THE INNOVATOR IN
SOUND & VIBRATION TECHNOLOGY

Welcome
SEES Meeting Borås, Sweden 2021
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NECESSARY SPECIFICATIONS FOR SINE, RANDOM AND SHOCK

TEST STANDARDS
CONSISTENT & REPEATABLE TESTS?

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TEST STANDARDS
CONSISTENT & REPEATABLE TESTS?

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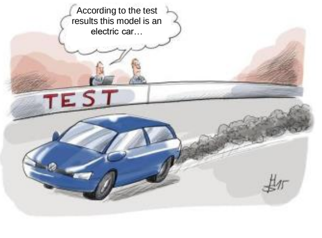
Vibration Research (UK)

COMPARISON STANDARDS AND TEST REQUIERMENTS

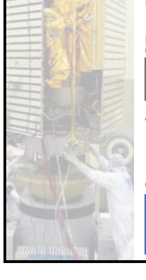
CONTENTS

- TEST STANDARDS
- GENERAL TEST CONTROLS
- RANDOM TESTS
- SINE TESTS
- SHOCK TESTS

TEST STANDARDS - WHY WE NEED THEM?



TEST STANDARDS



NATO STANDARD: STANAG 4370 (AECTP 400)

NATIONAL DEFENCE STANDARDS
(INCLUDING MOST MILITARY AIRCRAFT)

- USA: Mil Std 810, Method 514 & 516
- UK: Def Stan 00-35, Test M1 and M3

AEROSPACE / COMMERCIAL AIRCRAFT

- USA: RTCA - DO160, Section 8 & 7
- Europe: EUROCAE / ED-14, Section 8 & 7

COMMERCIAL STANDARDS

International (EN 60068 & IEC 60721)

Random	Sine	Shock
EN 60068-2-64	EN 60068-2-6	EN 60068-2-27

(Severities within many IEC ISO Standards)

THERE ARE MANY OTHER STANDARDS ASSOCIATED WITH OTHER SPECIFIC INDUSTRIES

(E.G. THE SPACE SECTOR) BUT MANY WILL HAVE THEIR ROOTS IN THESE STANDARDS OR REFER TO THESE STANDARDS / OR USE THE CONTROLS / TOLERANCES / PARAMETERS

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TEST STANDARDS - WHY WE NEED THEM?

We see a lot of pressure on the test departments that the test results are consistent, correct, reproducible and resilient.

We must invest a lot of money´s and time to do the calibration according ISO17025 and the local Authority for Accreditation and Conformity Assessment - A2LA, DAkkS or SWEDAC.

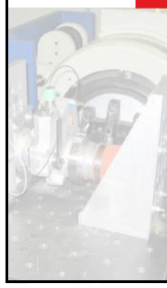
The tracible calibration and test performance are more and more important.

All Company's invest a lot of money and time to have an accurate vibration controller, accelerometers, test fixtures and vibration test system.

Beside the knowledge of the test engineer, detailed test specification, specification of the used shaker system, accelerometer, fixture…

How important is our Interpretation of the Test Standard and our Test Setup?

TEST STANDARDS - WHY WE NEED THEM?



REPEATABLE METHODS
- The results obtained in one laboratory or by one test engineer should be reproduceable within another laboratory / by another test engineer

Items ***must not*** go bang when we don't want them to…..

ADEQUATE TEST SEVERITIES
- not too severe but severe enough

….but ***must*** go bang when we need them to."

GENERAL TEST CONTROLS

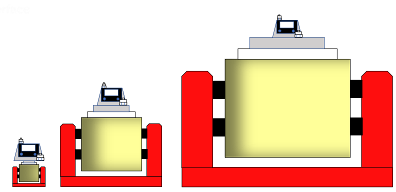
HOW TO ACHIEVE CONSISTANT AND REPEATABLE RESULTS

- Control position(s)
- Where we must apply or guarantee the Specified Test Amplitude
- Measurement positions, what is necessary and how many points we need?
- Additional Measurement POSITIONS
- Control strategies / averaging
- Average / maximum / extremal / weighted average
- Motion Controls
- Parallel MOTION - cross axis motion
- Limiting / Notching
- Advanced test Limiting and NOTCHING

GENERAL TEST CONTROLS

HOW TO ACHIEVE CONSISTANT AND REPEATABLE RESULTS

How do we ensure all tests would produce the same outcome?



GENERAL TEST CONTROLS

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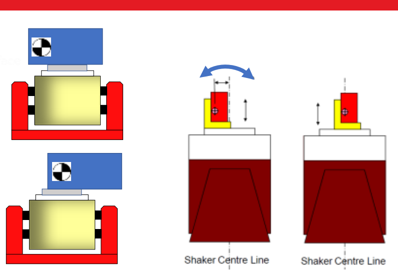

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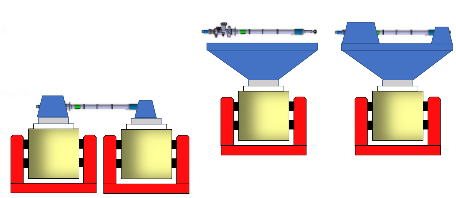

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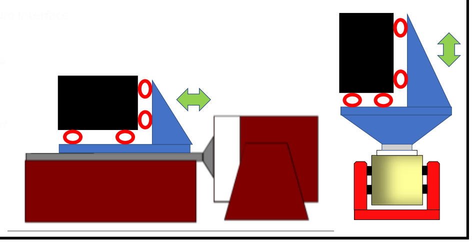

GENERAL TEST CONTROLS

CONTROL AND MEASUREMENT LOCATIONS TERMINOLOGY

Measurement Locations Terminology Used:

- Fixing Points
- Fixture / Test Item Interface
- Measurement Points
- Response Points
- Check Points
- Reference Point
- (single - point control)
- Fictitious Reference Points
- (multi - point control)

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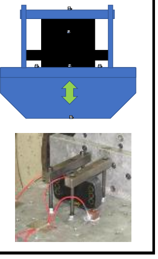

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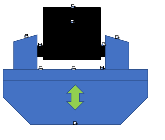

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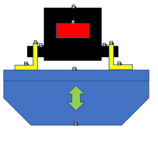

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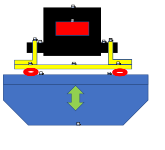

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CONTROL AND MEASUREMENT LOCATIONS TERMINOLOGY

MONITOR POINT ACCORDING EN60068-2-6

Monitor Point´s

"This is a point on the fixture, the armature or the test specimen that lies as close as possible to a mounting point and must always have a rigid connection to it.

"The measurement at one or more monitor points shall demonstrate compliance with the test conditions".

"If there are four or less attachment points, each of them is to be used as a monitor point."

"If there are more than four mounting points, the individual determination shall identify four of them as representative to be used as monitor points."

Control Point´s or Reference Point´s

"It is a selected monitor point whose signal is used to control the test equipment in accordance with the specifications of this standard.

CONTROL AND MEASUREMENT LOCATIONS TERMINOLOGY

MONITOR POINT ACCORDING EN60068-2-6

Monitor Point´s

Permissible deviations according to EN 60068 Part 2-6:
+/- 25 % equivalent to +/- 2,5 dB up to 500 Hz
+/- 50 % equivalent to +/- 6,0 dB from 500 Hz on

Control Point´s or Reference Point´s

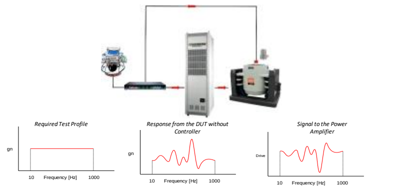
Permitted deviations according to EN 60068 Part 2-6
+/- 15 % equivalent to +/- 1,4 dB

PURPOSE OF THE VIBRAION CONTROLLER

WHAT DOES THE VIBRATION CONTROLLER?

The purpose of the controller is to ensure that the programmed vibration profile is the same as the actual vibration measured.

The controller does this by monitoring the input response from the accelerometer and making adjustments to the drive voltage.



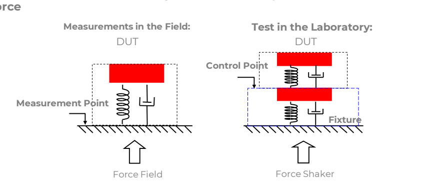
PURPOSE OF THE VIBRAION CONTROLLER

WHAT DOES THE VIBRATION CONTROLLER?

Purpose of the test under field condition is the determination of the Test Profile and Acceleration Level

As a general rule, the acceleration is measured on the DUT

Shaker and fixture influenced by their internal impedance of the transmission of force

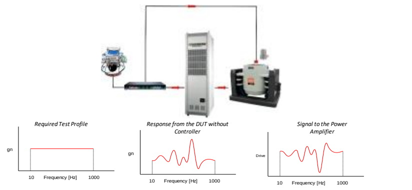


PURPOSE OF THE VIBRAION CONTROLLER

WHAT DOES THE VIBRATION CONTROLLER?

Or the purpose of the controller is to ensure that the programmed vibration profile is the same as in the used standard.

The controller does this by monitoring the input response from the accelerometer and making adjustments to the drive voltage.



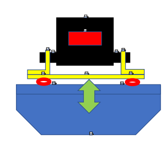
CONTROL AND MEASUREMENT LOCATIONS

CONTROL AND MEASUREMENT LOCATIONS TERMINOLOGY

The question of the "correct" or "true" acceleration on the DUT is not always easy to answer.

In most test specifications, there is only "vague" information and statements for the position of the control transducer.

However, the selected position of the control transducer determines the controlled acceleration and thus the entire test procedure.



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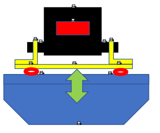
CONTROL AND MEASUREMENT LOCATIONS

CONTROL AND MEASUREMENT LOCATIONS TERMINOLOGY

Control Strategy Terminology Used:
- **Single point / Multi point Control**

- **Averaging Strategies**
  - Athematic Average - Average of multiple checkpoint locations
  - Weighted Averaging where a weighting factor is applied to individual locations before averaging
  - Extremal - computed from the Maximum (or Minimum) extreme value for each checkpoint location



CONTROL AND MEASUREMENT LOCATIONS

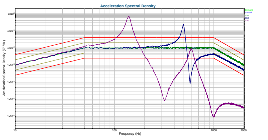
INFLUENCE OF THE DIFFERENT CONTROL STRATEGIES

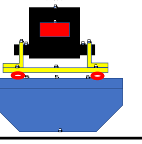
Control Types
Input Control
Response Control

Single Reference Control
Multiple Reference Control

Limit Control
- Limiting / Notching
- Superseding (Boosting)

Equipment System Limits





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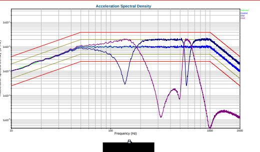

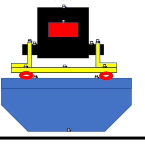

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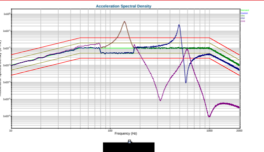
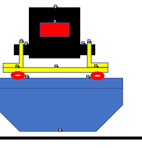


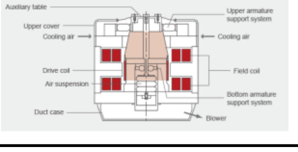


GENERAL CONTROLS - MOTION CONTROL

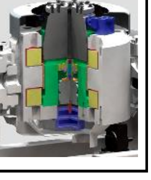
MOTION CONTROLS

Single Axis Testing

The motion induced by the shaker system should be such that the fixing points of the test item move substantially parallel to the axis of excitation.



What Does This Mean with regard to our Shaker System?



WHAT CHECKS SHOULD WE MAKE ON CROSS AXIS ACCELERATIONS?

MIL-STD-810 ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS

Standard	Summary of Standard	Additional Notes
Mil Std 810H	Less than 50% below 500 Hz Less than 100% above 500 Hz	If exceeded, source shall be identified and addressed
Mil Std 810G	Less than 45% of the drive axis (20% for the Spectral Density)	Frequency reference removed! If exceeded, source shall be identified and addressed
Mil Std 810F	Less than 45% of the drive axis any frequency (20% for the Spectral Density)	Also contains a note that cross axis spectral density often has high narrow peaks. Consider tailoring cross-axis tolerances
Mil Std 810E	NO REQUIREMENT	
Mil Std 810D	NO REQUIREMENT	

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CROSS AXIS ACCELERATIONS

DEF STAN 00-35
Environmental Handbook for Defence Material - Part 3 Environmental Test Methods

Standard	Summary of Requirement	Additional Notes
DEF STAN 00-35 Issue 5 (2017)	Less than 50% below 500 Hz Less than 100% above 500 Hz The out of axis overall RMS should not exceed 50% of the specified in-axis vibration	If exceeded, source shall be identified and addressed
DEF STAN 00-35 Issue 4 (2006)	**Random** - spectral content less than specified in-axis and out of axis overall RMS should not exceed 50% **Sine** - Less than 50% below 500 Hz Less than 100% above 500 Hz	Cross Axis to be checked prior to conducting the test. At some frequencies or on large or high mass items – cross axis or rotational motion in excess of requirements shall be monitored and stated in the test report

CROSS AXIS ACCELERATIONS

RTCA DO-160
EUROCAE ED-14
Environmental Conditions and Test Procedures For Airborne Equipment

Standard	Summary of Requirement	Additional Notes
RTCA DO-160G Section 8 (2010)	No specific requirement.	The test tolerances / control parameters do not seem to have been updated since 1997.
RTCA DO-160F Section 8 (2007)	"Motion should be parallel and fixture rigid and symmetrical"	However, there may be additional guidance within DO-357 – User Guide Supplement to DO-160G
RTCA DO-160E Section 8 (2007)		
RTCA DO-160D Section 8 (1997)		

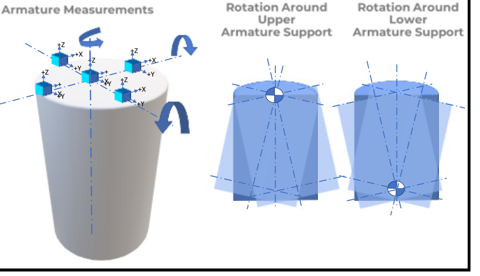
CROSS AXIS ACCELERATIONS

EN 60068-2-64
Environmental Conditions And Test Procedures

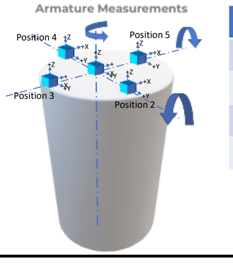
Standard	Summary of Requirement	Additional Notes
EN 60068-2-64	Motion of fixing points to be in phase and amplitude rectilinear to direction of excitation. Less than 50% below 500 Hz Less than 100% above 500 Hz The out of axis overall RMS should not exceed 50% of the specified in-axis vibration	At some frequencies or with large-size or high-mass specimens, it may be difficult to achieve these values. Also, in those cases where the relevant specification requires severities with a large dynamic range, it may also be difficult to achieve these. In such cases, the relevant specification shall state which of the following requirements applies: a) any cross-axis motion in excess of that given above shall be stated in the test report; b) cross-axis motion which is known to offer no hazard to the specimen need not be monitored

SHAKER ARMATURE ROTATIONAL MOTIONS (ARMATURE GUIDANCE SYSTEMS)

MOTION CONTROLS

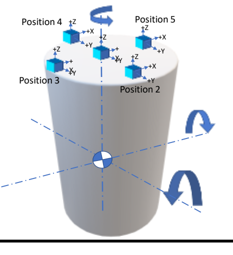


RIGID ROTATIONAL MOTIONS OF SHAKER ARMATURE (ARMATURE GUIDANCE SYSTEM)



Motion	Measurement Position				
	1	2	3	4	5
Rotation Around Z Axis	-	+X Axis	+ Y Axis	-X Axis	-Y Axis
Rotation About Y Axis	-	-	-Z Axis	-	+Z Axis
Rotation About X Axis	-	-Z Axis	-	+Z Axis	-

RIGID ROTATIONAL MOTIONS OF SHAKER ARMATURE (ARMATURE GUIDANCE SYSTEM)



Motion	Measurement Position				
	1	2	3	4	5
Rotation Around Z Axis	-	+X Axis	+ Y Axis	-X Axis	-Y Axis
Rotation About Y Axis	+Y Axis	+Y Axis -Z Axis	-Z Axis	+ Y Axis + Z Axis	+Z Axis
Rotation About X Axis	-X Axis		-X Axis +Z Axis		-X Axis -Z Axis

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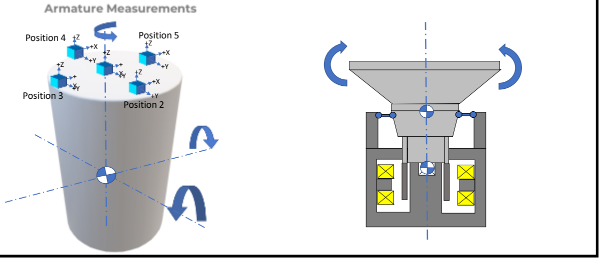
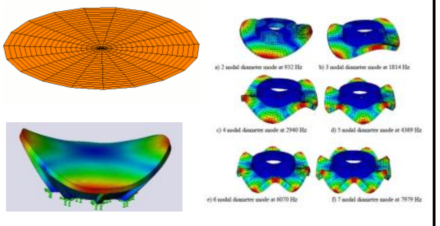


FIXTURE MODE SHAPES

Diaphragming of the Armature and Resonance of the Fixture can lead to large cross axis motion at specific frequencies

Watch For Phase Shifts in Your Measurement Channels

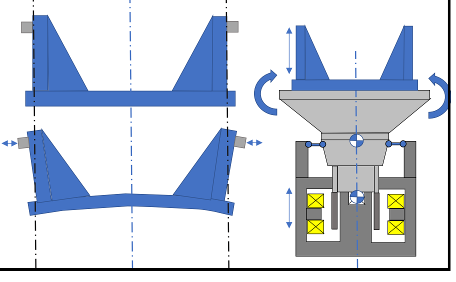


ARMATURE / FIXTURE MODE SHAPES AFFECTS ON CROSS AXIS EXCITATION

Armature and Fixture Resonances and Mode Shapes

Diaphragming of the Armature and Resonance of the Fixture can lead to large cross axis motion

Watch For Phase Shifts in Your Measurement Channels



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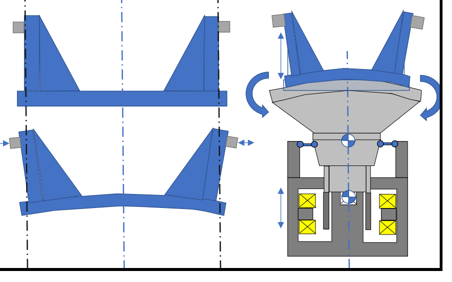


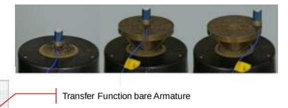
ARMATURE / FIXTURE MODE SHAPES AFFECTS ON CROSS AXIS EXCITATION

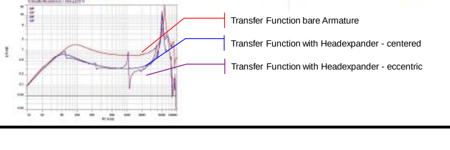
Eccentric loads cause Cross Acceleration:

the center of gravity (CoG) of the specimen is important!

Practical Example:

Sensor Weight app. 20 gr





CROSS AXIS ACCELERATIONS

WHAT SHOULD I DO? HOW CAN A VIBRATION CONTROLLER CAN HELP?

Action	Summary of Requirement	Vibration Software Features
Preventative Maintenance	Bare Armature / Slip Table Characterisation And Regular Comparisons	Set up a regular maintenance test Saved graph layout with baseline traces for comparison. Cut and Paste Measurements into graph layouts
Add More Measurement Channels	Measure Armature Surface to Characterise Motion Measure Cross Axis During Test	Add additional Channels (+16 Channels?) +5 Triaxials? Automated Test Reports - Add triaxial measurement of fixture attachments to test reports Add Math Trace to show limits
Pre- Cursor Tests	Fixture Resonance Search Low Level Test with Test Item Installed	Analyser Functions to review transfer Functions, Coherence and Phase Relationships / Cross Spectrum

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WHAT SHOULD I DO? HOW CAN A VIBRATION CONTROLLER CAN HELP?

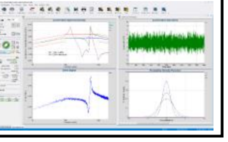
CROSS AXIS ACCELERATIONS

Action	Summary of Requirement	Vibration Software Features
Control / Measurement Accelerometers	Position Close to Test Item / Fixture Interface	Multiple channel control - average / maximum control Measure Cross Axis During Test
Channel Aborts		Set Channel Limits / Aborts for measurement Channels
Spectrum Notching / Limiting	After identifying cause of cross axis motion - create a limit or notch profile	Vibration Software comes with limiting and notching capability as standard / option

RANDOM TEST PARAMETERS

RANDOM TEST CONTROL PARAMETERS

- Power Spectral Density
- Statistical Random Sampling Error (Degrees of Freedom)
- Analyser Frequency Bandwidth (Spectral Lines / Resolution)
- Out of Test Frequency Range Response
- ROOT MEAN SQUARE (r.m.s.) (IN BAND and OUT OF BAND)
- Amplitude Distribution / Kurtosis
- Skewness

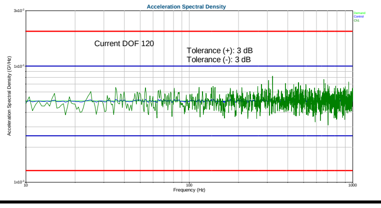


RANDOM TEST PARAMETERS

POWER SPECTRAL DENSITY AMPLITUDE

Maximum local amplitude deviation of the control ASD in relation to the specified ASD

± g²/Hz Tolerance (usually in decibels)

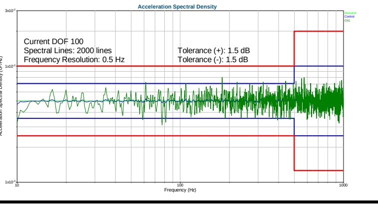


RANDOM TEST PARAMETERS (RTCA DO160)

POWER SPECTRAL DENSITY AMPLITUDE

Maximum local amplitude deviation of the control ASD in relation to the specified ASD

± g²/Hz Tolerance (usually in decibels)

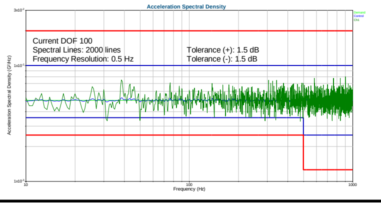


RANDOM TEST PARAMETERS Spectral DENSITY Statistical Accuracy

SPECTRAL DENSITY STATISTICAL ACCURACY - DEGREES OF FREEDOM (DOF)

Maximum local amplitude deviation of the control ASD in relation to the specified ASD

± g²/Hz Tolerance (usually in decibels)



RANDOM TEST PARAMETERS Spectral DENSITY Statistical Accuracy

SPECTRAL DENSITY STATISTICAL ACCURACY - DEGREES OF FREEDOM (DOF)

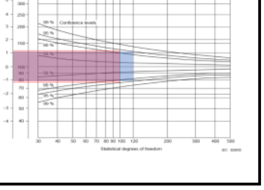
Degrees of Freedom = 2 x Frequency Resolution x Averaging Time

(Guide each FFT Loop provides 2 DoF) - No Overlapping

Mil Std 810	≥ 120 DOF
Def Stan 00-35	≥ 120 DOF
ÊN 60068-2-64	≥ 120 DOF

95% Confidence

AECTP 400	≥100 DOF
RTCA 160G	≥100 DOF



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Vibration Research
SEES Seminar 18th and 19th November Borås, Sweden

POWER SPECTRAL DENSITY AMPLITUDE AND STATISTICAL DEGREES OF FREEDOM

RANDOM TEST PARAMETERS
Spectral DENSITY Statistical Accuracy

Standard	Degrees of Freedom	PSD Tolerances (Control)
Mil Std 810	≥ 120 DOF	± 3 dB
Def STAN 00-35	≥ 120 DOF	± 3 dB
RTCA DO160	≥100 DOF	+3dB / -1,5 dB below 500 Hz ± 3 dB above 500 Hz
AECTP 400	≥100 DOF	± 3 dB below 500 Hz ± 6 dB above 500 Hz
EN 60068-2-64	≥ 120 DOF	± 3 dB

POWER SPECTRAL DENSITY AMPLITUDE AND STATISTICAL DEGREES OF FREEDOM

RANDOM TEST PARAMETERS
Spectral DENSITY Statistical Accuracy

Standard	PSD Tolerances (Control)	Additional Notes / Alleviations	
Mil Std 810H	± 3 dB below 500 Hz ± 6 dB above 500 Hz ± 10% overall g_{rms}	Average Control ± 6 dB below 500 Hz ± 9 dB above 500 Hz ± 25% overall g_{rms}	Extremal Control - 6 dB / + 3 dB below 500 Hz - 9 dB / + 6 dB above 500 Hz ± 25% overall g_{rms}
Def STAN 00-35 Issue 5	± 3 dB	Above 500Hz may allow ±6dB (but no more than 5% of frequencies) Multi-point control: +5dB -10dB at each control ppoint	
RTCA DO160G	+3 / -1.5 dB below 500 Hz ± 3 dB above 500 Hz		
AECTP 400	± 3 dB below 500 Hz ± 6 dB above 500 Hz	maximum of 5 % of the total test control bandwidth	
EN 60068-2-64	± 3 dB	Acknowledges it may be difficult with large / high mass items, wider tolerances may be specified.	

FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS
(Frequency Resolution)

RANDOM Test - Number of FFT lines

- EN 60068-2-64

$$B_e = f_{High} \ / \ n$$

B_e Filter bandwidth
f_{High} Bandwidth should be bigger than 2 times f_2
n number of FFT lines (minimum 200)

- B_e must be chosen in the way, that the first FFT line is 0,5 f_1, so two FFT lines determine the increase of the spectrum.
- If this result gives you two different values, the smaller of them must be chosen.

FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS
(Frequency Resolution)

Standard	Measurement Frequency Resolution (Hz)
Mil Std 810	**2.5 Hz at 25 Hz or below** **5 Hz above 25 Hz** (but use frequency resolution appropriate to the test – wheeled vehicle 1Hz is sufficient
Def STAN 00-35	**Not greater than 5Hz** (Shall be **at least 5 Spectral lines at ½ power point** on any resonances)
RTCA DO160	**Less than 5Hz**
AECTP 400	**Not Specified**
EN 60068-2-64	shall be chosen such that, as a minimum, a frequency line coincides with the frequency f1 in Figure 1 and the first frequency line is at 0,5 of f1; also that two frequency lines define the initial slope. If this gives two different values then the smallest be shall be chosen.

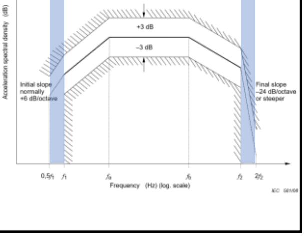
FREQUENCY RESOLUTION (LOW FREQUENCY)

RANDOM TEST PARAMETERS
(Frequency Resolution)

Example:

If f_1 = 5Hz
Two Spectral Lines should define slope between 0,5f_1 and f_1, so resolution would be 2,5Hz

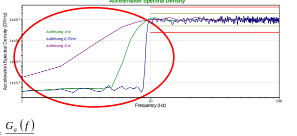
If f_1 = 1Hz
Two Spectral Lines should define slope between 0,5f_1 and f_1, so resolution would be 0,5Hz



FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS
(Frequency Resolution)

RANDOM Test - Number of FFT lines and Displacement



$$G_d\ (f) = \frac{G_a(f)}{\Omega^4}$$

$$d_{rms} = \sqrt{\sum_{i=1}^{N} \frac{G_i \cdot \Delta f}{\Omega_i^4}} = \sqrt{\frac{\Delta f}{(2\pi)^4}} \cdot \sum_{i=1}^{N} \frac{G_i}{f_i^4}$$

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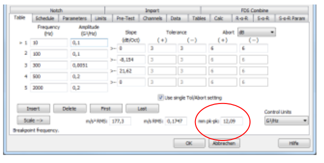
FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS (Frequency Resolution)

RANDOM Test - Number of FFT lines and Displacement

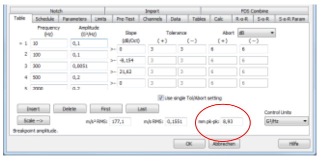


500 FFT lines gives a resolution of the frequency lines of 5 Hz (according to EN standard)

FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS (Frequency Resolution)

RANDOM Test - Number of FFT lines and Displacement



4.000 FFT lines gives a resolution of the frequency lines of 0,5 Hz and a reduction of the required displacement of approximately 25%.

FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS (Half Power Point)

$$\text{½ Power Point (-3dB) Bandwidth } (Hz) = \frac{Resonance\ Frequency\ (Hz)}{Q\ Factor}$$

$$\text{Q Factor} = \frac{1}{2*Damping\ Ratio(\xi)}$$

$$\text{Test Minimum Resolution } (\Delta Hz) = \frac{\text{½ Power Point (−3dB Bandwidth) } (Hz)}{5}$$

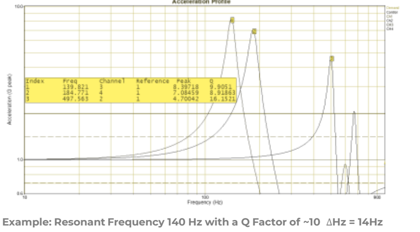
Example: Resonant Frequency 140 Hz with a Q Factor of 10

$$\text{½ Power Point (-3dB Bandwidth) } (Hz) = \frac{140Hz}{10} = 14Hz$$

$$\text{Test Minimum Resolution } (\Delta Hz) = \frac{14Hz}{5} = 2{,}8Hz$$

FREQUENCY RESOLUTION

RANDOM TEST PARAMETERS (Half Power Point)



Example: Resonant Frequency 140 Hz with a Q Factor of ~10 ΔHz = 14Hz

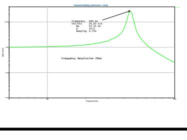
$$\text{Test Minimum Resolution } (\Delta Hz) = \left(\frac{\text{½ Power Point (−3dB Bandwidth) } (Hz)}{5}\right) = \frac{14Hz}{5} = 2{,}8Hz$$

FREQUENCY RESOLUTION

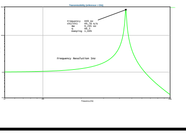
RANDOM TEST PARAMETERS (Half Power Point)

Higher Lines = better frequency resolution for control
For best and most accurate control / excitation of resonances, minimum of 5x FFT lines should exist at the 3 dB frequency bandwidth of the resonance

Test 1
- Frequency Resolution 20Hz
- BW 43,43 / Q - factor of 10,6
- Response amplitude 3,8g_{RMS}



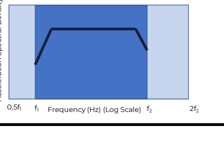
Test 2
- Frequency Resolution 1Hz
- BW 9,3 / Q - factor of 48,3
- Response amplitude 4,3g_{RMS}



OUT OF TEST FREQUENCY RANGE

RANDOM TEST PARAMETERS (Frequency Range)

Specifications require that the vibration response outside the test frequency shall be minimized.
And the frequency range of the overall measurement system shall extend below and above the test frequency range
Higher acceleration levels can be happen through non - linear effects, too much clipping from the controller or overdrive of the power amplifier.



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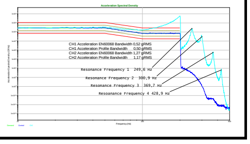
OUT OF TEST FREQUENCY RANGE

RANDOM TEST PARAMETERS (Frequency Range)

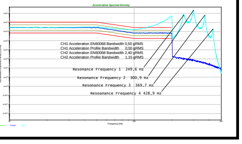
Depending on the clipping algorithmic from the controller you can create out of band energy when you define a setup with less as 3 sigma.
The EN60068-2-64 standard said only - you must have more as 2,5 sigma.
Higher Sigma value - mean higher peak acceleration and a higher damage potential for the test item, but you have a higher dynamic range.



OUT OF TEST FREQUENCY RANGE

RANDOM TEST PARAMETERS (Frequency Range)

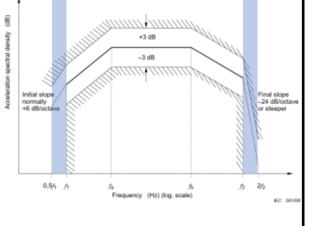
High risk when the power amplifier is clipping. The amplifier generates many harmonics, maybe outside the test profile.
This can be happen immediately when you have RANDOM profiles with a upper frequency below 1.000Hz.
The max. RMS output voltage is appr. 50% of the maximum PEAK output voltage.



OUT OF TEST FREQUENCY RANGE

RANDOM TEST PARAMETERS (Frequency Range)

- PARAMETERS ASSOCIATED WITH FREQUENCY RANGE
- MEASUREMENT FREQUENCY RANGE (OVER SAMPLING)
- INITIAL AND FINAL SLOPES
- IN BAND AND OUT OF BAND RMS



POWER SPECTRAL DENSITY AMPLITUDE AND STATISTICAL DEGREES OF FREEDOM

RANDOM TEST PARAMETERS (g_{RMS} Tolerance)

Standard	g_{rms} Tolerance (Control)	Additional Notes / Alleviations	
Mil Std 810H	± 10% overall g_{rms}	Average Control Individual Channels ± 25% overall g_{rms}	Extremal Control Individual Channels ± 25% overall g_{rms}
Def STAN 00-35 Issue 5	±10% at reference point	± 2 dB at reference point	
RTCA DO160G	+20% -5%		
AECTP 400	±10% of the preset RMS value at Control point	Individual Fixing Points ±25% of the preset RMS value	
EN 60068-2-64	±10% at reference point		

OUT OF TEST FREQUENCY RANGE RESPONSES

RANDOM TEST PARAMETERS (IN and OUT Band RMS value)

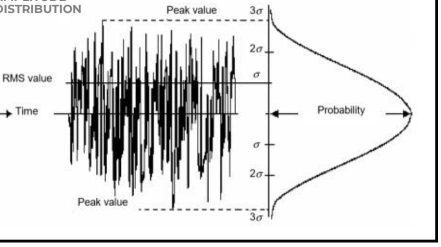
Standard	Out of Band Noise / Response	Frequency Range
DEF STAN 00-35 Issue 5	Out of Band RMS % shall be less than 20%	Out of Test Frequency shall be measured upto 5.000Hz or 5 times the driving frequency whichever is lesser
EN 60068-2-64	Not Specified	The frequency range of the measuring system shall extend from at least 0,5 times the lowest frequency (f_1) to 2,0 times the highest frequency (f_2) of the test frequency range
Mil Std 810H	Not Specified	Not Specified
RTCA DO160G	Not Specified	Not Specified
AECTP 400	Not Specified	Not Specified

$$\text{Out of Test Frequency Range Response} = \left(\frac{\text{Full Bandwidth Grms}}{\text{In Band Grms}} - 1\right) * 100\%$$

AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

RANDOM TEST PARAMETERS (Amplitude Distribution)

AMPLITUDE DISTRIBUTION

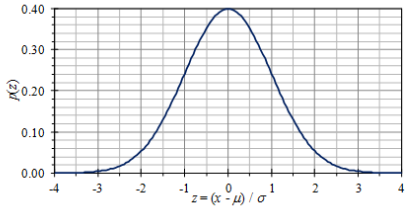


AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

RANDOM TEST PARAMETERS (Amplitude Distribution)

GAUSSIAN DISTRIBUTION

$$p(\chi) = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2(\chi/\sigma)^2}$$



AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

RANDOM TEST PARAMETERS (Amplitude Distribution)

SIGMA LIMITING / CLIPPING

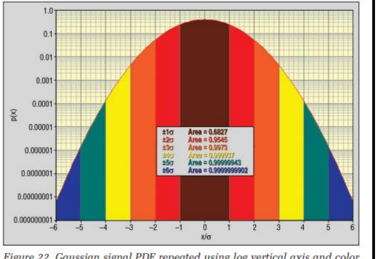


Figure 22. Gaussian signal PDF repeated using log vertical axis and color marking ±nσ bands.

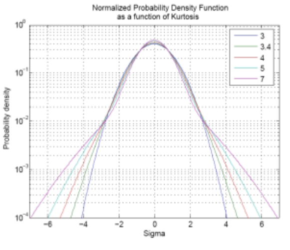
AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

RANDOM TEST PARAMETERS (Amplitude Distribution)

KURTOSIS

GAUSSIAN (NORMAL) DISTRIBUTION HAS A KURTOSIS OF 3

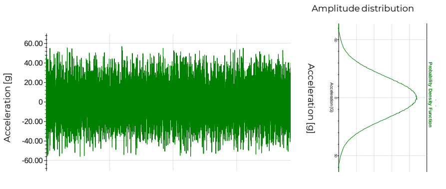
KURTOSIS TOLERANCES ARE SOMETIMES DEFINED AT ±10%



AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

RANDOM TEST PARAMETERS (Amplitude Distribution)

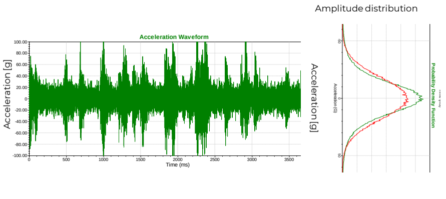
KURTOSIS 3



AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

RANDOM TEST PARAMETERS (Amplitude Distribution)

KURTOSIS 10



AMPLITUDE DISTRIBUTION - CLIPPING AND KURTOSIS

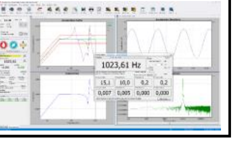
RANDOM TEST PARAMETERS (Amplitude Distribution)

Standard	Amplitude Distribution	Additional Notes
DEF STAN 00-35 Issue 5	Nominally Gaussian	Shall contain all occurrences up to 2,7 SD, while occurrences greater than 3 SD shall be kept to a minimum.
EN 60068-2-64	Instantaneous values at reference point shall be approximately normal (Gaussian)	The drive signal clipping – the Crest Factor at the reference point shall be examined to ensure it contains **at least 2,5 times** the rms value. (Crest Factor applies to each checkpoint) **Probability Density** shall be computed for the reference point **during testing**
Mil Std 810H	Gaussian at Drive Signal	Drive limiting should not be invoked and shall never be below 3
RTCA DO160G	Random Signal shall have a Gaussian distribution	The control signal (Drive?) **may** be limited to 3 times the g_{rms}
AECTP 400	Nominally Gaussian	Shall contain all occurrences up to 2,7 SD, while occurrences greater than 3 SD shall be kept to a minimum.

SINE TEST CONTROL PARAMETERS

SINE TEST PARAMETERS (General)

- Amplitude (g peak)
- Single point Control
- Multipoint control (average / Max)
- Frequency
- Signal Tolerance / distortion
- Tracking filters - Bandwidth



SINE TEST PARAMETERS

SINE TEST PARAMETERS (Amplitude)

Standard	Amplitude	Additional Amplitude Tolerance	
DEF STAN 00-35 Issue 5	Test Level Control **±10%**	General Multi-Point Control: ± 5 dB at each Control Point Additional Control Alleviation (Annex D) : ±10% below 500Hz, ±20% above 500Hz **Amplitudes outside the range ±10%** of the specified value should **not total more than 5% of control frequency range**	
EN 60068-2-6	Test Level Control **±15%**	Checkpoints ±25% below 500Hz Checkpoints ±50% above 500Hz (Note: Tolerance includes ±5% Instrumentation error.)	
Mil Std 810H	Test Level Control **±10%**	Multi-Point Control	
		Average Control ± 25% below 500 Hz ± 50% above 500 Hz	Maxi Control +10% / -25% below 500 Hz +10% / -50% above 500Hz
RTCA DO160G	Test Level Control **±10%**	No additional tolerances specified	
AECTP 400	Test Level Control **±15%**	± 25% at the fixing points up to 500 Hz ± 50% at the fixing points above 500 Hz	

SINE TEST PARAMETERS

SINE TEST PARAMETERS (Frequency)

Standard	Frequency Tolerance
DEF STAN 00-35	±2% or ±1.0 Hz of the specified value, whichever is the greater.
EN 60068-2-6	Endurance Tests Fixed frequencies: ±2 % Swept frequencies: ±0,05 Hz up to 0,25 Hz; ±20 % from 0,25 Hz to 5 Hz; ±1 Hz from 5 Hz to 50 Hz; ±2 % above 50 Hz. Measurement of Critical Frequencies ±0,05 Hz up to 0,5 Hz; ±10 % from 0,5 Hz to 5 Hz; ±0,5 Hz from 5 Hz to 100 Hz; ±0,5 % above 100 Hz
Mil Std 810H	Frequency ± 0.1 %
RTCA DO160G	±2% (Accuracy of Instrumentation)
AECTP 400	Test Profile Frequencies ±0,05 Hz up to 0,25 Hz; ±20 % from 0,25 Hz to 5 Hz; ±1 Hz from 5 Hz to 50 Hz; ±2 % above 50 Hz. Measurement of Critical Frequencies ±0,05 Hz up to 0,5 Hz; ±10 % from 0,5 Hz to 5 Hz; ±0,5 Hz from 5 Hz to 100 Hz; ±0,5 % above 100 Hz

SINE TEST PARAMETERS

SINE TEST PARAMETERS (Distortion / Signal Tolerance)

Standard	Distortion / Signal Tolerance	Notes
DEF STAN 00-35 Issue 5	**Signal Tolerance 5% or less**	**Unfiltered to be measured up to 5,000Hz or 5 times the drive frequency which ever is the lesser**
EN 60068-2-6	**Signal Tolerance shall not exceed 5%**	Reference Point shall be measured up to 5,000Hz or beyond or five times the drive frequency (a tracking filter shall be used if Signal Tol. above 5%)
Mil Std 810H	**±5% on g_{rms} values**	See distortion equation below
RTCA DO160G	**Not Specified**	
AECTP 400	**±5% on g_{rms} values**	See distortion equation below

$$\text{Distortion}(\%) = \frac{\sqrt{a^2_{unfiltered} - a^2_{filtered}}}{a_{filtered}} \times 100$$

$$\text{Signal Tolerance} = \left(\frac{a_{unfiltered}}{a_{filtered}} - 1\right) \times 100$$

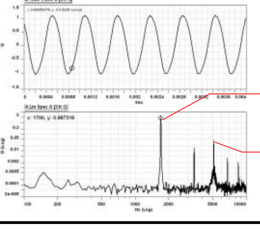
$$\frac{D}{100} = \sqrt{\left(\frac{T}{100}\right)^2 + \frac{2 * T}{100}}$$

Signal Tolerance of 5% corresponds to a distortion of 32%

SINE TEST PARAMETERS

SINE TEST PARAMETERS (Distortion / Signal Tolerance)

Harmonic Distortion of the shaker system



Excitation of the resonance frequency via the 3rd harmonic of the excitation signal

Resonance frequency of the shaker armature ~ 5.400Hz

SINE TEST PARAMETERS

SINE TEST PARAMETERS (Distortion / Signal Tolerance)

Harmonic Distortion of the shaker system

- Fundamental 50,0 m/s²RMS
- 3rd Harmonic 15,0 m/s²RMS
- 5th Harmonic 5,5 m/s²RMS

$$a_{total_{RMS}} = \sqrt{a_{0_{RMS}}{}^2 + a_{3_{RMS}}{}^2 + a_{5_{RMS}}{}^2} = 52{,}49\, m/s^2{}_{RMS}$$

Signal tolerance (Term from the EN 60068-2-6)

$$T = \left(\frac{a_{total_{RMS}}}{a_{o_{RMS}}} - 1\right) * 100\ \% \qquad T = \left(\frac{52{,}49\, m/s^2}{50{,}00\, m/s^2} - 1\right) * 100\,\% = 4{,}98\,\%$$

Distortion

$$\frac{k}{100} = \sqrt{\left(\frac{T}{100}\right)^2 + \frac{2\, x\, T}{100}} \qquad k = \sqrt{\left(\frac{4{,}98\,\%}{100}\right)^2 + \frac{2\, x\, 4{,}98\,\%}{100}}\ x\ 100\ \% = 31{,}95\,\%$$

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SINE TEST PARAMETERS

SINE TEST PARAMETERS (Tracking Filters)

Standard	Notes
DEF STAN 00-35 Issue 5	Advice - Tracking Filter response should be at lest 5 times the controller compression speed. The filter band width should be less than the drive frequency!
EN 60068-2-6	
Mil Std 810H	Not mentioned
RTCA DO160G	Constant Bandwidth: 10Hz max from 10-200Hz; 50Hz max from 200to 2kHz Constant Percentage Bandwidth: less than 23%
AECTP	Not mentioned

Response Time $(T_r) = \frac{1}{Filter\ Bandwidth(Hz)}$

10Hz Constant Bandwidth = 100ms Response Time

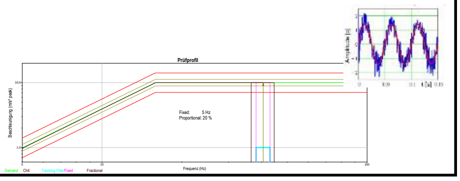
10% Constant Percentage Bandwidth = 10 periods at the drive frequency

SINE TEST PARAMETERS

SINE TEST PARAMETERS (Tracking Filters)

In the case of rattling test specimens, the calculation of the "correct" control value of the SINUS excitation is necessary. It is important if the test:

- was performed with or without a tracking filter.
- Properties such as bandwidth and filter quality of the tracking filter.

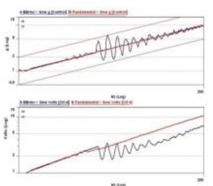


SINE TEST PARAMETERS

SINE TEST PARAMETERS (Tracking Filters)

Influence on the test results

- as an example a higher / lower test level



The measurement without tracking filter clearly shows the oscillation during control, caused by the rattling of the test setup.

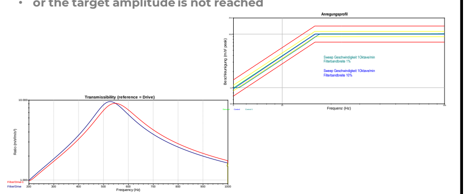
The drive signal with tracking filter is higher than with the measurement without tracking filter, which causes a higher dynamic stress on the test specimen.

SINE TEST PARAMETERS

SINE TEST PARAMETERS (Tracking Filters)

Influence on the test results

- the measured resonance frequency is shifted
- or the target amplitude is not reached

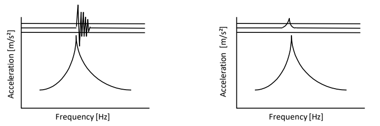


SINE TEST PARAMETERS

SINE TEST PARAMETERS (Tracking Filters)

Rules from the signal analysis

- The smaller the bandwidth and the faster the amplitude rise, the longer the settling time of the filter.
- With very dynamic signals and the use of tracking filters, the control signal can become unstable.



Too high control speed causes the tracking filter to oscillate

lower control speed prevents oscillating of the tracking filter

SHOCK TEST CONTROL PARAMETERS

SHOCK TEST PARAMETERS (General)

- Classical Shock Tolerances
- Pulse Shapes
- Acceleration Time History
- Velocity Change
- Frequency Response Filters
- Compensation pulse effects on Frequency Content

CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Pulse Shape)

Standard	Pulse Shapes					
	Half Sine	Terminal-Peak Sawtooth	Trapezoidal	Damped Sinusoidal	Synthesised Shock Response Spectrum	Time Waveform Replication
Mil Std 810 H Method 516	✓	✓	✓		✓	✓
Def STAN 00-35 Issue 5 M3	✓	✓	✓	✓	✓	✓
RTCA DO160G Section 7		✓				
AECTP 400 (Method 403) 415 417	✓	✓	✓		✓	✓
EN 60068-2-27 and -81	✓	✓	✓		✓	✓

CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Time Definition)

T_D : duration of nominal pulse (tolerance on T_D is ± 10%).

A : peak acceleration of nominal pulse

T_1 : minimum time duration which the pulse shall be monitored for shocks produced using a conventional mechanical shock machine.

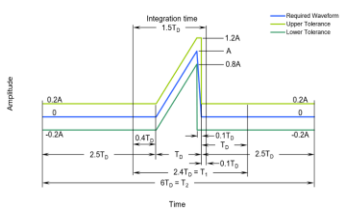
T_2 : minimum time during which the pulse shall be monitored for shocks produced using a vibration exciter.

The duration associated with the post-pulse slope of a terminal peak sawtooth and durations associated with the pre and post slopes of a trapezoidal pulse should be less than 10% T_D.

The tolerance on velocity, due to combined effects of any amplitude and/or duration deviations from the nominal pulse, is limited to ± 20% of the pulse's nominal velocity.

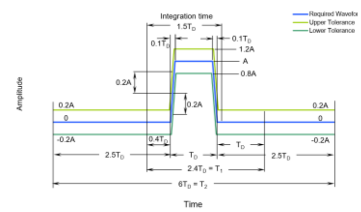
CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Time Definition)
Mil Std 810H, Def Stan 00-35
AECTP 403



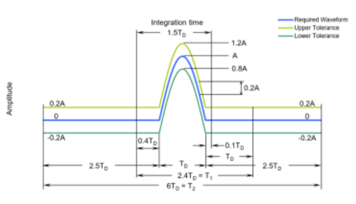
CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Time Definition)
Mil Std 810H, Def Stan 00-35
AECTP 403



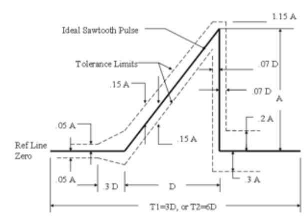
CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Time Definition)
Mil Std 810H, Def Stan 00-35
AECTP 403



CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Time Definition)
Mil Std 810G, RTCA 160G



The Tolerance on Velocity Change = ±10% from Nominal Pulse (with integration time $0.4T_D$ before the pulse and $0.1T_D$ after the pulse)

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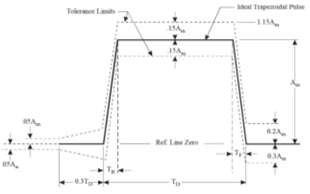
CLASSICAL SHOCK PARAMETERS

SHOCK TEST PARAMETERS (Time Definition) Mil Std 810G



Monitor Time History 3 times Pulse Duration (with Shock Centred).
The Tolerance on velocity = 10% with integration time 0,4T_D before the pulse and 0,1T_D after the pulse.
T_R and T_F = less than or equal to 0,1T_D

CLASSICAL SHOCK PARAMETERS (COMPENSATION PULSE AFFECTS)

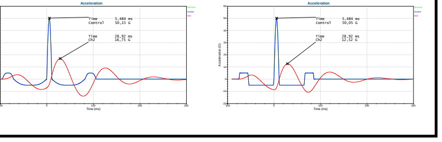
Compensation Pulse Effect Frequency Content

Simulation with different pre- and post-pulses
- Response functions on the real test object with different test definitions

Test 1
- Pre- and post-pulse half sine, 10%
- Response Amplitude DUT ~17g_{PEAK}

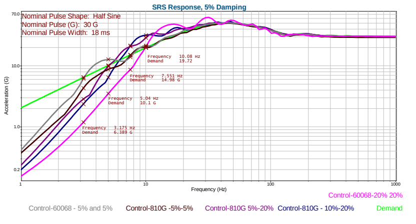
Test 2
- Pre- and post-pulse rechtangular, 10%
- Response Amplitude DUT ~13g_{PEAK}

~30% less acceleration on our DUT



CLASSICAL SHOCK PARAMETERS (COMPENSATION PULSE AFFECTS)

Compensation Pulse Effect Frequency Content



The drop-off at f_1 is considered to be acceptable if and only if the lowest resonant frequency of the item being tested (f_N), is greater than f_1 by a factor of two or more ($f_N \geq 2 * f_1$)

CLASSICAL SHOCK PARAMETERS (COMPENSATION PULSE AFFECTS)

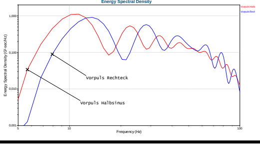
Compensation Pulse Effect Frequency Content

Simulation with different pre- and post-pulses
- Response functions on the real test object with different test definitions

Test 1
- Pre- and post-pulse half sine, 10%
- Amplitude DUT ~17g_{PEAK}

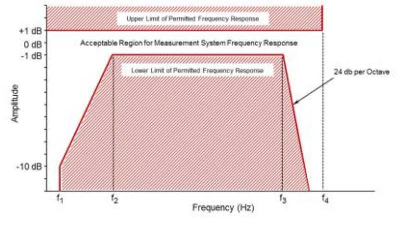
Test 2
- Pre- and post-pulse rechtangular, 10%
- Amplitude DUT ~13g_{PEAK}

~30% less acceleration on our DUT



CLASSICAL SHOCK PARAMETERS

Measurement Instruments Frequency Response Def Stan 00-35



CLASSICAL SHOCK PARAMETERS

Measurement Instruments Frequency Response Def Stan 00-35

Duration of Pulse (ms)	Low Frequency Cut Off (Hz)		High Frequency Cut Off (kHz)	Frequency at Which Response May Rise Above +1 dB (kHz)
	f_1	f_2	f_3	f_4
16, 18, 25 and 30	0.2	1	1	2
11	0.5	2	1	2
5 and 6	1	4	2	4
2 and 3	2	10	5	10
1	4	20	10	20
0.5	10	50	15	30
0.2 and 0.3	20	120	20	40

Note: Ideally there should be no significant phase shift over the frequency range of the measurement. However, a constant phase shift for all measurement channels may be acceptable with the agreement of the Test Specifier.

The requirements apply to the acceleration frequency response of the measuring system without the use of a low-pass filter on the control signal. When a low-pass filter is used, the characteristics of the filter should be such that its cut-off frequency (–3 dB point) is not lower than:

$$\text{Cut off frequency of low pass filter in kHz} = \frac{1.5}{\text{pulse duration in ms}}$$

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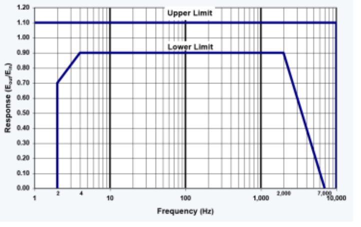
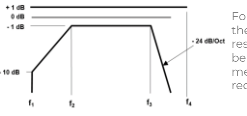
CLASSICAL SHOCK PARAMETERS



RTCA Operational and Crash Safety Shock Durations are either 11ms or 20ms

CLASSICAL SHOCK PARAMETERS



For shocks durations less than 3 ms, the high frequency cut-off and +1dB response frequencies indicated may be inadequate if accurate measurement of the pulse shape is required.

Duration of Pulse (ms)	Low frequency Cut off (Hz)		High frequency Cut Off (kHz)	Frequency at which response may rise above +1 dB (kHz)
	f_1	f_2	f_3	f_4
25	0.2	1	1	2
11	0.5	1	1	2
6	1	4	2	4
3	4	16	5	25
<3	4	16	15	25

CLASSICAL SHOCK PARAMETERS

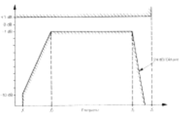
SCHOCK Test - Frequency range EN 60068-2-27

- **Half-Sine Schock with $50g_{PEAK}$ und 11ms**

lower frequency f_u : $f_u = \leq \frac{1}{2\cdot\pi}\frac{1}{20\cdot D} = \frac{1}{2\cdot\pi}\frac{1}{20\cdot 0{,}011s} = 0{,}7Hz$

upper frequency f_o : $f_o = \geq \frac{10}{D} = \frac{10}{0{,}011s} = 909Hz$

Pulse Width ms	lower Frequency f_u Hz		upper Frequency f_o kHz
	f_1	f_2	f_3
6	1	4	2
11	0,5	2	1
18	0,2	1	1



CLASSICAL SHOCK PARAMETERS (FREQUENCY CONTENT)

Simulation with different frequency ranges - pulse width 3ms

- **Response functions on the real test object with different test definitions**

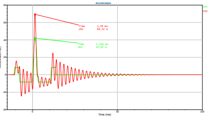
Test 1

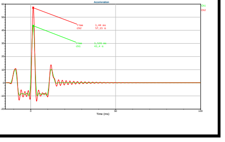
- Frequency content 10Hz to 1.500Hz
- Amplitude DUT ~$69g_{PEAK}$

Test 2

- Frequency content 10Hz to 400Hz
- Amplitude DUT ~$57g_{PEAK}$

~20% less acceleration on our DUT





ANY QUESTIONS?

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