24G millimeter-wave radar

R24AVD1 human presence radar

Data Book v1.9

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1.Product introduction

1.1 Product introduction

The R24AVD1 radar module employs the millimeter-wave radar technology to realize detection of human motion distance. Based on the 1T1R FMCW (frequency modulated continuous wave) signal processing mechanism, this module performs wireless sensing on the status of people in the specific area via the synchronous sensing technology that detects motion intensity and chest expansion parameters.

Radar frequency band	24G millimeter-wave radar
Number of antennas	1T1R
Detection mechanism	FMCW
Active detection	Detection of chest expansion with breath
	Distance measurement
Parameter settings	Scenario mode settings
	Sensitivity settings

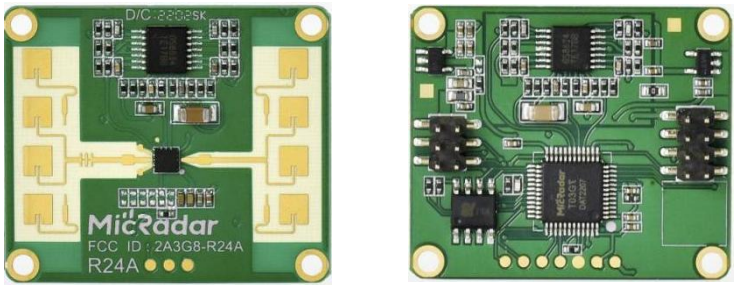

Fig. 1: Front and back sides of the radar

1.2 Theory of operation

The radar antenna transmits electromagnetic wave signals, and synchronically receives reflected echo signals. Then, the radar analyzes the waveform parameter of the echo signals, and gives feedback on distance, orientation and other information of the target to detect the status of the moving object.

1.3 Function description

Motion detection amplitude

- Motion information output, such as walking and minor arm swings, can be detected within the range of the radar, upon which the human presence state will be triggered

Breath detection

- When someone stays still in the detection range of the radar, his / her subtle motion arising from breath, such as chest expansion, can be detected, and the state of human presence will remain.

1.4 Parameter settings

Scenario mode settings

- Scenario modes are designed for detection of motion range. The radar comes with scenario settings of Default, Office, Hotel, Living Room, Bedroom, Area Detection, and Toilet, which have varying sizes of motion detection range (Default > Office > Hotel > Living Room > Bedroom > Area Detection > Toilet). You can adjust scenario settings by the size of actual environment.

Sensitivity settings

- Sensitivity allows you to adjust the static detection range from Level 1 - 3. A greater level leads to higher sensitivity and a greater static range for detection. You can adjust it by the size of the scenario.

1.5 Applications

- House intelligence
- Smart appliances (TVs, heat lamps, security, etc.)
- Office energy conservation (ACs / lighting)
- Sleep monitoring
- Human breath detection
- Regional human detection

- Babysitting
- Speed / distance measurement
- Home security
- IPC triggering

2.Product encapsulation diagram

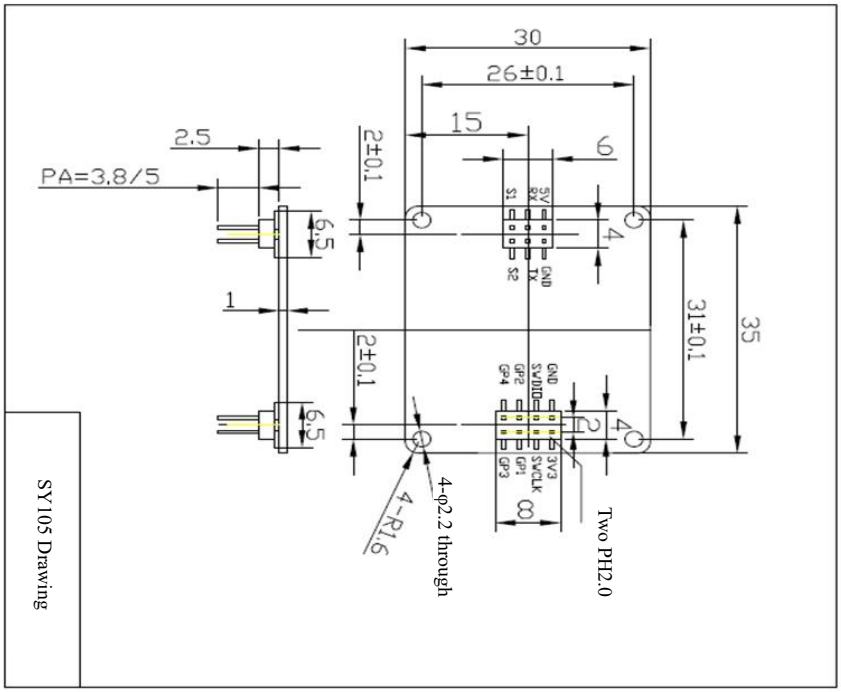

Fig. 2: Schematic diagram for radar module frame

- Volume: 35 mm × 31 mm × 7.5 mm
- Interface: Pitch 2.0 mm dual-row connector. 2 connectors in total: 2*3 and 2*4

3.Pin parameter explanation

3.1 Pin explanation

Interface	Pin	Description	Typical value	Notes
Interface 1	1	5V	5.0V	Power input positive
	2	GND		Ground
	3	RX	3.3v	Serial port reception

	4	TX	3.3v	Serial port send
	5	S1	3.3V/0V	Presence / Non-presence
	6	S2	3.3V/0V	Active / Still
Interface 2	1	3V3	3.3V	Output power
	2	GND		Ground
	3	SWC		Reserved
	4	SWD		Reserved
	5	GP1		Spare extension pin
	6	GP2		Spare extension pin
	7	GP3		Spare extension pin
	8	GP4		Spare extension pin

Note: 1) S1 output: High level - presence; and low level - non-presence;

2) GP1 - GP4 are control ends of parameter selection, and can be redefined as required by the user.

3) The output signals from this interface are all 3.3 V in level.

3.2 Serial port output parameters

- Presence / Non-presence
- Active / Still
- Physical sign parameter
- Product Info

3.3 Settable parameters

- Scenario settings
- Sensitivity settings
- Non-presence time settings

3.4 Output protocol

- Standard serial port protocol
- Standard protocol of Tuya

3.5 Naming conventions of models

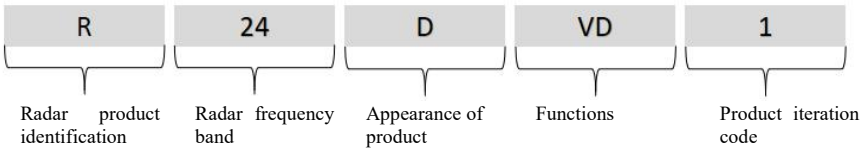

Fig. 3: Naming conventions of models

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4.Product features

The R24AVD1 radar module is of a two-element antenna form: the wide-beam radar module, which mainly applies to top mounting that realizes human breath detection of a large-angle coverage. If installed horizontal or inclined, attention should be paid to blocking in actual scene so that further distance can be reached for radar detection.

This radar module features the following:

- Realizing synchronous sensing on people who are moving and staying still;
- Capability to detect fall alarms and stay-still anomalies in a specific place;
- Capability to fast output the state of the target approaching or leaving away from the radar;
- Detecting different motion amplitudes, and outputting values and states in real time;
- Limiting detection to humans that bear biological features (moving or static) while eliminating the interference from other inanimate objects in the same place;
- The module is capable of eliminating interference from inanimate objects as well as realizing detection of inanimate moving objects;
- The product supports secondary development, making it applicable to a variety of scenarios;
- Universal UART communication interface, with universal protocol provided;
- 4 sets of I/O are reserved, allowing the user to define input and output as needed or perform simple interface simulation;
- The module is of small output power and hence harmless to health;
- The module is immune to temperature, lighting, dust and other factors while bearing high sensitivity, making it applicable in a variety of scenarios.

5.Electrical characteristics and parameters

5.1 Detection angle and distance

Parameter details	Minimum	Typical value	Maximum	Unit	Installation method
R24AVD1					
Detection distance for moving bodies	-	-	12	m	Side-mounted
Sensing distance for static persons	-	-	4	m	Side-mounted
Sensing diameter of sleeping persons	-	-	3	m	Top-mounted 2.75 m
Angle of radar detection (horizontal)	-	90	-	Degree(s)	
Angle of radar detection (inclined)	-	60	-	Degree(s)	

5.2 Electrical characteristics

Working Parameters	Minimum	Typical value	Maximum	Unit
Working voltage (VCC)	4.5	5.0	6	V
Working current (ICC)	90	93	100	mA
Working I/O input / output current (IIO)	—	8	20	mA
Working temperature (TOP)	-20	-	+60	℃
Storage temperature (TST)	-40	-	+80	℃

5.3 RF performance

Transmission parameter	Minimum	Typical value	Maximum	Unit
Working frequency (fTX)	24.0	-	24.25	GHz
Transmission power (Pout)	-	-	6	dBm
Antenna gain (GANT)			10	
Horizontal beam (3 dB)			100	
Vertical beam (3 dB)			80	

5.4 Application wiring diagram

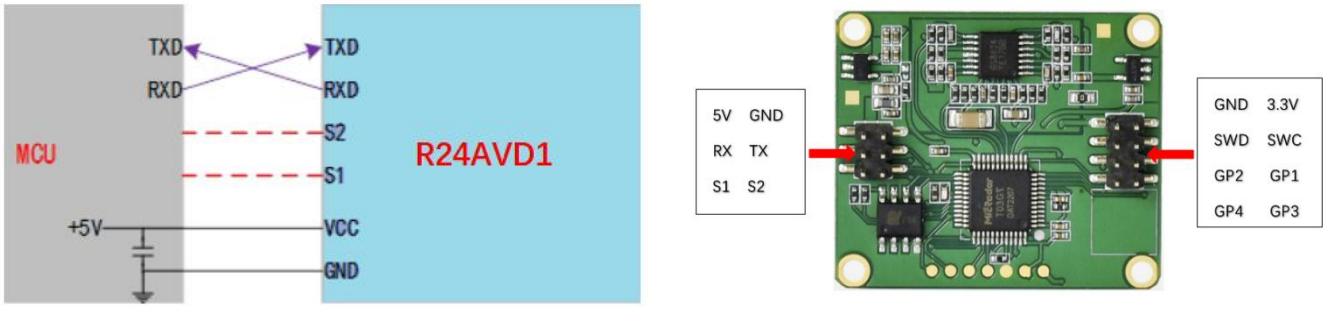

Fig. 4: Schematic diagram for connection between radar module and peripherals

6.Main functions and performance

6.1 Radar module coverage

The beam coverage of the R24AVD1 radar module is shown in Fig. 5. The coverage of the radar is a three-dimensional sector 90° horizontally and 60° vertically.

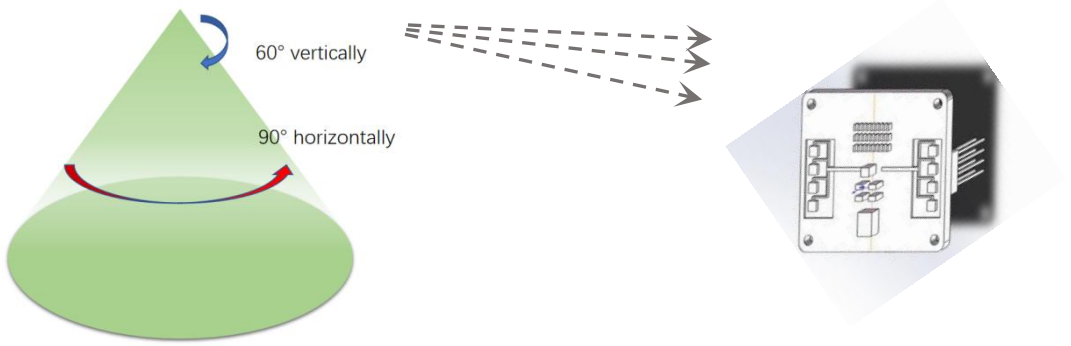

Fig. 5 Coverage of R24AVD1 radar

Affected by the characteristics of radar beams, the operating distance along the normal line to the antenna face is greater, while the one displacing from it is smaller.

Attention should be paid that when the radar is top-mounted, the range of the radar will be reduced as a result of radar beam coverage and effective radiation space.

6.2 Main functions and performance

The main functions of this radar module include:

- Motion detection (height for top mounting 2.75 m)

  a.Max. detection diameter: ≤ 14 m (adults);

  b.Detection sensitivity: ≤ 0.5 m/s;

  c.Time of reaction: ≤ 100 ms;

- Subtle motion detection (height for top mounting 2.75 m)

a.Max. detection diameter: ≤ 8 m;

b.Time of reaction: ≤ 1 s;

7.Installation method and working modes

7.1 Installation method

This radar module should be top-mounted.

7.1.1 Horizontal mounting

Figure 6 shows the horizontal mounting method, which applies to body detection of standing or seated persons and thus to the scenarios of living rooms, electrical appliances, etc.

The radar is recommended to be installed at a height of 1 m - 1.5 m, horizontally in forward direction, with a tilt < ±5°. The front of the radar should not be blocked or covered whatsoever.

The normal line of the radar should be aligned with the main point of detection to ensure the main beam of the radar antenna covers the detection area and the airspace of body activities.

Under this installation mode, the max. distance of moving body detection is L3 ≤ 9 m, sitting still / subtle motion L2 ≤ 5 m, and sleep L1 ≤ 3 m.

Limited by the beam coverage of the radar antenna, the effective working distance will be reduced if displaced from the normal line direction of the radar.

Electromagnetic waves in millimeter-wave frequency band can penetrate non-metallic matters - common glass, wooden boards, screens, and thin partition walls - to a certain degree, and hence can detect moving objects behind such obstacles. However, thick load-bearing walls, metal doors, and the like are not penetrable.

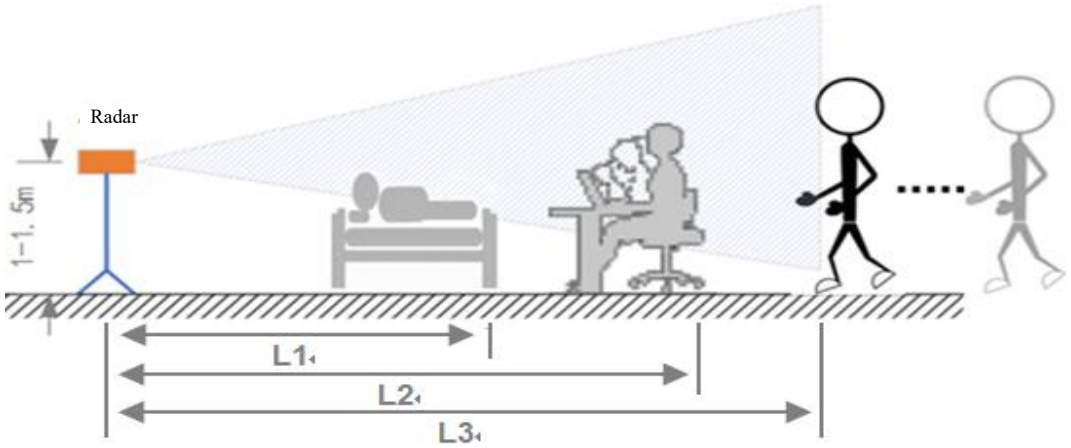

Fig. 6 Horizontal mounting diagram

7.1.2 Inclined mounting

Inclined mounting is as shown in Fig. 7. This mounting method is designed for detection of human motion in a room and hence applicable to hotels, lobbies and similar places.

The radar is recommended to be installed at a height of 2 m - 2.75 m, with a look-down tilt angle ranging from 10° - 30°. The front of the radar should not be blocked or covered whatsoever.

The normal line of the radar should be aligned with the main point of detection to ensure the main beam of the radar antenna covers the detection area and the airspace of body activities.

Under this installation mode, the max. distance of moving body detection is L3 ≈ 6 m, sitting still / subtle motion L2 ≈ 3.5 m, and sleep L1 ≈ 2 m;

In this mode, the area right beneath the radar as well as its adjacent areas might involve a dead zone.

With the increase in look-down tilt angle, the distance of body detection will be considerably reduced.

Limited by the radiation characteristics of the radar antenna, the effective working distance will be reduced if displaced from the normal line direction of the radar.

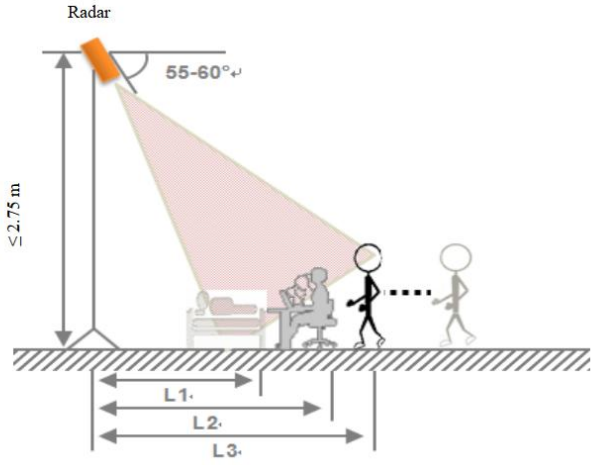

Fig. 7 Look-down mounting

7.1.3 Top mounting

Top mounting is as shown in Fig. 8. This mounting method is mainly designed for monitoring of a lying body and hence applicable to bedrooms, nursing places, sickbeds, etc.

The radar is installed vertical with a horizontal deviation angle of ≤ 3° to make sure the main beam of the radar covers the detection area. The recommended height (to the ground) of installation is ≤ 2.75 m without noticeable obstacles and coverings in front.

Depending on the height of installation and the coverage of radar beams, under this installation mode, the max. distance of moving body detection is L3 ≈ 7 m, sitting still / subtle motion L2 ≈ 4 m, and sleep L1 ≈ 1.5 m;

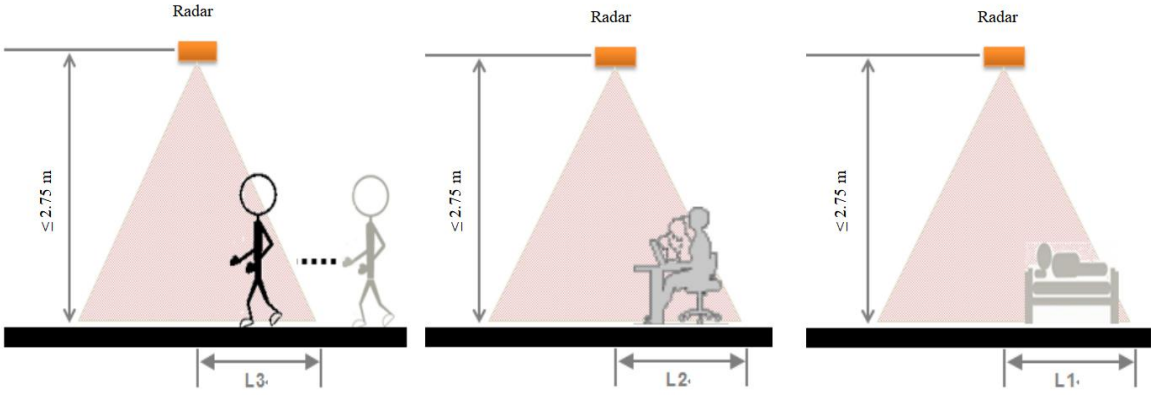

Fig. 8 Top mounting

Note:

All mounting methods mentioned above require coverage over the main area of body motion by main beam of the radar, with the alignment with the direction of normal line as far as possible;

In inclined mounting, horizontal working distance is reduced due to the change in horizontal projection of the coverage;

When the module works, no metal obstacles should exist on module surface;

Affected by the transmission characteristics of electromagnetic waves, the working distance of the radar varies with RCS, material of cover and thickness of the target.

For stay-still detection, the working distance of the radar is affected by postures. The maximum working distance is not guaranteed for all postures.

7.2 Work modes of radar

Upon statistical analysis, the radar module will perform a comprehensive assessment over the states of persons in current detection area, results of which are readily usable by the user.

State running mode

In this mode, the radar module periodically gives feedback on the presence and motion states of persons in current detection area, which mainly include:

- Absence
- Presence, static
- Presence, moving

In order to ensure accuracy of environmental condition judgement in state running mode, the radar module performs logical judgement internally. Below is the state output logic of radar module:

- only when a change in states is detected will the radar output corresponding state. In the other cases, the radar will remain silent;
- Time of switching ≤ 1 s;
- The radar will go through state confirmation several times before changing presence state to non-presence state. The typical value of switching time is 50 s;

8.Related documents

- User Manual
- Tutorial
- Development board

9.Typical application mode

This module is mainly applicable to scenarios such as homes, home appliances, and energy saving lamp control. Below are the details on the applications in typical scenarios.

9.1 Applications in smart appliances

The radar is installed inside appliances to monitor the status of people on working surface in real time, and adjust the working modes (working, low power, standby, shutdown, etc.) in real time or quasi-real time according to the status (presence / non-presence), thus realizing intellectualization for household appliances.

In this application, the radar is installed onto the appliance radar, either horizontal or inclined according to the working features, to ensure the beam is able to cover the main working area of the appliance.

Regular appliances include

- Smart TVs
- Smart loudspeakers
- Smart ACs
- Other smart appliances

9.2 Applications in house places

Designed for houses, hotels, offices, toilets and other similar places where real-time detection is required on entry or movement of the people inside to realize security, appliance control, person monitoring, etc. while avoiding privacy issues. Installed in a room, this radar is able to monitor the presence of moving targets, direction of motion, presence of humans, etc. in it, and, via IoT transmission and with the help of IoT supportive platforms, realize effective applications in relevant places.

This radar can be used in the following cases

- Home security

- Hotel management and monitoring
- Monitoring on people of community health care
- Office monitoring

9.3 Installation and applications in bedrooms

To give relevant information on people lying in bed in certain cases, e.g. presence / non-presence, so as to realize specific applications. The radar should be top-mounted in this mode.

Applications realizable based on this mode include

- Care for the aged
- Health care
- Hotel applications
- Home health

9.4 Applications in energy conservation control

Based on detection of moving targets and biological features, the radar is a good helper in energy conservation control. Below are the main applications:

- Home appliance energy conservation
- Office appliance energy conservation control
- Street light energy conservation control

10.Notes

10.1 Start-up time

The module needs to fully reset its internal circuits and performs a full assessment on ambient noise when it is powered on and starts to work, so as to ensure the module can work properly. As a result, the module requires a stabling time ≥ 30 s upon powering on to ensure the effectiveness of parameters output subsequently.

10.2 Effective distance of detection

The distance of detection of the radar module depends mainly on target RCS and environmental factors, and might vary with the environment and the target. This module is not provided with distance measurement feature for now, and hence it’s normal for the effective distance of detection to fluctuate in a certain range.

10.3 Bio-detection performance of radar

Due to the fact that the biological features of human bodies are characteristic signals of super low frequency and weak reflection, long-period accumulation is required for radar processing. However, a number of factors might affect the parameters of the radar during the course. On this account, it's normal that detection fails sporadically.

10.4 Power source

The radar module has requirements higher than regular low-frequency circuits on power source quality. When supplying power to the module, the power source is required to be free from any threshold glitches or ripples, and can effectively shield power supply noise from accessories.

The radar module requires proper grounding. Ground noise from other circuits might compromise the performance or even cause an anomaly in the module. A reduced distance of detection or increased false alarm rate is one of the commonest.

To ensure the VCO circuit inside the module works properly, power supply to this module should be +5V - +6V, with ripple voltage ≤ 100 mV.

External power supply must be able to provide sufficient current output and transient response capacity.

11.FAQs

Interference factors: The radar is a sensor for electromagnetic wave detection. Inanimate objects that are moving can lead to a false alarm. Movements of metal and liquid can lead to misjudgment. Normally, fans, pets close to the radar, and waving of metallic curtains can lead to misjudgment. Installation angle should be properly designed for the radar.

Non-interference factors: Electromagnetic waves of the radar can penetrate clothes, curtains, thin wooden boards, and glass. On this account, installation angle and performance should be determined according to applications.

Quasi-interference factors: The radar should not face an AC directly if it's to detect human presence. The internal motor of ACs can lead to misjudgment. Therefore, it's required that the radar product is not installed facing an AC directly or in the same orientation as an AC.

12.Disclaimer

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14.Contact

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15.Revision History

Revision	Release Data	Summary	Author
V1.0_1012	10/12/2020	First draft	OF_Frank
V1.1_1126	11/26/2020	Added with approaching / leaving away and scenario modes	Baron
V1.2_1209	12/9/2020	Separated approaching / leaving away from environment status	Baron
V1.3_1214	12/14/2020	1: Added with detailed environment parameters for heartbeat package 2: Modified the fixed character of approaching / leaving away as 0x01 0x01 3: Modified the definition of parameter intervals for physical signs of motion	Baron

V1.4_0106	1/6/2021	Rectified errors in data bits of scenario settings for passive reporting	Baron
V1.5_0317	03/17/2021	Overall perfection	Baron
V1.6_0221	02/21/2021	Modified correspondence for S2 in pin description	Baron
V1.7_0519	05/19/2022	Perfection of document details	Baron
V1.8_0313	03/13/2023	Perfection of document functions and product links	Baron
V1.9_1106	06/11/2023	Delete the parameter description of the fall function in the document	Mark