

TROMINO[®] BLU

Portable ultra-light acquisition system for seismic noise and vibrations

International patents: Pub. No. WO2006011021 (A1),
Pri. No. IT2004BO00449 20040719, USPTO 7.800.981

USER'S MANUAL





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DISCLAIMER. Tromino® is provided on an “as is” basis, without warranty of any kind, to the fullest extent permitted by law. Designers and developers have put the maximum attention in verifying it, although it is possible there are errors not yet verified at the time of release. The usage of Tromino® is intended for qualified personnel only, capable to understand the meaning of the input and output data. The designers, developers and distributors disclaim all warranties, express or implied and will not be liable for any direct, indirect or consequential damages or costs of any type arising out of any action taken by you or others related to the instrument.

TROMINO®: A DIGITAL TROMOGRAPH

International patents: Pub. No. WO2006011021 (A1), Pri. No. IT2004BO00449 20040719, USPTO 7.800.981

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History of an Italian tradition. Italy has been pioneering the instrumental measurement of Earth motions and, among them, the measurement of tremors. Around 1870 Timoteo Bertelli designed and built in Bologna an accurate yet simple, lightweight and comparatively inexpensive instrument to measure the tremors of the Earth. He named it tromometer from the name of the ancient Greek word for tremors, τρομοζ. MoHo s.r.l. - a company specialized in microelectronics applied to ultralow signals - revives this Italian tradition with **TROMINO®**.



TROMINO® is an ultra-compact and ultra-lightweight instrument for ambient (passive) and induced (active) vibration measurements on soils and structures, for vibration analysis and more.

INSIDE AND BEYOND SEISMIC TREMOR: THE MAIN APPLICATIONS OF TROMINO®

TROMINO® does not record only seismic noise. Here is a list of the main applications possible with one or more units.

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ONE TROMINO®

ON SUBSOILS

Determining whether a subsoil can amplify seismic motion and, if so, at what frequencies, is the first step in seismic site response assessment, both for seismic microzonation and structural dynamics characterization. This also helps to overcome some limits of a subsoil classification based on the Vs30 parameter. With **TROMINO®** this can be done by means of:

1. Standard spectral analysis to detect real 3D and 2D resonances¹

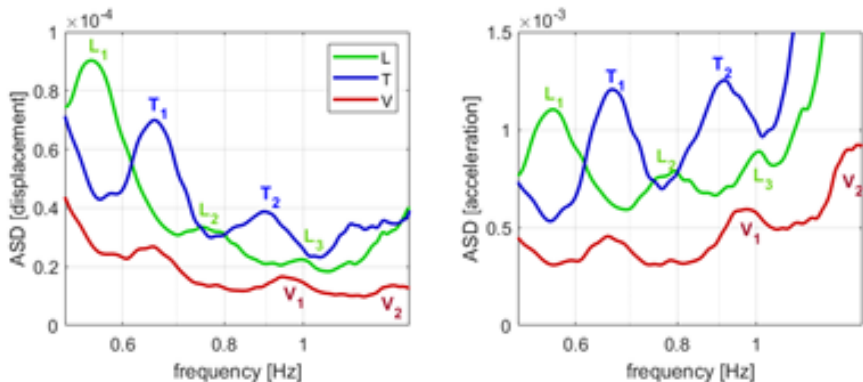
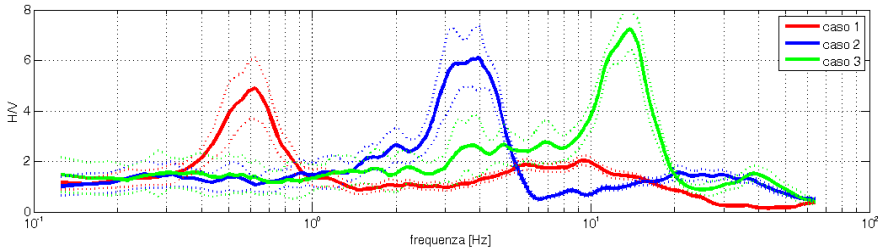


Figure 1. Longitudinal, transversal, and vertical eigen-modes of a valley surveyed with **TROMINO®**.

¹ see Castellaro and Musinu, BSSA (2023); Sgattoni and Castellaro, GJI (2020).

2. H/V ratios to assess the virtual 1D resonance from surface waves



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Figure 2. Example of seismic bedrock at different depths generating H/V peaks at different frequencies. Case 1: bedrock at 300 m depth, case 2: bedrock at 20 m depth, case 3: bedrock at 4 m depth.

3. V_s (seismic shear wave velocity) profiles from the fit of H/V curves constrained to independent data (typically drilling and penetration tests).

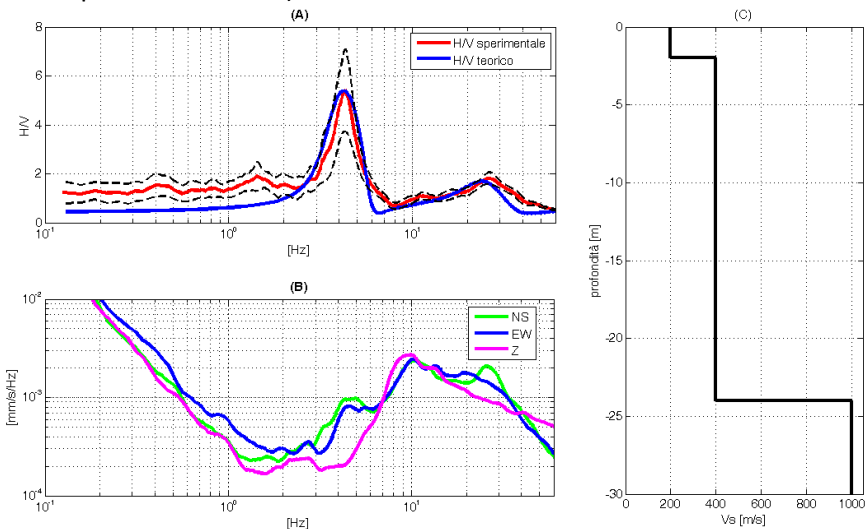


Figure 3. A) experimental (average in red, standard deviation in black) and theoretical H/V curve (blue) obtained for the V_s model of panel C); B) single component amplitude spectra used to obtain the H/V curve of panel A).

4. **V_s** (seismic shear wave velocity) **profiles from SASW/MASW (Spectral/Multichannel Analysis of Surface Waves)** performed with a single **TROMINO®** + the exclusive (wireless) trigger².
5. **V_s** (seismic shear wave velocity) **profiles from the joint fit of SASW/MASW** performed with a single **TROMINO®** + the exclusive (wireless) trigger² **and the H/V curve** (Figure 4).

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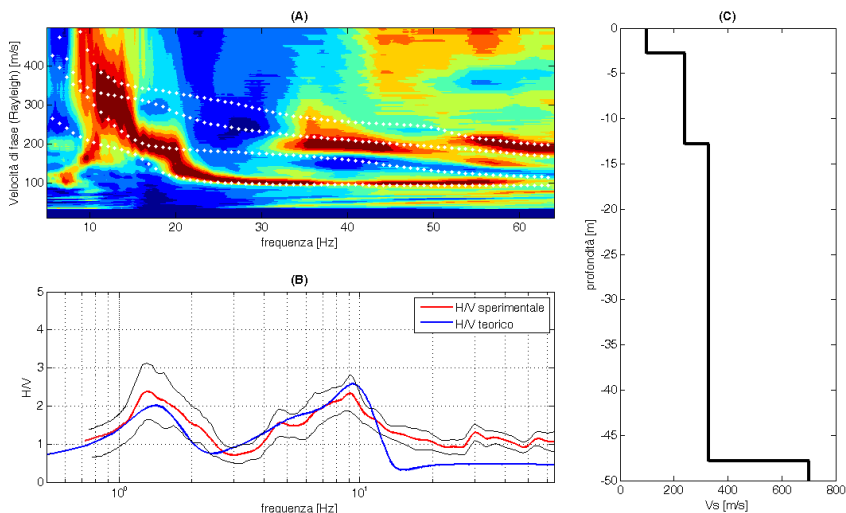


Figure 4. A) Phase velocity spectra of the Rayleigh waves (contour plot) and first 4 modes of the theoretical dispersion curve for the subsoil model of panel C) (white dots); B) experimental (average in red, standard deviation in black) and theoretical (blue) H/V curve for the subsoil model of panel C); C) subsoil V_s profile derived from the joint fit of the MASW and H/V curves obtained with a single **TROMINO®** + the exclusive (wireless) trigger².

6. In presence of a V_s profile, several H/V curves can be combined to get a **synthetic view of the main seismic reflectors** (e.g. bedrock, gravel layers, etc.) at local or regional scale (Figure 5).

² The wireless trigger does not apply to the **TROMINO® ZERO** models.

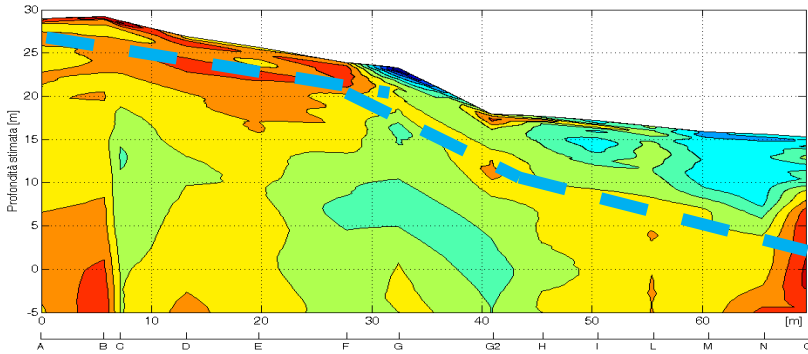


Figure 5. Synthetic view of several H/V curves acquired along a profile. According to the color scale adopted, this view shows the top of the bedrock (blue dashed line), which dips eastwards.

ON STRUCTURES

- 7. Characterization of structure dynamics** under passive and/or active sources. Determination of:
 - a. modal frequencies (1 instrument),
 - b. modal shapes (1 instrument for the first flexion mode under stationary microtremor, more than 1 instrument for higher modes),
 - c. modal damping (1 instrument).
- 8. Detection of subsoil-structure coincidence of resonances** (items 1 and 7 above).

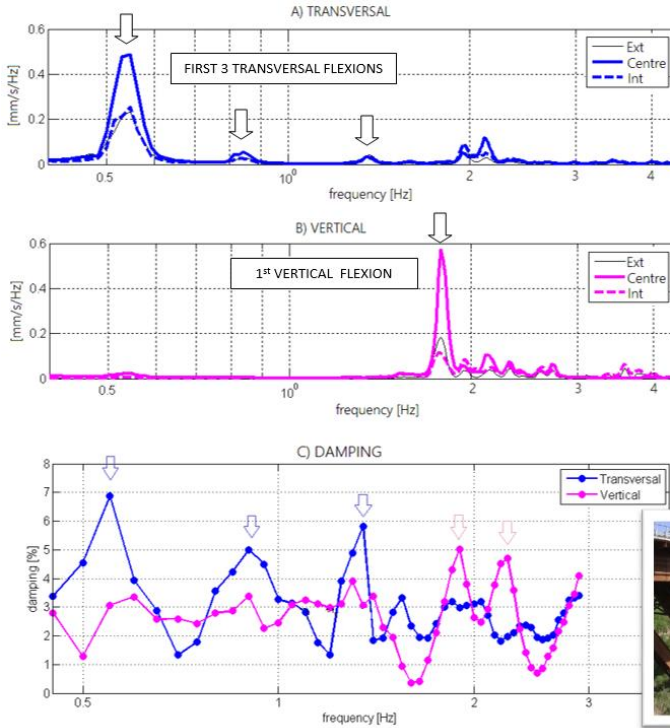
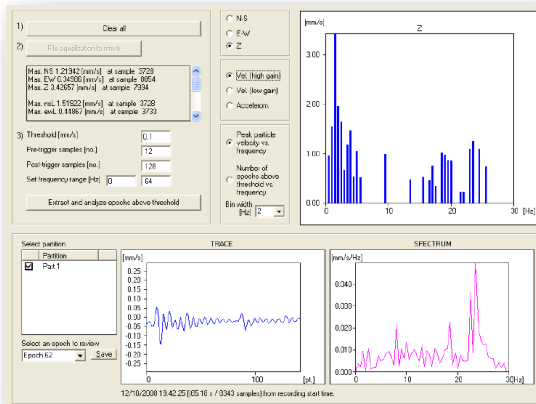


Figure 6. A) transversal and B) vertical modal frequencies of the bridge shown in the frame on the bottom right. C) damping as a function of the frequency for the same bridge. The blue and magenta arrows indicate the damping at the transversal and vertical mode frequencies.

9. Off-line vibration analyses according to European regulations (UNI9916, DIN4150, UNI9614) (e.g., damage caused by traffic on structures, vibration causing nuisance to persons, etc., Figure 7).

Note that MoHo developed also specific software (*Vibri*) to this aim ([more information](#)).



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Figure 7. Interface of the *Grilla* software module for vibration analysis.

10. On-line vibration monitoring, also remote (via web) and threshold-based alarm settings (Figure 8) by means MIM (MoHo Instrument Manager) .

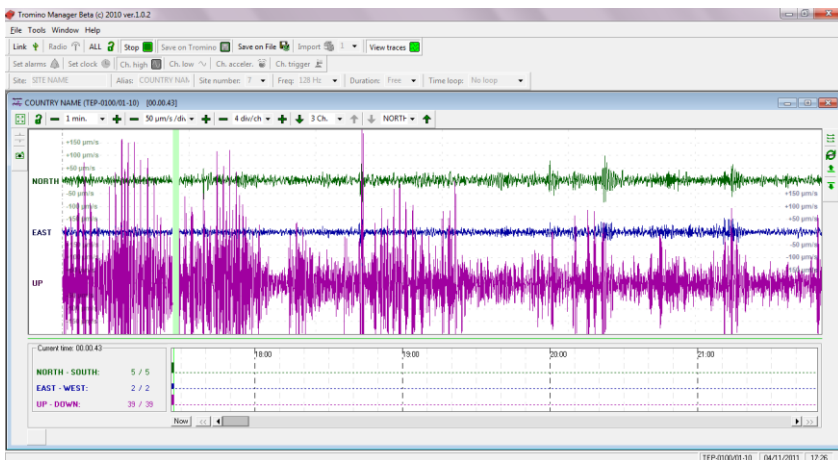


Figure 8. Interface of the **TROMINO®** Manager software for on-line vibration monitoring.

MORE THAN ONE TROMINO®

ON SUBSOILS

11. **2D seismic arrays** synchronized through the GPS time marker or the built-in radio³. These arrays (both active and passive) provide shear wave velocity profiles (Vs) from spatial autocorrelation techniques (or similar).

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ON STRUCTURES

12. Full active or passive dynamic characterizations (see item 6, p. 11) through **TROMINO®** networks, where the single units communicate via radio (or GPS)³.

³ The GPS and built-in radio antennas do not apply to the **TROMINO® ZERO** models.

TECHNICAL INTRODUCTION

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The original idea behind **TROMINO®** was to produce a truly portable seismometer and accelerometer, sensitive enough to capture the average vibration level that can be recorded at the quietest sites on the Earth in the frequency range of engineering interest (0.1-200 Hz).

TROMINO® does more. In fact, it allows one to measure also the large and potentially dangerous vibrations in buildings and structures (see norm UNI 9916 e DIN 4150).

The miniaturization (10 x 14 x 8 cm) and lightweight (1.1 kg), the ultra-low energy consumption and the total absence of external cables make **TROMINO®** an almost pocketable instrument which leaves the wave field virtually unperturbed.

The instrument has⁴:

- 3 channels connected to 3 orthogonal electrodynamic velocimeters with selectable gain for seismic tremor acquisition,
- 3 channels connected to 3 orthogonal digital accelerometers⁵,
- 1 channel for the GPS antenna (internal and/or external)⁵,
- 1 analog channel⁵ to be used, e.g., as trigger,
- 1 channel for radio synchronization⁵.

The Earth or structure motion is amplified, converted into digital form, transferred to a memory card and then to the PC, where the storage, analysis and the review of the data are performed through the *Grilla* software.

⁴ Features can change according to the specific **TROMINO®** model.

⁵ The accelerometers, wireless trigger, analog channel, GPS and radio antennas are not present in the **TROMINO® ZERO** models.

Setting **TROMINO®** into operation is easy thanks to its LCD which provides guidance in the parameter choice such as the recording mode, the acquisition time, the total available memory and the internal electronic noise monitoring. The display allows also viewing acquired traces in real time and in review. A set of 4 soft-touch keys let the user communicate with the system. Depending on the context, each key assumes different functions that are described on the display.

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TROMINO® is powered by internal rechargeable lithium ion batteries: this makes it easy to handle. Memory storage limits are only those imposed by memory card technology. However, the system can acquire also in continuous mode and send data to the PC through **TROMINO®** Manager or the MIM (MoHo Instrument Manager) software .

The radio and GPS synchronization allow **TROMINO®**s to be used in array or network configuration.

ACCESSORIES

Case

TROMINO® is delivered in a rigid, shock-proof case.

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Batteries

TROMINO® 3G+ and **BLU** models
released from 2017 onwards

TROMINO® is endowed with internal rechargeable lithium-ion batteries (2000 mA/h).

The batteries can be recharged by connecting **TROMINO®** to the electrical network (use the 5 V DC, 500 mA USB connector power supply provided with **TROMINO®** or any equivalent power supply). The batteries recharge also when **TROMINO®** is linked to the PC through the USB port.

A complete recharge takes approximately 10 hours when the device is turned off. The recording autonomy is 24-30 hours, depending on the acquisition parameters.

All **TROMINO®** models
released before 2017

Older **TROMINO®** models are furnished with 2 alkaline 1.5V AA batteries. Rechargeable batteries can be used but in this case the power level signal displayed on the **TROMINO®** screen could be misleading. If you are using rechargeable batteries and you observe anomalous behaviours of

TROMINO® (e.g. it does not start the recording or stops it in an anomalous way), replace the batteries with new alkaline batteries.

Memory Cards

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TROMINO® stores data in internal memory supports. The minimum capacity is 16 Gb but limits are imposed only by the memory card technology at the time of the order.

USB cable for PC connection

A USB cable is supplied for the connection of **TROMINO®** to the PC.

Spikes

TROMINO® is furnished with 2 sets of spikes for soil/ground coupling:

- 3 *long spikes* to be used on soft soils (read page 53)
- 3 *short spikes* to be used on stiff soils (read page 53).

External GPS antenna

*[On demand with **TROMINO®** non **ZERO** models].*

Connect the GPS antenna to the female connector on the right side of **TROMINO®** marked with the “G” label (Figure 9).

The GPS and radio antennas are not intended to work simultaneously.

Radio antenna

*[On demand with **TROMINO**® non **ZERO** models].*

Connect the radio antenna to the female connector on the right side of **TROMINO**® marked with the “R” label (Figure 9).

The radio and GPS antennas are not intended to work simultaneously.

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Trigger cable + geophone

*[On demand with **TROMINO**® non **ZERO** models].*

Connect the trigger cable to the female connector (AUX CHANNEL, p. 90) on the right side of **TROMINO**® marked with the “T” label (Figure 9).

Wireless trigger + geophone

*[On demand with **TROMINO**® non **ZERO** models].*

Connect the trigger cable to the female connector (AUX CHANNEL, p. 81) on the right side of **TROMINO**® marked with the “T” label (Figure 9).



Figure 9. **TROMINO**® right side connector panel. From left to right, G is the connector for the GPS antenna, R is the connector for the radio antenna (to be used also for the wireless trigger), T is the connector for the auxiliary channel (e.g., trigger cable). The GPS and radio antennas are not intended to work simultaneously.

Software

TROMINO® data can be downloaded, organized, archived, visualized and analyzed with the *Grilla* software, which provides routines for spectral and H/V analyses, also following the European SESAME project directives (2004).

HANDLING CARE



While **TROMINO®** has a robust construction, it is nevertheless a precision instrument and should be treated accordingly. Each instrument is delivered with a rigid, shock-proof carrying case, which protects it from falls, water splashes and dust and which we recommend using for transport and storage. Although the sensors self-lock when not in acquisition, they, as well as the electronics, **do not like crashes**. In case this happens, check the instrument functionality (see also p. 67). In presence of any irregularity **never open** the device but **contact the producer** (MoHo s.r.l.) for assistance.

Opening the device voids the warranty.

The sharp spikes which couple **TROMINO®** with the ground can be dangerous. **Keep them out of the reach of children**. After use, always put **TROMINO®** in its rigid case vertically with the spikes driven into the sponge.

The coupling spikes do not need to be unscrewed after every use. Leave them mounted on **TROMINO®** and drive them into the **TROMINO®** case sponge for storage.

The **TROMINO®** base is one of its most delicate parts: avoid direct contact with rough surfaces to prevent scratches.

MAINTENANCE

Inspect the container, the accessories and the cables to verify the presence of possible damages caused by transport. Such problems should be verified and reported to the producer (MoHo s.r.l.) before using the unit.

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Do not use abrasives or solvents of any type to clean the system.

Clean the recorder using a dry or 'humid' cloth (not wet) on the external part of the cover. Clean the connection cables also with a humid cloth.

Take care that the battery closure (where present), the USB closure and the holes in which spikes are inserted are always clean. In case of presence of dirt, remove it with a dry cloth or brush.

Do not open the cover of the system or expose it to abnormal conditions (high temperatures or excessive humidity).

Avoid spilling any materials, in particular liquids, on the system components.

Do not attempt any repair or substitution of any parts and always refer to the producer (MoHo s.r.l.) for any problem.

Contact the producer (MoHo s.r.l.) to organize a periodic maintenance check (on a 2-year basis).

WARRANTY

To be covered by warranty, the following rules must be respected:

- do not open the device
- do not move the instrument during the acquisition. **During the acquisition sensors are not locked and could be damaged under strong accelerations**
- do not draw the device in water
- do not let the device under heavy rain without an appropriate shelter
- do not put any weight on the device
- do not let the device fall down
- do not scratch its surface (especially the base and the display)
- do not reverse battery polarity
- do not connect it to electrical sources unless through the cables provided or recommended by MoHo s.r.l.
- keep all its external part and plugs clean with dry a cloth or brush
- always transport and store the device in the rigid case provided

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MoHo s.r.l. reserves the right to modify products, specifications or manuals whenever necessary without prior notice.

MoHo s.r.l. declines every responsibility regarding the security, reliability and services if the device is mishandled or repaired by non-authorized personnel. For all modifications regarding cables and accessories please contact MoHo s.r.l. in order to guarantee the device compatibility.

Avoid connecting **TROMINO®** to any other instrument (including computers) during the *passive* seismic microtremor acquisition, since this could disturb the acquisition.

WHAT MODEL OF TROMINO® DO I HAVE?

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The model of **TROMINO®** can be inferred from the serial number printed on the instrument upper side panel or on the display (keep the button ON pressed continuously to read the *serial n.* line). Then consult the correspondence table (Table 1).

The **TROMINO®** serial number is composed of 3 letters (L) and some numbers (#), according to this format LLL - # # # # / # # - # #. Consider only the first 3 letters.

First 3 letters of the serial number	TROMINO® model	Years of production
TR	First models and prototypes	2003-2006
TRE	EASY	2006-2008
TRS	STUDIO	2006-2008
TEN	ENGINEERING	2006-2008
TRY	SEISMO	2006-2008
TEP	ENGY / ENGY PLUS	2009-2013
TRZ	ZERO	2009-2013
T4K	TEP with enhanced sensor output (x 3)	2009
TE3	ENGY (3G series)	2013-2018
TZ3	ZERO (3G series)	2013-2018
TEB	ENGY BLU	Since 2019
TZB	ZERO BLU	Since 2020
Other	Experimental series	

Table 1. Serial codes for the different versions of **TROMINO®** and years of production.

The typical dynamic ranges of different models of **TROMINO®** are described in Table 2. The models are listed in chronological order of appearance. Please refer to Table 1 to identify the **TROMINO®** model from its serial number.

For vibration monitoring through **TROMINO®** Manager or MIM  and for alarm detection it is recommended to remove the offset as described on p. 66.

First 3 letters of the serial number	HIGH GAIN CHANNELS	HIGH GAIN CHANNELS	LOW GAIN CHANNELS	ACCELER.
STANDARD GAIN		Gx8 MODE		
	[mm/s]	[mm/s]	[mm/s]	[g]
TR	±1.2	-	-	
TRE	±1.2	-	-	
TRS	±1.2	-	-	
TEN	±1.2	-	±45.6	
TRY	±1.2	-	±45.6	
TEP	±1.2	±0.15	±45.6	±2
TRZ	±1.2	±0.15	±45.6	
T4K	±0.4	±0.01	±15.2	
TE3	HIGH GAIN ^a ±1.2 (FULL SCALE 51 mV) ±2.4 (FULL SCALE 102 mV) ±12.0 (FULL SCALE 512 mV) ±24.0 (FULL SCALE 1024 mV)			±2.5 (sensitivity ~±76 µg)
This TROMINO® 3G series has increased sensitivity				

<p>at low frequency compared to the older models. Set MODE >> FULL SCALE >> 51 mV to get the maximum sensitivity.</p> <p>a) Setting MODE >> HIGH/LOW GAIN will cause the TROMINO®3G sensitivity to be similar to the previous (non 3G series, like TEP).</p>		
TZ3	<p>HIGH GAIN ^a</p> <p>±1.2 (FULL SCALE 51 mV)</p> <p>This TROMINO®3G series has increased sensitivity at low frequency compared to the older models. Set MODE >> FULL SCALE >> 51 mV to get the maximum sensitivity.</p> <p>a) Setting MODE >> HIGH/LOW GAIN will cause the TROMINO®3G sensitivity to be similar to the previous (non 3G series, like TRZ).</p>	
TEB (2018)	<p>±0.5 mm/s (FULL SCALE ±44 mV)</p> <p>±1 mm/s (FULL SCALE ±89 mV)</p> <p>±2 mm/s (FULL SCALE ±178 mV)</p> <p>±5 mm/s (FULL SCALE ±447 mV)</p> <p>±10 mm/s (FULL SCALE ±894 mV)</p> <p>±20 mm/s (FULL SCALE ±1788 mV)</p> <p>Set MODE >> ±0.5 mm/s (FULL SCALE ±44 mV) to get the maximum sensitivity.</p>	<p>±2.5 (sensitivity ~±76 µg)</p>
TZB (2020)	To come	
Other	Contact support@moho.world	

Table 2. Saturation levels of the different versions of **TROMINO®**. On the TEB and TZB series use MODE >> ±0.5 mm/s (FULL SCALE ±44 mV) to record microtremors. On TE3 and TZR use MODE >> FULL SCALE >> 51 mV to record microtremors. On the older series,

use the HIGH GAIN channels to record microtremor and on low noise areas. Use the LOW GAIN channels only for very noisy sites (strong vibrations, e.g. traffic on bridges and similar). Whenever using the LOW GAIN channels, it is recommended to acquire also from the HIGH GAIN (STANDARD GAIN) channels.

This manual applies mostly to the **TROMINO® BLU** series released in 2018 but a number of functions of older **TROMINO®**s are still described to warrant compatibility and for better understanding.

SENSOR ORIENTATION

For both velocimeters and accelerometers the positive (upwards) phase corresponds to the direction of the applied forces indicated below, for each axis.

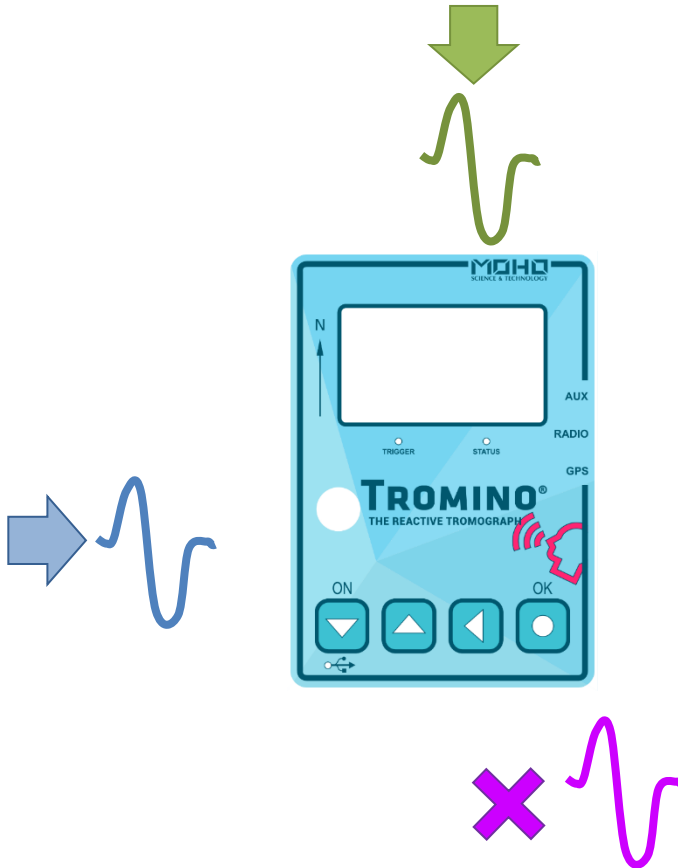


Figure 10. Arrows: direction of the applied force. The magenta cross indicates a force acting in vertical direction from top to bottom. Sinusoids: positive (upwards) phase convention.

SYMBOLS

EXTERNAL DESCRIPTION

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Figure 11. **TROMINO® BLU** front panel. The white hole corresponds to the level. The  symbol indicates the USB port position.

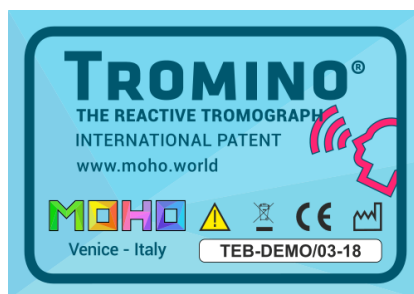


Figure 12. **TROMINO® BLU** side panel.

KEY DESCRIPTION

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The 4 soft-touch keys of the recorder will be hereafter referred to as:

Left (LE) ▼	Center Left (CL) ▲	Center Right (CR) ◀	Right (RI) ●
-------------------	--------------------------	---------------------------	--------------------

In general:

- ▼ and ▲ scroll the cursor vertically among the different functions,
- ● activates the selected function,
- ● and ◀ allows to set the selected function value.

The key to activate each command is described within brackets after the command. Commands are printed in underlined CAPITAL LETTERS.

Example: ESC (RI ●) means that the rightmost key activates the Escape function.

All the items of the menus will be indicated in CAPITAL LETTERS.

Example: ACQUISITION.

QUICK START GUIDE

1) Place **TROMINO®**

For further important information please refer to page 51.

In general, the instrument base should be kept as close as possible to the surface/object to be measured.

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1. Mount the 3 *short spikes* for recordings on hard rock, inside buildings or whenever the soil/ground is too stiff for significant spike penetration. Mount the 3 *long spikes* for recordings on soft soils/grounds or whenever significant spike penetration is possible.

Note: on stiff horizontal surfaces (e.g., pavements) **TROMINO®** can also be placed on the ground without any spike.

2. On very hard soil, inside buildings and in all cases in which penetration is not possible, level the instrument by the screws on the spikes. The major axis of **TROMINO®** is named N-S and can be aligned in the N-S direction or not, depending on the user's needs. For measures inside buildings and on clearly 2D/3D geological structures, align **TROMINO®** according to the structure main axes, not along the magnetic N-S direction.
3. On soft soil prepare an approximately levelled 15x20 cm spot. On grass, remove the few centimetres of topsoil with the help of a little spade or hammer or feet. Remove stones, cobbles and any other superficial dirt. Place **TROMINO®** on this spot.
4. By alternatively pressing on the lowermost corners of the box (at the edges below the ON and OK buttons) and on the middle of the top edge above the display, set **TROMINO®** in the horizontal position (the air bubble is at the center of the spirit level). Proceed in small steps, alternatively pressing each of the three points until spikes penetrate to all their length in the soil. Do not

extract the spikes to reach a better levelling. Spike coupling works in shear stress like that of nails, and working spikes back and forth destroys coupling. Please note that a few degrees off the horizontal position do not alter the measurements, but a poor coupling does. An acceptable horizontal levelling is achieved when the air bubble touches externally the circle at the centre of the spirit level. If this condition is not achieved, restart the levelling operation by making new holes. **A tight coupling is more important than an accurate levelling, thus stop levelling as soon as a sufficient horizontality is achieved.**

TROMINO® should be as close as possible to the object of measurement (typically, the ground). When spikes are used, insert them as much as possible into **TROMINO®** and into the ground. Avoid any additional layer between **TROMINO®** and the object of measurement (do not put tripods, metal plates or similar between **TROMINO®** and the ground).

IN THE GEOLOGICAL-GEOTECHNICAL MEASUREMENTS PREFER ALWAYS TO COUPLE THE INSTRUMENT DIRECTLY TO THE NATURAL SOIL RATHER THAN POSITIONING IT ON ASPHALT OR PAVEMENT SINCE THE LATTER ARE OFTEN RESPONSIBLE FOR VELOCITY INVERSIONS THAT MAKE THE INTERPRETATION OF THE MEASUREMENTS AT HIGH FREQUENCY MORE DIFFICULT (TYPICALLY $H/V < 1$).

2) Switch on

- click the ON button (LE ▼) to turn the **TROMINO®** on. The SET UP windows will appear.

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TROMINO
MoHo
DIGITAL TROMOGRAPH
hardware
Serial no. LLL-####-##-##
Hardware key
Firmware ver.
Development date



TROMINO

BATTERY 

DATE dd mmm yy

TIME hh : mm : ss

GO SET UP EXIT

- click the (LE ▼) key (GO). You will be redirected to the INITIAL MENU window.

▶
ACQUISITION

SWITCH OFF

DATE AND TIME

SITE NAME

PARTITION IN USE ## / ##

BLUETOOTH, LIGHT ON/OFF

VIEW CARD DATA

RADIO SET, GPS SHOW

▼

▲

◀

●

- click the (RI ●) key. The ACQUISITION window will appear.

▶
INITIAL MENU

ACQUIRE

AMPLIFIER TEST

SELECT PROGRAM

MODE

SAMPLING ### Hz

SITE ## name

ACQ. LENGTH ## : ## : ##

▼

▲

◀

●

3) Would you like to modify the sampling rate?

If so, then

proceed as below,

else

go to 4)

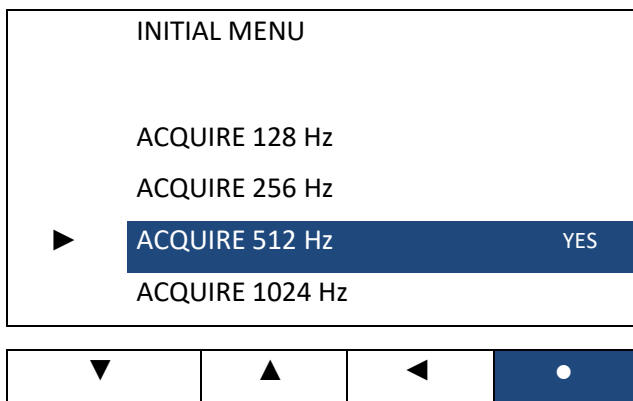
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- Scroll down with the (LE ▼) key until the SAMPLING item is selected as in figure below.

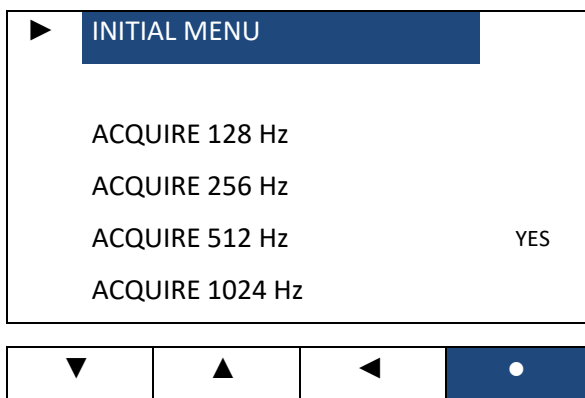
INITIAL MENU	
ACQUIRE	
AMPLIFIER TEST	
SELECT PROGRAM	selected acquisition program
MODE	
▶ SAMPLING	### Hz
SITE	## name
ACQ. LENGTH	## : ## : ##

▼	▲	◀	●
---	---	---	---

- Click the (RI ●) key and you will be redirected to the following window.



- Scroll up/down with the (LE ▼) (CL ▲) keys until the rate of interest is selected and click on the (● RI) key. The label YES appears next to the selected sampling rate.



- Scroll up with the (CL ▲) key until the INITIAL MENU item is selected and click the (RI ●) key. You will be redirected to the following window.

▶	INITIAL MENU	
	ACQUIRE	
	AMPLIFIER TEST	
	SELECT PROGRAM	selected acquisition program
	MODE	
	SAMPLING	### Hz
	SITE	## name
	ACQ. LENGTH	## : ## : ##

▼	▲	◀	●
---	---	---	---

WARNING! Only data sampled at 128 or 512 Hz can be equalized in amplitude in the [0.1 Hz, half the sampling rate] range, by using the *Grilla* software.

At present, only data sampled at 512 Hz can be filtered according to the UNI-9614 in *Grilla*.

If a different sampling rate was used, use the FILE > DESAMPLING function in *Grilla* before equalizing the acquired data.

4) Would you like to set a different acquisition program (with or without GPS / GPS marker)?

Please read also p. 77.

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If so, then

proceed as below,

else

go to 5)

- Scroll down with the (LE ▼) key until the SELECT PROGRAM item is selected.

INITIAL MENU	
ACQUIRE	
AMPLIFIER TEST	
▶	<div> <div>SELECT PROGRAM</div> <div>selected acquisition program</div> </div>
MODE	
SAMPLING	### Hz
SITE	## name
ACQ. LENGTH	

▼	▲	◀	●
---	---	---	---

- Scroll down or up with the (LE ▼) or (CL ▲) keys until the desired program number is selected. Then exit by clicking the OK button (RI ● key).

PROGRAM #	TOT. CHAN. NO.
CHANNELS	HIGH / LOW / ACC. ⁶
GPS DATA	YES/NO
START	MANUAL / AUTOMATIC
MARKER	YES/NO

DW
UP
OK

The different program functions are listed on p. 71.

⁶ On **TROMINO® BLU** set MODE >> FULL SCALE ± 44 mV ± 0.5 mm/s to record microtremors. On the **TROMINO® ENGY** and the **TROMINO® 3Q** series (TE3 **3Q**, TZR **3Q** instruments), set MODE >> FULL SCALE >> 51 mV to record microtremors. On the older series, use the HIGH GAIN channels to record microtremor. Use the LOW GAIN channels only strong vibrations (e.g. trains on bridges and similar). Set the ACCELEROMETERS to record acceleration. Due to the lower resolution of the LOW GAIN and ACCELEROMETRIC channels, it is recommended to keep the HIGH GAIN channels always active. Read also item 5) below and the caption of Table 2 (p. 27).

5) What is the maximum amplitude that you desire to measure in terms of velocity?

All the **TROMINO®** ENGY, **3G** and **BLU** series are equipped with different triplets of orthogonal sensors, with adjustable sensitivity and output.

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*[Applies to **TROMINO® BLU**]*

FULL SCALE (± 44 , ± 89 , ± 178 , ± 447 , ± 894 , ± 1788 mV, corresponding to ± 0.5 , ± 1 , ± 2 , ± 5 , ± 10 , ± 10 mm/s): velocimetric channels with different saturation levels (see Table 2 on p. 27). **Set FULL SCALE >> ± 44 mV, ± 0.5 mV to get the maximum system sensitivity** (suitable for ambient noise recordings).

*[Applies to **TROMINO® 3G**]*

FULL SCALE (51, 102, 512 and 2048 mV): velocimetric channels with different saturation levels (see Table 2 on p. 27). **Set FULL SCALE >> 51 mV to get the maximum system sensitivity** (suitable for ambient noise recordings).

*[Applies to **TROMINO®** ENGY and **TROMINO® 3G**]*

HIGH GAIN CHANNELS: corresponded to the highest possible sensitivity in the **TROMINO®** series before **3G** (before 2013, see Table 2 on p. 27). Use this setting preferably only for comparison with older instruments. In general, prefer the settings above that ensure higher sensitivity.

LOW GAIN CHANNELS: velocimetric channels with a gain conceived for strong vibrations like those induced on structures by heavy vehicle traffic or machineries (cf. norms UNI 9916 and DIN 4150). See Table 2 on p. 27 for the saturation level of these channels. It is recommended to use the LOW GAIN CHANNELS always in combination with the HIGH GAIN CHANNELS.

ACCELEROMETERS: accelerometric channels. Due to the higher intrinsic noise of accelerometers compared to velocimeters, it is recommended to acquire the data also from velocimetric channels. Accelerometers saturates at approx. $\pm 2g$ (the sensitivity threshold is $\sim \pm 76 \mu g$).

Any combination of channels described above can be set. This selection is to be effected in the acquisition menu, item MODE, as below.

- Scroll the menu with the (LE ▼) key until MODE is selected.

INITIAL MENU	
ACQUIRE	
AMPLIFIER TEST	
SELECT PROGRAM	selected acquisition program
▶ MODE	
SAMPLING	### Hz
SITE	## name
ACQ. LENGTH	

▼	▲	◀	●
---	---	---	---

- Press the (RI ●) key to be redirected to one of the following windows. Press the (LE ▼) key until the desired channels are selected. Enable the desired channels (FULL SCALE >> 44/89/178/... mV, HIGH GAIN, LOW GAIN, ACCELEROMETERS, AUX CHANNEL, WIRELESS TRIGGER) by pressing the keys YES/NO (CR ◀) e (RI ●).

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INITIAL MENU	
▶ HIGH GAIN CH. FULL SCALE	BLU: ±44/89/178/447/894/1788 mV 3G : 51/102/512/2048 mV
ACCELEROMETER	YES/NO
AUX CHANNEL	YES/NO
WIRELESS TRIGGER	YES/NO
GPS ANTENNA	INT/EXT
ALARM SETUP	

▼
▲
◀
●

INITIAL MENU	
▶ HIGH GAIN CH.	YES/Gx8/NO
LOW GAIN CH.	YES/NO
ACCELEROMETER	YES/NO
AUX CHANNEL	YES/NO
WIRELESS TRIGGER	YES/NO
GPS ANTENNA	INT/EXT
ALARM SETUP	

▼
▲
◀
●

For vibration monitoring through **TROMINO®** Manager and for alarm detection it is recommended to remove the offset as described on p. 66.

6) Would you like to set a different acquisition length?

If so, then

proceed as below,

else

go to 6)

- Scroll down with the (LE ▼) key until the ACQ. LENGTH item is selected.

INITIAL MENU	
ACQUIRE	
AMPLIFIER TEST	
SELECT PROGRAM	selected acquisition program
MODE	
SAMPLING	### Hz
SITE	## name
▶	ACQ. LENGTH

▼	▲	◀	●
---	---	---	---

- Click the (RI ●) key.

ACQUISITION LENGTH			
hh : mm : ss			
DW	UP	TIMER / FREE / MEMORY	OK

▼	▲	◀	●
---	---	---	---

- Use the (CR ◀) key to select
 - 1) TIMER → to acquire for a specified duration (e.g., 00 h:20 min:00 s)
 - 2) FREE → to acquire continuously. The partition will be overwritten until the user stops the acquisition manually
 - 3) MEMORY → the acquisition ends when the partition memory is filled up
- If you select TIME, then use the (LE ▼) and (CL ▲) keys to increase or decrease the acquisition length.
- Go back to the INITIAL MENU by clicking the (RI ●) key.

You are now ready to acquire.

- In the panel below, move down with the (LE ▼) key until the ACQUIRE item is selected and click the (RI ●) button.

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INITIAL MENU	
▶	ACQUIRE
AMPLIFIER TEST	
SELECT PROGRAM	selected acquisition program
MODE	
SAMPLING	### Hz
SITE	## name
ACQ. LENGTH	## : ## : ##

▼	▲	◀	●
---	---	---	---

- After a few seconds, the signals will be displayed on the screen.
- If the selected program is PROGRAM 2 or PROGRAM 4, then traces will automatically be saved on the current partition as soon as the GPS signal is collected. If satellites cannot be tracked, traces will be automatically recorded 5 minutes after start-up and after the set delay (page 62).
- If the selected program is PROGRAM 1, PROGRAM 3 or PROGRAM 5, then the traces you see on the display will not automatically be saved on the memory card.

To save them under PROGRAM 1, click the (LE ▼) or (CL ▲) button and scroll up with the (CL ▲) button until the SAVE option is active. Select OK with the (RI ●) key. Saving will start after delay time set by the user (usually 15 seconds) and will automatically stop after the time length set.

To save them under PROGRAM 3 and PROGRAM 5, click the START button (RI ● key).

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WARNING!

Avoid moving **TROMINO®** during the acquisition since this could damage the sensors. Stop the acquisition first by keeping the 2 central keys pressed at the same time and for a few seconds, then move **TROMINO®**.

To stop the recording also see p. 123.

SUMMING UP

We summarize the operations to start and save the recordings with **TROMINO®**. Here it is assumed that the sampling rate, acquisition length, instrumental sensitivity etc. have already been set. We just remind that the maximum sensitivity in the **TROMINO® BLU** series is achieved by setting MODE >> FULL SCALE >> ± 44 mV, ± 0.5 mm/s while in the **TROMINO® 3G** series it is achieved by setting MODE >> FULL SCALE >> 51 mV.

- 1) Click ON (LE ▼)
- 2) when the display shows the battery status, time and date, click GO (LE ▼)
- 3) set the cursor on **ACQUISITION** and click OK (RI ●)
- 4) move the cursor one line down (ACQUIRE) with the down arrow key (LE ▼)
- 5) click OK (RI ●)
- 6) wait a few seconds. The traces will appear on the display. The device is now ready to save data
- 7) click ON (LE ▼) and move the cursor up (CL ▲) to the item SAVE
- 8) click OK (RI ●) and the count-down will start. **TROMINO®** will start saving data in 10, 9, 8, 7... seconds (this time is meant to allow the user to move away from the instrument during the recording).

To stop the recording before the selected time, keep the 2 central buttons (CL ▲ + CR ◀) pressed for a few seconds.

HOW TO PLACE TROMINO® ON THE GROUND

The most important factor to obtain good recordings is a good coupling between **TROMINO® and the soil/ground.**



Whenever possible it is recommended to place **TROMINO® directly on the natural soil rather than on pavement, asphalt or similar since these could cause inversions of velocity affecting the H/V curves (Castellaro and Mulargia, *Pure Appl. Geophys.*, 166, 567-592, 2009).**

Choose the right spikes

TROMINO® is furnished with 2 sets of spikes:

- 3 *long spikes* (≈6 cm total length, ≈4 cm penetration length),
- 3 *short spikes* (≈3 cm total length).

Mount *short spikes* (Figure 13) for recordings on hard rock, inside buildings or whenever the soil/ground is too stiff for significant spike penetration⁷. Mount *long spikes* (Figure 14) for recordings on soft soils/grounds or whenever significant spike penetration is possible.

On very hard soil, inside buildings and in all cases in which penetration is impossible, level the instrument by the screws on the spikes. The major axis of **TROMINO®** is named N-S and can be aligned to the N-S direction, depending on the user's needs. For measures inside buildings or on 2D/3D geological structures, align **TROMINO®** according to the structure axes.

⁷ On stiff artificial soils – provided that they are enough horizontal and flat – **TROMINO®** can also be set directly, without any spikes.



Figure 13. Mount the short spikes to perform acquisitions on solid rock, inside buildings and in all cases where the soil/ground is too stiff to allow significant penetration. Level the instrument by slightly rotating the spikes.



Figure 14. Mount long spikes for recordings on soft soils/grounds or whenever significant spike penetration is possible.

Prepare soft ground

On soft soil prepare an approximately levelled 15x20 cm spot. On grass, remove the first few centimetres of topsoil with the help of a little spade, hammer or the foot. Remove stones, cobbles and other surficial dirt. Place **TROMINO®** on this spot.

Press down **TROMINO®** to level in small steps

By alternatively pressing on the lowermost corners of the box (at the edges below the ON and OK buttons) and on the middle of the top edge above the display, set **TROMINO®** in a horizontal position (the air bubble at the centre of the spirit level). Proceed in small steps, alternatively pressing each of the three points until level is achieved.

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Tight coupling is much more important than accurate levelling. Do not be too much concerned about perfect levelling

Do not extract the spikes to reach a better levelling. Spike coupling works in shear stress like that of nails and working spikes back and forth destroys coupling. Please note that a few degrees off the horizontal position do not alter the measurements, but a poor coupling does. The air bubble in the spirit level placed on the top surface of **TROMINO®** should be ideally positioned at the centre of the level, but the spirit level is extremely sensitive, and a small deviation from horizontal position does not alter recording results.



Figure 15. By alternatively pressing on the lowermost corners of the box and on the middle of the top edge above the display, set **TROMINO®** in a horizontal position.

Do not connect **TROMINO®** to external cables during the recording

TROMINO® is designed to minimise the influence on measurements of external noise (wind, electronic noise, noise induced by external cables and so on).

Keep the device far from electromagnetic sources such as mobile phones (cellular and cordless), PCs, displays, and monitors. These can emit strong pulsed electromagnetic fields which appear as background noise on the trace.

FUNCTION DESCRIPTION

➤ **SWITCH ON**

For all the **TROMINO®** models (**3G+** and **BLU**)
released since 2017

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- Press the (LE ▼) key to turn the recorder on.

If the device does not turn on, charge the internal battery by connecting **TROMINO®** to the provided power supply through the USB port.

For all the **TROMINO®** models
released before 2017

- Insert 2 AA alkaline batteries respecting the polarity from the side panel.
- Close the battery holder by turning the cap clockwise.
- Press the (LE ▼) key to turn the recorder on.



Figure 16. **TROMINO®** battery panel (only on models released before 2017).

➤ BOOT PHASE

- The following screen appears and remains on the display for a few seconds or until the (LE ▼) key is released.

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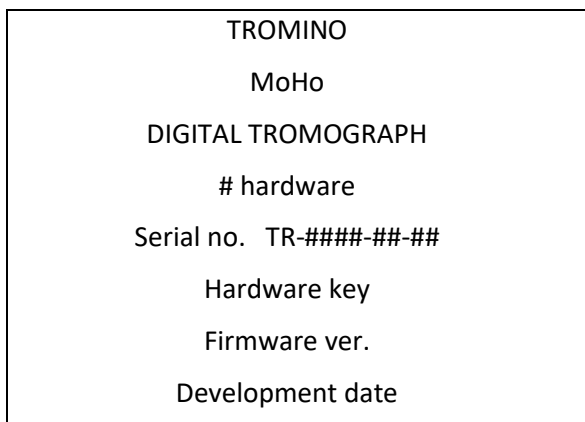


Figure 17. Start-up menu.

This window shows the name of the device (**TROMINO®**), the name of the producer (MoHo s.r.l.), the number of the hardware version, the serial number, the hardware key state, the firmware release and development date.

- After a few seconds, or when the (LE ▼) key is released, the window in Figure 18 appears, showing the battery state, the current date and time according to the internal clock.

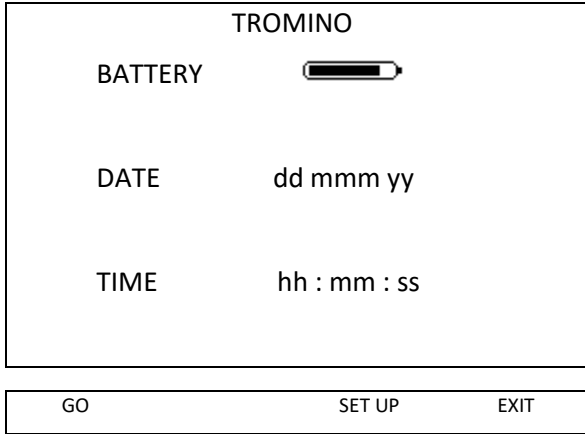


Figure 18. Boot menu.

- The three labels on the bottom indicate the key function:
 - ⇒ GO (LE ▼) opens the main menu window, called INITIAL MENU window,
 - ⇒ SET UP (CR ◀) redirects the user to the SET UP window,
 - ⇒ EXIT (RI ●) switches the device off.

➤ SET UP

INITIAL MENU		
DISPLAY CONTRAST	#	
SWITCH OFF	min	
ACQ. DELAY (GPS)	sec	
STORE GPS DATA	YES/NO	
DW	UP	ESC

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Figure 19. Set up menu.

The SET UP menu allows setting the following system parameters up:

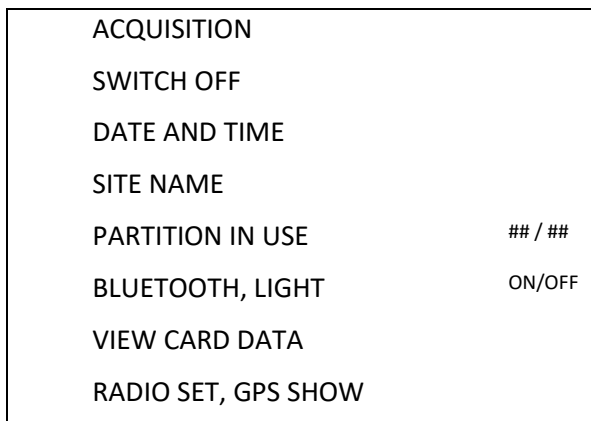
- ⇒ DISPLAY CONTRAST let the user adjust the display contrast in the range 1 (min) to 8 (max); a value of 6 is usually recommended.
- ⇒ SWITCH OFF let the user adjust the time of inactivity after which the device will automatically turn off (1 to 30 minutes).
- ⇒ ACQ. DELAY (GPS) let the user set the time after which the traces should be saved once the device has received the GPS signal (5 to 120 seconds). This can be used to delay the acquisition when, e.g., the GPS synchronization is performed outdoor while the measurement is meant to be indoor (e.g. in a building).

- ⇒ STORE GPS DATA saves a full GPS string per second of acquisition (available under PROGRAM 4 and 5, more info on p. 106). Enable this function only if you need to store the GPS position (latitude, longitude) of **TROMINO®** as a function of the time. **Do not enable this function if you just need to synchronize more TROMINO® units.** Use PROGRAM 4 or 5 to this aim.

Scroll up/down among the different items with the DW (LE ▼) and UP (CL ▲) keys.

Change the function value with the - (CR ◀) and ± (RI ●) keys.

➤ INITIAL MENU



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Figure 20. Initial menu.

The INITIAL MENU panel presents the following sub-menus:

- ⇒ ACQUISITION redirects to the acquisition menu (see page 66).
- ⇒ SWITCH OFF turns the recorder off.
- ⇒ DATE AND TIME set date and time.
- ⇒ SITE NAME sets site name; the current site name is shown on the right.
- ⇒ PARTITION IN USE divides the memory card into partitions (files) and sets the partition in use. The number of the current partition and the total number of enabled partitions are shown on the right. E.g.: 2/10 indicates that the memory card is divided into ten partitions and that the partition where the data will be saved is the number 2.

- ⇒ BLUETOOTH disables/enables the Bluetooth® permanently (ALWAYS ON), temporarily (approx. 2 minutes, BRIEFLY ON).
- ⇒ DISPLAY LIGHT enables/disables the display back-light. When ON, light automatically switches off after 15 s since the last click on any keys.
- ⇒ VIEW CARD DATA displays the traces recorded on the memory card partition in use and the most important acquisition parameters.
- ⇒ RADIO SET, GPS SHOW allows to set the parameters for the radio control and to view GPS data on the screen.

Scroll up/down among the different items with the (LE ▼) and (CL ▲) keys.

Use the (RI ●) key to enter the selected sub-menus.

➤ ACQUISITION

INITIAL MENU	
ACQUIRE	
AMPLIFIER TEST	
SELECT PROGRAM	selected acquisition program
MODE	
SAMPLING	### Hz
SITE	## name
ACQ. LENGTH	## : ## : ##

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Figure 21. Acquisition menu.

The ACQUISITION menu window let the user access the following commands:

- ⇒ INITIAL MENU to return to the main window (page 64).
- ⇒ ACQUIRE to view and/or record data.
- ⇒ AMPLIFIER TEST to test the amplifier electronic noise.
- ⇒ SELECT PROGRAM to choose among different acquisition programs (page 71).
- ⇒ MODE to select the:
 - Acquisition channels (velocity - different sensitivity levels, acceleration, auxiliary channel, wireless trigger),
 - GPS properties (min. satellite number, external/internal antenna),

- alarm properties.
- ⇒ SAMPLING to set the sampling rate.
- ⇒ SITE to manually scroll among different partitions.
- ⇒ ACQUISITION LENGTH to select the duration of the recording.

We hereby explain in detail the functions associated to each item of the ACQUISITION menu:

⇒ INITIAL MENU

Returns to the main window (page 64, Figure 17).

⇒ ACQUIRE

Starts the acquisition (page 90).

⇒ AMPLIFIER TEST



The following operations must be performed in a quiet environment. Place **TROMINO®** on a stiff surface (e.g. the floor) and avoid any noise around it.

Shows the channel noise when locked. This noise (which is the sum of electronic noise plus the residual suspension noise for the velocimetric channels and the vertical acceleration g on the accelerometric channels) is represented by the vertical black bars (one vertical bar per channel). The amplitude of the

vertical scale is indicated in the first line as number of μV per pixel ($\#\ \mu\text{V}/\text{pixel}$). The noise level on each channel should be approximately the same and below $2\ \mu\text{V}$ peak to peak (i.e., below 3 pixels when the vertical scale is set to $0.8\ \mu\text{V}/\text{pixel}$).

Each (NS, EW, Z) triplet (FULL SCALE, HIGH GAIN, LOW GAIN, ACCELEROMETERS) is represented by 3 vertical bars (numbered 1, 2, 3). The last group of 3 vertical bars represents the offset (i.e., detachment from the baseline) of each component, which can be removed by following the procedure below.

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⇒ **OFFSET REMOVAL.** The **AMPLIFIER TEST** function computes the average signal amplitude of each channel when sensors are locked (electronic noise plus residual suspension noise on the velocimetric channels, vertical acceleration g on accelerometric channels) and to remove it from the recording.

Place TROMINO® on a stiff surface (e.g. the floor) and avoid any noise around it. To remove the offset click SET (LE ▼), wait about 10 seconds, then click ESC (RI ●). You will be asked to save or ignore the computed offset.

This function can be used to correct for offset drifts in case of, e.g., strong temperature variations or as an initial calibration of the system.



Note that once the offset has been removed, g ($9.8\ \text{m/s}^2$) will be removed from the vertical accelerometric channel, which will therefore measure deviations from g .

Use the right (RI ●) key to exit the submenu and return to the ACQUISITION MENU.

⇒ SELECT PROGRAM

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TROMINO® can acquire data in 5 different ways, called PROGRAMs.

Scroll down or up with the (LE ▼) or (CL ▲) keys until the desired program number is selected. Then exit by clicking the OK button (RI ● key).

A summary of each program function appears in a window like Figure 22.

PROGRAM #	
CHANNELS	HIGH / LOW / ACC.
GPS DATA	YES/NO
START	AUTOMATIC/ MANUAL
MARKER	YES/NO

DW	UP	OK
----	----	----

Figure 22. Program selection window.

Although channels can be visualized in different orders, their traces are always stored in the internal memory according to the order shown in

Figure 23: channels 1 to n are associated to the triplets of orthogonal sensors, oriented respectively N-S (**TROMINO**® longitudinal axis), E-W (**TROMINO**® transversal axis) and up-down. Channel $n + 1$ is associated to the GPS time marker or to the auxiliary or wireless trigger channels.

1	NORTH	SOUTH
2	EAST	WEST
3	UP	DOWN
4	GPS+	GPS-

Figure 23. Channel order.

As an example, in a recording operated with both high (H) and low (L) gain channels, the order is as follows.

1	NORTH	SOUTH	H
2	EAST	WEST	H
3	UP	DOWN	H
4	north	south	L
5	east	west	L
6	up	down	L
7	GPS+	GPS-	
8	TRIGGER+	TRIGGER-	

Figure 24. Channel order in a recording with HIGH and LOW GAIN channels, trigger and GPS data.

Program description

PROGRAM 1	
CHANNELS	#
GPS DATA	NO
START	MANUAL
MARKER	NO

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PROGRAM 1

Acquires and saves the ground motion recorded from the channels N-S, E-W, Up-Down.

GPS data (positioning and absolute timing⁸) are **not** acquired. Synchronization with other devices will therefore not be possible through the GPS.

Time MARKER⁹ is **not** acquired.

Trace SAVING starts when user clicks the SAVE button.

⁸ The absolute start time of the recording could be used to synchronize the signals of different **TROMINO**®s in array/network studies.

⁹ The 'time marker' is a box function which signals the zero-cross of each second (p. 100). To have a time marker, GPS satellites must be on sight.

PROGRAM 2	
CHANNELS	#
GPS DATA	YES
START	AUTOMATIC
MARKER	NO

PROGRAM 2

Acquires and saves the ground motion recorded from the channels N-S, E-W, Up-Down.

GPS data (positioning) are acquired.

Synchronization with other devices will not be possible through the GPS.

Time MARKER⁹ is **not** acquired.

Trace SAVING starts automatically after the set delay time (see ACQ. DELAY (GPS), p. 62) after the GPS datum has been retrieved.

If no more than 2 satellites can be tracked within 5 minutes, the system starts recording ground motion without positioning data.

PROGRAM 3	
CHANNELS	#
GPS DATA	YES
START	MANUAL
MARKER	NO

PROGRAM 3

Acquires and saves the ground motion recorded from the channels N-S, E-W, Up-Down.

GPS data (positioning) are acquired.
Synchronization with other recordings will not be possible through the GPS.

Time MARKER⁹ is **not** acquired.

Trace SAVING starts manually. As soon as the GPS datum has been retrieved, the user is prompted to the following window:

SYSTEM IS READY TO START THE
ACQUISITION

EXIT
START

Click the (RI ●) key to START saving; click the (LE ▼) key to exit without starting the acquisition.

PROGRAM 4	
CHANNELS	#
GPS DATA	YES
START	AUTOMATIC
MARKER	YES

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PROGRAM 4

Acquires and saves the ground motion recorded from the channels N-S, E-W, Up-Down.

GPS data (positioning and absolute timing⁸) are acquired. Synchronization with other recordings will therefore be possible.

Time MARKER⁹ is acquired.

Trace SAVING starts automatically after the set delay time (see ACQ. DELAY (GPS), p. 62) once the GPS datum has been retrieved.

If enough satellites cannot be tracked within 5 minutes, the system starts recording ground motion without positioning data.

PROGRAM 5	
CHANNELS	#
GPS DATA	YES
START	ONLY MANUAL/AT 10 MIN/AT 15 MIN/AT 20 MIN/AT 30 MIN
MARKER	YES

PROGRAM 5

Acquires and saves the ground motion recorded from the channels N-S, E-W, Up-Down.

GPS data (positioning and absolute timing⁸) are acquired. Synchronization with other recordings is therefore possible.

Time MARKER⁹ is acquired.

Trace SAVING starts manually (ONLY MANUAL) or at the time specified by the user (AT 10/15/20/30 MIN).

In the manual option (ONLY MANUAL), as soon as the GPS datum has been retrieved, user is prompted to the following window:

SYSTEM IS READY TO START THE ACQUISITION	
EXIT	START

Click the (RI ●) key to START saving; click the (LE ▼) key to exit without starting the acquisition.

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With the other options (START AT 10/15/20/30 MIN), the signal will be saved when the absolute time is a multiple of the selected time (in minutes).

For example, when AT 10 MIN is selected, the acquisition starts at minutes 10, 20, 30, 40, 50 or 0 of the hour.

When AT 15 MIN is selected, the acquisition starts at minutes 15, 30, 45 or 0 of the hour.

When AT 20 MIN is selected, the acquisition starts at minutes 20, 40 or 0 of the hour.

When AT 30 MIN is selected, the acquisition starts at minutes 30 or 0 of the hour.

However, the acquisition can still be started at any time by pressing the (RI ●) key (START).

Which program should I use?

The choice of the program depends on my needs.

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PROGRAM 1

Can be used when:

- I do not need the GPS data,
- the GPS signal is not available (e.g., inside buildings),
- I do not need to synchronize the present recording with other recordings (e.g., for correlation),
- the recording length is short to intermediate (up to some hours). Long recordings (days long) should preferably be performed using PROGRAM 4 or PROGRAM 5, so that the internal clock drift is continuously corrected on the basis of the GPS time marker (otherwise the correction function calculated when satellites are on sight will be applied also when they are not on sight).

PROGRAM 2

Can be used when:

- I need the GPS data and the sky is on sight at least until the acquisition starts automatically (e.g., open field),
- I do not need to synchronize the present recording with other recordings (e.g., for correlation),
- the recording length is short to intermediate (up to some hours). Long recordings (days long) should preferably be performed using PROGRAM 4, so that the internal clock drift is continuously

corrected on the basis of the GPS time marker (otherwise the correction function calculated when satellites are on sight will be applied also when they are not on sight).

PROGRAM 3

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Can be used when:

- I need the GPS data but the sky will **not** be on sight when the acquisition starts or during the acquisition (e.g., recording will be performed inside a building),
- I do not need to synchronize the present recording with other recordings (e.g., for correlation),
- the recording length will be short to intermediate (up to some hours). Long recordings (days long) should preferably be performed using PROGRAM 5 so that the internal clock drift is continuously corrected on the basis of the GPS time marker (otherwise the correction function calculated when satellites are on sight will be applied also when they are not on sight).

In these cases: place **TROMINO®** outdoor until it retrieves the GPS signal, then move **TROMINO®** to the desired place. When positioned, start the acquisition by clicking the START button.

PROGRAM 4

Can be used when:

- I need the GPS data and the sky will be on sight at least until the acquisition starts automatically (e.g., open field),
- I need to synchronize the present recording with other

recordings (e.g., for correlation),

- the recording length will be intermediate to long (hours, days). The internal clock drift will be continuously corrected on the basis of the GPS time marker.

PROGRAM 5

Can be used when:

- I need the GPS data but the sky will **not** be on sight when the acquisition starts or during the acquisition (e.g., recording will be performed inside a building),
- I need to synchronize the present recording with other recordings (e.g., for correlation),
- the recording length will be intermediate to long (hours, days). The internal clock drift will be continuously corrected on the basis of the GPS time marker.

In these cases: place **TROMINO®** outdoor until it retrieves the GPS signal, then move **TROMINO®** to the desired place. When positioned, start the acquisition by clicking the START button.

If recording with no satellites on sight is very long, **TROMINO®** can be carried outdoor at the end of the recording for a few minutes in order to retrieve the time marker again, so that possible sampling rate drifts occurred during the recording can be detected and corrected.

⇒ MODE

SENSORS

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TROMINO® ENGY, **3G** and **BLU** are equipped with two triplets of orthogonal sensors: velocimeters and accelerometers. Different sensitivity levels can be set for the velocimeters.

*[Applies to **TROMINO® BLU**]*

FULL SCALE (**±44, ±89, ±178, ±447, ±894, ±1788 mV**, corresponding to **±0.5, ±1, ±2, ±5, ±10, ±10 mm/s**): velocimetric channels with different saturation levels (see Table 2 on p. 27). **Set FULL SCALE >> ±44 mV, ±0.5 mV to get the maximum system sensitivity** (suitable for ambient noise recordings).

*[Applies to **TROMINO® 3G**]*

FULL SCALE (**51, 102, 512 and 2048 mV**): velocimetric channels with different saturation levels (see Table 2 on p. 27). **Set FULL SCALE >> 51 mV to get the maximum system sensitivity** (suitable for ambient noise recordings).

*[Applies to **TROMINO®** ENGY and **TROMINO® 3G**]*

HIGH GAIN CHANNELS: corresponded to the highest possible sensitivity in the **TROMINO®** series before **3G** (before 2013, see Table 2 on p. 27). Use this setting preferably only for comparison with older instruments. In general, prefer the settings above that ensure higher sensitivity.

LOW GAIN CHANNELS: velocimetric channels with a gain conceived for strong vibrations like those induced on structures by heavy vehicle traffic or machineries (cf. norms UNI 9916 and DIN 4150). See Table 2 on p. 27 for the saturation level of these channels. It is recommended to use the LOW GAIN CHANNELS always in combination with the HIGH GAIN CHANNELS.

ACCELEROMETERS: these are accelerometric channels. Due to the higher intrinsic noise of accelerometers in respect to velocimeters, it is recommended to use them always in combination with the latter.

The signal can be acquired from any combination of the channels described above.

Select the sensors by using the keys (LE ▼) and (CL ▲). Select to enable or disable acquisition from each sensor triplet with the keys CHANGE (CR ◀) e (RI ●). Exit the procedure by moving back to the item INITIAL MENU and clicking OK (RI ●).

INITIAL MENU	
HIGH GAIN CH./FULL SCALE	±## mV, ±## mm/s YES/Gx8/NO
LOW GAIN CH./FULL SCALE	YES/NO
ACCELEROMETER	YES/NO
AUX CHANNEL	YES/NO
WIRELESS TRIGGER	YES/NO
GPS ANTENNA	INT/EXT
ALARM SETUP	

▼	▲	◀	●
---	---	---	---

Figure 25. The MODE window.

AUX CHANNEL

The auxiliary channel connector is described on p. 18 and Figure 9.

It is possible to acquire the signal from an external analog channel (e.g. to act as a trigger channel). It is not recommended to connect cables to **TROMINO®** during *passive seismic acquisitions* since the cable vibration could degrade the measurement quality.

To activate the auxiliary channel, select AUX CHANNEL by scrolling the menu with (LE ▼) and (CL ▲) keys. Select (YES/NO) through (CR ◀) and (RI ●). Then exit the procedure by selecting INITIAL MENU and pressing OK (RI ●).

WIRELESS TRIGGER

The wireless trigger is meant to acquire multichannel surveys (e.g., SASW, MASW, seismic refraction etc.).

Instruction on its usage is provided in a separate section (p. 115).

GPS ANTENNA

The GPS antenna connector is described on p. 18 and Figure 9.

Use this command to enable the external (EXT) or internal (INT) GPS antenna. The GPS antenna is not meant to work together with the radio antenna.

ALARM SETUP

Use this panel (Figure 26) to set the alarm threshold on each channel. Please note that the threshold setup can be effected more quickly by using the **TROMINO®** Manager software.

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- CH** is the channel number
- LEVEL** is the absolute threshold level [in digit] which activates the alarm (use the **TROMINO®** Manager to set the thresholds in mm/s)
- COUNT** is the number of samples that must pass the LEVEL threshold before the alarm is given.
- MODE** is the way in which the number of samples passing the LEVEL threshold is calculated.
- SUMMation** → each sample passing the threshold counts +1 in the sum, each sample not passing the threshold equals -1 in the sum. It follows that in order for the alarm to be activated there must be more samples above the threshold (considered as absolute values) than below it. When the COUNT value is reached, the alarm is activated.
- CONTinuous** → only contiguous samples above the threshold (considered as absolute values) are considered in the sum. When the COUNT number is reached, the alarm is activated.
- YES/NO** indicates whether the alarm on the corresponding channel is active.

Use (LE ▼) and (CL ▲) keys to modify the values, use (CR ◀) to scroll among columns and (RI ●) to exit.

CH	LEVEL	COUNT	MODE	
1	#	N	SUMM/CONT	YES/NO
2	#	N	SUMM/CONT	YES/NO
3	#	N	SUMM/CONT	YES/NO
4	#	N	SUMM/CONT	YES/NO
5	#	N	SUMM/CONT	YES/NO
6	#	N	SUMM/CONT	YES/NO
MODIFY VALUE		SEL.PARAM.		ESC

▼	▲	◀	●
---	---	---	---

Figure 26. The ALARM SETUP window.

⇒ SAMPLING

This command in the ACQUISITION menu is used to enter the SAMPLING rate selection menu.

The submenu offers the following functions:

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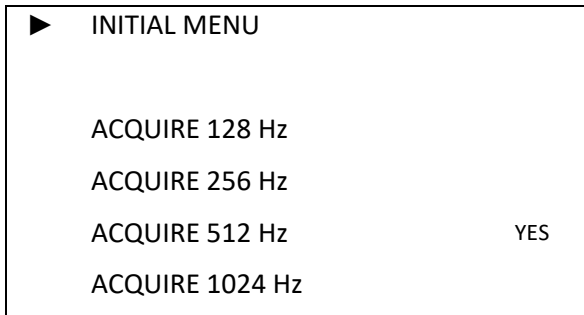


Figure 27. Sampling rate selection menu.

And keys:

- (LE ▼), (CL ▲) scroll down/up along the menu.
- (RI ●) toggles YES or NO.

⇒ ACQUIRE xxx Hz allows to select the desired sampling rate.

To exit, select INITIAL MENU.

When acquiring signals under PROGRAM 4 and PROGRAM 5 (with the GPS time marker, see p. 77), any drifts in the sampling rate is corrected from the internal controller.

WARNING! Only data sampled at 128 or 512 Hz can be equalized in amplitude in the [0.1 Hz, half the sampling rate] range, by using the *Grilla* software.

At present, only data sampled at 512 Hz can be filtered according to the UNI-9614 in *Grilla*.

If a different sampling rate was used, use the FILE > DESAMPLING function in *Grilla* before equalizing the acquired data.

⇒ SITE

This function allows to change the number of the partition in use but not the number of total partitions (for this option see page 97). Click on the (CR ◀) and (RI ●) buttons to change the partition. The current partition number and name are shown on the right of the SITE menu.

⇒ ACQUISITION LENGTH

This function let the user set the length of the recording. The system will automatically or manually start the acquisition as soon as the requested data (e.g. GPS) are retrieved and the set delay time (p. 62) has passed. The system will automatically switch off after the time selected by the user.

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By entering the ACQUISITION LENGTH menu, the following window is displayed:

ACQUISITION LENGTH			
hh : mm : ss			
DW	UP	TIMER/ FREE/MEMORY	OK

Figure 28. Acquisition length menu.

- Use the (CR ◀) key to select:
 - TIMER → to acquire for a specified time (e.g., 00 h:20 min:00 s)
 - FREE → to acquire continuously. The partition will be overwritten until the user stops the acquisition manually. Use this option when data are saved on the PC through **TROMINO®** Manager or MIM  and no data loss will be caused by the overwriting process

- MEMORY → the acquisition ends when the partition memory is filled up
- When the TIMER mode is selected, then use the (CL ▲) and (LE ▼) keys to increase or decrease the acquisition length.
- Go back to the INITIAL MENU clicking the (RI ●) key.

To stop the acquisition at any time, keep the 2 central keys (CL ▲) and (CR ◀) pressed together for a few seconds.

⇒ ACQUIRE (VIEW PROPERTIES)

By entering this menu (boot → ACQUISITION → ACQUIRE), sensors are automatically freed from their shunt position and traces are shown on the display. *By default, traces are shown on the display when saving is not active ('free' mode) and 'frozen' on the display when saving is in progress, in order to save batteries and reduce electronic noise.*

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- To stop data visualization, to exit acquisition and/or data saving, keep the two central keys (CL ▲) and (CR ◀) pressed at the same time for a few seconds.

- When the acquisition is started through the command ACQUIRE, traces appear on the display but are not stored in the memory card. To store them, recall the SAVE function (see below).



Warning. If the acquisition does not start or gives error messages, check that the **RADIO COMMUNICATION** is disabled on **TROMINO®** ENGY, **3G** and **BLU**. Go to the initial menu >> **RADIO SETUP** >> **RADIO ACTIVE** >> **NO**. See also p. 107.

To change the visualization parameters, recall the submenu shown in Figure 29 by clicking the left (LE ▼) or (CL ▲) key. The following window will appear:

SAVE	
DISPLAY	FROZEN / FREE
	TRACES / GPS DATA
SCREEN LAYOUT	LABELS / NONE / CARD / NUMBERS
TIME BASE	# SEC
TRACE NUMBER	# LINES
GAIN / PIXEL	## μ V / pixel
CHANNELS	## ##

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Figure 29. View property window.

The choice among the options of each item can be carried out through the keys (CR ◀) (-, decreases the value) and (RI ●) (+, increases the value).

Note that this submenu remains displayed for about 5 s. After this time, traces appear again. Nonetheless, the (CR ◀) and (RI ●) keys allow to modify the parameters of the last selected voice even when the submenu is no more visible.

We describe now the single voices of the submenu of Figure 29.

- ⇒ **SAVE:** saves the trace on the **TROMINO®** internal memory card. When selected, the indication **SAVING IN PROGRESS** flashes on the display.
- ⇒ **DISPLAY:** allows to switch between the **FREE** and **FROZEN** options. **FREE** displays the traces on the screen. **FROZEN** does not allow the trace representation on the screen. This saves batteries during the acquisition and reduces electronic noise. Press the (RI ●) key to perform the choice and *wait a few seconds* for the option to be enabled.
- ⇒ **SCREEN LAYOUT:** allows to select additional information to be displayed. The options are **NONE** (traces only), **CARD** (shows the clock and the battery status), **NUMBER** (shows the channel number on the left of the trace), **LABELS** (shows the channel name on the left of the trace).
- ⇒ **TIME BASE:** sets the time base to a value ranging 1 to 4 s (the present time base is displayed on the right).
- ⇒ **TRACE NUMBER:** allows displaying from 1 to 8 traces (the present number is visualized on the right).
- ⇒ **GAIN/PIXEL:** sets the graphical amplification of the visualized traces. Gain, which is a multiplication factor in the range 1/16 to 16, ranges from 25 $\mu\text{V}/\text{pixel}$ to 100 mV/pixel .
- ⇒ **CHANNELS:** allows to set the order of the channels to be displayed on the screen (the total number of displayed channels is given by **TRACE NUMBER**).

➤ SWITCH OFF

Switches **TROMINO®** off. During the acquisition, visualization and data transfer to the PC, the automatic switch-off is disabled. Once these operations are concluded, the automatic switch off occurs after a time ranging from 1 to 30 min, as set in the SET UP menu (p. 62).

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In case of no-response, to force the **TROMINO®** switch off, keep the ON button continuously pressed down for at least 20 seconds.

➤ DATE AND TIME

Selecting this option, date and time are displayed to be modified manually. On the display bottom, the following commands appear:

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- ⇒ ESC (RI ●) to go back to the initial menu.
- ⇒ SEL (CR ◀) to move the cursor on the parameter to be modified.

SEL enables other three commands:

- ⇒ – (LE ▼). Press repeatedly or keep pressed to decrease the selected number.
- ⇒ + (CL ▲). Press repeatedly or keep pressed to increase the selected number.
- ⇒ OK (RI ●). Confirm the changes and exit.

In **TROMINO®** ENG, **3G** and **BLU** the internal clock can be set to the UTC (Coordinated Universal Time) by entering the RADIO SET, GPS SHOW menu (p. 65) and the CLOCK TIME UTC +/- h:min function.

The variable +/- h:min can be set to the time difference between the local time and the UTC time (e.g. + 1h or 2h, depending on the daylight saving time, for Italy). Time steps of 15 min are allowed.

Leave the variable +/- h:min set to zero (00:00) if you wish to work with the UTC time.

To enable the settings based on the UTC time, **TROMINO®** has to retrieve the GPS signal at least once. Click RADIO SET, GPS SHOW >> GPS SHOW as explained on p. 65.

➤ SITE NAME

This submenu allows to set a name for the trace to be recorded. Users can input up to 4 labels into 4 lines. For convenience, each line is named by default as:

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SITE NAME
COUNTRY NAME
Position
Code

Functions available in this menu are:

- ⇒ ESC (RI ●) to go back to the previous menu.
- ⇒ SEL (CR ◀) to start entering text.

Selecting the last command, keys change function:

- ⇒ ← (LE ▼). Shifts the cursor ■ left along the alphanumerical character line.
- ⇒ → (CL ▲). Shifts the cursor ■ right along the alphanumerical character line.
- ⇒ ROW (CR ◀). Shifts among the rows SITE NAME/COUNTRY NAME/Position/Code.
- ⇒ WR (RI ●). Inserts the character selected with the cursor ▲ at the cursor ■ position. Characters < and > are not printable: they are functions to shift the cursor ■ horizontally.

Characters are inserted in two steps:

1. Recall and position the cursor (■) in one of the four available rows:

Move vertically using the command key ROW.

Move horizontally selecting the symbol "<" (left) or ">" (right) in the alphanumerical character line and pressing repeatedly the key command WR.

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2. Move the cursor ▲ on the chosen character and write it clicking WR. The cursor ■ will automatically step forward.

To exit the submenu press ROW until the cursor ■ disappears (on the 5th row). On the display bottom the following commands will reappear:

- ⇒ ESC (RI ●) instead of OK to go back to the previous menu.
- ⇒ SEL (CR ◀) instead of ROW to start the text input.

WARNING: the site name for the active partition must be set before starting saving the record. Once the trace saving has started, it is not possible to modify the site name by using **TROMINO®** but only from the *Grilla* software.

Files can be renamed at any time through *Grilla*.

Entering file names by means of the **TROMINO®** keyboard can be time consuming but is not mandatory. By leaving the SITE NAME field empty, the default names (GRILLA01, GRILLA02 etc.) will be assigned to any partitions.

➤ PARTITION IN USE

This function allows to divide the memory card into up to 99 partitions (files) and to select the active one.

⇒ SEL (CR ◀) accesses the submenu selection window.

⇒ ESC (RI ●) exits without modifications.

After entering the submenu with SEL the following key commands appear:

⇒ + (CL ▲) and – (LE ▼) increase or decrease the number of total partitions or the number of the active partition.

⇒ SEL (CR ◀) shifts between the line which allows to set the number of total partitions and the line which allows to set the partition in use.

⇒ OK (RI ●) saves the last settings and exit.

Changing the total number of partitions can cause the loss of stored data. Data recovery is only possible by resetting the previous partition number before performing any other acquisition.

➤ VIEW CARD DATA

This menu allows to view on the display the main information about the active partition (PARTITION IN USE, p. 97) and the recordings saved under the same partition.

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Go back to the initial menu with the ESC key (LE ▼) or enter the submenu with VIEW (RI ●). Press again the (RI ●) key to start displaying the traces on the screen.

During the review, (LE ▼) and (CL ▲) keys activates the following submenu:

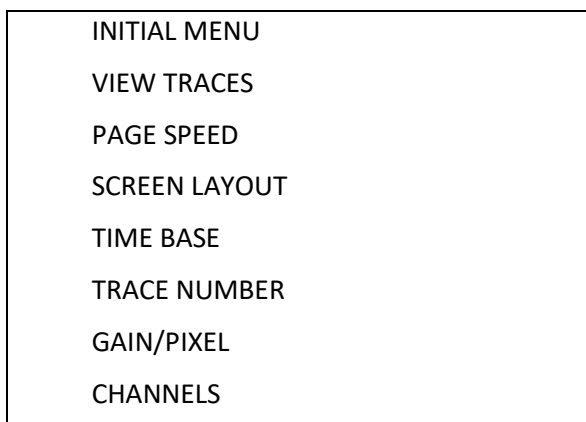


Figure 30. View card data menu.

- ⇒ INITIAL MENU goes back to the initial menu.
- ⇒ VIEW TRACES displays the traces selected with TRACE NUMBER. Traces can be scrolled left or right using (CR ◀) and (RI ●) keys respectively.

- ⇒ PAGE SPEED (CR ◀) and (RI ●) keys allow to select the automatic page scrolling (speed from 0.5 pages/s to 6 pages/s), the MANUAL page scrolling or the JUMP function, which scrolls along the trace with jumps of length equal to 4 times the selected time base.
- ⇒ SCREEN LAYOUT allows to select the optional information to be displayed. Options are NONE (trace only), CARD (displays the battery status and the clock time), NUMBER (shows the channel ordinal number on the left of the trace), LABELS (shows the channel name on the left of the trace).
- ⇒ TIME BASE sets the time base of the display. Use the (CR ◀) and (RI ●) keys to set the time base in the range 1 to 4 seconds (the currently selected time is shown on the left of the trace).
- ⇒ TRACE NUMBER sets the number of traces to be displayed. Use the (CR ◀) and (RI ●) keys to visualize 1 to 8 channels.
- ⇒ GAIN/PIXEL modifies the amplitude scale (only visual) of the trace representation from 25 μV to 100 mV per pixel. Gain is a multiplication factor ranging from 1/16 to 16.
- ⇒ CHANNELS modifies the order of the displayed traces. The channel sequence is shown on the right of the menu line and can be displayed also on the left of the trace during review by using the SCREEN LAYOUT command.

For all the items with the only exclusion of the INITIAL MENU function, use (CR ◀) and (RI ●) to modify the values.

NOTE: the above functions are intended to provide a basic visual inspection of the acquired traces. Use *Grilla* for more advanced visualization tools and data analysis.

➤ **BLUETOOTH, LIGHT**

Use the ON (LE ▼) key to disable/enable the Bluetooth® permanently (ALWAYS ON) or temporarily (approx. 2 minutes, BRIEFLY ON).

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Use the (CR ◀) key to enable/disable the back-illumination of the display.

➤ **RADIO SET, GPS SHOW**

The **TROMINO**® ENGY, **3G** and **BLU** radio setup and communication protocol is described on p. 107.

⇒ RADIO ACTIVE (see p. 107)

⇒ MODULE NUMBER (see p. 107)

The following GPS-related commands also apply to **TROMINO**® ENGY, **3G** and **BLU** only:

⇒ CLOCK TIME UTC +hh:mm. Use this function to set the **TROMINO**® internal clock to the UTC (Coordinated Universal Time). By using the (CR ◀) and (RI ●) keys to decrease or increase, set the time difference between the local time and the UTC time. Time steps of 15 min are allowed.

Leave the variable +/- h:min set to zero (00:00) if you wish to use the UTC time.

To enable the settings based on the UTC time, **TROMINO**® has to retrieve the GPS signal at least once. To do this, select GPS SHOW (see below).

- ⇒ GPS SHOW. This function allows to use **TROMINO®** as a simple GPS locator. No ground motion from any sensors will be recorded.

By pressing the key OK (RI ●), the screen will visualize the GPS data window according to the format given on page 103. To exit, press the OK (RI ●) key. To return to acquisition menu, select INITIAL MENU and press OK (RI ●).

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- ⇒ GPS ANTENNA. By clicking the (CR ◀) and (RI ●) keys, this function allows to select whether to work with the **TROMINO®** built-in antenna (INT) or with the external (EXT) antenna connected to the GPS plug-in (Figure 9, p. 19).

GPS

➤ **GPS data**

GPS data are presented on a screen as in Figure 31.

```

hhmmss dd,MM,yyyy
|
ZDA string
hhmmss.ss
|
1
IIII.II, N/S
|   |
2   3
yyyyy.yy, E/W
|   |
4   5
x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh
| | | | | | | | |
6 7 8 9 10 11 12 13 14 15

```

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Figure 31. GPS data windows

The meaning of each field is as follows:

ZDA string → time (hh:mm:ss) and date (dd, MM, yyyy) of the rising edge of the first time-marker (Figure 32). This string is used to synchronize the internal **TROMINO®** clock with the UTC and to synchronize recordings of several

TROMINO® units acquired under PROGRAM 4 and PROGRAM 5.

- 1 → Time (UTC)
- 2 → Latitude (in DD° MM.MMMM', degrees and minutes with decimals, according to the WGS-84 format)
- 3 → N or S (North or South)
- 4 → Longitude (in DD° MM.MMMM', degrees and minutes with decimals, according to the WGS-84 format)
- 5 → E or W (East or West)
- 6 → GPS quality indicator
 - 0 – fix not available,
 - 1 – GPS fix (2-D fix with 3 satellites in view, 3-D fix with more than 3 satellites in view),
 - 2 – differential GPS fix.
- 7 → Number of satellites in view (00 – 12)
- 8 → Horizontal dilution of precision
- 9 → Antenna altitude above/below mean-sea-level (geoid)
- 10 → Units of antenna altitude (meters)
- 11 → Geoidal separation, the difference between the WGS-84 earth ellipsoid and mean-sea-level (geoid), “-” means mean-sea-level below ellipsoid
- 12 → Units of geoidal separation (meters)
- 13 → Age of differential GPS data (time in seconds since last SC104 type 1 or 9 update, null field when DGPS is not used)
- 14 → Differential reference station ID, 0000-1023
- 15 → Checksum

➤ **GPS time marker**

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Under the acquisition PROGRAM 4 and PROGRAM 5 (p. 71), one channel is dedicated to the GPS time marker which signals the passage through the 0 (zero) of each second (Figure 32).

Time marker is a box function which repeats each second. Each box has a duration of $1/10$ s. The different amplitude of the boxes indicates seconds, minutes and hours.

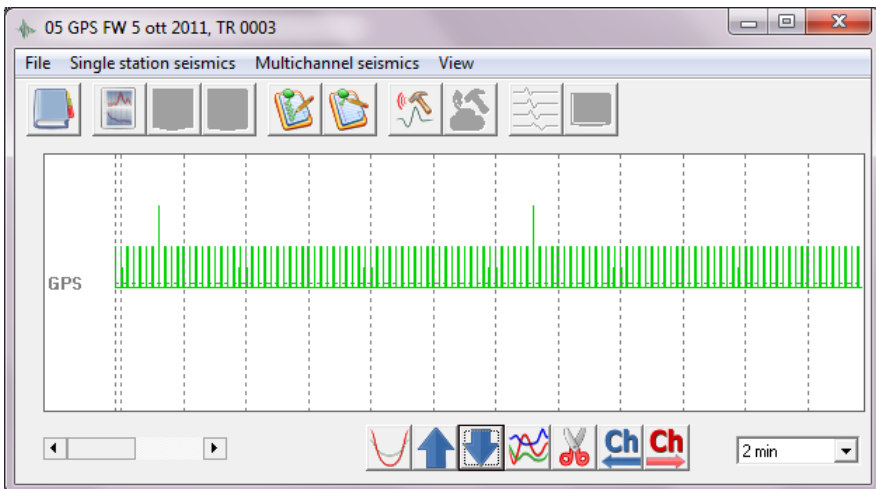


Figure 32. The time marker is a box function signaling the passage through the 0 of each second. The different amplitudes of the boxes indicate seconds/minutes and hours. The time marker is shown on the GPS channel (see the label on the left).

The ZDA time label (p. 103) that can be read from the *Grilla* software indicates the exact (UTC) time of the first recording sample, which corresponds to the passage through zero of the second and is used to synchronize recordings of different **TROMINO®** units.

➤ **GPS time marker-based sampling rate correction**

When the GPS marker is available (PROGRAM 4 and PROGRAM 5), **TROMINO®** automatically corrects possible drifts of the internal clock and sampling rate.

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➤ **GPS string (save continuously)**

Under acquisition PROGRAM 4 and 5 it is possible to save the full GPS string once per second by enabling the STORE GPS DATA function (p. 63). The GPS string list can be exported in a separate file by converting the **TROMINO®** .trc files into ASCII files through the *Grilla* software (IMPORT/EXPORT TOOLS > EXPORT AS > ASCII).

The GPS string format is explained in Figure 31.

RADIO COMMUNICATION

➤ RADIO SETUP

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Using the **TROMINO®** built-in radio¹⁰ is the most efficient way to synchronize recordings of several **TROMINO®** units placed within the distance covered by the radio signal.

One **TROMINO®** acts as a master and the others as slaves. Any settings of the master will be transmitted to the slaves. The preferred communication protocol is “in-line” (Figure 36), which means that the master **TROMINO®** (n. 1) communicates directly with the **TROMINO®** slave unit n. 2. The slave unit n. 2 communicates with the slave n. 3, ..., the slave N-1 communicates with the slave N. This should be reminded when placing a network of **TROMINOs®** on the ground, so that the master should be close to the slave 2, the slave 2 close to the slave 3 etc.

To set a network of **TROMINO®s**:

1. connect the radio antenna to each **TROMINO®** (use the connector marked with R-RADIO as shown on p. 18 and Figure 9). Note that the radio and the GPS antennas are not meant to work simultaneously.
2. select the *master* **TROMINO®¹¹**. Enter the RADIO SET, GPS SHOW menu of Figure 20. The panel of Figure 33 will open.

Use the (LE ▼) and (CL ▲) keys to move along the lines and the (CR ◀) and (RI ●) to change values.

On the *master* **TROMINO®** set RADIO ACTIVE (YES), MODULE NUMBER (1) and the number of DEVICES ON CHAIN (*my number*), that is the total number of **TROMINO®s** in the network (Figure 33).

¹⁰ Does not apply to the **TROMINO® ZERO** models.

¹¹ When different models of **TROMINO®** are going to be employed in the same network, use the most recent one as master.

The *master* **TROMINO®** must be module number 1 and the total number of devices on chain (*my number*) must be correct, otherwise the radio commands will give failure messages.

3. On each *slave* **TROMINO®** set RADIO ACTIVE (YES) and the MODULE NUMBER which must be a unique identifier ranging from 2 to (*my number*), where (*my number*) is the total number of devices in the network (DEVICES ON CHAIN, Figure 34).

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Note that for the radio communication to work it is necessary that:

RADIO ACTIVE is set to YES on all **TROMINO®**s.

MODULE NUMBER is correctly set (each **TROMINO®** must be identified by a unique, consecutive, number).

DEVICES ON CHAIN is the exact number of **TROMINO®**s which will be synchronized through the radio (this information has to be specified in the *master* **TROMINO®** only).

Also note that the *master* **TROMINO®** will communicate its acquisition settings (sampling frequency, acquisition length, number and type of active channels etc.) to all the *slave* **TROMINO®**s, therefore the user needs to modify the settings on the *master* **TROMINO®** only.

The master can communicate with the slaves only when the latter are switched on and display the INITIAL MENU window (Figure 20).

Once the radio-synchronized recordings have started, the *master* **TROMINO®** display will show a box (Figure 35) containing as many vertical bars as the number of **TROMINO®**s in the network. The horizontal shift among the bars indicates the delay time of each **TROMINO®** compared to the master. As long as all the bars are inside

the box, delays are lower than 1 sample (i.e., lower than [1 / sampling frequency] seconds) and the synchronization is reliable.

INITIAL MENU

RADIO ACTIVE

YES

MODULE NUMBER

1

DEVICES ON CHAIN

my number

TEST RADIO CHAIN

CLOCK TIME

UTC 00:00

GPS SHOW

GPS ANTENNA

EXT/INT

▼

▲

◀

●

Figure 33. The RADIO SETUP window for the *master* TROMINO®.

INITIAL MENU

RADIO ACTIVE

YES

MODULE NUMBER

2, 3, ..., my number

CLOCK TIME

UTC 00:00

GPS SHOW

GPS ANTENNA

EXT/INT

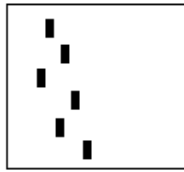
▼

▲

◀

●

Figure 34. The RADIO SETUP window for the *slave* TROMINO®s.



DEVICES SYNCHRONIZED.

ACQUISITION IN
PROGRESS.

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Figure 35. The synchronization panel on the *master* **TROMINO®**. Each bar represents a slave **TROMINO®** and the horizontal shift is proportional to the communication delay compared to the master unit. As long as the bars are inside the box, the synchronization delay among different modules is less than 1 sample and the synchronization is reliable.

The instrumental network will work properly under the condition that device 1 (the master) is close (i.e. within the radio coverage) to device 2; device 2 is close to device 3, device 3 is close to device 4, etc. The geometry of the network should therefore be planned as, e.g., Figure 36.

Click **TEST RADIO CHAIN** , from the master **TROMINO®** to test the network functioning.

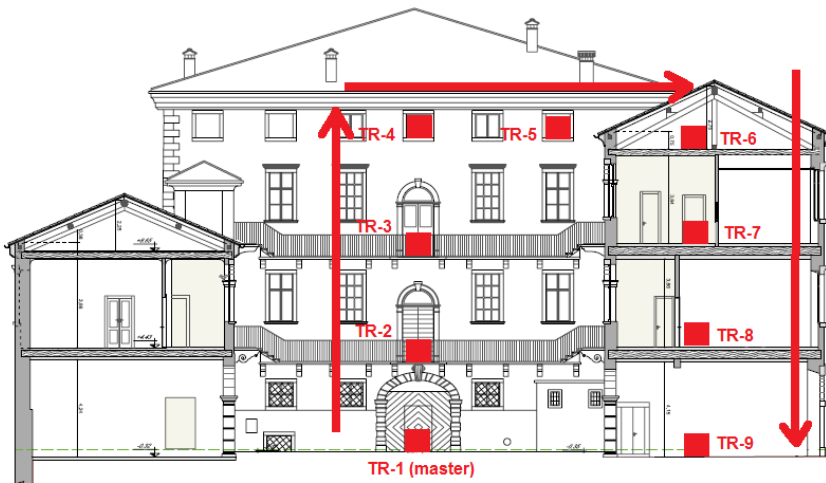


Figure 36. Example of a radio network of **TROMINO®**s. In order for the radio synchronization to work properly, the master (**TROMINO®** number 1) should be close to the slave 2 (**TROMINO®** number 2). The slave 2 should be close to the slave 3; the slave 3 close to slave 4 etc.

➤ RADIO AMPLIFIER (connection scheme)

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The radio amplifier is used to extend the radio communication coverage of a **TROMINO®** network, in case of interference signals that disturb the radio synchronization communication, or of obstructed or heavily shielded environments.

The amplifier works in the UHF band ($433.92 \text{ MHz} \pm 100 \text{ kHz}$). Transmission bursts are generated once per minute.

The device is powered by an alkaline 9V battery (6LR61) that provides an autonomy of 50 hours of continuous operation.

For amplifiers released before 2017, follow the footnote¹².

¹² For amplification modules *released before 2017* (gray front panel):

- connect 2 (two) antennas to the ANT-IN and ANT-OUT plug ins located on the top side of the amplifier. One antenna acts as a transmitter, the other as a receiver,
- connect the SMA RF cable to the **TROMINO®** plug in labeled with RADIO (Figure 9),
- switch the device on by switching to BATTERY or EXTERNAL POWER SUPPLY. This will boost the link.



- Connect the SMA RF cable to the INPUT plug-in of the amplifier (Figure 37) and to the **TROMINO®** plug-in labeled with RADIO (Figure 9),
- Switch the device on by clicking ON-OFF.

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Two LEDs show the device status:

- a green LED flashes when the device is ON,
- a red LED turns on when the battery is depleted (needs to be replaced).

If external power supply is available (e.g., wall adapter, DC 9V-300mA), this can be applied to the lateral plug (positive on central pin).

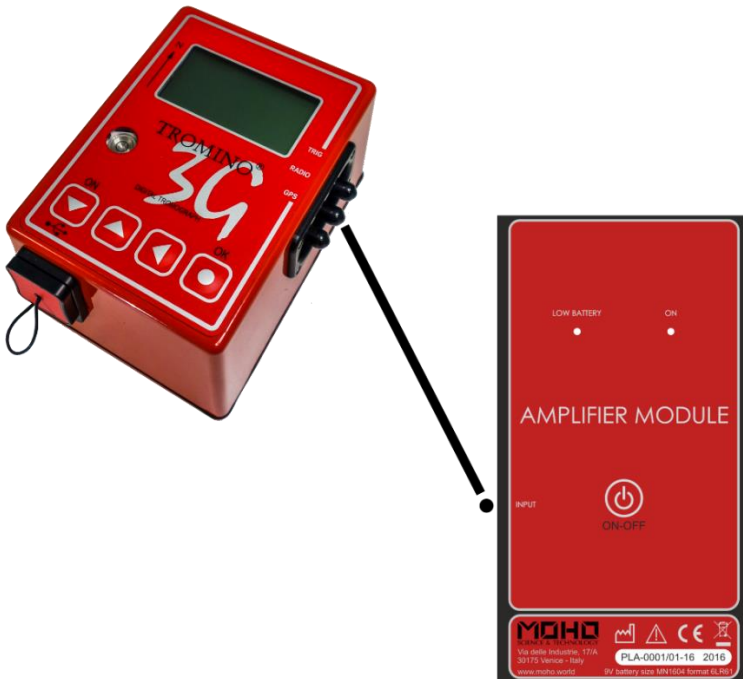


Figure 37. **TROMINO®** radio amplifier connection scheme. Note that 2 antennas are required (one acts as transmitter, the other acts as receiver).

WIRELESS TRIGGER

➤ OVERVIEW

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The Wireless Trigger (WT) is a radio device that transmits an impulse to **TROMINO®** when a threshold level is passed in the built-in tri-axial accelerometer, in an external geophone or other device connected to the WT.

Two parameters need to be defined:

1. the threshold measurement device (internal accelerometer, external geophone/other),
2. the trigger level (low, medium, high).

The WT is used to mark the origin time in the multichannel seismic techniques based on both body and surface waves (e.g. seismic refraction, MASW with Rayleigh and Love waves). By keeping the receiver (**TROMINO®**) at a fixed position and by moving the source and the WT at different offsets from **TROMINO®**, the *Grilla* software will automatically merge the recordings in a 3-D multichannel recording.

➤ SETTINGS

Some settings are required on both the WT and **TROMINO®**.

SETTINGS ON THE WIRELESS TRIGGER

Turn the device on (Figure 38), by clicking the ON-OFF button ,

- 1) Set the threshold level by using the ▲ ▼ keys.
 - a. LOW (a single LED is turned on): maximum sensitivity, a low energy source suffices to trigger the system,

- b. MEDIUM (two LEDs are turned on)
 - c. HIGH (three LEDs are turned on): lowest sensitivity. It requires a high energy source to trigger the system. This setting is recommended to avoid accidental triggering.
- 2) Couple the WT to the ground - by using the provided spike - at the desired offset from **TROMINO®** (see also the next paragraph about **TROMINO®** settings).
 - 3) Press ARM. The blue LED on the top-left starts blinking for about 5 seconds and the display shows the shot number.
 - 4) When the blue LED stops blinking, the WT is ready. Energize the ground (with a heavy jump, a sledgehammer or other conventional sources).
 - 5) When the threshold is passed, the WT beeps and is ready to be armed again for a new shot. At the same time a black rectangle appears on the **TROMINO®** display, which indicates the correct reception of the trigger time (see the next paragraph about **TROMINO®** settings).

When the radio signal has properly been received, the LEDs on the WT will flash.

- 6) Move the WT to the next shot position and repeat the process from item 5) above.



Figure 38. The **TROMINO®** Wireless Trigger (left) and its front panel (right).

Emergency options. Should a shot need to be repeated and overwritten, move the counter back to the desired shot number (see Figure 43 to be sure that you understand how the triggers are numbered):

- 1) click ARM. The blue LED blinks while the screen indicates the present trigger number.
- 2) Click SELECT (▲▼) to increase or decrease the trigger number on the display.
- 3) Click ARM to set the displayed number as the shot number to be acquired again.
- 4) Click ARM again to repeat the shot and overwrite the previous information. Note: the trigger counter is now set back to an older position. Unless you move the counter forward with the (▶) key, you could overwrite some data.

SETTINGS ON TROMINO®

To work with the Wireless Trigger (WT), **TROMINO®** has to be set as it follows:

- 1) Connect the radio antenna to the side panel of **TROMINO®** marked with R (Figure 9). Note that the radio and the GPS antennas are not meant to be used at the same time,
- 2) Enter the RADIO SET, GPS SHOW menu,
- 3) Use the (LE ▼) and (CL ▲) keys to move among the display items and the (CR ◀) and (RI ●) keys to modify the values.

Set RADIO ACTIVE (NO) as shown in the panel below.

INITIAL MENU	
RADIO ACTIVE	NO
MODULE NUMBER	1
DEVICES ON CHAIN	my number
CLOCK TIME	UTC 00:00
GPS SHOW	
GPS ANTENNA	EXT/INT

▼	▲	◀	●
---	---	---	---

Figure 39. The RADIO SET, GPS SHOW panel of **TROMINO®**.

- 4) Go back to INITIAL MENU,
- 5) Enter the ACQUISITION >> MODE menu. Use the (LE ▼) and (CL ▲) keys to move among the display items and the (CR ◀) and (RI ●) keys to modify the values.

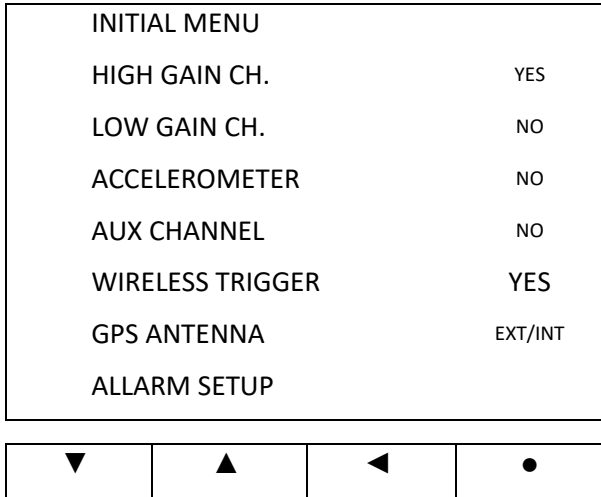


Figure 40. The ACQUISITION >> MODE panel of **TROMINO®**.

- 6) Set WIRELESS TRIGGER >> YES.
- 7) Go back to the ACQUISITION menu.
- 8) Set SELECT PROGRAM >> PROGRAM 1.
- 9) Go back to the ACQUISITION menu.
- 10) Click ACQUIRE. The traces are now visible on the **TROMINO®** display.
- 11) Click any keys. The display illustrated in Figure 41 appears.
- 12) Move the cursor to SAVE and click (●). Data will be saved on **TROMINO®** after 10-15 seconds, in order to let the operator move away from the instrument.

Recommended settings. For active seismic acquisitions (e.g. MASW), set also:

- SAMPLING RATE 512 Hz

If no transmission errors occur, the **TROMINO®** display shows a number of consecutive rectangles ranging from 1 to the number of performed shots (Figure 43).

Empty rectangles indicate attempts of the WT to transmit threshold times that were not received from **TROMINO®**. In the example of Figure 44, **TROMINO®** received 12 triggers (black rectangles) from the WT. However, the first 3 transmission attempts from WT to **TROMINO®** were not successful and a fourth energization in position 1 was required (shot position 1, received as trigger no. 4). The shot performed in position 2 was also repeated 2 times, since the first attempt to transmit the data from the WT to **TROMINO®** was unsuccessful. Shots in positions 3 to 5 were immediately successfully transmitted. The shot in position 6 was repeated 2 times before the data transmission to **TROMINO®** was successful and so on.

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In practice the user has just to be sure that a black rectangle is present on **TROMINO®** for any desired source position, no matter whether empty rectangles (i.e. unsuccessful attempts to transmit data from the WT to **TROMINO®**) are also present.

Should the user want to repeat a shot, move the WT back to the corresponding trigger number (referring to Figure 43, the trigger number is 1 for the shot position 1, it is 2 for the shot position 2 and so forth. However, referring to the different case of Figure 44, the trigger number is 4 for the shot position 1, it is 11 for the shot position 6, it is 17 for the shot position 10 and so on).

Note: data are saved in the internal memory of **TROMINO® every 12 seconds. Wait 12 seconds before stopping the acquisition after the last shot.**

Note: during the recordings with the WT, in order to get good quality recordings, it is important to avoid disturbances close to the receiver (i.e. **TROMINO®). People close to **TROMINO®** should be asked not to move, while the operator moves away from it with the WT.**

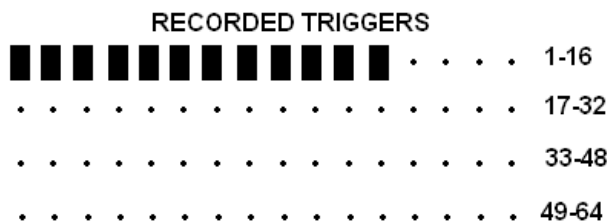


Figure 43. **TROMINO®** panel showing a standard receipt of 12 triggers (black boxes) from the WT.

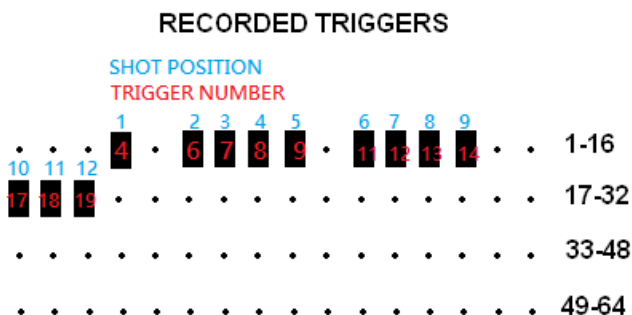


Figure 44. **TROMINO®** panel showing the receipt of 12 triggers from the WT. The first 3 transmission attempts from WT to **TROMINO®** were not successful and a fourth energization in position 1 was required (shot position 1, received as trigger no. 4). The shot performed in position 2 was also repeated 2 times, since the first attempt to transmit the data from the WT to **TROMINO®** was unsuccessful. Shots in positions 3 to 5 were immediately successfully transmitted. Shot in position 6 was repeated 2 times before the data transmission to **TROMINO®** was successful and so on. In practice the user has just to be sure that a black rectangle is present on **TROMINO®** for any desired source position, no matter whether empty rectangles (i.e. unsuccessful attempts to transmit data from the WT to **TROMINO®**) are also present.

STOP THE RECORDING

➤ STOP THE RECORDING

TROMINO® automatically stops recording:

1. after the user's defined time (page 88) has expired, thus giving the message "END FOR EXPIRED TIME",
2. when batteries are over, thus giving the message "END FOR FLAT BATTERIES". Batteries last approximately 80 hours in basic acquisition mode (GPS inactive),
3. when the memory card is full, thus giving the message "END FOR NO MEMORY".

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Other possible ending messages are:

4. "END FOR WRITING ERROR",
5. "END FOR SPEED ERROR",
6. "ANALOG CARD ERROR".

To stop any acquisition before its predefined length is reached (or when it is set to FREE LENGTH), keep the (CL ▲) and (CR ◀) keys pressed together for a few seconds. The combination of two keys guarantees against an involuntary stop.

The data recorded until the manual or automatic stop are stored in the memory card.

TROMINO® is now ready to transfer data to the PC or to start another acquisition.

In case of no-response, to force the **TROMINO®** switch off, keep the ON button continuously pressed down for at least 20 seconds.

Avoid moving **TROMINO®** during the acquisition since this could damage the sensors. Stop the acquisition first, then move **TROMINO®**.

DATA TRANSFER TO PC

➤ DATA TRANSFER TO PC

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Connect **TROMINO®** to the PC through the USB cable provided: remove the USB port cover on **TROMINO®**. Insert one cable end in the **TROMINO®** port and the other end in one of the PC ports.

TROMINO® will switch automatically on as soon as it is identified from the PC.

Appropriate drivers need to be installed in the PC for it to communicate with **TROMINO®**. These can be downloaded from www.moho.world/download

To install the drivers, double click the installation file (.exe). Properly installed drivers will make **TROMINO®** appear as *MoHo USB INTERFACE (COM#)* in the Device Manager window of the Control Panel (Figure 45), once it is connected to the computer and turned on.

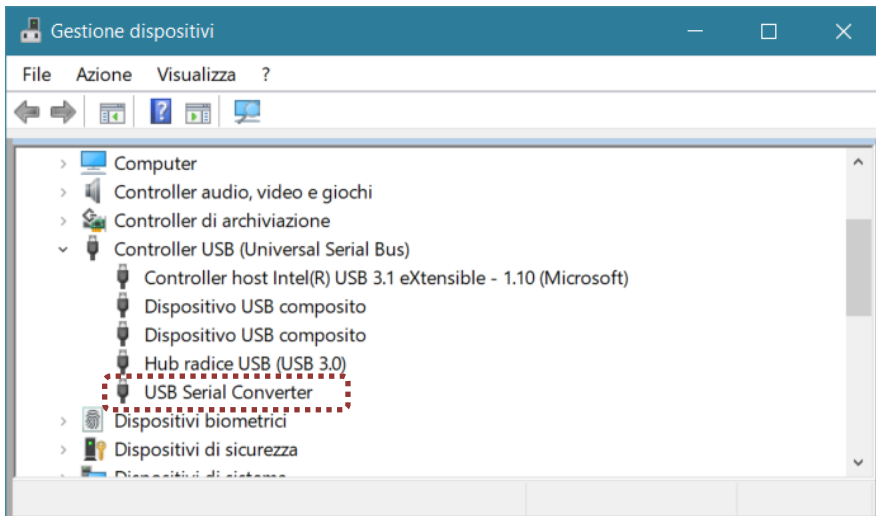


Figure 45. The device manager panel showing the MoHo USB interface drivers properly installed.

THE TROMINO® APP

The **TROMINO**® App for Android OS can be downloaded from the Google Play Store. Once installed, it appears on your mobile device (phone, pad, etc.) as in Figure 46.

Click the information icon  on the app for assistance about the main functions.

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The application communicates with **TROMINO**® by means of the Bluetooth®. It allows to visualize the **TROMINO**® display and recordings on the mobile device, to set all the acquisition parameters, to save the data, etc. Note that, in order to work, the app requires the positioning permissions.

By clicking the microphone icon, vocal commands can also be given to **TROMINO**® (start, stop, etc.).



Figure 46. The **TROMINO**® app for Android OS can be downloaded from the Google Play Store.

TECHNICAL NOTES

➤ BATTERY REPLACEMENT AND “STAND-BY” MODE

Applies only to **TROMINO®** models
released before 2017

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These **TROMINO®** models are powered by two 1.5 V alkaline AA battery. Two new alkaline batteries can last beyond 80 hours in continuous recording at 128 Hz sampling rate without GPS¹³.

In stand-by mode, batteries can last several months. The recorder is equipped with a temporary power supply pad that permits to replace batteries without losing the clock set up. When batteries are running out, the recorder warns the user by repetitively emitting sequences of 3 beeps.

Do not use batteries to the limit of their charge. Use only **1.5V alkaline AA batteries**. For the use and disposal of the batteries, follow the manufacturer instructions.

Respect polarity. Before inserting batteries, check for the correct polarity as printed on the label around the battery holder and on the battery holder cap.

Rechargeable batteries can be used but the power level indicated on **TROMINO®** display could be misleading. In case of any malfunctioning (e.g. problems saving data, problems switching the instrument on, etc.), replace the rechargeable batteries with new batteries.

¹³ Specification depending also on the **TROMINO®** model.

➤ MEMORY CARD

Several files are present in the **TROMINO®** memory card:

- FILEFORM.DAT contains the acquisition program data and the values of the user-defined variables,
- GRILLA##.TRC are the files storing the recording. The number of these data files (##) varies from 1 to 99 as set with the PARTITION IN USE function of the main menu (p. 64).

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Should the card present a wrong structure, the error message “NO FILE ON MEMORY CARD” will be displayed.

➤ RECORDING DURATION

All GRILLA##.TRC files (that is, the memory card partitions reserved to store recordings), have the same size and fill the card capacity, excluding sectors reserved to the re-programming of the device. File size can be modified by changing the number of PARTITIONS IN USE, as described on p. 64.

Grilla software provides a routine to calculate the maximum length of each recording as a function of the card size, the number of partitions, the number of channels and the sampling rate. Some examples are reported in Table 3.

Memory card size	Mode	Channels	Sampl. rate	No. of partitions	Duration
16 Gb	FULL SCALE	3+1 (GPS) 3x4 +1x2 byte	128 Hz	1	About 100 days
16 Gb	FULL SCALE	3+1 (GPS) 3x4 +1x2 byte	512 Hz	1	About 25 days
16 Gb	FULL SCALE	3+1 (GPS) 3x4 +1x2 byte	128 Hz	50	2 days

Table 3. Examples of recording duration in a **TROMINO® BLU**.

The formula to compute the duration (in hours) of a recording is:

$$\begin{aligned}
 & \text{duration [hours]} \\
 & = \frac{[(\text{size[Mb]} * 1048576 - 200 * 1024) / \text{no.partition}] - 512 * 64}{\text{no.channels} * \text{nByteCh} * \text{sampl.freq.} * 3600}
 \end{aligned}$$

where

- *size* is the size (in Mb) of the memory card (usually 16 Gb, this can be verified from *Grilla* when importing the traces from **TROMINO®**: click IMPORT TROMINO TRACES >> EXPAND)
- *sampl. freq.* means sampling rate (in Hz),
- *no. channels* is the number of channels defined in the acquisition program,
- *nByteCh* is the number of bytes for channel (4 bytes for the FULL SCALE velocimeters, 2 byte for all the other channels),
- *no. partitions* is the number of partitions present in the memory card.

Extra space can be required for damaged sectors.

➤ DATA TRANSFER CONNECTOR

TROMINO® data transfer connector to PC is a standard USB port (type B).

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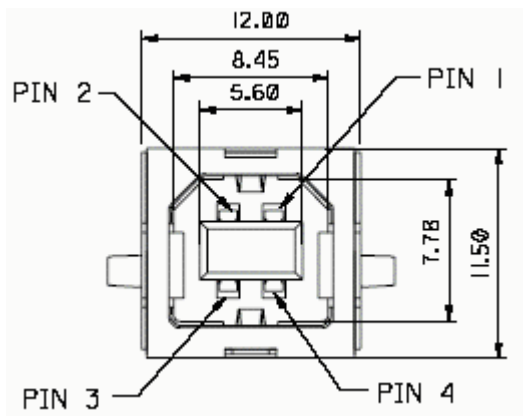


Figure 47. USB port scheme. Dimensions in mm.

➤ FIRMWARE UPDATE

The micro controller and the CPLD inside the recorder can be re-programmed directly by the user.

To update the firmware, connect **TROMINO®** to the PC with the USB cable (p. 127) and follow the instruction reported in www.moho.world/download (under TROMINO >> FIRMWARE).

➤ GENERAL FUNCTIONAL CONTROLS

Contact MoHo s.r.l. to schedule a periodic maintenance check and upgrade (at least every two years).

TROMINO® includes one utility for checking the internal electronic functionality, which has been described on page 66.

Verify that the background noise is **lower than 2μVpp** in a **10 s** time window.

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The observation of the three spectral components of microtremors at any site gives a preliminary indication about the functioning of the system. Figure 48 illustrates a typical good recording processed with *Grilla*. The NS, EW and Z spectra are approximately “parallel” (see also “The Quick **TROMINO®** How To” manual).

Figure 49 illustrates, on the opposite, a typical recording where some problems occurred: the N-S channel (green curve) shows a spectrum very different from the E-W and Z components at the same site. This can be due to a bad levelling of **TROMINO®** or to a malfunctioning of the N-S channel itself. Should this condition occur repeatedly and not due to a bad levelling, please contact the producer (MoHo s.r.l., support@moho.world) for assistance.

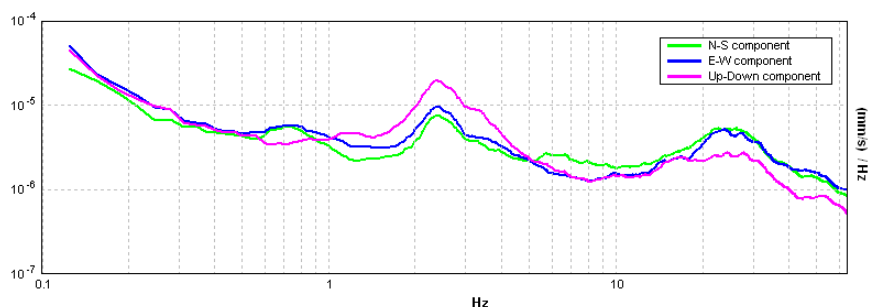


Figure 48. Spectra of a typically good recording. All the components show a similar average value (the vertical component usually shows a local minimum at the frequencies where the H/V function shows peaks).

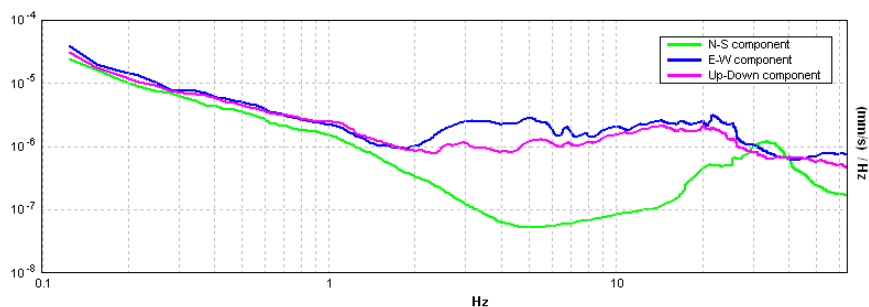


Figure 49. Spectra of a recording in which the N-S channel (green) shows problems due to a bad leveling or to a bad functioning of the channel itself.

➤ ELECTROMAGNETIC COMPATIBILITY

TROMINO® is intended to be used in the electromagnetic environments specified below. Customers or equipment users should assure that the device is used in such environments.

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RF EMISSIONS

- CISPR 11 - EN 55011 (Industrial, scientific and medical (ISM) radio-frequency equipment - Radio disturbance characteristics - Limits and methods of measurement), Group 1 Class B.

TROMINO® uses RF energy for its internal function only. Therefore, its RF emissions are very low and are not likely to cause any interference with nearby electronic equipment.

TROMINO® is suitable for use in all establishments, including domestic establishments and those directly connected to the public low-voltage power supply network that supplies buildings used for domestic purposes.

IMMUNITY TEST

- Electrostatic discharge (ESD): IEC 61000-4-2, ± 6 kV contact ± 8 kV in air.
- Electrical fast transient/burst: IEC 61000-4-4, ± 1 kV for input/output lines.
- Radiated RF: IEC 61000-4-3, 3 V/m in the 80 MHz to 2.5 GHz band.

Portable and mobile RF communication equipment should be used not closer to any part of the equipment, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter:

$$d = 1.2\sqrt{P} \text{ from 150 kHz to 800 MHz,}$$

$$d = 2.3\sqrt{P} \text{ from 800 MHz to 2,5 GHz,}$$

where P is the maximum output power rating of the transmitter in watt (W) according to the transmitter manufacturer and d is the recommended separation distance in meters (m).

Field strengths from fixed RF transmitters, as determined by electromagnetic site surveys, should be less than the compliance level in the whole frequency range. Interference may occur in the vicinity of



equipment marked with the following symbol:

To comply with EMC requirement, do not use USB cables longer than 3 m.

➤ TECHNICAL SPECIFICATIONS

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Manufacturer:	<p>MoHo s.r.l. c/o VEGA – building Lybra via delle Industrie 17/A 30175 Marghera (Venice) - Italy tel. +39 041 509 4004 fax +39 041 509 4007 Web: www.moho.world e-mail: info@moho.world</p>
Device:	TROMINO® portable ultra-light seismic noise acquisition system
Classification:	CISPR 11 - EN 55011 (Industrial, scientific and medical (ISM) radio-frequency equipment - Radio disturbance characteristics - Limits and methods of measurement), Group 1, Class B.
Conformity to standards:	EN 55011, IEC 61000-4-2, IEC 61000-4-4, IEC 61000-4-3.
Power supply	<p>TROMINO® 3G+ and following models (since 2017): internal rechargeable lithium ion batteries</p> <p>TROMINO® pre-3G+ models (before 2017): 2 x 1.5 V_{DC} AA, alkaline batteries</p>
Internal voltage	+3.3 V, +3.6 V for the analog section
Power consumption	75 mW (GPS inactive), 450 mW (GPS active)
Battery duration	TROMINO® 3G+ and following models (since 2017): 30 h, GPS inactive

TROMINO® pre-3G+ models (before 2017): 80 h, GPS inactive

Number of channels	9 (3 velocimetric, 3 accelerometric, 1 analog, 1 radio, 1 GPS)
Amplifiers	3 channels with differential input (velocimeters), 3 with monopolar input (accelerometers), 1 digital signal
Noise	< 0.5 μ V r.m.s. @128Hz sampling (on the HIGH GAIN differential input channels)
Amplifier input impedance	$10^6 \Omega$
Frequency range	DC – 360 Hz
Sampling rate	64 kHz per channel
Output sampling rate	128, 256, 512, 1024, [2048 Hz]
A/D resolution	24 bit
Max analog input	See Table 2 (p. 27)
Display	graphic, 128 x 64 pixels, back-lighted
Keyboard	soft-touch, 4 keys
Clock	internal, permanent with date and alarm, can be visualized also during the acquisition
GPS	12 channels with time-marker (precision 1 μ s)
Level	spirit, horizontal high precision, sensitivity 5' arc (0.083°)
Connections	type B, USB port
Data recording	internal memory, standard 16 Gb

Dimension and weight	10 x 14 x 7.7 (height) cm 1.1 kg aluminum case
Ground coupling	spikes or rheological cushion

Operating environmental conditions

temperature – 10 / +70°C
humidity 0-90% without condensation

Impermeability	IP protection index → 65 (dust proof, splash proof)
-----------------------	---



Sensors	VELOCIMETERS: 3 orthogonal electrodynamic velocimeters. See Table 2 (p. 27) for the dynamic range (in the pre-equalization band). Self-locking when not in acquisition.
----------------	---

Grilla software allows for off-line amplitude and phase equalization down to 0.3 Hz

ACCELEROMETERS: 3 orthogonal digital accelerometers. See Table 2 (p. 27) for the dynamic range.

Sensor frequency range	0.1 - 300 Hz
-------------------------------	--------------

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