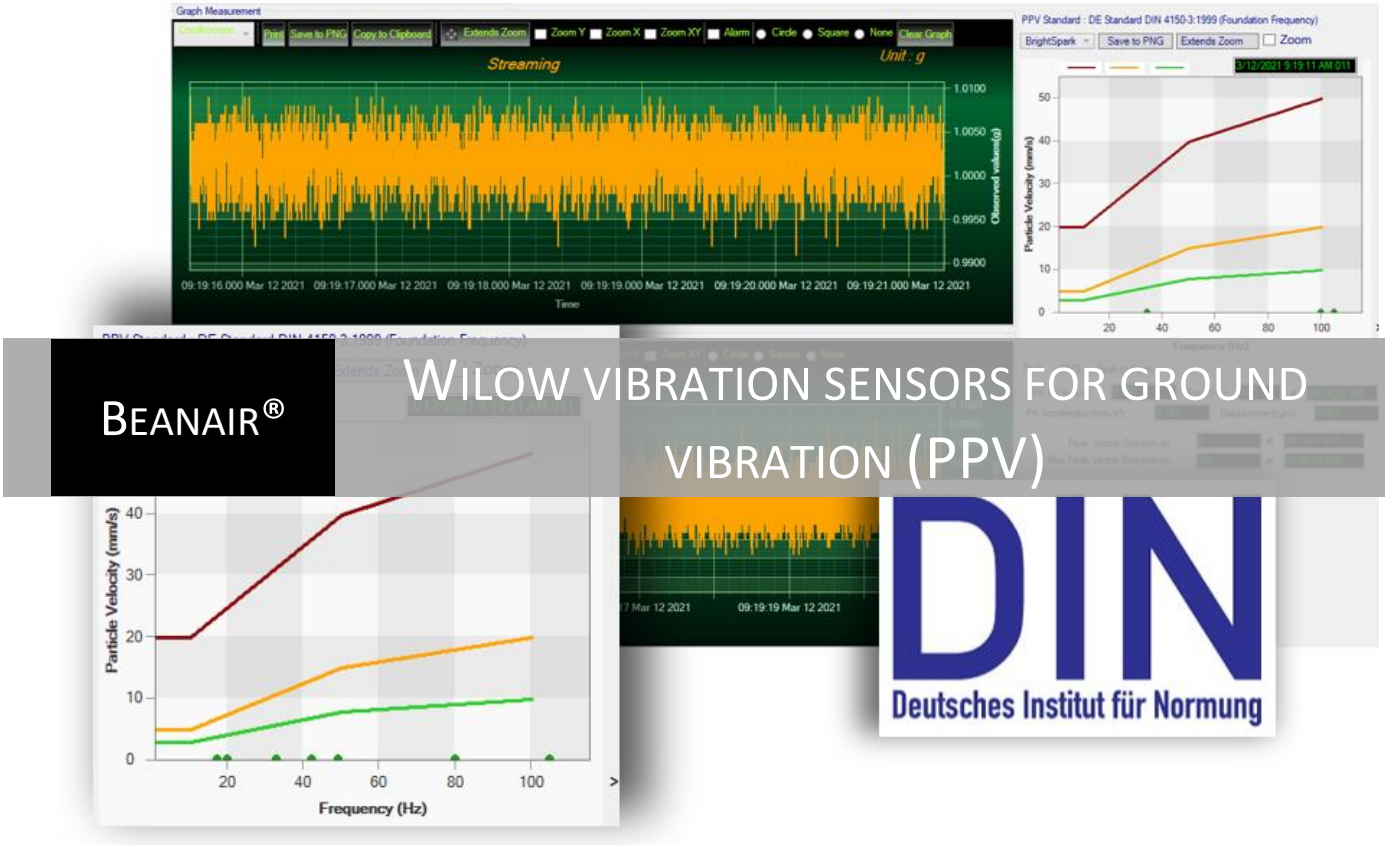
BeanDevice®

Version 1.2



BEANAIR®

WILOW VIBRATION SENSORS FOR GROUND VIBRATION (PPV)

DIN
Deutsches Institut für Normung

BeanAir
Rethinking Sensing Technology

DOCUMENT			
Document ID	TN_RF_23	**Version**	V1.2
External reference	N.A	**Date**	07/04/2021
Author	Seddik ATTIG, Application/Support Engineer		
		Project Code	
Document's name	Wilow vibration sensors for ground vibration (PPV) Technical Note		

VALIDATION			
Fonction	**Destination**	**For validation**	**For info**
Writer	Seddik ATTIG	✓	
Reader	Shimon ABADI	✓	
Validation	Mohamed MELLOULI		✓

DIFFUSION			
Fonction	**Destination**	**For action**	**For info**
Reader n°1	Mohamed MELLOULI, signal processing engineer	✓	
Reader n°2	Shimon ABADI, Application engineer	✓	

UPDATES			
Version	**Date**	**Auteur**	**Evolution & Status**
1.0	19/03/2021	Seddik ATTIG	• First version of the document
1.1	25/03/2021	Seddik ATTIG	• Online Velocity Configuration • Notes and tips
1.2	07/04/2021	Seddik ATTIG	• Add notification messages

Disclaimer

The contents are confidential and any disclosure to persons other than the officers, employees, agents or subcontractors of the owner or licensee of this document, without the prior written consent of Beanair GmbH, is strictly prohibited.

Beanair makes every effort to ensure the quality of the information it makes available. Notwithstanding the foregoing, Beanair does not make any warranty as to the information contained herein, and does not accept any liability for any injury, loss or damage of any kind incurred by use of or reliance upon the information.

Beanair disclaims any and all responsibility for the application of the devices characterized in this document, and notes that the application of the device must comply with the safety standards of the applicable country, and where applicable, with the relevant wiring rules.

Beanair reserves the right to make modifications, additions and deletions to this document due to typographical errors, inaccurate information, or improvements to programs and/or equipment at any time and without notice.

Such changes will, nevertheless be incorporated into new editions of this document.

Contents

List of Tables

List of Figures

1. TECHNICAL SUPPORT

For general contact, technical support, to report documentation errors and to order manuals, contact ***Beanair Technical Support Center*** (BTSC) at:

tech-support@Beanair.com

For detailed information about where you can buy the Beanair equipment/software or for recommendations on accessories and components visit:

www.Beanair.com

To register for product news and announcements or for product questions contact Beanair's Technical Support Center (BTSC).

Our aim is to make this user manual as helpful as possible. Keep us informed of your comments and suggestions for improvements.
Beanair appreciates feedback from the users of our information.

2. VISUAL SYMBOLS DEFINITION

Symbols	*Definition*
	***Caution or Warning** – Alerts the user with important information about Beanair wireless sensor networks (WSN), if this information is not followed, the equipment /software may fail or malfunction.*
	***Danger** – This information MUST be followed if not you may damage the equipment permanently or bodily injury may occur.*
	***Tip or Information** – Provides advice and suggestions that may be useful when installing Beanair Wireless Sensor Networks.*

3. ACRONYMS AND ABBREVIATIONS

AES	Advanced Encryption Standard
CCA	Clear Channel Assessment
CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
GTS	Guaranteed Time-Slot
kSps	Kilo samples per second
LLC	Logical Link Control
LQI	Link quality indicator
LDCDA	Low duty cycle data acquisition
MAC	Media Access Control
PAN	Personal Area Network
PER	Packet error rate
RF	Radio Frequency
SD	Secure Digital
WSN	Wireless sensor Network

4. DOCUMENT ORGANIZATION

DIN4150-3: 1999	• DIN standard overview & specifications
Restrictions	• Hard/software limitation & standard restrictions
Standard implementation	• DIN standard implementation in BeanScape® software
velocity supervision from BeanScape®	• How to use the DIN to trach the velocity

5. DIN4150-3:1999 SPECIFICATIONS

The BeanScape® software implements the DIN4150-3:1999 "Structural vibration-Part3: Effects of vibration on structures" in projects involving construction activities to track the velocity and PPV etc.

The Standard adopts the Peak Particle Velocity (PPV) metric and gives guideline values, "when complied with, will not result in damage that will have and adverse effect on the structure's serviceability."

The guideline values are different depending on the vibration source, and separated on the basis of **Short-term** and **long-term vibration.**

The standards defines Short-term vibration as "vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated".

Long-term vibration is defined as all other types of vibration not covered by the definition of short-term vibration.

Pragmatically, the short-term vibration definition applies to activities which follow the form of a single shock followed by period of rest such as blasting, drop hammer pile-driving (i.e. non-vibratory), dynamic consolidation etc.

All other construction activities (including majority of those proposed for this project) would be categorized as long-term.

The criteria for short-term and long-term vibration activities, as received by different building types, are summarized in the following table below.

Table 1: Summary of Building Damage Criteria in DIN4150-3:1999

Type of structure	Short-term vibration				Long-term vibration
	PPV at the foundation at a frequency of			PPV at horizontal plane of highest floor (mm/s)	PPV at horizontal plane of highest floor (mm/s)
	1 - 10Hz (mm/s)	10 - 50 Hz (mm/s)	50 - 100 Hz (mm/s)		
Commercial/Industrial	20	20 – 40	40 – 50	40	10
Residential/School	5	5 – 15	15 – 20	15	5
Historic or sensitive structures	3	3 – 8	8 – 10	8	2.5

The standard also contains criteria for buried pipework of different materials and the effects of vibration on the floor serviceability, as well as guidelines for measurement of vibration in building.

It should be noted that these criteria are designed to avoid all damage to building even superficial damage like cracking in plaster. Significantly greater limits would be applied for damage to structural foundations.

- For short-term vibration

Table 2: Guideline values for vibration velocity to be used when evaluating the effects of Short-term vibration on structures

Line	Type of structure	Guideline values for velocity, v_i, in mm/s			
		Vibration at the foundation at a frequency of			Vibration at horizontal plane of highest floor
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz*)	at all frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	3	3 to 8	8 to 10	8

*) At frequencies above 100 Hz, the values given in this column may be used as minimum values.

Table 3: Guideline values for vibration velocity to be used when evaluating the effects of Short-term vibration on buried pipework

Line	Pipe material	Guideline values for velocity measured on the pipe, v_i, in mm/s
1	Steel (including welded pipes)	100
2	Clay, concrete, reinforced concrete, pre-stressed concrete, metal (with or without flange)	80
3	Masonry, plastic	50

- For long-term vibration

Line	Type of structure	Guideline values for velocity, v_i, in mm/s, of vibration in horizontal plane of highest floor, at all frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	10
2	Dwellings and buildings of similar design and/or occupancy	5
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	2,5

Table 4: Guideline values for vibration velocity to be used when evaluating the effects of Long-term vibration on structures

Users can track the velocity and PPV measurement using only the Accelerometer AX-3D ±2g version.

- ***Only the AX-3D ±2g version is dedicated for ground vibration monitoring.***

6. HARD/SOFT LIMITATION AND STANDARD RESTRICTIONS

Typical frequency range for the environmental ground vibrations is in between 1Hz up to 200Hz

- ***The frequency range in the DIN4150-3:199 standard is in between 1Hz up to 100Hz, any frequency Higher than 100Hz will be displayed in the BeanScape® software on the graph extremity.***

- ***Each Standard has its own vibration criteria and specification values, in most of the cases the ground vibration frequencies did not exceed the 100 Hz that's why the DIN 4150-3 standard covers only that frequency range, if you want to track vibration higher than 100Hz maybe you should work with another standard.***

- ***The maximum BeanDevice® AX-3D® measurement range is ±2g, all acceleration values higher than ±2g will put the BeanDevice into saturation behavior, no PPV values for any measurements higher than ±2g.***

- ***The PPV values depend on the signal frequency and the BeanDevice measurement range, in order to have a good PPV measurement, user should use a sampling rate higher than 500Hz.***

7. HOW TO TRACK VELOCITY FROM BEANSCAPE® SOFTWARE

7.1 THE AVAILABLE VELOCITY STANDARDS ON BEANSCAPE® SOFTWARE

The US Standard, British Standard and the German Standard are available on BeanScape® software.

In this document we will focus only on the German Standard which is the DIN4150-3:1999.

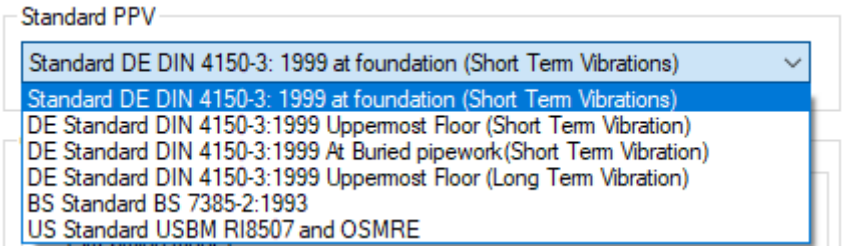


Figure 1: The Available Standard

The DIN standard contains different criteria for different application.

For users who want to track short vibration they should select one of the following standard specification

- Standard DE DIN4150-3:1999 at foundation (Short Term vibration)
- Standard DE DIN4150-3:1999 Uppermost Floor (Short Term vibration)
- Standard DE DIN4150-3:1999 at Buried Pipework (Short Term vibration)

For users who want to track Long vibration they should select

- Standard DE DIN4150-3:1999 Uppermost Floor (Long Term vibration)

User should carefully choose the Standard which suits his application because the PPV display graph and corresponding values will be based on the selected standard specification.

7.2 VELOCITY CONFIGURATION FROM BEANSCAPE® SOFTWARE

7.2.1 Online Velocity configuration

First of all, user should select a standard to work with before stat to track the velocity measurements.

To do so, click on Online Data Analysis tab, in the Online Velocity configuration frame click on the gear icon

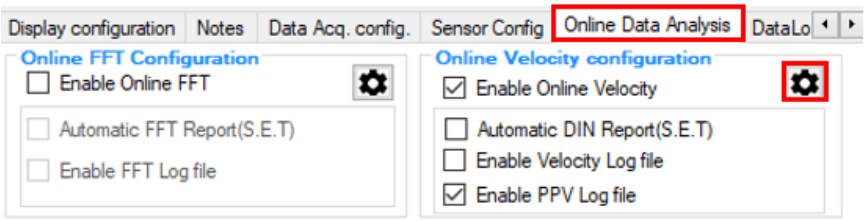


Figure 2: Online Data Analysis Tab

Right after clicking on the gear icon new window will pop up

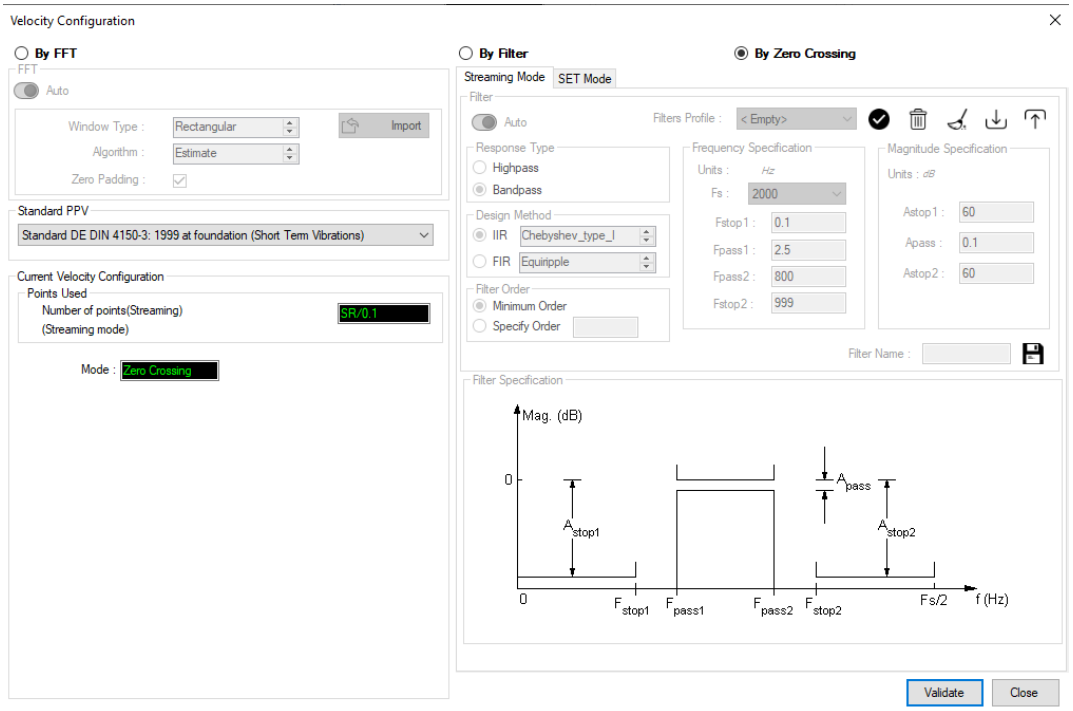


Figure 3: Velocity Configuration tab

On the window left side navigate to Standard PPV, from the scroll down list pick a DIN standard which suits your application needs.

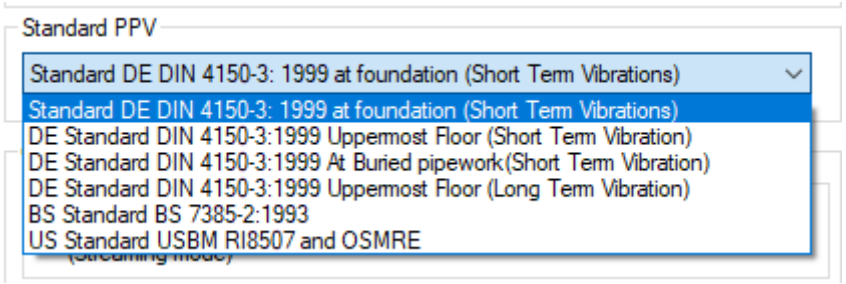


Figure 4: Available PPV DIN Standard

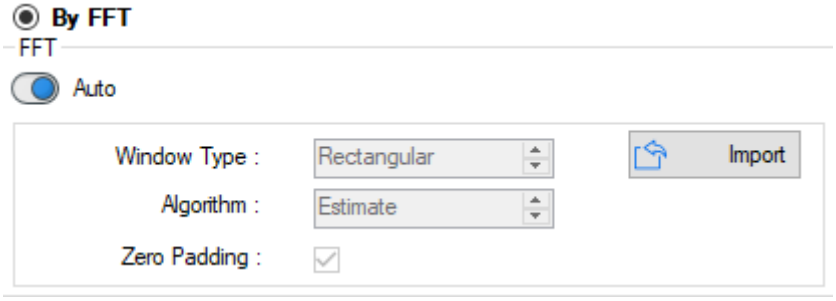
Each standard corresponds to a specific application at different floor level.

By default, the Velocity is configured “By Zero Crossing”, to edit the Velocity settings user must select “By FFT” or “By Filter”.

Figure 5: Velocity configuration

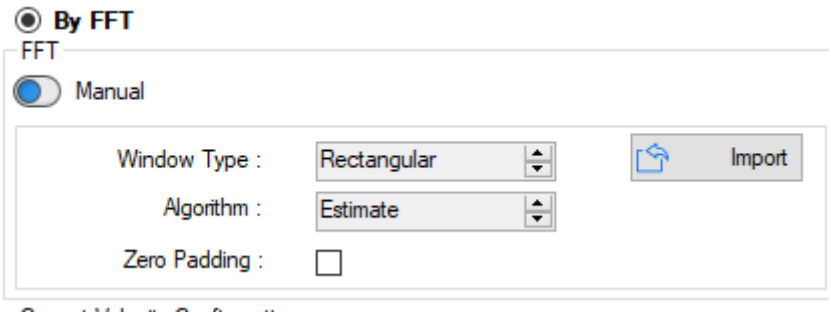
- **By FFT:** By selecting this option, the user will setup the Velocity basing on customized FFT settings.

  - Auto: If Auto is selected, The Velocity calculation will activate FFT Auto mode Settings



  - Manual: Once switched to Manual, the user can configure the FFT settings manually (Window Type, Algorithm & Zero Padding).

    By clicking on Import the Configuration will import the FFT current settings, already configured on the FFT frame.



To save all settings Press Validate. The new settings should be displayed on the Left side of the Window.

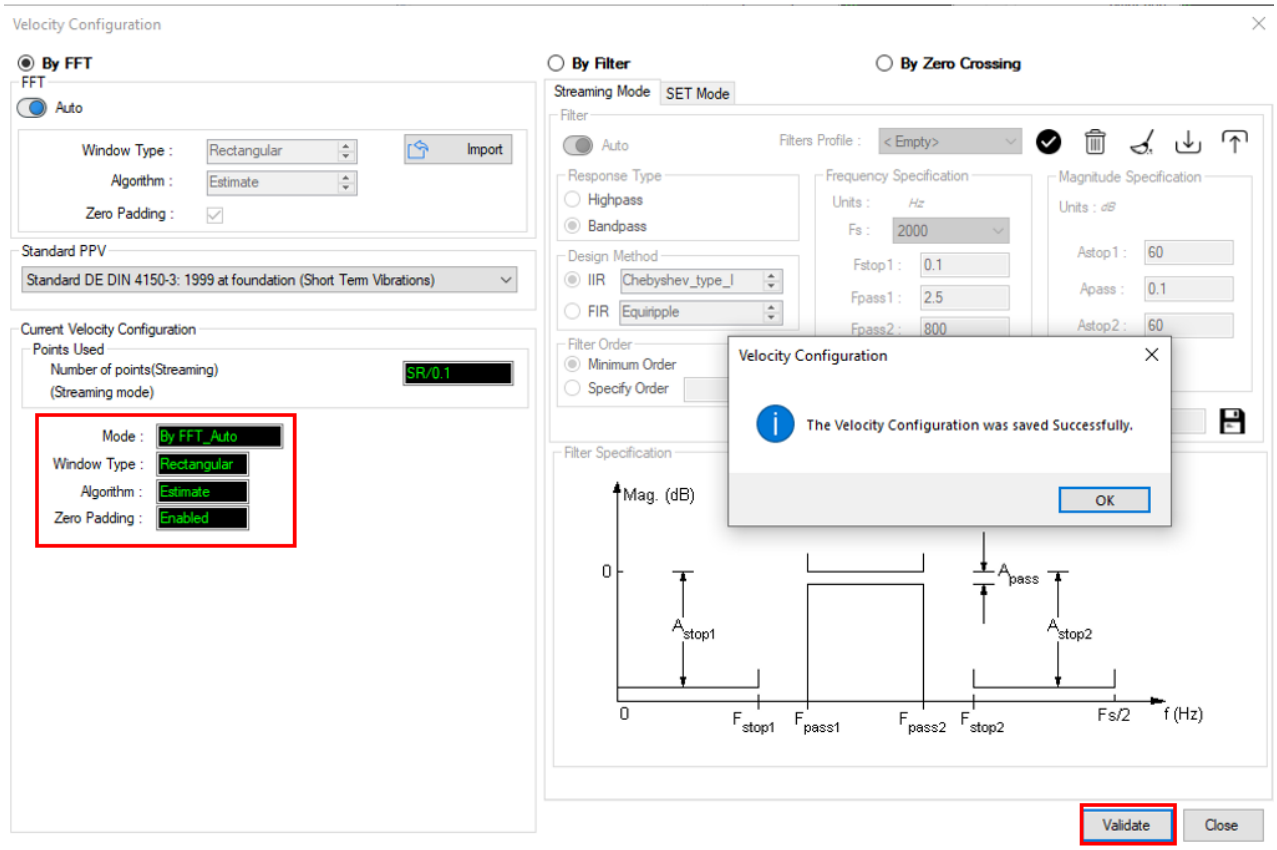
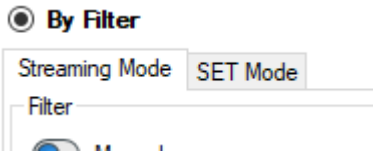


Figure 6: Velocity configuration based on the FFT

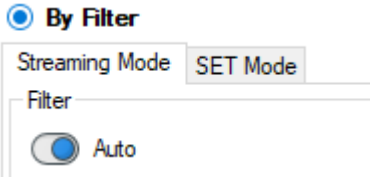
The Second velocity configuration is **By Filter** option

- **By Filter:** By selecting this option, the user will setup the Velocity basing on the Software Filter.

The Software filter is only available for Streaming and S.E.T Mode and each DOQ mode is configured from a separated corresponding tab.



  - Auto: If Auto is selected, Velocity configuration will obtain the preconfigured filter settings.



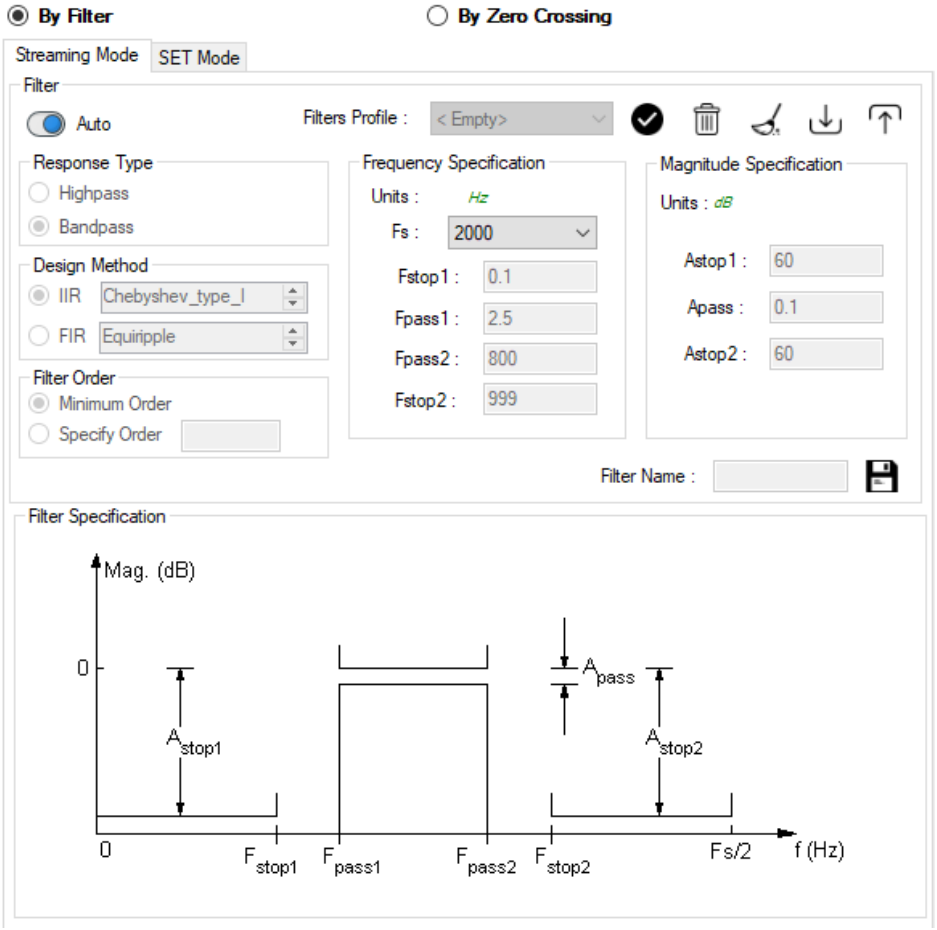
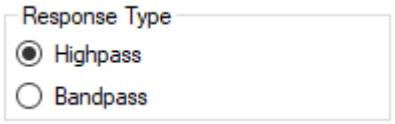


Figure 7: By filter configuration

- Manual: Once switched to Manual, the user can configure manually the Filter settings.

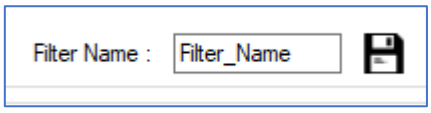
  - Response Type: User should specify if the Response is **Highpass** or **Bandpass**

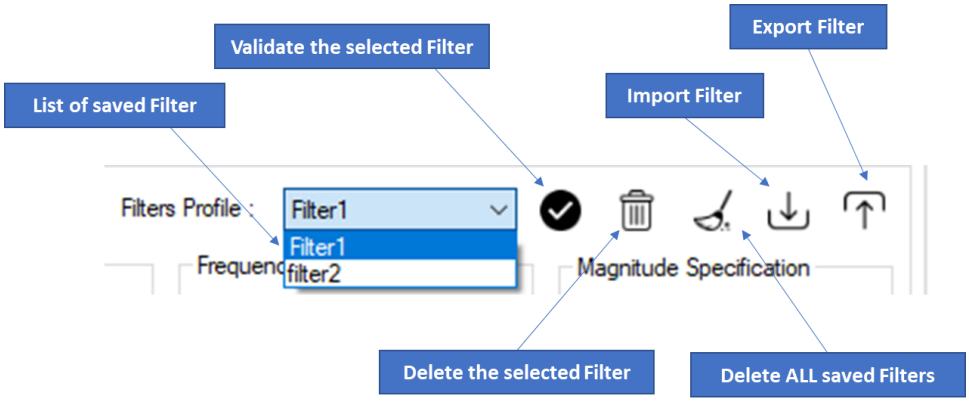


  - Design Method: User should Select the nature of the Filter between **IIR** or **FIR**
    From the List of every filter, user have to specify the method of the Filter:
    IIR: Chebyshev_type_I, Chebyshev_type_II or Butterworth
    FIR: Equiripple, Generalized_Equiripple or Kaiser_Window

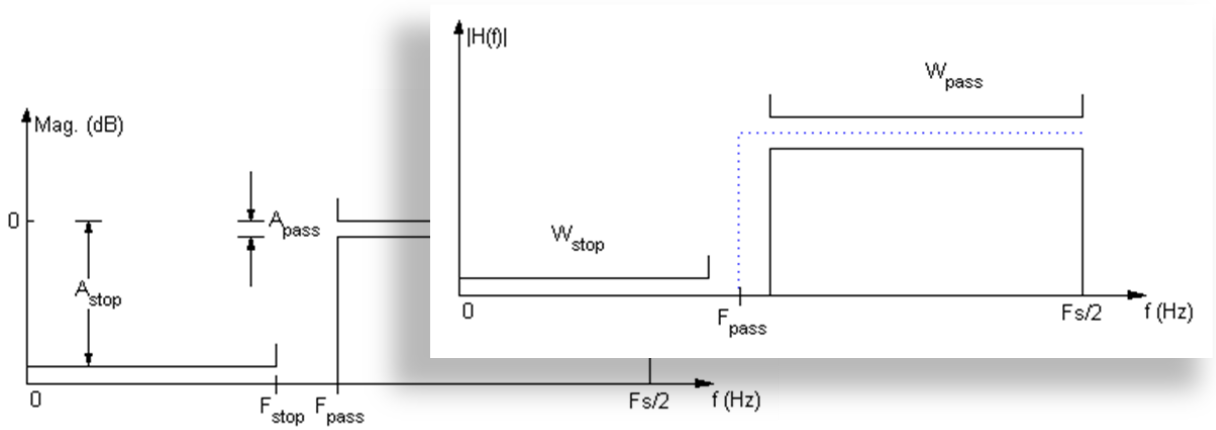
The Frequency Specification and The Magnitude Specification will be modified according the selected Design Method

- Filter Order: If the user is using IIR Design Method, Minimum Order will be selected automatically.
  If the FIR Design Method is selected, user must Specify Order.
- Frequency Specification: Is a customizable frame according to the Design Method.
- Magnitude Specification: Is a customizable frame according to the Design Method.
- Filter Profile: User can save a specific Configuration and re-use it later.





- Filter Specification: Is a Graphical Display of the Filter Specification depends on the user settings.



To save all settings Press Validate. The new settings should be displayed on the Left side of the Window.

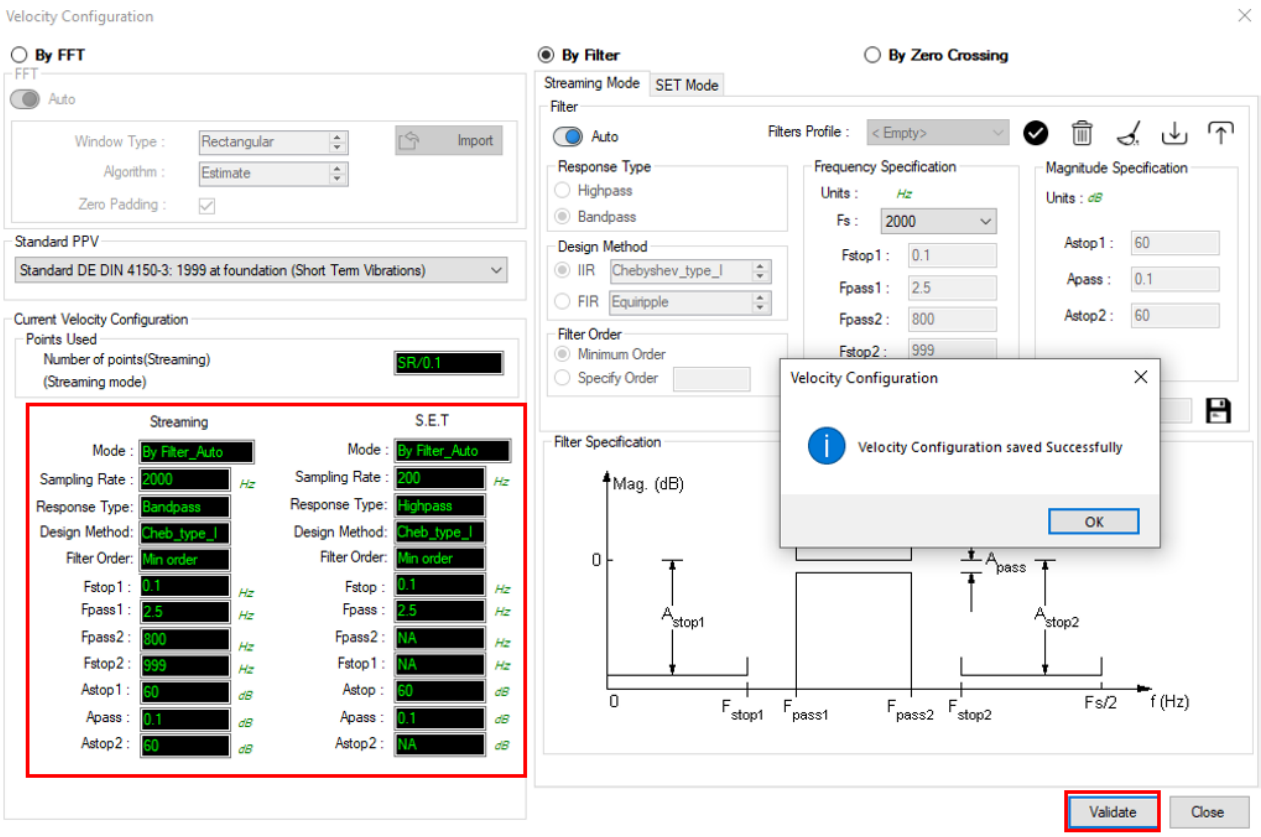


Figure 8: By Filter configuration

It's highly recommended to use By zero crossing option in the velocity configuration.

- ***BY FFT & By filter configuration are designed for advanced users who are experts in the signal processing field and have the know-how to use these advanced tools and who are familiar with such complex configurations.***
- ***The Zero crossing option is the default velocity configuration, it's highly suggested to use it to get the suitable results.***

Check Enable Online velocity to display the velocity real-time graph and PPV log file options, Velocity log file option to receive velocity and PPV values, then click on validate.

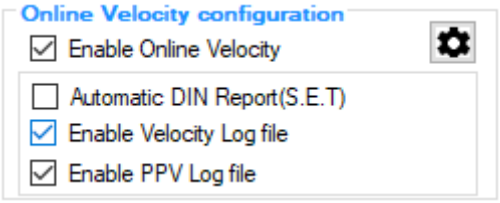


Figure 9: Velocity options selection

- ***Enable online Velocity***: check to enable real time Velocity processing, PPV and PVS, the velocity graph will be displayed.

On the Graph side a real time DIN 4150 graph will be displayed on the right side of the screen.

Under the DIN 4150 Graph, the PPV and the PVS values will be displayed in real time.

On the PPV frame, BeanScape will display PPV in mm/s, ZC Frequency in Hz, Peak Acceleration in g and Peak Displacement in mm.

- ***Terminology***

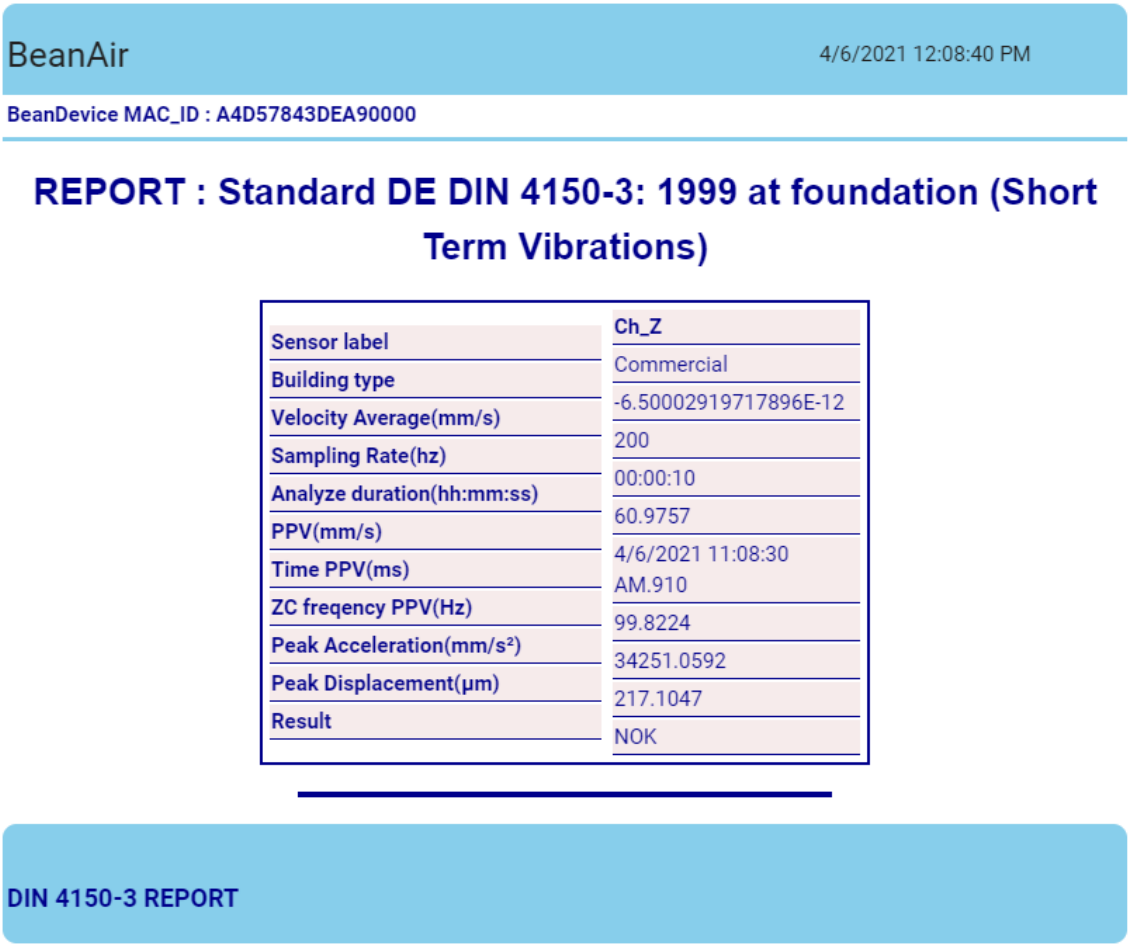
PPV (Peak Particle Velocity): is the maximum ground particle movement speed, it is expressed in millimeter per second (mm/sec), PPV is a "vector" quantity (i.e., it has both a value and an associated direction).

Peak Vector Sum (PVS): is simply the square root of the sum of the squares of the individual PPV values. PVS is a "scalar" quantity, i.e., one with only a value, which is always larger than the individual PPV vector values.

Figure 10: Velocity, FFT & PPV/PVS results

- ***Automatic DIN Report (S.E.T)***: check to enable DIN4150-3 report automatic generation when threshold is reached, or an acquisition cycle is reached on the S.E.T acquisition mode.

  An automatic Report will be sent to the email addresses configured on Alarm Management Option.



BeanAir 4/6/2021 12:08:40 PM

BeanDevice MAC_ID : A4D57843DEA90000

REPORT : Standard DE DIN 4150-3: 1999 at foundation (Short Term Vibrations)

	Ch_Z
Sensor label	Commercial
Building type	-6.50002919717896E-12
Velocity Average(mm/s)	200
Sampling Rate(hz)	00:00:10
Analyze duration(hh:mm:ss)	60.9757
PPV(mm/s)	4/6/2021 11:08:30 AM.910
Time PPV(ms)	99.8224
ZC freqency PPV(Hz)	34251.0592
Peak Acceleration(mm/s²)	217.1047
Peak Displacement(µm)	NOK
Result	

DIN 4150-3 REPORT

Figure 11: DIN 4150-3 Report sent by email

INFORMATION	DETAILS
Building type	User configurable (from Alarm Management option)
Velocity Average	Took the signal average value after transforming the acceleration signal into velocity signal
Sampling Rate	Used sampling rate In Hz
Analyze duration	DAQ duration (BeanScape property)
PPV (mm/s)	Peak Particle Velocity in mm/s
Time PPV (ms)	Peak Particle Velocity Time in milliseconds
ZC frequency PPV (Hz)	Corresponding PPV frequency
Peak Acceleration (mm/s²)	Peak in the acceleration signal
Peak Displacement (µm)	Maximum displacement value
Result	Depending on the selected DIN norm

- ***Enable Velocity Log file***: check to enable Velocity data to be stored in the log folder.

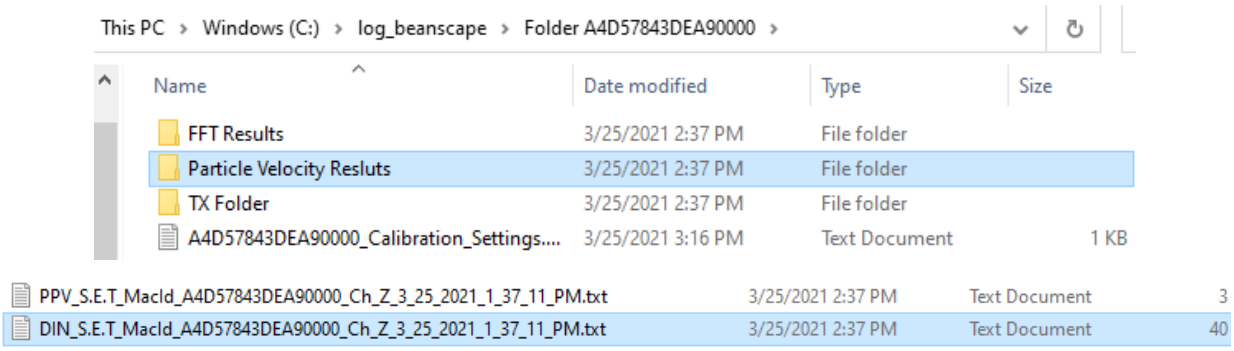


Figure 12: Velocity logfile

- ***Enable PPV Log file***

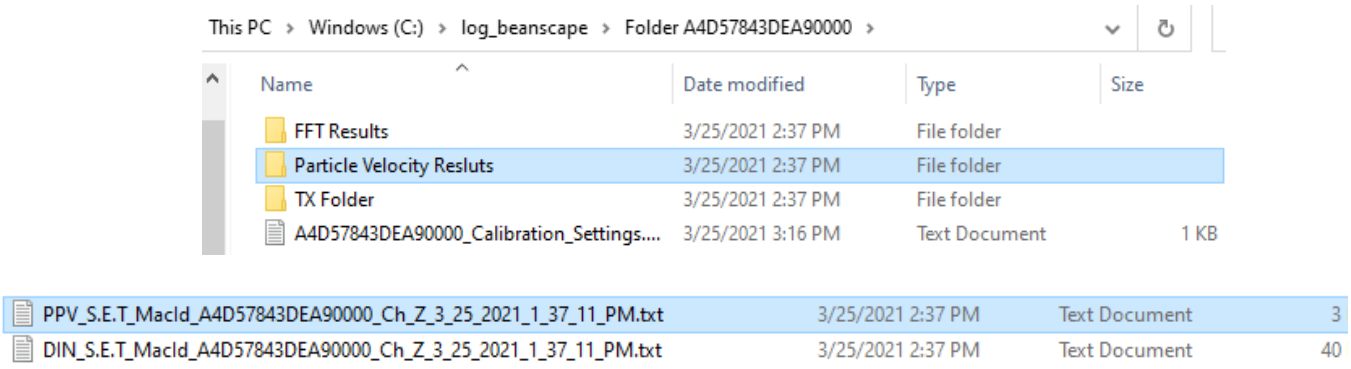


Figure 13: PPV logfile

7.2.2 Start a Data Acquisition Mode

Users can perform velocity measurement using only the following data acquisition modes:

- Streaming mode with a minimum sampling rate 500Hz or higher
- S.E.T mode with the maximum sampling rate 200Hz
- Soft S.E.T mode with a minimum sampling rate 500Hz or higher

users who work on low structure frequencies, they can use lower sampling rate than the suggested values, otherwise the mentioned values should be followed.

After configuring the velocity settings, choose a data acquisition mode to work with

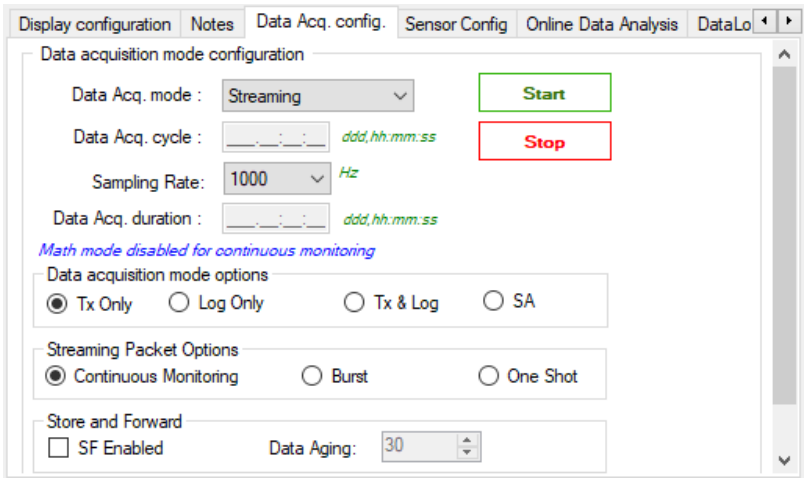


Figure 14: Data Acquisition configuration tab

For further information about the Shock detection mode please refer to this technical note TN_RF_008 – "Data acquisition modes available on the BeanDevice®"

7.2.3 Velocity/PPV graph visualization

To see the velocity graph and PPV values just click on the sensor profile

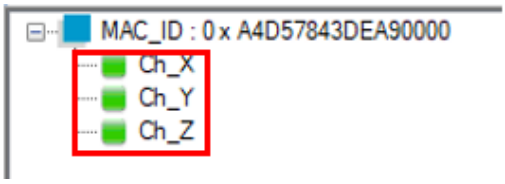


Figure 15: BeanDevice® sensor profile

Figure 16: Measurement reel-time graph

1. Acceleration reel-time graph
2. Velocity reel-time graph
3. Particle velocity vs frequency plot based on the DIN standard
4. Full signal results: Peak, RMS, PK-PK displacement values

7.2.4 PPV measurement in depth

All the measurement and plot results will be linked and based on the selected DIN Standard specification.

For example, if the user selects DIN standard to track short-term vibration on the structure the short vibration option will be checked by default.

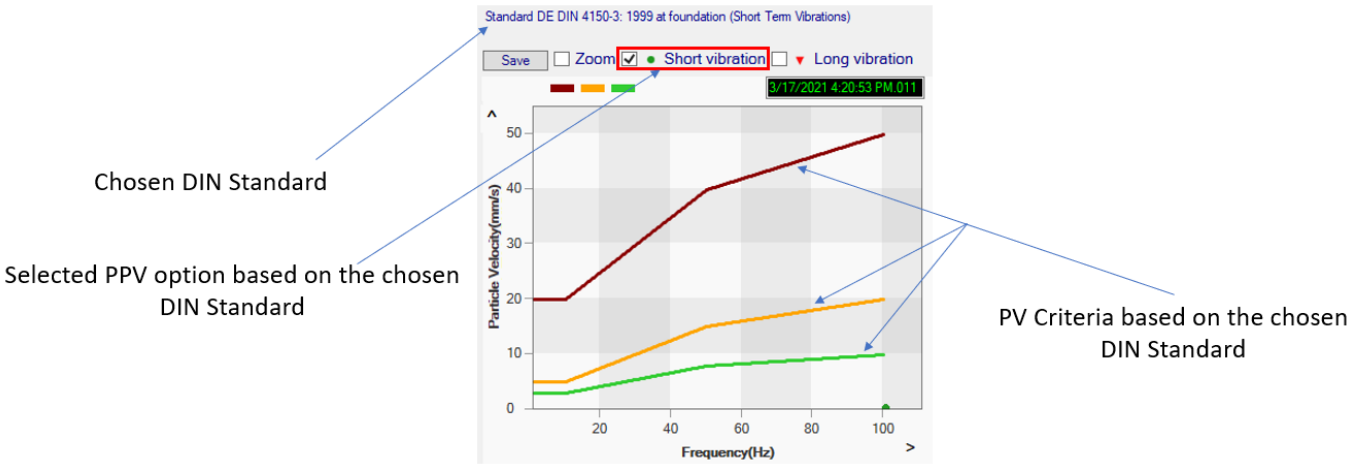


Figure 17: PV vs Frequency plot

7.2.4.1 Short-Term vibration monitoring

Any vibration that lasts between 1s up to 3s is treated as short-term vibration.

So, if you want to track shocks, blasting activities, jack hammer impacts etc. then, you should select the short-term vibration Standard.

3 different specification do exist for short-term vibration and each specification have its own criteria.

- Standard DE DIN 4150-3: 1999 at foundation (Short Term Vibration)

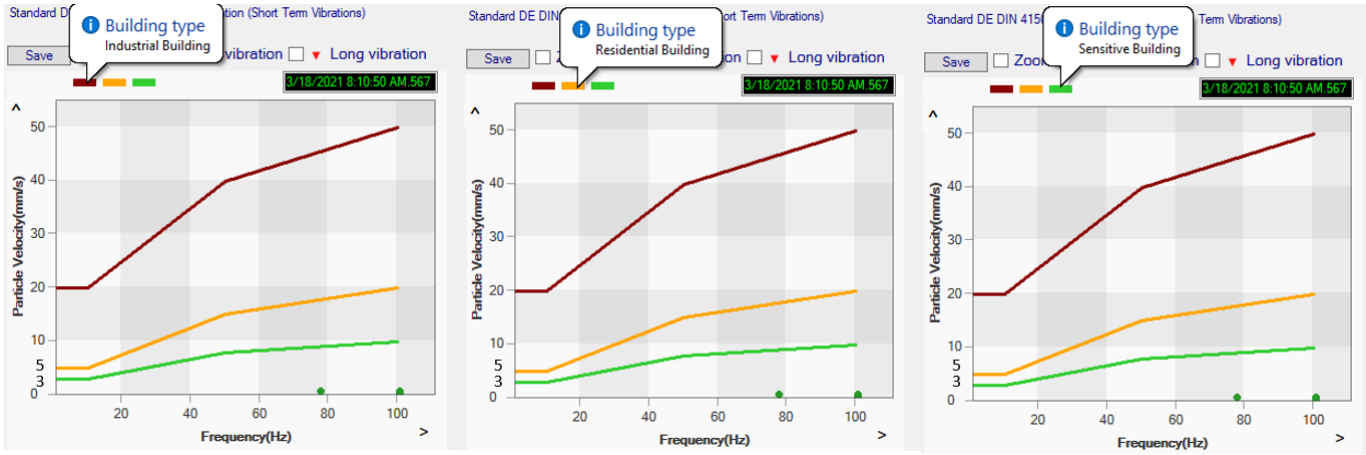


Figure 18: Short vibration at foundation level criteria

- Standard DE DIN 4150-3: 1999 Uppermost Floor (Short Term Vibration)

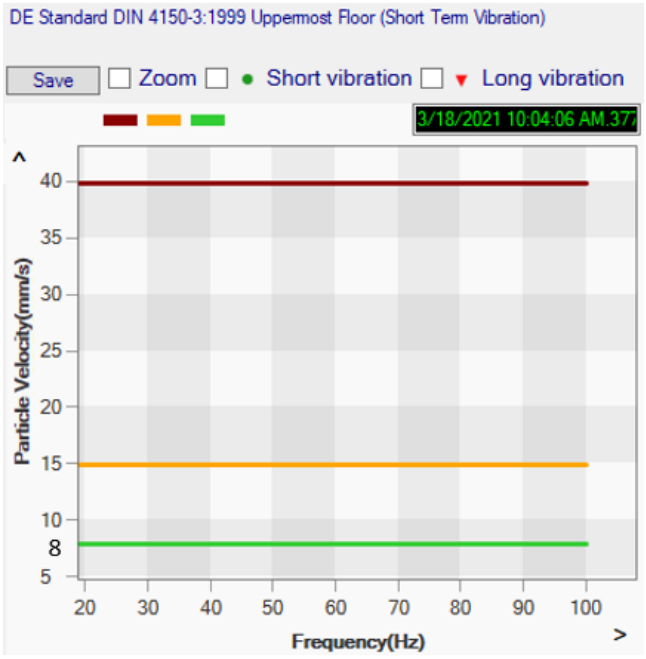


Figure 19: Short vibration at uppermost floor level criteria

- Standard DE DIN 4150-3: 1999 at Buried pipework (Short Term Vibration)

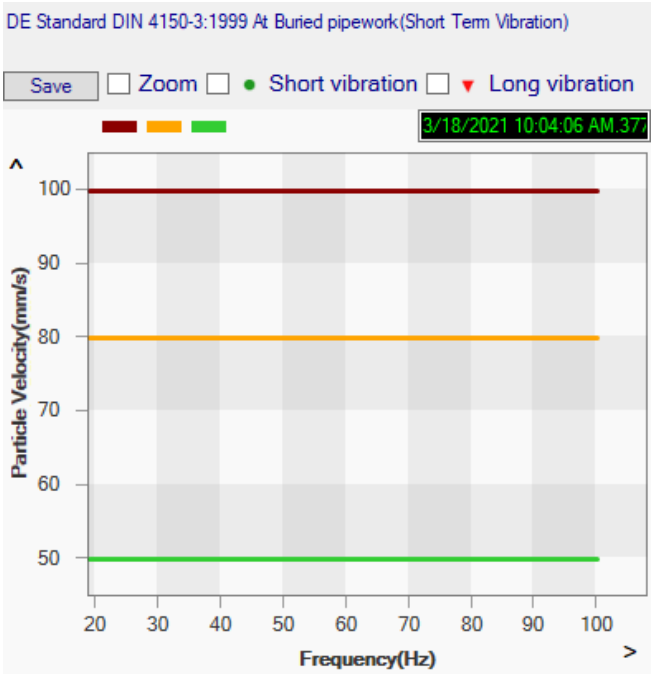


Figure 20:Short vibration at buried pipework level criteria

User should carefully choose the Standard criteria, because based on it the PPV values will be interpreted.

By default, the streaming's points number is set to automatic, then the Velocity graph and PV vs Frequency plot will be displayed after 10s from the DAQ starting time, and it will be refreshed every 10s.

Figure 21: real-time velocity graph

The peak particle velocity is the absolute highest velocity value.

All the shock vibration are followed by a long vibration with a small amplitude, in this case a notification message will pop up to notify you that the signal contains also a long vibration term which is not covered by the selected norm

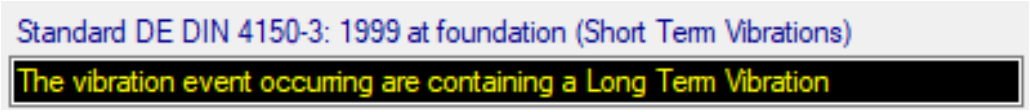


Figure 22: Notification message

In this case both short-term and long-term vibration are recorded on the plot, and you have the possibility to visualize both norms at the same time or separately.

if you want to visualize also the long vibration, just check Long vibration check box and both short and long vibration values will be displayed on the same graph at same time.

Figure 23: short & long vibration values

7.2.4.2 Long-term vibration monitoring

Any vibration that lasts more than 3s is treated as short-term vibration.

The DIN 4150-3: 1999 Standard has only one criteria for long vibration monitoring, any user who wants to track long vibration should select the following criteria

- Standard DE DIN 4150-3: 1999 Uppermost Floor (Long Term Vibration)

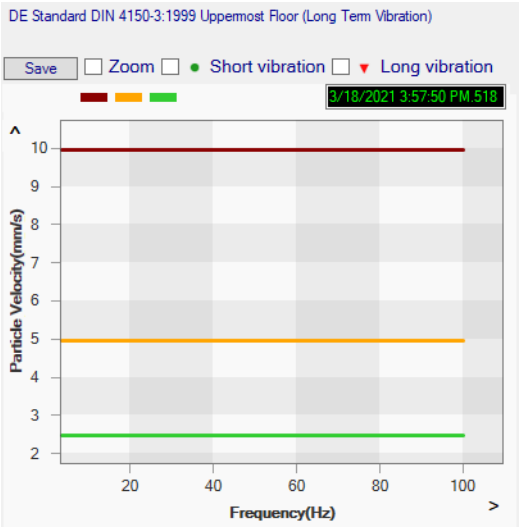
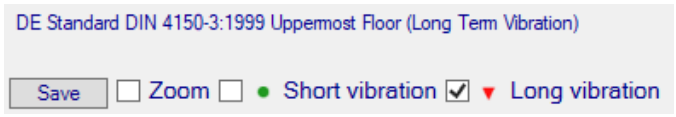


Figure 24: Long vibration at uppermost floor level criteria

By choosing the long-term vibration standard, Long vibration option will be checked by default



The long vibration velocity values are represented with a red triangle, the highest value represents the long vibration peak absolute value.

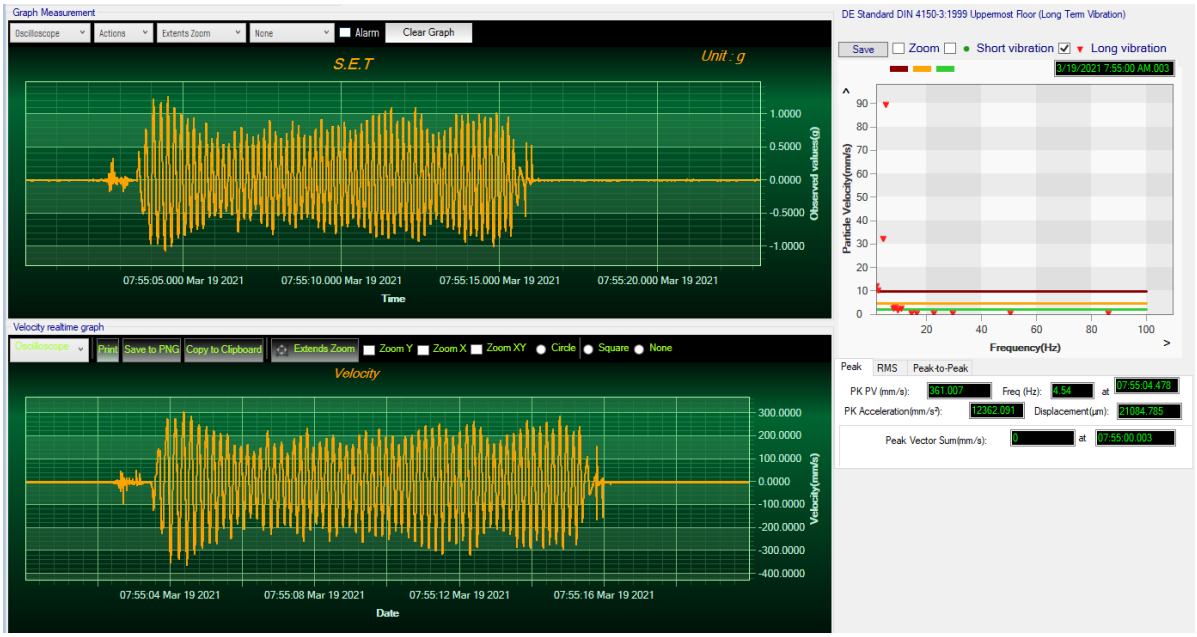


Figure 25: Long vibration values

A notification message will be displayed above the plot in case of the detection of any short-term vibration.

Figure 26: Notification message

The maximum frequency and peak particle velocity values are limited to 100Hz for the frequency range and 100 mm/s for the peak velocity in The DIN 4150-3: 1999 standard, all values higher than 100 for both frequency or peak velocity will be displayed at limit of the plot.

- ***The particle velocity corresponding to short vibration monitoring is dedicated and determined based on the velocity values***

- ***The particle velocity corresponding to long vibration monitoring is dedicated and determined based on the FFT algorithm***

- ***The PK PV (peak particle velocity) is the maximum of both maximum short vibration velocity and maximum long vibration velocity values.***

- ***The PK PV corresponds to the maximum value of the entire velocity graph which contains short/long vibrations***

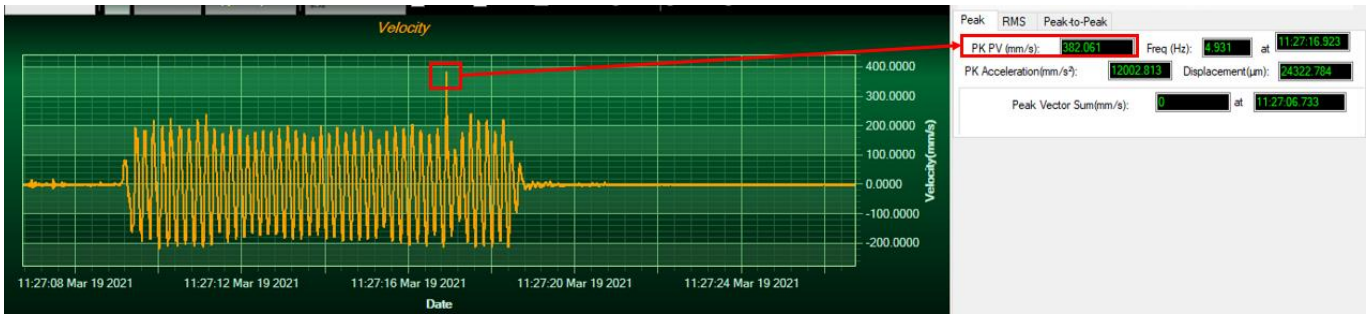


Figure 27: peak particle velocity

- ***Scientific studies have shown that the PPV correlates best with damage potential of all the tested characterizations of ground movement (e.g. acceleration, displacement, or strain). Most, though not all, ground vibration standards are quoted in PPV values, although the "acceptable" values of PPV differ with the standard applied and with the frequency of the vibration components.***

7.3 PPV LOG FILE

The PPV files are backed up on your PC in a folder named Particle Velocity Results.

In this folder you will find all the PPV log files also with the velocity log files.

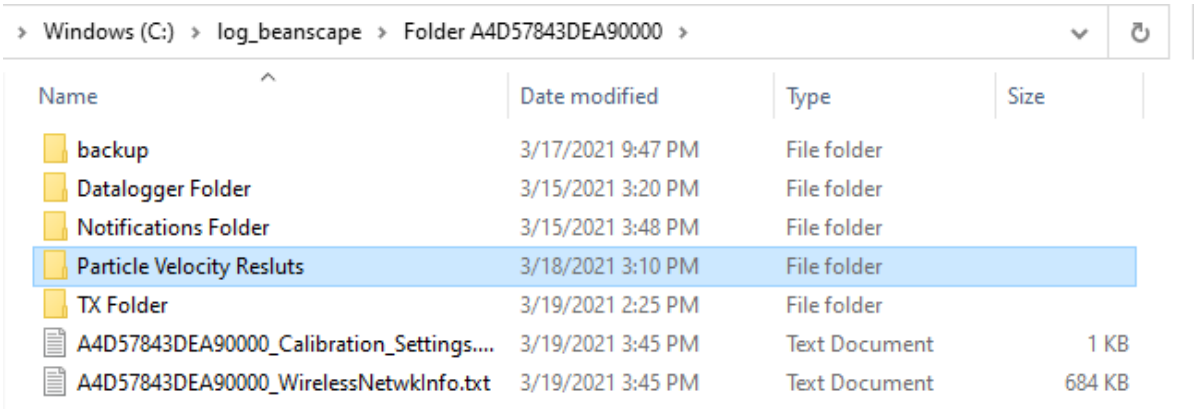


Figure 28: Particle Velocity Results folder

The log file contains the particle velocity values for both short and long vibration separately.

PPV_Soft_S.E.T__Ch_Z_A4D57843DEA90000_3_18_2021_9_20_03_AM.txt - Notepad

File Edit Format View Help

```
------------------------------------------------------------------
BeanDevice : AX 3D

Mac Id : A4D57843DEA90000
Range for accelerometer: -2g / +2g
Network Id : 0119
Pan Id : FFFE
Sensor Id : 0
Sensor Label : Ch_Z
Ratio : 1
Offset : 0
Unit for accelerometer : g
DATE_FORMAT : M/d/yyyy h:mm:ss tt.fff
Date : 3/18/2021 9:20:03 AM.795
Sampling rate : 1000

--------- Short Term Vibrations ---------
Time PV(ms);PV(mm/s);ZC Freq(Hz)
3/18/2021 9:20:01 AM.901;0.778968783;376.823338736
3/18/2021 9:20:02 AM.578;-0.575806055;478.314745973
3/18/2021 9:20:03 AM.797;-183.105881317;314.364810827
3/18/2021 9:20:04 AM.024;-11.426606293;314.448541737
3/18/2021 9:20:05 AM.610;-0.548537784;353.052631579
3/18/2021 9:20:06 AM.867;-0.568192464;391.68207024
3/18/2021 9:20:07 AM.020;-0.5705848;391.729323308
3/18/2021 9:20:08 AM.781;-0.523442942;376.774193548
3/18/2021 9:20:09 AM.260;-0.530932673;471.853638922

--------- Long Term Vibrations ---------

Time PV(ms);PV(mm/s);ZC Freq(Hz)
3/18/2021 9:20:03 AM.797;0.335619973;20.9
3/18/2021 9:20:03 AM.797;0.177291144;30.7
3/18/2021 9:20:03 AM.797;0.11659849;38.7
3/18/2021 9:20:03 AM.797;0.119686324;43.4
3/18/2021 9:20:03 AM.797;0.111946989;51.8
3/18/2021 9:20:03 AM.797;0.101890205;62.5
3/18/2021 9:20:03 AM.797;0.045460162;93.5
3/18/2021 9:20:03 AM.797;0.034766591;112.3
3/18/2021 9:20:03 AM.797;0.011096599;143.9
3/18/2021 9:20:03 AM.797;0.01240236;160.9
3/18/2021 9:20:03 AM.797;0.008048915;185.1
```

Particle velocity for short term vibration

Particle velocity for long term vibration

Figure 29: PV log file