

Ture Wireless Stereo (TWS) Charging Case Design Based on MSPM0L1105



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ABSTRACT

This application note demonstrates the implementation of a fun True Wireless Stereo (TWS) earbud case using the TI MSPM0L1105. The advanced features and low power consumption of the MSPM0 make it an ideal choice for this application.

Project collateral and source code can be downloaded from the following URL: <https://www.ti.com/lit/zip/slaaef8>.

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1 Introduction

The TWS earbud case is an essential accessory for wireless earbuds. It not only provides a convenient storage solution but also charges the earbuds when not in use. Additionally, the case can communicate with the earbuds using a single-wire interface based on universal asynchronous receiver/transmitter (UART).

2 Function Explanation

The basic function this reference design achieved includes:

- Power management
 - Device: BQ25628 [charger+boost], BQ51050B [Wireless charger], TPS7A05 [LDO]
 - Function: The most basic function of a TWS earphone case is charging, including charging the battery inside the case and charging the TWS earbuds. In this design, the system can be charged via a wired type-C connection or wirelessly via a wireless coil. The charger steps down the 5V from the type-C (or the wireless charger) to charge the battery, and the LDO stabilizes the battery voltage at 3.3V to power the MSPM0 and other peripheral devices. The Boost is needed to raise the battery voltage to 5V to charge the earphones. Those functions are running without the help of MSPM0 in this reference design, however, MSPM0 can be used to control the charger/boost through enable pin or inter-integrated circuit (I2C) for advanced control if needed.
- Lid close detection and status indication
 - Device: TMAG5231 [Hall sensor], LED
 - Function: The cradle should be able to detect the lid closing. This can be achieved by detecting the magnetic flux density change through a hall sensor. A magnet is mounted on the lid, hence the magnetic flux density around the TWS case main body also changes with the lid open and closed. The LED is used to indicate the status of the TWS, for instance: low battery, lid open/close, charging status, Bluetooth pairing, and so forth. MSPM0 is able to monitor the status of the TWS and control the LED through GPIO.
- Earbuds communication
 - Device: TPS22914 [Load switch], MSPM0L1105DGS20 [MCU]
 - Function: The cradle is able to communicate with the earbuds through the pogo pins. Currently, most TWS use two pogo pins, one of them is Ground and the other is for charging and communication. The load switch is used to control when to charge and when to communicate with the earbuds. In this design, communication is based on a single-wire UART communication protocol using MSPM0.

The block diagram of this design can be seen in [Figure 2-1](#).

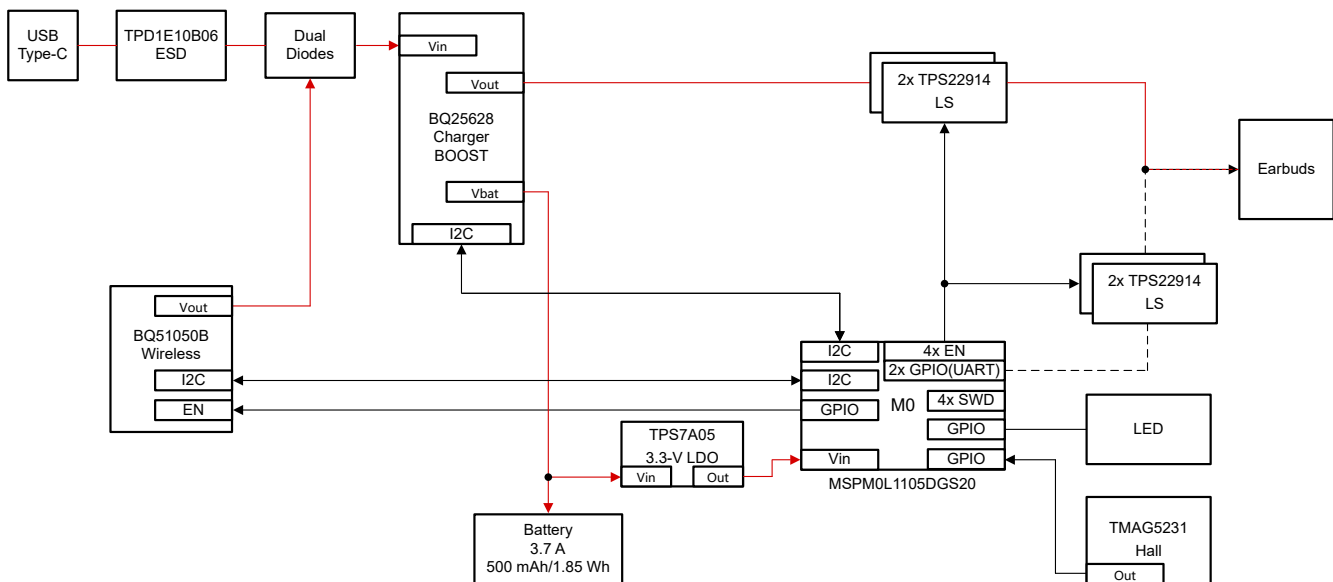


Figure 2-1. TWS Cradle Based on MSPM0 Block Diagram

The red line in Figure 2-1 indicates the power path while the black line shows the signal path. The corresponding schematic and PCB can be found in the design file. This design supports a 5V wired inputs through a type C port, or wirelessly from BQ51050B, which regulates the wireless AC power into 5V DC. The BQ25628 is highly-integrated 2A switch-mode battery charge management and system power path management device for single-cell Li-ion and Li-polymer batteries, it not only charges the battery but also provides power to the earbuds. MSPM0L here is used for overall board control, for example, it can manage the power and communication logic between the case and the cradle, lit LED, read battery status and control the charger/boost, and so forth. The Hall sensor TMAG5231 is ideal for detecting lid closing in TWS applications due to its small size, low power consumption and low price.

3 Single Wire UART

3.1 Background

Standard UART devices use receive (RXD) and transmit (TXD) connections to establish separate paths for sending and receiving data between multiple devices, hence at least two wires are used in a standard UART communication, see Figure 3-1.

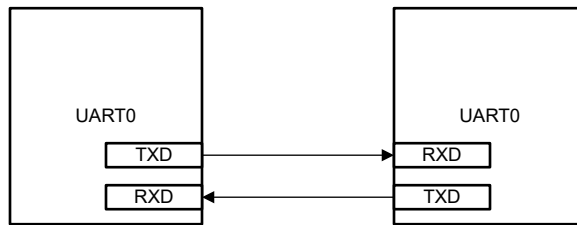


Figure 3-1. Standard UART Communication

A single-wire UART is a variation of the standard UART protocol that uses only one wire for both transmitting and receiving data. This can be useful in applications where the number of available pins is limited, like in the TWS application. As shown in Figure 3-2, with TXD and RXD on each device physically combined, two devices can communicate using only one physical wire.

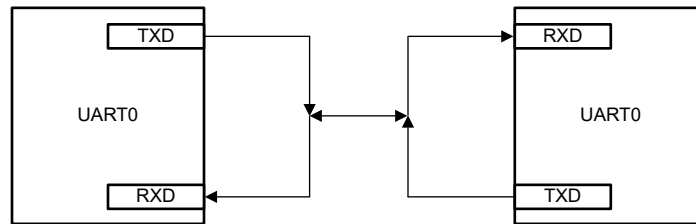


Figure 3-2. Single-Wire UART Communication

Figure 3-3 references single wire UART based on MSPM0.

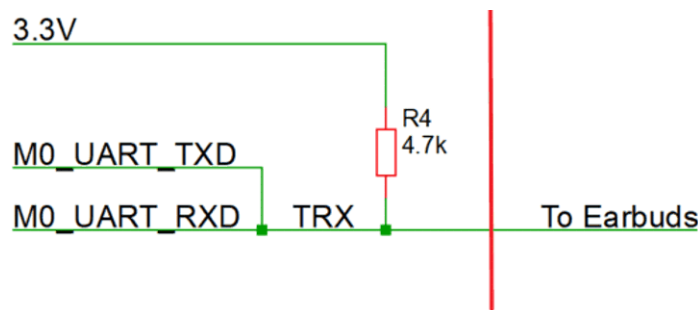


Figure 3-3. Reference Single Wire UART Design Based on MSPM0

In [Figure 3-3](#), the M0_UART_T/RXD connects to the I/Os of MSPM0 that support the UART peripheral. MSPM0L series supports two individual UART modules, meaning the left and right earbuds can communicate with the TWS case simultaneously, if needed. Unlike standard UART TXD I/O that has a push-pull structure, in this application, the UART TXD I/O structure needs to be open-drain to achieve the wired-AND logic. A pull-up resistor and 3.3V power rail provide the logic high voltage. RXD is high-Z by default, and when TXD is high-Z, the earbuds will sense high (3.3V), when TXD is GND, the earbuds will sense low (0V).

4 Power and Communication Logic

The charging and communication between the earbuds and the cradle happen on a single line. For example, [Figure 4-1](#) shows the communication and charging waveforms from a third-party TWS earbud. The red line shows the output of the hall sensor, and the voltage drop indicates the lid closing. The black line is measured at the right ear pogo pin. The orange line shows the digital information contained in the black line decoded using UART protocol, 1200 baud rate. When charging the earbuds, the Pogo pin is working at 5V. However, when the TWS cradle tries to communicate with the earbuds, the logic high is 3.3V.

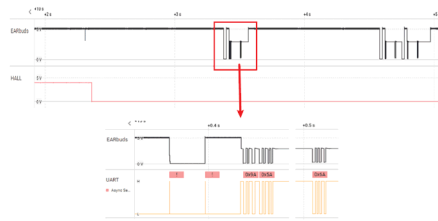


Figure 4-1. Waveforms From a Third-Party TWS Earbud

It can be seen that by default, the Pogo pin is 5V and is charging the earbuds. with the lid closing, the TWS case sends a fixed 5V-0 V-5V pattern to indicate the start of a command. Then the case sends 0x9A5A and the earbuds respond with 0x6A.

The pattern and design above are for reference only, the customer can customize their communication and power logic, and the TWS case can send customized commands/information to the earbuds, for example, case battery percentage, earbuds/case SN, charging status, and so forth.

[Figure 4-2](#) shows reference power and the communication design based on MSPM0.

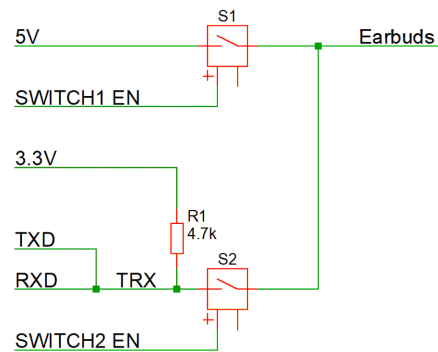


Figure 4-2. Reference Power and Communication Design Based on MSPM0

As shown in [Figure 4-2](#), switches S1 and S2 control when to charge the earbuds and when to start the communication. When S1 is closed and S2 is open, the cradle charges the earbuds, and when S2 is closed and S1 is open, the cradle can communicate with the earbuds with a 3.3V logic high.

As mentioned before, the MSPM0L series supports two UART peripherals, hence it can communicate with the left and right earbuds simultaneously. The corresponding design can be seen in the figure below. In this design, four switches are used to control the left and right earbuds separately, this is ideal for applications where a great amount of information needs to be transformed.

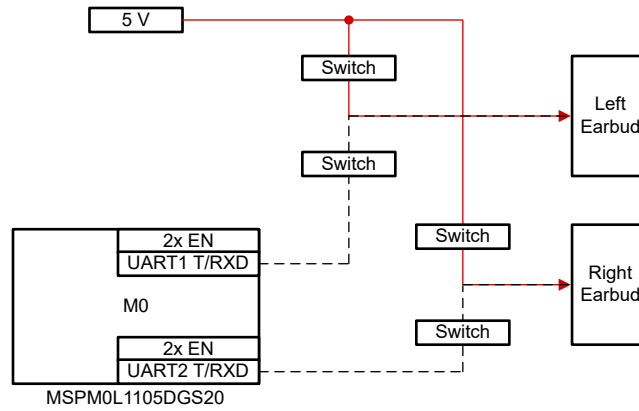


Figure 4-3. Reference Design 1

However, to save costs and resources, the following designs can also be used:

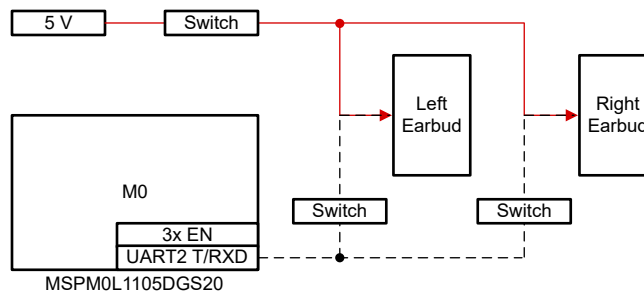


Figure 4-4. Reference Design 2

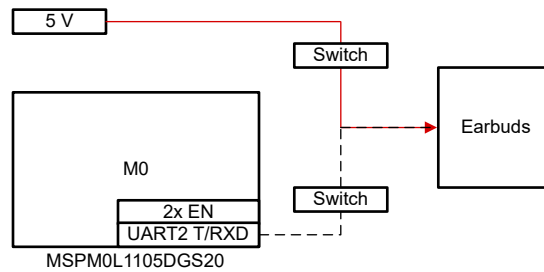


Figure 4-5. Reference Design 3

In [Figure 4-4](#), the left and right earbuds share the same MSPM0 UART peripheral. Hence, they cannot communicate with the TWS case simultaneously, but they still share separate communication lines. While in [Figure 4-5](#), the Pogo pins of the left and right earbuds are connected together, meaning they will receive the same message. This is like I2C communication where the TWS case is the master device and two earbuds are slave devices, and they share the same data line.

5 Software

5.1 Overall Flowchart

In this reference design, the cradle can achieve the following function: detect the lid closing and send different commands to a pair of third-party earbuds. The left and right earbuds respond differently to the commands, and the cradle flashes the LED once if it receives the response from the right earbud, twice if it receives the response from the left earbud, and three times if it receives responses from both earbuds. When not in communication, the Pogo pin is set to 5 V and ready to charge the earbuds. [Figure 5-1](#) shows a simple flowchart.

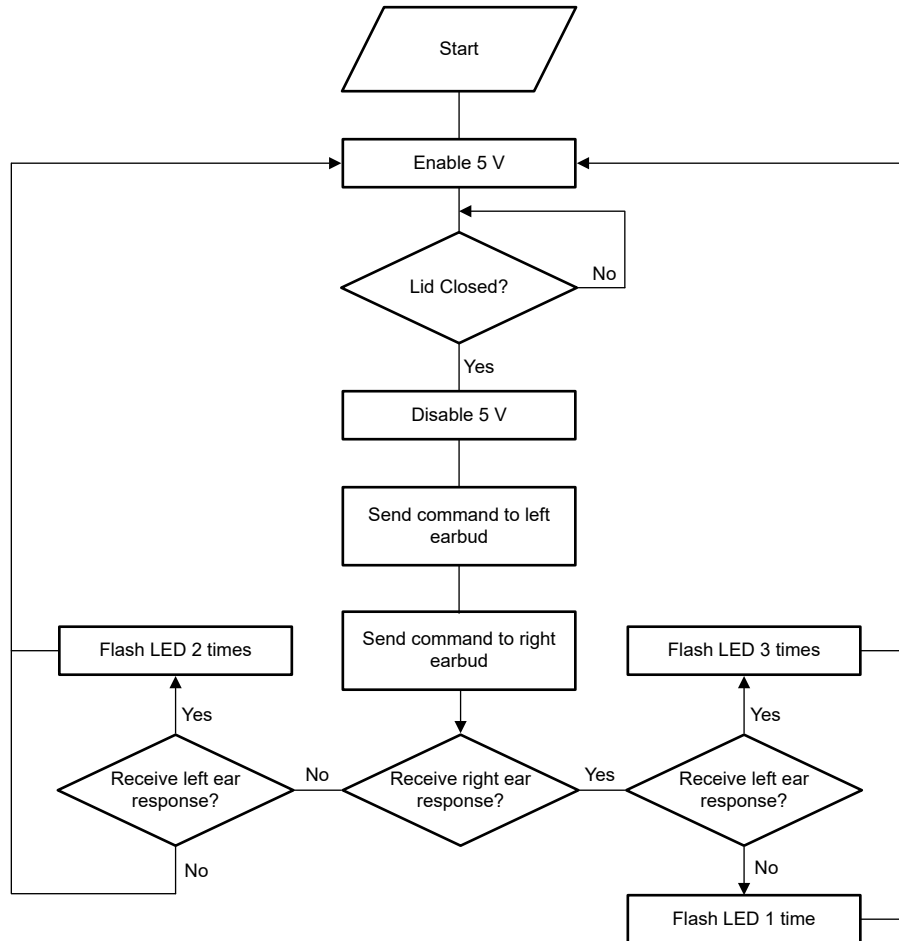


Figure 5-1. Flowchart

In this design, the main() function only contains the initialization, all the functions are achieved in the interrupts

5.2 IOMUX

As mentioned before, standard UART TXD has a push-pull I/O structure. However, in this application, the UART TXD I/O structure needs to be open-drain. MSPM0's IOMUX function gives the user an easy way to control the digital I/O outputs. It not only manages the selection of which peripheral function is to be used on a digital I/O, but also provides the controls for the output driver, input path, and the wakeup logic for wakeup from SHUTDOWN mode. [Figure 5-2](#) shows a detailed I/O structure of MSPM0.

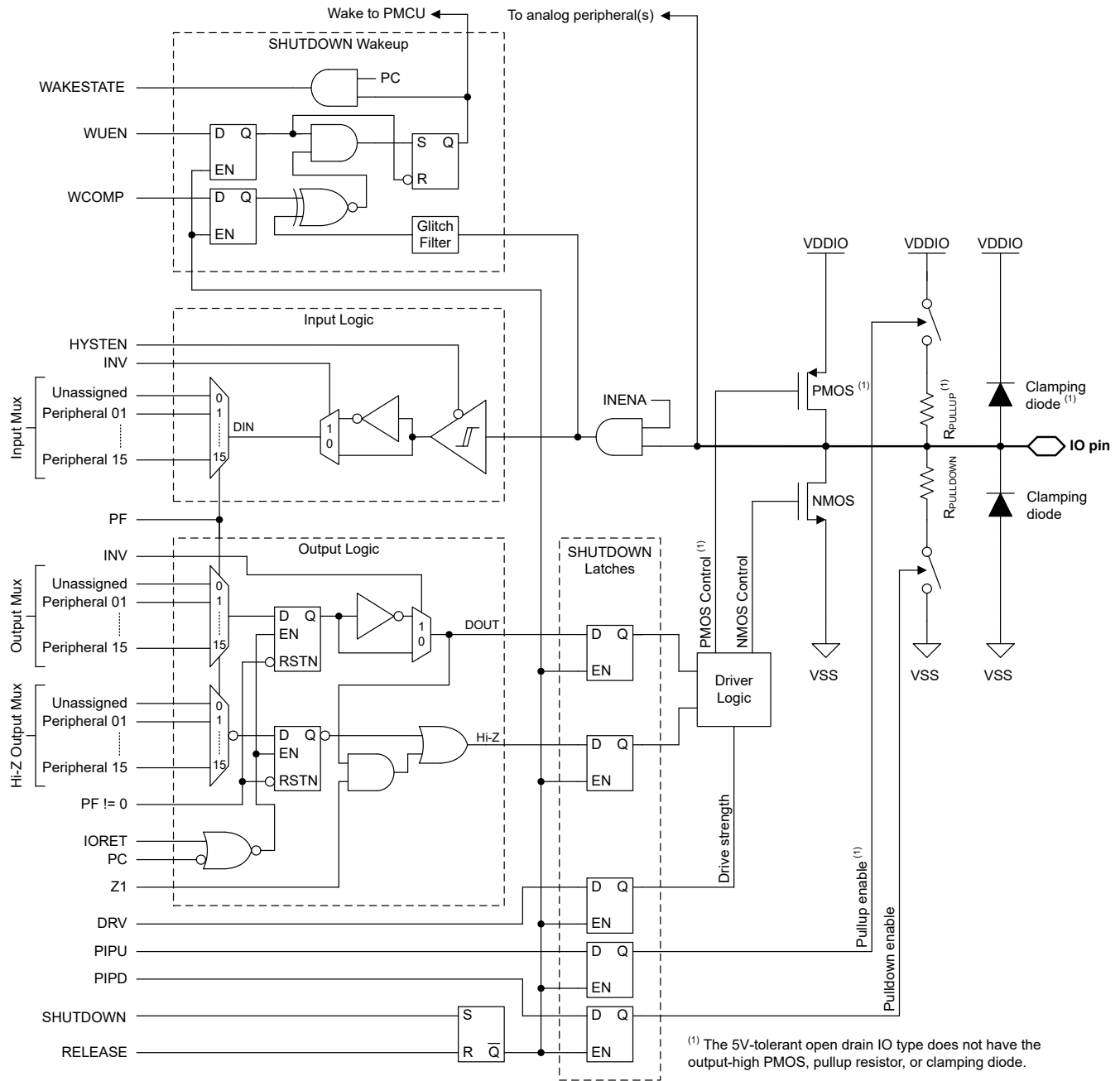


Figure 5-2. I/O Pin Structure

Note that not all pins have analog functions, wake-up logic, drive strength control, and pullup or pulldown resistors available. For specific designs, see the device-specific TRM and data sheet. In this TWS reference design, after the UART TXD function is selected for the I/O function, a logic high to Hi-z conversion is made to achieve an open-drain UART TXD. The code for setting up the IOMUX can be seen below, 'DL_GPIO_HIZ_ENABLE' will set the I/O structure to open-drain

```
DL_GPIO_initPeripheralOutputFunctionFeatures(
    GPIO_UART_L_IOMUX_TX, GPIO_UART_L_IOMUX_TX_FUNC,
    DL_GPIO_INVERSION_DISABLE, DL_GPIO_RESISTOR_NONE,
    DL_GPIO_DRIVE_STRENGTH_LOW, DL_GPIO_HIZ_ENABLE
);
```

5.3 Power/Communication Software Design

The general-purpose timer (TIMG) is used to mimic the waveform in [Figure 5-3](#). MSPM0L series provides up to four individual timer modules each has extensive event generation capabilities, such as counter overflow, reload, and capture/compare actions for a variety of use cases. In this design, the timer is used as a clock which triggers every 10 ms. The corresponding actions in each time sample can be seen in the figure below. This design successfully generates communication and power waveforms.

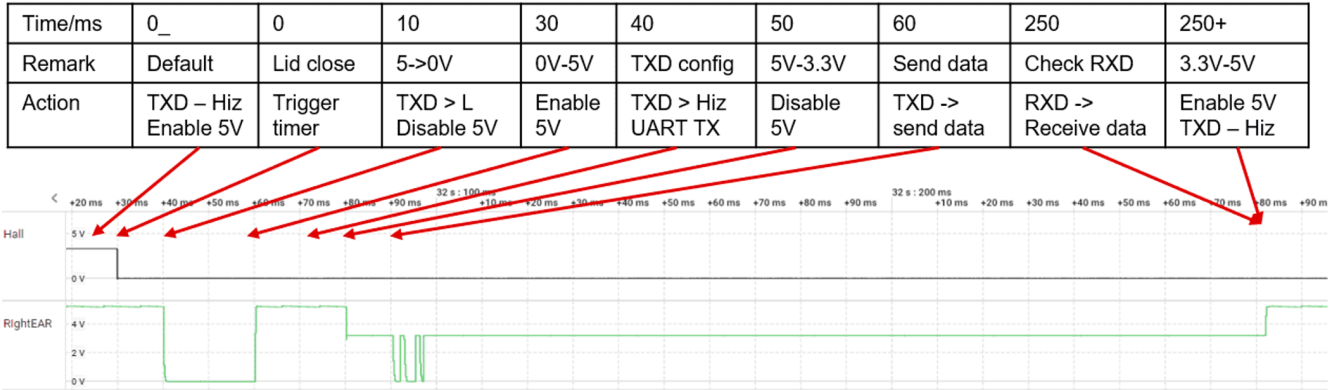


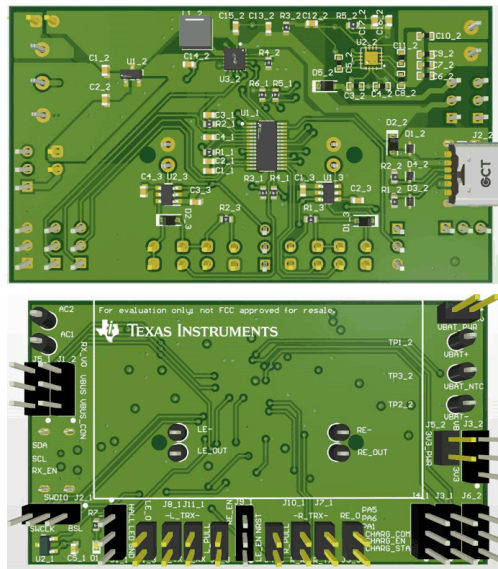
Figure 5-3. Actions in Each Time Sample and Final Waveform

5.4 Other Resources

- Low-power consumption and low cost with a small package
- Multiple communication peripherals (I2C/serial peripheral interface (SPI)/LIN/UART)
- ADC/DAV/OPA/GPA/COMP available

6 Hardware

The PCB design and final prototype can be seen in [Figure 6-1](#).



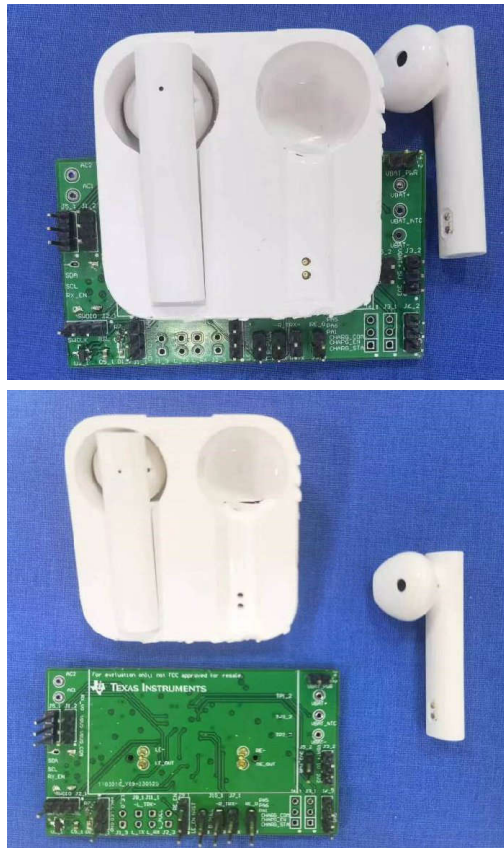


Figure 6-1. PCB Design and Final Prototype

The PCB is designed so that it can be perfectly fit with a third-party TWS cradle.

6.1 Test Results

The TWS cradle based on the MSPM0L successfully communicated with third-party earbuds, the waveform can be seen in [Figure 6-2](#). The blue line is the output of the hall sensor, indicating the closing of the lid; the green line shows the communication/power waveform between the right earbud and the TWS cradle, while the purple line shows that of the left earbud. The cradle can also flash the LED multiple times depending on the response it received from the earbuds. Apart from that, the cradle also charges the earbuds and is able to detect the opening/closing of the lid.

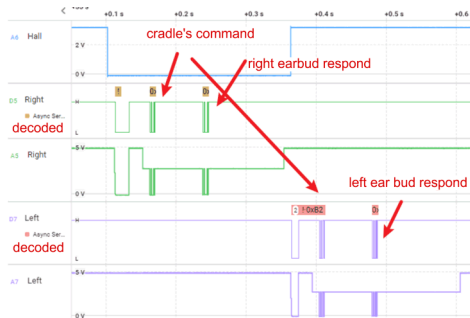


Figure 6-2. Final Waveform Between the Cradle and Earbuds

7 References

- Texas Instruments: [MSPM0 L-Series 32-MHz Microcontrollers Technical Reference Manual](#)
- Texas Instruments: [MSPM0L110x Mixed-Signal Microcontrollers Data Sheet](#)

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