Firmware Specification

**allears V2 – Inear Part**

**Ver 0.7**

# **Revision History**

|  |  |  |
| --- | --- | --- |
| **Revision** | **Date** | **History** |
| ver 0.1 | 26 APR 2022 | - First version is released |
| ver 0.5 | 17 MAY 2022 | - ver 0.5 is released |
| ver 0.6 | 08 JUN 2022 | - “Device state” is added  - “Sleep and Wake-up Conditions” is changed  - “Button Configuration” is changed  - “Safety and Error/Exception Handle” is added |
| ver 0.7 | 07 NOV 2022 | - Overall features are changed as system architecture |

# **Preface**

이 문서는 allears V2 프로젝트의 Firmware 명세서이다.

# **Terms Used**

## **Overview**

* 이 문서에서 사용되는 용어들을 정의한다.

## **Terms**

|  |  |
| --- | --- |
| **Term** | **Description** |
| Bluetooth | 근거리 무선 통신 규격 중의 하나 |
| BLE | Bluetooth Low Energy |
| allears | 자사가 개발하는 신경 자극 장치 |
| 인이어(Inear) | 신체의 귀부분에 착용되는 allears 구성중 하나 |
| 충전기(Charger) | 인이어 내부의 충전지를 충전시키는 allears 구성 부분 |

# **Version Format**

## **Format**



## **Number Meaning**

1. Major number
   * Numbering in order
2. Minor number

* Numbering in order

1. Subminor number
   * Numbering in order

* ASCII ‘B’ or ‘R’

1. B: Beta version. Test or experimental version
2. R: Release version officially

# **Basic Concept**



1. 충전기는 USB 전원을 사용한다.
2. 인이어는 충전기에서 충전이 된다.
3. 인이어는 사람의 귀에 착용되어 전기신호를 주어 미주신경을 자극한다.
4. Mobile manager가 설치되어 있는 스마트폰은 Bluetooth로 연결한다.
5. Mobile manager는 인이어와 BLE로 연결한다.
6. Mobile manager는 인이어의 설정값을 변경하거나 전기자극의 세기를 조정한다.
7. Mobile manager는 Audio를 Bluetooth을 통해 인이어에 전송할 수 있다.
8. 인이어 장치들은 BLE로 연결하여, 정보를 주고받는다.

# **Overview**



1. 인이어는 신체의 귀부분에 착용되어지는 장치이다.
2. 인이어는 신체에 전기자극을 주고, 음악을 재생한다.
3. 인이어는 Mobile manager와 Bluetooth 연결을 하여 통신한다.
4. Mobile manager는 인이어 장치에 전기자극 수준을 설정하고 음악을 Bluetooth로 전송한다.
5. 인이어는 충전기에 부착되어 충전된다.

# **Bluetooth Features**

## **Bluetooth Core Specification**

* Qualified to Bluetooth v5.2 specification

## **Bluetooth Profiles Supported**

1. Advanced Audio Distribution Profile (A2DP) 1.3.2
2. Audio/Video Remote Control Profile (AVRCP) 1.6.2
3. Device Information Service (DIS) 1.1
4. Battery Service (BAS) 1.0

## **Bluetooth Security**

1. BR/EDR
   * Security mode 4 level 0 (Just Works)
2. BLE
   * Security mode 1 level 4

# **Device State**

## **Overview**

1. 인이어의 상태는 안착되어 충전 중인 경우와 분리되는 경우로 구분된다.

## **System State Definitions**

### **Bluetooth**

|  |  |
| --- | --- |
| **System State** | **Description** |
| bt\_statet\_init | System initialization |
| bt\_state\_chg | Device is initialized and charging |
| bt\_statet\_idle | System is initialized and waiting to events but not charging |
| bt\_statet\_peer\_pairing | Device is in peer pairing (preparing to pair between inears) |
| bt\_statet\_pairing | Device is in pairing (preparing with other Bluetooth devices) |
| bt\_statet\_connected\_br\_edr | Device is connected in BR/EDR |
| bt\_statet\_connected\_ble | Device is connected in BLE |
| bt\_statet\_connected\_all | Device is connected in BR/EDR and BLE |
| bt\_statet\_streaming | Device is connected and in A2DP streaming |
| bt\_statet\_under\_test | System is under test |
| bt\_statet\_error | System is in HW or SW error |

### **Stimulation**

|  |  |
| --- | --- |
| **System State** | **Description** |
| st\_statet\_init | System initialization |
| st\_statet\_idle | System is initialized and waiting to events or handle jobs |
| st\_statet\_stimul | Device outputs stimulation |
| st\_statet\_error | System is in HW or SW error |

## **System State Diagram**

### **Bluetooth**



1. If system state is changed to charging in Bluetooth states, device get out from all Bluetooth states.
2. If device is paired with another Bluetooth device, device tried to connect to paired device in pairing state.
3. If device is paired with peer, device is tried to connect to peer in pairing and connected state.
4. Audio can be streamed only via BR/EDR connection and stimulation is controlled only in BLE connection.
5. If errors occur in system, system stop running and is in error state until power off.
6. Sleep and wake-up conditions

### **Stimulation**

1. If errors occur in system, system stop running and is in error state until power off.
2. Stop conditions
3. Stop request
4. Set to stimulation Mode 0
5. Set stimulation mode other than current mo de
6. T3 timeout
7. Deep sleep request
8. Errors occur

### **Timer**

|  |  |
| --- | --- |
| **Timer Type** | **Time** |
| T1 | 10 min |
| T2 | 1 min |
| T3 | 20 min |

# **Button Configuration**

## **Overview**

1. 장치의 버튼 구성을 정의한다

## **Handle Button Event**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Button Event** | **State** | | | | |
| **Power off** | **Charging** | **Pairing** | **Connected** | |
| **Stand-by** | **Stimulating** |
| Short held | Power on | None | None | None | Stop streaming and stimulation |
| Long held | None | None | Peer pairing | None | None |

## **Button Event Timing**

|  |  |
| --- | --- |
| **Button Event** | **Timing** |
| Short held | Pressed more than 1s |
| Long held | Pressed more than 3s |

# **LED Indication**

## **Overview**

장치의 LED 알림을 정의한다.

## **LED Indication**

|  |  |
| --- | --- |
| **State** | **LED Indication** |
| Power on | White LED 1s blink for 5s |
| Power off | White LED 500ms blink |
| Peer Pairing | Blue LED 1s blink |
| Connected and worn | Yellow LED 1s blink |
| Low battery | Yellow LED 500ms blink |
| Charging | White LED on for 10s |

# **Electrical Stimulation**

## **Overview**

1. 전기 자극 출력에 대한 개념과 제어 요구사항을 정의한다.
2. 전기 자극 방식은 정전류 방식이다. 즉, 전압은 일정하고 전류량를 조정하여 자극의 크기를 제어한다.

## **Concepts**



## **Control points**

|  |  |
| --- | --- |
| **Control points** | **Description** |
| an\_ctrl | Anode output control |
| ca\_ctrl | Cathode output control |
| cur\_ctrl | Current of stimulation control |
| peak\_detect | Impedance output. To check device wearing state |
| volt\_ctrl | Stimulation voltage control |
| monitor\_volt | Stimulation voltage level |

## **Stimulation control timing**



1. Stimulation output is real pulse output from device. Pulse width is pw and delay time between anode and cathode is d.
2. Pulse width of an\_ctrl and ca\_ctrl is pw + 2s. And d ≥ 2s
3. Pulse width of cur\_ctrl is pw, and not PWM pulse type.

## **Electrical Stimulation Output Parameters**





1. 1s / Period = stimulation Frequency
2. Anode와 Cathode의 Pulse width는 같다.
3. Anode가 먼저 출력 되고, Delay를 후에 Cathode를 출력한다.
4. 전기 자극은 한번의 Group으로 출력되고 멈추고, 다시 Group으로 출력된 후 멈추는 방식으로 반복된다.

## **Electrode Charging**

1. 전기 자극에서 사용되는 전압을 공급한다.
2. 공급되는 전압은 일정하게 유지되어야 한다.

## **Electrical Stimulation Level**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **자극 레벨** | **출력 전압 (V)** | **펄스 폭(us)** | **자극 레벨** | **출력 전압 (V)** | **펄스 폭(us)** |
| Level 0 | 0 | 0 | Level 8 | 40 |  |
| Level 1 | 40 |  | Level 9 | 40 |  |
| Level 2 | 40 |  | Level 10 | 40 |  |
| Level 3 | 40 |  | Level 11 | 40 |  |
| Level 4 | 40 |  | Level 12 | 40 |  |
| Level 5 | 40 |  | Level 13 | 40 |  |
| Level 6 | 40 |  | Level 14 | 40 |  |
| Level 7 | 40 |  | Level 15 | 40 |  |

## **Electrical Stimulation Mode**

|  |  |
| --- | --- |
| **Mode** | **Output** |
| Mode 0 | Stop stimulation |
| Mode 1 | Keep 1 Hz output |
| Mode 2 | 5Hz (3s) – Off (1s) |
| Mode 3 | 5Hz (1s) – Off (1s)-  5Hz (2s) – Off (1s)-  10Hz (1s) – Off (1s)-  5Hz (2s) – Off (1s)-  10Hz (2s) – Off (1s)- |
| Mode 4 | 5Hz (4s) – Off (1s)-  5Hz (2s) – Off (1s)-  10Hz (2s) – Off (1s)-  20Hz (2s) – Off (1s)-  10Hz (2s) – Off (1s) |
| Mode 5 | 30Hz (3s) – 5Hz (2s) |
| Mode 6 | 30Hz (5s) – Off (2s)- |

## **Electrical Stimulation Manual Mode**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | | **Value Range** | **Step** |
| Frequency (Hz) | | 1 ~ 50 | 1 |
| Pulse width (us) | | 100 ~ 1000 | 100 |
| Delay time (us) | | 10 ~ 1000 | 1 |
| Voltage (V) | | 0 ~ 50 | 5 |
| Group pulse | Off time (s) | 0 ~ 60 | 1 |
| On time (s) |

## **Peak Detection Level**

|  |  |  |
| --- | --- | --- |
| **Configuration** | | |
| **Frequency (Hz**) | **Pulse width (us)** | **Voltage (V)** |
|  |  |  |

# **Safety and Error Handle**

## **Overview**

1. 장치의 동작 중 발생하는 안전과 오류, 예외 처리 사항들을 정의하고 처리방법에 대해 설명한다.

## **Safety Handling**

|  |  |
| --- | --- |
| **Case** | **Handle** |
| Prevent peak current or voltage of stimulation when mode change | Stop stimulation when mode is changed |
| Too long stimulation | Stop stimulation when timeout |
| Try to stimulate when Bluetooth is not connected | Ignore stimulation request |
| Bluetooth is disconnected while stimulating | Stop stimulation immediately |
| Battery level is low | Alarm to user |
| Battery level is too low to work | Power off (Cut-off) |

## **Error Codes and Handling**

|  |  |  |
| --- | --- | --- |
| **Error Code** | **Description** | **Handle** |
| ERR00 | No error | None |
| ERR01 | Problem occurs in Bluetooth communication | Stop stimulation immediately and indicate to user |
| ERR02 | Problem occurs in communication internal to device (UART) | Stop stimulation immediately and indicate to user |
| ERR03 | Output voltage is out of control (too high or too low) | Stop stimulation immediately, indicate to user and power off |
| ERR04 | Device temperature is too high | Stop stimulation immediately, indicate to user and power off |