PiCUS TreeMotion Sensor

Application Manual

This manual has been created for the PTMS 3 device system with the following component versions:

Hardware version:	3.5.0002
Firmware version:	1.1.0006
App version:	2.0
PC program version:	3.1.1.1
Manual version:	20. September 2021

With Passion and Precision

Content

1 Abbreviations and conventions

PiCUS TMS 3	Tree Motion Sensor
TMS 3 App	TMS control software for mobile phones
TMS 3 Control	Software for Windows PCs for transferring and analysing data, which was measured with the PiCUS TMS 3
BLE	Bluetooth Low Energy

Input fields of the mobile phone's operation System are written in bold, italic and grey text ***EXAMPLE***.

Input fields of the TMS 3 App are written in bold, italic and green text ***EXAMPLE***.

Notifications from the TMS 3 App are written in bold, italic and blue text ***EXAMPLE***.

Links and references to other chapters in this manual or in the TMS 3 Control software manual *are written in italic*.

Potential error sources are warned of with a bold **Attention!** *Followed by a short explanation in italic*.

2 PiCUS TMS 3

2.1 Application

The PiCUS tree inspection equipment offers tree inspectors an extensive diagnostic suite for detecting and evaluating defects in trees. For evaluating a tree's stability, the PiCUS TreeQinetic pulling test and the PiCUS TMS 3 are suitable methods for measuring the root plate tilt in exhaustive tree inspections.

The PiCUS TMS 3 are the newest generation.

The PiCUS TMS 3 are accelerometer and can be influenced by strong ground shaking or by cracking in the wood. It is therefore imperative that, during the analysis of tilt measurements, exceptionally high tilt angles are checked for plausibility. For examination the analysis and raw data functions of the TMS 3 PC software will be used.

2.2 Disclaimer

The application of the PiCUS TMS 3 on other objects, can cause damages to both the sensor and the measured object. The measurement results obtained with the PiCUS TMS 3 require interpretation by a trained professional.

Conclusions about a tree's condition, based on the Wind Tipping Curves generated by the PiCUS TMS 3, are the sole responsibility of the interpreter. Neither manufacturer nor dealer are legally liable for any results caused by the application of the PiCUS TMS 3.

If the angle measurements made with PiCUS TMS 3 show a large tilt, indicating to fell the tree, the use of other inspection methods is required to verify the measurement results.

All technical specifications are subject to change without notice.

3 First time operation

3.1 General information

The PiCUS TMS 3 are (exclusively) controlled by a mobile phone application on **Android operating system version 4.4** or higher. This Application is henceforth called **TMS 3 App**.

For communication with the PiCUS TMS 3 the mobile phone requires **Bluetooth (Version 4.0 (BLE) – 5.0)**. It is also advantageous if the mobile phone has location tracking enabled while switching the sensor on and off.

3.2 Hardware

The PiCUS TMS 3 are completely sealed. Therefore, communication happens exclusively via Bluetooth.

The communication with the PiCUS TMS 3, while in charging mode and while placed in the charging cradle of the transport case, happens via Bluetooth 5 in high speed mode and the TMS PC program.

Outside of the charging mode Bluetooth 5 in BLE mode is used for communication with a mobile phone.

3.3 Ambient conditions for measurements

The PiCUS TMS 3 are protected against dust and constant submerging in water.

Temperature

Ambient temperature during measurement:	-20°C to +50 °C
Storage temperature:	0°C to +30 °C
Temperature for battery charging:	5°C to +35 °C

ATTENTION! *DO NOT charge or store at temperatures <0°C.*

3.4 First time operation of the TMS 3 App

The TMS 3 App realises communication with the PiCUS TMS 3, while they are not placed in their charging cradles.

The main function of the TMS 3 App is the configuration of the PiCUS TMS 3 and starting or stopping of measurements.

For connecting the PiCUS TMS 3 with a mobile phone an authentication code is necessary.

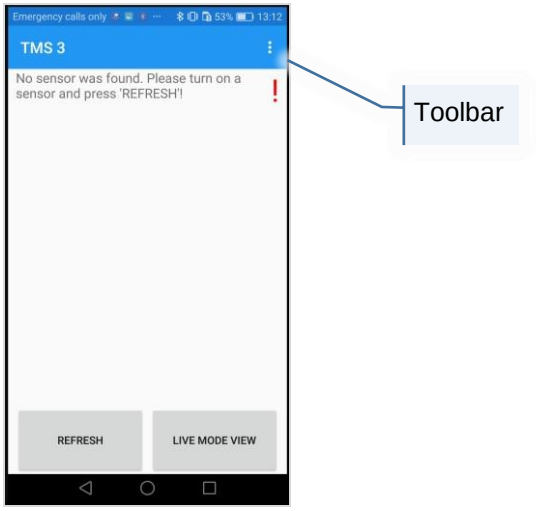
The authentication code must be set before establishing the first connection between the TMS 3 App and a PiCUS TMS 3.

Installation of the TMS 3 App on your mobile phone:

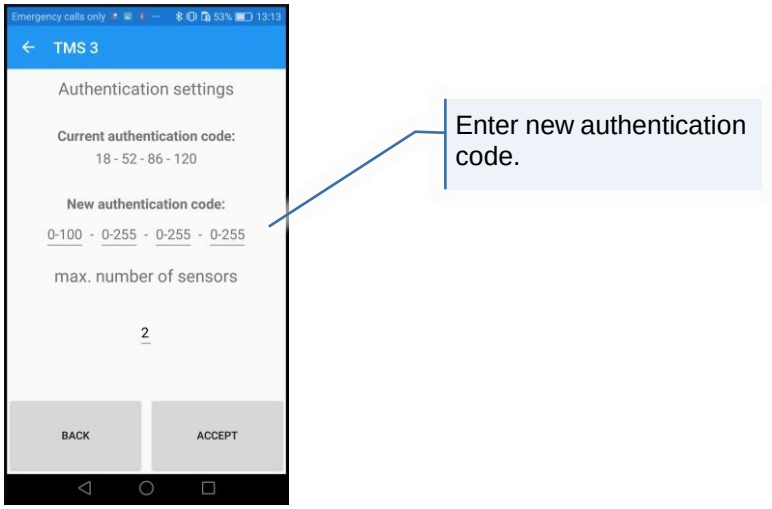
The TMS 3 App is available in Google Play Store (Android operating system) and in Apple Store. Just search for “TMS 3”.

Entering the authentication code:

1. Open the TMS 3 App.
2. Click the Toolbar in the upper right corner.



3. Choose ***SETTINGS*** → the view changes to the settings window of the App.
4. The top line shows the currently set authentication code, in the line below a new code can be entered.



5. The button ***ACCEPT*** saves the new code.

3.5 Tracking capabilities

The internal clock of the PiCUS TMS 3 is automatically synchronised with the mobile phone.
The basis is the system time or, in case of activated tracking functions, the GPS time in combination with the time zone set in the mobile phone.
This synchronises all PiCUS TMS 3 measurement data.

If no GPS is available, the system time of the mobile phone is transferred to the PiCUS TMS 3 when starting or stopping a measurement.

Attention! *The tracking capabilities of a mobile phone have a relatively large current consumption. Completely close the TMS 3 App, if it is no longer needed.*

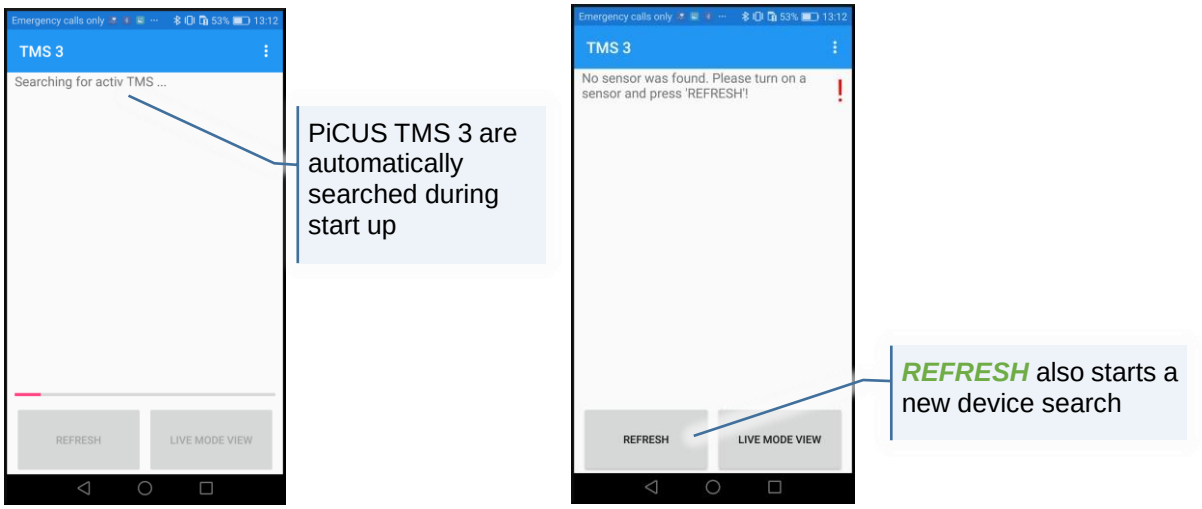
4 Performing measurements with PiCUS TMS 3

4.1 Activating the PiCUS TMS 3

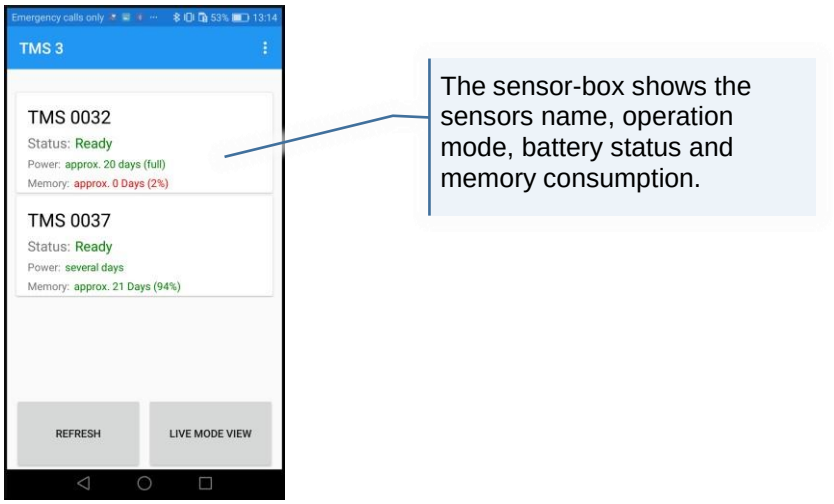
The PiCUS TMS 3 is switched on with a magnetic key. Therefore, the key has to be placed on the marked point of the PiCUS TMS 3 case for approx. 3 seconds.

Afterwards the TMS 3 App can be started.

The App automatically searches for active PiCUS TMS 3 during start up. If the App is already running, pressing ***REFRESH*** will also start a new search for active devices.



After the display refreshes all found PiCUS TMS 3 will be displayed in a sensor-box and then sorted in a device list. The PiCUS TMS 3 device name and additional information will be displayed.



The sensors status (2nd line) can have the following states:

- ***Ready***→ Standby mode, the PiCUS TMS 3 is waiting for commands
- ***Starting measurement***→ the PiCUS TMS 3 prepares for a measurement
- ***Measuring***→ a measurement is currently under way
- ***not connected***→ the PiCUS TMS 3 is not connected

The last two lines show information about battery level and memory consumption.

Additionally, every line is colour coded which allows it to easily discern relevant information.

The sorting of the list is done by sensor status (from first to last: standby, measurement mode, not connected). PiCUS TMS 3 with the same status are sorted by serial number.

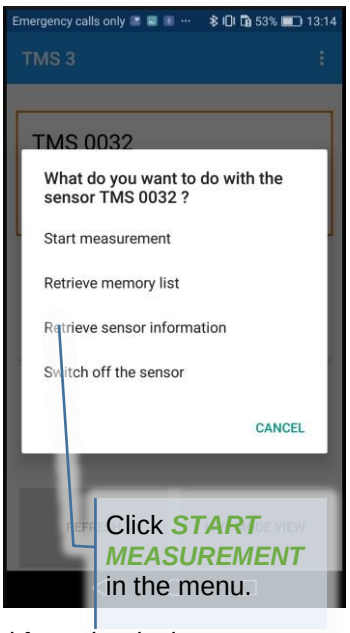
The PiCUS TMS 3 automatically deactivates Bluetooth communication, if no messages were received within the last 2 minutes. If the PiCUS TMS 3 was in standby mode beforehand, it will turn off completely. If it was in measurement mode, it will remain in measurement mode and merely deactivate Bluetooth communication.

Deactivation of the Bluetooth communication also removes the PiCUS TMS 3 from the device list of the TMS 3 App

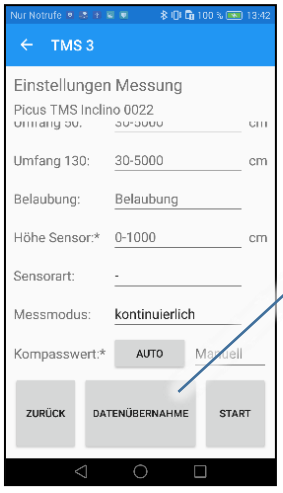
4.2 Starting a measurement

For starting a measurement with a PiCUS TMS 3 perform the following steps:

1. Mount the PiCUS TMS 3 on the tree.
   Please pay attention to chapter *6 PiCUS TMS 3 mounting instructions*.
2. Start the PiCUS TMS 3 with the magnetic key (see *4.1 Activating the PiCUS TMS 3*).
   ATTENTION! *Wait for the initialisation time of approx. 5 s.*
3. Start the TMS 3 App or press ***REFRESH*** for an update of the device list.
   This process may take a few seconds.
4. The activated PiCUS TMS 3 is now visible in the device list.
5. Check the sensor status: ***READY*** signalises readiness for a measurement.
6. Clicking on the sensor-box opens the control menu.
7. Menu item ***START MEASUREMENT*** → the view changes to the configuration window of the measurement. Here all relevant tree data is set.
   ATTENTION! *Some fields are required.*
8. Click the ***START MEASUREMENT*** button.
   If a setting is missing or incorrect an error message will be displayed so that a correction is possible.
9. The App will request the decision for the PiCUS TMS 3 to automatically deactivate its Bluetooth after completing the starting process.
10. GPS data is collected during the following wait time (time and position). If the GPS signal is not available the phone's internal system time is used as start time for the measurement.
11. After the end of the start process the view goes back to the device list. The status of the PiCUS TMS 3 is now displayed as ***STARTING MEASUREMENT***.
12. After approx. 20 s the PiCUS TMS 3 automatically changes to: ***MEASURING*** with a subsequent update in display. PiCUS TMS 3 which are now switching off their Bluetooth communication will be removed from the device list.
13. For all devices which shouldn't automatically deactivate their Bluetooth:
    For saving energy it is possible to manually deactivate Bluetooth communication (in the sensor's control menu → ***SWITCH OF THE BLUETOOTH***). Alternatively, the Bluetooth communication will automatically shut down after 2 minutes if the PiCUS TMS 3 receives no new messages from the mobile phone.



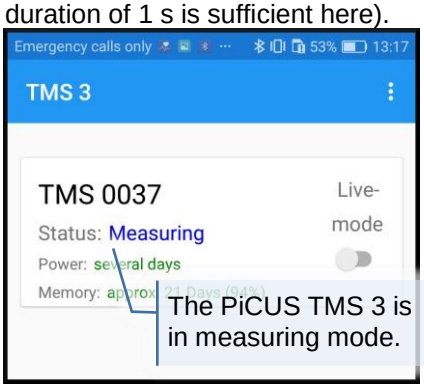
Tip! *At the bottom of the configuration menu for a measurement is a button called **LAST SETTINGS**. With the help of this button all settings from the previously made measurement can be taken. That way, tree parameters need not be entered twice when starting a base and a control sensor. Only the sensor data (sensor height, sensor type) and the compass value have to be filled in again.*



4.3 Stopping a measurement

For stopping a measurement with a PiCUS TMS 3 perform the following steps:

1. Activate BLE in the PiCUS TMS 3 with the magnetic key (a duration of 1 s is sufficient here).
   ATTENTION! *Wait for the initialisation time of the communication of approx. 5 s!*
2. Start the TMS 3 App or ***REFRESH*** for an update of the device list.
   This process may take a few seconds.
3. The activated PiCUS TMS 3 is now visible in the device list.
4. Check sensor status: ***MEASURING***
5. Clicking on the sensor-box opens the sensor control menu.



6. Choose ***SWITCH OF THE SENSOR*** → confirm the security query.
7. During the following wait time GPS data is collected (time and position). If the GPS signal is not available the phone's internal system time is used as stop time for the measurement.
8. After finishing the stopping procedure, the view changes back to the device list. The sensor is now no longer listed (has shut itself down).

4.4 Additional functions of the TMS 3 App

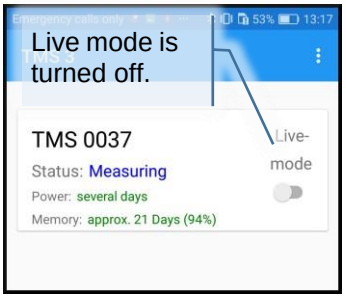
4.4.1 Live mode

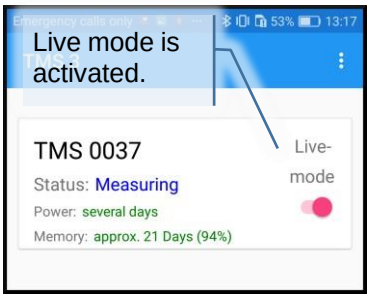
While the sensor is in measurement mode, the live mode shows the highest tilt in the last second. Live data from all connected sensors can be shown simultaneously.

The live mode has to be activated for the PiCUS TMS 3 to send live measurement data to the mobile phone.

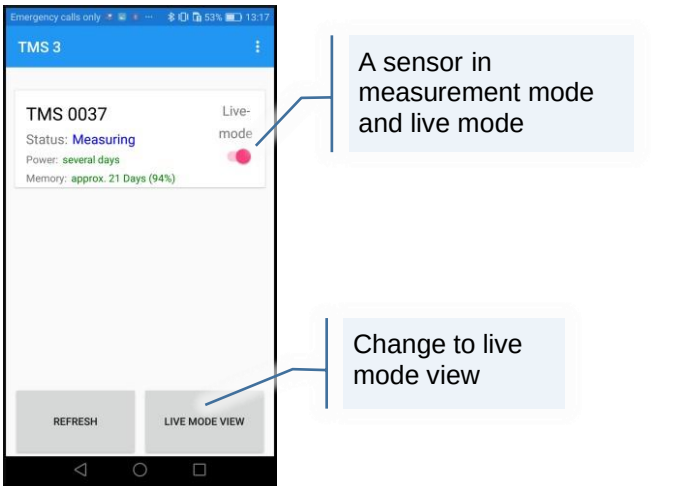
Proceed as follows:

1. Prerequisite is a running measurement (see *4.2 Starting a measurement*)
2. Every sensor-box in the device list has, while operating in measurement mode, a button on the right side. These buttons activate the ***LIVEMODE*** for the associated sensors.

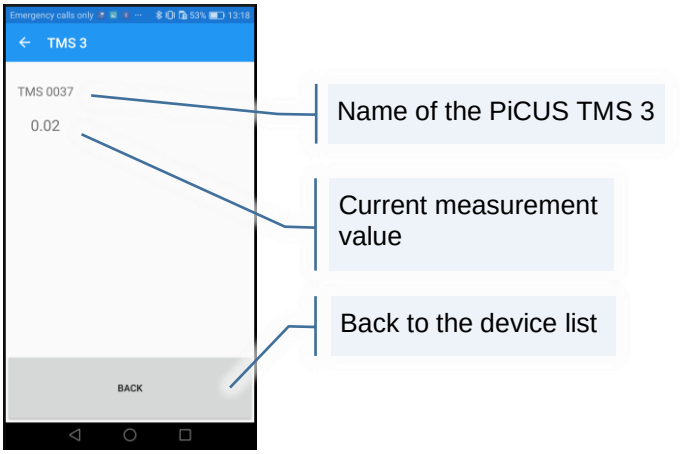




3. By clicking ***LIVE MODE VIEW*** the view changes to the life display. Here, all current measurements of the PiCUS TMS 3 with activated live mode are shown.

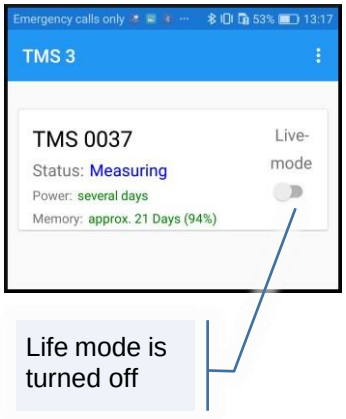


4. Live mode view:



5. With the button ***BACK*** the view changes back to the device list.
6. If the live mode is no longer required **it should be deactivated for all sensors** (click ***LIVEMODE*** in the sensor-box again).

   When turning off Bluetooth in the PiCUS TMS 3 or closing the TMS 3 App, the device will deactivate the life mode by itself.

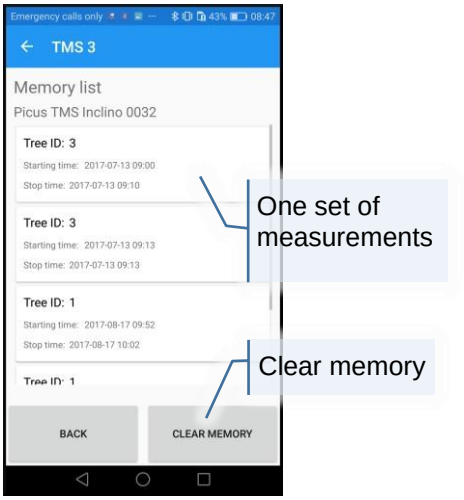


4.4.2 Downloading and clearing the PiCUS TMS 3 memory

For every PiCUS TMS 3 in the device list (main view of the TMS 3 App) the remaining free memory is shown. If the memory of a PiCUS TMS 3 is nearly full, it is recommended to clear it before a longer measurement.

ATTENTION! *The Memory of a PiCUS TMS 3 can only be cleared completely. All data not yet downloaded to the PC will be lost in the process.*

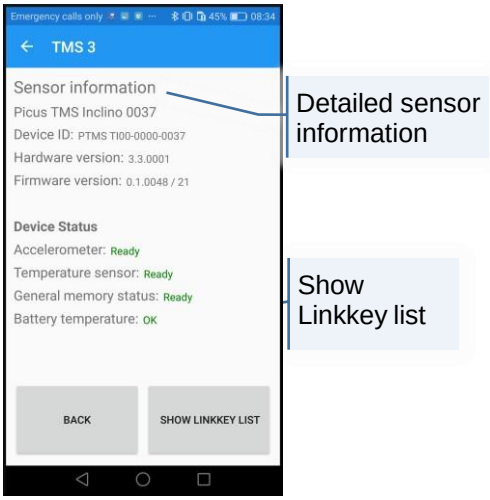
Proceed as follows:



1. Start the PiCUS TMS 3 with the magnetic key (see *4.1. Activating the PiCUS TMS 3*).
   ATTENTION! *Wait for the initialisation time of approx. 5 s!*
2. Start the TMS 3 App or click ***REFRESH*** in the device list.
   This may take a few seconds.
3. The activated PiCUS TMS 3 is now shown in the device list.
4. Check sensor status: ***READY*** → Sensor is ready to display the memory list.
5. Clicking the sensor in the device list opens the control menu.
6. Menu item ***RETRIEVE MEMORY LIST*** → the view changes to the **MEMORY LIST**.
7. Every entry in the list is one recorded measurement.
8. Click ***CLEAR MEMORY*** to delete all measurements.
   ATTENTION! *By clearing the memory of the PiCUS TMS 3, all files in the internal memory of the PiCUS TMS 3 will be deleted, without the possibility of recovery.*

4.4.3 Querying sensor information

The TMS 3 App allows querying of detailed sensor information from every PiCUS TMS 3:



1. Start the PiCUS TMS 3 with the magnetic key (see *4.1. Activating the PiCUS TMS 3*).
   ATTENTION! *Wait for the initialisation time of approx. 5 s.*
2. Start the TMS 3 App or click ***REFRESH*** in the device list.
   This may take a few seconds.
3. The activated PiCUS TMS 3 is now shown in the device list.
4. Check sensor status: ***READY*** → Querying sensor information is now possible
5. Clicking the sensor in the device list opens the control menu.
6. Menu item ***RETRIEVE SENSOR INFORMATION*** →
   The view changes to ***SENSOR INFORMATION***.

This site displays Bluetooth name, device-ID and the hardware and firmware version.

There is also information about the status of the tilt sensor and the temperature sensors, the internal memory and the battery temperature.

Especially important is the Battery temperature, because it indicates whether the device may be charged.

4.4.4 Querying and deleting the link key list

(obsolete, only relevant for TMS 3 Hardware Version 3.4)

The link key list saves all Bluetooth addresses from PCs that were already paired with the PiCUS TMS 3. This allows a fast and automated reconnection with these PCs.

A maximum number of 8 Bluetooth addresses can be saved. Afterwards, if a new computer is connected with the PiCUS TMS 3 the oldest entry in the list gets overwritten.

When connection problems happen, it can be necessary to delete the link key list.

1. Navigate to the page ***SENSOR INFORMATION*** (see *4.4.3 Querying sensor information*)
2. Press the button ***SHOW LINKKEY LIST*** → view changes to the link key list
3. For deleting the list press ***DELETE LIST***.

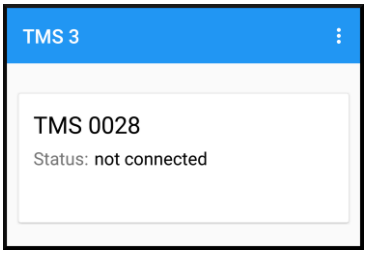
ATTENTION! *After deleting the link key list, all PCs have to be paired anew when connecting with the PiCUS TMS 3.*

4.4.5 Errors

If no connection can be established between the PiCUS TMS 3 and the mobile phone:

- Make sure that the sensor is switched on
- Shorten the distance between sensor and mobile phone (< 5 m)
- Establish a direct line of sight between sensor and mobile phone

➔ Search for active sensors again with ***REFRESH***



5 Notes on Bluetooth communication with Android devices

Due to the multitude of Android based mobile phones available Bluetooth communication via **BLE** can vary across platforms.

ATTENTION! *Android versions 4.4 and earlier are unable to communicate with BLE devices (like the PiCUS TMS 3).*

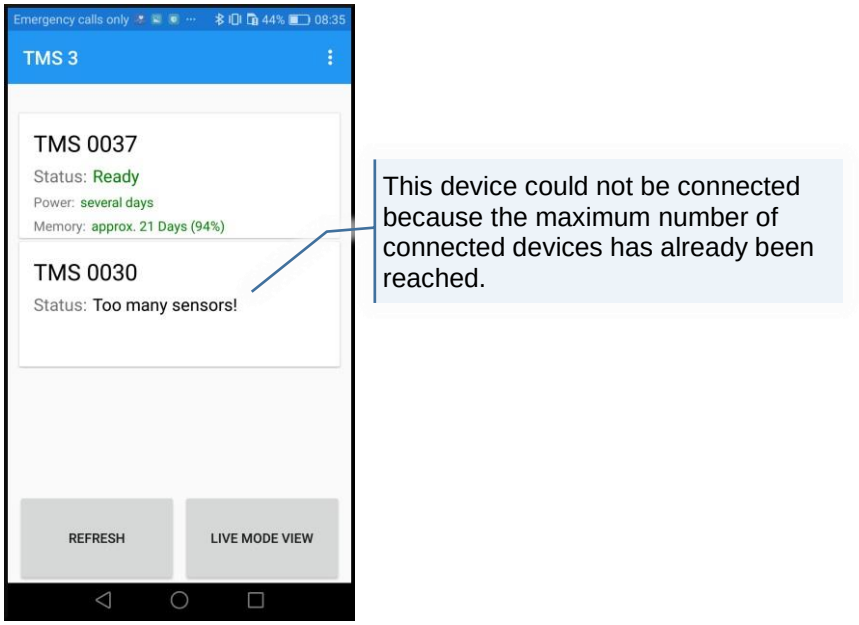
5.1 Maximum number of connected sensors

The maximum number of devices that can be connected via BLE is dependent on the hardware of the mobile phone and on the Android version used.

BLE can connect a maximum of 7 devices simultaneously. Depending on the mobile phone used, it might be less.

ATTENTION! *Other BLE devices, that are not part of the PiCUS TMS 3 System (e.g. BLE capable smartwatches), also factor into the maximum number of simultaneous BLE connections.*

When trying to connect one more sensor with the mobile phone, all previously connected PiCUS TMS 3 are shown simultaneously with all newly found ones. For not connected PiCUS TMS 3 the status line reads ***TOO MANY SENSORS!***



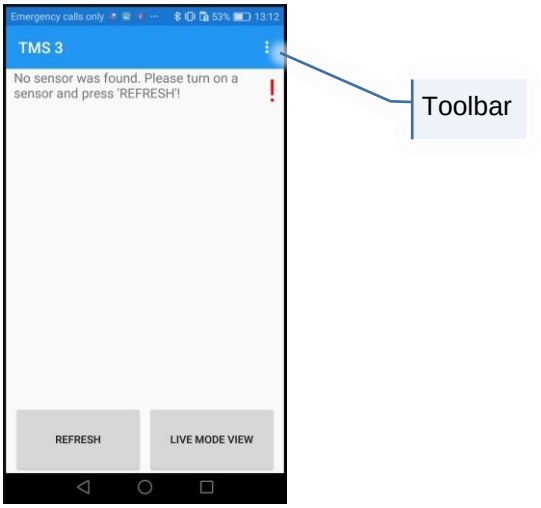
For establishing a connection with a new PiCUS TMS 3 that currently cannot be connected, switch off one of the other currently connected devices and press ***REFRESH***. Make sure the PiCUS TMS 3 hasn't been running for more than 2 minutes since switching on, because after 2 minutes without communication the PiCUS TMS 3 turn themselves off or deactivate their Bluetooth module while in measuring mode.

5.1.1 Controlling the maximum number of PiCUS TMS 3

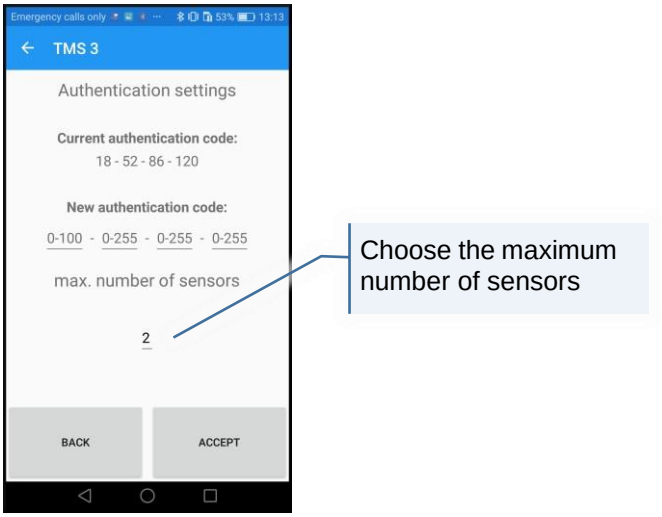
The TMS 3 App allows setting the maximum number of PiCUS TMS 3 to which it might connect simultaneously. The default setting is 2. This means that the TMS 3 App can connect to a maximum of 2 active PiCUS TMS 3 regardless of the mobile phones capabilities.

This setting can be changed as follows:

1. Start the TMS 3 App.
2. Click the toolbar in the upper right corner.



3. Click ***SETTINGS*** → the view changes to the settings page.
4. Choose ***MAX. NUMBER OF SENSORS***.



5. The button ***ACCEPT*** saves the new value → it is now displayed green.

If the set value is higher than what the mobile phone's hardware is capable of handling, the update process in the TMS 3 App may take a very long time and the connection attempts with the PiCUS TMS 3 will most likely fail. If the phones capabilities are unknown, this should be tested thoroughly.

Set the number of simultaneously allowed PiCUS TMS 3 to its maximum value of 7. Then switch on 7 PiCUS TMS 3 and click ***REFRESH***. If the mobile phone is capable of handling that number of device all PiCUS TMS 3 should connect. If not, reduce the number of allowed sensors and retry establishing a connection until a value is found where the connection works without fail.

5.2 Problems connecting to multiple sensors

When trying to simultaneously connect multiple sensors with the TMS 3 App (e.g. for showing them all in live mode) it may happen that not all sensors connect. That can have multiple causes.

For once, it is possible that the maximum number of devices that can simultaneously connect to the phone is reached (see *5.1. Maximum number of connected sensors*).

There is also the possibility that the connection fails due to too much radio noise in the vicinity. In this case it helps to turn on the sensors one by one and to perform the device search for each one separately.

6 PiCUS TMS 3 mounting instructions

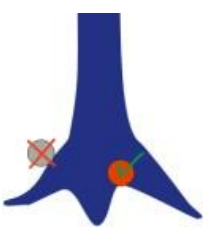
Pay attention to the following hints when choosing the mounting position of the PiCUS TMS 3 on the trunk.

6.1 Installation of base sensors

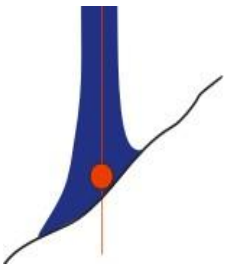
In principle, the base sensor is to be mounted as close to the ground as possible, so that the sensors centre is no more than 5 - 10 cm above ground. This is important for exclusively measuring the root plate tilt. If the sensor is mounted higher, the bending of the trunk gains a greater influence on the measuring result.

If the tree has large roots or buttress roots, the PiCUS TMS 3 should be mounted between the roots.

For trees on sloped ground it is recommended to mount the PiCUS TMS 3 sideways, which is halfway between the upper and lower ground entry points. This is determined arbitrarily. If you use other mounting points make sure to always use the same. This guarantees comparability between different trees or between different measurements on the same tree.



Tree with large roots



Tree on sloped ground

6.2 Installation of control sensors

The measurements done with the control sensor are primarily used for determining the source of the base sensors tilt.

Ongoing research in the field of Wind Reaction Measurements may yield new analysis algorithms in the future. In order to be prepared for such an eventuality, and therefore for the retroactive analysis of old measurement data, it is recommended to always log the exact height of the control sensor. The control sensors height should be between two and three metres.

For a methodical approach it is sensible to use the same mounting height for all measurements.

7 Copying PiCUS TMS 3 measurement data onto a PC

For downloading a measurement file onto a PC, a Windows operating system (Microsoft Windows 7/8/8.1/10) and a Bluetooth 5.0 interface is required (a Bluetooth 5.0 USB-Dongle is part of the delivery). Additionally, the TMS PC program has to be installed.

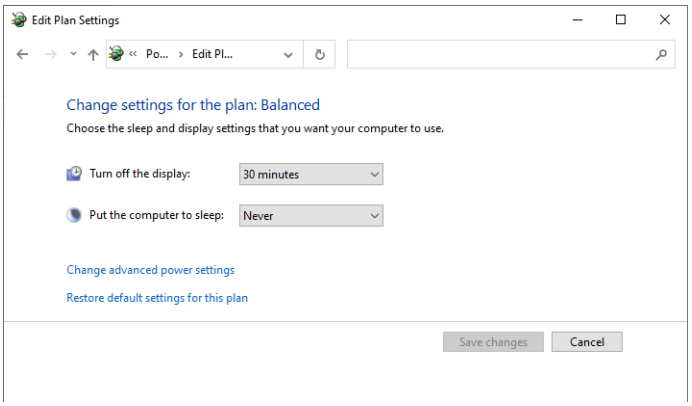
Choosing which files to download from the PiCUS TMS 3 can be done in the TMS PC program. The download itself is automated.

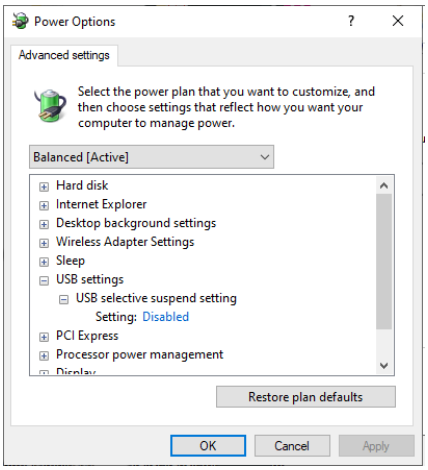
Instructions on how to initiate the file download can be found in the TMS Software manual in chapter "*4.8.7 Import Data".*

ATTENTION! *The data will be transferred in high speed mode of Bluetooth 5. Bad radio conditions can limit the transfer rate and in worst case can cause the transfer to abort!*

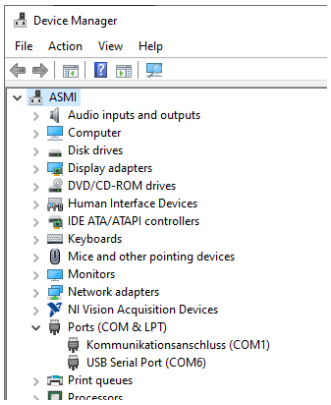
Following are some hints, how to improve the transfer performance:

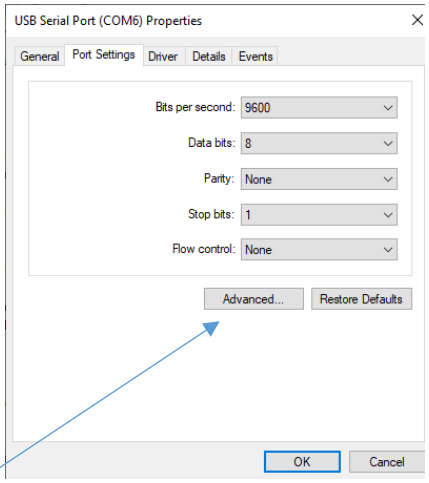
- Keep the TMS 3 and the Bluetooth receiver (the enclosed USB-Dongle) as close as possible!
- Under Windows disable the "USB selective suspend settings" in the "power plan settings" → "advanced power settings":





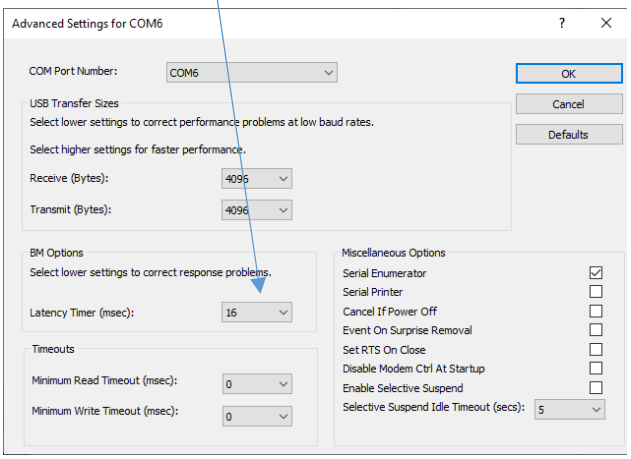
- Change the configuration of the FTDI-Driver for the serial Interface of the enclosed Bluetooth 5 USB-Dongle:
  - Open Windows device manager → Dongle should be displayed as USB Serial Port





  - Open port properties (double click or right click → "Properties")
  - In the following properties window go to tab "Port Settings" and klick on button "Advanced…"

- Under “BM Options” shorten the Latency Timer setting to less than 10 ms



8 Charging PiCUS TMS 3

The PiCUS TMS 3 are charged wireless in the charge bays of the TMS-case.

The charger electronic detects sensors placed in the charge bays and automatically chooses the optimal charging regime.

For charging the sensors proceed as follows:

1. Connect the TMS-case to the power supply.
2. Put a PiCUS TMS 3 into a charge bay.
3. The charge LED starts blinking green.
4. If the charge LED constantly shines green the PiCUS TMS 3 is fully charged.

ATTENTION! *The red error LED signals that the PiCUS TMS 3 is not being charged.*

The cause for this is that the PiCUS TMS 3 is either too cold or too hot. When this error occurs the PiCUS TMS 3 can remain in its charge bay. The charging automatically starts once the temperatures have equalized.

If this state persists for an extended period of time (1h), the temperature of the PiCUS TMS 3 can be checked as follows:

1. In the TMS 3 App navigate to ***SENSOR INFORMATION*** (see *4.4.3 Querying sensor information*)
2. Check the battery temperature (see *10 Technical data*)

9 Battery care

Due to the casting, the battery of the PiCUS TMS 3 cannot be changed.

Wrong handling may damage the battery and will shorten its life span.

To get the most out of the battery’s life span, special care should be taken when handling the PiCUS TMS 3.

The following instructions should be followed:

- Never store PiCUS TMS 3 in a discharged state!
- If stored for an extended period of time (e.g. during summer, when no wind events occur) it is recommended to charge the PiCUS TMS 3 to their storage level (approx. 60% charged, see TMS 3 Control manual chapter „*4.6.1.6 Battery Storage Mode*“.).
  If the battery has to be charged, it takes approx. 30 min until the storage level is reached. If on full charge, the battery has to be discharged. In this case reaching the storage level may take up to 12 h.

10 Technical data

Property	Value
General characteristics	
colour	grey
weight	73 g
dimensions	61 mm x 41 mm x 20 mm
protection	Protected against dust & permanent submerging in water
mounting	1 self-tapping, fillister head screw
min. lifetime	5 years
Battery	
Battery capacity	250 mAh
Battery runtime	> 14 days
Charging	Wireless, directly in the TMS-case
Maximum charge current	approx. 200 mA
Charge duration	approx. 2 h
Recommended charging temperature	5 – 35 °C (ambient temperature)
Maximum temperature range for charging	0 – 40 °C (ambient temperature)
Measurement	
Accuracy tilt measurement	0,03°
Resolution tilt measurement	0,005°
Measurement interval	0,05 s (20 Hz)
Type of tilt measurement	3D-measurement
Sensor orientation	arbitrary
Accuracy temperature measurement	1 °C
Temperature range	-20 – +50 °C
Accuracy battery voltage measurement	0,05 V
Memory	
Memory type	Internal Flash memory
Memory size	256 MB
Memory runtime	20 days
Communication	
Standby- and measuring mode	Bluetooth Version 5.0 BLE mode
Data download	Bluetooth Version 5.0 High Speed mode
max. transmission rate	approx. 200 kBps

Handling	
TMS power on	Magnetic key
Outdoor-handling	BLE- or Bluetooth 5-capable mobile phone (Android, iOS) + TMS 3 App
Data-download and analysis	PC with Bluetooth 5 (enclosed USB-Dongle) + TMS.Software
TMS-case	
Power supply	230 V AC, 50 Hz
Output power supply	24 V DC, 2,5 A (60 W)
Number of TMS chargers	10
Maximum number of TMS	20
max. charging power per charge bay	1,25 W
Weight, filled (screws, cable, 10 PiCUS TMS 3)	5,5 kg

11 Manufacturer

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