TOFSense Datasheet V2.5

Language: English

Firmware: V2.0.4

Product Series: TOFSense,TOFSense P,TOFSense PS

Content

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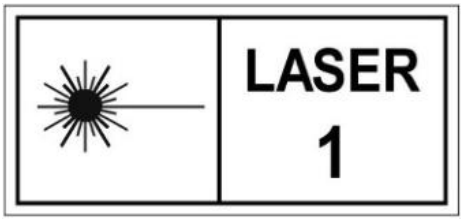
Certification Description:

- The TOFSense series products comply with the Class 1 standard specified in IEC 60825-1:2014 Edition 3.



1. Caution - Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.
2. According to IEC 60825-1:2014 Safety of laser products - Part 1:Equipment classification and requirements. The maximum output laser power of the product is 50.5uW.

- The TOFSense series products comply with the Class 1 laser product standard specified in GB 7247.1-2012.

1. Attention: Improper use of the control or adjustment device, or failure to follow each step of the operation may result in harmful radiation exposure.
2. According to GB 7247.1-2012 Safety of laser products - Part 1: Equipment classification and requirements, the maximum output laser power of the product is 50.5uW.

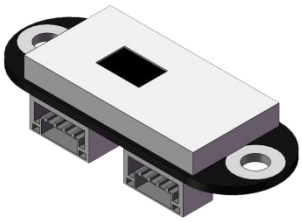
1 Introduction

1.1 Product Overview

TOFSense Datasheet

Overview

TOFSense/TOFSense P/TOFSense PS are laser ranging sensors based on the TOF (time-of-flight) technology. The ranging distance is 1.5cm~5m/3cm~8m/3cm~8m with a distance resolution of 1mm. The data update frequency is 10Hz/30Hz/30Hz. The field of view (FOV) is adjustable with a maximum viewing angle of 27° . The sensors support communication via UART and CAN, and can output data actively or upon request. They also support cascading multiple sensors for ranging, and TOFSense/TOFSense P support I/O complementary level output.



Key Features

- Based on the TOF (time-of-flight) laser ranging technology
- Measurement range

TOFSense	1.5cm~5m
TOFSense P/PS	3cm~8m

- Measurement resolution of 1mm
- Typical ranging accuracy

	TOFSense	TOFSense P/PS
Short-range	±1.0cm	±1.5cm
Mid-range	±1.0cm	±3.0cm
Long-range	±1.5cm	±3.0cm

- Standard deviation

TOFSense	0.3cm@2.5m
TOFSense P/PS	2.5cm@4.0m

- Adjustable field of view (FOV), ranging from 15 to 27 degrees
- Supports UART and CAN communication, and partially supports I/O communication.
- UART, CAN, and I/O share the same interface.
- Supports cascading multiple modules.
- Active and query output.
- One-click firmware upgrade.
- Power supply range is 3.75.2V for UART/ (I/O) and 4.25.2V for CAN, with reverse connection protection.
- Power consumption is approximately 290mW.

The 940nm laser complies with the Class 1 standard specified in IEC 60825-1:2014 Edition 3 and the Class 1 laser product standard specified in GB 7247.1-2012.

Applications

- UAV height determination and ceiling detection
- Robot obstacle avoidance
- Measurement and detection
- Intelligent gesture control
- 1D gesture recognition
- .....

1.2 Product Interface

The wire sequence for the UART interface is abbreviated as "V G R T" corresponding to VCC, GND, RX, and TX in the diagram; (Note: in UART communication, the TX and RX of both sides should be cross-connected, that is, module 1's TX is connected to module 2's RX, and module 1's RX is connected to module 2's TX).

The wire sequence for the IIC interface is abbreviated as "V G D C" corresponding to VCC, GND, IIC_SDA, and IIC_SCL in the diagram;

The I/O interface shares the same interface, and the wire sequence is "V G H L" corresponding to VCC, GND, I/O_H, and I/O_L in the order indicated in the diagram.

Where VCC is the power supply and GND is the ground.

Note: The diagram does not represent the actual size, please refer to Chapter 8 for the actual size.

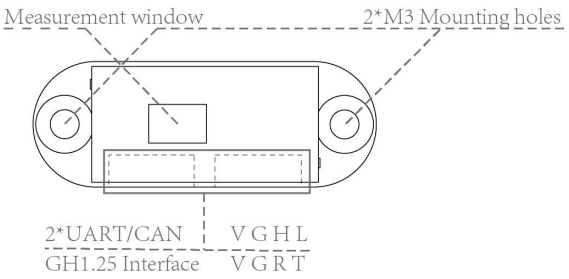


Figure 1: TOFSense/TOFSense P Interface

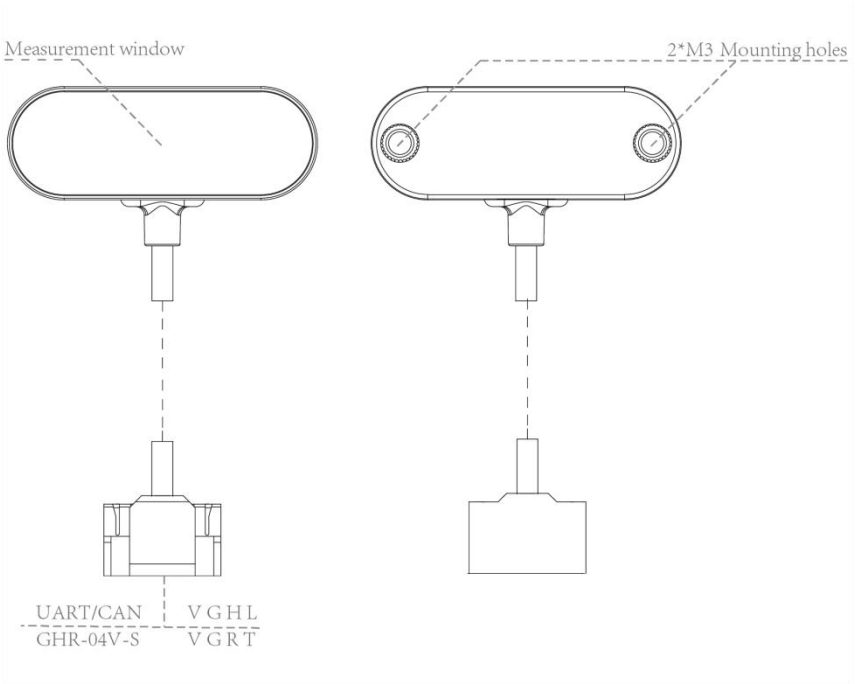


Figure 2: TOFSense PS Interface

1.3 Technology Overview

TOF is a technology for absolute distance detection, which means the sensor emits modulated

near-infrared light and detects the distance of the scene being captured by calculating the time difference or phase difference between the light emission and reflection after encountering an object. Compared to binocular schemes and 3D structured light schemes, TOF has advantages such as longer working distance, wider range of applications, and higher accuracy at longer distances. Therefore, it is often used in scenarios such as personnel proximity detection, robot obstacle avoidance, and camera auto-focus.In outdoor environments, near-infrared light from the sun can affect the measurement performance of the module.

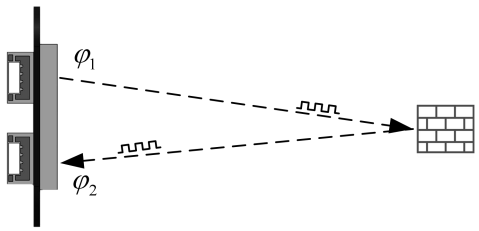


Figure 3: TOF ranging principle illustration

1.4 Functional Overview

TOFSense/TOFSense P/TOFSense PS support three distance measurement modes: short, mid, and long, and support various FOV angle settings to meet different application requirements. These sensors can output distance measurement values (dis), distance status (dis_status), and signal strength information.

Output mode: TOFSense/TOFSense P/TOFSense PS support both active and query output modes. In active mode, the module continuously sends measurement data frames at a frequency of 10Hz/30Hz/30Hz. In query mode, the module outputs measurement data frames upon receiving a query frame.

Connection mode: TOFSense/TOFSense P/TOFSense PS support both UART and CAN output modes, which share the same physical interface. The UART output mode supports active and query output for a single module, as well as query output for multiple cascaded modules. The CAN output mode supports active and query output for a single module, as well as active and query output for multiple cascaded modules. TOFSense/TOFSense P also support I/O output mode, which can output complementary levels.

2 Typical Specifications

Table 1: Typical Specification

Parameters	Typical			Note
Product model	TOFSense	TOFSense P	TOFSense PS	*
Product weight: g	2.7		5.8	*
Size: mm	35.6*13.0*8.1		35.6*13.0*7.0	Length * width * height. Refer to Chapter 8 for detailed dimensions.
Communication interface	UART			The interface can be used as a UART interface at the same time. TTL signal line level is 3.3V. The default baud rate is 921600.
	CAN			The interface can also be used as a CAN interface, and the default baud rate is 1Mbps.
	I/O		*	The interface can also be used as an I/O mode interface, and the signal line level is 3.3V.
Cascade quantity	UART: 8			The maximum number of cascaded levels supported has been tested.
	CAN: 7			
Typical ranging range: m	Short range: 0.015 ~ 2.16		Short range: 0.03~1.00	Data were obtained based on the experiment in Chapter 4.
	Mid-range: 0.015 ~ 3.60		Mid-range: 0.03~6.50	
	Long range: 0.015 ~ 5.05		Long range: 0.03~8.00	
Typical ranging accuracy	Short range: Accuracy ±1.0cm, Standard deviation <0.3cm.		Short range: Accuracy ±1.5cm, Standard deviation <0.3cm.	Data were obtained based on the experiment in Chapter 4.
	Mid-range: Accuracy ±1.0cm, Standard deviation <1.5cm.		Mid-range: Accuracy ±3.0cm, Standard deviation<3.0cm.	
	Long range: Accuracy ±1.5cm, Standard deviation <0.5cm [0.02, 3]m, Standard deviation <5.0cm (3, 5]m.		Long range: Accuracy ±3.0cm, Standard deviation<5.0cm.	
Wavelength: nm	940			Complies with Class 1 standards as defined by IEC 60825-1:2014 3rd edition and Class 1 laser product standards as defined by GB 7247.1-2012.
Field of view (FOV): degrees	15~ 27			Resolution is 1 degree and supports setting X and Y

			direction offsets.
Supply voltage: V	[3.7,5.2]@UART/(I/O), [4.2,5.2]@CAN		All communication interface power supplies have electrical connections, and the power supply interface can be any one of the interfaces.
Power consumption: mW	290		In UART active output mode, under the long-range distance measurement mode, the power supply voltage is 5.0V, and the current is 58mA.
Working temperature: ℃	[-20,85]		The data is obtained from rough testing in actual environment, and actual usage should be based on the working environment.
Protection level	*	IP65	Protection level.

3 Functional Description

3.1 ID

ID is a variable set to distinguish between different sensors.Used to identify each sensor when cascading multiple sensors together.

3.2 Interface & Baudrate

The TOFSense series supports configuration for UART, CAN, and I/O communication modes. (Some models may not support one or two of these communication modes, please refer to the actual supported communication modes.)

3.2.1 UART

Under the serial communication, the range of baud rate settings is as shown in Table 2.

Table 2: UART Baudrate parameter list

UART Baudrate	Note
115200,230400,460800,921600,1000000,1200000, 1500000,2000000,3000000	Default baud rate: 921600

3.2.2 CAN

Under the CAN output mode, the range of baud rate settings is as shown in Table 3.

Table 3: CAN Baudrate parameter list

CAN Baudrate	Note
100K、250K、500K、1M	Default baud rate: 1M

3.3 I/O Output Mode

In this mode, the module can output two complementary high and low levels based on the changes in the distance hysteresis interval.

3.4 Distance Status

The module can output the current distance status, and users can use the distance status for data processing. The meaning of the distance status is shown in Table 4.

Table 4: Meaning of distance status

Value	TOFSense	TOFSense P/TOFSense PS
0	Effective measurement distance	Effective measurement distance
1	Standard deviation greater than 15mm	Standard deviation greater than 15mm
2	Signal strength lower than 1 Mcps	Signal strength lower than 1 Mcps
3	*	Distance measurement below threshold.
4	Phase exceeding limit.	Phase exceeding limit.
5	HW or VCSEL malfunction.	HW or VCSEL malfunction.
6	*	Not fully checked.
7	Phase mismatch.	Phase mismatch.
8	Underflow in internal algorithm.	Underflow in internal algorithm.
9	*	Signal lower than crosstalk threshold.
10	*	Triggered once after startup, the measurement value must be ignored.
11	*	Distances of multiple targets.
12	*	Weak signal strength.
13	*	Invalid ROI setting, beyond SPAD range.
14	Invalid measurement distance.	Invalid measurement distance.
255	*	No target detected.

3.5 Indicator Light

There are two types of indicator light blinking states: Blink-fast and Blink-slow (1 flash per second). TOFSense PS does not have an indicator light. The LED states and meanings are shown in Table 5.

Table 5: Meaning of Indicator Light

Status	Note
Fast blinking (interval of 0.1 seconds)	Module startup phase
	Module firmware update
Slow blinking (interval of 1 second)	Module normal operation

3.6 Signal Strength

Indicates the strength of the current return signal, with larger values indicating a stronger return

signal.

3.7 FOV

The size of the FOV (field of view) determines the viewing range of TOFSense/TOFSense P/TOFSense PS. The module can change the X-direction FOV (fov.x), Y-direction FOV (fov.y), X-direction FOV offset (fov.x_offset), and Y-direction FOV offset (fov.y_offset). The setting range for the X and Y-direction FOV is 15° to 27°, and the setting range for the X and Y-direction FOV offset is -6° to 6°.

3.8 Function Key

It is used to switch back to UART mode when using CAN or other communication modes. First, hold down the button while the module is powered off, and then power on the module. Release the button when the indicator light changes from fast blinking to slow blinking. At this time, the module will enter temporary UART mode. You can use the NAssistant software to identify and enter the setting page to change the module's communication mode to UART and then click "Write Parameters" to switch back to UART mode. TOFSense PS does not have a button.

4 Typical Performance

4.1 Test Condition

Table 6: Test parameter configuration

Name	Content		Note
Hardware	TOFSense	TOFSense P	*
Temperature: ℃	[10,40]	[10,40]	*
Location	Nooploop 2rd Experiment Base (Shenzhen)	Nooploop 3rd Experiment Base (Shenzhen)	*
Time	201908	202107	*
Environment	Indoor open space	Indoor open space	*
Working mode	UART active output	UART active output	*
FOV:°	27	27	*
Power supply voltage: V	5	5	*
The refresh rate: Hz	10	30	*

In this configuration, the node periodically outputs measurement data, samples measurement at a certain distance interval, and each measurement time is 1 minute. Data recording and export can be done through NAssistant.Definition error:

$$error = measure\_value - real\_value$$

Among them: measure_value ---Measuring distance

real_value ---Actual distance

Defined standard deviation std:

$$std = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}|A_i - \mu|^2}$$

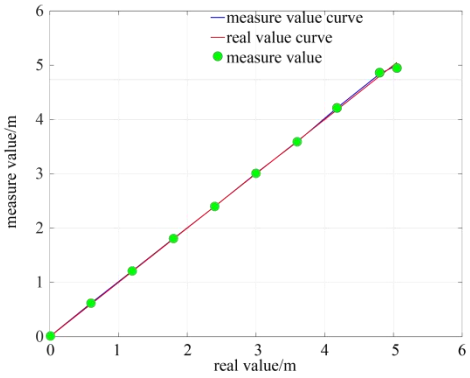
Among them: N ---Number of sampling points

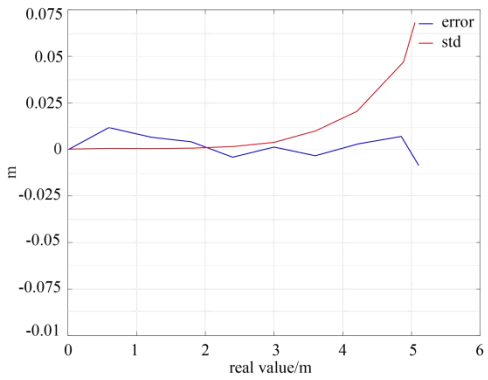
A ---A random variable consisting of N sampled values

$$\mu = \frac{1}{N}\sum_{i=1}^{N} A_i$$

4. 2 Result

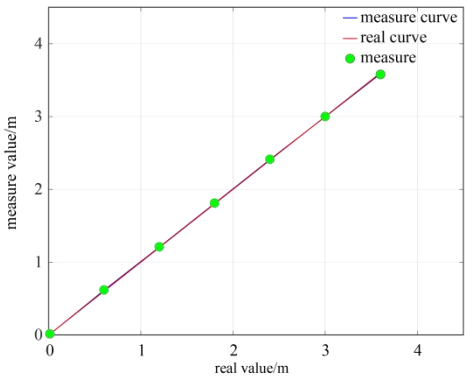
The final result of the TOFSense data are shown in Figure 4, Figure 5, and Figure 6, based on the above conditions for processing the measurement data.

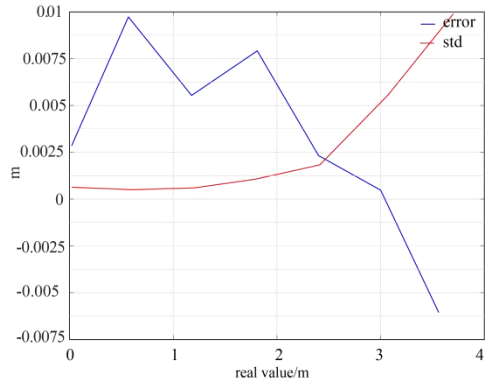




a.Measurement value and true value curve b.Error and standard deviation curve

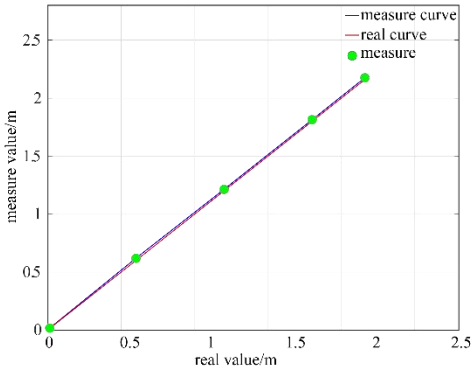
Figure 4: Long Distance Mode Test Results

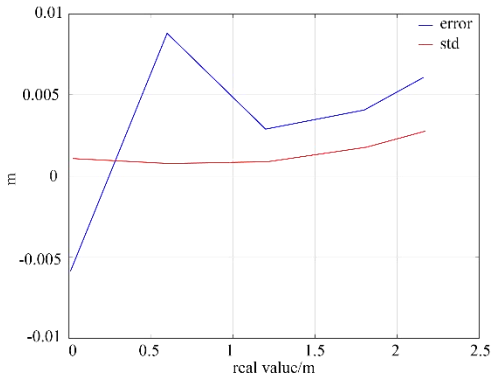




a.Measurement value and true value curve b.Error and standard deviation curve

Figure 5: Medium Distance Mode Test Results





a.Measurement value and true value curve b.Error and standard deviation curve

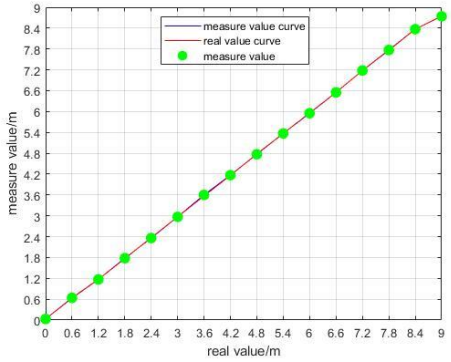
Figure 6: Short Distance Mode Test Results

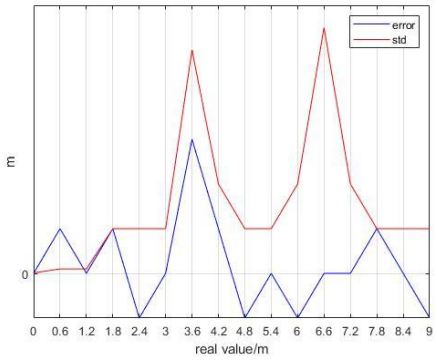
Calculated based on experimental results, as shown in Table 7.

Table 7: TOFSense Accuracy parameters

Mode	Blind zone (cm)	Maximum distance (m)	Accuracy (cm)	Standard deviation (cm)
Short	1.5	2.16	±1.0	<0.3
Medium	1.5	3.60	±1.0	<1.5
Long	1.5	5.05	±1.5	<0.5 @[0.02,3]m
				<5.0 @(3,5]m

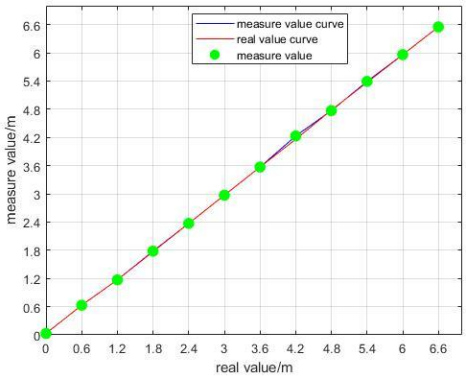
The final results of TOFSense P data are shown in Figure 7, Figure 8, and Figure 9.

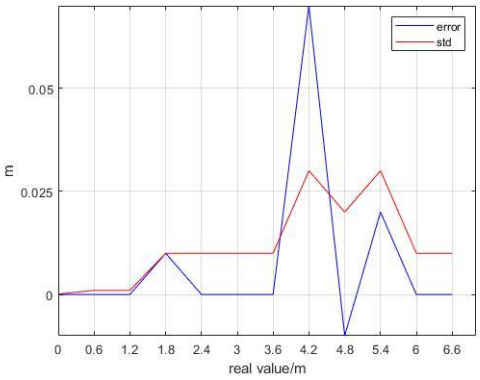




a.Measurement value and true value curve b.Error and standard deviation curve

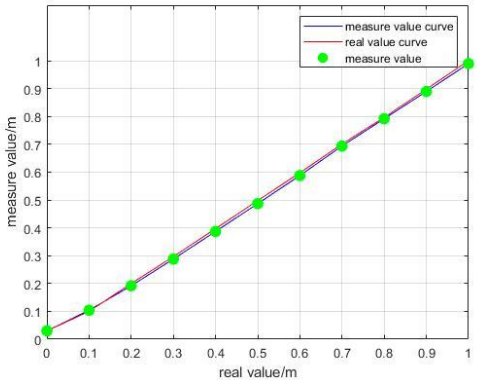
Figure 7: Long Distance Mode Test Results

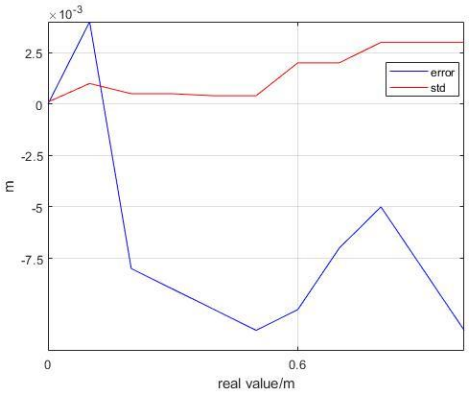




a.Measurement value and true value curve b.Error and standard deviation curve

Figure 8: Medium Distance Mode Test Results





a.Measurement value and true value curve b.Error and standard deviation curve

Figure 9: Short Distance Mode Test Results

Calculated based on experimental results, as shown in Table 8.

Table 8: TOFSense P Accuracy parameters

Mode	Blind zone (cm)	Maximum distance (m)	Accuracy (cm)	Standard deviation (cm)
Short	3.0	1.00	±1.5	<0.3
Medium	3.0	6.50	±3.0	<3.0
Long	3.0	8.00	±3.0	<5.0

5 Protocol

TOFSense/TOFSense P/TOFSense PS data communication format follows the NLink protocol. For details, please refer to the user manual.

5.1 Composition

As shown in Table 9, the Protocol consists of Frame Header, Function Mark, Data, and Sum Check. The Frame Header and Function Mark are fixed values. Data is the transmitted data content, and Sum Check is the lowest byte obtained by adding Frame Header, Function Mark, and Data (i.e., adding all the previous bytes).

Table 9 : Composition of Protocol

Frame Header	+	Function Mark	+	Data	+	Sum Check

5.2 Endian

NLink follows the Little-endian principle, meaning that the low byte comes first and the high byte comes later.

5.3 Type

Fixed length protocol: A protocol with fixed length.

Variable-length protocol: A protocol with varying length.

The NLink protocol consists of both fixed-length and variable-length protocols, meeting the needs of different scenarios.

5.4 Description

Table 10: NLink protocol content overview

Protocol	Type	Description
NLINK_TOFSENSE_FRAME0	Fixed-length	UART output protocol, which includes node timestamp, distance, distance status, and signal strength.
NLINK_TOFSENSE_READ _FRAME0	Fixed-length	UART read protocol, content includes node ID.
NLINK_TOFSENSE_CAN_FRAME0	Fixed-length	CAN output protocol, which includes distance, distance status, and signal strength.
NLINK_TOFSENSE_CAN_READ_FRAME0	Fixed-length	CAN reading protocol, which includes node ID.

6 Firmware

The format of the firmware version number for the official release is VA.B.C, and the format of

the firmware version number for testing release is VA.B.C.BetaD. Both can be checked for the latest firmware and upgraded via NAssistant, and support wired firmware upgrade.

7 Software

NAssistant is a debugging software that is compatible with TOFSense/TOFSense P/TOFSense PS. Its main functions include configuration and debugging, status display, function application, and firmware upgrade.

Configuration and debugging: Used to configure node-related parameters, such as ID, operating mode, baud rate, etc.

Function application: Used for application development, such as data import/export, distance waveform storage, historical data playback, etc.

Firmware upgrade: Used for wired firmware upgrade of the product.

8 Mechanical Specifications

8.1 Size

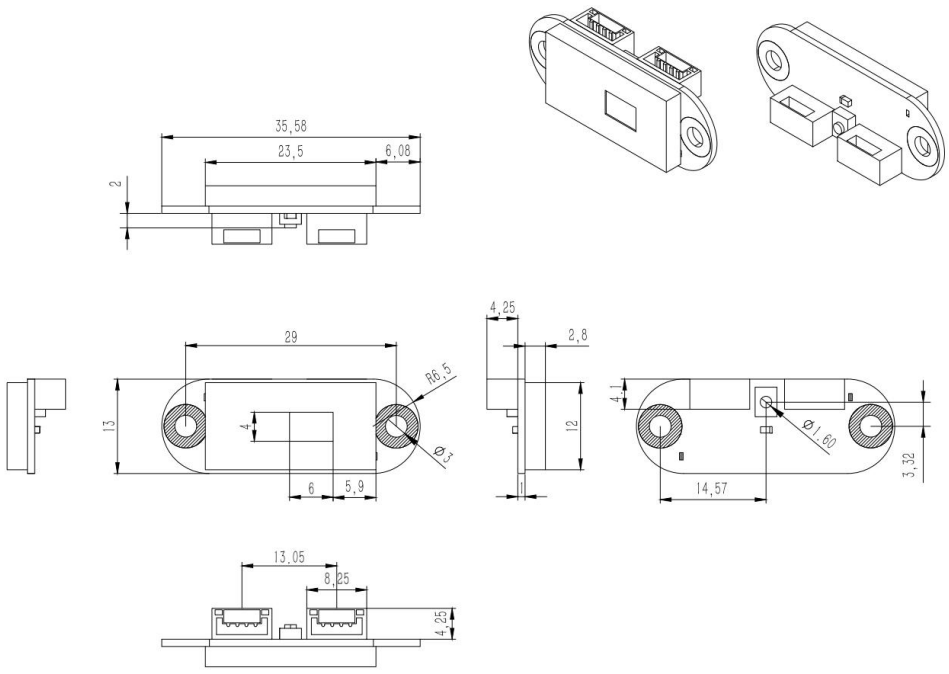


Figure 10: TOFSense/TOFSense P dimensional drawing, unit: mm

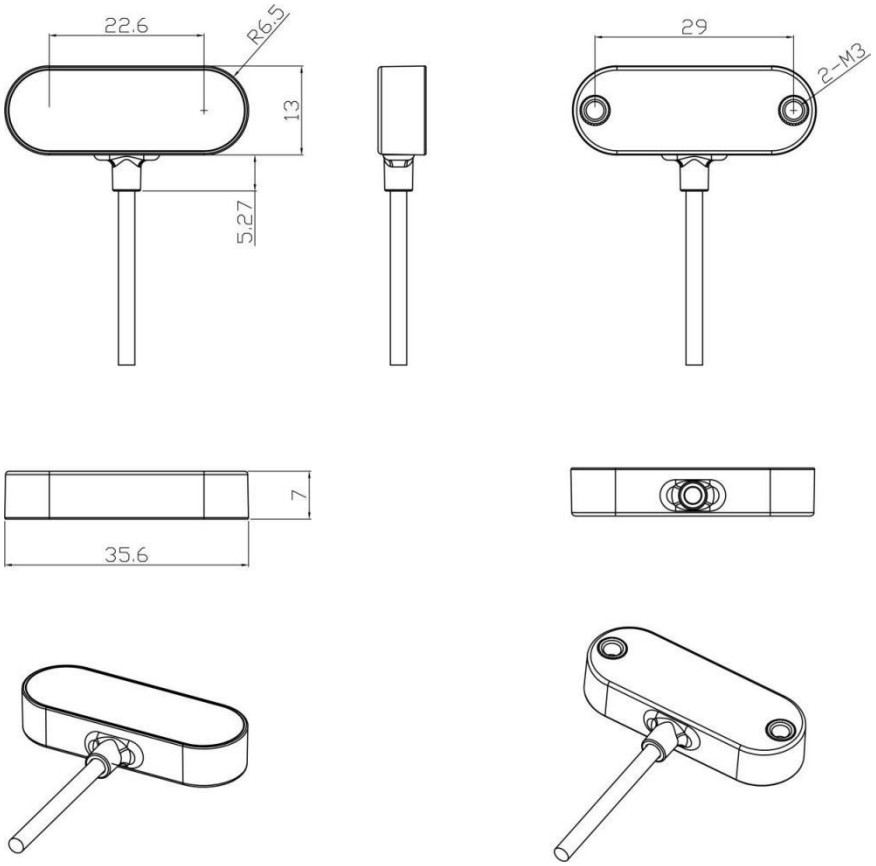


Figure 11: TOFSense PS dimensional drawing, unit: mm

8.2 Figure

Note: Product images do not represent actual size. Please refer to section 8.1 for actual size.

Figure 12: TOFSense/TOFSense P picture

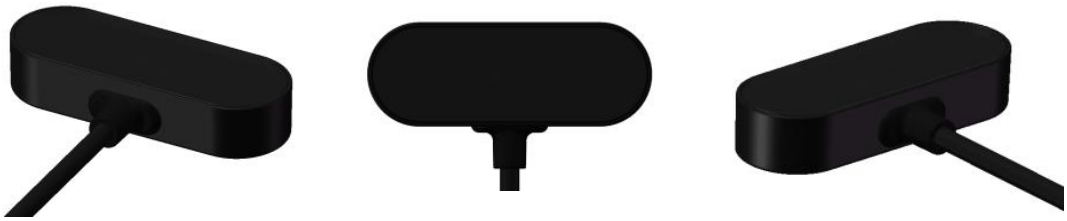


Figure 13: TOFSense PS picture

9 Abbreviation and Acronyms

Table 11: Abbreviation and Acronyms

Abbreviation	Full Title
TOF	Time of Flight
FOV	Field of View
HW	Half Wave
VCSEL	Vertical Cavity Surface Emitting Laser

10 Update Log

Table 12: Update log

Version	Firmware Version	Data	Description
1.0	1.0.0	20190817	1. Released initial version of the manual.
1.1	1.0.4	20190923	1. Updated FOV parameter description. 2. Adapted to the latest firmware version.
1.2	1.0.6	20191213	1. Corrected errors in the manual. 2. Adapted to the latest firmware version.
2.0	2.0.0	20200730	1. Added description of I/O output mode. 2. Adapted to the latest firmware version.
2.1	2.0.0	20210623	1. Added description of TOFSense P and TOFSense PS. 2. Corrected relevant descriptions.
2.2	2.0.3	20220211	1. Added experimental data on accuracy and standard deviation for TOFSense P and TOFSense PS. 2. Optimized partial description
2.3	2.0.4	20220924	1. Added description of certifications. 2. Optimized partial description
2.4	2.0.4	20221205	1. Added description of power supply voltage for CAN mode. 2. Updated dimensional drawing, added more dimensions.
2.5	2.0.4	20230404	1. Optimized partial description

11 Further Information

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