28 | GPIO8 | PWM2<br>SARADC<br>DMIC12_CLK<br>I2C0_SDA<br>I2C1_SCL<br>SPI1_MISO | DIO | 2/4/8/10<br>mA | Z | General purpose I/O   |
| 29 | HOSCI |                                                                   | AI  |                |   | 24MHz clock input     |
| 30 | HOSCO |                                                                   | AO  |                |   | 24MHz clock output    |
| 31 | NC    |                                                                   |     |                |   |                       |
| 32 | TRX   |                                                                   | RF  |                |   | Bluetooth antenna IO  |
| 33 | EPAD  |                                                                   | GND |                |   | Exposed pad as ground |

Note:

1. Z: high resistance;
2. There are two pull-up (100kΩ/10kΩ) and one pull-down (100kΩ) configurable resistance for the GPIO0 to GPIO9.

### 1.4.3 Package Dimensions



| SYMBOL  | MILLIMETER |      |      |
|---------|------------|------|------|
|         | MIN        | NOM  | MAX  |
| A       | 0.70       | 0.75 | 0.80 |
| A1      | 0          | 0.02 | 0.05 |
| b       | 0.15       | 0.20 | 0.25 |
| c       | 0.18       | 0.20 | 0.25 |
| D       | 3.90       | 4.00 | 4.10 |
| D2      | 2.70       | 2.80 | 2.90 |
| e       | 0.40BSC    |      |      |
| Ne      | 2.80BSC    |      |      |
| Nd      | 2.80BSC    |      |      |
| E       | 3.90       | 4.00 | 4.10 |
| E2      | 2.70       | 2.80 | 2.90 |
| L       | 0.25       | 0.30 | 0.35 |
| h       | 0.30       | 0.35 | 0.40 |
| L/F载体尺寸 | 122X122    |      |      |

## 2 Bluetooth

### 2.1 Features

- Support Bluetooth V5.2
- Compatible with Bluetooth V4.2/V4.2 LE/V3.0/V2.1 +EDR systems
- Supports all packet types in basic rate and enhanced data rate
- Support Bluetooth transceiver
- Supports SCO/eSCO link
- Supports Secure Simple Pairing
- Supports Low Power Mode ( Sniff / Sniff Sub-rating / Hold / Park )
- Bluetooth Dual Mode support: Simultaneous LE and BR / EDR
- Supports multiple Low Energy states
- Fast AGC control to improve receiving dynamic range
- Supports AFH to dynamically detect channel quality to improve transmission quality
- Supports GFSK,  $\pi/4$  DQPSK and 8DPSK modulation
- Supports Power / Enhanced Power Control

### 2.2 Bluetooth V5.2 Features

- LE Data Packet Length Extension
- LE 2M PHY
- Channel Selection Algorithm #2

### 2.3 Bluetooth Performance

- Max transmitting output power: 10dBm
- Bluetooth receiving sensitivity: -95dBm@GFSK, -95dBm@ $\pi/4$  DQPSK, -86dBm@8DPSK modulation

## 3 Processor Core

- 200MHz RISC32 processor Core
- 32-bit Address and Data Paths
- RISC32-Compatible Instruction Set
- RISC32 Enhanced Architecture (Release 2) Features
- RISC16e™ Code Compression

## 4 Memory Controller

The memory controller provides dynamically allocated ring buffers that hold the data that is in transit between the host and the air. The dynamic allocation of memory ensures efficient use of the available RAM and is performed by hardware to minimize the overheads on the processor during data/voice transfers. The use of DMA ports also helps with efficient transfer of data to other peripherals.

- Full synchronous design with operation clock rate up to 200MHz.
- Internal 32KB CPU ICACHE for SPI NorFlash, which can be switched to 32K SRAM when Cache is useless.
- Internal 188KB SRAM for data and program
- On-chip 4M bits serial Flash for custom defined software. Users can download program by UART.

- It is accessible for all the RAM blocks through DMA.
- Arbitrate the priority of CPU and DMA access internal RAM simultaneously.
- It is accessible for all the RAM and ROM block through CPU' data bus and program bus.

## 5 DMA Controller

- Support for memory-to-memory, memory-to-peripheral, and peripheral-to-memory.
- 7-channel ordinary DMA, including DMA0, DMA1, DMA2, DMA3, DMA4, DMA5, DMA6 supports for transmission in burst 8 mode. Only one of the DMA channels can transfer data at the same time.
- DMA0/DMA1/DMA2/DMA3/DMA4/DMA5/DMA6 transmission can be triggered on the occurrence of selected events as following: memory, baseband TX & RX, modem, UART0 RX & TX, UART1 RX & TX, SPI0 RX & TX, SPI1 RX & TX, ADC, DMIC, I2S RX & TX, DAC.
- Each channel can send two interrupts to the CPU on completion of certain operational events.
- Transmission width includes 16-bit, and 32-bit, which is determined by DMA transmission type as following:
  - 8-bit: UART
  - 16-bit: ADC, DAC, I2S RX & TX, DMIC
  - 32-bit: memory, BT-baseband, BT-modem, I2S RX, DMIC

## 6 PMU

### 6.1 Features

The ATS3015 integrates a comprehensive power supply system, including the following features:

- Supports Li-Ion battery and 5V power supply
- Supports 5V power supply plugged in reset
- Supports standby current <1uA and power on button
- Integrated linear battery charger, which supports CC/CV mode, do not support charging battery directly
- Integrated DC-DC buck converters output VD15
- Integrated linear regulators output VCC, AVCC, and AVDD
- Integrated Low precision A/D converters for battery voltage monitor, temperature monitor and wire-controller
- Supports DC5V insertion detection
- Supports DC5V pull out detection

### 6.2 Module Description

#### 6.2.1 DC-DC Converter

The DC-DC converter efficiently scales battery voltage to the required supply voltage. The DC-DC converters include several advanced features:

- Input power from BAT
- Low power consumption
- Synchronization DC-DC converter architecture
- Programmable output voltages 1.0~1.7V
- Work in Pulse Frequency Modulation (PFM) or Pulse-Width Modulation (PWM) automatically for different load current
- Support 2.2uH and 4.7uH power inductor

- If the system is to operate from linear regulators or an external power supply, then the internal DC-DC converters are powered down automatically.

## 6.2.2 Linear Regulators

The ATS3015 integrates 3 linear regulators respectively generate VCC, AVCC, AVDD.

The output voltages are precisely within  $\pm 2\%$ , providing large currents with a significantly small dropout voltage within  $\pm 5\%$ . Table below shows data of maximum output current.

**Table 6-1 Regulators Maximum Output Current**

| Block Name | Input Voltage(V) | Output Voltage(V) | Output Capacitor( $\mu$ F) | Load Capacity@ voltage drop to 95%(mA) |
|------------|------------------|-------------------|----------------------------|----------------------------------------|
| VCC        | BAT(2.8~4.3)     | 3.1               | 2.2                        | 80                                     |
| AVCC       | VCC(3.1)         | 2.95              | 1                          | 10                                     |
| AVDD       | VD15(1.5)        | 1.2               | 1                          | 100                                    |

## 6.2.3 Li-Ion Cell Charger

ATS3015 integrate charger for Li-Ion battery from a 5V source connected to the DC5V pin. The battery charger is essentially a linear regulator that has current limit and voltage limits. The charger is enable defaulted.

There is 3 phases through all the charging process: When battery voltage is below 2.8V, the charger outputs only 20mA for pre-charge. When battery voltage is between 3.0V to 4.2V, this phase is called constant current charging phase. At this phase, the charging current is constant and the voltage of battery is going up slowly. When battery voltage arrives 4.2V, the battery voltage will be constant, and the charging current will be reduced gradually, this phase is called constant voltage phase.

One can programmatically monitor the battery voltage using the BATADC. The charger has its own voltage limiting that operates independently of the BATADC. But monitoring the battery voltage and DC5V voltage during the charge might be helpful for reporting the charge progress.

# 7 System Control

## 7.1 RMU

- The RMU (Reset Management Unit) can reset all the peripherals.
- The MCU can enter power-saving mode by setting the registers of RMU.
- Each module has a separate reset control unit.

## 7.2 CMU

- Support only one oscillator inputs: 24MHz
- Supply 3 PLLs and special clocks of all modules
- The 3 PLLs is SPLL, CORE PLL, and Audio PLL
- CORE PLL support spread spectrum

## 7.3 Timer

- Built-in a 32k oscillator
- Two Timers with IRQS using High frequency oscillator
- A watch dog which can be configured as IRQ or Reset



## 7.4 Exceptions and Interrupts Controller (INTC)

The ATS3015 use RISC32 processor. The ATS3015 also adds additional controller to manage up to 32 interrupt sources.

Table below shows all interrupt sources.

| Interrupt Number | Sources     | Type       |
|------------------|-------------|------------|
| 0                | BT_BASEBAND | High Level |
| 1                | DMA         | High Level |
| 2                | Watch Dog   | High Level |
| 3                | TIMERO      | High Level |
| 4                | TIMER1      | High Level |
| 5                | SPIO        | High Level |
| 6                | UART0       | High Level |
| 7                | SIRQ        | High Level |
| 8                | BB_TWS      | High Level |
| 9                | DAC_I2S TX  | High Level |
| 10               | ADC         | High Level |
| 11               | VAD         | High Level |
| 12               | I2C0        | High Level |
| 13               | Reserved    | High Level |
| 14               | DMIC_I2S RX | High Level |
| 15               | UART1       | High Level |
| 16               | Reserved    | High Level |
| 17               | SPI1        | High Level |
| 18               | I2C1        | High Level |
| 21~31            | Reserved    | High Level |

## 8 Serial Interfaces

### 8.1 UART

ATS3015 contains two UART interfaces named UART0 and UART1. Each has the following features:

- 5-8 Data Bits and LSB first in Transmit and Received
- 1-2 Stop Bits
- Even, Odd, or No Parity
- 8 Byte Transmit and Receive FIFOs while both was in 16 levels depth
- Capable of speeds up to 6Mbps to other peripherals
- Support IRQ and DMA mode to transmit data
- Support RTS/CTS Automatic Hardware Flow Control to reduce interrupts to host system
- UART RX DMA counter for valid data in RAM

### 8.2 I2C

ATS3015 contains two I2C interfaces named I2C0 and I2C1. Each has the following features:

- Both master and slave functions support
- Support standard mode (100kbps) and fast-speed mode (400kbps)
- Support fifo and non\_fifo mode when W/R the data
- The sequence of data or address transfer from MSB
- Only 7-bit address mode support

- 8 Bit x8 TX FIFO and 8Bit x8 RX FIFO

Pull-up resistors are required on both of the I2C signal lines as the I2C drivers are open drain typically external 2.2k-Ohm resistors are used to pull the signals up to VCC if not select internal pull-Up resistor in standard and fast mode.

## 8.3 SPI

ATS3015 contains two SPI interfaces named SPI0 and SPI1. SPI0 is used to connect to NorFlash. SPI1 can be customized by customers.

- Support SPI normal mode: mode 0\1\2\3
- Only support normal 4 wire mode
- Support IRQ and DMA mode to transmit data

# 9 Audio Interfaces

## 9.1 ADC

- Built-in mono 16 bit input sigma-delta ADC, SNR>85dB, THD+N<-81dB
- ADC supports sample rate 8k/12k/11.025k/16k/22.05k/24k/32k/44.1k/48kHz
- Supports mono single-ended input analog microphone
- Supports digital microphones
- Supports stereo single-ended line in
- ADC and DMIC are mutually exclusive

## 9.2 DAC

- Built-in stereo 20 bit input sigma-delta DAC, SNR > 98dB, THD+N <- 84dB
- DAC supports sample rate 8k/12k/11.025k/ 16k/22.05k/24k/32k/44.1k/48k/96kHz
- Built-in stereo 20mW PA(Power Amplifier) for headphone
- The PA output supports traditional mode (non-direct drive mode) and differential mode
- The Power Amplifier drive external Power Amplifier with low noise, low distortion

## 9.3 I2S TX

- Support I2S Transmitter(TX) with master mode
- I2S TX supports Sample Rate 8k/12k/11.025k/16k/22.05k/24k/32k/44.1k/48k/88.2k/96kHz

## 9.4 I2S RX

- Support with master mode and slave mode
- I2S RX supports Sample Rate 8k/12k/11.025k/16k/22.05k/24k/32k/44.1k/48kHz
- Support I2S/ left-justified/ right-justified/ TDM format, with 16/20/24 bit data width
- Support TDM 4/8 channel, with A/B mode
- Support sample rate auto detect in slave mode

## 10 GPIO and I/O Multiplexer

### 10.1 GPIO Features

#### GPIO (General Purpose Input /Output) and MFP:

GPIO can output 0 or 1 and detect the signal level of the external circuit. Each GPIO has its own enable control bit and data registers. But the PADS are limited, so MFP module is designed for multiplexing these PADS.

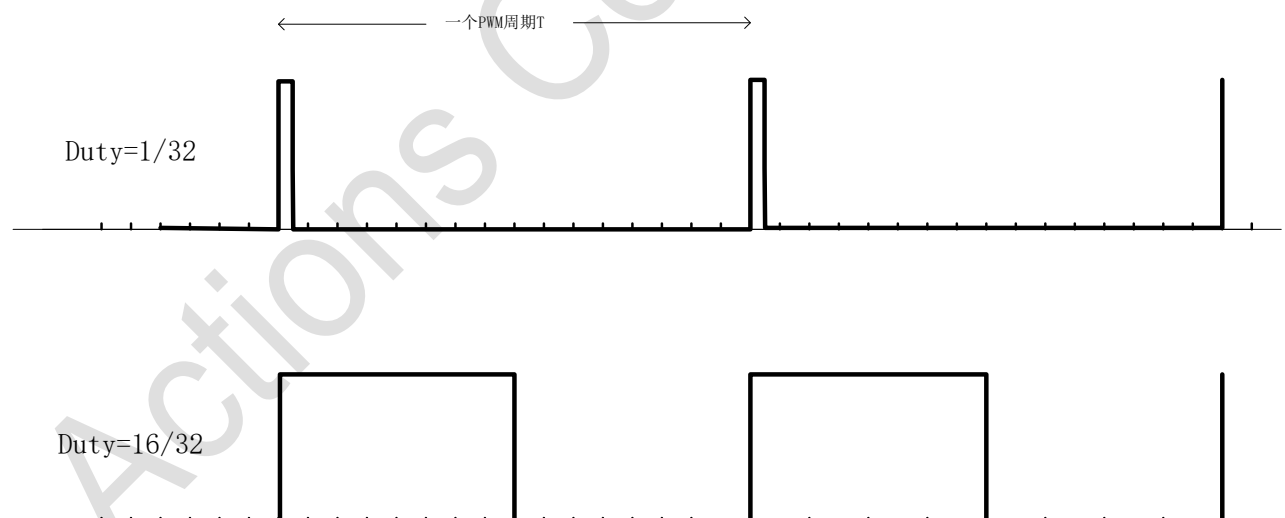
- Supports 10 GPIO
- Some PAD has internal pull down or pull up resistors
- Driving strength can be adjusted which has 4 Level
- Automatically switching PAD function
- The Schmitt trigger can be configured to open or close
- Support 5 channels PWM output
- An external interruption SIRQ

### 10.2 PWM

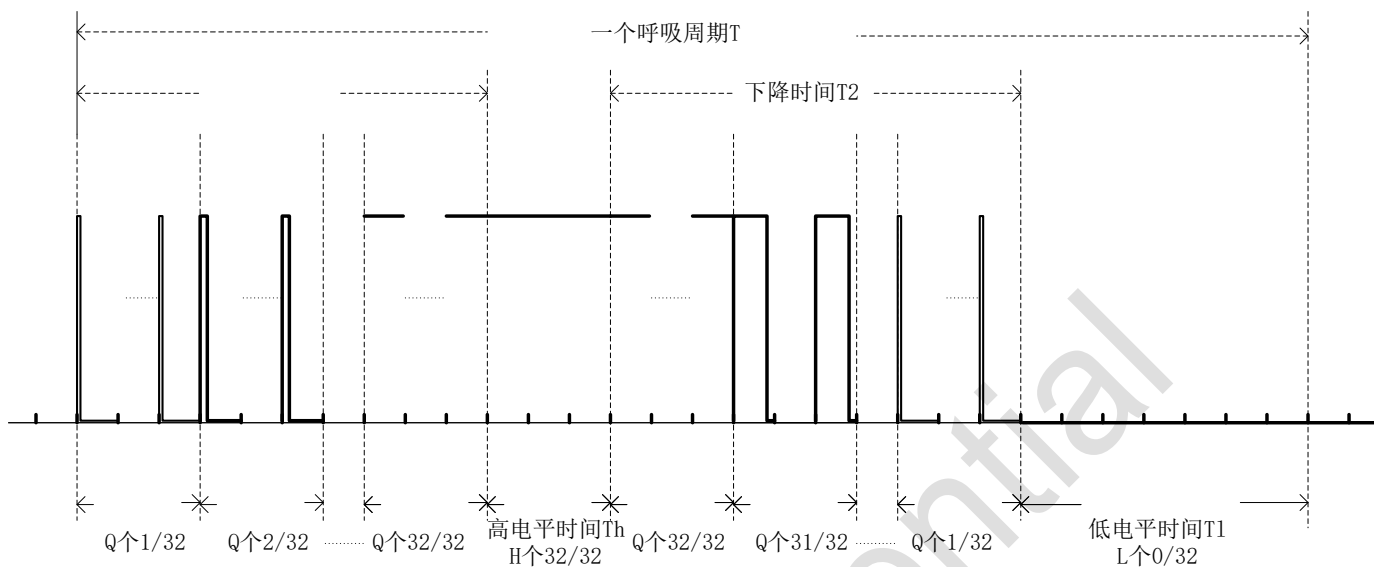
PWM output module is embedded in ATS3015, in the purpose of controlling the external backlight, indicator or Bluetooth Breath Led. It supplies widely variable output frequency from 32KHz to 24MHz and 32-level duty occupancy for precise adjustment.

There are five independent PWM can be used, namely PWM0, PWM1, PWM2, PWM3, PWM4. Each PWM has two modes, namely Normal Mode and Breath Mode.

#### 10.2.1 Normal Mode Timing



## 10.2.2 Breath Mode Timing



## 11 Electrical Characteristics

### 11.1 Absolute Maximum Ratings

| Parameter           | Symbol                  | Min  | Max  | Unit |
|---------------------|-------------------------|------|------|------|
| Ambient Temperature | Tamb                    | TBD  | TBD  | °C   |
| Storage temperature | Tstg                    | -55  | +150 | °C   |
| ESD Stress voltage  | Vesd (Human body model) | 4000 | -    | V    |
| Supply Voltage      | DC5V                    | -0.3 | 6    | V    |
|                     | BAT                     | -0.3 | 4.5  | V    |
|                     | VCC /AVCC               | -0.3 | 3.6  | V    |
|                     | AVDD                    | -0.3 | 1.5  | V    |
| Input Voltage       | 3.3V IO                 | -0.3 | 3.6  | V    |

Note:

- 1) Even if one of the above parameters exceeds the absolute maximum ratings momentarily, the quality of the product may be degraded. The absolute maximum ratings, therefore, specify the value exceeding, which the product may be physically damaged. Use the product well within these ratings.
- 2) All voltage values are with respect to GND.

### 11.2 Recommended Power Supply

| Supply Voltage | Min  | Typ | Max  | Unit |
|----------------|------|-----|------|------|
| BAT (Li)       | 3.2  | 3.8 | 4.35 | V    |
| DC5V           | 4.5  | 5   | 6    | V    |
| VCC/AVCC       | 2.8  | 3.1 | 3.4  | V    |
| AVDD           | 1.08 | 1.2 | 1.32 | V    |

### 11.3 DC Characteristics

DC Parameters for +3.3V IO PIN

| Parameter                 | Symbol | MIN. | MAX. | Unit | Condition                         |
|---------------------------|--------|------|------|------|-----------------------------------|
| Low-level input voltage   | VIL    |      | 0.8  | V    | VCC = 3.1V<br>Tamb = -10 to 70 °C |
| High-level input voltage  | VIH    | 2.0  |      | V    |                                   |
| Low-level output voltage  | VOL    |      | 0.4  | V    |                                   |
| High-level output voltage | VOH    | 2.4  |      | V    |                                   |

## 11.4 Battery Charger

| Parameter                        | Min.    | Typ. | Max. | Unit |
|----------------------------------|---------|------|------|------|
| Input Voltage                    | BAT+0.1 | 5    | 6    | V    |
| Charge Current (CC Mode)         | 10      | 60   | 300  | mA   |
| Trickle Charge Current           | -       | 20   | -    | mA   |
| Trickle Charge Threshold Voltage | -       | 2.8  | -    | V    |
| Regulated Output (Float) Voltage | 3.3     | 4.2  | 4.35 | V    |

## 11.5 Power Consumption

VDD = 1.2V @ 25°C, without speaker and led loading, RF TX power = +6dBm, Vbat = 3.8V

| Parameter  | Condition              | Min. | Typ. | Max. | Unit |
|------------|------------------------|------|------|------|------|
| A2DP       | TWS, SBC bit pool = 49 | -    | 7.5  | -    | mA   |
| HFP        | TWS, Sample Rate 16KHz | -    | 8.3  | -    | mA   |
| Sniff Mode | 500ms                  | -    | -    | 300  | μA   |
| Deep Sleep | Vbat = 3.8V            | 0.1  | -    | 1    | μA   |

## 11.6 Bluetooth Characteristics

### 11.6.1 Transmitter BT Classic Basic Data Rate(BDR)

| Parameter                            | Condition                 | Min. | Typ. | Max.  | Unit     |
|--------------------------------------|---------------------------|------|------|-------|----------|
| Maximum RF Transmit PWR              | -                         | -    | 8    | 10    | dBm      |
| RF PWR Control Step                  | -                         | 2    | 4    | 8     | dB       |
| 20dB Bandwidth for Modulated Carrier | -                         | -    | 914  | 1500- | KHz      |
| Adjacent Channel Transmit            | +2 MHz                    | -    |      | -20   | dBm      |
|                                      | -2 MHz                    | -    |      | -20   | dBm      |
|                                      | +3 MHz                    | -    |      | -40   | dBm      |
|                                      | -3 MHz                    | -    |      | -40   | dBm      |
| Frequency Deviation                  | Δf1avg Maximum Modulation | 140  | 166  | 175   | KHz      |
|                                      | Δf2max Maximum Modulation | 115  | 130  |       | KHz      |
|                                      | Δf1avg/Δf2avg             | 0.8  | 0.93 |       |          |
| Initial Carrier Frequency Tolerance  | -                         | -75  | 10   | 75    | KHz      |
| Frequency Drift                      | DH1 Packet                | -25  | -4.5 | 25    | KHz      |
|                                      | DH3 Packet                | -40  | -5.5 | 40    | KHz      |
|                                      | DH5 Packet                | -40  | -5.5 | 40    | KHz      |
| Frequency Drift Rate                 | -                         | -20  | 3    | 20    | KHz/50us |
| Harmonic Content                     | -                         | -    | -40  | -     | dBm      |

### 11.6.2 Transmitter BT Classic Enhanced Data Rate(EDR)

| Description                                                         |                         | Min | Typ. | Max. | Unit |
|---------------------------------------------------------------------|-------------------------|-----|------|------|------|
| Maximum RF Transmit PWR                                             |                         |     | 8    | 10   | dBm  |
| Relative Transmit PWR(EDR)                                          |                         | -4  | -2.5 | 1    | dB   |
| $\pi/4$ DQPSK max carrier frequency stability $ \omega_0 $          |                         | -10 | 2    | 10   | KHz  |
| $\pi/4$ DQPSK max carrier frequency stability $ \omega_i $          |                         | -75 | -3   | 75   | KHz  |
| $\pi/4$ DQPSK max carrier frequency stability $ \omega_0+\omega_i $ |                         | -75 | -3   | 75   | KHz  |
| 8DPSK max carrier frequency stability $ \omega_0 $                  |                         | -10 | -3   | 10   | KHz  |
| 8DPSK max carrier frequency stability $ \omega_i $                  |                         | -75 | -3   | 75   | KHz  |
| 8DPSK max carrier frequency stability $ \omega_0+\omega_i $         |                         | -75 | -3   | 75   | KHz  |
| $\pi/4$ DQPSK Modulation Accuracy                                   | RMS DEVM                |     | 6    | 20   | %    |
|                                                                     | 99% DEVM                | 99  | 100  |      | %    |
|                                                                     | Peak DEVM               |     | 15   | 35   | %    |
| In-band spurious emissions                                          | $F > F_0 + 3\text{MHz}$ |     |      | -40  | dBm  |
|                                                                     | $F < F_0 - 3\text{MHz}$ |     |      | -40  | dBm  |
|                                                                     | $F = F_0 + 3\text{MHz}$ |     |      | -40  | dBm  |
|                                                                     | $F = F_0 - 3\text{MHz}$ |     |      | -40  | dBm  |
|                                                                     | $F = F_0 + 2\text{MHz}$ |     |      | -20  | dBm  |
|                                                                     | $F = F_0 - 2\text{MHz}$ |     |      | -20  | dBm  |
|                                                                     | $F = F_0 + 1\text{MHz}$ |     |      | -26  | dBm  |
| EDR Differential Phase Encoding                                     |                         | 99  | 100  |      | %    |

### 11.6.3 Transmitter Bluetooth Low Energy(BLE) 1Mbps

| Description                |                                                 | Min. | Typ. | Max. | Unit |
|----------------------------|-------------------------------------------------|------|------|------|------|
| Maximum RF Transmit PWR    |                                                 |      | 8    |      | dBm  |
| In-band emissions          | +2 MHz                                          |      | -45  | -20  | dBm  |
|                            | -2 MHz                                          |      | -46  | -20  | dBm  |
|                            | +3 MHz                                          |      | -48  | -30  | dBm  |
|                            | -3 MHz                                          |      | -47  | -30  | dBm  |
| Modulation Characteristics | $\Delta f_{1\text{avg}}$<br>Maximum Modulation  | 225  | 240  | 275  | KHz  |
|                            | $\Delta f_{2\text{max}}$<br>Maximum Modulation  | 185  | 240  |      | KHz  |
|                            | $\Delta f_{1\text{avg}}/\Delta f_{2\text{avg}}$ | 0.8  | 1    |      |      |
| Carrier Frequency Offset   |                                                 | -150 | -5   | 150  | KHz  |
| Frequency Drift            |                                                 | -50  | -3   | 50   | KHz  |

### 11.6.4 Transmitter Bluetooth Low Energy(BLE) 2Mbps

| Description               |                                                 | Min. | Typ. | Max. | Unit |
|---------------------------|-------------------------------------------------|------|------|------|------|
| Maximum RF Transmit PWR   |                                                 |      | 8    |      | dBm  |
| Adjacent Channel Transmit | +2 MHz                                          |      | -54  | -20  | dBm  |
|                           | -2 MHz                                          |      | -54  | -20  | dBm  |
|                           | +3 MHz                                          |      | -57  | -30  | dBm  |
|                           | -3 MHz                                          |      | -57  | -30  | dBm  |
| Frequency Deviation       | $\Delta f_{1\text{avg}}$<br>Maximum Modulation  | 450  | 500  | 550  | KHz  |
|                           | $\Delta f_{2\text{max}}$<br>Maximum Modulation  | 370  | 420  |      | KHz  |
|                           | $\Delta f_{1\text{avg}}/\Delta f_{2\text{avg}}$ | 0.8  | 0.84 |      |      |
| Carrier Frequency Offset  |                                                 | -150 | -5   | 150  | KHz  |
| Frequency Drift           |                                                 | -50  | -5   | 50   | KHz  |

|                      |     |    |    |          |
|----------------------|-----|----|----|----------|
| Frequency Drift Rate | -20 | -3 | 20 | KHz/50us |
|----------------------|-----|----|----|----------|

### 11.6.5 Receiver BT Classic Basic Data Rate(BDR)

| Description                      | Min.                    | Typ. | Max. | Unit |
|----------------------------------|-------------------------|------|------|------|
| Sensitivity                      |                         | -95  |      | dBm  |
| Maximum Input PWR at 0.1% BER    | -20                     |      |      | dBm  |
| Co-Channel Interface             | -                       |      | 11   | dB   |
| Adjacent Channel Selectivity C/I | $F = F_0 + 1\text{MHz}$ | -    | 0    | dB   |
|                                  | $F = F_0 - 1\text{MHz}$ | -    | 0    | dB   |
|                                  | $F = F_0 + 2\text{MHz}$ | -    | -30  | dB   |
|                                  | $F = F_0 - 2\text{MHz}$ | -    | -30  | dB   |
|                                  | $F = F_0 + 3\text{MHz}$ | -    | -40  | dB   |
|                                  | $F = F_{\text{image}}$  | -    | -    | -9   |

### 11.6.6 Receiver BT Classic Enhanced Data Rate(EDR)

| Description                   | Min.          | Typ. | Max. | Unit |
|-------------------------------|---------------|------|------|------|
| Sensitivity at 0.1% BER       | $\pi/4$ DQPSK | -95  | -    | dBm  |
|                               | 8DPSK         | -    | -    | dBm  |
| Maximum Input PWR at 0.1% BER | $\pi/4$ DQPSK | -20  | -    | dBm  |
|                               | 8DPSK         | -20  | -    | dB   |
| CO-Channel Interference       | $\pi/4$ DQPSK | -    | 13   | dB   |
|                               | 8DPSK         | -    | 21   | dB   |

### 11.6.7 Receiver Bluetooth Low Energy(BLE) 1Mbps

| Description                   | Min.                                                            | Typ. | Max. | Specification                  |
|-------------------------------|-----------------------------------------------------------------|------|------|--------------------------------|
| Sensitivity LE 1M (dBm)       |                                                                 | -100 |      | <-70                           |
| Maximum Input PWR at 0.1% BER | -10                                                             |      |      | -10                            |
| C/I (dB)                      | Co-channel                                                      | 4    |      | <21dB                          |
|                               | Adjacent 1Mhz                                                   | -6   |      | <15dB                          |
|                               | Adjacent 2MHz                                                   | -44  |      | <-17dB                         |
|                               | Adjacent >=3Mhz                                                 | -50  |      | <-27dB                         |
|                               | Image interference                                              | -45  |      | <-9dB                          |
|                               | Imahe+/-1Mhz                                                    | -52  |      | <-15dB                         |
| Blocking(dBm)                 | 30Mhz~2000Mhz                                                   | -30  |      | -30                            |
|                               | 2000Mhz~2400MHz                                                 | -35  |      | -35                            |
|                               | 2500MHz~3000MHz                                                 | -35  |      | -35                            |
|                               | 3000MHz~12.75Ghz                                                | -30  |      | -30                            |
| Inter-Modulation              | Payload length: 37, n: 3,<br>Packets: 1500<br>RF Level: -64 dBm | -30  |      | PER $\leq$ 30.8%<br>$\geq$ -50 |
|                               | Payload length: 37, n: 4<br>Packets: 1500<br>RF Level: -64 dBm  | -30  |      | PER $\leq$ 30.8%<br>$\geq$ -50 |
|                               | Payload length: 37, n: 5<br>Packets: 1500<br>RF Level: -64 dBm  | -30  |      | PER $\leq$ 30.8%<br>$\geq$ -50 |

### 11.6.8 Receiver Bluetooth Low Energy(BLE) 2Mbps

| Description                   | Min.       | Typ. | Max. | Specification |
|-------------------------------|------------|------|------|---------------|
| Sensitivity LE 2M(dBm)        |            | -97  |      | <-70          |
| Maximum Input PWR at 0.1% BER | -10        |      |      | -10           |
| C/I (dB)                      | Co-channel | 17   |      | <21dB         |

|                  |                                                                 |     |     |  |                                |
|------------------|-----------------------------------------------------------------|-----|-----|--|--------------------------------|
|                  | Adjacent 1Mhz                                                   |     | -7  |  | <15dB                          |
|                  | Adjacent 2MHz                                                   |     | -47 |  | <-17dB                         |
|                  | Adjacent >=3Mhz                                                 |     | -52 |  | <-27dB                         |
|                  | Image interference                                              |     | -43 |  | <-9dB                          |
|                  | Image+/-2Mhz                                                    |     | -50 |  | <-15dB                         |
| Blocking(dBm)    | 30Mhz~2000Mhz                                                   | -30 |     |  | -30                            |
|                  | 2000Mhz~2400MHz                                                 | -35 |     |  | -35                            |
|                  | 2500MHz~3000MHz                                                 | -35 |     |  | -35                            |
|                  | 3000MHz~12.75Ghz                                                | -30 |     |  | -30                            |
| Inter-Modulation | Payload length: 37, n: 3,<br>Packets: 1500<br>RF Level: -64 dBm |     | -30 |  | PER $\leq$ 30.8%<br>$\geq$ -50 |
|                  | Payload length: 37, n: 4<br>Packets: 1500<br>RF Level: -64 dBm  |     | -30 |  | PER $\leq$ 30.8%<br>$\geq$ -50 |
|                  | Payload length: 37, n: 5<br>Packets: 1500<br>RF Level: -64 dBm  |     | -30 |  | PER $\leq$ 30.8%<br>$\geq$ -50 |

## 11.7 Audio ADC

| Pre-Amplifier                 |                                                          |              |     |     |      |      |
|-------------------------------|----------------------------------------------------------|--------------|-----|-----|------|------|
| Parameter                     | Conditions                                               |              | Min | Typ | Max  | Unit |
| Full Scale Input Voltage      | THD+N < 1%                                               |              | -   | -   | 0.56 | Vpp  |
| Analogue gain                 | AUX OP                                                   | -            | -6  | -   | 21   | dB   |
|                               | MIC OP                                                   | Single Ended | 9   | -   | 36   | dB   |
| Analogue to Digital Converter |                                                          |              |     |     |      |      |
| Resolution                    | -                                                        |              | -   | -   | 16   | Bits |
| Input Sample Rate             | -                                                        |              | 8   | -   | 48   | kHz  |
| SNR                           | fin = 1kHz@1.0Vpp<br>B/W = 22Hz~22kHz<br>Fs=48kHz        | -            | -   | 85  | -    | dB   |
|                               |                                                          | A-Weighting  | -   | 88  | -    | dB   |
| Dynamic Range                 | fin = 1kHz@10m Vpp<br>B/W = 22Hz~22kHz<br>Fs=48kHz       |              | -   | 85  | -    | dB   |
| THD+N                         | fin = 1kHz(input=0.4Vpp)<br>B/W = 22Hz~22kHz<br>Fs=48kHz |              | -   | -81 | -    | dB   |
| Digital gain                  | -                                                        |              | 0   | -   | 12   | dB   |

## 11.8 Stereo DAC

| Digital to Analogue Converter |                                                                  |             |     |     |     |      |
|-------------------------------|------------------------------------------------------------------|-------------|-----|-----|-----|------|
| Parameter                     | Conditions                                                       |             | Min | Typ | Max | Unit |
| Resolution                    | -                                                                |             | -   | -   | 20  | Bits |
| Output Sample Rate            | -                                                                |             | 8   | -   | 96  | kHz  |
| SNR                           | fin = 1kHz@0dBFS input<br>B/W = 22Hz~22kHz<br>Fs=48kHz, Load=16Ω | -           | -   | 98  | -   | dB   |
|                               |                                                                  | A-Weighting | -   | 100 | -   | dB   |
| Dynamic Range                 | fin = 1kHz@-40dBFS input                                         |             | -   | 92  | -   | dB   |



|                      |                                                                 |                             |      |      |     |       |
|----------------------|-----------------------------------------------------------------|-----------------------------|------|------|-----|-------|
|                      | B/W = 22Hz~22kHz<br>Fs=48kHz,Load=16Ω                           | A-Weighting                 | -    | 94   | -   | dB    |
| THD+N                | fin = 1kHz@0dBFS input<br>B/W = 22Hz~22kHz<br>Fs=48kHz,Load=16Ω | -                           | -    | -84  | -   | dB    |
| Digital gain         | -                                                               |                             | <-60 | -    | 30  | dB    |
| Stereo crosstalk     | fin = 1kHz@0dBFS input                                          | Differential output         | -    | -110 | -   | dB    |
| <b>PWR Amplifier</b> |                                                                 |                             |      |      |     |       |
| Max<br>Amplitude/PWR | fin = 1kHz@0dBFS input<br>Fs=48kHz,Load=16Ω                     | Single Ended<br>Output      | -    | -    | 283 | mVrms |
|                      |                                                                 |                             | -    | -    | 5   | mW    |
|                      | fin = 1kHz@0dBFS input<br>Fs=48kHz,Load=16Ω                     | Full Differential<br>Output | -    | -    | 566 | mVrms |
|                      |                                                                 |                             | -    | -    | 20  | mW    |
|                      | fin = 1kHz@0dBFS input<br>Fs=48kHz,Load=10KΩ                    | Full Differential<br>Output | -    | -    | 1.6 | Vpp   |

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## Acronyms and Abbreviations

| Abbreviations | Descriptions                                                  |
|---------------|---------------------------------------------------------------|
| AEC           | acoustic echo cancellers                                      |
| ADC           | Analog to Digital Converter                                   |
| AGC           | Auto Gain Control                                             |
| CMU           | Clock Management Unit                                         |
| DAC           | Digital to Analog Converter                                   |
| DMA           | Direct Memory Access                                          |
| GPIO          | General Purpose Input Output                                  |
| HOSC          | High Frequency OSC (24MHz)                                    |
| INTC          | Interrupt Controller                                          |
| IRQ           | Interrupt Request                                             |
| SARADC        | Successive Approximation Register Analog to Digital Converter |
| MIC           | Microphone                                                    |
| MFP           | Multiple Function PAD                                         |
| NMI           | Nonmaskable Interrupt                                         |
| OSC           | Oscillator                                                    |
| PA            | Power Amplifier                                               |
| PMU           | Power Management Unit                                         |
| PWM           | Pulse Width Modulation                                        |
| RMU           | Reset Management Unit                                         |
| SIE           | Serial Interface Engine                                       |
| VAD           | Voice Activity Detection                                      |
| TWS           | Ture Wireless Stereo                                          |

**Actions Technology Co., Ltd.**

**Address: No. 1 / C, Ke Ji Si Road, Hi-Tech Zone, Tangjia, Zhuhai**

**Tel: +86-756-3392353**

**Fax: +86-756-3392251**

**Post Code: 519085**

**<http://www.actions-semi.com>**

**Business Email: [mp-sales@actions-semi.com](mailto:mp-sales@actions-semi.com)**

**Technical Service Email: [mp-cs@actions-semi.com](mailto:mp-cs@actions-semi.com)**