ZC Sensor

ZCT1000ML-G01

LoRa Gateway

Datasheet

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ZCT1000ML-G01 LoRa Gateway Datasheet

1. Overview

Developed and produced by Shanghai Zhichuan Electronic Tech Co., Ltd., ZCT1000ML-G01 is a wireless gateway based on the latest LoRa technology. The gateway can automatically and timely collect and save tilt angle data from tiltmeters in the wireless network. The product supports RS-485 and Ethernet port, Modbus RTU, ASCII codes, TCP and, most importantly, FTP protocols. As a Modbus master and TCP client, it's able to work independently and automatically.

2. Product features

0.5W industrial class LoRa module
Signal coverage up to 3~5km (optimal)
Frequency bands can be preset and reset
Automatic and manual networking supportive
With user-friendly Ethernet port and USB port

3. Product application

Geotechnical monitoring
Structural health monitoring
Internet of Things

4. Technical parameters

(unless otherwise specified, the following are typical values at room temperature 25 ℃)

4.1 Working parameters

Parameters	Conditions	Minimum values	Typical values	Maximum values	Unit
Power supply	External power supply	12	24	30	V (DC)
Electrical current consumption	24V power supply, LoRa and 4G working		200	500	mA
	24V power supply, LoRa and 4G standby		80	120	mA
Network size(1)				246	pcs
Historical data storage	Built-in SD card			8	GB
Operating temperature	Without button cell	—40		85	Celcius
	With button cell(2)	-20		60	Celcius

range					
Dimensions	Aluminum alloy housing		123*120*50		mm

Note 1: The gateway supports up to 246 tiltmeters. When there are more tiltmeters in the network, the time for polling will be slower. It is recommended to add one or more gateways when polling becomes too low and to use different frequencies, and different network ID's for the tiltmeters and gateways that are working in the same area to avoid communications conflicts and confusion.

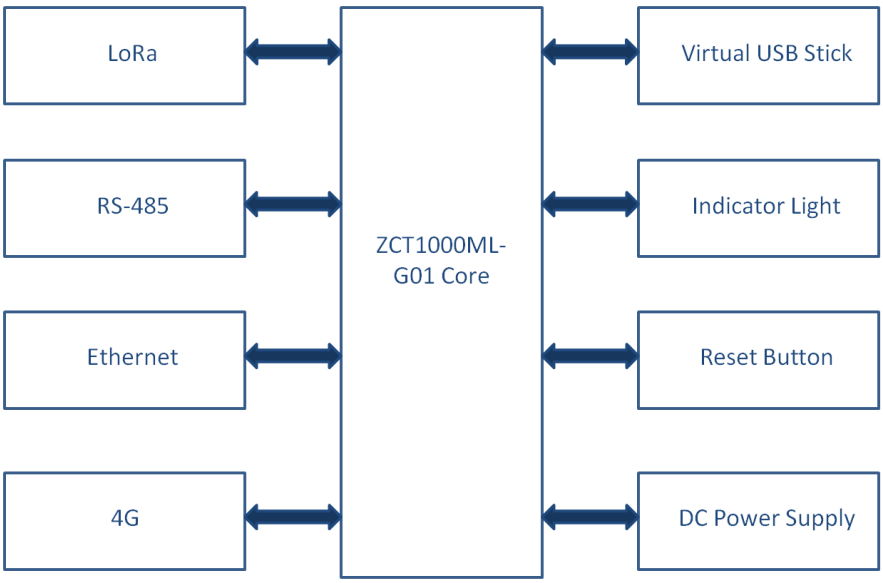
Note 2: The operating temperature range of the 3V button cell (CR1220) that powers the RTC chip is -20~60 ℃. Users may replace it with one that is able to work in a wider temperature range if such wider range is required for the product as a whole to work in.

4.2 LoRa technical specifications

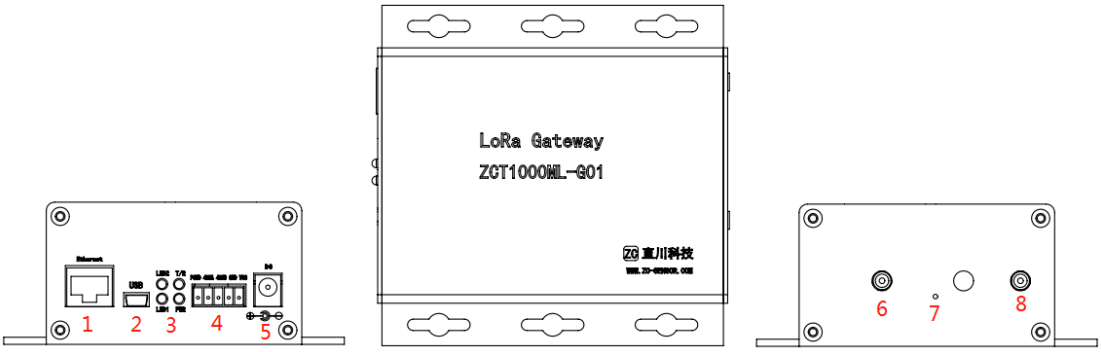
Parameters	Conditions	Minimum value	Typical value	Maximum Value	Unit
Transmitting power				27	dBm
Receiving sensitivity				-138	dBm
working frequency	433MHz band	420	433	510	MHz
	900MHz band	850	900	930	MHz
Maximum distance	Open space		3,000	5,000	m

5. Instructions for use:

5.1 Functional module diagram



5.2 Physical descriptions



No.	Name	Function
1	Ethernet port	For Ethernet cable, router with polarity automatic reversal recommended
2	USB port	USB virtual serial port used to configure the gateway, can be switched to virtual memory stick so historical data saved can be read
3	indicator light	4 indicator lights
4	RS-485 port	For power supply and RS-485 communication
5	DC power port	12~30V (12V 2A) power adapter to supply power to the gateway. Measurements of the DC plug is 5.5*2.1*10mm (outer diameter * inner diameter * length).
6	LoRa antenna port	Interface of external SMA antenna to the LoRa module
7	Reset button	For resetting the gateway
8	4G antenna port	Interface of external SMA antenna to the 4G module

Explanation on indicator lights:

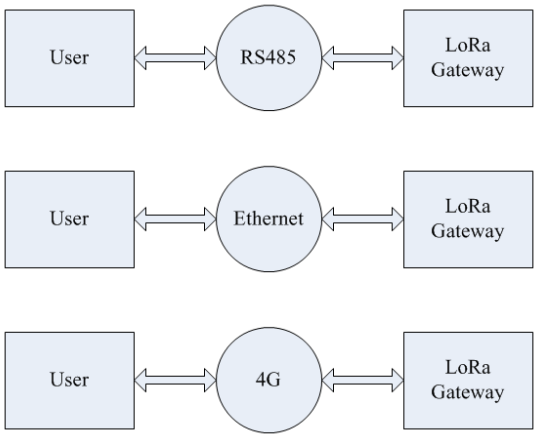
No.	What it means	What happens
1	power supply is normal	power light is on
2	LoRa module sends and/or receives data	TX/RX light is on during data transmission, and off at other times
3	LoRa module starts polling data	LED1 and T/R light turn on at the same time for 1s then goes off
4	LoRa module failed to read data	LED1 turns on for 1s then goes off
5	LoRa module failed to save data	LED2 turns on for 1s then goes off
6	LoRa node failure	LED2 truns on for 1s then goes off
7	Succeed/fail in turning on reset function	Press the reset button continuously ● for 1~2s, LED does not change / when releasing the button at this time, the reset function fails to start. ● for 3~9s, LED1 and LED2 turn on at the same time for 1s then go off / when releasing the button at this time, the reset function will be successfully started. ● for over 10s, LED1 and LED2 turn on for 1s then go off / when releasing the button at this time, the reset function fails to start.

Explanation on Ethernet port indicator:

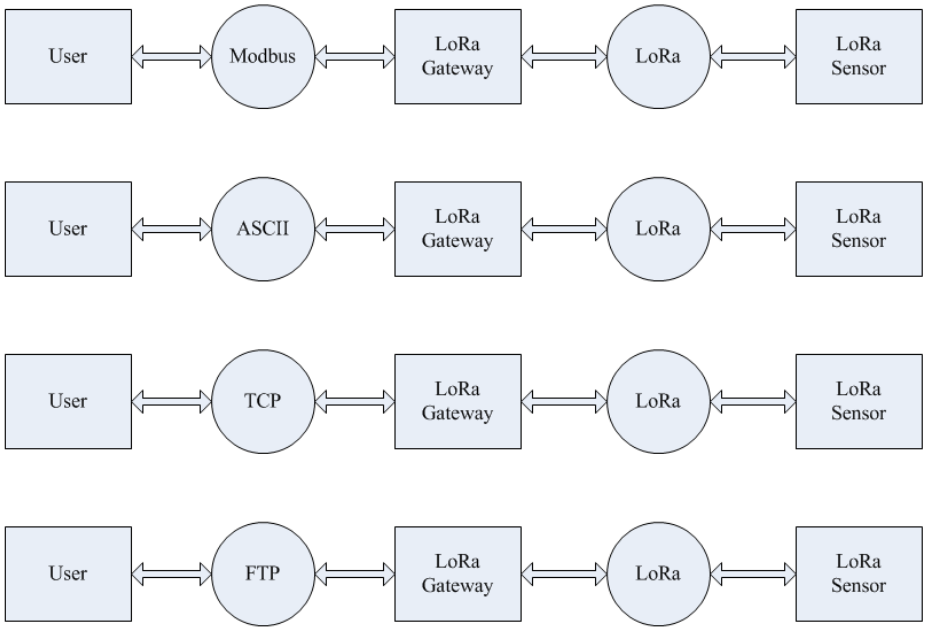
No.	What it means	What happens
1	Ethernet connection successful	yellow light keeps on
2	Ethernet connection failed	yellow light flashes
3	Sending and receiving data over Ethernet	green light flashes

5.3 Function introduction:

5.3.1 Hardware for the user to collect data



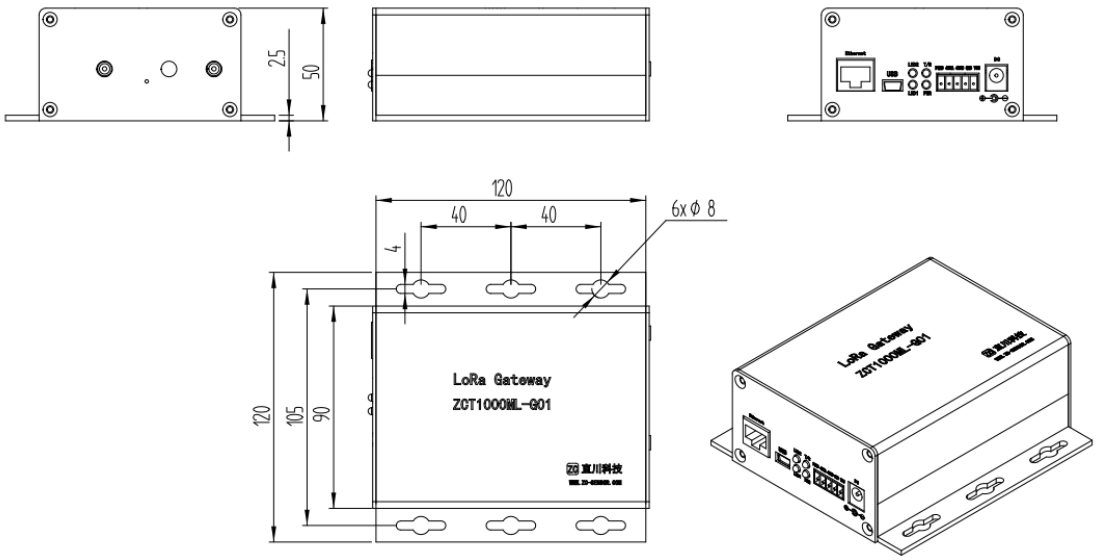
5.3.2 Protocols for the user to collect data



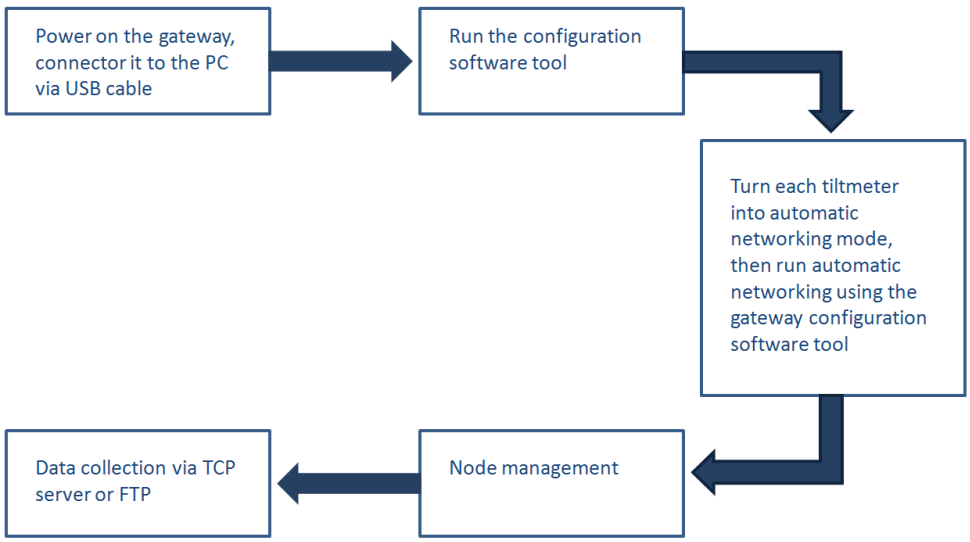
6. Pin definitions:

Pin No. →	PIN1	PIN2	PIN3	PIN4	PIN5
Definition	Positive pole of power supply	Negative pole of power supply	RS-485B	RS-485A	GND

7. Dimensions:



8. General configuration process



The above figure shows the general operating process for collecting data from the tiltmeters via the gateway. Please refer to "***ZCT1000ML High-accuracy Wireless Tilt Monitoring System Configuration Manual***" for details.

9. Frequently used ASCII commands

The ASCII commands are mainly used to configure the gateway and also to collect data from nodes. All the ASCII commands can be found in Appendix 1.

9.1 Command format

- All commands are capitalized.
- All commands end with carriage return (0x0D 0x0a).
- Command parameters written are placed in "()", and multiple parameters are separated by "," or ";".
- Symbols in all commands are in English (half width) format.
- All commands start with @. "R" as the second character indicates read command, while "W" indicates write. "\t" is a tab. "\tE" following the command (before the carriage return) indicates that the sensor is required to send the return value of the command. By contrast, without "\tE" following the command indicates that parameters are written to the sensor with no return value required. The latter case is used to broadcast and set parameters of multiple sensors in the networking mode of the gateway; after the setting, individual commands can be sent by the gateway to read the corresponding parameters of each sensor to confirm if the setting is successful.

9.2 Explanation on frequently used commands

9.2.1 Command for entering into RS-485 and USB virtual serial port configuration mode

00 06 00 0E DB DB F3 73 (hexadecimal command)

Send: 00 06 00 0E DB DB F3 73
Return: Configure mode!

By default, the RS-485 interface is ready to respond to Modbus RTU commands. After receiving the command and responding to it, the RS-485 interface enters configuration mode and the gateway can be configured by ASCII code commands.

The USB virtual serial port can be used for gateway configuration too. In fact it is for configuration purpose only and it does not support Modbus protocol. In order to avoid conflict with the RS-485 port, the USB port is required to receive the same command to enter configuration mode.

The following ASCII commands shall be followed by a carriage return to become effective.

9.2.2 Read gateway basic parameters command @RPRM

```
Send: @ RPRM
Return: general parameter:
Firmware Version: PG-936 V1.0
Series ID: 2006226022
RTC: 20-06-29-1 09:24:54
Power Voltage: 14.94V E
Temperature: 57.9℃

User Parameter:
Work Mode: 2 AutoSmp
Interval: 5
Starttime: 00-01-01-6 00:00:00
Overtime: 60
Modbus COM: 100 9600 N
Join net: 421.0 0 0 7 0 255
Data net: 496.0 0 4 7 255 1
LAN MAC: D8:80:39:66:FA:BE
LAN IP: 192,168,5,227
LAN SN: 255,255,255,0
LAN GW: 192,168,5,1
LAN DNS: 192,168,5,1
LAN DHCpm: DHCP
LAN NAME: 2006226022

LORA Parameter:
buad: 4 9600
parity: 0 N
freq: 8126484 496.000
frqcff: 7 128
mode: 1 C
frqwth: 7 125.0
nodeid: 104 104
netid: 1 1
power: 7 20
period: 4 10
breath: 4 32
```

9.2.3 Set gateway wireless data channel parameter command @ATJN(pm1,pm2,... pm7)

```
Send: @ATJN(1903073547,505.5,0,4,7,255)
Return: Set gateway data channel OK!
```

The command has 7 parameters. See Appendix 1 for definition of each parameter.

9.2.4 Set gateway basic parameters command @WGWB(pm1, pm2,... pm11)

```
Send: @WGWB(2006306001,1,0,0,0,246,12,0,19,0,3)
Return: @WGWB(2006306001,1,,,,246,12,0,19,0,)
```

There are 11 parameters in the command. See Appendix 1 for definition of each parameter.

9.2.5 Enable/disable gateway automatic networking command @ZDZW

```
Send: @ZDZW
Return (gateway not in automatic networking mode):
          Start automatic join network...
Return (gateway in automatic networking  mode):
          Stop automatic join network! ...
```

Before enabling gateway automatic networking, the user shall push the square micro-switch on the PCB of each tiltmeter so it enters automatic networking mode and waits for being included in the gateway network. This can be done one by one for the tiltmeters.

9.2.6 Read gateway network configuration list command @RNCF

```
Send: @RNCF
Return:
Modbus  LoRaID Enabled   Stutas RSSI   RefCNT SeriesID     Name
100     0      Enable    Online 0      1      2006226022   2006226022
102     102    Enable    Online 0      1      1907056002
104     104    Enable    Online 0      1      2005286006
Modbus size:  3   LoRa size:    2
```

The node with LoRa ID 0 is the gateway itself, and the others are the tiltmeters in the gateway network.

9.2.7 Manually add tiltmeter to gateway network command @WLID(pm1,pm2, pm3,pm4,pm5)

```
Send: @WLID(3,3,E,2004053333, ZC03)
Return: WLID# 3 3
```

The command has five parameters. See Appendix 1 for definition of each parameter.

9.2.8 Change tiltmeter wireless communication parameters (saved in the gateway) command @WNWC(pm1,pm2,... pm6,pm7)

Send: @WNWC(2,455.5,0,0,7,2,1)
Return when succeeding: OK

The command has seven parameters. The first parameter is the Modbus ID of the tiltmeter whose communication parameters are to be changed. See Appendix 1 for definition of the other parameters.

9.2.9 Delete network node command @CLID(pm1)

Send: @CLID(2)
Return: Net List: clear 101

The command has one parameter, which is the Modbus ID of the tiltmeter to be deleted.

9.2.10 Set TCP server IP, port and login frame parameters command, @WUPC(pm1,pm2)

To: @WUPC(101.224.201.29:5025,@LFRM:2006226022 2006226022)
Return: @WUPC(101.224.201.29:5025,@LFRM:2006226022 2006226022)

The login frame cannot be changed. Please keep it as the default value or leave it empty.

9.2.11 Set FTP server parameters command @WFTP(pm1,pm2,... pm6)

Send: @WFTP(47.101.212.93:21,/123,0,zcsenor,123456,0)
Return: @WFTP(47.101.212.93:21,/123,0,zcsenor,123456,0)

The command has six parameters. See Appendix 1 for definition of each parameter.

10. Commonly used Modbus commands

The gateway and the tiltmeters in the network can get access to data via RS-485 interface using extended Modbus protocol. The RS-485 port of the gateway will be in Modbus command mode by default after reboot, but it will not respond to Modbus commands during configuration operations. When the address in a Modbus command received by the gateway is the gateway's own address, the relevant parameters or data of the gateway will be returned. When the address in a Modbus command received by the gateway is the Modbus address of a tiltmeter in the gateway network, the data of the tiltmeter that have been collected and cached by the gateway will be returned. These cached data are collected and updated regularly at set interval. Data will not be collected or updated during power failure, and when power is resumed the value read out will be the default value. The default Modbus address of the gateway is 1 and can be changed as the user's wish. In

case of automatic networking, the Modbus address of the tiltmeters will start from gateway Modbus address + 1. In case of manual networking, the Modbus of the tiltmeters can be freely allocated by the user.

Modbus address is also called Modbus ID. Similarly, LoRa address is sometimes called LoRa ID.

10.1 Commonly used Modbus commands for gateway

All gateway Modbus commands can be found in Appendix 2.

10.1.1 Read gateway address command

```
Send command: 00 42 00 0D 00 01 CRC-low CRC-high
Return data: 01 42 02 01 01 CRC-low CRC-high
```

10.1.2 Read gateway power supply voltage command

```
Send command: 01 03 00 06 00 02 CRC-low CRC-high
Return data: 01 03 04 00 03 3C 00 CRC-low CRC-high
```

The voltage returned is 3.60V (voltage = [(0*100)+(0*16+3)+(3*16+12)/100]).

10.2 Commonly used Modbus commands for tiltmeter

See Appendix 3 for all the Modbus commands for tiltmeter.

10.2.1 Command to read X-axis angle

```
Send command: 02 03 00 00 02 CRC-low CRC-high
Return data: 02 03 04 00 03 3C 00 CRC-low CRC-high
```

The angle returned is 3.6000 degrees (angle value = [(-1)^(0)]*[(0*100)+(0*16+3)+(3*16+12)/100+(0*16+0)/10000]).

10.2.2 Command to read Y-axis angle

```
Send command: 02 03 00 02 00 02 CRC-low CRC-high
Return data: 02 03 04 10 03 3C 00 CRC-low CRC-high
```

The angle returned is -3.6000 degrees (angle value = [(-1)^(1)]*[(0*100)+(0*16+3)+(3*16+12)/100+(0*16+0)/10000]).

10.2.3 Read sensor temperature command

```
Send command: 02 03 00 04 00 02 CRC-low CRC-high
Return data: 02 03 04 00 03 3C 00 CRC-low CRC-high
```

The temperature returned is 3.60 degrees Celsius (temperature value = [(-1)^(0)]*[(0 * 100)+ (0*16+3)+(3*16+12)/100]).

10.2.4 Read power supply voltage command

```
Send command: 02 03 00 06 00 02 CRC-low CRC-high
Return data: 02 03 04 00 03 3C 00 CRC-low CRC-high
```

The voltage returned is 3.60V (voltage = [(0*100)+(0*16+3)+(3*16+12)/100]).

All the above return data can be obtained by sending a single command **02 03 00 00 00 08 CRC-low CRC-high**.

11. SMS setting commands

The SMS setting commands are used as a backup measure. When the IP address and port number of the TCP server and FTP server change, the relevant parameters of the gateway can be remotely configured through SMS to restore connection. This mode can only be used when 4G communication is adopted and a valid SIM card is inserted. The SMS setting commands are case sensitive, and the format is strictly required to be correct. Each punctuation must be correct, and the English half width format should be used. The maximum length of user name and password is 32 characters, and the path is not more than 128 characters. FTP user name and password shall be set together, they are case sensitive and cannot be empty, and only English letters and numbers are allowed. If the user name is set to anonymous (all lowercase letters), it is anonymous mode, and the password can be omitted (parsed as empty). For path, only English letters and numbers are allowed, and it is case sensitive. Punctuation or spaces are not allowed, while "/" can be used. The time needed for a reply from the gateway after a SMS command is sent depends on the working status of the 4G module. The shortest time can be about 30 seconds, and the longest time can be as long as 5-10 minutes.

11.1 Set TCP server address and port number: (ends with "/")

```
-SET-TCP/xxx.xxx.xxx.xxx:xxxxx/
-SET-TCP/192.168.5.25:5005/
```

11.2 Set FTP server address and port number: (ends with "/")

```
-SET-FTP/xxx.xxx.xxx.xxx:xxxxx/
-SET-FTP/192.168.1.1:21/
```

11.3 Set FTP user name and password: (ends with "/")

```
-SET-FTP/USR:xxxxxx/PSK:xxxxxx/
-SET-FTP/USR:ZCabCDe/PSK:12345ABc/
```

11.4 FTP address, port, user name and password set together: (ends with "/", address and port at the beginning, followed by user name and password)

```
-SET-FTP/192.168.1.1:21/USR:ZCabCDe/PSK:12345ABc/
```

11.5 Set FTP user path: (ends with "#")

```
-SET-PATH/zc/SYS/aaa#            after parsing: /zc/SYS/aaa
-SET-PATH/#                      after parsing: / (set FTP root path)
```

SMS reply format as follows:

```
Latest Config:
TCP:192.168.5.25:5005        (if the parameter exists in the SMS)
FTP:192.168.1.1:21           (if the parameter exists in the SMS)
User:ZCabCDe                 (if the parameter exists in the SMS)
Psk:12345ABc                 (if the parameter exists in the SMS)
Path:/ZC/sensorTilt/ABC      (if the parameter exists in the SMS)
```

12. Notice on placing orders

1] The product is equipped with an external LoRa sucker antenna, a 4G sucker antenna and a USB data cable.

2] Two types of LoRa module are used for production at the workshop: the lower frequency type (work frequency range: 420-510MHz) and the higher frequency type (work frequency range: 850-930MHz). Users need to decide on work frequency before placing an order. New frequency set must be within the same range of the old.

3] Users need to advise the country to use the product in, so the type of 4G module is known. Different countries may require different types of 4G module.

The information in the manual is for user's reference only. Shanghai Zhichuan Electronic Tech Co., Ltd. has the right to amend it without notice.

Appendix 1 ASCII commands

(carriage return is required after the command,

except for the command to enter configuration mode)

Command code	Effect	Parameters and parsing	Example	Remarks
00 06 00 0E DB DB F3 73 (Hex command)	Enter configuration mode via RS-485 or USB virtual serial port	-	Send HEX command "00 06 00 0E DB DB F3 73" via RS-485 port and the gateway enters configuration mode after responding.	Only when entering configuration mode can RS-485 port and USB virtual serial port respond to commands.
@RPRM	Read gateway basic parameters	-	Send "@RPRM", return parameter list	Read gateway basic parameters
@RNCF	Read network configuration list	-	Send "@RNCF", return network configuration	Read network configuration information
@RSSI	Read signal strength of last wireless communication	-	Send "@RSSI", return "RSSI# -101"	Read signal strength of last wireless communication (the strength value can only be obtained after communication for at least 2 times)
@RMBC	Read Modbus serial port setting	-	Send "@RMBC", return "MC# 3 9600 N"	Read Modbus serial port setting
@RCFG	Read gateway wireless module parameters	-	Send "@RCFG(pm1,pm2,...)", return the wireless module parameters	Read gateway wireless module parameters
@RRTC	Read gateway RTC time	-	Send "@RRTC", return "CT# 17-03-29-3 14:58:16"	Read current RTC info of gateway
@RINT	Read gateway automatic data collection interval	-	Send "@RINT", return "IT#2"	Valid in automatic data collection (AutoSmp) mode only
@RWTT	Read gateway run timeout	-	Send "@RWTT", return "WT#50"	Valid in sleep mode only
@RSTM	Read starting time of gateway's next data collection	-	Send "@RSTM", return "ST#1120"	Valid in automatic data collection (AutoSmp) mode only
@RWMD	Read gateway work mode	-	Send "@RWMD", return "WM#0"	2 = AutoSmp: automatic data collection mode, polling tiltmeters and saving angle data, passive communication; 0 = Normal: normal mode, passive communication
@WRTC(pm1,pm 2)	Write gateway RTC time	pm1: date, format 170209; pm2, time, format 110202	Send "@WRTC (170416,104130)", return "CT#170416 001041"	
@WINT (pm1,pm2)	Write gateway automatic data collection interval	pm1: hour; pm2: minute. The range of setting for this command is 1 minute to 23 hours 59 minutes.	Send "@WINT(00,02)", return "IT:0002"	Valid in automatic data collection (AutoSmp) mode only

@WSTM(pm1,pm2)	Write starting time of next gateway collection	pm1: hour; pm2: minute. The range of setting for this command is 0:0 ~ 23:59.	Send "@WSTM(11,02)", return "ST#1102"	Valid in automatic data collection (AutoSmp) mode only
@CECR	Reset node communication abnormal flag bit and count value	-	Send "@CECR", return "Error Counters: clear"	Reset node communication abnormal flag bit and count value
@WLID(pm1,pm2,pm3,pm4,pm5)	Write single node network logical ID	pm1: Modbus address, [1,247]; pm2: LoRa address, [1,247]; pm3: enable/disable data collection status {e, D} (optional / if not filled in, it is enabled by default); pm4: node serial number (optional / if not filled in, it is 0 by default); pm5: node name (optional; blank by default)	Send "@WLID(3,3)",return "WLID#33 Send "@WLID(3,3,D,2004053333,ZC03)", return "WLID# 3 3"	Write single node network logical ID
@CLID(pm1)	Delete network logical ID	pm1, Modbus address, [1,247], if it is 0XFF, delete all	Send "@CLID(255)", return "Net List: clear all"	Delete network logical ID
@WMBC(pm1,pm2,pm3)	Write gateway Modbus serial port setting	pm1, gateway Modbus address, [1,247]; pm2, baud rate, {4800,9600,19200}; pm3, parity, {N, O, E}	Send "@WMBC(3,9600,N)", return "MC# 3 9600 N"	Write gateway Modbus serial port setting
@SEND(prm1;prm2;prm3)	Read tiltmeter general command	pm1, LoRa address, [1,0xFFFF]; pm2, command code; pm3, when the command code is to write, E means return message required, no return message required for other value	Send "@SEND(3;@RAMD;)", return "AM@AB"	Read tiltmeter general command
@SCAN(prm1)	Polling tiltmeter general command	prm1, command code	Send "@SCAN(@RDAT)", return tiltmeter data	Polling tiltmeter general command
@EXIT	Exit configuration mode	-	Send "@EXIT", return "#EXIT"	Exit configuration mode
@ZDZW	Turn on/off automatic networking	-	After sending "@ZDZW" for the first time, the gateway will enter automatic networking mode. After automatic networking is successful, send "@ZDZW" again to exit automatic networking mode.	Each tiltmeter needs to enter automatic networking mode as well. This can be done by shorting the two pins of JI port on the tiltmeter PCB or pushing the square microswitch next to J1 for 3 seconds. When automatic networking is completed, the command must be sent again so the gateway exits automatic networking mode.

@ATJN(pm1,pm2,...pm7)\tE	Gateway wireless data channel parameter setting	pm1, gateway serial number; pm2, radio carrier frequency, [420,510] or [850,930]; pm3, power saving level [0,4]; pm4, wireless transmission speed [0,5]; pm5, wireless transmission power [1,7]; Pm6, LoRa ID, fixed to 0; pm7, LoRa Net (network) ID, [0,255]	Send "@ATJN (1903073547,505.5, 0,4,7,0,255)\tE"	Can use 0 for pm1 and pm6 , as the two parameters cannot be changed by users.
@RNWC(prm)	Read tiltmeter wireless communication parameters saved in the gateway	prm, tiltmeter Modbus address, [2,255], read wireless communication parameters of all the tiltmeters in the network	Send "@RNWC(2)" to read wireless communication parameters of the tiltmeter with Modbus address 2	Parameter is the Modbus address of the tiltmeter
@WNWC(pm1,pm2,...pm6, pm7)	Modify tiltmeter wireless communication parameters saved in the gateway	pm1, tiltmeter Modbus address; pm2, radio carrier frequency, [420,510] or [850,930]; pm3, power saving level [0,4]; pm4, wireless transmission speed [0,5]; pm5, wireless transmission power [1,7]; Pm6, LoRa ID, fixed to 0; pm7, LoRa Net (network) ID, [0,255]	Send "@WNWC (2,455.5,0,0,7,2,1)" command to modify wireless communication parameters of the tiltmeter with Modbus address 2; return "OK" after successful setting	The first parameter is the Modbus ID of the tiltmeter whose wireless communication parameters are to be modified, and the other parameter are the wireless communication parameters to be modified
@WFTP(pm1,pm2,...pm7)	Setting FTP parameters	pm1, FTP function enable switch: 0 = off, 1 = enabled; pm2, FTP server IP address and port, such as 192.168.1.1:21; pm3, storage path, such as /User_Path; pm4, 1 = anonymous FTP service, 0 = user name and password required for FTP server login; pm5, FTP server login user name, string; Pm6, FTP server login password, string; pm7, FTP work mode, 1 = active mode; 0 = passive mode	@WFTP(1,47.101.212.93:21,/,0,zcsensor,123456,0)	The storage path must be the full path and a path that has already been created. The default value "/" means that data is to be uploaded to the root directory of the FTP server
@RFTP	Read gateway FTP parameters	-	@RFTP(1,47.101.212.93:21,/,0,zcsensor,123456,0)	
@WGWB(pm1,pm2,...pm11)	Setting gateway basic working parameters	pm1: gateway name, string; pm2: gateway Modbus address; pm3: altitude; pm4: GPS longitude;	@WGWB(ZC01,1,0,0,0,246,0,5,16,45,3)	pm3, pm4, pm5 and pm11 are reserved for future use. They cannot be amended and must be fixed to the values in the instance.

		pm5: GPS latitude; pm6: number tiltmeter in the network; pm7: automatic data collection interval, hours; pm8: automatic data collection interval, minutes; pm9: automatic data collection start time, hour; pm10: automatic data collection start time, minutes; Pm11: repeating times of recollection after a data collection failure		
@RGWB	Read gateway basic working parameters	-	@RGWB(ZC01,1,,,,246,0,5,16,45,)	pm3, pm4, pm5 and pm11 are reserved for future use, so the readout is empty.
@WLNC(pm1,pm2,...pm5)	Write LAN port settings	pm1:0 = dynamic IP, 1 = static IP; pm2: local IP address; pm3: subnet mask; pm4: superior gateway (router) IP; pm5: DNS server IP	@WLNC(0,192.168.5.233,255.255.255.0,192.168.5.1,192.168.5.1)	
@RLNC	Read LAN port settings	-	@RLNC(1,192.168.5.233,255.255.255.0,192.168.5.1,192.168.5.1)	
@WUPC(pm1,pm2,pm3)	Set TCP server IP address and TCP login frame	pm1: enable/disable TCP server connection, 0 = disabled, 1 = enabled. pm2: TCP Server IP address and port; pm3: login frame	@WUPC(1,101.224.201.29:5025,@LFRM:2006226022 ZC01)	
@RUPC	Read TCP Server IP address and TCP login frame	-	@RUPC(1,101.224.201.29:5025,@LFRM:2006226022 ZC01)	
@WAPN(pm1,pm2,...pm5)	Setting 4G communications parameters	pm1: dialing number; pm2: APN; pm3: user name; pm4: password; pm5: mobile phone number		
@RAPN	Read 4G communications parameters	-	Send "@RAPN", return "@RAPN(18888888888,CMNET,,,18888888888)"	The return value in the instance is the default parameter, where APN user name and password are empty.
@FTPT	Test FTP function	-	Send "@FTPT", Return "@FTPT"	After the command is sent, the gateway will create a file "test.txt" on the FTP server.
@RSIT	Test RSSI signal strength	-		It is generally used to test signal strength after networking.
@STOP	Terminate operation triggered by LoRa commands (automatic data collection cannot be terminated)	-		Used to terminate LoRa operation while configuring or debugging the gateway

@STOP!	Terminate automatic data collection	-		Used to terminate LoRa operation during maintenance. Automatic data collection and saving to SD card will be stopped.
@GETL	Get status of LoRa operation	-		Used to check if there is LoRa operation going on while configuring or debugging the gateway.
@MNET	Query the relevant parameters of 4G module network access		Send "@MNET", return "@MNET (898604460918912730 12,863674040006585,460046670603012, FDD, LTE, LTE band 3,23)"	ICCID, IMEI, IMSI, NetType, BAND and CSQ can be queried, corresponding to the data separated by commas in the return value. If the return value shows all 6 data, 4G network access is successful.
@WRST	Restart the gateway	-		
@DBUG(prm)	Debug command	FAT_GTDINFO	Send "@DBUG(FAT_GTDINFO)"	Get disk information
		FAT_LTFILE(prm1)	Send "@DBUG(FAT_LTFILE(prm1))"	Read file directory
		FAT_RDFILE(prm1)	Send "@DBUG(FAT_RDFILE(prm1))"	Read file
		FAT_ERASE	Send "@DBUG(FAT_ERASE)"	Erase SPIFLASH
		FAT_FORMAT	Send "@DBUG (FAT_FORMAT)"	FATFS format

Appendix 2 Gateway Modbus register table and commands

1) Gateway Modbus register definition

In compliance with Modbus RTU protocol, default baud rate = 9600bps, check bit = none, data bit = 8, stop bit = 1

Register address	Data value name	Data type	Value range	Read/ write	Default value
0004H	Temperature - high	custom	range	R	0x00
0005H	Temperature - low	custom	range	R	0x00
0006H	Battery (power) voltage - high	custom	range	R	0x00
0007H	Battery (power) voltage - low	custom	range	R	0x00
0008H	Supply voltage identification	custom	0045 or 0049H	R	0x00
0009H	RTC time – high	custom	range	R/W	0x00
000AH	RTC time – middle	custom	range	R/W	0x00
000BH	RTC time – low	custom	range	R/W	0x00
000DH	Local address	int16U	1~247	R	0x01
000EH	Work mode	int16U	0~2	R/W	0x02
000FH	Data collection interval	custom	1~1439	R	0x3C
0010H	Sleep timeout	custom	1-300	R	0x3C
0018H	Reset node communication abnormal flag bit and count value	custom	0x00FF	W	0x0000

R = read only, W = write only, R/W = both readable and writable. Use 03H to read register, 06H to write register, 10H to write multiple registers and 42H to read local address.

2) Modbus function codes

2.1) 03H, read register value:

Request:

Device address	Function code	Register start address high byte	Register start address low byte	Register number high byte	Register number low byte	CRC check
1 byte	0x03	1 byte	1 byte	1 byte	1 byte	2 bytes

Response:

Device address	Function code	Number of bytes	Register value	CRC check
1 byte	0x03	1 byte	N*2 bytes	2 bytes

2.2) 06H, write single register:

Request:

Device address	Function code	Register start address high byte	Register start address low byte	Register value high byte	Low byte of register value	CRC check
1 byte	0x06	1 byte	1 byte	1 byte	1 byte	2 bytes

Response:

Device address	Function code	Register start address high byte	Register start address low byte	Register value high byte	Register value low byte	CRC check
1 byte	0x06	1 byte	1 byte	1 byte	1 byte	2 bytes

2.3) 10H, write multiple registers:

Request:

Device address	Function code	Register start address high byte	Register start address low byte	Register number high byte	Register number low byte	Number of bytes	Register value	CRC check
1 byte	0x10	1 byte	1 byte	1 byte	1 byte	1 byte	N*2 bytes	2 bytes

Device address	Function code	Register start address high byte	Register start address low byte	Register number high byte	Register number low byte	CRC check
1 byte	0x10	1 byte	1 byte	1 byte	1 byte	2 bytes

2.4) 42H, custom function code, read gateway local address register:

Request:

Broadcast address	Function code	Register start address high byte	Register start address low byte	Register number high byte	Register number low byte	CRC check
0x00	0x42	1 byte	1 byte	1 byte	1 byte	2 bytes

Response:

Broadcast address	Function code	Number of bytes	Register value	CRC check
0x00	0x42	1 byte	N*2 bytes	2 bytes

2.5) Abnormal response:

After receiving the complete information frame correctly, i.e. CRC, address and function code are correct, when illegal register address or illegal number of register or parameters being illegally written are detected, an exception code is returned.

Address code	Error code	Exception code	CRC check
1 byte	0x80 | function code	1 byte	2 bytes

3) Command details

Parsing and responding shall be based on below format. Note that 06H and 10H broadcasting command (no response) can be used for batch setting.

3.1) Read gateway temperature command:

Send command: 01 03 00 04 00 02 CRC-low CRC-high

Return data: 01 03 04 **00 03 3C** 00 CRC-low CRC-high

The returned temperature is 3.60 ℃ (temperature value = [(-1)^(**0**)]*[(**0***100)+(**0***16+**3**)+(**3***16+**12**)/100]).

3.2) Read gateway power supply voltage command:

Send command: 01 03 00 06 00 02 CRC-low CRC-high

Return data: 01 03 04 00 **03 3C** 00 CRC-low CRC-high

The returned voltage is 3.60v (voltage = [(**0***100)+(**0***16+**3**)+(**3***16+**12**)/100]).

3.3) Read the gateway power supply identification:

Send command: 01 03 00 08 00 01 CRC-low CRC-high

Return data: 01 03 02 **00 45** CRC-low CRC-high

Register **0x0045** means external power supply now, while **0x0049** means internal power supply now.

3.4) Read gateway RTC time:

Send command: 01 03 00 09 00 03 CRC-low CRC-high

Return data: 01 03 06 **11 04 10 0A 3B 00** CRC-low CRC-high

The returned time is 17-04-16 10:59:00 (year = (**1***16+**1**), month = (**0***16+**4**), day = (**1***16+**0**), hour = (**0***16+**10**), minute = (**3***16+**11**), second = (**0***16+**0**)).

3.5) Read gateway address command:

Send command: 00 42 00 0d 00 01 CRC-low CRC-high

Return data: 01 42 02 **01 01** CRC-low CRC-high

The returned address of the gateway is **0x01**.

3.6) Read gateway work mode command:

Send command: 01 03 00 0e 00 01 CRC-low CRC-high

Return data: 01 03 02 00 **00** CRC-low CRC-high

The returned work mode of the gateway is **0x00**, which means "Normal" mode.

3.7) Read gateway automatic data collection interval command:

Send command: 01 03 00 0f 00 01 CRC-low CRC-high

Return data: 01 03 02 **00 00** CRC-low CRC-high

The returned collection interval is 60 minutes (= (**0***16+**1**)*256+(**0***16+**0**)).

3.8) Read gateway timeout command:

Send command: 01 03 00 0f 00 01 CRC-low CRC-high

Return data: 01 03 02 **00 3C** CRC-low CRC-high

The returned timeout of the gateway is 60 seconds (= (**0***16+**0**)*256+(**3***16+**12**)).

3.9) Reset node communication abnormal flag bit and count value command:

Send command: 01 06 00 18 **00 FF** CRC-low CRC-high

Return data: 01 06 00 18 **00 FF** CRC-low CRC-high

This command will reset the node communication abnormal flag bit and count value.

Appendix 3 Tiltmeter Modbus register table and commands

1) Tiltmeter Modbus register definition

In compliance with Modbus RTU protocol, default baud rate = 9600bps, check bit = none, data bit = 8, stop bit = 1

Register address	Data value name	data type	Value range	Read/write	Default value
0000H	X-axis angle value - high	custom	range	R	-
0001H	X-axis angle value - low	custom	range	R	-
0002H	Y-axis angle value - high	custom	range	R	-
0003H	Y-axis angle value - low	custom	range	R	-
0004H	Sensor temperature - high	custom	range	R	-
0005H	Sensor temperature - low	custom	range	R	-
0006H	Battery (power) voltage - high	custom	range	R	-
0007H	Battery (power) voltage - low	custom	range	R	-
0008H	Supply voltage identification	custom	0045 or 0049H	R	-
0009H	RTC time - high	custom	range	R	-
000AH	RTC time middle	custom	range	R	-
000BH	RTC time - low	custom	range	R	-
000CH	Absolute or relative angle	int16U	0000~00FFH	R	-
000EH	Work mode	int16U	0-3	R	-
000FH	Sleep interval	custom	range	R	-
0010H	Sleep timeout	custom	range	R	-

R = read only, W = write only, R/W = both readable and writable. Use 03H to read the register. See below for other function codes.

2) Modbus Function codes

2.1) 03H, read register value:

Request:

Device address	Function code	Register start address high byte	Register start address low byte	Register number high byte	Register number low byte	CRC check
1 byte	0x03	1 byte	1 byte	1 byte	1 byte	2 bytes

Response:

Device address	Function code	Number of bytes	Register value	CRC check
1 byte	0x03	1 byte	N*2 bytes	2 bytes

2.2) 43H, read sensor real-time data:

Request:

Device address	Function code	Register start address high byte	Register start address low byte	Register number high byte	Register number low byte	CRC check
1 byte	0x43	1 byte	1 byte	1 byte	1 byte	2 bytes

Response:

Device address	Function code	Number of bytes	Register value	CRC check
1 byte	0x03	1 byte	N*2 bytes	2 bytes

43H is used to read real-time data. First the value stored in the register will be returned, then a wireless command is sent to communicate with the sensor. After a few seconds, the real-time data can be read using 03H. If the wireless communication is not yet finished and the data is not ready, an exception code of 0x06, which means busy, will be returned.

2.3) Abnormal response:

After receiving the complete information frame correctly, i.e. CRC, address and function code are correct, when illegal register address or illegal number of registers or parameters being illegally written are detected, an exception code is returned.

Address code	error code	Exception code	CRC check
1 byte	0x80 | function code	1 byte	2 bytes

3) Command details

Parsing and responding shall be based on below format.

3.1) Command to read X-axis angle data:

Send command: 02 03 00 00 02 CRC-low CRC-high

Return data: 02 03 04 **00 03 3C 00** CRC-low CRC-high

The angle returned is 3.6000 degree (angle value = [(- 1)^(**0**)]*[(**0***100)+(**0***16+**3**)+(**3***16+12)/100+(**0***16+**0**)/10000]).

3.2) Command to read Y-axis angle data:

Send command: 02 03 00 02 00 02 CRC-low CRC-high

Return data: 02 03 04 **10 03 3C 00** CRC-low CRC-high

The angle returned is -3.6000 degree (angle value = [(- 1)^(**1**)]*[(**0***100)+(**0***16+**3**)+(**3***16+**12**)/100+(**0***16+**0**)/10000]).

3.3) Read sensor temperature command:

Send command: 02 03 00 04 00 02 CRC-low CRC-high

Return data: 02 03 04 **00 03 3C** 00 CRC-low CRC-high

The returned temperature is 3.60 ℃ (temperature value = [(- 1)^(**0**)]*[(**0***100)+(**0***16+**3**)+(**3***16+**12**)/100]).

3.4) Read sensor power supply voltage command:

Send command: 02 03 00 06 00 02 CRC-low CRC-high

Return data: 02 03 04 00 **03 3C** 00 CRC-low CRC-high

The returned voltage is 3.60V (voltage = [(**0***100)+(**0***16+**3**)+(**3***16+**12**)/100]).

3.5) Read sensor power supply identification:

Send command: 02 03 00 08 00 01 CRC-low CRC-high

Return data: 02 03 02 **00 45** CRC-low CRC-high

Register value **0x0045** means external power supply now, while **0x0049** means internal power supply now.

3.6) Reading sensor RTC time:

Send command: 02 03 00 09 00 03 CRC-low CRC-high

Return data: 02 03 06 **11 04 10 0A 3B 00** CRC-low CRC-high

The returned time is 17-04-16 10:59:00 (year = (**1***16+**1**), month = (**0***16+**4**), day = (**1***16+**0**), hour = (**0***16+**10**), minute = (**3***16+**11**), second = (**0***16+**0**)).

The returned time may not be the real time, it may be the time of angle data collection. If you need to read the real time of the sensor, update the time using 43H function code and then read it using 03H.

3.7) Read absolute/relative angle output mode:

Send command: 02 03 00 0C 00 01 CRC-low CRC-high

Return data: 02 03 02 **00 FF** CRC-low CRC-high

The register value is **0x00FF**, indicating that the current angle output is relative angle.

3.8) Read work mode command:

Send command: 02 03 00 0e 00 01 CRC-low CRC-high

Return data: 02 03 02 00 **00** CRC-low CRC-high

The work mode returned is **0x00**, indicating that the work mode is "Normal" mode.

3.9) Read data collection interval command:

Send command: 02 03 00 0f 00 01 CRC-low CRC-high

Return data: 02 03 02 **00 3C** CRC-low CRC-high

The returned data collection interval is 60 minutes (= (**0***16+**0**)*256+(**3***16+**12**)).

3.10) Read timeout command:

Send command: 02 03 00 0f 00 01 CRC-low CRC-high

Return data: 02 03 02 **00 3C** CRC-low CRC-high

The returned timeout is 60 seconds (= (**0***16+**0**)*256+(**3***16+**12**)).