UM10032
XenP102RM User Manual

Rev.1.0 **User Manual**

Introduction

This document introduces the high precision human range measurement mmWave sensor of ICLM smart mmWave sensor XenP102RM, including its basic functions, hardware specification, software configuration, and installing condition etc.

The goal of this document is to guide users to get started with XenP102RM high precision human range measurement mmWave sensor quickly and easily, so that users can sort out suitable parameters for specified scenarios, and can design both precise and customized human detection and range measurement sensors.

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1. XenP102RM Overview

The XenP102RM is a high precision human range measurement mmWave sensor of ICLM EZ Sensor series. It contains a minimalist 24 GHz radar sensor hardware Xen102 and an intelligent algorithm firmware RM02. This reference design is optimal for single-target scenarios, and when there are multiple human targets in detection area, the sensor will report information of the target that generates the highest echo wave energy.

The Xen102 hardware incorporates an AIoT mmWave sensor SoC S3KM111L, high-performance 24 GHz 1T1R antennas, and peripheral circuits. Xen102 hardware adopts a narrow beamform design, with azimuth angle (E plane in Figure 6-2, also known as 4 patch direction, as shown in Figure 3-1) of ±20°, and pitch angle (H plane in Figure 6-2) of ±40°. Users can adjust the installation method of the Xen102 according to practical scenarios.

The intelligent algorithm firmware RM02 can accurately perform moving/micro-moving human detection and range measurement by adopting FMCW waveform and S3KM111L specified advanced signal processing technology.

Main features of the XenP102RM are listed below:

- 24 GHz ISM bandwidth
- Incorporate single chip smart mmWave radar S3KM111L and intelligent algorithm firmware
- Accurate indoors/outdoors moving/micro-moving human detection and range measurement
- Compact module size: 28 mm × 24 mm
- 5 V single power supply
- Average operating current of 51 mA@20 Hz reporting frequency
- Load default setting of life presence detection, support Plug and Play
- Provide a visualization tool, support configuring detection range and setting sensibility for each range gate
- Maximum range of human motion detection is 7 m, human micro-motion detection is 3.5 m
- High accuracy range detection: from 30 cm to 600 cm the accuracy is 3 cm; from 600 cm to 700 cm the accuracy is ±2%
- Detection angle: azimuth ±20°, pitch ±40°
- Wall mounted

The XenP102RM high precision human range measurement mmWave sensor can detect and distinguish moving and micro-moving human body, and report the range of the target in real time. The XenP102RM can be widely applied to various AIoT scenarios, including:

- **Smart Home**

  Detecting human presence, reporting results in real time, enabling the MCU to control smart domestic appliances accordingly.

- **Smart Business**

  Entrance control, automatic escalator, etc.

- **Intelligent Security**

  Entrance control, building intercom, visual doorbell etc.

- **Intelligent Lighting**

  Detecting human body presence and location precisely, applicable to public lighting, various motion-sensor lights, and LED bulbs etc.

2. System Characteristics

XenP102RM is a high precision human range measurement mmWave sensor developed based on ICLM S3KM111L SoC. It detects human movement in specified range and reports detection results in real time by adopting FMCW waveform and incorporating radar signal processing and built-in intelligent human presence detecting algorithm. With ICLM smart mmWave sensor reference solution, users can quickly develop customized human detection and range measurement products with high precision.

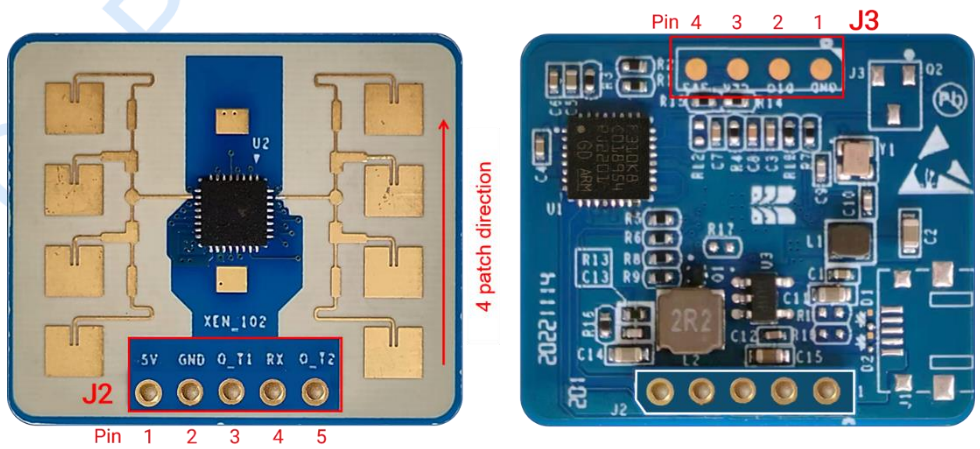
The systematic characteristics of XenP102RM are shown in Table 2-1.

Table 2-1 XenP102RM characteristics

Parameter	Min.	Typ.	Max.	Unit	Condition
Xen102 Hardware Characteristics					
Supporting frequency	24	-	24.25	GHz	
Max. bandwidth	-	0.25	-	GHz	--
Max. EIRP	9	16	16.8	dBm	Can be adjusted by modifying transmit power
Power supply	4.5	5.0	5.5	V	-
Size	-	28 × 24	-	mm^2	-
Environment temperature	-40	-	85	°C	-
XenP102RM System Characteristics					
Detection range	0.3	-	3.5	m	Human micro-motion detection
	0.3	-	7	m	Human motion detection
Detection accuracy	-	3	-	cm	Near: 30 cm~600 cm
	-	2%	-	-	Far: 600 cm~700 cm
Regulation	In accordance with FCC, CE and RC regulations			-	-
Average operating current	-	51	-	mA	Report cycle 50 ms

3. Hardware Overview

Figure 3-1 shows the device maps of hardware Xen102. Xen102 hardware reserves 5 pins (default without contact pin) called J2 for power supply and communication, as shown in Figure 3-1. The MCU programming interface is called J3. When programming the MCU, please connect the pins according to their names. (J1 is reserved USB interface, and will not be introduced in this document.)



(a)Top (b)Bottom

Figure 3-1 Device maps of hardware Xen102

Details of the J2 and J3 pins are listed in Table 3-1 and Table 3-2.

Table 3-1 J2 pin description [1]

J#PIN#	Name	Function	Operating Range
J2 Pin1	5V	Power input	4.5 V ~ 5.5 V, Typ. 5 V
J2 Pin2	GND	Ground	-
J2 Pin3	O_T1	MCU transfer data port	0 ~ 3.3V
J2 Pin4	RX	MCU receive data port	0 ~ 3.3V
J2 Pin5	O_T2	UART_TX (reserved)	0 ~ 3.3V

Table 3-2 J3 pin description

J#PIN#	Name	Function	Operating Range
J3 Pin1	GND	Ground	-
J3 Pin2	DIO	Data port	0~3.3 V
J3 Pin3	CLK	Clock signal	0~3.3 V
J3 Pin4	3V3	Power input	3.3 V

XenP102RM supports Keil5 IDE programming, either hex or firmware file is acceptable. XenP102RM supports common RW programmer such as J-Link (revisions no earlier than V9), CMSIS-DAP etc. Make sure the Keil5 IDE has installed GigaDevice.GD32E23x_DFP.1.0.1.pack, ARM.CMSIS.5.7.0.pack (or later version of CMSIS pack).

4. Software Overview

4.1 Firmware Description

Xen102 hardware requires 5 V power supply. When debugging the radar module, USB serial port board is applied for communication and power supply. When connecting the USB serial port tool to hardware Xen102, users should pay attention to the pin names and make sure that the TX of hardware Xen102 connects to the RX of the serial port tool, the RX of hardware Xen102 connects to the TX of the serial port tool, and the jumper cap connects to the 5 V power supply, as shown in Figure 4-1. If another type of serial port tool is used, make sure the power supply is 5 V.

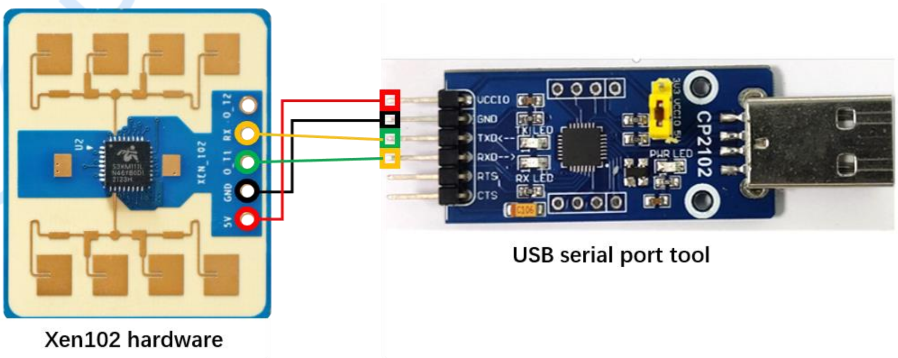


Figure 4-1 Illustration of the connection of hardware Xen102 and USB serial port tool

4.2 Visualization Tool Description

4.2.1 Driver of USB Serial Port Tool

Xen102 hardware transmits data via UART interface, and communicating to the host PC requires a USB serial port tool. The USB serial port tool is a serial port communication device that transferring USB to TTL. Common

USB serial port tool are CP2102 and CH340. The serial port tool in Figure 4-1 is CP2102. Before using the serial port tool, make sure to install corresponding driver[1] on the host PC.

4.2.2 Connecting Radar Module to a Host PC

After installing the serial port tool driver, users can connect Xen102 hardware to the host PC using a serial port tool. To make sure the radar module has successfully connected to the host PC, right click This PC icon, a menu appears as shown in Figure 4-2, click the **Manage** submenu and open the **Device Manager** of the host PC, click the **Ports (COM & LPT)** to obtain the COM number of the radar module. If a COM device exists under Port, as shown in Figure 4-3, it means that the driver is installed, and the radar module is successfully connected to the host PC and can communicate with the host PC via serial port.

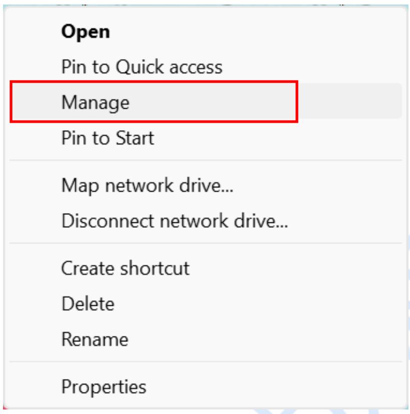


Figure 4-2 The menu shows up after right click on This PC

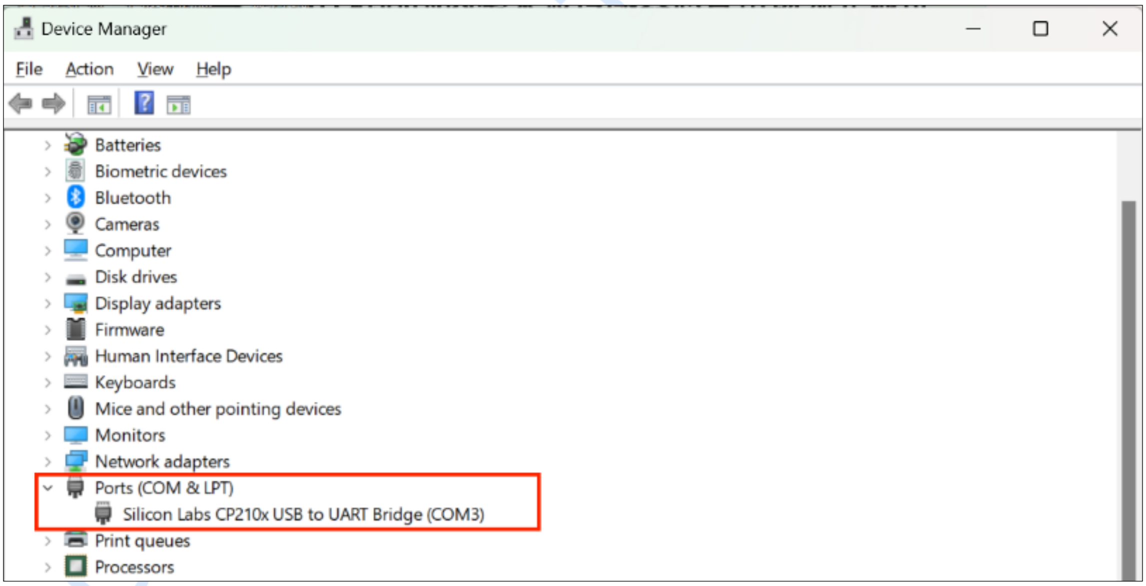


Figure 4-3 COM device on Device Manager

4.2.3 Using Visualization Tool

Download and unzip ICLM_XenP102_RM02Tool from [ICLM website](). The graphic user interface (GUI) is shown in Figure 4-4, it can be partitioned into 3 zones:

- Zone 1 provides functional buttons and input text box, displays firmware version and radar serial number (SN);

[1] CP2102 serial port tool driver: https://www.silabs.com/interface/usb-bridges/classic/device.cp2102?tab=softwareandtools
CH340 serial port tool driver: https://www.wch.cn/downloads/CH341SER_EXE.html

- Zone 2 displays information of the detected target, including target status and exact distance;
- Zone 3 displays the detected target distance in the last 15 s in real time.

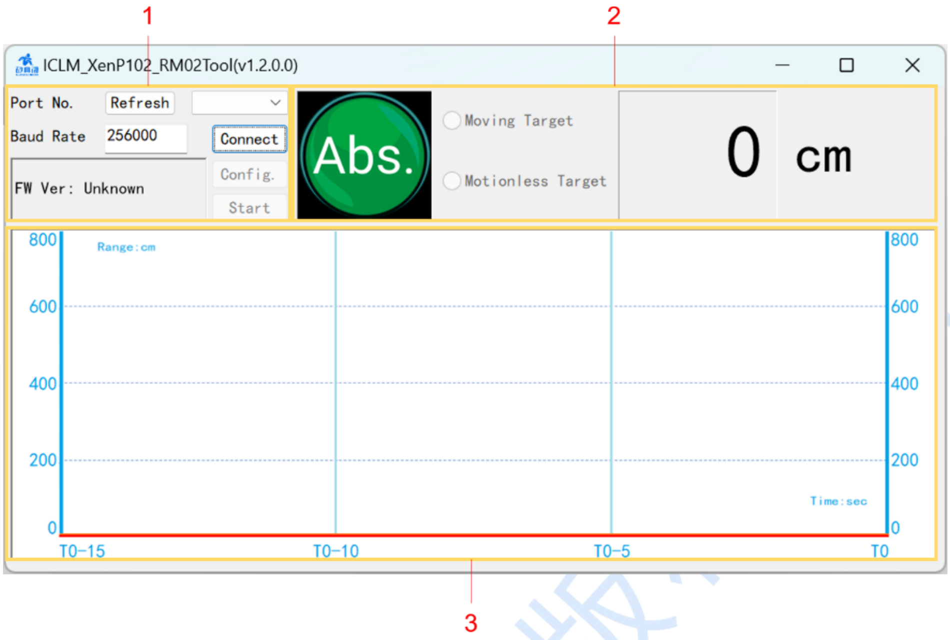


Figure 4-4 GUI before connecting the radar module to the host PC

After connecting the radar module to the host PC using a USP serial port tool, users can use and configurate the radar module parameter through the visualization tool.

Apply Radar Range Measurement

Step 1: Double click the **ICLM_XenP102_RM02Tool.exe** to open the visualization tool; in Zone 1, click the **Refresh** button, choose the serial port number of the radar module and type in the baud rate (default as 256000);

Step 2: Click the **Connect/Disconn.** toggle button to connect the visualization tool with the radar module; as shown in Figure 4-5, Zone 1 displays the firmware version and SN of the radar module (the SN of the radar module is a number of 8 digits; if the module has not written a new SN, Zone 1 will display its default value: 12345678);

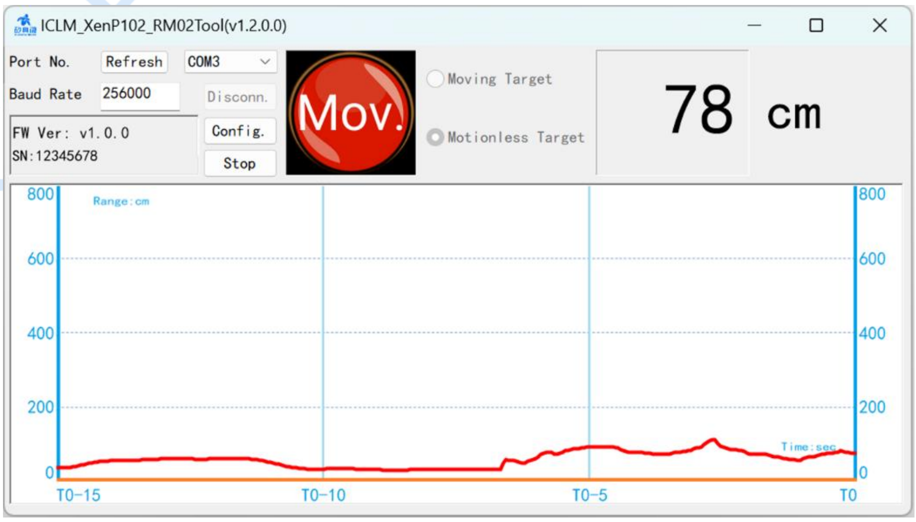


Figure 4-5 GUI after connecting the radar module to the host PC

Step 3: Click the **Start/Stop** toggle button to start detecting; as shown in Figure 4-5, information of the detected human target is displayed in Zone 2, and a line chart[2] of the target distance in the latest 15 seconds is shown in Zone 3;

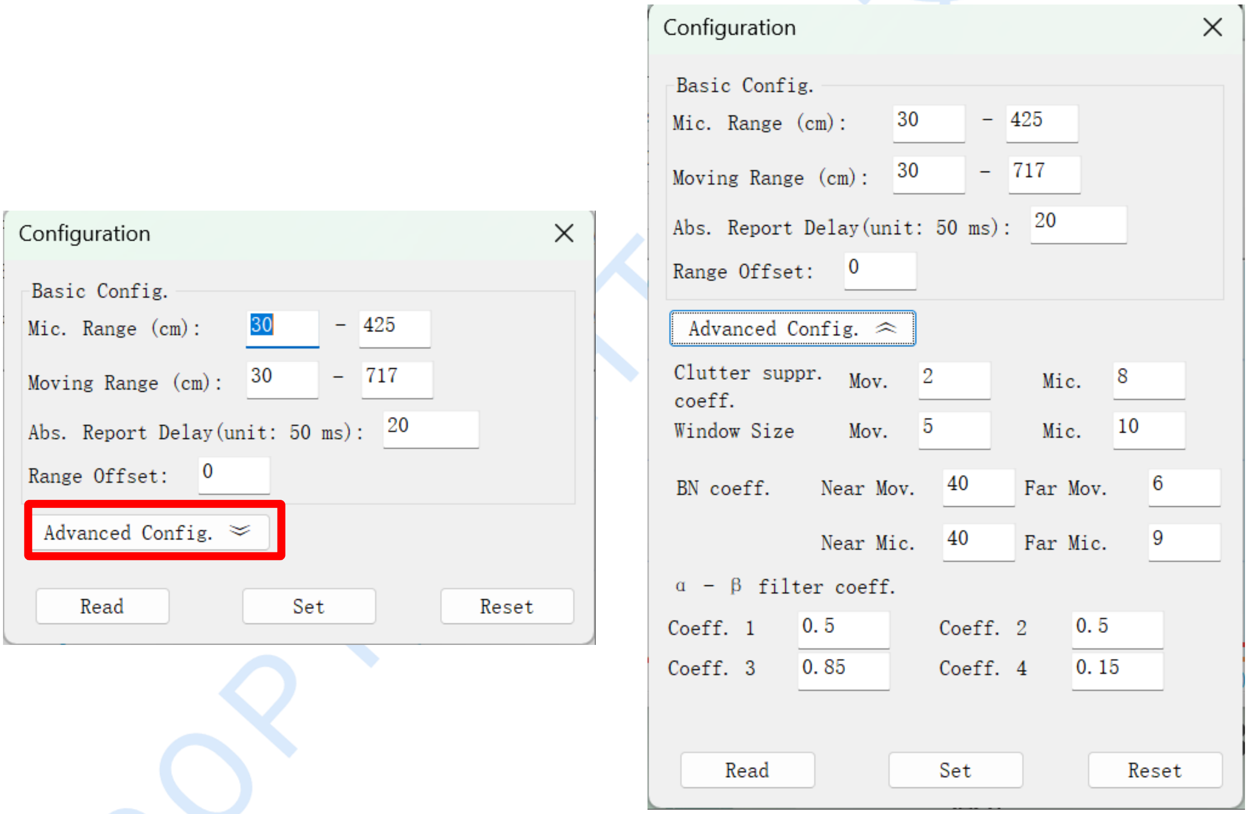
Step 4: To stop the detection, click the **Start/Stop** toggle button, and the data as well as the line chart in Zone 2 and Zone 3 will stop refreshing; users can find the log of this detection under the XenP102RM\Log\ directory in the software tool folder.

Read and Configure Radar Parameter

The ICLM_XenP102_RM02Tool.exe allows users to read, modify, and reset radar parameter.

Step 1: Connect the visualization tool with the radar module following the Step 1 and Step 2 of the Visualize Range Measurement task;

Step 2: Click the **Config.** button, the Configuration window will appear, as shown in Figure 4-6 (a), users can modify the radar parameters[3], for the meanings and value ranges of these parameters, please refer to Chapter 5 Communication Protocol;



(a) (b)

Figure 4-6 Parameter Config. Menu

Step 3(Optional): Click the **Advanced Config**. button to read or modify advanced parameters, the Configuration window will expand as shown in Figure 4-6 (b);

Step 4: Read, set, or reset parameters as follows:

- to read radar parameters, click the **Read** button, the Configuration window will display parameters

[2] The line shows human target distance in the latest 15 s, with the rightmost point of the line depicting current distance detected by the radar, and the line shifts from right to left as time flows.

[3] The advanced parameter configuration menu is shown in Figure 4-6 (b), and it is supposed to be modified by users with radar knowledge and experience according to the actual scenarios.

read from the radar;

- to modify radar parameters, type in new values in textboxes, click the **Set** button to send the latest parameters to the radar module;
- to set radar parameters back to default settings, click the **Reset** button.

There is an indicator light on the left side of Zone 2 whose color indicates the status of the detected target. If the light is green, it means there is no target detected within detection range; red means human motion is detected; and pink means human micro-motion is detected, as shown in Table 4-1.

Table 4-1 Mapping between target status and indicator light color

Target Status	Indicator Light Color
Absent	
Motion	
Micro-motion	

5. Communication Protocol

This communication protocol is mainly for users who needs to develop products without the visualization tool. Xen102 hardware transmits data via serial port. The output radar data have been processed by the algorithm. Baud rate of the radar serial port is 256000 by default, with 1 stop bit and no parity check digit.

5.1 Protocol Format

5.1.1 Data Format

XenP102RM data communication applies little endian format, and all the data in the rest of this chapter are in hexadecimal.

5.1.2 Command Frame Format

Table 5-1 shows the frame format of a command, the range information is a 2-bytes data in hexadecimal little-endian format, and the unit is cm. Table 5-2 shows the values and descriptions of target status. When the motion energy of the target lies in non-zero Doppler, XenP102RM will report target status as moving target; when the motion energy of the target lies in Zero Doppler, the sensor will further decide whether the target status is micro-moving or low speed moving, and the latter case is regarded as moving.

Table 5-1 Frame format of command

Header	Target Status	Target Distance	Tailer
AA AA	1 byte	2 bytes	55 55

Table 5-2 Description of target status value

Value	Description
0x00	Target absent
0x01	Target motion detected
0x02	Target micro-motion detected

5.2 Sending Command and ACK

5.2.1 Read Firmware Revision Command

This command reads he revision of radar firmware.

Command Word: 0x0000

Command Value: None

Return Value: 2 bytes major revision number + 2 bytes minor revision number + 2 bytes patch revision number

Sending data:

Header	Intra-Frame Data Length	Command Word	Tailer
FD FC FB FA	02 00	00 00	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	Major Rev. No.	Minor Rev. No.	Patch Rev. No	Tailer
FD FC FB FA	08 00	00 01	0x[4] 00	0x 00	0x 00	04 03 02 01

5.2.2 Enable Configuration Command

Any command sending to radar should be sent after this command, otherwise the command will be invalid.

Command Word: 0x00FF

Command Value: 0x0001

Return Value: 2 bytes ACK state (0-succeed, 1-fail) + 2 bytes protocol revision(0x0001) + 2 bytes buffer size (0x0040)

Sending data:

Header	Intra-Frame Data Length	Command Word	Command Value	Tailer
FD FC FB FA	04 00	FF 00	01 00	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Protocol Rev.	Buffer Size	Tailer
FD FC FB FA	08 00	FF 01	00 00	01 00	40 00	04 03 02 01

5.2.3 End Configuration Command

This command stops configuring radar and puts radar back to work. If there is a need to send command to radar again, an Enable Configuration Command should be sent first.

Command Word: 0x00FE

Command Value: None

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Sending data:

Header	Intra-Frame Data Length	Command Word	Tailer
FD FC FB FA	02 00	FE 00	04 03 02 01

[4] In this table, the x represents version number.

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	FE 01	00 00	04 03 02 01

5.2.4 Write Serial Number Command

This command writes a serial number to the radar module.

Command Word: 0x0010

Command Value: 2 bytes length of SN + 8 bytes SN

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Sending data: (example: SN is 12345678)

Header	Intra-Frame Data Length	Command Word	Length of SN	SN	Tailer
FD FC FB FA	0C 00	10 00	08 00	31 32 33 34 35 36 37 38	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	10 01	00 00	04 03 02 01

5.2.5 Read Serial Number Command

This command reads the serial number of the radar module.

Command Word: 0x0011

Command Value: None

Return Value: 2 bytes ACK state (0-succeed, 1-fail) + 2 bytes length of SN + 8 bytes SN

Sending data:

Header	Intra-Frame Data Length	Command Word	Tailer
FD FC FB FA	02 00	11 00	04 03 02 01

ACK from radar: (example: succeed, SN is 12345678)

Header	Intra-Frame Data Length	Command Word	ACK	Length of SN	SN	Tailer
FD FC FB FA	0E 00	11 01	00 00	08 00	31 32 33 34 35 36 37 38	04 03 02 01

5.2.6 Range Calibration Parameter Configuration Command

This command configures the range calibration parameter of the algorithm.

Command Word: 0x0072

Command Value: 2 bytes range calibration parameter word + 4 bytes range calibration parameter(int32)

Return Value: 2 ACK state (0-succeed, 1-fail)

Table 5-3 0x0072 parameter word

Parameter Name	Parameter Word
Range Calibration	0x0000

Sending data:

Header	Intra-Frame Data Length	Command Word	Range Calibration Word	Range Calibration	Tailer
FD FC FB FA	08 00	72 00	00 00	00 00 00 00	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	72 01	00 00	04 03 02 01

5.2.7 Configure Max. & Min. Range and Absence Report Delay Command

This command configures radar Maximum and Minimum detection range gate (motion/micro-motion), human motion detection range gate (30~717), human micro-motion detection range gate (30~425), and Absence Report Delay (0~65535, each unit represents 50 ms).

Command Word: 0x0067

Command Value: 2 bytes Max. Motion Range Gate Word + 4 bytes Max. Motion Range Gate (uint32_t) + 2 bytes Min. Motion Range Gate Word + 4 bytes Min. Motion Range Gate (uint32_t) + 2 bytes Max. Micro-motion Range Gate Word + 4 bytes Max. Micro-motion Range Gate (uint32_t) + 2 bytes Min. Micro-motion Range Gate Word + 4 bytes Min. Micro-motion Range Gate (uint32_t)

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Table 5-4 0x0067 parameter word

Parameter Name	Parameter Word
Max. Motion Range Gate	0x0000
Min. Motion Range Gate	0x0001
Max. Micro-motion Range Gate	0x0002
Min. Micro-motion Range Gate	0x0003
Absence Report Delay	0x0004

Sending data: (Max. Motion Range Gate = 717 cm; Min. Motion Range Gate = 30 cm;
Max. Micro-motion Range Gate = 425 cm; Min. Micro-motion Range Gate = 30 cm;
Absence Report Delay 1 s (20 * 50 ms))

Header	Intra-Frame Data Length	Command Word	Max. Motion R.G. Word	Max. Motion R.G.	Min. Motion R.G. Word	Min. Motion R.G.
FD FC FB FA	20 00	67 00	00 00	CD 02 00 00	01 00	1E 00 00 00
Max. Micro-motion R.G. Word	**Max. Micro-motion R.G.**	**Min. Micro-motion R.G. Word**	**Min. Micro-motion R.G.**	**Absence Report Delay Word**	**Absence Report Delay (*50 ms)**	**Tailer**
02 00	A9 01 00 00	03 00	1E 00 00 00	04 00	14 00 00 00	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	67 01	00 00	04 03 02 01

Note: The following protocol commands are about advanced parameters related to key functions of the algorithm. If they are not properly set, the algorithm may work abnormally. They are recommended to be carefully adjusted by users with radar knowledge and experience.

5.2.8 Configure Base Noise Coefficient Command

This command configures the Noise parameter of the algorithm. Noise parameter in the algorithm is for computing base noise. It is defined as float format in protocol and will be automatically transferred by the host PC. Its value ranges from -3.40E+38 to +3.40E+38. Increasing the noise parameter, the computed base noise will increase, and vice versa.

Command Word: 0x0068

Command Value: 2 bytes Near-end Motion Noise Coefficient Word + 4 bytes Near-end Motion Noise Coefficient (float) + 2 bytes Far-end Motion Noise Coefficient Word + 4 bytes Far-end Motion Noise Coefficient (float) + 2 bytes Near-end Micro-motion Noise Coefficient Word + 4 bytes Near-end Micro-motion Noise Coefficient (float) + 2 bytes Far-end Micro-motion Noise Coefficient Word + 4 bytes Far-end Micro-motion Noise Coefficient (float)

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Table 5-5 0x0068 parameter word

Parameter Name	Parameter Word
Near-end Motion Noise Coefficient	0x0000
Far-end Motion Noise Coefficient	0x0001
Near-end Micro-motion Noise Coefficient	0x0002
Far-end Micro-motion Noise Coefficient	0x0003

Sending data: (Near-end Motion Noise Coefficient = 40;
Far-end Motion Noise Coefficient = 6;
Near-end Micro-motion Noise Coefficient = 40;
Far-end Micro-motion Noise Coefficient = 9)

Header	Intra-Frame Data Length	Command Word	Near-end Motion Noise Word	Near-end Motion Noise	Far-end Motion Noise Word
FD FC FB FA	0E 00	68 00	00 00	00 00 20 42	01 00
Far-end Motion Noise	**Near-end Micro-motion Noise Word**	**Near-end Micro-motion Noise**	**Far-end Micro-motion Noise Word**	**Far-end Micro-motion Noise**	**Tailer**
00 00 C0 40	02 00	00 00 20 42	03 00	00 00 10 41	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	68 01	00 00	04 03 02 01

5.2.9 Clutter Suppression Coefficient Command

This command configures the Clutter Suppression Coefficient of the algorithm. Clutter suppression coefficient is used in the algorithm for clutter suppression. It is defined as uint32_t format in protocol, and will be automatically transferred by the host PC. Its value ranges from 0 to 255. Increasing this coefficient will weaken the algorithm ability of filtering micro-moving background, and vice versa.

Command Word: 0x0069

Command Value: 2 bytes Motion Branch Clutter Suppression Coefficient Word + 4 bytes Motion Branch Clutter Suppression Coefficient Parameter (uint_32) + 2 bytes Micro-motion Branch Clutter Suppression Coefficient Word + 4 bytes Micro-motion Branch Clutter Suppression Coefficient Parameter (uint_32)

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Table 5-6 0x0069 parameter word

Parameter Name	Parameter Word
Motion Branch Clutter Suppression Coefficient	0x0000
Micro-motion Branch Clutter Suppression Coefficient	0x0001

Sending data: (Motion branch clutter suppression coefficient = 2;
Micro-motion branch clutter suppression coefficient = 8)

Header	Intra-Frame Data Length	Command Word	Motion Branch Clutter Suppression Word	Motion Branch Clutter Suppression Coefficient	Micro-motion Branch Clutter Suppression Word	Micro-motion Branch Clutter Suppression Coefficient	Tailer
FD FC FB FA	0E 00	69 00	00 00	02 00 00 00	01 00	08 00 00 00	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	69 01	00 00	04 03 02 01

5.2.10 Configure FRAME Sliding Window Size Command

This command configures the size of FRAME Sliding Window of the algorithm. FRAME sliding window size is a parameter for setting the window length when computing overlapping average in the algorithm. It is defined as uint32_t format in protocol, and will be automatically transferred by the host PC. Its value ranges from 0 to 255. In RM02 firmware, the default maximum sliding window size of motion branch is 5, micro-motion branch is 10. Users can set the maximum sliding window size by modifying corresponding macro definition in bodysensing_type.h file.

Command Word: 0x0070

Command Value: 2 bytes Motion Branch FRAME Sliding Window Size Word + 4 bytes Motion Branch FRAME Sliding Window Size (uint32_t) + 2 bytes Micro-motion Branch FRAME Sliding Window Size Word + 4 bytes Micro-motion Branch FRAME Sliding Window Size (uint32_t)

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Table 5-7 0x0070 parameter word

Parameter Name	Parameter Word
Motion Branch FRAME Sliding Window Size	0x0000
Micro-motion Branch FRAME Sliding Window Size	0x0001

Sending data: (Motion Branch FRAME Sliding Window Size = 5;
Micro-motion Branch FRAME Sliding Window Size = 10)

Header	Intra-Frame Data Length	Command Word	Motion Branch FRAME Sliding Window Size Word	Motion Branch FRAME Sliding Window Size	Micro-motion Branch FRAME Sliding Window Size Word	Micro-motion Branch FRAME Sliding Window Size	Tailer
FD FC FB FA	0E 00	70 00	00 00	05 00 00 00	01 00	0A 00 00 00	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	70 01	00 00	04 03 02 01

5.2.11 α-β Filter Coefficient Configuration Command

This command configures the α-β filter parameters of the algorithm. The α-β filter parameters are for conducting α-β filtering in the algorithm. It is defined as float format in protocol, and will be automatically transferred by the host PC. Its value ranges from -3.40E+38 to +3.40E+38. The coefficients are applied in pairs called α-β, with filter coefficient 1 and 2 be a pair, and filter coefficient 3 and 4 be a pair. Increasing the values of α, β coefficients will increase the speed of filtering, and the noise will increase as well; while decreasing the values of α, β coefficients, the filtered data will be smoother, and the dynamic response will be slower.

Command Word: 0x0071

Command Value: 2 bytes α-β Filter Coefficient 1 Word + 4 bytes α-β Filter Coefficient 1 (float) + 2 bytes α-β Filter Coefficient 2 Word + 4 bytes α-β Filter Coefficient 2 (float)+ 2 bytes α-β Filter Coefficient 3 Word + 4 bytes α-β Filter Coefficient 3 (float)+ 2 bytes α-β Filter Coefficient 4 Word + 4 bytes α-β Filter Coefficient 4 (float)

Return Value: 2 bytes ACK state (0-succeed, 1-fail)

Table 5-8 0x0071 parameter word

Parameter Name	Parameter Word
α-β Filter Coefficient 1	0x0000
α-β Filter Coefficient 2	0x0001
α-β Filter Coefficient 3	0x0002
α-β Filter Coefficient 4	0x0003

Sending data: (α-β Filter Coefficient 1 = 0.5; α-β Filter Coefficient 2 = 0.5;
α-β Filter Coefficient 3 = 0.85; α-β Filter Coefficient 4 = 0.15)

Header	Intra-Frame Data Length	Command Word	α-β Filter Coefficient 1 Word	α-β Filter Coefficient 1	α-β Filter Coefficient 2 Word
FD FC FB FA	1A 00	71 00	00 00	00 00 00 3F	01 00
α-β Filter Coefficient 2	**α-β Filter Coefficient 3 Word**	**α-β Filter Coefficient 3**	**α-β Filter Coefficient 4 Word**	**α-β Filter Coefficient 4**	**Tailer**
00 00 00 3F	02 00	99 99 59 3F	03 00	99 99 19 3E	04 03 02 01

ACK from radar(succeed):

Header	Intra-Frame Data Length	Command Word	ACK	Tailer
FD FC FB FA	04 00	71 01	00 00	04 03 02 01

5.2.12 Read Algorithm Parameter Configuration Command

This command reads parameters of the algorithm.

Command Word: 0x0073

Command Value: None

Return Value: 2 bytes ACK state (0-succeed, 1-fail) + 2 bytes Max. Motion Range Gate + 2 bytes Min. Motion Range Gate + 2 bytes Max. Micro-motion Range Gate + 2 bytes Min. Micro-motion Range Gate + 2 bytes Absence Report Delay + 4 bytes Near-end Motion Noise Coefficient (float) + 4 bytes Far-end Motion Noise Coefficient (float) + 4 bytes Near-end Micro-motion Noise Coefficient (float) + 4 bytes Far-end Micro-motion Noise

Coefficient (float) + 1 byte Motion Branch Clutter Suppression Coefficient + 1 byte Micro-motion Branch Clutter Suppression Coefficient + 1 byte Motion Branch Sliding Window Size +1 byte Micro-motion Branch Sliding Window Size + 4 bytes α-β Filter Coefficient 1 (float) + 4 bytes α-β Filter Coefficient 2 (float) + 4 bytes α-β Filter Coefficient 3 (float) + 4 bytes α-β Filter Coefficient 4 (float) + 4 bytes Range Calibration (int32)

Sending data:

Header	Intra-Frame Data Length	Command Word	Tailer
FD FC FB FA	02 00	73 00	04 03 02 01

ACK from radar(succeed): (Example:
Max. Motion Range Gate = 717 cm;
Min. Motion Range Gate = 30 cm;
Max. Micro-motion Range Gate = 425 cm;
Min. Micro-motion Range Gate = 30 cm;
Absence Report Delay = 20 (*50 ms);
Near-end Motion Noise Coefficient1(float) = 40;
Far-end Motion Noise Coefficient 2(float) = 6;
Near-end Micro-motion Noise Coefficient3(float) = 40;
Far-end Micro-motion Noise Coefficient4(float) = 9;
Motion Branch Clutter Suppression Coefficient = 2;
Micro-motion Branch Clutter Suppression Coefficient = 8;
Motion Branch Sliding Window Size = 5;
Micro-motion Branch Sliding Window Size = 10;
α-β Filter Coefficient1(float) = 0.5;
α-β Filter Coefficient2(float)= 0.5;
α-β Filter Coefficient3(float)= 0.85;
α-β Filter Coefficient4(float) = 0.15;
Range Calibration = 0)

<table>
<tr><th>Header</th><th colspan="2">Intra-Frame Data Length</th><th>Command Word</th><th>ACK</th><th>Max. Motion Range Gate</th><th>Min. Motion Range Gate</th><th>Max. Micro-motion Range Gate</th><th>Min. Micro-motion Range Gate</th></tr>
<tr><td>FD FC FB FA</td><td colspan="2">36 00</td><td>73 01</td><td>00 00</td><td>CD 02</td><td>1E 00</td><td>A9 01</td><td>1E 00</td></tr>
<tr><th>Absence Report Delay</th><th colspan="4">Near-end Motion Noise Coefficient</th><th colspan="2">Far-end Motion Noise Coefficient</th><th colspan="2">Near-end Micro-motion Noise Coefficient</th></tr>
<tr><td>14 00</td><td colspan="4">00 00 20 42</td><td colspan="2">00 00 C0 40</td><td colspan="2">00 00 20 42</td></tr>
<tr><th>Far-end Micro-motion Noise Coefficient</th><th>Motion Branch Clutter Suppression Coefficient</th><th>Micro-motion Branch Clutter Suppression Coefficient</th><th>Motion Branch Sliding Window Size</th><th>Micro-motion Branch Sliding Window Size</th><th colspan="2">α-β Filter Coefficient 1</th><th colspan="2">α-β Filter Coefficient 2</th></tr>
<tr><td>00 00 10 41</td><td>2</td><td>8</td><td>5</td><td>10</td><td colspan="2">00 00 00 3F</td><td colspan="2">00 00 00 3F</td></tr>
<tr><th>α-β Filter Coefficient 3</th><th colspan="4">α-β Filter Coefficient 4</th><th colspan="2">Range Calibration</th><th colspan="2">Tailer</th></tr>
<tr><td>99 99 59 3F</td><td colspan="4">99 99 19 3E</td><td colspan="2">00 00 00 00</td><td colspan="2">04 03 02 01</td></tr>
</table>

6. Installation and Detection Range

When installing the radar module, it is suggested to apply wall mounted method with the antenna plane be vertical and 1.3 m above the ground, as shown in Figure 6-1. Please make sure that the antenna 4 patch direction is horizontal.

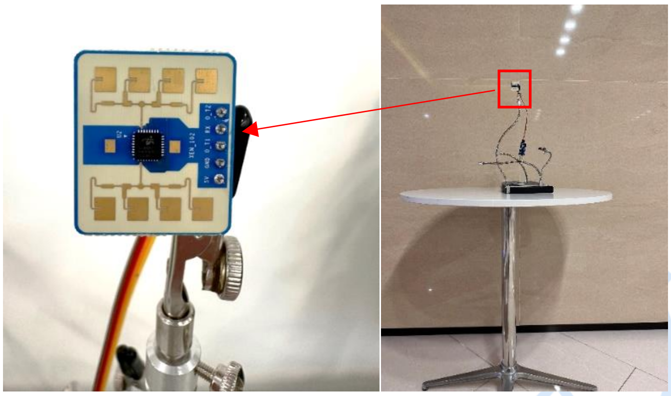


Figure 6-1 Installation example

After installation, radar detection area is a cubic fan-shaped area with the radar module be the original point, ±40° in H plane, and ±20° in E plane. Illustration of radar H and E plane is shown in Figure 6-2.

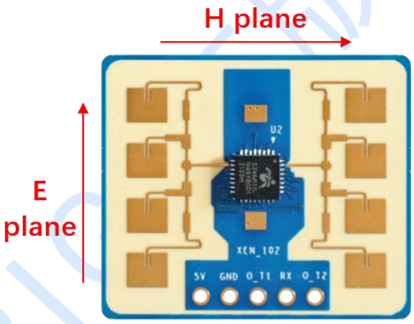


Figure 6-2 H plane and E plane of the radar module

The detection ability of XenP102RM is shown in Figure 6-3. The detection range of human motion is a fan-shaped area with azimuth angle of ±20° and radius of 0.3 m~6 m (in normal direction, the radar can detect human motion as far as 7 m); detection range of human micro-motion is a fan-shaped area with azimuth angle of ±20° and radius of 0.3 m~3.5 m.

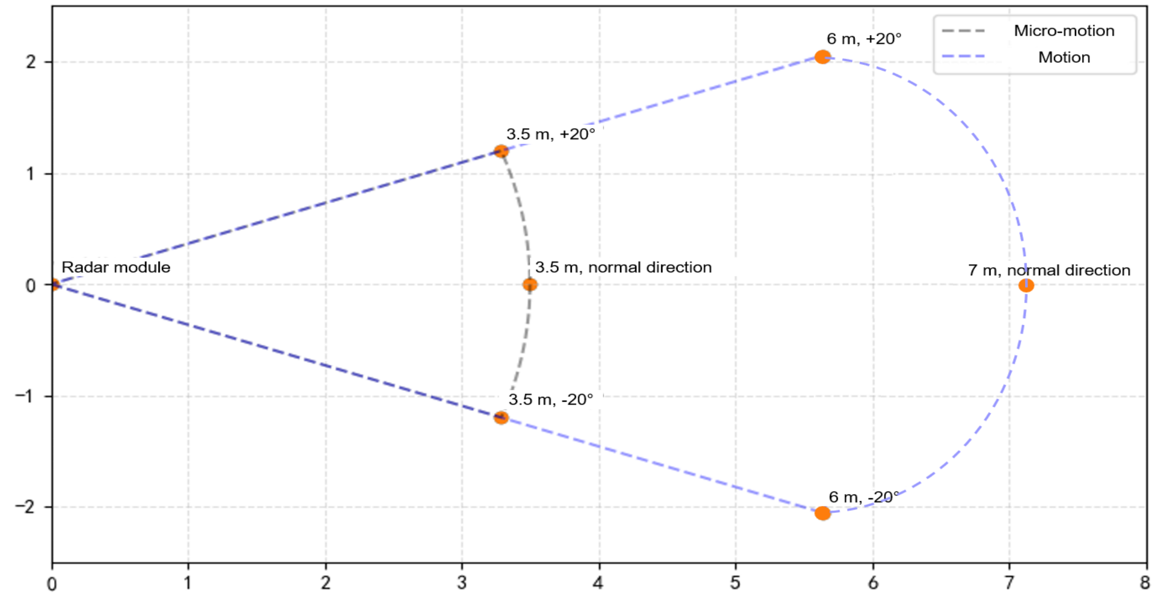


Figure 6-3 Radar detection ability diagram

7. Mechanical Size

Figure 7-1 presents the mechanical size of Xen102 hardware, the units are all mm. The PCB size is 28 mm × 24 mm with a tolerance of ±10%, and the board thickness is 1.2 mm with a tolerance of ±10%.

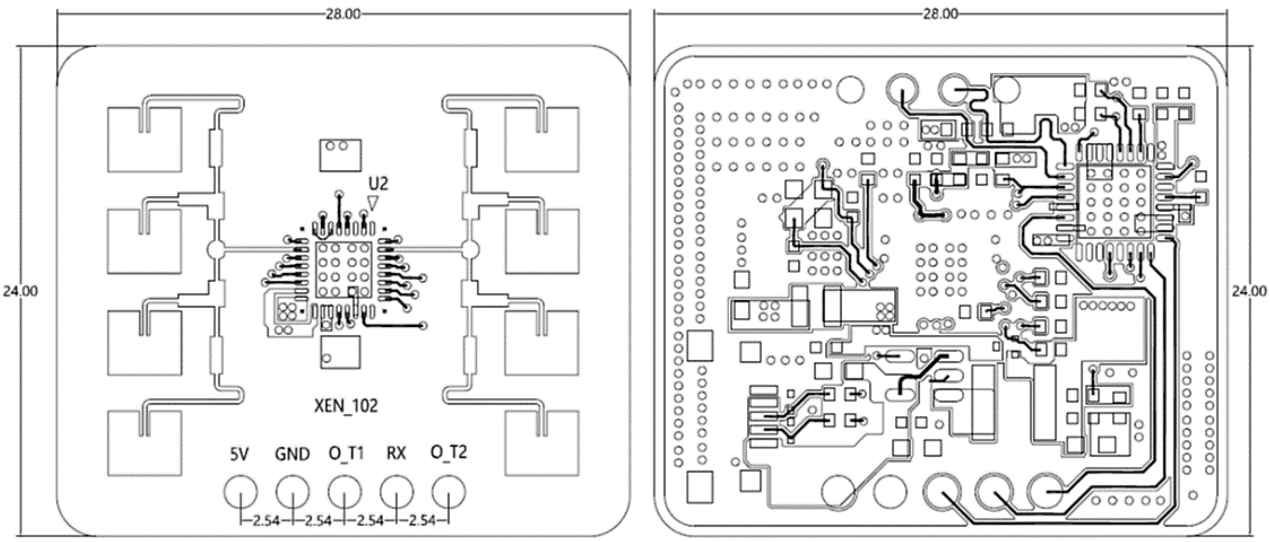


Figure 7-1 Xen102 mechanical size (mm)

8. Installation Requirement

Radome Requirements

If there is a need to install a radome, the material selected must have good transparency for 24 GHz wave, and do not contain any material that may block electromagnetic wave such as metal. More details please refer to Guide of mmWave Sensor Antenna Radome Design[5] .

Installation Environment

When installing the product, certain requirements should be taken into consideration in case the detection performance is interfered. Features of unsuitable environment are listed below.

- Continuous moving non-human objects in detection area, such as moving animals, swinging curtains, big shaking plants in front of an active vent etc.
- Large strong reflectors will interfere with detection performance when put in front of the antennas.
- Interferences of on-ceiling home appliances such as air-conditioners, fans, etc. should be taken into consideration while wall mounted.

Important Requirements

- Ensure the radar antennas are facing squarely to desired detection area with a clear field of view.
- Ensure the installation position of the sensor is solid and stable. Motion of the radar itself can hugely impact signal processing.
- Ensure there is no object moving or vibrating behind the radar. Motion behind antennas can also be detected due to the penetrability of radar RF wave, thus interferes detection accuracy. It is recommended to use a radome or a backplane to reduce the interference.
- When there are multiple 24 GHz radar installed in close areas, make sure their beamforms do not face to each other, try to separate them as far as possible to avoid interference.

Power Supply

XenP102RM supports power supply within range 4.5~5.5 V, and power ripple shows no obvious spectral peaks within 100 kHz. This radar solution is a reference design, so developers should take EMC design such as ESD and lightning surge into consideration.

9. Important Tips

Maximum Detection Range

The maximum detection range for human motion is 7 m, for human micro-motion is 3.5 m. Within the detection range, radar will report target radial distance.

Modifying Firmware Baud Rate

XenP102RM default baud rate is 256000. It can be modified through the macro USART1_BAUDRATE defined under engineering directory \Middleware\platform\gd32\inc\gd32_uart.h.

Maximum Detection Range and Range Accuracy

Theoretically, the detection accuracy is ±3 cm during range 30 ~ 600 cm, and ±3% during range 600 ~ 700 cm. The detection accuracy and the maximum detection range may slightly vary due to the size, motion state and RCS of the target.

[5] Currently, only Chinese version is available.

Absence Report Delay

When human absence is detected in detection area, the radar will delay the absence report. The delay mechanism works as such: once no human target is detected in detection area, the radar will start a timer whose duration is the parameter absence report delay, and if there is no target showing up during this timing the radar will end the timer and send the non-human report; however, if a human target is detected in detection area during the timing, the radar will end and refresh the timer before sending the target information.

10. Revision History

Revision	Date	Modification
1.0	2023/8/14	Initial release.

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