User Guide

Loadsensing Wireless Tiltmeter

LS-G6-TIL90

WORLD SENSING

BARCELONA
Viriat 47, Edificio Numancia 1, 10th floor,
08014 Barcelona, Spain
(+34) 93 418 05 85
www.worldsensing.com
connect@worldsensing.com

London
Los Angeles
Singapore

Table of contents

Document version	Date	Description
Version 1.0	February 2022	First edition of the loadsensing Wireless Tiltmeter user guide
Version 1.1	January 2024	New arrows engraved, horizontal support recommended for vertical installation, temperature readings from the device, battery life estimation with two SAFT battery models
Version 1.1.1	September 2024	Images from the sign convention for vertical and horizontal mounting.

1.Important instructions prior to use

Please read these instructions carefully and ensure that the required conditions specified in this document are met before using the product. Each of our edge devices includes this information inside the packaging

General warnings

- Follow these precautions to avoid a battery explosion or leakage of flammable liquid or gas:
  - Use the correct battery type. Dispose of the batteries according to instructions. Do not dispose of the batteries by throwing them into a fire or a hot oven, or mechanically crush or cut them.
  - Do not leave the batteries in an extremely high-temperature environment.
  - Do not subject the batteries to extremely low air pressure. It may result in an explosion or leakage of flammable liquid or gas.
  - Do not short circuit the batteries. This will blow the protection fuse.
- Batteries and equipment to be connected via the data port must meet IEC 62368-1 ES1 and PS1 requirements.
- Equipment to be installed in restricted access areas.

Symbol	Description
	Caution. Do not proceed until the instructions are clearly understood and all required conditions are met.
	Read the instructions for use carefully before using.
	Caution, hot surface.
	According to the European Union WEEE Directive 2012/19/EU, this product and its batteries should not be discarded as unsorted waste. Please send them to separate collection facilities for recovery and recycling. It is your responsibility to dispose of your waste equipment and batteries properly. The correct disposal of your old equipment and batteries will help prevent potential negative consequences for the environment and human health.

2.Device Overview

This user guide explains how to configure and operate Worldsensing's Loadsensing Wireless Tiltmeter90. Further technical descriptions are available in the datasheets.

The Loadsensing Wireless Tilt90 is a long-range, low-power wireless data logger with a 3 axes tiltmeter. It measures 3-axis inclination with respect to gravity's direction and reports the two axes of rotation from the horizontal plane in any orientation.

There are two models of Tilt90, the one with an external antenna (LS-G6-TIL90-X) and the one with an internal antenna (LS-G6-TIL90-I), which differ from specifications (see the specifications on next chapter).

The devices have the 3 axes engraved on the case, so the user can understand the X, Y and Z axes measured when installed it on any position.

The wireless tilt90 can be used connected to the CMT or as a standalone logger for manual monitoring, and can be easily configured by connecting it to an Android phone with a USB cable.

Tiltmeters for monitoring applications provide measurements of changes from the vertical level, either on the ground or in structures. This makes them key sensors to monitor inclinations, movements and differential settlements of slopes or infrastructures.

Tiltmeters have been extensively used in landslides, embankments and mines monitoring to control the stability of the slopes.

3.Device Specifications

Please refer to the TIL90-X datasheet and TIL90-I datasheet.

4. System requirements

The TIL90 is:

- available from version 2.63 onwards

- Needs to be configured by using the Worldsensing App (instead of the Dlog)

- CMT Edge version: from firmware version 2.5 (4G Gateways) and 2.5.1 (3G Gateways) onwards

- CMT Cloud version: from firmware version 1.4.0 onwards

5. Equipment Provided

As mentioned above, there are two wireless tiltmeter variants.

Figure 1: LS-G6-TILT90-X view

The wireless tilt90 with an external antenna **(LS-G6-TIL90-X)**

1. Metallic casing
2. USB connector
3. RP N Female connector, which complies with Federal Communications Commission (FCC) regulations, for the sensor network radio antenna
4. Pressure stabilizer for protection against condensation (protective vent)
5. Connector male RP N to RP - SMA male and aerial with RP - SMA male
6. Antenna

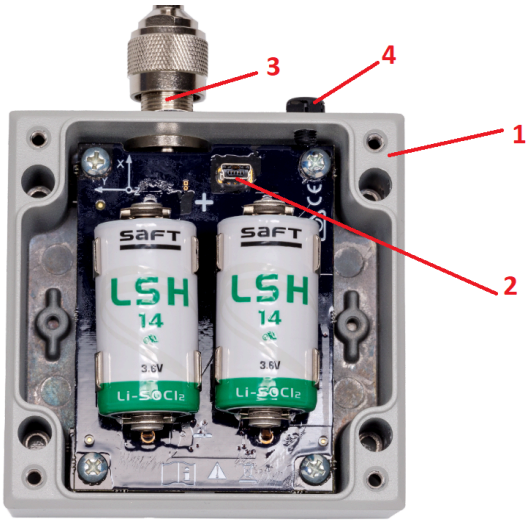


Figure 2: LS-G6-TILT90-X elements

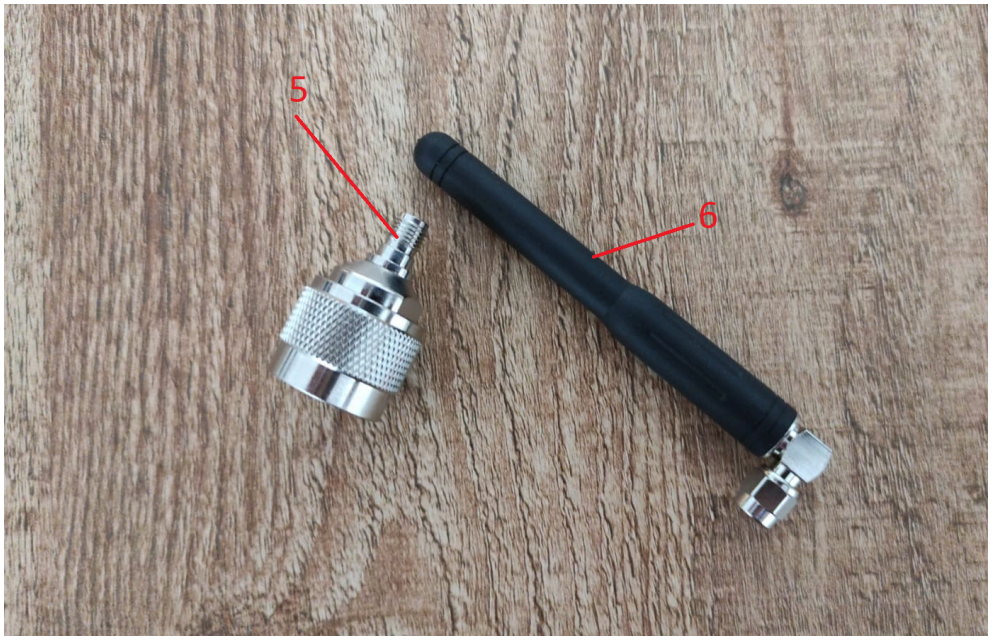


Figure 3: LS-G6-TILT90-X antenna with N-connector

The LS-G6-TIL90-X can also be equipped with a more robust antenna, placed horizontally, instead of the standard L-antenna that is installed vertically. Please contact us for more details.

Figure 4: LS-G6-TILT90-I view

The wireless tiltmeter with an internal antenna **(LS-G6-TILT90-I)** has the following elements:

1. Polycarbonate lid
2. Metallic box
3. Pressure stabilizer for protection against condensation (protective vent)
4. Internal antenna

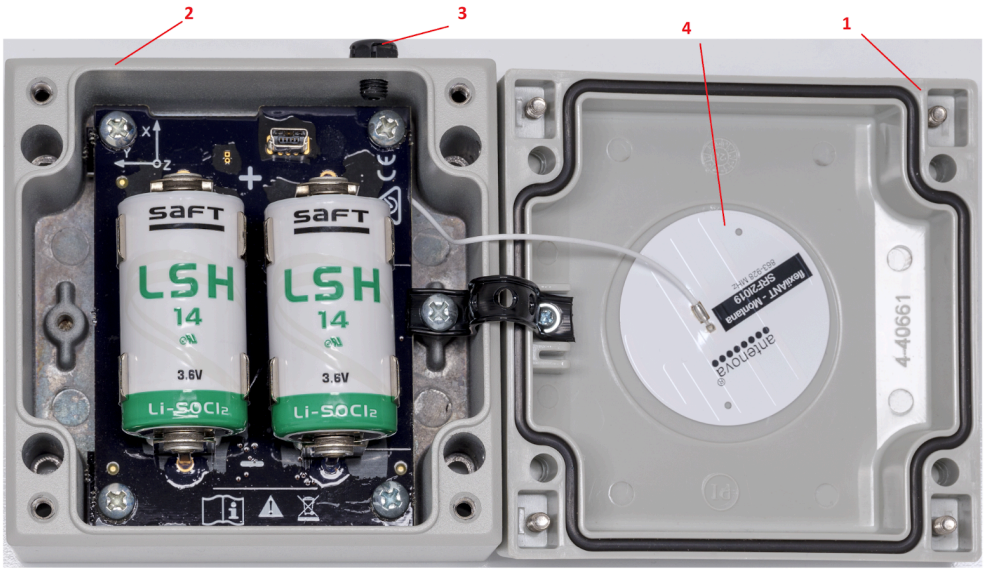


Figure 5: LS-G6-TILT90-I elements

The following elements are sold separately for both tiltmeters:

- Mounting supports. See the mounting instructions for each support
- USB-OTG configuration cable
- Batteries

6. Wireless Tiltmeter remarks

Since serial number 90805 and 94973 onwards, new axis marking was engraved on the case in order to facilitate the understanding of the sign convention of the TIL90X and TIL90I.

For the TIL90X, arrows have been added to a second side for the TIL90X, while for the TIL90I, arrows have been included on the lid. The sign convention has been preserved by referencing either the antenna (in the case of TIL90X) and the Gore valve, both located on the same side, or the side with the barcode and serial number. Only the markings of the external arrows have been modified.

7. Wireless Tiltmeter installation

The first task of getting your Loadsensing Tiltmeter node up and running on your site is to install it. There are three major factors to consider when installing the node: the various supports you might use, the mounting of the Tiltmeter node, and powering the node once it is installed. We discuss each of these three here.

Supports

The Tilt90 node needs to be mounted on a support. Depending on the application, it needs to be installed with a certain inclination to achieve curved surfaces and on others applications it can be just installed aligned to the surface (horizontally, vertically or inclined). Worldsensing provides several accessories for mounting the device:

Description	Code
Mounting plate for vertical mounting	LS-ACC-IN15-VP
Versatile plate for horizontal surface mounting recommended for both horizontal and vertical mounting; attachment option: anchor rods or glue. Includes a threaded hole available for installing a monitoring prism or a button head screw for precise levelling.	LS-ACC-IN15-HP
Horizontal surface mounting plate for track monitoring; attachment option: glue.	LS-ACC-IN-HPTM
Versatile double plate for horizontal surface mounting (includes a threaded hole for a prism or a button head screw, for precise leveling)	LS-ACC-IN15DP
Vertical mounting plate (pole mounting)[1]	LS-ACC-IN15VPP2

[1] *This mounting plate can be used for some applications, but it will be important to take into account that using it will affect the quality of the data.*

Important Note: **the horizontal surface mounting plate (LS-ACC-IN15-HP) is recommended for both horizontal and vertical mounting**, as this way the cantilevered length of the tilt meter is reduced and the thermal inertia is minor.

Further information and drawings can be found in the accessory user guides.

8. Powering up the Device

Loadsensing devices are shipped closed and without batteries. To power up the device:

1. Open the device using a 2.5 mm Allen wrench.
2. Insert **C-type batteries** in the battery holders, checking they match the polarity indicated. You can connect one or more batteries; the more you use, the longer the device will operate in the field. See our **LS G6 Datalogger recommended batteries guide** for further information on the batteries.
   Please note that the device has reverse battery protection but it is not safe to keep batteries reversed in the device for a long time.

   Note: The Loadsensing Wireless tiltmeter does not have a real-time clock battery to keep time, so it is very important for the device to be powered with batteries when the time is set during installation. Otherwise the device will default to the year 1970 and data will not appear in the gateway. A warning will appear in the log's tab.

3. Please consider that the TIL90 can only be powered by batteries, thus when attempting to update node firmware or downloading data from the node, make sure that batteries are placed.

General warnings

- Follow these precautions to avoid a battery explosion or leakage of flammable liquid or gas:
    - Use the correct battery type. Dispose of the batteries according to instructions. Do not dispose of the batteries by throwing them into a fire or a hot oven, or mechanically crush or cut them.
    - Do not leave the batteries in an extremely high-temperature environment.
    - Do not subject the batteries to extremely low air pressure. It may result in an explosion or leakage of flammable liquid or gas.
    - Do not short circuit the batteries. This will blow the protection fuse.
- Batteries and equipment to be connected via the data port must meet IEC 62368-1 ES1 and PS1 requirements.
- Equipment to be installed in restricted access areas.

9. Loadsensing Device Configuration

We strongly recommend configuring the Loadsensing device on location so you can conduct an on-site radio coverage test at the same time.

Device configuration has to be carried out using the Worldsensing Android app, which is compatible with USB On-The-Go (OTG) Android devices. Please refer to the Worldsensing app User Guide for more details. To make sure the app works properly, we recommend purchasing one of the mobile phone models in stock from Worldsensing. Please contact the technical support team for more information.

WorldsensingApp starts up once the Android device is connected to the Loadsensing node using an USB-OTG cable. It does not need to be started up manually.

The whole configuration process takes no more than five minutes. From then on, the Loadsensing node will start taking readings and sending data to the gateway.

Please take note of the following credentials in the Gateway Information Sheet. These will be necessary to perform the radio coverage test:

Gateway Information Sheet	Mobile app field
Default network ID	Network ID
Default network key	Password
Default network access password	Server password

The process for configuring the TIL90 node is the same as the other nodes and it is detailed on the WorldsensingApp user guide.

There are some functionalities that are particular for the TIL90 node as the **"use last configuration mode"**. This functionality, available from Worldsensing app version 2.0, allows applying the last completed setup configuration on the node. If there is any parameter that has a different configuration, it would be necessary to configure the node again.

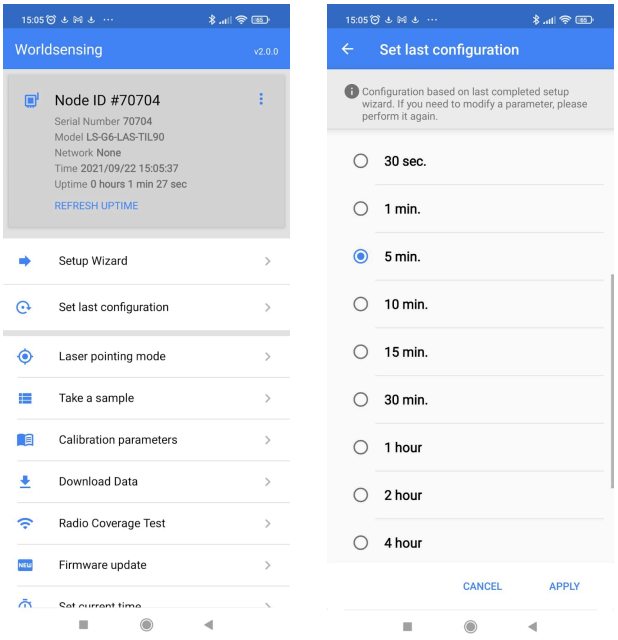


Figure 6: Worldsensing app screenshot of "use last configuration mode"

This node integrates one sensor, and it is not necessary to configure the sensor's settings on the WorldsensingApp.

Once the radio configuration is finished the app will show the option of taking a sample. Taking a sample will show the parameters measured and allow you to check the consistency of the readings.

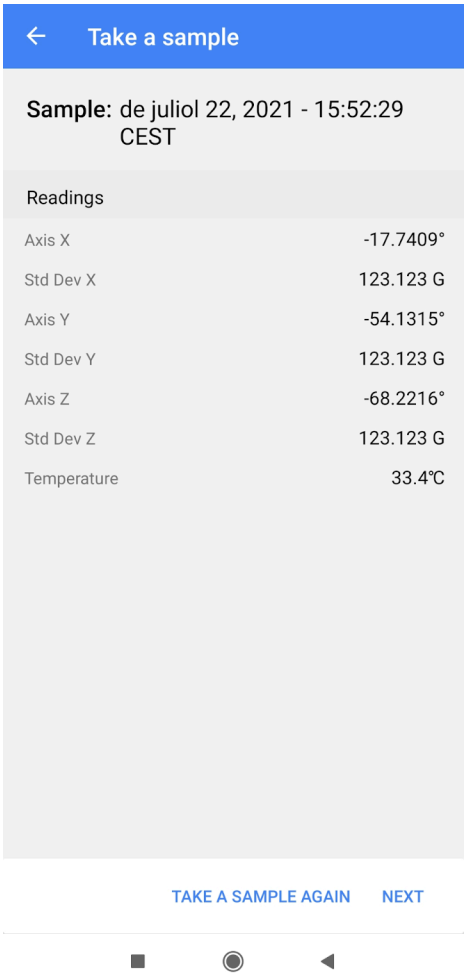


Figure 7: Worldsensing app screenshot taking a sample.

The app will show tiltmeter readings: the 3-axis inclination measurement with respect to gravity's direction, its standard deviation (expressed in Gravity) and also the internal temperature of the node.

3-axis Inclination measured by the tiltmeter is calculated as the average of a certain amount of acceleration samples in a period. At the same time the standard deviation of the sample is obtained, and it could be useful to filter anomalous readings collected by the Til90 affected by some movements.

Please take into consideration that the logger provides temperature from the microcontroller and the specs are published on the datasheet (0,1°C sensor resolution). These sensors have different offsets from factory, so it is possible that temperature measured by different chips at the same place (with the same temperature conditions) differs from one and other.

As the sensor is embedded in a metallic case, the temperature readings will be highly affected by the sun exposure. For those applications where monitoring the temperature of the asset is required, we strongly recommend using thermistors prepared for those specific purposes.
Do not mix this information with the temperature influence of the accelerometer data which is published in the datasheet of each device.

10. Safely Closing the Device

The wireless TIL90 has undergone watertightness testing by an external laboratory and has been rated IP68 at 2 m for 2 hours

To guarantee water tightness:

- Lock the box by tightening screws crosswise on the lid. Adjust the screws using a torque wrench. If this is not done properly, the base faces and cover may not be parallel, screwing may become more difficult and the screw threads or the Helicoil

inserts may be damaged. Moreover, the O-ring (seal) may not be properly sealed and the degree of protection against water intrusion could be compromised.

- Screw the box at 2 Nm (the force that needs to be applied is marked on the outside of the device) using a torque screwdriver (e.g. Ref. 1227107 from WERA).
- Mount the antenna or cover the antenna connector with a cap.
- Make sure the sealing ring has not been physically or chemically manipulated.

Note: There is no need to seal the GORE valve to comply with IP68.

Note: We can't guarantee the IP68 rating if any of the above conditions are not met or if one or several components (e.g. the GORE valve) are damaged.

Note that box screws shouldn't be torqued more than 2 Nm. If you exceed the torque, the Helicoil insert may be damaged. We do not recommend using electric drills or electric screwdrivers.

11. Understanding data

In this chapter we will explain how the TIL90 can be installed, what it measures and which parameters can be read.

The TIL90 can be installed on any orientation among the 360°, it has a 90 ° range and it does not require to be installed in horizontal position. The tilt angle is calculated from a 3 axis MEMS accelerometer, reports the 3 axis inclination measurements with respect to the gravity's direction and measures the inclination of the two horizontal planes (it does not measure rotation around gravity's direction-Yaw).

Find attached a schematic of the different angle installation with respect to the 3 axis.

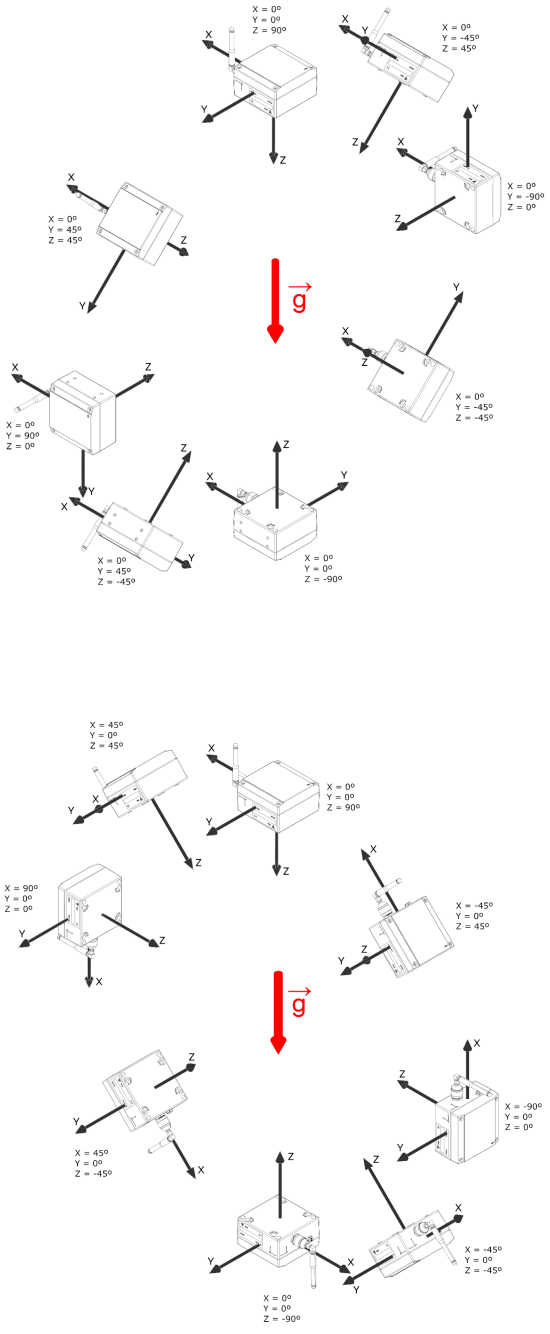
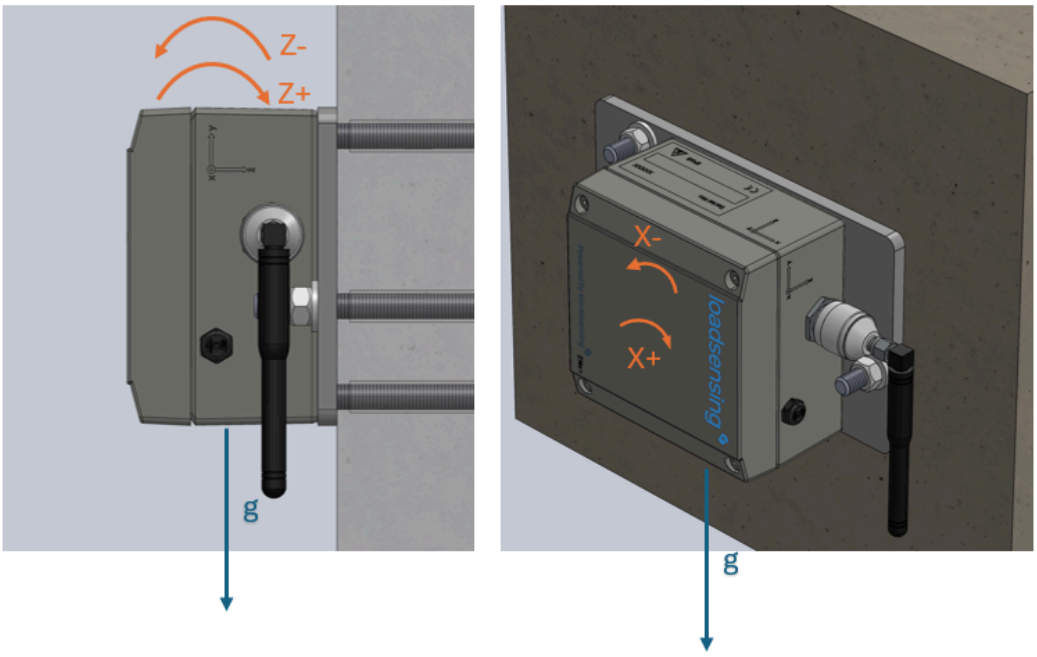


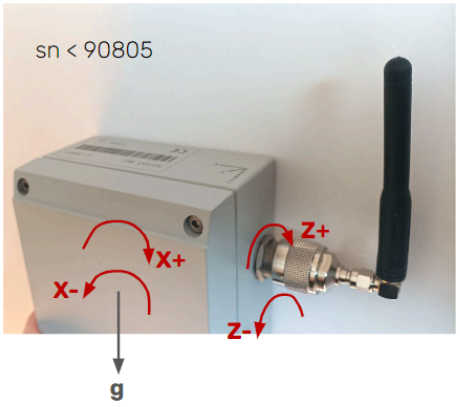
Figure 8: Values of 3 axes on different angle installations.

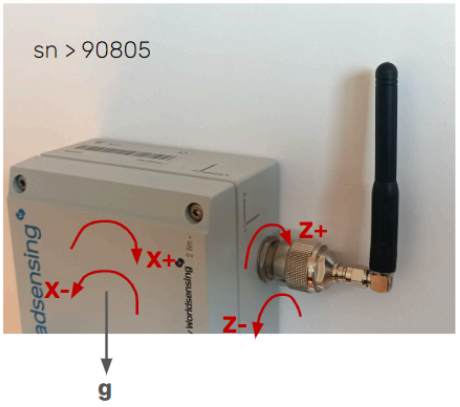
Below is a drawing positioning the tiltmeter attached to a vertical estructure through a horizontal mounting plate showing the different axes of interest and their sign convention with the new engraved (gravity is also indicated).



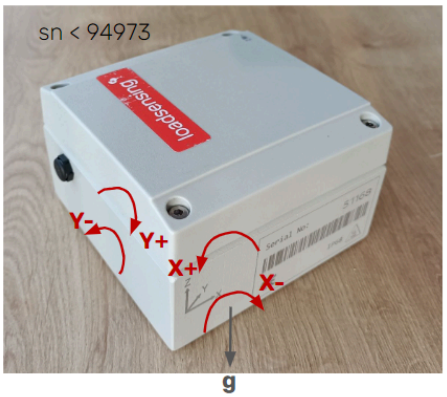
Also the axes of interest and their sign convention is shown on the image below for mounting the tiltmeter in horizontal position (gravity is also indicated).

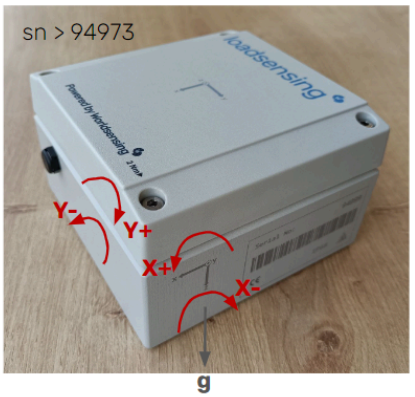
On the pictures below an image comparing the old versus de new engraved from the TIL90X and the sign criteria can be seen. Please note that the criteria has not changed and the references to elements such as the antenna, the gore valve or the barcode and the serial number have been maintained.





The same criteria applies for the TIL90I





11.1.1 Calibration

The tiltmeter sensor is assembled, calibrated and tested under stringent quality control standards.

The coefficients for the linear equation are determined with 4 inclination steps (0, 90, 180, 270 degrees) between the XZ and YZ planes. The calibration formula is directly applied to the collected readings by the wireless tiltmeter. As a consequence, data transmitted and logged into the device is already corrected.

You can take a look to an example calibration sheet published on the article.

DO NOT REAPPLY THE CALIBRATION FORMULA.

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

- When a tiltmeter certificate is required according to the quality program of the company/project. In this case, the certificate may be obtained locally. If a laboratory with a proper rotary frame is locally accessible, the wireless tiltmeter may be placed on the calibration frame to 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 wireless 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 Worldsensing.
- The tiltmeter requires repair. After repairing the device, it must be recalibrated. See the **Troubleshooting** section for more details.
- After completing a monitoring project. Civil works and mines are hard environments. During the project, the wireless tiltmeter can be affected by impacts, different levels of vibration, physical stresses and so on. Depending on the state of the wireless tiltmeter after project completion, you may need to return the tiltmeter to Worldsensing for inspection of the mechanical parts, reassembly and recalibration.

In case recalibration is needed, Worldsensing provides a calibration service. Please contact support@worldsensing.com for more information.

For the calibration process, Worldsensing will disassemble the wireless tiltmeter to inspect the mechanical parts before recalibrating the device.

12. Dataserver visualization

When connecting the TIL90 to the Dataserver, last readings will be shown.

Temperature (°C)	X Axis (°)	Y Axis (°)	Z Axis (°)	X Std	Y Std	Z Std	ΔX Axis (°)	ΔY Axis (°)	ΔZ Axis (°)
27.5	1.6754	2.6883	86.8317	1.17E-5	1.56E-5	1.56E-5	0.1370	-0.0646	-0.0141

Received on 2021-06-18T09:41:05Z

Figure 9: Readings from the TIL90 shown on the dataserver

Note that with the TILT90 several conversions can be done on the Gateway such as calculating:

- Angle variation

$$\Delta X = X_i - X_0$$
$$\Delta Y = Y_i - Y_0$$
$$\Delta Z = Z_i - Z_0$$

ΔX: Angle variation in degrees
ΔY: Angle variation in degrees
ΔZ: Angle variation in degrees
X_i: Current angle reading in degrees
Y_i: Current angle reading in degrees
Z_i: Current angle reading in degrees

Where:

AX: angle variation in degrees
AY: angle variation in degrees
AZ: angle variation in degrees
X_i: Current angle reading in degrees
Y_i: Current angle reading in degrees
Z_i: Current angle reading in degrees

- *Tangent generic equation (necessary to adjust it for the three axis)*

$$E_x = C_x tan(X_i - X_0) + D_x$$
$$E_y = C_y tan(Y_i - Y_0) + D_y$$
$$E_z = C_z tan(Z_i - Z_0) + D_z$$

E_x: Converted data in units.
E_y: Converted data in units.
E_z: Converted data in units.
X_i: Current angle reading in degrees.
Y_i: Current angle reading in degrees.
Z_i: Current angle reading in degrees.

Where:

$E_{x,y,z}$: converted data in units
$C_{x,y,z}$: Multiplicative factor
$D_{x,y,z}$: Offset in units
X,Y,Z_0: Zero reading
X,Y,Z_i: Current reading

- *Sine generic equation (It is necessary to adjust it for the three axis)*

$$E_x = C_x sin(X_i - X_0) + D_x$$
$$E_y = C_y sin(Y_i - Y_0) + D_y$$
$$E_z = C_z sin(Z_i - Z_0) + D_z$$

E_x: Converted data in units.
E_y: Converted data in units.
E_z: Converted data in units.
X_i: Current angle reading in degrees.
Y_i: Current angle reading in degrees.
Z_i: Current angle reading in degrees.

Where:

$E_{x,y,z}$: converted data in units
$C_{x,y,z}$: Multiplicative factor
$D_{x,y,z}$: Offset in units
X,Y,Z_0: Zero reading
X,Y,Z_i: Current reading

Figure 10: Different formulae applicable for the angle conversion

13. Errors implemented

When an error is returned a new timestamp is registered on the reading error CSV file on the Gateway, the reading file will show blank readings corresponding to that timestamp.

There are several errors that can be returned on the CSV file, related to the tiltmeter sensor or the laser distance meter. On the table below there is a relation between the codes and the error description:

Type	Code	Description
General	1	Sensor does not respond
Specific	2	Sensor self test error.
	3	Sensor temperature bad reading.

14. Maintenance and troubleshooting

The node is packaged in a rugged aluminum box for the TIL90-X option and with a plastic lid for the TIL90-I option, and should provide many years of trouble-free operation.

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

The wireless TIL90 is a precision instrument. Minor external actions or changes in the initial conditions of the structure, such as rust in the supports, construction pathology or thermal behavior, can cause changes in the tilt readings. Visual inspections can help to understand the cause of some registered movements.

It is important to avoid any impact to protect the internal sensors and to avoid distorting the mechanics of the device, as the reliability of the wireless tiltmeter reading can be affected by impacts, high vibration levels or Water ingress. The wireless node should never

be submerged in water. **WATER DAMAGE TO INTERNAL COMPONENTS VOIDS THE WARRANTY.**

In case of doubt regarding the reliability of the readings, first inspect the wireless node mounting and the structure where it is attached. Any compromise to or mechanical deformation of the mounting hardware can cause unstable readings.

After ruling out issues related to the structure or the mounting hardware, we recommend installing the device on a known stable place and compare data. If the results of the wireless tiltmeter lead to think that the unit is not working as expected, please open a ticket to support@worldsensing.com in our Help Center to request a Return Material Authorization (RMA).

After receiving the device, Worldsensing will inspect the mechanical parts, reassemble and recalibrate the device. If this occurs after expiration of the warranty, Worldsensing will repair the equipment at its factory and may require additional charges for parts and labor charges. Worldsensing will provide a quote for repairs, if feasible, for products returned after warranty expiration.

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

15. Battery Life Estimates

On the table below, battery life estimations are presented. These results are based on tests conducted by SAFT considering Typical Europe radio configuration (Spreading factor 9, radio transmit power 14dBm), laboratory conditions, Barcelona weather profile and average values for two different SAFT battery models (LSH14 and LM26500).

Results from 1 and 2 cells are presented to visualize the difference lifespan according to the battery models.

Battery Model		LSH14	LM26500	
Number of cells		**2 cell**	**1 cell**	**2 cells**
Reporting period	**30 s**	4.8 months	3.1 months	6.2 months
	5 min	3.6 years	2.5 years	5.1 years
	1 h	12.9 years	17.2 years	>25 years
	6 h	15.5 years	>25 years	>25 years

Table 1. Battery life estimations for typical Europe radio configuration, considering laboratory conditions. Consumption varies depending on the sensor used, sampling rate and environmental and wireless network conditions

Battery consumption varies depending on the sampling rate and environmental and wireless network conditions.

The following tables provide an estimation, according to numerical models, of the battery lifespan in years indicated according to different wireless network conditions by using two different types of SAFT batteries, LSH14 and LM26500.

SF8@20dBm				
Battery Model		LSH14	LM26500	
Number of cells		**2 cell**	**1 cell**	**2 cells**
Reporting period	**30 s**	5 months	3.3 months	6.6 months
	1 min	9.8 months	6.5 months	1 year
	5 min	3.3 years	2.5 years	4.8 years
	30 min	8.8 months	10 years	18 years
	1 h	10.7 years	14.1 years	24.5 years
	6 h	12.8 years	21.8 years	>25 years
	12 h	13.1 years	23.1 years	>25 years

Table 2: Battery lifespan estimations in years assuming intermediate environmental Radio conditions for FCC radio

SF7@14dBm				
Battery Model		LSH14	LM26500	
Number of cells		**2 cell**	**1 cell**	**2 cells**
Reporting period	**30 s**	10.3 months	6.8 months	1.1 years
	1 min	1.6 years	1.1 years	2.2 years
	5 min	5.5 years	4.7 years	9 years
	30 min	1.8 years	14.5 years	25 years
	1 h	11,9 years	18.2 years	>25 years
	6 h	13.1 years	23.2 years	>25 years
	12 h	13.3 years	23.8 years	>25 years

Table 3: Battery lifespan estimations in years assuming good Radio conditions for European radio.

SF11@14dBm				
Battery Model		LSH14	LM26500	
Number of cells		**2 cell**	**1 cell**	**2 cells**
Reporting period	**30 s**	1 months	0.7 months	1.4 months
	1 min	2.1 months	1.4 months	2.8 months
	5 min	0.8 months	7 months	1.1 years
	30 min	4 years	3 years	6 years
	1 h	6 years	5.5 years	10.3 years
	6 h	11,1 years	15.5 years	>25 years
	12 h	12.2 years	19 years	>25 years

Table 4: Battery lifespan in years per wireless tiltmeter, assuming extreme environmental Radio conditions in Europe.

16. Data storage

The internal data logger memory size is 4 MB. The wireless tiltmeter stores up to 140,000 readings. Data storage periods are indicated in Table 3. Memory mode is a circular buffer. When the memory is full, logging continues by overwriting the earliest readings. Aside from the sensor readings, the device also collects health data hourly, which indicates the battery voltage, the internal temperature of the device and the device uptime.

Number of sensors	Sampling rate		
	60 minutes	30 minutes	10 minutes
1	~16 years	~8 years	2.6 years

Table 5: Data storage periods (without overwriting) for the wireless laser tiltmeter

Data is stored in comma-separated value (CSV) files. You can download readings and health files using LoadsensingApp.

To do this, connect an Android device to the data logger Mini USB port with a USB-OTG cable. When LoadsensingApp loads, press “Download data” . You need to set a start and end date for the data you want to download or alternatively you can enable “All data”. The Android device allows these CSV files to be opened with applications such as e-mail or cloud apps. Files are also stored in the device memory, on the SD card in the Dlog folder.

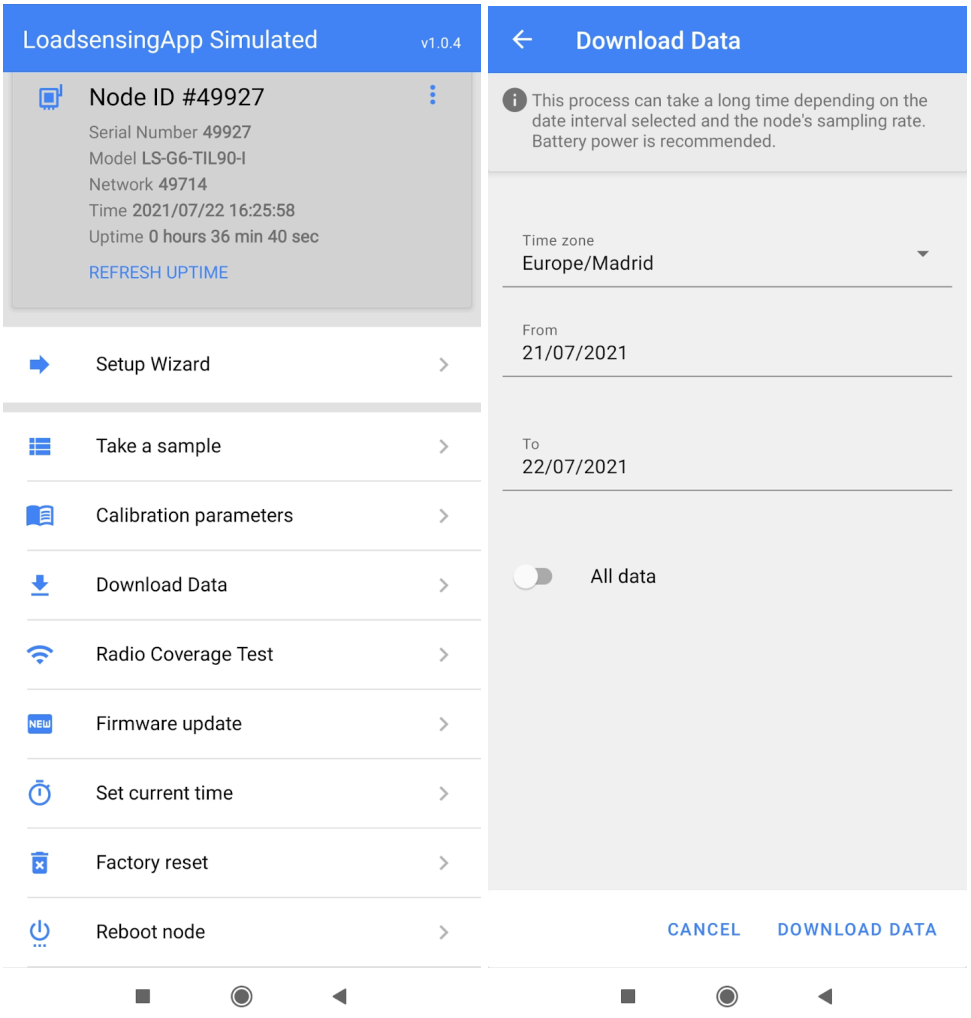


Figure 11: Downloading data manually from the wireless LASTIL90

17. FAQs

Do I need to apply temperature correction to the wireless tiltmeter?

The wireless sensor temperature dependency is up to +/-0.002°C for the TIL90-X and +/-0.005°C for the TIL90-I .

To reduce thermal effects, we recommend installing the device indoors where possible in order to avoid sun exposure. If not, we suggest installing it in the shade, as sun exposure causes a thermal gradient on the enclosure.

Changes in temperature will cause structure and tiltmeter thermal effects. The best way to measure tilt is to determine the temperature behavior of the structure before activities start. Ideally, this baseline should be extended for a year to cover seasonal changes. With this baseline, it will be possible to distinguish temperature-induced movements (including those of the tiltmeter) from others.

Is the accuracy from the wireless tiltmeter the same on all the ranges?

We have tested the accuracy within different positions (+/-4°, +/-15°, +/-45°, +/-86°). The results are shown on the specs (the biggest is the angle measured, the accuracy is reduced).

As the device can be installed on any position, we always recommend when possible to refer the measurements to the lowest angle measured to obtain higher accuracy.

We could say that as in most of the applications where the TIL90-X is used an angle below 4 ° is being measured, so the accuracy is +/-0.005° and +/-0.006° for the TIL90-i.

Why is there a difference in the accuracy between both devices?

The main difference is due to the vibration resistance of TIL90-I. This device has been designed to work in environments with accelerations below +-80g , this is mainly due to the fact that this device has been designed for railway application, where vibration is an important point to be considered. This makes the specs from TIL90-I lower than the TIL90-X.

I have several TIL90 devices installed next to each other and the temperature readings differ, What is the reason for this difference?

Please take into consideration that the logger provides temperature from the microcontroller and the specs are published on the datasheet (0,1°C sensor resolution). These sensors have different offsets from factory, so it is possible that temperature measured by different chips at the same place (with the same temperature conditions) differs from one and other.

As the sensor is embedded in a metallic case, the temperature readings will be highly affected by the sun exposure. For those applications where monitoring the temperature of the asset is required, we strongly recommend using thermistors prepared for those specific purposes.
Do not mix this information with the temperature influence of the accelerometer data which is published in the datasheet of each device.

Environmental best practices

Installation and operation

Please install Worldsensing products in an energy-efficient manner by minimizing power usage for computers, mobile phones or other devices needed for setup and configuration. Minimize the use of small components needed for installation, like mounting brackets and other connection materials. Avoid using toxic materials and/or hazardous substances.
- Set the sampling rate only in the nodes you need.
- When configuring the nodes, use "Set last configuration" whenever possible.
- Remove the batteries if you are not using the node.
- For nodes with switch, use the usb mode when not in operation.

Return Material Authorization (RMA)

In the event of requesting a Return Material Authorization (RMA) please make sure to use the most environmentally friendly mode of transportation possible.

Product End of Life and disposal

Please take the necessary measures to extend the life of the product and reuse it when possible.
Once the product reaches its end of life (EoL) recycling is crucial to divert material from waste streams into new applications.
Electrical and electronic devices, and batteries must be recycled according to the European Union WEEE Directive 2012/19/EU.
Please separate batteries from equipment.
This product and the batteries it may contain should not be discarded as unsorted waste. Please send them to separate collection facilities for recovery and recycling.

Product packaging

Worldsensing's product packaging is recyclable. Separate the different materials for a correct waste management.

Safety and emergency procedures

Please read the safety sheet that comes with our products before installing them. For safety information on batteries and other materials, as well as instructions in case of emergency please read the safety information available at: https://info.worldsensing.com/safety-information/
In the case of an emergency and after it has been managed, please evaluate the waste generated in order to dispose of it in accordance with current legislation and local regulation.
It is your responsibility to dispose of your waste equipment, batteries and packaging properly to help prevent potential negative consequences for the environment and human health.

The cost of environmental waste management is included in the battery's selling price.
By following these best practices you can help protect the environment. Thank you for your cooperation.

Appendix A. CSV example and JSON format

TIL90-X reading file example

til90ReadingsV1


```
{
  "temperature": 14.4,
  "nodeModel": "LS-G6-TIL90-X",
  "commMetaData": {
    "networkId": "21781",
    "macAddress": "80791748",
    "receivedTimestamp": "2021-11-04T16:01:20Z",
    "frequencyHertz": 869.05,
    "messageFrames": 1,
    "snr": 9,
    "sequenceCounter": [
      2719
    ],
    "gatewayId": 22891,
    "rssi": -59,
    "type": "longRangeRadioMetaDataV2",
    "sf": 7,
    "macType": "ETSIV1"
  },
  "nodeId": 51396,
  "readings": [
    {
      "std": 1.17e-5,
      "tilt": -2.0302,
      "channel": 0,
      "engineeringValue": -0.0518
    },
    {
      "std": 1.17e-5,
      "tilt": 0.6081,
      "channel": 1,
      "engineeringValue": 0.092
    },
    {
      "std": 2.34e-5,
      "tilt": 87.8806,
      "channel": 2,
      "engineeringValue": -0.0748
    }
  ],
  "readTimestamp": "2021-11-04T16:00:00Z",
  "highPrecision": 1,
  "type": "til90ReadingsV1"
}
```

Appendix B. Vibration Resistance Test (LS-G6-TIL90-I)

Below are the results from the vibration resistance test for the LS-G6-TIL90-I (LS-G6-INC360R) conducted by an external laboratory.

Device Under Test (DUT): 4 Inclinometers model LS-G6-INC360R

Technician: [redacted]

Applicable Standards:

The tests/inspections marked with * are not covered by ENAC accreditation

Procedure:	• -
Standard:	• EN 50125-3:2003+CORR2010. Railway applications. Environmental conditions for equipment. Part 3: Equipment for signalling and telecommunications (*) • EN 60068-2-64:2008. Environmental testing. Part 2-64: Tests. Test Fh: Vibration, broadband and guidance
Test according to:	• Random Vibration Test according to specifications of 4.13 Vibrations and impacts section (for level C.2) of the EN 50125-3:2003+CORR2010 standard and methodology of the EN 60068-2-64:2008 standard

TEST CONDITIONS				
RANDOM VIBRATION PARAMETERS				
TESTING DIRECTIONS	**FREQUENCY**	**PSD LEVEL**	**r.m.s. LEVEL**	**DURATION**
Vertical	5 Hz 850 Hz 2000 Hz	1 $(m/s^2)^2/Hz$ 20 $(m/s^2)^2/Hz$ 3 $(m/s^2)^2/Hz$	140.6 m/s^2	10 minutes
Longitudinal (1)	5 Hz 100 Hz 680 Hz 2000 Hz	0.2 $(m/s^2)^2/Hz$ 0.04 $(m/s^2)^2/Hz$ 6 $(m/s^2)^2/Hz$ 4 $(m/s^2)^2/Hz$	86.4 m/s^2	10 minutes
Transversal (1)	5 Hz 200 Hz 470 Hz 2000 Hz	0.1 $(m/s^2)^2/Hz$ 0.8 $(m/s^2)^2/Hz$ 2.2 $(m/s^2)^2/Hz$ 1.0 $(m/s^2)^2/Hz$	50.6 m/s^2	10 minutes
(1) The position of the sensor can be rotated horizontally 90 degrees when installed so the position is not clearly defined with respect to the axes stated in the standard. In this case the maximum level for horizontal axes is applied.				

CONTROL STRATEGY	Weighted control between two verification points placed on the fixture (see pictures 1 to 3)	
RESPONSE POINTS	NA	
FUNCTIONAL CONDITIONS	The DUTs are functional during the test. Technical personnel of the applying company is responsible of the functional conditions during the test (*)	
INITIAL AND FINAL MEASUREMENTS	Apparent visual inspection (no damages or incidences must be detected) Functional verification carried out by the applying company (*)	
INTERMEDIATE MEASUREMENTS	NA	
CLIMATIC CONDITIONS DURING THE TESTS	Temperature [min-max]:	20ºC - 25ºC
	Relative Humidity [min-max]:	25%HR – 75%HR
	Atmospheric Pressure [min-max]:	990mbar – 1010mbar

File Number: 20/36401787
Page Number: 6/11

Applus laboratories

3. OBTAINED RESULTS

3.1. RESULTS SUMMARY TABLE

REQUERIMIENT – TEST	RESULTS – REMARK
RANDOM VIBRACIÓN TEST (LONGITUDINAL AXIS – FIRST TEST)	
Intermediate measurements	NA
Initial and final measurements	No damages or incidences are detected
RANDOM VIBRATION TEST (LONGITUDINAL AXIS – SECOND TEST)	
Intermediate measurements	NA
Initial and final measurements	No damages or incidences are detected
RANDOM VIBRATION TEST (VERTICAL AXIS)	
Intermediate measurements	NA
Initial and final measurements	No damages or incidences are detected

CONTACT WORLDSENSING

Need more support? Get in touch with our Customer Success team:
Email: support@worldsensing.com

Phone: +34 93 418 05 85 (08.30h - 16.30h UTC)

Want to stay up-to-date about Worldsensing? Sign up for our newsletter:
www.worldsensing.com

Visit our blog for interesting content:
blog.worldsensing.com

Download the latest datasheets and infographics:
www.worldsensing.com/download-center

Follow us online