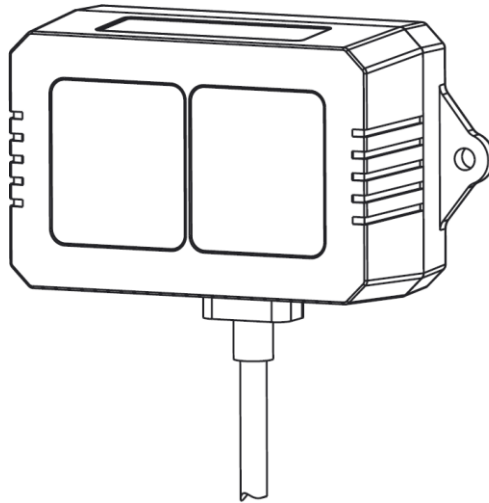# TF02-i User Manual

PREFACE

Dear users:

Thank you for choosing Benewake products. For the purpose of offering better operation experience to you, we hereby write this manual for an easier and simpler operation of our product, hoping to better solve the common problems you may meet. This user manual contains the relevant information on product introduction, usage and maintenance of TF02-i, covers the product operation introduction and common problem solutions. Please read this manual carefully before using the product. Remember the precautions to avoid hazards, and please follow the described steps in the manual when using it.

If you have any problems in the process of usage, you are welcome to contact Benewake at any time for help.

Contact details

Official website: en.benewake.com

TEL：+86-10- 57456983

Technical questions，please contact：support@benewake.com

Consult sale information or request brochure，please contact：bw@benewake.com

Headquarters Address

Benewake (Beijing) Co., Ltd.

No.3030, 3rd Floor, Independent Innovation Building, No.6 Chuangye Road, Haidian District, Beijing, China

Copyright Statement

This User Manual is copyright © of Benewake. Please do not modify, delete or translate the description of this manual contents without the official written permission from Benewake.

Disclaimer

As our products are constantly improving and updating, the specifications of TF02-i are subject to change. Please refer to the official website for latest version.

CONTENTS

1   ONEVIEW

TF02-i is a single-point ranging LiDAR upgraded based on TF02-Pro. It has been optimized and upgraded in terms of communication interface, input voltage, etc., to meet the needs of various industrial scenarios. The product is based on the principle of ToF (time of flight) and has stable, accurate and highly sensitive measurement performance.

1.1   Technical Specification

Table 1-1 Technical Specification of TF02-i

Type	Parameters		Values
Product performance	Operating range	90% reflectivity, 0Klux	0.1m~40m
		10% reflectivity, 0Klux	0.1m~13.5m
		90% reflectivity, 100Klux	0.1m~40m
		10% reflectivity, 100Klux	0.1m~13.5m
	Accuracy①		±5cm (0.1m~5m), ±1% (5m~40m)
	Distance resolution①		1cm
	Frame rate②		1Hz~100Hz (adjustable, default100Hz)
	Repeatability①		1σ: ＜2cm (0.1m~35m@90% reflectivity)
	Ambient light immunity		100Klux
	Enclosure rating		IP65
Optical parameters	Photobiological safety		Class1 (IEC60825)
	Central wavelength		850nm
	Light source		VCSEL
	FoV③		3°
Electrical parameters	Supply voltage		DC 7V~30V
	Average current		≤70mA @12V
	Power consumption		≤0.85W @12V
	Peak current		100mA
Others	Dimension		69mm×41.5mm×31.5mm (L×H×W)
	Housing		ABS/PC/PMMA
	Operating temperature		-20℃~60℃
	Storage temperature		-30℃~80℃
	Weight		60g (with cables)
	Cable length		70cm

> **Note**
> ① The detection is measured with the standard white board (90% reflectivity).
> ② The frame rate can be adjusted. The default value is 100Hz and the maximum value is 100Hz, the customized frame rate should be calculated by the formula: 200/n (n is an integer with ≥ 2).
> ③ The angle is a theoretical value, the actual angle value has some deviation.

1.2   Maintenance and Cleaning

- Before switching on, please check if the exposed window mirror is clean, and clean it promptly if it is dirty.
- After using the device, check the optics. If it is contaminated, please clean it promptly.
- The optics should be cleaned regularly if the device be operated in a severe environment for a long time.
- Before regular cleaning, please disconnect the power. Using a soft cloth to gently wipe the window in the same direction when the device is not operating, to avoid repeated wiping and damage to the window mirror.
- When cleaning the window, do not use alcohol to clean, so as not to damage the window.
- If you require deep cleaning of internal optics, please contact bw@benewake.com to offer professional advice.

1.3   Appearance and Structure

The appearance and dimensions of TF02-i are shown in Figure 1-1 and Figure 1-2:
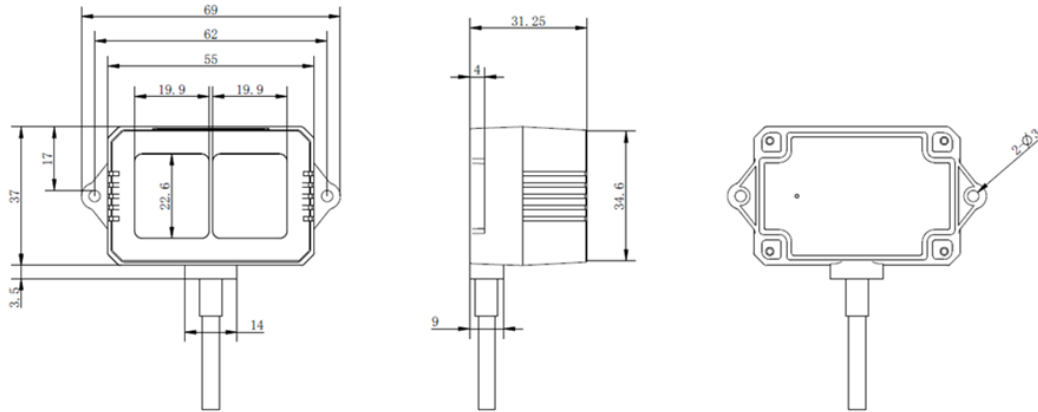

Figure 1-1 Appearance of TF02-i

Figure 1-2 Dimension of TF02-i (Unit: mm)

TF02-i is recommended to use M2.5 round Phillips screws for installation. Please remove the protective film of the optical lens before use. The lens of front panel of LiDAR cannot be covered. Please keep it clean. The surface of optical lens is the ranging zero of LiDAR. The detection angle of TF02-i is 3°. At different distances, the size of light spot, namely the edge length of the detection range, is different. Side length of the detection range at different distances (the detection range is a square), as shown in Table 1-2.

Table 1-2 Spot Size at Different Distances

Distance (m)	1	2	3	5	7	10	20	30	40
Spot size (cm)	5	10	16	26	37	52	105	156	208

Note

The side length of target object generally should be larger than size of the TF02-i light spot; if the side length of the detected object is smaller than size of light spot, the output (Distance) from TF02-i will be a value between the actual distance values of the two objects.

1.4   Storage

• Device should be stored at -30°C to 80°C with a relative humidity ≤ 60% and ventilation free from corrosive gases.

• Before storage, please make sure that all connections are disconnected or dust covers are inserted or covered to ensure cleanliness.

• If storage time is over three months, please carry out a working test before using, to ensure that the device can be used in normal condition.

• For ensuring the product performance, do not open the product shell or remove the IR-pass filter.

1.5   Application

When using the product, please read the specifications, user manual and the precautions mentioned in the user manual in detail to ensure that the product is used within the rated specifications. The product is designed for use in the following scenarios:

- Robot
- Intelligent Transportation
- Intelligent Device
- UAV
- Other Industrial Products

If you use the product beyond the above application scope, please carefully evaluate whether the reliability requirements of the product to be applied match this product, or contact Benewake at any time to assist in solving it.

2 INTERFACE

2.1 Description About Wiring Sequence

Terminal model: MH1.25-7P-W/B, size of single wire is AWG26, diameter of single wire is 0.404mm, cross-sectional area is 0.129mm^2, which show in Table 2-1.
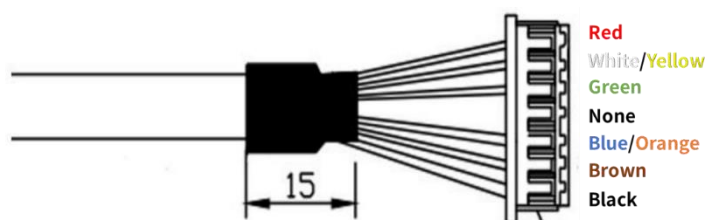

Figure 2-1 TF02-i external wiring connector and wiring sequence

Table 2-1 The Function Description of Each Wire

Pin	Wiring color	Function	Comment
1	Red	VCC	Power supply
2	White/Yellow	RS485-B/CAN_L	RS485-B/CAN bus
3	Green	RS485-A/CAN_H	RS485-A/CAN bus
4	N/A	N/A	N/A
5	Blue/Orange	UART_RXD	UART receive (Debug)
6	Brown	UART_TXD	UART transmit (Debug)
7	Black	GND	Ground

Warning

① The hardware of RS-485 and CAN is different; Do not mix UART cable with RS485 or CAN bus, otherwise it will cause damage of MCU.

② TF02-i with RS-485 interface does not support UART debugging pins.

2.2 Electrical Characteristics

Table 2-2 Main Electrical Parameters of TF02-i

Parameter	Values
Supply voltage	DC 7V~30V
Average current	≤70mA@12V
Peak current	100mA
Average power consumption	≤0.85W@12V

3 COMMUNICATION PROTOCOL

There are two communication interfaces available. The hardware of RS485 and CAN is different. The interface can not be switched by command.

3.1 RS-485 Communication Protocol

3.1.1 Communication protocol

Modbus protocol is the default setting for RS-485 interface. The parameter is shown in Table 3-1. The default value of baud rate and slave ID is 115200 and 0x01.

Table 3-1 RS-485 Communication protocol of TF02-i

Characteristics	Values
Communication interface	RS-485
Baud rate	115200
Data bit	8
Stop bit	1
Parity	None

> **Note**
> The following baud rates are supported: 9600，14400，19200，38400，43000，57600， 768000， 115200(default)， 128000， 230400， 256000. It is not recommended to use a baud rate above 115200 for communication because of communication stability.

3.1.2 Parameter configuration description of Modbus protocol

3.1.2.1 Description of data frame

When Modbus protocol of TF02-i is enabled, the Modbus command format of reading distance is shown in Table 3-2.

Table 3-2 The command format of reading distance

Addr.	Function code	Register Addr.		Register Value		CRC_Low	CRC_High
01(Default)	03	00	00	00	01	xx	xx

The response data frame format is shown in Table 3-3.

Table 3-3 The response date frame format

Addr.	Function code	Length	Dist_High	Dist_Low	CRC_Low	CRC_High
01(Default)	03	02	XX	XX	xx	xx

3.1.2.2   Function code

The function code of TF02-I is shown in Table 3-4.

Table 3-4 The function code

Function Code	Description
03	Read register
06	Write register

3.1.2.3   Register address list

- All register addresses are hexadecimal and register values are 16 bits;

- After setting parameter, save and restart to take effect.

Register address list using function code: 0x03(read only)

Table 3-5 Register address of function code (0x03)

Register Addr.	Definition	Description
00 00	Dist	Distance value, unit: cm
00 01	Strength	Signal strength
00 03	High 16 bits of timestamp	High 2 bytes of time stamp, unit: ms
00 04	Low 16 bits of timestamp	Low 2 bytes of time stamp, unit: ms
00 06	High 16 bits of firmware version	0x00 and main version number
00 07	Low 16 bits of firmware version	Sub-version and revised version number

Register address list using function code: 0x06(write only)：

Table 3-6 Register address of function code (0x06)

Register Addr.	Definition	Description
00 80	Save setting	Write any value to save settings
00 81	Power off/Reboot	Register value: 0x00: power off (Not currently supported) 0x01: reboot
00 82	Disable Modbus	Register Value: 0x01: Disable Modbus
00 83	High 16 bits of baud rate	Set baud rate, save and reboot to take effect
00 84	Low 16 bits of baud rate	Set baud rate, save and reboot to take effect
00 85	Slave ID	Set slave ID, save and reboot to take effect (default 0x01)
00 86	Frame rate	Set frame rate, save and reboot to take

		effect (default 100Hz)
00 87	Working mode	Set working mode, save and reboot to take effect. Register value: 0x00: continuous detection mode (default) 0x01: triggering mode
00 88	Low power consumption mode	Set low power consumption mode, save and reboot to take effect. Register value: 0x00: Disable (default) 0x0N: Enable, N is a positive integer with ≤10,which is sampling frequent of TF02-i
00 89	Restore default	Write any value, save and reboot to take effect

3.1.3   Parameter configuration

Table 3-7 General command of RS-485 serial communication mode

Function	Command	Respnse	Description
Enable Modbus	5A 05 15 01 75	5A 05 15 01 75	Save and reboot to take effect
Strength threshold and distance under threshold	5A 07 22 XX LL HH SU	5A 07 22 XX LL HH SU	The default setting is: When strength is below 60, make distance output 4500cm: XX=60/10=6(DEC)=06(HEX) 4500(DEC)=1194(HEX) LL=94，HH=11
Save setting	5A 04 11 6F	5A 05 11 00 70	

Table 3-8 General command of Modbus protocol

Function	Command	Response	Description
Read distance	01 03 00 00 00 01 84 0A	01 03 02 DH DL CL CH	DH: High 8 bits of distance DL: Low 8 bits of distance CH: High 8 bits of CRC CL: Low 8 bits of CRC
Read distance and signal strength	01 03 00 00 00 02 C4 0B	01 03 04 DH DL SH SL CL CH	SH: High 8 bits of signal strength SL: Low 8 bits of signal strength
Read firmware version	01 03 00 06 00 02 24 0A	01 03 04 00 VM VS VC CL CH	VM: Main version number VS: Sub-version number VC: Revised version number

Set baud rate	01 06 00 83 BH1 BH2 CL CH 01 06 00 84 BL1 BL2 CL CH	01 06 00 83 BH1 BH2 CL CH 01 06 00 84 BL1 BL2 CL CH	BH1: High 8 bits of baud rate BH2: Secondary high 8 bits of baud rate BL1: Secondary low 8 bits of baud rate BL2: Low 8 bits of baud rate For example: Set baud rate to 9600 (0x00002580): BH1=00 BH2=00 CL=78 CH=22, BL1=25 BL2=80 CL=D2 CH=D3
Modify slave ID	01 06 00 85 IH IL CL CH	01 06 00 85 IH IL CL CH	IH: High 8 bits of slave ID IL: Low 8 bits of slave ID For example: Modify slave ID to 0x0002: IH=00 IL=02 CL=19 CH=E2
Modify frame rate	01 06 00 86 FH FL CL CH	01 06 00 86 FH FL CL CH	FH: High 8 bits of frame rate FL: Low 8 bits of frame rate For example: Modify frame rate to 100 (0x0064): FH=00 FL=64 CL=69 CH=C8
Low power consumption mode	01 06 00 88 LH LL CL CH	01 06 00 88 LH LL CL CH	LH: High 8 bits of sampling frequent in low power consumption mode LL: Low 8 bits of sampling frequent in low power consumption mode For example: Set it to 5Hz low power consumption mode, LH=00 LL=05 CL=C9 CH=E3
Save setting	01 06 00 80 00 00 88 22	01 06 00 80 00 00 88 22	Save and reboot to take effect
Disable Modbus	01 06 00 82 00 01 E8 22	01 06 00 82 00 01 E8 22	Save and reboot to take effect
Restore default	01 06 00 89 00 00 58 20	01 06 00 89 00 00 58 20	

> **Warning**
> ① RTU mode is only supported for communication in serial communication.

For example:

1) Enable Modbus protocol in RS-485 serial communication mode:

5A 05 15 01 75   //Enable Modbus protocol

5A 04 11 6F //Save settings

Enter Modbus protocol mode after rebooting.

2) Disable Modbus protocol:

01 06 00 82 00 01 E8 22   //Default address is 0x01, disable Modbus protocol

01 06 00 80 00 00 88 22   //Default address is 0x01, save setting

Exit Modbus protocol after rebooting.

3.2   CAN Communication Protocol

3.2.1   Communication Protocol

The CAN communication protocol of TF02-i supports customer-defined protocol parameters or customized services, and the CAN protocol baud rate and ID can be modified. The CAN protocol is shown in Table 3-9.

Table 3-9 CAN communication protocol of TF02-i

Characteristics	Default values
Communication interface	CAN
Baud rate	250kbps
Transmitting ID	0x00000003
Receiving ID	0x00000003
Frame format	Standard frame

Warning

① 0 is the broadcast ID, the transmitting and receiving ID cannot be set to 0.

② The following baud rates are supported: 1000kbps，900 kbps，800 kbps，666 kbps，500 kbps，400 kbps， 250 kbps， 200 kbps，160 kbps，125 kbps， 100 kbps.

3.2.2   CAN Communication Data Frame

The data protocol of CAN is shown in Table 3-10. Each data frame consists of 8 bytes and the data contains the distance (unit: cm), signal strength and timestamp (unit: ms).

Table 3-10 The date frame format of CAN communication

Data byte	Definition	Description
Byte0	Dist_L	Low 8 bits of distance
Byte1	Dist_H	High 8 bits of distance
Byte2	Strength_L	Low 8 bits of signal strength
Byte3	Strength_H	High 8 bits of signal strength
Byte4	Timestamp	Low 8 bits of timestamp
Byte5	Timestamp	Secondary low 8 bits of timestamp
Byte6	Timestamp	Secondary high 8 bits of timestamp
Byte7	Timestamp	High 8 bits of timestamp

3.2.3   CAN Bus Network

The CAN bus network is mainly hung in CAN_H and CAN_L, and each node performs

serial differential transmission of signals through two lines. In order to avoid signal reflection and interference, it is recommended to connect 120Ω end point resistors at both ends of the bus, as shown in Figure 3-1.
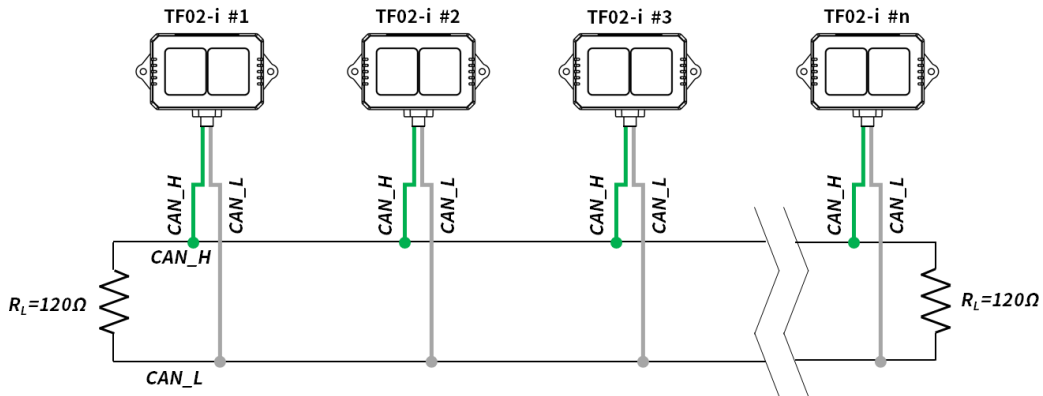

Figure 3-1 CAN bus network of TF02-i

> **Note**
>
> It is recommended to contact Benewake to communicate the details of use to complete networking requirements.

3.2.4 Parameter Configuration of CAN Communication

The configuration command format of CAN communication is shown as below.

Table 3-11 The configuration command format

Byte	0	1	2	3	4	5-8	9-12	13
Description	Header	Length	ID	Type	Baudrate	Recv_id	Trans_id	Check_sum
Default	0x5A	0x0E	0x51	0	0x08	0x00000003	0x00000003	SU

Type: 0(Standard Frame), 1(Extended Frame);

Recv_id: TF02-i receiving ID, Little Endian;

Send_id: TF02-i transmitting ID, Little Endian.

Baudrate: The code of baud rate, default 250kbps, corresponding to 0x08. The relation between baud rate(unit: kbps) and Byte4 is shown as below:

Table 3-12 The byte4 value corresponds to the baud rate

Byte4 value	0	1	2	3	5	6
Baud rate (unit: kbps)	1000	900	800	666	500	400
Byte4 value	**8**	**10**	**11**	**14**	**16**	
Baud rate (unit: kbps)	250	200	160	125	100	

Example of configuration:

Example1: Standard frame, Baud rate 500kbps, receiving ID=0x00000010, transmitting ID=0x00000020

Command: 5A 0E 51 00 05 10 00 00 00 20 00 00 00 EE

Example2: Extended Frame, Baud rate 250kbps, receiving ID=0x0000AABB, transmitting ID=0x0000CCDD

Command: 5A 0E 51 01 08 BB AA 00 00 DD CC 00 00 D0

3.2.5   Other Parameter Configuration

Table 3-13 General parameter configuration of TF02-i

Function	Command	Response	Description
Read firmware version	5A 04 01 5F	5A 07 01 V1 V2 V3 SU	Version V3.V2.V1
Frame rate①	5A 06 03 LL HH SU①	5A 06 03 LL HH SU	1-100Hz, default 100Hz LL: Low 8 bits of frame rate HH: High 8 bits of frame rate
Trigger detection	5A 04 04 62	Data frame	Set frame rate to 0, detection can be triggered with this command
System reset③	5A 04 02 60	5A 05 02 00 61	Succeeded
		5A 05 02 01 62	Failed
Disable/Enable output	5A 05 07 00 66	5A 05 07 00 66	Disable data output
	5A 05 07 01 67	5A 05 07 01 67	Enable data output
Strength threshold and distance under threshold	5A 07 22 XX LL HH SU	5A 07 22 XX LL HH SU	The default setting is: When strength is below 60, make distance output 4500cm: XX=60/10=6(DEC)=06(HEX) 4500(DEC)=1194(HEX) LL=94，HH=11
Restore to factory settings	5A 04 10 6E	5A 05 10 00 6F	Succeeded
		5A 05 10 01 70	Failed
Save setting④	5A 04 11 6F	5A 05 11 00 70	Succeeded
		5A 05 11 01 71	Failed
Enable/Disable 120Ω terminal resistor⑤	5A 05 60 01 C0	5A 05 60 01 C0	Enable 120Ω terminal resistor
	5A 05 60 00 BF	5A 05 60 00 BF	Disable 120Ω terminal resistor

> **⚠ Warning**
>
> ①   The customized frame rate should be calculated by the formula: 200/n (n is an integer with ≥ 2).
>
> ②   SU is checksum, checksum is disable by default.
>
> ③   Please keep power on and wait 1s after sending system reset command, otherwise the settings will not take effect.
>
> ④   After parameters configuration, send saving settings command to save the configuration, otherwise the settings will not take effect.
>
> ⑤   120Ω terminal resistor is disable in default.