WI-SOS 480 WIRELESS TILT METER MODEL LS-G6-INC15

USER GUIDE V1.8
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CONTENTS

TABLES

1. DATALOGGER EQUIPMENT

Geosense wireless Tilt Meters/nodes are shipped with the following accessories:

- Data-Logger/Wireless tiltmeter (includes grounding connector)
- Antenna
- Antenna adapter

Not included:

- Horizontal/vertical support
- USB-OTG configuration cable
- Batteries
- Sensor surge protector
- Grounding rod

2. INTRODUCTION

This document describes WI-SOS 480 Tiltmeter model LS-G6-INC15 and details its installation and the basic procedure for data acquisition.

3. TILTMETER OVERVIEW

The WI-SOS 480 Tiltmeter is a low-power long-range wireless datalogger and inclinometer in a single compact box. It measures tilt in two (biaxial) perpendicular axes in the plane of the base with a highly precise MEMS sensor.

The tiltmeter can also be used as a standalone logger for manual monitoring and can be configured easily and connected with a USB cable and an Android phone.

It is designed for monitoring tilt in structures such as buildings, towers, monuments, bridges, tunnels, piles, walls, and dams. It can also be used to measure rock mass rotation or slopes.

The tiltmeter is composed of:

1. The casing

2. RP N Female connector, which complies with Federal Communications Commission (FCC) regulations, for the sensor network radio antenna

3. Pressure stabilizer for protection against condensation (protective vent)

4. Grounding

5. Connector male RP N to RP - SMA male and aerial with RP - SMA male.

Figure 1: LS-G6-INC15 elements

Figure 2: LS-G6-INC15 Antenna with N-connector

The wireless tiltmeter can also be provided with a more robust antenna, to be placed horizontally, instead of the standard L-antenna that is installed vertically. Please contact us with questions or for additional details.

4. TECHNICAL SPECIFICATIONS

SPECIFICATIONS	
SENSOR	
Type	MEMS (Micro-Electro-Mechanical) inclinometer
Range	$\pm 15^0$
Axes	Two (biaxial)
Accuracy ($\pm 5^0$)	0.03% FS / 0.004°
Accuracy full range	0.17% FS / 0.025°
Resolution	0.00°
Repeatability	0.005°
Temperature dependency	0.002°/°C
Time required for a reading	$\lessgtr$ 10 seconds
Temperature sensor resolution	0.1 °C
Temperature sensor accuracy	±0.5 °C
MEMORY	
Reading capacity	200,000 readings
ENVIRONMENTAL / MECHANICAL	
Box dimensions (W×L×H)	100×100×61 mm
Overall dimensions	150×120×61 mm (excluding antenna)
Operating temperature	-40 °C to 80 °C (-40 °F to 175 °F)
Weather protection	IP67
External antenna	100 mm length (including connector)
Box material	Aluminum alloy
Vibration resistance	Test: Random vibration test Railroad profile according to level C.3 (on ballast) of standard EN 50125-3:2003
Impact resistance[1]	Drop from 1 meter onto a concrete surface (20,000g)
RADIO	
Range open sight	15 km
Range with obstacles	> 1 km
Maximum link budget	151 dB
Configuration	Star (no repeaters needed)

Table 1: Product technical specifications

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[1] The tiltmeter has a good impact resistance. However it should be treated gently like any precision instrument. In particular, care should be taken to avoid any impact, to protect the internal MEMS tilt sensor and to avoid distorting the mechanics of the device.

5. INSTALLATION

The WI-SOS 480 Wireless Tilt Meter can be mounted horizontally or over a vertical plane, depending on the aim of the monitoring. Geosense provides several supports to fix the device.

5.1 Zero position

The WI-SOS 480 Wireless Tilt Meter has to be installed horizontally. In the following figure you will see the sign criteria for both axes.
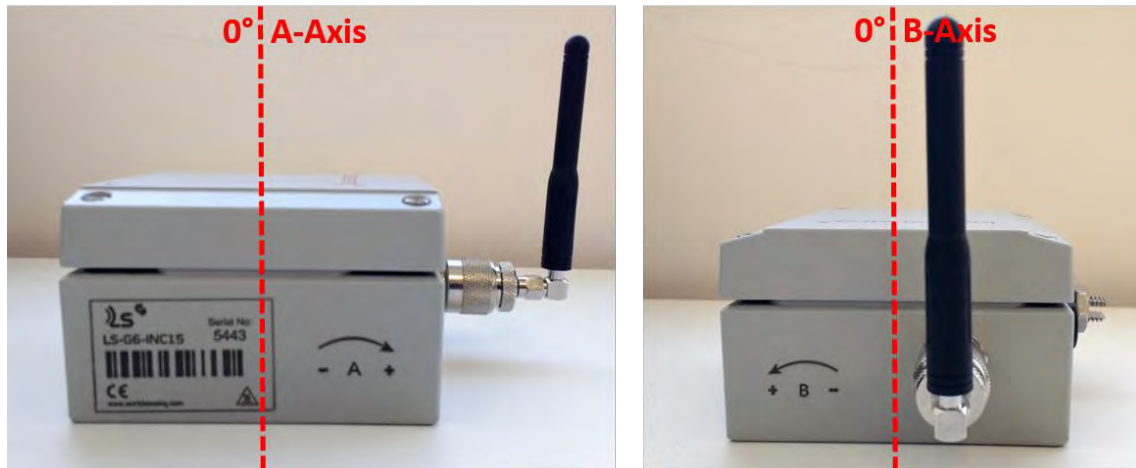

Figure 3: LS-G6-INC15 A-Axis and B-Axis zero position

5.2 Supports

The WI-SOS 480 Wireless Tilt Meters can be attached to the measurement surface using threaded rods and chemical anchors (bonded anchors) or using torque-controlled expansion anchors that go into the surface. Three-point mounting is the best option because it prevents bending and torsion that can lead to unstable readings. Single-anchor mounting is more prone to drift and disturbance. It is not recommended for long-term applications.

Geosense supplies torque-controlled expansion anchors with its horizontal and vertical supports. For long-term applications, chemical anchors are preferable because their performance is more stable and the vibration resistance is higher. Torque-controlled expansion anchors can also be used, but only if the mounting plate or bracket is drawn tight against the surface and cannot shift laterally.

Geosense recommends sourcing the chemical anchors locally because they are considered dangerous goods for air transportation. If you want to install chemical anchors, Geosense can supply the mounting plates with the M4 lock washers and socket screws required to attach the tiltmeter to the mounting plate. Please contact us with questions or for additional details.

The following drawings illustrate the installation procedure for the LS-G6-INC15 wireless tiltmeter and its supports for horizontal and vertical surfaces.

With the aim of reducing the thermal effects on the tiltmeter, we suggest installing a plastic cover or similar, to keep the tiltmeter in the shade. Sun exposure causes a thermal gradient in the enclosure.
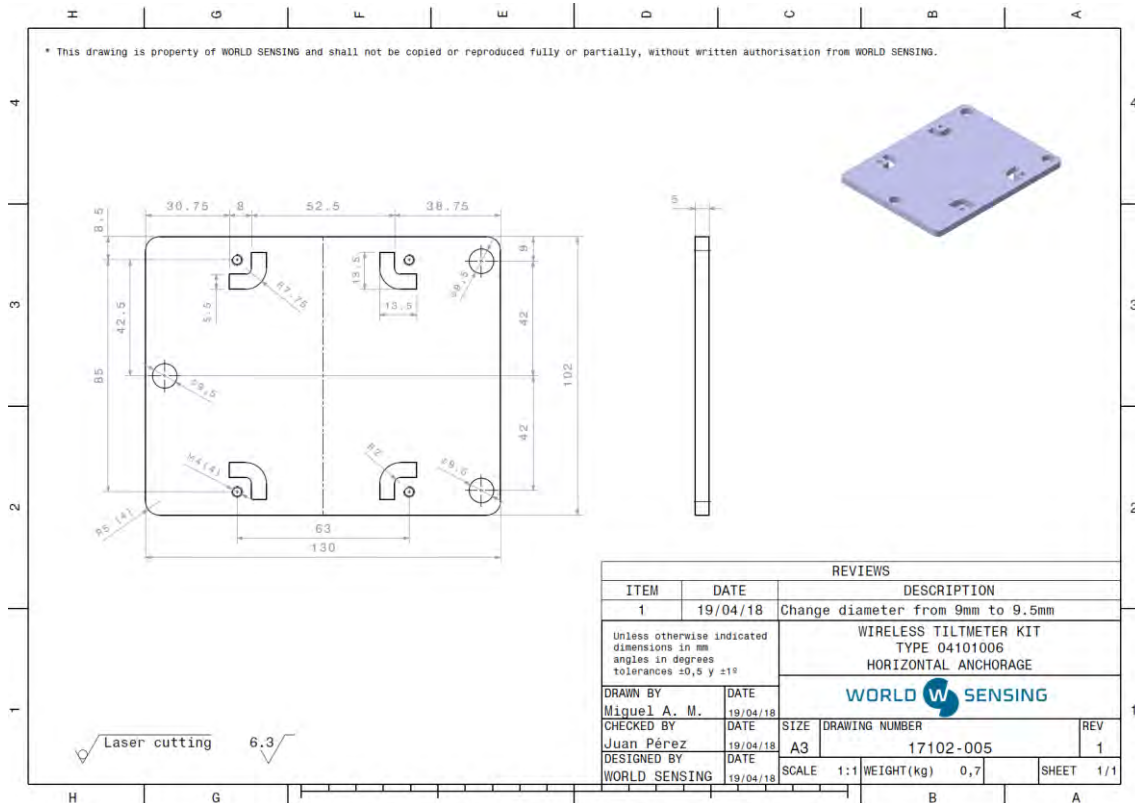
HORIZONTAL MOUNTING PLATE

Figure 4: Horizontal mounting plate

It is also possible to glue the WI-SOS 480 Wireless Tilt Meter to the measurement surface. In this case, we also recommend attaching the horizontal mounting plate to the tiltmeter because the plate will offer a greater surface area to increase its adhesion.
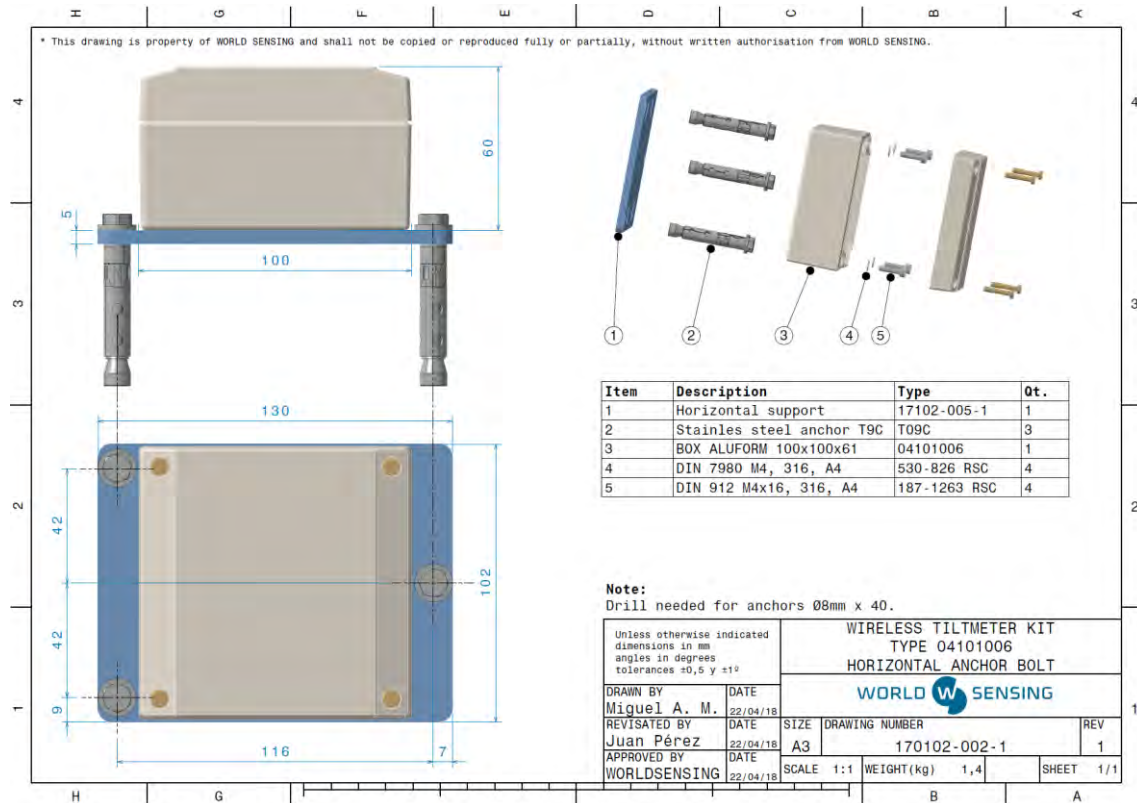
Figure 5: Horizontal mounting plate mounting procedure

VERTICAL MOUNTING PLATE (wall mounting)
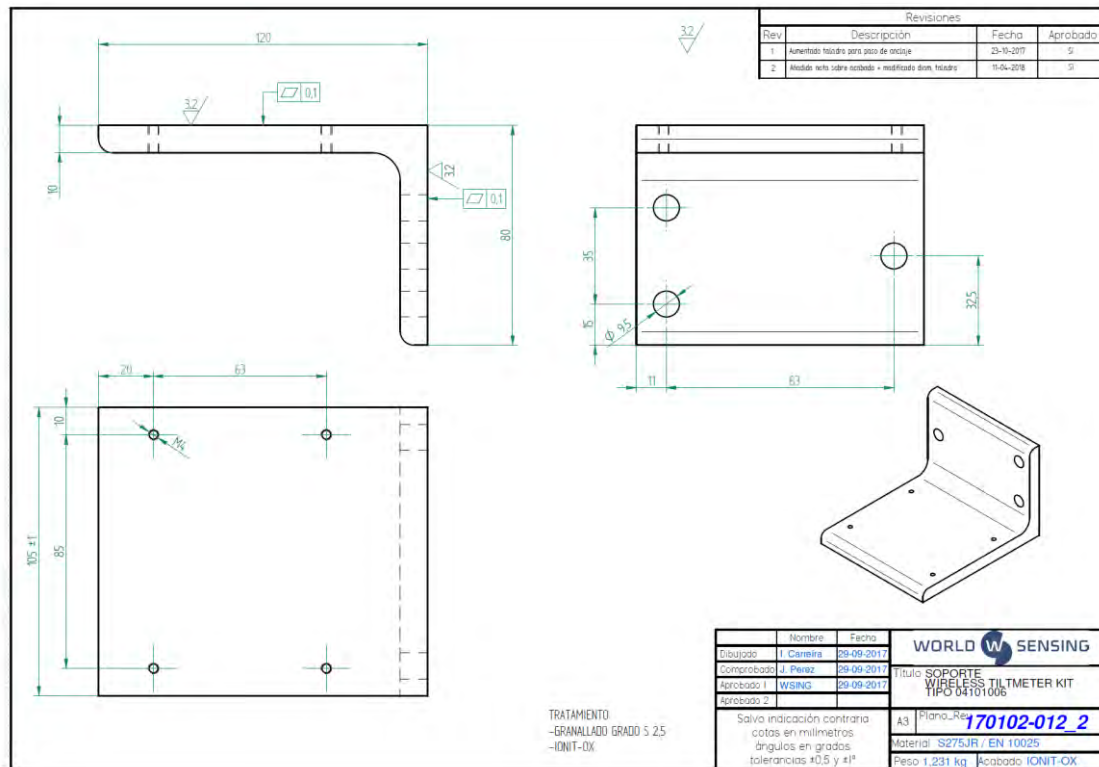
Figure 6: Vertical L-Shaped mounting bracket
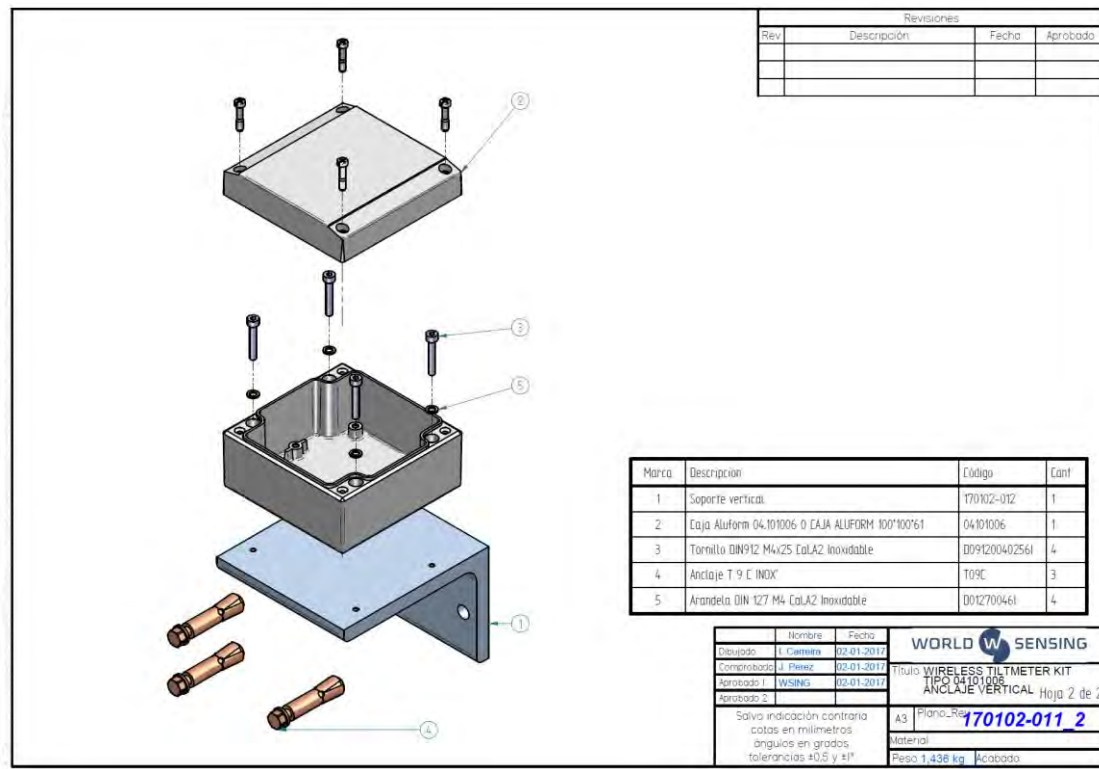
Figure 7: Vertical mounting plate installation procedure

VERTICAL MOUNTING PLATE (pole mounting)

The WI-SOS 480 Wireless Tilt Meters can be also mounted on a pole using metallic supports.

The installation of the pole and its stability will be critical for the reliability of the readings. Depending on the installation, a pole can be more sensitive to deformation caused by environmental loads (wind, rain, snow, groundwater, frost, etc.) than other structures.
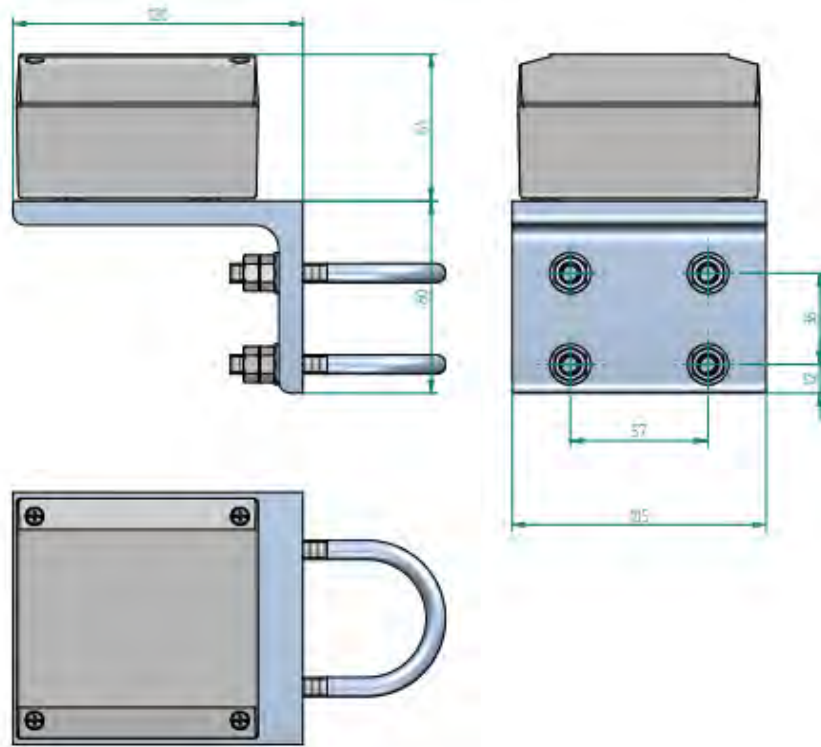
Figure 8: Vertical mounting plate for pole mounting

5.3. Mounting the tiltmeter

The WI-SOS 480 Wireless Tilt Meter can be installed on any concrete or rocky wall, affixed to the structure by a vertical or a horizontal plate support, bolted to the concrete or to a rock.

To mounting it, these steps should be followed:

1. Drill the measurement surface
2. Adjust bolts between the wall and the plate
3. Open tiltmeter and place it over the plate
4. Adjust bolts between tiltmeter and plate
5. Close the tiltmeter (see section 1.3 of LS G6 Nodes User Guide)
6. Place the aerial in the vertical position

Figure 9 Bolts adjusted to the plate
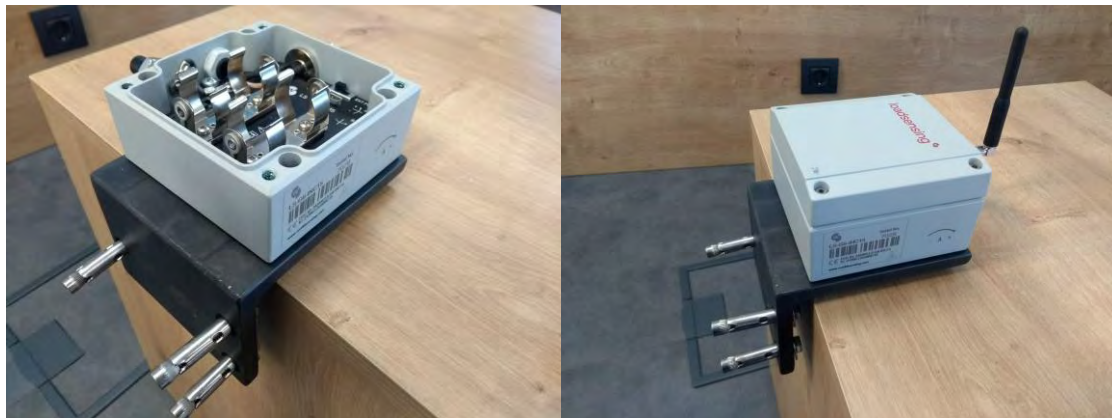
Figure 10 correct placement on the plate

5.4. Tiltmeter configuration

The WI-SOS 480 Wireless Tilt Meters is shipped closed and without batteries installed. In order to initialize it, the user should follow these steps:

a. Open the WI-SOS 480 Wireless Tilt Meter LS-G6-INC15 (using a 2.5 mm Allen wrench).

Figure 11: Different views of the tiltmeter.

b. The WI-SOS 480 Wireless Tilt Meters is designed to work with either a type-C battery or an external power source (e.g., a solar panel). If battery mode is selected, be sure that C-type batteries are in the battery holders; 1 to 2 batteries can be connected. Polarity is indicated.

Figure 12: Detail of power switch.

The WI-SOS 480 Wireless Tilt Meter does not have an RTC battery to keep time, so it is very important for the node to be powered with batteries and the time set during the installation. Otherwise the node will default to the year 1970 and data will not appear in the gateway (a warning will appear in the log's tab).

Note that there is reverse battery protection, but it is not safe to keep batteries reversed in the datalogger for a long time.

WARNING: RISK OF EXPLOSION IF THE BATTERIES ARE SUBSTITUTED WITH AN INCORRECT MODEL. DISPOSE OF BATTERIES ACCORDING TO THE INSTRUCTIONS. THIS EQUIPMENT IS MEANT TO BE INSTALLED IN RESTRICTED ACCESS AREAS.

Complete configuration is done through the Android Configuration App (see chapter 2 of the WI-SOS 480 Nodes User Guide). When a new version of the app is available, a message appears automatically when connecting the datalogger by USB.

The configuration of the tiltmeter and the radio is accessed by selecting the Setup wizard (in the tab menu, "Node configuration," Figure 5). Inside the Node configuration menu, there are also other parameters that the user can change, such as the Node ID or the date and time (especially important when accessing the Node for the first time).
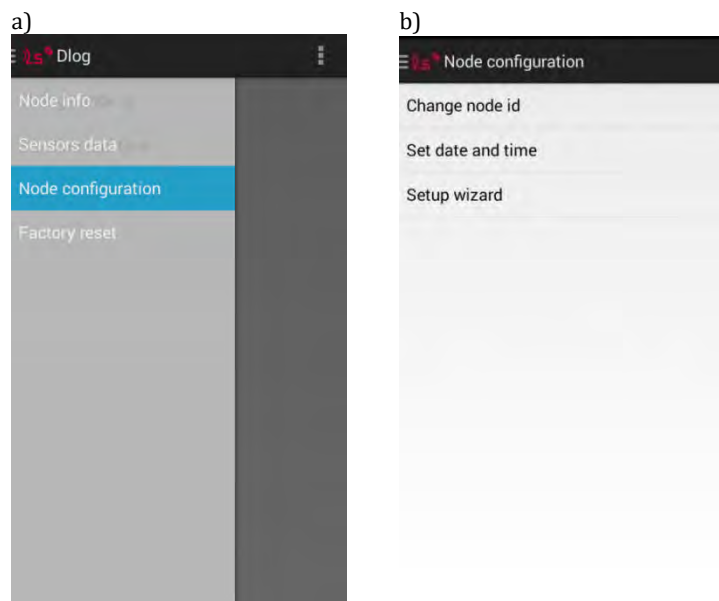
Figure 13: a) Main screen of the Android Configuration App and b) Node configuration screen, which has to be accessed to configure the datalogger.

Selecting the Setup wizard initiates the step-by-step configuration of the sensors and the radio:

1) Network size.

The size of the network (Figure 6) defines the slot time for each of the nodes to send data to the gateway, in order to avoid data collision (see section 5 of LS G6 Gateway User Guide).
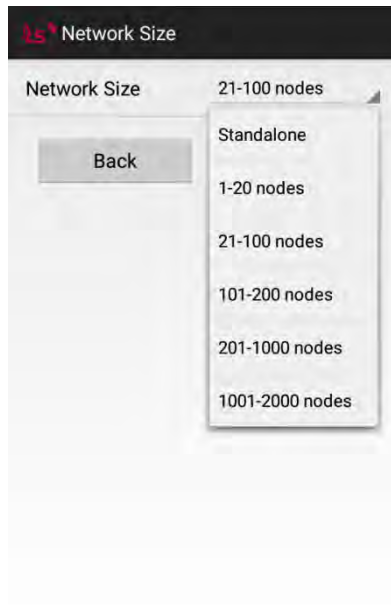
Figure 14: Network size configuration.

2) Tiltmeter configuration.

On the sensor configuration screen, user can configure the sampling rate interval. Calibration coefficients (obtained for each device) are given by the app.
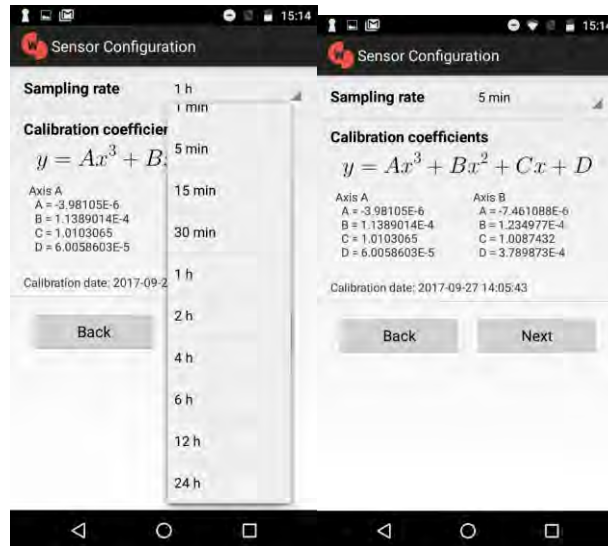
Figure 15: Sensor configuration options for LS-G6-VW-5 ch.

NOTE: Each unit is individually calibrated to provide the ultimate in system accuracy and repeatability. The calibration formula is directly applied to the collected reading, so data transmitted and logged into the node is already corrected, and the user does not have to reapply the calibration formula.

3) Sensor data.

A reading of the sensor is displayed (Figure 10). In this stage, the user can see the readings in this specific moment, and also the temperature.

Figure 16: Data readings of active sensors.

4) Radio configuration.

The user must set the correct region and country to comply with local regulations. See chapter 56.2 on the WI-SOS 480 Gateway User Guide. The network is identified by a Network ID and protected with a password. All tiltmeters and the gateway of an installation need to have identical settings (region and password). The default credentials of the radio network are specified in the Gateway Information Sheet (Figure 11).

For the majority of installations, the advanced options should not be changed. For more details on the advanced options, check chapter 2 of the WI-SOS 480 Gateway User Guide.
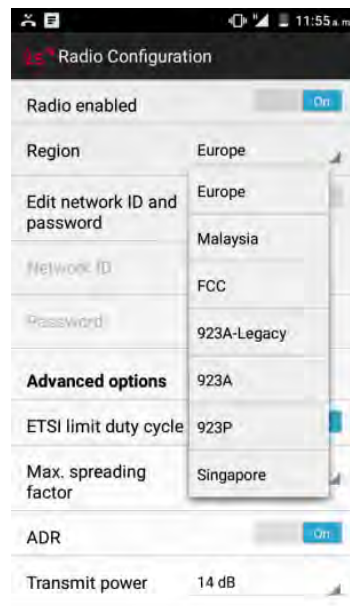
Figure 17: Radio configuration screen.

Note that in order to simplify the datalogger configuration tasks, especially in large installations, the network ID and password of the last datalogger configured are saved in the Android app. To edit them, the option has to be activated by the user; otherwise the credentials introduced in the configuration of the datalogger will be the ones that were introduced the last time the Android app was used.

5) Radio signal coverage test

Once the gateway is configured, a signal coverage test can be performed (Figure 12).

This test will check for correct connectivity between the datalogger and the gateway. Some test packages will be sent by the datalogger, and then the Android app will check reception on the gateway (using the Internet connection). The test will check for:

- Correct gateway operation and communication
- Correct radio configuration on both gateway and datalogger (including matching region and ID / password configurations)
- Quality of the signal received by the gateway from the datalogger

For the results of this test to be displayed immediately on the Android device, the gateway needs to be installed with a working Internet connection, and the Android device also needs to be connected to the Internet. This is what we call an "online test."

In order to perform an online test, the Glog app needs to be supplied with the gateway's serial number and remote access password.

The remote access password is used to protect access to the gateway from the local network or the Internet. It is separate from the radio network password, even though it is set to the same value by default.

The gateway ID and default password are specified in the Gateway Information Sheet. Before starting the test itself, the gateway connectivity is checked. In the case of any problem with the credentials, an error message will appear.

The results displayed are listed for each Spreading Factor (SF). The SF represents a way of modulating data. The gateway is capable of receiving all frequencies with several SFs at the same time. The lower the SF number is, the shorter the message, so more messages can be sent on the network. The SF is proportional to the distance between datalogger and gateway: higher spreading factors are capable of transmitting data at higher distances, while lower spreading factors reach lower distances.

During the radio signal coverage test, the datalogger sends 5 or 10 packages of data at SF7 to SF12. The number of data packages that reach the gateway can be viewed in the results in order to ensure correct communication.

When performing a Radio signal coverage test, the position of the Android device is kept (if the user gave permission to the app to access to the GPS data), and a security token number identifies each test.

If the gateway and/or the Android device do not have Internet connectivity during the test, the online test will fail (since it will have been impossible to contact the gateway over the Internet), and the user will need to perform an "Offline test." In this mode, however, the results of the test cannot be displayed in the Android device. The security token number identifies each test. The user must write down the token number, along with a description of where and under what conditions the test was taken. The user will then have to check the results of the coverage test on the gateway's web interface (under network → Signal coverage test map → Download all tests of this network).

A coverage test is considered correct if any of the Spreading Factors are able to deliver at least half the packets sent.

Note that running the Radio signal coverage test takes approximately 2 minutes.

a)

Radio signal coverage	
Gateway II	)18
Server pas	ıraifau

Offline test - Perform the coverage test, but don't fetch results from the gateway. The results can be checked later at the gateway interface.

Back	Next
Offline test	Skip

b)

Radio signal coverage	
Date	
Token	
Node ID	
Network ID	
Latitude	
Longitude	
SF7	1 / 10
SF8	3 / 10
SF9	2 / 10
SF10	1 / 5
SF11	1 / 5

Figure 18: Radio signal coverage performed at the end of the datalogger setup (using the Setup wizard).

Once the coverage test has finished, a message with the text "You have completed the configuration of the node. Please make sure to check the coverage test results and data readings before permanently installing the nodes onsite" will appear on the screen. This means the user has followed all the steps needed to configure the node, but it may be necessary to check the signal coverage first to ensure that the node can communicate with the gateway.

5.5. Data storage

The internal node memory size is 4 MB. The WI-SOS 480 Wireless Tilt Meter stores up to 200,000 readings. Data storage times are indicated in Table 3. Memory mode is a circular buffer. When the memory is full, logging continues by overwriting the earliest readings. Besides the data from the sensor, the logger also collects health data hourly, which indicates the battery voltage, the internal temperature of the node and the node uptime.

Number of sensors	Sampling rate		
	60 minutes	30 minutes	10 minutes
1	more than 10 years	more than 20 years	3.5 years

Table 2: Indicative storage capacity of the tiltmeter datalogger.

5.6. Battery life estimate

The following table gives approximate battery lifespans. The user should take into account that consumption varies depending on sampling rate and the environmental conditions.

Sampling rate	SF9@14dBm	SF8@20dBm
30 sec	5 weeks	5 weeks
1 min	10 weeks	11 weeks
5 min	48 weeks	1.1 years
30 min	3.3 years	3.6 years
1 h	4.6 years	4.7 years
6 h	6.7 years	6.4 years
12 h	>7 years	>7 years

Table 3: Indicative lifespan for LS-G6 INC15-3. Estimates using 2 C-size batteries.

Table 3 shows the lifetime estimate for three different temperature profiles to present how the environmental conditions are also relevant to the battery life.

Sampling rate	Lifetime estimates in years		
	Singapore	Barcelona	Moscow
5 min	1.1	1.2	1.2
1 h	4.7	5.8	6.0
6 h	6.4	8.3	8.9

Table 4: Life time estimations based on the lifetime mathematical model from Saft for three different temperature profiles

6. CALIBRATION

All tiltmeters are assembled, calibrated, and tested under stringent quality control standards.

Coefficients for a third-degree polynomial are determined by the least-squares method with 7 inclination steps (0, 2, 5, 9, -2, -5 and -9 degrees). The calibration formula is directly applied to the collected readings by the LS-G6-INC15 node. As a consequence, data transmitted and logged into the node is already corrected.

DO NOT REAPPLY THE CALIBRATION FORMULA.

Regarding the recalibration of the wireless tiltmeter, Geosense recommends recalibrations only for the following situations:

- When it is required a certificate of the tiltmeter according to the quality program of your company/project.
  In this case, it can also be possible to obtain the certificate locally. If you can find a laboratory with a proper rotary frame, you can place the wireless tiltmeter on the calibration frame and take measurements at different inclination steps. Then, if the probe is found to be within the specifications, the laboratory will be able to print out a certificate for the tiltmeter. Coefficients of the third-order polynomial will not be recalculated in this case. However, if the wireless tiltmeter is found to be out of tolerance, it will be necessary to send the device to Geosense.

- The tiltmeter requires repair. After repairing a tiltmeter, it must be recalibrated. (See "Troubleshooting" section)

- After completing a monitoring project. Civil works and mines are hard environments. During the project, the tiltmeter can be affected by: impacts, different levels of vibration, physical stresses, etc. Depending on the state of the tiltmeter after project completion, it may be recommendable to return the tiltmeter to Geosense for inspection of the mechanical parts, reassembly and recalibration.

- In the case of recalibration, Geosense will disassemble the wireless tiltmeter to inspect the mechanical parts before recalibrating.

7. MAINTENANCE

The WI-SOS 480 Wireless Tilt Meter is packaged in a rugged aluminum box and should provide many years of trouble-free operation.

The tiltmeters require no maintenance other than normal cleaning, battery replacement, and inspection of the seals. Apart from this maintenance, the tiltmeters are not field-serviceable.

The tiltmeter is a precision instrument. Apparently minor external actions or changes in the initial conditions of the structure can cause changes in the tilt readings, such as: rust in the supports, any construction pathology, the structure's thermal behavior, etc. Visual inspections can help to understand the cause of some registered movements.

The tiltmeter should be treated gently like any precision instrument. In particular, care should be taken to avoid any impact, to protect the internal MEMS tilt sensor and to avoid distorting the mechanics of the device.

8. TROUBLESHOOTING

Readings that appear unreliable

Unstable and anomalous readings, such as the following, are signs of a possible fault in the tiltmeter:

- Excessive thermal effects. Temperature dependency of LS-G6-INC15 is 0.002°/°C
- Anomalous behavior that cannot be easily explained according to the expected movements, such as values going up and suddenly going down and then going back up again or vice versa.
- Anomalous behavior of one of the two measurement axes.

The reliability of the wireless tiltmeter reading can be affected by:

- Impacts. Dents on the tiltmeter enclosure are signs of impacts.
- High vibration levels.
- Water ingress. The LS-G6-INC15 wireless tiltmeter ingress protection is IP67 (1 meter of water column for 30 minutes). The tiltmeters should never be submerged in water. **WATER DAMAGE TO INTERNAL COMPONENTS VOIDS THE WARRANTY!**

The LS wireless tiltmeter can be damaged by the above causes.

In case of doubt regarding the reliability of the readings, the best way to detect and identify the defect is to compare the collected readings. Geosense recommends the following steps:

- First, inspect the structure where the tiltmeter is attached and the mounting hardware (mounting plates, anchors, etc.). Any compromise to or mechanical deformation of the mounting hardware can cause unstable readings in the tiltmeter.
- After ruling out issues related to the structure or the mounting hardware, it is recommended to install an additional tiltmeter close to the possibly affected one.
- Check and compare the tilt readings of the original and the verifying tiltmeter.
- If the results of the new tiltmeter are as expected, while the results of the originally installed one continue to be erratic, it will be concluded that the original has been damaged in the field.

Upon detecting an affected tiltmeter, the user must contact support@geosense.co.uk to open a ticket and request a Return Material Authorization (RMA).

After receiving the returned tiltmeter, Geosense will inspect the mechanical parts, reassemble and recalibrate the node. If this occurs after expiration of the warranty, Geosense will repair the equipment at its factory for parts and labor charges. Geosense will provide a quote for repairs – if feasible – for products returned after warranty expiration.

Geosense is not liable for damages or erroneous decisions caused by defective units, since it is only responsible for the warranty of the equipment.

9. CONTACT GEOSENSE

Phone: +44 1359 270457

Technical support support@geosense.co.uk

General information:sales@geosense.co.uk

www.geosense.co.uk

Geosense Ltd

Nova House,

Rougham Industrial Estate,

Rougham,

Bury St Edmunds,

Suffolk,

IP30 9ND

England,

APPENDIX A. Vibration resistance test

Applus⊕ laboratories

2.2. RANDOM VIBRATION TEST – LEVEL C3

DEVICE UNDER TEST (DUT)	3 inclinometers models LSG6-INC15 (x2) and Pre-LSG6-INC15 (x1)
TEST	Random vibration test Railroad profile according to level C.3 (on ballast) of standard EN 50125-3: 2003

TEST CONDITIONS

RANDOM VIBRATION PARAMETERS

TESTING DIRECTIONS	FREQUENCY	PSD LEVEL	rms LEVEL	DURATION
Transversal Longitudinal Vertical	At 5 Hz At 600 Hz At 1150 Hz At 2000 Hz	0,2 $(ms^2)^2$/Hz 0,1 $(ms^2)^2$/Hz 0,01 $(ms^2)^2$/Hz 0,01 $(ms^2)^2$/Hz	9,83 m/s^2	10 min / axis

Table 5: Results from vibration resistance test.

CONTROL STRATEGY

Weighted control between two points placed on the tooling, for all testing directions.

See pictures in section 5.2

FINAL MEASUREMENTS

Final measurements according to specifications

CLIMATIC CONDITIONS

Temperature (ºC):   23.4

Relative Humidity (HR):   36

Atmospheric Pressure (hPa):   993