

# Instruction Manual

## Vibration Analyzer

### VM100

Valid from Version 001.006



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Appendix: Warranty  
CE Declaration of Conformity



*Thank you for choosing a vibration meter from Metra.*

## **1. Purpose**

The VM100 vibration analyzer is suitable for many tasks of vibration measurement tasks, such as:

- General measurements of overall values in time domain with recording
- Frequency analysis (FFT)
- Amplitude/RPM measurement
- Machine vibration monitoring
- Roller bearing analysis
- Balancing
- Third-octave analysis of extremely low vibration using “VC” and “Nano” criteria
- Hand-arm vibration to ISO 5349 with one or two hands
- Whole-body vibration (triaxial) to ISO 2631 with health and comfort evaluation, vibration on passenger and merchant ships to ISO 6954
- The instrument complies with the standard ISO 8041-1 for human vibration meters
- Whole-body vibration with three triaxial sensors for the evaluation of passenger comfort in vehicles

## **2. Properties**

The VM100 can measure on up to nine channels simultaneously. It works with all commercially available IEPE accelerometers. TEDS sensors are recognized. In addition, a photoelectric reflex switch can be connected for speed measurement.

The instrument is available in two versions:

- VM100A with 9 inputs and internal infrared temperature sensor
- VM100B with 3 inputs

The instrument is fully touch-operated making it simple and intuitive. The removable micro SD card serves for storing measured values. A USB interface is used for data transfer. Measurement data is stored in CSV format. This allows common spreadsheet programs to be used for further processing on a PC.

### 3. Operation

#### 3.1. Connectors and Controls

On the upper side of the case you will find a small keypad with the power button, the reset button and a function key. The VM100A also has an infrared temperature sensor here. (Figures 1 and 2). The charge LED lights up red when connected to a USB charger or PC.

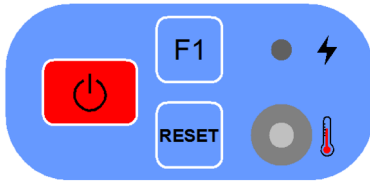


Figure 1: Keypad of VM100A

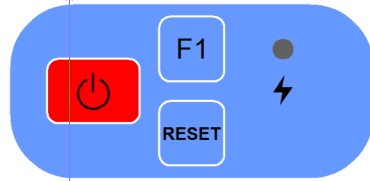


Figure 2: Keypad of VM100B

The USB port (Type C) for charging and transferring data as well as the micro-SD card are also located behind a flap on the upper side.

On the lower side you will find three sensor sockets for the VM100A and one for the VM100B. Each of the four-pole sensor sockets is suitable for connecting a triaxial sensor (X/Y/Z). Figure 3 shows a view of the connectors from outside. The assignment is:

- 1: Ground
- 2: Channel X
- 3: Channel Y
- 4: Channel Z

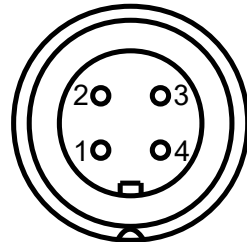


Figure 3: Sensor input

The VM100 has standard IEPE inputs.

A triaxial sensor requires three inputs. All triaxial accelerometers from Metra can be connected via their standard cables.

Alternatively three single-axis sensors can be connected to each input socket. Metra offers for this purpose an optional adapter cable with three female BNC connectors.

Here you will find also the tacho input (Figure 4) for a photoelectric reflex switch as RPM sensor which has the following assignment:

- 1: +26 V
- 2: Digital input D1
- 3: Digital input D2
- 4: +5 V
- 5: Analog input A1
- 6: Analog input A2
- 7: Ground

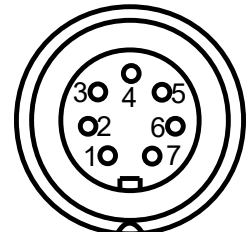



Figure 4: Tacho input

The inputs D2, A1 and A2 are currently not used.


Behind a cover is another USB port, which is only for firmware updates.

## 3.2. Switching On / Off and Reset

The VM100 is switched on by briefly pressing the red key on the side keypad (Figures 1 and 2). It always starts with the last selected settings and is immediately ready for use in measuring mode. If the battery is completely discharged, it may be necessary to connect a charger to start it.

To switch off, touch the on/off symbol  at the top left of the screen.

When a battery charger or USB cable is connected the unit is started by a screen button.

Should the instrument not start normally, you may perform a factory reset by holding the F1 button and pressing shortly RESET or by holding F1 while pressing .

The unit can be restarted from any program point by pressing the **Reset** key. Any entries made previously are retained.








## 3.3. Menu Bar

All function modules use a uniform menu bar at the top of the screen (Figure5).



Figure 5: Menu bar

The menu bar contains the following components:

- Off button 
- Function menu: Touch the menu text to open a drop-down menu with all function modules. Unlicensed functions are grayed out. Touching a menu item selects the function. If no selection is made, the menu closes again after a few seconds.
- The info button  provides a short help text to each measuring module.
- The menu button  opens a menu structure with various settings and for USB data transfer (see section 7).
- The save button  opens the menu for saving data to SD card (Section 5). If no SD card is inserted, the symbol appears crossed out.
- The USB button  establishes a data connection to a PC.
- The battery indicator  shows the current charge status of the unit. In case of advanced discharge, the display bar turns yellow and in case of critical charge state, it turns red. When the charger is connected, the charging symbol  is displayed alternating with the actual charge current. After charging is complete, a plug symbol for battery support appears on the right (see section 3.6).
- The menu bar shows the date and time. In the VM100A, you can see the measured temperature of the built-in infrared sensor below it (Figure 1).

### 3.4. Sensors

The sensor menu (Figure 6) opens by selecting the **Sensors** item in the main menu.




Figure 6: Sensor menu

It shows the sensitivities of the connected sensors. As in the entire user interface of the VM100, three input channels (X/Y/Z) are displayed for each input socket ("1" to "3" for VM100A or "1" for VM100B). For inputs without a sensor, "No sensor" appears.

The VM100 supports TEDS sensors. TEDS stands for "Transducer Electronic Data Sheet" and is standardized according to IEEE 1451.4. The most important technical data is stored digitally in the sensor and can be read out automatically by the measuring instrument. Measurement errors due to confusion or incorrect entries are thus eliminated. The standard data arrangement for accelerometers according to "Template 25" is supported. If a TEDS transducer is detected, the sensor menu shows its sensitivity, type designation and serial number. In Figure 6 this is shown for a TEDS triaxial sensor at socket 1. The sensitivity of TEDS sensors cannot be edited in the menu.

For conventional IEPE sensors, touching the sensitivity opens a numeric input pad for entering the sensitivity. The unit of measurement can be changed to mV/Pa for pressure transducers and measuring microphones or mV/N for force transducers. The units of measurement Pascal or Newton are then displayed instead of acceleration in certain operating modes. Some modes, like balancing, only work with accelerometers.

With the button  sensor detection can be repeated.

The sensor detection takes place in the background each time the device is switched on. Hence, after changing a TEDS sensor, the sensor menu does not have to be opened. It is only needed for manual sensitivity input of and for checking sensors.



The checkbox above the sensitivities disables the IEPE constant current supply for all channels. This can be useful in some cases if the instrument measures with AC voltage sources instead of IEPE sensors. The VM100 will then issue the warning “IEPE supply off - No support for IEPE sensors!” every time it is switched on.

### 3.5. USB Connection

On the upper side, you will find the USB port behind a flap (Figure 10). It is a USB-C type connector which is used to charge the battery and to transfer data. To transfer the files stored on the SD card, connect the VM100 to a PC via a USB cable. To activate data transfer, press the USB symbol in the menu bar (Figure 7). You will then see the display corresponding to Figure 8.

The VM100 is now in USB mass storage mode. It does not need a device driver and behaves like a USB stick by providing the file system of the SD card.



Figure 7: USB connection



Figure 8: USB connection


➔ For sensitive measurements, the USB cable should be disconnected.


### 3.6. Charging the Accumulator

The built-in nickel-metal hydride rechargeable battery is charged via the USB-C socket (Figure 10). A USB mains adapter is used for charging, which should deliver at least 3 A from 5 V. Otherwise, the full charging current may not be provided and the charge time is extended.

If a USB supply is connected, the red charging LED lights up (Figures 1 and 2).

If the USB supply is connected when the VM100 is switched off, the charge screen opens (Figure 9). It will be dimmed after a short time. You can check whether the device is still charging by touching the screen.

When switched on, the status bar on the top right shows the charging symbol  alternating with the actual charge current flowing into the battery. Depending on the connected USB interface or charger the input current may be in the range from 0.5 to 2.5 A. About 0.7 A of this current are needed for the instrument itself. Standard USB 2.0 sockets provide only 0.5 A which means that there may be no current left for charging the battery and instead it may be further discharged.

When charging is complete, the battery and plug icon appears .

At advanced discharge, the indicator bar turns yellow and in case of critical charge state, it turns red.

➔ Reducing the display brightness (see section 7.1) may considerably increase the battery operating time.

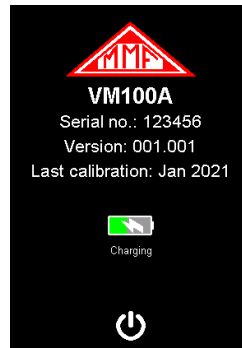


Figure 9: Charge screen

- For sensitive measurements, the charger should be disconnected.
- After accidental deep discharge, e.g. after long storage, it may be necessary to start the charging process several times by disconnecting and reconnecting the USB cable before the full charging capacity is reached again.



Figure 10: Charge connector and SD card slot

### 3.7. SD Card and File System

A Micro SD card serves as a measurement data memory. It is located behind the flap next to the USB socket (Figure 10). The VM100 uses the FAT file system. The files can be transferred to a PC via a USB cable as shown in section 3.5. If necessary, the SD card can be removed after unlocking it by pressing slightly on its edge. You can read out the data in other devices. Insert the SD card into the VM100 with the contacts facing up. It is recommended only to use memory cards of size 2 or 4 GB.

New SD cards should be formatted with the FAT(16) file system. FAT32 may result in a slower detection via USB.

For more details on measured data storage, refer to section 5.

- It is strongly recommended to make regular backups of the data stored on the SD card.
- Do not open files directly from the VM100 on your PC to avoid the creation of temporary files on the SD card. Always start with copying the files from the VM100 to a folder on the PC.
- Saving additional files to the SD card or creating additional folders using other devices is not advisable.

## 4. Measurement Modules

### 4.1. Licenses

The VM100 supports a number of tasks, which are divided into measurement modules. Figure 11 shows the menu with all available modules.

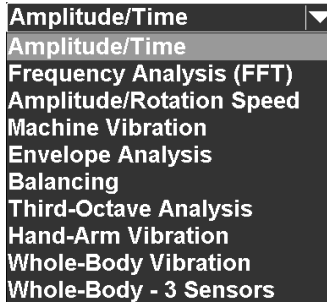


Figure 11: Measurement modules

Amplitude/Time and Frequency Analysis are pre-installed by default. The other functions can be activated by purchasing license codes. This is done by a text file with the name VM100 #xxxxxx licence.key, which has to be saved in the main directory of the SD card. Here x...x stands for the 6-digit serial number of the device according to the type label or device data menu (see section 7.6). You receive this license file from the manufacturer. It is only required for entering the licenses once. The licenses are read automatically after the device is switched on. Later the license file is not needed anymore but it can be left on the SD card. A note will be displayed for each newly added license.

### 4.2. Module Amplitude/Time

This module is pre-installed by default and is suitable for overall value measurements in time domain. In the upper part there is the unified menu bar, which is described in section 3.3. On the left, up to nine vibration values are displayed. On the right, the measurements are displayed graphically as a time graph (Figure 12). In addition you can measure and plot rotation speed (rpm). Prerequisite for rotation speed measurement is the connection of a photoelectric reflex switch VM100-LS (see Figure 68 on page 46).

The writing of the amplitude graphs starts 15 s after the start of the module in order to suppress transients. The waiting time can be skipped by touching the respective message in the diagram.

➔ For sensitive measurements, the USB cable should be disconnected.

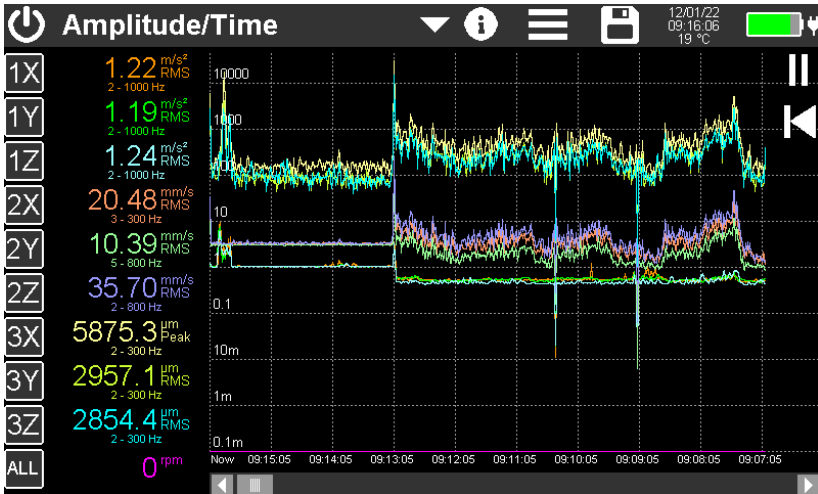
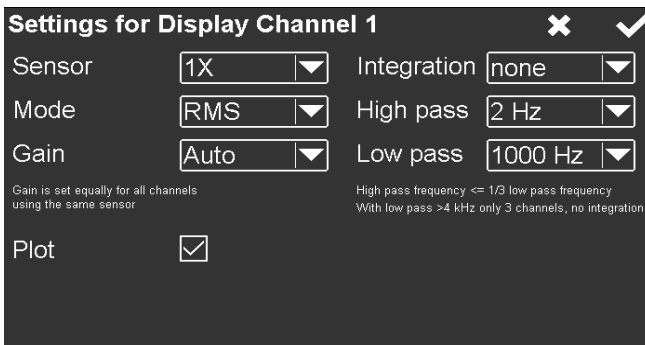


Figure 12: Display in the module Amplitude/Time

Touching one of the channel buttons on the left edge opens the menu for setting the measuring channel (Figure 13).

Alternatively, you can apply the same settings to all channels by touching the lowest button “ALL” (Figure 14). In this mode you can also choose between the units 1/min and Hz for rotation speed.



Fig

Figure 13: Settings for one channel

The display channels 1 to 9 can be connected freely with any of the physical sensor inputs 1X, 1Y and 1Z for model VM100B and with sensor inputs 1X to 3Y for model VM100A.

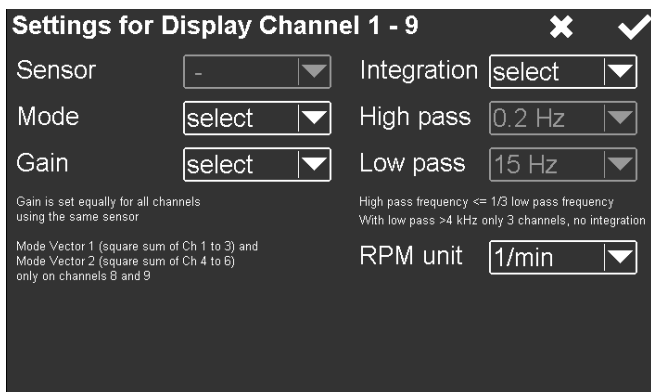


Figure 14: Settings for all channels simultaneously

The selection in the **Sensor** menu connects the display channel with a physical sensor input. Even with the three-channel VM100B, up to nine measured values can thus be displayed. For example, different overall values or frequency bands can be displayed for one sensor.

The value to be displayed is selected under **Mode**. The following overall values can be measured:

|          |  |
|----------|--|
| RMS      | Root-mean-square value with 1 s averaging time   |
| RMS(T)   | Root-mean-square value with unlimited averaging time   |
| Peak     | Peak value (0 – Peak) with 1 s hold time   |
| Pk-Pk    | Peak-to-peak value with 1 s hold time  |
| Pk hold  | Maximum peak value (0 – Peak) with unlimited hold time   |
| Crest    | Crest factor (Peak/RMS)  |
| Frequ.   | Main frequency (frequency of highest FFT amplitude), only with 4 kHz bandwidth and for 3 channels max.                         |
| Vector 1 | Square root of the sum of squares (vibration total value) of display channels 1, 2 and 3; only selectable at channels 8 and 9* |
| Vector 2 | Square root of the sum of squares (vibration total value) of display channels 4, 5 and 6; only selectable at channels 8 and 9* |

\* The vector values are calculated by adding the squared amplitudes of the respective display channels without consideration of same mode, filters etc.

In the **Integration** menu, you can select whether no integration, single integration or double integration is to be performed. Integration is only useful in connection with accelerometers. Single integration provides the vibration velocity, double integration the vibration displacement.

Furthermore, **high pass** filters between 0.2 and 5000 Hz and **low pass** filters between 10 and 24 000 Hz can be selected. The following restrictions apply:

- The highest selectable high-pass frequency is one third of the low-pass frequency.

- The maximum frequency range for single integration is from 2 to 2000 Hz.
- The maximum frequency range for double integration extends from 2 to 300 Hz.
- Low pass filters above 4000 Hz can only be used for three-channel measurements with fixed channel/sensor assignment. Frequencies above 4000 Hz can only be selected on the upper three display channels. The high pass frequencies 2, 3 and 4 Hz are not available in this case. Main frequency and square root of the sum of squares are not available.

The high and low passes are second order Butterworth filters with an attenuation of 40 dB per frequency decade. The low passes 4 kHz and 24 kHz are an exception. For these, the very steep digital filter of the analog-to-digital converter becomes effective. The attenuation is already over 100 dB at 1.5 times the cutoff frequency. In Figure 15 you can see the amplitude frequency responses with some filters as well as integrators, related to the measurand acceleration of the sensor.

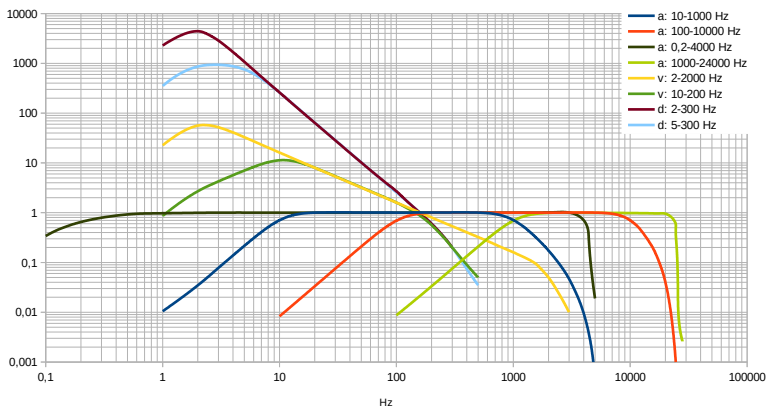


Figure 15: Frequency response of selected filters and integrators

In the **Gain** menu, you can choose between automatic gain setting and the fixed gains 1, 10 and 100. For most applications the "Auto" setting is recommended. Only for strongly fluctuating amplitudes a fixed gain can be useful, in order to avoid continuous switching.

**Plot** selects whether the channel is displayed in the time diagram. Each channel has an individual color which is used for the measured value and the time graph. If a channel is not displayed in the time graph, its measured value appears in white.


All settings are retained even after the device is switched off or the measuring module is changed.

In the time diagram, a data point is generated for each measured value. The diagram is drawn starting from the left. On the left edge there is always the current recording time. Towards the right, the measured data becomes older. The visible diagram area covers 10 minutes. With the scroll bar you can browse the entire recording time of up to 10 hours. After 10 hours, the oldest measurement data are shifted out of the memory.

The Y-axis is logarithmically scaled. The units of measurement correspond to those of the measured values.

In addition, rotational speed is displayed if this is activated in the sensor menu (Section 3.4).


Diagram plotting can be halted (II) or restarted (I◀).

The storage of measured values takes place independently of the diagram as a CSV data table. To do this, open the storage menu with  and select CSV storage (see section 5). The storage button then appears in yellow with the text "LOG". The measured values are now written to a file every second. The file name and the number of measured values are displayed at the top of the diagram. To end the recording, touch the save button again. The saved files can be found on the SD card in the "AMP-TIME" directory.

| AMPLITUDE/TIME |                  |                  |                  |                  |                  |                     |       |       |       |     |
|----------------|------------------|------------------|------------------|------------------|------------------|---------------------|-------|-------|-------|-----|
| Instr.:        | VM100A           | Ser.:            | 123456           |                  |                  |                     |       |       |       |     |
| Comment:       | TEST 2           |                  |                  |                  |                  |                     |       |       |       |     |
| NFC id:        |                  |                  |                  |                  |                  |                     |       |       |       |     |
| Sensor 1X:     |                  | Ser.:            | 170345           | Sensit.:         | 10.313           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 1Y:     |                  | Ser.:            | 170345           | Sensit.:         | 10.354           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 1Z:     |                  | Ser.:            | 170345           | Sensit.:         | 10.879           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 2X:     |                  | Ser.:            | 181653           | Sensit.:         | 100.45           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 2Y:     |                  | Ser.:            | 181653           | Sensit.:         | 100.35           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 2Z:     |                  | Ser.:            | 181653           | Sensit.:         | 100.18           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 3X:     |                  | Ser.:            | 173871           | Sensit.:         | 10.313           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 3Y:     |                  | Ser.:            | 173871           | Sensit.:         | 10.354           | mV/m/s <sup>2</sup> |       |       |       |     |
| Sensor 3Z:     |                  | Ser.:            | 173871           | Sensit.:         | 10.879           | mV/m/s <sup>2</sup> |       |       |       |     |
| Date:          | 20.01.2022       | Temp.:           | 22               | °C               |                  |                     |       |       |       |     |
| Sensor:        | 1X               | 1Y               | 1Z               | 2X               | 2Y               | 2Z                  | 3X    | 3Y    | 3Z    | RPM |
| HP (Hz):       | 5                | 5                | 1000             | 5                | 5                | 5                   | 5     | 5     | 5     |     |
| LP (Hz):       | 1000             | 1000             | 4000             | 4000             | 4000             | 4000                | 4000  | 4000  | 4000  |     |
| Mode:          | RMS              | RMS              | RMS              | RMS              | RMS              | RMS                 | RMS   | RMS   | RMS   |     |
| Unit:          | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup>    | mm/s  | mm/s  | mm/s  | rpm |
| 11:36:38       | 0.962            | 0.963            | 0.600            | 1.275            | 1.275            | 1.216               | 1.016 | 0.936 | 0.924 | 0   |
| 11:36:39       | 0.963            | 0.923            | 0.601            | 1.275            | 1.187            | 1.216               | 1.009 | 0.936 | 0.924 | 0   |
| 11:36:40       | 0.777            | 0.726            | 0.578            | 1.103            | 1.043            | 1.061               | 1.025 | 0.921 | 0.928 | 0   |
| 11:36:41       | 0.775            | 0.733            | 0.575            | 1.103            | 1.040            | 1.062               | 1.029 | 0.930 | 0.940 | 0   |
| 11:36:42       | 0.779            | 0.730            | 0.575            | 1.088            | 1.048            | 1.049               | 1.018 | 0.921 | 0.939 | 0   |
| 11:36:43       | 0.769            | 0.735            | 0.580            | 1.100            | 1.035            | 1.062               | 1.013 | 0.921 | 0.933 | 0   |
| 11:36:44       | 0.770            | 0.735            | 0.578            | 1.097            | 1.048            | 1.062               | 1.019 | 0.925 | 0.937 | 0   |

figure 16: Example of a CSV recording

Figure 16 shows an example of a CSV recording. In the header you will find information about the measuring device and the sensors used. The table starts with the channel settings, such as filters, overall values and measurement units. From line 20 start the recorded measured values of 9 channels and rotation speed with time stamp. For channels without sensor, "IEPE!" is saved instead of measured values.

To stop recording press the  button again.

After 24 hours a CSV log file is closed. A new file is opened automatically. It gets the same file name with the appendix "...\_a.csv", the next file "...\_b.csv" until recording stops after 27 days with file "...\_z.csv".

Alternatively, the diagram can be saved as BMP screenshot.

For more details on measured value storage, see section 5.

### 4.3. Module Frequency Analysis (FFT)

This module is pre-installed by default. It performs a Fourier transform (FFT) and is used to display the spectral composition of the acceleration signal of the three channels of sensor input 1. In the upper part there is the unified menu bar described in section 3.3.

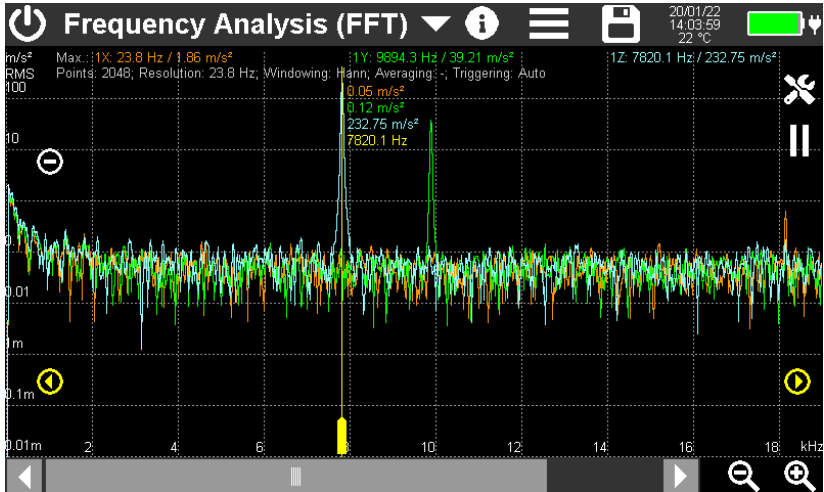


Figure 17: Measurement screen of frequency analysis

The frequency range extends up to 22 kHz.

The entire screen width of 800 points is used to display the spectrum. At the bottom right, you will see two buttons for zooming in and out of the visible frequency range. In the selected frequency range you can navigate with the scroll bar. An exception is the lowest zoom level, in which the entire frequency range is displayed on a width of only 460 points.


The scaling of amplitude and frequency axis is done with the plus/minus keys. Alternatively, you may place two fingers on the screen and pinch in or stretch out vertically or horizontally.

To the right or above the diagram, the largest spectral components of the three channels are displayed with frequency and amplitude. In addition, you can see there the number of points with which the FFT is calculated. Depending on the zoom level, it can be between 1024 and 32786 which is about 2.2 times the shown number of points. This results in a certain frequency step size per point, which is also shown. In addition, there are window function, averaging and trigger mode.

The yellow measurement cursor is shifted with the wider lower end. In addition, there are yellow arrow keys on the left and right for moving the cursor in single steps. In the upper area of the cursor the three amplitudes and the frequency at the selected cursor position are shown.

All graphic and numerical value outputs are in the characteristic color of the respective measuring channel.



→ The higher the number of points, the longer the calculation takes.  
 FFT calculation can be paused and continued with the buttons **||** and **▶**.  
 The tools icon  opens the FFT menu (Figure 18).

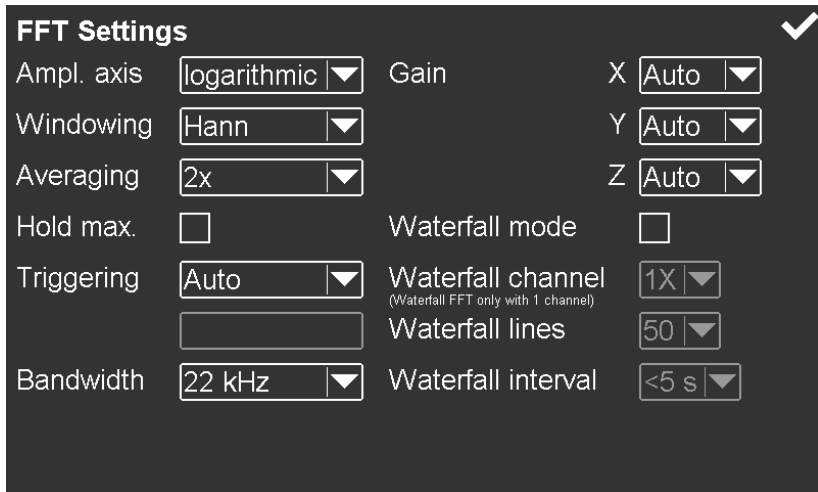


Figure 18: FFT menu

The scaling of the **amplitude axis** can be switched between linear and logarithmic.

**Windowing** determines with which weighting the obtained sample values within a section (window) are used in subsequent calculations. Due to the block-wise processing of the signal, so-called leakage effects occur on the edges of a block, which make the spectral components appear too wide. This effect can be reduced by using a suitable window function. The window function also influences the frequency selectivity and the spectral error. The choice of window functions is a compromise between side-band suppression and width of the spectral lines.

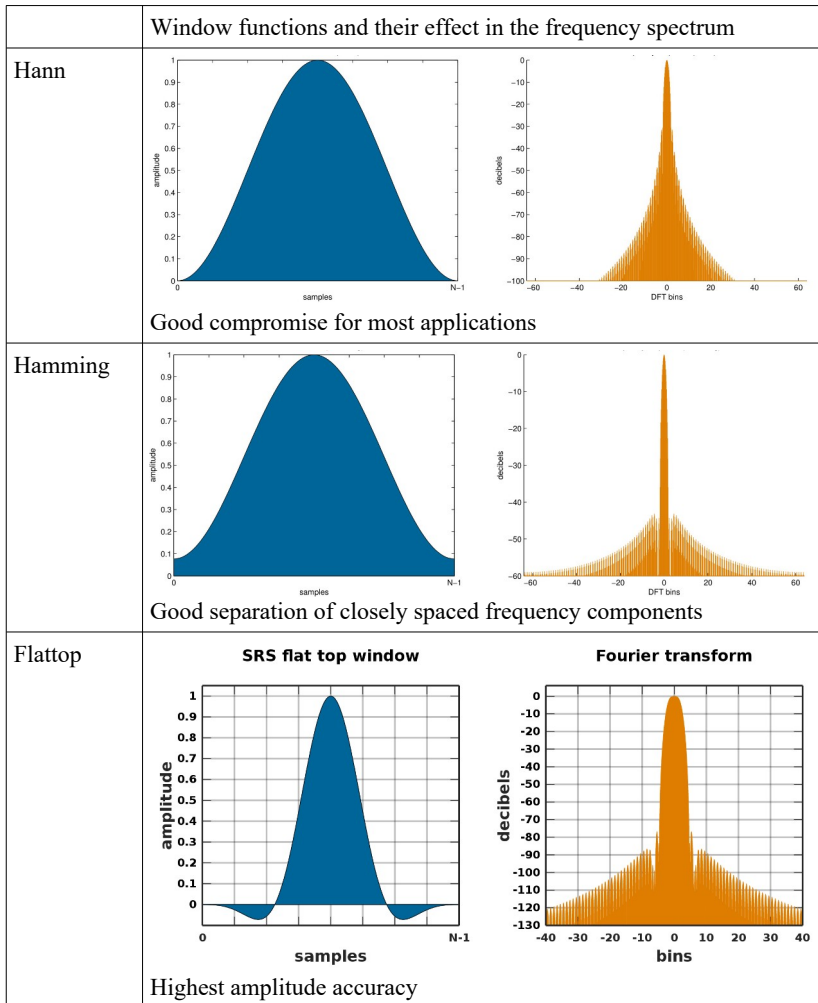



Figure 19: Window functions used in the VM100 (Wikimedia Commons)

**Averaging** of 2 to 16 spectra can be performed. This can significantly reduce the "noise carpet" contributed by random signal components and improve the sharpness of the displayed spectrum. Averaging has a disadvantageous effect on the reaction time after signal changes.

With the key  averaging can be restarted.

With **Hold max.** the previous FFT is not deleted, but displayed one above the other (Figure 20). This allows changes in the spectral composition of the signal to be made visible. The previous spectra appear in darker colors.

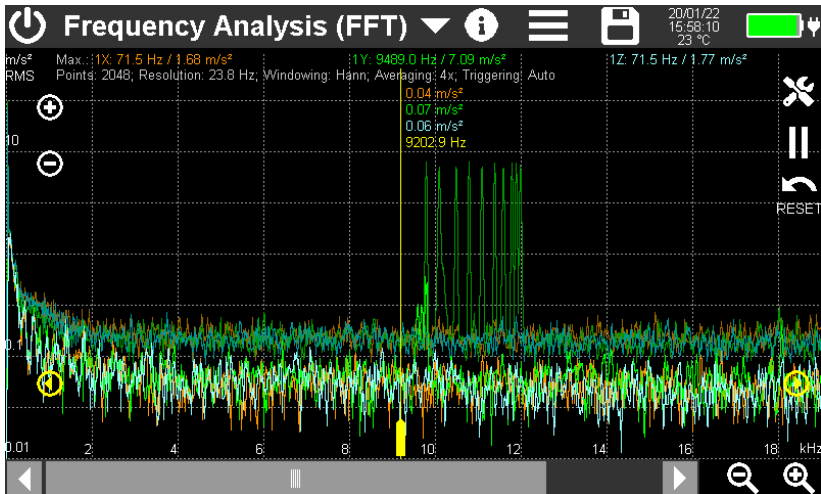


Figure 20: FFT with active hold function

In the **Triggering** menu, you can define the conditions under which a frequency analysis is performed.

- **Auto**: The calculation is carried out continuously in the time interval determined by the frequency resolution.
- **DIG1**: The calculation is performed when a pulse is detected at the RPM input.
- **Amplitude**: Calculation is performed when an amplitude within the spectrum exceeds the specified limit value. The limit value is entered as a numerical value below the trigger menu.

**Bandwidth** can be switched between 4.5 and 22 kHz. This is the highest measurable frequency. A bandwidth of 4.5 kHz is useful if higher frequencies are not of interest. It increases the frequency resolution. With the same resolution the measurement becomes faster.

**Gain** can be selected between automatic gain and the fixed gains of 1, 10 and 100. For most applications the "Auto" setting is recommended. Only in the case of strongly fluctuating amplitudes is a fixed gain can be more suited to avoid continuous switching.

In the **waterfall** mode a pseudo-3D graphics is shown for the spectra. In the "background" of the currently measured spectrum, up to 50 previous spectra are displayed. This can be useful, for example, to make resonance points visible during the run-up or coast-down of a machine (Figure 21).

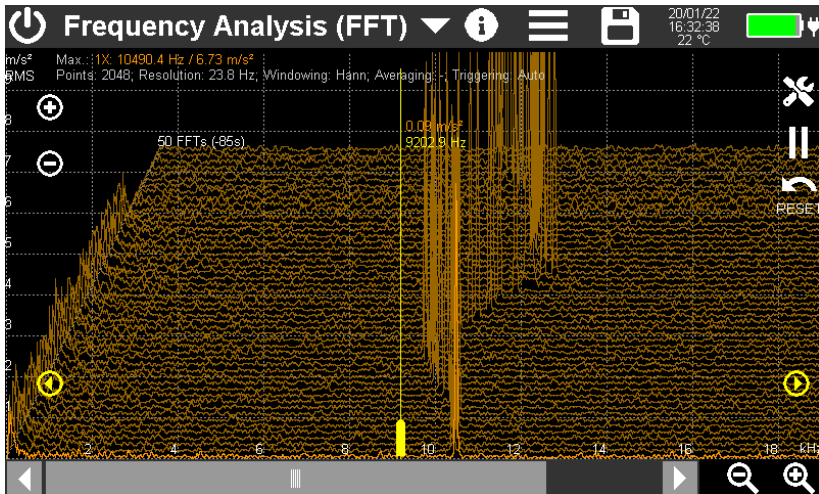



Figure 21: FFT in waterfall mode

Waterfall mode is only possible for one channel which is selected in the menu. The number of displayed spectra can be set between 10 and 50. The time interval between two adjacent spectra can be selected between 5 and 50 s.

For the waterfall display, it is recommended to select a linear amplitude axis, as this produces clearer results.

The  key is used to clear the history and restart the recording.

The cursor measures the currently measured spectrum.

In **spectrogram** mode, the change of spectra over time also becomes visible. Each pixel line represents a spectrum. Up to 340 spectra can be displayed (Fig. 22). The amplitudes are displayed by colors. The highest amplitudes are red, the lowest black. In the upper part of the screen you can see a color scale labeled with the amplitudes. The plus/minus buttons are used to change the amplitude range. The spectrogram display is only available for one channel which is selected in the menu.

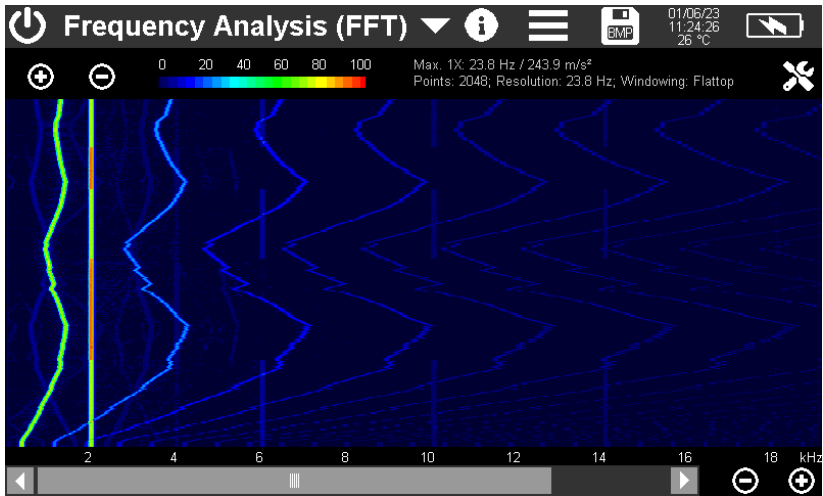



Figure 22: Spectrogram view

The following options are available for saving with the button . The spectrum is saved as a CSV file in a data table (Figure 23) with a header containing information about the measuring device, sensor and FFT settings. From line 20 the frequency points and the corresponding amplitudes of the three channels are listed. The number of lines depends on the selected number of points.

Waterfall history and maximum hold data are not exported as CSV. The data format is identical with normal FFT mode. To save spectra measured in the operating modes Waterfall, Spectrogram or Hold maximum value, bitmap screenshots (BMP) are suitable.

The saved files are found on the SD card in the "FFT" directory.

Further details on saving can be found in section 5.

| FREQUENCY ANALYSIS (FFT) |                     |                     |                     |          |                            |
|--------------------------|---------------------|---------------------|---------------------|----------|----------------------------|
| Instr.:                  | VM100A              | Serial no.:         | 123456              |          |                            |
| Comment:                 |                     |                     |                     |          |                            |
| NFC Id:                  |                     |                     |                     |          |                            |
| Sensor 1X:               |                     | Serial no.:         |                     | Sensit.: | 10.313 mV/m/s <sup>2</sup> |
| Sensor 1Y:               |                     | Serial no.:         |                     | Sensit.: | 10.354 mV/m/s <sup>2</sup> |
| Sensor 1Z:               |                     | Serial no.:         |                     | Sensit.: | 10.879 mV/m/s <sup>2</sup> |
| Date:                    | 21.01.2022          |                     |                     |          |                            |
| Time:                    | 07:36:50            |                     |                     |          |                            |
| Temp:                    | 20                  | °C                  |                     |          |                            |
| Points:                  | 2048                |                     |                     |          |                            |
| Window:                  | Hann                |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
|                          |                     |                     |                     |          |                            |
| Hz                       | X: m/s <sup>2</sup> | Y: m/s <sup>2</sup> | Z: m/s <sup>2</sup> |          |                            |
| 4.8                      | 0.011               | 0.785               | 0.780               |          |                            |
| 9.5                      | 0.012               | 0.067               | 0.072               |          |                            |
| 14.3                     | 0.024               | 0.064               | 0.061               |          |                            |
| 19.1                     | 0.037               | 0.032               | 0.033               |          |                            |
| 23.8                     | 0.028               | 0.053               | 0.022               |          |                            |
| 28.6                     | 0.039               | 0.066               | 0.041               |          |                            |

Figure 23: FFT saved as CSV table (only first six frequencies shown)

## 4.4. Module Amplitude/Rotation Speed

This measuring module graphically displays the vibration amplitude as a function of rotation speed. The main application is the detection of resonances. Figure 24 shows a screenshot of an example measurement. In the upper part there is the uniform menu bar, which is described in section 3.3.

Prerequisite for the measurement is the connection of a photoelectric reflex switch VM100-LS (see Figure 68 on page 46) to the input "RPM" of the VM100, which serves as rotary speed sensor.

The vibration measurement can be done on 1 to 9 channels.

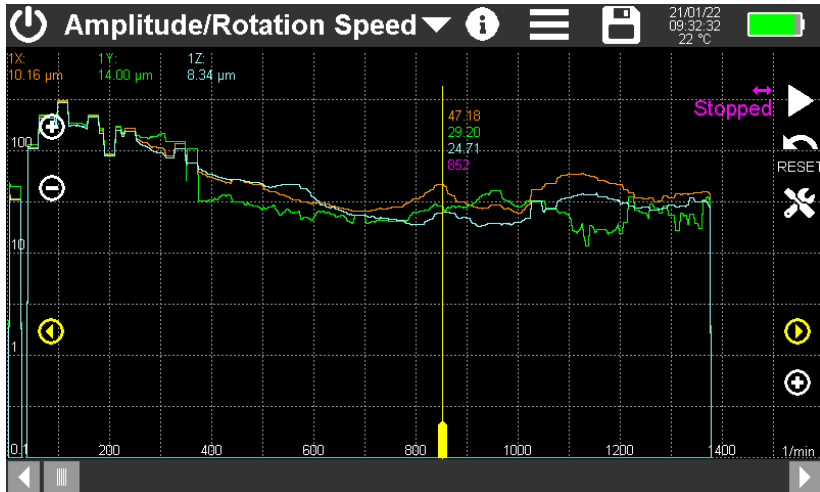



Figure 24: Amplitude/rotation speed measurement

Touch  to open the setup menu (Figure 25).

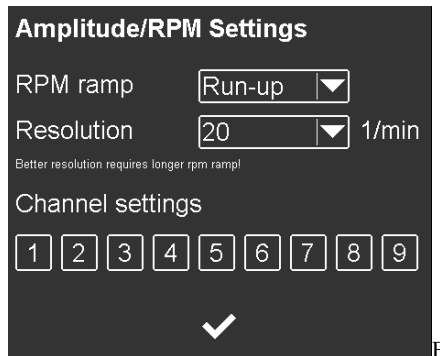


Figure 25: Amplitude/rotation speed setup

**RPM ramp** determines the direction in which the RPM must change in order for the amplitudes to be recorded. The following choices are possible:


- Undefined: Both increasing and decreasing speeds are taken into account.
- Run-up: Only increasing speeds are taken into account.
- Coast-down: Only decreasing speeds are taken into account.

**Resolution** determines how wide an RPM step should be in the diagram. The higher the value, the more staggered the amplitude curves appear. Small values for the resolution provide smoother progressions, but on the other hand require a slower change of the speed, because the detection of the speed and the corresponding amplitude takes a certain time. If the instrument does not succeed in recording a measurement in a speed interval, gaps appear in the curve. In Figure 24 this can be seen on the left edge of the diagram.

**Channel settings** are made individually for up to nine channels. The menu is identical to the Amplitude/Time module (see p. 10). Here it is also possible to connect a physical sensor input to more than one display channel using different settings.

➔ Vibration displacement or vibration velocity sometimes provide clearer results regarding resonances.

At the top of the rotation speed diagram (Figure 24) the currently measured amplitudes of the measuring channels are displayed. Channels without a sensor are not displayed. The rotation speed is displayed on the right side. If no pulses are detected, "Stopped" is shown instead. The arrow above indicates the selected speed ramp.

With the reset button  the diagram content is deleted.


As soon as revolutions are detected, the recording of the amplitude graph starts. A purple arrow on the horizontal axis marks the current speed.

The measurement is ended either by stopping the rotation or by pressing the || button.

The yellow measurement cursor is shifted with its wider lower end. In addition, there are yellow arrow keys on the left and right for moving the cursor in single steps. In the upper part of the cursor, the amplitudes and the rotation speed at the selected point are output.

With the +/- buttons at the diagram axes can be rescaled. Alternatively, you may place two fingers on the screen and pinch in or stretch out vertically or horizontally.

All graphical and numerical outputs take place in the characteristic color of the respective measuring channel.

The following options are available for saving with the  button:

As a CSV file, the diagram is saved as data table (Figure 26).



| AMPLITUDE/ROTATION SPEED |            |             |          |                  |                  |                     |                  |                  |                  |
|--------------------------|------------|-------------|----------|------------------|------------------|---------------------|------------------|------------------|------------------|
| Instr.:                  | VM100A     | Serial no.: | 123456   |                  |                  |                     |                  |                  |                  |
| Comment:                 |            |             |          |                  |                  |                     |                  |                  |                  |
| NFC Id:                  |            |             |          |                  |                  |                     |                  |                  |                  |
| Sensor 1X:               | K5903B10   | Ser.:       | 20014    | Sensit.:         | 10.313           | mV/mm/s             |                  |                  |                  |
| Sensor 1Y:               | K5903B10   | Ser.:       | 20014    | Sensit.:         | 10.354           | mV/mm/s             |                  |                  |                  |
| Sensor 1Z:               | K5903B10   | Ser.:       | 20014    | Sensit.:         | 10.879           | mV/mm/s             |                  |                  |                  |
| Sensor 2X:               |            | Ser.:       |          | Sensit.:         | 10.000           | mV/m/s <sup>2</sup> |                  |                  |                  |
| Sensor 2Y:               |            | Ser.:       |          | Sensit.:         | 10.000           | mV/m/s <sup>2</sup> |                  |                  |                  |
| Sensor 2Z:               |            | Ser.:       |          | Sensit.:         | 10.000           | mV/m/s <sup>2</sup> |                  |                  |                  |
| Sensor 3X:               |            | Ser.:       |          | Sensit.:         | 10.313           | mV/m/s <sup>2</sup> |                  |                  |                  |
| Sensor 3Y:               |            | Ser.:       |          | Sensit.:         | 10.354           | mV/m/s <sup>2</sup> |                  |                  |                  |
| Sensor 3Z:               |            | Ser.:       |          | Sensit.:         | 10.879           | mV/m/s <sup>2</sup> |                  |                  |                  |
| Date:                    | 21.01.2022 | Time:       | 10:39:23 | Temp:            | 22               | °C                  |                  |                  |                  |
| Channel:                 | 1X         | 1Y          | 1Z       | 2X               | 2Y               | 2Z                  | 3X               | 3Y               | 3Z               |
| HP (Hz):                 | 3          | 2           | 2        | 2                | 2                | 2                   | 2                | 2                | 2                |
| LP (Hz):                 | 2000       | 300         | 2000     | 4000             | 4000             | 4000                | 4000             | 4000             | 4000             |
| Mode:                    | RMS        | RMS         | RMS      | RMS              | RMS              | RMS                 | RMS              | RMS              | RMS              |
| rpm                      | mm/s       | mm/s        | mm/s     | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup>    | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> |
| 0                        | 7.629      | 9.709       | 9.485    | 0.000            | 0.000            | 0.000               | 0.000            | 0.000            | 0.000            |
| 2                        | 4.978      | 6.522       | 6.373    | 0.000            | 0.000            | 0.000               | 0.000            | 0.000            | 0.000            |
| 4                        | 25.391     | 32.789      | 30.695   | 0.000            | 0.000            | 0.000               | 0.000            | 0.000            | 0.000            |
| 6                        | 14.945     | 22.660      | 21.217   | 0.000            | 0.000            | 0.000               | 0.000            | 0.000            | 0.000            |

Figure 26: Amplitude/Rotation Speed data as CSV table (section)

The header includes information about the measuring device, sensor and settings. Starting from line 20, the speed values with corresponding amplitudes of all channels follow.

The saved files are located on the SD card in the "AMP-RPM" directory.

Further information on saving can be found in section 5.

## 4.5. Module Machine Vibration

### 4.5.1. Introduction

The vibrations generated by machines can provide information about the maintenance condition. Vibration monitoring can be useful to predict machine failures and thus prevent unexpected breakdowns or major consequential damage. For example, looseness, deformations or imbalances are noticeable the vibration behavior.

In order to make such statements, it is not always necessary to adhere to a specific limit value. Often, the trend of the vibration amplitude over time already provides a statement about arising problems. As a "good" condition, an initial value can serve, which is taken in the new condition of the machine. If such values are not available, decision criteria from standards can be used, such as those found in the ISO 10816 / ISO 20816 series of standards.

- ISO 20816-2: Stationary gas turbines, steam turbines and generators above 40 MW with plain bearings and rated speeds of 1500 min<sup>-1</sup>, 1800 min<sup>-1</sup>, 3000 min<sup>-1</sup> and 3600 min<sup>-1</sup>
- ISO 20816-3: Industrial machines with power above 15 kW and operating speeds between 120 min<sup>-1</sup> and 30000 min<sup>-1</sup>
- ISO 20816-5: Machine sets in hydropower and pumped storage plants
- ISO 10816-7: Centrifugal pumps for industrial use
- ISO 20816-8: Reciprocating compressors
- ISO 20816-9: Gear units
- ISO 14694: Industrial fans

Common to the above standards is the RMS value of the vibration velocity as monitored measurand. An exception is the measurement on reciprocating compressors, where the vibration displacement and vibration acceleration are also recorded.

Trend monitoring can be done with permanently installed measurement equipment, such as Metra's M12, M14 or VS11 vibration monitors. Sometimes, however, the installation of permanent monitoring equipment is not economic, not possible or undesirable for other reasons. In such cases, so-called measurement routes are used, on which vibration values are recorded at a fixed number of machines at the same measurement points in regular intervals.

The VM100 features two monitoring modes that are fundamentally different:

1. Monitoring of vibration severity (velocity) in three orthogonal directions (X/Y/Z) to evaluate unbalance and running smoothness based on the above listed standards
2. Monitoring of roller bearings by uniaxial measurement of vibration acceleration up to 24 kHz, namely RMS and peak values, spectral distribution and envelope analysis

## 4.5.2. Entering Measurement Routes

Machine vibration measurement with the VM100 can be performed with one axis or triaxial with the accelerometer on input 1, channel X or X/Y/Z respectively. Metra recommends rugged, electrically isolated industrial types, such as the single-axis KS80D and KS74C100 or the triaxial KS813B.

A measurement route is a list of measurement points to be acquired that are in close proximity to each other. It allows the condition of many machines to be recorded effectively.

Figure 27 shows the screen after the first use of the Machine Vibration module. You see the measuring route in the form of a list, which is initially still empty, because no measuring points have been created yet. The measuring route is saved under the default file name routes.csv. You can use this route file for the beginning or create a new one.

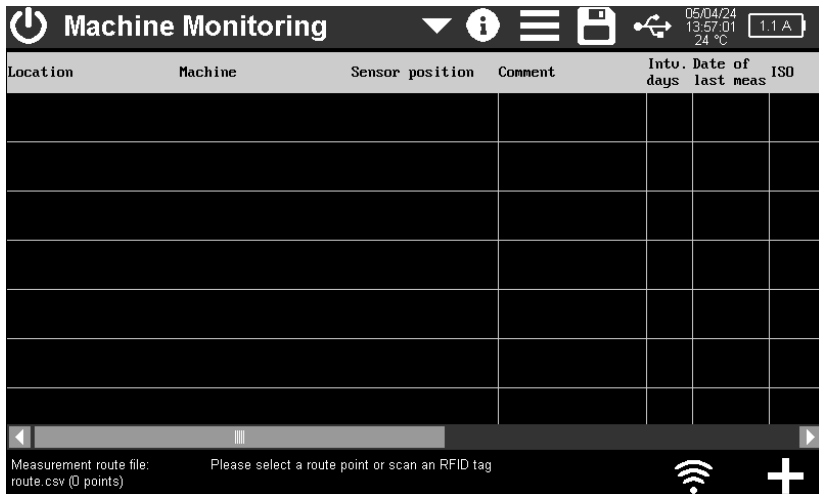


Figure 27: Module Machine Vibration with empty measurement route



To create a new route file, touch the Save button . Enter the file name for the new route file (Figure 28). Measurement routes are always saved as a CSV file in the ROUTES folder of the SD card. The file extension does not need to be entered.



Figure 28: Creating a route file

### 4.5.3. Creating Measurement Points in a Route

Each measuring point is created as a CSV file in the TREND folder of the SD card. The measuring point ID is used as file name. In addition, the measuring point ID is saved in the associated measuring route file.

The VM100 offers the possibility of measuring point identification with NFC tags. Especially for more extensive measurement routes or a large number of measurement objects, this can be very helpful to keep track. All you have to do is attaching an NFC tag to the measurement location. Touch  to start the detection (Figure 29). To do this, bring the upper left corner of the VM100 close to the NFC tag (see section 5.2). If the NFC tag was recognized, confirm the creation of a new measuring point. The NFC serial number is used as measuring point ID.

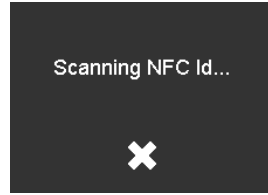


Figure 29: NFC detection

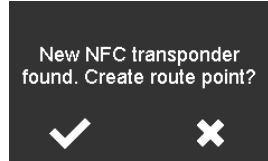



Figure 30: NFC tag found

To create a measuring point without NFC, touch . The measuring point ID is in this case assembled from the date and time.

A window opens for entering the measuring point data (Figure 32). Here you enter a description and define the measurement mode, limit values and measurement interval. The measuring interval is used to mark overdue measuring points (see p. 32).

➔ If you select another measuring point with a similar description by touching the respective line before creating a new measuring point, its description data will be used for the new measuring point as default. This can simplify the input.

Under Location, Machine, Position and Comment you enter information about the measuring point with the key pad. The entries ideally follow a hierarchy from general to detail.

Now select a monitoring mode (Figure 31). You can select whether RMS or peak values are measured, in both cases in three axes for X/Y/Z. You can set integration and filtering in the menus below. For example, you can select the most common settings RMS, single integration, high pass 10 Hz and low pass 1000 Hz to measure the vibration severity.

Alternatively, you can select the bearing mode if you want to monitor the condition of a roller bearing. This is a single-channel measurement. The three menu entries are used to define the sensor output used if a triaxial sensor is used.

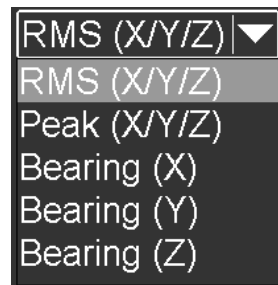


Figure 31: Monitoring mode

## Add a Route Point ID: 240405142416 ✕ ✓

|             |   |              |    |
|-------------|---|--------------|----|
| Location    | Saxonia AG Hall 2                             |              |    |
| Machine     | Waste water pump                              |              |    |
| Position    | Top   |              |    |
| Comment     | x dir. marked                                 |              |    |
| Help        | RMS (X/Y/Z) ▼                                 | Sensor 1/min | 3  |
|             |   | avg. no.     | 30 |
|             | days  |              |    |
| Integration | single ▼                                      |              |    |
| High pass   | 10 Hz ▼                                       |              |    |
| Low pass    | 2000 Hz ▼                                     |              |    |
|             | High pass frequency <= 1/3 low pass frequency |              |    |
| Alarm       | 7.1 mm/s                                      |              |    |
| Warning     | 4.5 mm/s                                      |              |    |

Figure 32: Adding a new route point

Acceleration is always measured in bearing mode. Integration is therefore not available for selection. The low-pass filter is permanently set to the highest frequency of 24 kHz in order to detect the widest possible range of damaging frequencies. The high-pass filter can be freely selected. It is used to keep out low-frequency unbalance vibrations from other machine components. In many cases, a high-pass filter with 1 kHz is appropriate, as rolling bearing damaging frequencies mostly occur at higher frequencies.

Vibration measurements on machines are often influenced by several components and can therefore exhibit short-term fluctuations. For reproducible measurement results, averaging over a specified number of display cycles can be useful. The entry  avg. no. determines how many measurements of one second duration are averaged. Averaging is used for displaying and saving the measured values. If “1” is entered, no averaging takes place.

A vibration measurement becomes more informative and comparable if the rotation speed is also recorded. The VM100 allows the connection of a VM100-LS photoelectric reflex switch (see figure 68 on page 46) to the "RPM" input of the VM100, which serves as rotation speed sensor. This requires a reflex mark on the rotor. Under  is indicated whether the speed is to be measured. In this case, “Sensor” is displayed. If the speed is known or constant, its value can be entered here in 1/min and no measurement is carried out. You can return to the “Sensor” display by entering a zero.

Finally, the required measuring interval  days is displayed in days. This serves as a reminder that a measurement is due. Overdue measuring points are highlighted in red in the route table.

No limit values for pre-alarm or warning and alarm must be entered.

After you have closed the measuring point menu with , the newly created measuring point appears with all its settings in the measuring route table (Figure 33).

- ➔ Each time a measurement route file (\*.csv) is changed, the previous file is saved under the same name with the extension “bak”. The old route file can be restored by renaming the extension to “csv”.

The lines of the measuring route table appear in alphabetical order according to the details for location, machine and sensor position. The sorting direction can be changed using the arrow in the table header.


The screenshot shows the 'Machine Monitoring' application interface. At the top, there is a title bar with a power icon, the text 'Machine Monitoring', and several utility icons (dropdown, info, menu, save, share, battery, and temperature). The temperature is displayed as 24 °C. Below the title bar is a table with the following columns: Location, Machine, Sensor position, Comment, Intu. days, Date of last meas, and ISO. The table contains one row of data: Saxonia AG, Hall 2, Water pump A, Red circle, 30, ---/---, and ISO 10816-7. At the bottom of the screen, there is a status bar with the text 'Measurement route file: saxonia.csv (1 points)', a prompt 'Please select a route point or scan an RFID tag', and icons for Wi-Fi and a plus sign.

| Location   | Machine | Sensor position▲ | Comment    | Intu. days | Date of last meas | ISO         |
|------------|---------|------------------|------------|------------|-------------------|-------------|
| Saxonia AG | Hall 2  | Water pump A     | Red circle | 30         | ---/---           | ISO 10816-7 |

Figure 33: Route table with one route point

#### 4.5.4. ISO Standard Assistant for Vibration Severity

If no empirical values are available for the warning and alarm limits, the limits from the relevant ISO standards can be used for vibration severity monitoring.

 opens a selection menu with the most common ISO standards for measuring vibration severity on different machine types with the relevant selection criteria (Figure 34). Once the selection has been made, the corresponding limit values for warning and alarm are displayed. Exit with  to transfer them to the measuring point menu. The measurement settings are also made according to the selected standard.

No limit value recommendations from ISO standards are available for roll bearing monitoring.

### Machine Monitoring Standards Assistant

Standard: ISO 20816-3: Industrial machine >15 kW

Group: Medium (15-300 kW), motor shaft height 160-315 mm

Support: Rigid

Rotary speed: >600 rpm

Mode: RMS

Integration: single

High pass: 10 Hz

Low pass: 1000 Hz

Alarm: 4.5 mm/s


Warning: 2.8 mm/s

Figure 34: ISO assistant

## 4.5.5. Measurement of Machine Vibration

### 4.5.5.1. Measurement Screen

Once a measuring point has been created, measurements can be taken for trend monitoring. Touch the line of the route table with the desired measuring point to select it. The background color is then highlighted in blue (Figure 35).

If the measuring point was created with an NFC tag, you can also have the measuring point selected automatically after touching  and reading in the NFC serial number.

Machine Monitoring


08/04/24 14:32:56 25 °C


| Location   | Machine | Sensor position  | Comment | Intv. days | Date of last meas | ISO |
|------------|---------|------------------|---------|------------|-------------------|-----|
| Saxonia AG | Hall 2  | Waste water Pump | Top     | 30         | ---/---/---       |     |
|            |         |                  |         |            |                   |     |
|            |         |                  |         |            |                   |     |
|            |         |                  |         |            |                   |     |
|            |         |                  |         |            |                   |     |
|            |         |                  |         |            |                   |     |

Measurement route file: saxonia.csv (1 points)


mm/s

Figure 35: Route table with selected measuring point

You can use the button  to subsequently edit the selected measuring point. This applies to the location, machine, position, comment, speed, averaging, measuring interval and limit values. For reasons of consistency with measurements that have already been saved, the information on the measured variable can no longer be edited.

Press  to delete the selected measurement point from the measurement route.

➔ This does not delete the file with the measured values from the SD card.

Touch  to switch to the measurement and trend view ().

#### 4.5.5.2. Measurement of Vibration Severity

The display for vibration severity measurement in RMS/peak or ISO mode is explained below (Figure 36).

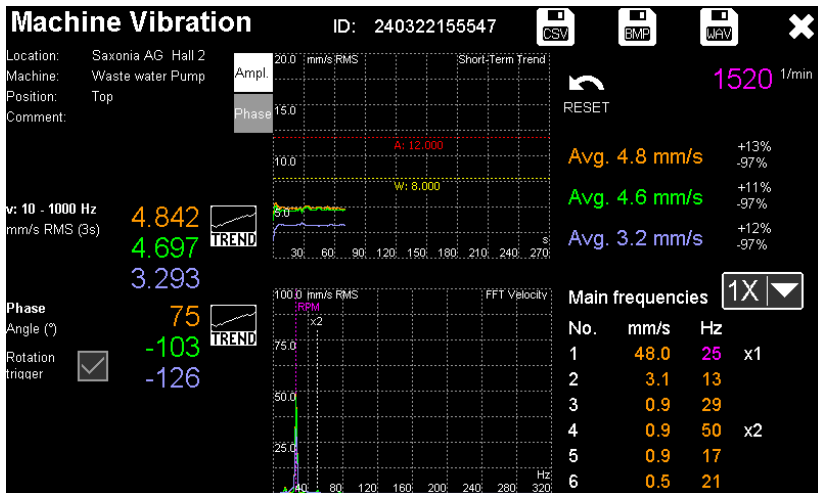


Figure 36: Vibration severity measurement in RMS/Peak or ISO mode

##### 4.5.5.2.1 Display of Overall Values and Phase Angles

After a 15-second settling time, you will see the currently measured vibration values for X/Y/Z in the unit of measurement of the selected vibration quantity in the left-hand area below the measuring point description. These can be RMS or peak values for acceleration, velocity or displacement. The set filters are also displayed. The measured values are averaged according to the setting (value in brackets in seconds). The filter and measurand settings of the three direction values X/Y/Z are always the same.

The amplitude values are compared with the warning and alarm limit values stored in the route table. If they are exceeded, a yellow warning or red alarm symbol (Figure 37) appears.



Figure 37: Alarm icon



Below you will find the phase angles of the three measured values. Observing the phase angles over a longer period of time provides sensitive information when the machine condition changes. It is not the absolute phase angles that are relevant here, but the relative phase differences between the three channels.

The VM100 supports two methods of phase measurement:

1. Phase relative to a trigger pulse: This method is preferable because it provides more reliable results, especially when the signal consists of different vibration frequencies and the signals are noisy. The trigger pulse is provided by a VM100-LS speed sensor (see Figure 68 on page 46) at the “RPM” input of the VM100 and a reflex marker on the rotor. The tick at  activates the trigger pulse. It is set automatically when a rotation signal is detected (top right-hand corner of the screen). Otherwise, “Red.?” is displayed instead of the phase angle.
2. Phase relative between channels X/Y/Z: If it is not possible to use a speed sensor, the phase angles between the channels can be determined by cross-correlation. Channel X provides the reference phase and is set to zero. Channels Y and Z show the phase angle relative to X.

The value range of the phase measurement is  $-180^{\circ}$  to  $180^{\circ}$ .

- ➔ Unstable phase angles or a frequent change of sign are indications of unreliable detection of the main frequency due to noisy vibration signals.
- ➔ For measurements according to ISO 20816-8 with acceleration, velocity and displacement, no phase angles are output for reasons of space (Figure 38).

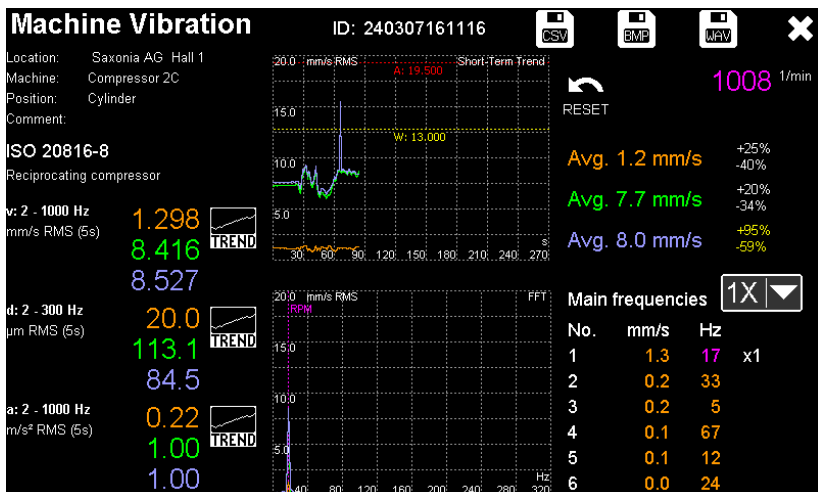


Figure 38: Measurement according to ISO 20816-8


#### 4.5.5.2.2 Short-Term Trend of Overall Values

The short-term trend of the three vibration values of the last 270 seconds is displayed graphically in the top center of the screen. The color assignment corresponds to the measured value display. These are the unaveraged measuring values. The diagram also contains the two limit lines for warning (yellow) and alarm (red). It is automatically scaled so that both the maximum value and the limit values can be displayed.

To the right of the diagram, the three mean values and fluctuations in percent are displayed. The color of the percentages is yellow above 50 % and red above 100 %. The short-term trend provides information about the stability and plausibility of the measured values. In the event of fluctuations of more than 100 %, an immediate investigation should be carried out to check for measurement errors or acute machine damage.

Alternatively, you can also switch to the short-term trend of the phase angle (Figure 39).

The graphical display of the phase can also be used to determine resonance points at variable speed.

Press  to delete the short-term trend and restart recording.

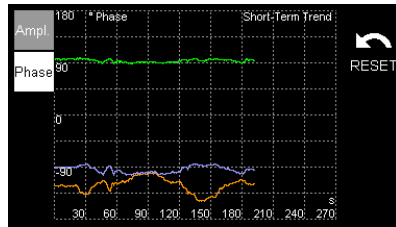


Figure 39: Short-term trend of phase

#### 4.5.5.2.3 Frequency Spectrum (FFT)

In the lower center of the screen you will find the spectral representation of the measured vibration magnitude in the range from 3 to 300 Hz (Figure 40). This can help to assign the vibrations to specific components of the machine. The rotational frequency measured or entered by the sensor is displayed as a spectral line labeled "RPM". The color assignment of the frequency spectra corresponds to the measured value display. To the right of the spectrum you will find a list of the six largest amplitudes for the selected measurement channel. The rotational frequency is displayed in the color of the speed and marked with "x1" for the fundamental frequency. Any harmonics that occur, i.e. integer multiples of the rotational frequency, are also marked. Harmonics occur, for example, due to misalignment of coupled rotors, meshing frequencies in gears or blade passing frequencies in blowers. Structural looseness can also be detected via harmonics.

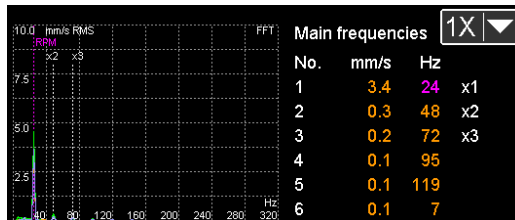



Figure 40: Frequency spectrum and main frequencies

#### 4.5.5.2.4 Long-Term Trend of Vibration Severity and Phase

Pressing  in the measurement display opens the trend diagram of vibration severity or phase angle. It shows the development of the measured values and thus the machine status over the entire monitoring period. This can be weeks, months or even years. The data is taken from the TREND\_\*.csv file in the TREND folder. Figures 41 and 42 show an example.

The warning and alarm limits are also displayed in the vibration severity diagram.

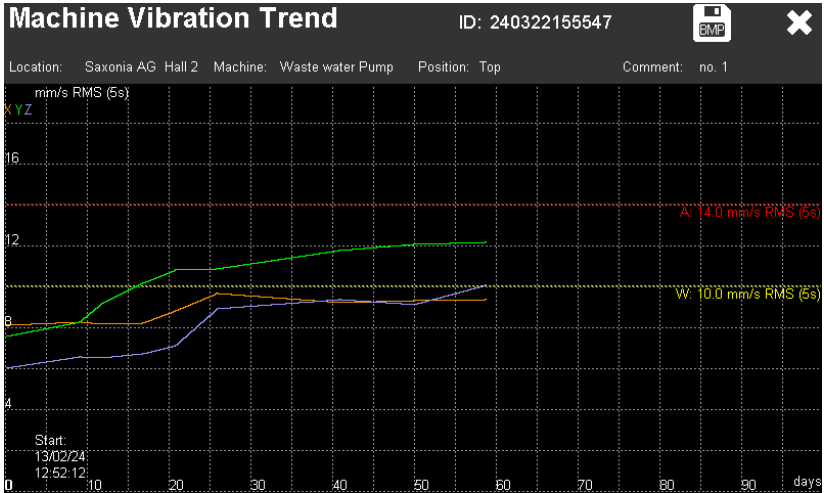


Figure 41: Long-term trend of vibration severity

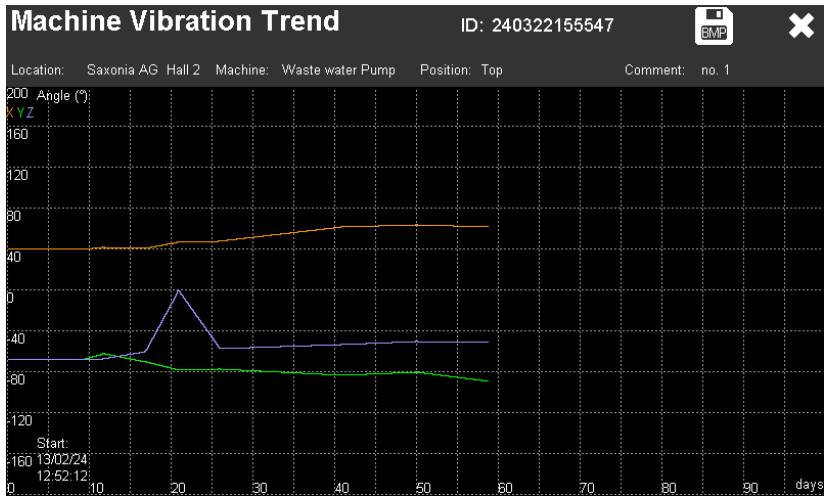


Figure 42: Long-term trend of phase

## 4.5.6. Measurement of Bearing Vibration

In addition to the vibration severity caused by rotating unbalance and moving parts, the vibrations in roller bearings can also be measured. The VM100 offers a set of analysis functions for this purpose, which can be used to make a statement about the maintenance condition of a bearing without profound knowledge of bearing diagnostics. In contrast to the vibration severity, high frequencies in the kilohertz range, where the damage mainly manifests itself, are considered here. Only one channel and only acceleration is measured. As shown in Figure 31 on page 26, the sensor channel used (X/Y/Z) is defined when the measuring point is created. Figure 43 shows the structure of the measurement screen.

All measured values and graphics are displayed in the color of the specified channel.

→ For reliable transmission of high vibration frequencies, the sensor must be mounted as close as possible to the rolling bearing. The mounting point must be flat and smooth.

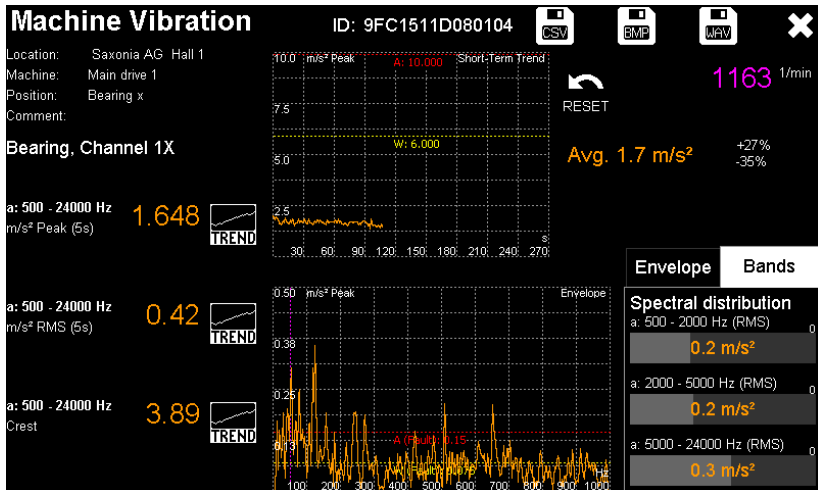


Figure 43: Measurement in bearing mode

### 4.5.6.1.1 Measurement of Overall Values

On the left-hand side of the screen, below the measuring point information, the three broadband overall values relevant for roller bearings - peak value, RMS value and crest factor of acceleration - are displayed. They are each determined from the entered high-pass frequency up to 24 kHz (see section 4.5.3). The averaging number set when the measuring point is created is applied (value in brackets in seconds).

The crest factor is the quotient of peak and RMS value and is therefore unitless. It is a measure of the “peakiness” of a signal. For a pure sinusoidal oscillation, the crest factor would be  $\sqrt{2}$ . If steep pulses are present, such as those that occur when rolling over damaged areas in the bearing, the crest factor increases significantly and can reach values above 10.

The peak value is compared with the warning and alarm limits stored in the route table. If they are exceeded, a yellow warning or red alarm symbol (Figure 44) appears.




Figure 44: Warning icon

#### 4.5.6.1.2 Short-Term Trend of Peak Value

The short-term trend of the peak value of the last 270 seconds is displayed graphically in the top center of the screen. These are the unaveraged values. The diagram also contains the two limit lines for warning (yellow) and alarm (red) specified in the route table. The amplitude axis is automatically scaled so that both the highest peak value and the limit values are displayed.

To the right of the diagram, the mean value and the fluctuation in percent are displayed.

Press  to delete the short-term trend and restart recording. The short-term trend provides information about stability and plausibility of the measured values.

#### 4.5.6.1.3 Envelope Spectrum

The envelope spectrum is a very powerful tool in bearing diagnostics. In the lower center of the screen you can see the spectrum of the envelope signal. The envelope curve is formed by rectifying and low-pass filtering the signal. The result is subjected to a frequency analysis (FFT), the result of which you can see in the diagram. In contrast to the frequency analysis of the direct vibration signal, the envelope spectrum allows periodic signal components, such as those generated by damaged roller bearings, to emerge particularly clearly.

The amplitude axis is scaled as the peak value of the acceleration. Warning and alarm limits are shown in the diagram as yellow and red lines. These are the following empirical values (“rule of 1” according to D. Franke):

- $<0.075 \text{ m/s}^2$ : No fault
- $0.075 \text{ m/s}^2$ : Warning limit for faults
- $0.15 \text{ m/s}^2$ : Alarm limit for faults
- $0.75 \text{ m/s}^2$ : Warning limit for damage
- $1.5 \text{ m/s}^2$ : Alarm limit for damage

In this context, faults are wear-related changes which do not affect operation. Damage, on the other hand, is a serious change that requires repair.

Depending on the maximum amplitude present, either the limits for faults or for damage are displayed.

Figures 46 and 45 show the difference between a slightly worn and a damaged ball bearing (note the amplitude scaling).

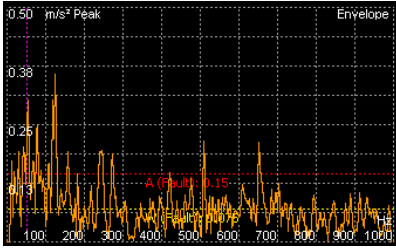


Figure 45: Envelope spectrum of a slightly worn bearing without damage

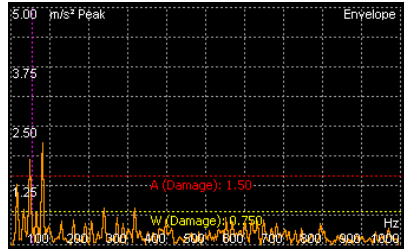


Figure 46: Envelope spectrum of a similar bearing with inner race damage

The six largest spectral amplitudes and the corresponding frequencies are displayed to the right of the envelope spectrum (figure 47).

The envelope analysis used here is a simplified tool for route measurements. It is not intended to diagnose bearing damage in detail. Special analyzers, such as the envelope module of the VM100 (see section 4.6), are suitable for this purpose.

| Envelope                | Bands                         |
|-------------------------|-------------------------------|
| <b>Main frequencies</b> |                               |
| 1                       | 80 Hz: 2.13 m/s <sup>2</sup>  |
| 2                       | 48 Hz: 1.78 m/s <sup>2</sup>  |
| 3                       | 15 Hz: 1.26 m/s <sup>2</sup>  |
| 4                       | 319 Hz: 0.79 m/s <sup>2</sup> |
| 5                       | 238 Hz: 0.77 m/s <sup>2</sup> |
| 6                       | 33 Hz: 0.74 m/s <sup>2</sup>  |

Figure 47: Amplitude list


#### 4.5.6.1.4 Frequency Bands

This display section provides an overview of whether the dominant vibration frequencies are in the lower, middle or upper frequency range. As the damage progresses, a statement can be derived from the trend of these measured values. The more severe the damage, the more the damaging frequencies shift towards lower frequencies.

| Envelope                     | Bands                |
|------------------------------|----------------------|
| <b>Spectral distribution</b> |                      |
| a: 500 - 2000 Hz (RMS)       | 0.4 m/s <sup>2</sup> |
| a: 2000 - 5000 Hz (RMS)      | 0.4 m/s <sup>2</sup> |
| a: 5000 - 24000 Hz (RMS)     | 0.5 m/s <sup>2</sup> |

Figure 48: Frequency bands

#### 4.5.6.1.5 Long-Term Trend

Pressing  on the measurement screen opens the trend diagram of the peak value, RMS value or crest factor. It illustrates the development of the respective values and thus the change of the bearing condition over the entire monitoring period. This can be weeks, months or even years. The data is taken from the TREN\*\_\*.csv file in the TRENDFolder. Figure 49 shows an example.

The peak value diagram additionally shows the warning and alarm limits.

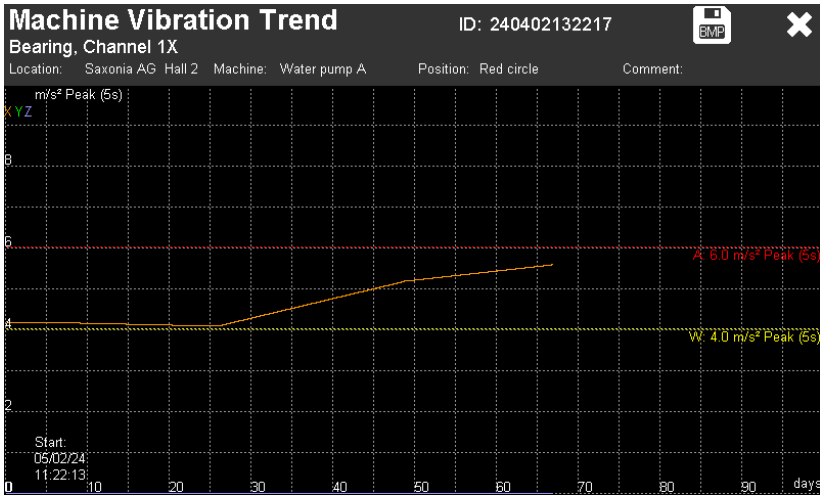


Figure 49: Peak long-term trend

#### 4.5.7. Saving Machine Vibration Measurements

On the measurement screen, you will find three options for saving (Figure 50).



Figure 50: Saving functions

- **CSV:** All displayed values are saved with a time stamp in a table belonging to the corresponding measuring point in CSV format on the SD card in the TREND directory to enable a trend view. You can also import the CSV files into a spreadsheet program. Figure 54 shows an example.
- **BMP:** A screenshot of the measurement screen, but with the controls hidden, is saved as a bitmap file (extension bmp) on the SD card in the TREND directory. The file name consists of “MEAS”, the measuring point ID and the date and time, e.g.: MEAS\_240410125946\_100424\_153447.bmp.
- **WAV:** Enables the raw data recording of the captured samples of a measurement channel in wave format, saved on an SD card in the TREND directory. A channel is recorded for 20 seconds at a sampling rate of 48828 samples/second with 24 bit resolution (figures 51 and 52). The samples are the raw data from the analog-to-digital converter. A gain of 1, 10 or 100 can be set before saving. The resulting output ranges are  $\pm 10$  V,  $\pm 1$  V or  $\pm 0.1$  V. A comment block ICMT containing information on the instrument and its settings is stored in the header data.  
Example:

```
VM100A 22136 001.010 001.042. 001.147 100 1X
```

Included are the device type, its serial number, the transducer sensitivities of 1X/1Y/1Z, the gain (1/10/100) and the channel used. The file name consists of “MEAS”, the measuring point identifier and the date and time, e.g.: MEAS\_240410125946\_100424\_153658.wav

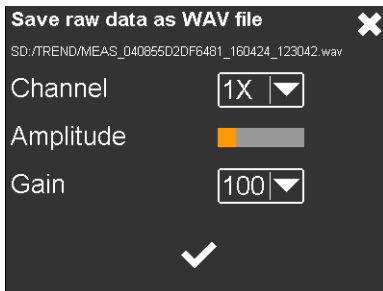


Figure 52: WAV recording menu

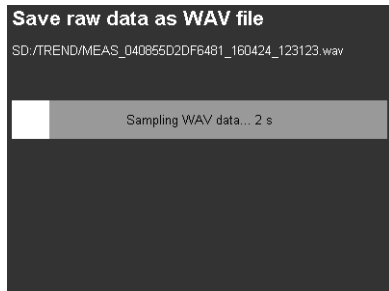


Figure 51: WAV recording

The date of the last measurement saved in CSV format is displayed in the measuring route table for each measuring point. The VM100 uses the date to determine whether it is still within the defined measurement interval (see section 4.5.3) or whether a new measurement is due. Figure 53 shows an example.

The colors mean:

- Green: The last measurement is within the interval
- Orange: The measurement interval was exceeded by < 20 %.
- Dark red: The measurement interval was exceeded by > 20 %
- Light red: The measurement interval was exceeded by > 100 %

| Intv. days | Date of last meas | ISO        |
|------------|-------------------|------------|
| 10         | 08-03-24          | ISO 20816- |
| 15         | 12-04-24          |            |

Figure 53: Date of saving

|    | A            | B  | C | D | E    | F | G | H    | I | J | K   | L  | M   | N  | O   | P   | Q   | R  | S   | T  | U   | V   | W   | X    | Y    | Z    | AA |  |
|----|--------------|--|---|---|------|---|---|------|---|---|-----|----|-----|----|-----|-----|-----|----|-----|----|-----|-----|-----|------|------|------|----|--|
| 1  | TREND DATA   |  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 2  | ID           | ZE-111   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 3  | Instr.       | VM100*Ser.: ZE+05  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 4  | Sen.         | 1*KS82*Ser.: ZE+05 Sensit* 10.12 mV/ms*-2  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 5  | Sen.         | 1*KS82*Ser.: ZE+05 Sensit* 10.09 mV/ms*-2  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 6  | Sen.         | 1*KS82*Ser.: ZE+05 Sensit* 10.071 mV/ms*-2   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 7  | Locat*       | Saxonia AG Hall 2  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 8  | Mach*        | Water pump A   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 9  | Posit*       | Red stripe   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 10 | Conn*        |  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 11 | Monit*       | Bearing Channel 1X   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 12 | Warn*        | m/s² 4 4 4 0.1 0.1 0.1 0.8 0.8 0.8   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 13 | Alarm        | m/s² 6 6 6 0.2 0.2 0.2 1.5 1.5 1.5   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 14 | Channel      | 1X 1Y 1Z 1X 1Y 1Z 1X 1Y 1Z   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 15 | HP (Hz)      | 2 2 2 0.2 0.2 0.2 0.2 0.2 0.2  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 16 | LP (Hz)      | 24000 24000 24000 10 10 10 10 10 10  |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 17 | Mode         | Peak Peak Peak RMS RMS RMS Crest Crest Crest RPM Erv1 Erv2 Erv3 Erv4 Erv5 Erv6 Band1 Band2 Band3 |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 18 | Unit         | m/s² m/s² m/s² m/s² m/s² m/s² 1/min Hz Hz m/s² Hz m/s² Hz m/s² Hz m/s² m/s² m/s²                 |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 19 | Date         | Time   |   |   |      |   |   |      |   |   |     |    |     |    |     |     |     |    |     |    |     |     |     |      |      |      |    |  |
| 20 | 12/03*12:02* | 5.1  | 0 | 0 | 0.83 | 0 | 0 | 6.15 | 0 | 0 | 800 | 75 | 1.7 | 15 | 1.3 | 170 | 0.6 | 10 | 0.5 | 60 | 0.2 | 295 | 0.2 | 0.34 | 0.34 | 0.52 |    |  |
| 21 | 25/03*10:52* | 5.2  | 0 | 0 | 0.84 | 0 | 0 | 6.19 | 0 | 0 | 800 | 74 | 1.5 | 15 | 1.2 | 191 | 0.7 | 22 | 0.4 | 60 | 0.3 | 200 | 0.2 | 0.42 | 0.33 | 0.45 |    |  |
| 22 | 12/04*10:32* | 5.6  | 0 | 0 | 0.84 | 0 | 0 | 6.73 | 0 | 0 | 800 | 72 | 1.7 | 15 | 1.4 | 221 | 0.6 | 68 | 0.4 | 60 | 0.2 | 84  | 0.1 | 0.43 | 0.33 | 0.41 |    |  |

Figure 54: Example of CSV file with bearing measurement dat

➔ It is strongly recommended that you regularly create backup copies of the route data stored on the SD card.



| Location   | Machine              | Sensor position | Comment | Intv. days | Date of last meas | ISO     |
|------------|----------------------|-----------------|---------|------------|-------------------|---------|
| Saxonia AG | Hall 1 Compressor ZC | Cylinder        |         | 10         | 12/04/24          | ISO 208 |
| Saxonia AG | Hall 1 Fan A1        | Motor           | left    | 15         | 25/03/24          |         |
| Saxonia AG | Hall 1 Fan A2        | Motor           | bottom  | 15         | 15/03/24          |         |
| Saxonia AG | Hall 1 Fan A3        | Motor           | bottom  | 15         | 12/02/24          |         |
| Saxonia AG | Hall 1 Fan dryer 1   | Motor           | bottom  | 15         | 12/04/24          |         |
| Saxonia AG | Hall 1 Fan dryer 2   | Motor           | side    | 15         | 10/04/24          | ISO 146 |
| Saxonia AG | Hall 1 Gear box drv  | Bearing z       |         | 30         | 06/04/24          |         |

Measurement route file: saxonia.csv (14 points)      Please select a route point or scan an RFID tag

Figure 55: Measurement route table with due measurements

## 4.6. Module Envelope Analysis

### 4.6.1. Introduction

Envelope analysis is a method for roller bearing diagnosis. A roller bearing, consisting of outer ring, inner ring, rolling elements and cage, generates certain characteristic rollover frequencies during when rotating, which are by their design in a relationship to the rotor rotational frequency. From an increased spectral amplitude at one of these characteristic frequencies, conclusions about wear can be drawn.

With an ordinary Fourier transform (FFT), it is hardly possible to extract the relatively weak pulses from the vibration spectrum of a roller bearing. Envelope analysis is a useful tool for this purpose. By band pass filtering and fast peak rectification, the envelope curve of the acceleration signal is obtained (Figure 56)

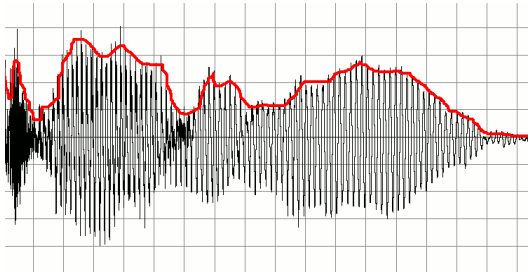


Figure 56: Envelope detection (Wikimedia)

The envelope curve then undergoes a Fourier transformation (FFT). The result is a spectral representation from which the rollover frequencies stand out more clearly.

An undamaged roller bearing usually only has a prominent amplitude at the rotational frequency in the envelope spectrum. When damage occurs, the rollover frequencies become visible as fundamental frequencies. The amplitudes increase with increasing damage.

A prerequisite for the envelope analysis is a known rotation speed and the geometry of the roller bearing for calculating the damage frequencies. Bearing manufacturers usually provide these parameters on their websites.

## 4.6.2. Measurement

A single-axis accelerometer or one axis of a triaxial transducer is used for measurement. Rugged, electrically insulated industrial types are recommended. The linear frequency range should be at least 10 kHz.

This module provides the envelope spectrum of a measuring channel (Figure 57).

In the upper section you can find the uniform menu bar, which is described in section 3.3.

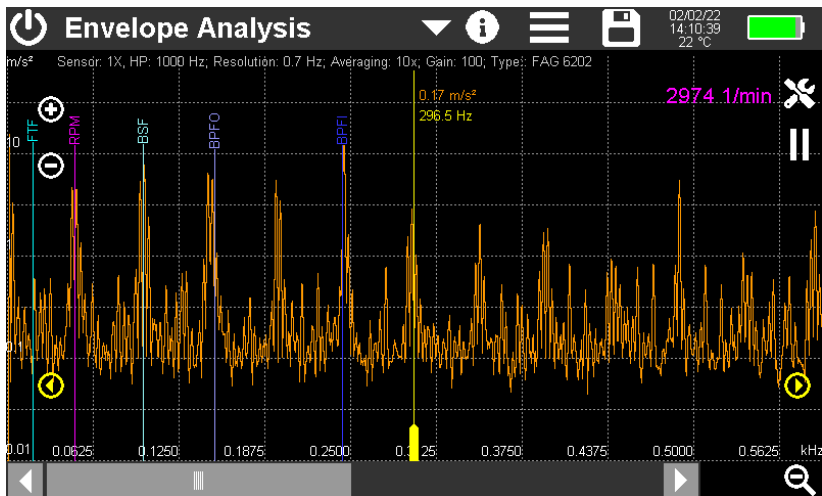


Figure 57: Measurement view of envelope analysis

The entire screen width of 800 points is used to display the envelope spectrum. At the bottom right, you will see a plus or minus button for zooming in or out of the visible frequency range. In the higher resolution frequency range you can navigate with the scroll bar. The scaling of the logarithmic amplitude axis is also done with plus/minus keys. Alternatively, you may place two fingers on the screen and pinch in or stretch out vertically or horizontally.

The speed is displayed in the upper right corner. In the upper part of the diagram the selected settings are displayed, these are measuring channel, high pass frequency, resolution, averaging, amplification and roller bearing type.

In the envelope spectrum, up to five colored markers are displayed, whose position depends on the selected roller bearing type and speed. They have the following meaning:

RPM (revolutions per minute): rotational frequency

BPFI (ball passing frequency inner race): inner ring damage frequency

BPFO (ball passing frequency outer race): outer ring damage frequency

BSF (ball spin frequency): rolling element damage frequency


FTF (fundamental train frequency): cage damage frequency

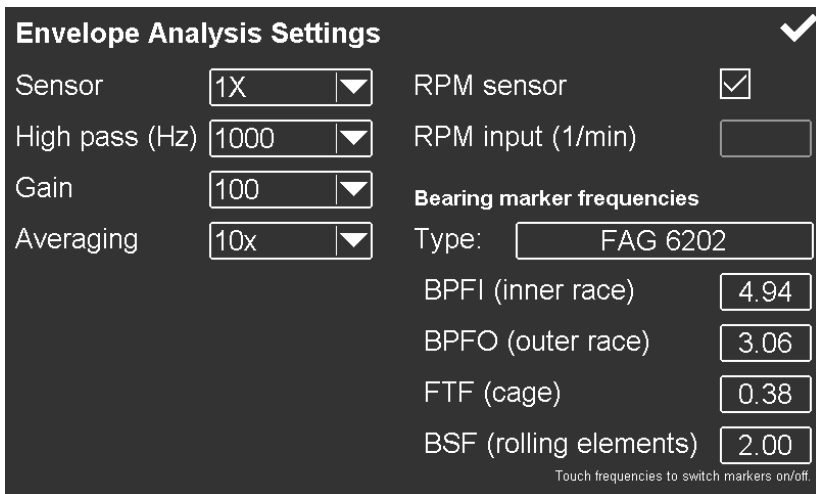
The example in Figure 57 shows the largest amplitude at marker BPFI, indicating damage to the inner ring of the bearing.

The yellow measurement cursor is shifted with the wider lower end. In addition, there are yellow arrow keys on the left and right for moving the cursor in single steps. Amplitude and frequency are shown in the upper part of the cursor.

All graphic and numerical values are shown in the characteristic color of the selected measuring channel.

FFT calculation can be paused or continued with the **||** or **▶** buttons.

Use the  button to open the settings menu (Figure 58).



| Envelope Analysis Settings |                                     |
|----------------------------|-------------------------------------|
| Sensor                     | 1X                                  |
| High pass (Hz)             | 1000                                |
| Gain                       | 100                                 |
| Averaging                  | 10x                                 |
| RPM sensor                 | <input checked="" type="checkbox"/> |
| RPM input (1/min)          |                                     |
| Bearing marker frequencies |                                     |
| Type:                      | FAG 6202                            |
| BPFI (inner race)          | 4.94                                |
| BPFO (outer race)          | 3.06                                |
| FTF (cage)                 | 0.38                                |
| BSF (rolling elements)     | 2.00                                |

Touch frequencies to switch markers on/off.

Figure 58: Setup menu for envelope analysis

With **Sensor** you select which channel of input 1 is analyzed.

**High pass** is used to suppress low-frequency vibration components, e.g. due to imbalances.

In the **Gain** menu, you can choose between automatic gain setting and the fixed gains 1, 10 and 100. In most cases "Auto" setting is recommended.

**Averaging** of 2 to 16 spectra is possible. This can significantly reduce the "noise carpet" by random signal components and improve the sharpness of the display. Averaging has a negative effect on the measuring time, however.

Select **RPM sensor** if you can measure the speed. The prerequisite for this is the connection of a VM100-PS photoelectric reflex switch to the "RPM" input of the VM100 and the attachment of a reflective label on the rotor.

If the RPM value is known, it can also be entered manually instead of RPM measurement after the check mark has been removed.

Prerequisite for the display of the damage frequencies in the spectrum is the input of the Bearing marker frequencies. This is done by touching the **Type** field. A list with the bearing types already entered opens. On the SD card, it is located in the file bearings.csv in the BEARINGS folder. File name and folder cannot be changed. If there is no such file on the SD card yet, it will be created and saved with a sample entry for the roller bearing type 6202.

When the modified file is saved, the previous version is stored as bearings.bak. By renaming it to bearings.csv, the previous state can be restored after accidental changes.

| Type       | ▲ BPF1 | BPFO  | FTF   | BSF   |
|------------|--------|-------|-------|-------|
| 6202       | 4.95   | 3.05  | 0.381 | 1.986 |
| FAG 6202   | 4.94   | 3.06  | 0.38  | 2.00  |
| ISO 7000D  | 6.13   | 3.87  | 0.39  | 1.90  |
| SKF 23960C | 18.30  | 15.70 | 0.46  | 6.46  |
| SNR 6206N  | 5.43   | 3.57  | 4.62  | 2.31  |
|            |        |       |       |       |
|            |        |       |       |       |
|            |        |       |       |       |
|            |        |       |       |       |
|            |        |       |       |       |

Figure 59: Bearing list

Touch **+** to add a new bearing. A menu opens for entering the damage frequencies (Figure 60).

**Add Bearing** ✓ ✕

Type:

BPF1 (inner race)


BPFO (outer race)

FTF (cage)


BSF (rolling elements)

Figure 60: Entering damage frequencies

The bearing name and the damage frequencies are entered by touching the corresponding input field using the screen keyboard. The damage frequencies are entered as factors relative to the rotational frequency as unitless values. You can find them either in lists provided by bearing manufacturers on their websites or you can calculate them yourself with damage frequency calculators also available on the Internet on the basis of the bearing geometry, i.e. number and diameter of rolling elements, center distance of two opposite rolling elements (pitch).

Use the  button to delete the selected line.

By touching the damage frequency values in the setup menu (Figure 58), their markers can be hidden in the measuring screen.

The following options are available for saving with the  button: The envelope spectrum is saved as CSV file in a data table (Figure 61). The header data contains information about the measuring device, sensor and roller bearing. From line 14 you will find the relative damage frequencies as factors and the measured frequencies at the rotational frequency. The measured or entered rotational speed can be found in line 18. From line 20 the frequency points and the corresponding amplitudes follow. The number of lines depends on the selected resolution.

```

ENVELOPE ANALYSIS
Instr.: VM100A Serial no.: 123456
Comment:
NFC Id:
Sensor 1X: KS903B10 Serial no.: 20014 Sensit.: 1,0313 mV/ms^2
Sensor 1Y: KS903B10 Serial no.: 20014 Sensit.: 1,0354 mV/ms^2
Sensor 1Z: KS903B10 Serial no.: 20014 Sensit.: 1,0879 mV/ms^2
Date: 02/02/22
Time: 16:54:53
Temp: 21 °C
High pass 1000 Hz
Averaging 3x
Bearing FAG 6202
BPFI 4,94 245 Hz
BPFO 3,06 151 Hz
FTF 0,38 19 Hz
BSF 2 99 Hz
Rot. speed 2970 1/min
Hz 1Y: m/s^2
0,7 6,854
1,5 0,107
2,2 0,377
3 0,73
3,7 0,433
4,5 0,063
5,2 0,046

```

Figure 61: CSV formatted envelope data (only first seven frequencies shown)

Alternatively, the graph can be saved as BMP screenshot.

For more information on the storage of measured values, see section 5.

## 4.7. Module Balancing

### 4.7.1. Introduction

Unbalance occurs when masses rotate whose center of gravity is not on the axis of rotation. A centrifugal force is generated in the direction of the unbalanced mass (Figure 62). This centrifugal force increases with the square of the rotational speed.

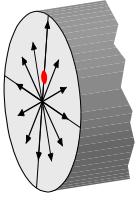


Figure 62: Unbalanced rotor

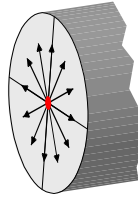


Figure 63: Balanced rotor

This results in vibrations, which are often undesirable because they impair product quality, reduce service life or lead to disturbing noises. The aim of balancing is to reduce the unbalance by changing the mass distribution (Figure 63).

The amount of mass located outside the axis of rotation multiplied by the radial distance from the shaft axis is called the unbalance. The unit typically used is gmm (gram-millimeter). An unbalance is also characterized by its direction. The combination of amount and direction is called a vector. It is convenient to use polar coordinates for the graphical representation of an unbalance.

The following types of unbalance can be distinguished:

**Static balance** occurs when the rotor axis and the mass axis are not coincident, but both axes are parallel to each other. Figure 64 shows the amount and direction of the resulting unbalance forces. The force acting on both bearings is the same.

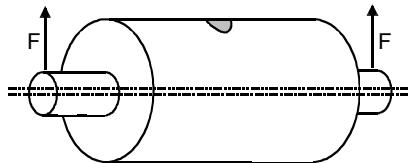


Figure 64: Static balance

**Couple balance** occurs when the rotor axis and the mass axis are not congruent and when both axes intersect at the center of mass. The resulting force effect on the bearings is equal in amount but different in direction by  $180^\circ$  (Figure 65).

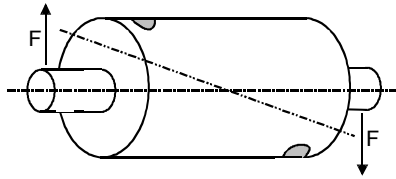


Figure 65: Couple balance

**Dynamic balance** occurs when the rotor axis and the mass axis are not congruent and when both axes intersect outside the center of mass. This case is also called two-plane unbalance. Dynamic balance is a combination of static and moment balance (Figure 66).

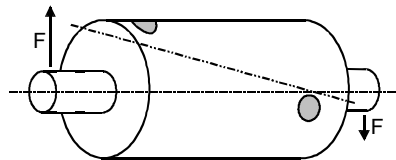


Figure 66: Dynamic balance

The rotating centrifugal force is transmitted to the rotor bearings and can be measured there with accelerometers. Depending on whether measurements are made on one or two bearings, this is referred to as one- or two-plane balancing. For disc-shaped rotors at speeds below  $1000 \text{ min}^{-1}$ , one-plane balancing is often sufficient, while longish rotors should be balanced in two planes. As a rule of thumb, rotors with a length greater than twice their diameter require two-plane balancing.

**ISO 1940** provides basic knowledge on balancing.

In addition to one or two accelerometers, a rotation speed sensor is required to provide the angular information for balancing.

The VM100 supports field balancing which means the rotor can remain in its installed state and does not need to be transported to a balancing bench. Operational balancing proceeds in the following steps:

3. In the **initial run**, the vibrations of the rotor in its initial state are recorded.
4. In the **test run**, a known test mass is applied to one end of the rotor at a known angular position. This generates a defined unbalance. The resulting vibration is recorded.
5. In the case of two-plane balancing, the test run is repeated at the other end of the rotor.
6. The balancing system calculates the **corrections** required to compensate for the unbalance on the basis of the measurements taken. This can be done by adding or removing mass at certain angular positions.
7. The success of the correction measures is verified in a **check run**.

The measurement method assumes a linear vibration system. This means that an increase in the magnitude of the vibration corresponds to an increase in the unbalance by the same magnitude. Furthermore, phase fidelity is assumed, i.e. a displacement

of the test mass by a certain angle also results in a displacement in the vibration signal by the same angle.

In practice, these prerequisites are often not met, for example because resonances or damping occur, which lead to nonlinear relationships between vibration quantities and unbalance. Therefore, it is usually necessary to approach the desired balance target in several steps.

#### 4.7.2. Measurement

Depending on the number of planes, one or two uniaxial accelerometers are used for the measurement. Robust, electrically insulated industrial types are recommended, e.g. KS80D or KS74C100. In most cases, sensors with a sensitivity of approx. 100 mV/g are recommended. At lower speeds and thus lower centrifugal forces, the accelerations are also lower, which may require the use of more sensitive transducers. The sensors are mounted radially to the axis of rotation, ideally directly on the shaft bearings. At the VM100 the sensors are connected to the measuring channels 1X and 1Y. In the operating dialog, the sensor positions are designated as plane A and plane B.

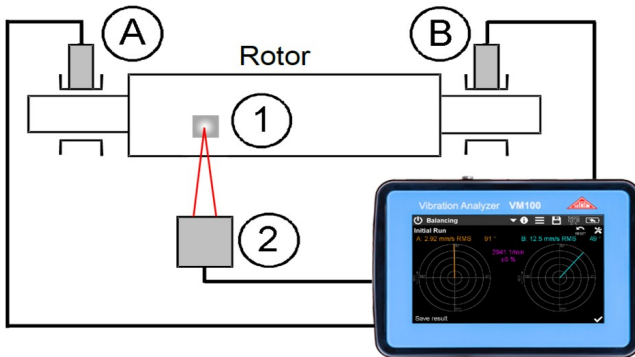


Figure 67: Two-plane balancing;  
A/B: rotor bearings (planes) with accelerometers; 1: reflective label; 2: RPM sensor

The balancing algorithm requires a rotation pulse. For this purpose, a VM100-LS photoelectric reflex switch with magnetic stand (Figure 68) is connected to the "RPM" input of the VM100 and a reflective label is attached to the rotor. The angular position of the reflective label can be freely selected. Please note that the reflective label must have a certain size at higher speeds in order to generate a sufficient pulse length.



Figure 68: VM100-LS



All angle positions of the calculated corrections are measured against the direction of rotation (Figure 69). The angles are referred to the position where the test mass was attached for the test run. This is the zero angle. The position of the reflective sticker is not relevant in this context.

In the upper section of the balancing screen you find the uniform menu bar, which is described in section 3.3.

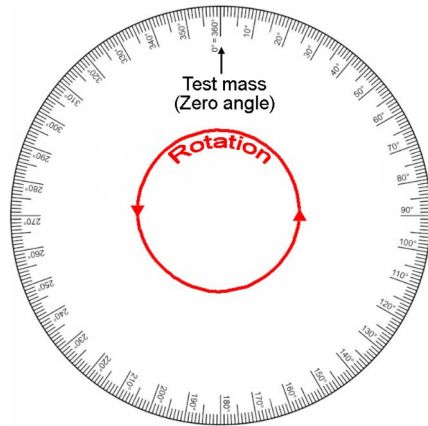



Figure 69: Angle conventions

Touch the tools icon  to open the setup menu (Figure 70).

**Balancing mode** selects between one and two plane balancing.

**RPM tolerance** is the permissible fluctuation range of the measured speed in percent. If it is exceeded, the balancing process cannot be continued.

**Gain** can be switched for both planes between automatic gain setting and the fixed gains of 1, 10 and 100. In most cases a fixed gain is recommended for balancing. If the gain is too high, overload is indicated instead of amplitude values.

**Balancing radius** is the radius on the rotor to which the test and correction masses are attached or removed. It is not mandatory to enter it. The radius is only used to calculate the residual unbalance.

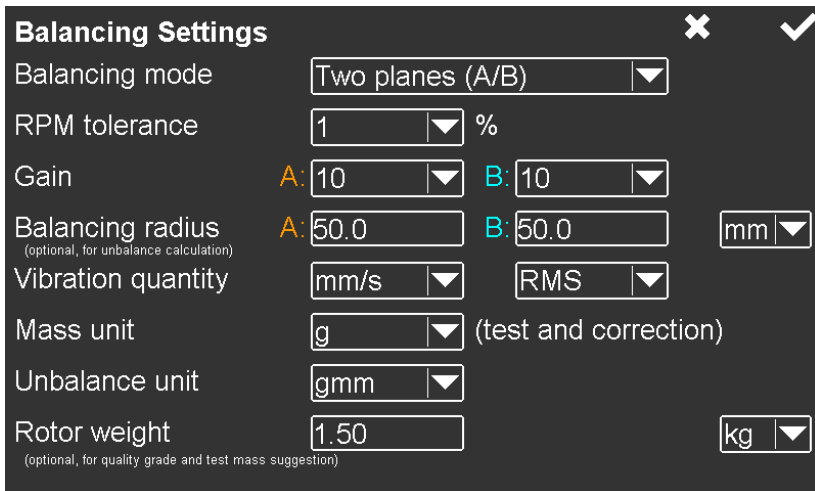


Figure 70: Balancing settings (example for two planes)

**Vibration quantity** can be selected between vibration acceleration in  $\text{m/s}^2$  and vibration velocity in  $\text{mm/s}$ . In most cases, vibration velocity will be the preferred measurement quantity.

**Mass unit** is the unit of measurement of the test masses to be entered as well as the calculated correction masses. It should be selected according to the rotor size and the desired balance quality.

**Unbalance unit** is the unit of measurement of the residual unbalance output.



**Rotor mass** can be specified optionally in order to obtain a test mass suggestion and to calculate balance qualities.

Once the settings have been made, balancing can be started.

Depending on whether one or two-plane balancing has been selected, the screen shows one or two polar diagrams for the unbalance vectors.

The following example shows the procedure for one-plane balancing.

Balancing begins with the initial unbalance run. After the accelerometer and the RPM sensor have been mounted, start rotation. The VM100 measures the speed and its variation during the last ten seconds. If speed variation is below the required tolerance, the acceleration or velocity vector is displayed in  $\text{m/s}^2$  or  $\text{mm/s}$  (Figure 71).

Amplitude and phase angle are averaged over the measurement duration so that the measured values and the vector become increasingly stable the longer the measurement runs. With the reset button  you can delete the average values and restart averaging. If a good stability is reached, the measurement is saved with  and the rotor is stopped.

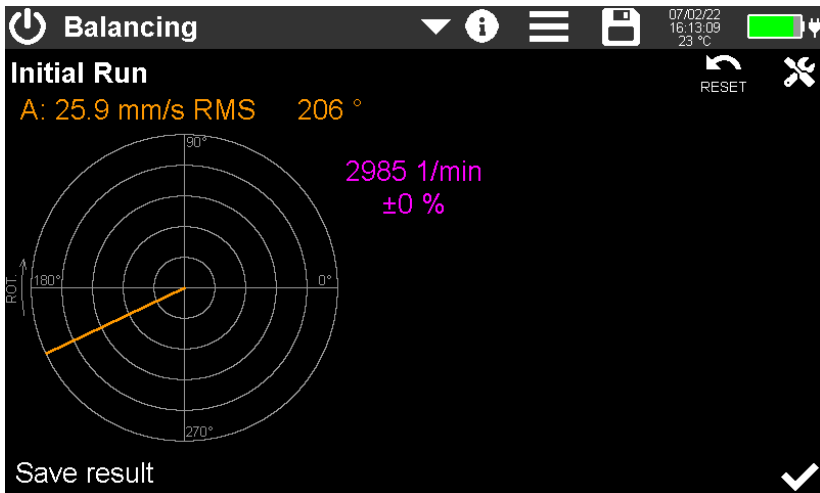


Figure 71: Initial run (1 plane)

➔ Rotation speed must remain constant during all subsequent runs. Therefore, the measured speed and its deviation from the speed in the initial run is displayed in the further runs.

After standstill, the VM100 switches to the test run. The measured initial unbalance is displayed as "O" mark in the polar diagram (Figure 72). You are prompted to apply a test mass. If the rotor mass was specified in the settings, a suggestion for the test mass based on a balance quality of 6.3 according to ISO 1940 can be given. When the mass input field is touched, a numeric input pad appears for entering the mass in the specified unit. The entered mass is displayed on the diagram at the angle 0°. The attachment angle of the test mass is the reference angle (zero angle) for all subsequent balancing steps.

The correct choice of size and angular position of the test mass requires some practice. After attaching the test mass, there must be a sufficient change in the vibration vector. It is not relevant whether the test mass increases or decreases the unbalance.

Now the test run begins (Figure 73). If the vibration vector is stable, the measurement is stored with the  button. Then the rotor is stopped again.

It may occur that the change of the unbalance is too small after the test mass has been applied. If the amplitude change is less than 20 % and at the same time the angle changes less than 10 %, a warning is issued. You can decide for yourself whether to continue or to apply a different test mass or choose another angle for it.

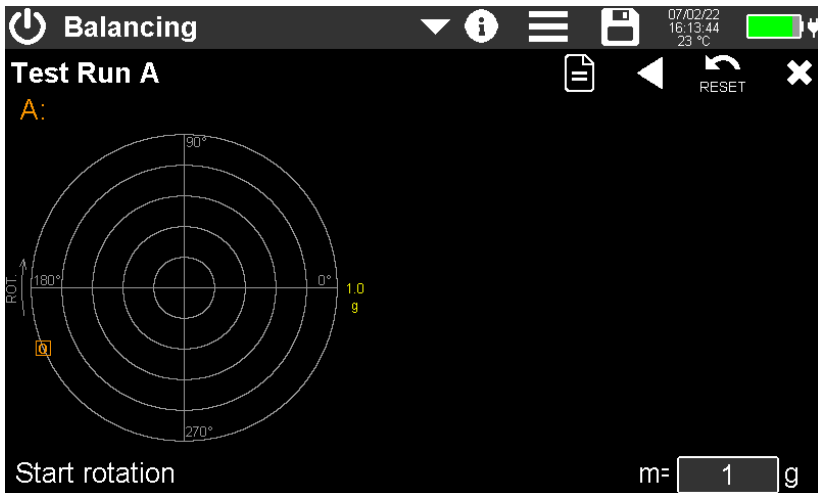


Figure 72: Attaching a test mass (1 plane)

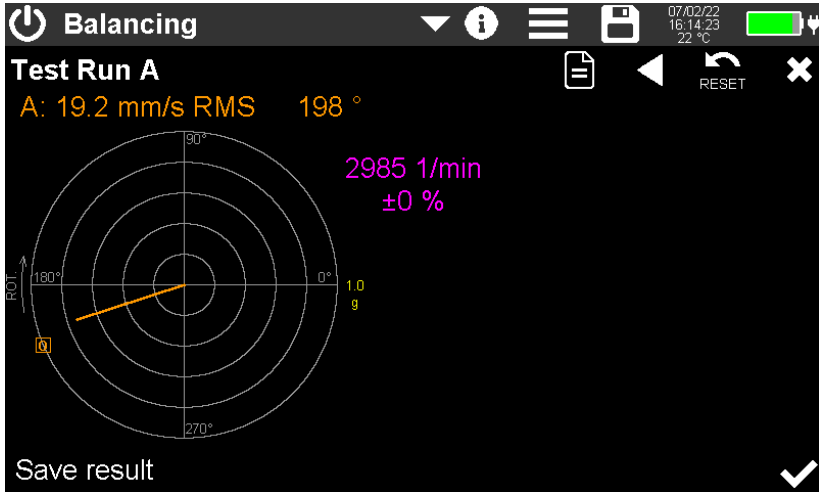


Figure 73: Test run (1 plane)

After standstill, you will be asked whether the test mass should remain on the rotor (keep) or be removed again (Figure 74). Keeping the test mass can be useful, for example, if it has been welded on. In this case, it will be considered in the subsequent correction mass calculation. Otherwise, remove the test mass and touch .

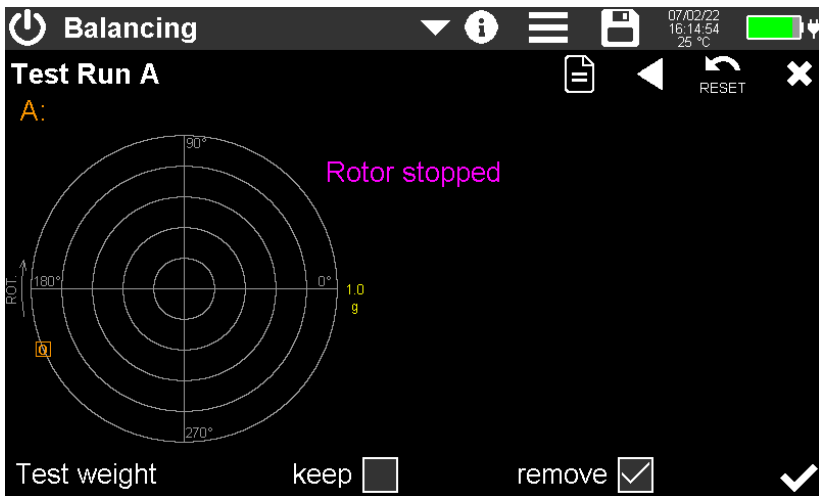


Figure 74: Keep or remove test mass (1 plane)

The unit now displays the required **corrections** (Figure 75). You have the option of adding or removing masses only at specified **fixed angle positions**. This can be useful, for example, on fan wheels with a certain number of blades. Check the box and enter the desired number of angles. If fixed locations are selected, two masses are calculated for adjacent angles, since the calculated correction practically never coincides with one fixed angle.

The results for **add** and **remove** differ only in an angular offset of 180° and the sign of the mass.

The calculated angles refer to the attachment angle of the test mass and are measured against the direction of rotation. For fixed angle positions, the angles are numbered consecutively. The angle "#0" is the angle at which the test mass was attached.

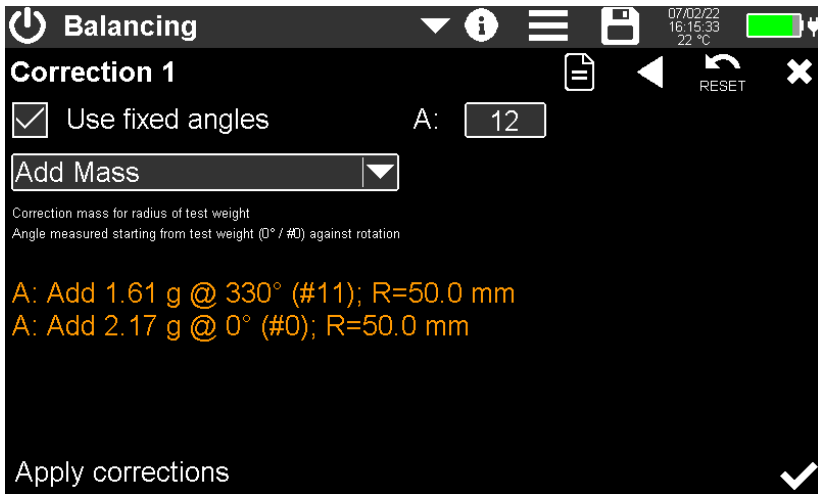


Figure 75: Corrections (1 plane)

Once the corrections have been made, confirm with  and start the rotor for the **check run** (Figure 76). You will see the resulting unbalance vector. Under amplitude and angle, the difference to the original state is displayed as a percentage. It provides information about the balancing progress. If a rotor radius was entered in the settings menu, you will see the residual unbalance in gram-millimeters. In the example shown, the residual unbalance corresponds to a mass of 1 gram at a radius of 32.1 mm. Save the result with  and bring the rotor to a stop.

You will now be asked if you want to continue balancing (Figure 77). If you are satisfied with the result, you can finish balancing with  or save a report before. If you continue balancing, correction masses are calculated again and another test run is performed.

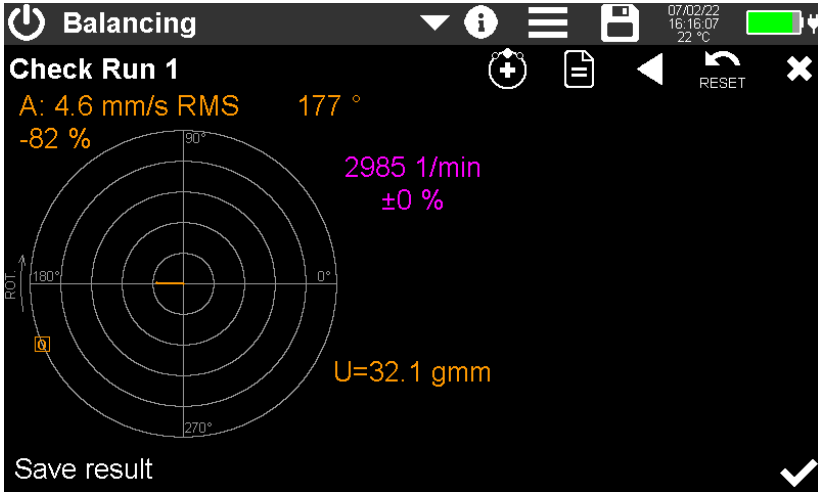


Figure 76: Check run (1 plane)

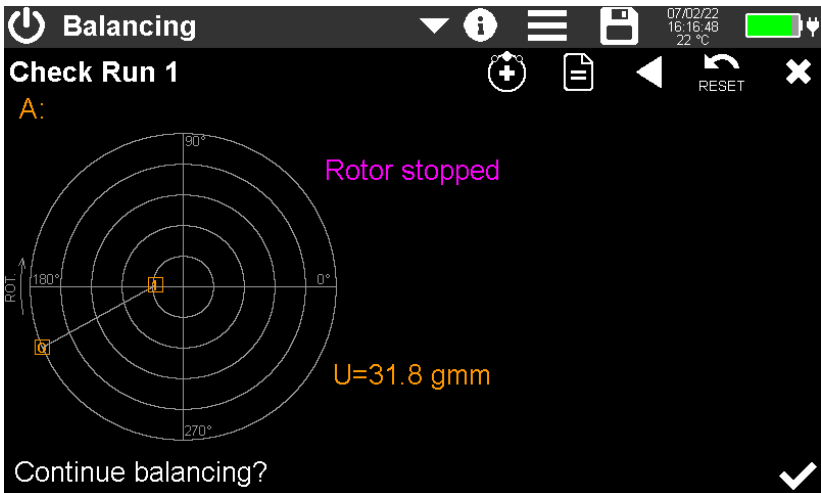


Figure 77: Continue or finish

If you ever fail to reach the desired balancing result, the following measures may be helpful:

- Change the speed to avoid possible resonances.
- Experiment with different masses and angle positions (zero angle) in the test run.
- Make tests with different sensor positions (horizontal, vertical).

**Two-plane balancing** is performed in a similar way. In addition, a second test mass is applied and a second test run is performed for plane B. The following is a brief description of the procedure based on an example.

First, the unbalance for both planes is measured in the initial condition (Figure 78).

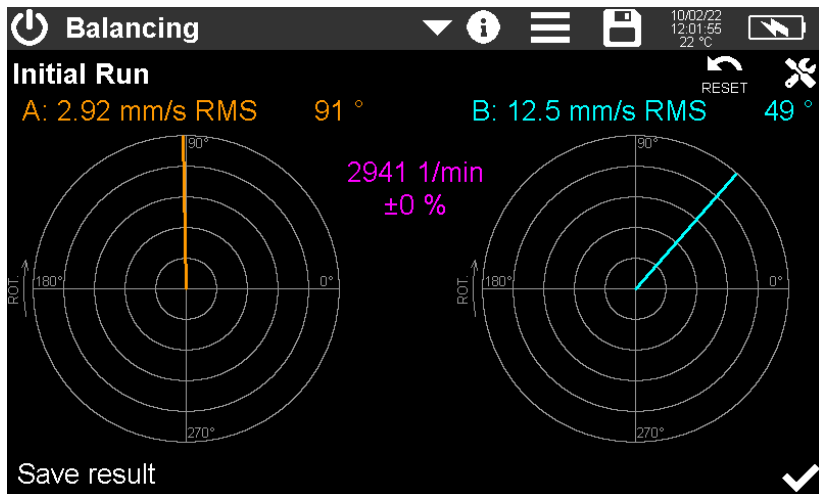


Figure 78: Initial run (2 planes)

This is followed by the application of a test mass in plane A and a restart of rotation (Figure 79).

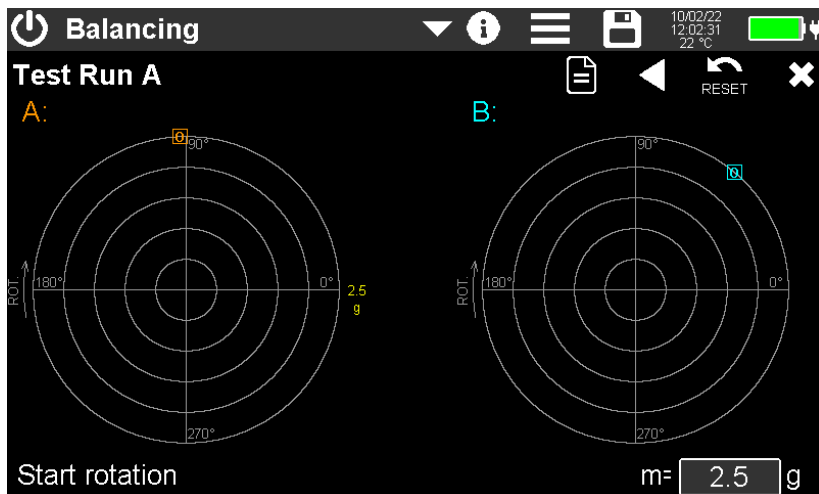


Figure 79: Attaching a test mass to plane A (2 planes)

The results of the test run at plane A are saved (Figure 80) and rotation is stopped.

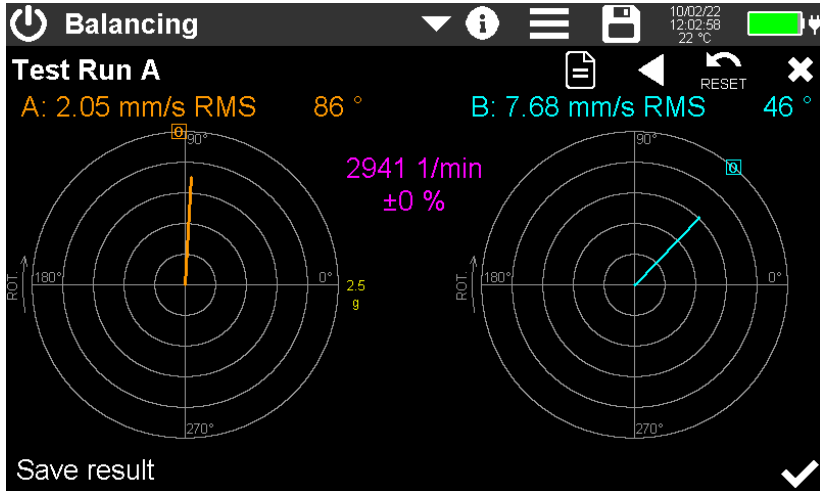


Figure 80: Test run of plane A (2 planes)

Now decide whether you want to leave the test mass on the rotor or remove it again (Figure 81). The selection later also applies to plane B.

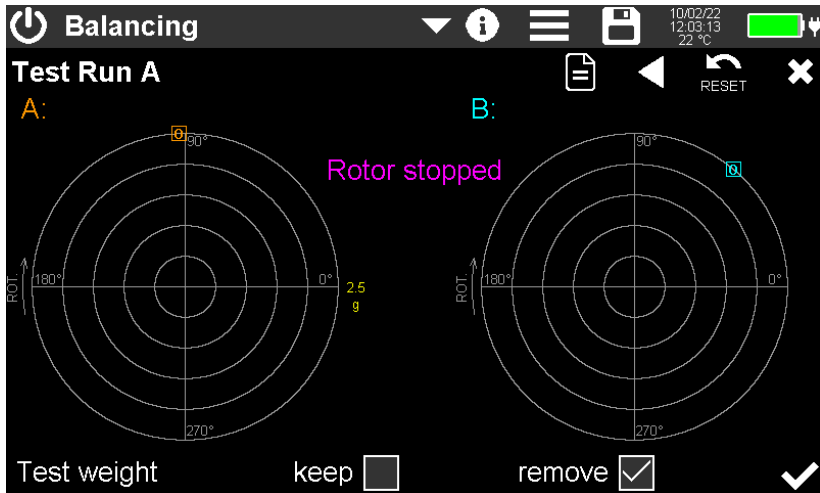


Figure 81: Keep or remove test mass of plane A (2 planes)



Then place a test mass in plane B and start rotation again (Figure 82).

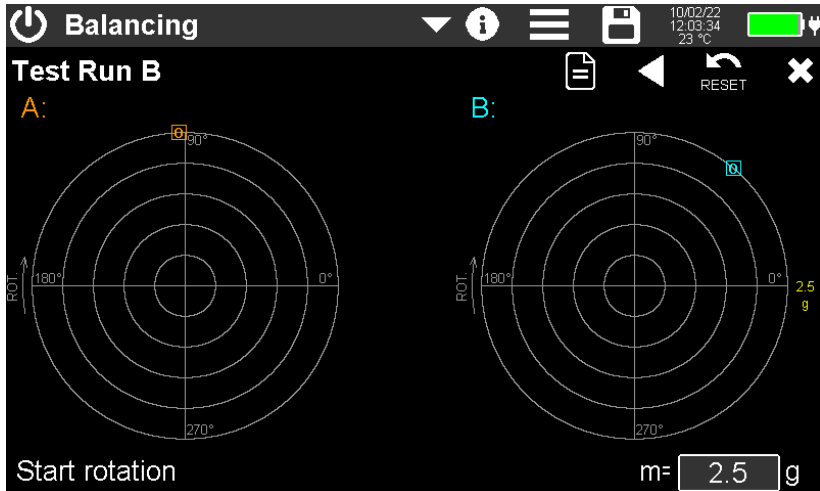


Figure 82: Attach a test mass for plane B (2 planes)

Test run B is performed. After saving and stopping the rotation, confirm that you have removed or left the test mass in plane B (Figure 83).

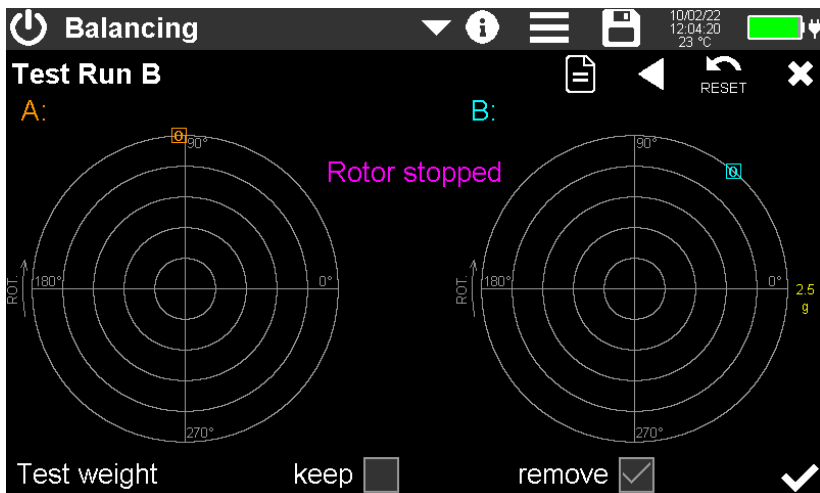


Figure 83: Confirm keeping or removing the test mass B (2 planes)

Now the calculated correction masses and their angles are displayed for both planes (Figure 84). In the example, 16 angular steps (fixed locations) were selected.

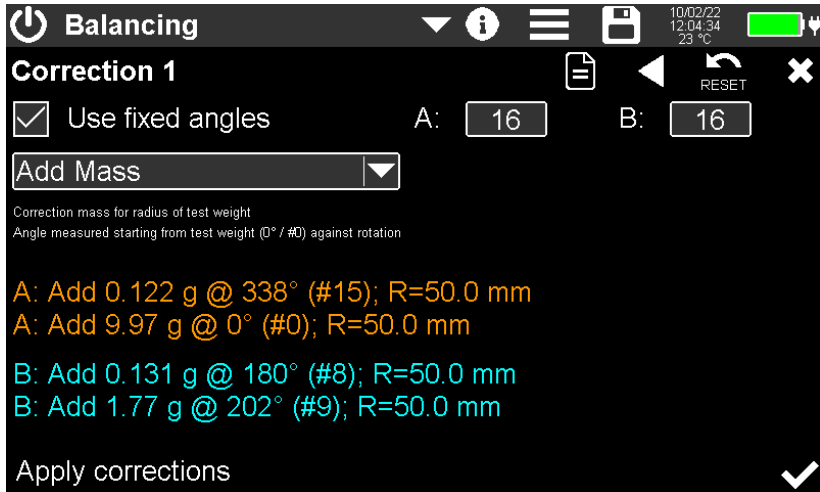


Figure 84: First correction (2 planes)

Make the corrections and confirm. Start rotation for the first check run (Figure 85).

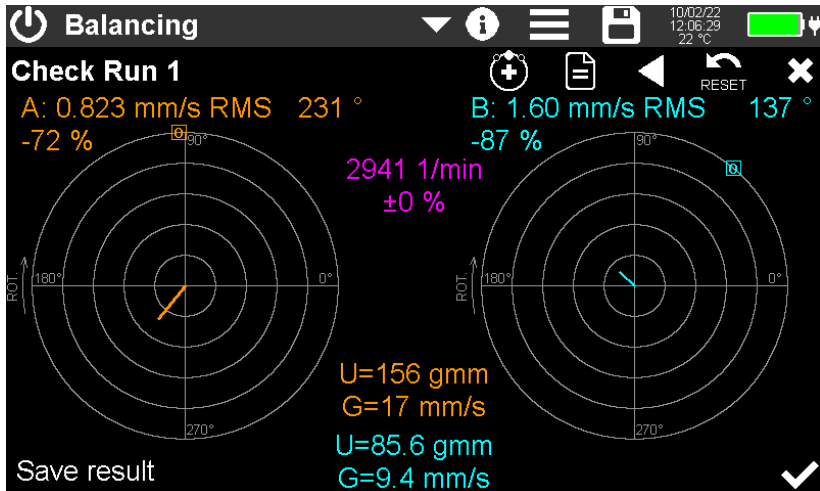


Figure 85: First check run (2 planes)

Unbalance (U) in the selected unit of measurement and balance quality (G) according to ISO 1940 for both planes are displayed below the diagram. This information is only given if rotor diameter and rotor mass have been entered in the settings menu.

After saving the result and stopping the rotation, you will be asked whether you want to finish or continue the balancing process here (Figure 86).

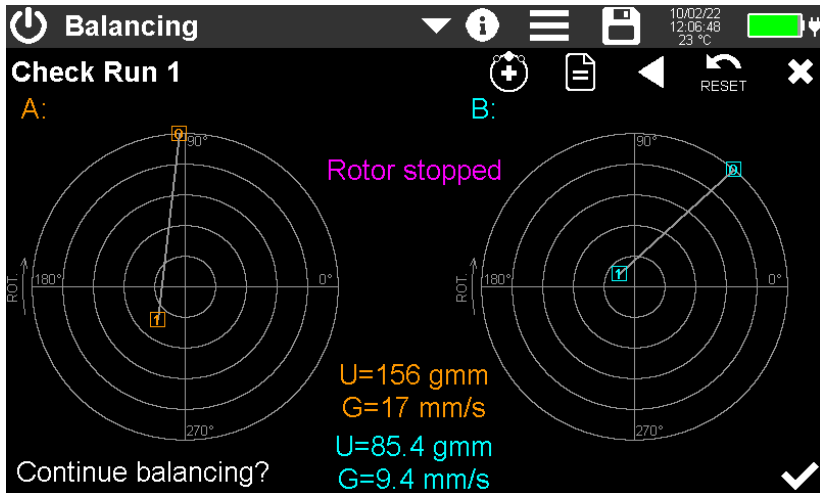


Figure 86: Continue or finish balancing after first check run (2 planes)

In this example, balancing is continued. Further corrections for both planes are displayed (Figure 87).

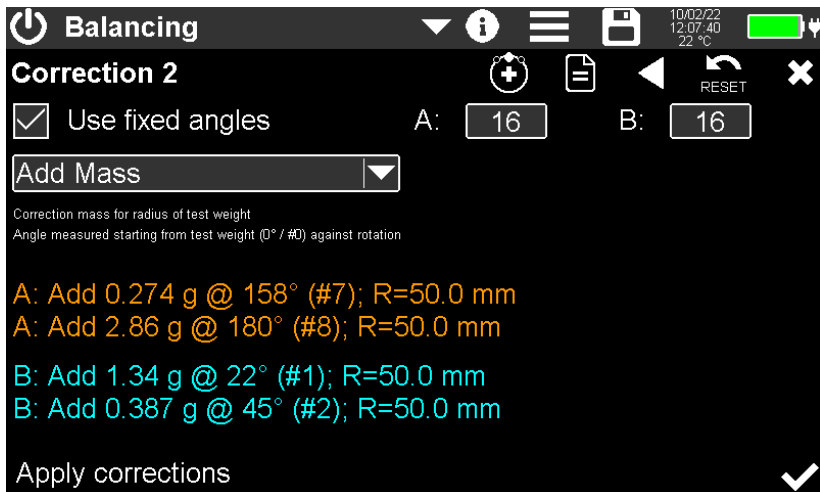


Figure 87: Second correction (2 planes)

In the second check run, there has been another improvement. In the polar diagrams, the numbered vectors of the check runs are displayed next to the initial unbalance (Figure 88).

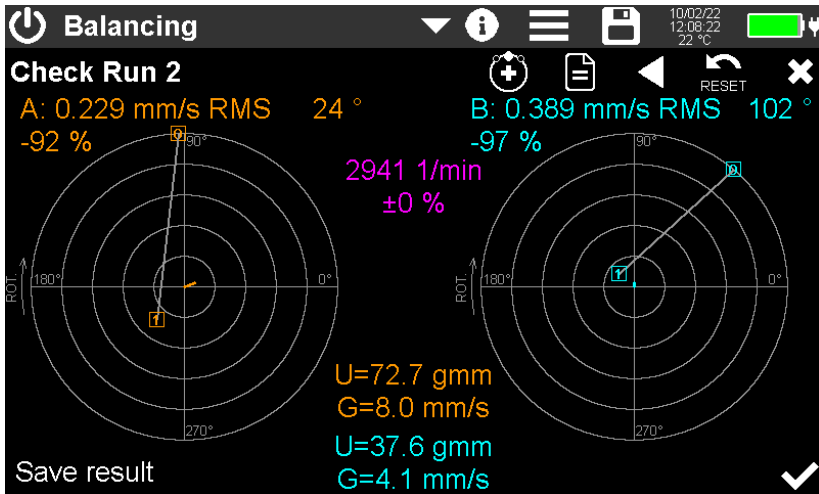



Figure 88: Second check run (2 planes)

By  the correction masses applied to each plane can be combined into one mass or, in the case of angle fixed positions, into two masses (Figure 90). For this purpose, all attached correction masses must be removed and the calculated masses attached. Test masses left on the rotor are not affected.

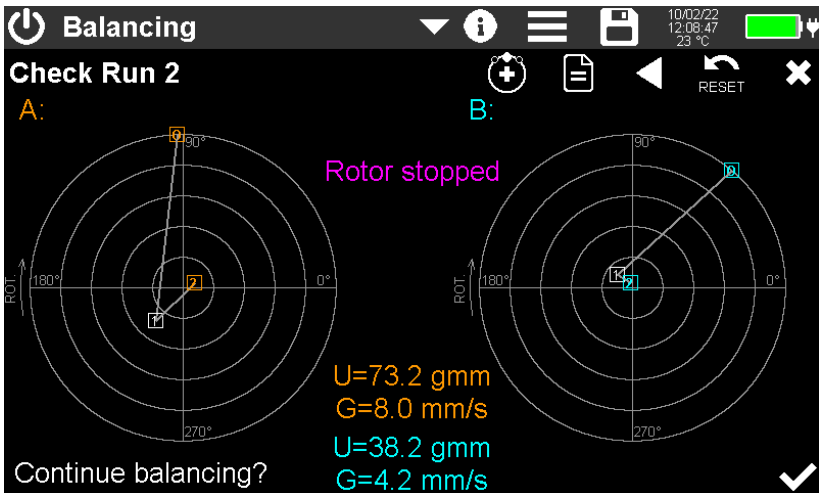


Figure 89: Continue balancing after second check run (2 planes)

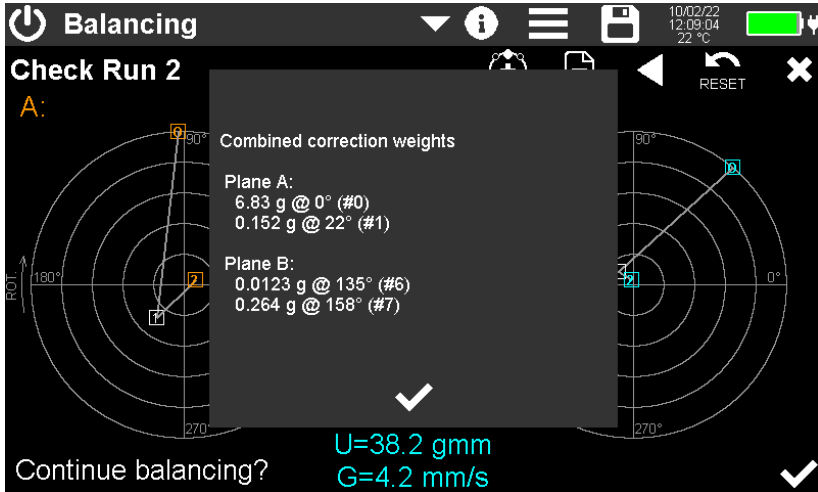



Figure 90: Combination of corrections (2 planes)

 opens a text window with a summary of all changes made and the resulting vibration or unbalance vectors (Figure 91). You can use it to replace all previously applied correction masses by the calculated mass(es).

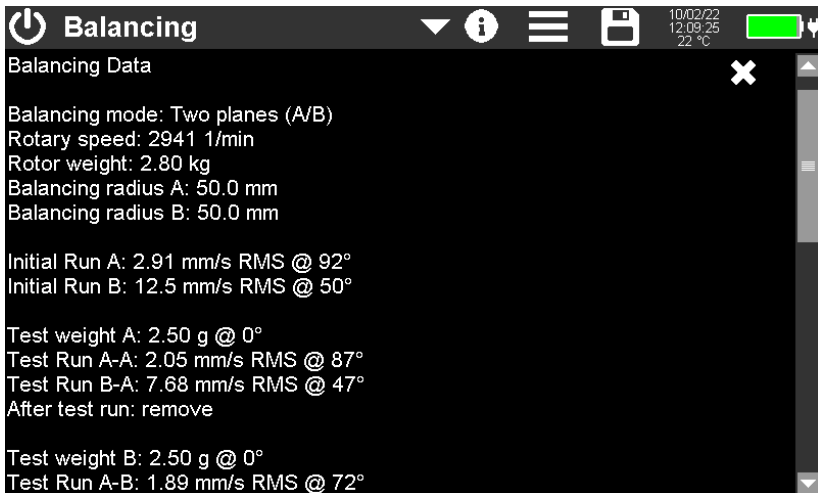



Figure 91: Auswuchtprotokoll

To save this report, touch  and select **Save CSV balancing report**. An example of a saved CSV file is shown in Figure 92.

Alternatively, the display content can be saved as BMP screenshot. The files are found on the SD card in the "BAL" folder.

BALANCING REPORT

|                     |           |          |        |          |            |
|---------------------|-----------|----------|--------|----------|------------|
| Instr.:             | VM100A    | Ser.:    | 123456 |          |            |
| Sensor A:           |           | Ser.:    |        | Sensit.: | 10 mV/ms^2 |
| Date & Time:        | 10/02/22  | 13:55:52 |        |          |            |
| Temp:               | 22        | °C       |        |          |            |
| Comment:            |           |          |        |          |            |
| NFC Id:             |           |          |        |          |            |
| Balancing mode:     | One plane |          |        |          |            |
| Rotary speed:       | 2941      | rpm      | <1     | %        |            |
| Rotor weight:       | 3         | kg       |        |          |            |
| Balancing radius:   | 50        | mm       |        |          |            |
| Initial Run:        | 2,68      | mm/s RMS | 108    | °        |            |
| Test weight:        | 2,5       | g        | 0      | °        |            |
| Test Run:           | 1,57      | mm/s RMS | 95     | °        |            |
| After test run:     | keep      |          |        |          |            |
| Correction 1-1:     | 1,05      | g        | 315    | °        |            |
| Correction 1-2:     | 2,28      | g        | 338    | °        |            |
| Check Run 1:        | 1,19      | mm/s RMS | 174    | °        |            |
| Resid. unbalance 1: | 124       | gmm      |        |          |            |
| Bal. quality (G) 1: | 13        | mm/s     |        |          |            |

<END>

Figure 92: CSV formatted balancing report

If the balancing results should be not satisfying please read the tips on page 52.

## 4.8. Module Third Octave Analysis (VC and Nano Criteria)

### 4.8.1. Introduction

This module is used for vibration measurements on very sensitive equipment, e.g. electron microscopes, photo-lithography equipment or microelectronics and nanotechnology equipment. In order to standardize the installation and operating conditions of these systems, so called VC limits (Vibration Criteria) were developed in the 1980s. There are the levels VC-A to VC-G according to Table 1.

| <i>Vibration Criterion</i> | <i>Amplitude in Third Octave Spectrum</i> | <i>Application</i>  | <i>Structure size</i> |
|----------------------------|---|---|-----------------------|
| Perception threshold       | 100 $\mu\text{m}$ (4 – 80 Hz)             | Threshold of human perception, for sensitive sleeping areas, opera halls, theaters, microscopes with 100 $\times$ magnification   | 30 $\mu\text{m}$      |
| VC-A                       | 50 $\mu\text{m}$ (4 – 80 Hz)              | Microscopes with 400 $\times$ magnification   | 8 $\mu\text{m}$       |
| VC-B                       | 25 $\mu\text{m}$ (1 – 80 Hz)              | Inspection instruments, high-quality laboratories, lithography equipment (including steppers)   | 3 $\mu\text{m}$       |
| VC-C                       | 12.5 $\mu\text{m}$ (1 – 80 Hz)            | Microscopes with magnifications up to 1000 $\times$ , good standard for most lithography and inspection equipment   | 1 $\mu\text{m}$       |
| VC-D                       | 6.25 $\mu\text{m}$ (1 – 80 Hz)            | high-quality electron microscopes (REM, TEM), electron beam systems   | 0.3 $\mu\text{m}$     |
| VC-E                       | 3.1 $\mu\text{m}$ (1 – 80 Hz)             | Compliance with this criterion is very difficult and may only be possible in a few cases, preferably on foundation slabs without an underlying cellar. Necessary for equipment of the highest precision | 0.1 $\mu\text{m}$     |
| VC-F                       | 1.6 $\mu\text{m}$ (1 – 80 Hz)             | Extremely still research rooms, very difficult to achieve; only suitable for characterization and not as a design criterion.  |                       |
| VC-G                       | 0.8 $\mu\text{m}$ (1 – 80 Hz)             | Extremely still research rooms, very difficult to achieve; only suitable for characterization and not as a design criterion   |                       |

Table 1: “VC” criteria according to VDI 2038-2

Especially for the requirements of nano technology, the so-called “Nano” criteria with even stricter limit values have been defined (Table 2).

| Vibration Criterion | Amplitude in Third Octave Spectrum   | Application   | Structure size |
|---------------------|--|---|----------------|
| Nano-D              | 1.6 $\mu\text{m/s}$<br>1 to 5 Hz and<br>6.4 $\mu\text{m/s}$<br>20 to 100 Hz  | Very hard to observe criterion for REMs in nanotechnology, top floors with high requirements regarding dynamic stiffness and natural frequency  | 1 nm           |
| Nano-E              | 0.8 $\mu\text{m/s}$<br>1 to 5 Hz and<br>3.2 $\mu\text{m/s}$<br>20 to 100 Hz  | Extreme criterion for REMs in nanotechnology, compliance only possible on very massive foundation slabs and with very favorable soil conditions   | 0.2 – 0.5 nm   |
| Nano-EF             | 0.53 $\mu\text{m/s}$<br>1 to 5 Hz and<br>2.1 $\mu\text{m/s}$<br>20 to 100 Hz | Strictest criterion for REMs and TEMs in nanotechnology for resolutions in the sub-Ångström range, compliance only possible under very special conditions and with special building designs | <0,1 nm        |

Table 2: “Nano” criteria according to VDI 2038-2

The VC and nano evaluations are performed in the third octave spectrum of vibration velocity between 1 and 100 Hz. Figure 93 shows the limit lines in the frequency range.

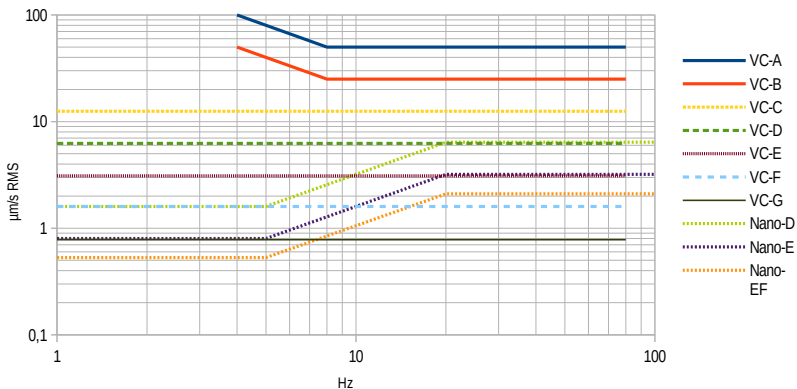


Figure 93: Limits of “VC” and “Nano” criteria



#### 4.8.2. Sensors for VC and Nano Criteria

This measurement has the highest demands in terms of resolution and noise for used vibration transducers. Only piezoelectric accelerometers with high sensitivity can be considered.



Figure 94: Triaxial accelerometer KS823B



Figure 95: Uniaxial accelerometer KS48C



Figure 96: Uniaxial accelerometer KB12VD

The triaxial accelerometer KS823B (Figure 94) and the single-axis KS48C (Figure 95) are suitable for measurements up to VC-D. The extremely high-resolution single-axis KB12VD (Figure 96) can be used up to VC-G or Nano-EF. For mounting uniaxial sensors in three spatial directions, Metra offers triaxial mounting cubes as accessories (Figure 98).

Another practical accessory for sensor installation on floors is the tripod floor plate Type 729 (Figure 97).



Figure 97: Tripod floor plate model 729



Figure 98: Triaxial mounting cube

Sensors for third-octave band analysis must be connected to input 1.

### 4.8.3. Measurement

The instrument measures the third-octave spectrum of vibration velocity with three channels. This allows measurement in three orthogonal directions (X/Y/Z) or at three different positions simultaneously. Figure 99 shows the measured value display.

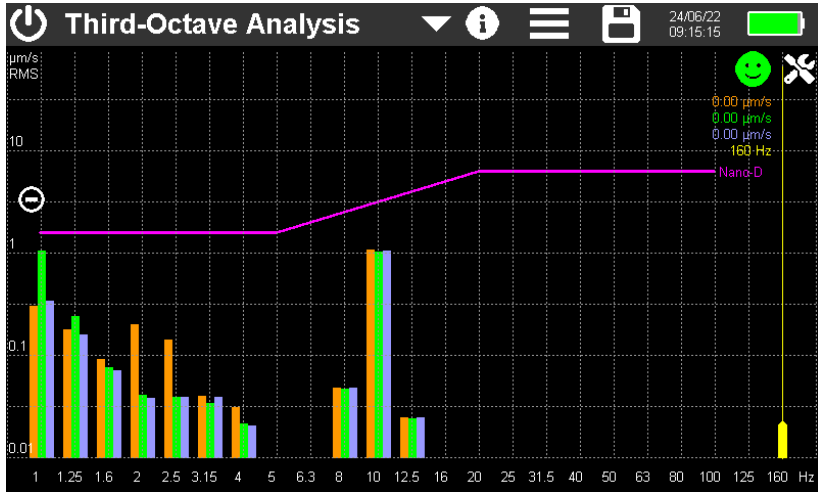


Figure 99: Third octave analysis example for Nano-D


In the upper section you find the uniform menu bar described in section 3.3.

23 spectral lines from 1 to 160 Hz are displayed for each measuring channel. The purple limit line corresponds to the values from Tables 1 or 2. The yellow measurement cursor can be shifted over the spectrum by touching its lower end. It shows the three amplitudes and the frequency at the upper end.

With the plus/minus keys you can change the scaling of the amplitude axis. Alternatively, you may place two fingers on the screen and pinch in or stretch out vertically.

At the top right you will see an alarm indicator in the form of a smiley. This appears green when the highest amplitude in the frequency range is below 80 % of the limit value. Between 80 and 100 % the indicator is yellow, above that red.

- ➔ Always disconnect the VM100 from the USB port during high-sensitivity measurements to minimize interference.
- ➔ For very sensitive measurements, avoid drafts or temperature fluctuations at the sensor and measuring instrument. We recommend protective covers made of insulating material, such as foam, for this purpose.

Use the  button to open the settings menu (Figure 100).

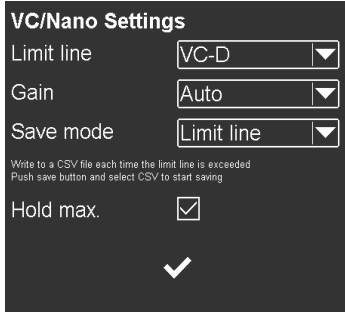


Figure 100: Menu for settings

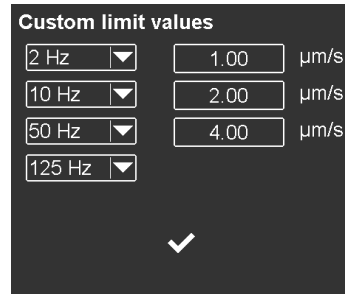


Figure 101: Menu for custom limits

In the **Limit line** menu, select the required vibration criterion. In addition to the VC and Nano criteria, it is also possible to define your own limit values. To do this, select "Custom", whereupon the menu for entering the limit values opens (Figure 101). Three ranges can be defined here. The first frequency is the lowest frequency from which monitoring starts. Spectral lines below it are not evaluated. Next to it is the amplitude, which applies up to the second frequency, and so on. The fourth frequency marks the upper end of the monitoring range. Spectral lines above it are not evaluated. The frequencies must be selected in an ascending order. The amplitudes can be in the range from 0.1 to 1000  $\mu\text{m/s}$ . Figure 104 shows the limit line resulting from the example.

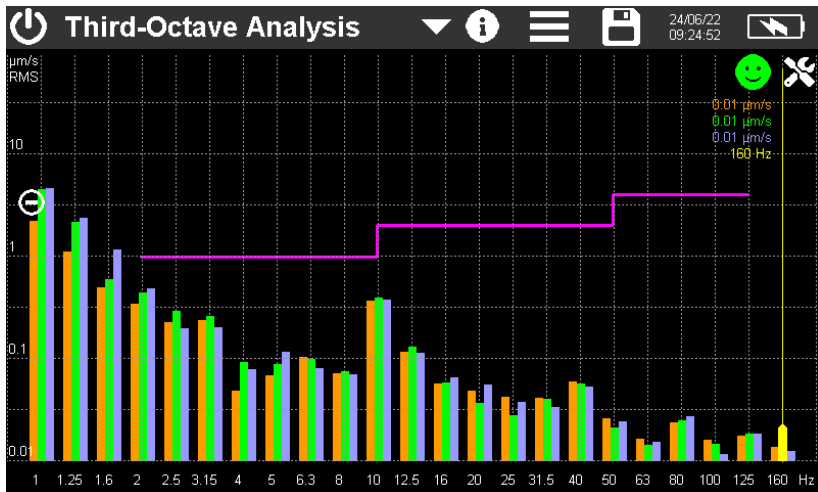



Figure 102: Custom limit line of Figure 101

**Gain** will be usually set to Auto or 100.

With the option **Hold max.** the largest spectral lines remain in the diagram. They are displayed in a darker tone of the respective channel color (Figure 103). The Reset button  deletes the maximum values.

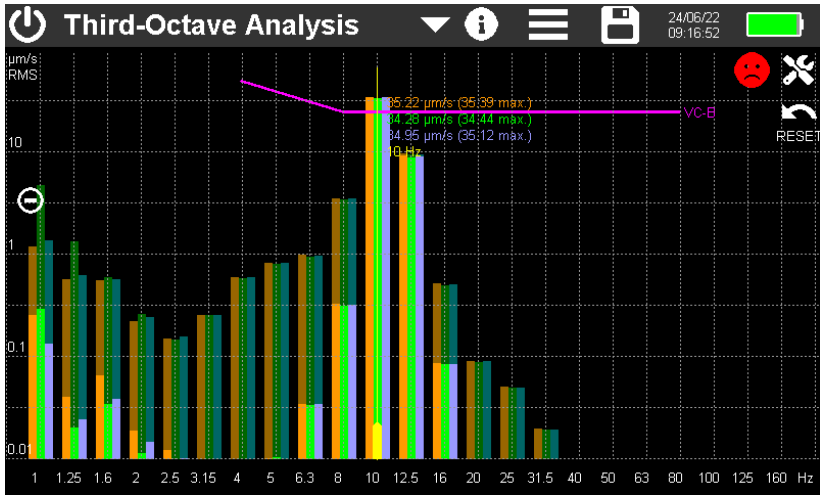




Figure 103: Spectrum with held maximum values

The **Save mode** menu has two options:

- **Limit line:** Each time the spectrum crosses the limit line a measurement is saved. Touch  to open the save menu and select Save CSV. You may enter a file name or use the default name composed of date and time (example: "OCTAVE\_220607\_100645.csv"). Each time the limit line is crossed a new line is added to the file. This continues until the memory button is pressed again.
- **Every second:** In this mode, one measurement is saved every second even without crossing the limit line. Recording can be stopped by touching  again. After 24 hours the CSV log file will be closed. A new file is opened automatically. It gets the same file name with the appendix "...\_a.csv", the next file "...\_b.csv" until recording stops after 27 days with file "...\_z.csv".

The stored measurements can be found on the SD card in the "OCTAVE" folder.

Figure 104 shows an example. The header contains information on instrument and sensor, gain, date and time as well as the selected vibration criterion.

The measurements are listed in tabular form. The table head includes the frequencies, channels and limit values.

The measured values start in line 20. For each third octave band, the three vibration velocities in µm/s are shown.

| THIRD OCTAVE ANALYSIS (VC/NANO CRITERIA) |          |             |        |          |            |                     |       |       |       |        |        |        |       |
|--|----------|-------------|--------|----------|------------|---------------------|-------|-------|-------|--------|--------|--------|-------|
| Instr:                                   | VM100B   | Serial no.: | 123456 |          |            |                     |       |       |       |        |        |        |       |
| Comment:                                 |          |             |        |          |            |                     |       |       |       |        |        |        |       |
| NFC id:                                  |          |             |        |          |            |                     |       |       |       |        |        |        |       |
| Sensor 1X:                               |          | Serial no.: |        | Sensit.: | 10000.0000 | mV/ms <sup>-2</sup> |       |       |       |        |        |        |       |
| Sensor 1Y:                               |          | Serial no.: |        | Sensit.: | 10000.0000 | mV/ms <sup>-2</sup> |       |       |       |        |        |        |       |
| Sensor 1Z:                               |          | Serial no.: |        | Sensit.: | 10000.0000 | mV/ms <sup>-2</sup> |       |       |       |        |        |        |       |
| Gains:                                   | Auto     | Auto        | Auto   |          |            |                     |       |       |       |        |        |        |       |
| Date:                                    | 24/06/22 |             |        |          |            |                     |       |       |       |        |        |        |       |
| Criterion:                               | VC-B     |             |        |          |            |                     |       |       |       |        |        |        |       |
| Hz                                       | 1        | 1           | 1      | 1.25     | 1.25       | 1.25                | 1.6   | 1.6   | 1.6   | 2      | 2      | 2      | 2.5   |
| µms                                      | X        | Y           | Z      | X        | Y          | Z                   | X     | Y     | Z     | X      | Y      | Z      | X     |
| Limits                                   |          |             |        |          |            |                     |       |       |       |        |        |        |       |
| 09:32:47                                 | 3.00     | 1.56        | 1.49   | 1.93     | 1.05       | 1.25                | 0.42  | 0.40  | 0.46  | 0.46   | 0.10   | 0.21   | 0.13  |
| 09:32:48                                 | 1.53     | 3.14        | 2.79   | 1.02     | 1.17       | 1.09                | 0.74  | 0.47  | 0.38  | 0.55   | 0.24   | 0.24   | 0.37  |
| 09:32:49                                 | 2.56     | 2.92        | 2.48   | 2.95     | 1.29       | 1.23                | 1.32  | 1.26  | 1.27  | 0.34   | 0.17   | 0.20   | 1.23  |
| 09:32:50                                 | 2.44     | 2.65        | 2.35   | 4.41     | 3.25       | 3.35                | 1.67  | 1.96  | 2.02  | 0.40   | 0.50   | 0.37   | 1.01  |
| 09:32:57                                 | 1.59     | 1.82        | 1.82   | 0.83     | 0.64       | 0.83                | 0.95  | 0.83  | 0.82  | 0.76   | 0.84   | 0.77   | 1.69  |
| 09:32:58                                 | 2.53     | 2.87        | 2.71   | 2.21     | 2.04       | 2.22                | 2.50  | 2.29  | 2.34  | 1.64   | 1.62   | 1.60   | 1.53  |
| 09:33:04                                 | 16.25    | 16.52       | 15.89  | 37.86    | 37.93      | 37.84               | 42.06 | 40.31 | 41.47 | 37.02  | 34.40  | 37.10  | 86.60 |
| 09:33:05                                 | 70.48    | 72.10       | 70.86  | 92.61    | 94.31      | 91.93               | 90.87 | 86.91 | 89.71 | 108.90 | 100.63 | 109.10 | 179.1 |
| 09:33:06                                 | 152.37   | 156.26      | 152.00 | 167.36   | 172.61     | 165.91              | 89.93 | 85.23 | 88.66 | 110.48 | 100.98 | 109.51 | 96.11 |
| 09:33:07                                 | 215.72   | 223.28      | 215.05 | 163.92   | 172.90     | 162.58              | 43.23 | 41.16 | 42.51 | 39.43  | 36.50  | 38.52  | 37.66 |
| 09:33:08                                 | 229.29   | 239.64      | 228.75 | 127.65   | 136.72     | 126.83              | 21.43 | 24.13 | 21.06 | 28.50  | 26.11  | 28.55  | 22.10 |
| 09:33:09                                 | 187.68   | 198.28      | 187.48 | 55.86    | 61.47      | 56.05               | 31.54 | 31.09 | 31.26 | 18.27  | 16.32  | 18.01  | 17.86 |
| <END>                                    |          |             |        |          |            |                     |       |       |       |        |        |        |       |

Figure 104: CSV formatted third-octave data (only left part shown)

For more information on storing measured values, refer to section 5.

## 4.9. Module Hand-Arm Vibration

### 4.9.1. Introduction

This module supports the measurement of hand-arm vibrations according to ISO 5349 and VDI 2057 with one or two hands. These are vibrations that are introduced into the body via the hand. They can cause, for example, circulatory diseases, bone or joint damages and muscle disorders. Relevant for the evaluation of vibrations measured in this way is the EU Directive 2002/44/EC. The complete text is available at <https://eur-lex.europa.eu/>. The directive contains minimum requirements for the protection of workers' health against risks from vibrations. Manufacturers of machinery and equipment, as well as employers who use them, are required to carry out a risk assessment with regard to the operator's exposure to vibrations. The risk assessment can be based on the manufacturer's information on the extent of vibration, observing specific work practices, or by measurement. The directive specifies the following limit values:

|                              | <b>Hand-Arm, RMS</b> |
|------------------------------|----------------------|
| <b>Exposure action value</b> | 2.5 m/s <sup>2</sup> |
| <b>Exposure limit</b>        | 5 m/s <sup>2</sup>   |

If the **exposure action value** is exceeded, technical and organizational measures must be taken to reduce the vibration exposure.

The **exposure limit** value must not be exceeded under any circumstances. Should this occur, measures to reduce the vibration exposure must be taken immediately.

The vibration exposure can be determined on the basis of random sample measurements.

The above limit values correspond to the standardized **daily exposure value A(8)**, which refers to a working day of 8 hours. This calculated value is used for comparison of vibration exposure. An eight-hour measurement is not required to determine A(8). It is sufficient to carry out short-time measurements during representative work periods and normalizes the results to eight hours. The daily exposure value is calculated as shown in Equation 1.

$$A(8) = a_w \sqrt{\frac{T_e}{T_0}} \quad \text{Equation 1}$$

where

$A(8)$  is the daily exposure

$a_w$  is the energy equivalent mean value of the frequency weighted acceleration during exposure, which means the vector sum of Wh frequency-weighted RMS values in the directions X/Y/Z

$$a_w = \sqrt{a_{wx}^2 + a_{wy}^2 + a_{wz}^2} \quad \text{Equation 2}$$

$T_e$  is the total duration of exposure during one work day

$T_0$  is the reference duration of 8 hours

The daily exposure value can be composed of several exposure sections with different vibration amplitudes. This applies if, for example, there are longer interruptions, or if work equipment or its operating conditions change. An exposure section is characterized by an approximately constant vibration exposure with less than 10% interruptions. A daily exposure value resulting from several exposure sections is calculated as shown in Equation 3.

$$A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^n a_{wi}^2 T_{ei}} \quad \text{Equation 3}$$

where

$A(8)$  is the daily exposure

$a_{wi}$  is the energy equivalent mean value of the Wh frequency weighted acceleration of partial exposure section  $i$

$n$  is the number of partial exposure sections

$T_{ei}$  is the duration of exposure  $i$

$T_0$  is the reference duration of 8 hours

The vibration acceleration of each of the three measuring directions (X/Y/Z) is measured with the frequency weighting Wh according to ISO 8041-1. The range from 6.3 to 1250 Hz is considered. It can be seen from Figure 105 that low frequencies have a greater influence on the evaluation than high frequencies.

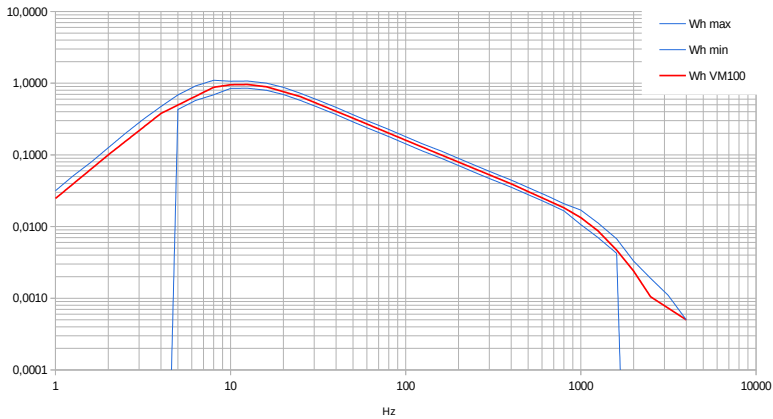


Figure 105: Frequency weighting Wh

#### 4.9.2. Hand-Arm Sensors

Metra recommends the KS963B10 triaxial accelerometer for hand-arm measurements.

Select a measurement point that is as close as possible to the gripping points of the hand, but without interfering with the normal working process. The measurement should be made using forces that correspond to typical operating conditions. Since the handles of work tools usually do not have flat surfaces for mounting the sensor, Metra offers coupling accessories for curved surfaces.



Figure 106: KS963B10

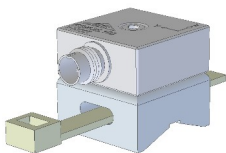


Figure 108: Strap adapter 141B

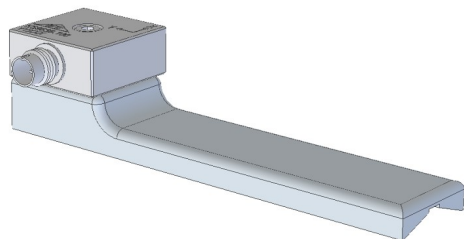


Figure 107: Hand-held adapter 143B

The adapter model 141B is fastened with a cable tie. The adapter type 143B is pressed against the handle by the hand.

It is important that the sensor is firmly coupled. It must not have any motion of its own, as this could falsify the vibration measurement.

Figure 109 shows the coordinate alignment to be observed when mounting the sensor. For cylindrical handles, the Y-axis is parallel to the axis of the handle. The Z axis lies approximately in the extension of the metacarpal bone.



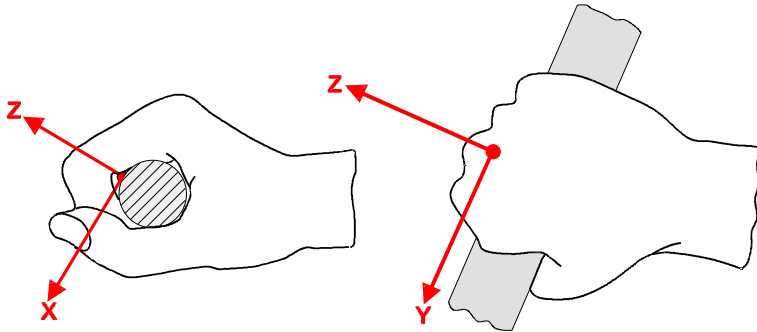


Figure 109: Coordinate system of the hand (from ISO 5349-1)

### 4.9.3. In Situ Checks

The standard ISO 8041-1 describes in chapter 15 a test of instrument and sensor in the field prior to and following a measurement. Metra's Vibration Calibrator VC21 is suited for this purpose. It provides the standardized mechanical reference signal of  $10 \text{ m/s}^2$  at 80 Hz. The sensor KS963B10 has threaded holes for mounting the sensor in X, Y and Z direction on the calibrator.

### 4.9.4. Measurement

Figure 111 shows the measurement screen in the Hand-Arm Vibration module. In the upper section you find the uniform menu bar described in section 3.3.

On the left, the vibration values for both hands are displayed. These are interval RMS values averaged over the entire measurement period. This means that these values become more and more stable, the longer the measurement takes.

Below this, the energy-equivalent average values (total vibration values)  $a_{w1}$  and  $a_{w2}$  are displayed. They are used to calculate the daily exposure value  $A(8)$  (cf. Section 4.9.1). Based on the higher of the two energy-equivalent mean values, the VM100 calculates the exposure time at which the action value and the exposure limit value according to EU Directive 2002/44/EC would be reached. In addition, the elapsed measurement time is displayed. It should be at least 30 seconds. However, the decisive factor for the measuring time is that the energy equivalent average value changes only insignificantly.

The VM100A allows simultaneous measurement on both hands using two triaxial accelerometers. If measurements are made with the VM100B or with only one transducer, the latter must be connected to input 1 and the measurement for both hands must be carried out separately. The display values of sensor 2 are then not relevant.




Figure 110: Vibration Calibrator VC21

On the right, the measured values are plotted as a time graph (Figure 12). These are the three or six RMS values for X/Y/Z. Unlike the numerical values on the left they are calculated with 1 s averaging time, which has the advantage that even short-term changes are visible. Furthermore, the energy equivalent mean value(s) with unlimited averaging time is/are displayed. The plotting of the amplitude graphs starts 15 s after opening the module in order to suppress transients. The waiting time can be skipped by touching the relevant message in the diagram.

Diagram plotting can be paused (II) or restarted (I◀).

Important: A measurement always starts by touching the reset button. This restarts the figuring of the interval RMS values and resets the measurement duration display.

➔ A measurement always starts by touching the reset button . This restarts the calculation of the interval RMS values and resets the measurement duration timer.

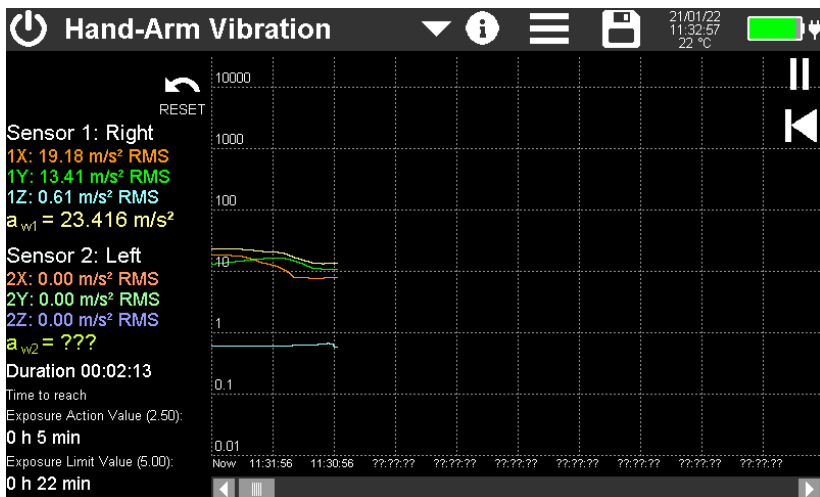


Figure 111: Measurement screen for hand-arm vibration


Measuring value can be stored as CSV data table. To do this, open the storage menu with  and select Save CSV (see section 5). The save button then appears in yellow with the text "LOG" on it. The measured values are now written to a file every second. The file name and the number of measured RMS values with 1 s averaging time are displayed in the diagram. To stop recording, touch the save button again. The saved files can be found on the SD card in the "HAND-ARM" directory. After 24 hours of recording the CSV log file will be closed. A new file is opened automatically. It gets the same file name with the appendix "...\_a.csv", the next file "...\_b.csv" until recording stops after 27 days with file "...\_z.csv".

Figure 112 shows an example of a CSV recording. In the header you will find information about the measuring device and the sensors used. The measured value table starts with the channel settings, such as filters and measurement units. From line 20 on, the recorded RMS values of three or six channels with 1 s averaging time and

energy-equivalent mean values with unlimited averaging for one or both hands with time stamp follow.

Alternatively, the diagram can be saved as BMP screenshot.

For more details on data storage, see section 5.

| HAND-ARM VIBRATION |                  |                  |                  |                  |                  |                     |                  |                  |
|--------------------|------------------|------------------|------------------|------------------|------------------|---------------------|------------------|------------------|
| Instr.:            | VM100A           | Ser.:            | 123456           |                  |                  |                     |                  |                  |
| Comment:           |                  |                  |                  |                  |                  |                     |                  |                  |
| NFC Id:            |                  |                  |                  |                  |                  |                     |                  |                  |
| Sensor 1X:         | KS963B10         | Ser.:            | 20013            | Sensit.:         | 10.221           | mV/ms <sup>-2</sup> |                  |                  |
| Sensor 1Y:         | KS963B11         | Ser.:            | 20013            | Sensit.:         | 10.154           | mV/ms <sup>-2</sup> |                  |                  |
| Sensor 1Z:         | KS963B12         | Ser.:            | 20013            | Sensit.:         | 10.167           | mV/ms <sup>-2</sup> |                  |                  |
| Sensor 2X:         | KS963B13         | Ser.:            | 20014            | Sensit.:         | 10.313           | mV/ms <sup>-2</sup> |                  |                  |
| Sensor 2Y:         | KS963B14         | Ser.:            | 20014            | Sensit.:         | 10.354           | mV/ms <sup>-2</sup> |                  |                  |
| Sensor 2Z:         | KS963B15         | Ser.:            | 20014            | Sensit.:         | 10.879           | mV/ms <sup>-2</sup> |                  |                  |
| Date:              | 21.01.2022       |                  |                  |                  |                  |                     |                  |                  |
| Temp:              | 22               | °C               |                  |                  |                  |                     |                  |                  |
|                    |                  |                  |                  |                  |                  |                     |                  |                  |
|                    |                  |                  |                  |                  |                  |                     |                  |                  |
| Channel:           | 1X               | 1Y               | 1Z               | 2X               | 2Y               | 2Z                  | a_v1             | a_v2             |
| Filter:            | Wh               | Wh               | Wh               | Wh               | Wh               | Wh                  |                  |                  |
| Factor:            | 1.00             | 1.00             | 1.00             | 1.00             | 1.00             | 1.00                |                  |                  |
| Unit:              | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup>    | m/s <sup>2</sup> | m/s <sup>2</sup> |
| 13:56:39           | 6.434            | 1.551            | 6.128            | 0.478            | 0.477            | 0.476               | 9.020            | 0.826            |
| 13:56:40           | 6.433            | 1.551            | 6.127            | 0.478            | 0.477            | 0.477               | 9.018            | 0.827            |
| 13:56:41           | 6.432            | 1.551            | 6.126            | 0.478            | 0.477            | 0.477               | 9.017            | 0.827            |
| 13:56:42           | 6.431            | 1.551            | 6.125            | 0.478            | 0.477            | 0.477               | 9.016            | 0.827            |

Figure 112: Example of a hand-arm CSV file

Note: To avoid operation errors the VM100 does not allow unweighted measurements for hand-arm vibration. If it should be necessary for calibration to measure without the Wh weighting filter, please switch to amplitude/time mode (see section 4.2) and make the following settings for channels 1X, 1Y and 1Z:

- High pass: 6 Hz
- Low pass: 1500 Hz
- Mode: RMS(T)
- Gain: 1

## 4.10. Module Whole-Body Vibration

### 4.10.1. Introduction

This module supports the measurement of whole-body vibrations according to ISO 2631. These are vibrations acting over the buttocks and back of the seated person, the feet of the standing person and the head and back of the lying person. These can lead, for example, to back pain and damage to the spine. Relevant for the evaluation of the vibrations measured in this way is the EU Directive 2002/44/EC. The directive specifies the following limit values:

|                       | Whole-Body, RMS       | Whole-Body, VDV         |
|-----------------------|-----------------------|-------------------------|
| Exposure action value | 0.5 m/s <sup>2</sup>  | 9.1 m/s <sup>1.75</sup> |
| Exposure limit        | 1.15 m/s <sup>2</sup> | 21 m/s <sup>1.75</sup>  |

If the exposure action value is exceeded, technical and organizational measures must be taken to reduce the vibration exposure.

The exposure limit value must not be exceeded under any circumstances. Should this occur, measures to reduce the vibration exposure must be taken immediately.

The vibration exposure can be determined on the basis of random sample measurements.

The above limit values correspond to the standardized daily exposure value A(8), which refers to a working day of 8 hours. This calculated value is used for comparison of vibration exposure. An eight-hour measurement is not required to determine A(8). It is sufficient to carry out short-time measurements during representative work periods and normalizes the results to eight hours. The daily exposure value is then calculated according to:

$$A(8) = a_w \sqrt{\frac{T_e}{T_0}} \quad \text{Equation 4}$$

where:

A(8) is the daily exposure

$a_w$  are the 3 RMS values  $a_{wx}$ ,  $a_{wy}$  and  $a_{wz}$ ,  
measured with the following weighting filters:  
X and Y with weighting filter Wd and weighting factor 1,4  
Z with weighting filter Wk and weighting factor 1,0

$T_e$  is the duration of exposure per work day

$T_0$  is the reference duration of 8 hours

The daily exposure value can be composed of several exposure sections with different vibration amplitudes. This applies if, for example, there are longer interruptions, or if work equipment or its operating conditions change. A load section is characterized by an approximately constant vibration load with a proportion of interruptions of less than 10%. A daily exposure value resulting from several exposure sections is calculated as follows. Three separate daily exposure values are determined for the

X/Y/Z directions. The largest of the three values is used for risk assessment, i.e. compared with limit values according to the EU Directive.

$$A_x(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^n a_{wxi}^2 T_{ei}} \quad \text{Equation 5}$$

$$A_y(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^n a_{wyi}^2 T_{ei}} \quad \text{Equation 6}$$

$$A_z(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^n a_{wzi}^2 T_{ei}} \quad \text{Equation 7}$$

where:

$A_{x/y/z}(8)$  are the daily exposure values for direction X/Y/Z

$a_{wx/y/zi}$  are the energy equivalent mean values ( $a_w$ ) for acceleration in directions X/Y/Z for partial exposure section i, using the following weightings:  
 - X and Y with weighting filter  $W_d$  and weighting factor 1,4  
 - Z with weighting filter  $W_k$  and weighting factor 1,0

$n$  is the number of partial exposure sections

$T_{ei}$  is the duration of exposure i

$T_0$  is the reference duration of 8 hours

The calculations of the daily exposure value shown are based on root mean square (RMS) values.

Alternatively, the calculation based on **vibration dose values (VDV)** has become established for whole-body vibration, especially in Anglo-Saxon countries. This is the fourth root of the sum of the fourth powers with the unit of measurement  $m/s^{1.75}$ . This method evaluates shock-like individual vibrations more strongly than the root mean square value.

The daily exposure value  $VDV(8)$  is calculated according to:

$$VDV(8) = VDV \cdot \sqrt[4]{\frac{T_{exp}}{T_{meas}}} \quad \text{Equation 8}$$

where

$VDV(8)$  is the daily exposure value

$VDV$  is the frequency-weighted vibration dose value

$T_{exp}$  is the duration of exposure

$T_{meas}$  is the duration of VDV measurement

The daily exposure value based on VDV values can also be composed of several exposure sections with different vibration dose values.

Three separate daily exposure values are calculated for the X/Y/Z directions. The largest of the three values is used for risk assessment, i.e. compared with the limit values according to the EU Directive.

$$VDV_x(8) = \sqrt[4]{\sum_{i=1}^n VDV_{xi}^4 \cdot \frac{T_{iexp}}{T_{imeas}}} \quad \text{Equation 9}$$

$$VDV_y(8) = \sqrt[4]{\sum_{i=1}^n VDV_{yi}^4 \cdot \frac{T_{iexp}}{T_{imeas}}} \quad \text{Equation 10}$$

$$VDV_z(8) = \sqrt[4]{\sum_{i=1}^n VDV_{zi}^4 \cdot \frac{T_{iexp}}{T_{imeas}}} \quad \text{Equation 11}$$

where

$VDV_{x/y/z}(8)$  are the daily exposures of directions X/Y/Z

$VDV_{x/y/zi}$  are the frequency-weighted vibration dose values of directions X/Y/Z during exposure section i

$T_{exp}$  is the duration of exposure section i

$T_{meas}$  is the duration of VDV measurement during exposure section i

#### 4.10.2. Whole-Body Sensors

For the measurement of whole-body vibrations, a triaxial seat accelerometer according to ISO 10326-1 is commonly used, which is installed in a flat rubber pad. It optimally adapts to the interface between the test subject and the vibration source. Metra offers the type KS963B100-S. The sensor must be connected to input 1.



Figure 113: KS963B100-S

The following measurement locations can be considered:

- The seat surface in a sitting position
- The backrest in the sitting position
- Under the feet in the sitting position
- Under the feet in the standing position
- Under the pelvis in a lying position
- Under the head in lying position

Figure 114 shows the coordinate directions according to ISO 2631. It can be seen that the X-axis is always aligned in the viewing direction and the Z-axis along the spinal column. The vibration sensor must be aligned accordingly. An exception is the sensor alignment for measurements at the backrest (see note under Table 3).

A distinction is made in whole-body vibration between health and comfort evaluation. Depending on the body posture and evaluation, the evaluation filters and weighting factors to be used differ. Table 3 shows the assignment.

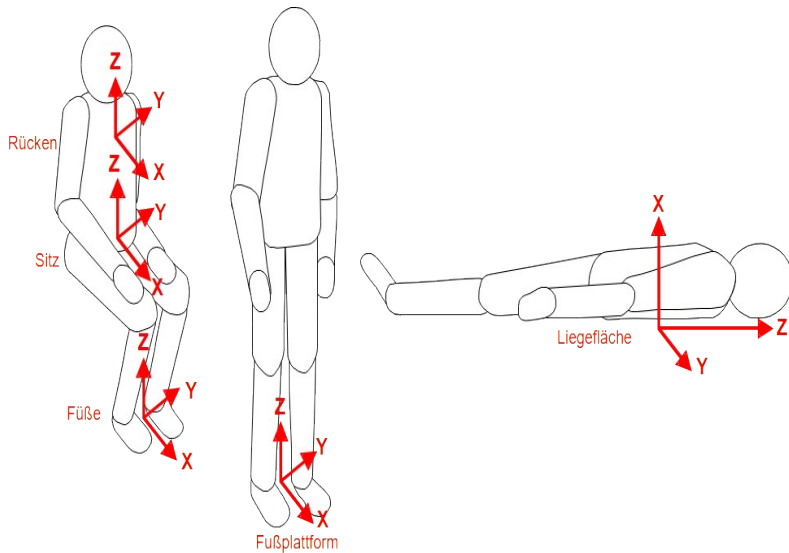


Figure 114: Coordinate systems for whole-body vibration to ISO 2631

| <b>Whole-Body Health Evaluation</b>  |                               |                                    |                            |                             |
|--------------------------------------|-------------------------------|------------------------------------|----------------------------|-----------------------------|
| <i>Posture</i>                       | <i>Position</i>               | <i>Sensor axis</i>                 | <i>Frequency weighting</i> | <i>Weighting factor (k)</i> |
| sitting                              | seat surface                  | X / Y<br>Z                         | $W_d$<br>$W_k$             | 1.4<br>1                    |
| <b>Whole-Body Comfort Evaluation</b> |                               |                                    |                            |                             |
| sitting                              | seat surface                  | X / Y<br>Z                         | $W_d$<br>$W_k$             | 1<br>1                      |
|                                      | feet platform                 | X / Y<br>Z                         | $W_k$                      | 0.25<br>0.4                 |
|                                      | backrest                      | X*<br>Y<br>Z*                      | $W_d$<br>$W_d$<br>$W_c$    | 0.4<br>0.5<br>0.8           |
| standing                             | feet platform                 | X / Y<br>Z                         | $W_d$<br>$W_k$             | 1<br>1                      |
| recumbent                            | under pelvis                  | X (vertical)<br>Y / Z (horizontal) | $W_k$<br>$W_d$             | 1<br>1                      |
|                                      | under head                    | X (vertical)                       | $W_i$                      | 1                           |
| In railway vehicles:                 |                               |                                    |                            |                             |
| standing                             | feet platform                 | X / Y / Z                          | $W_b$                      | 1                           |
| sitting                              | seat/backrest/feet            |                                    |                            |                             |
| recumbent                            | support. surface, pelvis/head |                                    |                            |                             |
| In buildings:                        |                               |                                    |                            |                             |
| undefined                            | in buildings                  | X / Y / Z                          | $W_m$                      | 1                           |

Table 3: Weighting filters and factors for whole-body vibration

\* For measurements at the backrest, the Z-axis should be in the direction of the spine, as for all positions. However, if a seat pad accelerometer is placed between the person and the backrest, its Z-axis is perpendicular to the backrest and therefore also to the spine. To establish the correct axis assignment, the weighting filters and factors for X and Z are swapped in the VM100 for measurements on the backrest, as shown in the table.

When measuring whole-body vibrations, the frequency range from 0.4 to 100 Hz is considered. Depending on the application, different weighting filters are used. Figures 115 to 119 show the frequency weightings implemented in the VM100.

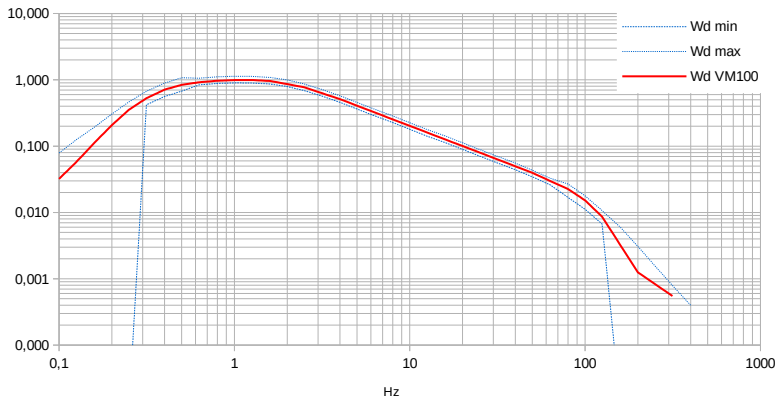


Figure 115: Weighting filter  $W_d$

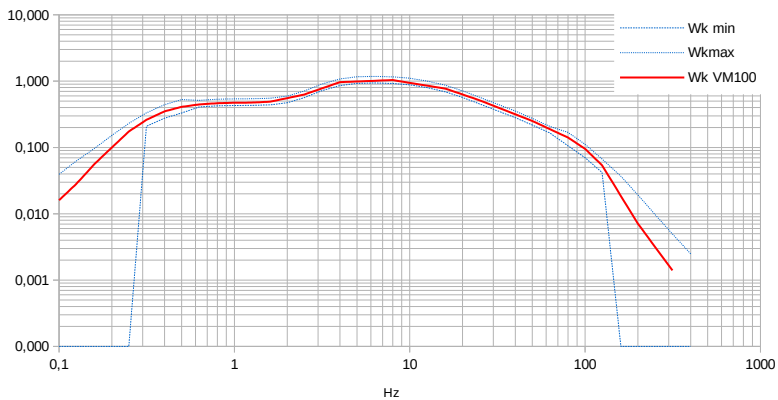


Figure 116: Weighting filter  $W_k$



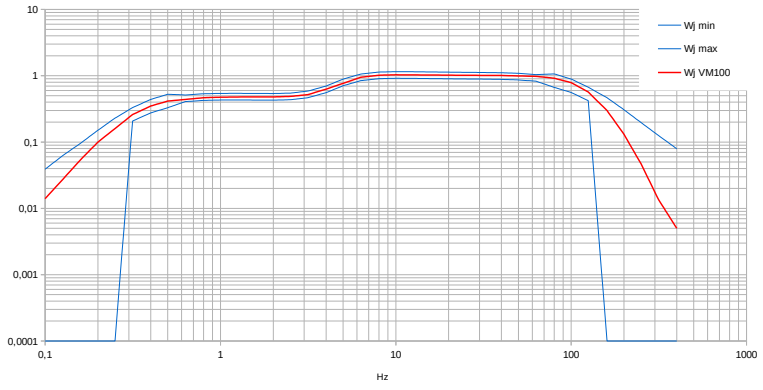


Figure 117: Weighting filter  $W_j$

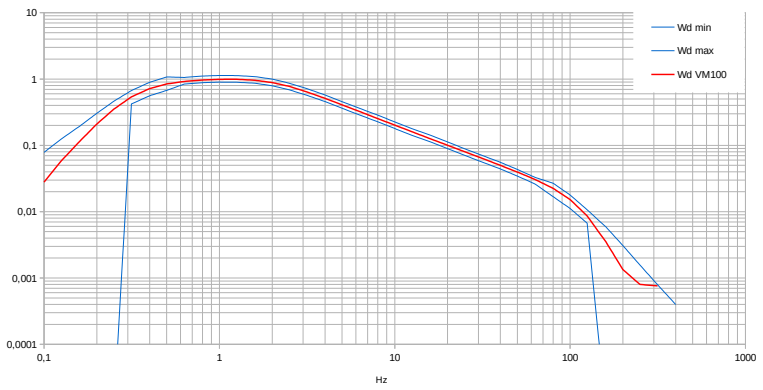


Figure 118: Weighting filter  $W_c$

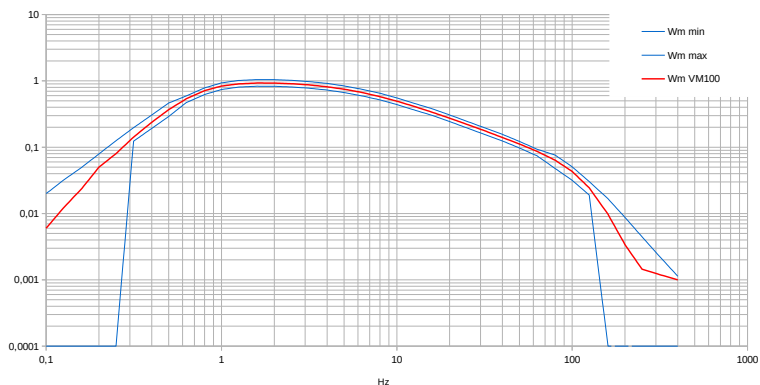


Figure 119: Weighting filter  $W_m$

For calibration and test purposes the instrument also allows unweighted measurements. In this case only the band limiting filters from 0.4 to 100 Hz (-3 dB) are enabled.

#### 4.10.3. In Situ Checks

The standard ISO 8041-1 specifies in chapter 15 a test of instrument and sensor in the field prior to and following a measurement. Metra's Vibration Calibrator VC21 is suited for this purpose (see section 4.9.3). It provides the standardized mechanical reference signal of  $1 \text{ m/s}^2$  at 15.92 Hz. The sensor KS963B100 has threaded holes for mounting the sensor in X, Y and Z direction on the calibrator. It has to be removed from the flexible pad for testing by unscrewing the bottom plate.

#### 4.10.4. Measurement

Figure 120 shows the measurement screen of the whole-body vibration module. In the upper section is the uniform menu bar described in section 3.3. On the top left, the selected evaluation (health or comfort) is displayed. You will also find the corresponding weighting filters of the three axis directions as well as the weighting factors according to ISO 2631 (cf. Table 3).

Below this, the vibration values for the three directions X/Y/Z are shown. These are interval RMS values that are averaged over the entire measurement period. This means that these values become more and more stable as the measurement period becomes longer.

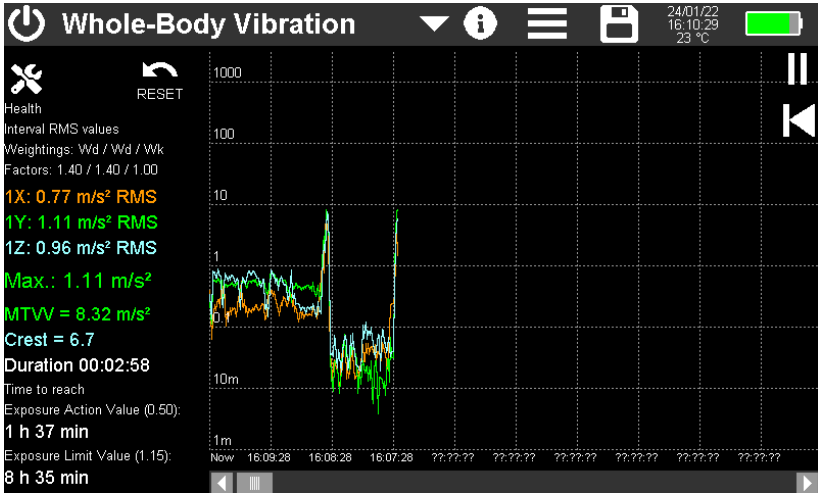


Figure 120: Measurement display of whole-body vibration

Below the largest of the three axis values is displayed, which is used to calculate the daily exposure value  $A(8)$  according to ISO 2631 (cf. Section 4.10.1). From this, the VM100 calculates the exposure time at which the action value and the exposure limit value according to EU Directive 2002/44/EC would be reached. In addition, the elapsed measuring time is displayed. It should be at least 2 minutes. However, the decisive factor for the measuring time is that the RMS values of the three directions change only insignificantly.

According to ISO 2631-1, a distinction is made between the basic evaluation using interval RMS values and the additional evaluation via the vibration dose value (VDV). The vibration dose value should be used if the vibration contains multiple shocks. ISO 2631-1 recommends the crest factor as a decision criterion. This is the quotient of the peak value and the interval RMS value. If the crest factor is below 9, the basic evaluation is usually sufficient. If it is above that, VDV value should be measured.

The MTVV (Maximum Transient Vibration Value) also provides information about the shock content. It stands for the largest measured RMS value with 1 s averaging time.


All measured values are displayed in the respective channel color.


On the right, the measured values are plotted as time graph. Unlike the numerical RMS values on the left they are calculated with 1 s averaging time, which has the advantage that even short-term changes are visible. This makes it possible, for example, to recognize disturbances during the measurement time or to detect individual events, such as the crossing of a threshold by a forklift truck.

In VDV mode the diagram plots the VDV values with unlimited averaging time.

Plotting the graph starts 15 s after the start of the module in order to suppress transient processes. The waiting time can be skipped by touching the relevant message in the diagram.

The diagram recording can be paused (II) or restarted (I◀).

➔ A measurement always starts by touching the reset button . This restarts the calculation of interval RMS values and resets the measurement duration timer.

Use the button  to open the menu for settings (Figure 121). Here you define whether a measurement is performed for health or comfort evaluation. In addition, you can switch between RMS value and vibration dose value (VDV) (cf. Section 4.10.1).

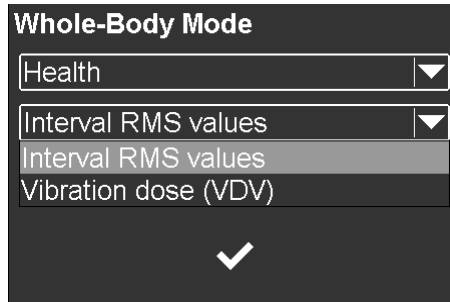



Figure 121: Whole-body setup menu

The measured values can be stored as CSV data table. To do this, press  to open the storage menu and select Store CSV (see section 5). The save button then appears in yellow with the text "LOG" on it. The measured RMS values with 1 s averaging time are now written to a file every second. The file name and the number of saved values are displayed at the top of the diagram. To finish recording, touch the save button again. The saved files can be found on the SD card in the "WHOLE-BODY" directory.

After 24 hours of recording the CSV log file will be closed. A new file is opened automatically. It gets the same file name with the appendix "...\_a.csv", the next file "...\_b.csv" until recording stops after 27 days with file "...\_z.csv".

Figure 122 shows an example of a CSV recording. In the header you will find information about the measuring device and the sensors used. The measurement value table starts with the channel settings, such as filters and measurement units. The recorded measured values (interval RMS values) of the three channels X/Y/Z with time stamp follow from line 20.

| WHOLE-BODY VIBRATION |                  |                  |                  |          |        |                     |
|----------------------|------------------|------------------|------------------|----------|--------|---------------------|
| Instr.:              | VM100A           | Ser.:            | 123456           |          |        |                     |
| Comment:             |                  |                  |                  |          |        |                     |
| NFC Id:              |                  |                  |                  |          |        |                     |
| Sensor 1X:           | KS903B10         | Ser.:            | 20014            | Sensit.: | 10.313 | mV/ms <sup>-2</sup> |
| Sensor 1Y:           | KS903B10         | Ser.:            | 20014            | Sensit.: | 10.354 | mV/ms <sup>-2</sup> |
| Sensor 1Z:           | KS903B10         | Ser.:            | 20014            | Sensit.: | 10.879 | mV/ms <sup>-2</sup> |
| Date:                | 25.01.2021       |                  |                  |          |        |                     |
| Temp:                | 21               | °C               |                  |          |        |                     |
|                      |                  |                  |                  |          |        |                     |
|                      |                  |                  |                  |          |        |                     |
|                      |                  |                  |                  |          |        |                     |
|                      |                  |                  |                  |          |        |                     |
|                      |                  |                  |                  |          |        |                     |
| Channel:             | 1X               | 1Y               | 1Z               |          |        |                     |
| Filter:              | Wd               | Wd               | Wk               |          |        |                     |
| Factor:              | Jan 40           | Jan 40           | 1.00             |          |        |                     |
| Unit:                | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> |          |        |                     |
| 11:37:37             | 1.087            | 1.059            | 0.388            |          |        |                     |
| 11:37:38             | 1.012            | 1.123            | 0.335            |          |        |                     |
| 11:37:39             | 0.965            | 0.953            | 0.248            |          |        |                     |

Figure 122: Example of CSV recording for whole-body vibration

Alternatively, the graph can be saved as BMP screenshot.  
 For more details on saving measured values, see section 5.

## 4.11. Module Whole-Body – 3 Sensors

### 4.11.1. Introduction

This module is used to evaluate ride comfort in motor vehicles in accordance with GB/T 4970-2009. It is based on the measurement of whole-body vibrations in accordance with ISO 2631. In this case, the vibrations on the seat surface, the seat back and the foot platform are measured simultaneously when driving along a specified test track. The three vibration amplitudes recorded in each case on three axes are added vectorially to form a total vibration value. Specific weighting filters and factors are used for each measurement position.

The mode of operation of this measurement corresponds to that of the whole-body vibration module (cf. Section 4.10) with the difference that three triaxial sensor signals are recorded here. The connection of three sensors to the inputs 1/2/3 is mandatory. Otherwise an error message will be displayed. This module is not available on the three-channel unit VM100B.

### 4.11.2. Whole-Body Sensors

To measure whole-body vibration, tri-axial seat accelerometers conforming to ISO 10326-1 are used, which are installed in a flat rubber pad. Metra offers model KS963B100-S, which complies with the specifications of Annex B of GB/T 4970-2009. The assignment of the sensors to the measurement inputs is as follows:

Input 1: Seat surface

Input 2: Seat back

Input 3: Foot surface



Figure 123: KS963B100-S

### 4.11.3. Measurement

120 shows the measurement screen in the whole-body vibration module. In the upper section you see the uniform menu bar as described in section 3.3.

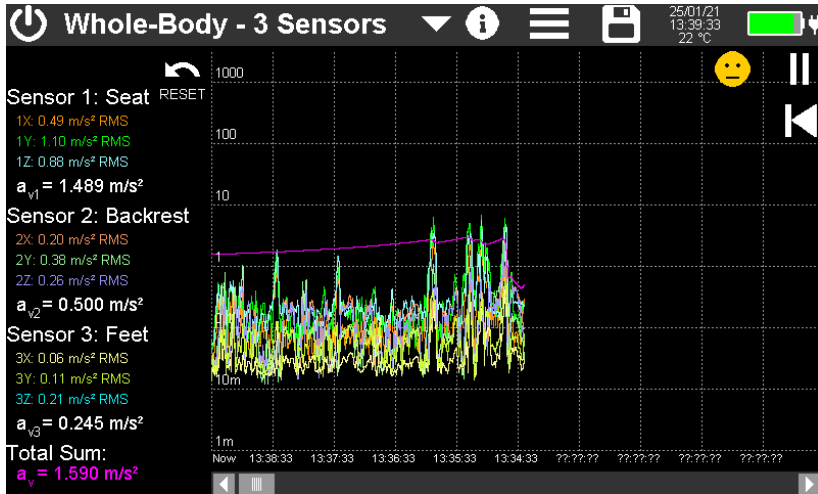


Figure 124: Measurement screen in the whole-body vibration mode with 3 sensors

On the left, the vibration values for the measurement positions Seat, Backrest and Feet are output for three axis directions each. These are interval RMS values that are averaged over the entire measurement period. This means that these values become more and more stable the longer the measurement takes. In addition, the total vibration values are determined for each position.

$$a_{vi} = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2} \quad \text{Equation 12}$$

where

- $a_{wi}$  is the energy-equivalent mean value (total vibration value) of the frequency weighted acceleration of point  $i$
- $k$  the weighting factor (Table 4)
- $a$  the frequency-weighted acceleration of the respective axis (weighting filters see Table 4)

| Measuring Point | Direction | Weighting Factor | Weighting Filter |
|-----------------|-----------|------------------|------------------|
| Seat surface    | X         | 1.00             | Wd               |
|                 | Y         | 1.00             | Wd               |
|                 | Z         | 1.00             | Wk               |
| Seat backrest   | X*        | 0.40             | Wd               |
|                 | Y         | 0.50             | Wd               |
|                 | Z*        | 0.80             | Wc               |
| Foot platform   | X         | 0.25             | Wk               |
|                 | Y         | 0.25             | Wk               |
|                 | Z         | 0.40             | Wk               |

Table 4: Weighting factors and filters to GB/T 4970-2009

\* For measurements at the backrest, the Z-axis should be in the direction of the spine, as for all positions. However, if a seat pad accelerometer is placed between the person and the backrest, its Z-axis is perpendicular to the backrest and therefore also to the spine. To establish the correct axis assignment, the weighting filters and factors for X and Z are swapped in the VM100 for measurements on the backrest.

The alignment of the measuring axes in the measuring positions can be found in Figure 114 on page 77.

Under Total Sum you will find the vector sum  $a_v$  from the vibration total values of the three measuring positions.

$$a_v = \sqrt{(a_{v1}^2 + a_{v2}^2 + a_{v3}^2)} \quad \text{Equation 13}$$

On the right, the nine measured X/Y/Z values are plotted as a time graph. Unlike the numerical values on the left they are calculated with 1 s averaging time, which has the advantage that even short-term changes are visible. Disturbances during the measurement time can be recognized or single events can be detected. In addition, the diagram shows the total sum with unlimited averaging time.

Plotting starts 15 s after opening the module in order to suppress transients. The waiting time can be skipped by touching the relevant message in the diagram.

The diagram recording can be paused (II) or restarted (II).

All measured values are displayed in the respective channel colors.

At the top right, you will see a colored indicator in the form of a smiley that shows in which of the six comfort zones the calculated total value lies. Touching the indicator opens a menu for entering the limit values. The default setting corresponds to GB/T 4970-2009.



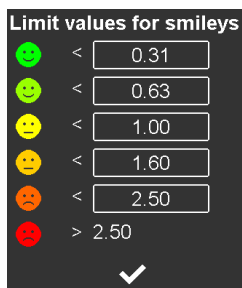




Figure 125: Comfort zones

➔ A measurement always starts by touching the reset button . This restarts the calculation of the interval RMS values and resets the measurement timer.

The measured values can be stored as CSV data table. To do this, press  to open the storage menu and select Store CSV (see section 5). The save button then appears in yellow with the text "LOG" on it. The measured values are now written to a file every second. The file name and the number of saved values are displayed at the top of the diagram. To finish recording, touch the save button again. The saved files can be found on the SD card in the "WHOLE-BODY" directory.

After 24 hours of recording the CSV log file will be closed. A new file is opened automatically. It gets the same file name with the appendix "...\_a.csv", the next file "...\_b.csv" until recording stops after 27 days with file "...\_z.csv".

Figure 126 shows an example of a CSV recording. In the header you will find information about the measuring device and the sensors used. The measurement value table starts with the channel settings, such as filters and measurement units. The recorded measured values (RMS values with 1 s averaging time and vector sums) of the nine channels X/Y/Z with time stamp follow from line 20.


WHOLE-BODY VIBRATION WITH 3 SENSORS

| Instr.:    | VM100A           | Ser.:            | 221236           |                  |                  |                  |                  |                  |                  |                  |                  |                  |                    |  |  |
|------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|--------------------|--|--|
| Comment:   |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                    |  |  |
| NFC id:    |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                    |  |  |
| Sensor 1X: | KS963B100-S      | Ser.:            | 220139           | Sensit.:         | 10,231           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 1Y: | KS963B100-S      | Ser.:            | 220139           | Sensit.:         | 10,147           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 1Z: | KS963B100-S      | Ser.:            | 220139           | Sensit.:         | 10,183           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 2X: | KS963B100-S      | Ser.:            | 220156           | Sensit.:         | 10,201           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 2Y: | KS963B100-S      | Ser.:            | 220156           | Sensit.:         | 10,158           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 2Z: | KS963B100-S      | Ser.:            | 220156           | Sensit.:         | 10,215           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 3X: | KS903B100        | Ser.:            | 20014            | Sensit.:         | 10,033           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 3Y: | KS903B100        | Ser.:            | 20014            | Sensit.:         | 10,054           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Sensor 3Z: | KS903B100        | Ser.:            | 20014            | Sensit.:         | 10,079           |                  |                  |                  |                  |                  |                  |                  | mV/ms <sup>2</sup> |  |  |
| Date:      | 09/03/23         |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                    |  |  |
| Temp:      | 21 °C            |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                  |                    |  |  |
| Channel:   | 1X               | 1Y               | 1Z               | 2X               | 2Y               | 2Z               | 3X               | 3Y               | 3Z               | a_v1             | a_v2             | a_v3             | a_vtot             |  |  |
| Filter:    | Wd               | Wd               | Wk               | Wc               | Wd               | Wd               | Wk               | Wk               | Wk               |                  |                  |                  |                    |  |  |
| Factor:    | 1                | 1                | 1                | 0,8              | 0,5              | 0,4              | 0,25             | 0,25             | 0,4              |                  |                  |                  |                    |  |  |
| Unit:      | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup> | m/s <sup>2</sup>   |  |  |
| 10:01:30   | 662,776          | 816,289          | 492,845          | 64,716           | 76,272           | 115,661          | 186,345          | 190,646          | 305,835          | 1161,248         | 152,916          | 405,716          | 1239,55            |  |  |
| 10:01:32   | 572,242          | 679,005          | 390,835          | 47,142           | 56,395           | 85,899           | 134,502          | 137,626          | 221,518          | 970,186          | 113,054          | 293,431          | 1019,875           |  |  |
| 10:01:33   | 500,216          | 578,082          | 323,749          | 38,496           | 46,067           | 70,19            | 109,846          | 112,402          | 180,909          | 830,185          | 92,362           | 239,642          | 869,003            |  |  |
| 10:01:34   | 433,592          | 500,813          | 280,407          | 33,34            | 39,896           | 60,788           | 95,134           | 97,348           | 156,679          | 719,336          | 79,99            | 207,546          | 752,939            |  |  |
| 10:01:35   | 387,847          | 447,957          | 250,825          | 29,82            | 35,694           | 54,372           | 85,092           | 87,072           | 140,145          | 643,431          | 71,547           | 185,641          | 673,487            |  |  |
| 10:01:36   | 354,101          | 408,954          | 228,992          | 27,222           | 32,576           | 49,635           | 77,68            | 79,488           | 127,943          | 587,425          | 65,214           | 169,476          | 614,863            |  |  |
| 10:01:37   | 327,848          | 378,625          | 212,022          | 25,204           | 30,159           | 45,953           | 71,919           | 73,595           | 118,489          | 543,869          | 60,469           | 156,934          | 569,279            |  |  |
| 10:01:38   | 306,68           | 354,174          | 198,342          | 23,76            | 28,212           | 42,987           | 67,276           | 68,847           | 110,853          | 508,755          | 56,565           | 146,814          | 532,527            |  |  |
| 10:01:39   | 289,143          | 333,92           | 187,013          | 22,228           | 26,598           | 40,531           | 63,431           | 64,912           | 104,523          | 479,667          | 53,332           | 138,427          | 502,082            |  |  |
| 10:01:40   | 274,306          | 316,786          | 177,429          | 21,087           | 25,233           | 38,454           | 60,177           | 61,583           | 99,174           | 455,059          | 50,597           | 131,336          | 476,327            |  |  |

Figure 126: CSV recording example

## 5. Saving Measurements and NFC Function

### 5.1. Folders and File Names

You can access the data saving menu by touching  in the menu bar. Its appearance may differ depending on the selected measuring module. Figure 127 shows the memory menu for amplitude/time measurements.

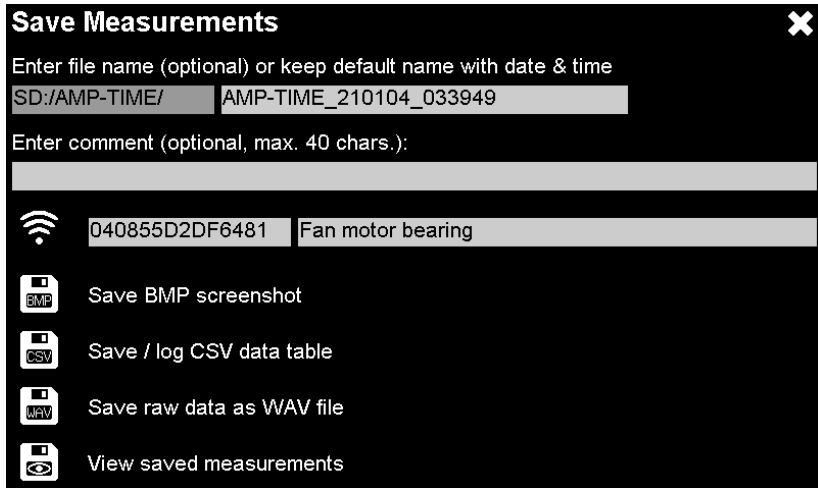


Figure 127: Save menu

The VM100 uses only the following standard file formats:

- BMP** (Bitmap) is a pixel graphics format and is used for screenshots. Bitmap files can be opened in common image viewers.
- CSV** (Character-Separated Values) is used for measuring data. Separator is the semicolon. The text-based files can be imported into spreadsheet programs.
- WAV** (WAVE) is a format for audio files. It is used in the VM100 for raw data. WAV files can be opened in audio players and imported into many signal analysis programs.

The VM100 stores the data in a fixed folder structure. The following folder names are used:

|          |   |
|----------|---|
| AMP-TIME | Measurement data from the Amplitude/Time module           |
| FFT      | Measurement data from the Frequency Analysis (FFT) module |
| AMP-RPM  | Measurement data from the Amplitude/RPM module            |
| ROUTES   | Measurement routes from the Machine Monitoring module     |
| TREND    | Measurement/trend data from the Machine Monitoring module |
| ENVELOPE | Measurement data from the Envelope Analysis module        |
| BEARINGS | Roller bearing list for the Envelope Analysis module      |
| BAL      | Measurement data from the Balancing module                |


|            |   |
|------------|---|
| OCTAVE     | Measurement data from the Third-octave Analyzer module  |
| HAND-ARM   | Measurement data from the Hand-Arm Vibration module     |
| WHOLE-BODY | Measurement data from both Whole-Body Vibration modules |
| WAV        | Raw data  |
| NFC        | Stored NFC tags   |

In the upper line you will find the folder used for saving, which depends on the measurement module and is fixed. Behind it is the file name without extension, in the example "AMP\_TIME\_210104\_033949". This is a name suggested by the device, which is composed of the measuring module, date (January 4, 2021) and time (03:39:49). This prevents duplication of names. By touching the file name, however, you can also enter your own name using the screen keyboard.

Below this, a comment text of maximum 40 characters can be entered, which will be saved with the measured values.

- ➔ Please do not add files or folders using other devices.
- ➔ Do not open files directly from the VM100 on your PC to avoid the creation of temporary files on the SD card. Always start with copying the files from the VM100 to a folder on the PC.
- ➔ It is strongly recommended to make regular backup copies of the data stored on the SD card.

## 5.2. NFC Identification of Measuring Points

By touching , the reading function for NFC tags is activated. These are robust memories in the form of plastic chips which communicate via radio. They can be attached, for example, at measurement locations where recurring measurements take place. The VM100 reads NFC tags of types, A, B, F and V. Each NFC tag contains a unique serial number, which the VM100 uses for identification. Other NFC functions are not used.

For recognition, bring the VM100 to within a few centimeters of the NFC tag (Figure 128) with the upper left corner after activating the read function. When the tag is recognized, you will hear a beep and the serial number will be displayed next to the NFC button.




Figure 128: NFC detection and sensitive corner

If desired, you can assign a plain text name to it. The input field to the right of the serial number is used for this purpose. This text will then also be displayed the next time the NFC tag is recognized. The NFC serial numbers and the names entered are stored in the "NFC" directory under the file name "NFC\_IDS.csv" on the SD card (Figure 129).


|   | A              | B                  |
|---|----------------|--------------------|
| 1 | 044E3BD2DF6480 | Motor shaft        |
| 2 | 040855D2DF6481 | Fan motor bearing  |
| 3 | 04D125D2DF6480 | Gearbox drive side |
| 4 | 04C60E5A0C5B80 | Centrifuge 22a     |

Figure 129: Example of the file NFC\_IDS.csv


### 5.3. Saving Bitmap Screenshots

By touching , you can save a bitmap screenshot of the measuring module from which you have called the save menu. This is a simple way to store graphics and texts in a standard file. At the upper edge of the bitmap graphics you find the entered comment and if NFC was used the serial number as well as the associated name. The BMP file is saved in the folder belonging to the measuring module on the SD card.

## 5.4. Saving Data in CSV Format

With the  button you can create a CSV file with measured values. CSV (character-separated values) is a text-based format that contains tabulated data. It can be opened in spreadsheet programs, for example. The chapters on the measurement modules show examples of this. The VM100 uses the semicolon as separator. The files always consist of a header, which contains information about the sensors, the device and selected settings. In the header there is also the entered comment text and if used the NFC serial number. The measured values start from line 20. The CSV file is saved in the folder belonging to the measuring module on the SD card. For modules measuring in time domain, the measured values are logged to the CSV file. For modules measuring in the frequency domain, the frequency spectrum is stored as a table.

## 5.5. Viewing Saved Measurement Data

The button  is used to view the saved BMP and CSV files. To open them, touch the relevant folder and then the name of the desired file (Figure 130).

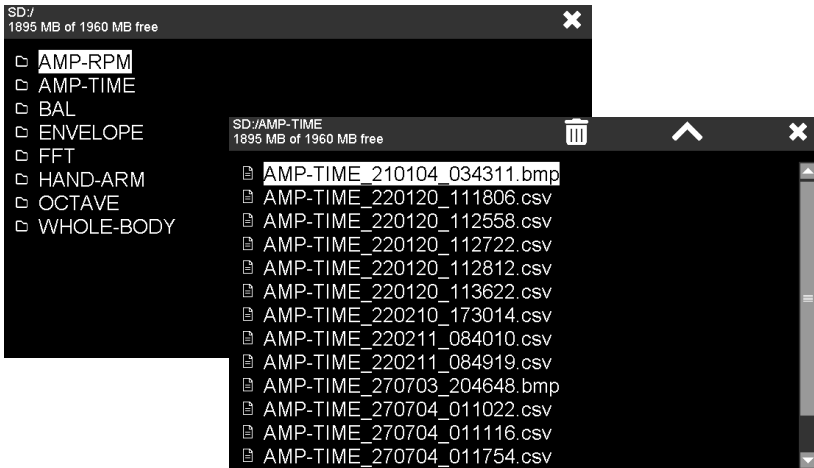



Figure 130: Viewing BMP-/CSV files

Section 3.5 describes how you can transfer the data stored on the SD card to a PC via the USB interface.

## 5.6. Recording Raw Data in WAV Format

The VM100 can record raw data regardless of the measuring module selected. It records the unfiltered sample values of the analog-to-digital converter. Recording takes place in WAV format (Waveform Audio Format). WAV files are read by many signal analysis programs and audio players. To switch to the raw data menu, touch . Figure 131 shows the raw data view, which corresponds to that of an oscilloscope.

The raw data is recorded for the three channels X/Y/Z of input 1.

When opening the raw data recording, the gain is set so that the signal fits into the amplitude range without clipping. The gain is the same for all three channels. The level is displayed as a percentage of full scale in the diagram area.

Recording takes place with a bandwidth of 4.5 kHz at a sampling rate of 9765 samples/s and 24 bit resolution. The maximum recording time per file is one hour. The file size is then approx. 300 MB.

You can change the displayed signal section using the +/- buttons. The selected section has no influence on the storage.

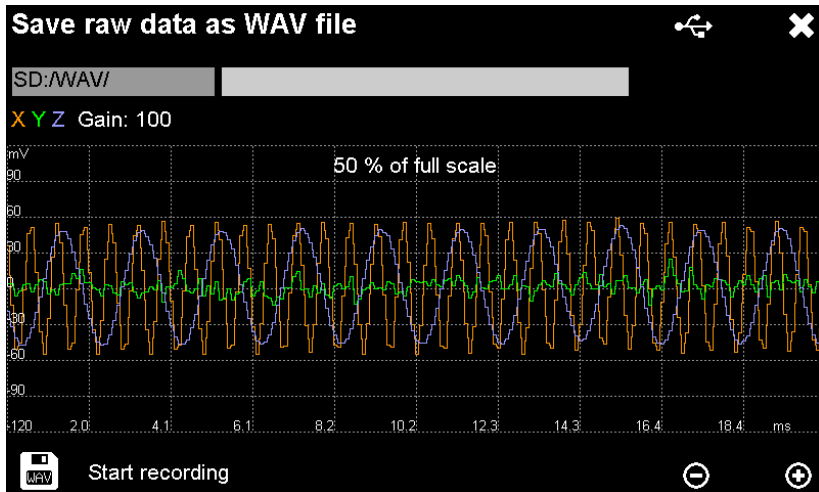




Figure 131: Raw data recording

Touch  to start saving. The signal diagram is then no longer updated. The file name is automatically generated from the date, start time and amplitude range. Example: 240423\_115424\_120mV.wav.

The recording duration is displayed at the bottom left. Saving takes place in blocks of 720 kB each. The maximum duration is one hour. Touch STOP to end the recording. The recorded raw data is stored on the SD card in the WAV directory.

Section 3.5 describes how you can transfer the data stored on the SD card to a PC via the USB interface.

## 6. Presets

You can save up to 10 sets of settings for faster access. This is done in the main menu  under "Presets".

All current menu settings including the settings of the measuring graph are saved.

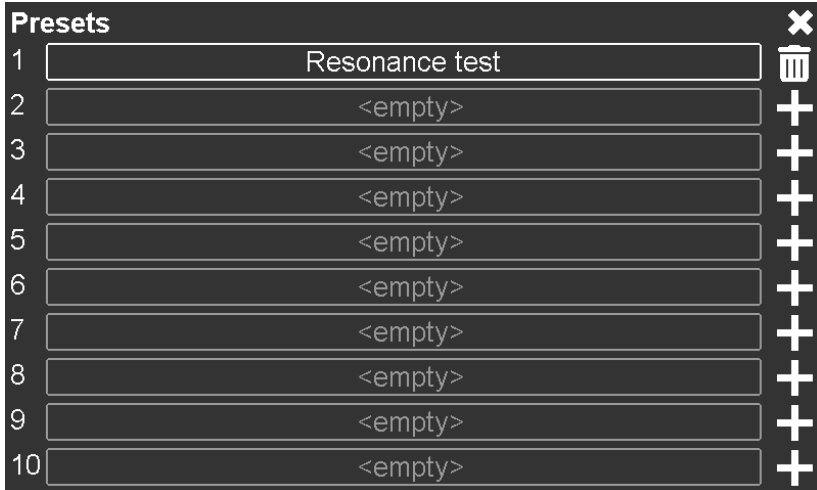






Figure 132: Saving and loading settings

In the delivery state, all entries are empty. Each of the buttons numbered 1 to 10 can be assigned a set of settings. This is done with the Plus button . The touch keypad opens for entering a name. The default name is "Preset" with the corresponding number. By pressing the Enter key of the keypad, the settings are saved under the name entered. These are always the last settings before the menu was opened. If you want to change an existing setting while keeping its name, proceed as follows:

- Open the presets menu.
  - Press the corresponding button to load the saved settings. The menu closes and the instrument switches to measuring mode.
  - Change the desired setting.
  - Open the menu for presets again.
  - Delete the entry to be changed with .
  - Create the same entry again with . The previous name appears as default. Confirm with the Enter button.
- ➔ Regardless of the 10 saved presets, all settings will always be saved before the device is switched off and reloaded at startup.

## 7. Other Settings

### 7.1. Display Settings

Touch the  button and open the main menu to select Settings and Display (Figure 133).

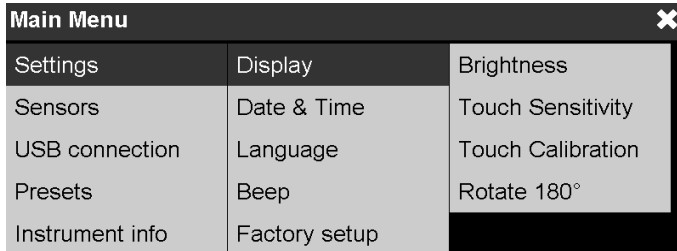


Figure 133: Display settings

Touch **Brightness** to open the menu for setting the display brightness (Figure 134). The share of the backlight can be up to 50 % of the total power consumption of the device. Reducing the brightness to the required level is therefore useful, as is the **Dim out after** function, which dims the brightness considerably a certain time after the last touch operation.

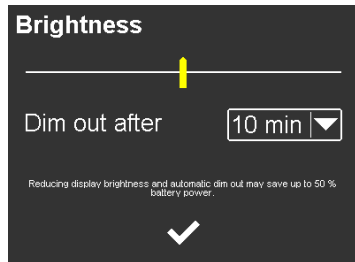


Figure 134: Display brightness

In the **Touch Sensitivity** menu item, you set how sensitive the display should be (Figure 135).



Figure 135: Touch sensitivity

With **Calibrate** you can readjust the accuracy of the touch screen by touching five points in succession (Figure 136).

The menu item **Rotate 180°** turns the screen content upside down. The sensor connectors are then on the upper side, which may be useful for handling.

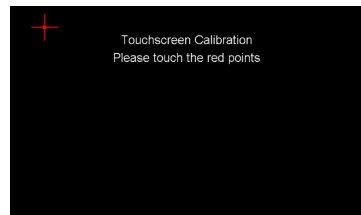


Figure 136: Touch calibration



## 7.2. Date and Time

The setting of date and time is done by moving up or down in the respective input field (Figure 137).

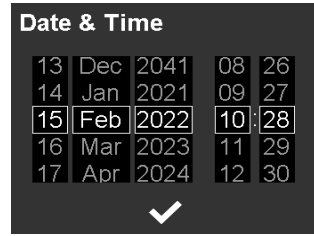


Figure 137: Date and time

## 7.3. Language

In Figure 138 you can see how to select the display language of the VM100. The selection of the language only affects the operating dialog. All stored data remains in English.

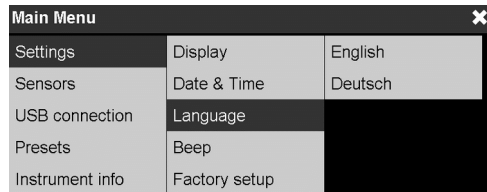


Figure 138: Display language selection

## 7.4. Beep Signal

You can deactivate the signal tone (beep) if desired (Figure 139).

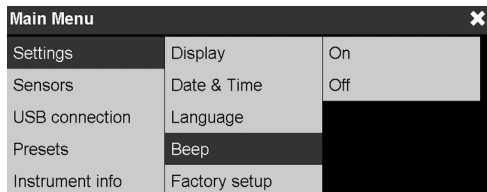



Figure 139: Switch the beep tone on and off

## 7.5. Factory Reset

With a factory reset, the device is reset to the default settings. This is done by holding the F1 button and pressing shortly RESET or by holding F1 while pressing  (Figures 1 and 2).

The data stored on the SD card and the calibration data remains unaffected.

## 7.6. Device Data

Under Instrument info you will find the serial number, version and calibration date of your instrument. (Figure 140).



Figure 140: Device data

## 8. Firmware Update

Updating the VM100 software is done via USB in DFU (Device Firmware Upgrade) mode. This method allows complete reprogramming from virtually any state. Prerequisite is the installation of the program **STM32CubeProgrammer** on your PC. The program is available for download on our website

<https://mmf.de/en/produkt/vm100a>.

for Windows systems with 32 and 64 bit. Unpack and install the software on your PC.

You can also obtain the current firmware file **vm100.zip** from our download page. Unpack the contained file **vm100.hex** and save it in a folder of your choice.

➔ Please follow the instructions below exactly. The firmware update affects memory sectors 2 to 7. Sectors 0 and 1 contain the settings and calibration values. They must not be deleted or overwritten.

Start STM32CubeProgrammer (Figure 141).

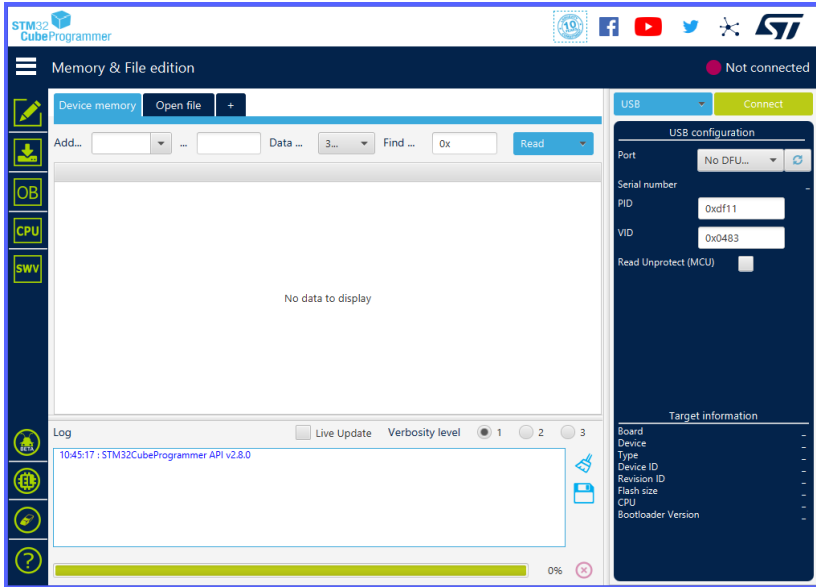


Figure 141: Update software STM32CubeProgrammer

Click  to select „Memory & File edition“.

Select the tab “Open file” and load the firmware file vm100.hex (Figure 142).

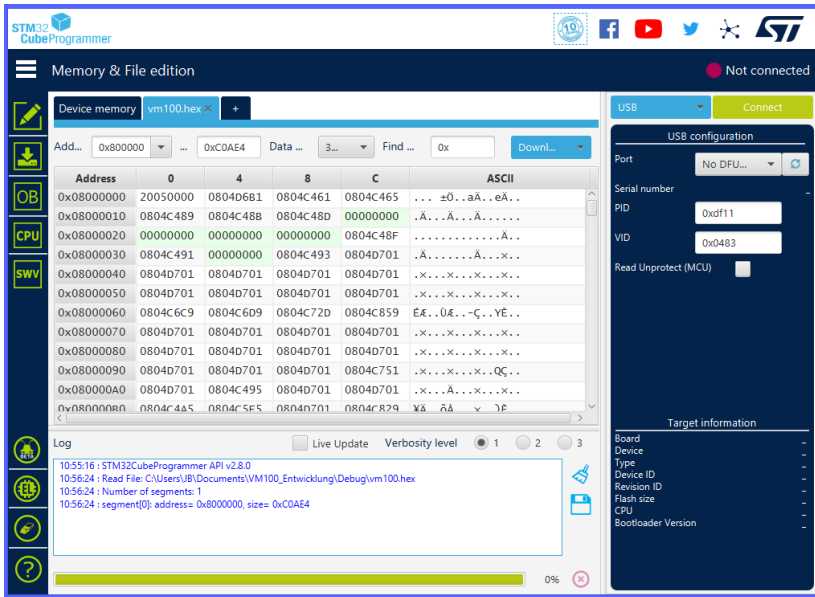


Figure 142: STM32CubeProgrammer with loaded firmware file

Now the VM100 needs to be prepared for the update. To do so, switch the VM100 off. Unscrew the cover of the update interface (Figure 143). Connect the USB-C update interface to a PC (Figure 144).



Figure 143: Open cover



Figure 144: Connect USB cable

The VM100 switches on with the update screen giving some instruction (Figure 145).

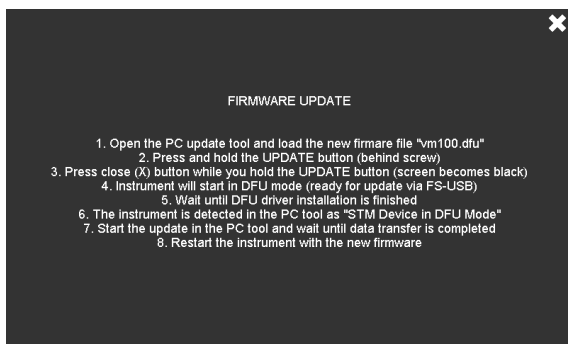


Figure 145: VM100 in update mode

Use a pointed, non-metallic object, for example a toothpick to press the button behind the screw hole of the update USB cover (Figure 146).



Figure 146: Press update button

While holding down the button, close the window with . The screen goes dark. The device is now in DFU mode.

The DFU device driver is part of the installation package of STM32CubeProgrammer.

Click the button under “USB” to refresh the display. If the VM100 is recognized by the PC as a DFU device, it will appear in the update program as port "USB1" (Figure 147). Click .

The button starts the firmware transfer to the VM100. Figure 148 shows the completion of a successful transfer. After that you can disconnect the USB cable and restart the device with the new firmware.

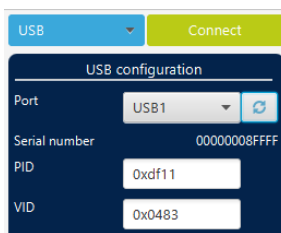


Figure 147: DFU connection

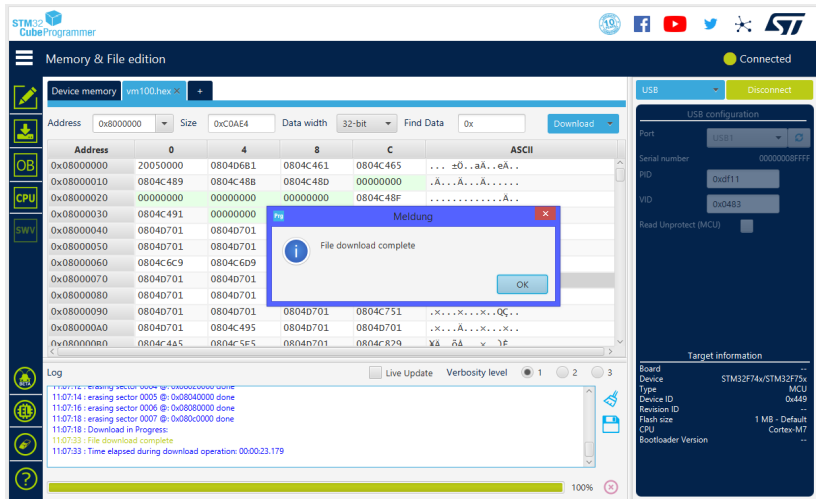


Figure 148: Finished firmware update

## 9. Troubleshooting

Files are saved with errors.

Back up the files from the SD card. Remove the SD card and either format or check and repair it with a PC.

The measurements are noisy.

For sensitive measurements the USB cable should be unplugged.

In Amplitude/Time mode the rotation speed is not displayed although the rpm sensor is connected.

In the common settings for channel 1 to 9 (button “ALL”) the rpm unit needs to be selected.

Charging the battery takes very long.

The VM100 should be charged at a USB port or power supply providing at least 2 A output current. At standard USB sockets the charge icon will appear but there will be just enough current to power the instrument itself.

It takes too long to detect the SD card from the PC via USB.

The SD card must be formatted with the FAT(16) file system. SD cards are factory formatted with FAT32.

WAV recording stops unintentionally.

Use an SD card with 4 GB capacity and speed class 10.

## 10. Technical Data

|                        | <b>VM100A</b>  | <b>VM100B</b>                                |
|------------------------|--|--|
| Sensor inputs          | 9 IEPE sensors<br>3 Binder 712, 4 pin sockets  | 3 IEPE sensors<br>1 Binder 712, 4 pin socket |
| IEPE sensor supply     | 4 mA / 24 V, can be switched off<br>Input impedance: > 1 M $\Omega$  |  |
| TEDS sensor detection  | IEEE 1451.4, Templates 25, 27, 28  |  |
| Measuring point ID     | NFC transponders of types A, B, F and V  |  |
| Tacho input            | Hi level: +3 to +28 V; Lo level: 0 to +1 V<br>Frequency: 1 to 1000 Hz / 60 to 60 000 min <sup>-1</sup><br>Supply voltages: +5 V / <0.1 A and +26 V / < 0.1 A<br>Binder 712, 7 pin socket |  |
| Measuring range        | 1 $\mu\text{m/s}^2$ to 10 000 m/s <sup>2</sup> (depending on sensors)  |  |
| A/D conversion         | 24 Bit Sigma Delta converters for each channel   |  |
| Analog gains           | 1 / 10 / 100 / autoranging   |  |
| Accuracy               | <1 % (at reference conditions)   |  |
| Amplitude linearity    | >85 dB (<6 % error)  |  |
| Cross-talk attenuation | >80 dB (2500 mV <sub>RMS</sub> / 160 Hz at input)  |  |

### Measurement Modules

|                       |                                     |
|-----------------------|-------------------------------------|
| Amplitude/time        | VM100-AMP (pre-installed)           |
| Frequency analysis    | VM100-FFT (pre-installed)           |
| Amplitude/rot. speed  | VM100-RPM (option)                  |
| Machine vibration     | VM100-MACH (option)                 |
| Envelope analysis     | VM100-ENV (option)                  |
| Balancing             | VM100-BAL (option)                  |
| Third-octave analysis | VM100-VC (option)                   |
| Hand-arm              | VM100-HA (option)                   |
| Whole-body            | VM100-WB1 (option)                  |
| Whole-body-3 sensors  | VM100-WB3 (option, only for VM100A) |

**Overall value measurement in time domain and human vibration  
(VM100-AMP / VM100-HA / VM100-WB1 / VM100-WB3)**

|                                       |   |        |
|---------------------------------------|---|--------|
| Channels                              | 1 to 9  | 1 to 3 |
| Measurands                            | Acceleration; velocity (<4 kHz); displacement (<300 Hz)   |        |
| Overall values                        | Interval RMS (unlimited), RMS (1s), peak value, peak-to-peak value, maximum peak, crest factor, main frequency, square root of square sum of 3 channels |        |
| Band filters                          | 34 high pass filters from 0.2 to 5000 Hz<br>38 low pass filters from 10 Hz to 24 kHz  |        |
| Weighting filters for human vibration | Wb; Wc; Wd; We; Wh; Wj; Wk; Wm<br>unweighted: 6.3 to 1259 Hz (H-A); 0.4 to 100 Hz (W-B)   |        |
| Data plotter                          | 1 value per second, max. 10 hours, 3 or 9 channels  |        |

**Frequency Analyzer VM100-FFT)**

|                      |   |
|----------------------|---|
| Channels             | 1 to 3                                    |
| Frequency range      | 1 Hz to 22 kHz                            |
| Frequency points     | 1024 to 65536                             |
| Frequency resolution | 0.7 to 48 Hz                              |
| Windowing            | Hann, Hamming, Flattop                    |
| Amplitude axis       | RMS, linear / logarithmic, maximum hold   |
| Triggering           | Automatic, tacho input, amplitude trigger |
| Waterfall mode       | 1 channel, up to 50 spectra               |

**Third-Octave Band Analyzer (VM100-VC)**

|                    |                                       |
|--------------------|---------------------------------------|
| Channels           | 1 to 3                                |
| Frequency range    | 1 to 100 Hz; 21 third-octave bands    |
| Amplitude axis     | Vibration velocity in $\mu\text{m/s}$ |
| Vibration criteria | VC-A to VC-G; Nano-D; Nano-E; Nano-EF |

**Envelope Analysis for Roller Bearings (VM100-ENV)**

|                   |   |
|-------------------|---|
| Frequency markers | RPM, BPFI (inner ring), BPFO (outer ring), FTF (cage), BSF (rolling elements) |
| RPM input         | Tacho input with photoelectric reflex switch or value input                   |
| Bearing list      | Up to 1000 bearing types  |

## Machine Vibration (VM100-MACH)

|   |  |
|---|--|
| Channels                                      | 1 (bearing), 3 (vibration severity)  |
| Frequency range for bearing mode              | Acceleration 0.2 – 24000 Hz  |
| Frequency ranges for vibration severity       | Acceleration 0.2 - 2000 Hz<br>Velocity 2 – 4000 Hz<br>Displacement 2 – 300 Hz  |
| Measuring routes                              | Measurement point definition with location, machine, position and comment, detection by NFC tags supported   |
| Trend view                                    | Diagram with limit lines   |
| Measurement functions for bearings            | Peak, RMS, crest with short-term trend, envelope analysis, 3 frequency bands, rotation speed   |
| Measurement functions for vibration severity  | Peak, RMS of velocity, acceleration or displacement with short-term trend, phase angle, frequency analysis, main frequencies/harmonics, rotation speed   |
| ISO standard assistant for vibration severity | ISO 20816-2: Gas/steam turbines, generators >40 MW<br>ISO 20816-3: Industrial machines >15 kW<br>ISO 20816-5: Hydro power generating/pump storage<br>ISO 10816-7: Rotodynamic pumps<br>ISO 20816-8: Reciprocating compressors<br>ISO 20816-9: Gear units<br>ISO 14694: Industrial fans |

## Balancing (VM100-BAL)

|                    |  |
|--------------------|--|
| Planes             | 1 or 2   |
| RPM range          | 100 to 60000 min <sup>-1</sup>   |
| Angle index sensor | Tacho input with photoelectric reflex switch                               |
| Modes              | Free or fixed angles, add or remove mass                                   |
| Displayed values   | Vibration velocity / acceleration;<br>remaining unbalance; balance quality |

## Measurement Storage and Interface

|               |  |
|---------------|--|
| Data memory   | Micro SD card; 4 GB; FAT file system, removable                      |
| Data formats  | CSV for measuring data<br>BMP for screenshots<br>WAV for raw signals |
| USB interface | USB 2.0 high-speed, type C connector                                 |



### **Power Supply**

|                |  |
|----------------|--|
| Battery        | NiMH; built-in; 4.8 V; 9Ah               |
| Operating time | 10 to 14 h                               |
| Charging       | USB plug adapter 5 V / >2 A; approx. 6 h |

### **Miscellaneous**

|                       |   |
|-----------------------|---|
| Screen                | RGB TFT with touch operation; 800 x 480 pixels            |
| Operating temperature | -20 to 60 °C; < 95 % humidity; without condensation       |
| Protection grade      | IP65  |
| Dimensions            | 215 mm x 150 mm x 50 mm                                   |
| Weight                | 1,3 kg  |
| Scope of delivery     | Instrument; USB-C cable; USB mains adapter; carrying case |

### **Optional Accessories**

|                        |  |
|------------------------|--|
| Sensor adapter cable   | 034-B711-BNCf: Binder to BNC female; 0.5 m |
| Photoel. reflex switch | VM100-PS                                   |

## Limited Warranty

Metra warrants for a period of

**24 months**

that its products will be free from defects in material or workmanship and shall conform to the specifications current at the time of shipment.

The warranty period starts with the date of invoice.

The customer must provide the dated bill of sale as evidence.

The warranty period ends after 24 months.

Repairs do not extend the warranty period.

This limited warranty covers only defects which arise as a result of normal use according to the instruction manual.

Metra's responsibility under this warranty does not apply to any improper or inadequate maintenance or modification and operation outside the product's specifications.

Shipment to Metra will be paid by the customer.

The repaired or replaced product will be sent back at Metra's expense.

## Declaration of Conformity

According to EMC Directive 2014/30/EC and  
UK Electromagnetic Compatibility Regulations 2016

Product: Vibration Analyzers

Type: VM100A/B

It is hereby certified that the above mentioned product complies with the demands pursuant to the following standards:

DIN / BS EN 61326-1: 2013

DIN / BS EN 61010-1: 2011

DIN 45669-1: 2010

The producer is responsible for this declaration  
Metra Mess- und Frequenztechnik in Radebeul e.K.

Meißner Str. 58, D-01445 Radebeul  
declared by



Michael Weber  
Radebeul, November 21, 2022

The pattern evaluation according to ISO 8041-1 was performed in May 2022.