True Wireless Stereo Cradle and Earbuds

MAXREFDES1263

Introduction

The MAXREFDES1263 is a reference design for the TWS (True Wireless Stereo) application base. This reference design is a power management platform for TWS cradle and earbuds (left and right). It also supplies data communication between the cradle and earbuds, which includes the MAX77651B, MAX17270, MAX32660, MAX77818, MAX77813, MAX20340, MAX17260, and MAX98090. This solution demonstrates a small-size, low-power, highly effective, high-accuracy power management system.

On the cradle side, the MAX77818 integrates a high-performance3A switching charger and proprietary ModelGauge™ m5 fuel gauge, which provides fast charging and industry-leading battery fuel-gauge accuracy. The Smart Power Selector™ architecture includes a network of internal switches and control loops that distributes energy among USB, wireless charging, BYP, SYS, and BATT. The MAX77813 is used to produce stable 5V output from a Li+ battery or VSYS from the earbud charger. The MAX17270 SIMO regulator provides 3.3V outputs with 0.8V to 5.175V programmable voltage range to support a Bluetooth®/sensor module or processor power supply. The MAX20340 is a universal bidirectional powerline communication (PLC) management IC. It features a slave detection circuit that flags an interrupt to the system when the PLC master detects the presence of a PLC slave on the power line. The slave MAX20340 on the earbuds can transmit data to the master MAX20340 on cradle, like battery charging status or information such as remaining capacity (mAH), etc. The MAX32660 is used to configure the SIMO, charger and fuel gauge, and PLC (MAX20340). It also is used to read the battery status and fuel gauge data.

On the earbuds, the MAX20340 is configured in slave mode and transfers to the master detection state. The MAX77651B features a SIMO buck-boost regulator that provides three independently programmable power rails from a single inductor to minimize total solution size and to support the MCU, Bluetooth/sensor module, and other devices' power supplies. A 150mA LDO provides ripple rejection for audio (audio CODEC) and other noise-sensi-tive applications. A highly configurable linear charger supports a wide range of Li+ battery capacities and includes battery temperature monitoring for additional safety (JEITA). The MAX17260 ultra-low-power fuel-gauge IC monitors a single-cell battery pack and supports internal current sensing. The MAX32660 is used to configure the MAX77651B, MAX17260, MAX20340, and MAX98090. The MAX98090 provides I^2S interface pins to connect customer processor and microphone inputs along with headphone outputs for audio function evaluation.

Main features and benefits:

- Integrated Solution
- Small Size
- Low Power
- High Accuracy

Table 1. Cradle Design Specification

PARAMETER	SYMBOL	MIN	MAX
Battery Voltage	V_{BAT}	3.1V	4.6V
USB Input Voltage	V_{USB}	5V	
Average Operation Current	$I_{OPERATION}$	10mA	
5V Out	5V	4.8V	5.2V
VPLC Out	PLC	4.5V	5.2V
3.3V Out	3V3	3V	3.6V
1.8V Out	1V8	1.7V	2.0V
1.2V Out	1V2	1.1V	1.3V

Table 2. Earbuds Design Specification

PARAMETER	SYMBOL	MIN	MAX
Battery Voltage	V_{BAT}	3.1V	4.6V
Average Operation Current	$I_{OPERATION}$	10mA	
3.7V out	3V7	3.6V	3.9V
VPLC in	PLC	4.5V	5.2V
3.3V out	3V3	3V	3.6V
1.8V out	1V8	1.7V	2.0V
LDO out	VLDO	1.7V	1.9V

Designed–Built–Tested

This document describes the hardware shown in Figure 1 and provides a detailed systematic technical guide to designing a small-size, low-power, highly effective, high-accuracy TWS power management platform. The design has been built and tested; details will be shown later in this document.

Design Considerations

The power platform for the TWS application should have the following important characteristics and features:

- Small size – Earbuds are placed in ear, with a size that is as small as possible. And as designers try to incorporate more functions into the devices, the size of the device's individual components becomes even more important. The number of components that can fit on a device directly determines the number of functions that the device can feature.
- Low power – They use batteries for the system power supply. Because of the limited size and energy density of the battery, low power means longer use time. Wearable devices often have two working modes: standby mode and operation mode. Most devices are in standby mode more than 90% of the time, so the standby current is very important. For a 70mAh battery, if the standby current can be limited within 1mA and operation current is 7mA, the system can work for approximately 64 hours.
- Highly Effective – Even in emerging TWS applications, the earbuds are typically charged in the case. However, at any given time, the cradle battery voltage may be higher or lower than the earbud battery's voltage. But boosting the charging voltage for the worst case is not a good solution. When there is a high V_{IN} V_{OUT} ratio at the earbud charger, the cradle energy is wasted and heat is generated on an earbud.
- Accuracy – The devices require a higher accuracy measurement for battery SOC since the market only accepts the more accurate devices.

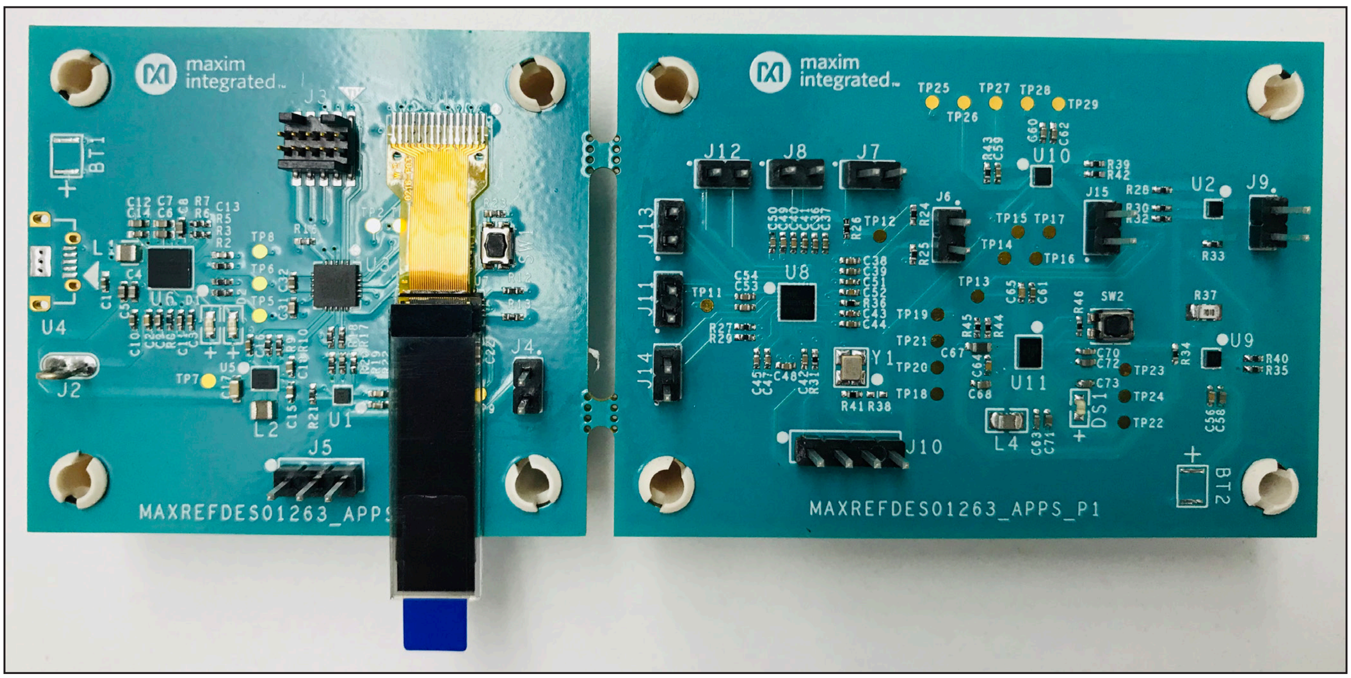

Figure 1. MAXREFDES01263 hardware.

Design Procedure Power Solution

This power management platform includes cradle, earbuds, and power delivery between them.

Step 1: Select the power delivery solution

For TWS applications, the cradle needs to deliver power to the earbuds at the same time data communication is added, such as cradle battery information, earbud battery information, or firmware update. Since size is extremely important in TWS solutions, we selected a small, space saving, reliable solution. The MAX20340, bidirectional powerline communication (PLC) management IC is used to support up to 1.2A charge current with 166.7kbps, which meets the TWS requirement.

Step 2: Select the cradle power management

The cradle receives input from the USB and generates 5V output for PLC charging. The MAX77813 is a low-power boost which generates 5V for PLC special. There are three other power rails required: 3.3V, 1.8V, and 1.2V. One 3.3V rail is used for the MAX32660 MCU, the OLED panel, and the interface. The MAX32660 needs 3.3V for full operation while the OLED panel needs one 3.3V supply. Since they are mainly used for the digital power supply, one 3.3V rail is used for both parts. There are optional outputs of 1.8V and 1.2V for external use. The MAX17270 has three outputs (three buck-boost regulators) that can be flexibly configured for 1.8V, 3.3V, 1.2V or other value outputs to meet system requirements.

Step 3: Select earbuds power management

The cradle delivers power to the earbuds through the MAX20340 and charges the battery of the earbuds. The MAX17260 is an ultra-low-power fuel gauge that measures a single-cell battery pack. The MAX98090 needs 3.7V, 1.8V analog, and 1.8V digital. The MAX32660 needs 1.8V for low power operation. The MAX77651B features a SIMO buck-boost regulator that provides three independently programmable power rails from a single inductor to not only minimize total solution size, but to support the MCU and the MAX98090. The MAX77651B also provides a 150mA LDO for the MAX98090 audio CODEC's analog power supply.

Step 4: Calculate current

In this step, we calculate the earbuds' consumer current for normal work when using the battery supply. The full current of the MAX32660 MCU can be calculated using the following equation:

$$I_{MCU} = 96MH_Z \times \frac{85uA}{MH_Z} = 8.16mA$$

where 96MHz is the maximum frequency of the MAX32660 MCU with an average of 85μA/MHz, its max power is about 15mW.

The MAX17260 consumes 15μA when in active mode, the MAX98090 consumes about 6mW for the digital headphone, the MAX77651B uses 5.6μA operating current, the oscillator ECS-2033-130 uses 7mA (max), i.e., 23mW (max). So the total maximum power is 44mW. With a 125mAH battery, it can continue working for approximately 10 hours.

Detailed Description of Hardware

Figure 2 shows the MAXREFDES1263 block diagram. When the earbuds are connected to the cradle by 2 touch points, the cradle will detect earbuds and shake hands with it. If the earbuds are recognized, then the cradle will deliver power to the earbuds to charge the battery of the earbuds. At the same time, the cradle will get the earbuds' battery charge information in a timely manner and displays the battery SOC. The cradle also measures its own battery information and displays its own SOC. When the earbuds are charging, they can also play audio (this needs an additional I²S audio input and output connection).

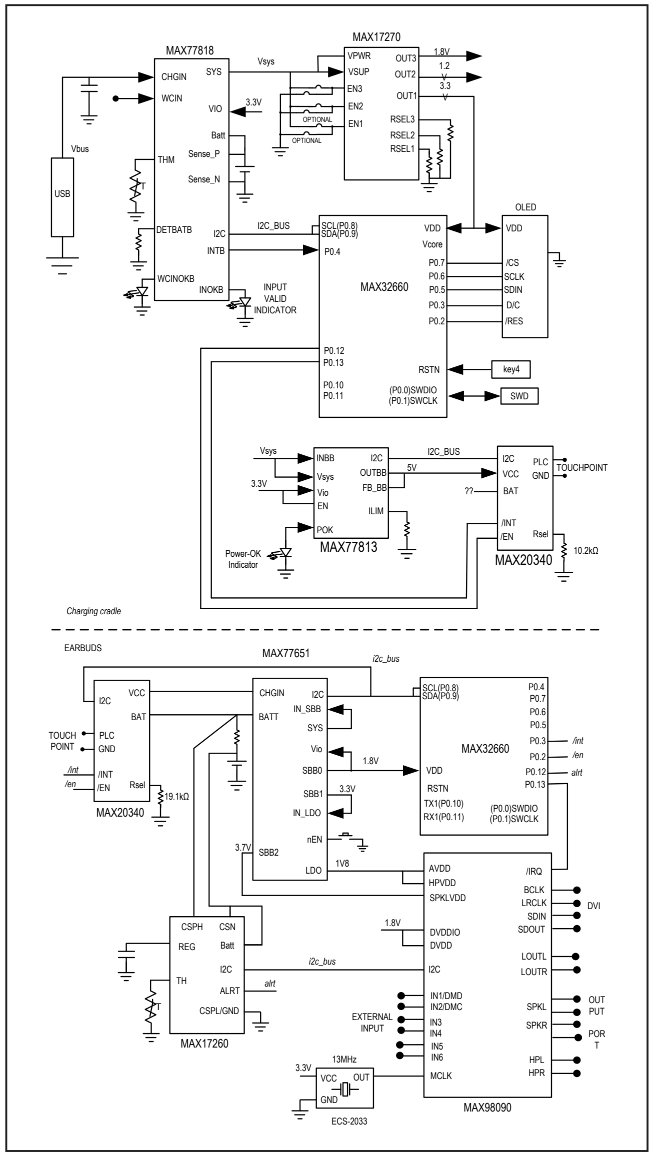

Figure 2. MAXREFDES01263 block diagram.

Microcontroller

The MAXREFDES1263 (both cradle and earbuds) uses the MAX32660 as its MCU. The MAX32660 is an ultra-low-power, cost-effective, highly integrated MCU designed for battery-powered devices and wireless sensors. It combines a flexible and versatile power management unit with the powerful Arm® Cortex®-M4 with floating point unit (FPU). This chip is dedicated for low-power applications used in wearables. Because the Arm Cortex-M4 is small, it not only uses low power but has a lot of memory to perform to our requirements. The pushbutton SW1 and SW2 can manually reset the respective MCU.

Audio Codec

The MAX98090 is a fully integrated audio codec whose high-performance, ultra-low power consumption and small footprint make it ideal for portable applications. The device features a highly flexible input scheme with six input pins (WLP) that can be configured as analog or digital microphone inputs, differential or single-ended line inputs, or as full-scale direct differential inputs. Analog inputs can be routed to the record path ADC or directly to any analog output mixer. The digital audio interface supports standard PCM formats such as I^2S, left/right-justified, and TDM. The stereo Class D speaker amplifier provides efficient amplification, features low radiated emissions, supports filterless operation, and can drive both 4Ω and 8Ω loads. The DirectDrive® stereo Class H headphone amplifier provides a ground-referenced output eliminating the need for large DC-blocking capacitors. We use the MAX98090 on the earbud board and keep all inputs and outputs interfaced, this can help in testing the performance.

Battery measurement

The MAX77818 is used for cradle battery management, and the MAX17260 is used for earbud battery management.

The MAX77818 integrates a high-performance 3A switching charger and proprietary ModelGauge m5 fuel gauge in a space-saving WLP package. This is ideal for USB-powered portable devices. The smart power path charger supports two inputs with reverse blocking and USB On-the-Go (OTG). It integrates all power switches, operates at high-switching frequency with high efficiency, and enables low heat designs with small external components. The ModelGauge m5 algorithm combines the excellent short-term accuracy and linearity of a coulomb counter with the long-term stability of a voltage-based fuel gauge, along with temperature compensation to provide industry-leading fuel-gauge accuracy. The device also integrates two high-voltage input LDOs and is highly programmable with I^2C interface.

The MAX17260 is an ultra-low-power fuel gauge IC which also implements the ModelGauge m5 EZ algorithm. The IC monitors a single-cell battery pack and supports both high-side and low-side current sensing. The ModelGauge m5 EZ algorithm makes fuel gauge implementation easy by eliminating battery characterization requirements and simplifying host software interaction. The IC automatically compensates for cell-aging, temperature, discharge rate, and provides accurate SOC in percentage (%) and the remaining capacity in milliampere-hours (mAH) over a wide range of operating conditions. As the battery approaches the critical region near empty, the algorithm invokes a special correction mechanism that eliminates any error. A 2-wire I^2C interface provides access to data and control registers.

Power Supply

On the cradle side, the MAX77813 is used to produce a stable 5V output from the Li+ battery or VSYS for the MAX20340 university bidirectional PLC management IC, which supplies data communication and charger current for the earbuds. The MAX17270 SIMO regulator provides 3.3V/1.8V/1.2V outputs with a resistor program to support the Bluetooth/sensor module and processor power supply.

The MAX20340 features a slave detection circuit that flags an interrupt to the system when the PLC master detects the presence of a PLC slave on the powerline. The slave MAX20340 on the earbuds can transmit data to the master MAX20340 on the cradle, this is mainly to update battery charging status and the remaining capacity (mAH) and error information.

On the earbuds, the MAX20340 is configured in slave mode and transfers to the master detection state. The MAX77651B features a SIMO buck-boost regulator that provides three independently programmable power rails from a single inductor to not only minimize total solution size, but to support the MCU, the Bluetooth/sensor module, and the device power supply. A 150mA LDO provides ripple rejection for the audio (audio CODEC) and other noise-sensitive applications. A highly configurable linear charger supports a wide range of Li+ battery capacities and includes battery temperature monitoring for additional safety (JEITA).

The battery must be small and supply enough energy for the earbuds to continue working. A 125mAh, 3.7V Li+ battery is chosen for this design. Usually the charge rate is 1C, which means the charge current has a maximum of 125mA, with a stop voltage of 3V.

Data Communication

The cradle and earbuds need to shake hands and communicate information. The MAX20340 is the featured product. It can transmit data and charge the slave simultaneously. It features a slave detection circuit that flags an interrupt to the system when the PLC master detects the presence of a PLC slave on the powerline. The master MAX20340 can communicate with the slave MAX20340 and deliver current to charge the slave-side battery.

Detailed Description of Software

The MAXREFDES1263 software includes two parts: the cradle and earbuds. Each part includes the MAX32660 firmware (main loop), the MAX20340 PLC protocol configuration, and a fuel gauge algorithm and configuration, as well as a SIMO/PMIC configuration.

Main Loop

The MAXREFDES1263 firmware is based on an infinite-loop design model. After power-up, the MCU configures itself, the MAX20340, the fuel gauge, the SIMO/PMIC; and then goes into an infinite loop waiting for a data interrupt to perform measurements.

Figure 3 shows the flow of the cradle and earbuds main loop.

Operation Overview

The MAXREFDES01263 operation is simple, the cradle is always available and connected to the USB socket for charging and display information. When the earbuds are connected to the cradle, the cradle automatically detects the connection gathers the earbud information periodically and charges the earbuds battery.

Program Download Interface

The serial wire debug interface (SWD) is used for the earbuds code programming. There are connectors (TP25, TP26, and TP29) for the SWD connection on the board. The standard JTAG J3 is used for cradle board code programming. TheMAX32625PICO board is used as emulator for debug.

Design Resources

Refer to **Design Resources** to download the complete set, including schematics, bill of materials, PCB layout, and test files.

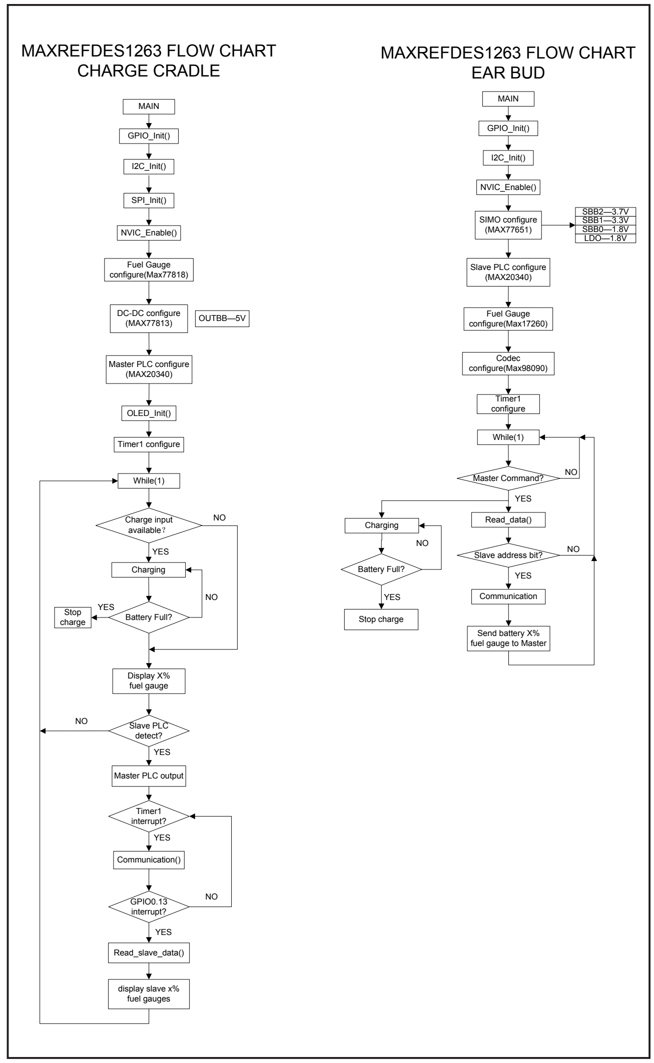

Figure 3. Cradle and earbuds main function flowchart.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	3/21	Initial release	—