Instruction Manual

Vibration Analyzer

VM100

Valid from Version 001.012

Dec/ 25

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 and whole-body vibration 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.

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 device can read contactless NFC tags for measuring point detection.

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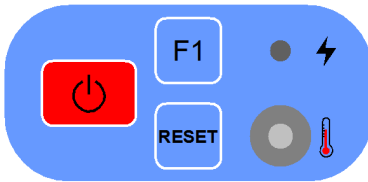
Figure 1: Keypad of VM100A
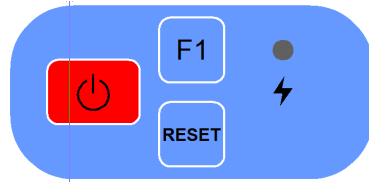
Figure 2: Keypad of VM100B

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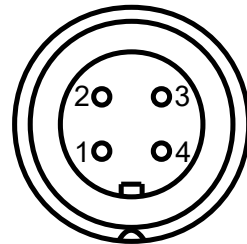
A triaxial sensor requires three inputs. All triaxial accelerometers from Metra can be connected via their standard cables.

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: Output +26 V

2: Digital (tacho) input D1 (24 V)

3: Digital (tacho) input D2 (3.3 / 5 V)

4: Output +5 V

5: Analog input A1

6: Analog input A2

7: Ground
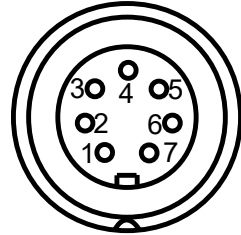
Figure 4: Tacho input

Further details can be found in section 10.

The inputs A1 and A2 are currently not used.

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

3.2. Switching On / Off and Reset

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

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

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

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

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

3.3. Menu Bar

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

Figure 5: Menu bar

The menu bar contains the following components:

• Off button ⏻

• Function menu: Touch the menu text to open a drop-down menu with all function modules. Unlicensed functions are grayed out. Touching a menu item selects the function. If no selection is made, the menu closes again after a few seconds.

• The info button ⓘ provides a short help text to each measuring module.

- The menu button ▤ opens a menu structure with various settings and for USB data transfer (see section 7).

- The save button 💾 opens the menu for saving data to SD card (Section 5). If no SD card is inserted, the symbol appears crossed out.

- The USB button ⟷ establishes a data connection to a PC.

- The battery indicator 🔋 shows the current charge status of the unit. In case of advanced discharge, the display bar turns yellow and in case of critical charge state, it turns red. When the charger is connected, the charging symbol 🔋 is displayed alternating with the actual charge current. After charging is complete, a plug symbol for battery support appears on the right (see section 3.6).

- The menu bar shows the date and time. In the VM100A, you can see the measured temperature of the built-in infrared sensor below it (Figure 1).

3.4. Sensors

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

Sensors			⟳ ✖ ✔
☑ IEPE supply on			Pk max.
1X	1.1197	mV/m/s² (TEDS) KS903B10 #23015	±6.0 V
1Y	1.0631	mV/m/s² (TEDS) KS903B10 #23015	±6.0 V
1Z	1.1517	mV/m/s² (TEDS) KS903B10 #23015	±6.0 V
2X	10.125	mV/m/s² ▼	±6.0 V
2Y	10.096	mV/m/s² ▼	±6.0 V
2Z	10.214	mV/m/s² ▼	±6.0 V
3X	101.12	mV/m/s² ▼	±5.0 V
3Y	100.99	mV/m/s² ▼	±5.0 V
3Z	101.06	mV/m/s² ▼	±5.0 V

Figure 6: Sensor menu with a TEDS triaxial accelerometer at input 1

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

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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.

For each sensor, the maximum output amplitude in volts can be entered under "Pk max." IEPE sensors typically have peak output amplitudes between ±4 V and ±8 V. If the maximum amplitude is exceeded, the VM100 indicates overload. This ensures that the sensor output does not reach saturation unnoticed.

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

3.5. USB Connection

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

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

Figure 7: USB connection

Figure 8: USB connection

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

3.6. Charging the Accumulator

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

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

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

When switched on, the status bar on the top right shows the charging symbol ▆ alternating with the actual

Figure 9: Charge screen

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

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

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

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

➔ For sensitive measurements, the charger should be disconnected.

➔ After accidental deep discharge, e.g. after long storage, it may be necessary to start the charging process several times by disconnecting and reconnecting the USB cable before the full charging capacity is reached again.
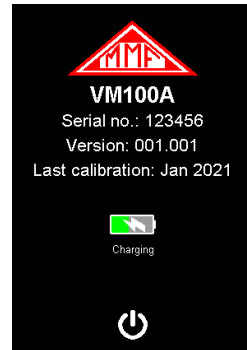
3.7. SD Card and File System

A Micro SD card serves as a measurement data memory. It is located behind the flap next to the USB socket (Figure 10). The supplied SD card has 4 GB and class 10. The VM100 uses the FAT file system (not FAT32). The files can be transferred to a PC via a USB cable as shown in section 3.5. If necessary, the SD card can be removed after unlocking it by pressing slightly on its edge. You can read out the data in other devices. Insert the SD card into the VM100 with the contacts facing up. It is recommended only to use memory cards of size 2 or 4 GB.

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

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

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

Figure 10: Charge connector and SD card slot

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
Amplitude/Rotation Speed
Machine Monitoring
Envelope Analysis
Balancing
Third-Octave Analysis
Human Vibration
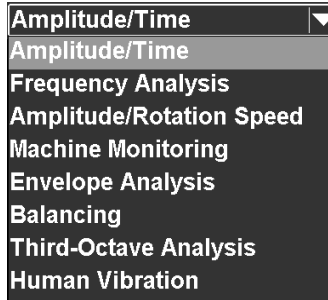
Figure 11: Measurement modules

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 7.7). 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

4.2.1. Overall Values

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 80 on page 55).

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

4.2.2. Settings

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

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.

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Figure 14: Settings for all channels simultaneously

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

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

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

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

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

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

- The highest selectable high-pass frequency is one third of the low-pass frequency.
- The maximum frequency range for single integration is from 1 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.
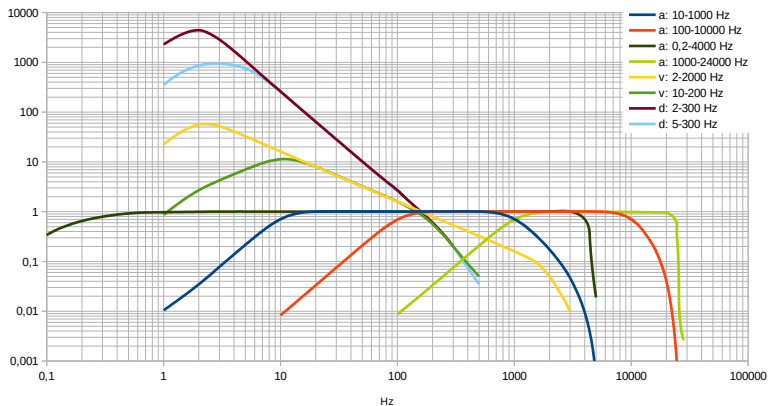
Figure 15: Frequency response of selected filters and integrators

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 amplitude axis is logarithmically scaled. The buttons ⊕ and ⊖ can be used to scale the amplitude axis. 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).

The measurement display can be paused or restarted with ▮▮ and ▶. The measurement continues to run in the background. The button ◀▮ restarts the plot graph.

4.2.3. Storage

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.

	A	B	C	D	E	F	G	H	I	J	K
1	Amplitude/Time										
2	Instr.:	VM100A	Ser.:	221236							
3	Comment:										
4	NFC Id:										
5	Sensor 1X:	KS903B100	Ser.:	23029	Sensit.:	1,012	mV/m/s²				
6	Sensor 1Y:	KS903B100	Ser.:	23029	Sensit.:	1,004	mV/m/s²				
7	Sensor 1Z:	KS903B100	Ser.:	23029	Sensit.:	1,054	mV/m/s²				
8	Sensor 2X:	KS903B100	Ser.:	23030	Sensit.:	11,0585	mV/m/s²				
9	Sensor 2Y:	KS903B100	Ser.:	23030	Sensit.:	10,1982	mV/m/s²				
10	Sensor 2Z:	KS903B100	Ser.:	23030	Sensit.:	10,8255	mV/m/s²				
11											
12											
13											
14	Date:	03/01/25	Time:	16:51:23	Temp.:	23	°C				
15											
16											
17	Input:	1X	1Y	1Z	2X	2Y	2Z	3X	3Y	3Z	RPM
18	HP (Hz):	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	
19	LP (Hz):	4000	4000	4000	4000	4000	4000	4000	4000	4000	
20	Mode:	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RPM
21	Unit:	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	1/min
22	03/01/25 16:51:24	24,828	24,737	25,134	0,185	0,151	0,255	IEPE!	IEPE!	IEPE!	0
23	03/01/25 16:51:25	24,856	24,773	25,157	0,186	0,143	0,253	IEPE!	IEPE!	IEPE!	0
24	03/01/25 16:51:26	24,851	24,757	25,169	0,181	0,134	0,242	IEPE!	IEPE!	IEPE!	0
25	03/01/25 16:51:27	24,86	24,761	25,171	0,181	0,141	0,239	IEPE!	IEPE!	IEPE!	0
26	03/01/25 16:51:28	24,844	24,754	25,159	0,182	0,14	0,237	IEPE!	IEPE!	IEPE!	0
27	03/01/25 16:51:29	24,843	24,771	25,166	0,182	0,135	0,231	IEPE!	IEPE!	IEPE!	0
28	<END>										

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 22 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.

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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

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.
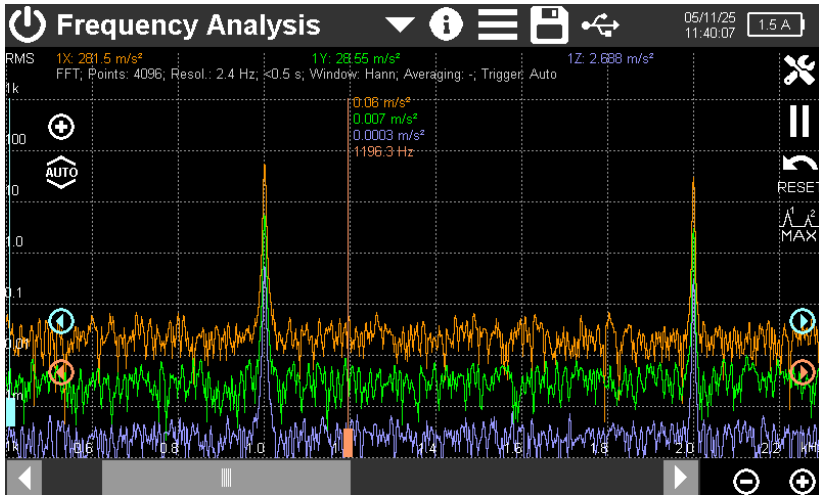
Figure 17: Measurement screen of frequency analysis with three channels

The amplitudes are scaled as peak values.

The acceleration or velocity spectrum can be measured as required. It is also possible to measure the power spectral density (PSD) and the frequency response function (FRF).

The frequency range of the spectrum for acceleration and power density extends up to a maximum of 22 kHz. The bandwidth for velocity and frequency response function is 4.4 kHz.

The entire screen width of 800 points is used to display the spectrum (Fig. 17). At the bottom right you will see two zoom buttons for enlarging or reducing the visible frequency range. The scroll bar can be used to navigate within the selected frequency range. An exception is the lowest zoom level, in which the entire frequency range is displayed at a width of 460 points.

The amplitude axis is scaled using the plus/minus buttons at the top left. An auto-scaling function can be activated with ⬡.

The peak or RMS values of the three channels are displayed above the diagram or, with 1024 points, on the right. You can also see the number of points used to calculate the FFT. Depending on the zoom level, it can be between 1024 and 32768 and is approximately 2.2 times the number of points visible. This results in the frequency step size per point, which is also displayed. You will find here also the window function, averaging and trigger mode.

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The orange and blue measurement cursors are moved at their wider lower end. There are also orange and blue arrow keys on the left and right for moving the cursor in fine steps. The three amplitudes and the frequency at the selected point are displayed in the upper area of the cursor, and the frequency difference to the orange cursor is also displayed for the blue cursor.

All graphical and numerical values are displayed 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 ►.

Pressing ⬛ opens a window with the five highest amplitudes and corresponding frequencies of the three channels. This window can be moved with ⬦.

Figure 18: Highest amplitudes

The button ⬛ opens a window for measuring the RMS values in the frequency range between cursors 1 and 2. This function is only available in operating modes FFT and FFT velocity and not in waterfall display mode. The window can be moved with ⬦.
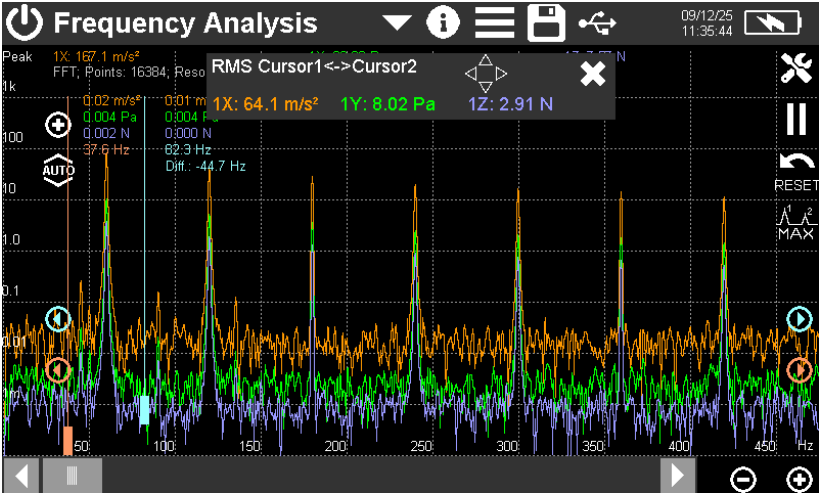
Figure 19: RMS measurement between cursor 1 and 2

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The tools icon ⊠ opens the FFT menu (Figure 20).

Frequency Analysis Settings ✓

Mode	FFT Accel. ▼	Gain	X	1 ▼
Ampl. axis	logarithmic ▼		Y	1 ▼
Window	Rectang. ▼		Z	1 ▼
Averaging	- ▼	Waterfall mode	☐	
Hold max.	☐	Spectrogram	☐	
Trigger	Single amp ▼	Trigger channel	1X ▼	
Amplitude	50.00	Waterfall lines	10 ▼	
Bandwidth	4.5 kHz ▼	Waterfall interval	<6 s ▼	

Figure 20: FFT menu

The menu for the operating mode (Fig. 21) has 10 selectable options. In addition to the FFT of acceleration and velocity, these are the power spectral density (PSD), energy spectral density (ESD) and frequency response functions (FRF) of acceleration, velocity and displacement as well as the respective inverse transfer functions.

For acceleration, PSD and ESD the instrument displays the measurement units of the sensor used, e.g. m/s², N or Pa. For velocity, however, the unit is always mm/s, as integration is only useful for acceleration.

Power spectral density (PSD) characterizes the power distribution of a signal over the frequency range (see section 4.3.1).

Energy spectral density (ESD) characterizes the energy distribution of a signal over the frequency range (see section Fehler: Verweis nicht gefunden).

Frequency response function (FRF) can identify resonances, damping and vibration modes of a structure (see section 4.3.3).

FFT ▼
FFT
FFT Veloc.
PSD
ESD
FRF a/F
FRF F/a
FRF v/F
FRF F/v
FRF x/F
FRF F/x

Figure 21: Modes

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The scaling of the **amplitude axis** can be switched between linear and logarithmic. Furthermore, you can choose between RMS and peak value (Figure 22). The latter refers to the scaling of the spectrum, as well as the cursor values and maxima above the diagram. The selected mode is displayed in the top left corner (Figure 23). For PSD and ESD only the RMS value is available.
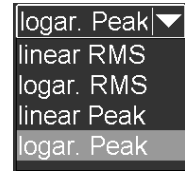
Figure 22: Amplitude axis

Figure 23: RMS and peak display

Window determines with which weighting the obtained sample values within a section (window) are used in subsequent calculations. Due to the block-wise processing of the signal, so-called leakage effects occur on the edges of a block, which make the spectral components appear too wide. This effect can be reduced by using a suitable window function. The window function also influences the frequency selectivity and the spectral error. The choice of window functions is a compromise between side-band suppression and width of the spectral lines (Figure 24).

The rectangular window is not actually a window function, as it leaves the spectrum unchanged. It can be advantageous if single pulses are analyzed.

Window functions and their effect in the frequency spectrum	
Hann	
	Good compromise for many applications
Hamming	
	Good separation of closely spaced frequency components
Flattop	
	Highest amplitude accuracy
Rectangular/ Uniform (no windowing)	
	High frequency accuracy
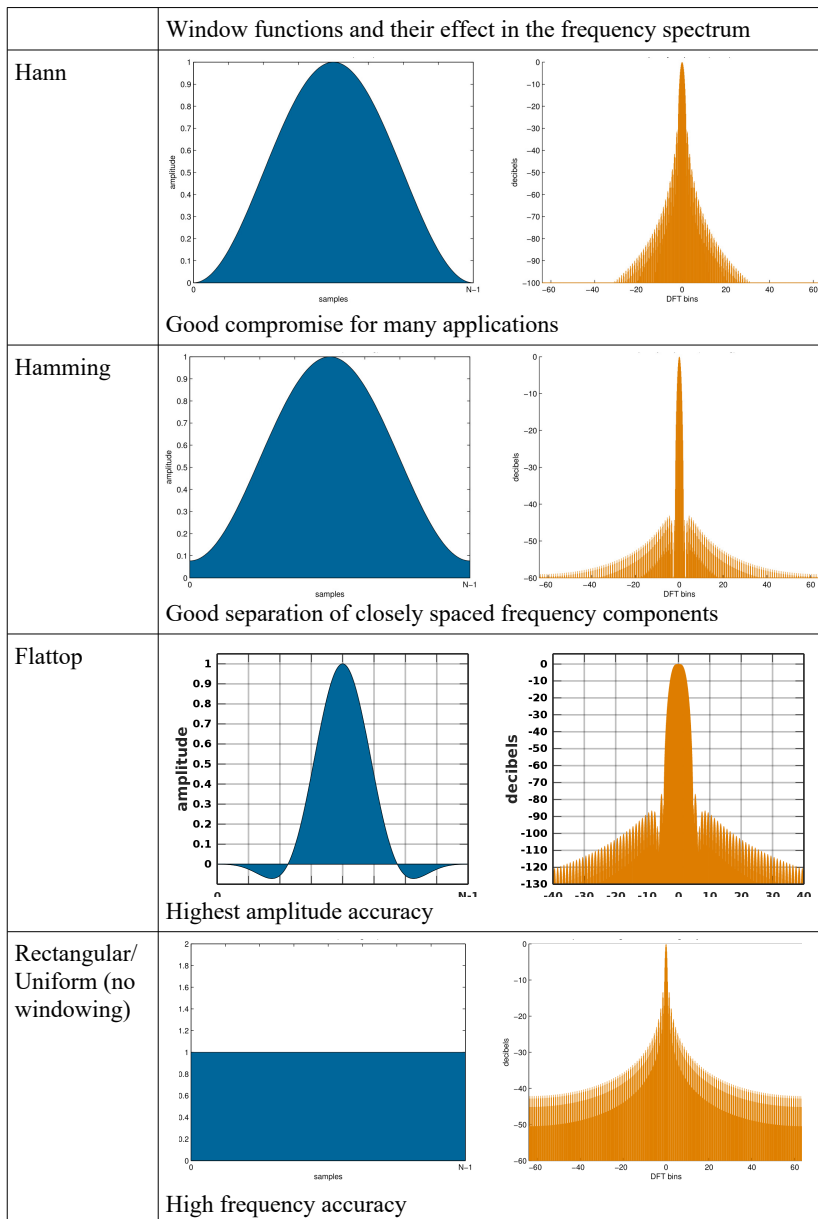
Figure 24: Window functions used in the VM100 (Wikimedia Commons)

Averaging of 2 to 16 spectra can be performed. This can significantly reduce the noise floor 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 ![key] averaging can be restarted.

With **Hold max.** the previous FFT is not deleted, but displayed one above the other (Figure 25). This allows changes in the spectral composition of the signal to be made visible. The previous spectra appear in darker colors.
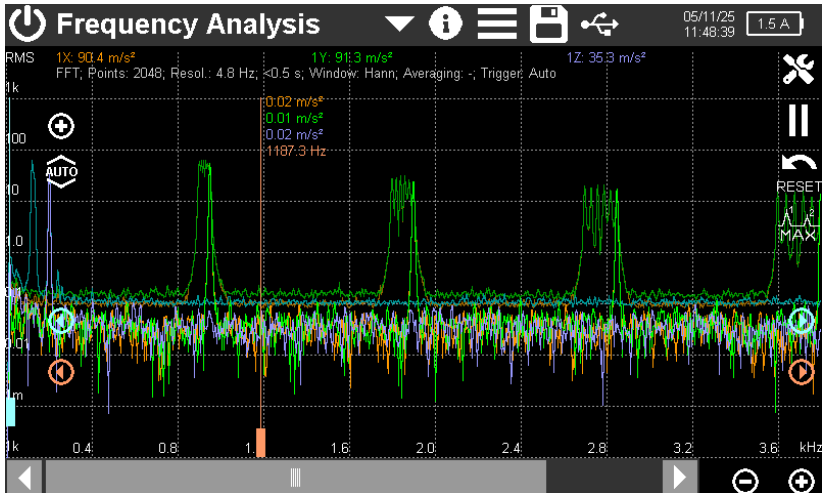
Figure 25: FFT with hold function

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

- Auto: The spectrum is displayed continuously in the time interval determined by the frequency resolution.
- D1 pulse: The spectrum is displayed when a pulse is detected at the RPM input.
- Amplitude: The spectrum is continuously displayed when a sample exceeds the specified amplitude value.
- Single amplitude: The spectrum is displayed once when when a sample exceeds the specified limit value. Reset must be pressed for a further measurement.

The triggering channel for amplitude/single amplitude triggering is selected in the "Trigger channel" menu. In FRF mode the trigger channel is always 1X with the impact hammer.

In the Amplitude and Single amplitude trigger modes, the analysis is performed so that the trigger point is in the middle of the FFT window. The calculation of the spectrum therefore begins before the trigger moment. This has the advantage that even short impulses are not attenuated by the window function and reproducible results are obtained.

The trigger amplitude is entered as a numerical value below the trigger menu. In FRF mode, this is the force trigger value on channel 1X when the impulse hammer strikes.

In trigger modes D1, Amplitude and Single amplitude, the last measured spectrum remains on the screen until a new trigger event occurs. The number of trigger events is displayed above the diagram (Figure 26). The window with the highest amplitudes (Figure 18) shows the maximum values before the trigger event. However, the line with the maximum amplitudes above the diagram continues to be updated even without triggering and shows the currently measured spectral maxima. This can be helpful for finding a suitable trigger amplitude.

Figure 26: Amplitude trigger

Figure 27: Single amplitude trigger

If the frequency resolution is changed, the held spectrum is deleted.

With the reset button the the stored spectrum data can be erased and the single amplitude trigger is reset (Figure 27).

Bandwidth can be switched between 4.4 and 22 kHz. This is the highest measurable frequency. A bandwidth of 4.4 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 and transients, for example modal analysis in FRF mode, a fixed gain is better suited to avoid continuous switching.

4.3.1. Power Spectral Density (PSD)

Power spectral density (PSD) characterizes the energy distribution of a signal over the frequency range. The spectrum is normalized. The power density of acceleration has the unit $(m/s^2)^2/Hz$, resulting from the calculation of the power density as the square of the RMS divided by the distance between the frequency lines.

Power density is particularly suitable for analyzing random signals, i.e. signals that consist of non-periodic components.

With PSD it is also possible to compare measurements at different sampling rates and measurement durations, because the normalization to the spacing of the frequency lines ensures an independent energy scale.

The VM100 measures power spectral density on up to three channels.

4.3.2. Energy Spectral Density (ESD)

Energy spectral density can be useful for signals with finite energy, for example short-term oscillations (transients). It is calculated by multiplying the power spectral density (PSD) by the measurement duration per spectrum. This makes the amplitude of the displayed spectrum independent of the selected frequency resolution. The unit of measurement using the example of acceleration is therefore $(m/s^2)^2s/Hz$.
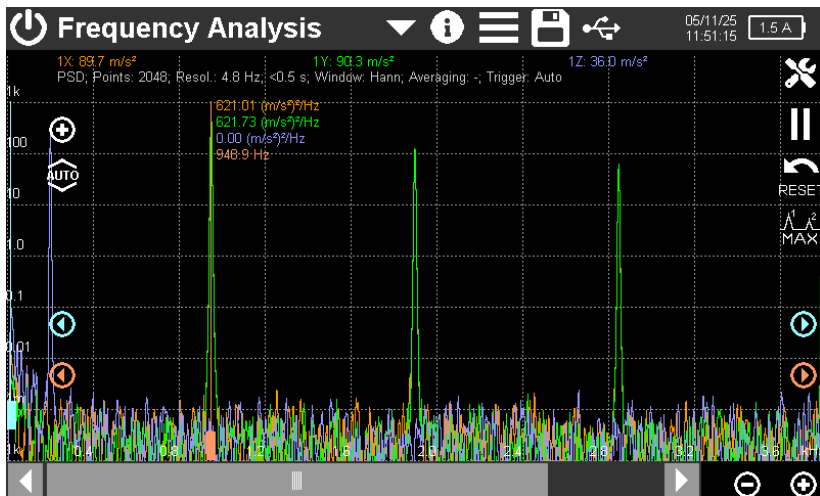
Figure 28: Power spectral density

It is possible to output the spectral power density in waterfall display for one channel.

4.3.3. Frequency Response Function (FRF)

The frequency response function (FRF) is used to identify resonances, damping and vibration modes of a structure. It represents the relationship between an applied force impulse from an impulse hammer and the resulting vibration in the structure.

The following terms are commonly used for the individual FRF types:

Acceleration by force (a/F):	Accelerance, inertance
Force due to acceleration (F/a):	Dynamic mass
Velocity through force (v/F):	Mobility, admittance
Force due to velocity (F/v):	Mechanical impedance
Displacement due to force (x/F):	Dynamic compliance
Force through displacement (F/x):	Dynamic stiffness

An impulse or impact hammer with built-in force transducer must be connected to input 1X.

When one of the FRF modes is selected, a diagram for displaying the excitation impulse appears in the FFT menu (Fig. 29). By experimentally striking the structure, you can determine a suitable trigger amplitude at which the transfer function is calculated. The diagram shows the last 16 pulses. The amplitude entered under "Triggering" is shown as a blue dot in the pulse diagram.

Frequency Analysis Settings ✓

Mode	FRF a/F ▼	Gain	X 10 ▼
Ampl. axis	logarithmic ▼		Y 10 ▼
Window	Rectangula ▼		Z 10 ▼
Averaging	- ▼		
Hold max.	☐		
Triggering	Amplitude ▼		
	10		
Bandwidth	4.5 kHz ▼		
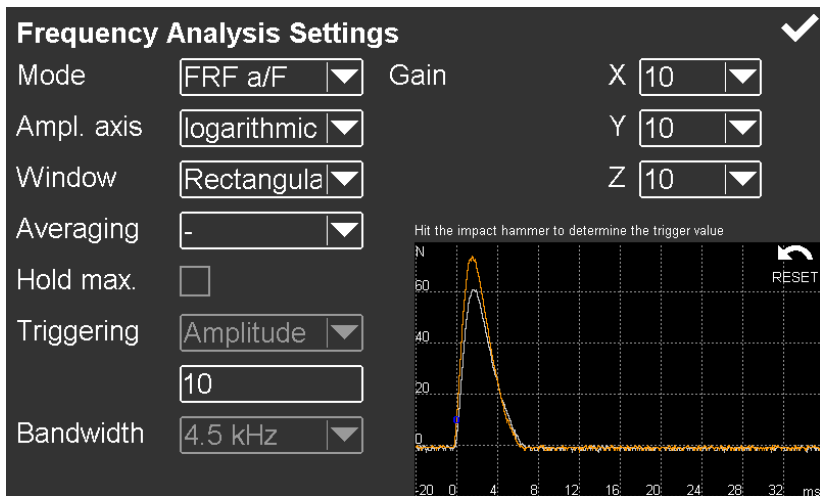
Figure 29: FFT menu with impulse diagram for FRF mode

Accelerometers which are attached to the structure are connected to 1Y and, if required, to 1Z. The structure is struck by the hammer. If the force applied exceeds the trigger amplitude entered, the FFT calculation begins for all three channels. The built-in force transducer of the hammer provides the strength of the impulse applied. Taking the force into account, the resulting transmission spectrum of sensors 1Y and 1Z is approximately constant even if the impact force varies.

➔ For FRF the rectangular window is used.

The shape of the impulse and thus the width of the excited spectrum can be changed by selecting the hammer tip. The harder the tip, the broader the excited spectrum.

➔ It is essential to avoid bouncing the hammer.

The resonance frequencies of the structure under investigation can be read from the peaks of the response spectrum (or the dips in the inverse function) (Fig. 30).

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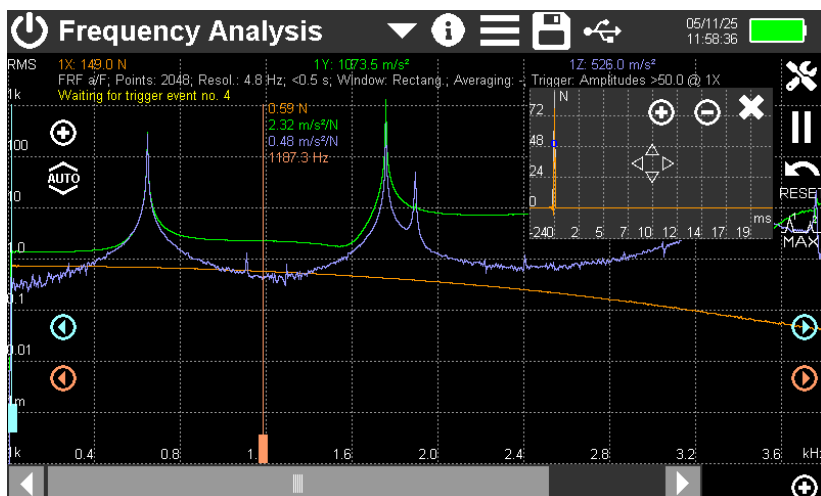
Figure 30:Frequency response function with force impulse in time domain

The excitation pulse in time domain is displayed in the transfer function. The window can be moved or closed as required. The button ⊞ opens the pulse window again.

The excitation pulse (channel 1X) is also displayed in the spectrum.

By pressing the button ⊞ the five largest spectral amplitudes are displayed sorted by size (Fig. 31).
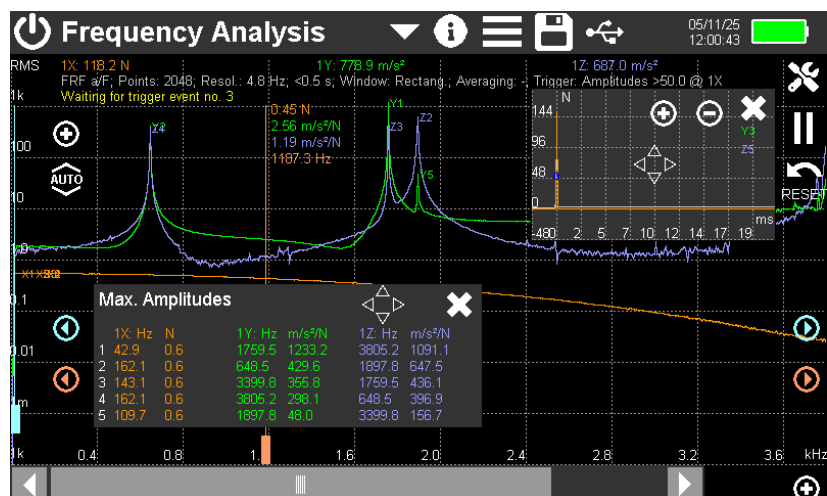
Figure 31: Highest spectral amplitudes

4.3.4. Waterfall Mode

In waterfall mode, the spectra are displayed in pseudo 3D. These can be spectra of acceleration, velocity or spectral power density. Up to 50 previous spectra are displayed in the "background" of the currently measured spectrum. This can be useful, for example, to make resonance points visible during run up or coast down tests (Figure 32).
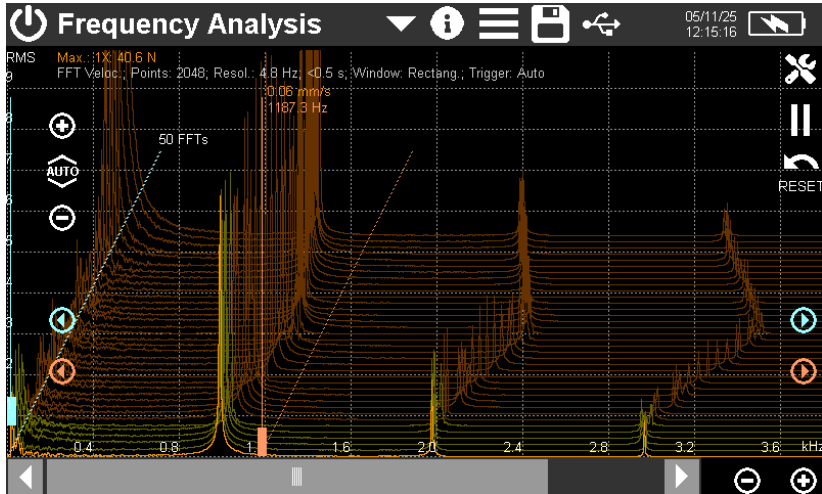
Figure 32: FFT in waterfall mode

Waterfall mode is only possible for one channel which is selected in the menu "Display channel". 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 icon] key is used to clear the history and restart the recording.

The cursor measures the currently measured spectrum.

4.3.5. Spectrogram Mode

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. 33). 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. Overloaded values appear as pink pixels. The plus/minus buttons are used to change the amplitude range. The output rate depends on the resolution / number of points.

The spectrogram display is only available for one channel which is selected in the menu "Display channel".
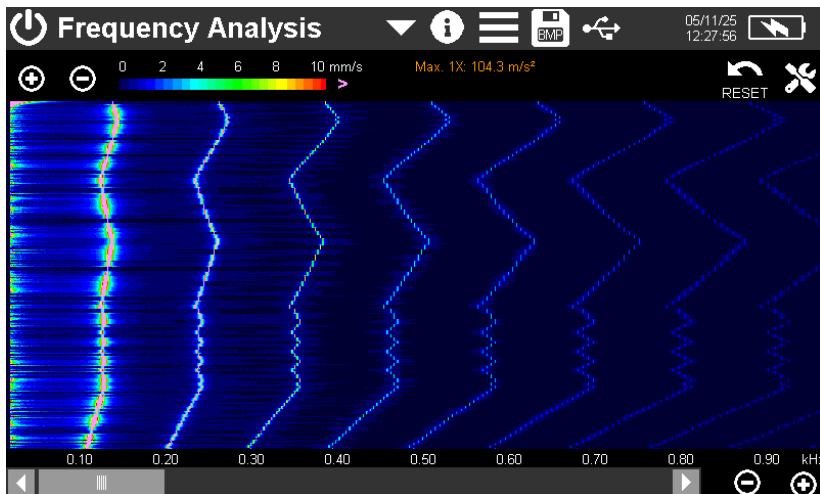
Figure 33: Spectrogram view

4.3.6. Storage

The following options are available for saving with the button ⊟. The spectrum is saved as a CSV file in a data table (Figure 34) with a header containing information about the measuring device, sensor and FFT settings. From line 22 the frequency points and the corresponding amplitudes of the three channels are listed. The number of lines depends on the selected number of points.

In FFT and FFT integrated modes, the RMS values in the frequency range between cursor 1 and cursor 2 are also stored (see Figure 19).

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.

	A	B	C	D	E	F	G	H	I	J
1	FFT									
2	Instr.:	VM100B	Ser.:	123456						
3	Comment:									
4	NFC Id:									
5	Sensor 1X:		Ser.:		Sensit.:	1.0000	mV/m/s²			
6	Sensor 1Y:		Ser.:		Sensit.:	8.0000	mV/Pa			
7	Sensor 1Z:		Ser.:		Sensit.:	22.0000	mV/N			
8										
9										
10										
11										
12										
13										
14	Date:	09/12/25	Time:	11:31:59						
15	Points:	16384								
16	Window:	Hann								
17	Trigger:	Auto			RMS between cursors					
18	Magnitude:	Peak		Cursor1:	37.6	Hz	X: m/s²	Y: Pa	Z: N	
19	Averaging:	1x		Cursor2:	82.3	Hz	64.096	8.022	2.909	
20										
21	Hz	X: m/s²	Y: Pa	Z: N						
22	0.6	0.000	0.000	0.000						
23	1.2	0.036	0.006	0.002						
24	1.8	0.037	0.006	0.001						
25	2.4	0.036	0.005	0.002						
26	3.0	0.005	0.002	0.002						
27	3.6	0.022	0.004	0.002						
28	4.2	0.048	0.008	0.002						
29	4.8	0.034	0.004	0.002						
30	5.4	0.018	0.004	0.001						

Figure 34: FFT saved as CSV table (only first frequencies shown)

4.4. Module Amplitude/Rotation Speed

4.4.1. Introduction

This measuring module graphically displays the vibration amplitude as a function of rotation speed. The main application is the detection of resonances. Figure 35 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 80 on page 55) to the input "RPM" of the VM100, which serves as rotary speed sensor.

The vibration measurement can be done on 1 to 9 channels.
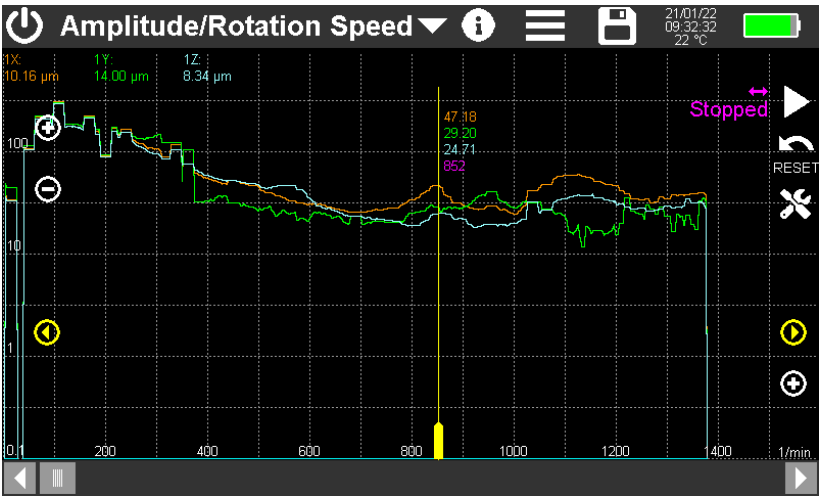
Figure 35: Amplitude/rotation speed measurement

4.4.2. Settings

Touch ⚒ to open the setup menu (Figure 36).

Figure 36: Amplitude/rotation speed setup

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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 35 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.

4.4.3. Measurement

At the top of the rotation speed diagram (Figure 35) 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, "No rotation" is shown instead. The arrow above indicates the selected speed ramp.

With the reset button 🔄 the diagram content is deleted.

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

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

The orange measurement cursor is shifted with its wider lower end. In addition, there are orange 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.

The buttons ⊕ and ⊖ can be used to scale the amplitude axis. 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.

4.4.4. Storage

The following options are available for saving with the ⊟ button:

As a CSV file, the diagram is saved as data table (Figure 37).

	A	B	C	D	E	F	G	H	I	J
1	Amplitude/Rotation Speed									
2	Instr.:	VM100A	Ser.:	221236						
3	Comment:									
4	NFC Id:									
5	Sensor 1X:	KS903B100	Ser.:	23029	Sensit.:	1,01	mV/m/s²			
6	Sensor 1Y:	KS903B100	Ser.:	23029	Sensit.:	1,006	mV/m/s²			
7	Sensor 1Z:	KS903B100	Ser.:	23029	Sensit.:	1,05	mV/m/s²			
8	Sensor 2X:	KS903B100	Ser.:	23030	Sensit.:	11,0585	mV/m/s²			
9	Sensor 2Y:	KS903B100	Ser.:	23030	Sensit.:	10,1982	mV/m/s²			
10	Sensor 2Z:	KS903B100	Ser.:	23030	Sensit.:	10,8255	mV/m/s²			
11	Sensor 3X:	KS903B10	Ser.:	23015	Sensit.:	1,1197	mV/m/s²			
12	Sensor 3Y:	KS903B10	Ser.:	23015	Sensit.:	1,0631	mV/m/s²			
13	Sensor 3Z:	KS903B10	Ser.:	23015	Sensit.:	1,1517	mV/m/s²			
14	Date:	07/01/25	Time:	10:17:59	Temp.:	21	°C			
15										
16										
17	Input:	1X	1X	1Z	2X	2Y	2Z	3X	3Y	3Z
18	LP (Hz):	1000	1000	1000	1000	1000	300	1000	1000	1000
19	HP (Hz):	2	2	2	2	2	2	2	2	2
20	Mode:	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS
21	RPM	m/s²	mm/s	m/s²	m/s²	m/s²	µm	m/s²	m/s²	m/s²
22	0	0,739	4,038	0,667	0,081	0,079	19,606	0,469	0,414	0,389
23	2	0	0	0	0	0	0	0	0	0
24	4	0	0	0	0	0	0	0	0	0
25	6	0,741	4,206	0,79	0,471	0,405	669,036	0,88	0,63	1,526
26	8	0,741	4,206	0,79	0,471	0,405	669,036	0,88	0,63	1,526
27	10	0,741	4,206	0,79	0,471	0,405	669,036	0,88	0,63	1,526
28	12	0,741	4,206	0,79	0,471	0,405	669,036	0,88	0,63	1,526
29	14	0,741	4,206	0,79	0,471	0,405	669,036	0,88	0,63	1,526
30	16	0	0	0	0	0	0	0	0	0
31	18	0	0	0	0	0	0	0	0	0
32	20	0	0	0	0	0	0	0	0	0
33	22	0	0	0	0	0	0	0	0	0

Figure 37: Amplitude/Rotation Speed data as CSV table (section)

The header includes information about the measuring device, sensor and settings. Starting from line 22, 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 mainte-nance 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
- ISO 14694: Industrial fans

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

Trend monitoring can be done with permanently installed measurement equipment, such as Metra's M12, M14 or VS11 vibration monitors. Sometimes, however, the in-stallation of permanent monitoring equipment is not economic, not possible or unde-sirable 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 mea-surement points in regular intervals.

The VM100 features two monitoring modes that are fundamentally different:

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

4.5.2. Entering Measurement Routes

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

A measurement route is a list of measurement points to be acquired that are in close proximity to each other. It allows the condition of many machines to be recorded effectively.
Figure 38 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.
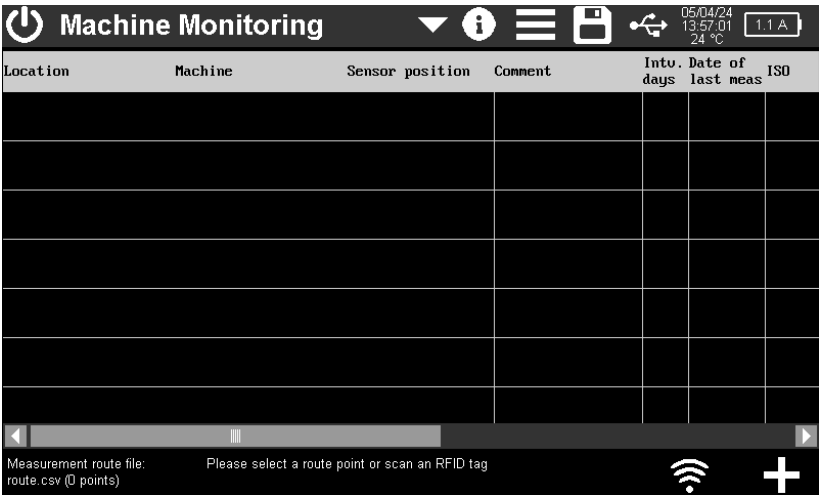

Figure 38: Module Machine Vibration with empty measurement route

To create a new route file, touch the Save button [ ]. Enter the file name for the new route file (Figure 39). 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 39: 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.

Figure 40: NFC detection

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 40). 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.
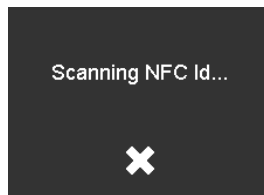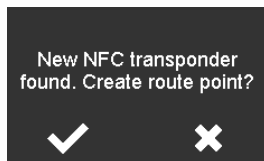
Figure 41: NFC tag found

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 43). 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. 43).

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

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

Now select a monitoring mode (Figure 42). You can select whether RMS or peak values are measured, in both cases in three axes for X/Y/Z. You can set integration and filtering in the menus below. For example, you can select the most common settings RMS, single integration, high pass 10 Hz and low pass 1000 Hz to measure the vibration severity.

Figure 42: Monitoring mode

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

Figure 43: Adding a new route point

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

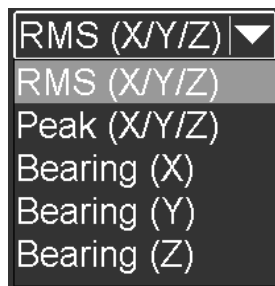Vibration measurements on machines are often influenced by several components and can therefore exhibit short-term fluctuations. For reproducible measurement results, averaging over a specified number of display cycles can be useful. The entry [1 avg. no.] determines how many measurements of one second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

A vibration measurement becomes more informative and comparable if the rotation speed is also recorded. The VM100 allows the connection of a VM100-LS photoelectric reflex switch (see figure 80 on page 55) to the "RPM" input of the VM100, which serves as rotation speed sensor. This requires a reflex mark on the rotor. Under [Sensor 1/min] is indicated whether the speed is to be measured. In this case, "Sensor" is displayed. If the speed is known or constant, its value can be entered here in 1/min and no measurement is carried out. You can return to the "Sensor" display by entering a zero.

Finally, the required measuring interval [30 days] is displayed in days. This serves as a reminder that a measurement is due. Overdue measuring points are highlighted in red in the route table.

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

After you have closed the measuring point menu with [✓], the newly created measuring point appears with all its settings in the measuring route table (Figure 44).

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

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

Figure 44: Route table with one route point

4.5.4. ISO Standard Assistant for Vibration Severity

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

ISO Help opens a selection menu with the most common ISO standards for measuring vibration severity on different machine types with the relevant selection criteria (Figure 45). Once the selection has been made, the corresponding limit values for warning and alarm are displayed. Exit with ✓ to transfer them to the measuring point menu. The measurement settings are also made according to the selected standard.

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

Machine Monitoring Standards Assistant	✖ ✔
Standard	ISO 20816-3: Industrial machine >15 kW ▼
Group	Medium (15-300 kW), motor shaft height 160-315 mm ▼
Support	Rigid ▼
Rotary speed	>600 rpm ▼
Mode	RMS
Integration	single
High pass	10 Hz
Low pass	1000 Hz
Alarm	4.5 mm/s
Warning	2.8 mm/s

Figure 45: ISO assistant

4.5.5. Measurement of Machine Vibration

4.5.5.1. Measurement Screen

Once a measuring point has been created, measurements can be taken for trend monitoring. Touch the line of the route table with the desired measuring point to select it. The background color is then highlighted in blue (Figure 46).

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

Figure 46: Route table with selected measuring point

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

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

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

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

4.5.5.2. Measurement of Vibration Severity

The display for vibration severity measurement in RMS/peak or ISO mode is explained below (Figure 47).
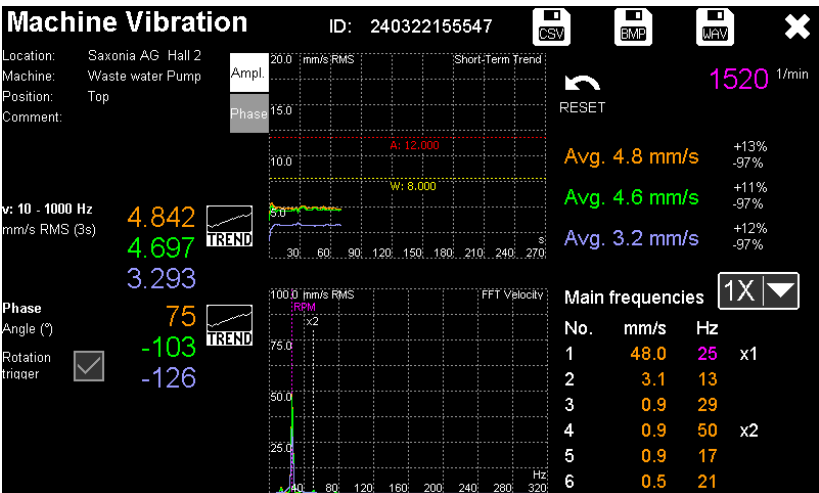
Figure 47: Vibration severity measurement in RMS/Peak or ISO mode

4.5.5.2.1 Display of Overall Values and Phase Angles

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

The amplitude values are compared with the warning and alarm limit values stored in the route table. If they are exceeded, a yellow warning or red alarm symbol (Figure 48) appears.

Figure 48: Alarm icon

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

The VM100 supports two methods of phase measurement:

1. Phase relative to a trigger pulse: This method is preferable because it provides more reliable results, especially when the signal consists of different vibration frequencies and the signals are noisy. The trigger pulse is provided by a VM100-LS speed sensor (see Figure 80 on page 55) at the "RPM" input of the VM100 and a reflex marker on the rotor. The tick at [Rotation trigger ☑] activates the trigger pulse. It is set automatically when a rotation signal is detected (top right-hand corner of the screen). Otherwise, "Red.?" is displayed instead of the phase angle.

2. Phase relative between channels X/Y/Z: If it is not possible to use a speed sensor, the phase angles between the channels can be determined by cross-correlation. Channel X provides the reference phase and is set to zero. Channels Y and Z show the phase angle relative to X.

The value range of the phase measurement is -180° to 180°.

➔ Unstable phase angles or a frequent change of sign are indications of unreliable detection of the main frequency due to noisy vibration signals.

➔ For measurements according to ISO 20816-8 with acceleration, velocity and displacement, no phase angles are output for reasons of space (Figure 49).
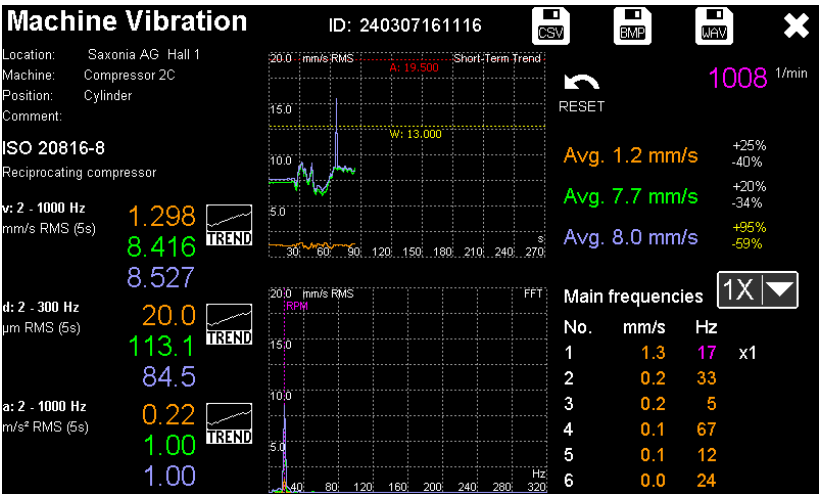
Figure 49: Measurement according to ISO 20816-8

4.5.5.2.2 Short-Term Trend of Overall Values

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

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

Alternatively, you can also switch to the short-term trend of the phase angle (Figure 50).

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

Press ⟳ to delete the short-term trend and restart recording.
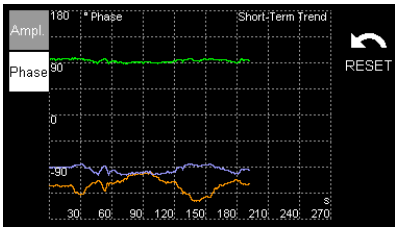
Figure 50: Short-term trend of phase

4.5.5.2.3 Frequency Spectrum (FFT)

In the lower center of the screen you will find the spectral representation of the measured vibration magnitude in the range from 3 to 300 Hz (Figure 51). This can help to assign the vibrations to specific components of the machine. The rotational frequency measured or entered by the sensor is displayed as a spectral line labeled "RPM". The color assignment of the frequency spectra corresponds to the measured value display. To the right of the spectrum you will find a list of the six largest amplitudes for the selected measurement channel. The rotational frequency is displayed in the color of the speed and marked with "x1" for the fundamental frequency. Any harmonics that occur, i.e. integer multiples of the rotational frequency, are also marked. Harmonics occur, for example, due to misalignment of coupled rotors, meshing frequencies in gears or blade passing frequencies in blowers. Structural looseness can also be detected via harmonics.
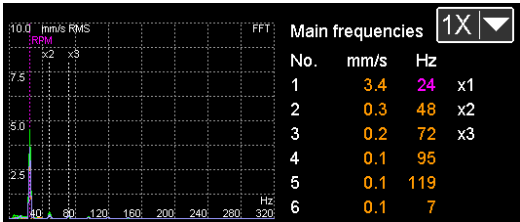
Figure 51: Frequency spectrum and main frequencies

4.5.5.2.4 Long-Term Trend of Vibration Severity and Phase

Pressing ▱ in the measurement display opens the trend diagram of vibration severity or phase angle. It shows the development of the measured values and thus the machine status over the entire monitoring period. This can be weeks, months or even years. The data is taken from the TREND_*.csv file in the TREND folder. Figures 52 and 53 show an example.

The warning and alarm limits are also displayed in the vibration severity diagram.
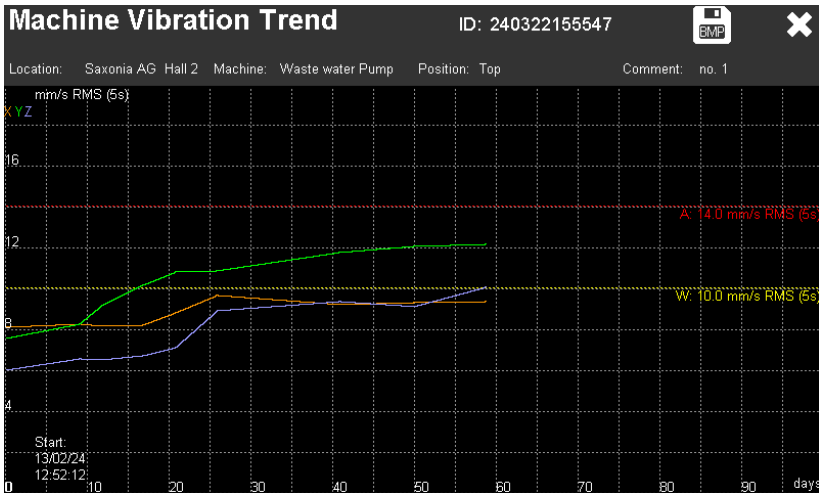
Figure 52: Long-term trend of vibration severity

Figure 53: Long-term trend of phase

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4.5.6. Measurement of Bearing Vibration

In addition to the vibration severity caused by rotating unbalance and moving parts, the vibrations in roller bearings can also be measured. The VM100 offers a set of analysis functions for this purpose, which can be used to make a statement about the maintenance condition of a bearing without profound knowledge of bearing diagnostics. In contrast to the vibration severity, high frequencies in the kilohertz range, where the damage mainly manifests itself, are considered here. Only one channel and only acceleration is measured. As shown in Figure 42 on page 34, the sensor channel used (X/Y/Z) is defined when the measuring point is created. Figure 54 shows the structure of the measurement screen.

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

➔ For reliable transmission of high vibration frequencies, the sensor must be mounted as close as possible to the rolling bearing. The mounting point must be flat and smooth.
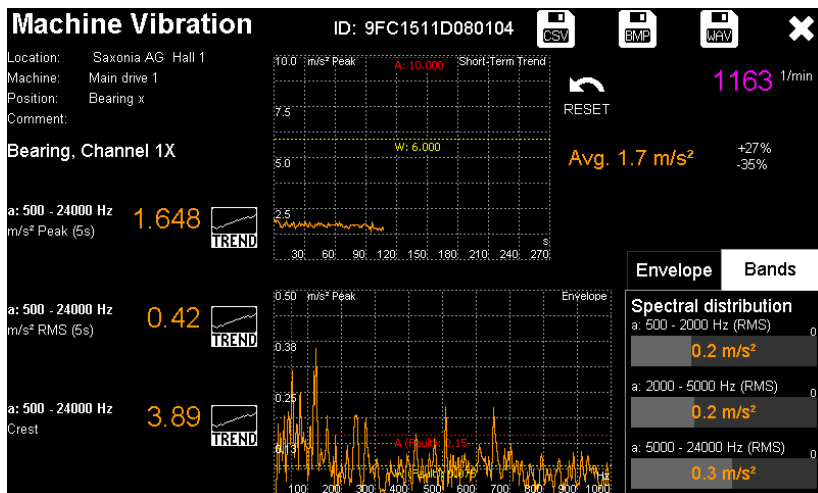
Figure 54: Measurement in bearing mode

4.5.6.1.1 Measurement of Overall Values

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

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

The peak value is compared with the warning and alarm limits stored in the route table. If they are exceeded, a yellow warning or red alarm symbol (Figure 55) appears.

4.5.6.1.2 Short-Term Trend of Peak Value

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

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

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

4.5.6.1.3 Envelope Spectrum

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

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

- <0.075 m/s²: No fault
- 0.075 m/s²: Warning limit for faults
- 0.15 m/s²: Alarm limit for faults
- 0.75 m/s²: Warning limit for damage
- 1.5 m/s²: Alarm limit for damage

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

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

Figures 57 and 56 show the difference between a slightly worn and a damaged ball bearing (note the amplitude scaling).
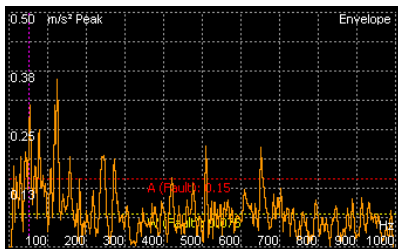
Figure 56: Envelope spectrum of a slightly worn bearing without damage
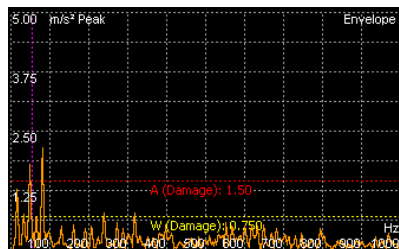
Figure 57: Envelope spectrum of a similar bearing with inner race damage

The six largest spectral amplitudes and the corresponding frequencies are displayed to the right of the envelope spectrum (figure 58).

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

Figure 58: Amplitude list

4.5.6.1.4 Frequency Bands

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

Figure 59: Frequency bands

4.5.6.1.5 Long-Term Trend

Pressing on the measurement screen opens the trend diagram of the peak value, RMS value or crest factor. It illustrates the development of the respective values and thus the change of the bearing condition over the entire monitoring period. This can be weeks, months or even years. The data is taken from the TREND_*.csv file in the TREND folder. Figure 60 shows an example.

The peak value diagram additionally shows the warning and alarm limits.
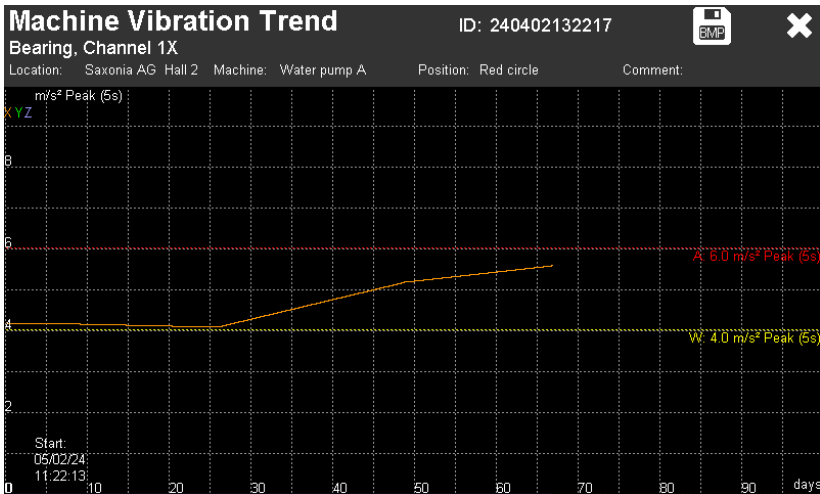
Figure 60: Peak long-term trend

4.5.7. Storage

On the measurement screen, you will find three options for saving (Figure 61).

Figure 61: Saving functions

- CSV: All displayed values are saved with a time stamp in a table belonging to the corresponding measuring point in CSV format on the SD card in the TREND directory to enable a trend view. You can also import the CSV files into a spreadsheet program. Figure 67 shows an example.

- BMP: A screenshot of the measurement screen, but with the controls hidden, is saved as a bitmap file (extension bmp) on the SD card in the TREND directory. The file name consists of "MEAS", the measuring point ID and the date and time, e.g.: MEAS_240410125946_100424_153447.bmp.

- WAV: Enables the raw data recording of the captured samples of a measurement channel in wave format, saved on an SD card in the TREND directory. A channel is recorded for 20 seconds at a sampling rate of 48828 samples/second with 24 bit resolution (figures 62 and 63). The samples are the raw data from the analog-to-digital converter. A gain of 1, 10 or 100 can be set before saving. The resulting output ranges are ±10 V, ±1 V or ±0.1 V. A comment block ICMT containing information on the instrument and its settings is stored in the header data. Example:

VM100A 22136 001.010 001.042. 001.147 100 1X

Included are the device type, its serial number, the transducer sensitivities of 1X/1Y/1Z, the gain (1/10/100) and the channel used. The file name consists of "MEAS", the measuring point identifier and the date and time, e.g.: MEAS_240410125946_100424_153658.wav

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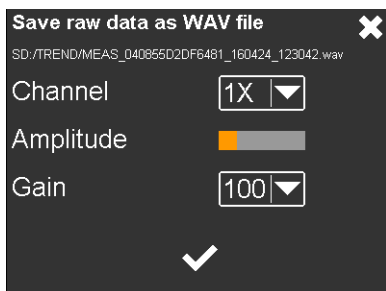
Figure 63: WAV recording menu
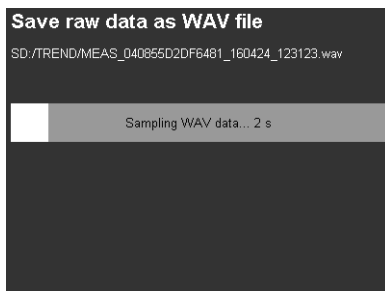
Figure 62: WAV recording

The date of the last measurement saved in CSV format is displayed in the measuring route table for each measuring point. The VM100 uses the date to determine whether it is still within the defined measurement interval (see section 4.5.3) or whether a new measurement is due. Figure 64 shows an example.

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

Figure 64: Date of saving

Figure 65: Measurement route table with due measurements

Figure 66: Example of CSV file with vibration severity measurement data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Machine Monitoring																						
2	Instr.:	VM100A	Ser.:	221236																			
3	Comment:																						
4	NFC Id:	82C0511D080104																					
5	Sensor 1X:		Ser.:		Sensit.:	1	mV/m/s²																
6	Sensor 1Y:		Ser.:		Sensit.:	10	mV/m/s²																
7	Sensor 1Z:		Ser.:		Sensit.:	100	mV/m/s²																
14	Date:	03/01/24	Time:	22:11:34	Temp.:	25	°C																
15	Location:	Dresden	Machine:	Pumpe	Position:	rechts	Commen	Gestell	ISO:	ISO 20816-8													
16	Warning:	8	8	8	127	127	127	10,1	10,1	10,1													
17	Alarm:	12	12	12	191	191	191	15,1	15,1	15,1													
18	HP (Hz):	2	2	2	2	2	2	2	2	2													
19	LP (Hz):	1000	1000	1000	300	300	300	1000	1000	1000													
20	Mode:	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RPM	FFT1		FFT2		FFT3		FFT4		FFT5		FFT6	
21	Unit:	mm/s	mm/s	mm/s	µm	µm	µm	m/s²	m/s²	m/s²	1/min	Hz	mm/s	Hz	mm/s	Hz	mm/s	Hz	mm/s	Hz	mm/s	Hz	mm/s
22	03/01/2	3,15	0,3	0,02	25,4	15,6	0,7	0,831	0,063	0,006	0	4	1,9	23	0,6	17	0,6	8	0,4	13	0,3	36	0,3
23	21/01/2	3,34	0,22	0,03	30,1	10,1	1,6	0,777	0,065	0,007	0	4	1,4	17	0,6	11	0,5	7	0,4	30	0,3	21	0,3
24	08/02/2	2,63	0,22	0,03	33,5	8,8	1,3	0,802	0,067	0,007	0	5	1,5	11	0,8	18	0,6	14	0,4	21	0,3	25	0,2

Figure 67: Example of CSV file with bearing measurement data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Machine Monitoring																						
2	Instr.:	VM100A	Ser.:	221236																			
3	Comment:																						
4	NFC Id:	82C0511D080104																					
5	Sensor 1X:		Ser.:		Sensit.:	1	mV/m/s²																
6	Sensor 1Y:		Ser.:		Sensit.:	10	mV/m/s²																
7	Sensor 1Z:		Ser.:		Sensit.:	100	mV/m/s²																
14	Date:	03/01/24	Time:	22:11:34	Temp.:	25	°C																
15	Location:	Dresden	Machine:	Pumpe	Position:	rechts	Commen	Gestell	ISO:	ISO 20816-8													
16	Warning:	8	8	8	127	127	127	10,1	10,1	10,1													
17	Alarm:	12	12	12	191	191	191	15,1	15,1	15,1													
18	HP (Hz):	2	2	2	2	2	2	2	2	2													
19	LP (Hz):	1000	1000	1000	300	300	300	1000	1000	1000													
20	Mode:	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RMS	RPM	FFT1		FFT2		FFT3		FFT4		FFT5		FFT6	
21	Unit:	mm/s	mm/s	mm/s	µm	µm	µm	m/s²	m/s²	m/s²	1/min	Hz	mm/s	Hz	mm/s	Hz	mm/s	Hz	mm/s	Hz	mm/s	Hz	mm/s
22	03/01/2	3,15	0,3	0,02	25,4	15,6	0,7	0,831	0,063	0,006	0	4	1,9	23	0,6	17	0,6	8	0,4	13	0,3	36	0,3
23	21/01/2	3,34	0,22	0,03	30,1	10,1	1,6	0,777	0,065	0,007	0	4	1,4	17	0,6	11	0,5	7	0,4	30	0,3	21	0,3
24	08/02/2	2,63	0,22	0,03	33,5	8,8	1,3	0,802	0,067	0,007	0	5	1,5	11	0,8	18	0,6	14	0,4	21	0,3	25	0,2

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

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 68)
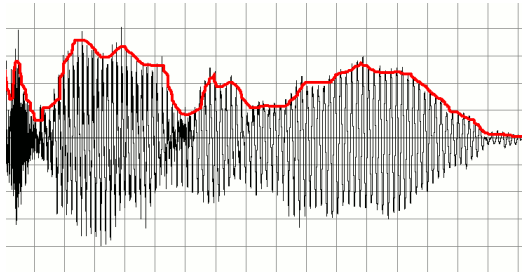
Figure 68: Envelope detection (Wikimedia)

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 69).

In the upper section you can find the uniform menu bar, which is described in section 3.3.
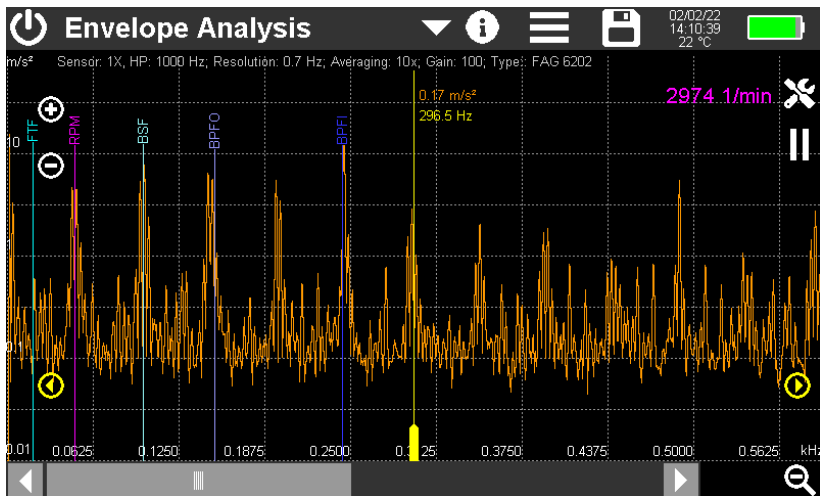
Figure 69: Measurement view of envelope analysis

The entire screen width of 800 points is used to display the envelope spectrum. At the bottom right, you will see a plus or minus button for zooming in or out of the visible frequency range. In the higher resolution frequency range you can navigate with the scroll bar.

The buttons ⊕ and ⊖ can be used to scale the amplitude axis. 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 69 shows the largest amplitude at marker BPFI, indicating damage to the inner ring of the bearing.

The orange measurement cursor is shifted with the wider lower end. In addition, there are orange 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 **II** or **►** buttons.

Use the ⚙ button to open the settings menu (Figure 70).

Figure 70: 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-LS 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 71: Bearing list

Touch ✚ to add a new bearing. A menu opens for entering the damage frequencies (Figure 72).

Figure 72: 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 70), their markers can be hidden in the measuring screen.

4.6.3. Saving

The following options are available for saving with the ⊟ button: The envelope spectrum is saved as CSV file in a data table (Figure 73). The header data contains information about the measuring device, sensor and roller bearing. From line 14 you will find the relative damage frequencies as factors and the measured frequencies at the rotational frequency. The measured or entered rotational speed can be found in line 18. From line 20 the frequency points and the corresponding amplitudes follow. The number of lines depends on the selected resolution.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Envelope Analysis													
2	Instr.:	VM100A	Ser.:	221236										
3	Comment:													
4	NFC Id:													
5														
6	Sensor 1Y:	KS903B100	Ser.:	23030	Sensit.:	10,1982	mV/m/s²							
7														
8														
9														
10														
11														
12														
13														
14	Date:	07/01/25	Time:	16:10:15	Temp.:	23	°C							
15	HP:	500	Hz	Averaging	-	Rot. speed:	3000	1/min						
16	Bearing:	6202	BPFI:	4,95	247	BPFO:	3,05	152	FTF:	0,38	19	BSF:	1,99	99
17														
18														
19														
20														
21	Hz	1Y: m/s²												
22	1,5	0,141												
23	3	0,011												
24	4,5	0,003												
25	6	0,004												
26	7,5	0,008												
27	8,9	0,003												
28	10,4	0,002												
29	11,9	0,002												
30	13,4	0,004												
31	14,9	0,003												
32	16,4	0,003												
33	17,9	0												
34	19,4	0,002												
35	20,9	0,001												
36	22,4	0,003												
37	23,8	0,004												
38	25,3	0,002												
39	26,8	0,002												
40	28,3	0,001												
41	29,8	0,003												

Figure 73: CSV formatted envelope data (only first 20 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 74). This centrifugal force increases with the square of the rotational speed.
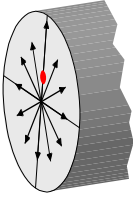
Figure 74: Unbalanced rotor
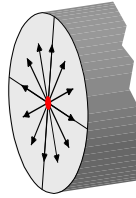
Figure 75: Balanced rotor

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 75).

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 76 shows the amount and direction of the resulting unbalance forces. The force acting on both bearings is the same.
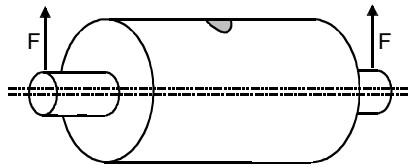
Figure 76: Static balance

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 77).

53
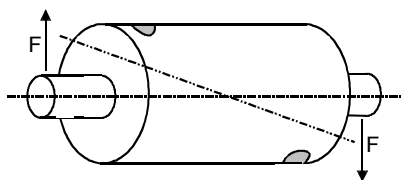
Figure 77: Couple balance

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 78).
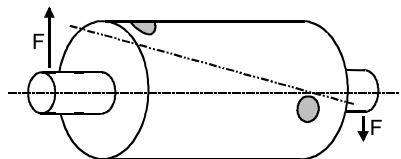
Figure 78: Dynamic balance

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:

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

4. In the **test run**, a known test mass is applied to one end of the rotor at a known angular position. This generates a defined unbalance. The resulting vibration is recorded.

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

6. The balancing system calculates the **corrections** required to compensate for the unbalance on the basis of the measurements taken. This can be done by adding or removing mass at certain angular positions.

7. The success of the correction measures is verified in a **check run**.

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

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

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

4.7.2. Measurement

Depending on the number of planes, one or two uniaxial accelerometers are used for the measurement. Robust, electrically insulated industrial types are recommended, e.g. KS80D or KS74C100. In most cases, sensors with a sensitivity of approx. 100 mV/g are recommended. At lower speeds and thus lower centrifugal forces, the accelerations are also lower, which may require the use of more sensitive transducers. The sensors are mounted radially to the axis of rotation, ideally directly on the shaft bearings. At the VM100 the sensors are connected to the measuring channels 1X and 1Y. In the operating dialog, the sensor positions are designated as plane A and plane B.
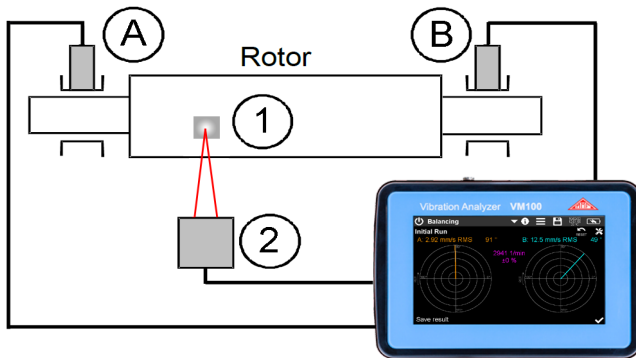
Figure 79: Two-plane balancing;
A/B: rotor bearings (planes) with accelerometers; 1: reflective label; 2: RPM sensor

The balancing algorithm requires a rotation pulse. For this purpose, a VM100-LS photoelectric reflex switch with magnetic stand (Figure 80) 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 80: VM100-LS

All angle positions of the calculated corrections are measured against the direction of rotation (Figure 81). 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 82).
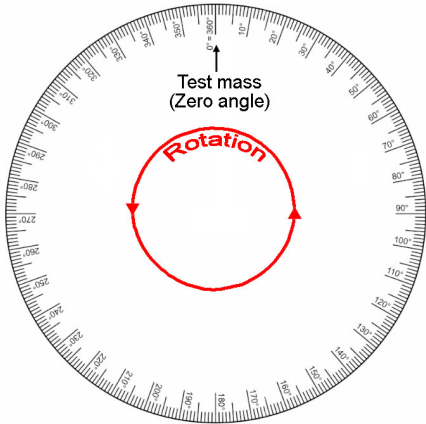
Figure 81: Angle conventions

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 82: Balancing settings (example for two planes)

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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 83).

In addition, a band filter with the rotational frequency as the center frequency is set in the unbalance run to attenuate vibrations that do not correlate with the unbalance.

The checkbox **Averaging** Averaging ☑ switches averaging for amplitudes and phase angles on or off. When averaging is enabled, the display becomes more stable. To detect fluctuations, averaging can be disabled. With the reset button 🔄 you can delete the average values and restart averaging. If a good stability is reached, the measurement is saved with ✅ and the rotor is stopped.
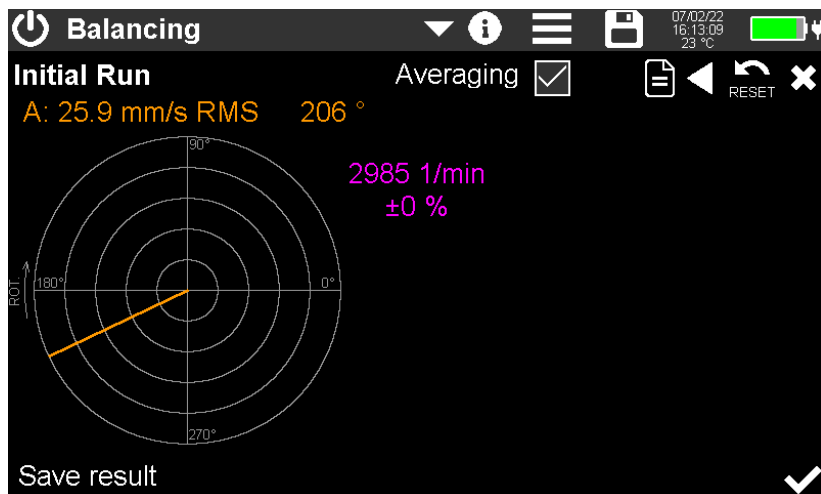
Figure 83: Initial run (1 plane)

➔ 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 84). 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 85). 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.
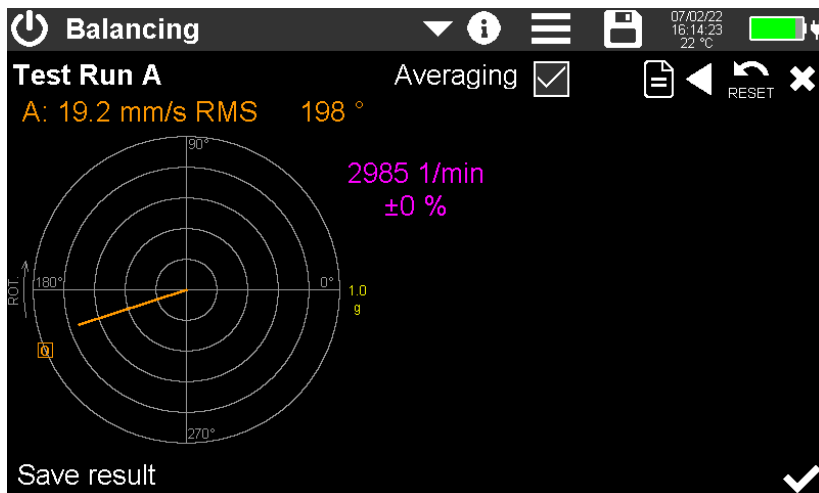
Figure 84: Attaching a test mass (1 plane)

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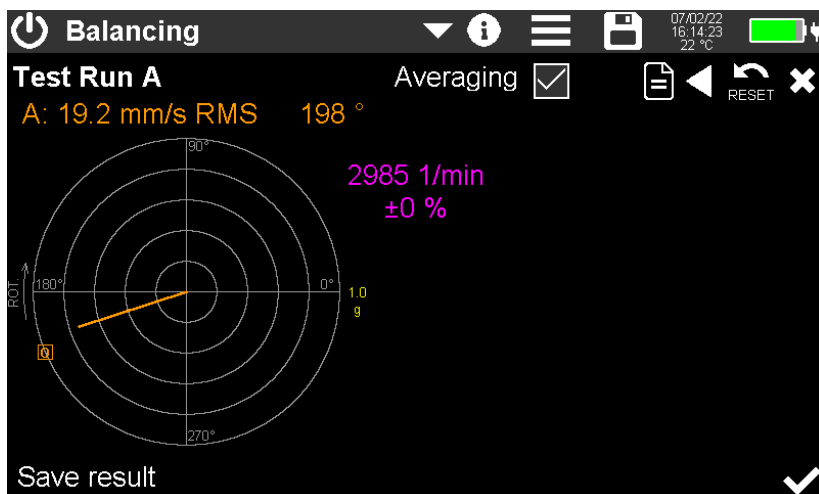
Figure 85: Test run (1 plane)

After standstill, you will be asked whether the test mass should remain on the rotor (keep) or be removed again (Figure 86). 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 ✓.
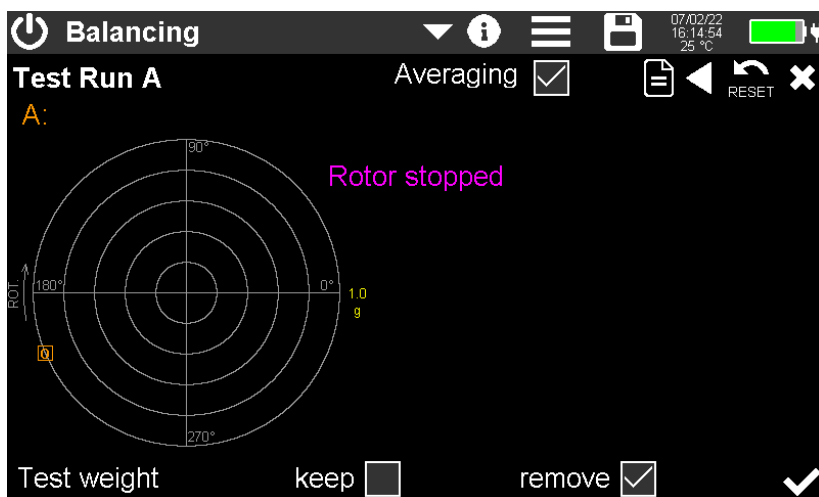
Figure 86: Keep or remove test mass (1 plane)

The unit now displays the required **corrections** (Figure 87). 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.
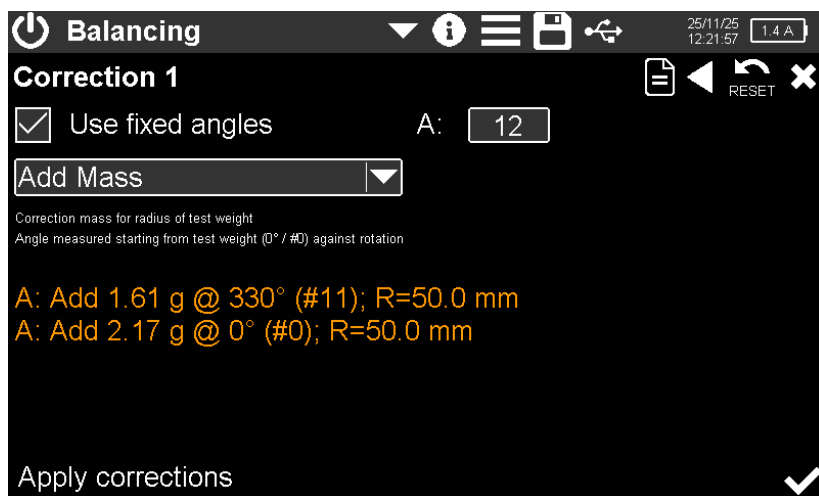
Figure 87: Corrections (1 plane)

Once the corrections have been made, confirm with ✔ and start the rotor for the **check run** (Figure 88). 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 89). 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.

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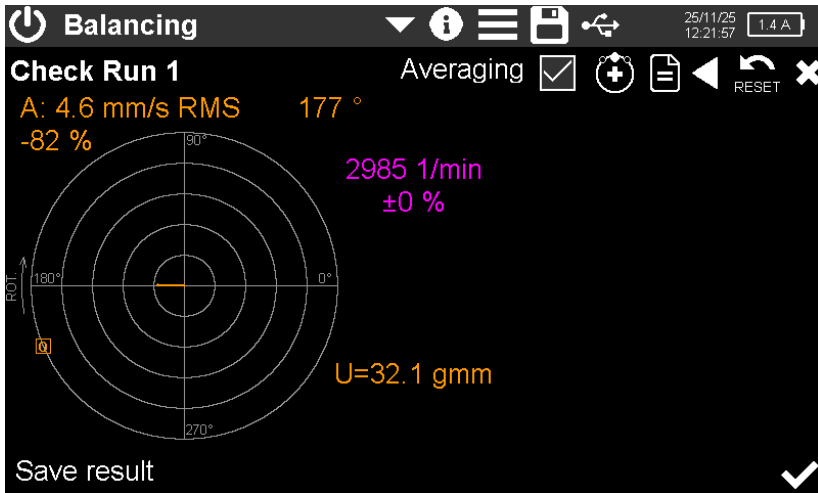
Figure 88: Check run (1 plane)
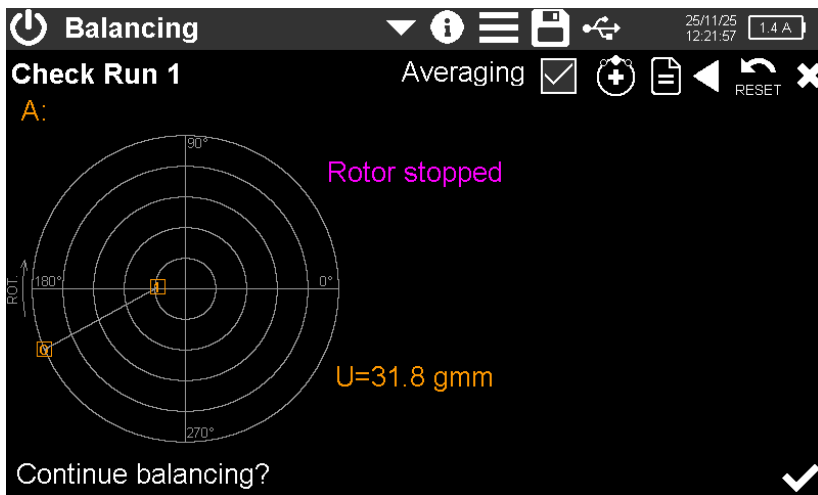
Figure 89: Continue or finish

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).

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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 90).
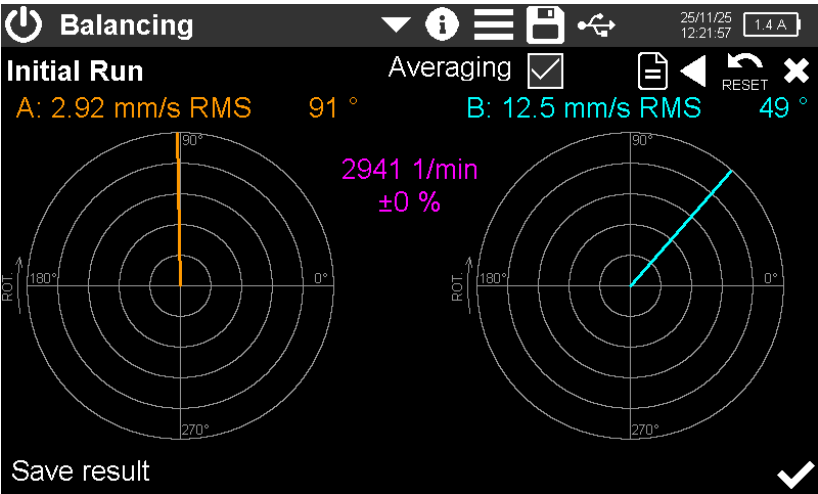
Figure 90: Initial run (2 planes)

This is followed by the application of a test mass in plane A and a restart of rotation (Figure 91).
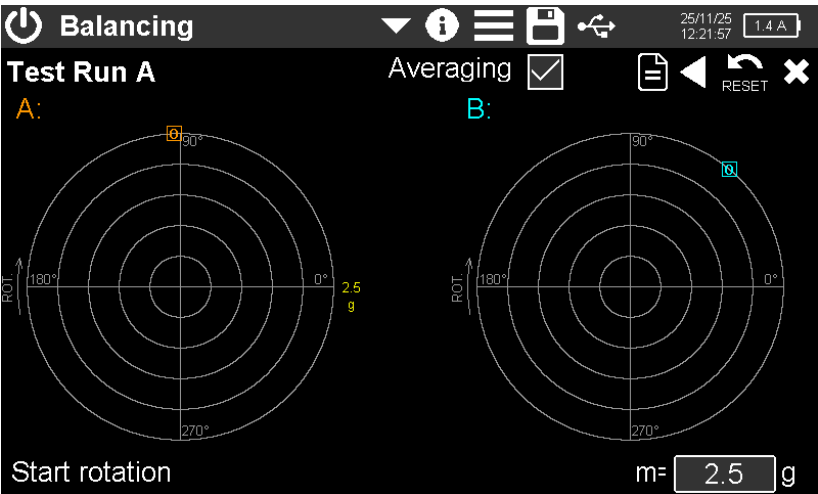
Figure 91: Attaching a test mass to plane A (2 planes)

The results of the test run at plane A are saved (Figure 92) and rotation is stopped.
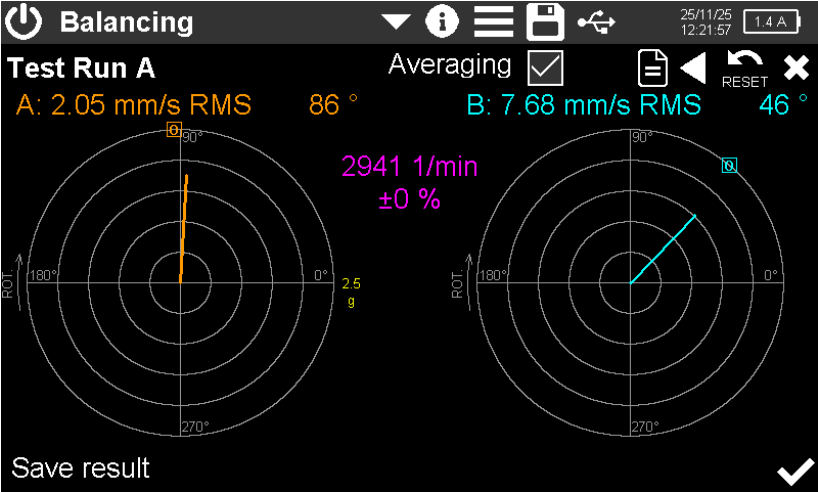
Figure 92: Test run of plane A (2 planes)

Now decide whether you want to leave the test mass on the rotor or remove it again (Figure 93). The selection later also applies to plane B.
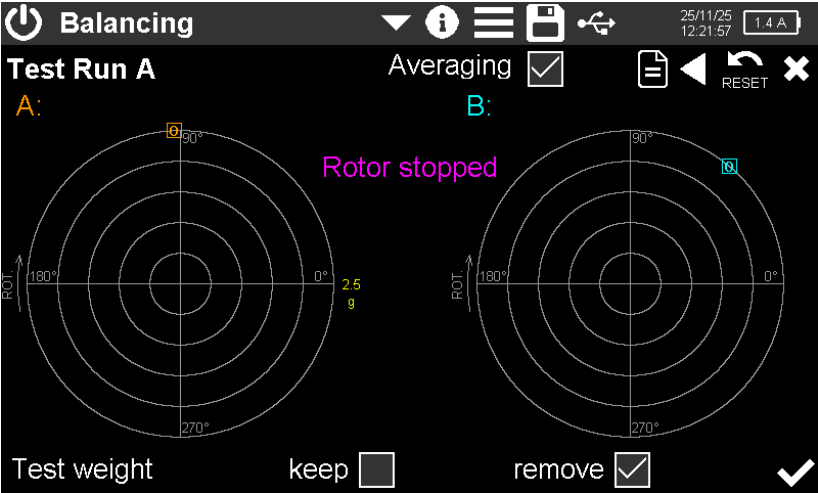
Figure 93: Keep or remove test mass of plane A (2 planes)

Then place a test mass in plane B and start rotation again (Figure 94).
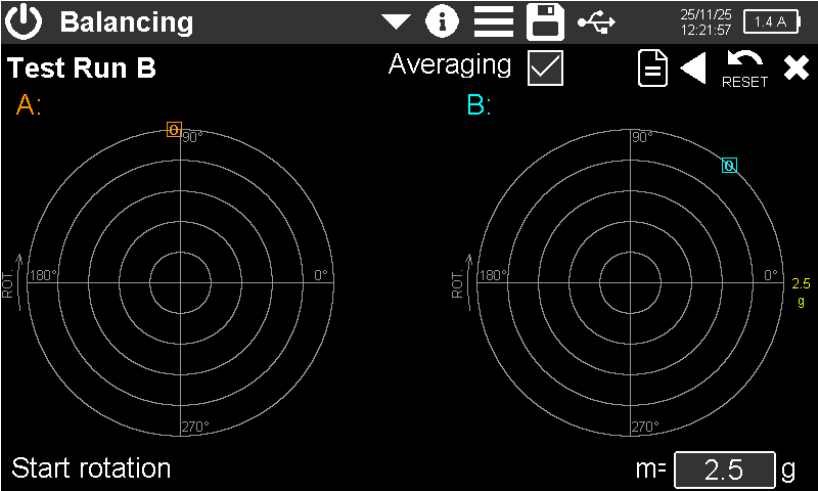
Figure 94: Attach a test mass for plane B (2 planes)

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 95).
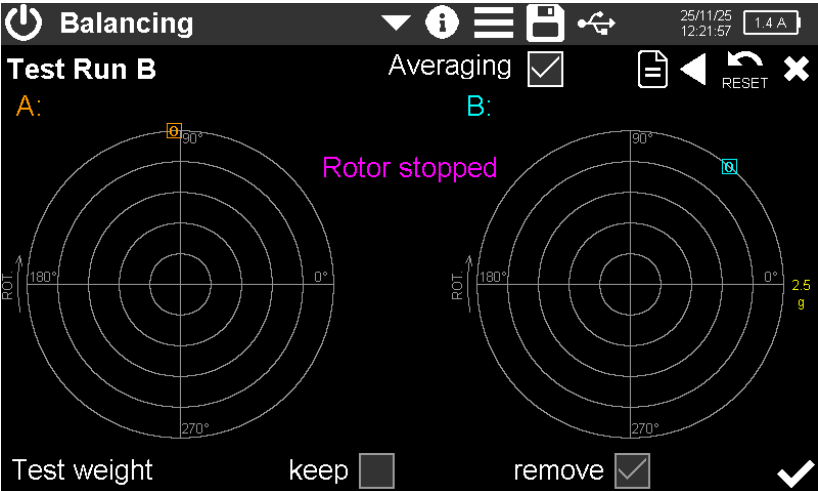
Figure 95: Confirm keeping or removing the test mass B (2 planes)

Now the calculated correction masses and their angles are displayed for both planes (Figure 96). In the example, 16 angular steps (fixed locations) were selected.
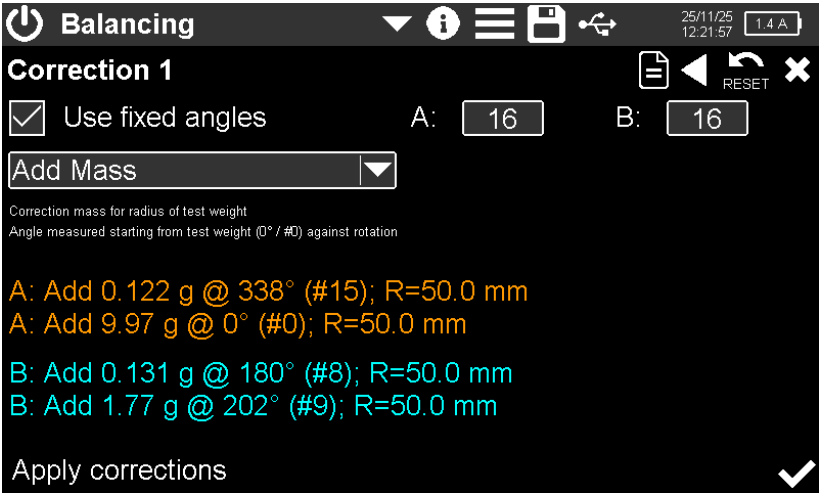
Figure 96: First correction (2 planes)

Make the corrections and confirm. Start rotation for the first check run (Figure 97).
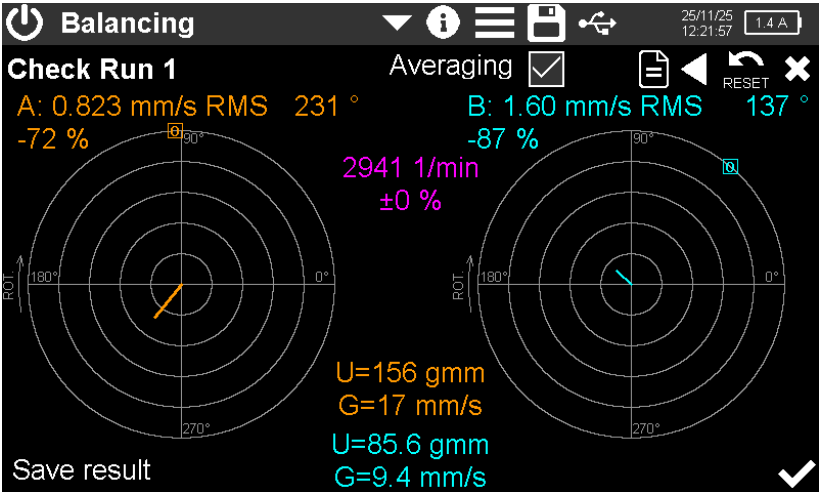
Figure 97: First check run (2 planes)

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 98).
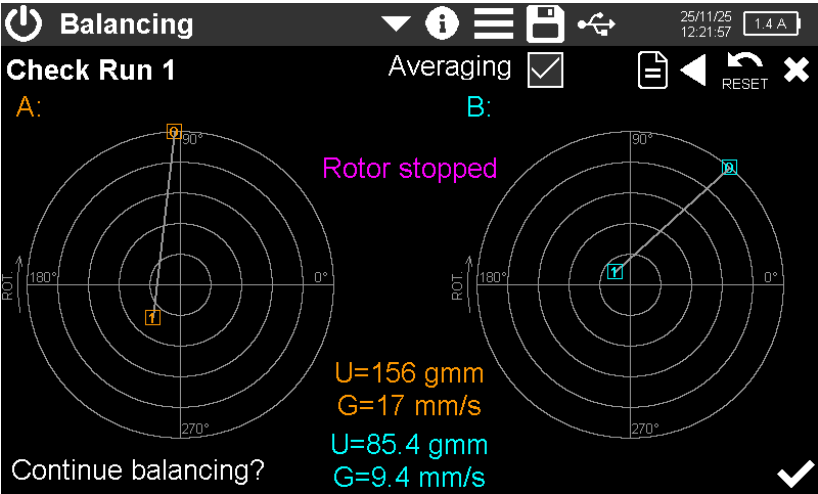
Figure 98: Continue or finish balancing after first check run (2 planes)

In this example, balancing is continued. Further corrections for both planes are displayed (Figure 99).
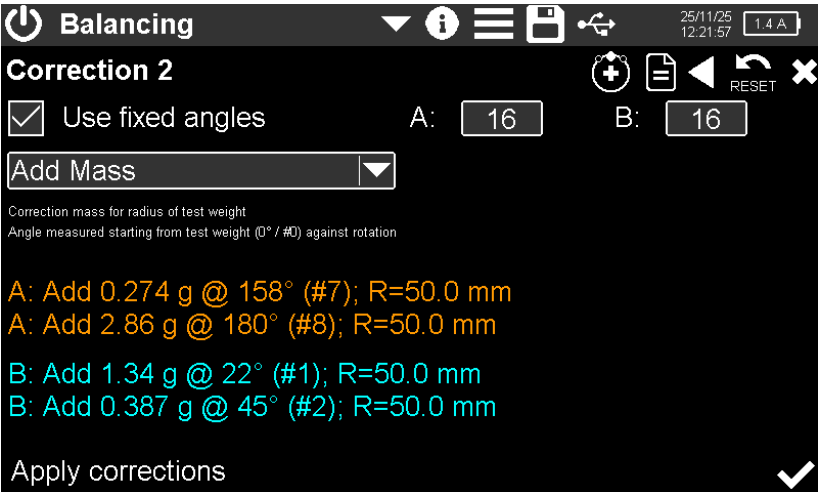
Figure 99: Second correction (2 planes)

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 100).
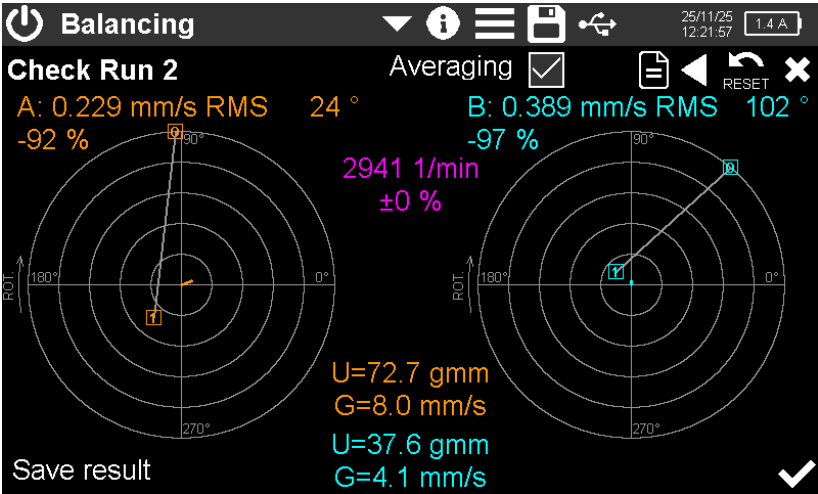
Figure 100: Second check run (2 planes)

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 102). For this purpose, all attached correction masses must be removed and the calculated masses attached. Test masses left on the rotor are not affected.
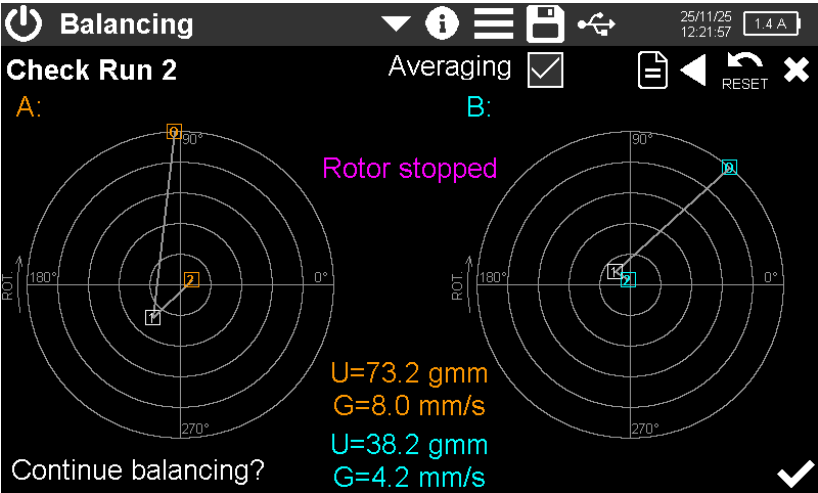
Figure 101: Continue balancing after second check run (2 planes)
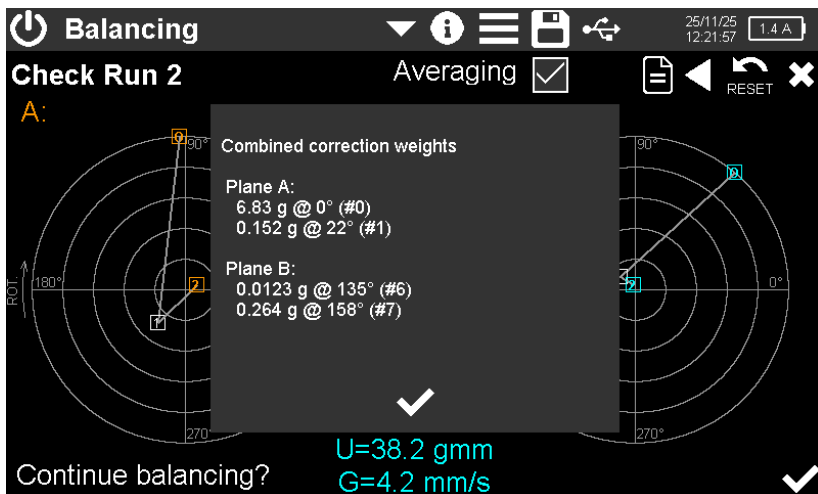
Figure 102: Combination of corrections (2 planes)

📄 opens a text window with a summary of all changes made and the resulting vibration or unbalance vectors (Figure 103). You can use it to replace all previously applied correction masses by the calculated mass(es).
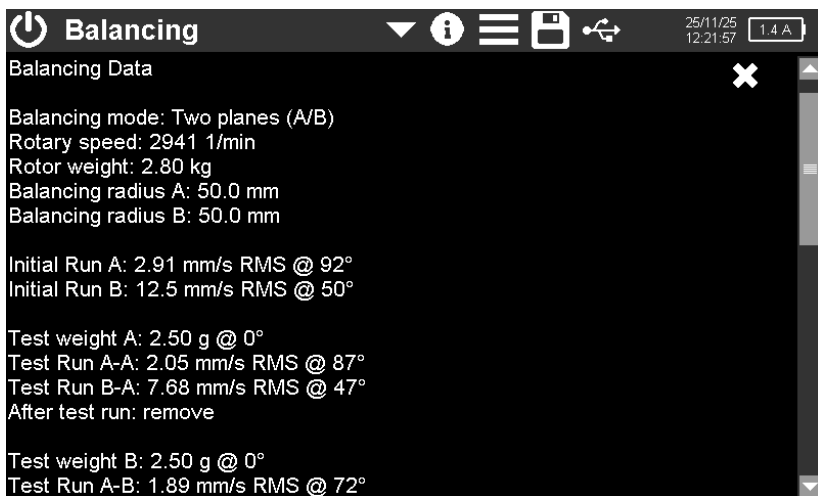
Figure 103: Auswuchtprotokoll

To save this report, touch 💾 and select **Save CSV balancing report**. An example of a saved CSV file is shown in Figure 104.

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 104: CSV formatted balancing report

If the balancing results should be not satisfying please read the tips on page 61.

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 105 shows the limit lines in the frequency range.
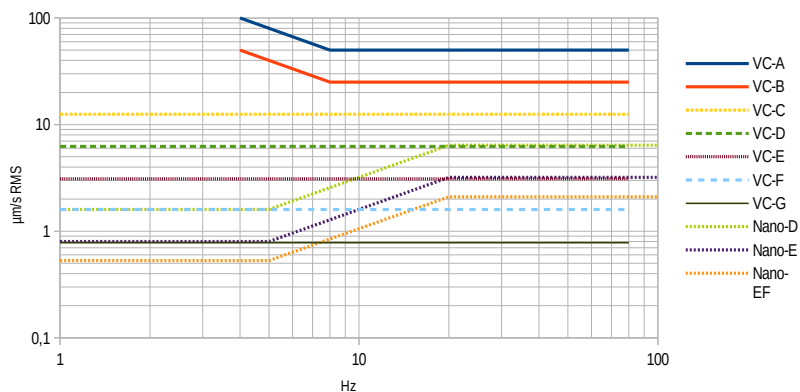
Figure 105: Limits of "VC" and "Nano" criteria

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 106: Triaxial accelerometer KS823B

Figure 107: Uniaxial accelerometer KS48C

Figure 108: Uniaxial accelerometer KB12VD

The triaxial accelerometer KS823B (Figure 106) and the single-axis KS48C (Figure 107) are suitable for measurements up to VC-D. The extremely high-resolution single-axis KB12VD (Figure 108) 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 110).

Another practical accessory for sensor installation on floors is the tripod floor plate Type 729 (Figure 109).

Figure 110: Triaxial mounting cube

Figure 109: 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 111 shows the measured value display.
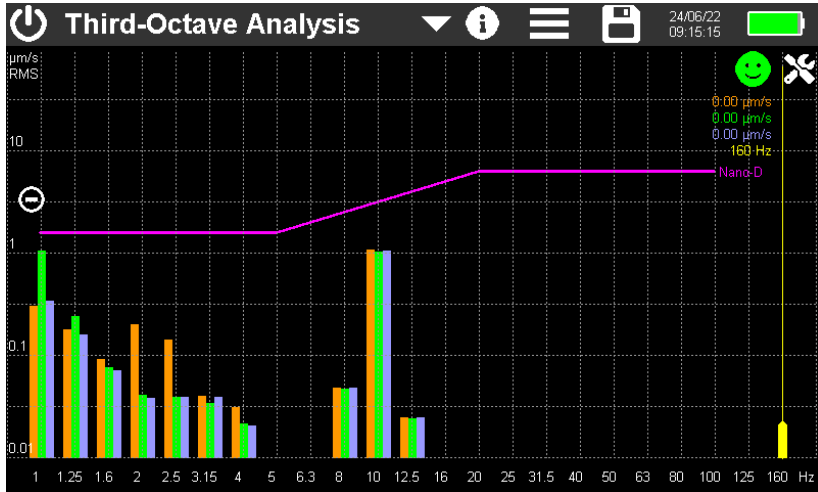
Figure 111: Third octave analysis example for Nano-D

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 orange 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 112).

VC/Nano Settings

Limit line	VC-D ▼
Gain	Auto ▼
Save mode	Limit line ▼

Write to a CSV file each time the limit line is exceeded
Push save button and select CSV to start saving

| Hold max. | ☑ |

✓

Custom limit values

2 Hz ▼	1.00	µm/s
10 Hz ▼	2.00	µm/s
50 Hz ▼	4.00	µm/s
125 Hz ▼		

✓
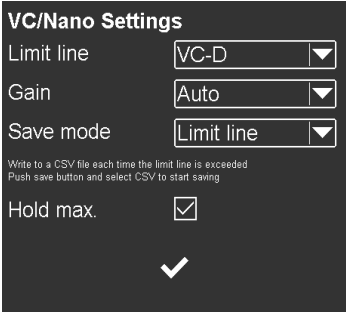
Figure 112: Menu for settings

Figure 113: 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, se-lect "Custom", whereupon the menu for entering the limit values opens (Figure 113). 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 fre-quency 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 116 shows the limit line resulting from the example.
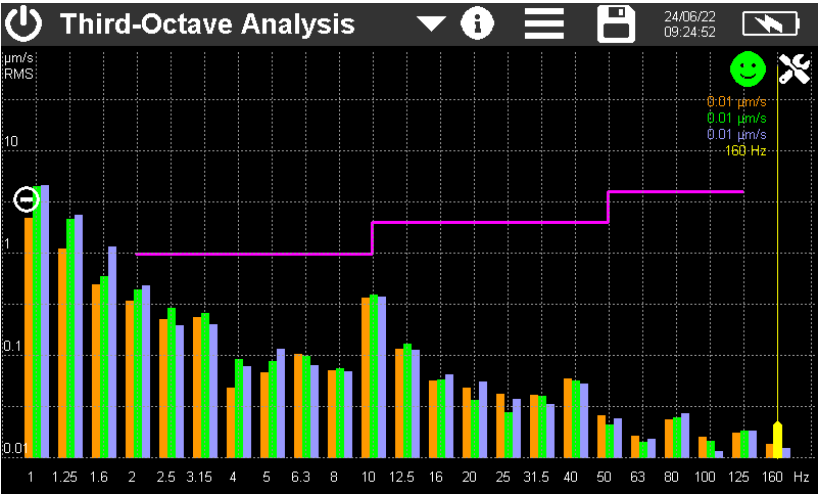
Figure 114: Custom limit line of Figure 113

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 115). The Reset button ⎙ deletes the maximum values.
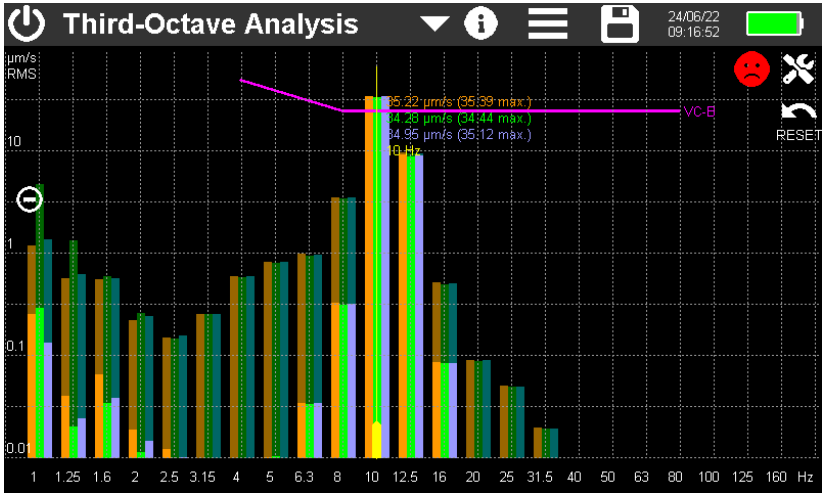
Figure 115: Spectrum with held maximum values

4.8.4. Storage

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 116 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 22. For each third octave band, the three vibration velocities in µm/s are shown.

	A	B	C	D	E	F	G
Comment:							
NFC Id:							
Sensor 1X:	KS903B100	Ser.:	23030	Sensit.:	11,0585	mV/m/s²	
Sensor 1Y:	KS903B100	Ser.:	23030	Sensit.:	10,1982	mV/m/s²	
Sensor 1Z:	KS903B100	Ser.:	23030	Sensit.:	10,8255	mV/m/s²	
Date:	08/01/25	Time:	11:14:24	Temp.:	22	°C	
Criterion:	Custom						

Input:	1X	1Y	1Z	1X	1Y	1Z	1X	1Y	1Z	...
Hz:	1	1	1	1,25	1,25	1,25	1,6	1,6	1,6	...
Limits (µm/s):										

08/01/25 11:19:28	OVER	OVER	OVER	631,08	708,5	645,72	...
08/01/25 11:19:29	OVER	OVER	OVER	551,48	668,60	629,29	...
08/01/25 11:19:30	OVER	OVER	OVER	710,55	842,74	795,27	...
08/01/25 11:19:31	OVER	OVER	OVER	484,65	534,92	493,21	...
08/01/25 11:19:32	OVER	OVER	OVER	319,87	305,37	272,94	...
08/01/25 11:19:33	OVER	OVER	OVER	378,12	377,15	340,69	...
08/01/25 11:19:34	OVER	OVER	OVER	384,57	379,28	353,67	...
08/01/25 11:19:35	545	654,59	555,54	231,8	213,53	184,01	...
08/01/25 11:19:36	775,88	919	865,18	157,91	189,22	122,4	...
08/01/25 11:19:37	859,44	988,92	961,4	143,52	204,38	150,86	...
08/01/25 11:19:38	642,69	760,7	739,76	90,45	154,6	157,23	...
08/01/25 11:19:39	335,64	411,76	395,77	56,02	86,9	129,3	...
08/01/25 11:19:40	323,16	303,50	273,64	85,22	95,67	87,06	...
08/01/25 11:19:41	429,89	379,46	349,02	78,41	83,87	49,5	...
08/01/25 11:19:42	381,06	343,28	307,59	64,93	50,69	30,85	...
08/01/25 11:19:43	218,4	239,52	169,61	35,96	79,83	77,64	...
08/01/25 11:19:44	197,55	215,11	163,32	23,1	130,3	103,47	...
08/01/25 11:19:45	337,67	261,03	287,18	28,17	118,49	106,22	...
08/01/25 11:19:46	390,63	264,96	334,31	18,66	87,67	69,04	...
08/01/25 11:19:47	316,73	208,01	206,91	18,13	54,18	27,92	...
<END>							

Figure 116: CSV formatted third-octave data (only up to 10 Hz shown)

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

4.9. Module Human Vibration

4.9.1. Introduction

Human vibration refers to vibrations that affect people. Sources of these vibrations can include machines or vehicles. These vibrations are evaluated from the perspectives of occupational safety and health assessment or comfort.

The most basic distinction is between hand-arm and whole-body vibrations. The differences lie in both the sensor technology and the measurement method.

4.9.2. Hand-Arm Vibration

4.9.2.1. Basic Principles

The VM100 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 117 that low frequencies have a greater influence on the evaluation than high frequencies.
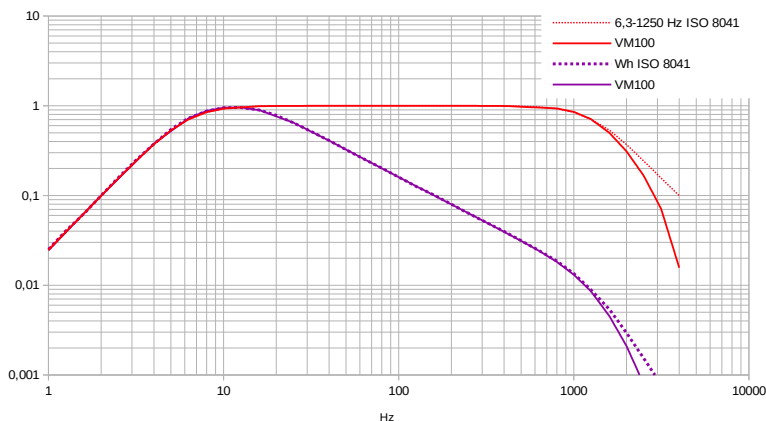
Figure 117: Band limiting filter 6.3 to 1250 Hz and frequency weighting Wh

For calibration and test purposes the instrument also allows unweighted measurements. In this case only the band limiting filters from 6.3 to 1259 Hz (-3 dB) are enabled.

4.9.2.2. Hand-Arm Shock Vibration to ISO/FDIS 5349-3

The revised EU Machinery Regulation (EU) 2023/1230 stipulates that, from 2027, the operating instructions for hand-held or hand-guided portable machinery and related products must contain information about the vibrations they emit. This refers to the total vibration value from continuous vibrations (see section 4.9.2.1) and the mean value of the peak acceleration from repeated shock vibrations.

ISO/FDIS 5349-3 specifies the measurement method for determining shock vibrations that affect the hand-arm system. The measurement is based on ISO 8041-1. The peak amplitude **VPM** (vibration peak magnitude) is introduced as the measurand. It represents the mean peak value of the acceleration and is calculated from the sum of the sixth powers of the acceleration divided by the sum of the fourth powers. The root is calculated from the quotient:

$$VPM = \sqrt{\frac{\sum_{i=1}^{i=N} a_i^6}{\sum_{i=1}^{i=N} a_i^4}}$$

Equation 4

The VPM value has the unit of measurement m/s². Acceleration is measured using the band-limited but unweighted signal (Figure 117) in accordance with ISO 8041-1.

The Vibration Shock Index **VSI** provides additional information on the characterization of hand-transmitted shock vibration. It is calculated from the quotient of VPM and RMS value and corresponds approximately to the crest factor.

$$VSI = \frac{VPM}{RMS} * \sqrt{2/3}$$
Equation 5

Unlike the crest factor, VSI is approximately 1 for purely sinusoidal signals. In addition, the repetition rate of the pulses **R** is measured.

4.9.2.3. Hand-Arm Sensors

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

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

Figure 118: KS963B10
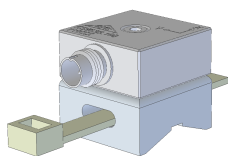
Figure 120: Strap adapter 141B
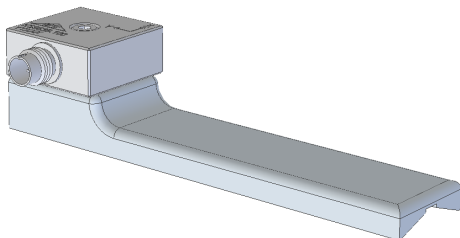
Figure 119: Hand-held adapter 143B

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 121 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 121: Coordinate system of the hand (from ISO 5349-1)

4.9.3. Whole-Body Vibration

4.9.3.1. Basic Principles

The VM100 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 lea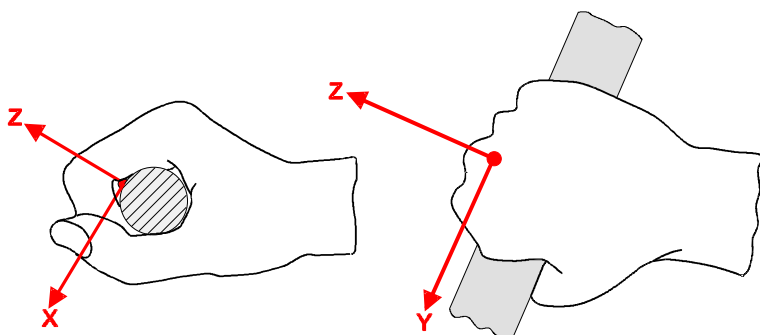d, for example, to back pain and damage to the spine. Relevant for the evaluation of the vibrations measured in this way is the EU Directive 2002/44/EC. The directive specifies the following limit values:

	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:

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

<div align="right">Equation 6</div>

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 (exposure time)

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.

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

<div align="right">Equation 7</div>

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

<div align="right">Equation 8</div>

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

<div align="right">Equation 9</div>

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 10

where

VDV(8)   is the daily exposure value

VDV   is the frequency-weighted vibration dose value

T_{exp} is the duration of exposure (exposure time)

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.

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

Equation 11

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

Equation 12

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

Equation 13

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

4.9.3.2. 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 122: 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 123 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).
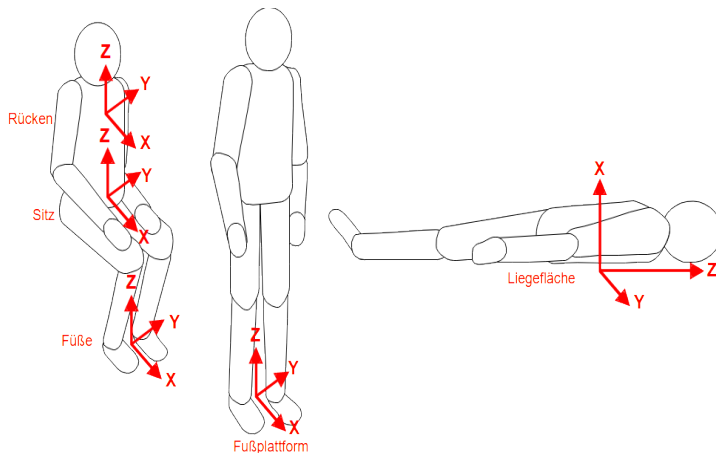

Figure 123: Coordinate systems for whole-body vibration to ISO 2631

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.

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
Buildings/ships:				
undefined	buildings/ships	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.

For the evaluation of vibrations on passenger and commercial ships with regard to human tolerance (ISO 20283-5) the triaxial accelerometer KS823B is recommended (Figure 106 on page 72).

The nine-channel instrument VM100A can also be 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 special feature of this measurement is that three triaxial sensor signals are measured simultaneously.

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 124 to 127 show the frequency weightings implemented in the VM100.
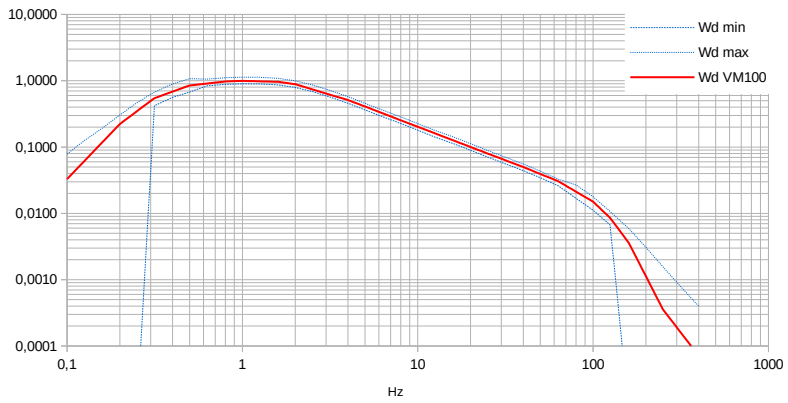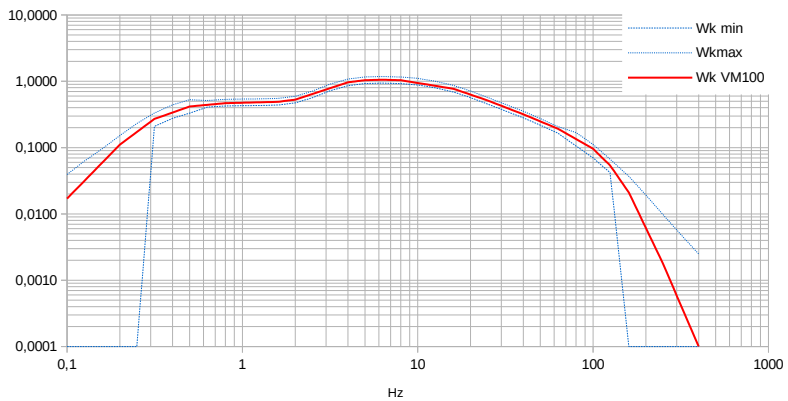
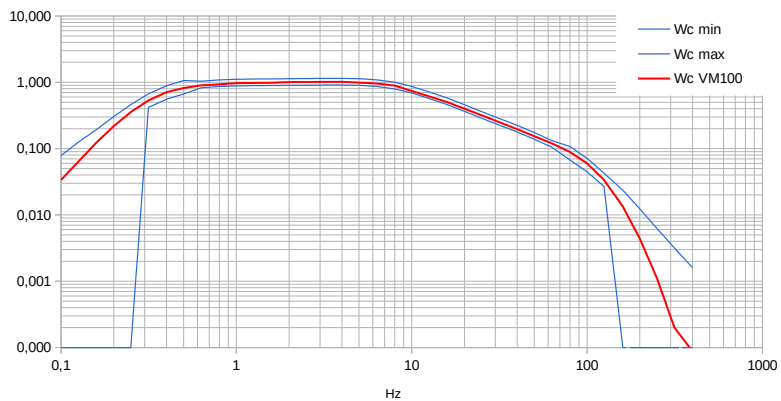Figure 124: Weighting filter Wd

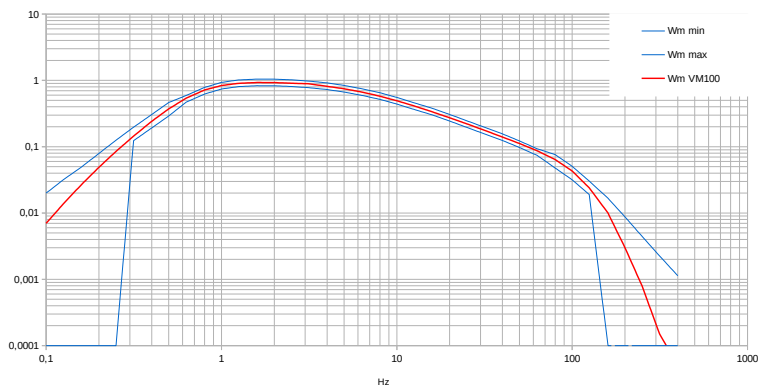Figure 125: Weighting filter Wk

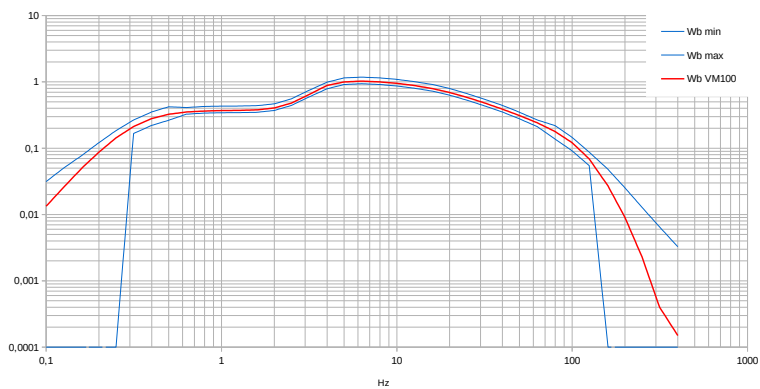Figure 126: Weighting filter Wc

Figure 127: Weighting filter Wm
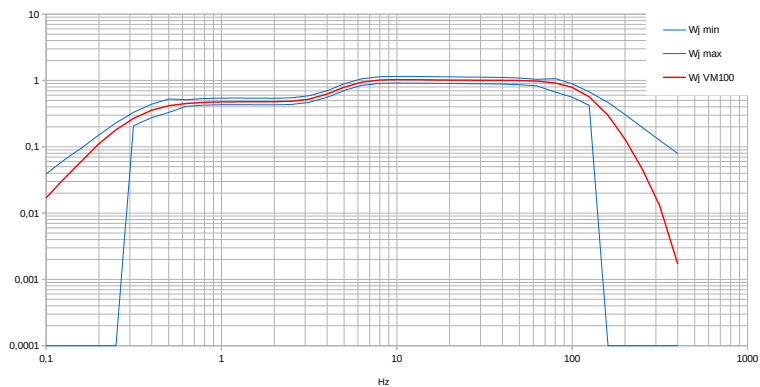
Figure 128: Weighting filter Wb

Figure 129: Weighting filter Wj

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

4.9.4. Measurement of Human Vibration
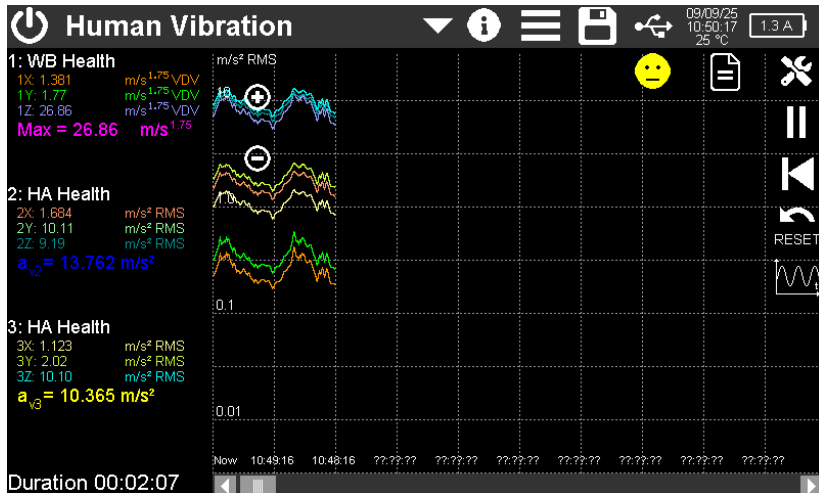
4.9.4.1. Measurement Screen

Figure 130: VM100A measurement screen for 3 sensors

Figure 130 shows an example of the measured value output for three triaxial sensors on the VM100A. Sensor 1 measures whole-body vibration with health evaluation, while sensors 2 and 3 measure hand-arm vibration.

With the three-channel unit VM100B, measurement is only possible with one sensor, either for whole-body or hand-arm vibration.

In the upper part is the uniform menu bar, which is described in section 3.3.

4.9.4.2. Setup Menu

The measurement mode is selected in the settings menu, which you open by pressing . Figure 131 shows the menu for the VM100A.

First select the desired measurement mode (Fig. 132). The menu offers the health and comfort evaluations for hand-arm and whole-body measurements and velocity from 1 to 100 Hz. The respective evaluation filters and factors are displayed below the selection menu.

With the VM100A, you can configure up to three sensors with any measurement modes. However, it is also possible to perform two or three different measurements in parallel with the same sensor.

With the VM100B, only the settings for one sensor are available. However, three different evaluations can be performed in parallel with this sensor.
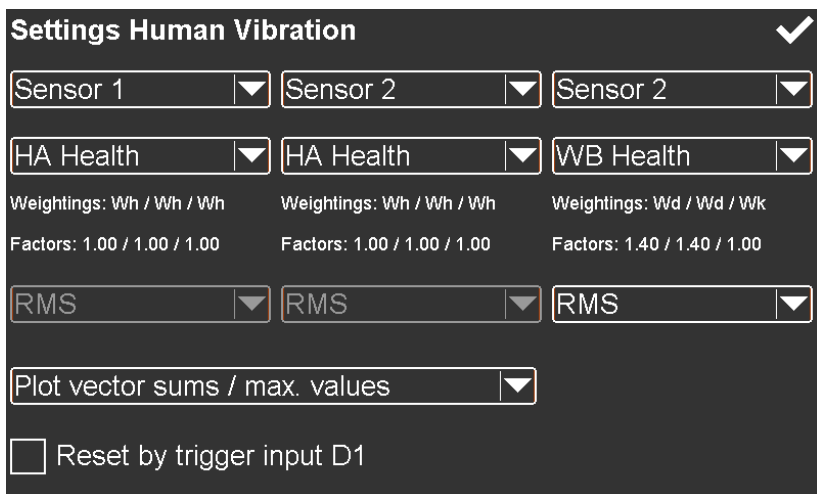
Figure 131: Human vibration setup menu of VM100A

In the VM100A, the menu for sensor 1 also contains the measurement in accordance with GB/T 4970-2009. In this special case, sensors 2 and 3 are automatically configured in accordingly.

Use the RMS/VDV/VPM menu to select whether the RMS value or the vibration dose value (see section 4.9.3.1) is measured for whole-body vibration. For hand-arm vibration, RMS and VPM are available (see section 4.9.2.2).

The menu below concerns the plot graph in the measurement window. You can plot either the RMS values or the sum/maximum values. For hand-arm vibration this is the vector sum and for whole-body vibration the largest of the three interval RMS values.

The displayed axis RMS values are running RMS values with 1 s averaging time. This means that the plot graphic also shows short-term fluctuations that are not visible in the interval RMS value.
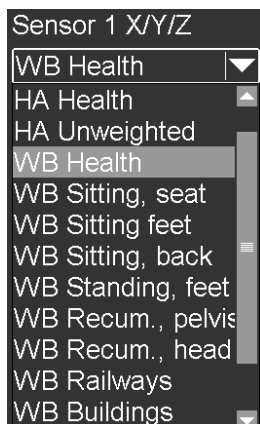

Figure 132: Measurement mode

4.9.4.3. Reset before Measurement

Important: The measured values must be reset to zero before each measurement. This is done using the reset button ![RESET] on the measurement screen after the vibration exposure to be examined has started.

The reset can also be triggered by a high-low transition at the digital input D1 (see section 3.1). To do this, check the box in the settings menu (Figure 131).

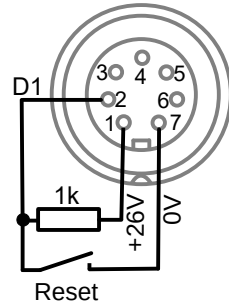The wiring of the digital input for an external reset button is shown in Figure 133.

Figure 133: Reset at D1

4.9.4.4. Display of Measurement Duration

At the bottom left you can see the elapsed measurement duration. This is the time during which the measured RMS or VDV values are averaged. The longer the measurement lasts, the more stable the results will be. The measurement duration should be at least half a minute for hand-arm vibration and at least 2 minutes for whole-body vibration.

However, the decisive factor for the measurement duration is that the energy-equivalent mean value changes only insignificantly.

4.9.4.5. Measuring Values

The interval RMS values of the three sensor axes are displayed on the left-hand side of the screen. This can be up to nine values depending on instrument type and sensor number.

For hand-arm measurements, the energy-equivalent mean value (total vibration value) a_v is displayed for each sensor (Figure 134). It is used to calculate the daily exposure value A(8) (see section 4.9.2.1).

Figure 134: Measuring values for hand-arm mode

For hand transmitted shocks (section 4.9.2.2), the Vibration Peak Magnitude VPM is shown. As additional information, the device displays the Vibration Shock Index VSI and the repetition rate of the shocks R (Figure 135).
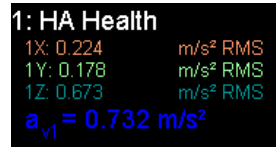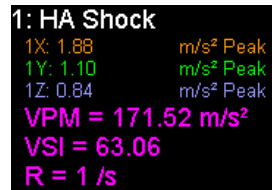

Figure 135: Measuring values for hand-arm shock vibration

For whole-body vibration, the largest of the three axis values is determined, which is used to calculate the daily exposure value A(8) in accordance with ISO 2631 (see section 4.9.3.1).

Figure 136: Measuring values for whole-body mode

According to ISO 2631-1, a distinction is made between the basic assessment using the interval RMS value and the additional assessment using the vibration dose value (VDV). The vibration dose value should be used if the vibrations are very impulsive.

ISO 2631-1 recommends the peak value (crest factor) as a decision criterion. This is the quotient of the peak value and the interval effective value. If the crest factor is below 9, the basic evaluation will usually sufficient. If it is higher, the VDV value should be measured instead.

The MTVV (Maximum Transient Vibration Value) also provides an indication of the shock content in the vibration signal. It stands for the highest measured RMS value with an averaging period of 1 s. Crest factor and MTVV are displayed below the RMS values (Figure 136).

When measuring the vibration velocity from 1 to 100 Hz, the vector sum v_v of X/Y/Z is displayed.

If the sensor input is overloaded, "OVER!" is displayed instead of the measured value. This message disappears again as soon as the measured value is within the valid range. In addition, "OVER!" appears in red next to the total/maximum values (Figure 137). This message only disappears after pressing Reset. It indicates that invalid values were measured during the measurement period.
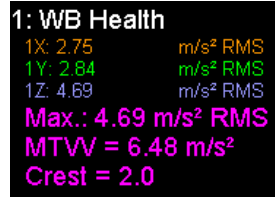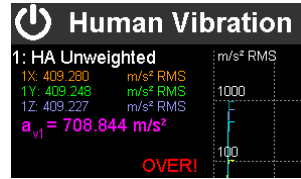

Figure 137: Overload indication

4.9.4.6. Measurement of Ride Comfort to GB/T 4970-2009

The nine-channel VM100A allows the evaluation of ride comfort in motor vehicles according to GB/T 4970-2009. The basis is the measurement of whole-body vibrations according to ISO 2631. In this case, the vibrations on the seat surface, the seat backrest and the foot surface are measured simultaneously while driving on a specified test track.

The three vibration amplitudes, each recorded in three axes, are added to form a total vibration value. Specified evaluation filters and factors are used for each measurement position.

The data from three triaxial sensors of type KS963B100-S is recorded, which corresponds to the specifications in Appendix B of GB/T 4970-2009. The assignment of the three sensors to the measurement inputs is as follows:

Input 1: Seat surface

Input 2: Seat backrest

Input 3: Foot surface

The interval RMS values of the seat, backrest and feet are shown in the measurement window for each of the three axial directions. The total vibration value is also determined for each position.

$$a_{vi} = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2} \qquad \text{Equation 14}$$

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 123 on page 84.

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

$$a_v = \sqrt{(a_{v1}^2 + a_{v2}^2 + a_{v3}^2)} \qquad \text{Equation 15}$$

In contrast to the display of the exposure time in the health assessment (see section 4.9.4.9), the color of the smileys is determined by the total sum in relation to comfort zones when measuring according to GB/T 4970-2009 (Figure 138).
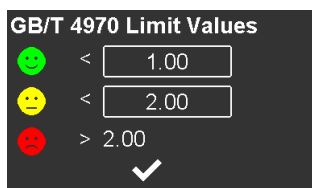

Figure 138: Smileys for comfort zones

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4.9.4.7. Time Chart

Most of the measurement screen is taken up by the amplitude/time diagram.

The graphs are not written until 15 s after the start of the measurement in order to suppress transients. The waiting time can be skipped by touching the corresponding message in the diagram.

The measurement display can be paused or restarted with ▮▮ and ▶. The measurement continues to run in the background. The button ◀▮ restarts the plot graph.

The buttons ⊕ and ⊖ can be used to scale the amplitude axis.

All measured values are displayed in the respective channel color.

In contrast to the numerical values on the left, the graphs are RMS values with an averaging time of 1 second. This also makes short-term changes visible. For example, transients during the measurement time can be recognized or individual events can be detected, such as a forklift truck driving over a threshold.

Alternatively, the total vibration values or maximum values can also be displayed (see Figure 131).

4.9.4.8. Waveform Diagram

Clicking the button 〰 opens a window that graphically displays the currently measured signal waveform. The waveform signal is unfiltered and unweighted. With the VM100A, you must first select which sensor is to be displayed. Figure 139 shows an example of the signal waveform display.

The size of the diagram can be changed using ⊕ and ⊖. The amplitude axis is adjusted automatically. The time axis is adjustable.
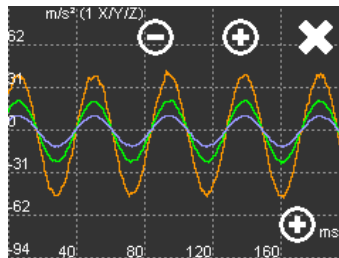
Figure 139: Waveform diagram

4.9.4.9. Display of Exposure Time

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 with the currently measured values. For hand-arm vibration, this is done on the basis of the energy-equivalent mean values, for whole-body vibration with the highest of the three axis values.

Solving equation 6 or 10 for to the exposure time yields the remaining time until the limits are reached.

Pressing opens a window with the times until the action values and exposure limit values are reached (Fig. 140).

Figure 140: Action value and exposure limit value

In the diagram area, green, yellow and red smileys indicate the time until the exposure limit value is reached. The color is determined by the sensor with the shortest remaining time.

Pressing the smiley symbol opens a menu for specifying the corresponding remaining time in minutes (Figure 141).
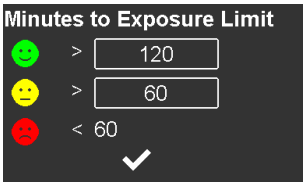
Figure 141: Smiley menu

4.9.5. Storage

The measured values are saved as a CSV data table. To do this, use to open the storage menu and select CSV storage (see section 5). The save button will then appear in yellow color with the text "LOG". Th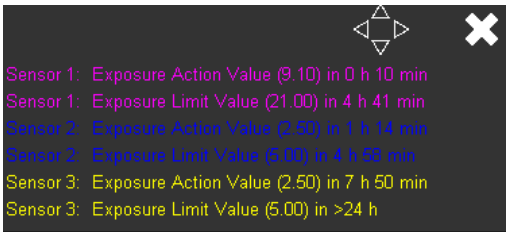e measured values are now written to a file every second. The file name and the number of measured values are displayed at the top of the diagram. To end the recording, touch the save button again.

After 24 hours of recording, the CSV file is closed and a new one is automatically created. It gets the same file name with the extension "..._a.csv", the next "..._b.csv", until the recording is ended after 27 days at "..._z.csv".

The saved files can be found on the SD card in the "HUMAN" directory.

Figure 142 shows an example of a CSV recording of the VM100B measuring whole-body vibration. The header contains information on the measuring device and the sensors used. The table of measured values begins with the channel settings, such as filters, factors and units of measurement. The recorded measuring values of three or nine channels with time stamp follow from line 22.

Depending on the mode set, some columns remain empty, e.g. MTVV and Crest for hand-arm measurement.

With the VM100A, there are more columns for the results of channels 2X/2Y/2Z and 3X/3Y/3Z.

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The last column contains a letter "X" if the reset button [RESET] was pressed or an external reset impulse at input D1 was detected (see section 4.9.4.3).

	A	B	C	D	E	F	G	H	I	J	K	L
1	Human Vibration											
2	Instr.:	VM100B	Ser.:	221236								
3	Comment:											
4	NFC Id:											
5	Sensor 1X:		Ser.:		Sensit.:	1	mV/m/s²					
6	Sensor 1Y:		Ser.:		Sensit.:	1	mV/m/s²					
7	Sensor 1Z:		Ser.:		Sensit.:	1	mV/m/s²					
8												
9												
10												
11												
12												
13												
14	Date:	04/07/25	Time:	16:23:20								
15												
16												
17	Channel:	1X	1Y	1Z	1X	1Y	1Z					
18	Measurand:	Intv. RMS	Intv. RMS	Intv. RMS	RMS 1s	RMS 1s	RMS 1s	Max	MTVV	Crest	a_v	Reset
19	Filter:	Wh	Wh	Wh	Wh	Wh	Wh					
20	Factor:	1	1	1	1	1	1					
21	Unit:	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	m/s²	
22	04/07/25 16:23:20	0,66	0,727	0,729	1,137	1,257	1,26				1,223	X
23	04/07/25 16:23:21	0,573	0,63	0,631	0,074	0,056	0,035				1,06	
24	04/07/25 16:23:22	0,514	0,566	0,565	0,083	0,103	0,036				0,95	
25	04/07/25 16:23:23	0,47	0,52	0,516	0,085	0,152	0,032				0,87	
26	04/07/25 16:23:24	0	0	0	0	0	0				0	X
27	04/07/25 16:23:26	0,087	0,062	0,034	0,087	0,062	0,034				0,112	
28	04/07/25 16:23:27	0,092	0,053	0,033	0,096	0,043	0,033				0,111	
29	04/07/25 16:23:28	0,092	0,05	0,034	0,094	0,043	0,035				0,11	
30	04/07/25 16:23:29	0,091	0,047	0,034	0,086	0,037	0,034				0,108	
31	04/07/25 16:23:30	0,089	0,045	0,034	0,084	0,038	0,032				0,106	
32	04/07/25 16:23:33	0,075	0,049	0,032	0,075	0,049	0,032				0,095	
33	04/07/25 16:23:34	0,08	0,047	0,035	0,084	0,044	0,038				0,099	
34	04/07/25 16:23:35	0,079	0,044	0,034	0,078	0,04	0,03				0,097	
35	04/07/25 16:23:36	0,081	0,044	0,033	0,086	0,041	0,032				0,098	
36	04/07/25 16:23:37	0,081	0,043	0,033	0,081	0,042	0,034				0,098	
37	<END>											

Figure 142: Example of a VM100B CSV recording

With the VM100A, the measured values are arranged as follows:

Column 1: time stamp
Column 2 – 10: interval RMS or VDV of 1X/1Y/1Z/2X/2Y/2Z/3X/3Y/3Z
Column 11 – 19: running RMS of 1X/1Y/1Z/2X/2Y/2Z/3X/3Y/3Z
Column 20 – 21: max. RMS or VDV of sensor 1/2/3 (whole-body)
Column 22 – 24: MTVV of sensor 1/2/3 (whole-body)
Column 25 – 27: crest factor of sensor 1/2/3 (whole-body)
Column 28 – 30: vector sum of sensor 1/2/3 (hand-arm, GB/T 4970)
Column 31: vector total sum (GB/T 4970)
Column 32: reset mark „X"

With the VM100B, the measured values are arranged as follows:

Column 2 – 4: interval RMS or VDV of 1X/1Y/1Z
Column 5 – 7: running RMS of 1X/1Y/1Z
Column 8: max. RMS or VDV (whole-body)
Column 9: MTVV (whole-body)
Column 10: crest factor (whole-body)
Column 11: vector sum (hand-arm)
Column 12: reset mark „X"

Alternatively, the screen can be saved as a BMP screenshot.

You can find more information on saving measured values in section 5.

4.9.6. 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.

The KS963B100 whole-body sensor built into a seat pad can be removed for a function check and excited with 1 m/s² at 15.92 Hz.
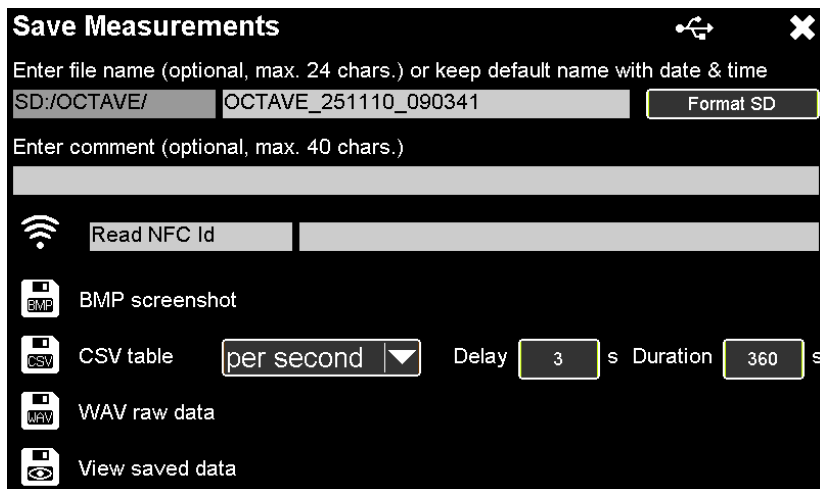

Figure 143: Vibration Calibrator VC21

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 144 shows the memory menu for amplitude/time measurements.

Figure 144: 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. In some modules the storage mode can be selected. Storage can take place at time intervals or when limit values are exceeded. It is possible to set a start delay before the first storage and the storage duration in seconds. The maximum duration is 10 hours (36000 s) Saving begins after pressing the CSV icon.

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
HUMAN	Measurement data from the Human Vibration module
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 145) 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 145: 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 146).

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

Figure 146: Example of the file NFC_IDs.csv

5.3. Saving Bitmap Screenshots

By touching [BMP 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.
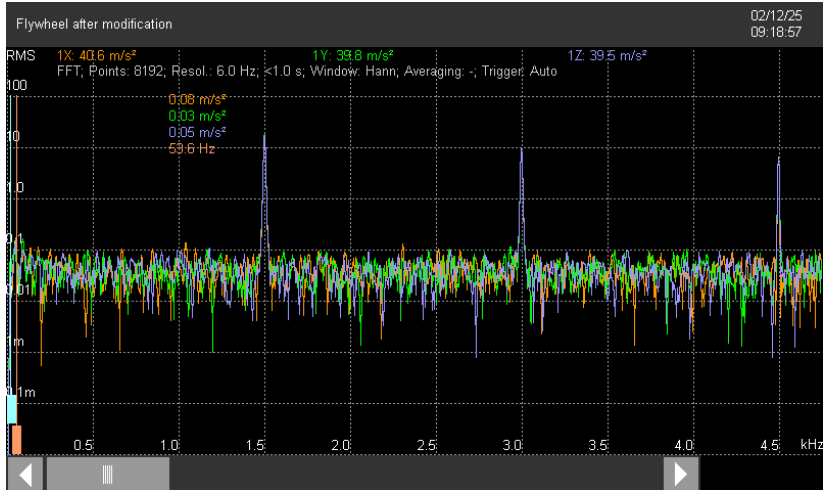
Figure 147: Bitmap example

5.4. Saving Data in CSV Format

With the [CSV icon] button you can create a CSV file with measured values. CSV (character-separated values) is a text-based format that contains tabulated data. It can be opened in spreadsheet programs, for example.
The CSV files of the individual function modules have a uniform basic structure:

Row 1: Module name
Row 2: Type and serial no. of instrument
Row 3: Comment text
Row 4: NFC-ID, if known
Rows 5 – 13: Type and serial no. of sensors
Row 14: Date, time, temperature (VM100A)
Rows 15 – 21: Module specific data and header of measurement data table
Row 22: Start of measurement data table

The CSV file is saved in the folder belonging to the measuring module on the SD card. For modules measuring in time domain, the measured values are logged to the CSV file. For modules measuring in the frequency domain, the frequency spectrum is stored as a table.

5.5. Viewing Saved Measurement Data

The button ⊡ is used to view the saved BMP and CSV files. To open them, touch the relevant folder and then the name of the desired file (Figure 148).

Figure 148: Viewing BMP-/CSV files

Figure 149: CSV data in the viewer

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

5.6. Recording Raw Data in WAV Format

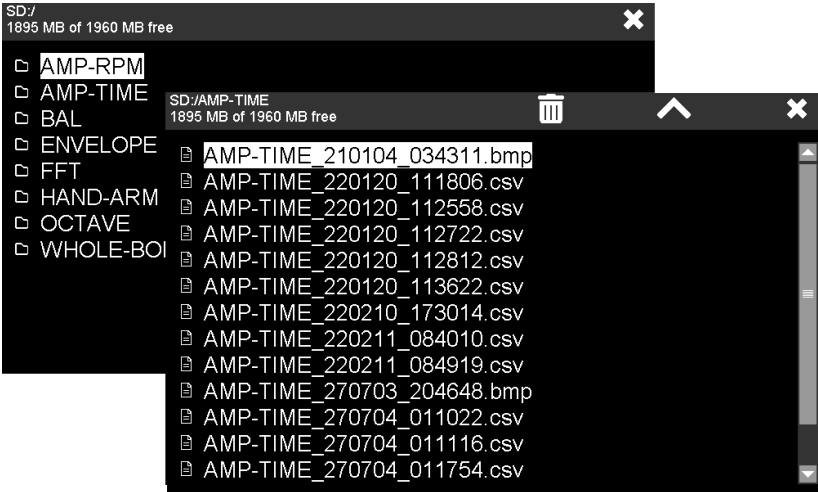The VM100 can record raw data regardless of the measuring module selected. This is the unfiltered sample data of the analog-to-digital converter. Recording takes place in WAV format (Waveform Audio Format). WAV files are read by many programs for signal analysis[1] and by audio players. To switch to WAV data storage, open the storage menu and press ![icon]. Fig. 131 shows the raw data view, which corresponds to that of an oscilloscope. The time signals of X/Y/Z are displayed in the channel colors.
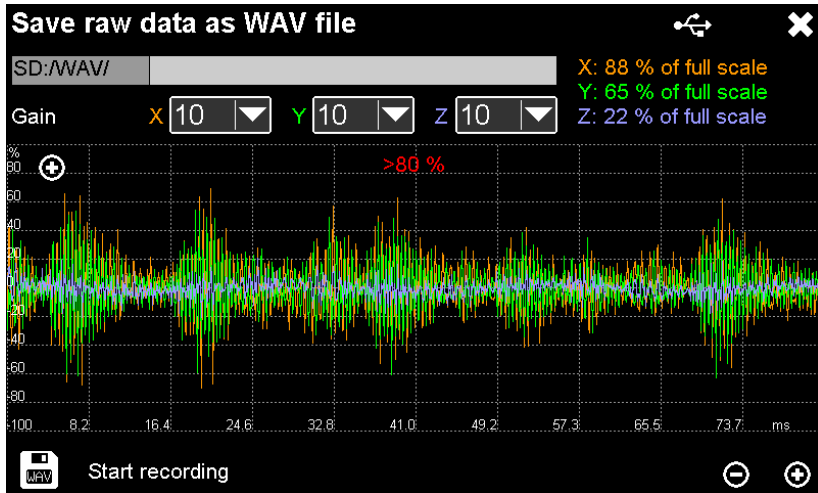
Figure 150: Raw data view

Raw data is recorded in three channels for X/Y/Z from input 1.

The gain has to be set so that the signal fits into the amplitude range without clipping. The level of the three measuring channels is displayed at the top right. A warning is shown in the diagram area if the level is too high or too low.

Recording takes place with a bandwidth of 4.4 kHz at a sampling rate of 9765 samples/s and with 24 bit resolution.

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

The file name can be entered using the on-screen keyboard by touching the empty field after "SD:/WAV/". If a file with the same name already exists, it will be overwritten without warning. If you do not enter a file name, it will be generated automatically from the date and start time, for example: 250204_142128.wav.

Press ![icon] to start recording (Fig. 151).

---

1   A free open source program for viewing WAV files can be downloaded from https://www.sonicvisualiser.org/

The recording duration is displayed at the bottom left. The maximum duration per file is one hour. This results in approx. 300 MB of data. A new file is automatically started after reaching one hour. Touch STOP to end the recording. The recorded raw data is stored on the SD card in the WAV directory. Section 3.5 describes how you can transfer the data stored on the SD card to a PC via the USB interface.
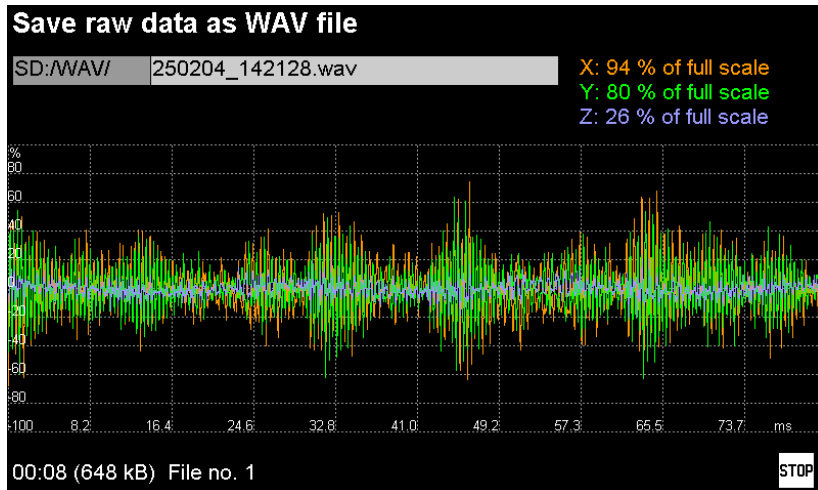
Figure 151: WAV recording

Fig. 152 shows the format of the generated WAV data.

The header contains the fixed format settings:

NumChannels = 3

SampleRate = 9765 (0x00002625)

ByteRate = SampleRate * NumChannels * BitsPerSample / 8 = 87885 (0x0001574D)

BlockAlign = NumChannels * BitsPerSample / 8 = 9 (0x0009)

BitsPerSample = 24 (0x0018)

The following parameters depend on the data contained:

a RIFF ChunkSize: File size – 8, in bytes

b ICMT: Comment field (80 bytes)
    device name, ser. no., transducer sensitivity X/Y/Z, gain X/Y/Z, measuring channels
    DevName SerNo Sen.xxx Sen.yyy Sen.zzz GnX GnY GnZ 1x 1Y 1Z (16 spaces)
    Example: VM100A 221236 001.012 010.110 009.998 001 010 100 1X 1Y 1Z

c data ChunkSize: Number of subsequent measurement data in bytes

The header is followed by the actual measurement data:

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Xl, Xm, Xh, Yl, Ym, Yh, Zl, Zm, Zh: lower/middle/upper byte of the samples of X/Y/Z

Numbers are stored as "little endian" (LSB in front).

	0x0	0x1	0x2	0x3	0x4	0x5	0x6	0x7	0x8	0x9	0xA	0xB	0xC	0xD	0xE	0xF
Header:																
0x00	ChunkID = „RIFF"				RIFF ChunkSize				Format = „WAVE"				SubChunkID = „fmt "			
	0x52	0x49	0x46	0x46	a	a	a	a	0x57	0x41	0x56	0x45	0x66	0x6D	0x74	0x20
0x10	fmt ChunkSize = 16				PCM-Audio		NumChannels		Sample-Rate				Byterate			
	0x10	0x00	0x00	0x00	0x01	0x00	0x03	0x00	0x25	0x26	0x00	0x00	0x4D	0x57	0x01	0x00
0x20	BlockAlign		BitsPerSample		SubChunkID = „LIST"				LIST ChunkSize = 92				ListType = „INFO"			
	0x09	0x00	0x18	0x00	0x4C	0x49	0x53	0x54	0x5C	0x00	0x00	0x00	0x49	0x4E	0x46	0x4F
0x30	INFO Id = „ICMT" (gen. comment)				ICMT ChunkSize = 80				b	b	b	b	b	b	b	b
	0x49	0x43	0x4D	0x54	0x50	0x00	0x00	0x00								
0x40								ICMT								
	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
0x50								ICMT								
	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
0x60								ICMT								
	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
0x70								ICMT								
	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
0x80				ICMT					SubChunkID = „data"				data ChunkSize			
	b	b	b	b	b	b	b	b	0x64	0x61	0x74	0x61	c	c	c	c
Data:																
0x90								data								
	Xl	Xm	Xh	Yl	Ym	Yh	Zl	Zm	Zh	Xl	Xm	Xh	Yl	Ym	Yh	Zl
0xA0								data								
	Zm	Zh	Xl	Xm	Xh	Yl	Ym	Yh	Zl	Zm	Zh	Xl	Xm	Xh	Yl	Ym
0xB0								data								
	Yh	Zl	Zm	Zh	Xl	Xm	Xh	Yl	Ym	Yh	Zl	Zm	Zh	Xl	Xm	Xh

Figure 152: WAV format

➔ Physical units are not coded in the WAV file. They need to be entered manually in the processing software.

The amplitudes in a WAV file are encoded as follows:

• The recorded signal represents the unfiltered sensor signal after amplification. The amplifier gain can be 1, 10, or 100.
• An amplitude of 1 corresponds to full scale of ±10 V at the amplifier output.
• The amplitude corresponds to the voltage. There is no correction of the transducer sensitivity.

Example:

The WAV recording has a peak amplitude U_{pk} of ±5 V. The recording was made with an amplification of G = 10. The sensor had a sensitivity of S = 0.01 V/m/s².

The acceleration resulting from the peak amplitude is:

$$a = \frac{U_{pk}}{G \cdot S} = 50 \, m/s^2$$

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.
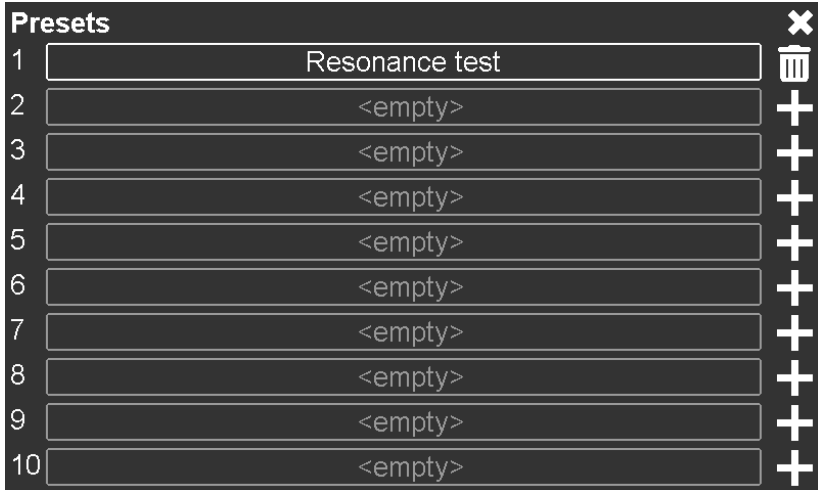

Figure 153: Saving and loading settings

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

• Open the presets menu.

• Press the corresponding button to load the saved settings. The menu closes and the instrument switches to measuring mode.

• Change the desired setting.

• Open the menu for presets again.

• Delete the entry to be changed with 🗑.

• Create the same entry again with ⚏. The previous name appears as default. Confirm with the Enter button.

➔ Regardless of the 10 saved presets, all settings will always be saved before the device is switched off and reloaded at startup.

7. Other Settings

7.1. Display Settings

Touch the ▤ button and open the main menu to select Settings and Display (Figure 154).

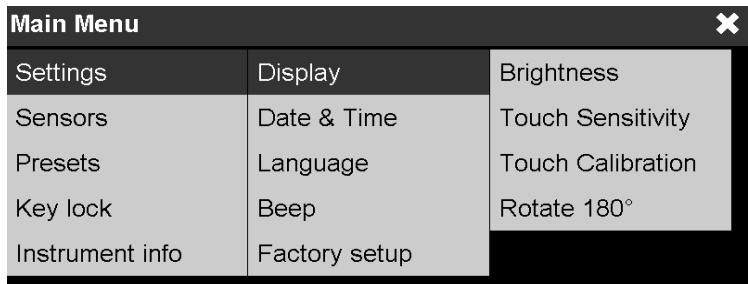| Main Menu		✕
Settings	Display	Brightness
Sensors	Date & Time	Touch Sensitivity
Presets	Language	Touch Calibration
Key lock	Beep	Rotate 180°
Instrument info	Factory setup	

Figure 154: Display settings

Touch Brightness to open the menu for setting the display brightness (Figure 155). 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.

✓
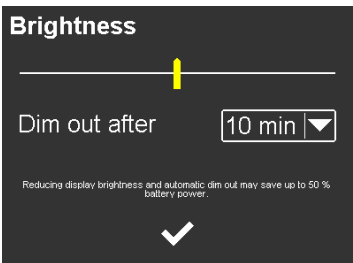
Figure 155: Display brightness

In the Touch Sensitivity menu item, you set how sensitive the display should be (Figure 156).

Touch Sensitivity

✓

Figure 156: Touch sensitivity

With Calibrate you can readjust the accuracy of the touch screen by touching five points in succession (Figure 157).

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 157: 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 158).
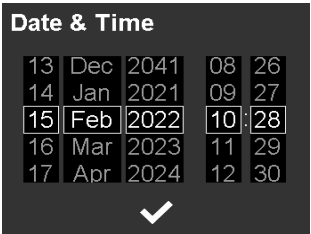
Figure 158: Date and time

7.3. Language

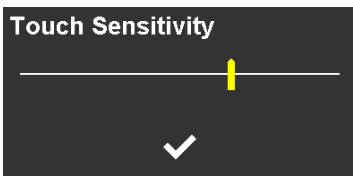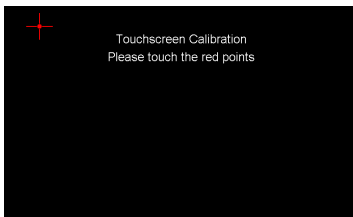In Figure 159 you can see how to select the display language of the VM100. The selection of the language only affects the operating dialog. All stored data remains in English.
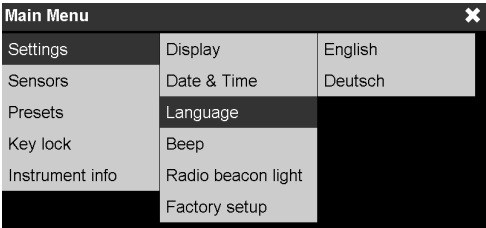
Figure 159: Display language selection

7.4. Beep Signal

You can deactivate the signal tone (beep) if desired (Figure 160).
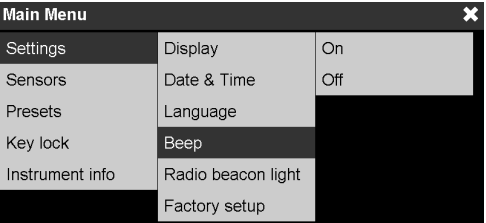
Figure 160: Switch the beep tone on and off

7.5. Factory Reset

With a factory reset, the device is reset to the default settings. This is done by hold-ing 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. Key Lock

After selecting the "Key lock" menu item, the device restarts with touch operation deactivated. A corresponding message is displayed in the status bar. To reactivate the touch screen, press the F1 key.
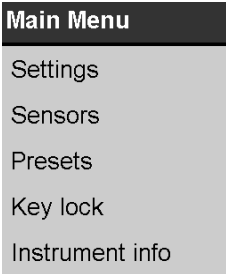
Figure 161: Key lock

7.7. Device Data

Under Instrument info you will find the serial number, version, compilation date and calibration date of your instrument. (Figure 162).
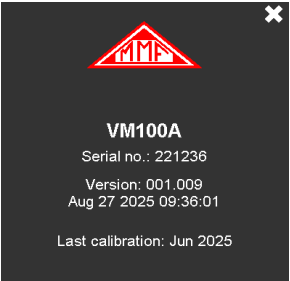
Figure 162: Instrument info

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 163).
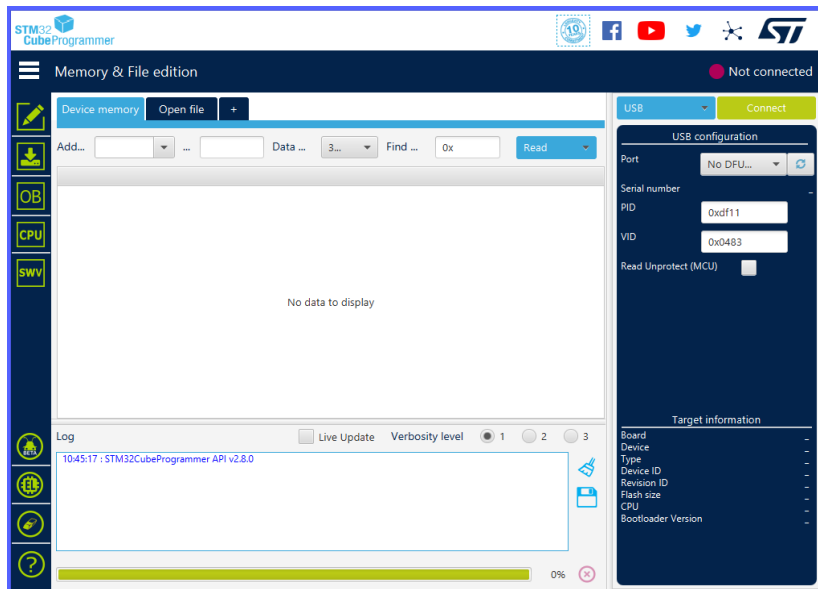
Figure 163: Update software STM32CubeProgrammer

Click to select „Memory & File edition".

Select the tab "Open file" and load the firmware file vm100.hex (Figure 164).
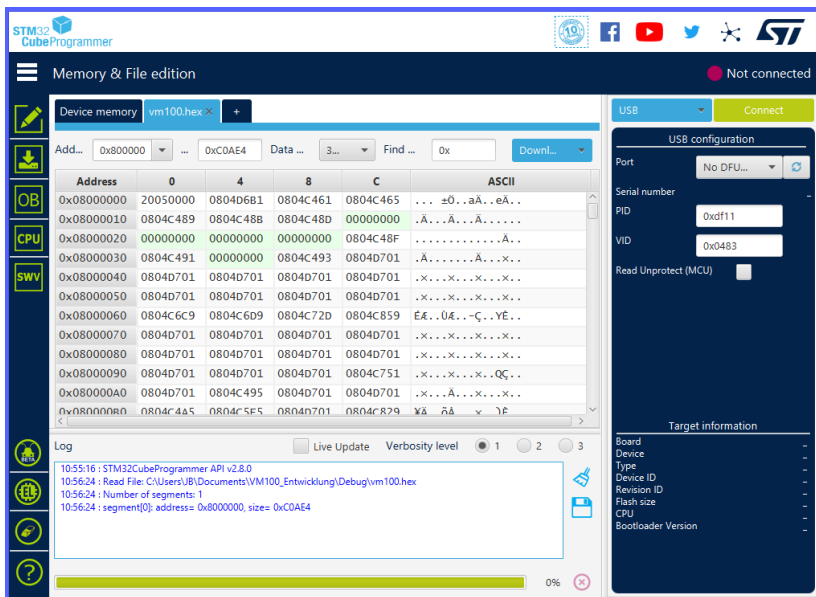
Figure 164: STM32CubeProgrammer with loaded firmware file

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 165). Connect the USB-C update interface to a PC (Figure 166).

Figure 165: Open cover

Figure 166: Connect USB cable

The VM100 switches on with the update screen giving some instruction (Figure 167).
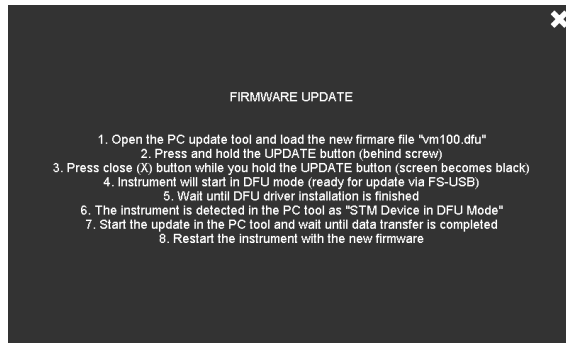
Figure 167: VM100 in update mode

Use a pointed, non-metallic object, for example a toothpick to press the button behind the screw hole of the update USB cover (Figure 168).

Figure 168: 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 169). Click .

The button starts the firmware transfer to the VM100. Figure 170 shows the completion of a successful transfer. After that you can disconnect the USB cable, press Reset and restart the device with the new firmware.
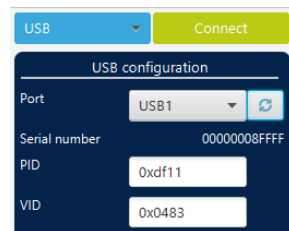
Figure 169: DFU connection

➔ After a firmware update the instrument to be reset to factory default settings (see section 7.5).

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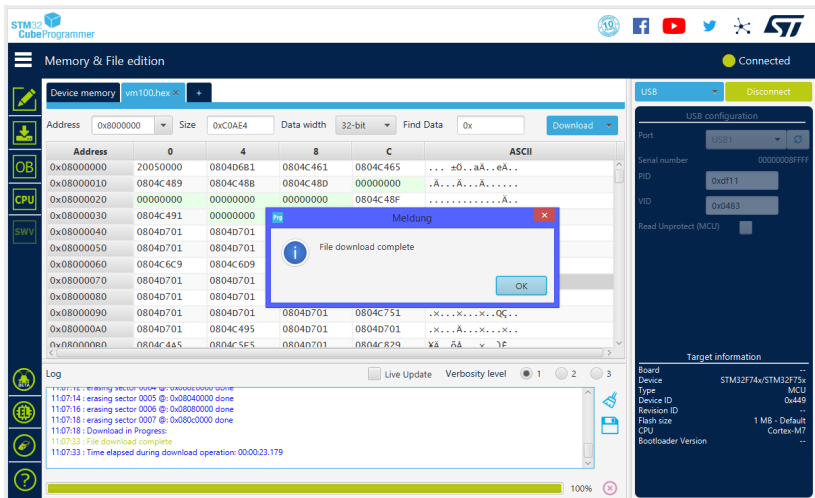
Figure 170: Finished firmware update

9. Troubleshooting

Files are saved with errors.	Back up the files from the SD card. Remove the SD card and either format or check and repair it with a PC.
The measurements are noisy.	For sensitive measurements the USB cable should be unplugged.
In Amplitude/Time mode the rotation speed is not displayed although the rpm sensor is connected.	In the common settings for channel 1 to 9 (button "ALL") the rpm unit needs to be selected.
Charging the battery takes very long.	The VM100 should be charged at a USB port or power supply providing at least 2 A output current. At standard USB sockets the charge icon will appear but there will be just enough current to power the instrument itself.
It takes too long to detect the SD card from the PC via USB.	The SD card must be formatted with the FAT(16) file system. SD cards are factory formatted with FAT32.
WAV recording stops unintentionally.	Use an SD card with 4 GB capacity and speed class 10.
Measured FFT amplitudes are too small.	Choose an appropriate window function. You may be using a rectangular window, which causes particularly strong leakage effects to adjacent frequency points.

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
Input voltage	± 10 V	
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 inputs	D1: H: >+10 V; L: <+5 V; $U_{max} = +28$ V D2: H: >+2 V: L: <+1 V; $U_{max} = +5$ V (for 3.3 and 5 V logic) Frequency: 1 to 1000 Hz / 60 to 60 000 min^{-1} Supply voltages: +5 V and +26 V / < 0.1 A Binder 712, 7 pin socket (see Figure 4)	
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)	
Cross-talk 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)
Human vibration	VM100-HUM (option)

Overall value measurement in time domain and human vibration (VM100-AMP / VM100-HUM)

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, VDV, VPM, VSI	
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; 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, up to 9 channels	

Frequency Analyzer VM100-FFT)

Channels	1 to 3
Frequency range	1 Hz to 4.4 kHz; 1 Hz to 22 kHz (only FFT, PSD, ESD)
Frequency points	1024 to 65536
Frequency resolution	0.7 to 48 Hz
Spectral functions	Acceleration, velocity, PSD, ESD, FRF
Windowing	Hann, Hamming, Flattop, Rectangular
Amplitude axis	RMS /peak; 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 160 Hz; 23 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-MAC)

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

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; class 10; 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	7" 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 (without connectors)
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-LS with 5 m cable and magnetic stand

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 Radebeul GmbH & Co. KG

Meißner Str. 58a, D-01445 Radebeul
declared by

Michael Weber
Radebeul, November 21, 2022

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