Benewake

TF03 Series User Manual

Preface

This user manual contains the introduction, use and maintenance of TF03 series 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.

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Disclaimer

The TF03 series 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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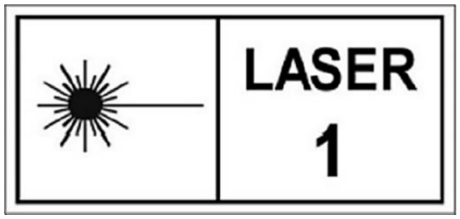
1. Laser Safety Information

The LiDAR contains IR and invisible laser spots. IR laser: Wavelength 905nm;
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!

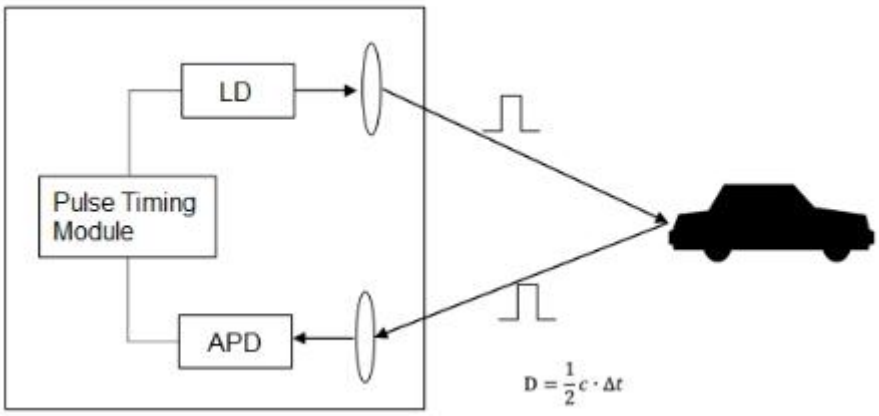
This laser product is classified as Class 1 during operational procedures. When the ranging feature is activated, the laser emitter of the LiDAR module may emit laser radiation, therefore, the LiDAR should NOT be aimed at humans and animals to ensure safety.

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 at 905nm wavelength 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

Measuring principle

TF03 series is a typical Pulse Time of Flight (PToF) sensor. TF03 series 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 APD 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 TF03 series and the measured target can be calculated through the speed of light.



Pulsed time of flight

Technical Specifications

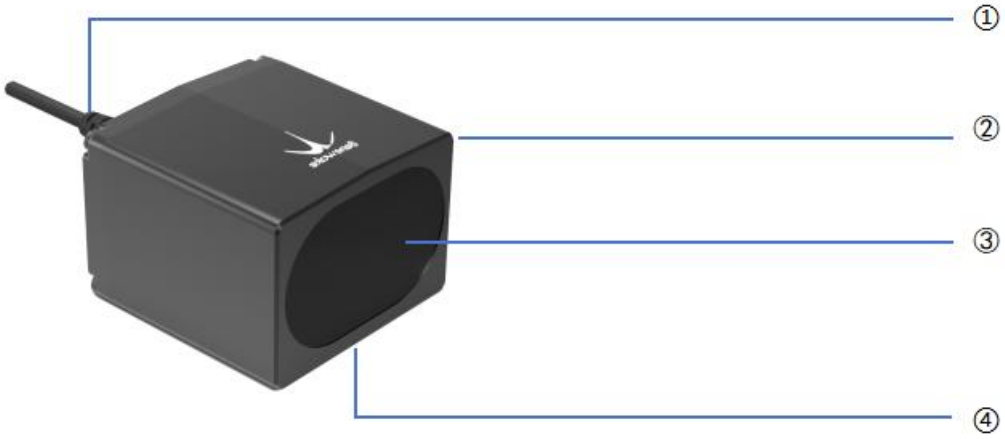
Performance Parameters		
Model	TF03-100	TF03-180
Detection range①	100 m @ 90% ref. 40 m @ 10% ref.	180 m @ 90% ref. 70 m @ 10% ref.
Blind zone	≤ 0.1 m	
Accuracy ①	± 10 cm (< 10 m)，1% (≥ 10 m)	
Repeatability ①	< 3 cm @ 1 σ	
Distance resolution	1 cm	
Default frame rate	Up to 9,800 Hz (1 ~ 9,800 Hz configurable, default 100 Hz)	
Ambient light resistance	100 KLux	
Optical Parameters		
Light source	EEL	
Central wavelength	905 nm	
FoV②	< 0.5°	
Eye safety	Class1 (IEC 60825-1:2014; EN 60825-1:2014+A11:2021)	
Mechanical and Electrical Parameters		
Average power consumption③	≤ 800 mW	
Peak current③	< 480mA @ 12V	
Power supply	DC 5V ~ 24V	
Logical voltage	3.3 V TTL	
Connector	Molex standard 7pin terminal, model MH1.25-7P-W/B	
Operating temperature	- 25 ℃ ~ + 60 ℃	
Storage temperature	- 40 ℃ ~ + 85 ℃	
Protection level	IP67	
Typ. Dimensions②	44.0 mm x 43.0 mm x 32.0 mm	
Cable length②	70 cm	
Typ. Weight②	86 ±3g (excluding cables)	
Communication Protocol		
Communication Interface	UART / CAN (Can be switched by command), RS232, RS485	

Notes:

1. When all the light spots fall on the target object, the accuracy, distance resolution, and repeatability are measured under the conditions of a diffuse reflection whiteboard (90% reflectivity) at 25 ℃ indoors;
2. The weight and size are typical values for reference only. For detailed tolerance parameters, please consult the technical personnel of Benewake;
3. Measured at a temperature of 25 ℃, 100 Hz;

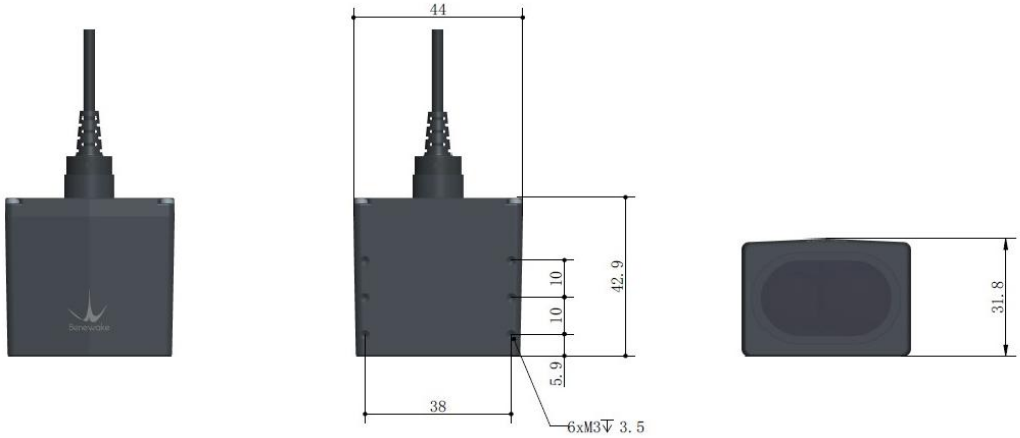
Structural Appearance

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



TF03 series Appearance

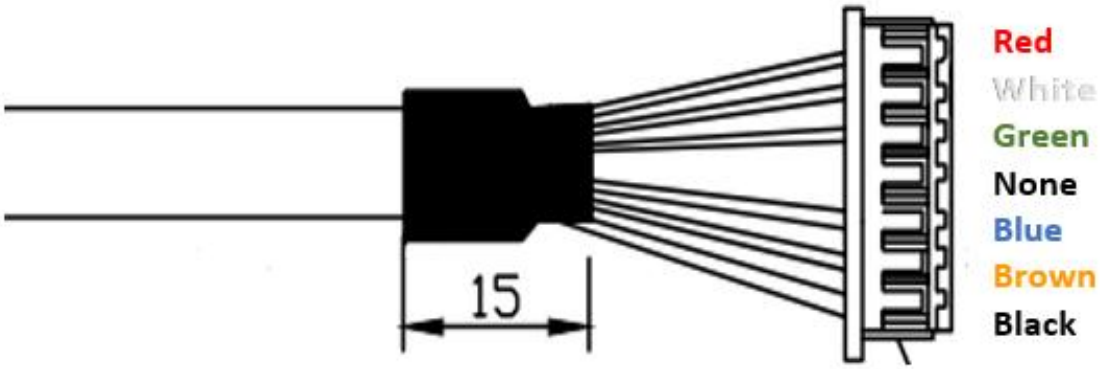
① Cable with male connector, Molex SD-51021-007, 7pin also called MH1.25-7P-W/B
② Laser window (Receiving)
③ Laser window (Emitting)
④ 3mm diameter hole (6mm deep) for mounting (x6)



Unit: mm

Connector

TF03's cable has six 26 AWG wires. The connector is Molex SD-51021-007 1.25 W/B-7Pin also called MH1.25-7P-W/B.



Male connector, Molex SD-51021-007 1.25 W/B-7Pin

Pin assignment on 7-pin male connector

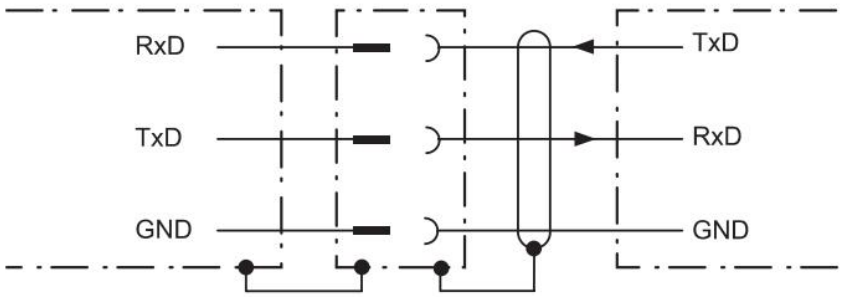
Pin	Signal	Color	Function
1	VCC	Red	Supply voltage DC 5 ~ 24V
2	RS-485-B/RS-232-RXD/CAN_L	White	Rx/CAN-BUS Low
3	RS-485-A/RS-232-TXD/CAN_H	Green	Tx/CAN-BUS High
4	N/A	N/A	N/A
5	UART_RXD	Blue	UART Receive
6	UART_TXD	Brown	UART Transmit
7	GND	Black	Ground

4. Communication Protocol

The TF03 series products are divided into three independent versions. The UART/CAN version supports dual communication interfaces of UART and CAN. Users can choose to connect the corresponding cables and terminals according to their needs, and then activate the corresponding protocol output through command switching. The LiDAR defaults to UART protocol output; The RS485 and RS232 versions support corresponding protocol data output, and can also send instructions to the LiDAR to change configuration through the built-in integrated UART serial port.

UART, RS485, RS232 Communication

Communication protocol



UART Interface Wiring Diagram

To connect two devices for UART communication, the transmitter's TxD should be connected to the receiver's RxD, and the receiver's TxD should be connected to the transmitter's RxD.
The TF03 series UART interface adopts the UART-LVTTL interface, with an output level of LVTTL level (3.3 V). The UART, RS232, and RS485 communication protocols are shown in the following table:
UART Communication protocol details

Character	Value
Baud rate	115200
Data bit	8
Stop bit	1
Parity	None

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, TF03 series will set it to 115200.

Data Frame

Each data frame under the UART interface contains distance and signal strength and consists of 9 bytes of hexadecimal values. Both distance and signal strength are represented by 2 bytes each, arranged in little-endian format . For details, refer to the table below:
Standard Data Frame Format

Data Byte	0	1	2	3	4	5	6	7	8
Description	Header	Header	Distance		Signal Strength		Reserved		Checksum
Typical Value	0x59	0x59	Low byte	High byte	Low byte	High byte	0x00	0x00	Sum

Among them, "signal strength" represents the strength of the reflected light signal received by the LiDAR, and the value is related to the reflectivity and distance of the detected object. The lower the reflectivity and the farther the distance, the smaller the signal strength value will generally be. Low signal strength may affect the accuracy of distance measurement and even fail to achieve the required

signal-to-noise ratio, resulting in the phenomenon of outputting "over range values". The range of signal strength values is 10 ~ 4000. When the signal strength is below 40, TF03 will output an over range value. During normal distance measurement, the range of signal strength variation is 40 ~ 1200; When measuring high reflectivity objects, the signal strength will exceed 1500.

RS485 Modbus Protocol

The TF03 Modbus uses a 2-wire interface; see the physical interface description for wire sequence. For parity and baud rate settings, refer to the communication protocol and data format. Custom parameter configuration requires switching to serial port mode to set the baud rate. The TF03 RS485 interface operates in half-duplex mode. For reliability reasons, using baud rates above 115200 is not recommended.
When the Modbus protocol is enabled, the command format for reading distance from the TF03 via Modbus is as follows:

TF03 RS485 Modbus Command Protocol

Address Field	Function Code	Register Address		Number of Registers		CRC_low	CRC_high
01 (Default)	03	00	00	00	01	xx	xx

TF03 RS485 Modbus Data Protocol

Address Field	Function Code	Data Length	Dist_high	Dist_low	CRC_low	CRC_high
01 (Default)	03	02	xx	xx	xx	xx

Modbus Function Codes Supported by TF03

Function Code	Description
03	Read Registers
06	Write Single Register

TF03 RS485 Modbus Function Code (03) Accessible Register List

Register Address	Definition	Description
00 00	Dist	Distance Value
00 01	Strength	Signal Strength Value
00 03	Timestamp High 16 bits	Timestamp high 2 bytes, relative time since TF03 startup, unit: ms
00 04	Timestamp Low 16 bits	Timestamp low 2 bytes, relative time since TF03 startup, unit: ms
00 06	Software Version High 16 bits	00 + Major Version Number
00 07	Software Version Low 16 bits	Minor Version Number + Revision Number

TF03 RS485 Modbus Function Code (06) Accessible Register List

Register Address	Definition	Description
00 80	Save Configuration	Writing any value to this register will execute the save configuration operation.
00 81	Shutdown/Reboot	Register value description: 0-Shutdown (not supported yet); 1-Reboot
00 82	Disable Modbus Protocol	1-Disable Modbus protocol
00 83	Baud Rate High	Configure baud rate, takes effect after saving and restarting.
00 84	Baud Rate Low	Configure baud rate, takes effect after saving and restarting.

00 85	Slave ID	Configure device address, takes effect after saving and restarting.
00 86	fps	Configure frame rate, takes effect after saving and restarting.

All register addresses are in hexadecimal. Register values are all defined as 16-bit. After configuring parameters, they will only take effect after saving the configuration and restarting the device.

Common Modbus Commands
The default interface for the TF03 Industrial version is the universal RS485 interface protocol. If you need to use the Modbus protocol, you must enable it using a command. The enable command is shown in the table below:

Function	Command	Successful Return Value	Description
Enable Modbus Protocol	5A 05 6F 00 CE	5A 05 6F 00 CE	Takes effect after saving and restarting. This command only works under the universal RS485 interface.
Configure Modbus Device Address	5A 05 70 ADDR SU	5A 05 70 00 CF	This command only works under the universal RS485 interface.

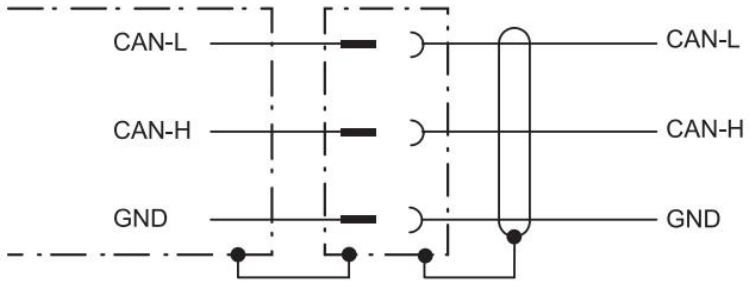
TF03 only supports RTU mode for communication over serial links.
The LiDAR's default Modbus address is 0x01. The commands in the tables are edited according to this default address. If the Modbus address is modified, the first byte in the corresponding command must be modified accordingly to take effect. The commands in the table below only take effect when the Modbus protocol is enabled. Do not send commands not listed in the table.

TF03 RS485 Modbus Protocol Common Command Set

Function	Command	Successful Return Value	Description
Get Distance Value	01 03 00 00 00 01 84 0A	01 03 02 DH DL CL CH	DH, DL are the high 8 bits and low 8 bits of Distance, respectively; CL, CH are the low 8 bits and high 8 bits of the CRC.
Get Distance and Strength Values	01 03 00 00 00 02 C4 0B	01 03 04 DH DL SH SL CL CH	DH, DL are the high 8 bits and low 8 bits of Distance, respectively; SH, SL are the high 8 bits and low 8 bits of Strength.
Get Version Number	01 03 00 06 00 02 24 0A	01 03 04 00 VM VS VC CL CH	VM, VS, VC are the major, minor, and revision version numbers, respectively.
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, BH2, BL1, BL2 are the high, second high, second low, and low bytes of the baud rate, respectively. Example: Set baud rate to 9600: 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, IL are the high and low bytes of the ID. Example: Modify ID to 2:IH=00 IL=02 CL=19 CH=E2
Modify Output Frame Rate	01 06 00 86 FH FL CL CH	01 06 00 86 FH FL CL CH	FH, FL are the high and low bytes of the frame rate. Example: Modify frame rate to 100: FH=00 FL=64 CL=69 CH=C8
Save Configuration	01 06 00 80 00 00 88 22	01 06 00 80 00 00 88 22	Takes effect after saving and restarting.
Disable Modbus Protocol	01 06 00 82 00 01 E8 22	01 06 00 82 00 01 E8 22	Takes effect after saving and restarting.

CAN Communication

The TF03 series CAN interface supports the DroneCAN protocol. If needed, please enable it using custom configuration commands.



CAN Interface Wiring Diagram

Communication protocol

The CAN communication protocol of the TF03 series can be customized according to customer needs, with adjustable CAN baud rate, ID, and frame format. The content of the agreement is as follows:

TF03 Series CAN Interface Communication Protocol

Parameter	Value
Baud Rate	1 Mbps
Receive ID	Standard Frame: 0x3 Extended Frame: 0x3
Transmit ID	0x3
Frame Format	Transmitted Frames: Standard Frame (default) Received Frames: Supports both Standard and Extended Frames

The CAN interface baud rate setting only supports commonly used baud rates, such as 20000, 33330, 40000, 50000, 66660, 80000, 83330, 100000, 125000, 200000, 250000, 400000, 500000, 666000, 800000, 1000000. If other values are set, TF03 will set it to 1000000.

Data Frame

Data frames under the CAN interface consist of 6 bytes of hexadecimal values, containing measured distance and signal strength, with the remaining bytes reserved.

TF03 CAN Communication Data Frame Format

Data Byte	0	1	2	3	4	5
Description	Distance (Low)	Distance (High)	Signal Strength (Low)	Signal Strength (High)	Reserved	Reserved
Typical Value	DIST_L	DIST_H	Strength_L	Strength_H	–	–

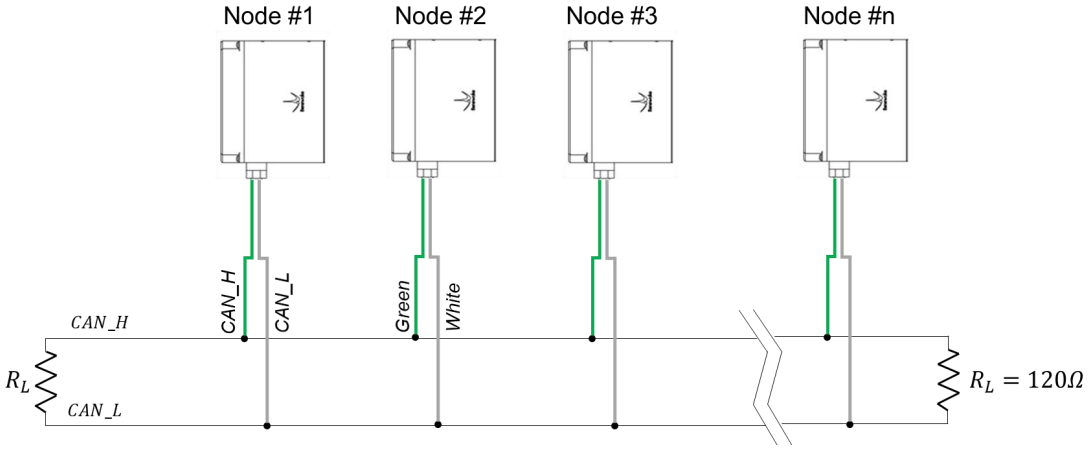
Among them, "signal strength" represents the strength of the reflected light signal received by the LiDAR, and the value is related to the reflectivity and distance of the detected object. The lower the reflectivity and the farther the distance, the smaller the signal strength value will generally be. Low signal strength may affect the accuracy of distance measurement and even fail to achieve the required signal-to-noise ratio, resulting in the phenomenon of outputting "over range values". The range of signal strength values is 10 ~ 4000. When the signal strength is below 40, TF03 will output an over range value. During normal distance measurement, the range of signal strength variation is 40 ~ 1200; When measuring high reflectivity objects, the signal strength will exceed 1500.

Attention: When using CAN communication, if the LiDAR needs to output a frame rate exceeding 6000 Hz, please set the baud rate to 1 M to ensure data transmission quality.

CAN networking

The CAN bus network operates via the CAN_H and CAN_L lines, enabling serial differential signal transmission between nodes. To minimize signal reflection and electrical interference, a 120-ohm termination resistor must be connected between CAN_H and CAN_L.

The TF03 series includes a built-in 120-ohm termination resistor, disabled by default. To simplify network setup, you can enable the built-in resistor via command only on devices located at the two ends of the CAN network. This eliminates the need for additional external termination resistors.



TF03 series CAN networking

Custom configuration instructions

Protocol description

To accommodate diverse customer requirements, the TF03 series allows users to configure operational parameters such as data format, frame rate, and more via command settings. Always strictly follow the instructions in this manual for product configuration and avoid sending undeclared commands.

TF03 Series Command Protocol Format

Data Byte	Definition	Description
Byte 0	Header	Fixed value: 0x5A (hexadecimal).
Byte 1	Len	Total length of the command frame in bytes
Byte 2	ID	Command identifier (unique for each function).
Byte 3~N-2	Payload	Command-specific parameters (variable length and interpretation).
Byte N-1	Check Sum	Lower 8 bits of the sum of the first Len-1 bytes

Common configuration instructions

TTF03 RS485, RS232 Command Protocol List

Description	Downstream	Upstream	Explanation	Default Value
Get Firmware Version	5A 04 01 5F	5A 07 01 VA VB VC SU	Version is VC.VB.VA	/
System Reset	5A 04 02 60	5A 05 02 00 61	/	/
Modify Frame Rate	5A 06 03 LL HH SU	Original Command	LL: Frame Rate Low Byte, HH: Frame Rate High Byte	/
Enable Command Trigger Mode	5A 05 07 00 66	Original Command	/	/
Single Measurement Trigger	5A 04 04 62	Data Frame	Only effective in Command Trigger Mode	/
Modify Baud Rate	5A 08 06 H1 H2 H3 H4 SU	Same as Downstream		115200
Output Enable	ON: 5A 05 07 01 67 OFF: 5A 05 07 00 66	Original Command		Enabled
Save Settings	5A 04 11 6F	Original Command		/
Restore Factory Settings	5A 04 10 6E	Original Command		/
Modbus Protocol Enable	5A 05 6F 00 CE	5A 05 6F 00 CE	/	Disabled
Modbus Device Address	5A 05 70 ADDR SU	5A 05 70 00 CF	ADDR: Modbus device address	0x01

TF03 CAN Command Protocol List

Description	Downstream	Upstream	Explanation	Default Value
Switch Communication Interface	TTL: 5A 05 45 01 A5 CAN: 5A 05 45 02 A6	5A 05 45 00 A4	Takes effect after restart	TTL
Configure Out-of-Range Value	5A 06 4F LL HH SU	5A 05 4F 00 AE	Out-of-range value = (HH << 8) + LL, unit: cm	18000

Configure CAN Transmit ID	5A 08 50 H1 H2 H3 H4 SU	5A 05 50 00 AF	ID = (H4<<24) + (H3<<16) + (H2<<8) + H1 Effective under CAN interface	0x03
Configure CAN Receive ID	5A 08 51 H1 H2 H3 H4 SU	5A 05 51 00 B0	ID = (H4<<24) + (H3<<16) + (H2<<8) + H1 Effective under CAN interface	0x03
Configure CAN Baud Rate	5A 08 52 H1 H2 H3 H4 SU	5A 05 52 00 B1	Baudrate = (H4<<24) + (H3<<16) + (H2<<8) + H1 Effective under CAN interface	1M
CAN Frame Type Setting	Standard Frame: 5A 05 5D 00 BC Extended Frame: 5A 05 5D 01 BD	5A 05 5D 00 BC		Standard Frame
DroneCAN Enable	Enable: 5A 05 84 00 E3 Disable: 5A 05 84 01 E4	5A 05 84 00 E3		Disabled
Configure Offset	5A 06 69 LL HH SU	5A 05 69 00 C8	Offset = (HH << 8) + LL, unit: cm	0
Set CAN Termination Resistor Switch	ON: 5A 05 91 01 F1 OFF: 5A 05 91 00 F0	5A 05 91 00 F0		Off
Enable Low Power Mode	5A 05 83 01 E3	Original Command	Only effective under UART interface	/
Disable Low Power Mode	5A 05 83 00 E2	Original Command	Only effective under UART interface	/

Note: After using configuration commands to change one or more product parameters, please send the "Save Current Settings" command to write the changed parameters to the product. Otherwise, the parameters will revert to the last saved values after power cycling.

Command editing

This section describes the Command Channel of TF03 which is used to read and set TF03's working parameters. The command channel is available via all the interfaces.
A standard TF03 command consists of frame header, command length, command ID, parameters and checksum. Follow these steps to generate a command:

1. Choose the right command ID and confirm its length
2. Convert parameter from the decimal value to hexadecimal value
3. Fill the hexadecimal parameter into the command
4. Calculate the checksum and fill its low 8-bits into the command

Example: Setting Baud Rate to 460800

1. Identify Command ID and Length
   Assume the command ID is 0x06 and total length is 8 bytes (including header and checksum).

2. Convert 460800 to Hexadecimal
   460800 → 0x00 07 08 00 (hex, little-endian).

3. Construct the Command Frame

Header	Len	ID	Param 1	Param 2	Param 3	Param 4	Checksum
0x5A	0x08	0x06	0x00	0x08	0x07	0x00	

4. Calculate Checksum
   Sum: 0x5A + 0x08 + 0x06 + 0x00 + 0x08 + 0x07 + 0x00 = 0x77 (lower 8 bits).
   Final Command: 0x5A 0x08 0x06 0x00 0x08 0x07 0x00 0x77