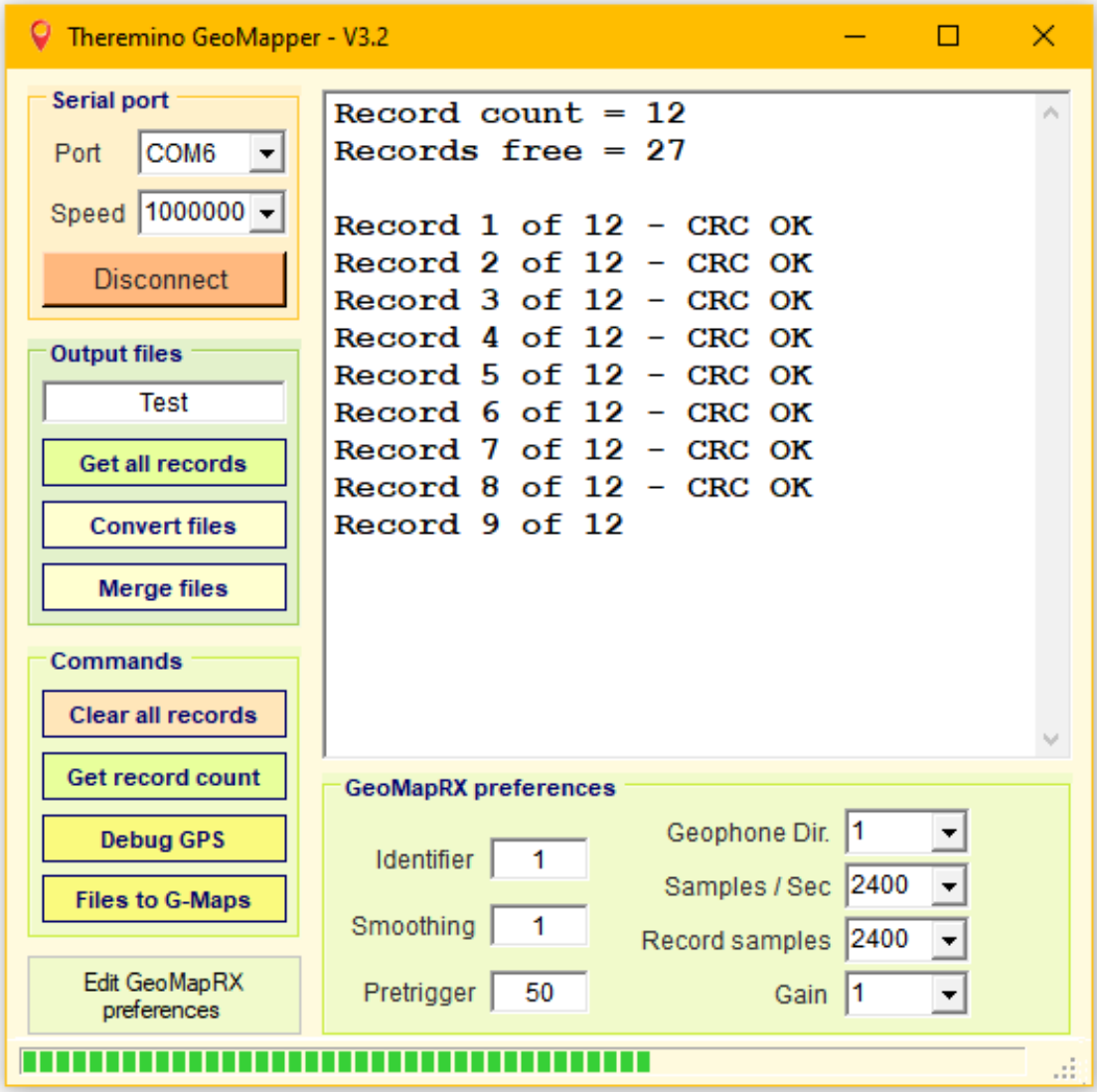
System theremino



Theremino GeoMapper V3.2.x

General index

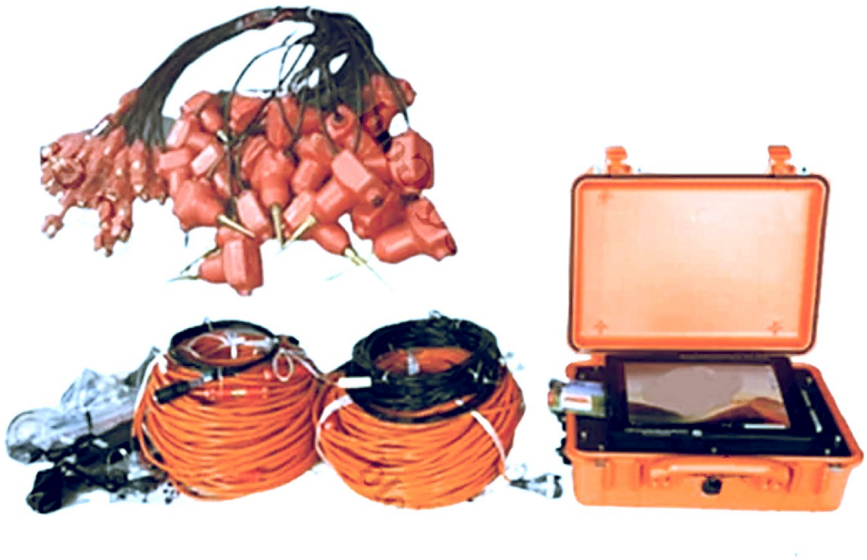
Advantages of the GeoMapper system

Traditional seismic refraction, reflection, and MASW systems use long cables, both to synchronize the striking hammer with the data recording device and to connect the geophones to each other.

Here is an example of what needs to be transported with such systems.

In this system the geophones, which seem like a big pile, are only 24. If there were 48 it would be even worse.

Much of the weight is due to the cables, which also take a lot of time to unwind, clean, and rewind.



And here you see an example with fewer geophones.

Even with just 12 geophones, there is a lot of weight to carry and also many meters of cable to lay out, clean, and rewind.

We therefore studied a system to eliminate cables and synchronize the geophones via radio.

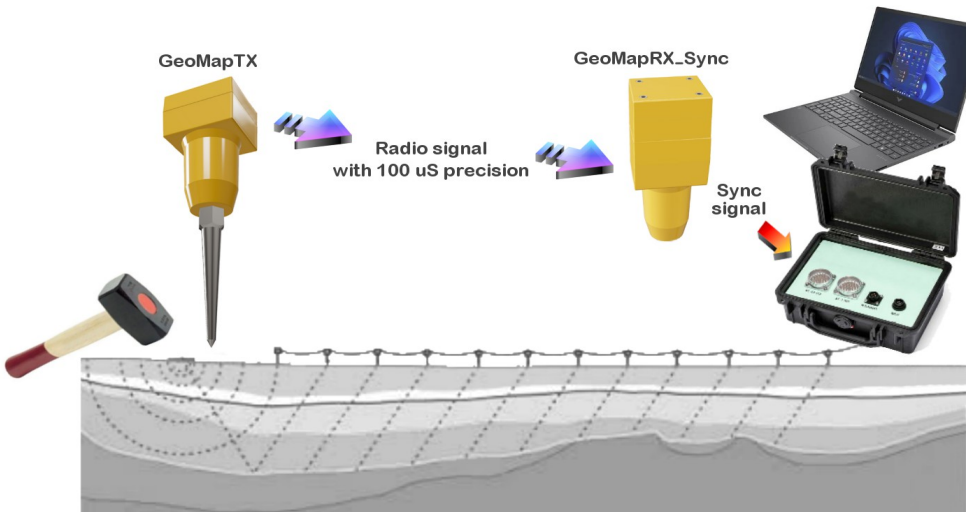
The system **GeoMapper** In addition to the cables, it also eliminates the control unit and stores the recordings (up to several hundred) directly in the geophones themselves.

You get better performance, a good time saving, less weight to carry and also a significant economic saving.

Remove the sync cable

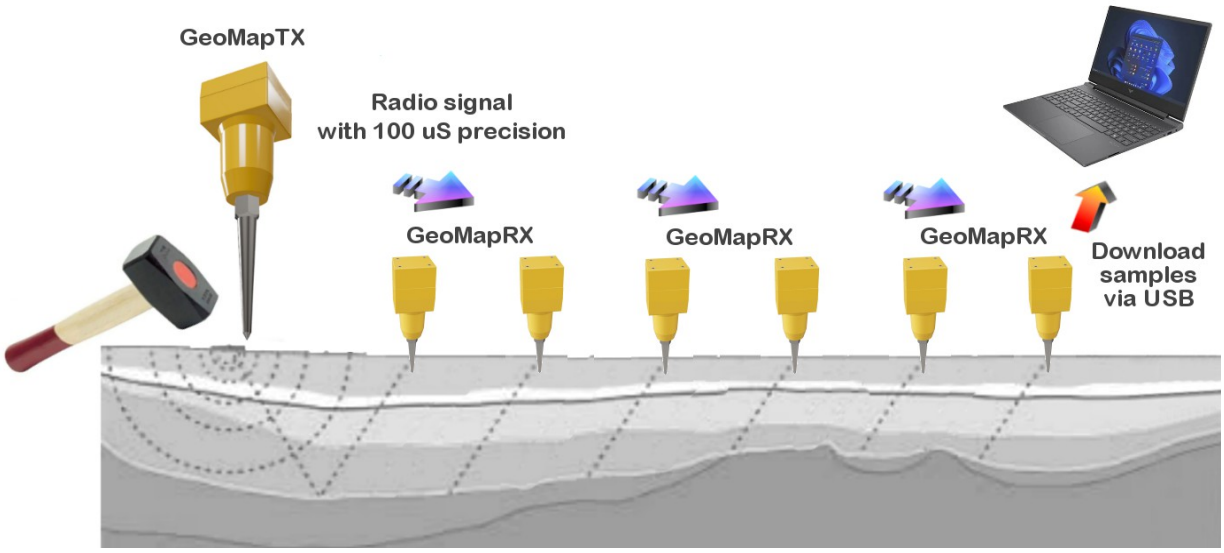
The system **GeoMapper** can eliminate the sync cable and replace it with a **GeoMapTX** and a **GeoMapRX_Sync**.

This already means a good saving, less weight to carry in the car and to unroll, less expense and fewer cables to clean.



Eliminateare all the cables

With the system **GeoMapper** all cables and even the control unit can be eliminated, reducing overall cost and achieving better performance. It can sample at higher frequencies, with lower ADC noise, and requires less time to prepare the layout.



The **GeoMapRX** there can be 6, 12, 24, 48 or even more, the limit is only due to the number of devices to be transported, cleaned and recharged.

But you can also use just one **GeoMapRX** and move it with each energization, or move the striking point. You'll make more strikes, but you'll spend less time laying them out and less on purchasing the geophones.

System Features

Required hardware

- A form **GeoMapTX**
- One or more modules **GeoMapRX** (Note 1)

GeoMapTX Module

- 5V power supply with about 40but
- An 18650 lithium battery that allows for thousands of recordings.

GeoMapRX Module

- Up to 309 0.125 second recordings.
- Recordings remain stored even when turned off.
- Recording duration from a minimum of 0.125 seconds up to 32 seconds.
- 24-bit sampling up to 19200 samples per second.
- Synchronized sampling with an accuracy of +/-10 uS.
- Noise less than 0.6 uV rms (4800 samples per second and gain 128).
- Storing Latitude, Longitude and Altitude in meters.
- Variable smoothing for more accurate Latitude, Longitude and Altitude
- Stores date and time accurate to within a second.
- Flexibility in programming operating modes.
- 5V power supply with approximately 70 mA
- A single 18650 lithium battery allows for thousands of recordings.

Software and firmware

- An application **GeoMapper** on the PC
- Firmware for modules **GeoMapTX, GeoMapRX** and **GeoMapRX_Sync**

Note 1

You can use a single **GeoMapRX** and manually move it to the next position. Or you can use multiple ones, such as 12 or 24.

The modules **GeoMapRX** they can be programmed in various ways, to carry out surveys and layouts of all kinds, see the "GeoMapRX - Configuration" pages.

The modules **GeoMapRX** and **GeoMapRX_Sync** can send a command to the module **GeoMapTX** to initiate automatic energization via radio.

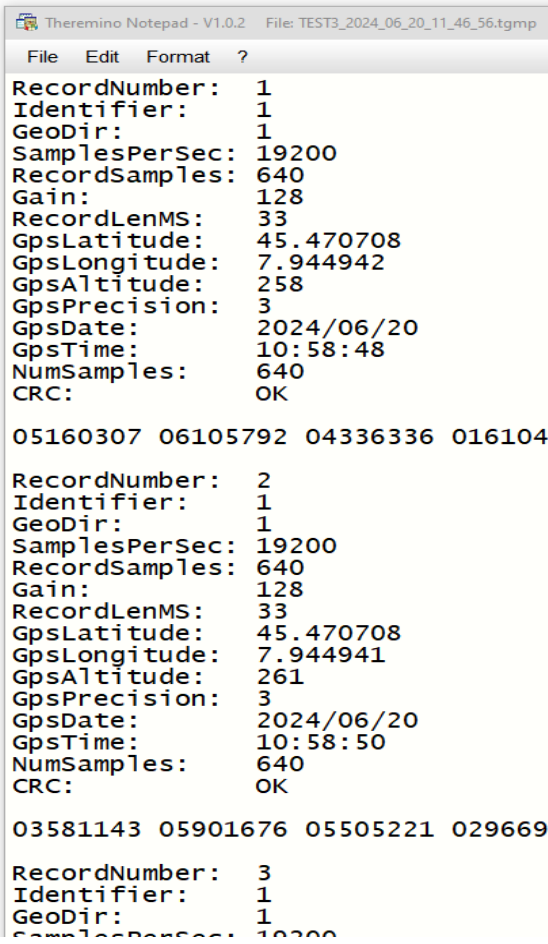
Recorded file format

Files are downloaded from the form **GeoMapRX** with the "Get all records" button andare written to the "Files" folder with the extension ".tgm", which is short for **Theremino_GeoMapper**.

Each file can contain from one to over a thousand recordings, and each recording contains a few lines of information followed by the samples, which can be 19200, 9600, 4800, 2400, 1280, or 640 depending on the "RecordSamples" setting.

The initial lines contain:

- **Record Number**- Progressive registration identifier (from 1 to 1117)
- **Identifier**- Module identifier (1 to 99)
- **GeoDir**- The direction of the geophone (1=Vertical or 0=Horizontal)
- **SamplesPerSec**- Samples per second (from 19200 to 640)
- **RecordSamples**- Number of samples in each record (from 19200 to 640)
- **Gain**- ADC gain set (1, 2, 4, 8, 16, 32, 64 or 128)
- **RecordLenMS**- Recording length (from 33 mS to 30 000 mS)
- **GPSLatitude**- Latitude in degrees and fractions of a degree
- **GPS Longitude**- Longitude in degrees and fractions of a degree
- **GPS Altitude**- Height above sea level in meters
- **GPS Precision**- Horizontal accuracy in meters
- **GpsDate**- Date (year, month and day)
- **GPSTime**- Time (hour, minutes and seconds)
- **NumSamples**- Number of stored samples (same as RecordSamples)
- **CRC**- The result of the validity test on the read values (OK or WRONG)



The following part contains the raw 24-bit samples, i.e.numbers from 00 000 000 to 16 777 215.

The samples are all on a single line and all eight characters long plus one space, as in the following example:

```
01320630 15762321 01676050 00010658 .....
```

The date and coordinates produced by the GPS are not very precise (1 second and 1 meter in the best cases) and are therefore only used to identify the recordings and place them correctly in the drafts.

The accuracy is given by the radio signal that synchronized the start of recording and the pretrigger.

Format of files converted to CSV

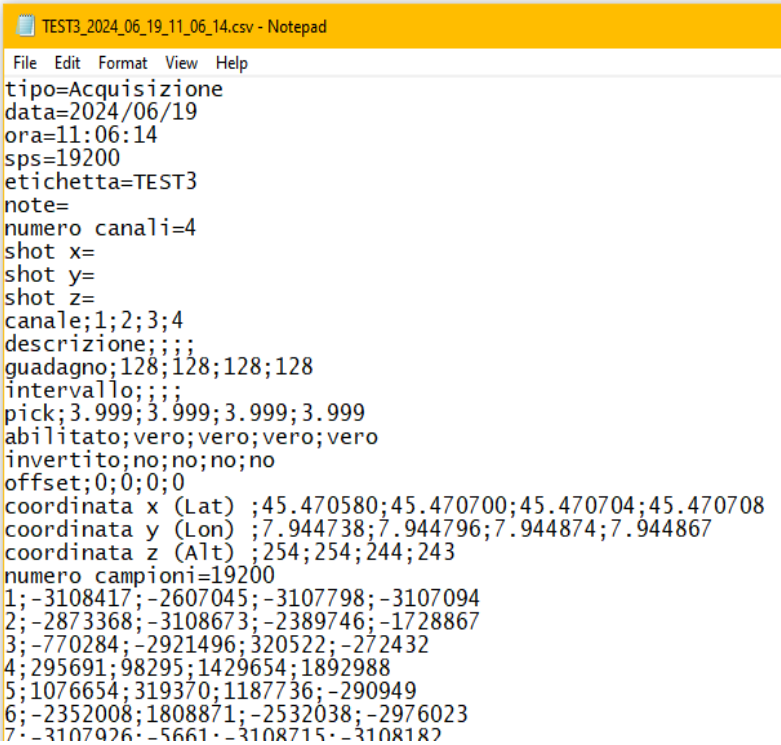
The buttons **Convert files** and **Merge files** of the application **Geo Mapper** (explained in the next pages) create CSV type files, like the one in the following image.

The CSV format produced is one of the most used; we may add more formats in the future.

Our TGM files contain all the information relating to the recordings made, but when converting them some of this information is lost, so we decided to keep them as an intermediate format.

Later using **Convert files** and **Merge files** they convert them to CSV format.

TGM files contain a list of recordings one below the other sorted in the same sequence as when they were made, while CSV files contain rows with a certain number of samples, one for each geophone, and each geophone should be in a different physical position along the "layout".



If you use only one **GeoMapRX** by moving it along the layout with each new energization, or by leaving it still and moving the energization point, you will eventually have a single file with all the recordings one after the other. In this case you will use **Convert files** which will transform this file into CSV format

If you have used many instead **GeoMapRX** with just one power up, you will eventually have many files, each downloaded from a **GeoMapRX** different. In this case you will have to use **Merge files** and select all downloaded files. **Merge files** will read all the files and combine them into a single file in CSV format.

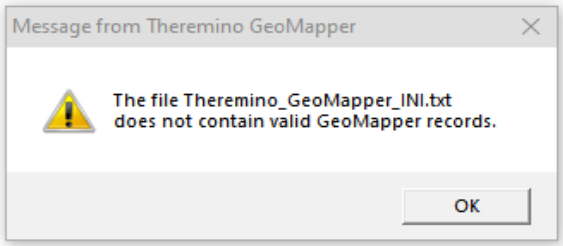
There are also many other hybrid possibilities, such as using a certain number of **GeoMapRX** and carry out successive energizations in several different points.

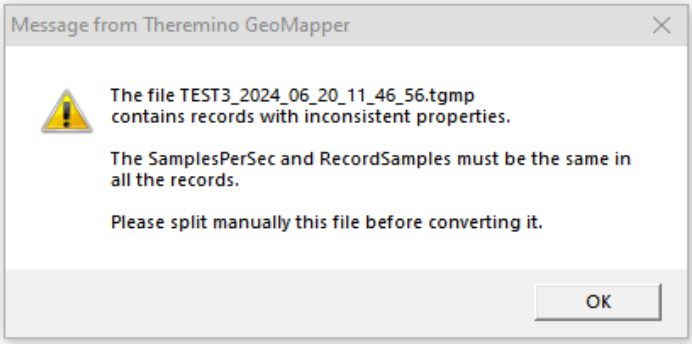
The converters **Convert files** and **Merge files** they wouldn't know how to handle these cases, so they'll have to use special programs to prepare the files, edit them, and modify them appropriately.

Files suitable for Convert files and Merge files

You use the button **Convert files** when several subsequent registrations have been made with a single form **GeoMapRX** and usually you only have it convert one file, but it could also convert more than one and in this case it will not join them together but for each selected TGM file it will produce a CSV file.

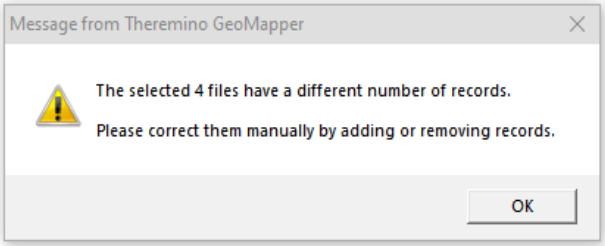
Each file to be converted with **Convert files** It must contain many consecutive recordings, and all recordings must have been made with the same SamplesPerSec and RecordSamples values. Otherwise, you will receive the following error messages.

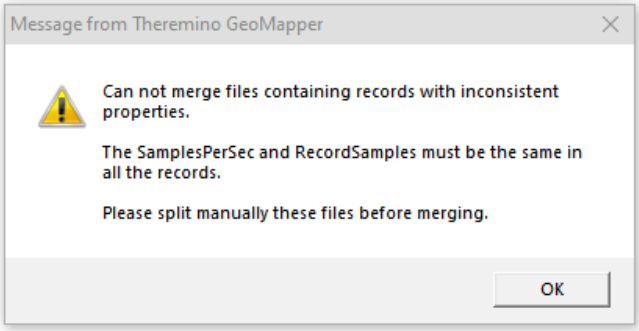




You use the button **Merge files** when numerous modules have been used **GeoMapRX** and so you have many files, each produced by one of the modules.

All files to convert with **Merge files** they must contain the same number of records and be registered with the same SamplesPerSec and RecordSamples values. Otherwise, you will receive the following error messages.



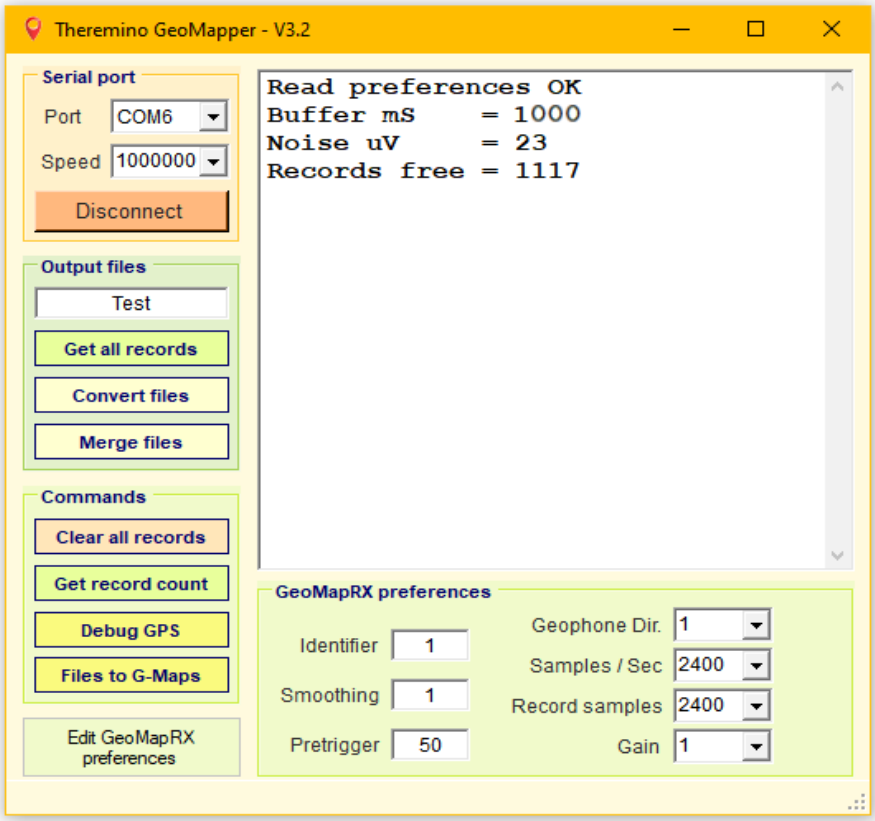


If there are errors, the only way to recover the files is to fix them manually.

In the case of **Convert files** you can split the file into multiple files, so that each contains recordings with the same properties.

In the case of **Merge files** with different record numbers, some records have probably been lost and some will have to be duplicated, it's not easy but it can be done.

The Geo Mapper application



This application reads the data stored in the form **GeoMapRX** (explained in the next pages) and writes them to a file with the format suitable for seismic refraction, reflection and Masw programs.

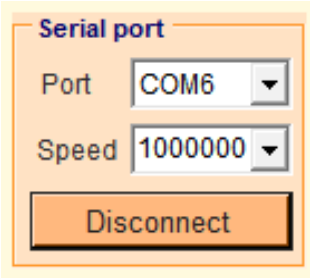
The form **GeoMapRX** stores a large number of recordings (from 39 to 1117 depending on settings).

Each recording contains the date down to the second (accurate to one second) and the position of the module (latitude, longitude, and altitude in meters) at the time of that recording.

- - - - - - -

To download the recordings, connect the module to a USB connector
and use the buttons on the "Commands" panel,
as explained on the next page.

Options and commands - Serial port

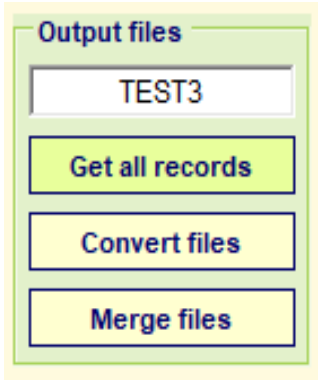


Select the serial port.

Select the BaudRate (1 mega for **GeoMapRX**)

The button turns red when connected.

Options and Commands - Output Files



Here you set the prefix to use for the data file. If you leave this box blank, the data file will not be written. This allows you to test and verify that the data is downloaded correctly without writing the files to disk.

With the button **Get all records** all recordings are downloaded into a single file, in the "Files" folder.

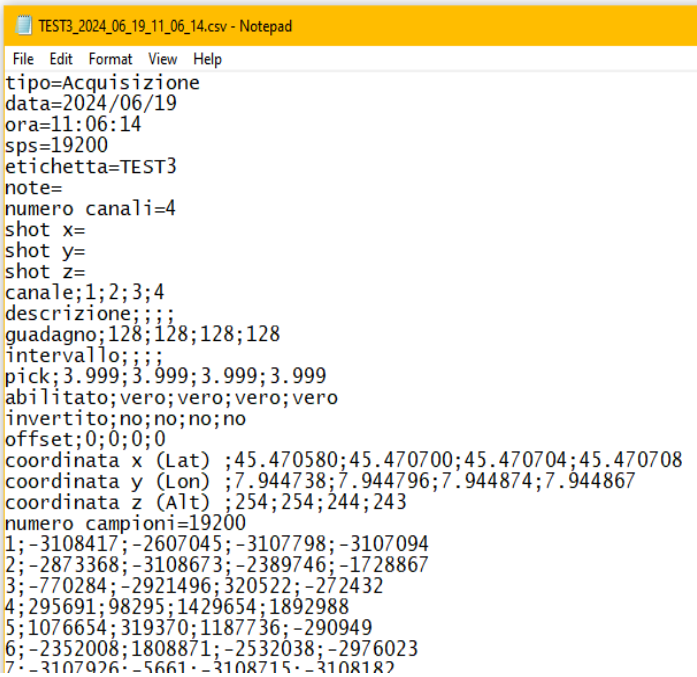
The downloaded file starts with the prefix, continues with"Year_Month_Day_Hours_Minutes_Seconds" and ends with the extension "*.tgm", which stands for "Theremino_GeoMapper".

With the button **Convert files** convert one or more recording files into one or more files in CSV format.

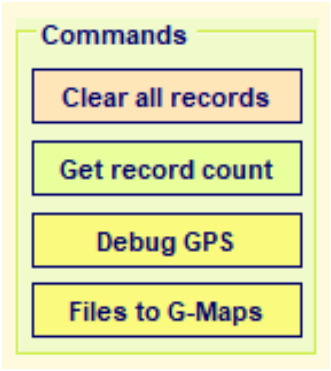
With the button **Merge files** merge multiple recording files into a single file in CSV format.

How to use these two commands is explained on the next page.

The formats of the recording files and CSV files are explained on the opening pages of this document.



Options and Commands - Commands



With "**Clear all records**"all the records in the form are deleted **GeoMapRX** to make room for others.

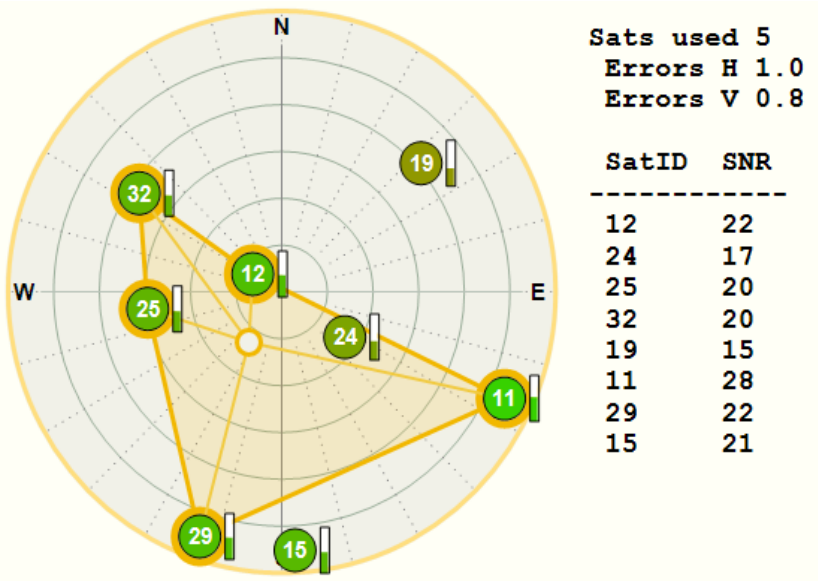
With**"Get record count"**the number of registrations is requested.

With the button**"GPS Debugging"**the application opens **Theremino_GPS** which is explained at the end of this document.

In this image you can see the page that shows the satellites in the application **Theremino_GPS**.

Normally you don't need to use this application because you can know if the GPS is synchronized to the satellites by checking the LED on the **GeoMapRX**.

If the LED flashes triple every second then the satellites are synchronized and the coordinates are valid, otherwise the flash is still every second but single.



Use this application if you have problems with satellite synchronization or if you want to check the accuracy of your coordinates.

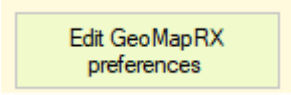
- - - - - -

With the button **"Files to G-Maps"** send the coordinates of the files (TGM or CSV) to Google Maps.

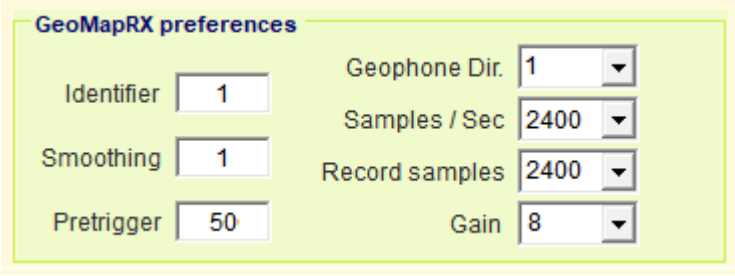
Due to Google Maps limitations, you can only submit a limited number of coordinates, so only the first and last coordinates will appear.

The Google Maps page opens with the coordinates in the center and you have to use the mouse wheel to zoom in.

Options and Commands - Edit GeoMapRX preferences



By clicking the button **Edit GeoMapRX preferences** opens and closes the properties panel.



- **IDENTIFIER** can be used to identify the **GeoMapRX** in the recording files. This value is used if you use many **GeoMapRX** and it is recommended that you write it on a label on each form.
- **GEO-DIR** identifies the direction of the geophone in case many are used **GeoMapRX** and if they have some with the geophone arranged horizontally.
- **SamplesPerSec** is the speed in samples per second (from 19200 to 640).
- **RecordSamples** is the number of samples per recording (from 19200 to 640).
- **Gain** amplifies the geophone signal (from 1 to 128 times). Set it as high as possible to reduce sampling noise. Typically, set it to 8 or 16 and only lower it if signal clipping occurs..
- **Smoothing** It's a moving average to improve the accuracy of GPS latitude, longitude, and altitude. It can be adjusted from 1 second to 600 seconds. Typically, it's set to 10 to 30 seconds. Using longer times will result in excessive waiting time each time you move the device.
- **PRETRIGGER**(from 0 to 200 mS) is normally set to two or three milliseconds to compensate for the slight delay in reading the seismic sensor signal. However, 50 or 100 milliseconds can be added if desired to provide an initial zone before the data, useful for measuring the background noise level.

Whenever you change one of these properties all preferences are sent to the form **GeoMapRX** which must be connected with the USB cable to the computer.

If communication is successful, the main application window will display the information shown on the right.

```
Write preferences OK
Read preferences OK
Buffer mS     = 66
Noise uV      = 9
Records free = 778
```

The GeoMapTX and GeoMapRX modules

At least one module is required for the system to function **GeoMapTX** and one or more modules **GeoMapRX**.

Mechanical structure of the modules

Both the **GeoMapTX** that the **GeoMapRX** they have an external appearance similar to this image.

The top should be high enough to keep the vertical antenna off the ground and the controls clearly visible above the grass.

The **GeoMapTX** on the bottom it has a piezoelectric sensor or a geophone to sense when the ground is hit by the impactor or explosive.

The controls of the **GeoMapTX** are:

- A switch (or button) to turn on and off.
- One button for controls.
- A piezoelectric buzzer and an LED.
- A USB connector for programming the firmware and charging the battery.

The **GeoMapRX** at the bottom it has a geophone (horizontal or vertical) to record ground movements.

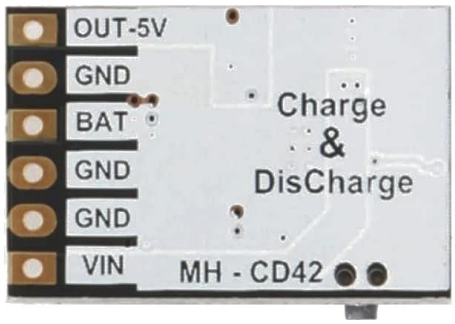
The controls of the **GeoMapRX** are:

- A switch (or button) to turn on and off.
- One button for controls.
- A piezoelectric buzzer and an LED
- A USB connector for programming the firmware, downloading recordings andcharge the battery.

Charging circuit

Both in the **GeoMapTX** that in **GeoMapRX** The USB connector goes to the module (Nano or ESP32) through a battery charging and control circuit.

There are also other models different from this one but you should check their features carefully.



An important feature is that the 5 volt output works even while supplying 5 volts to the input and charging the battery, and only the 134N3P seen in these pictures specifically states "Supports charging while discharging."

Another very useful feature is the ability to use a button instead of a switch for power.

This MH-CD42 has solder wires which makes wiring easier, and it also has, well specified, that by connecting an external button to the "KEY" pad and to GND you can turn the output on and off.

The CD42 chip is actually an IP5306and its datasheet specifies:

- If the button is pressed for less than 2 seconds, it turns on the LEDs and the 5V output

- If the button is pressed for more than 2 seconds, it turns off the LEDs and the 5V output

You can find further documentation and datasheets in thefolder:
"GeoMapper \ HARDWARE \ BMS"

Batteries to use

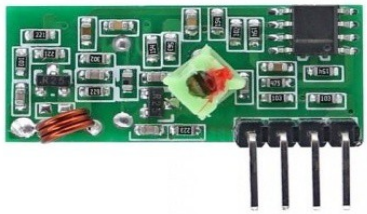
The battery used is a classic 18650 which can guarantee thousands of recordings before running out.

If desired, two or three could be used in parallel, but they must be identical and in the same state of preservation.

To connect them easily, without having to solder the terminals with a spot welder, there are convenient battery holders for 18650 batteries.

Transceivers

In previous versions we used 433MHz transmitters and receivers like the ones in these pictures, which are easily found on eBay and Amazon.



But after many tests, we realized they're not reliable enough (an understatement for not saying they're absolutely rubbish). They struggle to reach 20 meters, and even the best models cause too many problems.

So we changed the system and from version 3 onwards we use LoRa RA-01 or RA-02 modules from AI-Thinker or similar ones, for example the Reyax RYLR998 or RYLR498.

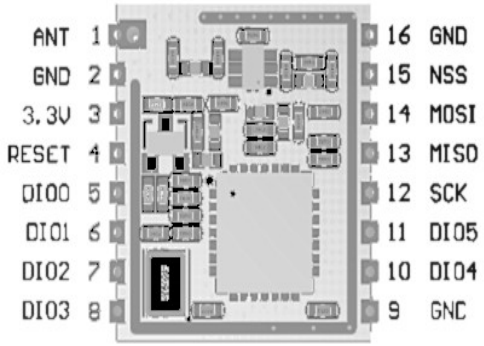
LoRa modules have amazing features, reception is reliable even in extremely low signal conditions and even in the presence of electrical noise and disturbances of all kinds.

If there are no obstacles between the antennas,
they can work at distances of several kilometers,
look ***this video***.

Many videos and tests online show that the Reyax modules reach up to seven kilometers, while the RA01 modules only reach one kilometer.

This is because the Reyax are configured to transmit for longer times (160 milliseconds instead of about 27 milliseconds). If you configure them the same way, they cover more or less the same distances.

Features of the RA-01 and RA-02 modules



LoRa modules are more difficult to wire than simple 433 MHz receivers (6 wires for the transmitter and 8 for the receiver) and require more elaborate firmware, but they work significantly better because they use the Spread Spectrum (CSS) modulation technique.

CSS modulation turns the carrier on and off with frequency modulated pulses and can work, without a license, on the ISM (Industrial, Scientific, and Medical) bands at frequencies of 433 MHz, 868 MHz and 915 MHz.

Frequencies

You can also change the frequency in the firmware (from 360 to 500 MHz), so as to avoid the most crowded part of the 433 MHz band. We set it to 439 MHz and we don't recommend moving too far from 433 MHz, as the internal components and antennas work best in the center of the band.

Power and consumption

The output power, and therefore also the current consumption, are adjustable in the firmware. But you don't have to worry about consumption because we use them in transmission for less than 20 milliseconds and only when we energize the ground with the bat. So the average consumption of the transmitter is practically zero, leaving only the 10 mA of the receiver plus the 20 or 30 mA of the Nano or ESP32.

When performing the transceiver test, transmission is made for 30 mS every 100 mS, so even in this case the average consumption is very low, from 20 to 50 mA and only for the time that the transceiver test is kept active.

Modify the firmware

The transmission frequency, output power and other transmission parameters can be modified in the initial parts of the RTX.cpp file.

The frequency can be adjusted at will by about ten megahertz, up or down. Only change the other parameters if you know what you're doing.

ATTENTION
Any changes must be made exactly the same in all three firmwares:
GeoMapTX, GeoMapRX and GeoMapRX_Sync

LoRa Module Variants

In the folder**HARDWARE \ _RTX**You can find datasheets and a lot of information about LoRa modules. These modules come in three versions +18dB, +20dB and +22dB, outputting up to 60mW, 100mW and 160mW and consuming from 80mA to 180mA. But in reality the 22 dB would only be obtained by powering them at 3.6V and not 3.3V as we normally do.

Ai-Thinker RA01 and RA02 Modules

The RA-01 and Ra-02 modules are based on the chip ***Semtech's SX1278***, they work in the band around 433 MHz and are fully compatible with our system.

Normally they are 18 dBm, but those with S extension are 20 dBm and those with SC extension are 22 dBm

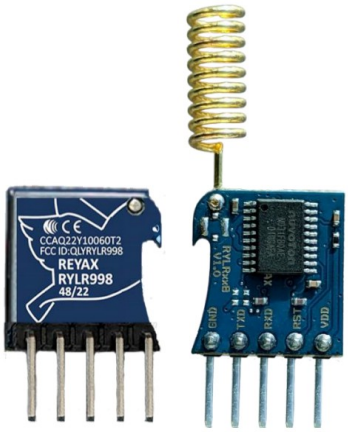
Ebyte E32 Modules

The E32 modules, based on the chip ***Semtech's SX1278***, they work in the band around 433 MHz and are fully compatible with our system.

The E32-433T20DC and E32-433T20S are 100 mW, consume approximately 100 mA in transmission and can be connected to our system without modifications.

The E32-433T30D are 1 Watt and consume 610 mA at 5 V,so you have to modify the circuit and connect them to 5 voltsto get maximum power.

Reyax RYLR684 and RYLR998 modules



These modules are based on the chip ***LLCC68 by Semtech*** and to make them compatible with our system you should replace the RTX.cpp file with a modified one.

The 684 module operates in the 433 MHz band and has an output power of up to +20 dBm at 3.3V (100 mW) with a consumption of 107 mA. The connections are SPI, therefore compatible with our firmware, but the registers are different and incompatible.

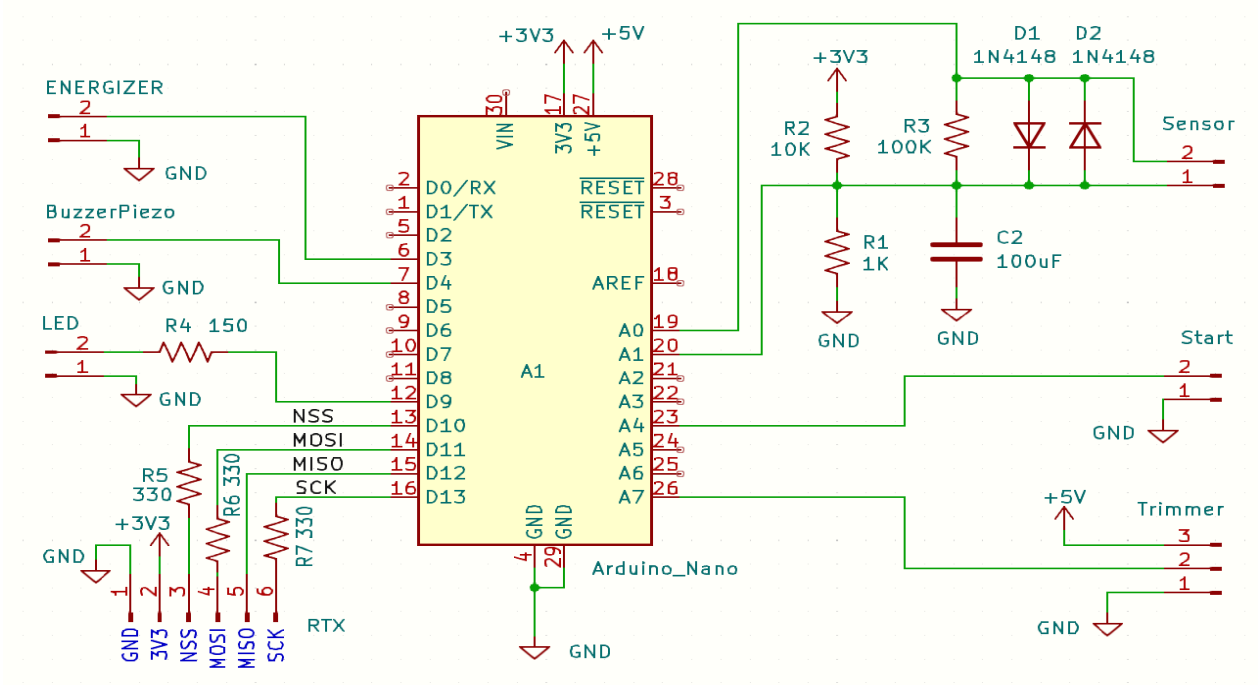
The 998 module operates in the 820 to 960 MHz band and has an output power of up to +20 dBm at 3.3V (100 mW) with a current consumption of 145 mA.Communicates serially (RX and TX) with AT commands.

GeoMapTX Module

This module consists of:

- An Arduino Nano.
- An ignition switch (or button) and a start-stop switch.
- A piezoelectric buzzer and an LED.
- A lithium battery and a power and charging module.
- A 10K trimmer to adjust the sensitivity of the vibration sensor.
- A vibration sensor (geophone or piezoelectric sensor).
- A LoRa transceiver of type RA-01 or RA-02

Electrical diagram



R1 and R2 bias the sensor and C2 eliminates the noise coming from the 3.3V.

D1, D2 and R3 adapt and limit the sensor signal (piezo or geophone).

The Trimmer (about 10K) adjusts the sensitivity of the sensor signal.

The Buzzer emits characteristic signals to indicate the three operating modes.

The LED flashes once per second to indicate that the module is on, and longer flashes follow the sounds of the various operating modes.

On the TX2 connector you connect a LoRa RA-01 or RA-02 transceiver

In the folder HARDWARE \ GeoMapTX \ Docs You can also find the Kicad files of the PCB and an image to mount it on a perforated board.

GeoMapTX - Synchronization Sequence

- It lights up **GeoMapTX** and the LED produces a short flash every second.
- Every time the **GeoMapTX** detects a vibrationIt emits a double beep and its LED producesa very bright flash for half a second.You can use this information to adjust the sensitivity trimmer.
- The operator of the **GeoMapTX** press the button and send the transmission-reception test and all the **GeoMapRX** they respond. If the transmission works The receiver LEDs flash ten times per second. If the **GeoMapRX** they answer the transmitter LED also flashes but slower, ten times per second divided by the number of receivers. So with just one RX it flashes quickly, with 12 it flashes about every second and with 24 every two seconds.
- If everything is OK the operator of the **GeoMapTX** press the button again and the **GeoMapTX** start to emit a continuous sound and flash twice per second with full light.
- At this point you can energize the ground with the mallet. OrYou could press the button and abort the process without recording. In this case the LED will start flashing once per second again and this can be used for testing.
- **GeoMapTX** It uses a vibration sensor which can be a Geophone or a piezoelectric sensor to detect that the ground is being hit.
- When it detects vibration the **GeoMapTX** It emits a radio signal that tells the receivers to acquire the data and if they respond OK it does three flashes and three beeps of increasing frequency. If they respond that they haven't memorized it, it gives two flashes and two beeps of decreasing frequency.
- Signal transmission takes a few tens of milliseconds, which are automatically compensated for in the firmware.
- If the operator wishes, he can add a pretrigger time to have a flat initial zone over which the software can measure the background noise.
- All RX modules synchronize the start of recording by subtracting the transmission and pretrigger times from the instant the radio signal arrives.
- In conclusion, the file recorded in the receivers' memory starts before the ground is energized, exactly at the desired moment, with a precision of about ten microseconds more or less.
- After sending the sync you can turn off the **GeoMapTX** to save battery power.

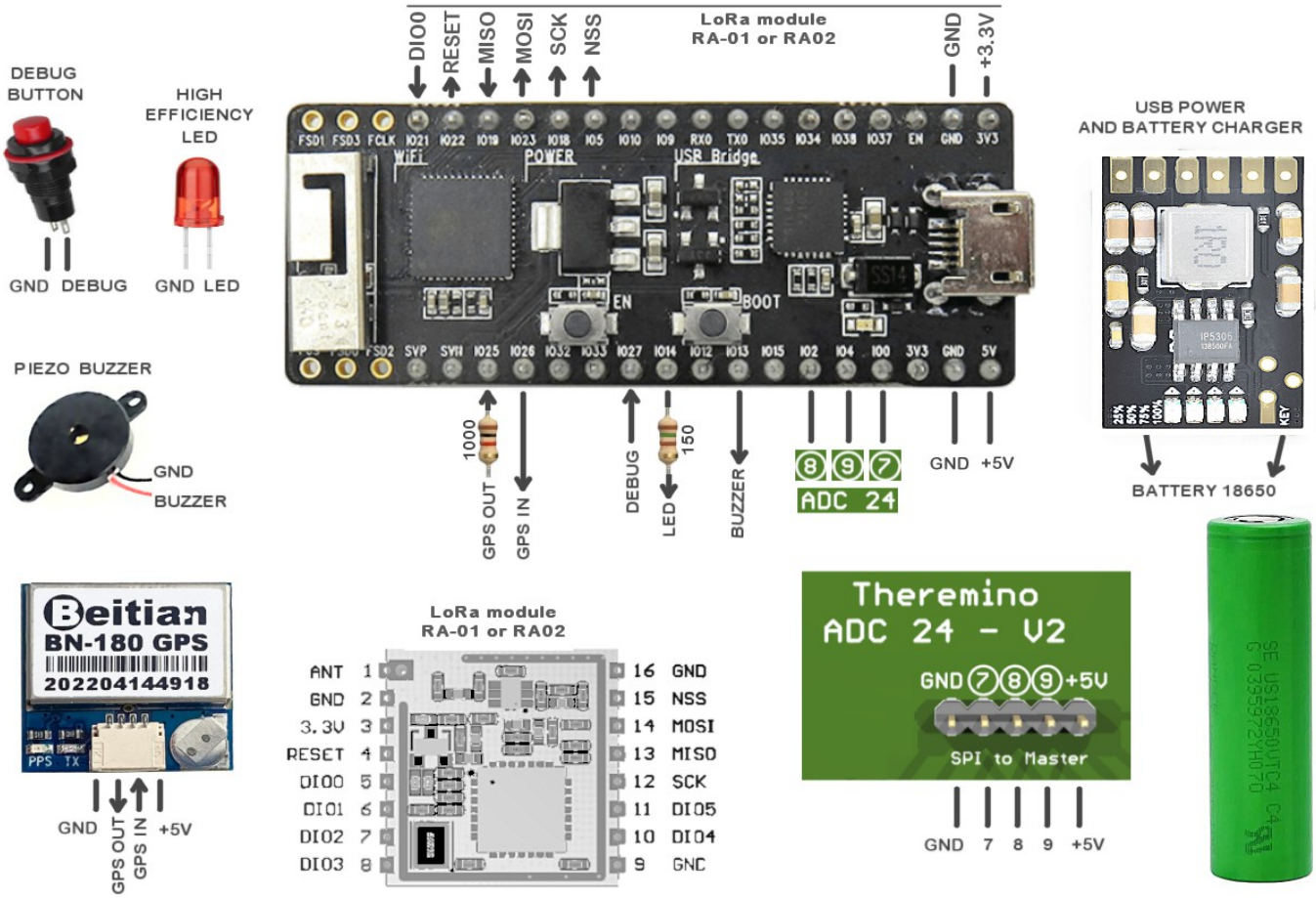
GeoMapRX Module

The modules **GeoMapRX** they can also be just one and in this case it will be moved manually with each new energization of the ground.

The form **GeoMapRX** It is composed of:

- A switch (or button) to turn on and off.
- A lithium battery and a power and charging module.
- An LED to indicate operating states.
- A piezoelectric buzzer.
- An ESP32 PicoKit with the WiFi section turned off to reduce power consumption.
- A Theremino_ADC24 module
- A LoRa transceiver of type RA-01 or RA-02
- A GPS module (see Appendix 2 at the end of this document)

Electrical diagram



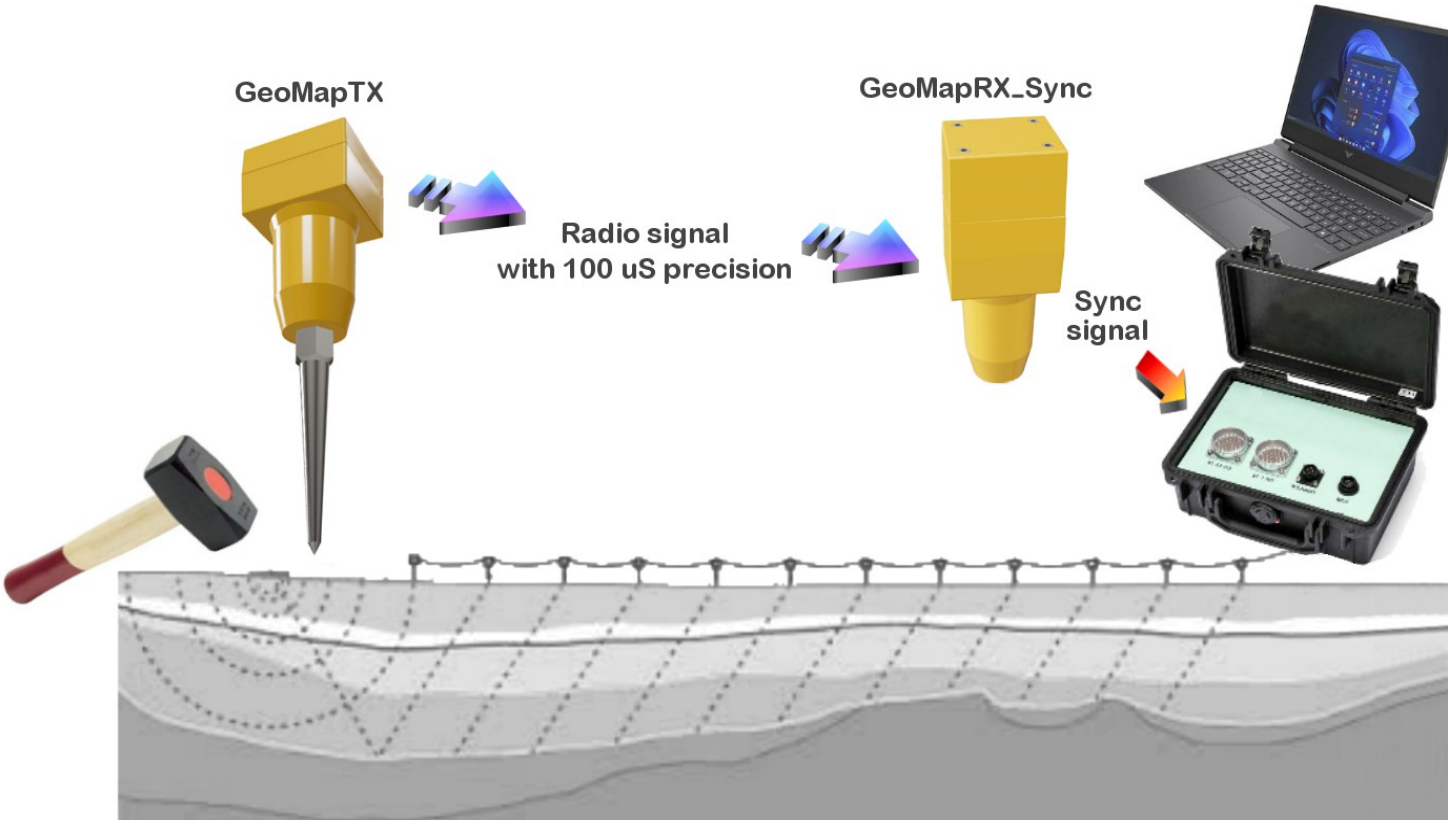
GeoMapRX - Synchronization Sequence

- One or more modules are turned on **GeoMapRX**.
- The LED of the **GeoMapRX** produces a short flash every second.
- It's recommended to wait for the GPS to sync with the satellites. If the sky above is clear, it will take a few dozen seconds, but it may take longer the first few times you use the GPS. Therefore, when you're new, it's recommended to leave it turned on outdoors for a few dozen minutes.
- When the GPS is synchronized with the satellites the LED produces three short flashes every second.
- The operator of the **GeoMapTX** press the button and send the transmission-reception test and all the **GeoMapRX** they respond. If the transceiver works The receiver LEDs flash ten times per second and the transmitter LED flashes ten times per second divided by the number of receivers.
- If everything is OK the operator of the **GeoMapTX** press the button again and the **GeoMapTX** start to emit a continuous sound and flash twice per second with full light.
- The operator of the **GeoMapTX** can then energize the ground with the club.
- If you have an automatic energizer, you can send it a start signal from any of the RX or RXsync modules. To do this, press the button on the RX module and hold it down. After three seconds the LED will flash quickly for ten times and then the signal will be sent.
- If the form **GeoMapTX** receives the energization signal, it will also emit ten flashes and then it will send the electrical signal to the energizer.
- After energization, the RX modules receive the acquisition signal and synchronize the start of recording by subtracting the transmission delay and pretrigger time.
- After a short time the registration is done and **GeoMapRX** they indicate it withthree strong flashes on the LED and three sounds with increasing pitch.
- If the memory is full, they are emitted two sounds with decreasing pitchand the registration is not done.
- Now you can turn off the modules, or leave them on and move them to make a new recording.
- If the travel time is long (tens of minutes), it is advisable to turn off the modules between one energization and the next, to save battery power.

GeoMapRX_Sync

You can use the **GeoMapRX** also as a radio receiver to synchronize older systems that used a long cable between the energizer and the acquisition device.

The **GeoMapTX** remains exactly the same and the **GeoMapRX** It will be simplified (without ADC24 and without GPS module) but on the SYNC connector it provides the same output signal that would arrive through the long cable.



With this system you can continue to use the devices you already know, but you will save yourself having to carry around the starter cable, which is long, heavy, difficult to lay out and also very expensive.

The firmware of the **GeoMapTX** remains unchanged but for the **GeoMapRX** the firmware will be used **GeoMapRX_Sync**

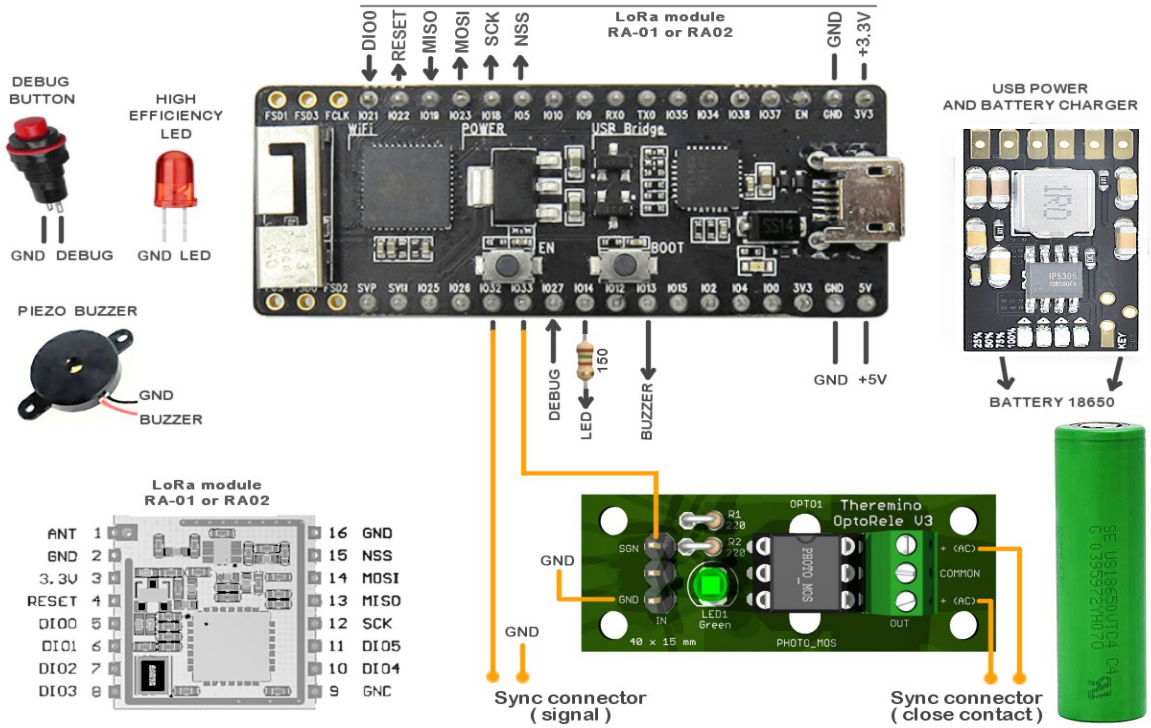
Again, you need to set the pre-trigger to 27 milliseconds plus a few milliseconds, as explained on the next page "Programming the Firmware", but you will need to set this in the acquisition device.

All acquisition devices have pre-trigger adjustments that go up to one hundred milliseconds or more, but you will have to consult their documentation for details.

GeoMapRX_Sync - Connections

The **GeoMapRX_Sync** It's similar to normal ones **GeoMapRX**

To build it, the ADC24 and GPS modules are eliminated and a connector is added that provides the appropriate output signal for the system being used.



In this image the connections in orange are those related to the trigger signal, which were not present in the normal ones. **GeoMapRX.**

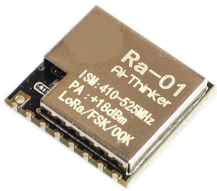
If the system to be synchronized used an electrical signal for the trigger (Piezo or TTL systems) the "Sync connector (signal)" output will be used, otherwise the one called "Sync connector (close contact)" will be used.

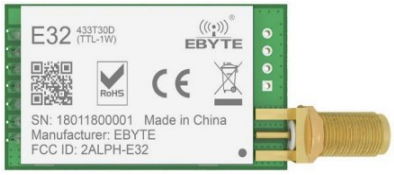
The "signal" type can be modified in the firmware to suit different systems while the "close contact" type simulates the simple reed contacts, connected to a vibrating mass, which are used by many manufacturers.

Programming the firmware of the modules

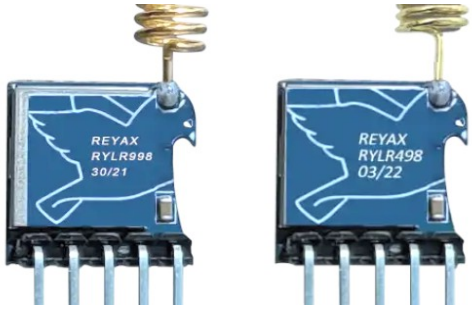
The modules **GeoMapRX, GeoMapRX** and **GeoMapRX_Sync** they must be programmed with the Arduino IDE and with the ".ino" files found in the folders: **HARDWARE** sub-folder **FIRMWARE_XXX** and then in the sub-folders **MapTX, GeoMapRX** and **GeoMapRX_Sync.**

If the modules are RA-01, RA-02 or E32 you must use the files located in the sub-folders of **FIRMWARE_SPI**





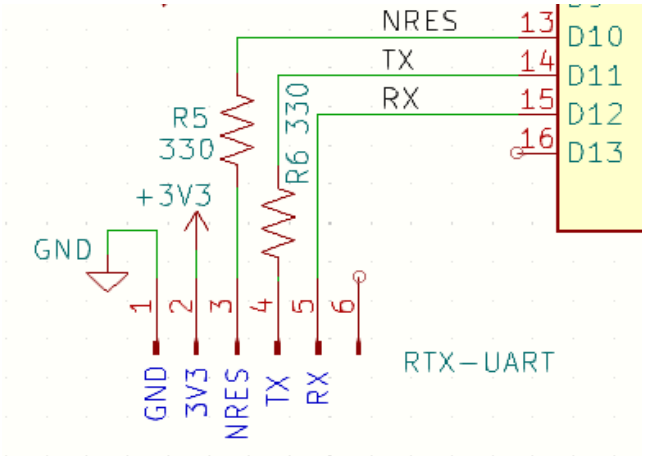
If they are REYAX files, you must use the files found in the sub-folders of **FIRMWARE_UART**

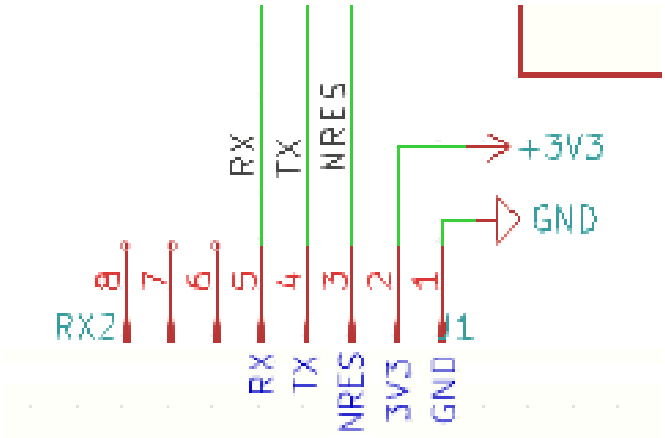


Connections for REYAX

The wiring diagrams and assembly plans for the REYAX are in the DOCS folders located starting from the folder **FIRMWARE_UART**.

You can use the same pins and PCBs as the others, but there are small differences regarding the wires for connecting the radio modules.





Connections from REYAX modules to the NanoConnections from REYAX to ESP32

The connections must not be reversed (as is done in some cases), so TX goes to the TXD pin of the Reyax module, and RX goes to the RXD pin.

Instructions valid for all firmware

At the beginning of the INO files follow the instructions **COMPILER SETTINGS** to configure the IDE. Without these instructions you will not be able to complete.

Schedule the **GeoMapTX**

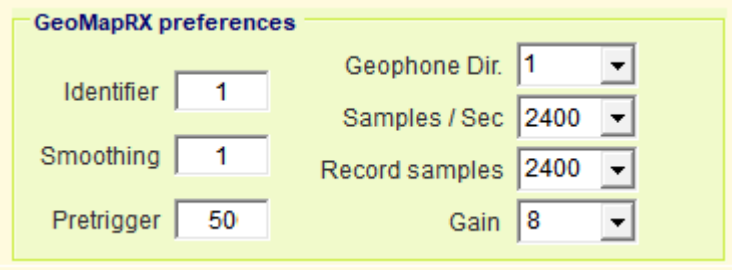
Right at the beginning there is the section "**`Number of GeoMapRX in the system`**". If you have more than one GeoMapRX receiver in your system then you need to follow the instructions in that section. In practice it is just a matter of writing the number of receivers in the variable, for example "`NumberOfGeoMapRX = 12;`"

Leave everything that follows unchanged.

Schedule the **GeoMapRX**

The section **INITIALIZATIONS** defines the serial port speed and the PINs used.Leave this section and the following ones as they are without modifying them.

All available options are adjusted with the panel **GeoMapRX preferences** of the application **GeoMapper** (see the first pages of this document), without needing to recompile and write the firmware with the Arduino IDE.



The pre-trigger time is adjustable0 to 200 mS

The "Pretrigger" box should be set to a few milliseconds (2 or 3 mS) to compensate for the delay due to the slowness of the vibration sensor.

If desired, the operator can increase the pretrigger time to create a flat initial zone for the software to measure background noise. Typically, this is set to 50 or 100 mS.

In the latest firmware versions, from 3.2 onwards, the radio transmission delay is automatically compensated and it is no longer necessary to add it to the pretrigger.

Change radio communication parameters

The communication parameters are at the beginning of RTX.cpp files and should work fine in most cases.

You could modify them to use modules that operate on a different frequency band, or because you're using them in the USA, China, or Russia. Or you could get a longer range and perform deployments beyond 500 meters.

But be careful: the settings must be identical in all three modules **GeoMapTX**, **GeoMapRX** and **GeoMapRX_Sync**, otherwise they no longer communicate.

RTX_FREQUENCY

- In Europe, the 433 MHz and 863-870 MHz bands can be used
- In China the gangs470-510 MHz and 779-787MHz
- In Russia the band 864-870 MHz and in the USA the band902-928 MHz

If you use the 433 MHz band, we recommend staying at least one MHz away from the 433.95 MHz frequency used by all gate and door openers. Keep in mind that these devices are very basic and can drift by a few MHz. However, their receivers still receive them because almost all of them are broadband.

RTX_Power

You can change the output power.Normally, it should be set to 20 or 22, which is the maximum, but check before programming the modules, as it is sometimes lowered for testing. Or, if the power supply is insufficient when powering the module without a battery, using long, low-quality USB cables.

RTX_Speed

The communication speed we have chosen allows for a fairly low transmission delay (less than 30 milliseconds) and a good range (up to a few hundred meters in the best conditions). If you need to increase the range (even up to a kilometer or more), you can lower this speed from the normal value of 14 to 6 or 5 (RA-01, Ra-02, and E32 modules) or from the normal value of 7 to 4 or even less (REYAX modules).

RTX_RepeatMS

This parameter is only in the **GeoMapTX** and is only used during the communication test. Normally, it is kept at 100 mS and should only be changed if RTX_Speed is lowered and the transmission time exceeds 30 milliseconds.

Adjust RTX_Speed on the RA-01, RA-02 and E32 modules

At the beginning of the files **RTX.cpp** (which are located in the FIRMWARE_SPI sub-folders) you will find a timing table and the setting of **RTX_Speed**.

```
// ----------------------------------- RTX_Speed and RTX_RepeatMS
// RTX_Speed 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
// TX-RX delay1425 713 696 700 425 345 107 106866060 53 53 30 27 15 14 7.2 6.6
// RTX_RepeatMS 3000 1600 1600 1600 1000 800 220 220 200 150 150 120 120 100 100 100 100 100 100

uint8_t RTX_Speed = 14; // RTX_Speed 0 to 18 (normally 14)
```

In the files for the modules **GeoMapTX**, there is also the regulation of **RTX_RepeatMS**.

```
uint16_t RTX_RepeatMS = 100; // if RTX_Speed < 13 increase up to 3000 mS
```

With **RTX_Speed** nineteen different communication parameter configurations are set:**Spreading Factor**, **Bandwidth**, **Coding Rate** and **PreambleLen.**

With this simplified method, you simply set a single value from 0 to 19 to change the data transmission speed and the maximum achievable distance.

With **RTX_Speed =**18 you get a delay between transmission and reception of a few milliseconds but the communication distance would be low, probably no more than 100 meters.

With the value of 14 we chose, the delay is 27 mS and should reach 500 meters and beyond.

To increase the flow rate you could reduce **RTX_Speed**up to 6 or at most 5, we do not recommend going below 5, because it would raise it too much **RTX_RepeatMS** and the communication test would become very slow.

Normally the communication test occurs ten times per second but if you use more modules **GeoMapRX** this repetition slows down. With 16 or 32 modules, the LED flashes and confirmation beeps are quite slow, a few seconds. And these seconds would become dozens if the speed is lowered significantly **RTX_Speed.**

In case you use only one GeoMapRX this slowdown is less serious and could even go down to **RTX_Speed =**1 and then **RTX_RepeatMS**=1600 milliseconds which would give a still reasonable test rate of about a second and a half.

Warning: The settings must be identical in all three modules **GeoMapTX**, **GeoMapRX** and **GeoMapRX_Sync**, otherwise entities no longer communicate.

In the latest firmware versions, from 3.2 onwards, the delay TX-RX delay
is automatically compensated in the firmware
and you no longer have to add it to the pretrigger..

Adjust RTX_Speed on Reyax modules

At the beginning of the files **RTX.cpp** (which are located in the FIRMWARE_UART sub-folders) you will find a timing table and the setting of **RTX_Speed**.

```
// ---------------------------------- RTX_Speed and RTX_RepeatMS
// RTX_Speed 0 1 2 3 4 5 6 7 8 9 10
// TX-RX delay 180 170 165 150 83 53 35 24 13 10 9
// RTX_RepeatMS 390 370 350 330 180 120 100 100 100 100 100

uint8_t RTX_Speed = 7; // RTX_Speed 0 to 10 (normally 7)
```

In the files for the modules **GeoMapTX**, there is also the regulation of **RTX_RepeatMS**.

```
uint16_t RTX_RepeatMS = 100; // if RTX_Speed < 6 increase up to 400 mS
```

With **RTX_Speed** eleven different communication parameter configurations are set: **Spreading Factor**, **Bandwidth**, **Coding Rate** and **PreambleLen.**

With this simplified method, you simply set a single value from 0 to 10 to change the data transmission speed and the maximum reachable distance.

With **RTX_Speed =**10 you get a delay between transmission and reception of a few milliseconds but the communication distance would be low, probably no more than 100 meters.

With the value of 7 we chose, the delay is 24 mS and you should get to 500 meters and beyond.

To increase the flow rate you could reduce **RTX_Speed also**down to zero, bearing in mind that the communication test becomes quite slow.

Normally the communication test occurs ten times per second but if you use more modules **GeoMapRX** this repetition slows down. With 16 or 32 modules the LED flashes and confirmation beeps are quite slow, a few seconds. And these seconds become dozens if the speed is lowered a lot **RTX_Speed.**

In case you use only one GeoMapRX this slowdown is less serious and with **RTX_Speed =** 0 and then **RTX_RepeatMS** = 390milliseconds still gives a reasonable test rate of about three times per second.

Warning: The settings must be identical in all three modules **GeoMapTX**, **GeoMapRX** and **GeoMapRX_Sync**, otherwise entities no longer communicate.

In the latest firmware versions, from 3.2 onwards, the delayTX-RX delay
is automatically compensated in the firmware
and you no longer have to add it to the pretrigger.

Appendix 1 - Configuring GeoMapRX

The setting **AD7124_SetWorkingMode** it is commented and not used.
We are keeping it for those who want to use GeoMapRX with other applications.

All available options are adjusted with the panel **GeoMapRX preferences** of the application **GeoMapper** (see the first pages of this document), without needing to recompile and write the firmware with the Arduino IDE.

GeoMapRX Setup -Samples per second

The SamplesPerSecond value determines the sampling rate (SPS) and consequently the noise generated by the ADC.

```
 // ========================================================
//Max Record-Seconds by Record-Samples
// ========================================================
//------------- RECORD SAMPLES -------------------
//SPS| 192009600480024001280640|
// --------------------------------------------------------
// 192001 s0.5 s0.25 s125 mS66 mS33 mS
//96002 s1 s0.5 s250 mS133 mS66 mS
//48004 s2 s1 s0.5 s266 mS133 mS
//24008 s4 s2 s1 s533 mS266 mS
//128015 s7.5 s3.8 s1.9 s1 S0.5 S
//64030 s15 s7.5 s3.8 s2 S1 S
// ========================================================
//RECORD SAMPLES must be set to 19200/9600/.../1280/640
//If you set a wrong value the default is 1
// ========================================================
```

A higher sampling rate isn't always an advantage because it can also increase noise. Therefore, a compromise must be made based on the minimum sampling rate necessary for the type of analysis being performed.

For shallow analyses, tens of meters deep, the frequency should be increased as much as possible, even up to 19,200 SPS. Fortunately, in these cases, the useful signal is strong and the noise is less significant. For deep analyses, the opposite should be done to minimize the noise.

It is recommended to use mode 3 which provides an excellent compromise between low noise and a high sampling rate of almost 5000 samples per second.

GeoMapRX Setup - Record Samples

With Record Samples a compromise is chosen between the length of the recordings and the maximum number of recordings that can fit in memory.

```
// ============================================================
//Max memorizable Records by Record-samples
// ============================================================
//Record samples19200960048002400128064O
// ------------------------------------------------------------
//Max records39781553095741121
// ============================================================
```

GeoMapRX Setup - Gain

```
 // ============================================================
//ADC NOISE by GAIN and SAMPLES PER SECOND
// ============================================================
//------------ Samples per second ----------------
//19200960048002400128064O
//GAIN----------- Noise PeakToPeak (*) ----------------
// ------------------------------------------------------------
//1500 uV76 uV38 uV25 uV19 uV13 uV
//2270 uV61 uV25 uV16 uV13 uV8 uV
//4150 uV34 uV20 uV12 uV8 uV6 uV
//895 uV27 uV13 uV8 uV6 uV4 uV
//1657 uV21 uV9 uV6 uV4 uV3 uV
//3233 uV13 uV6 uV4 uV3 uV2 uV
//6426 uV12 uV5 uV3 uV2 uV1 uV
//12823 uV9 uV4 uV2 uV1 uV1 uV
// ============================================================
//Gain must be set to 1/2/4/8/16/32/64/128
//If you set a wrong value the default is 1
//(*) The RMS noise is about 7 times lower
// ============================================================
```

The gain should be set as high as possible, in many cases 128 should be fine.

However, it is a good idea to do some tests and check that you do not have too much saturation in the channels closest to the energization point.

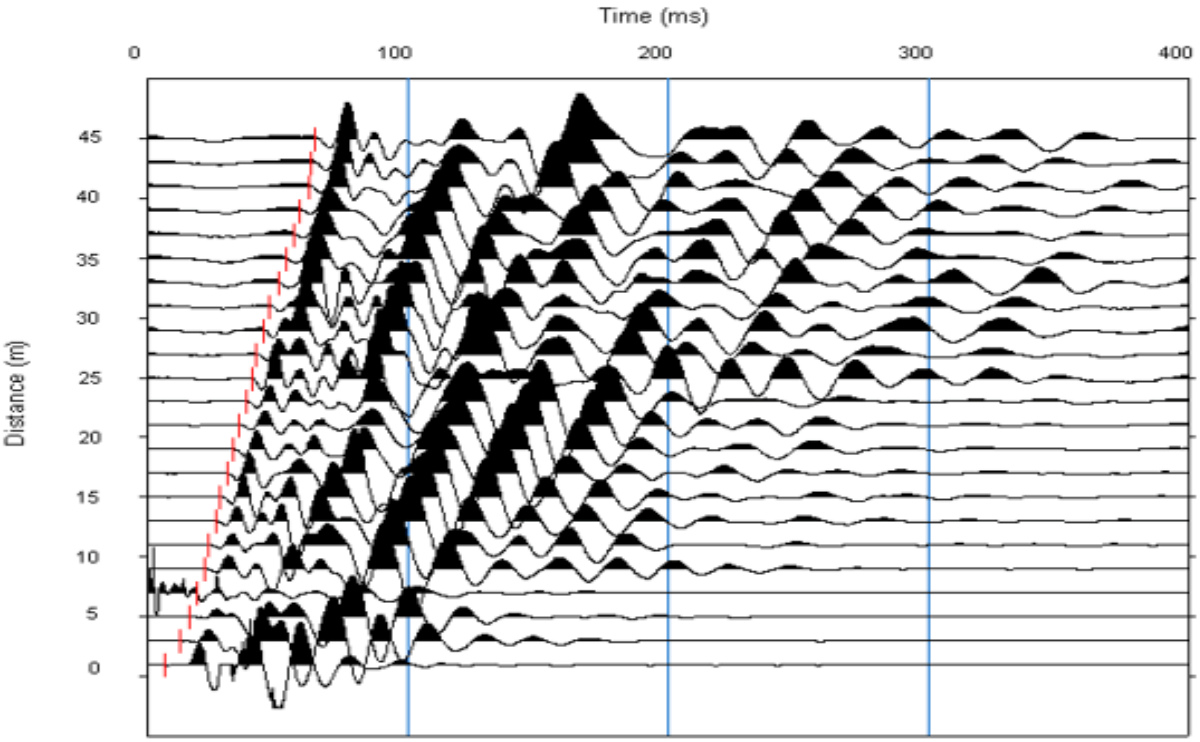
Using gains lower than 128 might be appropriate for analyses of a few tens of meters and therefore short distances between the impactor and the geophones.

Appendix 2 - Seismic analysis methods

Computed tomography

Various analysis techniques allow us to analyze the stratification and characteristics of the soil, from a few meters to thousands of meters deep.

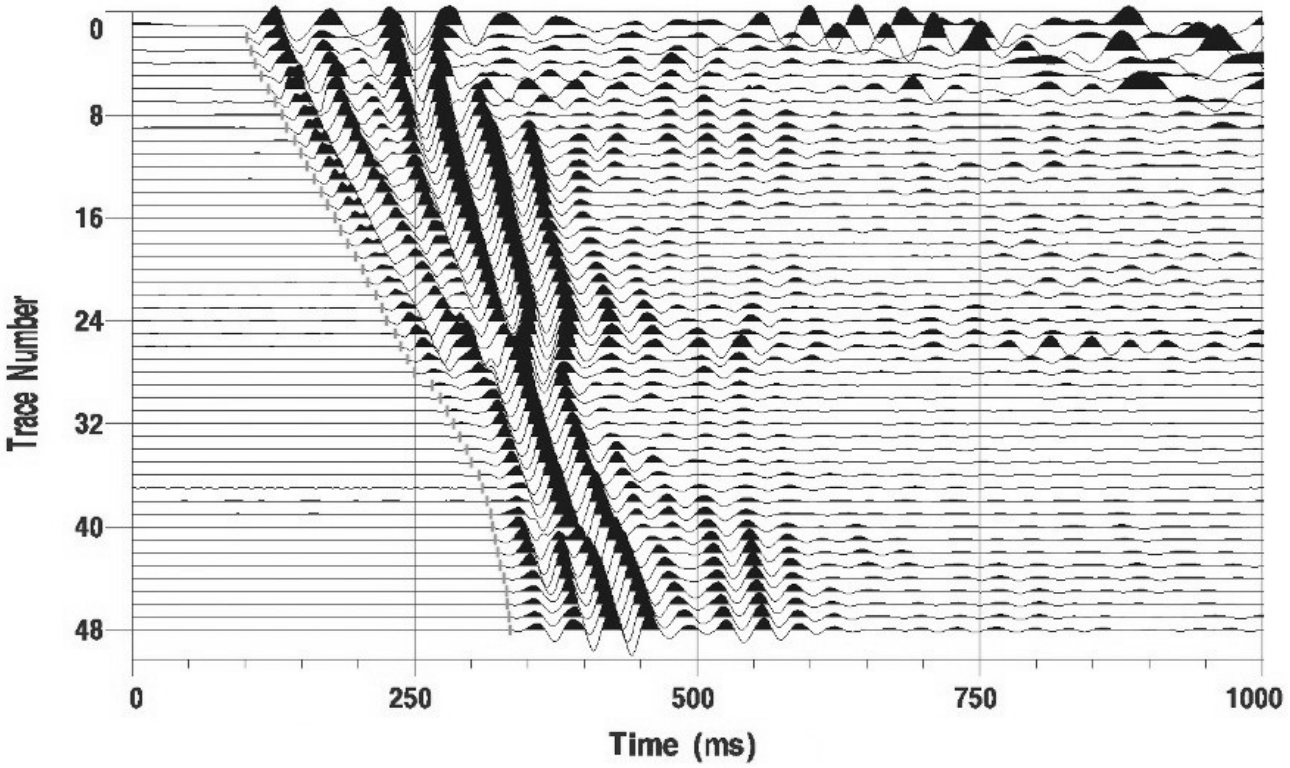
Seismic waves, generated by explosives or impactors, are detected by geophones placed at regular distances in a straight line.

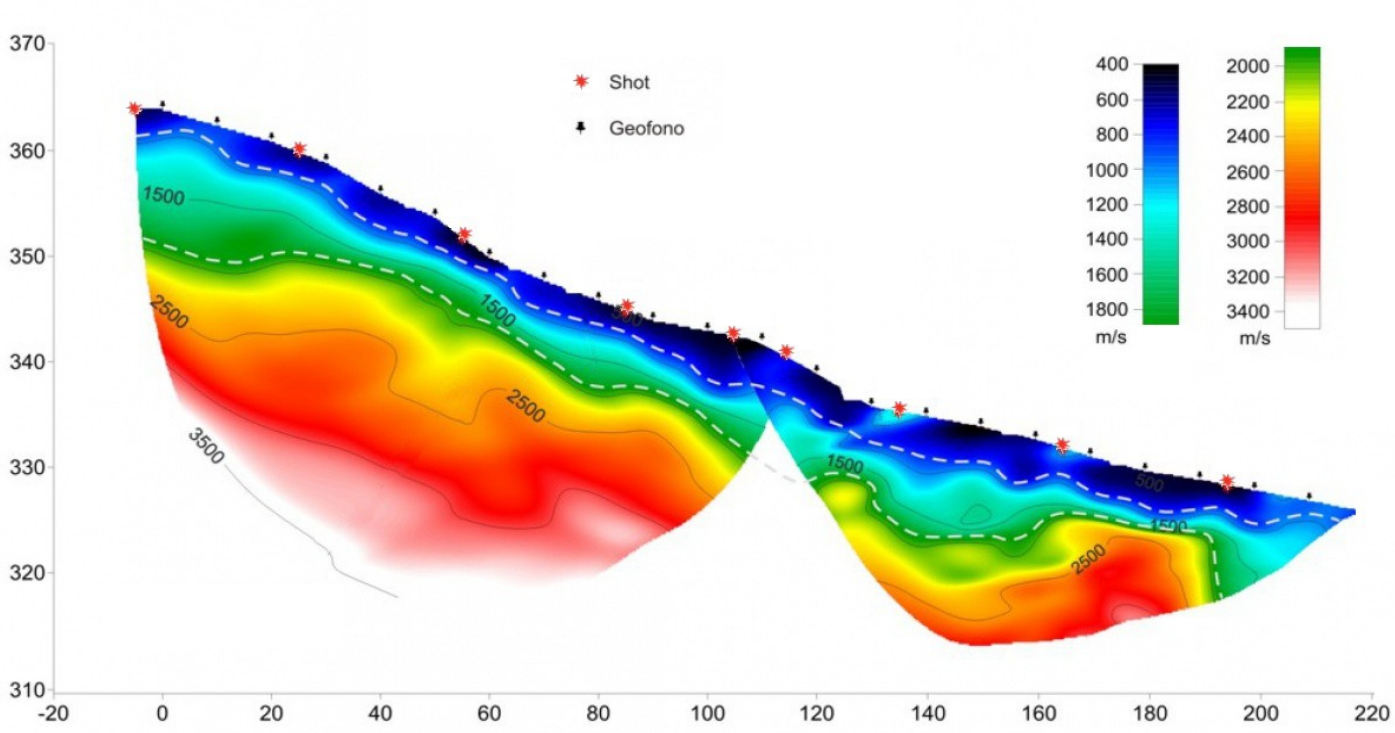


Typically, connecting cables are used, which are inconvenient to use and very expensive. Our system **GeoMapper** eliminates cables and significantly reduces costs.

Signal Analysis

By analyzing the received signals, it is possible to obtain images that represent the characteristics of the soil layers with different colors.





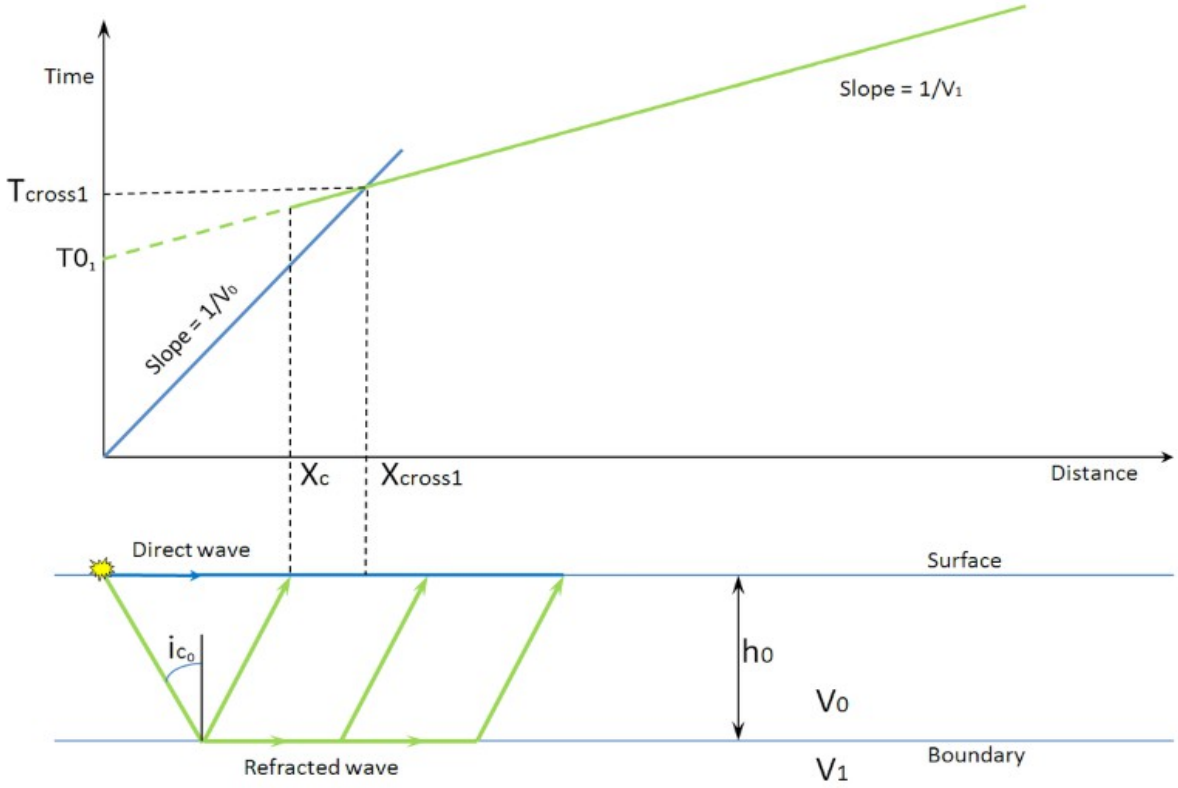
Analysis techniques

There are numerous software programs, including open source and free ones, for performing the analyses. Therefore, we limit ourselves to detecting the seismic waves and preparing the data with the utmost accuracy.

The techniques currently most used for studying the characteristics of the subsoil are seismic reflection, seismic refraction and MASW.

The foundation of these techniques is the interaction between the elastic energy of the waves seismic and discontinuity surfaces between different media.

This allows us to define the lithological units present along a profile, determining the thickness, geometry and elastic properties of the investigated soils.



i_{c_0} - critical angle
V_0 - velocity of the first layer
V_1 - velocity of the second layer
h_0 - thickness of the first layer
$T0_1$ - intercept

$$i_{c_0} = asin\left(\frac{V_0}{V_1}\right)$$

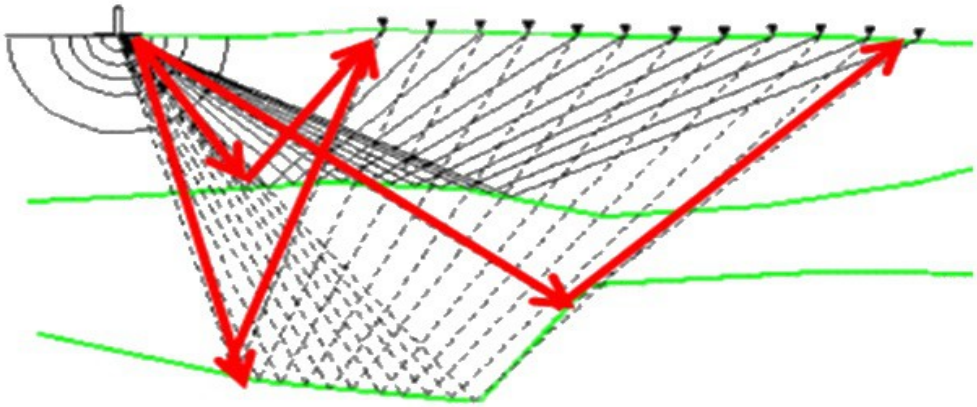
$$T = \frac{2h_0 cos(i_{c_0})}{V_0} + \frac{X}{V_1} = T0_1 + \frac{X}{V_1}$$

$$h_0 = \frac{T0_1 V_0}{2cos(i_c)}$$

$$h_0 = \frac{X_{cross_1}}{2}\sqrt{\frac{V_1 - V_0}{V_1 + V_0}}$$

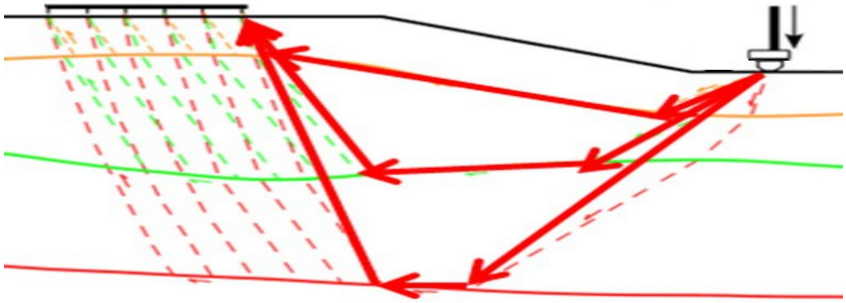
This image shows an example of mathematical analysis of stratifications.

Seismic Reflection



Reflection seismicity analyzes the time between the generated elastic pulse and its reception at the surface after reflections from reflective surfaces. This method exploits the elastic properties of the ground to identify lithological discontinuities.

Seismic Refraction



Seismic refraction, on the other hand, is based on the reception of seismic waves refracted by geological discontinuities, allowing us to determine the propagation speed of the different layers and to trace the geological nature of the formations.

Seismic MASW

The MASW technique, together with other recent developments, represents a particular type of seismic refraction that allows us to identify the dynamic characteristics of soils and obtain the velocity profile of vertical shear waves, which is essential for the design and prediction of the behavior of structures subjected to dynamic actions such as earthquakes, winds, vibrations, and explosions.

Appendix 3 - Notes on GPS systems

The following pages provide key information on GPS systems and modules for receiving GPS signals.

Modules for receiving satellite signals.

The most commonly used modules (2024) are the BN-180, BN-220, BN-280 and BN-880.

These modules on Amazon cost around 25 Euro (BN-180) up to around 45 Euro (Bn-880).

In our case, FLASH memory is not needed, since we have plenty of it on the ESP32 processor.

And we have even less use for the BN-880's compass, since we don't fly a drone.

Therefore the best choice is definitely the BN-180 which is also very small and can be easily positioned on the upper face of the tube containing the geophone.

An important feature of these BN-xxx modules is that they also work with GNSS techniques, see the next pages.

1 2 3 4

1	GND	Ground
2	TX	Serial Data Output
3	RX	Serial Data Input
4	VCC	DC 3.0V - 5.5V supply input,Typical: 5.0V

Model	Interface	Size	Flash	Compass	Antenna Type
BN-180	1.0mm 4pin	18*18*6mm	/	/	Passive
BN-220	1.0mm 4pin	22*20*6mm	4M Flash	/	Passive
BN-280	1.25mm 6pin	28*28*8mm	4M Flash	/	Passive
BN-880	1.25mm 6pin	28*28*10mm	4M Flash	HMC5883L	Active

There are also other less expensive modules, such as theGY-NEO6MV2 NEO-6M which can be found on Amazon for less than 10 euros, shipping included.

However, these modules are larger and only receive GPS satellites (no GNSS), so they might take longer to sync. But we've tried them, and they work very well outdoors.

Features of the BN-180 module

- **Size: 18mm * 18mm * 6mm**
- **Weight: 4.9 g**

- **Channels: 72**
- **Tracking: -167 dBm**
- **Reacquisition: -160dBm**
- **Cold start: -148 dBm**
- **Warm start: -156 dBm**
-
- **Reception format: GPS, GLONASS, Galileo, BeiDou, QZSS and SBAS**
- **Frequencies: GPS L1, GLONASS L1, BeiDou B1, SBAS L1, Galileo E1**

- **Horizontal accuracy: 2 m CEP 2D RMS Enable SBAS (typical open sky)**
- **Speed: 0.1 m/sec 95% (SA off)**
- **Timing: 1us synchronized with GPS time**

- **Cold start: 26 seconds**
- **Warm start: 1 second to 25 seconds**

- **Communication Baud Rate: 4800 bps to 921600 bps(default 9600)**
- **Levels: TTL or RS-232(default TTL)**
- **Protocol: NMEA-0183 or UBX(default NMEA-0183)**
- **Single GNSS: 1Hz to 18Hz**
- **Simultaneous GNSS: 1Hz to 10Hz(default 1Hz)**

- **Max altitude: 50,000 m**
- **Max speed: 515 m/s**
- **Max acceleration: 4 g**

- **Power supply: 3.6V to 5.5V(typical 5V)**
- **Current: Captures 50 mA at 5V**
- **Operating temperature: -40°C to +85°C**
- **Storage temperature: -40°C to +105°C**

- **TX LED - BLUE - Flashing during data transmission**
- **PPS LED - RED -Flashing when satellites are valid**

- **Connections: 1=GND, 2=TX (data output), 3=RX (data input), 4=VCC (3.0v-5.5v)**
- **Connector: 1mm pitch (4 connectors included in the package)**

GNSS devices

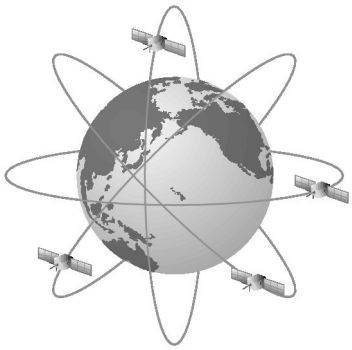
GNSS devices (G*lobal Navigation Satellite System*) can receive data from satellites of several different nations.

GNSS-1 is the first generation and combines the systemsGPS (USA) and GLONASS (Russia),

GNSS-2 It is the second generation and combines the GPS (USA), GLONASS (Russia), Beidou (China), Galileo (Europe), QZSS (Japan) and IRNSS (India) systems.

Receivers that implement GNSS provide superior performance because they can more easily receive signals from a greater number of satellites. This allows them to achieve greater precision, in many cases below one meter horizontally, and also to be able to operate in difficult positions, under obstacles such as large trees or even indoors.

GPS, GLONASS and BEIDOU satellites



GPS satellites orbit at an operational altitude of between 18,000 and 22,000 km and their rotation period around the Earth is 12 hours.

There are approximately 24 GPS (Global Positioning System) satellites launched by the United States.

The GLONASS (GLObal NAvigation Satellite System) satellites, launched by Russia, include 24 operational satellites and several spares.

In 2012, Russia and China approved a new space cooperation program and began interaction on the GLONASS and BeiDou satellite navigation systems.

The Beidou satellite constellation was completed in 2020 and consists of a total of 36 active satellites, mostly in medium Earth orbit and with some units placed in geostationary orbit and others in inclined geosynchronous orbit.

NNMEA codes for GLONASS and BEIDOU

The NMEA standard, used by GPS receivers, has evolved to include Russian, Chinese, Indian, Japanese, and European satellites.

So the $GPXXX messages from the GPS receivers become:

- $GP - referring to GPS
- $GL - referring to Glonass
- $GN - refers to GNSS (GPS + Glonass + others)

For example, the messages GPRMC and GPGGA become GNRMC and GNGGA.

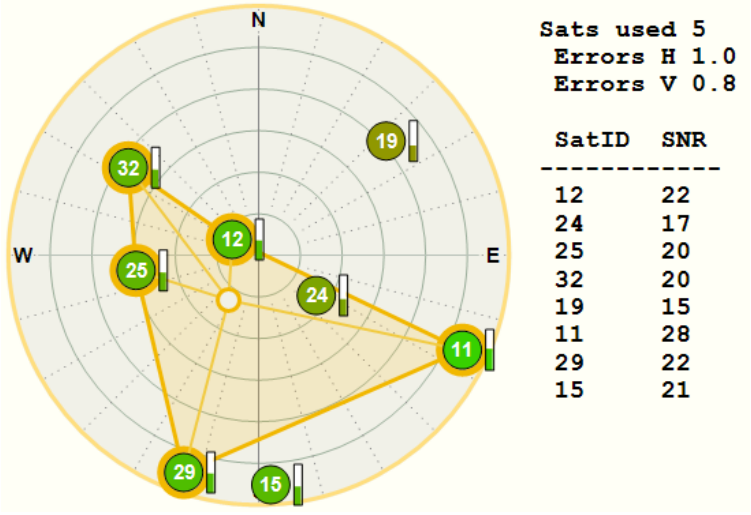
The string GNGSA (which indicates accuracy and active satellites) refers to GNSS and includes the list of satellites for both constellations.

The GPGSA string, which was a single string, becomes multiple GNGSA strings because the number of usable satellites, by adding Glonass, grows significantly and it would not be possible to include the entire list of satellites used for the fix within a single string.

The GPGSV message has not changed, but the GLGSV message has been added, which refers exclusively to Glonass satellites.

Satellite identifiers

GNSS standards do not specify satellite identifiers. Only IDs 1 to 32 are definitely valid.belonging to the GPS system (USA). However, according to some sources, the satellites should follow the following table.



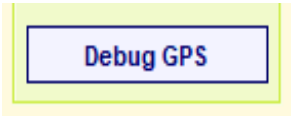
- GPS: 1-32
- Galileo: 1-36
- Beidou: 1-63
- IRNSS: 1-14
- QZSS: 183-206
- SBAS: 120-151, 183-192

Appendix 4 -The GPS application

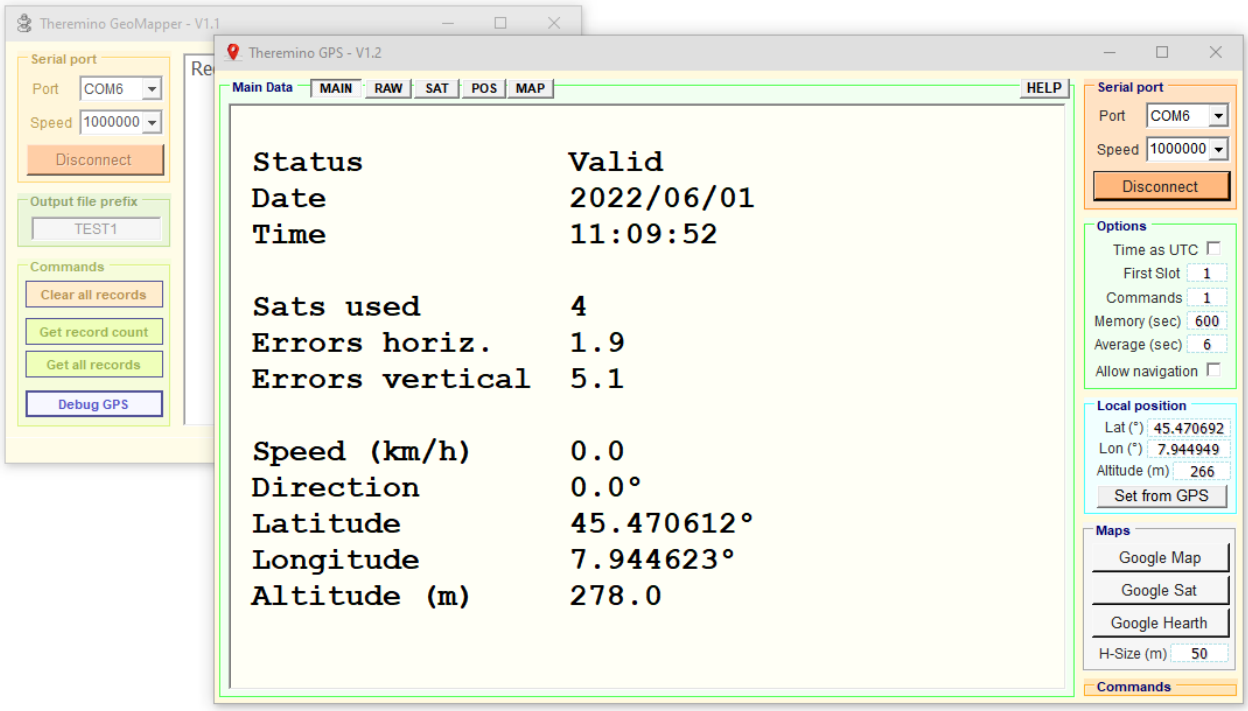
With the application **Theremino_GPS** the proper functioning of the GPS module present in the receivers is checked **GeoMapRX**.

Normally, you don't need to use this application because you can tell if your GPS is synchronized with the satellites by checking if the appropriate LED is flashing.

Use this application if you are having problems with satellite synchronization or if you want to check the accuracy of your coordinates or other satellite data.



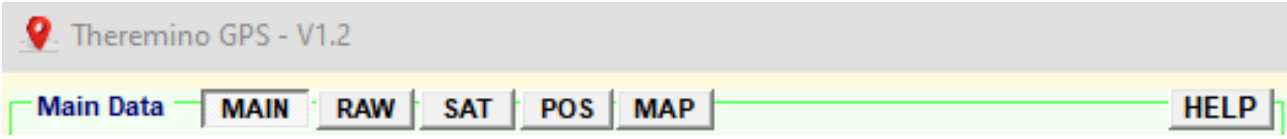
To open the GPS application use the "Debug GPS" button in the application **GeoMapper**.



By pressing this button the application **GeoMapper** it is disabled and becomes transparent until you close the GPS application with the cross.
On this first page (which is selected with the "MAIN" button located in the top bar) we see the general status of the satellites, whether they are valid, how many are used, the measurement precision and the speed and position data.

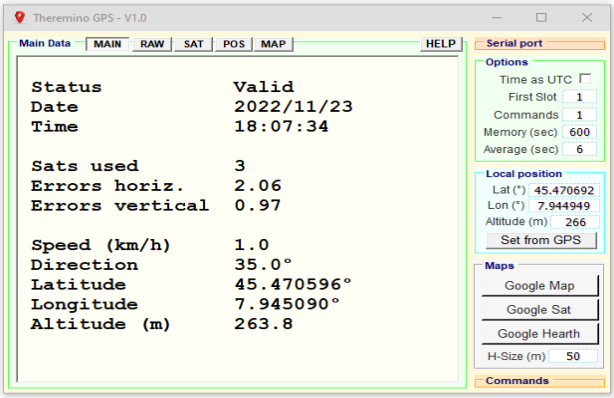
On the right side there is the command column which we will explain in the next pages.

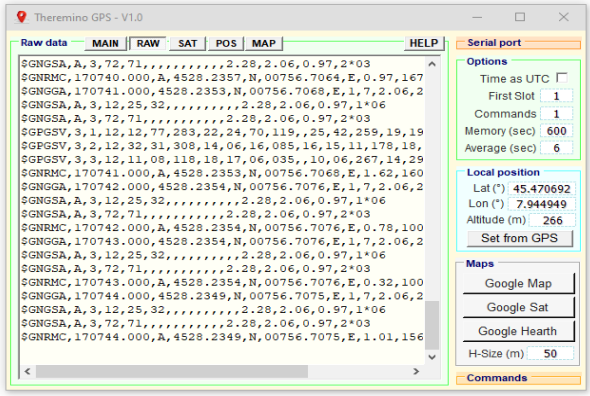
The top bar

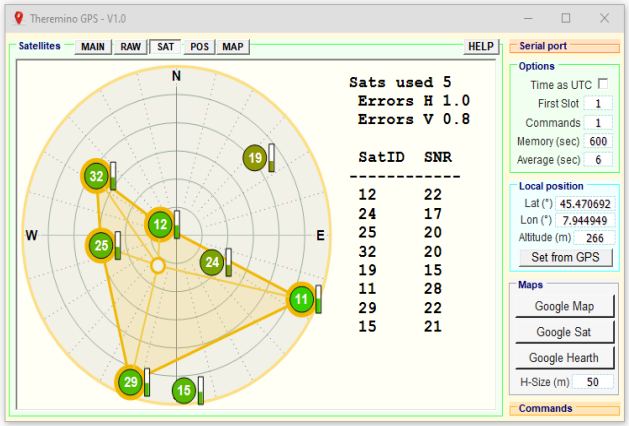


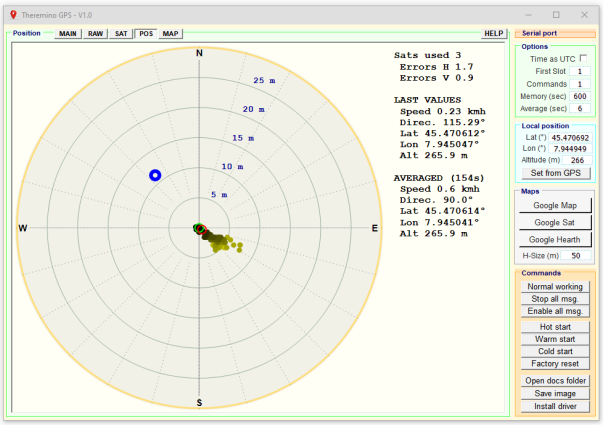
With these buttons you can choose the type of display among those of the following images.

The "HELP" button opens a brief summary of the instructions. Part of the instructions refers to GPS modules with USB cable and is not valid for **GeoMapper**.

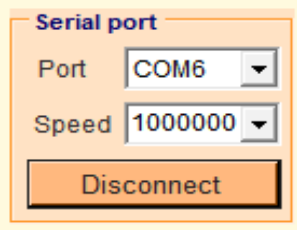








The Command Bar - Part One



Select the serial port.

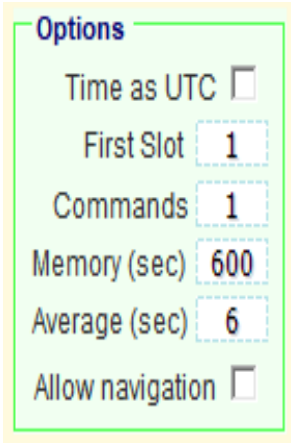
Select the BaudRate (1 mega for the **GeoMapRX**)

The button turns red when connected.

All panels of this application can be closed as shown in the image on the right.

To close and reopen panels, click on the panel name.

It is recommended to keep panels that you are not using closed, especially the "Serial Port" panel, because when it is open it flashes and wastes processor time.



To get the time in "Coordinated Universal Time" select the "Time as UTC" box.

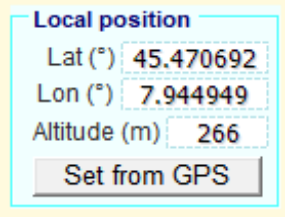
The "First Slot" text box indicates the first slot to use (see next paragraph).

Set the "Memory (sec)" text box to a time in seconds. This time will be used to store the route data. The maximum time is 9999 seconds, which is approximately three hours.

Set the "Average (sec)" text box to "1" to get fast but noisy data.

With average = 60 the latitude, longitude and altitude are the average of the last minute. The maximum average time is 600 seconds which is equivalent to 10 minutes. Average positions are calculated only if H and V errors are less than 10

The "Allow navigation" checkbox should normally be left unchecked (white). This prevents Google from displaying annoying messages. However, in some cases, you may need to enable it, for example, to accept Google's privacy policy.

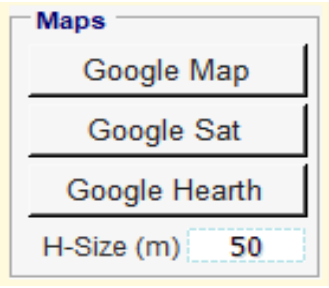


Manually set Lat, Lon and Altitude.

Use the "Set from GPS" button only if you are sure of the decoded GPS location.

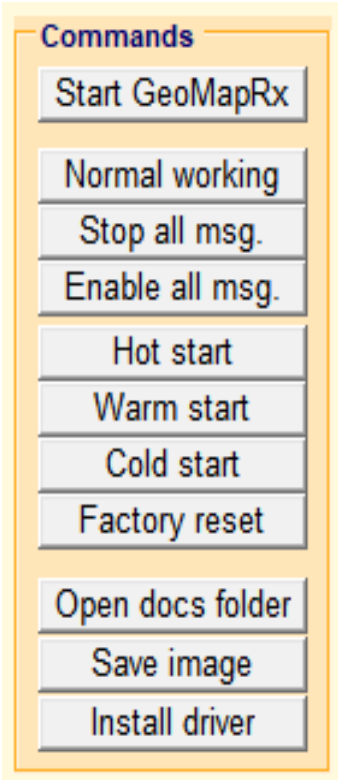
Your local location is used to display a blue circle in the POS graph and also to facilitate initial operations with the "Hot Start" and "Warm Start" commands.

The Command Bar - Part Two



With "Google Map", "Google Sat" and "Google Hearth" you can open the relevant WEB pages.

With H-Size you set the height of the visible window in meters.



Start GeoMapRX Send the “Debug GPS” command to the modules **GeoMapRX**.

Normal working - Send RMC, GGA, GSA messages every second and GSV every 4 seconds

Stop all messages - Stops all messages to check if the serial buffer is overflowed.

Enable all messages - Send RMC, GGA, GSA, GSV and also GLL and VTG every second (for testing).

Hot start - Reboot using local location.

Warm start - Clear ephemeris data and set local location.

Cold start - Clear all data in memory and set local location.

Factory reset - Erase all data, set local location and reset to factory settings.

Open docs folder - Opens the "Documents" folder where you will find useful documentation and applications.

Save image - Save the current image in the "Images" folder.

Install driver - For almost all USB modules you need to install the "Prolific" driver.

When using the application GeoMapper
All commands in red are disabled and do not work.

First use and after the Warm start, Cold start and Factory reset commands
In these cases the receiver may take a long time to restart.
Place it outdoors and wait for it to connect many satellites.

The data that is sent to the Slots

To check the GPS operation it is not necessary to send data to the Slots but this application is also used for other configurations of the Theremino System and therefore can also do so.

- - - - - -

To disable sending data to the Slots, set the "First Slot" box to -1

The decoded values are sent to the first Slot and subsequent Slots.

For example, if you set "First Slot" = 1, the slots are updated as in the following table:

- Slot 1 Status 0 = Not valid / 1000 = Valid

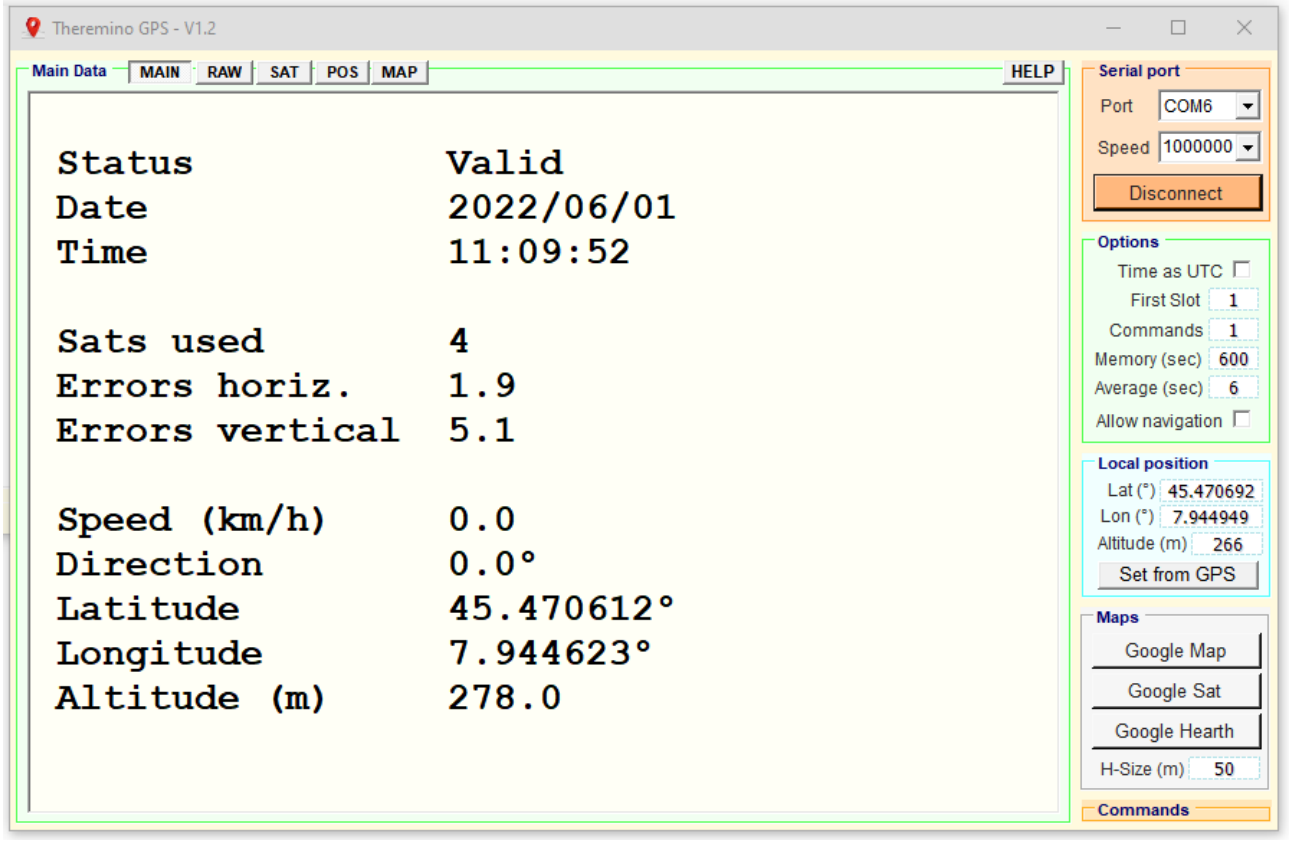
- Slot 2 Year
- Slot 3 Month
- Slot 4 Day
- 5 Hour Slot
- 6 Minute Slots
- Slot 7 Second

- Slot 8 Number of used satellites
- Slot 9 Horizontal errors (1 good / 5 medium / 10 bad)
- Slot 10 Vertical errors (1 good / 5 medium / 10 bad)

- Slot 11 Speed in km/h
- Slot 12 Direction in degrees and fractions
- Slot 13 Latitude in degrees and fractions (averaged)
- Slot 14 Longitude in degrees and fractions (averaged)
- Slot 15 Altitude in meters (averaged)

Average positions are calculated only if H and V errors are less than 10

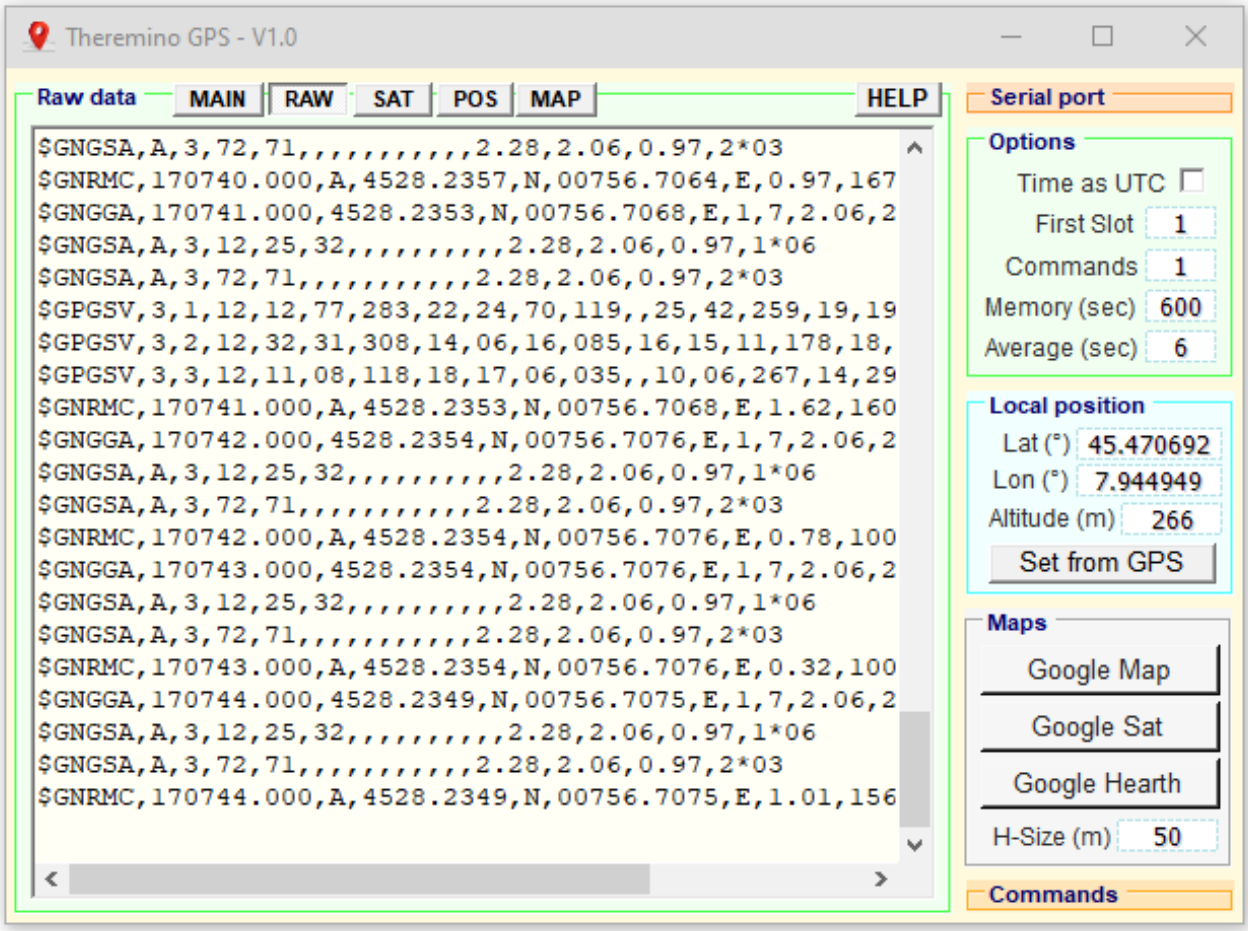
The MAIN window



Pressing the "MAIN" button opens this page which shows the general status of the satellites.

- Status - Indicates whether there are at least four satellites and whether they are valid.
- Date and Time - Indicate the current date obtained from satellites with an accuracy of approximately one second.
- Sats used - Indicates how many satellites were used in the coordinate calculations.
- Errors horiz. - Indicates the horizontal error in meters.
- Errors vertical - Indicates the vertical error in meters.
- Speed - Indicates the speed of movement in kilometers per hour.
- Direction - Indicates the direction of movement in degrees (zero degrees is North)
- Latitude and Longitude - These are coordinates in degrees and fractions, not minutes and seconds to be compatible with the Google Maps format.
- Altitude - Indicates the height in meters above sea level.

The RAW window



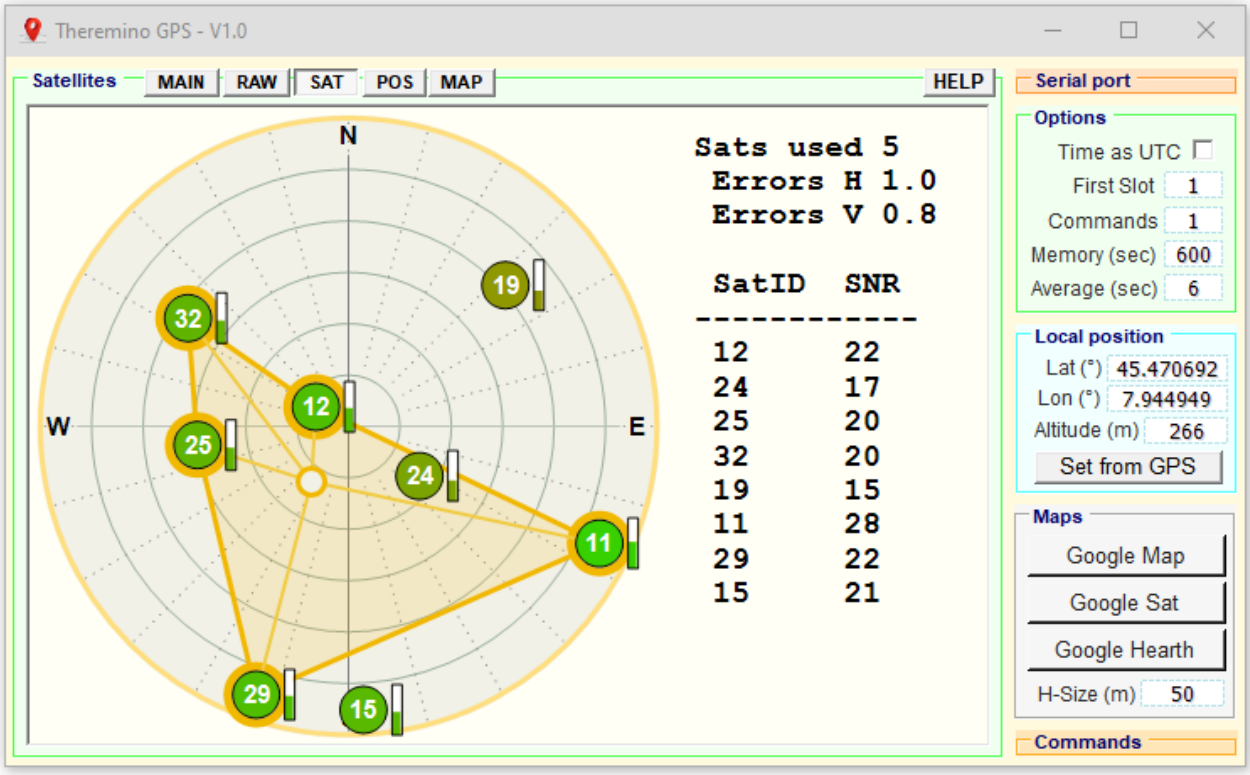
Pressing the "RAW" button opens this page which shows the raw data from the GPS module.

In "Appendix 2" of this document you can find information on the meaning of these lines according to the NMEA protocol.

- - - - - -

You can find more information and examples
on satellites and the NMEA protocol, in the "GPS \ DOCS" folder
can also be opened with the "Open docs folder" button in the "Commands" panel

The SAT window



The "SAT" page shows which satellites are visible, their identifiers, and the signal strength of each satellite (SNR column in the table and vertical bars).

The top right part indicates the number of satellites used and the horizontal and vertical errors in meters.

The satellites used produce a polygon highlighted in yellow which visually indicates whether they are well distributed around the centre of gravity.

The best accuracy in meters is achieved with a good distribution of satellites and with a good strength of their signals.

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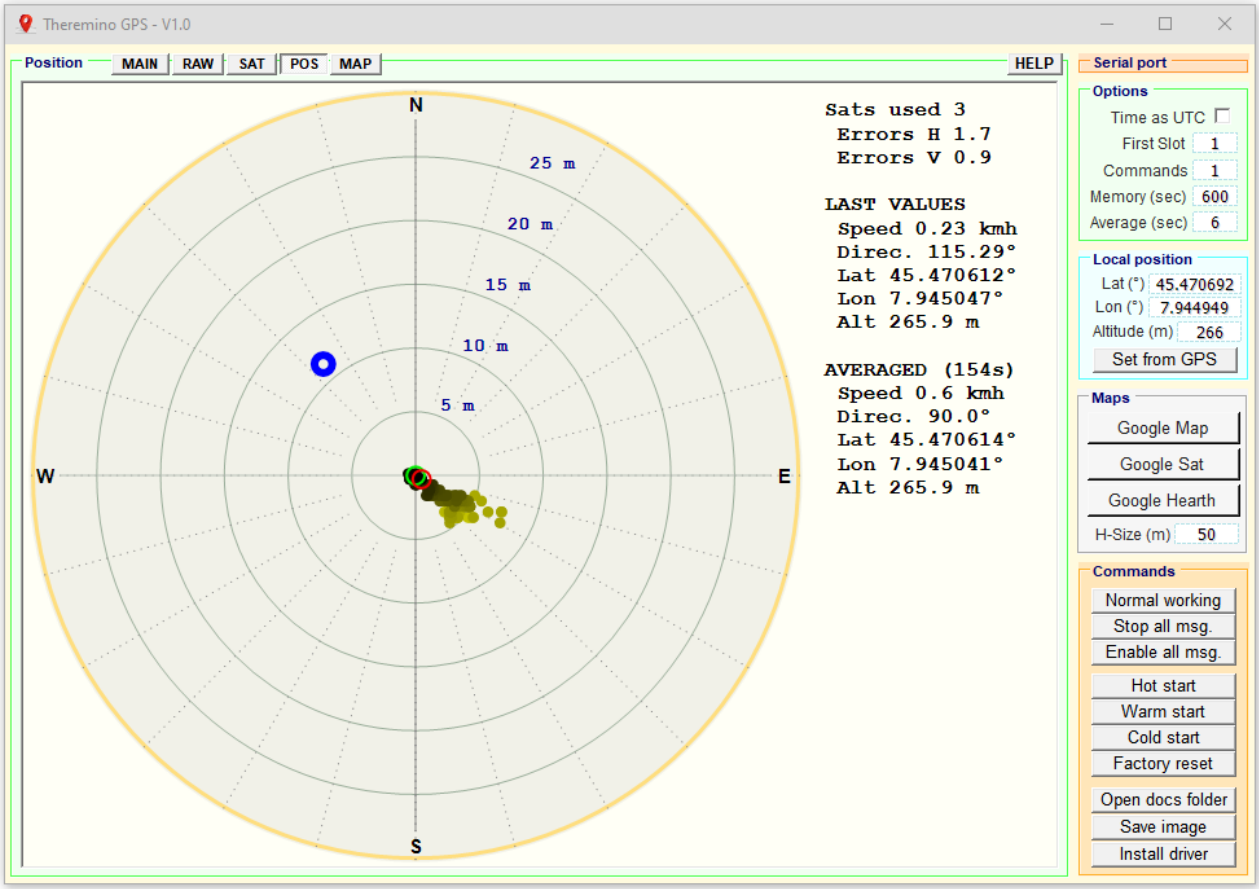
You can find more information about satellites in the "GPS\DOCS" folder. can also be opened with the "Open docs folder" button in the "Commands" panel

The POS window



You can change the zoom with the mouse wheel.

Positions are updated only if H and V errors are less than 10 meters.

The positions indicated are:

- RED Circle = Last decoded position.
- GREEN Circle = Average position.
- BLUE circle = Position set in the "Local position" panel

- - - - - -

You can find more information about satellites in the "GPS\DOCS" folder.
can also be opened with the "Open docs folder" button in the "Commands" panel

The Google Maps window

The MAP page opens centered on the average position and its height in meters depends on the value you set in H-Size (in the "Maps" panel).

This is the on Google Maps page (satellite type) with the points of the position obtained from GPS signals.

The lighter colors of the dots indicate which are the most recent.

You can move the page with the left mouse button and zoom it with the wheel.

- - - - - -

You can find more information and examples
on satellites and the NMEA protocol, in the "GPS \ DOCS" folder
can also be opened with the "Open docs folder" button in the "Commands" panel