TF03 Long-Distance LiDAR

UART-CAN

Product Manual

Specified Product

Product model: TF03 RS232-RS485

Product Name: Long-Distance LiDAR

Manufacturer

Company name: Benewake(Beijing) Co., Ltd.

Address: NO.28 Xinxi Road, Haidian District, Beijing, PRC

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Foreword

Dear users:

Thanks for choosing Benewake products, and it's our pleasure to help you to solve any technical question.

For the purpose of offering a 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 maybe meet. Please contact us if you have any questions.(bw@benewake.com)

This operation manual covers the product operation introduction and common problem solutions, but it is really hard to cover all the problems you maybe meet. So if you have any further questions or problems, please feel free to consult our technical support service (support@benewake.com). We will do our best to solve any problem related to the product. If you have any other good advice or suggestions, welcome to visit our official website and offer us your feedback there (http://en.benewake.com/contact_us), and we are looking forwards to your participation.

We are Benewake who dedicated to making the best "Robotic Eyes" worldwide!

目录

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1   Attentions

1.1   About this Document

- This Manual provides information necessary for the use of this product.

- Please read this Manual carefully before using this product and make sure that you have fully understood its contents.

1.2   Usage of Product

- This product can only be maintained by qualified professionals and only the original spare parts can be used to ensure its performance and safety.

- The product itself has no polarity and overvoltage protection. Please complete wiring and supply power correctly according to the contents of the Manual.

- The working temperature of the product is -25°C~60°C; please do not use it beyond this temperature range, so as to avoid risks.

- The storage temperature of the product is -40°C~85°C; please do not store it beyond this temperature range, so as to avoid risks.

- Do not open its enclosure for assembly or maintenance beyond this Manual; otherwise, it will affect the product performance.

1.3   Conditions with Potential Product Failure

- When the product transmitter and receiver lens are covered by dirt, there will be a risk of failures. Please keep the lens clean.

- The product will have a risk of failure when immersed completely in water. Do not use it underwater.

- When detecting objects with high reflectivity, such as mirrors and smooth tiles, the product may have a high risk of failures.

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2   Physical Interface

2.1   Description about the line sequence and connection

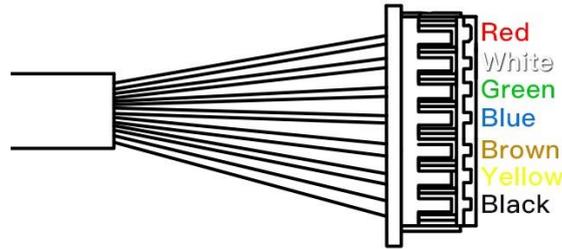Wiring terminal model: MH1.25-7P, core wire: AWG30, diameter:0.254mm, cross-sectional area:0.05mm^2.

Figure 1 TF03 Line Sequence

Table 1 TF03 Pin functions and connection instructions

No.	color	Pin	Function
1	Red	VCC	Voltage Input
2	White	CAN_L	CAN
3	Green	CAN_H	CAN
4	Blue	GPIO	IO output[1]
5	brown	TTL_RXD	receiver
6	Yellow	TTL_TXD	transmitter
7	Black	GND	GND

Note: If the serial port version is used, the TTL_RXD and TTL_TXD of the serial port must be connected and not allowed to be left floating, So as not to be affected by electromagnetic interference.

2.2   Electrical Characteristics

This product has no overvoltage or polarity protection. Please ensure that the wiring and power supply are normal. Voltage of power supply is allowed to fluctuate in the range of ±0.5V.

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[1] The IO output function needs to be customized according to actual needs, IO high and low level 0-3.3V.

Table 2 main electrical parameters

Parameter	Typical value
Power supply voltage	5V
Average current	≤180mA
Peak current	≤180mA
Average power	≤0.9W

3   Installation Instructions
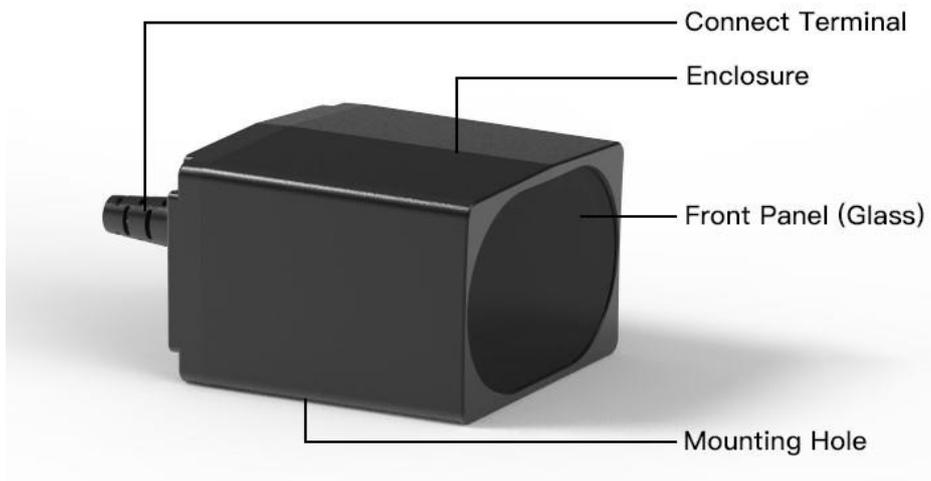
3.1 Product Overview

Figure 2 Exterior

3.2   Product Structure

The LiDAR mounting holes are applicable to M3 screws. Note that the length of the screw entering the enclosure shall be no more than 3.5mm.

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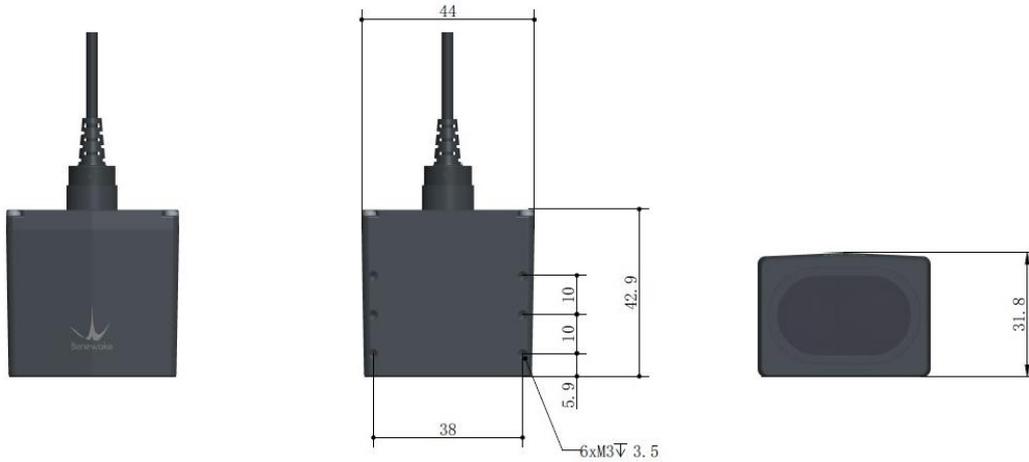
Figure 2   TF03 dimensions (Left 1: top view; Left 2: vertical view; Left 3: front view)

3.3 Detection angle descriptions

TF03 has a 0.5-degree detection angle and rectangular light spots; see Table 3 for simulated diagrams of the light spots. Therefore, at different distances, the spot size, namely detecting range, is different as shown in Figure 4.

Note: The side length of common objects detected should be greater than that of the detection range of TF03; When the side length of the detected object is less than that of the detection range, the LiDAR effective range will be reduced
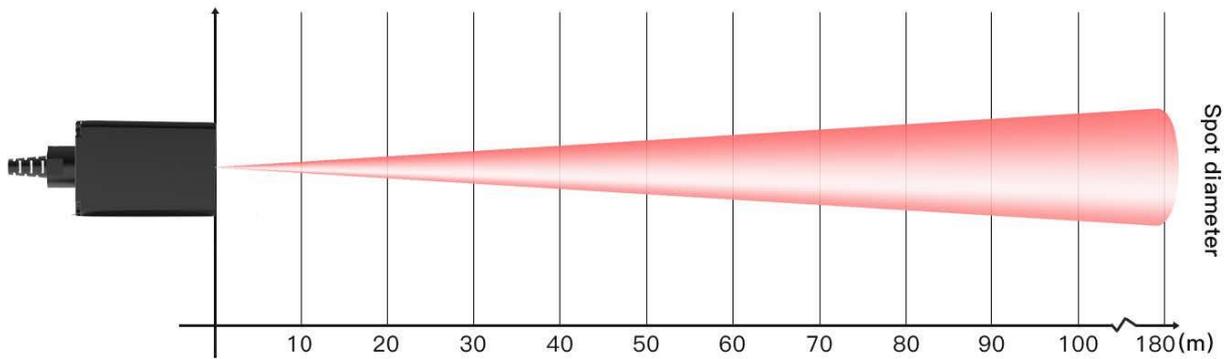
Figure 3 Detection angle schematic of TF03

Table 3 Spot simulated diagrams and sizes at different distances

Spot 20m away	Size：20cm*6cm	Spot 50m away	Size：50cm*14cm
Spot 100m away	Size：100cm*28cm	Spot 150m away	Size：150cm*42cm
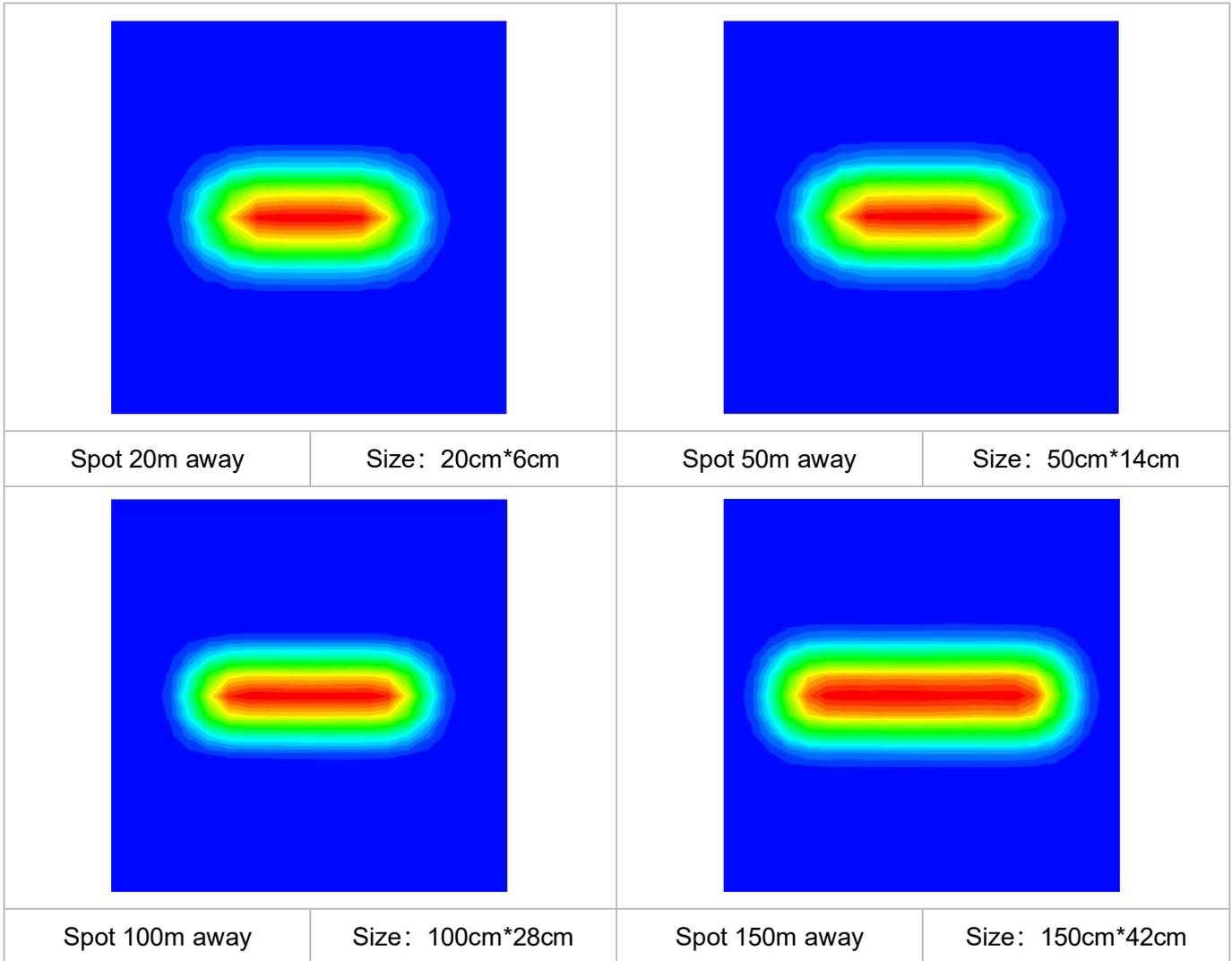
Note: In it, the red is the strongest, the green is weak, and the dark blue is the background, and the spot size is the length and width of the green in the figure.

4   Communication protocol and Data format

The standard version of TF03 supports TTL serial port and CAN communication modes. The default is TTL serial port communication. If necessary, the command can be modified to CAN communication mode. The two communication modes are selected one by one and cannot be output at the same time.

4.1 TTL serial port

he serial port version of TF03 adopts UART-LVTTL interface, and the output level is LVTTL level (0-3.3V). The specific communication protocol is shown in Table 4.

Table 4 communication protocol of TF03 Serial port

Item	Content
Communication protocol	UART
Baud rate	115200
Data bit	8
Stop bit	1
Checksum bit	None

1) Standard data output format of Serial port（UART）

The output data (hexadecimal numbers) of TF03 is shown in table 5. Each data frame consists of 9 bytes and the data contains the measured distance information; namely, DIST; the frame tail acts as a data checksum bit; other bytes are reserved.

Table 5 TF03 serial data format

Data bit	Definition	Description
Byte0	Frame header	0x59
Byte1	Frame header	0x59
Byte2	DIST_L	DIST low 8-bits
Byte3	DIST_H	DIST high 8-bits
Byte4	Reserved bit	/
Byte5	Reserved bit	/
Byte6	Reserved bit	/
Byte7	Reserved bit	/
Byte8	Checksum	Low 8 bits of Checksum bit. Checksum = Byte0 + Byte2+…+Byte7

2) Character string data format(Pix Mode)

The Pixhawk data format is output as a string and its unit is m(meter). For example, if the measurement distance is 1.21m, the string 1.21 will be output, followed by the escape character \r\n. The serial version supports editing to Pixhawk mode output by command.

3) IO high and low level output

Set a threshold (the threshold is adjustable), when the distance is less than the threshold, output high level/low level, and when the distance is greater than the threshold, output low

level/high level. Setup command is refer to 4.3.2.

a) High and low level can be adjusted, default: high level in close distance and low level in long distance;

b) Adjustable buffer interval (used to prevent back-and-forth jumps caused by data jitter);

c) High and low level delay is adjustable;

The delay before triggering is adjusted, assuming that the threshold is set to 10m and the distance is set less than 10m, the output is high level; when the distance is less than 10m, an adjustable delay (default is 0ms) is added, After the delay, the distance is still less than 10m, the output is high level.

The trigger delay is adjustable, assuming that the threshold is set to 10m and the distance is set less than 10m, the output is high level; when the distance is greater than 10m, an adjustable delay (default 0ms) is added. After the delay, the distance is still higher 10m, the output is low level.

Example:

a) Change TF03 to IO output with the following command:

5A 05 05 05 69

B) Set the distance less than the threshold to be a high level and the distance above the threshold to be a low level mode. The command is:

5A 05 61 01 C1

C) The delay of setting distance from less than threshold to greater than threshold and from greater than threshold to less than threshold is 100 ms. The command is:

5A 08 62 64 00 64 00 8C

D) Set a distance threshold of 500 cm and a buffer interval of 5 cm. The command is:

5A 08 63 F4 01 05 00 BF

E) Save the configuration with the following command:

5A 04 11 6F

F) Restore the factory settings (if necessary), with the following command:

5A 04 10 6E

4.2 CAN BUS

The CAN communication protocol of TF03 can be customized according to the customer's needs. The CAN baud rate can be modified, the ID can be modified, and the frame format can be modified. The contents of the protocol are shown in Table 6.

Table 6 Communication Protocol of TF03 CAN

Item	Content
Communication protocol	CAN
Baud rate	1M
Receive ID	0x3003
Transmit ID	0x3
Frame format	The transmit frame defaults to a standard frame. receive frames support standard and extended frames

The output data (hexadecimal numbers) of TF03 CAN is shown in table 5. Each data frame consists of 8 bytes and the data contains the measured distance information; namely, DIST; other bytes are reserved.

Table 7 TF03 CAN data format

Data bit	Definition	Description
Byte0	DIST_L	DIST low 8-bits
Byte1	DIST_H	DIST high 8-bits
Byte2	Reserved bit	/
Byte3	Reserved bit	/
Byte4	Reserved bit	/
Byte5	Reserved bit	/

4.3 Customer parameter configurations

4.3.1 The General Format Description of Commands

Custom parameters configurations are open in order that problems could be solved conveniently. Parameters, such as output data format, output frame rate could be changed by sending command. Parameter will be stored in flash and needn't to be configured again if restart after configured successfully.

Please change the configuration according to the real demands and never try uncorrelated

command frequently thus unnecessary loss from wrong command; please configure the product according to the demands of the manual and never send unstated command.

The Format of Command is:

Byte	byte0	byte1	byte2	byte3~ byteN-2	byteN-1
Descriptions	Head	Len	ID	Payload	Check sum

Head：fixed to 0x5A

Len：the length of the entire instruction frame (unit: Byte)

ID：identifies the function of each instruction

Payload：have different meanings and lengths in different ID instruction frames

Check sum：the lower 8 bits of the Len-1 byte data.

4.3.2 Commands

Function	Command	Response	Remark	Default setting
Obtaining version number	5A 04 01 5F	5A 07 01 V1 V2 V3 SU	the version number V3.V2.V1 SU is check sum，the same below	/
System reset	5A 04 02 60	success：5A 05 02 00 61 fail：there isn't any reaction over 1s	/	/
Frame rate	5A 06 03 LL HH SU	success：is same as command fail：there isn't any reaction over 1s	/	100fps
Output enabling switch	enable：5A 05 07 01 67 disable：5A 05 07 00 66	success：is same as command fail：there isn't any reaction over 1s	/	enabled
Single trigger instruction	5A 04 04 62	Data frame	/	/
Setting output format	5A 05 05 LL SU	success：is same as command fail：there isn't any reaction over 1s	LL：format, 00: ASCII Code output (Reserved) 01: Binary output 02: PIX output 05: I/O output	Binary output

Serial port baud rate	5A 08 06 H1 H2 H3 H4 SU	success：is same as command fail：there isn't any reaction over 1s	baud rate = (H4 << 24)+(H3 << 16)+(H2 << 8)+H1	115200
Enabling checksum switch	enable：5A 05 08 01 68 disable：5A 05 08 00 67	success：is same as command fail：there isn't any reaction over 1s	/	enable
Restoring factory settings	5A 04 10 6E	success：5A 05 10 00 6F fail：5A 05 10 ER SU	Fail(when ER is not 0)	/
Save settings	5A 04 11 6F	success：5A 05 11 00 70 fail：5A 05 11 ER SU	same as above	/
Configuring over range threshold value	5A 06 4F LL HH SU	success：5A 05 4F 00 AE fail：there isn't any reaction over 1s	over range threshold value =(HH << 8) + LL，unit cm	18000
Transmit CAN ID	5A 08 50 H1 H2 H3 H4 SU	success：5A 05 50 00 AF fail：there isn't any reaction over 1s	ID=(H4 << 24)+(H3 << 16)+(H2 << 8)+H1	0x3
Receive CAN ID	5A 08 51 H1 H2 H3 H4 SU	success：5A 05 51 00 B0 fail：there isn't any reaction over 1s	ID=(H4 << 24)+(H3 << 16)+(H2 << 8)+H1	0x3003
CAN baud rate	5A 08 52 H1 H2 H3 H4 SU	success：5A 05 52 00 B1 fail：there isn't any reaction over 1s	Baud rate = (H4 << 24)+(H3 << 16)+(H2 << 8)+H1	1000000
CAN transmit frame defaults	standard frame：5A 05 5D 00 BC extended frame：5A 05 5D 01 BD	success：5A 05 5D 00 BC fail：there isn't any reaction over 1s	/	standard frame
Output format	Serial：5A 05 45 01 A5 CAN：5A 05 45 02 A6	success：5A 05 45 00 A4 fail：there isn't any reaction over 1s	/	Serial
Enabling rain-fog algorithm	enable：5A 05 64 00 C3 disable：5A 05 64 01 C4	success：5A 05 64 00 C3 fail：there isn't any reaction over 1s	/	enable
Configuring offset	5A 06 69 LL HH SU	success：5A 05 69 00 C8 fail：there isn't any reaction over 1s	Offset = (HH << 8) + LL, unit cm	0
Distance trigger level	5A 05 61 LV SU	success：5A 05 61 00 C0 fail：there isn't any reaction over 1s	LV = 0 low level trigger LV = 1 high level trigger	low level trigger
Setting IO output delay	5A 08 62 L1 H1 L2 H2 SU	success：5A 05 62 00 C1 fail：there isn't any	Delay1 = (H1 << 8) + L1, Delay2 = (H2 << 8) + L2, Unit ms, representing the IO level change delay at	0, 0

		reaction over 1s	short and long distances, respectively. The range of values is 0-65000.	
Distance threshold and buffer distance of IO change	5A 08 63 L1 H1 L2 H2 SU	success：5A 05 63 00 C2 fail：there isn't any reaction over 1s	Dist= (H1 << 8) + L1, Buff= (H2 << 8) + L2，unit cm，The range thresholds and buffer distances of IO changes are expressed respectively. Value range 0-18000.	18000，0

Interpretation:

1) The supported output frame rate is as follows:

1、2、…9、

10、20、…90、

100、200…900、

1000、2000…9000、10000；

2) When using the trigger mode, you need to disable data output, and then use the trigger command;

3) The Pixhawk data format is output as "x.yz\r\n". For example, if the measurement distance is 1.21m, the string 1.21 will be output, followed by the escape character \r\n.

4) CAN baud rate supports 1M, 500K, 250K and 125K.

5) "Configuring offset" can be used for customer secondary calibration radar distance, supported from firmware version v1.11.3.

6) Please configure the legal CAN ID. Unexpected results may occur for illegal IDs.

7) If you want to use IO trigger function, you need to configure the output format to IO output, and configure IO trigger level, output delay, distance threshold and buffer distance by command.

5 Quick Test Procedures

5.1 Required Tools of Product Test

Note: the product package contains only TF03 products and factory certificate, and other accessories are collected by yourself. For TTL-USB boards, please contact sales or technical

support.

The serial port version TF03 needs to use a TTL-USB board when connecting to a computer. the following example represents the serial port version TF03 connected to the computer tools and methods.

TF03 (UART)	TTL - USB Board	USB Cable	PC	TF display program

Figure   4 Tools example

5.2   Test procedures

1）Download the TF display program

Please download the TF display program from http://benewake.com/en/down.html

Note: Please close the anti-virus software before unpacking the TF display program; otherwise, the files in the TF display program will be deleted as viruses; The TF display program currently only supports running on the Windows system. See Attachment 1: Instruction of TF Series PC Display Software.
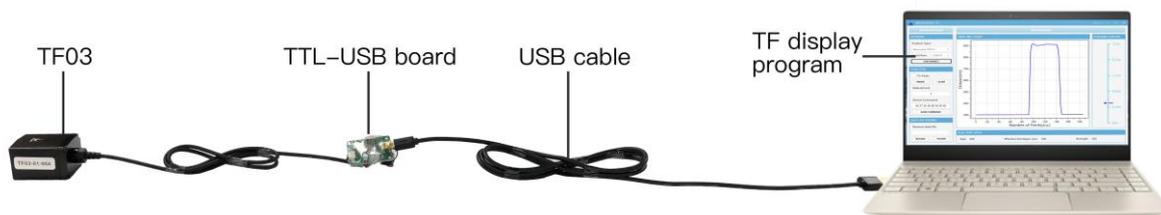
2）Connecting

图 5 TF03 与电脑连接示意图

As figure 6 shown, connect 『TF03』-> 『TTL- USB board』-> 『USB cable』， ensure no looseness, and then connect the 『USB cable』with the 『computer』.

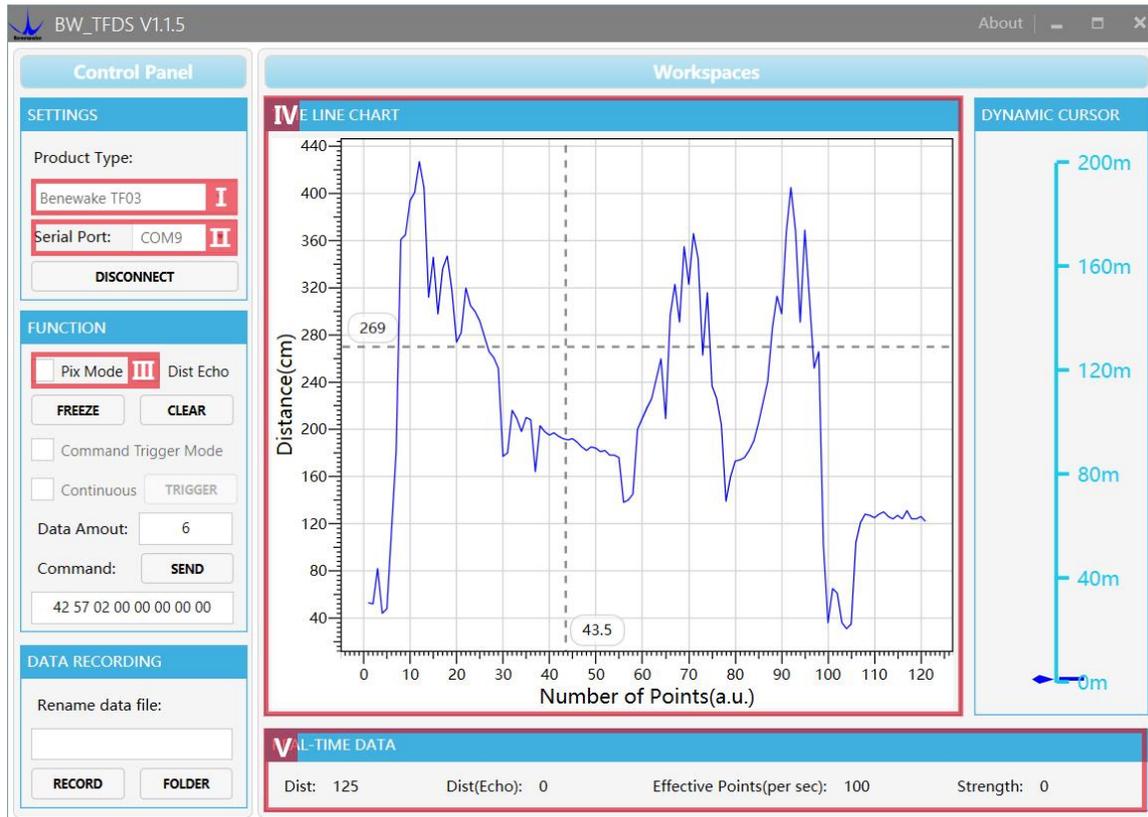3）TF display software connection and reading

Figure 6   The interface of TF display software

As shown in Figure 7, open the TF display program, select Ⅰ 『Benewake TF03』 and select the serial port for automatic identification (here is Ⅱ 『COM9』).

Then, click 『CONNECT』 to connect to the TF display program.

After connected successfully, continuous output data images will occur in the right Ⅳ 『TIME LINE CHART』 area and the Ⅴ 『REAL TIME DATA』 area below will display the current test distance (Dist: 125cm), the output frame rate (Effective Points: 100Hz).

Note: the Dist(Echo) and Strength are unmeaning in here.

4) Another note

If TF03 is required to output in Pixhawk mode, check Ⅲ 『Pix Mode』 first and then the data images will be normally output in the Ⅳ『TIME LINE CHART』 area. After the Pix Mode is checked, the distance unit will change to m.

5.3 Test Example

5.3.1   Test Range with Different Reflectivity

As shown in Figure 8, the 180m version of TF03, red and blue curves represent the relationship between the reflectance and range of the target under different ambient light
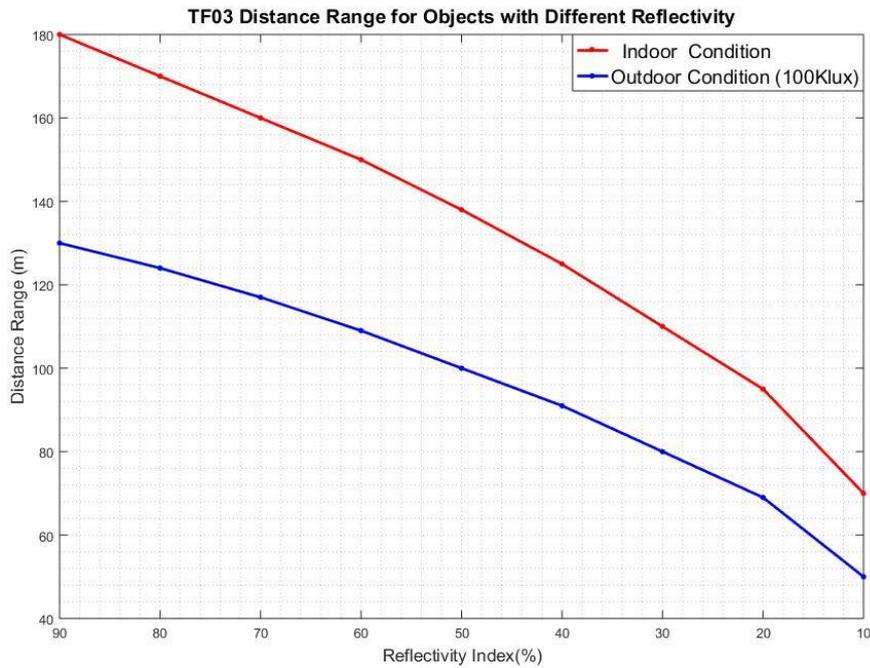
intensities indoors and outdoors, respectively.

Figure 8 The relationship between TF03 range and reflectance (version 180m)

5.3.2　Testing Accuracy of Different Materials

The test accuracy of TF03 at different distances and reflectivity is shown in Figure 9. Two typical background boards(blackboard and whiteboard), are selected. The reflectivity of whiteboard is 90% and that of blackboard is 10%.
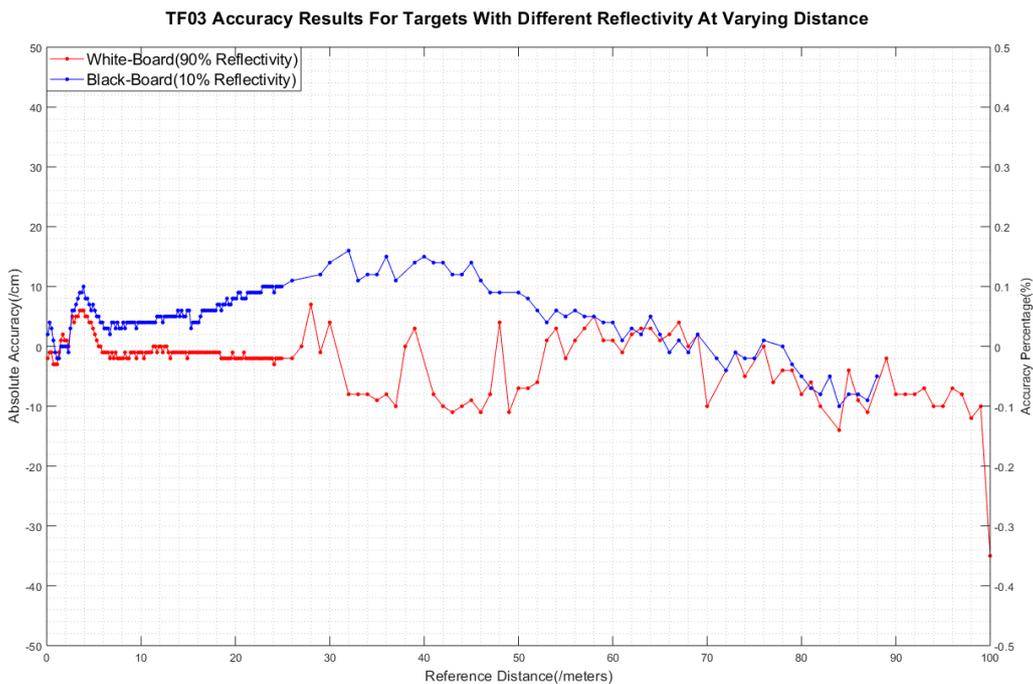

Figure 9 Error curves of TF03 at different distances and reflectivity

5.3.3 Reflectivity of Common Materials

The reflectivity of common materials is listed below, ranging from low to high. According to the test target and the corresponding reflectivity, we can measure whether the range of TF03 and other parameters meet the requirements.

| No.	Materials	Reflectivity
1	black foam rubber	2.4%
2	black cloth	3%
3	black rubber	4%
4	Coal (varies from coal to coal)	4~8%
5	Black car paint	5%
6	Black paper	10%
7	opaque black plastic	14%
8	Clean rough board	20%
9	newspapers	55%
10	translucent plastic bottles	62%
11	packing case cardboard	68%
12	Clean pine	70%
13	opaque white plastic	87%
14	white card	90%
15	Kodak standard whiteboard	100%
16	Unpolished white metal surface	130%
17	Shiny light metal surface	150%
18	stainless steel	200%
19	Reflective board, reflective adhesive tape	>300%

6   TF03 Software Setup
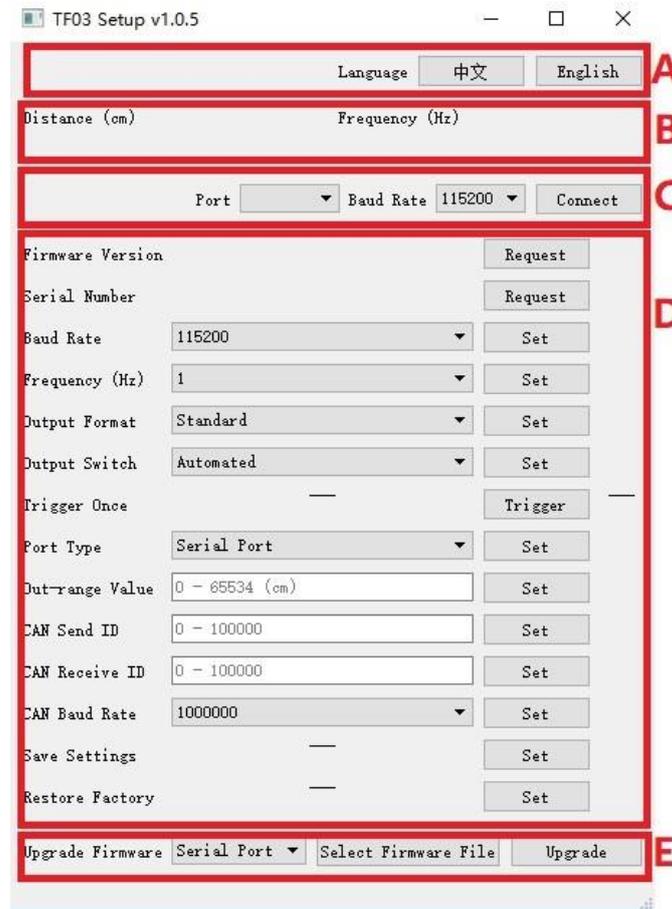
Figure 10 TF03 Setup software display

Interface of custom TF display software is shown in the figure above.

1) After TF03 is connected to the computer, select the correct port number and baud rate in Zone C manually and click the 『Connect』 button to realize communication between the TF display software and TF03.

2) After connection is successfully established, zone B will display the ranging distance and the frequency of data obtained by the TF display software. When no data is received after two seconds, the data and frequency display will disappear.

3) Zone D is dedicated to function configuration and its third column lists the buttons for sending instructions. After clicking such buttons, the setup software will send instructions and wait for reply from TF03. When no reply is received for a long time, 『No Response』 will be displayed on the right side of the instruction-sending buttons. Please note that in order to ensure that TF03 reply instructions can be obtained normally, lower the 『frame

rate』or set the『output mode』as『instruction trigger』before configuration. If the changed

parameters need to be saved, click the settings button corresponding to 『 Save

Configuration』before power down TF03.

4) Region E is dedicated to firmware upgrade, which enables the BootLoader function to be used for upgrading the product firmware.

7　Failure reasons and troubleshooting

1) Under normal operation, TF03 sometimes will output 18000(cm).

Reasons：The actual distance measured is beyond the range of TF03, TF03 will output 18000.

Troubleshooting：Use the value 18000 as a value representing abnormal data. In other words, after value 18000 is received, the TF03 output data is not used.

2) No data output after TF03 is connected to the TF display software.

Reason Ⅰ： The computer uses and operating system other than Windows.

Troubleshooting： Currently, the TF display software can only support the Windows operating system. Use a computer with the Window operating system installed.

Reason Ⅱ： Poor connection between TF03 and computer.

Troubleshooting： Please confirm that TF03 is correctly and reliably connected to the computer, and ensure that the cables and adapter board work properly.

3) TF03 does not cover the nominal range in some cases.

Reason： TF03 bases on the time-of-flight (TOF) principle, to achieve ranging by calculating the round-trip time of flight of laser pulses. The intensity of ambient light or the reflectivity of objects under testing is different, and thus will increase the intensity of ambient noise or return light intensity. Therefore, the ranging performance of TF03 varies with different ambient light intensities and reflectivities.

Troubleshooting： Under different ambient light intensity and reflectivity of objects under testing, having different ranges is a normal phenomenon and does not affect the accuracy or repeatability. Therefore, it can be used normally.

8   Frequently asked questions

Q1：Can TF03 support other voltage input?

A1：At present, other voltage input are not supported. If you have other needs, you can contact our sales staff for further inquiries about customization.

Q2：Can the divergence angle (spot) of TF03 be increased or decreased?

A2： Generally, this is a custom requirement. You need to contact the sales staff for further details. Divergence angle is determined at the beginning of product design. Determination of divergence angle is also closely linked to the optical system and the product structure. Therefore, it cannot be easily changed, and needs to be customized.

Q3： Can TF03 change the frequency of data output? Can TF03 output switching values?

A3： So far, customization of parameter configurations and adjustment of output modes have been enabled for TF03. However, switching values have to be customized according to requirements. You may consult our sales staff or technical support for further details.

Q4: Can TF03 work normally in rain, snow and fog?

A4: TF03 has a firmware version of the algorithm that penetrates the rain and fog. Contact the sales or technical support personnel for firmware upgrade. The algorithm is turned on by default in V1.11.15.

Attachment 1: Instruction of TF Series PC Display Software

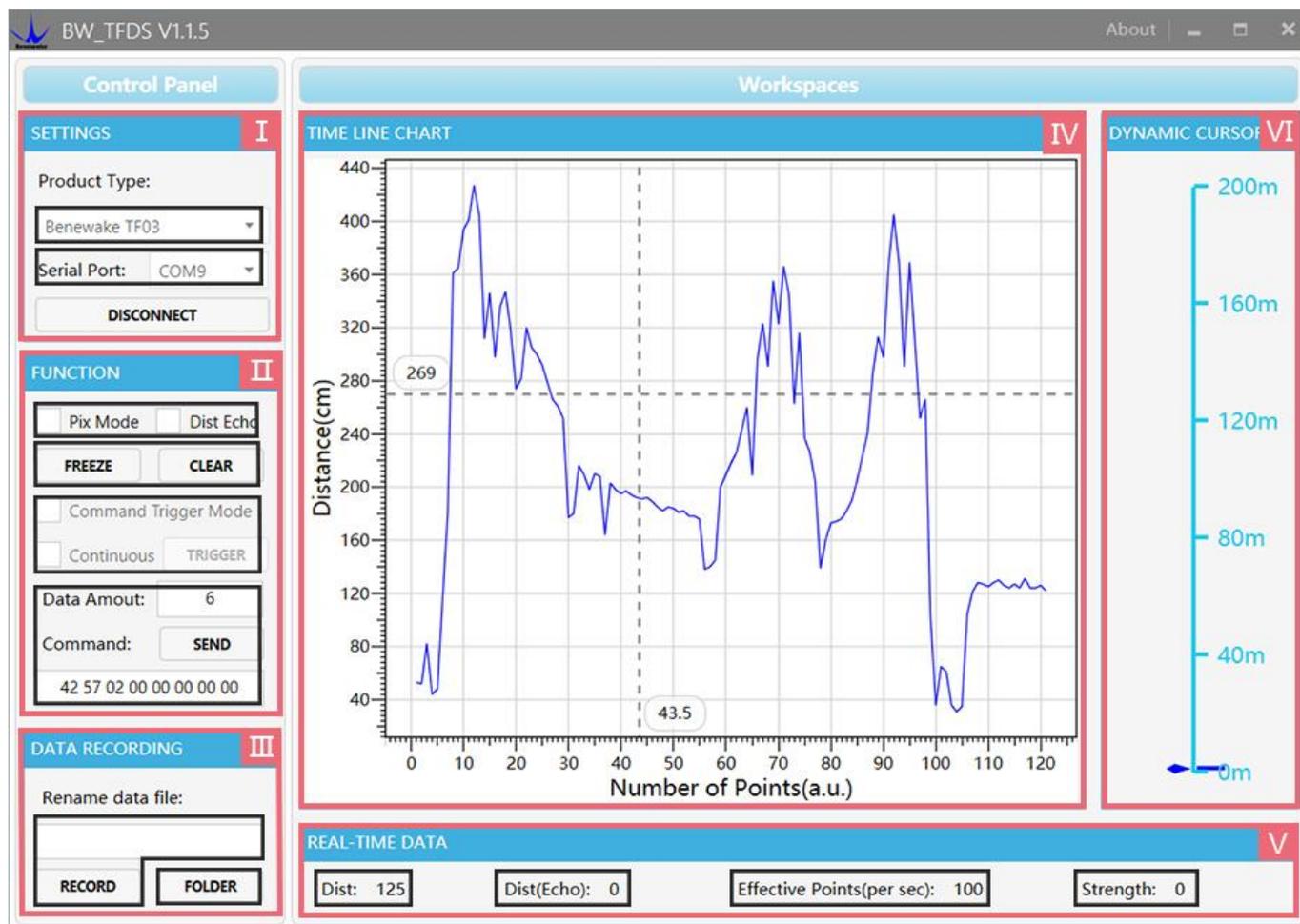### Ⅰ Product model/serial port control area 『SETTINGS』

Figure 11 Interface for TF series PC display software

『Product Type』:   Use the TTL-USB pin board to connect the corresponding LiDAR model at the computer terminal; if you use the product TF03 of our company, just select Benewake TF03.

『Serial Port』:   Select to identify the corresponding LiDAR port number at the computer terminal.

『CONNECT/DISCONNECT』:   Click the『CONNECT』button to establish a connection with LiDAR; click the 『DISCONNECT』 button to cancel the connection.

Ⅱ Function area 『FUNCTION』

『Pix Mode』:   For the Pixhawk data format, check and enable the PIX mode; uncheck and restore the standard output format.

『Dist Echo』: Unmeaning.

『FREEZE/CLEAR』: Click 『FREEZE』to pause the PC for analysis of the images in 『IV』; click 『CLEAR』to clear the drawing curve in 『IV』and restart drawing.

『Date Amount』: 5 by default, namely, once receiving 5 points, the PC will average the numerical values of the 5 frames and then output a frame. Modification is allowable as needed (You'd better set the numerical value larger or equal to 5 for preventing stagnation of the PC). After entering the value, press the keyboard enter key to forward commands.

『Device Command』: Hexadecimal commands can be sent from this window to TF, but it should be noted that you should first enter commands, then click the enter key and then click 『SEND COMMAND』 below.

Ⅲ Data recording area 『DATA RECORDING』

『RECORD』: Name the data to be saved in the text window, enter the file name, press the enter key, use the 『RECORD』button to record the TF data and the data will be stored in the named text file; click the button 『FINISHED』to stop data recording.

『FOLDER』: Use 『FOLDER』to open the folder with data saved.

Ⅳ Data image display area 『TIME LINE CHART』

The PC will draw continuous ranging images according to the data received. The vertical and horizontal coordinates represent the current distance and the number of effective points respectively

Ⅴ Real-time data display area 『REAL-TIME DATA』

『Dist』: Unit: cm by default.

『EffectivePoint（per sec）』: It represents the effective data refreshed by TF per second.

『Strength』: In the pix mode, there is no strength input, so the "Strength" value is 0 by default.

Ⅵ Range scale 『DYNAMIC CURSOR』

Display the real-time distance detected according to the current product model.