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 93 shows the limit lines in the frequency range.

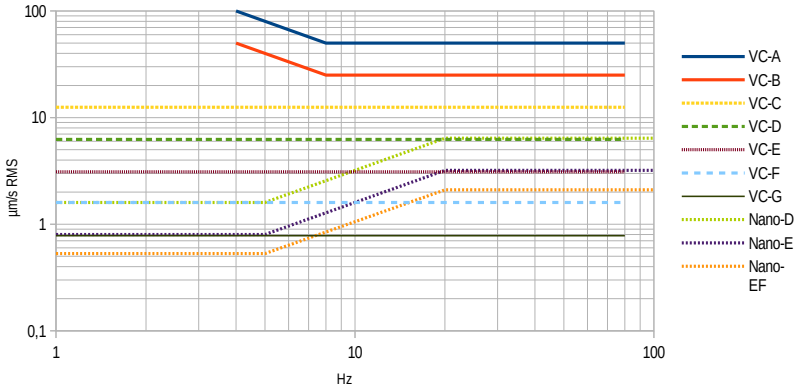

Figure 93: Limits of “VC” and “Nano” criteria

4.8.2. Sensors for VC and Nano Criteria

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

Figure 94: Triaxial accelerometer KS823B

Figure 95: Uniaxial accelerometer KS48C

Figure 96: Uniaxial accelerometer KB12VD

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

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

Figure 97: Tripod floor plate model 729

Figure 98: Triaxial mounting cube

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

4.8.3. Measurement

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

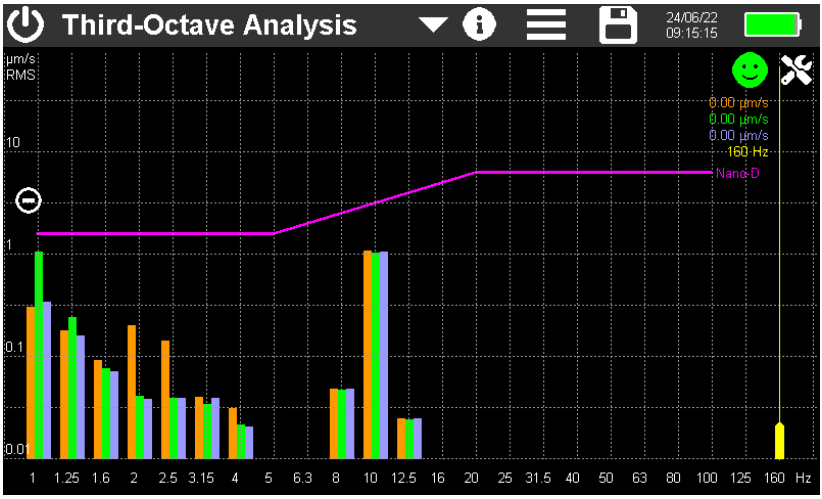

Figure 99: Third octave analysis example for Nano-D

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

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

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

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

➔ Always disconnect the VM100 from the USB port during high-sensitivity measurements to minimize interference.

➔ For very sensitive measurements, avoid drafts or temperature fluctuations at the sensor and measuring instrument. We recommend protective covers made of insulating material, such as foam, for this purpose.

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

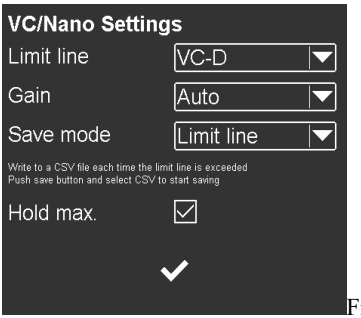

Figure 100: Menu for settings

Figure 101: Menu for custom limits

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

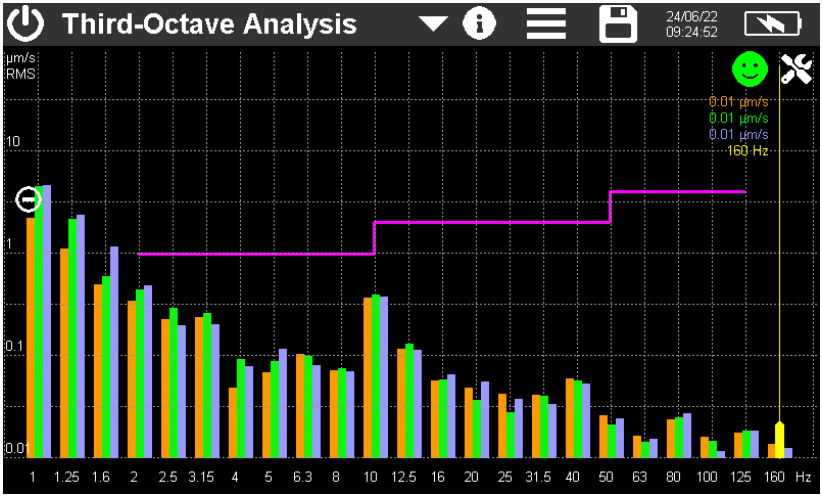

Figure 102: Custom limit line of Figure 101

Gain will be usually set to Auto or 100.

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

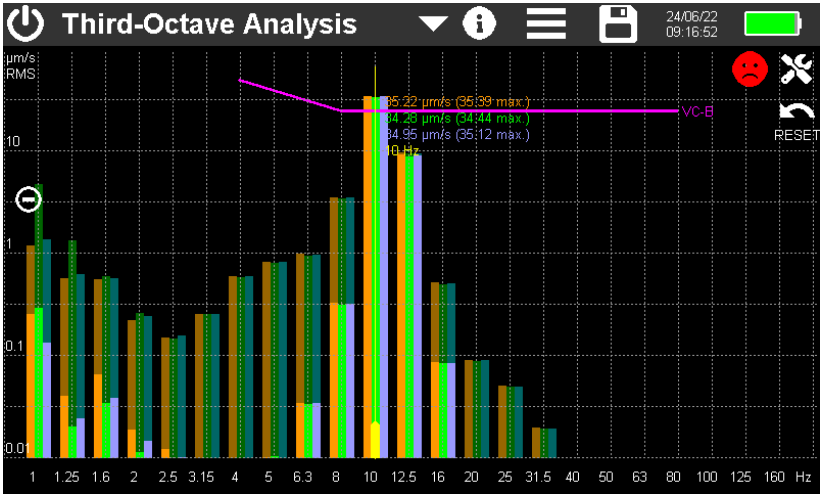

Figure 103: Spectrum with held maximum values

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

- **Limit line**: Each time the spectrum crosses the limit line a measurement is saved. Touch to open the save menu and select Save CSV. You may enter a file name or use the default name composed of date and time (example: “OCTAVE_220607_100645.csv”). Each time the limit line is crossed a new line is added to the file. This continues until the memory button is pressed again.
- **Every second**: In this mode, one measurement is saved every second even without crossing the limit line. Recording can be stopped by touching again. After 24 hours the CSV log file will be closed. A new file is opened automatically. It gets the same file name with the appendix “..._a.csv”, the next file “..._b.csv” until recording stops after 27 days with file “..._z.csv”.

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

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

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

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

THIRD OCTAVE ANALYSIS (VC/NANO CRITERIA)													
Instr.:	VM100B	Serial no.:	123456										
Comment:													
NFC Id:													
Sensor 1X:		Serial no.:		Sensit.:	10000.0000	mV/ms^-2							
Sensor 1Y:		Serial no.:		Sensit.:	10000.0000	mV/ms^-2							
Sensor 1Z:		Serial no.:		Sensit.:	10000.0000	mV/ms^-2							
Gains:	Auto	Auto	Auto										
Date:	24/06/22												
Criterion:	VC-B												
Hz	1	1	1	1.25	1.25	1.25	1.6	1.6	1.6	2	2	2	2.5
µm/s	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X
Limits													
09:32:47	3.00	1.56	1.49	1.93	1.05	1.25	0.42	0.40	0.46	0.46	0.10	0.21	0.13
09:32:48	1.53	3.14	2.79	1.02	1.17	1.09	0.74	0.47	0.38	0.55	0.24	0.24	0.37
09:32:49	2.56	2.92	2.48	2.95	1.29	1.23	1.32	1.26	1.27	0.34	0.17	0.20	1.23
09:32:50	2.44	2.65	2.35	4.41	3.25	3.35	1.67	1.86	2.02	0.40	0.50	0.37	1.01
09:32:57	1.59	1.82	1.82	0.83	0.64	0.83	0.95	0.83	0.82	0.76	0.84	0.77	1.69
09:32:58	2.53	2.87	2.71	2.21	2.04	2.22	2.50	2.29	2.34	1.64	1.62	1.60	1.53
09:33:04	16.25	16.52	15.89	37.86	37.93	37.84	42.06	40.31	41.47	37.02	34.40	37.10	86.60
09:33:05	70.48	72.10	70.86	92.61	94.31	91.93	90.87	86.91	89.71	108.90	100.63	109.10	179.1
09:33:06	152.37	156.26	152.00	167.36	172.61	165.91	89.93	85.23	88.66	110.48	100.98	109.51	96.11
09:33:07	215.72	223.28	215.05	163.92	172.90	162.58	43.23	41.16	42.51	39.43	36.50	38.52	37.68
09:33:08	229.29	239.64	228.75	127.65	136.72	126.83	21.43	24.13	21.06	28.50	26.11	28.55	22.10
09:33:09	187.68	198.28	187.48	55.86	61.47	56.05	31.54	31.09	31.26	18.27	16.32	18.01	17.86
<END>													

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

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