Shenzhen Hi-link Electronics Co., Ltd.

HLK- LD2413 User Manual

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Contents

1. Product Introduction

1.1. Overview

HLK-LD2413 is a miniaturized high-precision liquid level detection sensor from Hi-link . It combines a minimalist 24 GHz millimeter wave sensor HLK-LD2413 with a high-precision liquid level detection intelligent algorithm firmware.

The sensor HLK-LD2413 adopts a compact design, maintaining an ultra-small size while having excellent performance. HLK-LD2413 is equipped with an AIoT millimeter wave sensor chip, a high-performance one-transmit-one-receive microstrip antenna, an MCU and peripheral auxiliary circuits. The high-precision liquid level detection intelligent algorithm firmware uses FMCW waveforms and chip-specific advanced radar signal processing to achieve accurate detection of liquid and material heights .

The detection range of HLK-LD2413 is 0.15 m ~ 10 m, and the ranging accuracy is ±3 mm . The sensor is equipped with a visualization tool, which can easily configure detection parameters such as data reporting cycle. In addition, this solution supports real-time reporting of detection results via the UART interface , which is plug-and-play.

1.2. Product Features

- Equipped with single-chip intelligent millimeter wave sensor SoC and intelligent algorithm firmware
- High-precision detection
- Ultra-small sensor size of 44 mm x 36 mm
- 3.3 V single power supply, supports 3.0 V ~ 3.6 V
- Average working current 23 mA @ 160ms reporting period (the period can be configured according to the scenario)
- Provides visualization tools to support distance calibration and reporting cycle configuration
- Report detection results in real time
- Beamwidth ≤ ±12° @-6 dB (two-way)

In practical applications, the HLK-LD2413 miniaturized high-precision liquid level detection sensor can non-contactly measure the liquid and material height in closed or open containers under

the influence of various environmental factors (such as temperature, pressure, dust). Therefore, it has broad application prospects in the following fields:

- Industrial field

Continuous contactless detection of the liquid level/material level of chemical materials, corrosive liquids, etc. stored in tanks to ensure safe production.

- Smart Home Appliances

Real-time and high-precision monitoring of water levels in smart water dispensers, coffee machines and other home appliances to prevent safety issues such as overflow and dry burning.

- Hydrological monitoring

Real-time monitoring of water levels in natural water bodies such as reservoirs, rivers, and lakes to provide support for water resources management.

- Smart City

Real-time monitoring of urban ditches and underground water levels to help solve urban drainage problems.

2. System Description

HLK-LD2413 is a miniaturized high-precision liquid level detection sensor reference solution developed based on Hi-link chip. The sensor uses FMCW waveform, combined with MCU's proprietary radar signal processing and built-in high-precision liquid level detection intelligent algorithm , to achieve accurate detection of target distances in a specified area and report results in real time. Based on this reference solution, users can quickly develop corresponding miniaturized high-precision liquid level detection sensing products.

HLK-LD2413 is mainly composed of a fully integrated Hi-link intelligent millimeter wave sensor SoC, 24 GHz transmit-receive antenna and main control MCU ; the software part is equipped with high-precision liquid level detection intelligent algorithm firmware and a visual configuration tool, allowing users to flexibly configure the refresh frequency and view the detection distance results in real time.

The specifications of HLK-LD2413 are shown in Table - 2-1 .

Table 2-1 Specifications of HLK-LD2413

Parameter	Min	Typical	Max	Unit	Remark
HLK-LD2413 Specifications					
Working frequency band	23	-	27	GHz	-
Sweep bandwidth	-	4	-	GHz	
Beam width	-12	-	12	°	-6 dB (two-way)
Maximum equivalent isotropic radiated power	-	11	-	dBm	Assembling the radome
Supply voltage	3.0	3.3	3.6	V	-
size	-	44 * 36	-	mm^2	-
Ambient temperature	-40	-	85	°C	-
HLK-LD2413 System Performance					
Distance measurement range	0.15	-	10	m	Water surface, large angle reflection
Distance measurement accuracy	-3	-	3	mm	
Reporting cycle	50	160	1000	ms	Configurable, see Section 5.2.7 for details
Average operating current	-	1 6	740	mA	@ 1 s reporting period
	-	23	705		@ 160 ms reporting period

3. Hardware Description

Figure 3- 1 is a physical picture of the front and back of HLK-LD2413 . The hardware reserves 5 pin holes, marked as J1, for power supply and communication. Interface J2 is the SWD (Single Wire Debug) interface, which is used to burn and debug MCU programs. When burning the firmware, be sure to connect according to the corresponding pin names.

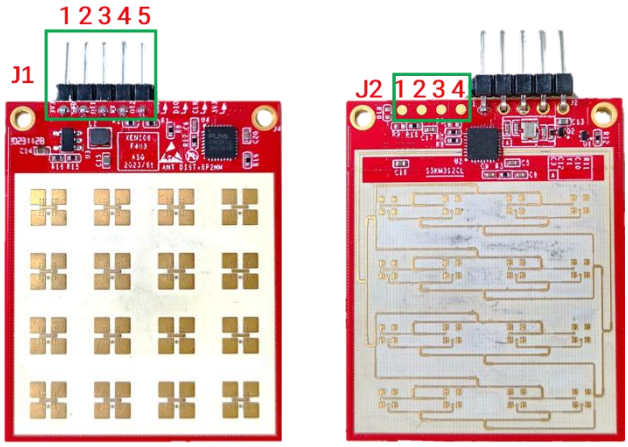


Figure 3-1 HLK - LD2413 front and back pictures

For the pin descriptions of J1 and J2, please refer to Table 3.1 - and Table 3.2 - respectively .

Table 3-1 J1 Pin Description

J#Pin#	Name	Function	Illustrate
J1Pin1	3V3	Power Input	3.0 V~3.6 V, Typ. 3.3 V
J1Pin2	GND	Grounding	-
J1Pin3	OT1	UART_TX	0~3.3 V
J1Pin4	RX	UART_RX	0~3.3 V
J1Pin5	OT2	IO Port	0~3.3 V

Table 3- 2 J2 Pin Description

J#Pin#	name	Function	Illustrate
J2Pin1	3V3	Power Input	3.0 V~3.6 V, Typ. 3.3 V
J2Pin2	CLK	Clock signal	0~3.3 V
J2Pin3	DIO	Data port	0~3.3 V
J2Pin4	GND	Grounding	-

4. Software Description

This chapter introduces the firmware debugging of the HLK-LD2413 miniaturized high-precision liquid level detection millimeter wave sensor and the use of host computer tools.

HLK-LD2413 has been factory-burned with system firmware. For the firmware version, please refer to the sensor packaging. Hilink provides a visual host configuration tool software for HLK-LD2413 , which is convenient for developers to configure parameters of HLK-LD2413

according to the usage scenario and optimize the sensing effect.

4.1. Firmware Debugging

This section introduces how to use third-party serial port tool software to debug the HLK-LD2413 firmware. Please follow the steps below to debug the firmware:

Step 1: Use the USB to TTL serial port adapter board to connect the host computer and the HLK-LD2413 millimeter wave sensor. The pin connection method is shown in Table 4 - 1 and Figure 4 - 1 ;

Table 4 - Correspondence between the pins when the sensor is connected to the USB serial port adapter board

Sensor	Serial port adapter board
RX	TXD
OT1	RxD
GND	GND
3V3	VCCIO

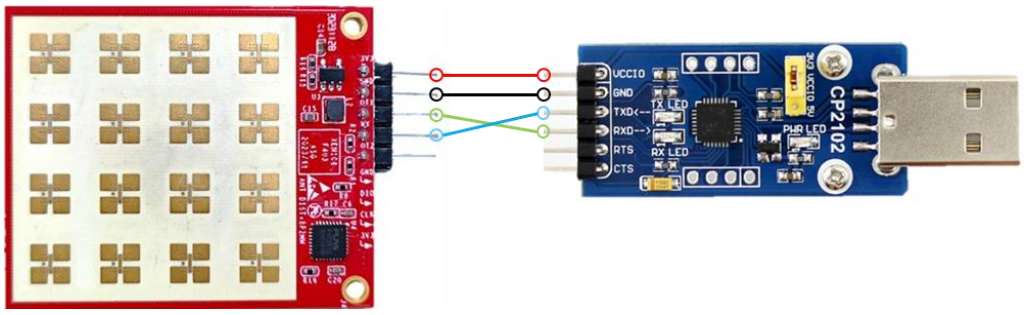


Figure 4 - 1 Schematic diagram of connecting HLK-LD2413 and USB serial port adapter board

Step 2: Open the device manager of the host computer and check the serial port number of the millimeter wave sensor;

Step 3. Open the third-party serial port tool, select the serial port number of the millimeter wave sensor, and set the baud rate to 115200;

Step 4. Click the "Open Serial Port" button to view the detection results of the current sensor at the output end of the tool interface.

For the format and parsing method of the test results output by the third-party serial port tool, see 5.3 Reporting Data .

4.2. Host computer tool description

To help users understand, obtain and configure millimeter wave sensor parameters, Hilink provides a dedicated host computer tool " HLK-LD2413 _Tool".

Note: The host computer tool and the third-party serial port tool cannot be used at the same time!

4.2.1.Connect the sensor to the host computer

Before using the functions of the host computer tool, the user should first connect HLK-LD2413 and the host computer tool. The steps are as follows:

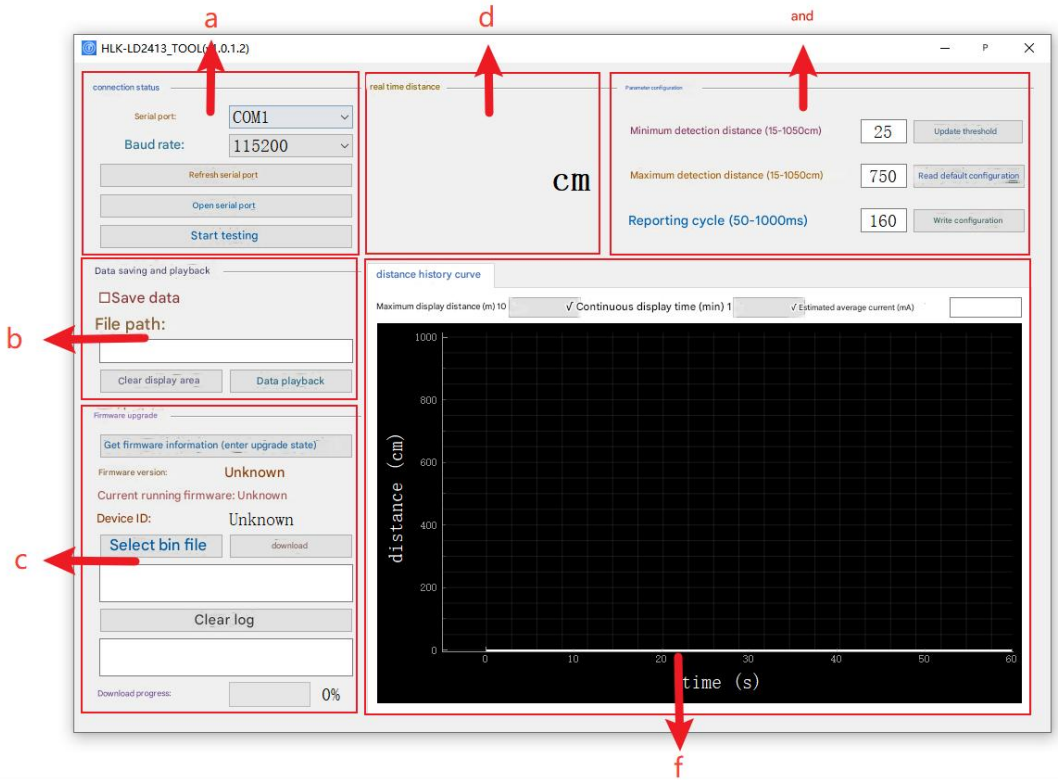
Step 1: Get the host computer tool " HLK-LD2413_Tool " for HLK-LD2413 from the official website of Hilink .

Step 2: Use the serial port adapter board to connect the HLK-LD2413 sensor and the host computer, as shown in Figure 4 - 1 ;

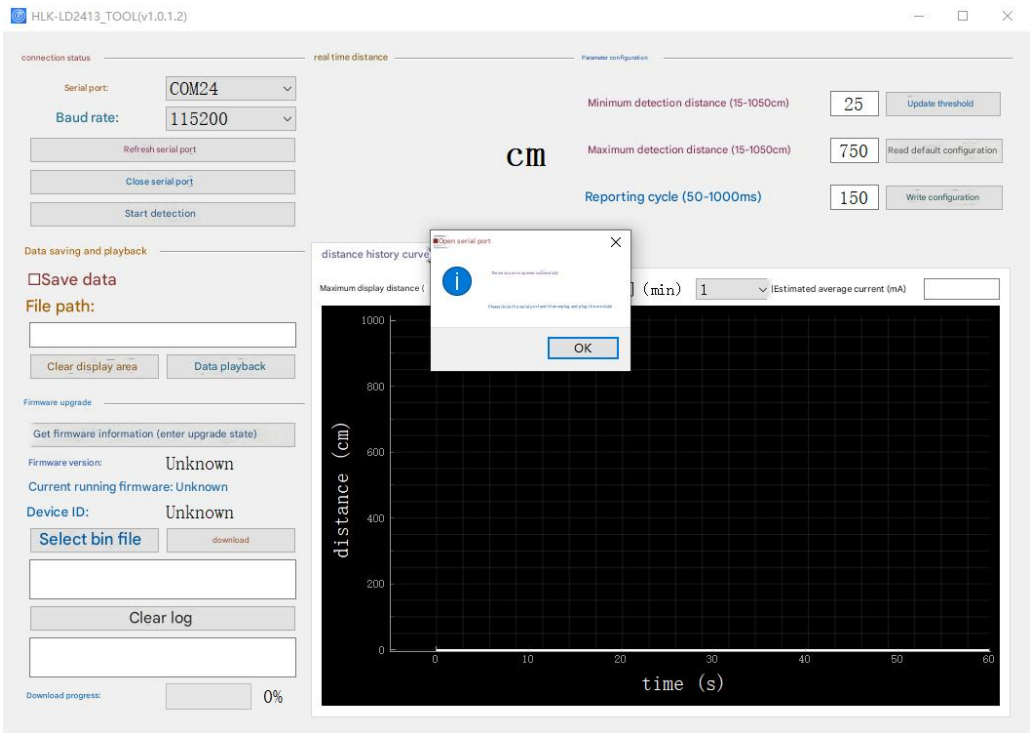
Step 3. Open the host computer tool (see Figure 4 - 2 (a) for the interface), click the "Refresh Serial Port" button, select the serial port number of HLK-LD2413 in the "Serial Port" drop-down box , confirm that the "Baud Rate" is 115200, and click the "Open Serial Port" button to start connecting the host computer and the sensor.

After the connection is successful, a pop-up window of "Serial port opened successfully" will appear, and the text on the original "Open serial port" button will be switched to "Close serial port", as shown in Figure 4 - 2 (b).

If the connection fails, please confirm whether the host computer has correctly installed the driver of the serial port adapter tool, and confirm whether the serial port adapter tool is correctly connected to the sensor.



(a) Before connecting the device



(b) After the device is connected (successfully)

Figure 4 - 2 HLK-LD2413 _Tool

In the Figure 4 - 2 (a), the upper computer tool interface can be divided into five areas: (a) connection status area; (b) data storage and playback area; (c) firmware upgrade area; (d) real-time distance display area; (e) parameter configuration area; and (f) distance history curve display area.

4.2.2.Parameter configuration

After the sensor is successfully connected to the host computer, the user can configure parameters in area (e) of the interface to meet the needs of specific application scenarios . The user can modify the parameter value in the corresponding text box and click " Write Configuration " to successfully configure the parameter. The user can also display the default parameter value by clicking " Read Default Configuration " and then click " Write Configuration " to restore the default configuration. After the configuration is completed, click the " Start Detection " button in area (a) to start the distance detection function.

The Min and Max of detection range of HLK-LD2413 are set to 250 mm and 7500 mm respectively by default , and the reporting period is set to 160 ms by default.

●Read parameter configuration

The steps to read the default configuration through the host computer tool are as follows: connect HLK-LD2413 and the host computer tool (the serial port is open), and in the stop detection state, click the "Read Default Configuration" button to display the corresponding default parameter value in the text box.

- **Write parameter configuration**

The steps to write parameter configuration through the host computer tool are as follows:

Step 1. Connect HLK-LD2413 to the host computer tool (serial port is open) and stop detection. Enter the corresponding parameter values in the "Minimum detection distance (cm)", "Maximum detection distance (cm)", and "Report cycle (ms)" text boxes. The minimum and maximum detection distance ranges from "150 mm to 10500 mm", and the reporting cycle configuration range is from "50 ms to 1000 ms". All parameter values only support integer values;

Step 2. Click the "Write Configuration" button to configure.

After the configuration is written, a pop-up window will appear with the message "Configuration written successfully!", as - shown in Figure 4 3.

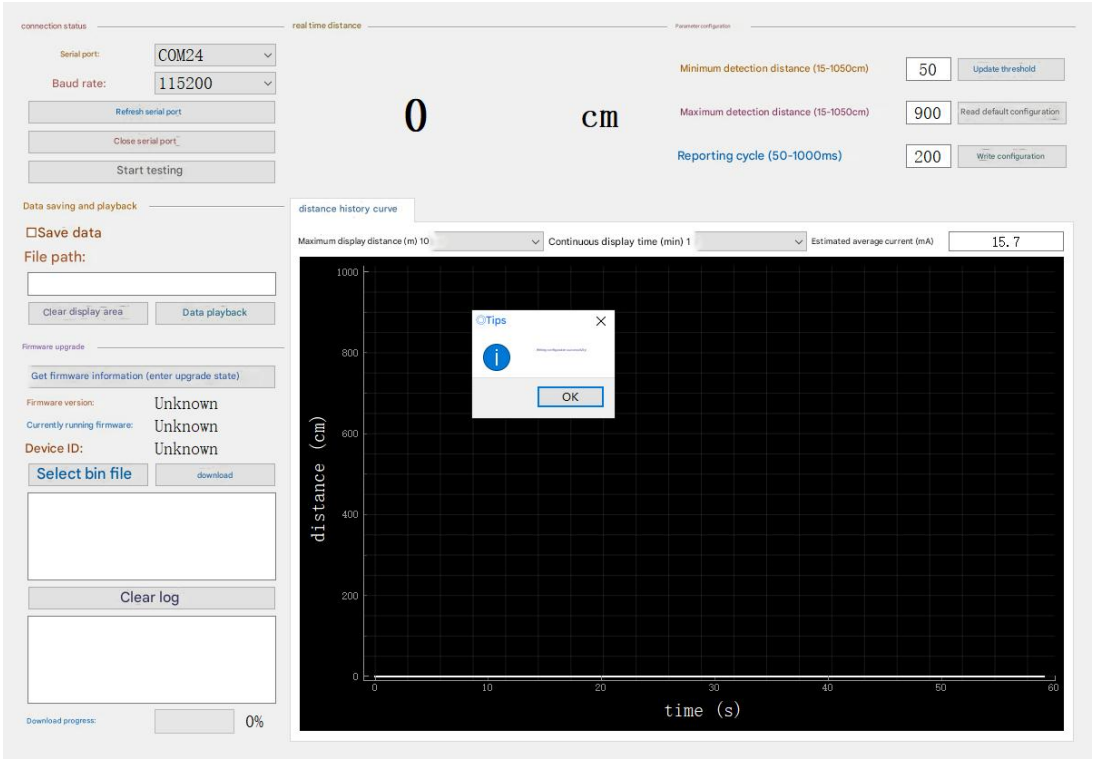


Figure 4 - 3 Parameter setting successful display interface

The perform operations such as " update threshold " and "report cycle configuration" in area (e) of the interface to meet the needs of specific application scenarios . After the configuration is completed , click the "Start Detection" button to start the distance detection function .

" Update Threshold " is used to reduce the impact of the sensor's own background noise on the detection results ; "Reporting Cycle Configuration" is used to modify the module data reporting interval .

HLK-LD2413 has completed the update threshold before leaving the factory , and the default reporting period is 160 ms . If there is no special requirement (such as re-disassembly and re-assembly of the sensor housing, etc.) , the user can keep the default configuration for use .

- **Update Threshold**

Update the threshold through the host computer tool are as follows:

Step 1: Align the antenna surface of the HLK-LD2413 sensor with the antenna cover to the open sky outdoors, or to the absorbing material in a dark room; ensure that there is no metal material on the sensor feeder surface (i.e. the back of the antenna surface); and keep the

environment consistent throughout the threshold update operation;

Step 2: After connecting HLK-LD2413 to the host computer tool (serial port is open), click the "Start Detection" button for about 10 seconds, and then click the "End Detection" button;

Step 3. Click the " Update Threshold " button. After the update is completed, a pop-up window of " Threshold Update Successful" will appear, as shown in Figure 4 - 4 .

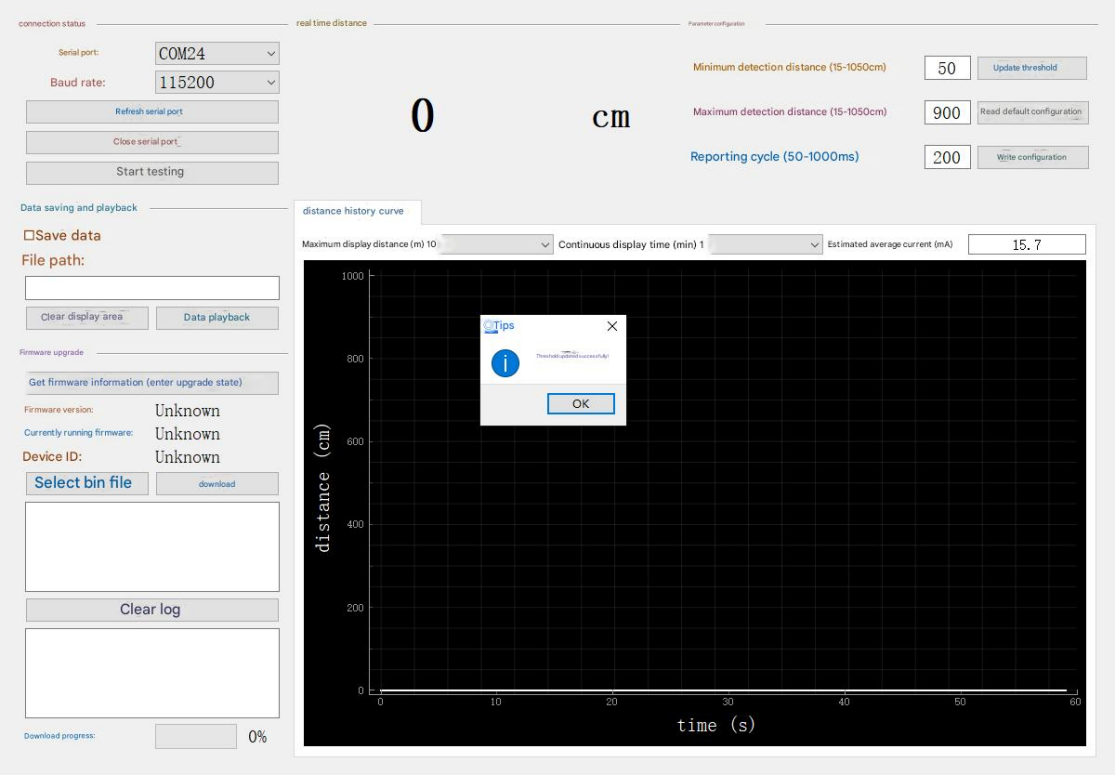


Figure 4 - 4 The threshold update success display interface

4.2.3.Detection information display

Areas (d) and (f) of the host computer tool interface are used to display real-time detection information. Area (d) displays the detection distance at the current moment in cm , and the displayed value is retained to two decimal places; Area (f) displays the distance history curve. Users can adjust the maximum display distance and display time of the distance history curve through the "Maximum display distance (m)" drop-down box and the "Continuous display time (min)" drop-down box. The text box above the curve will also display the estimated average current (mA) under the current configuration.

After the sensor is successfully connected to the host computer tool (the serial port is open), click the "Start Detection" button to start the detection. Figure 4 - 5 is a schematic diagram of the

detection information . The detection distance is 131.11cm , the maximum display distance is 10m, the continuous display time is 1min, and the current estimated average current is 15mA .

Figure 4 - 5 Detection information diagram

4.2.4.Data storage and playback

Area (b) of the host computer tool interface provides the function of saving and replaying the detection distance.

- **Saving Data**

The steps to save the test data are as follows:

Step 1: After the millimeter wave sensor is successfully connected to the host computer (the serial port is open), check the "Save Data" checkbox;

Step 2: Select the save path of the file in the pop-up "Select Path" interface. After completing the selection, the save path will be displayed in the display box under "File Path";

Step 3. Click the "Start Detection" button to save the data during the detection. The default name of the saved data file is "Data_year_month_day_hour_minute_second.dat".

- **Clear the display area**

Click the "Clear Display Area" button to clear the distance history curve and the currently displayed detection distance value.

- **Data playback**

The steps to play back the test data are as follows:

Step 1: After the millimeter wave sensor is successfully connected to the host computer (the serial port is open), click the "Data Playback" button;

Step 2: Select the previously saved test data file in the pop-up "Select Path" interface.

After completing the selection, you can view the test results of the selected data on the upper computer tool interface.

4.2.5.Update the firmware

The steps to update the mmWave sensor firmware through the host computer tool are as follows:

Step 1: After connecting HLK-LD2413 to the host computer tool (the serial port is open), click the "Get Firmware Information" button. The current firmware version, the firmware running on the device, and the device ID will be displayed below the button;

Step 2: Click the "Select Bin File" button and select the target bin file in the pop-up "Select Bin File" interface; after completion, the bin file path will be displayed in the information box below;

Step 3: Click the "Download" button to start the firmware upgrade. The "Download Progress" bar below will display the download progress in real time.

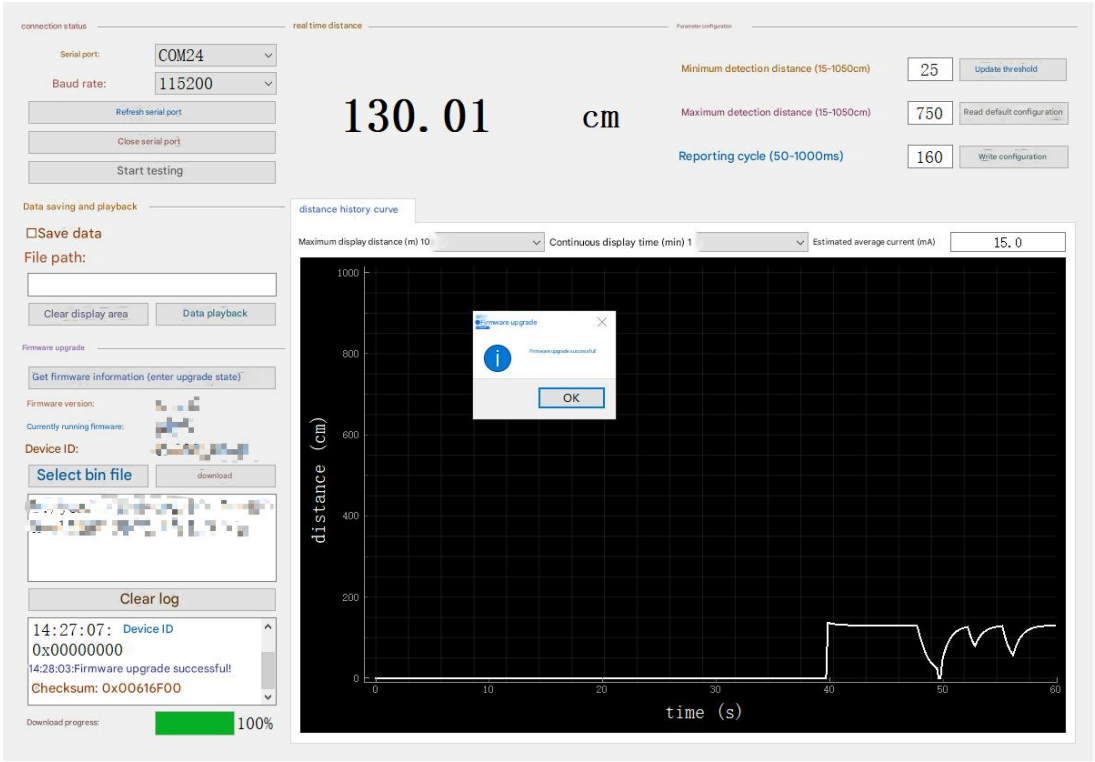


Figure 4-6 Schematic diagram of the firmware upgrade interface

After the firmware upgrade is successful, a pop-up window of "Firmware upgrade successful" will appear, as shown in Figure 4 - 6. When the firmware upgrade fails, the corresponding error message will be displayed in the prompt message box.

5. Communication Protocol

This communication protocol is mainly used by users who need to perform secondary development without visualization tools. The HLK-LD2413 miniaturized high-precision liquid level detection millimeter wave sensor communicates with the outside world through the serial port (TTL level). The sensor's data output and parameter configuration commands are all performed under this protocol. The default baud rate of the sensor serial port is 115200, 1 stop bit, and no parity bit.

This chapter mainly introduces this communication protocol from three parts:

1) Protocol Format

- Describes the formats of protocol data frames and command frames .

2) Send command and ACK format

- Sending command format: details the format of the command frame sent to the sensor ;
- ACK Format: Details the frame format that the sensor uses to reply to each command.

3) Reporting data format

- This section describes the data frame format that the millimeter-wave radar sends to the host computer tool.

5.1. Protocol Format

5.1.1.Protocol data format

HLK-LD2413 uses the little endian format. All the data in the following table are in hexadecimal.

5.1.2.Command protocol frame format

Table - 5.1 and Table - 5.3 respectively .

Table 5 - 1 Send command protocol frame format

Frame Header	Data length in frame	Intra-frame data	Frame end
FD FC FB FA	2 bytes	See Table 5 - 2	04 03 02 01

Table 5 - 2 Transmit frame data format

Command word (2 bytes)	Command value (N bytes)

Table 5 - 3 ACK command protocol frame format

Frame Header	Data length in frame	Intra-frame data	Frame end
FD FC FB FA	2 bytes	See Table 5 - 4	04 03 02 01

Table 5 - 4 ACK frame data format

Send command word (2 bytes)	Command execution status (2 bytes)	Return value (N bytes)

5.2. Send command and ACK

The basic process of using commands to configure and obtain sensor parameters is:

1. Enter command mode (see 5.2.2 Enabling Configuration Commands);
2. Send configuration parameter command/get parameter command (see 5.2.1 , and 5.2.4 ~

5.2.7);

3. Exit command mode (see 5.2.3 End Configuration Command).

The following is a detailed introduction to each command and ACK.

5.2.1.Read firmware version command

This command reads the mmWave sensor firmware version information.

Command word: 0x0000

Command value: None

Return value: version number length (2 bytes) + 2-byte major version number + 2-byte minor version number + 2-byte patch version number .

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	00 00	04 03 02 01

ACK (success, data is example):

Frame Header	Data length in frame	Command word	Major version number	Minor version number	Patch version number	Frame end
FD FC FB FA	08 00	00 01	01 00	04 00	0E 00	04 03 02 01

5.2.2.Enable configuration command

This command is used to open the configuration mode of the sensor. Any other commands sent to the sensor must be executed after this command is sent, otherwise they will be invalid.

Command word: 0x00FF

Command value: 0x0001

Return value: 2-byte ACK status (0 for success, 1 for failure)

Sending data:

Frame Header	Data length in frame	Command word	Command Value	Frame end
FD FC FB FA	0 4 00	FF 00	01 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	FF 01	00 00	04 03 02 01

5.2.3.End configuration command

After executing the end configuration command, the millimeter wave sensor resumes working mode. If you need to send other commands again, you need to send the enable configuration command first.

Command word: 0x00FE

Command value: None

Return value: 2-byte ACK status (0 for success, 1 for failure)

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	FE 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	FE 01	00 00	04 03 02 01

5.2.4.Minimum detection distance configuration command

This command is used to configure the minimum detection distance . The configuration range is 150 mm ~ 10500 mm (only integer values are supported) .

Command word: 0x007 4

Command value: 2-byte parameter word (minimum detection distance converted to hexadecimal in little-endian format)

Return value: 2-byte ACK status (0 for success, 1 for failure)

Send data: (Example: minimum detection distance = 200 mm)

Frame Header	Data length in frame	Command word	Command Value	Frame end
FD FC FB FA	04 00	7 4 00	C8 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	7 4 01	00 00	04 03 02 01

5.2.5.Maximum detection distance configuration command

This command is used to configure the maximum detection distance . The configuration range is 150 mm ~ 10500 mm (only integer values are supported).

Command word: 0x007 5

Command value: 2-byte parameter word (maximum detection distance converted to hexadecimal in little-endian format)

Return value: 2-byte ACK status (0 for success, 1 for failure)

Send data: (Example: Maximum detection distance = 1000 mm)

Frame Header	Data length in frame	Command word	Command Value	Frame end
FD FC FB FA	04 00	7 5 00	E8 03	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	7 5 01	00 00	04 03 02 01

5.2.6.Update Threshold Command

This command is used to update the threshold .

Command word: 0x0072

Command value: None

Return value: 2-byte ACK status (0 for success, 1 for failure)

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	72 00	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	72 01	00 00	04 03 02 01

5.2.7.Reporting cycle configuration command

This command is used to configure the reporting period. The configuration range is 50 ms to 1000 ms (only integer values are supported).

Command word: 0x0071

Command value: 2-byte parameter word (the reporting period is converted to hexadecimal in

little-endian format)

Return value: 2-byte ACK status (0 for success, 1 for failure)

Send data: (Example: reporting period = 500 ms)

Frame Header	Data length in frame	Command word	Command Value	Frame end
FD FC FB FA	04 00	71 00	F4 01	04 03 02 01

ACK (Success):

Frame Header	Data length in frame	Command word	ACK	Frame end
FD FC FB FA	04 00	71 01	00 00	04 03 02 01

5.2.8.Report cycle read command

This command is used to read the reporting period.

Command word: 0x0070

Command value: None

Return value: 4-byte reporting period

Sending data:

Frame Header	Data length in frame	Command word	Frame end
FD FC FB FA	02 00	70 00	04 03 02 01

ACK (success): (Example: reporting period is 1000 ms)

Frame Header	Data length in frame	Command word	Reporting cycle	Frame end
FD FC FB FA	06 00	70 01	E8 03 00 00	04 03 02 01

5.3. Reporting data

The factory firmware of HLK-LD2413 outputs the distance detection result through the serial port by default, and the unit is mm (the unit of the host computer is cm).

Table 5 - 5 Reporting data format

Frame Header	Data length in frame	Detection distance	Frame end
F4 F3 F2 F1	2 bytes	4 bytes (Float type)	F8 F7 F6 F5

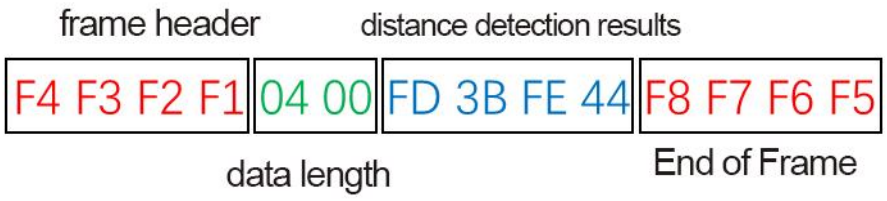


Figure 5 - 1 Example of reported data

In the example:

Data length: indicates the number of bytes occupied by the reported distance detection result;

Detection result: indicates the distance between the target and the millimeter wave sensor at the current moment.

Therefore, the data frame analysis example in Figure - 5.1 is as follows:

Data length: 00 04, indicating that the number of bytes occupied by the reported distance detection result is 4;

Distance detection result: The distance detection result FD 3B FE 44 stored in the little-endian format is converted to a single-precision floating point number, which is 2033.87 (retained to two decimal places), that is, the target is 2033.87 mm away from the millimeter wave sensor at the current moment.

6. Installation and detection range

The recommended installation method for the HLK-LD2413 miniaturized high-precision liquid level detector is to install it on the top of a storage tank or barrel, with the antenna facing the material or liquid to be measured, and the normal of the sensor perpendicular to the cross section or surface of the material or liquid to be measured. In the default configuration, the range of HLK-LD2413 is 0.15 m~ 10 m, and the ranging accuracy is ±3 mm .

The direction definition of the - HLK-LD2413 millimeter wave sensor is shown in Figure 6 1. Among them, the X-axis direction is 0°, the Z-axis direction is 90°, and the Y-axis is perpendicular to the XZ plane (also called the normal direction).

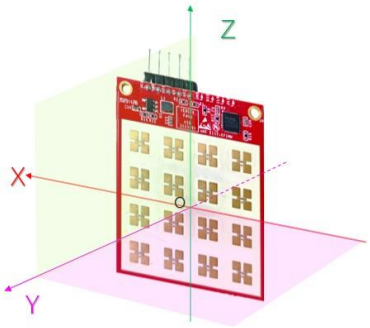
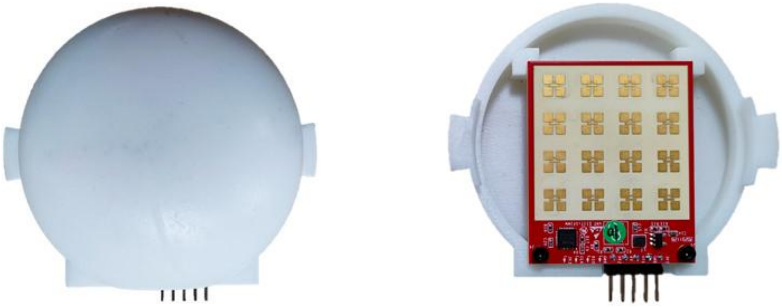


Figure 6 - 1 HLK-LD2413 Direction Definition Diagram

HLK-LD2413 millimeter wave sensor equipped with a fully transparent radome is shown in Figure 6 - 2. The radome is mainly used for installation and fixing. (The radome is not included by default)



(a) Sensor with fully transparent radome

(b) Schematic diagram of sensor fixation inside the radome

Figure 6 - Schematic diagram of HLK-LD2413 with radome

If the object to be tested is in a storage tank or barrel, it is recommended to install the HLK-LD2413 sensor on the ceiling. The installation method is shown in Figure 6 - 3 .

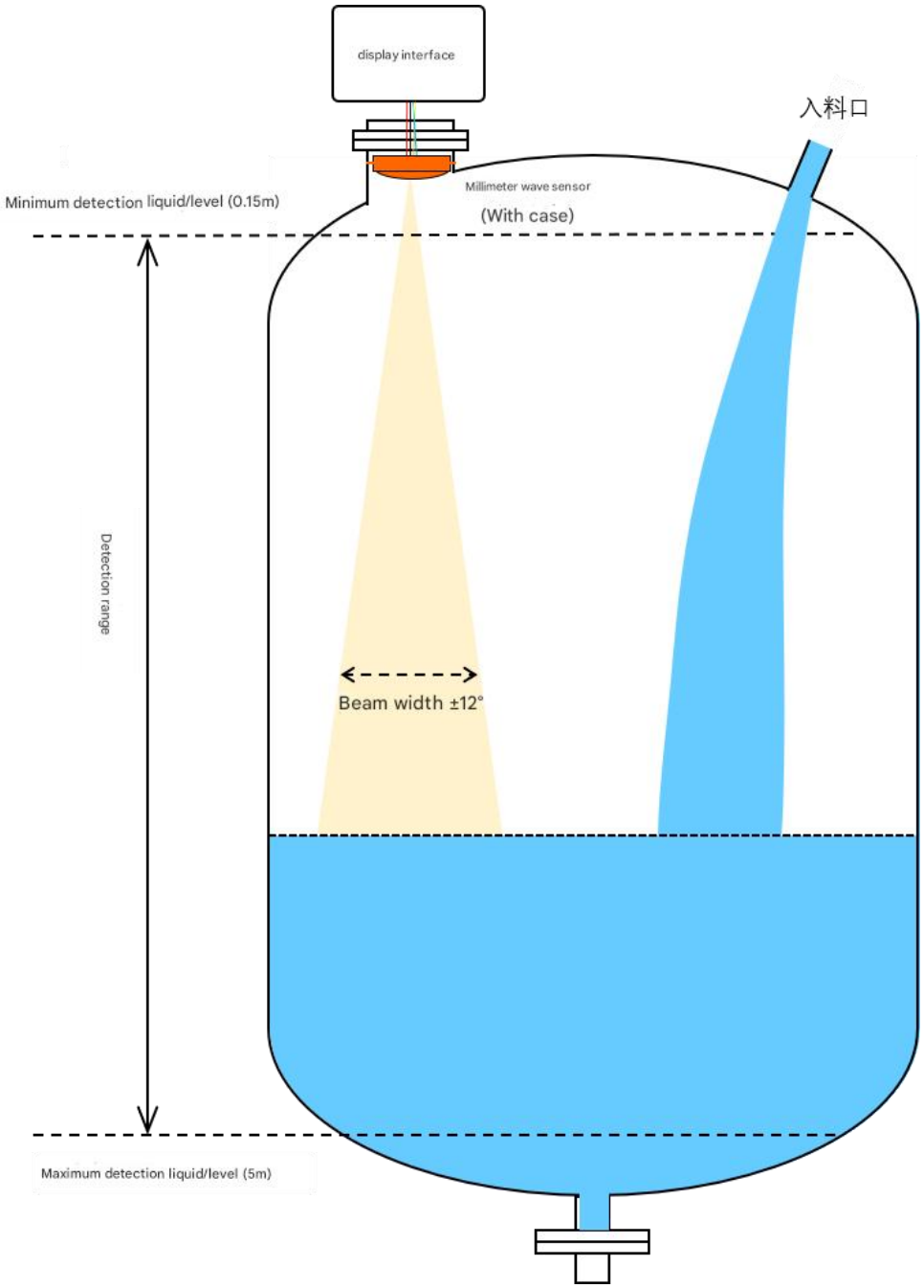


Figure 6 - 3 Schematic diagram of HLK-LD2413 detection installed in a storage tank

When adjusting the sensor position, please note:

(1) The antenna plane (i.e., the XOZ plane in Figure 6 - 1) should be parallel to the surface or cross section of the object to be measured;

(2) Avoid installing the sensor above the feed inlet;

(3) A certain distance should be maintained between the tank wall and the sensor in the horizontal direction. The recommended minimum safe distance is 1/5 of the maximum detection

distance inside the tank.

(4) Avoid installing any internal devices within the ±12° beam range.

7. Mechanical Dimensions

Figure 7 - 1 shows the mechanical dimensions of HLK-LD2413 , all units are in mm. The board thickness of the module is 2 mm with a tolerance of ±10%.

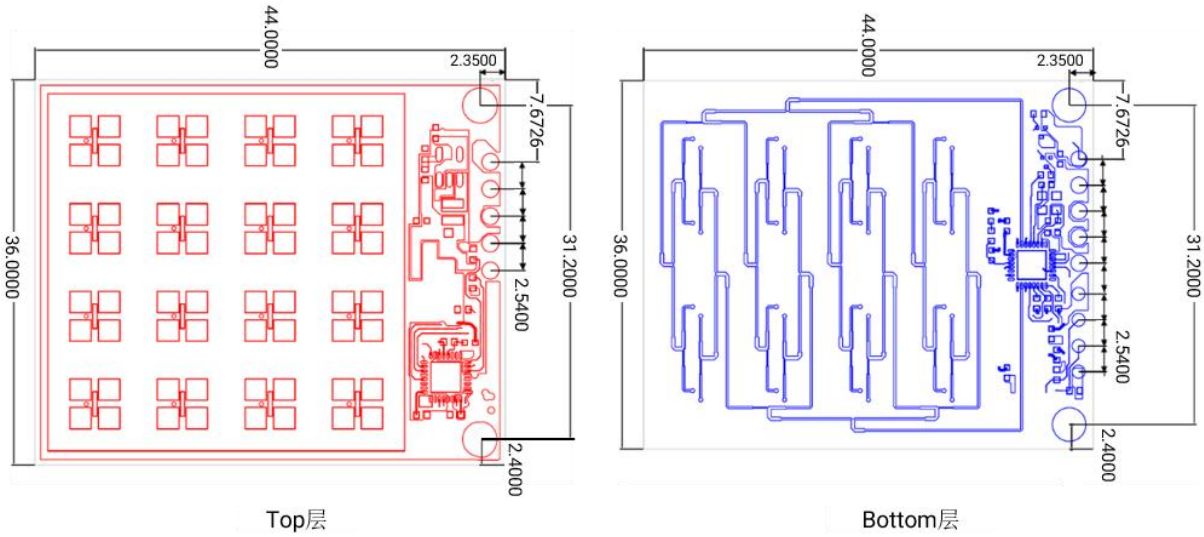


Figure 7 - 1 HLK-LD2413 Mechanical Dimensions

8. Installation Instructions

8.1. mmWave sensor housing requirements

HLK-LD2413 millimeter wave sensor has been equipped with a fully transparent radome, which is mainly used for installation and fixing.

If you need to install a different shape of housing for the sensor, the housing must have good wave transmission characteristics in the 24 GHz frequency band and cannot contain metal or materials that have a shielding effect on electromagnetic waves. For more considerations, please refer to the "Millimeter Wave Sensor Antenna Cover Design Guide" .

8.2. Installation environment requirements

This product needs to be installed in a suitable environment. If used in the following environment, the detection effect will be affected:

●There is an object in continuous motion within the sensing area;

●There is a large area of strong reflective plane that is not a detection target in the sensing area. Strong reflective objects facing the sensor antenna will cause interference.

8.3. Notes on installation

●Try to ensure that the sensor antenna is facing the area to be detected and that there is an open area around the antenna.

●Make sure the sensor is installed firmly and stably; any shaking of the sensor will affect the detection effect.

●Make sure that there is no movement or vibration on the back of the sensor. Since radar waves are penetrating, the antenna back lobe may detect moving objects on the back of the sensor. A metal shield or metal back plate can be used to shield the radar back lobe and reduce the impact of objects on the back of the sensor.

●When there are multiple 24 GHz radars in the working environment, please avoid direct beam alignment and install them as far away as possible to avoid possible mutual interference.

8.4. Power Supply Considerations

The power input voltage range is 3.0 V~3.6 V, and the power ripple has no obvious spectrum peak within 2 MHz. This solution is a reference design, and users need to consider the corresponding electromagnetic compatibility design such as ESD and lightning surge.

9. Precautions

9.1. Detection range

of HLK-LD2413 is 0.15 m~ 10 m. Within the detection range, the millimeter wave sensor will report the straight-line distance between the target and the sensor.

9.2. Firmware baud rate

HLK-LD241 3 is 115200.

9.3. Maximum distance and accuracy

When the beam width of ±12° is guaranteed to be free of interference, the ranging accuracy is characterized by the standard deviation of the measured value at a fixed specific measurement distance . The ranging accuracy of this reference solution within the detection range is ±3 mm , which is obtained by actual measurement of a rigid target with strong reflection.

The measurement accuracy of ±3 mm does not apply in the following cases:

- Distance measurement of detection targets outside the range;
- Distance measurement where the detected target will experience unstable distance displacement;
- There are multiple adjacent strong scattering points near the detection target.

When the target is a large-angle reflection, the sensor can detect up to 10 m; when the target is a solid ground or open water, the sensor can detect up to 10.5 m . Due to the size, motion state and RCS (Radar Cross Section) of the target, the ranging accuracy of the sensor will fluctuate, and the maximum detection distance will also fluctuate to a certain extent.

9.4. Response time

The response time is defined as the time it takes for the sensor's output distance to reach 90% of the stable value for the first time after the distance to the detected target changes suddenly. The response time of the millimeter wave sensor is positively correlated with the reporting period . For example, when the reporting period is 160 ms, the response time is 2.4 s.

9.5. Update Threshold

If the sensor has not been calibrated in advance, the reported data will all show 0. In this case, the threshold of the sensor equipped with the radome needs to be updated. For the calibration method, refer to 4.2.2 Parameter Configuration . The millimeter wave sensor that has been updated does not need to be calibrated again.

9.6. Impact of reporting cycle on average operating current

The default reporting period of HLK-LD2413 is 160ms , and its average working current is 23 mA . Users can use the host computer tool to flexibly configure different reporting cycles according to actual needs, thereby adjusting the power consumption of the sensor. The specific correspondence between the average working current and the reporting cycle is shown in Table 9-1 .

Table 9-1 Correspondence between average working current and reporting period

Reporting cycle (s)	Average operating current (mA)
0.05	40
0.16 (default)	23
1	1 6

9.7. Reporting cycle description

the HLK-LD2413 host computer interface is the time interval for reporting only the distance detection results (the display interface is the distance history curve). If the interface is switched to the real-time waveform, the actual reporting cycle is longer than the configured reporting cycle, and the actual average working current will increase accordingly.

Appendix A Document Revision History

Version Number	Scope of Revision	date
V1.0	Initial release.	August 23, 2024