Instruction Manual

Vibration Analyzer

VM100

Valid from Version 001.004

Manfred Weber

Metra Mess- und Frequenztechnik in Radebeul e.K.

Meissner Str. 58 - D-01445 Radebeul

Tel. +49-351 836 2191 Fax +49-351 836 2940

Email: Info@MMF.de   Internet: www.MMF.de

Dec/ 23

Contents

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.
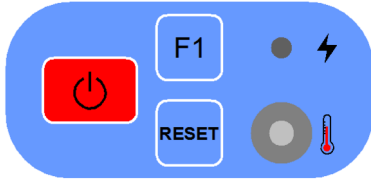
Figure 1: Keypad of VM100A
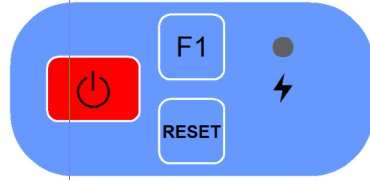
Figure 2: Keypad of VM100B

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:

Figure 3: Sensor input

1: Ground

2: Channel X

3: Channel Y

4: Channel Z
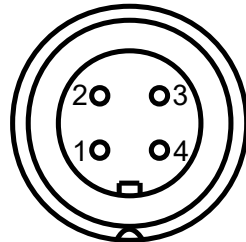
The VM100 has standard IEPE inputs.

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

5: Analog input A2

7: Ground
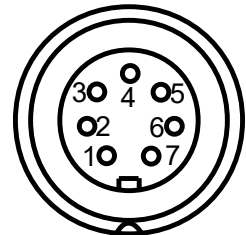
Figure 4: Tacho input

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).

⏻ **Third-Octave Analysis** ▼ ⓘ ☰ 💾 12/01/22 10:12:46 19 °C 🔋

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 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).

- 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).

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 connector. It is used to charge the battery and 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, select **USB connection** in the main menu (Figure 7). You will then see the display corresponding to Figure 7.
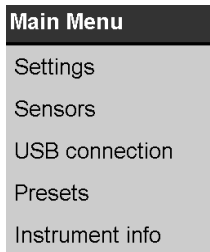
Figure 7: Main menu

Figure 8: USB connection

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.

➔ 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.

Figure 9: Charge 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 ![battery icon].

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.

➔ For sensitive measurements, the charger should be disconnected.

Figure 10: Charge connector and SD card slot

3.7. SD Card and File System

The 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. For more details on measured value 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.

➔ Before inserting a new SD card it has to be formatted in FAT format.

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.

Amplitude/Time ▼
Amplitude/Time
Frequency Analysis (FFT)
Amplitude/Rotation Speed
Machine Vibration
Envelope Analysis
Balancing
Third-Octave Analysis
Hand-Arm Vibration
Whole-Body Vibration
Whole-Body - 3 Sensors
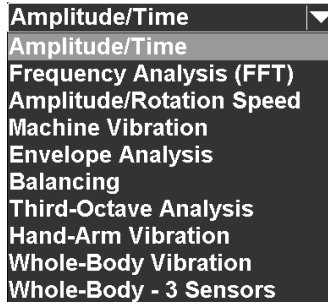
Figure 11: Measurement modules

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 53 on page 42).

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.
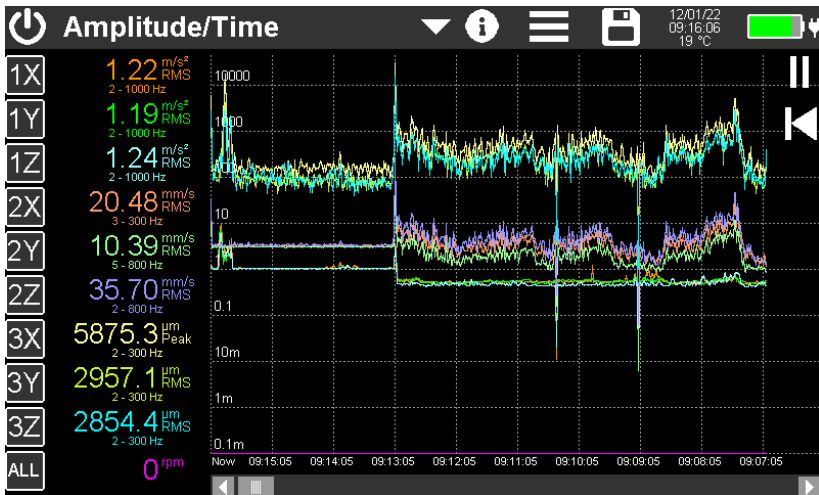
Figure 12: Display in the module Amplitude/Time

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.
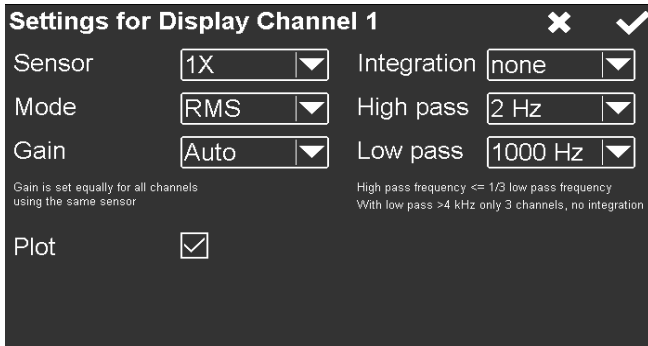
Figure 13: Settings for one channel
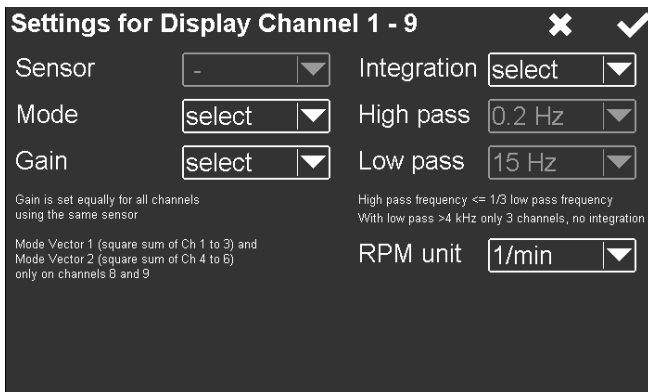
Figure 14: Settings for all channels simultaneously

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.

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.
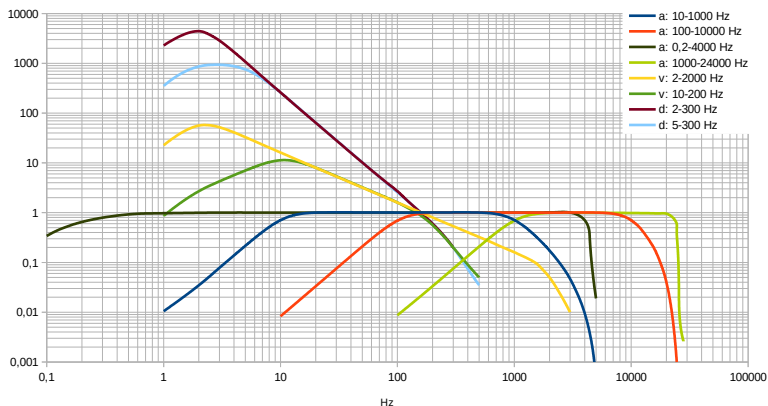
Figure 15: Frequency response of selected filters and integrators

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/s²				
Sensor 1Y:		Ser.:	170345	Sensit.:	10.354	mV/m/s²				
Sensor 1Z:		Ser.:	170345	Sensit.:	10.879	mV/m/s²				
Sensor 2X:		Ser.:	181653	Sensit.:	100.45	mV/m/s²				
Sensor 2Y:		Ser.:	181653	Sensit.:	100.35	mV/m/s²				
Sensor 2Z:		Ser.:	181653	Sensit.:	100.18	mV/m/s²				
Sensor 3X:		Ser.:	173871	Sensit.:	10.313	mV/m/s²				
Sensor 3Y:		Ser.:	173871	Sensit.:	10.354	mV/m/s²				
Sensor 3Z:		Ser.:	173871	Sensit.:	10.879	mV/m/s²				
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/s²	m/s²	m/s²	m/s²	m/s²	m/s²	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.
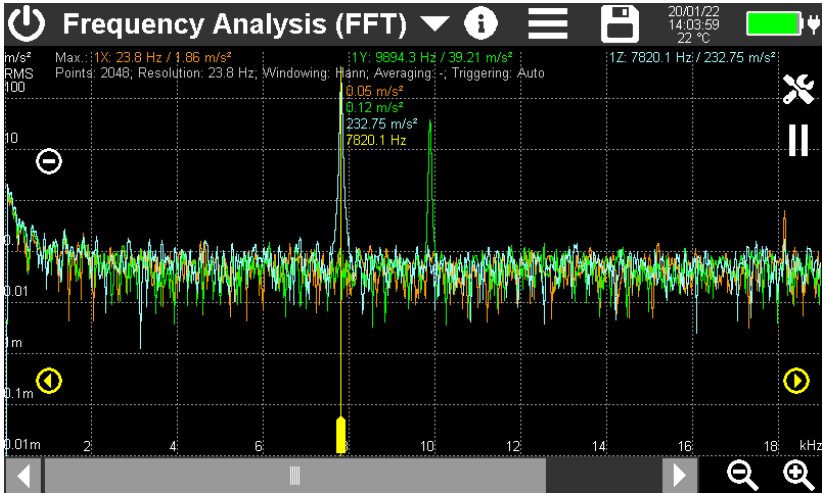
Figure 17: Measurement screen of frequency analysis

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).
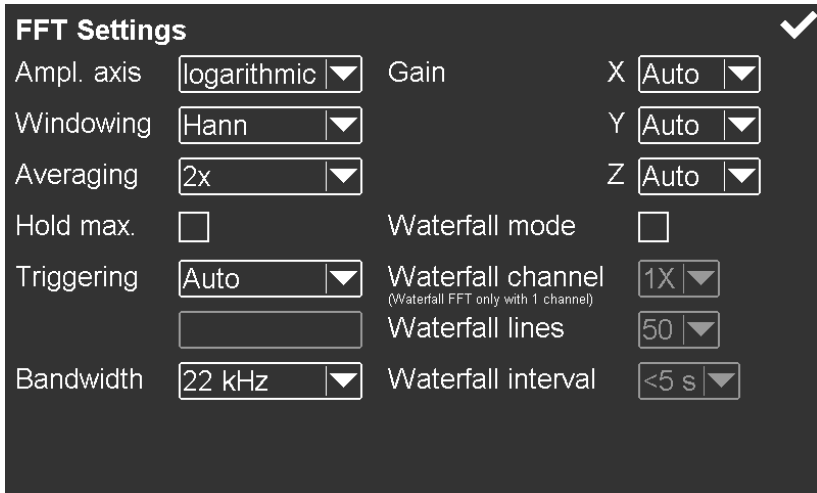
Figure 18: FFT menu

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.

	Window functions and their effect in the frequency spectrum
Hann	
	Good compromise for most applications
Hamming	
	Good separation of closely spaced frequency components
Flattop	
	Highest amplitude accuracy
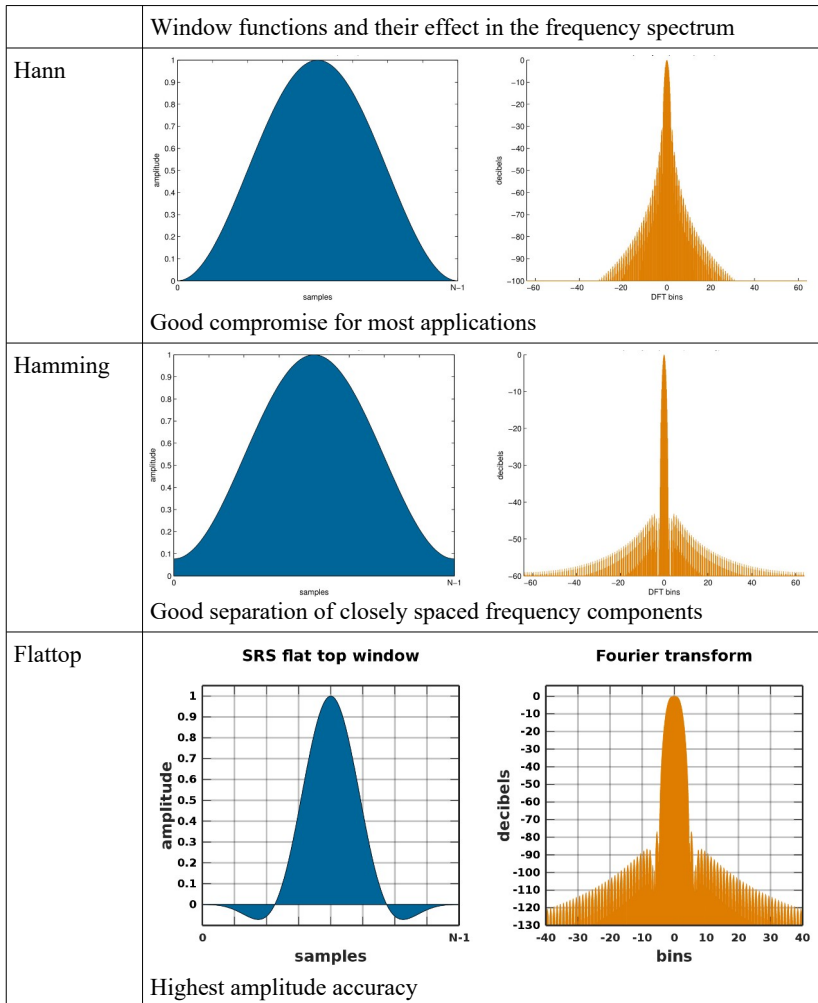
Figure 19: Window functions used in the VM100 (Wikimedia Commons)

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 ![RESET] 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.
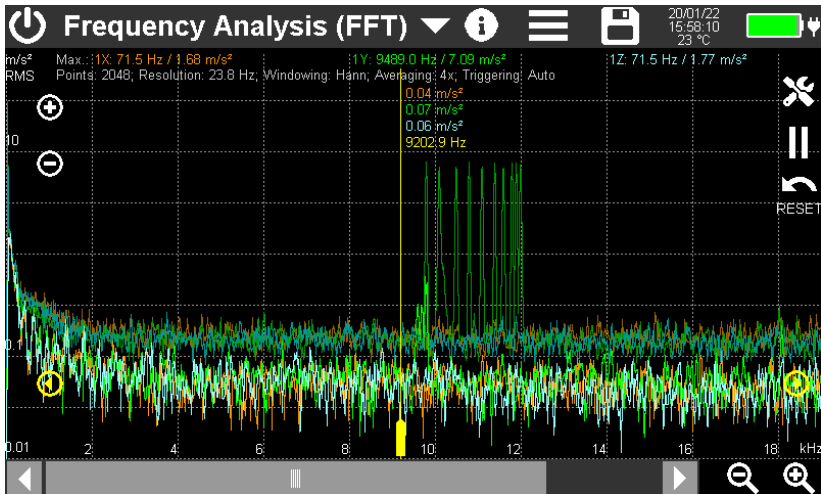
Figure 20: FFT with active hold function

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).
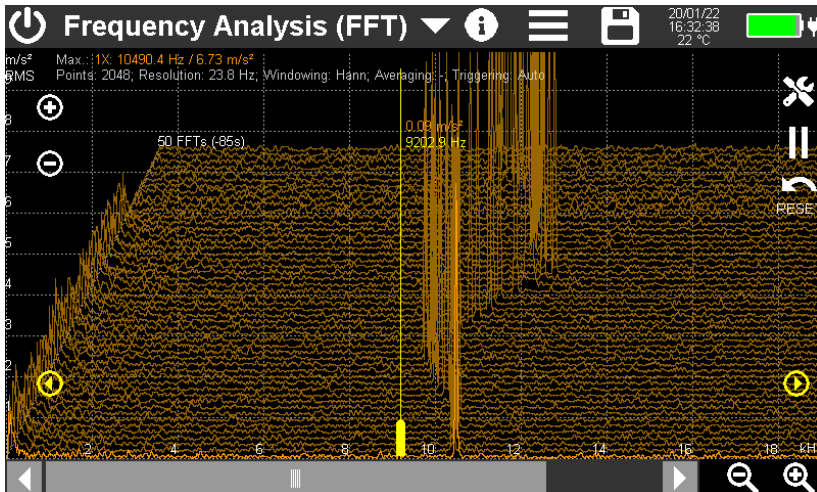
Figure 21: FFT in waterfall mode

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 ![RESET] 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.
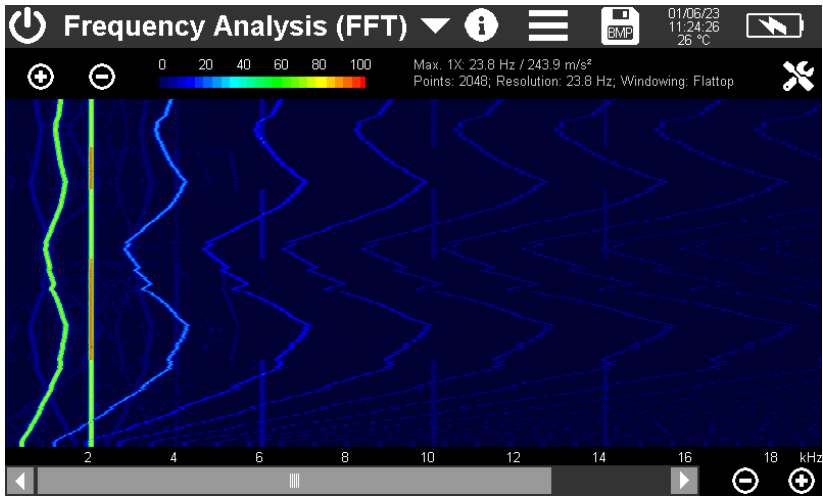
Figure 22: Spectrogram view

The following options are available for saving with the button [image]. 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/s²
Sensor 1Y:		Serial no.:		Sensit.:	10.354	mV/m/s²
Sensor 1Z:		Serial no.:		Sensit.:	10.879	mV/m/s²
Date:	21.01.2022					
Time:	07:36:50					
Temp:	20	°C				
Points:	2048					
Window:	Hann					
Hz	X: m/s²	Y: m/s²	Z: m/s²			
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 53 on page 42) to the input "RPM" of the VM100, which serves as rotary speed sensor.

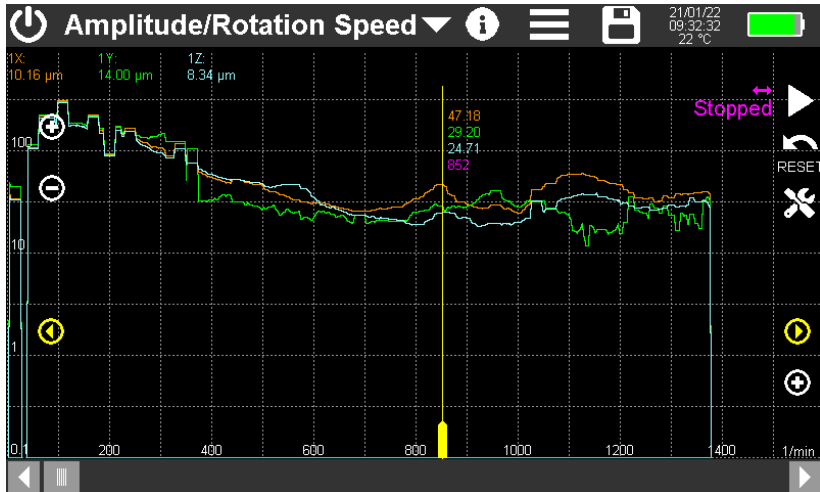The vibration measurement can be done on 1 to 9 channels.

Figure 24: Amplitude/rotation speed measurement
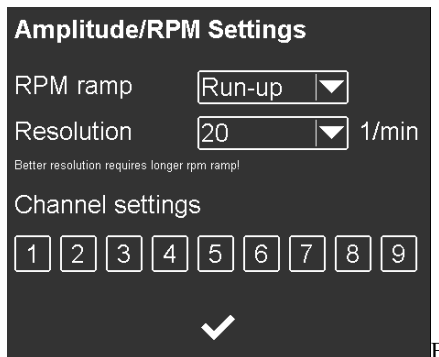
Touch ✖ to open the setup menu (Figure 25).

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. 11). 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 **II** 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:	KS903B10	Ser.:	20014	Sensit.:	10.313	mV/mm/s			
Sensor 1Y:	KS903B10	Ser.:	20014	Sensit.:	10.354	mV/mm/s			
Sensor 1Z:	KS903B10	Ser.:	20014	Sensit.:	10.879	mV/mm/s			
Sensor 2X:		Ser.:		Sensit.:	10.000	mV/m/s²			
Sensor 2Y:		Ser.:		Sensit.:	10.000	mV/m/s²			
Sensor 2Z:		Ser.:		Sensit.:	10.000	mV/m/s²			
Sensor 3X:		Ser.:		Sensit.:	10.313	mV/m/s²			
Sensor 3Y:		Ser.:		Sensit.:	10.354	mV/m/s²			
Sensor 3Z:		Ser.:		Sensit.:	10.879	mV/m/s²			
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/s²	m/s²	m/s²	m/s²	m/s²	m/s²
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-¹, 1800 min-¹, 3000 min-¹ and 3600 min-¹
- ISO 20816-3: Industrial machines with power above 15 kW and operating speeds between 120 min-¹ and 30000 min-¹
- 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

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. The VM100 also supports the monitoring of roller bearings according to ISO 13373-3 on the basis of RMS and peak values of the vibration acceleration in the frequency range from 10 Hz to 10 kHz.

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.

4.5.2. 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. 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.
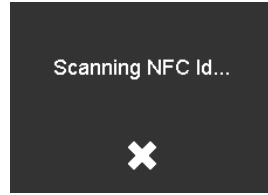

Figure 29: NFC detection
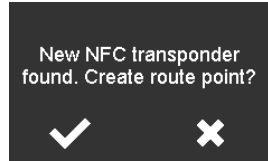
Figure 30: NFC tag found

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 31). 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. 31).

➜ 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.

Below this, you select the measurand and the filtering. You can choose between uniaxial and triaxial measurement. The measurement interval has to be specified in days.

Finally, limit values for pre-alarm (warning) and alarm are entered.

If no empirical values are available, the limit values from relevant ISO standards can be used by touching the icon 🌐ISO.

Figure 31: Adding a new route point

A menu opens with the above-mentioned standards and the required selection criteria (Figure 32). After the selection has been made, the limit values for warning and alarm are displayed (Figure 33). By touching ✔ these are transferred into the measuring point menu. The measured variable settings are also made according to the selected standard.

Figure 32: ISO assistant

Figure 33: Settings and limit value for the selected standard

After closing the measuring point menu with ✅, the newly created measuring point appears with its settings in the measuring route (Figure 34).

Figure 34: Measuring route with measuring point

Each time a route file (*csv) is modified the previous version is saved as Backup file with the file name extension "bak". The old route file can be restored by renaming it to "csv".

4.5.4. Trend Monitoring of Vibration Severity

On rotating machines, the RMS value of vibration velocity serves as a monitoring variable for trend recording. For reciprocating compressors, vibration displacement and vibration acceleration are also measured.

If a measuring point has been created, measured values can be recorded for trend monitoring. Touch the line with the desired measuring point to select it. The background color turns into 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 detecting the NFC serial number.

Figure 35: Measuring route with selected point

With the ✖ button you can edit an already created measuring point afterwards. This concerns location, machine, position, comment, measuring interval and limit values. For reasons of consistency with previously saved measurements, the information on the measured variable can no longer be edited.

Touch 🗑 to delete the selected measurement point from the measurement route.

➔ This will not delete the file with the measured data from the SD card.

Touch ![icon] to switch to the measurement and trend view (Figure 36). In the upper part you can see the currently measured value(s). In the diagram below, the previous trend graphs are shown in the channel color, together with the two limit lines in yellow and red. At the left edge is the beginning of the measurement series. The time axis is scaled in an appropriate unit (minutes, hours, days or years).
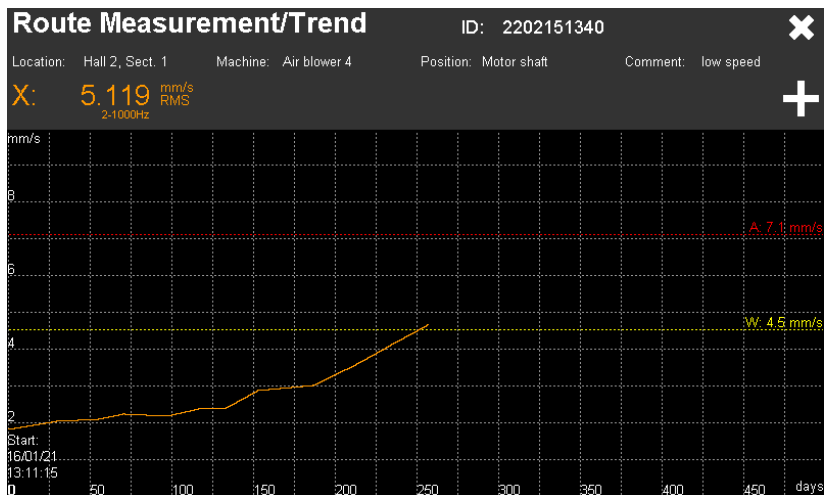
Figure 36: Measurement and trend view

By touching ![plus icon] the current measuring values are added to the trend.

The VM100 saves the measuring points and their measured values in the TREND folder on the SD card in CSV format. The file name is made from the measuring point ID and the ending "csv". The header contains the device and sensor data, the description of the measuring point and the selected measurement settings. From line 20 the measured values start, each with a timestamp. Figure 37 shows an example.

```
TREND DATA
ID:            2202151340
Instr.:        VM100A      Ser.:        123456
Sen. 1X:                   Ser.:                   Sensit.:  10.1   mV/ms^-2
Sen. 1Y:       none        Ser.:        none       Sensit.:  none
Sen. 1Z:       none        Ser.:        none       Sensit.:  none
Location:      Hall 2         Sect. 1
Machine:       Air blower 4
Position:      Motor shaft
Comment:       low speed
Warning:       4,5         mm/s
Alarm:         7,1         mm/s


Channel:                   1X
HP (Hz):                   2
LP (Hz):                   1000
Mode:                      RMS
Date           Time        mm/s
 16/01/21      13:11:15    1,856
 15/02/21      14:41:45    2,058
 13/03/21      12:13:09    2,122
 28/03/21      08:10:16    2,268
 24/04/21      15:13:25    2,214
 13/05/21      12:53:15    2,416
 30/05/21      11:13:49    2,426
 18/06/21      15:25:19    2,895
 22/07/21      11:12:14    3,03
 18/08/21      11:54:24    3,62
 08/09/21      16:15:01    4,16
 30/09/21      12:51:54    4,682
```

Figure 37: Measuring point file example

The date of the last measurement performed is displayed in the last column of the measurement route for each measurement point. The VM100 uses this date to determine whether it is still within the defined measurement interval (cf. Section 4.5.3) or whether a new measurement is due. Figure 38 gives an example.

The meaning of the colors is:

Green: The last measurement is within the measurement interval.

Orange: The measurement interval was exceeded by a maximum of 20%.

Dark red: The measurement interval has been exceeded by more than 20%.

Light red: The measurement interval has been exceeded by more than 100%.

t	Intv. days	Ch. no.	Mode	Inte-gration	High pass	Low pass	Warning limit	Alarm limit	ID	Date of last meas
eed	30	1	RMS	single	2 Hz	1000 Hz	4.5	7.1	220215134005	15/02/22
eed	30	1	RMS	single	10 Hz	1000 Hz	6.0	8.0	040855D2DF6481	16/01/22
eed	30	1	RMS	single	10 Hz	1000 Hz	8.0	12.0	044E3BD2DF6480	28/12/21
eed	30	1	RMS	single	10 Hz	1000 Hz	7.0	10.0	04D125D2DF6480	10/11/21
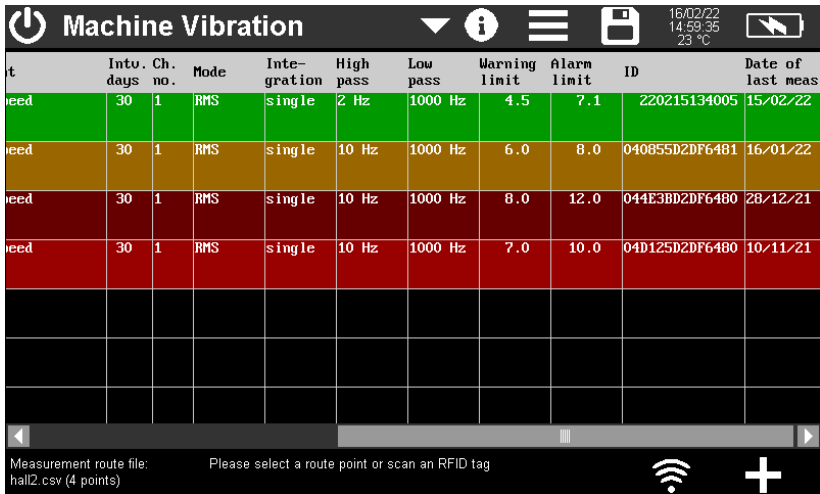
Figure 38: Measurement route with color coded due points

4.5.5. Roller Bearing Monitoring Using Overall Values

In addition to monitoring unbalance vibrations, the VM100 supports the monitoring of roller bearings according to ISO 13373-3 based on RMS and peak values of vibration acceleration in the frequency range from 10 Hz to 10 kHz. The peak value of the acceleration indicates defects generating shock pulses. These are, for example, unevenness or deformations on the inner and outer ring or on the rolling elements. The RMS value is more related to friction, for example as a result of inadequate lubrication or contamination.

According to ISO 13373-3, the condition of a roller bearing can be assessed with the aid of a zone diagram, with the RMS value on the horizontal axis and the peak acceleration value on the vertical axis.

Figure 39 shows the screen for roller bearing monitoring with the zone diagram. If the intersection of the measured RMS value and peak value is in the green zone, normal bearing condition can be assumed. The yellow zone stands for warning. The red zone indicates severe problems and signals an alarm.

The trend diagram contains the graphs of RMS and peak value for channel X of input 1. The limit lines depend on the vibration values according to the diagram.

The measurement method is not recommended for machines that are driven by a gearbox or otherwise generate strong background noise.
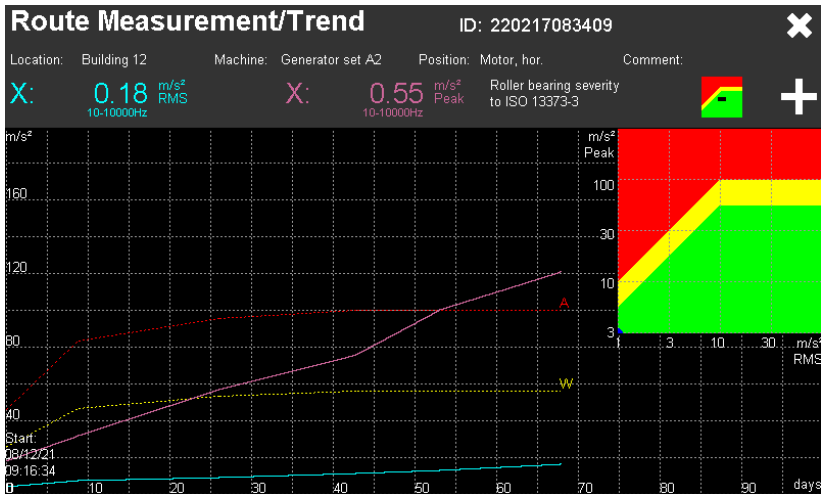
Figure 39: Roller Bearing monitoring to ISO 13373-3

Figure 40 shows an example of stored CSV measurement data of a roller bearing. The columns to the right of the date and time contain the RMS value, the peak value and the resulting alarm limit. The warning limit is 0.56 times the alarm limit.

TREND DATA
ID: 220217083409
Instr.:   VM100A   Ser.:   123456
Sen. 1X: Ser.:   Sensit.: 10,1   mV/ms^-2
Sen. 1Y: none   Ser.:   none   Sensit.: none
Sen. 1Z: none   Ser.:   none   Sensit.: none
Location: Building 12
Machine: Generator set A2
Position: Motor   hor.
Comment:
Warning: 0.56 * Alarm
Alarm: RMS dependent

Channel:		1X	1X	
HP (Hz):		10	10	
LP (Hz):		10000	10000	
Mode:		RMS	peak	Alarm
Date	Time	m/s²	m/s²	m/s²
08/12/21	09:16:34	4,536	18,833	45,361
17/12/21	08:45:30	8,315	32,344	83,154
03/01/22	12:19:59	9,522	57,599	95,219
20/01/22	08:59:16	12,052	76,365	100
30/01/22	13:46:34	13,714	100,736	100
14/02/22	08:46:53	17,126	121,366	100

Figure 40: CSV file with bearing 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 41)
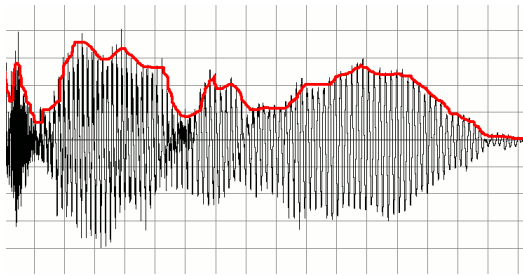
Figure 41: Envelope detection (Wikimedia)

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 42).

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

Figure 42: 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. Th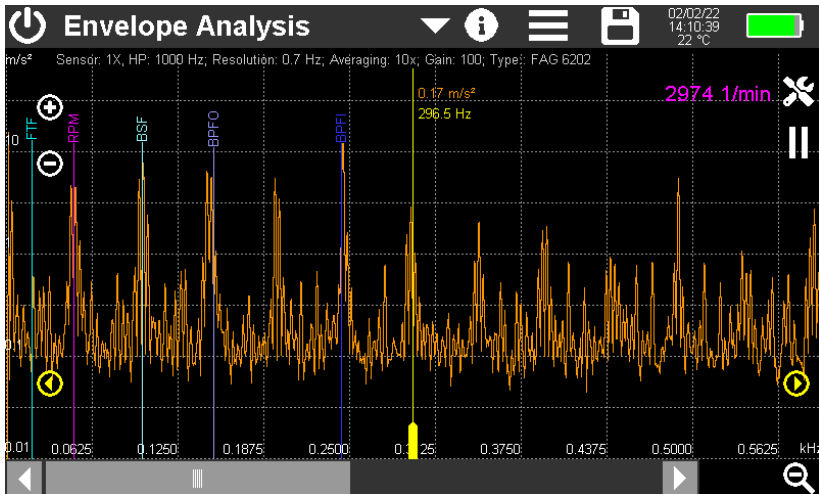e scaling of the logarithmic amplitude axis is also done with plus/minus keys. Alternatively, you may place two fingers on the screen and pinch in or stretch out vertically or horizontally.

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
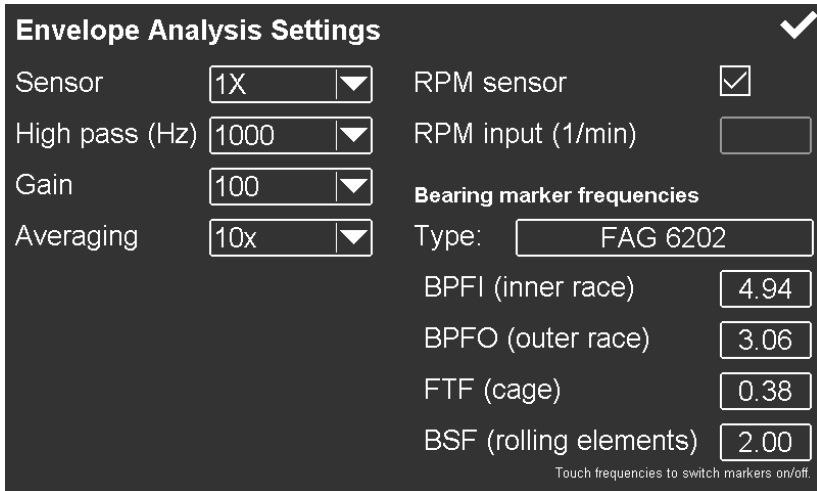
The example in Figure 42 shows the largest amplitude at marker BPFI, indicating damage to the inner ring of the bearing.

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 43).

Figure 43: 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		BPFI	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 44: Bearing list

Touch ✚ to add a new bearing. A menu opens for entering the damage frequencies (Figure 45).

Figure 45: 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 43), 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 46). 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

38

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/s²
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 46: 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 47). This centrifugal force increases with the square of the rotational speed.
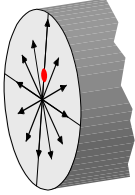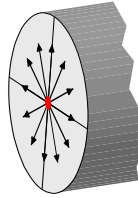

Figure 47: Unbalanced rotor

Figure 48: 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 48).

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 49 shows the amount and direction of the resulting unbalance forces. The force acting on both bearings is the same.
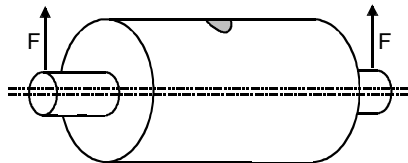

Figure 49: Static balance

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° (Figure 50).
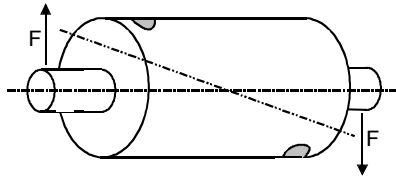
Figure 50: Couple balance

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 51).
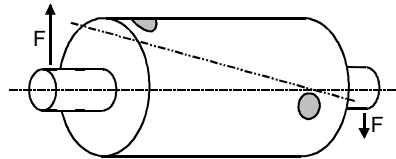

Figure 51: Dynamic balance

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 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:

1. In the **initial run**, the vibrations of the rotor in its initial state are recorded.

2. 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.

3. In the case of two-plane balancing, the test run is repeated at the other end of the rotor.

4. 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.

5. 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.
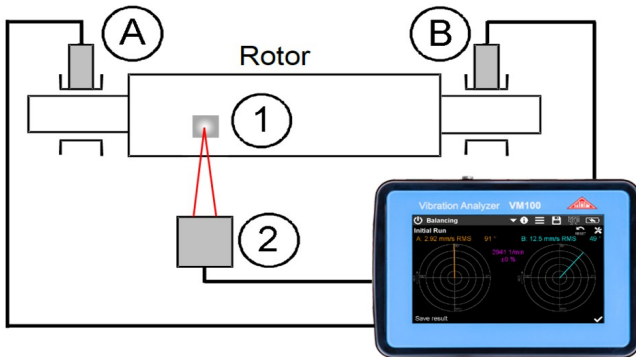
Figure 52: Two-plane balancing;
A/B: rotor bearings (planes) with accelerometers; 1: reflective label; 2: RPM sensor

The balancing algorithm requires a rotation pulse. For this purpose, a VM100-LS photo-electric reflex switch with magnetic stand (Figure 53) 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 53: VM100-LS

42

All angle positions of the calculated corrections are measured against the direction of rotation (Figure 54). 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.

Touch the tools icon ⚙ to open the setup menu (Figure 55).
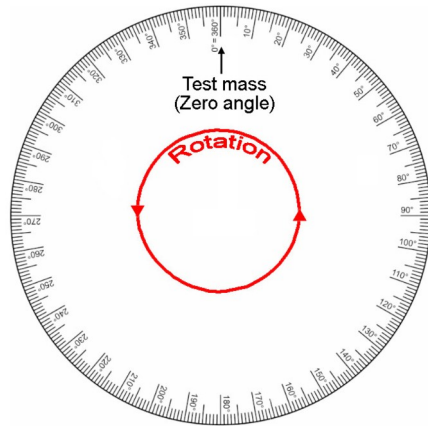
Figure 54: Angle conventions

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 55: Balancing settings (example for two planes)

Vibration quantity can be selected between vibration acceleration in m/s² and vibration velocity in 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.
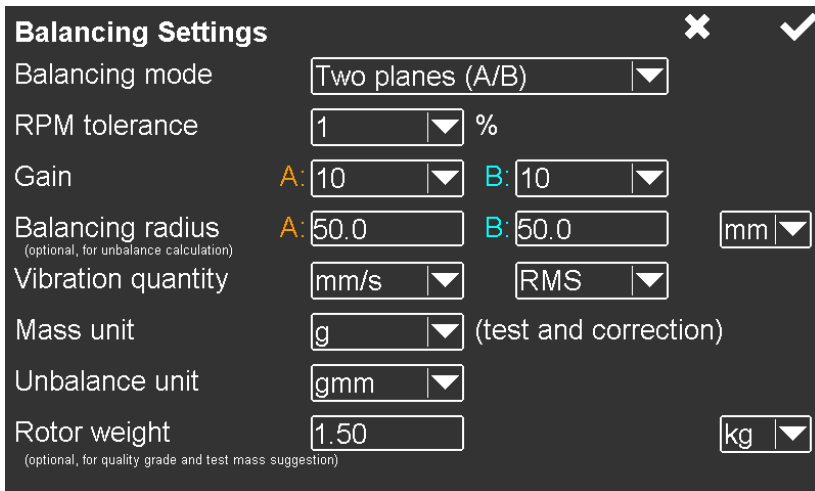
Unbalance unit is the unit of measurement of the residual unbalance output.

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 m/s² or mm/s (Figure 56).

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 ![reset] you can delete the average values and restart averaging. If a good stability is reached, the measurement is saved with ![checkmark] and the rotor is stopped.

Figure 56: 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.

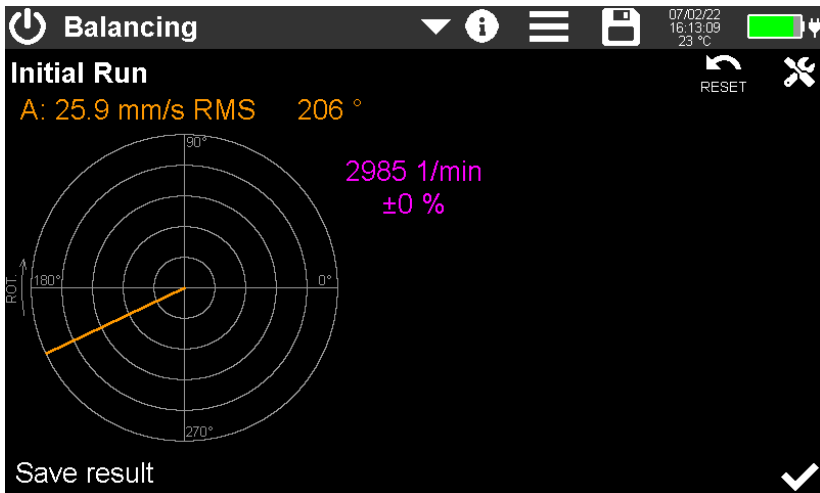After standstill, the VM100 switches to the test run. The measured initial unbalance is displayed as "O" mark in the polar diagram (Figure 57). You are prompted to apply a test mass. If the rotor mass was specified in the settings, a suggestion for the test mass based on a balance quality of 6.3 according 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 58). 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.
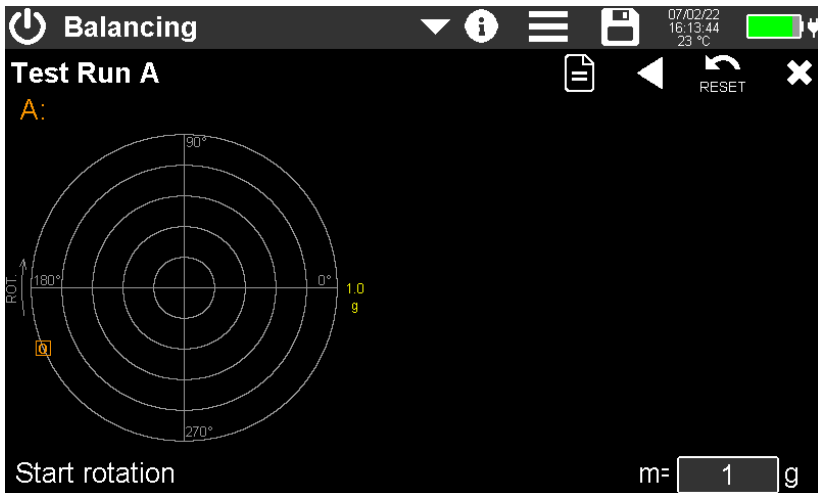
Figure 57: Attaching a test mass (1 plane)

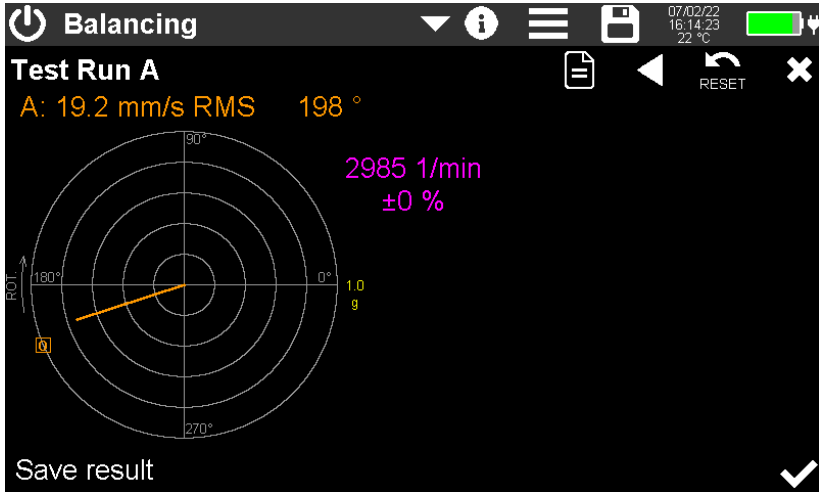Figure 58: Test run (1 plane)

After standstill, you will be asked whether the test mass should remain on the rotor (keep) or be removed again (Figure 59). 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 ✅.
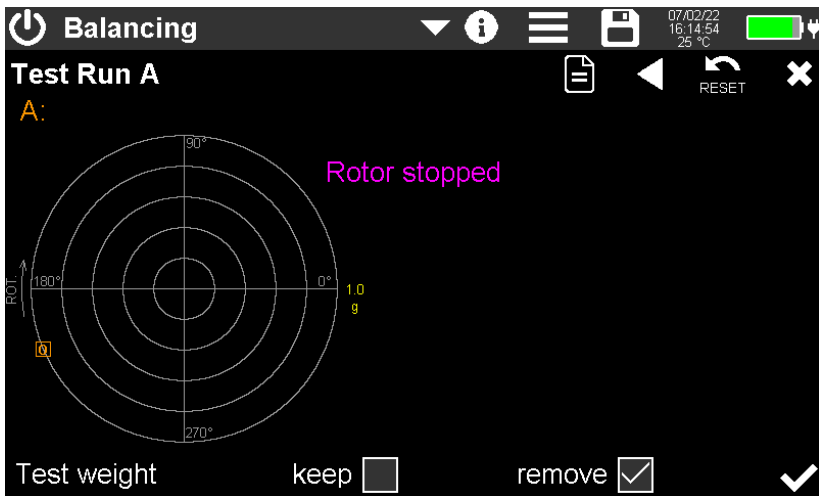

Figure 59: Keep or remove test mass (1 plane)

The unit now displays the required **corrections** (Figure 60). 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.
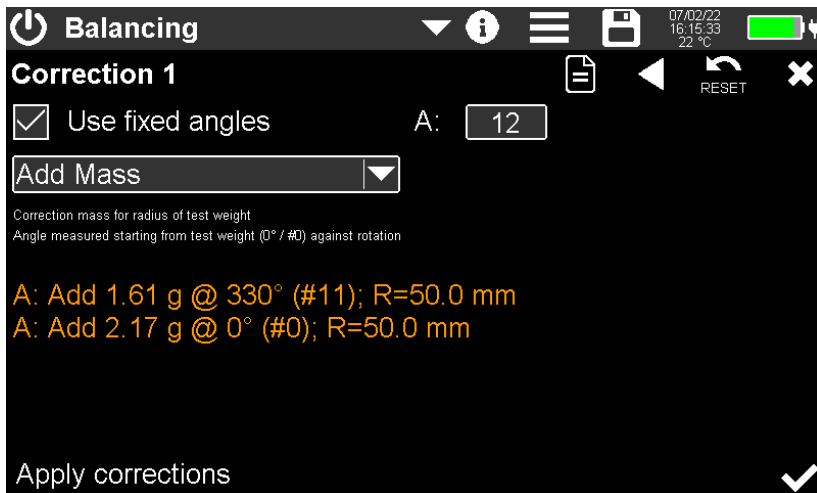
Figure 60: Corrections (1 plane)

Once the corrections have been made, confirm with ✅ and start the rotor for the **check run** (Figure 61). 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 62). 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.
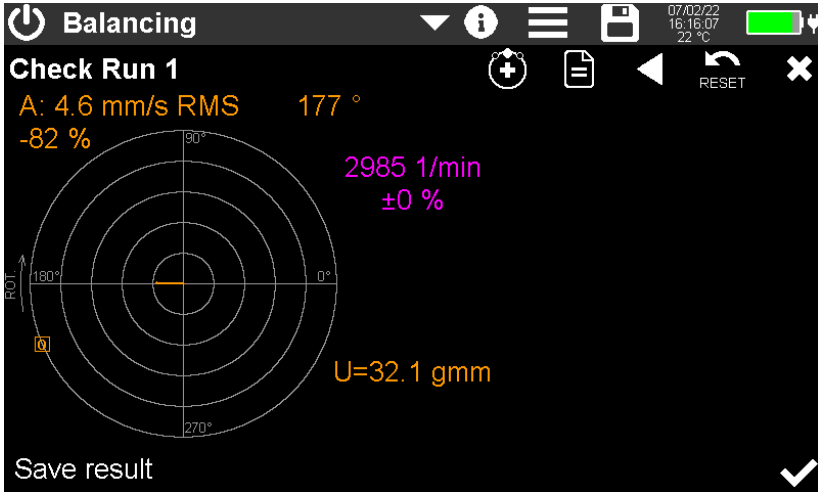
Figure 61: Check run (1 plane)
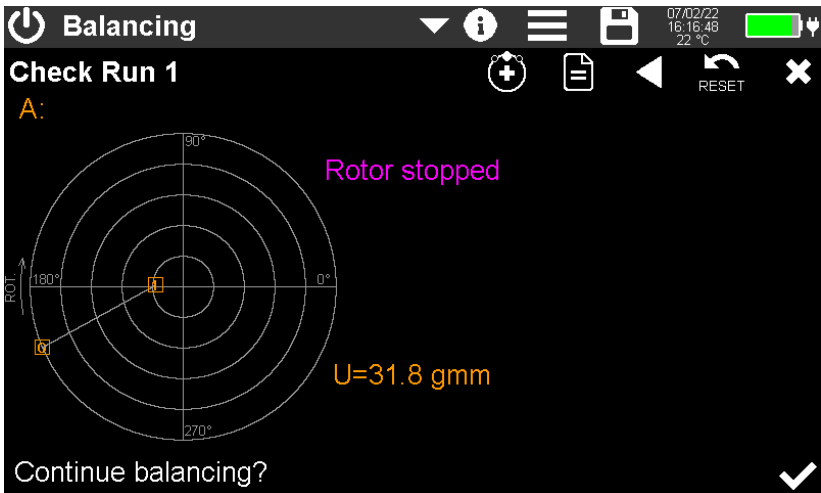
Figure 62: Continue or finish

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 63).
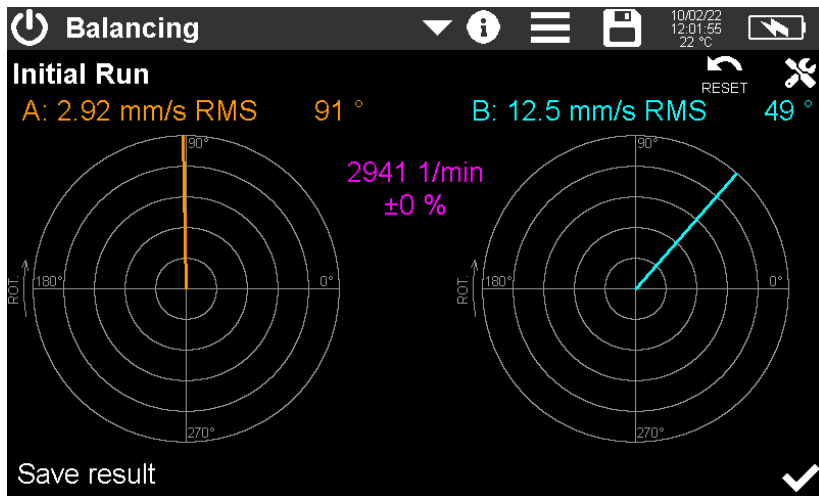
Figure 63: Initial run (2 planes)

This is followed by the application of a test mass in plane A and a restart of rotation (Figure 64).
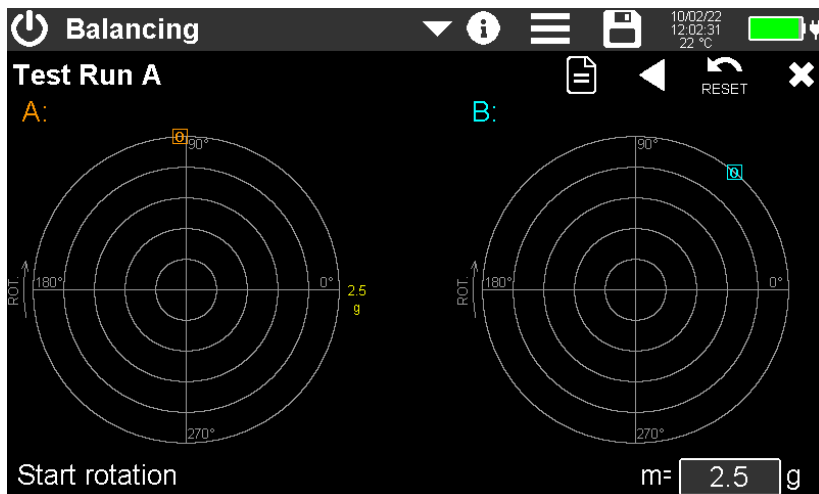
Figure 64: Attaching a test mass to plane A (2 planes)

49

The results of the test run at plane A are saved (Figure 65) and rotation is stopped.
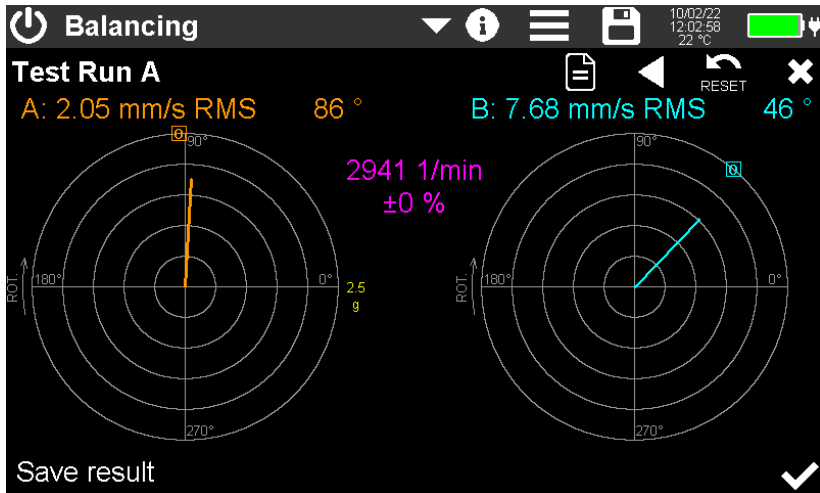
Figure 65: Test run of plane A (2 planes)

Now decide whether you want to leave the test mass on the rotor or remove it again (Figure 66). The selection later also applies to plane B.
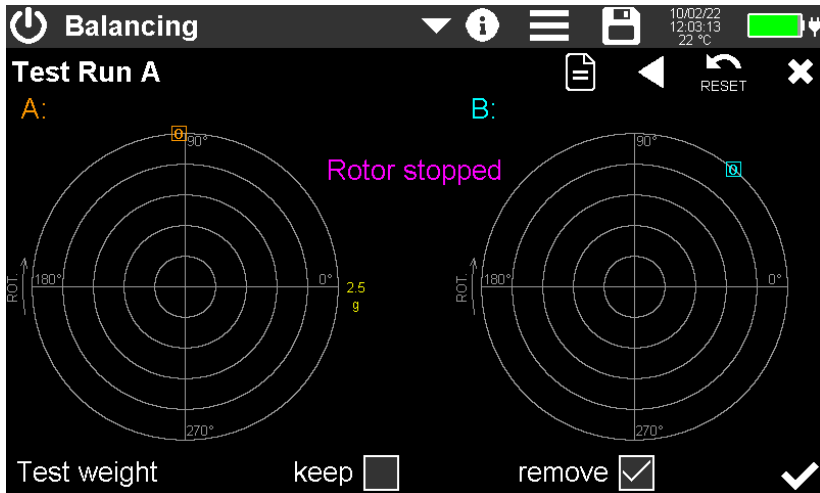
Figure 66: Keep or remove test mass of plane A (2 planes)

Then place a test mass in plane B and start rotation again (Figure 67).
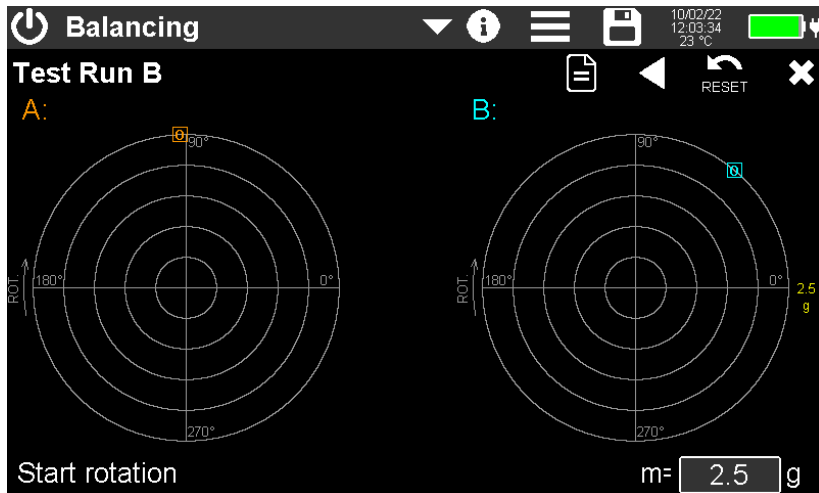
Figure 67: Attach a test mass for plane B (2 planes)

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 68).
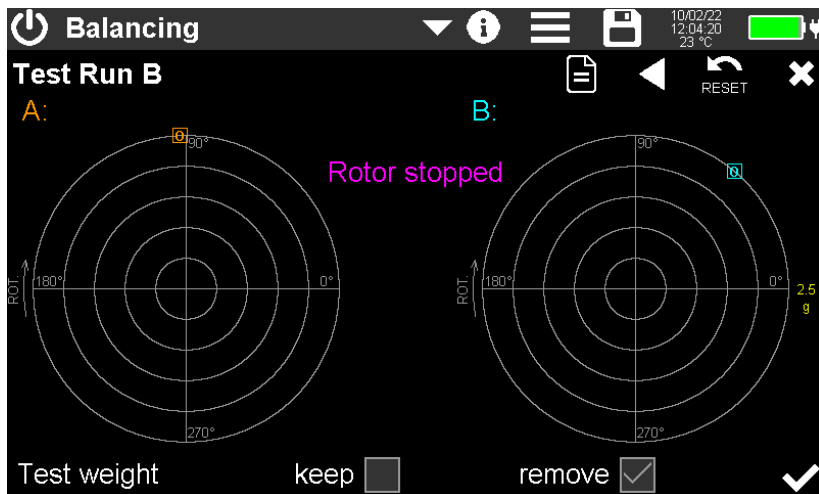
Figure 68: Confirm keeping or removing the test mass B (2 planes)

Now the calculated correction masses and their angles are displayed for both planes (Figure 69). In the example, 16 angular steps (fixed locations) were selected.
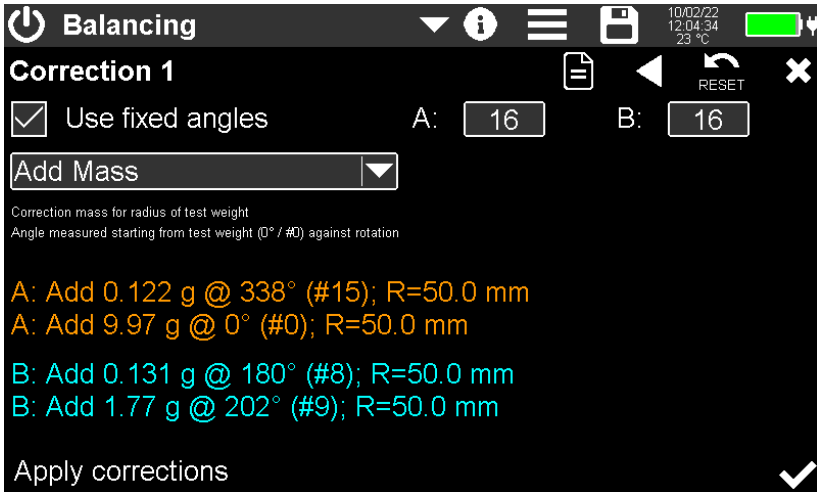
Figure 69: First correction (2 planes)

Make the corrections and confirm. Start rotation for the first check run (Figure 70).
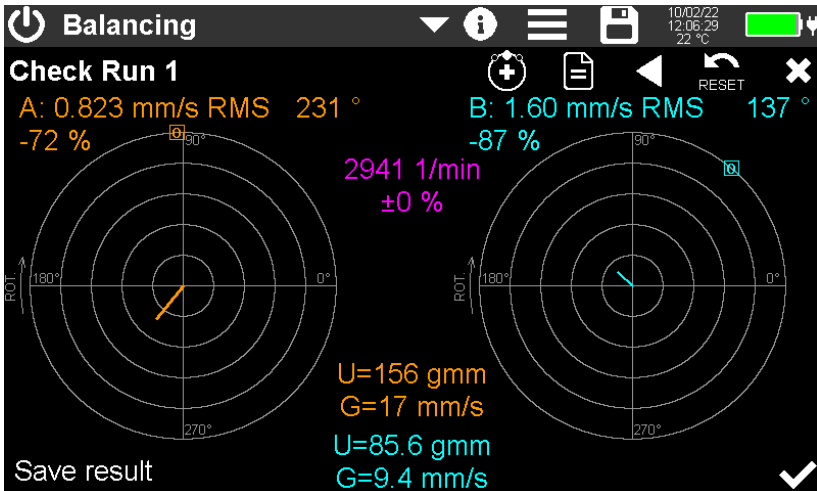
Figure 70: First check run (2 planes)

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 71).
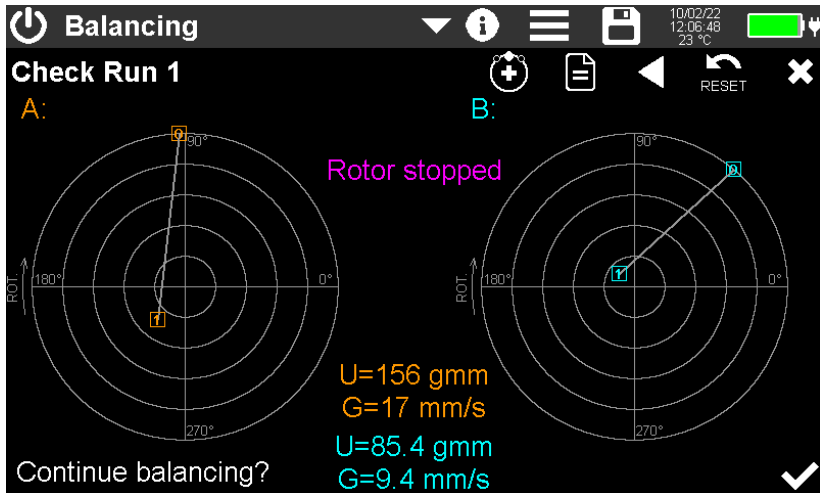
Figure 71: Continue or finish balancing after first check run (2 planes)

In this example, balancing is continued. Further corrections for both planes are displayed (Figure 72).
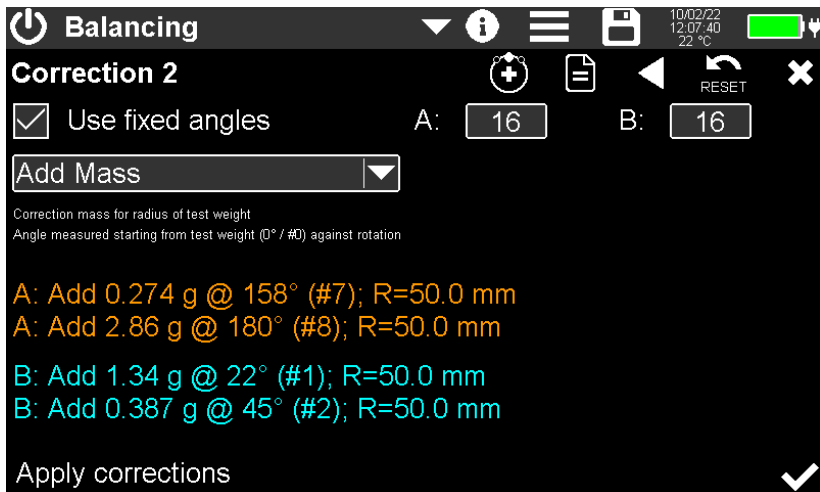
Figure 72: Second correction (2 planes)

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 73).
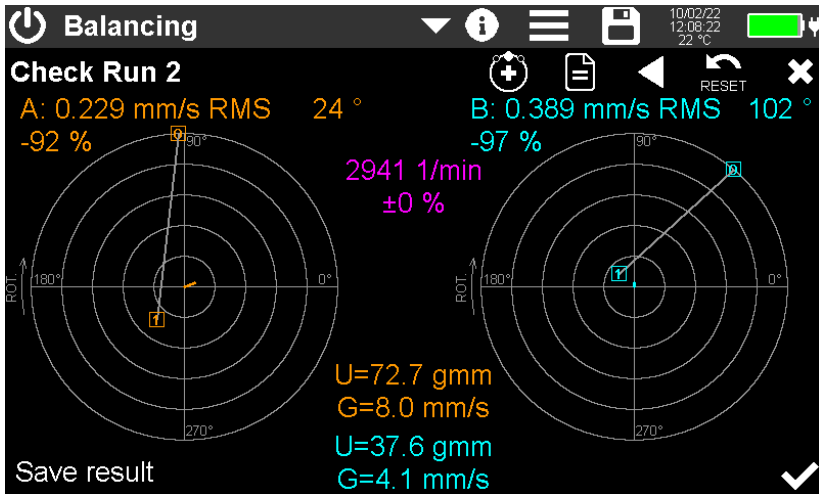
Figure 73: Second check run (2 planes)

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 75). For this purpose, all attached correction masses must be removed and the calculated masses attached. Test masses left on the rotor are not affected.
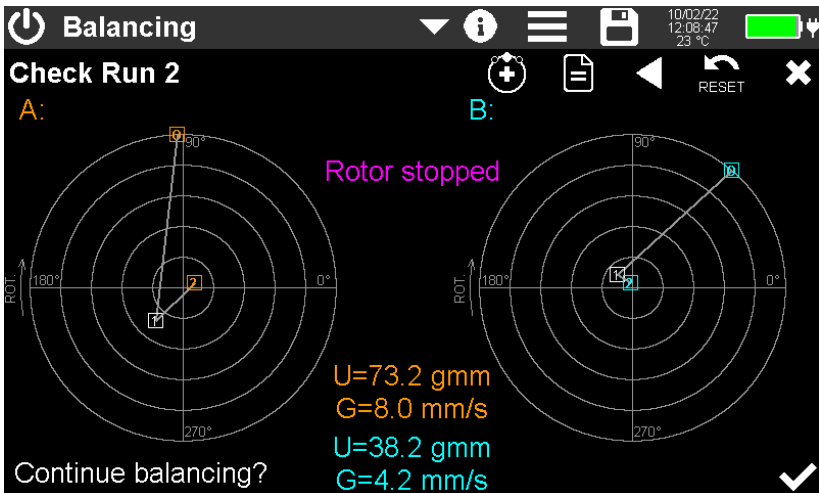
Figure 74: Continue balancing after second check run (2 planes)
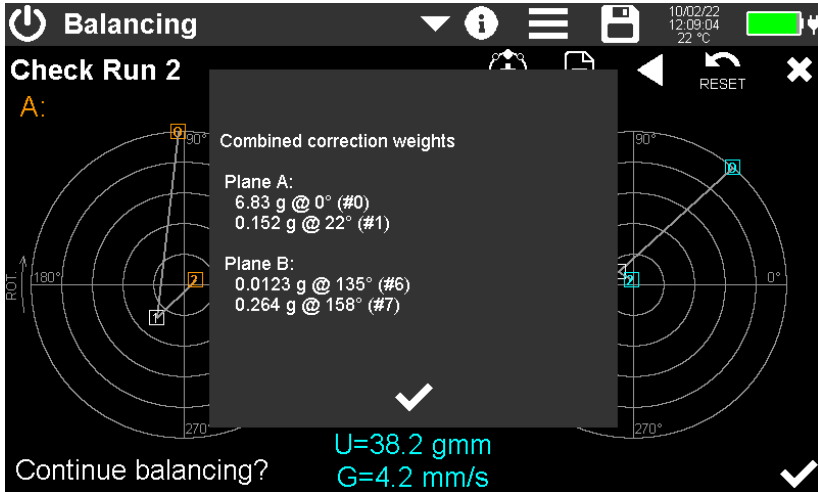
Figure 75: Combination of corrections (2 planes)

📄 opens a text window with a summary of all changes made and the resulting vibration or unbalance vectors (Figure 76). You can use it to replace all previously applied correction masses by the calculated mass(es).
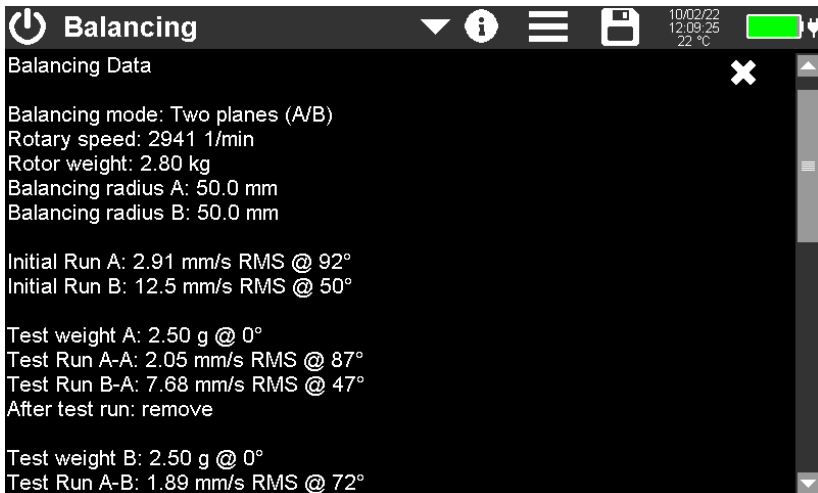
Figure 76: Auswuchtprotokoll

To save this report, touch 💾 and select **Save CSV balancing report**. An example of a saved CSV file is shown in Figure 77.

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 77: CSV formatted balancing report

If the balancing results should be not satisfying please read the tips on page 48.

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.

Vibration Criterion	Amplitude in Third Octave Spectrum	Application	Structure size
Perception threshold	100 µm (4 – 80 Hz)	Threshold of human perception, for sensitive sleeping areas, opera halls, theaters, microscopes with 100× magnification	30 µm
VC-A	50 µm (4 – 80 Hz)	Microscopes with 400× magnification	8 µm
VC-B	25 µm (1 – 80 Hz)	Inspection instruments, high-quality laboratories, lithography equipment (including steppers)	3 µm
VC-C	12.5 µm (1 – 80 Hz)	Microscopes with magnifications up to 1000×, good standard for most lithography and inspection equipment	1 µm
VC-D	6.25 µm (1 – 80 Hz)	high-quality electron microscopes (REM, TEM), electron beam systems	0.3 µm
VC-E	3.1 µm (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 µm
VC-F	1.6 µm (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 µm (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 µm/s 1 to 5 Hz and 6.4 µm/s 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 µm/s 1 to 5 Hz and 3.2 µm/s 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 µm/s 1 to 5 Hz and 2.1 µm/s 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 78 shows the limit lines in the frequency range.
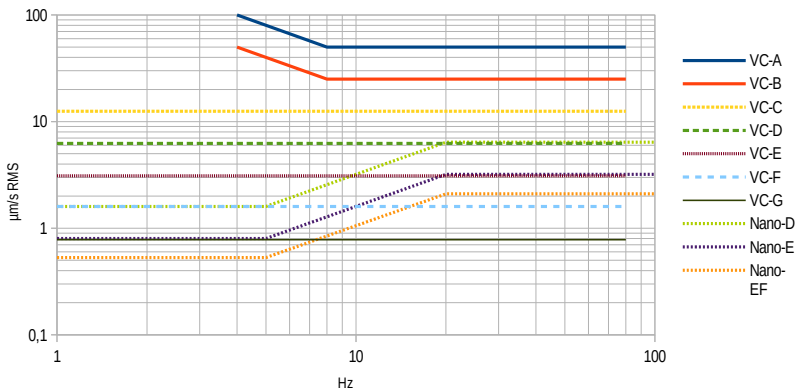
Figure 78: Limits of "VC" and "Nano" criteria

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 79: Triaxial accelerometer KS823B

Figure 80: Uniaxial accelerometer KS48C

Figure 81: Uniaxial accelerometer KB12VD

The triaxial accelerometer KS823B (Figure 79) and the single-axis KS48C (Figure 80) are suitable for measurements up to VC-D. The extremely high-resolution single-axis KB12VD (Figure 81) 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 83).

Another practical accessory for sensor installation on floors is the tripod floor plate Type 729 (Figure 82).

Figure 83: Triaxial mounting cube

Figure 82: Tripod floor plate model 729

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 84 shows the measured value display.
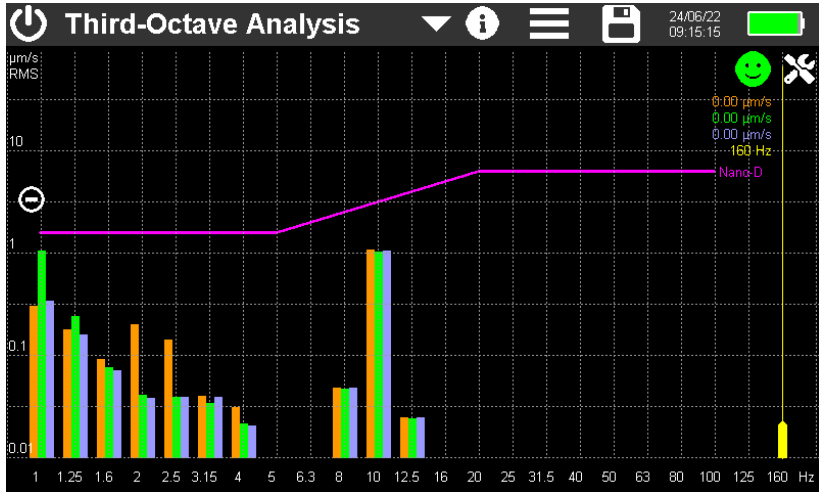
Figure 84: Third octave analysis example for Nano-D

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 85).
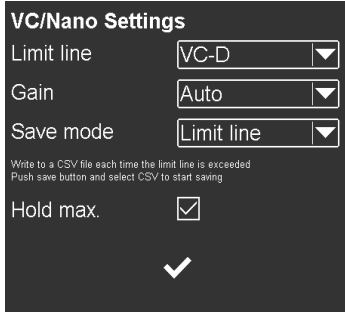
Figure 85: Menu for settings
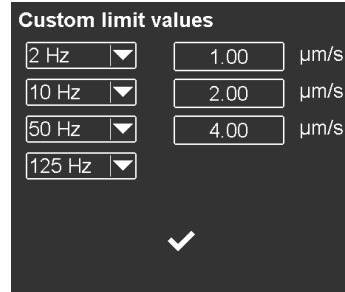
Figure 86: Menu for custom limits

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 86). 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 μm/s. Figure 89 shows the limit line resulting from the example.
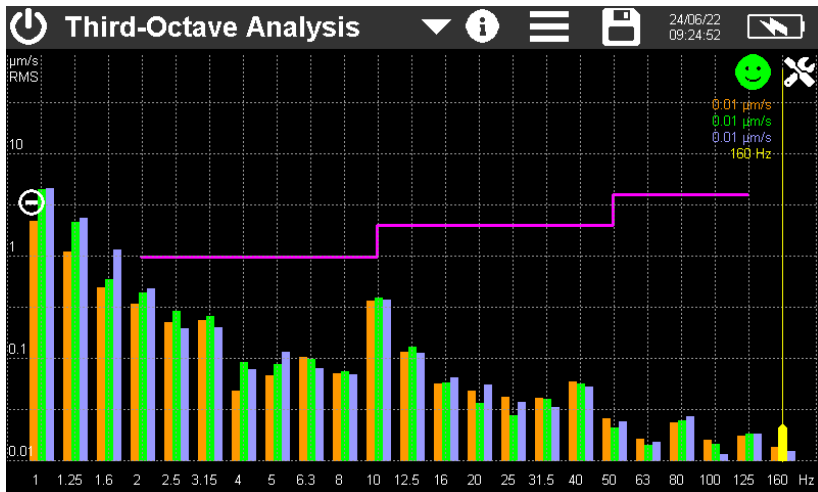
Figure 87: Custom limit line of Figure 86

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 88). The Reset button 🔄 deletes the maximum values.

61
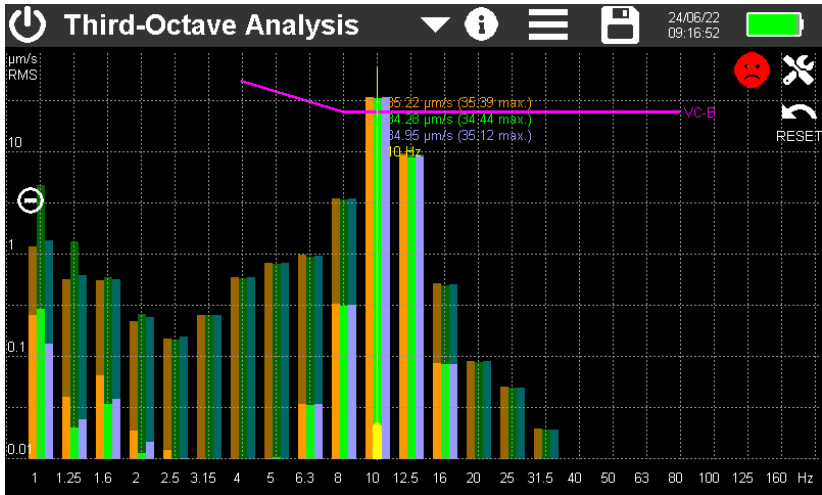
Figure 88: Spectrum with held maximum values

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 89 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^-2
Sensor 1Y:		Serial no.:		Sensit.:	10000.0000	mV/ms^-2
Sensor 1Z:		Serial no.:		Sensit.:	10000.0000	mV/ms^-2

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
µm/s	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	1.86	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	37.68
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 89: 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:

	Hand-Arm, RMS
Exposure action value	2.5 m/s²
Exposure limit	5 m/s²

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.

$$A(8) = a_w \sqrt{\frac{T_e}{T_0}}$$ 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

$$a_w = \sqrt{a_{wx}^2 + a_{wy}^2 + a_{wz}^2}$$ 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.

$$A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^{n} a_{wi}^2 T_{ei}}$$ 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 90 that low frequencies have a greater influence on the evaluation than high frequencies.
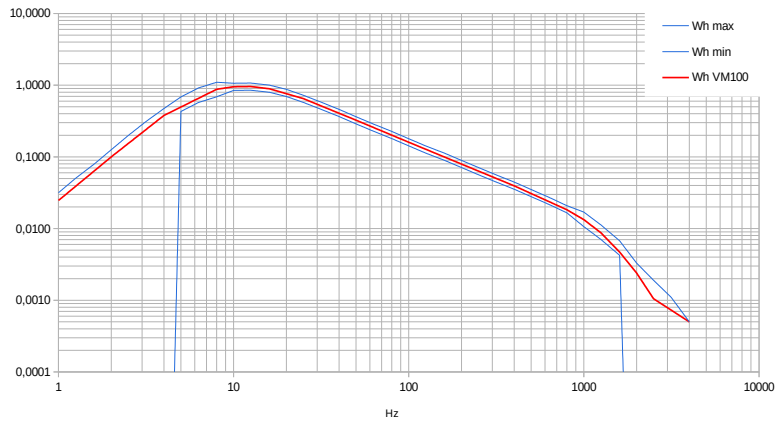
Figure 90: Frequency weighting Wh

4.9.2. Hand-Arm Sensors

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

Figure 91: KS963B10

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.
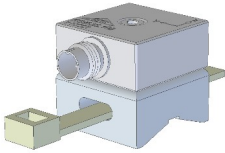
Figure 93: Strap adapter 141B
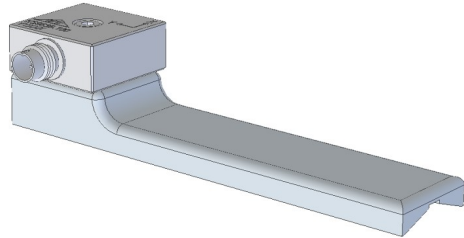
Figure 92: Hand-held adapter 143B

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 94 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.
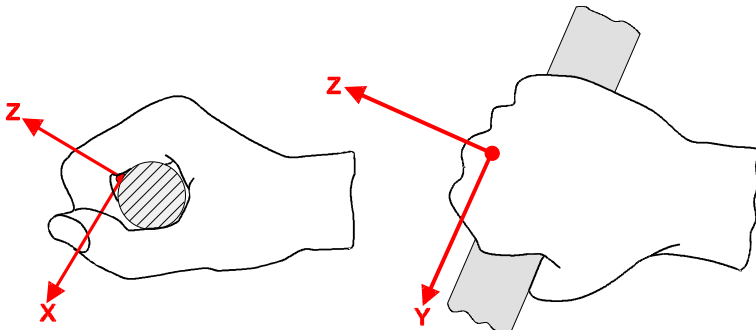
Figure 94: Coordinate system of the hand (from ISO 5349-1)

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 m/s² at 80 Hz. The sensor KS963B10 has threaded holes for mounting the sensor in X, Y and Z direction on the calibrator.

Figure 95: Vibration Calibrator VC21

4.9.4. Measurement

Figure 96 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.

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 ![reset]. This restarts the calculation of the interval RMS values and resets the measurement duration timer.

68
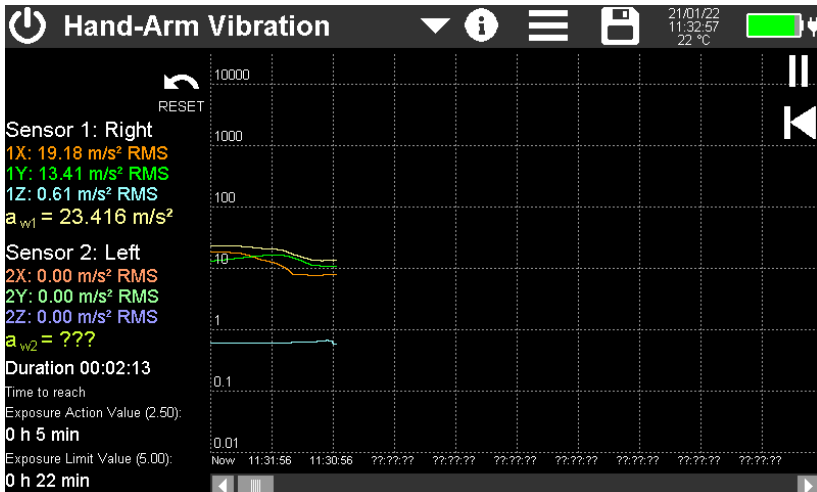
Figure 96: Measurement screen for hand-arm vibration

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 97 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^-2		
Sensor 1Y:	KS963B11	Ser.:	20013	Sensit.:	10.154	mV/ms^-2		
Sensor 1Z:	KS963B12	Ser.:	20013	Sensit.:	10.167	mV/ms^-2		
Sensor 2X:	KS963B13	Ser.:	20014	Sensit.:	10.313	mV/ms^-2		
Sensor 2Y:	KS963B14	Ser.:	20014	Sensit.:	10.354	mV/ms^-2		
Sensor 2Z:	KS963B15	Ser.:	20014	Sensit.:	10.879	mV/ms^-2		
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/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²
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 97: Example of a hand-arm CSV file

Note: To avoid operation errors the VM100 does not allow unweighted measure-ments 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/s²	9.1 m/s^{1,75}
Exposure limit	1.15 m/s²	21 m/s^{1,75}

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:

$$A(8) = a_w \sqrt{\frac{T_e}{T_0}}$$

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.

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

Equation 5

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

Equation 6

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

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 Wd and weighting factor 1,4
- Z with weighting filter Wk 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:

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

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.

$$VDV_x(8) = \sqrt[4]{\sum_{i=1}^{n} VDV_{xi}^4 \cdot \frac{T_{iexp}}{T_{imeas}}}$$ <div style="text-align:right">Equation 9</div>

$$VDV_y(8) = \sqrt[4]{\sum_{i=1}^{n} VDV_{yi}^4 \cdot \frac{T_{iexp}}{T_{imeas}}}$$ <div style="text-align:right">Equation 10</div>

$$VDV_z(8) = \sqrt[4]{\sum_{i=1}^{n} VDV_{zi}^4 \cdot \frac{T_{iexp}}{T_{imeas}}}$$ <div style="text-align:right">Equation 11</div>

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 98: 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 99 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.
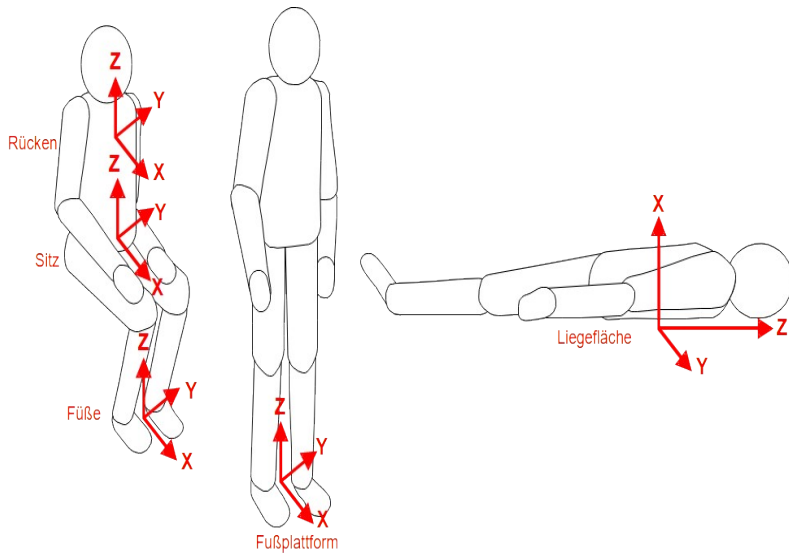
Figure 99: Coordinate systems for whole-body vibration to ISO 2631

Whole-Body Health Evaluation				
Posture	*Position*	*Sensor axis*	*Frequency weighting*	*Weighting factor (k)*
sitting	seat surface	X / Y	W_d	1.4
		Z	W_k	1
Whole-Body Comfort Evaluation				
sitting	seat surface	X / Y	W_d	1
		Z	W_k	1
	feet platform	X / Y	W_k	0.25
		Z		0.4
	backrest	X*	W_d	0.4
		Y	W_d	0.5
		Z*	W_c	0.8
standing	feet platform	X / Y	W_d	1
		Z	W_k	1
recumbent	under pelvis	X (vertical)	W_k	1
		Y / Z (horizontal)	W_d	1
	under head	X (vertical)	W_j	1
In railway vehicles:				
standing sitting recumbent	feet platform seat/backrest/feet support. surface, pelvis/head	X / Y / Z	W_b	1
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 100 to 104 show the frequency weightings implemented in the VM100.
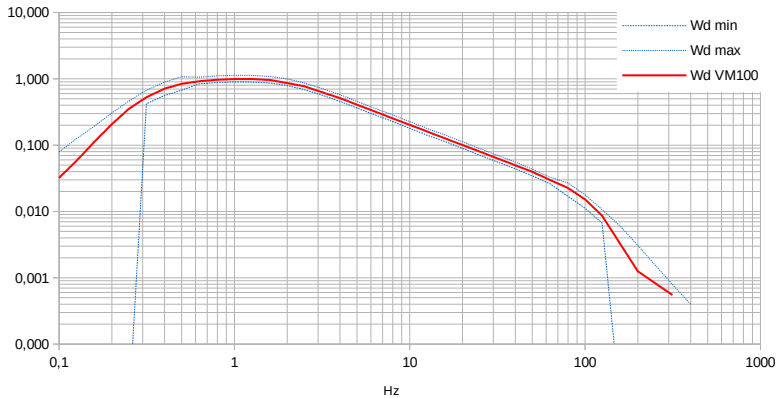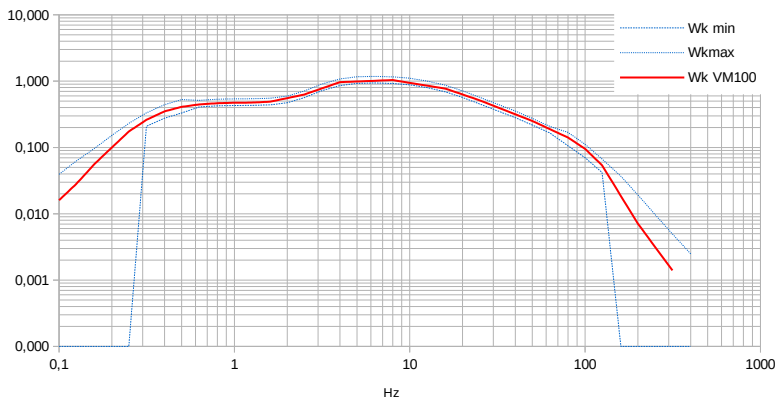

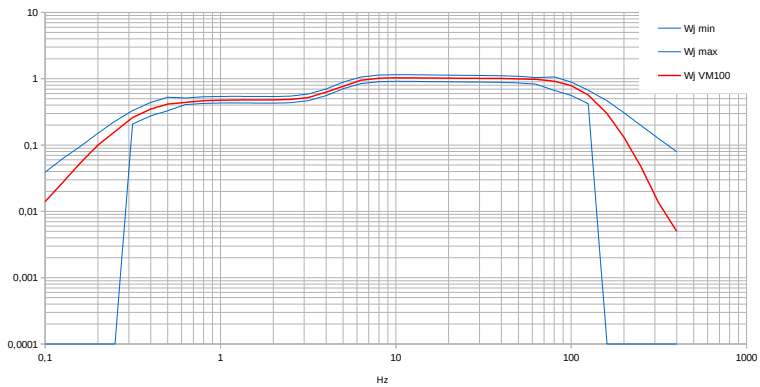Figure 100: Weighting filter Wd

Figure 101: Weighting filter Wk

Figure 102: Weighting filter Wj
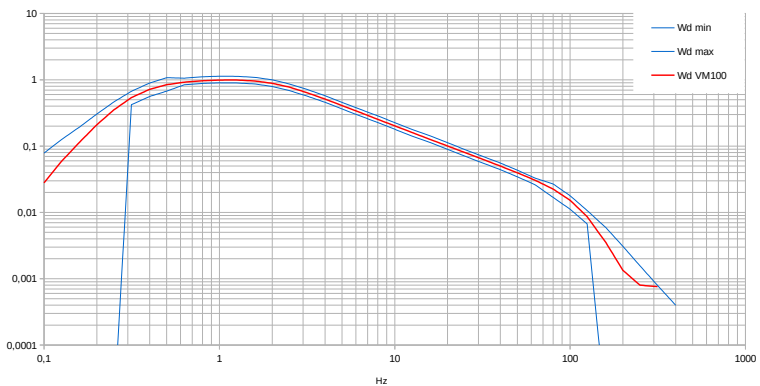

Figure 103: Weighting filter Wc
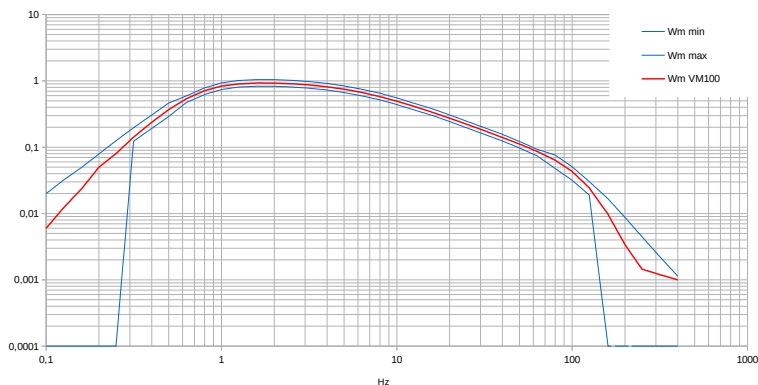
Figure 104: Weighting filter Wm

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 m/s² 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 105 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.

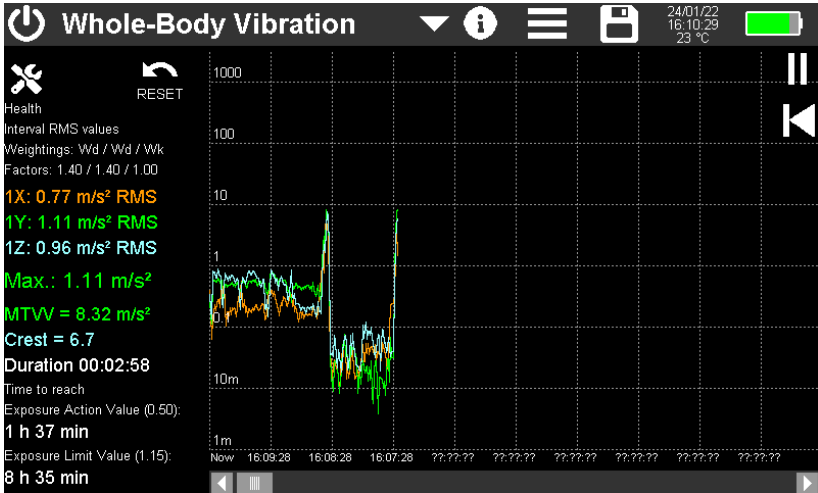Figure 105: Measurement display of whole-body vibration

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.

78

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

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

Use the button [X] to open the menu for settings (Figure 106). 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).
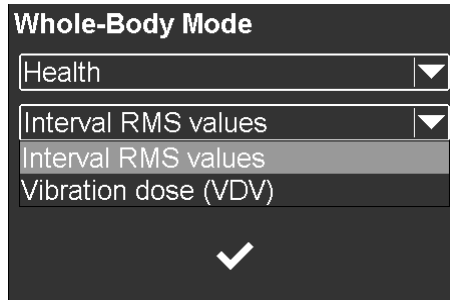
Figure 106: Whole-body setup menu

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 107 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.

79

WHOLE-BODY VIBRATION						
Instr.:	VM100A	Ser.:	123456			
Comment:						
NFC Id:						
Sensor 1X:	KS903B10	Ser.:	20014	Sensit.:	10.313	mV/ms^-2
Sensor 1Y:	KS903B10	Ser.:	20014	Sensit.:	10.354	mV/ms^-2
Sensor 1Z:	KS903B10	Ser.:	20014	Sensit.:	10.879	mV/ms^-2
Date:	25.01.2021					
Temp:	21	°C				
Channel:	1X	1Y	1Z			
Filter:	Wd	Wd	Wk			
Factor:	Jan 40	Jan 40	1.00			
Unit:	m/s²	m/s²	m/s²			
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 107: 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, triaxial 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:

Figure 108: KS963B100-S

Input 1: Seat surface

Input 2: Seat back

Input 3: Foot surface

4.11.3. Measurement

105 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.
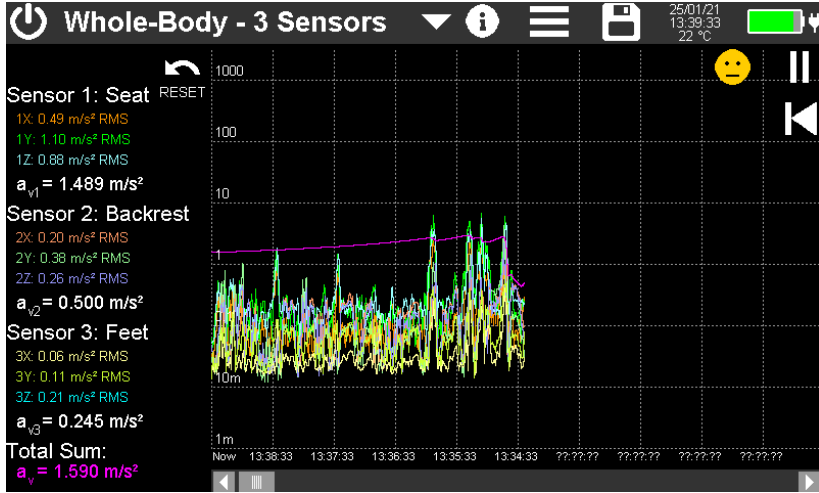
Figure 109: Measurement screen in the whole-body vibration mode with 3 sensors

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.

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

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 99 on page 74.

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

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

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.
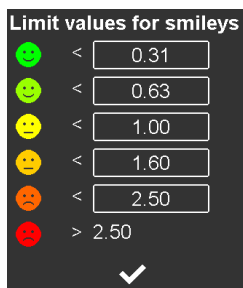
Figure 110: Comfort zones

➔ A measurement always starts by touching the reset button [RESET]. 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 [icon] 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 111 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^-2							
Sensor 1Y:	KS963B100-S	Ser.:	220139	Sensit.:	10,147	mV/ms^-2							
Sensor 1Z:	KS963B100-S	Ser.:	220139	Sensit.:	10,183	mV/ms^-2							
Sensor 2X:	KS963B100-S	Ser.:	220156	Sensit.:	10,201	mV/ms^-2							
Sensor 2Y:	KS963B100-S	Ser.:	220156	Sensit.:	10,158	mV/ms^-2							
Sensor 2Z:	KS963B100-S	Ser.:	220156	Sensit.:	10,215	mV/ms^-2							
Sensor 3X:	KS903B100	Ser.:	20014	Sensit.:	10,033	mV/ms^-2							
Sensor 3Y:	KS903B100	Ser.:	20014	Sensit.:	10,054	mV/ms^-2							
Sensor 3Z:	KS903B100	Ser.:	20014	Sensit.:	10,079	mV/ms^-2							
Date:	08/03/23												
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/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²
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	35,684	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	65,314	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	23,576	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 111: 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 112 shows the memory menu for amplitude/time measurements.
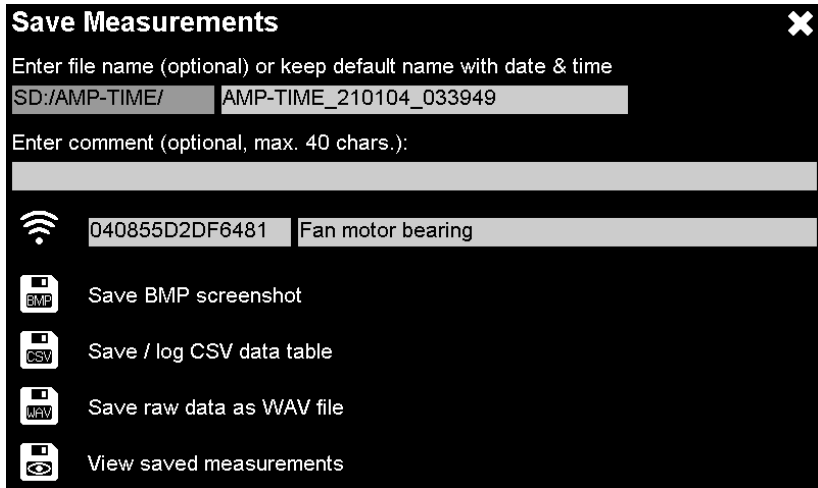

Figure 112: Save menu

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 113) 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 113: 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 114).

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

Figure 114: Example of the file NFC_IDs.csv

5.3. Saving Bitmap Screenshots

By touching ![icon], 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 ![icon] button you can create a CSV file with measured values. CSV (charac-
ter-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 ![icon] 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 115).

Figure 115: 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

Independent of the selected measuring module, the VM100 can record raw data for a
limited duration. These are the unfiltered samples of the analog-to-digital converter.
The recording is in WAV format (Waveform Audio Format). WAV files are im-
ported by many signal analysis programs and audio players. To switch to the raw
data menu, touch ![icon]. Figure 116 displays the raw data view, which is similar to
that of an oscilloscope.

Raw data recording is available for one channel. You may choose it from the three channels of input 1 using the **Channel** menu.

At opening the raw data view the amplifier gain is set automatically so that the signal fits into the amplitude range without clipping. You may also change the **Gain** manually. In the diagram area the signal amplitude is displayed in percent of full scale.

Depending on the sampling rate of the analog-to-digital converter, the a signal **bandwidth** of 4.5 kHz for a maximum recording duration of 100 s or 22 kHz for 20 s of recording are selectable.

You can change the displayed signal portion with the +/- keys. The visible portion has no influence on the stored data.

As file name you can use either the name suggested by the instrument with date and time or enter a name yourself. For the actual file name the VM100 adds the measuring channel, e.g. "C1X" and the selected gain, e.g. "G100". The complete file name is then for example "210104_045152C1XG100.wav".
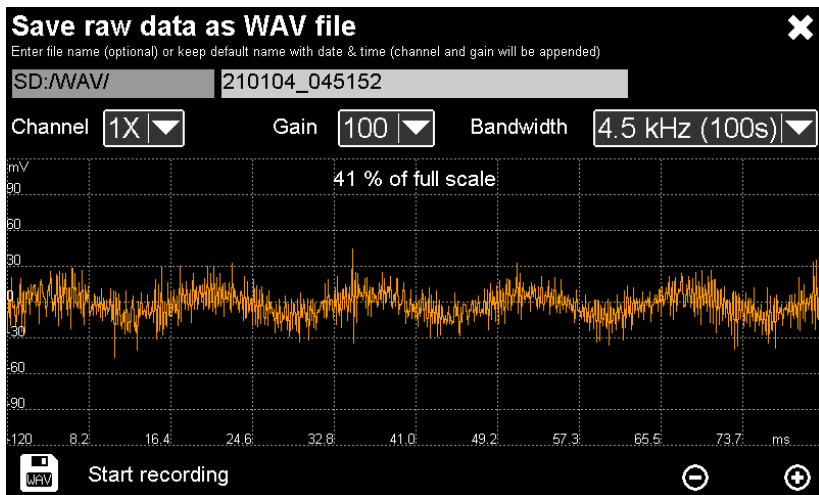

Figure 116: Raw data recording

Touch to start recording. A progress bar shows the duration of the WAV recording (Figure 117). If desired, you can also stop the recording before the maximum duration has elapsed by touching STOP. The captured raw data is subsequently written from the raw data buffer to the SD card, where it is found in the WAV directory.
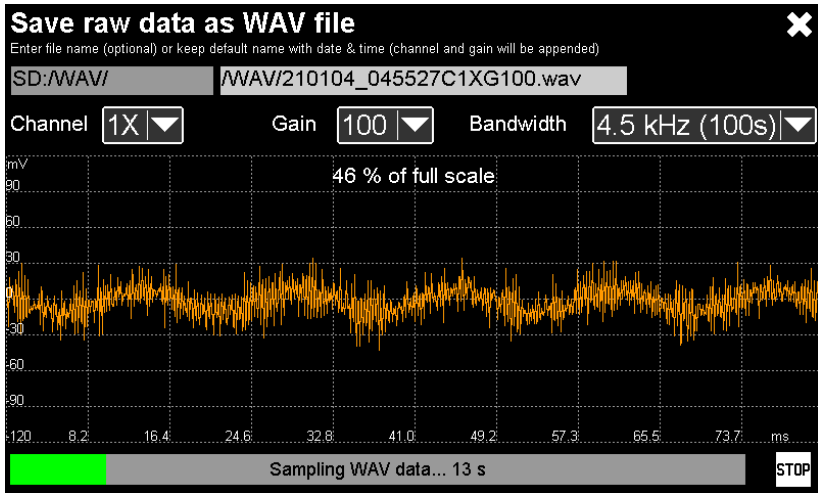
Figure 117: Raw data saving

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.
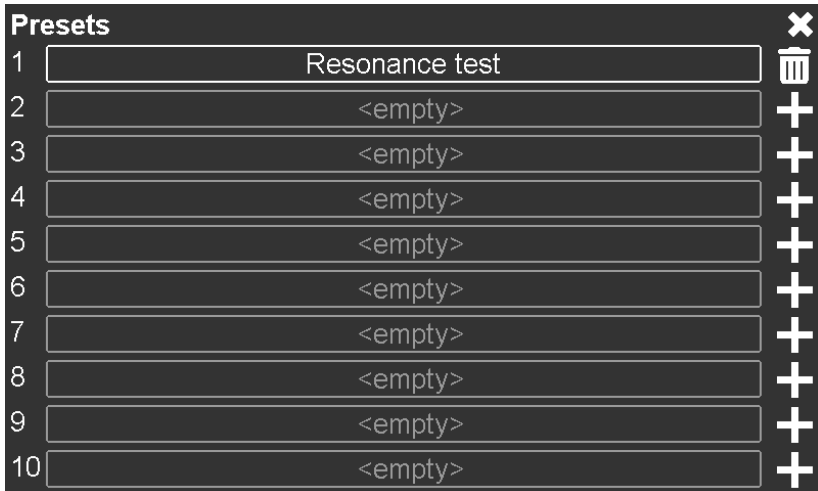

Figure 118: Saving and loading settings

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 fol-lows:

- 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. Con-firm 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 119).

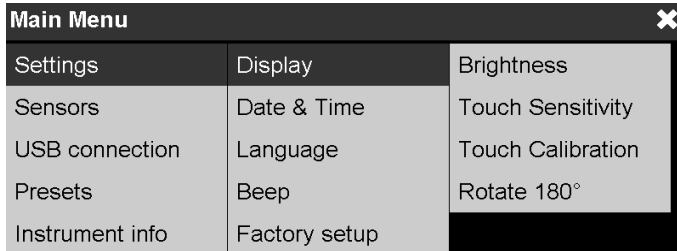| Main Menu		✖
Settings	Display	Brightness
Sensors	Date & Time	Touch Sensitivity
USB connection	Language	Touch Calibration
Presets	Beep	Rotate 180°
Instrument info	Factory setup	

Figure 119: Display settings

Touch **Brightness** to open the menu for setting the display brightness (Figure 120). 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.
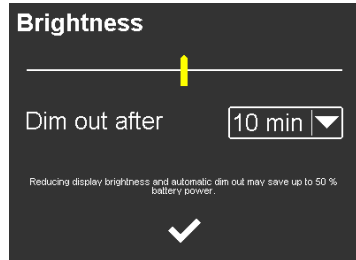
Brightness

Dim out after   10 min ▼

Reducing display brightness and automatic dim out may save up to 50 % battery power.

✔

Figure 120: Display brightness

In the **Touch Sensitivity** menu item, you set how sensitive the display should be (Figure 121).

Touch Sensitivity

✔

Figure 121: Touch sensitivity

With **Calibrate** you can readjust the accuracy of the touch screen by touching five points in succession (Figure 122).

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.

Touchscreen Calibration
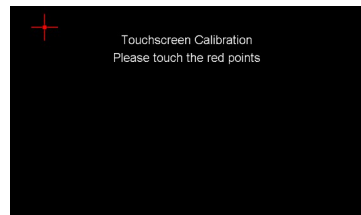Please touch the red points

Figure 122: 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 123).
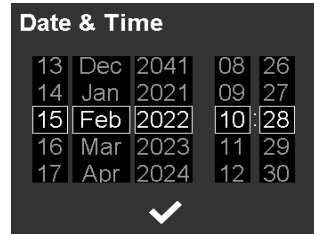

Figure 123: Date and time

7.3. Language

In Figure 124 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.
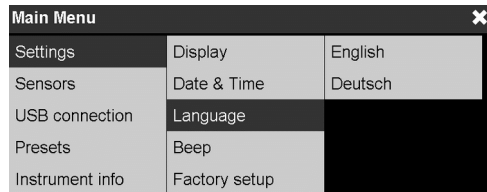
Figure 124: Display language selection

7.4. Beep Signal

You can deactivate the signal tone (beep) if desired (Figure 125).
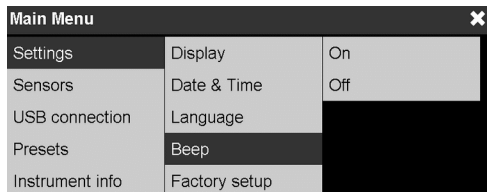
Figure 125: Switch the beep tone on and off

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 126).

Figure 126: 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 127).
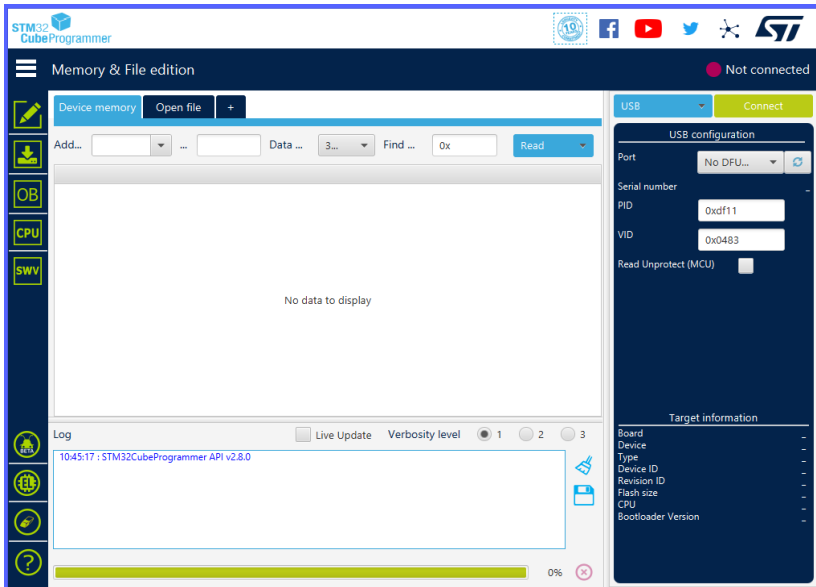
Figure 127: Update software STM32CubeProgrammer

Click to select „Memory & File edition".

Select the tab "Open file" and load the firmware file vm100.hex (Figure 128).
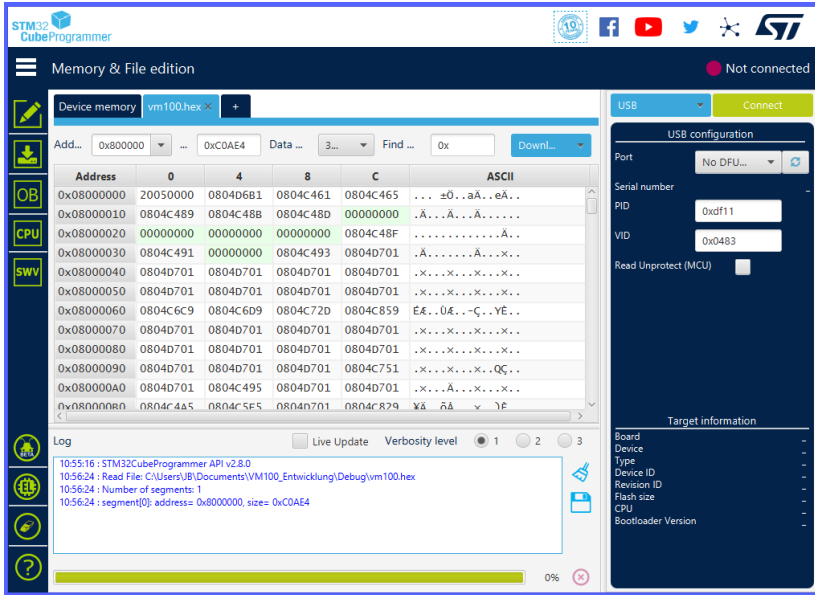
Figure 128: STM32CubeProgrammer with loaded firmware file

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 129). Connect the USB-C update interface to a PC (Figure 130).

Figure 129: Open cover

Figure 130: Connect USB cable

The VM100 switches on with the update screen giving some instruction (Figure 131).
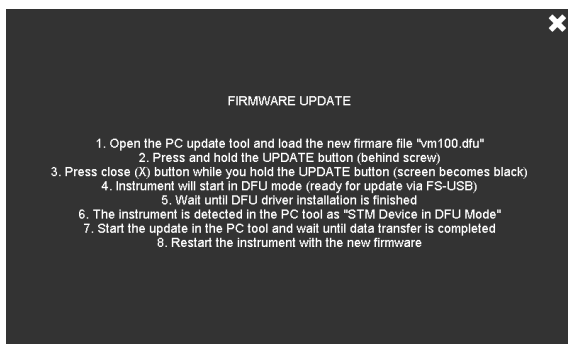
Figure 131: VM100 in update mode

Use a pointed, non-metallic object, for example a toothpick to press the button behind the screw hole of the update USB cover (Figure 132).

Figure 132: 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 133). Click .

The button starts the firmware transfer to the VM100. Figure 134 shows the completion of a successful transfer. After that you can disconnect the USB cable and restart the device with the new firmware.
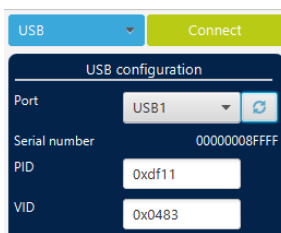
Figure 133: DFU connection
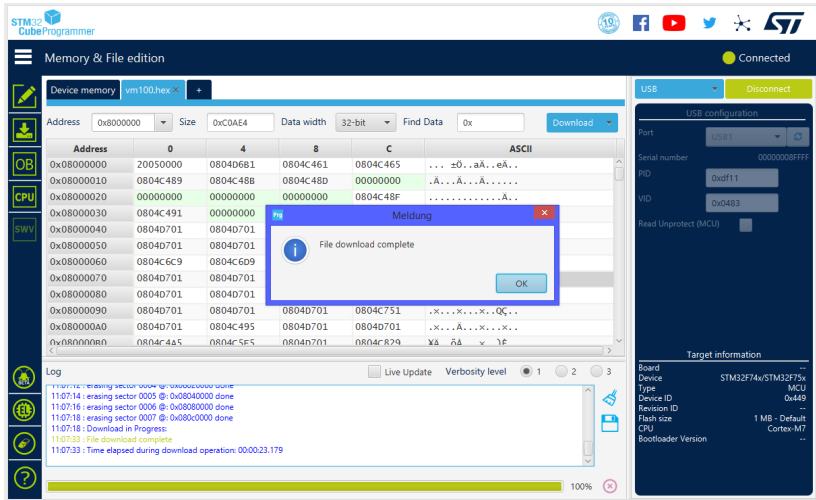
Figure 134: Finished firmware update

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.

97

10. Technical Data

	VM100A	**VM100B**
Sensor inputs	9 IEPE sensors 3 Binder 712, 4 pin sockets	3 IEPE sensors 1 Binder 712, 4 pin socket
IEPE sensor supply	4 mA / 24 V, can be switched off Input impedance: > 1 MΩ	
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 Frequency: 1 to 1000 Hz / 60 to 60 000 min^{-1} Supply voltages: +5 V / <0.1 A and +26 V / < 0.1 A Binder 712, 7 pin socket	
Measuring range	1 μm/s² to 10 000 m/s² (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)	
Crosstalk attenuation	>80 dB (2500 mV$_{RMS}$ / 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 38 low pass filters from 10 Hz to 24 kHz	
Weighting filters for human vibration	Wb; Wc; Wd; We; Wh; Wj; Wk; Wm 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 µm/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 to 3
Measuring routes	Measurement point description with location, machine, position and comment; automatic detection with NFC tags
Trend view	Amplitude time graph with limit lines
ISO standard assistant	ISO 20816-2: Gas and steam turbines >40 MW ISO 20816-3: Industrial machines >15 kW ISO 20816-5: Hydraulic power and pump storage plants ISO 10816-7: Rotodynamic pumps ISO 20816-8: Reciprocating compressors ISO 20816-9: Gear units ISO 13373-3: Roller bearings

Balancing (VM100-BAL)

Planes	1 or 2
RPM range	100 to 60000 min^{-1}
Angle index sensor	Tacho input with photoelectric reflex switch
Modes	Free or fixed angles, add or remove mass
Displayed values	Vibration velocity / acceleration; 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 BMP for screenshots 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.