Benewake

TF-UW500 User Manual

Preface

This user manual contains the introduction, use and maintenance of TF-UW500 LiDAR. Please read this manual carefully before formal use, and strictly follow the steps described in the manual during use to avoid product damage, property loss, personal injury or/and violation of product warranty terms.

If you encounter problems that cannot be solved during use, please contact Benewake staff for assistance.

Contact Details

Official website: en.benewake.com

Contact number: 400-880-9610

For technical questions, please contact: support@benewake.com

For sales inquiries or to request brochure, please contact: bw@benewake.com

Headquarter Address

Benewake (Beijing) Co., Ltd.

3rd Floor, Haiguo Jiaye Sci-Tech Park, Haidian District, Beijing, China

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The TF-UW500 product is constantly being improved, and its specifications and parameters will undergo iterative changes. Please refer to the official website for latest version.

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1 Laser Safety Information

This LiDAR uses visible red laser spots.
Class 1 according to IEC 60825-1:2014, EN 60825-1:2014+A11:2021.

CAUTION!
Use of controls, adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

2 Installation and Maintenance

CAUTION!
This laser product is classified as Class 1 during operational procedures. When the ranging feature is activated, the laser emitter of the LiDAR module may emit laser radiation, therefore, the LiDAR should NOT be aimed at humans and animals to ensure safety.

This product is designed and calibrated for installation with exposed lenses. If a protective window needs to be added in front of the lens, it is necessary to ensure the use of materials with high transmission and anti-reflective coating.
Avoid the presence of smoke and fog in the detection field.
Avoid condensation.
Avoid direct exposure to moisture and water.
Do not use rough fabric or dirty towels or aggressive products to clean the laser lenses.
Do not use a supply voltage higher than the maximum required in the specifications to power the product.
Clean the laser lenses with compressed air. When needed, wipe the laser lenses only with a soft, clean microfiber cloth.
Make sure the sensor is securely mounted to prevent false readings or damage.
Only trained and qualified personnel may install, setup and repair the LiDAR.

3 Product Overview

This chapter mainly introduces the measuring principle, technical specifications, structural description, equipment coordinates and field of view distribution of the TF-UW500 LiDAR.

3.1 Measuring principle

TF-UW500 is a typical Pulse Time of Flight (PToF) sensor. TF-UW500 emits a narrow pulse laser, which is collimated by the transmitting lens, which enters the receiving system after being reflected by the measured target and is focused on the detector by the receiving lens. The time between the transmitted signal and the received signal is calculated through the circuit amplification and filtering, and the distance between TF-UW500 and the measured target can be calculated through the speed of light.

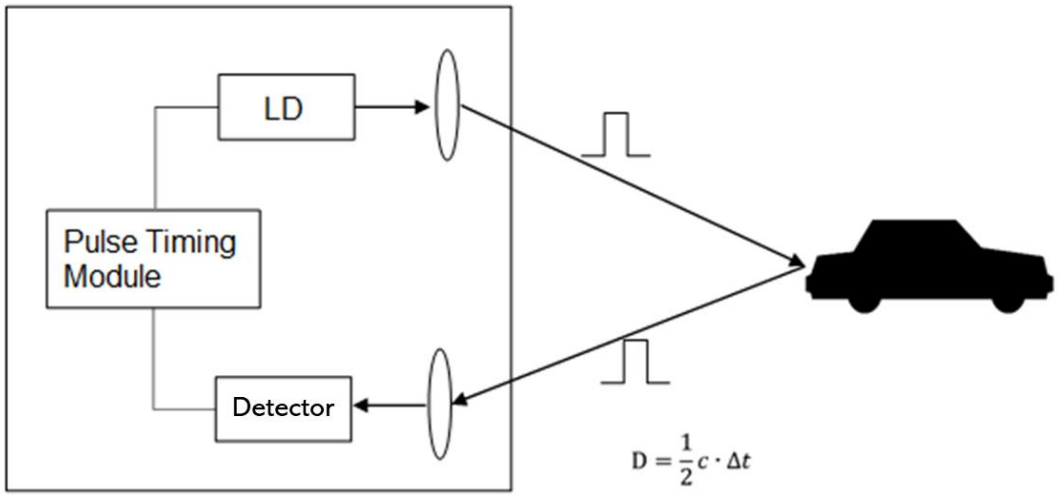
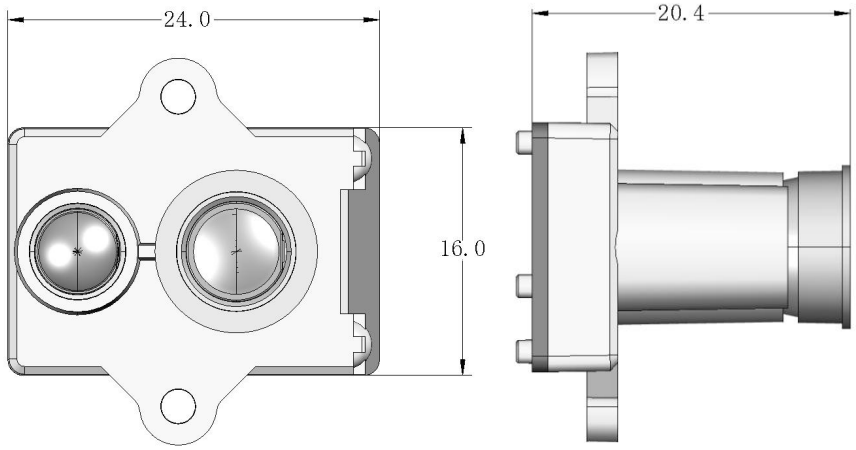


Figure. 1: Pulsed time of flight

3.2 Technical Specifications

Performance Parameters	
Model	TF-UW500
Detection range under water	＞ 5 m Indoor, NTU< 0.5, 30% reflectivity, the light beam is perpendicular to the target surface
Blind zone	≤ 0.1 m
Accuracy①	< 3 cm (0.1 ~ 2m)
Repeatability①	< 1 cm @ 1 σ (0.1 ~ 2m)
Distance resolution	1 mm
Default frame rate	Default 20 Hz
Ambient light resistance	100 KLux
Optical Parameters	
Light source	Laser
Central wavelength	Red
FoV	< 0.5°
Eye safety	Class1 (IEC 60825-1:2014; EN 60825-1:2014+A11:2021)
Mechanical and Electrical Parameters	
Average power consumption②	< 5V × 100mA
Peak current at start up②	< 700mA
Power supply	DC 5±0.2 V
Logical voltage	3.3 V TTL
Connector	1.0mm-4P, model is HC-1.0-4PWT
Operating temperature	0 ℃ ~ + 50 ℃
Storage temperature	- 20 ℃ ~ + 70 ℃
Protection level	NA
Typ. Dimensions③	24.0 mm × 16.0 mm × 20.4 mm
Typ. Weight③	< 5 g (excluding cables)
Communication Protocol	
Communication Interface	UART / I²C (Can be switched by command)
Baud rate	Default 115200 (Configurable)
Data bit	8
Stop bit	1

Parity	None
Dimensions (Unit: mm)	
	

Notes:

1. 100 KLux，NTU＜ 0.5，30% reflectivity (Common materials such as white tiles, blue and white tiles, marble, cement, etc), vertical incidence, water depth greater than 1m;
2. Measured indoors at 0 Klux, 25 ℃, for reference only, parameters may change due to environmental changes;
3. The weight and size are typical values for reference only. For detailed tolerance parameters, please consult the technical personnel of Benewake.

3.3 Structural Appearance

The overall appearance of the LiDAR is as shown in the figure below:

Figure. 2: TF-UW500 Appearance

3.4 FoV

The field of view of TF-UW500 is shown in the following figure, with a rectangular spot shape and a divergence angle of less than 0.5 ° in any direction.

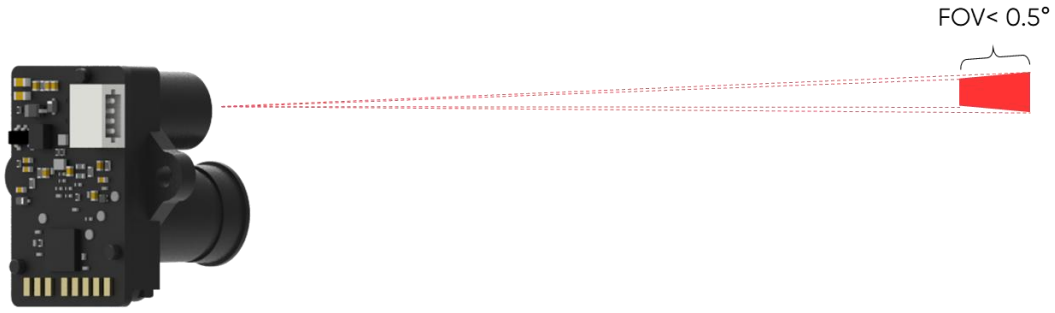


Figure. 3: FoV of TF-UW500

NOTICE

0.5° is theoretic values. Because the manufacturing error and the installing error exist, there is divergence between actual and theoretic values.

4 Device Installation

This section introduces the mechanical installation and connection information of TF-UW500 LiDAR.

4.1 Mechanical installation

As shown in the following figure. TF-UW500 has 2 installation positioning holes available for use.

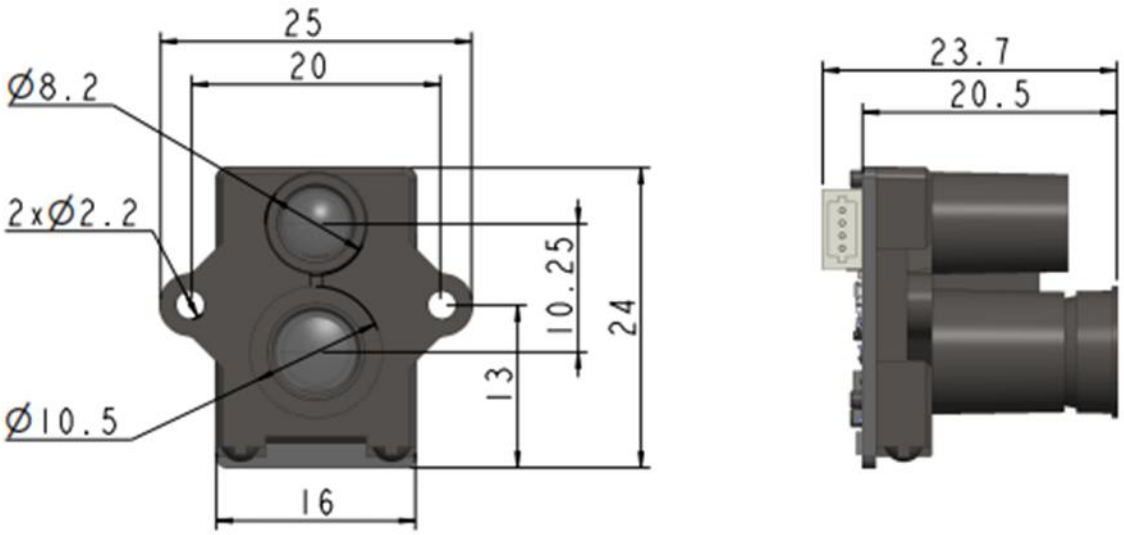
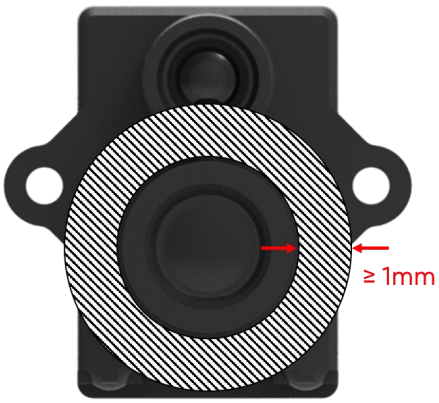


Figure. 4: Diagram of TF-UW500 installation hole



Due to optical assembly tolerances, please leave at least 1mm of additional space in all directions around the circular barrel.

4.2 Connector

The connector is 1.0mm-4P, model is HC-1.0-4PWT, appearance and definition are shown as below:

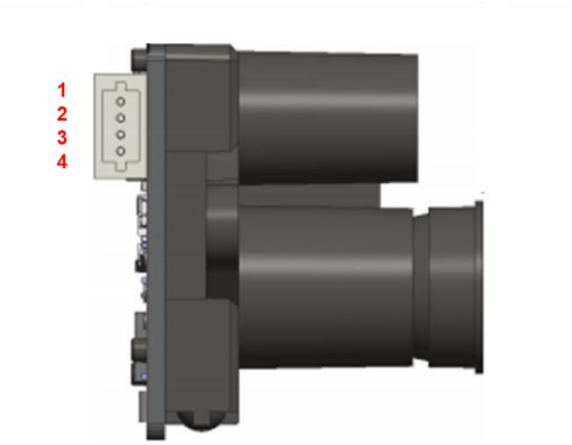


Figure. 5: LiDAR connector appearance

Table. 2: Interface connector pin definitions

NO.	UART	I^2C
PIN 1	GND	GND
PIN 2	VCC	VCC
PIN 3	RX	SDA
PIN 4	TX	SCL

5 Communication Protocol and data format

5.1 Serial Communication

To connect two devices for TTL communication, the TXD of the transmitter should be connected to the RXD of the receiver, and the TXD of the receiver should be connected to the RXD of the transmitter.

The LiDAR does not include a power switch. When power is supplied to the LiDAR, data will begin to be automatically transmitted.

Table. 3: Characteristics of UART Interface

Character	Value	Configurability
Baud rate	115200	Configurable
Data bit	8	Non-configurable
Stop bit	1	Non-configurable
Parity	None	Non-configurable

NOTE

Baud rate can be set to 9600, 14400, 19200, 38400, 56000, 57600, 115200, 128000, 230400, 256000, 460800, 500000, 512000, 600000, 750000, and 921600. If other value were set, TF-UW500 will set it to 115200.

Serial port output format:

9-byte/cm (Default)

Byte	0	1	2	3	4	5	6	7	8
Description	0x59	0x59	Dist_L	Dist_H	Peak_L	Peak_H	Temp	Confidence	Check_sum

Dist: Output underwater distance measurement value, multiplied by a coefficient of 1.33 in air, can be configured to output in millimeters or centimeters as needed, mm is default.

Peak: Signal strength. In general, data quality is good when Peak ⩾ 200; When 100<Peak<200, the data repeatability accuracy begins to decrease; Poor repeatability and accuracy when 30 ⩽ Peak ⩽ 100; When Peak<30, the signal strength is too low for process, LiDAR output 65535.

Temp: Chip Temperature ℃

Confidence: Confidence level

5.2 I² C Communication

TF-UW500 supports up to 400kps clock speed as slave machine and its default address is 0x10. For more information about I² C register table refer to **Appendix I² C register table**.

Note: In this document, the address of I² C slave device is a 7-bit value with value range [0x08, 0x77] ([08, 119] in decimal). For the first byte after I² C releases a start signal, the 7-bit address should be shifted leftward for one bit (i.e. multiplied with 2), and then filled with the read-write sign on the lowest bit. For TF-UW500 , the default address of slave device is 0x10, the address for write operations is 0x20, and the address for read operations is 0x21.

Write register timing:

Start	Slave Addr	W	Ack	Register Addr	Ack	Data1	Ack	...	DataN	Ack	Stop

Read register timing:

Start	Slave Addr	W	Ack	Register Addr	Ack	Stop

Start	Slave Addr	R	Ack	Data1	Ack	...	DataN	Nack	Stop

Note that in the read register sequence, the host can directly generate the second Start signal without generating the first Stop signal. The last Nack can also be an Ack signal.

After a write operation on the I² C register, it takes TF-UW500 some time to process. If users need to read the value from the register for validation purposes, we recommend waiting for 100ms after the write operation, prior to the next read operation.

5.3 Serial communication commands

Some parameters in TF-UW500 can be customized by customers, such as data frame format, frame rate, etc., which can be changed by sending specific instructions. After successful configuration, all parameters will be saved in Flash and do not need to be reconfigured when powered on again.

When configuring parameters, please follow specific formats and rules to avoid sending commends not introduced below.

Byte	Definition	Description
Byte 0	Head	Fixed 0x5A
Byte 1	Length	The length of bytes from the head byte to check-sum
Byte 2	ID	Indicates how to parse the payload data
Byte 3~Byte N-2	Payload	Data segment, parsed based on ID, Little Endian Opt: Non 1 read/ 1. Write in
Byte N-1	Check sum	The lower 8 bytes of the sum from Head to Payload

5.3.1 Version information ID_GET_VERSION=0x01

Downward:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	ID	Check_sum

Upward:

Byte	0	1	2	3-5	Len-1
Description	Head(0x5A)	Len	ID	Version	Check_sum

Version: For instance, if the third, fourth, and fifth bytes are 112, 50, 9, then the version is 9.50.112.

Sample:

Command [5A 04 01 5F]

5.3.2 System software restore ID_SOFT_RESET=0x02

Downward:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	ID	Check_sum

Upward:

Byte	0	1	2	3	Len-1

Description	Head(0x5A)	Len	ID	Status	Check_sum

Status: 0: success, otherwise: fail

Note: Any change without “save current setting” instruction will not be saved and will restore to original setting.

Sample:

Command [5A 04 02 60]

5.3.3 Output frequency ID_SAMPLE_FREQ=0x03

Downward:

Byte	0	1	2	3~4	Len-1
Description	Head(0x5A)	Len	ID	FPS	Check_sum
Default				20	

Freq: The actual operating frequency achieved by the LiDAR.

Upward:

Byte	0	1	2	3~4	Len-1
Description	Head(0x5A)	Len	ID	FPS	Check_sum

Freq: The actual operating frequency achieved by the LiDAR.

Sample:

20Hz [5A 06 03 14 00 77]

5.3.4 Output format setting ID_OUTPUT_FORMAT=0x05

Downward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Format	Check_sum
Default				0x01	

Format: 0x01: 9byte cm, 0x06: 9byte mm

Upward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Format	Check_sum

Format: current output format setting

Sample:

9byte mm [5A 05 05 06 6A]

5.3.5 Baud rate setting ID_BAUD_RATE=0x06

Downward:

Byte	0	1	2	3~6	Len-1
Description	Head(0x5A)	Len	ID	Baudrate	Check_sum
Default				115200	

Baudrate: current baud rate.

Note: Configurable baud rate range [9600, 921600], effective after saving.

Upward:

Byte	0	1	2	3~6	7	Len-1
Description	Head(0x5A)	Len	ID	Baudrate	Status 0: success !0: fail	Check_sum

Sample:

9600 [5A 08 06 80 25 00 00 0D]

19200 [5A 08 06 00 4B 00 00 B3]

38400 [5A 08 06 00 96 00 00 FE]

57600 [5A 08 06 00 E1 00 00 49]

115200 [5A 08 06 00 C2 01 00 2B]

230400 [5A 08 06 00 84 03 00 EF]

460800 [5A 08 06 00 08 07 00 77]

921600 [5A 08 06 00 10 0E 00 86]

5.3.6 Enable/disable output ID_OUTPUT_EN=0x07

Downward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Enable	Check_sum
Default				1	

Enable: 0: disable, 1: enable

Upward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Enable	Check_sum

Sample:

Enable output [5A 05 07 01 67]

Disable output [5A 05 07 00 66]

5.3.7 Enable/disable checksum comparison ID_FRAME_CHECKSUM_EN=0x08

Downward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Enable	Check_sum
Default				0	

Enable: 0: disable, 1: enable

Note: Even if the Downward data checksum comparison is disabled, the valid checksum is still included in the upward data frame.

Upward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Enable	Check_sum

Sample:

Enable checksum comparison [5A 05 08 01 68]

Disable checksum comparison [5A 05 08 00 67]

5.3.8 Communication interface settings ID_IF_PROTOCOL=0x0A

Downward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Opt	If_protocol	Check_sum
Default					!1	

Opt: !1: read, 1: write

If_protocol: !1: UART, 1: I² C

Upward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Status 0: success !0:fail	If_protocol	Check_sum

Sample:

Set to I² C [5A 06 0A 01 01 6C]

Note: Effective after saving

5.3.9 I² C slave machine address configuration ID_I² C_SLAVE_ADDR=0x0B

Downward:

Byte	0	1	2	3	4	Len-1

Description	Head(0x5A)	Len	ID	Opt	I² C_slave_addr	Check_sum
Default					0x10	

Opt: !1: read, 1: write

I² C_slave_addr: range[0x08, 0x77];

Upward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Status 0:success !0:fail	I² C_slave_addr	Check_sum

Sample:

Set to 0x20 [5A 05 0B 01 20 8B]

5.3.10 Restore default setting ID_RESTORE_DEFAULT=0x10

Downward:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	ID	Check_sum

Upward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Status	Check_sum

Status: 0: success, Non 0: fail

Sample:

Command [5A 04 10 6E]

5.3.11 Save current setting ID_SAVE_SETTINGS=0x11

Downward:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	ID	Check_sum

Upward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Status	Check_sum

Status: 0: success, Non 0: fail

Sample:

Command [5A 04 11 6F]

5.3.12 Distance limit setting range ID_DIST_RANGE=0x3A

Downward:

Byte	0	1	2	3	4-5	6-7	Len-1
Description	Head(0x5A)	Len	ID	Opt	Min_dist	Max_dist	Check_sum
Default					0	65535	

Opt: !1: read, 1: write

Min_dist: minimum distance output in mm

Max_dist: maximum distance output in mm

Upward:

Byte	0	1	2	3	4-5	6-7	Len-1
Description	Head(0x5A)	Len	ID	Status	Dist_min	Dist_max	Check_sum

Status: 0: success, Non 0: fail

Sample:

Output limit when out of range with the minimum set to be 200mm and the maximum set to be 5000mm [5A 09 3A 01 C8 00 88 13 01]

CAUTION

Do not send the command that is not in the list above.

Appendix I²C REGISTER TABLE

Address	R/W	Name	Initial Value	Description
0x00	R	DIST_LOW	--	Ranging value in cm as the unit
0x01	R	DIST_HIGH	--	
0x3C	R	DIST_LOW	--	Ranging value in mm as the unit
0x3D	R	DIST_HIGH	--	
0x02	R	PEAK_LOW	--	
0x03	R	PEAK _HIGH	--	
0x04	R	TEMP_LOW	--	Unit: 0.01 Celsius
0x05	R	TEMP_HIGH	--	
0x0A	R	VERSION_REVISION	--	
0x0B	R	VERSION_MINOR	--	
0x0C	R	VERSION_MAJOR	--	
0x10-0x1D	R	SN	--	Production code in 14 bytes ASCI code (0x10 is the first byte)
0x1E	W/R	IF_PROTOCOL	0x00	0x00: UART 0x01: I²C Save and restart to take effect
0x20	W	SAVE	--	Write 0x01 to save current setting
0x21	W	SHUTDOWN/REBOOT	--	Write 0x02 to reboot
0x22	W/R	SLAVE_ADDR	0x10	range: [0x08, 0x77]
0x2C	W/R	PEAK_THR_FILTER_LOW	--	PEAK threshold filtering
0x2D	W/R	PEAK_THR_FILTER_HIGH	--	