UM10002
XenD101Pro User Manual

Rev.1.4   User Manual

Introduction

This document introduces the human presence detection reference design of ICLM smart mmWave sensor XenD101Pro, 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 XenD101Pro human presence detection solution quickly and easily, so that users can sort out suitable parameters for specified scenarios, and can design both precise and customized human presence detection sensors.

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1. XenD101Pro Overview

Human presence detection refers to detecting living beings with vital signs of respiratory and heartbeats (mainly human beings) in detection area, so as to detect human body in any pose and without body movement, including human body in sound sleep.

XenD101Pro is a human presence detection reference design of ICLM EZ Sensor series. It contains a minimalist 24 GHz radar sensor hardware XenD101Pro and an intelligent algorithm firmware HPS01.

XenD101Pro hardware incorporates an AIoT mmWave sensor SoC S3KM111L, high-performance 24 GHz 1T1R antennas and peripheral circuits. The intelligent algorithm firmware HPS01 applies FMCW waveform and S3 series chip specified advanced signal processing technology. This reference design is mainly applied to common indoors scenarios such as home, office and hotels for human presence detection.

XenD101Pro detects human presence that as far as 4.5 m. Users can adjust key parameters such as maximum detectable range, sensibility of each range gate, and absence report delay are configurable via a visualization tool (refer to Chapter 9). XenD101Pro supports both GPIO and UART interfaces, and supports Plug and Play.

Main features of XenD101Pro are listed below:

- 24 GHz ISM bandwidth
- Integrate single chip smart mmWave sensor S3KM111L and intelligent algorithm firmware
- Indoors human presence detection (motion & motionless)
- Compact module size: 18 mm x 15 mm
- 3.3 V single power supply, support a wide voltage range of 3.0 V ~ 3.6 V
- Average operating current of 50 mA @ 10 Hz report frequency

- Load default setting of human presence detection, support Plug and Play
- Provide a visualization tool, support configuring detection range and sensibility of each range gate
- Maximum detectable range up to 4.5 m
- Azimuth angle $\pm45°$, pitch angle $\pm45°$
- Support multiple installation methods such as top mounted and wall mounted

XenD101Pro human presence detection sensor can detect moving, micro-moving and motionless human body. It can be widely applied to various AIoT scenarios listed as follows.

- **Smart Home**

  Detect human presence, report results in real time, enable the MCU to control smart domestic appliances accordingly.

- **Smart Business**

  Detect human approach or leaving in specified range to turn on/off devices, keeping devices on when human presence is detected.

- **Intelligent Security**

  Entrance control, building intercom, visual doorbell etc.

- **Intelligent Lighting**

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

- **Medical and Aged Care**

  Detect vital signs such as respiration and heartbeats, detect human presence in real time.

2. System Characteristics

XenD101Pro is a smart and precise human presence detection sensor reference solution developed based on ICLM S3KM111L sensor chip. It detects human in specified range and reports detection results in real time by incorporating FMCW, radar signal process, and built-in intelligent human presence detection algorithm. With this reference solution, users can quickly develop customized human presence detection products with high precision.

The systematic characteristics of XenD101Pro are shown in Table 2-1:

Table 2-1 XenD101Pro characteristics

Parameter	Condition	Min.	Typ.	Max.	Unit
XenD101Pro Hardware Characteristics					
Supporting frequency		24	-	25	GHz
Max. bandwidth		-	0.25	1	GHz
Max. EIRP		-	-	15	dBm
Power supply		3.0	3.3	3.6	V
Size		-	18 × 15	-	mm × mm
Environment temperature		-40	-	85	°C
XenD101Pro System Characteristics					
Detection range	Motion/motionless human target	0.2	4	4.5	m
Resolution	Motion/motionless human target	0.75	-	-	m
Detection accuracy		-	0.15	-	m
Operating frequency	In accordance with FCC, CE and RC certification standards	24	-	24.25	GHz
Sweeping Bandwidth		-	-	0.25	GHz
Average operating current	Report cycle 100 ms	-	50	-	mA

3. Hardware Overview

Device maps of XenD101Pro hardware is shown in Figure 3-1. XenD101Pro hardware reserves 5 pins (default without contact pin) called J1 for power supply and communication; 4 pins called J2 for programming the radar module. Please pay attention to the pin names when connecting radar module for programming.

Figure 3-1 Top and bottom device map of XenD101Pro

Details of the J1 and J2 pins are listed in Table 3-1 and Table 3-2.

Table 3-1 J1 pin description [1]

J#PIN#	Name	Function	Operating Range
J1 Pin1	3V3	Power input	3.0 V ~ 3.6 V, Typ. 3.3 V
J1 Pin2	GND	Ground	-
J1 Pin3	O_T1	Can be configured as UART_TX or IO. Cannot be configured as UART_TX with O_T2 at the same time. Default as UART_TX	0 ~ 3.3 V
J1 Pin4	RX	UART_RX	0 ~ 3.3 V
J1 Pin5	O_T2	Can be configured as UART_TX or IO. Cannot be configured as UART_TX with O_T1 at the same time. Default as IO	0 ~ 3.3 V

Table 3-2 J2 pin description

J#PIN#	Name	Function	Operating Range
J2 Pin1	GND	Ground	-
J2 Pin2	DIO	Data port	0 ~ 3.3 V
J2 Pin3	CLK	Clock signal	0 ~ 3.3 V
J2 Pin4	3V3	Power input	1.8 V ~ 3.6 V, Typ. 3.3 V

XenD101Pro supports Keil5 IDE programming. When programming the board, either hex or firmware file is acceptable. XenD101Pro also supports common RW programmer such as J-Link (revisions no earlier than V9), CMSIS-DAP etc. Make sure the Keil5 IDE has installed relevant packs (GigaDevice.GD32E23x_DFP.1.0.1.pack and ARM.CMSIS.5.6.0.pack[1]), which are both accessible from Arm official website.

4. Software Overview

XenD101Pro [2] is released with firmware HPS01 programmed into the system. ICLM provides a visualization software tool that can configure XenD101Pro from host PC, users can optimize detection results by adjusting parameters according to the applied scenarios.

4.1 Firmware Description

XenD101Pro can detect as far as 4.5 m (motion & motionless) under default settings, the default parameter descriptions are presented in Table 4-1. Users can adjust these parameters according to actual scenarios.

Table 4-1 XenD101Pro default parameter description

Parameter	Operating Range	Default Value	Description
Max. range gate	2 ~ 6	6	Each range gate represents 75 cm
Absence report delay	1 ~ 65535 s	5 s	
Motion Sensibility	1 ~ 100	20	
Motionless Sensibility	1 ~ 100	25	

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[1] The packs listed above are the lowest working version required.
[2] All the characteristics described in this document are based on the latest firmware XenD101Pro_HPS01 Rev.1.6.0.

The default output data from the radar contains target state, radial distance (motion & motionless), and energy level (motion & motionless). Users can set the radar to Engineering Mode by ticking the checkbox in front of Engineering Mode on the graphical user interface (GUI) of the visualization tool, or sending an Enable Engineering Mode Command via serial port. In addition to the above output data, the radar reports the energy level of each range gate, which is also called Engineering Data. For more details of the radar output data format, please refer to 6.3 Output Protocol.

4.2   Visualization Tool Description

4.2.1   Visualization Tool Introduction

ICLM_XenD101ProTool is a portable software that is specifically developed for XenD101Pro. After connect the visualization tool with the XenD101Pro module, the tool can display and record radar data, and enable users to configure radar parameters.

Instructions of using the visualization tool are as follows.

Step 1: Download ICLM_XenD101ProTool.zip from ICLM official website, unzip the folder using an unzip program such as 7zip, and enter the XenD101ProTool/ directory.

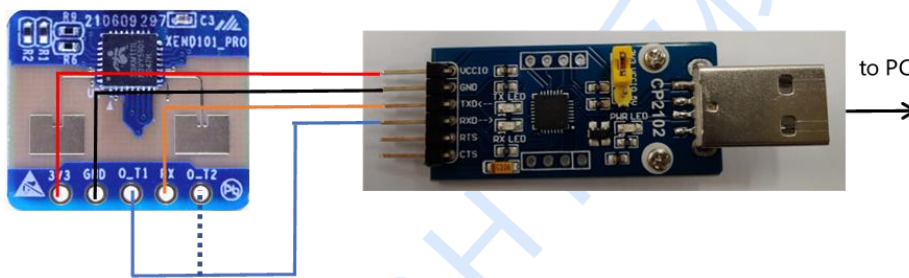Step 2: Connect XenD101Pro to the host PC via a serial port tool, as is shown in Figure 4-1.

Figure 4-1 Connect XenD101Pro to PC via serial port tool

Step 3: Double click the **ICLM_XenD101ProTool.exe** to open the GUI, as shown in Figure 4-2.
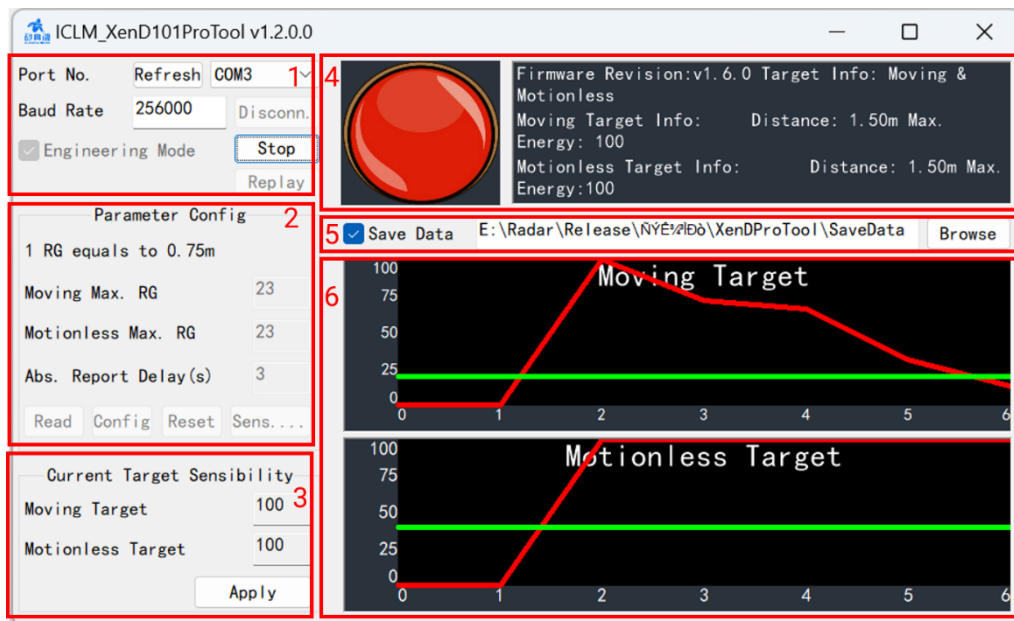
Figure 4-2 GUI of XenD101 Configuration Tool

The GUI of the visualization tool is separated into 5 zones, as is shown in Figure 4-2. They are Port and Data Format Zone (1), Parameter Config. Zone (2), Current Target Sensibility Zone (3), Target and Revision Info. Zone (4), and Engineering Mode Display Zone (5). Their functions are listed below.

Port and Data Format	Presents the number of the port that has connected to the radar, allows users to configure baud rate and data format (basic data or Engineering Data).
Parameter Info.	Allows users to configure radar parameters and displays them, including the maximum range gate (motion & motionless), absence report delay, sensibility of each range gate (motion & motionless) etc.
Current Target Sensibility	Displays the maximum energy of all range gates in each frame of radar data and updates it in real time.
Target and FW Info.	Displays the firmware revision number and the basic information of the target, including its state, radial distance to radar and maximum energy level (motion & motionless).
Save Data	When the Save Data is ticked, users can set the directory of recorded radar data by clicking the Browse button.
Engineering Mode Display	When Engineering Mode is ticked, this zone displays the energy value of each radar range gate in curves. Red curves depict energy values of the target and are refreshed in real time, while green curves depict the sensibility levels and are only updated after requesting for radar parameters.

4.2.2   Guide to Use the Visualization Tool

ICLM_XenD101ProTool provides functions including Connect to Device, Start/Stop Receiving Data,

Read/Configure Radar Parameters, and Configure Sensibility. The steps for each function are introduced below.

Connect to Device

Step 1: Connect the radar module to a host PC using a Serial Port to USB board, as is shown in Figure 4-1. Enter the directory of the visualization tool and double click the **ICLM_XenD101ProTool.exe** to open the GUI, as is shown in Figure 4-2.

Step 2: Click the **Refresh** button in Zone (1) to obtain radar port number. If multiple port numbers are obtained, select the one that communicates with the radar.

Step 3: Configure the baud rate as the same with the radar in Zone (1). For modifying firmware baud rate please refer to Chapter 9.

Step 4: Click the **Connect** button in Zone (1), the firmware revision information will be shown in Zone (4), meaning the visualization tool has been connected to the radar successfully.

Start/Stop Receiving Data

Step 1: After connecting the module to the host as instructed in Connect to Device, click the **Start** button in Zone (1) (once clicked, the text on the button will turn to Stop), the host PC will display detailed information of the target in Zone (4). The energy value (motion & motionless) of each range gate will be displayed in Zone (5) if the Engineering Mode checkbox is ticked. Please note that once the host PC starts receiving data from the radar, it is unable to send configuration parameters to the radar.

Step 2: Click the **Stop** button, the visualization tool will stop parsing radar data; users are able to configure radar parameters via the visualization tool.

Read/Configure Radar Parameters

Step 1: After connecting the module to the host as instructed in Connect to Device, and the Start/Stop toggle button shows Start, click the **Read** button in Zone (2), the GUI will display radar current parameters in Zone (2).

Step 2: There are two ways to modify radar parameters:

- If users need to configure radar parameters, type in the target values in Zone (2), then click the **Config.** and the **Confirm** button in turn, the host PC will send current parameters to the radar.

- If users need to set radar parameters back to default settings, click the **Reset** and the **Confirm** button in turn, the host PC will send default parameters to the radar.

Configure Sensibility

Step 1: After connecting the module to the host as instructed in Connect to Device, click the **Sensibility** button in Zone (2), and a new window Sensibility Configuration will appear, as is shown in Figure 4-3. Users can configure the sensibility of each range gate in multiple ways.

Step 2: There are three ways to modify radar sensibilities:

- If users need to set all the sensibilities to the same values, type in the target values on the new window, click the **Set** and the **Confirm** button in turn, and the new parameters will be sent to the

radar.

- If users need to set all the sensibilities back to default settings, click the **Reset** and the **Confirm** button in turn, and the default settings will be sent to the radar.

- If users need to set the sensibility of each range gate (except for range gate 0 and 1, which are unconfigurable) to different values, double click the parameter in the table, type in a new value (multiple parameters can be changed in this sub-step), click the **Confirm** button, and the new parameter will be sent to the radar.

Click the **Start** button after reading or configuring radar parameters so that the radar will start reporting data using the latest configuration.

Once the Start button is clicked, log files will be automatically generated and saved under the directory of the visualization tool for further analysis.
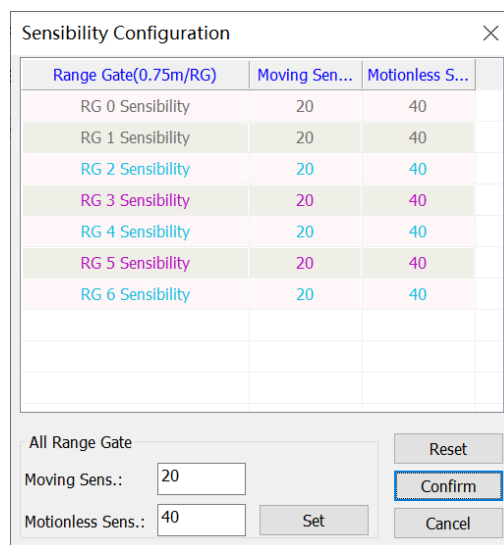
Range Gate(0.75m/RG)	Moving Sen...	Motionless S...
RG 0 Sensibility	20	40
RG 1 Sensibility	20	40
RG 2 Sensibility	20	40
RG 3 Sensibility	20	40
RG 4 Sensibility	20	40
RG 5 Sensibility	20	40
RG 6 Sensibility	20	40

All Range Gate
Moving Sens.: 20
Motionless Sens.: 40   Set   Reset   Confirm   Cancel

Figure 4-3 GUI of Sensibility Configuration

Save and Replay Radar Data

The XenD101ProTool turns on the Save Data function by default, and steps for saving radar data are as follows:

Step 1: After conducting the **Connect to Device** operation, the check box and the button in Zone (5) becomes active;

Step 2: Ensure the **Save Data** check box is checked, click the **Browse** button to select a directory for saving radar data;

Step 3: Click the **Start/Stop** toggle button to start the radar;

Step 4: Click the **Start/Stop** toggle button to stop the detection, users can find the radar data file under the directory set in Step 2, the name of radar data file follows the pattern of:

XenDProTool_YYYY_MM_DD_HH_MM_SS.dat,

in which the YYYY_MM_DD_HH_MM_SS is the time stamp of saving the radar file.

Steps of replaying radar data file using the XenD101ProTool are as follows:

Step 1: Conduct the **Connect to Device** operation;

Step 2: Click the **Replay/Stop** toggle button in Zone (1), select a radar data file, then the Zone (4) and Zone (6) starts displaying the target information;

Step 3: Click the **Replay/Stop** toggle button in Zone (1) to stop the replay, or wait till the replay finishes before conducting other operation.
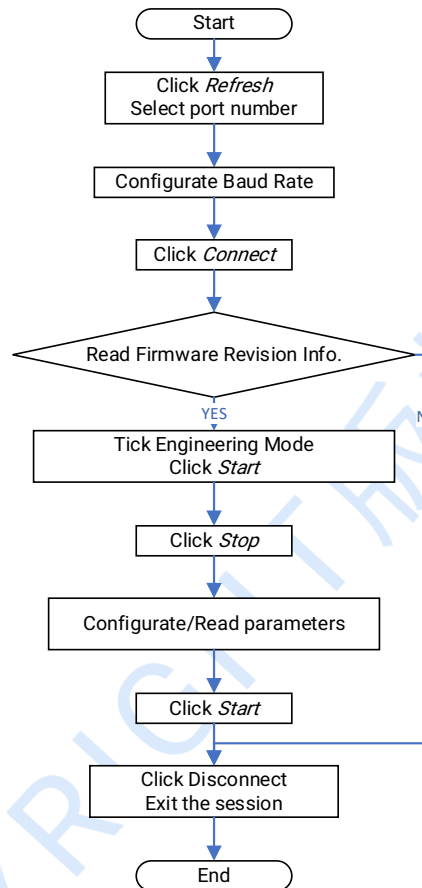
The process of using the visualization tool is illustrated in Figure 4-4.

Figure 4-4 Operating flow chart on host PC

5. Communication Protocol

Communication protocol is mainly for users who are conducting further development without using the visualization tool of XenD101Pro. XenD101Pro communicates with peripherals via serial ports (TTL electrical level). Both parameter configuration and output data should follow the proposed protocol. Default serial port baud rate is 256000. Data contains 1 stop bit, and no parity bit.

5.1　Format

5.1.1 Data Format

XenD101Pro adopts little endian 2-byte data format, and all the data presented in the following tables are hexadecimal.

5.1.2 Command Frame Format

Radar configuration and ACK command frame formats are defined as shown in Table 5-1 to Table 5-4.

Table 5-1 Configuration command frame

Head	Data Length	Data Value	Tail
FD FC FB FA	2 bytes	Refer to Table 5-2	04 03 02 01

Table 5-2 Data format inside the configuration command

Command Word (2 bytes)	Command Value (N bytes)

Table 5-3 ACK command frame

Head	Data Length	Data Value	Tail
FD FC FB FA	2 bytes	Refer to Table 5-4	04 03 02 01

Table 5-4 Data format inside the ACK

Command Word & 0x0100 (2 bytes)	Return Value (N bytes)

5.2 Command and ACK

5.2.1 Read Firmware Revision Command

This command is for reading the radar firmware revision information.

Command Word:　0x0000

Command Value:　None

Return Value:　2 bytes ACK state (0-succeed, 1-fail) + 2 bytes product type(0x8004) + 2 bytes firmware type (0x0000) + 2 bytes major revision number + 2 bytes minor revision number + 2 bytes patch revision number

Sending data:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9 ~ 12
FD FC FB FA	02 00	00 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11, 12	Byte 13, 14	Byte 15, 16	Byte 17, 18	Byte 19, 20	Byte 21 ~ 24
FD FC FB FA	0E 00	00 01	00 00	04 80	00 00	0x3 00	0x 00	0x 00	04 03 02 01

5.2.2 Enable Command

Before sending any other commands, an Enable Command should be sent. Otherwise, these commands will

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3 x in this table represents revision number.

be ineffective.

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:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	FF 00	01 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11, 12	Byte 13, 14	Byte 15 ~ 18
FD FC FB FA	08 00	FF 01	00 00	01 00	40 00	04 03 02 01

5.2.3   End Command

After sending the End Command, no other command will be effective until an Enable Command is sent again.

Command word: 0x00FE

Command value: None

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

Sending data:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9 ~ 12
FD FC FB FA	02 00	FE 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	FE 01	00 00	04 03 02 01

5.2.4   Configure Maximum Range Gate and Absence Report Delay Command

This command configures the maximum range gate (motion & motionless) of the radar (parameter range 2 ~ 6), and the absence report delay (parameter range 0 ~ 65535 s). More details please refer to Table 5-5.

Command word: 0x0060

Command value: 2 bytes maximum motion range gate word + 4 bytes maximum motion range gate parameter + 2 bytes maximum motionless range gate word + 4 bytes maximum motionless range gate parameter + 2 bytes absence report delay word + 4 bytes absence report delay parameter

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

Table 5-5 Parameter word description

Parameter Name	Parameter Word
Maximum Motion Range Gate	0x0000
Maximum Motionless Range Gate	0x0001
Absence Report Delay	0x0002

Sending data: Maximum Range Gate (motion & motionless) is 6, Absence Report Delay is 5 s

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14	Byte 15, 16	Byte 17 ~ 20	Byte 21, 22	Byte 23 ~ 26	Byte 27 ~ 30
FD FC FB FA	14 00	60 00	00 00	06 00 00 00	01 00	06 00 00 00	02 00	05 00 00 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	60 01	00 00	04 03 02 01

5.2.5 Reading Parameter Command

This command reads the radar's current configuration parameters.

Command word: 0x0061

Command value: None

Return value: 2 bytes ACK state (0-succeed, 1-fail) + head (0xAA) + maximum motion range gate parameter + maximum motionless range gate parameter + motion range gate 0 sensibility + motion range gate 1 sensibility + … + motion range gate N sensibility + motionless range gate 0 sensibility + motionless range gate 1 sensibility + … + motionless range gate N sensibility + absence report delay (2 bytes)

Sending data:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9 ~ 12
FD FC FB FA	02 00	61 00	04 03 02 01

ACK from radar: (succeed, maximum range gate is 6, motion range gate is 5, motionless range gate is 4, motion sensibility is 20, motionless sensibility 25, absence report delay is 3 s)

Byte 1 ~ 4			Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11	Byte 12	Byte 13	Byte 14	Byte 15	Byte 16	Byte 17	Byte 18
FD FC FB FA			18 00	61 01	00 00	AA	06	05	04	14	14	14	14
Byte 19	Byte 20	Byte 21	Byte 22	Byte 23	Byte 24	Byte 25	Byte 26	Byte 27	Byte 28	Byte 29, 30		Byte 31 ~ 34
14	14	14	19	19	19	19	19	19	19	03 00		04 03 02 01

5.2.6 Enable Engineering Mode Command

This command switches on Engineering Mode for the radar. In this mode, the radar additionally reports energy values for each range gate. For more details, please refer to 6.3.2 Target Data Composition.

Command word: 0x0062

Command value: None

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

Sending data:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9 ~ 12
FD FC FB FA	02 00	62 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	62 01	00 00	04 03 02 01

5.2.7 Disable Engineering Mode Command

This command switches off Engineering Mode. For more details related to radar report data format, please refer to 6.3.2 Target Data Composition.

Command word: 0x0063

Command value: None

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

Sending data:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9 ~ 12
FD FC FB FA	02 00	63 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	63 01	00 00	04 03 02 01

5.2.8 Configure Range Gate Sensibility Command

This command configures sensibilities for each range gate. It can either configure individual range gate, or configure the sensibility of multiple range gates to a same value. When setting multiple range gates to a same value, please configure the Range Gate Value as 0xFFFF. Parameter words refer to Table 5-6.

Command word: 0x0064

Command value: 2 bytes range gate word + 4 bytes range gate value + 2 bytes motion sensibility word + 4 bytes motion sensibility value + 2 bytes motionless sensibility word + 4 bytes motionless sensibility value

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

Table 5-6 Parameter word for sensibility configuration

Parameter Name	Parameter Word
Range Gate	0x0000
Motion Sensibility Word	0x0001
Motionless Sensibility Word	0x0002

Sending data: range gate value 3, motion sensibility 15, motionless sensibility 25

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14	Byte 15, 16	Byte 17 ~ 20	Byte 21, 22	Byte 23 ~ 26	Byte 27 ~ 30
FD FC FB FA	14 00	64 00	00 00	03 00 00 00	01 00	0F 00 00 00	02 00	19 00 00 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	64 01	00 00	04 03 02 01

Sending data: for all range gates, motion sensibility 15, motionless sensibility 25

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14	Byte 15, 16	Byte 17 ~ 20	Byte 21, 22	Byte 23 ~ 26	Byte 27 ~ 30
FD FC FB FA	14 00	64 00	00 00	FF FF 00 00	01 00	0F 00 00 00	02 00	19 00 00 00	04 03 02 01

ACK from radar(succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11 ~ 14
FD FC FB FA	04 00	64 01	00 00	04 03 02 01

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

5.2.9   Reset MCU Command

This command resets MCU and the radar sensor. Please note that the radar will not reset immediately after receiving the Reset MCU Command. Instead, it will reset after receiving an End Command, or receiving no command after 3 s timeout.

Command word: 0x0065

Command value: None

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

Sending data:

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10
FD FC FB FA	02 00	65 00	04 03 02 01

ACK from radar (succeed):

Byte 1 ~ 4	Byte 5, 6	Byte 7, 8	Byte 9, 10	Byte 11, 12
FD FC FB FA	04 00	65 01	00 00	04 03 02 01

5.3   Output Protocol

XenD101Pro outputs the radar detection results through its serial ports. By default, it reports the basic information of the target, including its state, motion and motionless energy level, radial distance etc. When the Engineering Mode checkbox is ticked, it will report energy level of each range gate (motion & motionless) at the same time. All radar data frame is reported in accordance with the protocol.

5.3.1   Output Report Format

According to the protocol, the report data frame formats of the radar are shown in Table 5-7 and Table 5-8.

The data type values for radar normal mode and Engineering Mode are presented in Table 5-9.

Table 5-7 Output report format

Head	Data Length	Data Value	Tail
F1 F2 F3 F4	2 bytes	Refer to Table 5-8	F5 F6 F7 F8

Table 5-8 Data frame format

Data Type	Head	Target Data	Tail	Check
1 byte	0xAA	Refer to Table 5-10 and Table 5-12	0x55	0x00

Table 5-9 Description of data type

Data Type Value	Description
0x01	Engineering mode data
0x01	Basic target information data

5.3.2 Target Data Composition

Radar report data changes based on whether it is in Enable Engineering Mode. The radar reports the target basic information by default, and when it is in Enable Engineering Mode, the radar will additionally report energy level of each range gate. This means that the target's basic information is always reported, while the energy levels of each range gate are only reported when the radar is in Enable Engineering Mode command.

In normal working mode, the composition of target data reported by the radar is shown in Table 5-10, and the definition of target state value is shown in Table 5-11. In Engineering Mode, the composition of target data reported by the radar is shown in Table 5-12.

Table 5-10 Composition of target data

Target State	Motion Target Distance (cm)	Motion Target Energy	Motionless Target Distance(cm)	Motionless Target Energy
1 byte	2 bytes	1 byte	2 bytes	1 byte

Table 5-11 Description of target state value

Target State Value	Description
0x00	No target detected.
0x01	Motion target detected.
0x02	Motionless target detected.
0x03	Motion and motionless targets detected.

Table 5-12 Composition of target data in Engineering Mode

…	Motionless Target Distance	Energy of Motionless Target	Max. Motion Range Gate N	Max. Motionless Range Gate N	Energy of Motion Range Gate 0	…	Energy of Motion Range Gate N	Energy of Motionless Range Gate 0	…	Energy of Motionless Range Gate N
…	2 bytes	1 byte	1 byte	1 byte	1 byte	…	1 byte	1 byte	…	1 byte

5.4 Guide to Configure the Radar

5.4.1 Steps of Configuration

A complete process of carrying out a command consists of the radar receiving a command from a host PC and sending an ACK message back to the host PC. If no ACK message or a failed ACK is sent from the radar, that means the radar failed to implement the latest command.

Before sending any command to the radar, an Enable Command must be sent. Then users should send configuration command(s) within in predefined time window (please refer to 6.4.2 Notifications of Configuration). After sending all the configuration commands, an End Command should be sent to the radar to end the configuration process.

For example, to read the radar configuration, first send an Enable Command. After receiving a successful ACK from the radar, send the Read Parameter Command. After receiving the second successful ACK, send an End Command. The whole process ends as soon as the third successful ACK is received from the radar.

The flow chart of the communication process is shown in Figure 5-1.
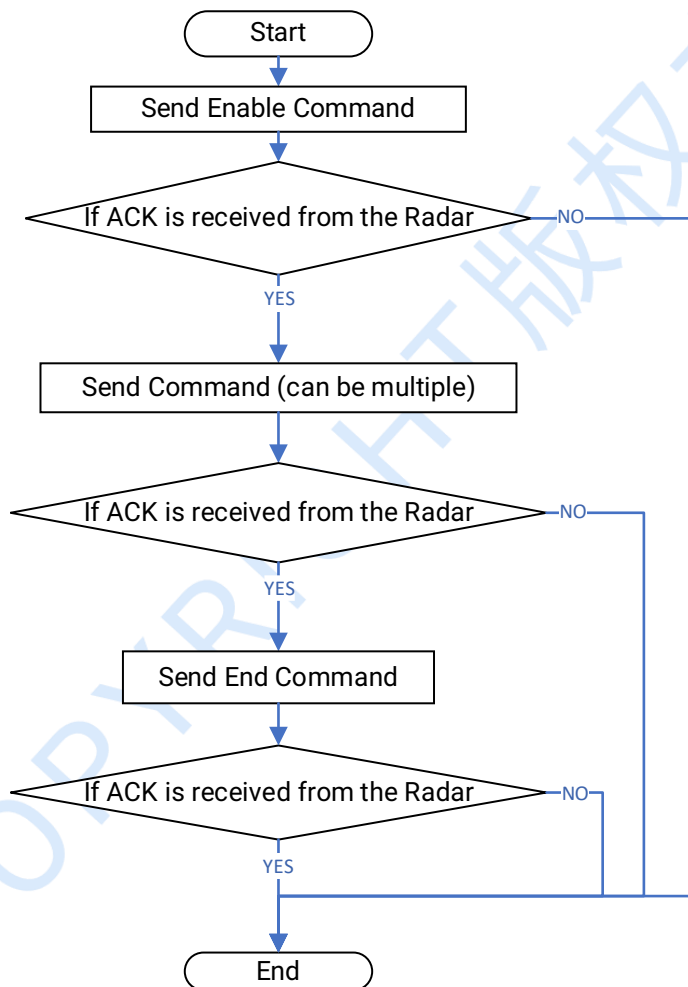

Figure 5-1 Flow chart of configuring or commanding the radar

5.4.2 Notifications of Configuration

Timeout: Before sending any command to the radar, an Enable Command should be sent. As soon as the radar receives this command, a timer of 3 s will start when the radar is waiting for the commands. When the timer

is running, the radar receives and implements configuration command(s), and each time a command is received, the timer will restart timing. During this time, the radar only responds to configuration commands and does not report detection data. When no command is received before the 3 s timer ends, the radar will automatically exit the configuration process and start detecting targets and reporting detection results. If there is a need to configure the radar again, another Enable Command should be sent to the radar.

6. Installation and Detection Range

There are two typical installing methods for XenD101Pro, wall mounted and top mounted. XenD101Pro provides precise range configuration when it is wall mounted, with a deviation of ±15 cm. When it is top mounted, due to the variations of the installation height, target height and shape, the detection range of XenD101Pro may vary accordingly. The maximum detection range in radial direction is 4.5 m.

XenD101Pro is a wide beamforming radar, the recommended top mounted height is about 2.6 ~ 3 m, which allows the radar to perform better and have a wider detection range. While adopting wall mounted installation, the recommended height is about 1.5 ~ 2 m considering there might be shields in the application scenarios and disturbances from the top.

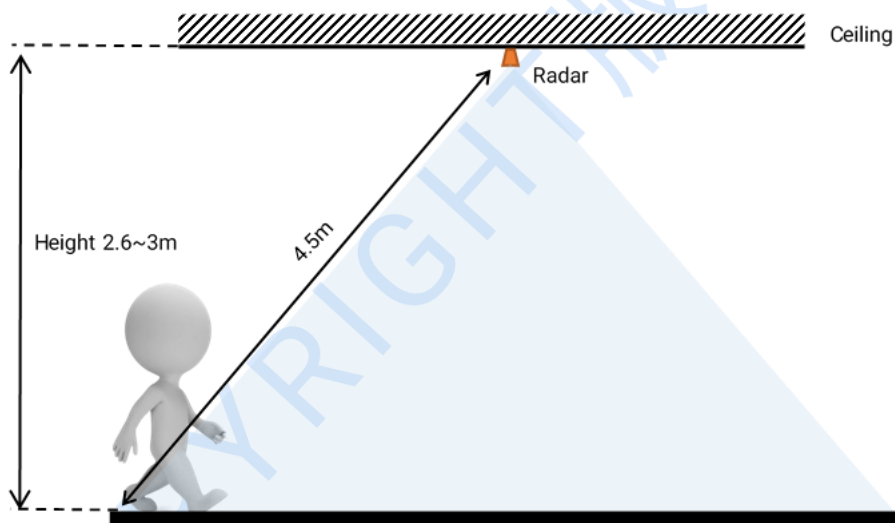## 6.1 Top Mounted Installation and Detection Range

Figure 6-1 Top mounted installation method

When installing XenD101Pro using top mounted method (as is shown in Figure 6-1), the normal direction of its antennas is 0 degree, and azimuth on the left of the radar is considered as negative, while azimuth on the right side positive (as is shown in Figure 6-2).
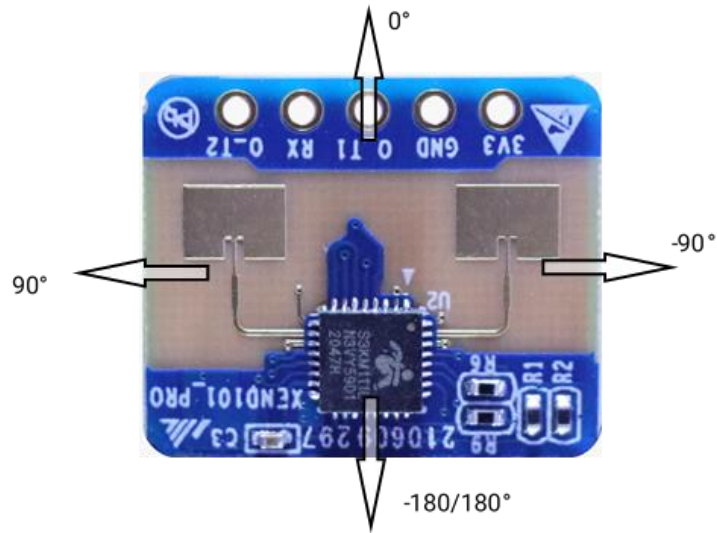
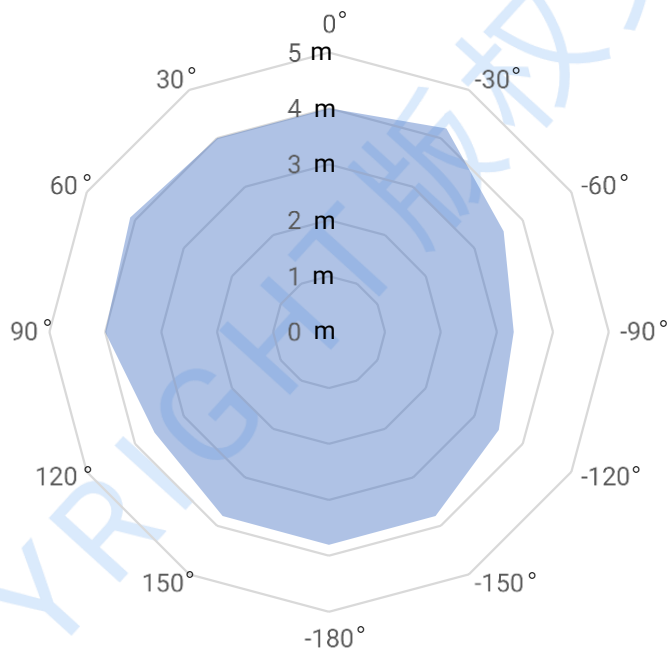Figure 6-2 Definition of directions for top mounted installation

Figure 6-3 Detection range for top mounted installation (installation height 2.7 m)

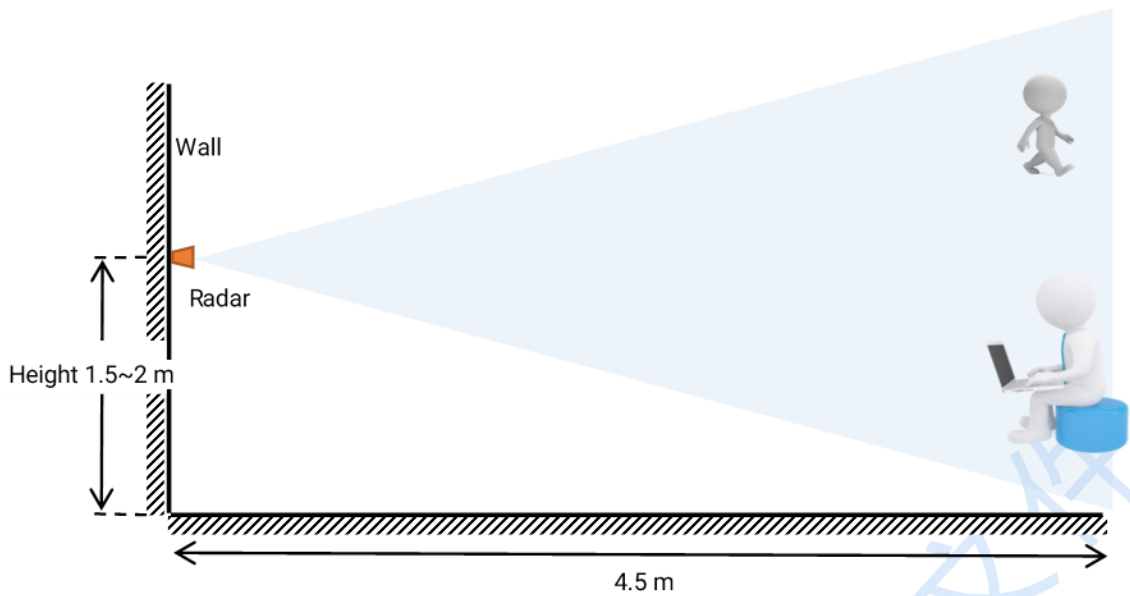## 6.2 Wall Mounted Installation and Detection Range

Figure 6-4 Wall mounted installation method

When installing XenD101Pro using wall mounted method (as is shown in Figure 6-4), the normal direction of its antennas is 0 degree, and azimuth on the left of the radar is considered as negative, while azimuth on the right side positive (as is shown in Figure 6-5). As shown in Figure 6-6, when installed wall mounted, the angular detection range of XenD101Pro is $\pm45°$ in relation to the normal direction of the antennas. And the maximum detection range is 4.5 m.
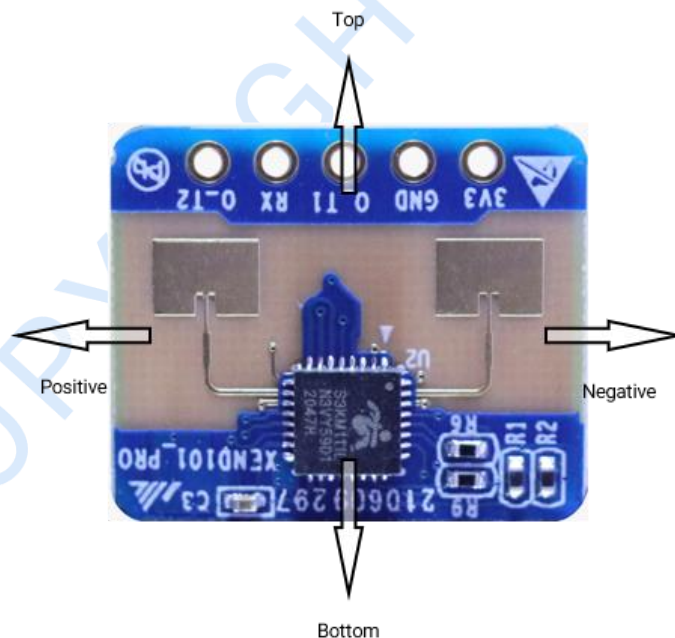

Figure 6-5 Definition of directions for wall mounted installation

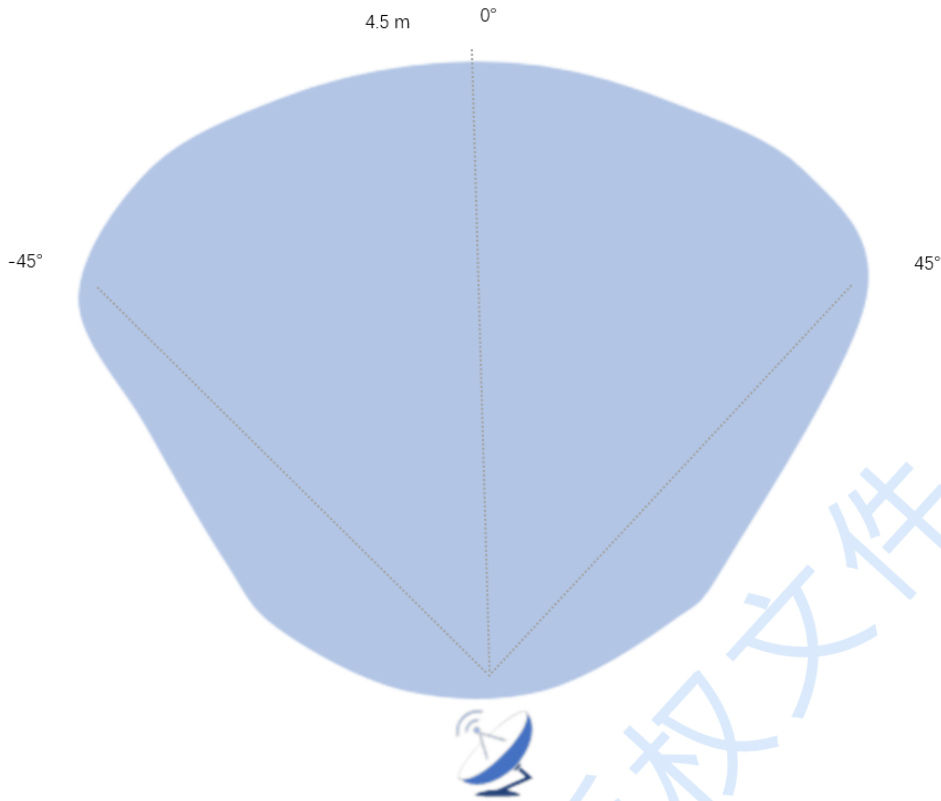**Figure 6-6 Detection range for wall mounted installation (installation height 1.5 m)**

7. Mechanical Size

This chapter introduces the mechanical size of XenD101Pro PCB, as shown in Figure 7-1. The unit of the size is mm, and the board thickness is 1.6 mm with a tolerance of $\pm10\%$.
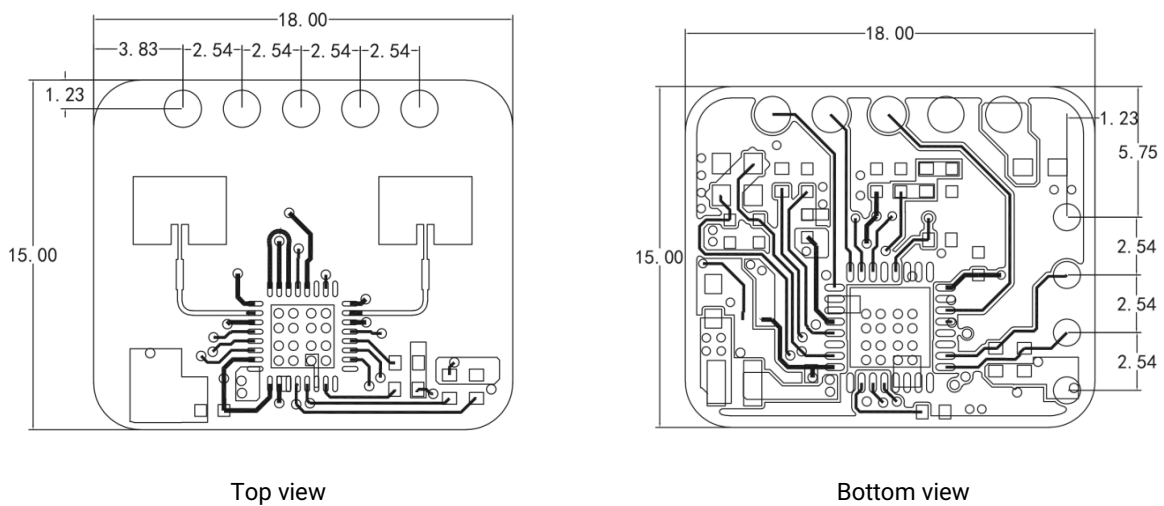

Top view   Bottom view

Figure 7-1 Top and bottom view of XenD101Pro module

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8. Installation Requirements

Minimum Mounting Clearances

If a cover is to be installed with the radar, the cover must have high-performance penetrability in 24 GHz. Also, the cover material should contain no metal nor other materials that may shield electromagnetic wave. More details please refer to [Design Guidelines for mmWave Sensor Radome](#)[4].

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.

- When installing using wall mounted method, external interference sources such as air-conditioners or fans on the ceiling should be taken into consideration.

Important Requirements

- Ensure the antennas are facing the target detection area, with no shield or obstacles around them.

- 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.

- To avoid mutual interference among radar sensors, when multiple 24 GHz radar sensors are installed, please make sure that their beamforms are not facing to each other; when top mounted, make sure the spacing between two sensors should be no less than 3m.

Notice on Power Supply

The input power should range from 3.0 V to 3.6 V, and the power ripple should have no obvious peaks within 100 kHz. Due to the fact that this is a reference design, developers should take EMC design such as ESD and lightning surge into consideration.

9. Important Tips

Detection Range

The detection range of XenD101Pro is 1.5 ~ 4.5 m. Within this range, the radar will report the radial distance between the target and the radar. However, when the target's radial distance with the radar is less than 1.5 m,

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[4] Currently, only Chinese version is available.

the radar cannot provide precise range measurement due to the higher signal noise caused by DC. As a result, for target that is less than 1.5 m from the radar, the radar will report 1.5 m instead.

Selecting J1 Pin Sequence

Users can choose Pin function through modifying macro definitions. For example, the macro UART_OUT_OT1 under engineering directory \App\algo\inc\AlgorithmConfig.h can be modified as such: when defined, O_T1 functions as UART_TX while O_T2 as IO; when disabled, O_T1 functions as IO while O_T2 as UART_TX.

Modifying Firmware Baud Rate

XenD101Pro default baud rate is 256000. It can be modified using the macro USART_BAUDRATE defined under engineering directory \Middleware\platform\gd32f3x0\inc\uart.h.

Enable MCU Low Power Consumption

XenD101Pro supports MCU Low Power Mode, which is configurable through modifying the macro MCU_SLEEP_MODE is under engineering directory \Config\global_conf.h. The MCU Low Power Mode is enabled when macro MCU_SLEEP_MODE is defined as 1, and disabled when the macro is defined as 0. While the MCU Low Power Mode is enabled, the average current of the whole module can be as low as 52±1 mA.

Start-up Time

After the radar starts up, it will report motion target in 2 s and motionless target in 3 s.

Maximum Detection Distance and Accuracy

Theoretically, the detection accuracy of XenD101Pro is up to 0.15 m which is computed based on the physical resolution of 0.75 m and the process of specific algorithm. While detection accuracy and the maximum detection distance may slightly vary due to the size, state and RCS of the target.

Time Limit for Programming

Before programming the radar, an Enable Command should be sent, and the whole programming process should finish within 3 s.

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	2022/3/3	Initial edition.
1.1	2022/3/17	Firmware update, add Enable MCU Low Power Consumption.
1.2	2022/5/7	Add Reset MCU Command, add power supply notice during installation.
1.3	2022/9/15	Remove the information of the hardware design that no longer used.
1.4	2023/6/5	Update product name from XenD101ProHPS01 to XenD101Pro; Modify the document revision number so that it is independent from the firmware number; The visualization tool has upgraded to v1.2.0.0, update the figures of the visualization tool; Add the instruction of using Save and Replay Radar Data function; Optimize the document structure by moving the Communication Protocol chapter to chapter 5.

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