

TF03 Single-Point Long-Distance LiDAR



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Benewake (Beijing) Co., Ltd.

Specified Product

Product model: TF03

Product Name: Single-Point Long-Distance LiDAR

Manufacturer

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

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Forward

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://www.benewake.com/feedback.html>), and we are looking forwards to your participation.

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

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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 $-25^{\circ}\text{C}\sim 60^{\circ}\text{C}$; please do not use it beyond this temperature range, so as to avoid risks.
- The storage temperature of the product is $-40^{\circ}\text{C}\sim 85^{\circ}\text{C}$; 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.

2 Physical Interface

2.1 Description about the line sequence and connection

Wiring terminal model: MH1.25-7P.

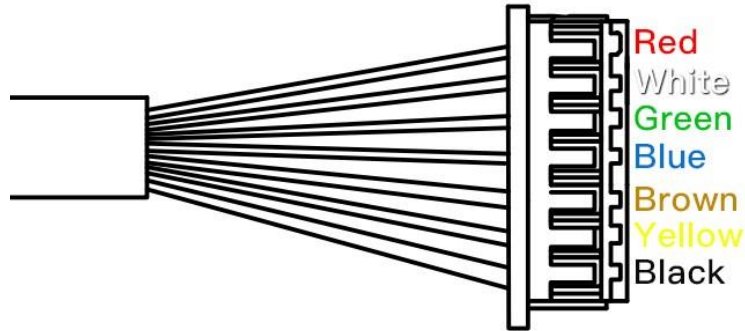


Figure 1 TF03 Line Sequence

Table 1 TF03 Pin functions and connection instructions

No	Color	Pin	Function
1	Red	VCC	Voltage Input
2	White	CAN_L	CAN bus low
3	Green	CAN_H	CAN bus high
4	Blue	GPIO	IO output
5	brown	TTL_RXD	UART receiver
6	Yellow	TTL_TXD	UART transmitter
7	Black	GND	GND

2.2 Electrical Characteristics

This product has no overvoltage or polarity protection. Please ensure that the wiring and power supply are normal, and the supply voltage is allowed to fluctuate by $\pm 0.5V$.

Table 2 main electrical parameters

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

3 Installation Instructions

3.1 Product Overview

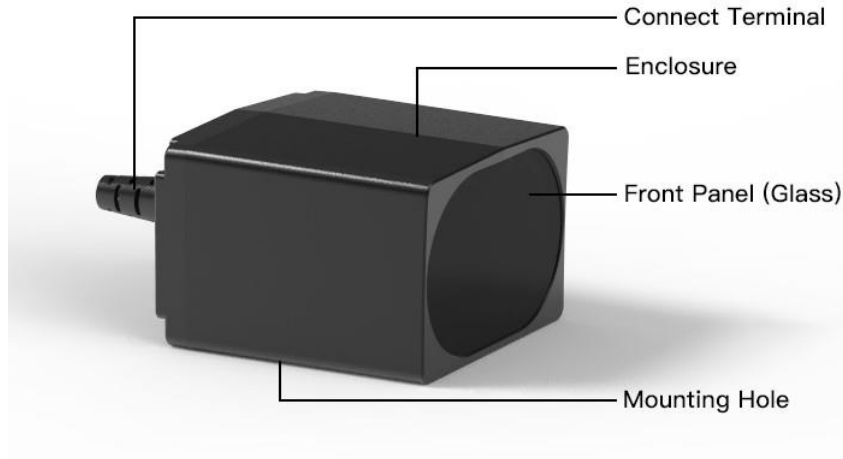


Figure 2 Exterior

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.

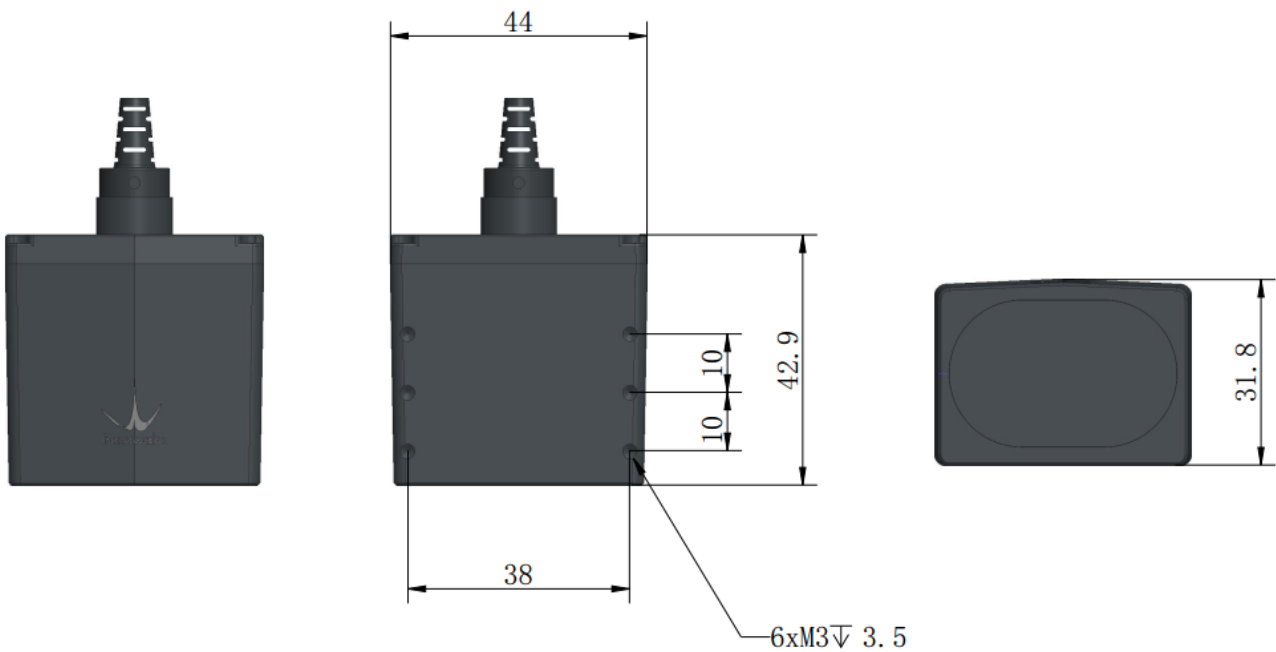


Figure 2 TF03 dimensions (Left 1: top view; Left 2: vertical view; Left 3: front view)

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

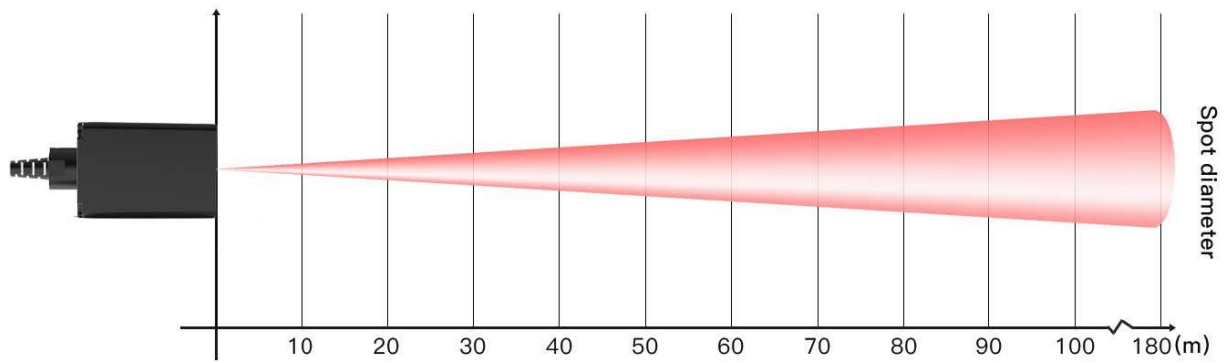
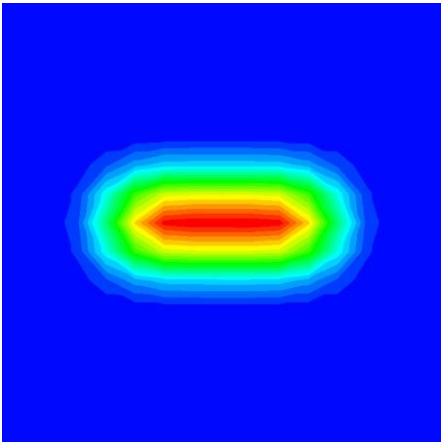
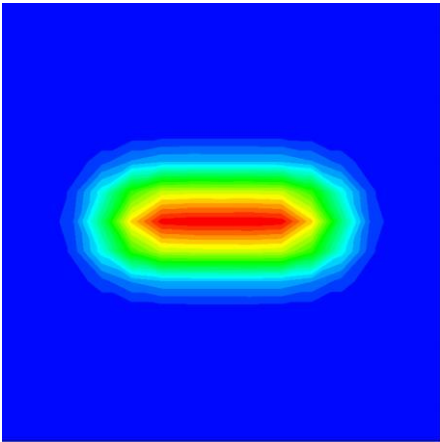
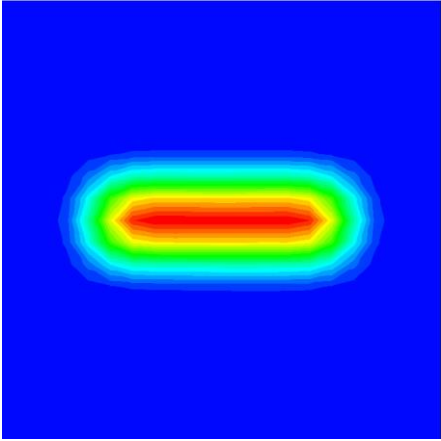
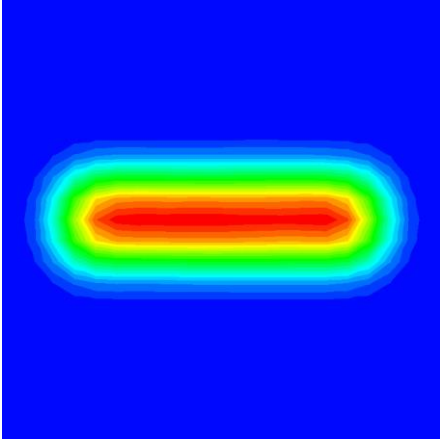


Figure 3 Detection angle schematic of TF03

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



4 Communication protocol and Data format

There are two type of communication version: serial port version and CAN bus communication version.

4.1 Serial port version

The serial port version of TF03 adopts an UART-LVTTL interface; refer to the specific communication in Table 4. The output level of the serial port is a LVTTL level (0-3.3V).

Table 4 TF03 Serial port communication protocol

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

1) Serial data format

The output data (hexadecimal numbers) of TF02 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, Checksum are the low 8 bits of the checksum of former 8 bytes.



2) Pixhawk serial data format

The pixhawk data format refers that the unit of output string is M(meter). For example, if the ranging distance is 1.21m, then it will output the string 1.21 and each distance value ends with a symbol of line break. The serial port products can support to be modified with Pixhawk format output via host computers or commands.

4.2 CAN bus version

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

Table 6 CAN communication protocol of TF03

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

See Table 7 for TF03 data format of the CAN version; all data is hexadecimal numbers, each frame of data has a total of 8 bytes and the data contains the measured distance information, namely, DIST; other bytes are reserved.

Table 7 Data frame format of CAN version

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 Custome parameter configurations

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 instruction frame includes Head, Len, ID, parameters (optional) and Check sum, where Head is fixed to 0x5A; Len is the length of the entire instruction frame (unit: Byte); ID identifies the function of each instruction; parameters have different meanings and lengths in different ID instruction frames; and Check sum is the lower 8 bits of the Len-1 byte data.

4.3.1 Obtaining version number

Send to TF03:

Byte	0	1	2	Len-1
Descriptions	Head(0x5A)	Len	0x01	Check_sum

TF03 returns:

Byte	0	1	2	3~5	Len-1
Description	Head(0x5A)	Len	0x01	Version	Check_sum

Version: For example, the third, fourth, and fifth bytes are 112, 50, and 9 respectively, indicating the version number 9.50.112.

4.3.2 System software result

Send to TF03:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	0x02	Check_sum

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x02	Status	Check_sum

Status: 0 (Successful); -1 (Failed)。



4.3.3 Setting operating frequency

Send to TF03:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	0x03	Freq_low	Freq_high	Check_sum

Freq: Operating frequency, >0 (operating frequency set).

TF03 returns:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	0x03	Freq_low	Freq_high	Check_sum

Freq: Operating frequency actually achieved in the TF03

This command takes effect immediately and the configurations are not saved by default.

The serial port baud rate supports 1Hz and Hz x 10/100/1000, such as 10 Hz, 20Hz...100Hz, 200Hz...1000Hz, 2000Hz...10000Hz.Up to 1000Hz is supported when the baud rate is 115200; while up to 10000Hz is supported when the baud rate is 1M.

4.3.4 Single trigger instruction

Send to TF03:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	0x04	Check_sum

TF03 returns :

Data frame, see in Figure 4.

4.3.5 Setting output format

Send to TF03:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x05	Format	Check_sum

Format:0x01 (Standard data format output), 0x02 (Pixhawk data format output)



TF03 returns :

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x05	Format	Check_sum

Format: Output format configured in the TF03. 0x01 (Standard data format output), 0x02 (Pixhawk data format output). This instruction takes effect immediately and configurations are not saved by default.

4.3.6 Setting serial port baud rate

Send to TF03 :

Byte	0	1	2	3	4	5	6	Len-1
Description	Head (0x5A)	Len	0x06	baudrate_low_0	baudrate_low_8	baudrate_high_16	baudrate_high_24	Check_sum

E.g: 115200, byte3: 0x00, byte4: 0xC2, byte5: 0x01, byte6: 0x00

TF03 returns :

Byte	0	1	2	3	4	5	6	Len-1
Description	Head (0x5A)	Len	0x06	baudrate_low_0	baudrate_low_8	baudrate_high_16	baudrate_high_24	Check_sum

baudrate: The serial port baud rate actually configured in the TF03

This instruction cannot take effect until it is executed and restarted with saved configurations.

4.3.7 Output enabling switch

Send to TF03 :

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x07	Enable	Check_sum

Enable: 0 (Output disabled), 1 (Output enabled)。

TF03 returns :

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x07	Enable	Check_sum



Enable: 0 (Output disabled), 1 (Output enabled)。

This instruction takes effect immediately and configurations are not saved by default.

4.3.8 Enabling checksum switch

Send to TF03:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x08	Enable	Check_sum

Enable: 0 (Checksum disabled, Check_sum may be any value), 1 (Checksum enabled)。

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x08	Enable	Check_sum

Enable: 0 (Checksum disabled), 1 (Checksum enabled)。

This instruction takes effect immediately and configurations are not saved by default.

4.3.9 Restoring factory settings

Send to TF03:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	0x10	Check_sum

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x10	Status	Check_sum

Status: 0 (Successful) ; non-0 (Failed) . This instruction takes effect immediately.

4.3.10 Saving current settings to FLASH

Send to TF03:

Byte	0	1	2	Len-1
Description	Head(0x5A)	Len	0x11	Check_sum

TF03 returns:



Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x11	Status	Check_sum

Status: 0 (Successful) ; non-0 (Failed) .

Interpretation:

- 1) After this instruction has been executed, all configuration information is still effective upon reboot.
- 2) The power cannot be cut off during the execution of this instruction, otherwise the configuration may be lost. If this happens, please use the restore factory setting instruction to restore the radar configuration to the factory state.

4.3.11 Configuring over range threshold value

Send to TF03:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	0x4F	Value_low	Value_high	Check_sum

Value: over range threshold value, unsigned short Type. 0 indicates no range limit; in addition, it cannot be configured as 0xFFFF.

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x4F	Status	Check_sum

Status: 0 (Successful) ; non-0 (Failed) .

This instruction takes effect immediately and configurations are not saved by default.

4.3.12 Configuring CAN Send ID

Send to TF03:

Byte	0	1	2	3	4	5	6	Len-1
Description	Head (0x5A)	Len	0x50	ID_low_0	ID_low_8	ID_high_16	ID_high_24	Check_sum

ID:CAN Send ID

TF03 returns:

Byte	0	1	2	3	Len-1
------	---	---	---	---	-------

Description	Head(0x5A)	Len	0x50	Status	Check_sum
-------------	------------	-----	------	--------	-----------

Status: 0 (Successful) ; non-0 (Failed) .

This instruction cannot take effect until it is executed and restarted with saved configurations

4.3.13 Configuring Can Receive ID

Send to TF03:

Byte	0	1	2	3	4	5	6	Len-1
Description	Head (0x5A)	Len	0x51	ID_low_ 0	ID_low_ 8	ID_high_16	ID_high_24	Check_sum

ID:CAN Receive ID

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x51	Status	Check_sum

Status: 0 (Successful) non-0 (Failed) .

This instruction cannot take effects until it is executed and restart with saved configurations.

4.3.14 Configuring CAN baud rate

Send to TF03:

Byte	0	1	2	3	4	5	6	Len-1
Description	Head (0x5A)	Len	0x52	baudrate_l ow_0	baudrate_l ow_8	baudrate_ high_16	baudrate_ high_24	Check_su m

baudrate: CAN Communication baud rate, currently able to support 1M, 500k, 250k and 125k only.

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x52	Status	Check_sum



ription n					
--------------	--	--	--	--	--

Status: 0 (Successful) ; non-0 (Failed) .

This instruction cannot take effect until it is executed and restarted with saved configurations.

4.3.15 CAN Frame type configuration

Send to TF03:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x5D	Type	Check_sum

type– CAN frame type, 0 – Standard frame, 1 – Extended frame

TF03 returns:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	0x5D	Status	Check_sum

Status: 0 (Successful) ; non-0 (Failed) .

This instruction cannot take effect until it is executed and restarted with saved configurations.

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.






				
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) Equipment connection



Figure 5 How to connect TF03 to PC for test

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

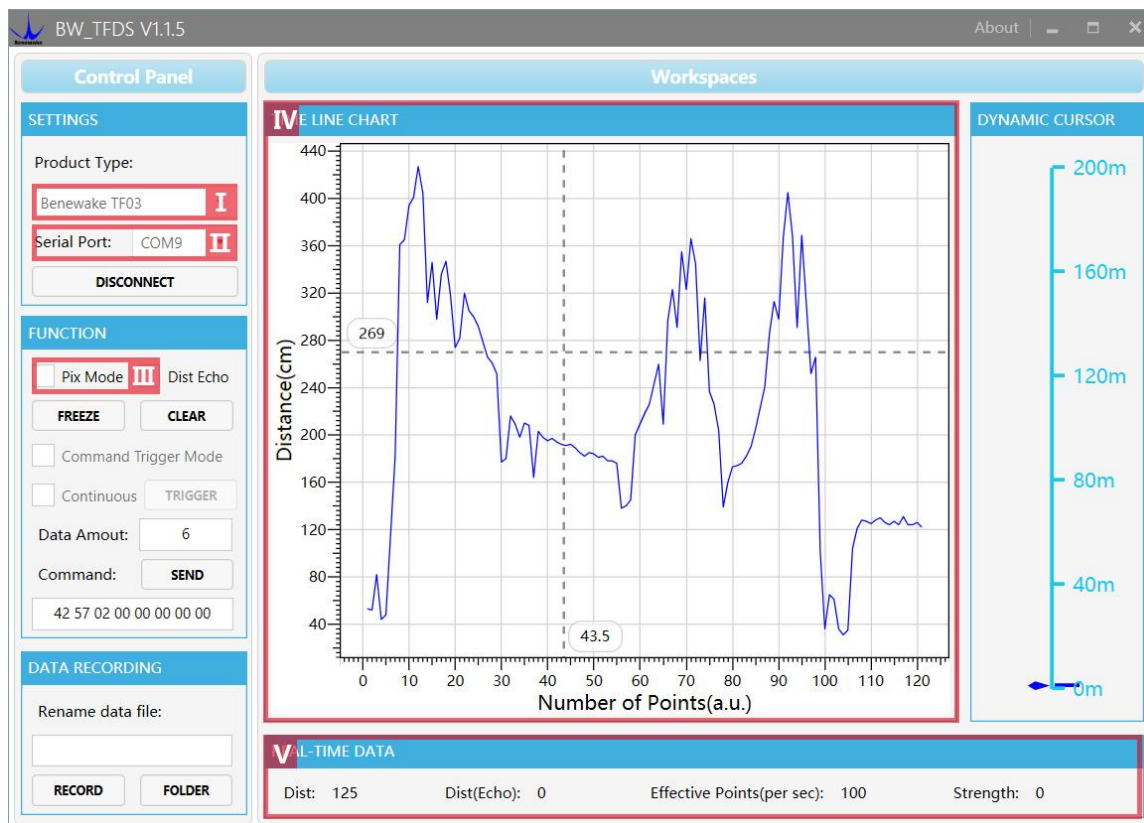


Figure 6 The interface of TF display software

As shown in Figure 7, open the TF display program, selectI 『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.

6 TF03 Software Setup

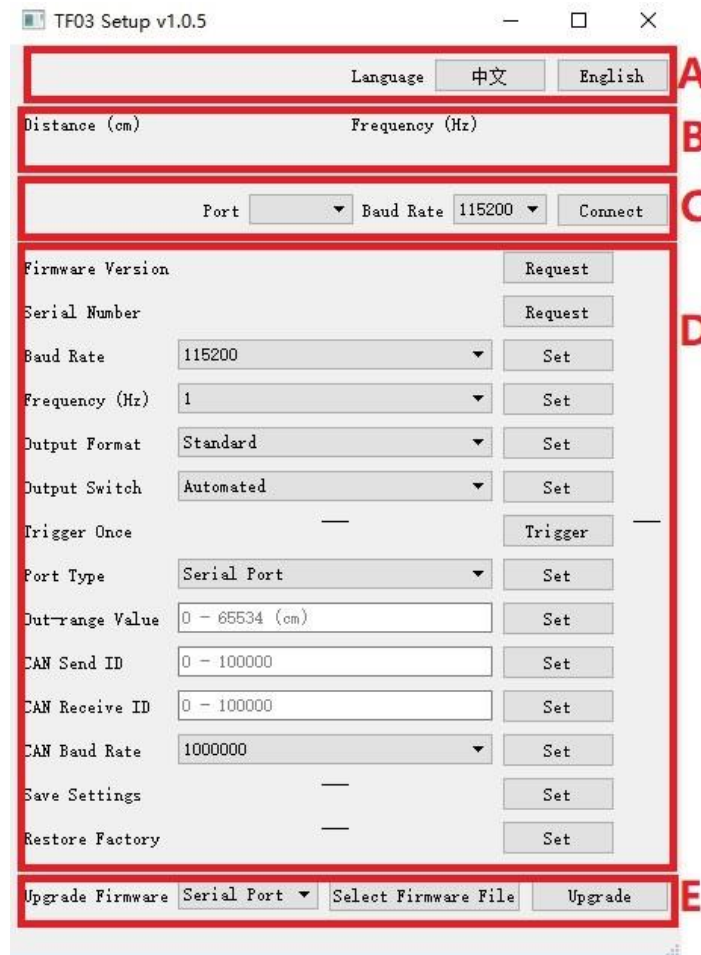


Figure 7 TF03 Setup software display

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. The standard voltage input for TF03 is 5V. 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.

Attachment 1: Instruction of TF Series PC Display Software

I Product model/serial port control area 『SETTINGS』

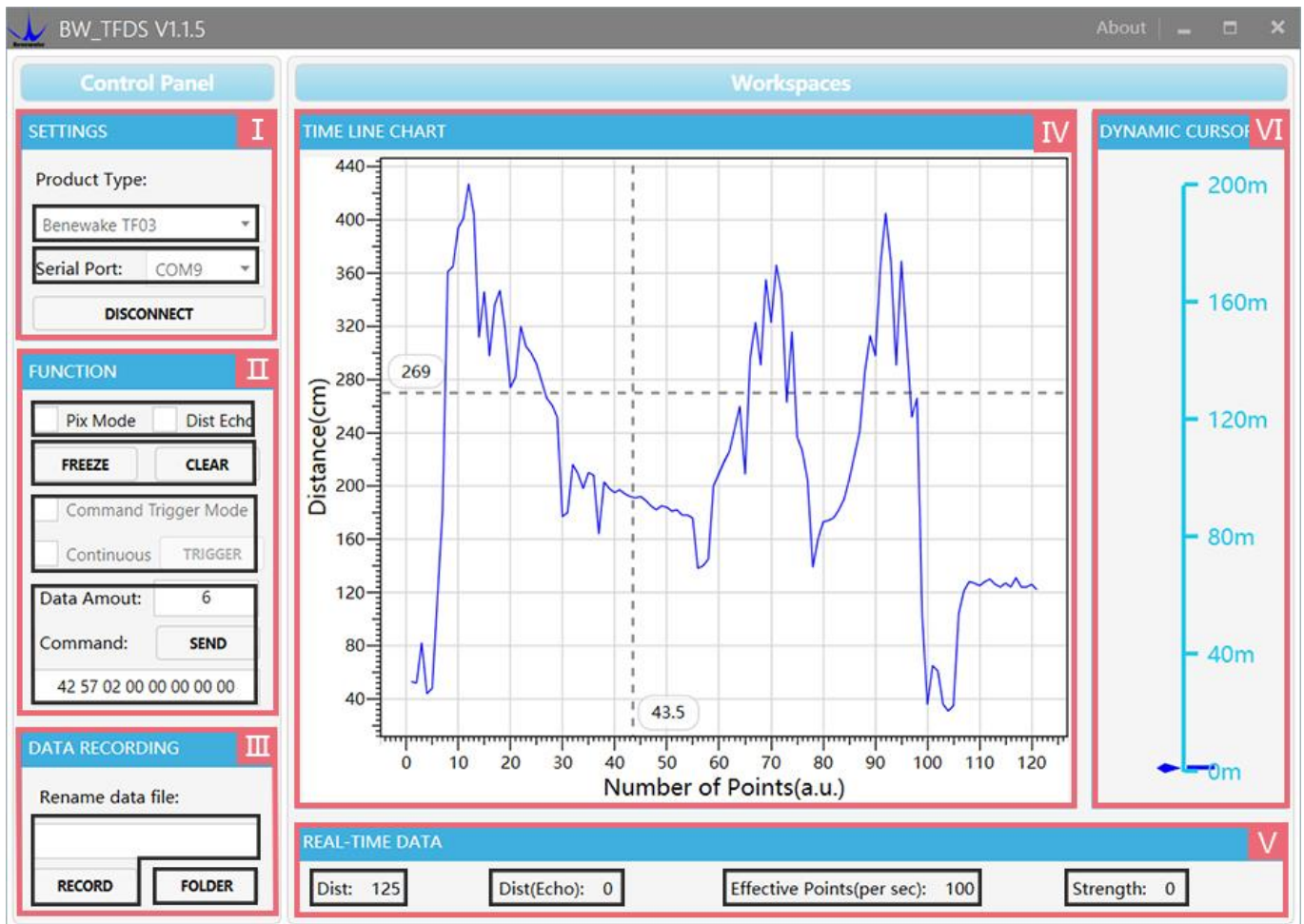


Figure 8 Interface for TF series PC display software

『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.

