



# XT-S1

## Distance Range Finder

### Product Manual 2023-10





# About Manual

## ■ Using Tips

- Please be sure to read the manual carefully before use the product, and operate the product following the instruction to avoid product damage, damage to other property, personal injury or violation of warranty terms.
- This manual does not contain the product authentication information, please check the authentication information at the bottom of the product brand, and query the corresponding certification reminder.
- If this laser radar products as part of your product, please provide this manual to your product expectation users, or provide the acquiring method of the manual.

## ■ Access

Please acquire the latest version of manual through the following ways:

- Contact sales staff or corresponding sales channel staff of Toffuture
- Contact technical support of Toffuture: [info@toffuture.com](mailto:info@toffuture.com)

## ■ Technical Support

If the manual can't solve problems, please contact us through the following way:

[info@toffuture.com](mailto:info@toffuture.com)

## ■ Legend


Warning: be sure to follow the safety instructions or the correct operation method.

Attention: supplementary information, for better usage of the product



## Safety Warning

### ■ Laser Safety

	Laser Safety
	<p>This product will emit the invisible laser during operation, please avoid eye damage during operation.</p> <p>This product <b>is not Class1 laser safety product</b>, The laser emitted from the product might damage human eye or body.</p> <p>Please use this product correctly! Avoid directly looking at laser radar at close range.</p>

**Attention:** This product is not Class1 laser safety product, please pay attention to the human eye safety during product operation.

### ■ Abnormal Stop

If any of the following circumstances occur, please immediately stop using the product:

- Suspect product failure or damage, for example, the product have obvious noise, smell or smoke
- User or people around feel any discomfort of themselves
- Abnormal running equipment in the surrounding environment

And contact the Toffuture or corresponding sales channel staff of Toffuture for the damage product, please check the about manual chapter for the detail contact information.

### ■ Disassembly Prohibited

Without the written consent form from Toffutre, disassembly is explicitly prohibited of this product.



# Catalogue

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## Product Introduction

This product is the distance measurement module based on the TOF (Time Of Flight) concept, using 940nm VCSEL light source, combined with the unique optics, electronic, structure design, this product could meet the requirement of high speed, high accuracy distance measurement.

This product using the UART and IIC for the communication, and received the distance measurement information. And this product also support the IO mode, could be used for the target existence detection within certain range.

Because of the limit from the optical character, power and other parameters, the valid distance measurement range is maximum 30 m, minimum 30 cm for the 90% reflectance white paper target.

## 1 Product Parameter(T=25°C, VCC=+5V)

### 1.1 Basic Parameter Table

Parameter	Value
Product Name	XT-S1
Measurement Range	0.3 ~ 30m(indoor/outdoor@90%reflectance) <sup>①</sup>
	0.3 ~ 30m(indoor/outdoor@50%)reflectance
	0.3 ~ 24m(outdoor)/0.3~30mindoor@10%)reflectance
Voltage Range	4.8 ~ 5.2V
Module Measurement Mode	active continuous measurement <sup>②</sup> passive single measurement
Received Angle of Visual Field	half-angle: 1°
Transmitted Angle of Visual Field	half-angle: 2° <sup>③</sup>
Background Light	100kLux
Integration Time	20us ~ 2000us
Measurement Accuracy	30 ~ 250cm ±5cm
	250 ~ 3000cm ±2%
Noisy variation(1σ)	2cm
Infrared Light Source Centroid Wavelength	940nm
Module Size	Length 43mm Width 17.5mm Height 24mm
Working Temperature	-10°C ~ 60°C (non-condensation)
Preserve Temperature	-20°C ~ 70°C



Communication Protocol	UART、IIC、IO
Minimum Resolution	1cm
Measure Frequency	Max 50(Hz)
Weight	9g

Attention:

① : 0 ~ 0.3m is blind zone, using the measurement data is not recommended.

② : The default factory setting of measurement mode is passive signal measurement.

The distance measurement will be triggered after the host send out the measurement request command.

③ : The side length of facula that at 30 m is around 1m, if the target object is small, it will have the impact to the measurement result.

Distance: m	5	10	20	30
Facula Area Unit: m <sup>2</sup>	0.03	0.12	0.49	1.10

Distance and facula area relationship

If the target distance is far or the reflectance is low, the actual output frame rate will decrease due to the multi frame process within the module.

## 1.2 Electric Parameter Table

Parameter	Symbol	Typical Value	Unit
Input Voltage	DC	5	V
Average Current	I	100	mA
Average Power	P	400	mW
Peak Current	I <sub>max</sub>	500	mA
UART level	V <sub>TTL</sub>	3.3	V
IIC level	V <sub>TTL</sub>	3.3	V

## 1.3 Target Object Minimum Side Length and Target Object Distance Relationship

Target Object Distance/Unit: m	1	5	10	15	20
Target Object Minimum Side Length/Unit: cm	4	17	34	51	68



Attention: Normally the side length of target object should longer than the minimum length, then the output distance data is reliable;

When the side length of the target object is less than the minimum value, then the output distance data of module might have larger deviation.

## 1.4 Distance Measurement Mode

### **Active Continuous Measurement:**

The host set the module output frequency through the communication port, after the start of the measurement operation, module will start the continuous measurement with the fixed frequency. It will output the measurement result once a measurement is done, host will wait for the received result.

When there is no measurement, host will send the continuous measurement stop command, then the module will enter the idle state.

### **Passive Single Measurement:**

Host send out the measurement request command through the communication port, module will stop the measurement after it finish the measurement, and send out the measurement distance data.

## 1.5 Filter Mode Selection

For the measurement distance output of the module, customer could select different ways for different case.

Due to the filter algorithm, the output distance data will have certain deviation in time domain comparing to the real time measurement data value.

In order to get the higher respond speed, customer could remove the filter setting. The customer could process according to the measurement data .

When the filter is active of the module, we could improve the frame rate to decrease the output delay in time domain.

## 2 Interface and Function

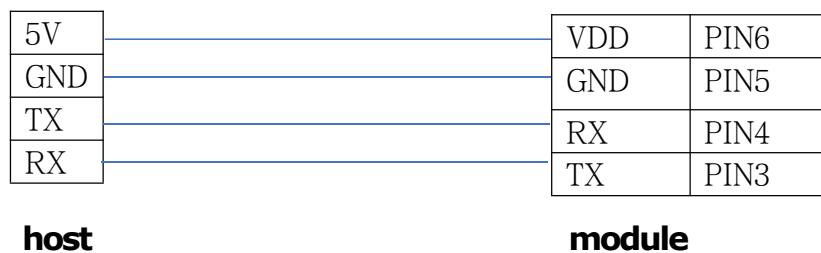




Pin NO	Definition	Function
6	VCC	5V power supply
5	GND	Ground
4	RX/SDA	In UART mode, is the Rx communication lane In IIC mode, is the SDA communication lane
3	TX/SCL	In UART mode, is the Tx communication lane In IIC mode, is the SCL communication lane
2	GPIO/ DATA READY	Target detection switch When detect the object exist within the range, output high leve. If no object detected, output low level. In IIC mode, this PIN will be used as the interrupt notification.
1	Mode	Mode selection, different level for different communication mode selection 1: UART mode (default mode) 0: IIC mode

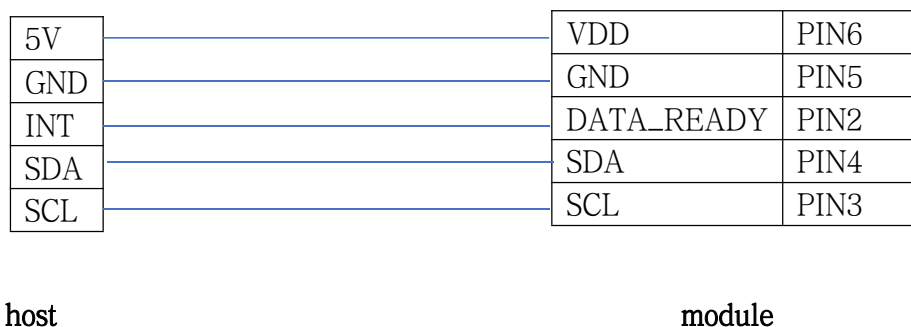
### 3 Typical Application Loop

#### 3.1 UART



Using the single power supply, and UART communication mode, there is pull-up resistances for TX/RX within the module, no need for extra circuit for host side.  
UART communication parameter, check chapter 4.1

#### 3.2 IIC





Using the single power supply, in IIC mode, DATA\_READY is the port indicate the terminal that module data is ready.

When the data is ready, this port will change from low level to high level.

The host side need to set to the receiver mode, or it might cause error.

For SDA/SCL communication lane, there are pull-up resistance, no need for extra circuit for host side.

For IIC communication parameter, please check chapter 4.2 and 4.7

## 4 Communication Protocol

### 4.1 UART Parameter

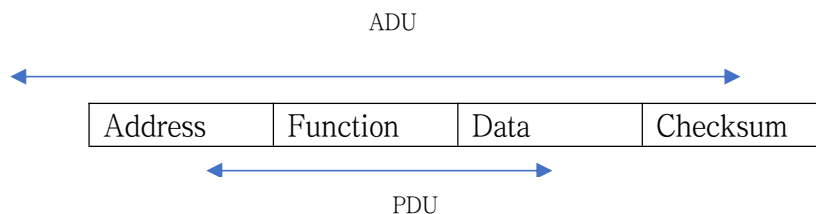
Parameter	Value	Unit	Comment
Baud Rate	115200	Bit/s	
Start Bit	1	Bit	low level
Stop Bit	1	Bit	
Data Bits	8	Bit	high level
Checksum Bit	None		

### 4.2 IIC Parameter

Parameter	Value	Unit
Master Slave mode	Slave mode	
Baud Rate	400K	Bps
Address	0x20	7bits

### 4.3 Communication Protocol (UART)

UART follow the Modbus protocol, support the module address change, easier for the multiple module communication.



One complete frame contain Address/function/data/checksum 4 parts.



The content of the data part is different according to the function part content.  
ADU has maximum 256 bytes length, the maximum length of PDU is 253 bytes.

#### 4.3.1 Functional Code Table

Functional Code	Name	Description
0x03	READ HOLDING REGISTER	reading the holding register
0x04	READ INPUT REGISTER	reading the input register
0x06	WRITE SINGLE REGISTER	write the single register
0x10	WRITE MULTIPLE REGISTER	write multiple register
0x17	READ/WRITE MULTIPLE REGISTERS	write multiple register and read multiple register

#### 4.3.2 Functional Code 0x03 Read Holding Register

- Master request

Functional code	1Byte	0x03
Start address	2Byte	-
Register number	2Byte	1~125(max)

- Slave Respond

Functional code	1Byte	0x03
Data length	1Byte	N * 2
Register value	N * 2Byte	

- Error Code

Functional code	1Byte	0x83
Error code	1Byte	

#### 4.3.3 Functional Code 0x04 Read Input Register

- Master Request

Functional code	1Byte	0x04
Start address	2Byte	-
Register number	2Byte	1~125(max)

- Slave Respond

Functional code	1Byte	0x04
Data length	1Byte	N * 2
Register value	N * 2Byte	

- Error Code

Functional code	1Byte	0x84
Error code	1Byte	

#### 4.3.4 Functional Code 0x06 Write Single Register

- Master Request

Functional code	1Byte	0x06
Register address	2Byte	



Register value	2Byte	
----------------	-------	--

- Slave Respond

Functional code	1Byte	0x06
Register address	2Byte	
Register value	2Byte	

- Error Code

Functional code	1Byte	0x86
Error code	1Byte	

#### 4.3.5 Functional Code 0x10 Write Multiple Register

- Master Request

Functional code	1Byte	0x10
Register start address	2Byte	-
Register number	2Byte	1~123(max)
Data length	2Byte	N * 2
Register value	N * 2 Byte	

- Slave Respond

Functional code	1Byte	0x10
Register start address	2Byte	
Register number	2Byte	1~123(max)

- Error Code

Functional code	1Byte	0x90
Error code	1Byte	

#### 4.3.6 Functional Code 0x17 Write Multiple Register, Read Back Multiple Register

- Master Request

Functional code	1Byte	0x17
Read start address	2Byte	-
read register length	2Byte	1~125(max)
Write start address	2Byte	
Write register length	2Byte	1~121
Write data length	1Byte	N * 2
Write register data	N * 2Byte	

- Slave Respond

Functional code	1Byte	0x17
Data length	1Byte	N * 2
Register value	N * 2Byte	

- Error Code

Functional code	1Byte	0x97
Error code	1Byte	



## 4.4 Register Map

### 4.4.1 Functional Description

IIC and Modbus communication interface share the same register list, which could achieve the unified control, outside interface control the module and acquire the data by read/write the register.

### 4.4.2 Register List

index	start address		function	comment	W/R	length
0	0	0x00	Distance measurement current selection	0x01 small current state 0x02 large current state Under auto intergration time, it will indicate the real current mode. Under fixed intergration time, start the measurement according to the set current, the module would not change the current selection.	W/R	2
1	2	0x02	Intergration time setting	0x00 auto intergraion time(default) 0x001~0xFFFFconfigurable intergarion time, us as the unit	W/R	2
2	4	0x04	module extra delay timing setting	low bit for DLL length setting, 0-49,defaule value 0 high bit for PLL length setting, 0-12, default value 0	W/R	2
3	6	0x06	Distance measurement command	0x00, ignore 0x01,start measurement,for single measurement, after the measurement is done, the register value will become 0x00. 0x02,stop measurement(for continuous measurement, set 0x02 for stop the measurement)	W/R	2
4	8	0x08	Chip register operation	0x00,no action 0x01,write register 0x02,read register During write operation, it will write register 9 data into chip register address which corresponding to the register 8. During read operation, it will read the data from address corresponding to the register 8, and read back the data to the register 9.	W/R	2
5	10	0x0A	Register address	low bytes for chip register address,0x00-0xFF. high bytes for chip register data.	W/R	2
6	12	0x0C	FLASH operation command	0x00,no action 0x01,wrtie RAM data into FLASH 0x02,read FLASH data back to RAM	W/R	2



7	14	0x0E	Register write protection	0x5AA5: register writeable, if not read-only register is not writeable	W/R	2
8	16	0x10	Reserve		W/R	16
16	32	0x20	System error code	0x00000001 : SPI communication error 0x00000002 : pixel saturation 0x00000004 : sample data beyond max value 0x00000008 : sample data below min value 0x00000010 : reserve 0x00000020 : signal too strong 0x00000040 : signal too weak 0x00000080 : reserve 0x00000100 : abnormal gray scale image 0x00000200 : abnormal temperature image 0x00000400 : abnormal TOF image 0x00000800 : no object detected, for max integration time, AMP still below min threshold value 0x00001000 : overexposure, for min integration time, AMP still beyond the max threshold value	R	4
22	44	0x2C	Current measurement integration time	For UFS mode, current integration time, us as the unit.	R	2
23	46	0x2E	Distance information	For UFS mode, current distance information, cm as the unit -1(65535): SPI communication error -2(65534): pixel saturation -3(65533): sample data beyond max value -4(65532): sample data below min value -5(65531): reserve -6(65530): signal too strong -7(65529): signal too weak -8(65528): reserve -9(65527): abnormal gray scale image -10(65526): abnormal temperature image	R	2



				-11(65525): abnormal TOF image -12(65524): no object detected, for max intergration time, AMP still below min threshold value -13: overexposure, for min intergration time, AMP still beyond the max threshold value		
24	48	0x30	Tempreture	0.1° as the unit	R	2

index	start address		function	comment	R/W	length
25	50	0x32	Signal Amplitude	for UFS mode, signal amplitude of current measurement, LSB as the unit.	R	2
26	52	0x34	Backgroun d Light	for UFS mode, background light amplitude of current measurement, LSB as the unit.	R	2
59	118	0x76	wafer ID	EPC611 chip, WaferID	R	2
60	120	0x78	chip ID	EPC611 chip, CHIP ID	R	2
61	122	0x7A	Serial Output	0: respond according to the command 1: output data automatically output format : 01 04 04 00 82 10 a2 d7 d5 00 82 as the distance data, 10 a2 as the tempreture data	R	2

index	start address		function	comment	R/W	length
64	128	0x80	IICaddress+ UARTaddr ess	low byte for IIC address, default 0X20. high byte for modbus address, default 0x01	W/R	2
65	130	0x82	module operation mode	low byte 0x00, filter disable(default) 0x01,median filter high byte 0x00,passive measurement, process one measurement after recevied the master distance measurement request, then enter the idle state(default) 0x01,active measurement, continuous measurement according to the	W/R	2



				measurement period, and send out the result.		
66	132	0x84	Continuous measurement period	During the active measurement mode, start the measurement following the measurement period value(this register value), ms as the unit.	W/R	2
86	172	0xAC	AMP value of UFS mode	For UFS mode, the threshold value for the valid data, only when AMP is larger than threshold value, the measurement distance is valid.		2
87	174	0xAE	Best AMP value for UFS mode	For UFS mode, change the intergration time to make the AMP value stay in the suitable zone		2

index	start address		function	comment	R/W	length
304	608	0x260	Factory Code	The SN code wirtten into the chip	R	16
312	624	0x270	Reserve		R	12
318	636	0x27C	Customer Code	Low byte for different customer 0x00-0xFF high byte reserve	R	2
319	638	0x27E	main version number+secondary version number	Low byte for the software main version 0x00-0xFF High byte for the software secondary version 0x00-0xFF	R	2

## 4.5 IIC Communication

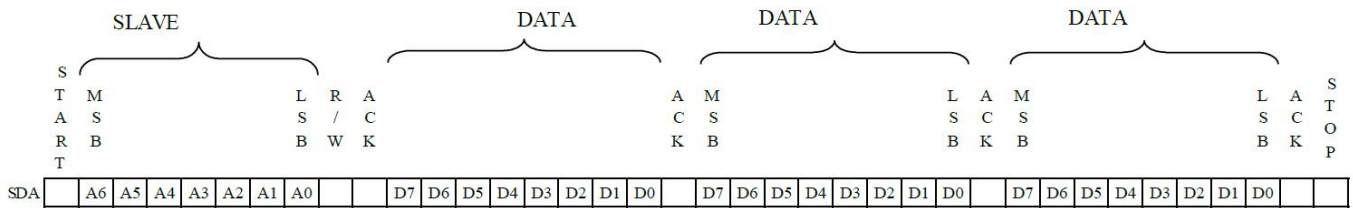
### 4.5.1 Interface Parameter

Parameter	Value
IIC speed	100 kbps



IIC level	hardware pull-up(VCC)
default communication address	0x20(7bit)

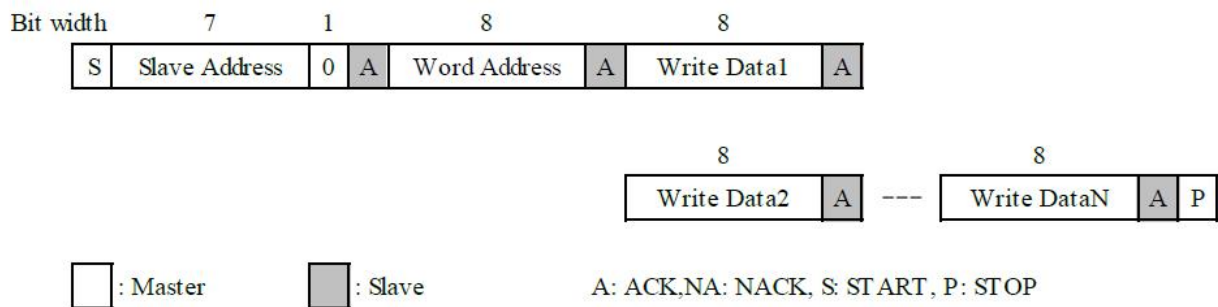
Basic communication format can be found at below figure



#### 4.5.2 IIC Write Data

IIC write data format is below, support single data write or multiple data write, every register contain 2 Byte data, in total 16 bits.

When the address match, the sensor and host will start the handshake, send the ACK respond every time after received the data.



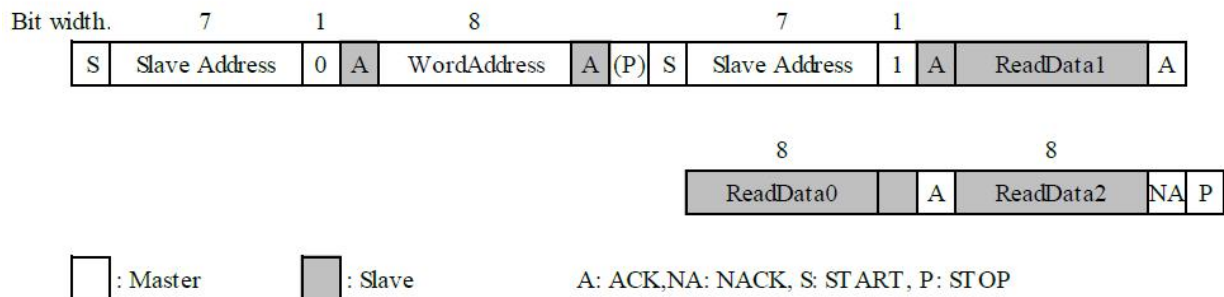
□ : Master

■ : Slave

A: ACK, NA: NACK, S: START, P: STOP

#### 4.5.3 IIC Read Data

Every time when reading the register, set the register address firstly, then start the read operation. Master will respond the sensor data, if keep read operation, respond with ACK, if stop read operation, respond with NACK.



□ : Master

■ : Slave

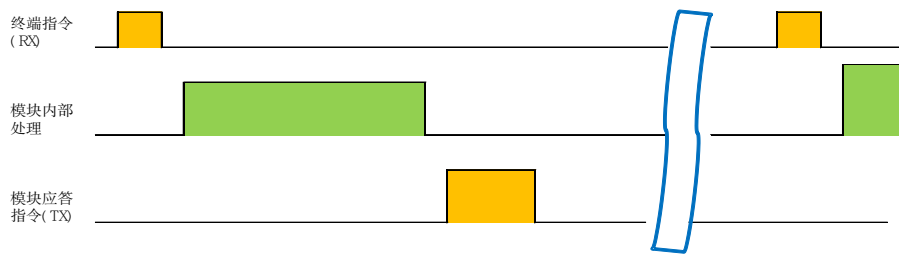
A: ACK, NA: NACK, S: START, P: STOP

#### 4.6 Communication Timing

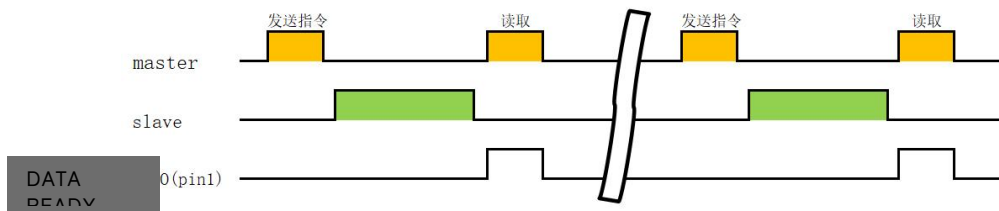
When host request the distance measurement through UART or IIC, check below figure for the timing of the host request command and module respond command.



## 1) UART Timing



## 2) IIC Timing



Comment:

When IIC read the measurement data, after the module measurement finished, PIN5 will be pull up from low to high, which will indicate the host to start data reading. After the data reading finished, PIN5 will be pull down from high to low. As the result, please use this port and host will be set to read state or external trigger mode for IIC communication.

### 4.7 UART measurment output data

- **Auto continuous mode: default mode after power on**

reference data 01 04 04 08 02 0f 79 9c 36

01	04 04	08 02	0f 79	9c 36
Device 1	Fixed	Distance0x0802 = 2050mm	Temperature 0x0f79=39.61℃	CRC value previous 7 bytes

- **Active read:**

Active read command to read register data, for detail register map check chapter 4.4 Register Map

#### 1. Read all registers related to the measurement result



Sent out command data 01 04 00 12 00 09 90 09, last 2 bytes are CRC value

Which means the 9 registers data starting from the index18 (0x12=18), 2bytes data for each register data, in total 18 bytes register data.

Reference data 01 04 12 10 45 08 f9 ef f4 f7 80 00 5c 08 46 0f 57 12 5e 00 1a ff 90

01	04	12	10 45 08 f9 ef f4 f7 80	00 5c	08 46	0f 57	12 5e	00 1a
Device 1	Read operation	Data length 18 bytes	Internal data	Integration time	Distance 2118mm	Temperature	Signal amplitude	Internal data

Some of the registers is not for customer, we could reduce the length of the readout register

## 2. Only readout distance, temperature and signal amplitude registers

Sent out command data 01 04 00 17 00 03 00 0f, read 3 registers data starting from register 23

Reference data 01 04 06 08 46 0f 57 12 5e d7 88

01	04	06	08 46	0f 57	12 5e
Device 1	Read operation	Data length 6 bytes	Distance 2118mm	Temperature	Signal amplitude

## 3. Common command data

Set measurement period 50ms: 01 06 00 42 00 32 a8 0b  
Set active reporting: 01 06 00 3d 00 01 d9 c6  
Set passive read mode: 01 06 00 3d 00 00 18 06  
Start measurement command: 01 06 00 03 00 01 b8 0a  
Stop measurement command: 01 06 00 03 00 02 f8 0b

## 4. CRC16 algorithm code

```
uint16_t crc16(const std::vector<uint8_t> data)
{
    std::uint16_t crc = 0xFFFF;
    for (std::size_t i = 0; i < data.size(); ++i)
    {
        crc ^= static_cast<std::uint16_t>(data[i]);
        for (std::size_t j = 0; j < 8; ++j)
        {
            if (crc & 0x0001)
                crc = (crc >> 1) ^ 0xA001;
            else
                crc >>= 1;
        }
    }
}
```



```
    return crc;  
}
```

## 4.8 Noise and Filter

This module is based on the 3D TOF concept for the distance measurement. The distance noise is related to the target object shape and depth, which known as the time noise, it will change for every measurement. Since this noise is statistical data, which could be reduced by the filter. The module output the measurement result without any filter algorithm as the factory default setting to make sure the quick dynamic measurement respond.

## 5 Attention

To avoid the damage to the product, carefully operate the module

Avoid drop or impact to the product, and take action for the ESD and dust protection during storage, processing, assembling and test stage.

### Version History

Version	Comment	Data
V1.0	Initial version	20230117
V1.1	Update and fix: Register	20230510
V1.2	Add new function	20230621
V1.3	Add “UART measurement data ”	20231017