

# 24G Millimeter Wave Radar Module

**R24AVD1 Human Presence Radar**

User manual (Ver.1.7)

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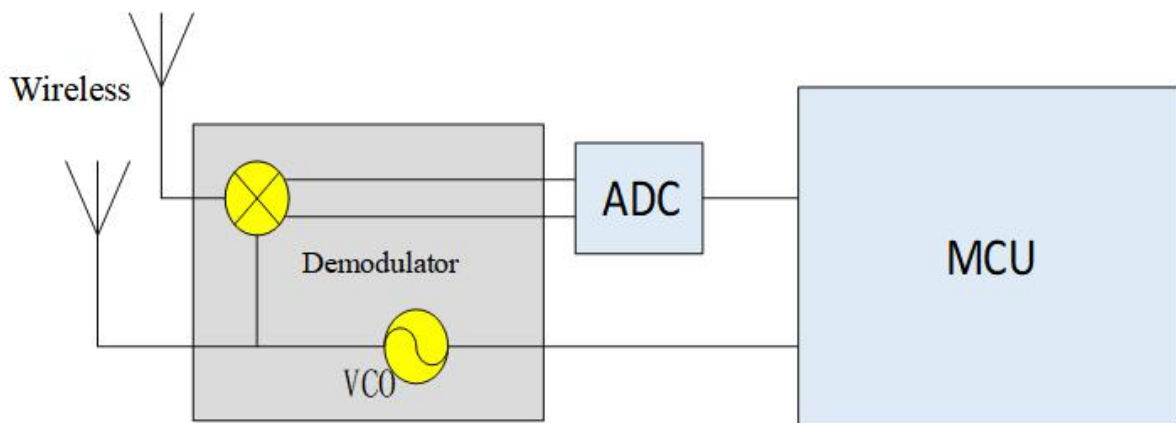
## 1. Product introduction

This document mainly describes the use of radar, the problems that may be encountered at different stages, to minimize the design costs and increase the stability of the product, and to improve the efficiency of the project.

Hardware circuit reference design, radar antenna and housing layout requirements, how to distinguish between interference and multi-functional UART protocol output.

The radar is a self-contained space sensing sensor, which is composed of RF antenna, radar chip and high speed main frequency MCU. It relies on stable and flexible algorithm architecture core to provide solution for scene detections. It's equipped with upper computer or host computer to output detection status and data, and meet several groups of GPIO for user customization and development.

## 2. Theory of operation



**Figure 1**

The radar transmits 24G band millimeter wave signal, the measured target reflects the electromagnetic wave signal, and demodulates the transmitted signal, which is then amplified, filtered, and processed by ADC to obtain the echo demodulated signal data. Information about the amplitude, frequency, and phase of the echo signal is calculated in the MCU unit, thereby completing target parameter (breath, motion, and micro-motion) measurement and scene evaluation.

### 3. Notes for hardware design

The rated supply voltage of this radar shall be 4.9 - 6V, and in normal circumstances, the rated current shall be at least 200mA. Power supply design, power supply ripple shall be  $\leq 100\text{mv}$ .

#### 3.1 For the power supply, refer to the circuit design below

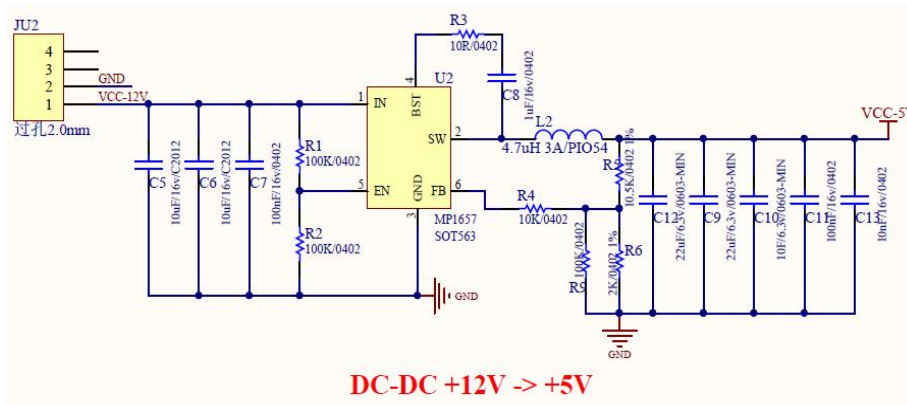


Figure 2

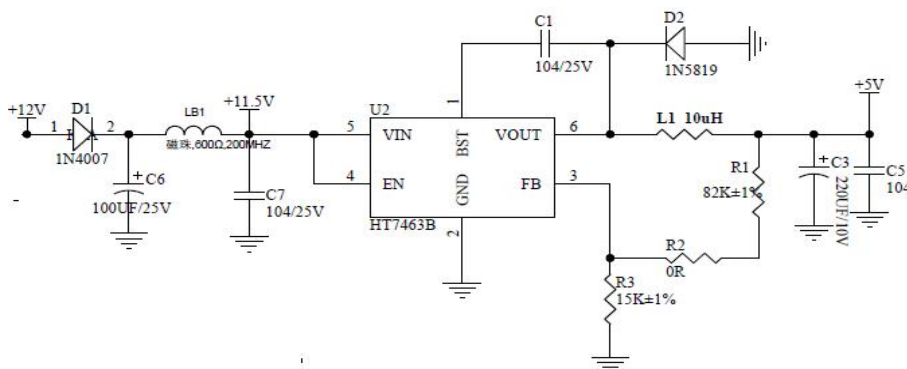


Figure 3

#### 3.2 Application wiring diagram

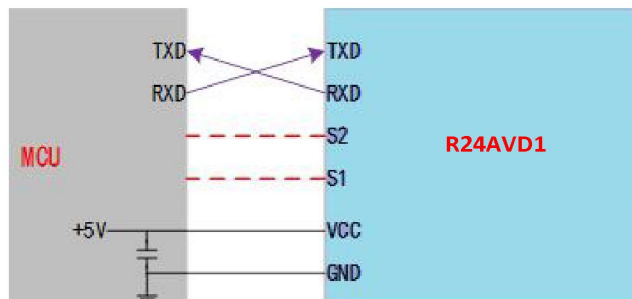


Figure 4 Schematic diagram for connection between radar module and peripherals

## 4. Requirements for antenna and housing layout

PCBA: Mounting height for radar shall be  $\geq 1\text{mm}$  compared with other components

Housing structure: Radar antenna surface and housing surface shall be kept at a distance of 2 - 5mm

Housing detection surface: Non-metallic shell shall be flat, otherwise it may affect the performance of the entire scanning surface

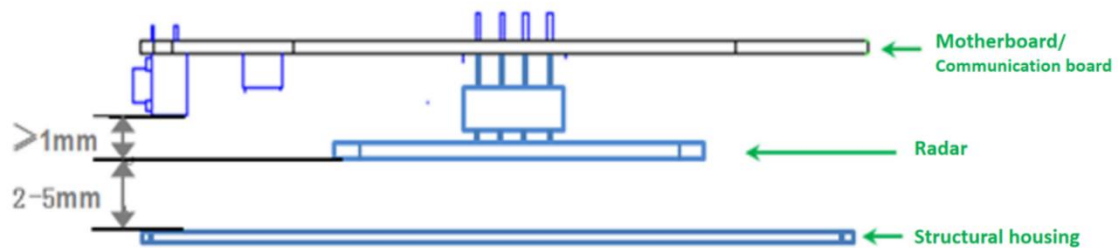


Figure 5

## 5. Electrostatic protection

Radar products contain electrostatic sensitive circuits, and shall be protected from static electricity during transportation, storage, working and picking up. Do not touch the radar module antenna surface and connector pins.

Hold the components by their edge.

When handling the radar sensor, please wear anti-static gloves.

## 6. Functional interference factors

### 6.1 Abnormal non-presence output under presence state

Under normal conditions, the radar will accurately judge the sitting still and sleeping state of human, and output corresponding vital signs and other information

- A. The radar scanning area is large, and the motion near the door and the wooden wall is detected  
Adjustment: Reduce radar sensitivity, set scenarios within the coverage of the radar
- B. The radar directly faces the running air conditioner and fan  
Adjustment: Adjust the radar position, and do not directly face the air conditioner or fan
- C. Object shaking caused by the air conditioning wind  
Adjustment: Cotton and non-metallic objects will not cause false alarms, and metals need to be fixed

**D.** The radar is not fixed and vibrates, causing false alarms

Avoid shaking and vibration of the radar support

**E.** Moving objects such as pets and birds

Due to the high sensitivity of radar measurement for subtle motion, the interference cannot be eliminated

**F.** Power interference, resulting in occasional misjudgment

Try to maintain stable power supply current and reduce ripple

**6.2 Abnormal non-presence output under presence state**

Radar transmits and receives the electromagnetic waves to detect the human presence. The closer the distance to the radar, the higher the accuracy.

**A.** Human is outside the radar range

Radar scanning range, adjust the installation angle. For the radar measurement range, the scanning area varies slightly due to differences in the reflection area of electromagnetic wave under different conditions.

**B.** Metal obstruction causing incorrect output

Overstuffed office desks and chairs and metal seats will block the penetration of electromagnetic waves, causing misjudgment.

**C.** Scanning angle difference

The radar did not scan the body, causing misjudgment.

**D.** Very low radar sensitivity

The radar provides parameter adjustment capability, so sensitivity can be increased for improvement.

**7. Function description****7.1 Description of function point**

| Function point  | State change time/function explanation  |
|---|---|
| DP1: Presence/Non-presence  | Report within 0.5s from non-presence to presence<br>Output non-presence state in 50s from presence to non-presence                                    |
| DP2: Presence, static/active  | Report within 0.5s when changing from static state to moving state  |
| DP3: Someone approaching the device/Someone leaving away from the device/Someone moving without direction | Report within 0.5s; if someone is continuously approaching/leaving away from the device for 3s, report such continuous approaching/leaving away state |
| DP4: Body motion amplitude parameter 0-100  | Output data every 1 second<br>Reference (Description of body motion amplitude parameter output)   |
| DP5: Sensitivity settings, Level 1-3  | Sensitivity 3 by default; support three-level adjustment; the higher the sensitivity, the larger the static detection area                            |
| DP6: Scenario mode (default, area detection, bathroom, hotel, bedroom, office)                            | Adapt to different scenarios based on area size   |

## 7.2 Description of body motion amplitude parameter output

| Body motion amplitude parameter |                                  |                                      |
|---------------------------------|----------------------------------|--------------------------------------|
| 0%                              | Absence                          | No one present in the environment    |
| 1%                              | Static (Sleep)                   | Only breathing without limb movement |
| 2%-30%                          | Subtle motion                    | Only slight head or limb movement    |
| 31%-60%                         | Walking/rapid limb movement      | Slower body movement                 |
| 61%-100%                        | Running/close-range big movement | Rapid body movement                  |

## 8. Protocol description

This protocol is applied to the communication between the 24G millimeter wave human presence detection radar and the host computer.

This protocol outlines the radar workflow, gives a brief introduction to the interface protocol composition architecture, and explains the control commands and data required for radar operation. The serial communication is defined as follows:

- Interface level: TTL
- Baud rate: 9600bps
- Stop bit: 1
- Data bit: 8
- Parity check: N/A

## 9. Definition of communication command and parameter

### 9.1 Definition and description of frame structure

#### Definition of frame structure

| Start code | Data length |         | Function code code | Address code 1 | Address code 2 | Data   | Check digit |         |
|------------|-------------|---------|--------------------|----------------|----------------|--------|-------------|---------|
|            | Lenth_L     | Lenth_H |                    |                |                |        | Crc16_L     | Crc16_H |
| 0X55       |             |         | Command            | Address_1      | Address_2      | Data   |             |         |
| 1 Byte     | 1 Byte      | 1 Byte  | 1 Byte             | 1 Byte         | 1 Byte         | n Byte | 1 Byte      | 1 Byte  |

#### Description of frame structure

- Start code: 1Byte, fixed to 0X55
- Data length: 2 Bytes, low byte followed by high byte.

Length = Data length + Function code + Address code 1 + Address code 2 + Data + Check digit.

- Function code: 1 Byte  
Read command: 0X01  
Write command: 0X02  
Passive report command: 0X03  
Active report command: 0X04
- Address code: Address code 1 represents the function classification, and address code 2 represents the specific function.  
See the “Description of address assignment and data information” section.
- Data: n Byte
- Check digit: 2 Bytes, low byte followed by high byte.  
CRC16 check, refer to Appendix 1 for reference codes.

## 9.2 Description of address assignment and data information

| 24G Biosensing Radar Interface Content |                                 |  |                                      |  |
|--|---------------------------------|--|--------------------------------------|--|
| Function code                          | Address code 1                  | Address code 2   | Data                                 | Remarks  |
| Read command<br>0x01                   | Identification query<br>0x01    | Device ID 0X01   |                                      |  |
|  |                                 | Software version 0x02                                    |                                      |  |
|  |                                 | Hardware version 0x03                                    |                                      |  |
|  |                                 | Protocol version 0x04                                    |                                      |  |
|  | Radar information query<br>0x03 | Environmental state 0X05                                 |                                      |  |
|  |                                 | Physical sign parameter 0x06                             |                                      |  |
|  | System parameter<br>0x04        | Threshold level 0x0C                                     |                                      |  |
|  |                                 | Scenario settings 0x10                                   |                                      |  |
|  |                                 | Forced entry into non-presence level<br>0X12             |                                      |  |
| Write command<br>0x02                  | System parameter<br>0x04        | Threshold level 0x0C                                     | Enumeration range<br>1~3             | Corresponding to Level 1, 2, and 3 (Level 3 by default). The higher the level, the greater the sensitivity |
|  |                                 | Scenario settings 0x10                                   | Default mode 0x00                    |  |
|  |                                 |  | Area detection (top-mounted)<br>0x01 |  |
|  |                                 |  | Toilet (top-mounted) 0x02            |  |
|  |                                 |  | Bedroom (top-mounted) 0x03           |  |
|  |                                 |  | Living room (top-mounted) 0x04       |  |
|  |                                 |  | Office (top-mounted) 0x05            |  |
|  |                                 |  | Hotel (top-mounted) 0x06             |  |
|  |                                 | Not use the forced entry into non-presence function 0X00 |                                      |  |
| 10s 0X01                               |                                 |  |                                      |  |

|                                   |   |  |   |  |  |
|-----------------------------------|---|--|---|--|--|
|                                   |   | Forced entry into non-presence level<br>0X12 | 30s 0X02  |  |  |
|                                   |   |  | 1min 0X03   |  |  |
|                                   |   |  | 2min 0X04   |  |  |
|                                   |   |  | 5min 0X05   |  |  |
|                                   |   |  | 10min 0X06  |  |  |
|                                   |   |  | 30min 0X07  |  |  |
|                                   |   |  | 60min 0X08  |  |  |
|                                   | Other functions<br>0X05                                     | Restart 0X04                                 |   |  |  |
|                                   |   | Start OTA upgrade 0X08                       | 4Byte shaping data<br>(Firmware package size)<br>+<br>15Byte firmware information |  |  |
|                                   |   | Upgrade package transmission 0X09            | Packet offset (4Byte)<br>+<br>Data packet (1024Byte)                              | The first four bytes are fixed as the packet<br>offset, followed by the packet content |  |
| Upgrade end information 0X0A      |   | Fixed character 0X0F                         |   |  |  |
| Passive report<br>command<br>0x03 | Report module<br>identification<br>0x01                     | Device ID 0X01                               | 12Byte data   |  |  |
|                                   |   | Software version 0x02                        | 10Byte data   |  |  |
|                                   |   | Hardware version 0x03                        | 8Byte data  |  |  |
|                                   |   | Protocol version 0x04                        | 8Byte data  |  |  |
|                                   | Report radar information<br>0X03                            | Environmental state 0X05                     | Non-presence state 00 FF FF   |  |  |
|                                   |   |  | Presence, static 01 00 FF   |  |  |
|                                   |   |  | Presence, moving 01 01 01   |  |  |
|                                   | Physical sign parameter 0x06                                | 4 Byte Float data<br><b>(See Appendix 2)</b> |   |  |  |
|                                   | Report system parameter<br>0X04                             | Threshold level 0x0C                         | Current level (0X01~0X03)   |  |  |
|                                   |   | Scenario settings 0x10                       | Default mode 0x00   |  |  |
|                                   |   |  | Area detection (top-mounted)<br>0x01  |  |  |
|                                   |   |  | Toilet (top-mounted) 0x02   |  |  |
|                                   |   |  | Bedroom (top-mounted) 0x03  |  |  |
|                                   |   |  | Living room (top-mounted) 0x04  |  |  |
|                                   |   |  | Office (top-mounted) 0x05   |  |  |
|                                   |   |  | Hotel (top-mounted) 0x06  |  |  |
|                                   | Not use the forced entry into<br>non-presence function 0X00 |  |   |  |  |
|                                   | 10s 0X01  |  |   |  |  |

|                                  |   |  |                                   |   |  |
|----------------------------------|---|--|-----------------------------------|---|--|
|                                  |   | Forced entry into non-presence level<br>0X12 | 30s 0X02                          |   |  |
|                                  |   |  | 1min 0X03                         |   |  |
|                                  |   |  | 2min 0X04                         |   |  |
|                                  |   |  | 5min 0X05                         |   |  |
|                                  |   |  | 10min 0X06                        |   |  |
|                                  |   |  | 30min 0X07                        |   |  |
|                                  |   |  | 60min 0X08                        |   |  |
|                                  | Report other information                | Start OTA upgrade feedback<br>0X08           | Feedback OTA transmission<br>0X09 | Failed 0X00   |  |
| Succeeded 0X01                   |   |  |                                   |   |  |
| Active report<br>command<br>0x04 | Report module<br>identification<br>0x01 | Software version 0x02                        | 15 Byte data                      |   |  |
|                                  | Report radar information<br>0x03        | Environmental state 0X05                     | Non-presence state 00 FF FF       |   |  |
|                                  |   |  | Presence, static 01 00 FF         |   |  |
|                                  |   |  | Presence, moving 01 01 01         |   |  |
|                                  |   | Physical sign parameter for motion<br>0x06   | 4 Byte Float data                 |   |  |
|                                  | Approaching/leaving away state 0x07     |  | Fixed<br>character<br>0x01        | Non-presence 0x01   |  |
|                                  |   |  |                                   | Approaching<br>0x02   |  |
|                                  |   |  |                                   | Leaving away<br>0x03  |  |
|                                  |   |  |                                   | Continuously<br>approaching<br>0x04   |  |
|                                  |   |  |                                   | Continuously leaving<br>away<br>0x05  |  |
|                                  | Report other information<br>0X05        | Heartbeat package 0X01                       | Non-presence state 00 FF FF       |   |  |
|                                  |   |  | Presence, static 01 00 FF         |   |  |
| Presence, moving 01 01 01        |   |  |                                   |   |  |
| Abnormal reset 0X02              |   | 0X0F   |                                   | When the radar restarts or powered up again, it will first report an abnormal reset command, then start initialization, and finally report a successful initialization command<br><br>Indicate the successful initialization of the radar and the start of normal operation |  |
| Initialized successfully 0X0A    | 0X0F                                    |  |                                   |   |  |

**Notes:**

- 1) The read and write command is an instruction sent by the host computer to the radar.
- 2) The report command is a message sent by the radar to the host computer.
- 3) There are three levels of body sensitivity - Level 1-3 (Level 3 by default). The higher the level, the more sensitive

## Appendix 1: Reference Parsing Code for CRC Check Digit

```

1. const unsigned char cuc_CRChi[256]=
2. {
3.     0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
4.     0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
5.     0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
6.     0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
7.     0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
8.     0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
9.     0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
10.    0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
11.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
12.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
13.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
14.    0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
15.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
16.    0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
17.    0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
18.    0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
19.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
20.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x00, 0xC1, 0x81, 0x40,
21.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
22.    0x00, 0xC1, 0x81, 0x40, 0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41,
23.    0x00, 0xC1, 0x81, 0x40, 0x01, 0xC0, 0x80, 0x41, 0x01, 0xC0, 0x80, 0x41,
24.    0x00, 0xC1, 0x81, 0x40
25. };

```

```

1. const unsigned char cuc_CRCLo[256]=
2. {
3.     0x00, 0xC0, 0xC1, 0x01, 0xC3, 0x03, 0x02, 0xC2, 0xC6, 0x06, 0x07, 0xC7,
4.     0x05, 0xC5, 0xC4, 0x04, 0xCC, 0x0C, 0x0D, 0xCD, 0x0F, 0xCF, 0xCE, 0x0E,
5.     0x0A, 0xCA, 0xCB, 0x0B, 0xC9, 0x09, 0x08, 0xC8, 0xD8, 0x18, 0x19, 0xD9,
6.     0x1B, 0xDB, 0xDA, 0x1A, 0x1E, 0xDE, 0xDF, 0x1F, 0xDD, 0x1D, 0x1C, 0xDC,
7.     0x14, 0xD4, 0xD5, 0x15, 0xD7, 0x17, 0x16, 0xD6, 0xD2, 0x12, 0x13, 0xD3,
8.     0x11, 0xD1, 0xD0, 0x10, 0xF0, 0x30, 0x31, 0xF1, 0x33, 0xF3, 0xF2, 0x32,
9.     0x36, 0xF6, 0xF7, 0x37, 0xF5, 0x35, 0x34, 0xF4, 0x3C, 0xFC, 0xFD, 0x3D,
10.    0xFF, 0x3F, 0x3E, 0xFE, 0xFA, 0x3A, 0x3B, 0xFB, 0x39, 0xF9, 0xF8, 0x38,
11.    0x28, 0xE8, 0xE9, 0x29, 0xEB, 0x2B, 0x2A, 0xEA, 0xEE, 0x2E, 0x2F, 0xEF,
12.    0x2D, 0xED, 0xEC, 0x2C, 0xE4, 0x24, 0x25, 0xE5, 0x27, 0xE7, 0xE6, 0x26,
13.    0x22, 0xE2, 0xE3, 0x23, 0xE1, 0x21, 0x20, 0xE0, 0xA0, 0x60, 0x61, 0xA1,
14.    0x63, 0xA3, 0xA2, 0x62, 0x66, 0xA6, 0xA7, 0x67, 0xA5, 0x65, 0x64, 0xA4,
15.    0x6C, 0xAC, 0xAD, 0x6D, 0xAF, 0x6F, 0x6E, 0xAE, 0xAA, 0x6A, 0x6B, 0xAB,
16.    0x69, 0xA9, 0xA8, 0x68, 0x78, 0xB8, 0xB9, 0x79, 0xBB, 0x7B, 0x7A, 0xBA,
17.    0xBE, 0x7E, 0x7F, 0xBF, 0x7D, 0xBD, 0xBC, 0x7C, 0xB4, 0x74, 0x75, 0xB5,
18.    0x77, 0xB7, 0xB6, 0x76, 0x72, 0xB2, 0xB3, 0x73, 0xB1, 0x71, 0x70, 0xB0,
19.    0x50, 0x90, 0x91, 0x51, 0x93, 0x53, 0x52, 0x92, 0x96, 0x56, 0x57, 0x97,
20.    0x55, 0x95, 0x94, 0x54, 0x9C, 0x5C, 0x5D, 0x9D, 0x5F, 0x9F, 0x9E, 0x5E,
21.    0x5A, 0x9A, 0x9B, 0x5B, 0x99, 0x59, 0x58, 0x98, 0x88, 0x48, 0x49, 0x89,
22.    0x4B, 0x8B, 0x8A, 0x4A, 0x4E, 0x8E, 0x8F, 0x4F, 0x8D, 0x4D, 0x4C, 0x8C,
23.    0x44, 0x84, 0x85, 0x45, 0x87, 0x47, 0x46, 0x86, 0x82, 0x42, 0x43, 0x83,
24.    0x41, 0x81, 0x80, 0x40
25. };

```

```

1. static unsigned short int us_CalculateCrc16(unsigned char *lpuc_Frame, unsigned short int lus_Len)
2. {
3.     unsigned char luc_CRCHi = 0xFF;
4.     unsigned char luc_CRCLo = 0xFF;
5.     int li_Index=0;
6.
7.     while(lus_Len--)
8.     {
9.         li_Index = luc_CRCLo ^ *(lpuc_Frame++);
10.        luc_CRCLo = (t_BYTE)( luc_CRCHi ^ cuc_CRCHi[li_Index]);
11.        luc_CRCHi = cuc_CRCLo[li_Index];
12.    }
13.    return (unsigned short int)(luc_CRCLo << 8 | luc_CRCHi);
14. }

```

Example: Read command for sensitivity query:

55 07 00 01 04 0C sum (2byte) Check digit parsing → 55 07 00 01 04 0C EA DB

## Appendix 2: Parsing Code for Motion Physical Sign Parameters

```
typedef union
{
    unsigned char Byte[4];
    float Float;
}Float_Byte;

void main()
{
    Float_Byte fb;
    fb.Byte[0] = 0x9A;
    fb.Byte[1] = 0xFB;
    fb.Byte[2] = 0xE7;
    fb.Byte[3] = 0x3F;
    printf("%f\r\n",fb.Float);
}
```

## 10.Updates history

| Revision  | Release Date | Summary  |
|-----------|--------------|--|
| V1.0_0212 | 2020/02/12   | First draft  |
| V1.1_0319 | 2021/03/19   | Readjusted   |
| V1.2_0628 | 2021/6/28    | Added the description of body sensitivity levels                                       |
| V1.3_0906 | 2021/9/06    | Modified sensitivity level from 0-9 to 1-10  |
| V1.4_0210 | 2022/2/10    | Added initialization success instruction protocol                                      |
| V1.5_0221 | 2022/2/21    | Added protocol for forced entry into non-presence level                                |
| V1.6_0606 | 2022/6/6     | Adjusted the document cover and related data details                                   |
| V1.7_0223 | 2023/2/23    | Added continuous approaching/leaving away protocol, and improved relevant data details |