Benewake

TF-NOVA User Manual

This user manual is only applicable to TF-NOVA prototypes between October 1st and November 15th, 2024

Preface

This user manual contains the introduction, use and maintenance of TF-NOVA 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 TF-NOVA product is constantly being improved, and its specifications and parameters will undergo iterative changes. Please refer to the official website for latest version.

Contents

1 Laser Safety Information

The LiDAR contains IR and visible 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

This chapter mainly introduces the measuring principle, technical specifications, structural description, equipment coordinates and field of view distribution of the TF-NOVA LiDAR.

3.1 Measuring principle

TF-NOVA is a typical Pulse Time of Flight (PToF) sensor. TF-NOVA 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 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 TF-NOVA and the measured target can be calculated through the speed of light.

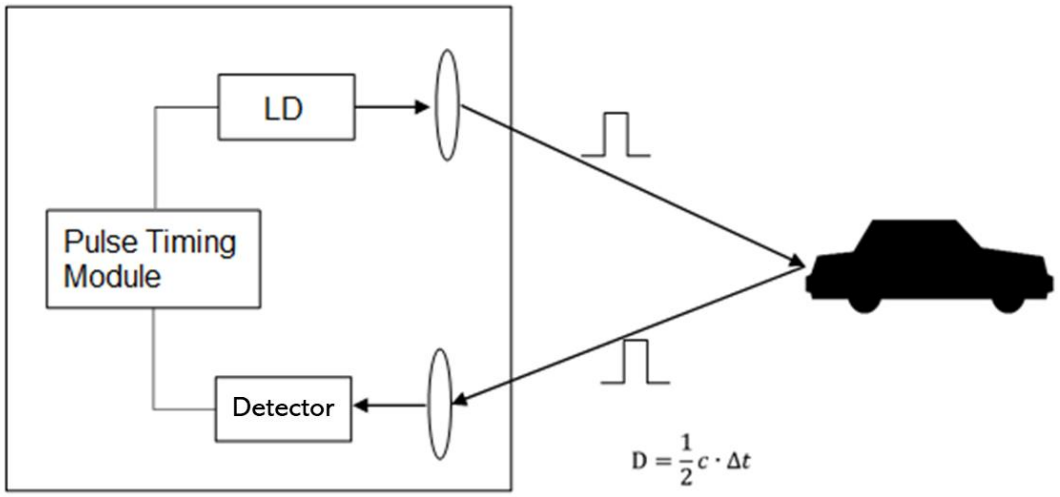

Figure. 1: Pulsed time of flight

3.2 Technical Specifications

Table. 1: Specification

Performance Parameter	
Detection range①	≥3m @3%reflectivity, 0Klux ≥7m @10% reflectivity, 0Klux ≥2m @10% reflectivity, 100Klux
Blind zone	≤ 0.1m
Accuracy②	±3cm @ 0.1-4m
Repeatability	1cm (1 sigma)
Distance resolution	1cm
Default frame rate	Default 100Hz, 1-500Hz customizable
Laser Parameters	
Light source	VCSEL
Central wavelength	905nm
FoV	Typ. 14°×1°
Eye safety	Class 1 Eye-safe[EN60825] (Design assurance, the current prototype has not yet obtained third-party
Mechanical/Electrical	
Average power	TBD
Peak current	TBD
Power supply	DC 5±10%V
Operating temperature	-25℃ ~ +70℃
Storage temperature	-30℃ ~ +80℃
Dimensions	TYP. 26.5x 21.05 x 12.0mm³
Weight	<5g
Connector	1.25mm-5P
Protection Level	N.A.
Cable length	10cm
Communication Protocol	
Communication Interface	UART, IIC, I/O
Baud rate	Default 115200
Data bit	8
Stop bit	1

Parity	None

NOTICE

① The measurement range is measured when all light spots are placed on the target board, at 25 ℃. Changes in conditions may cause variations in the measurement results.

② The accuracy is measured under the condition of 25 ℃, 0Klux and 10% reflectance background board, and changes in conditions may cause changes in the measurement results.

3.3 Structural Appearance

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

Figure. 2: TF-NOVA Appearance

3.4 FoV

The FoV (field of view) is the angle covered by the LiDAR sensor. The horizontal FoV is 14° and the vertical FoV is 1°.

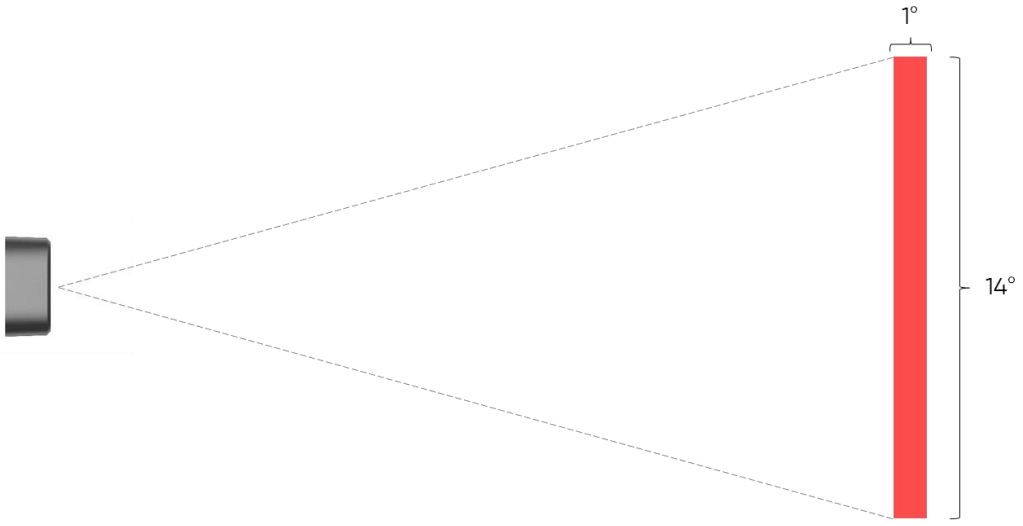

Figure. 3: FoV of TF-NOVA

NOTICE

14° and 1° are theoretic values. Because the manufacturing error and the installing error exist, there is divergence between actual and theoretic values.

4 Device Installation

This section introduces the mechanical installation and connection information of TF-NOVA LiDAR.

4.1 Mechanical installation

As shown in the following figure. TF-NOVA has 2 installation positioning holes available for use.

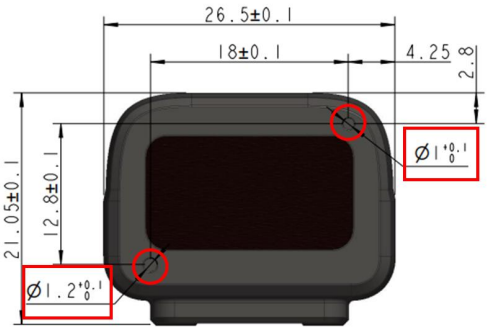

Figure. 4: Diagram of TF-NOVA installation hole

4.2 Connector

The connector is 1.25mm-5P, appearance and definition are shown as below:

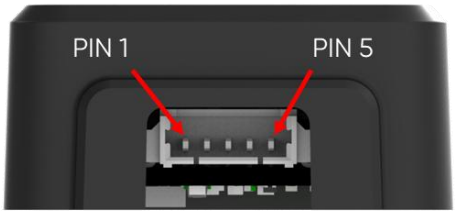

Figure. 5: LiDAR connector appearance

Table. 2: Interface connector pin definitions

Pin number	Definition
PIN 1	VCC
PIN 2	GND
PIN 3	TXD(3.3V)/SDA
PIN 4	RXD(3.3V)/SCL
PIN 5	IO

5 Communication Protocol and data format

5.1 Serial Communication

To connect two devices for TTL communication, the TXD of the transmitter should be connected to the RXD of the receiver, and the TXD of the receiver should be connected to the RXD of the transmitter.

The LiDAR does not include a power switch. When power is supplied to the LiDAR, data will begin to be automatically transmitted.

Table. 3: Characteristics of UART Interface

Character	Value	Configurability
Baud rate	115200	Configurable
Data bit	8	Non-configurable
Stop bit	1	Non-configurable
Parity	None	Non-configurable

NOTE

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, TF-NOVA will set it to 115200.

Serial port output format:

9-byte/cm (Default)

Byte	0	1	2	3	4	5	6	7	8
Description	0x59	0x59	Dist_L	Dist_H	Peak_L	Peak_H	Temp	Confidence	Check_sum

Dist: cm

Peak: Signal strength

Temp: Chip Temperature ℃

Confidence: Confidence level 0-100

9-byte/cm

Byte	0	1	2	3	4	5	6	7	8
Description	0x59	0x59	Dist_L	Dist_H	Peak_L	Peak_H	Temp	Confidence	Check_sum

Dist :mm

Peak: Signal strength

Temp: Chip Temperature ℃

Confidence: Confidence level 0-100

5.2 I² C Communication

TF-NOVA supports up to 400kps clock speed as slave machine and its default address is 0x10. For more information about I² C register table refer to **Appendix I² C register table**.

Note: In this document, the address of I² C slave device is a 7-bit value with value range [0x08, 0x77] ([08, 119] in decimal). For the first byte after I² C releases a start signal, the 7-bit address should be shifted leftward for one bit (i.e. multiplied with 2), and then filled with the read-write sign on the lowest bit. For TF-NOVA, the default address of slave device is 0x10, the address for write operations is 0x20, and the address for read operations is 0x21.

Write register timing:

Start	Slave Addr	W	Ack	Register Addr	Ack	Data1	Ack	…	DataN	Ack	Stop

Read register timing:

Start	Slave Addr	W	Ack	Register Addr	Ack	Stop

Start	Slave Addr	R	Ack	Data1	Ack	…	DataN	Nack	Stop

Note that in the read register sequence, the host can directly generate the second Start signal without generating the first Stop signal. The last Nack can also be an Ack signal.

After a write operation on the I² C register, it takes TF-NOVA some time to process. If users need to read the value from the register for validation purposes, we recommend waiting for 100ms after the write operation, prior to the next read operation.

5.3 On/off Mode

On/off mode is designed from those users who only need to detect the existence of an object. TF-NOVA can start this mode using "**Enable/disable on-off mode ID_ON_OFF_MODE=0x3B**" and then shows result through pin 5. Figure 5 below shows how the mode works when a high level is set to represent an object is detected.

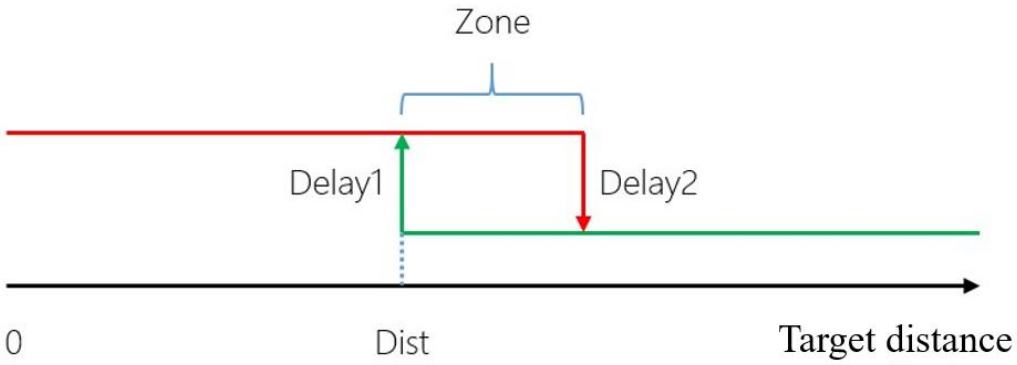

Figure 6 On/off mode that high level means closer

Zone value: If an object is detected closer than Dist, then Pin 5 outputs high-level, but only if an object is detected farther than Dist + Zone, then Pin 5 outputs low-level. When zone is set to 0, pin 5 may output up and down cause by fluctuation of the measuring when the real distance happens to be the same as Dist. That is why a proper zone value is needed to help avoid this situation by having a hysteretic interval.

Delay is also supported to avoid inaccurate jumping output. Pin 5 changes its output depends on the Dist value condition and the time it lasts. Delay1 (ms) and Delay2 (ms) determine how long that approaching changes and leaving changes should wait after Dist value is already over the line.

Note: Since the Dist value is set to 0 under factory setting when no object is detected and Amp is too low, then pin 6 may have false output in the on/off mode.

5.4 Serial communication commands

Some parameters in TF-NOVA can be customized by customers, such as data frame format, frame rate, etc., which can be changed by sending specific instructions. After successful configuration, all parameters will be saved in Flash and do not need to be reconfigured when powered on again.
When configuring parameters, please follow specific formats and rules to avoid sending commends not introduced below.

Byte	Definition	Description
Byte 0	Head	Fixed 0x5A
Byte 1	Length	The length of bytes from the head byte to check-sum
Byte 2	ID	Indicates how to parse the payload data
Byte 3~Byte N-2	Payload	Data segment, parsed based on ID, Little Endian Opt: Non 1 read/ 1. Write in
Byte N-1	Check sum	The lower 8 bytes of the sum from Head to Payload

5.4.1 Version information ID_GET_VERSION=0x01

Downward:

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

Upward:

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

Version: For instance, if the third, fourth, and fifth bytes are 112, 50, 9, then the version is 9.50.112.

Sample:

Command [5A 04 01 5F]

5.4.2 System software restore ID_SOFT_RESET=0x02

Downward:

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

Upward:

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

Status: 0 (success), otherwise (fail)

Note: Any change without "save current setting" instruction will not be saved and will restore to original setting.

Sample:

Command [5A 04 02 60]

5.4.3 Output frequency ID_SAMPLE_FREQ=0x03

Downward:

Byte	0	1	2	3~4	Len-1
Description	Head(0x5A)	Len	ID	FPS	Check_sum
Default				100	

Freq: The actual operating frequency achieved by the LiDAR.

Upward:

Byte	0	1	2	3~4	Len-1
Description	Head(0x5A)	Len	ID	FPS	Check_sum

Freq: The actual operating frequency achieved by the LiDAR.

Sample:

10Hz [5A 06 03 0A 00 6D]

5.4.4 Output format setting ID_OUTPUT_FORMAT=0x05

Downward:

Byte	0	1	2	3	Len-1
Description	Head(0x5A)	Len	ID	Format	Check_sum
Default				0x01	

Format: 0x01(9byte cm),0x06(9byte mm)

Upward:

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

Format: current output format setting

Sample:

9byt mm [5A 05 05 06 6A]

5.4.5 Baud rate setting ID_BAUD_RATE=0x06

Downward:

Byte	0	1	2	3~6	Len-1
Description	Head(0x5A)	Len	ID	Baudrate	Check_sum
Default				115200	

Baudrate: current baud rate.

Note: Configurable baud rate range [9600921600], effective after saving.

Upward:

Byte	0	1	2	3~6	7	Len-1
Description	Head(0x5A)	Len	ID	Baudrate	Status 0: success !0: fail	Check_sum

Sample:

9600 [5A 08 06 80 25 00 00 0D]

19200 [5A 08 06 00 4B 00 00 B3]

38400 [5A 08 06 00 96 00 00 FE]

57600 [5A 08 06 00 E1 00 00 49]

115200 [5A 08 06 00 C2 01 00 2B]

230400 [5A 08 06 00 84 03 00 EF]

460800 [5A 08 06 00 08 07 00 77]

921600 [5A 08 06 00 10 0E 00 86]

5.4.6 Enable/disable output ID_OUTPUT_EN=0x07

Downward:

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

Enable: 0 (disable),1 (enable).

Upward:

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

Sample:

Enable output [5A 05 07 01 67]

Disable output [5A 05 07 00 66]

5.4.7 Enable/disable checksum compariso

ID_FRAME_CHECKSUM_EN=0x08

Downward:

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

Enable: 0 (disable), 1 (enable)

Note: Even if the Downward data checksum comparison is disabled, the valid checksum is still included in the upward data frame.

Upward:

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

Sample:

Enable checksum comparison [5A 05 08 01 68]

Disable checksum comparison [5A 05 08 00 67]

5.4.8 Communication interface settings

ID_IF_PROTOCOL=0x0A

Downward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Opt	If_protocol	Check_sum
Default					!1	

Opt: !1:read, 1:write

If_protocol: !1:UART, 1:I² C

Upward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Status 0: success !0:fail	If_protocol	Check_sum

Sample:

Set to I² C [5A 06 0A 01 01 6C]

Note: Effective after saving

5.4.9 I² C slave machine address configuration ID_I² C_SLAVE_ADDR=0x0B

Downward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Opt	I² C_slave_addr	Check_sum
Default					0x10	

Opt: !1: read, 1:write

I² C_slave_addr: range[0x08, 0x77];

Upward:

Byte	0	1	2	3	4	Len-1
Description	Head(0x5A)	Len	ID	Status 0:success !0:fail	I² C_slave_addr	Check_sum

Sample:

Set to 0x20 [5A 05 0B 01 20 8B]

5.4.10 Restore default setting ID_RESTORE_DEFAULT=0x10

Downward:

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

Upward:

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

Status: 0(success), Non 0(fail).

Sample:

Command [5A 04 10 6E]

5.4.11 Save current setting ID_SAVE_SETTINGS=0x11

Downward:

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

Upward:

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

Status: 0 (success), Non 0 (fail).

Sample:

Command [5A 04 11 6F]

5.4.12 Distance limit setting rangeID_DIST_RANGE=0x3A

Downward:

Byte	0	1	2	3	4-5	6-7	Len-1
Description	Head(0x5A)	Len	ID	Opt	Min_dist	Max_dist	Check_sum
Default					0	65535	

Opt: !1:read, 1:write

Min_dist: minimum distance output in mm

Max_dist: maximum distance output in mm

Upward:

Byte	0	1	2	3	4-5	6-7	Len-1
Description	Head(0x5A)	Len	ID	Status	Dist_min	Dist_max	Check_sum

Status: 0 (success), Non 0 (fail).

Sample:

Output limit when out of range with the minimum set to be 200mm and the maximum set to be 5000mm [5A 09 3A 01 C8 00 88 13 01]

5.4.13 Enable/disable on-off mode ID_ON_OFF_MODE=0x3B

Downward:

Byte	0	1	2	3	44	5-6	7-8	9-10	11-12	Len-1
Description	Head(0x5A)	Len	ID	Opt	Mode	Dist	Zone	Delay1	Delay2	Check_sum
Default					0	0	0	0	0	

Opt:!1:read, 1:write

Mode: 0 (Normal output), 1 (On-off mode with high level output when closer) , 2 (On-off mode with low level output when closer)

Dist: critical dist value (the closer one) in centimeters.

Zone: Zone size in centimeters

Delay1: Delay time 1 in millisecond. Pin 6 switch level only if the distance detected is less than Dist and the situation last for Delay1 long.

Delay2: Delay time 2 in millisecond. Pin 6 switch level only if the distance detected is more than Dist + Zone and the situation last for Delay2 long.

Upward:

Byte	0	1	2	3	44	5-6	7-8	9-10	11-12	Len-1
Description	Head(0x5A)	Len	ID	Status	Mode	Dist	Zone	Delay1	Delay2	Check_sum

Sample:

Enable on-off mode with high level output when closer, and set Dist = 200cm, Zone=10cm, Delay1 = Delay2 = 1000ms: [5A 0E 3B 01 01 C8 00 0A 00 E8 03 E8 03 4D]

CAUTION

Do not send the command that is not in the list above.

Appendix I²C REGISTER TABLE

Address	R/W	Name	Initial Value	Description
0x00	R	DIST_LOW	--	cm
0x01	R	DIST_HIGH	--	
0x02	R	PEAK_LOW	--	
0x03	R	PEAK _HIGH	--	
0x04	R	TEMP_LOW	--	Unit: 0.01 Celsius
0x05	R	TEMP_HIGH	--	
0x06	R	TICK_LOW	--	Timestamp
0x07	R	TICK_HIGH	--	
0x08	R	ERROR_LOW	--	Error code
0x09	R	ERROR_HIGH	--	
0x0A	R	VERSION_REVISION	--	
0x0B	R	VERSION_MINOR	--	
0x0C	R	VERSION_MAJOR	--	
0x0D	W/R	IIC_SLAVE_IO_SPEED	0x00	0(2MHz),1(10MHz),2(50MHz)
0x0E	W/R	FITLER_DIST_LOW	--	distance filter threshold
0x0F	W/R	FILTER_DIST_HIGH	--	
0x10-0x1D	R	SN	--	Production code in 14 bytes ASCI code (0x10 is the first byte)
0x1E	W/R	IF_PROTOCOL	0x00	0x00: UART 0x01: IIC Save and restart to take effect
0x20	W	SAVE	--	Write 0x01 to save current setting
0x21	W	SHUTDOWN/REBOOT	--	Write 0x02 to reboot
0x22	W/R	SLAVE_ADDR	0x10	range: [0x08, 0x77]

0x25	W/R	ENABLE	0x01	0x00: Turn off LiDAR 0x01: Turn on LiDAR
0x26	W/R	FPS_LOW	0x64	Frame rate
0x27	W/R	FPS_HIGH	0x00	
0x29	W	RESTORE_FACTORY_DEFAULTS	--	Write 0x01 to restore factory default settings
0x2A	W/R	PEAK_THR_LOW	--	PEAK threshold
0x2B	W/R	PEAK_THR_HIGH	--	
0x2C	W/R	PEAK_THR_FILTER_LOW	--	PEAK threshold filtering
0x2D	W/R	PEAK_THR_FILTER_HIGH	--	
0x2E	W/R	MIN_DIST_LOW	0x00	Minimum dist in mm, but not working on DUMMY_DIST
0x2F	W/R	MIN_DIST_HIGH	0x00	
0x30	W/R	MAX_DIST_LOW	0xFF	Maximum dist in mm, but not working on DUMMY_DIST
0x31	W/R	MAX_DIST_HIGH	0xFF	
0x32	W/R	ON_OFF_MODE_DIST_LOW	0x00	ON_OFF mode related registers, please refer to: ON_OFF mode. Note that the distance unit in the IIC register is mm. Note: Minimum firmware version V1.3.19
0x33	W/R	ON_OFF_MODE_DIST_HIGH	0x00	

0x34	W/R	ON_OFF_MODE_ZONE_LOW	0x00	
0x35	W/R	ON_OFF_MODE_ZONE_HIGH	0x00	
0x36	W/R	ON_OFF_MODE_DELAY1_LOW	0x00	
0x37	W/R	ON_OFF_MODE_DELAY1_HIGH	0x00	
0x38	W/R	ON_OFF_MODE_DELAY2_LOW	0x00	
0x39	W/R	ON_OFF_MODE_DELAY2_HIGH	0x00	
0x3A	W/R	ON_OFF_MODE_EN	0x00	
0x3C-0x3F	R	SIGNATURE	--	'S' 'P' 'A' 'D'