谢拉林 SEES

(Nearly) 50 Years of Environmental Engineering

Kjell Ahlin
Xielalin Consulting, Sweden
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Kjell Ahlin Short CV

- KTH, Telecommunication Theory, PhD student, ass. professor 66 – 72
  Where I learned signal processing, we started to go digital
- Tre Konsulter AB, 3K 72 – 87
  We used digital signal processing for mechanical problems
- Akustikbyrån, Ingemansson, Saven EduTech 87 – 03
  A lot of consulting projects, courses
- BTH, Mechanical Engineering, full professor, project leader 03 – 11
  Manager International Master Program in Measurement Techniques and Structural Dynamics, Nonlinear Systems
- Xielalin Consulting 10 –

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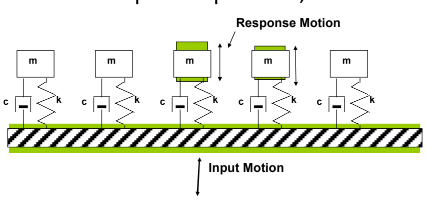
Shock Response Spectrum, SRS



Sampled time history acceleration input.
How to calculate response to SDOF?
In the 1970s many people, including me, used the digital *impulse invariant* filter.
That method has an accuracy problem.

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AN IMPROVED RECURSIVE FORMULA
FOR CALCULATING SHOCK RESPONSE SPECTRA

David O. Smallwood
Sandia National Laboratories
Albuquerque, New Mexico 87185

Currently used recursive formulas for calculating the shock response spectra are based on an impulse invariant digital simulation of a single degree of freedom system. This simulation can result in significant errors when the natural frequencies are greater than 1/6 the sample rate. It is shown that a ramp invariant simulation results in a recursive filter with one additional filter weight that can be used with good results over a broad frequency range including natural frequencies which exceed the sample rate.

Shock and Vibration Bulletin, No. 51, May 1981.

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I did two things!

1. Tried to use Smallwood's method to derive ramp invariant filter for the complex pole/residue pair for a linear mechanical system.

$$H(s) = \sum_i \frac{R_i}{s - s_i} + \frac{R_i^*}{s - s_i^*}$$

2. Tried to understand why ramp invariant was better than impulse invariant.

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Ramp invariant filter for the complex pole pair Using Smallwood's method to calculated coeffs

```
T = 1/fs;
for mm = 1:length(modes)
   m = modes(mm);     a = -real(LLL(m));     b = -imag(LLL(m));
   r = real(RRR(m));     i = imag(RRR(m));     E = exp(-a*T);
   F = exp(-2*a*T);    C = cos(b*T)*E;     S = sin(b*T)*E;     A = [1,-2*C,F];

   b1 = b^2*r + T*i*b*a^2 - 2*a*i*b + b^2*r*a*T + 2*C*a*i*b - 2*b*r*a*S ...
     +a^3*r*T + i*b^3*T -r*a^2 +a^2*i*S -b^2*r*C -b^2*i*S + C*r*a*a;

   b2 = b^2*r*F - 2*a*i*b*F +2*b^2*i*S  + 2*a*i*b -2*a^2*i*S +r*a^2 -2*C*b^2*r*a*T ...
     -b^2*r -r*a^2*F +4*b*r*a*S -2*C*a^3*r*T -2*C*T*i*b^3 -2*C*i*b*T*a^2;

   b3 = a^3*r*T*F +i*b^3*T*F +r*a^2*F + 2*a*i*b*F +b^2*r*a*T*F -C*r*a^2 +a^2*i*S ...
     +T*i*b*a^2*F -2*C*a*i*b -b^2*i*S +C*b^2*r -b^2*r*F -2*b*r*a*S;

   B = [b1 b2 b3]*2/T/(a^2 + b^2)^2;     (B(1)+B(2)+B(3))/(A(1)+A(2)+A(3));
```

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Impulse Invariant and *Ramp Invariant* filters are members of a family building on the convolution integral.

$$y(t)=\int_0^t h(t-\tau)\cdot x(\tau)d\tau \qquad H(s)=\frac{1}{s+a} \qquad h(t)=exp(-at)$$

$$y(t)=\int_0^t exp\{-a(t-\tau)\}\cdot x(\tau)d\tau$$

$$y(nT+T)=\int_0^{nT+T} exp\{-a(nT+T-\tau)\}\cdot x(\tau)d\tau=$$

$$=exp(-aT)\cdot\{\int_0^{nT} exp\{-a(nT-\tau)\}\cdot x(\tau)d\tau+\int_{nT}^{nT+T} exp\{-a(nT-\tau)\}\cdot x(\tau)d\tau\}=$$

$$=exp(-aT)\cdot\{y(nT)+\int_0^T exp(au)\cdot x(u+nT)du\}$$

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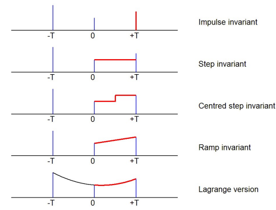
Filter type is determined of how we handle the input between nT and nT+T

$$\int_{nT}^{nT+T} exp\{-a(nT-\tau)\}\cdot x(\tau)d\tau$$



We need a continuous approximation of the input between 0 and T from the samples at 0 and T

It may be seen as a convolution between the samples and a convolution kernel

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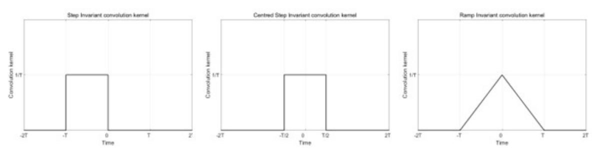
As we have a *convolution* in time domain, it corresponds to a *multiplication* in the frequency domain.

The wanted result is multiplied by the Fourier transform of the convolution kernel.
That is the key to understanding!



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What is the difference between the methods?
All sampled systems have aliasing.

$$Y_a(f)=Y(f)+\sum_n Y(f-n\cdot f_s)+Y(f+n\cdot f_s)$$

We get the wanted function Y(f) plus contributions from the function around multiples of the sampling frequency.

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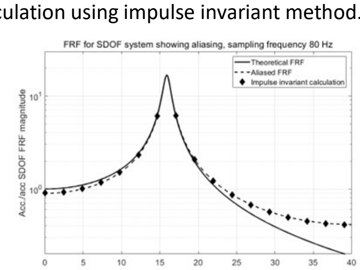
The aliasing may be shown and compared with calculation using impulse invariant method.



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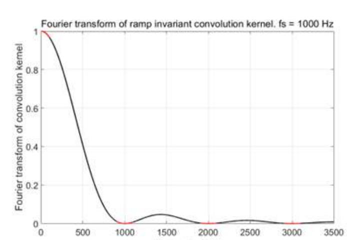
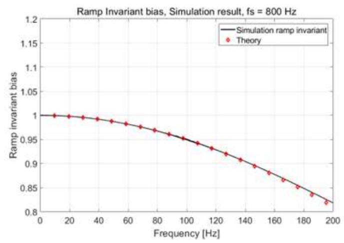
Fourier transform of ramp convolution kernel has zeros at multiples of sampling frequency.
Mitigates aliasing. But at the cost of a bias error!



The bias for Ramp Invariant is the Fourier transform of the convolution kernel, a triangle.

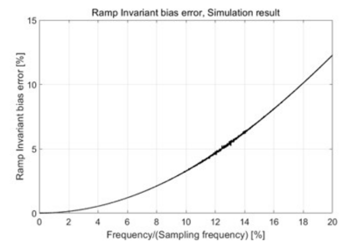
$$bias(f) = \left(\frac{\sin(\frac{\pi f}{fs})}{\frac{\pi f}{fs}} \right)^2$$



The bias is only a function of f/fs, not of the system.

We may plot the bias error in % versus frequency in % of fs.

An obvious fix is to increase the sampling frequency by upsampling the input signal.



I tried many times to explain my findings for Smallwood

Shock and Vibration Symposium in Albuquerque 1999

Shock Response Spectrum Calculation – An Improvement of the Smallwood Algorithm

Kjell Ahlin

Ingemansson Technology

The Smallwood method was made into ISO standard. I was the project leader.
Unofficial reference group: Dave Smallwood, Alan Piersol, Strether Smith.
Filter coefficients for different scaling of SRS, like acceleration, relative displacement, pseudo velocity, etc. Dave Smallwood did the final proof reading.

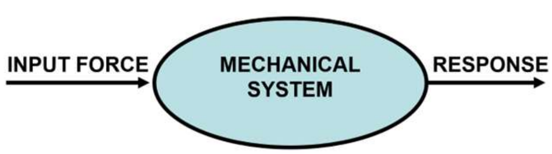
INTERNATIONAL STANDARD **ISO 18431-4**

First edition 2007-02-01

Mechanical vibration and shock — Signal processing —

Part 4:
Shock-response spectrum analysis

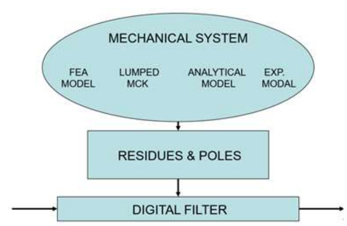
We want to apply digital filters to the forced response problem for linear mechanical systems. System is given, force input is a sampled time history.



74th Shock and vibration symposium in San Diego 2003:

On the use of Digital Filters for Mechanical System Simulation

Kjell Ahlin
Department of Mechanical Engineering
Blekinge Institute of Technology
Sweden



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Program Committee Co-Chairs Mr. Jim Sullivan, Mr. Travis Kerr, and Mr. James E. Howell III presented the 2004 Henry Pusey Award to Mr. Kjell Ahlin of Blekinge Institute of Technology, for his paper "On the use of digital filters for mechanical system simulation."

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CEEES Round Robin 1992

A Round Robin Exercise on Road Transportation Data
D. Richards;
B. Hibbert
Journal of the IEST (1993) 36 (4): 19–27.
https://doi.org/10.17764/jiet.2.36.4.166473405m520718

This paper presents the results of a round robin exercise undertaken recently under the auspices of the Transportation Stresses Working Group of the Committee of European Environmental Engineering Societies (CEEES). Twenty-two agencies from six European countries participated in this work. Each participant undertook the analysis of an identical piece of measured data. The majority of the participants reported the data analysis, and many also derived test severities. This paper presents a basic comparison of the responses and assesses the results

TRICKY PART: Handle transients, “shocks”

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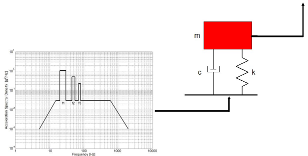
How to get SRS from test specification, given as PSD?

One SRS SDOF system

$$\sigma^2 = \int P(f) \cdot |H(f)|^2 \, df$$



σ and T gives max!

$$c_n = \sqrt{2 \ln(f_n \cdot T)}$$

$$C_n = c_n + \frac{0.5772}{c_n}$$

$$max_n = C_n \cdot \sigma_n$$

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Do we need a separate shock test?

- ❑ Calculate SRS_T from test psd
- ❑ Calculate SRS_F from field data
- ❑ If $SRS_F > SRS_T$ somewhere, a separate test is needed
- ❑ Same idea may be used to just detect shocks

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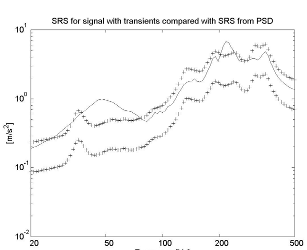
If you have a Test PSD, use that!

For just Shock Indication, test versus an amplified field PSD

Lower curve: SRS from Field PSD

Upper curve: SRS from Amplified Field PSD



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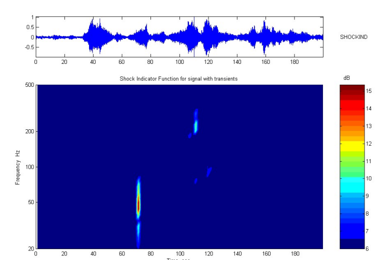
We can find WHERE the shocks (or transients) are, BOTH in frequency and time!



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Fatigue

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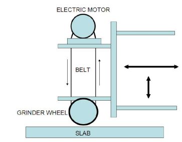

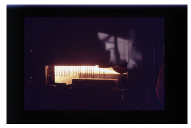

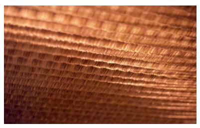

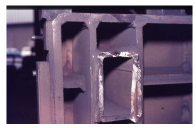

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Fatigue

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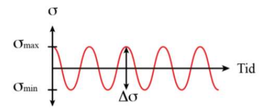
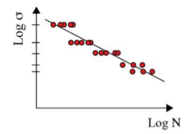


Definition of Range for cyclic load



Wöhler curve, S/N diagram

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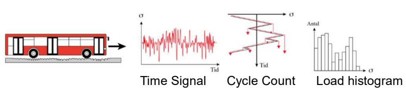

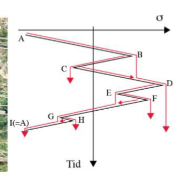

Rain Flow Cycle Count, RFCC

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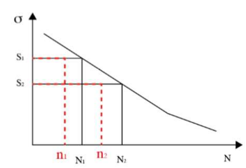

Palmgren - Miner, Miner's rule

$$D = \sum_i \frac{n_i}{N_i}$$

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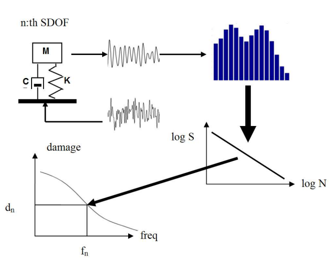

Principle for Fatigue Damage Spectrum, FDS

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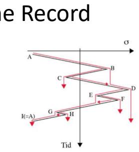
Hägglunds in Örnsköldsvik asked me to check their Rain Flow Cycle Count program

I programmed in TRAS, our Time Record Acquisition System, using this and the cycle rules.
Took a few hours, but how to handle the ongoing rains in the end?
Asked SAAB, Linköping



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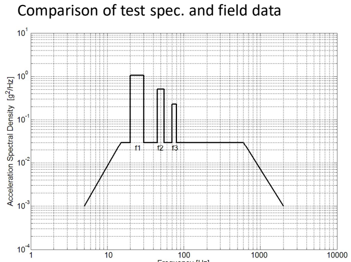
Some years later, Hägglunds came with a new question.

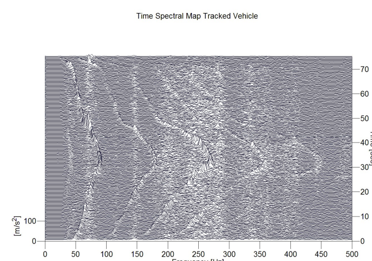
How to compare a test specification with measurement data?

Is measured environment more or less severe than the test specification an equipment has been tested for?

Comparison of test spec. and field data



AECTP 400, method 401 Annex B 1-4

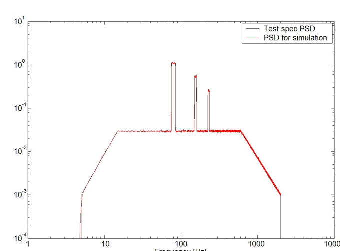


Measured Field Data

Basically two different approaches:

1. Maximum perspective.
   "It must not break, and it has to work all the time!"
   Shock Response Spectrum, SRS

2. Dose perspective.
   "It has to last!“
   Fatigue Damage Spectrum, FDS



Simulate time history from PSD, *psdsynt*

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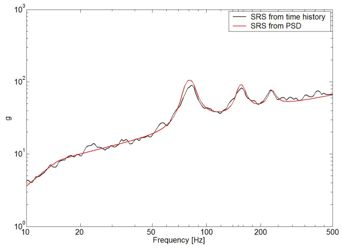

Compare SRS from time history and from PSD, *psd2srs*
& SRS on psdsynt

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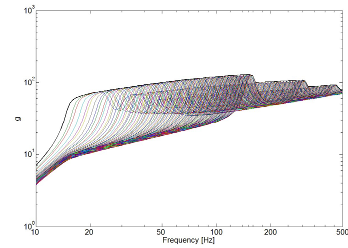

Calculate total SRS for sweep of one hour

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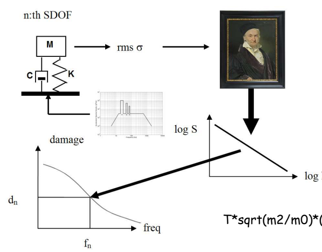

T*sqrt(m2/m0)*(m0*2)^(b/2)*gamma(b/2+1);

Principle for *psd2fds*

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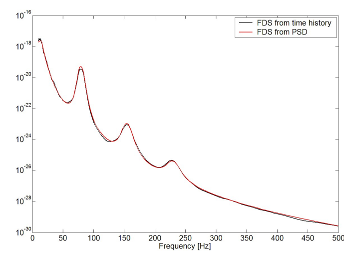

Compare FDS from time history and from
PSD, *psd2fds & fdsdispl*

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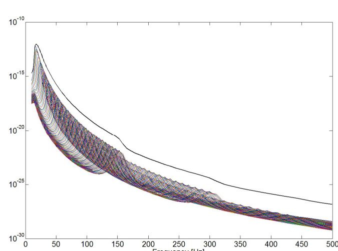

Calculate total FDS for sweep of one hour

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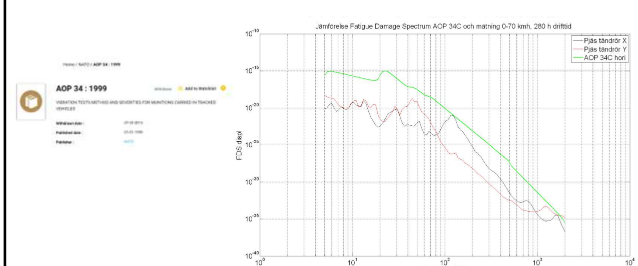

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MIL-STD-810C

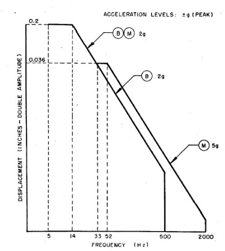

Figure 514.2-3. Vibration Test Curves for Equipment Installed in Helicopters, Equipment Category c.

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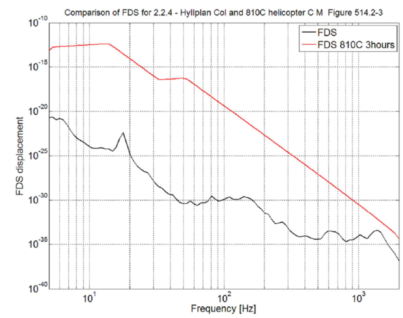

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Comparison of Test Specifications and Measured Field Data

Kjell Ahlin, Blekinge Institute of Technology, Karlskrona, Sweden

It is not always obvious how to compare a given test specification with measured field data. This article presents a systematic method based on the shock response spectrum and the fatigue damage spectrum. A random-on-random test specification for tracked vehicles, AECTP 400, is used as an example.

A common situation for the test engineer is comparing test specifications with measured field data. In many cases, the test specification is intended to mimic the real environment, but usually there is no way to directly make the comparison. A typical test specification for munitions transported as secure cargo in tracked vehicles, AECTP 400, is shown in Figure 1.

The bandwidth of each narrow band is 10 Hz. The frequencies of the band should be harmonically related and swept, so that:

- 15 Hz < f_1 < 150 Hz
- 30 Hz < f_2 < 300 Hz
- 45 Hz < f_3 < 450 Hz

There are versions of the test specification where the bandwidths of the frequency bands are 5, 10, and 15 Hz, respec-

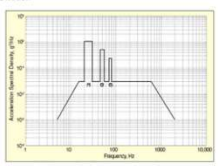

Figure 1. AECTP 400, method 401; test specification for munitions transported as secure cargo in tracked vehicles.

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Another ISO project
A standard under revision, ISO 8569

ISO/TC 108/SC 2 N 67
Date: 1997-08-21
ISO/WD 8569
ISO/TC 108/SC 2/WG 16
Secretariat: DIN

Mechanical vibration and shock – Measurement and evaluation of shock and vibration effects on sensitive equipment in buildings

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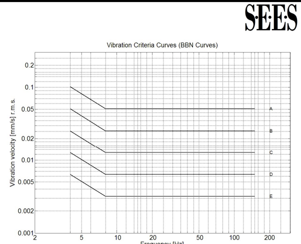
- The existing standard was not good
- There existed an accepted classification of vibrations for sensitive equipment in buildings, BBN curves
- We used that to determine the best place in a building to put a measuring device



Rms velocity in 1/3 octave band

Colin Gordon, Eric Ungar

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I complained a lot, so ISO made me chairman of the working group responsible for the revision. ISO/TC 108/SC 2/WG 16

I set up twelve requirements for the standard.
Major points:

- Should handle all kinds of vibrations, random, sines, transients
- Should be compatible to blasting praxis, maximum peak velocity and typical frequency
- Should be compatible with "Vibration Sensitivity Spectrum", VSS. Malfunction, not damage!

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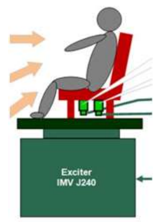
Pennsylvania Code § 88.135.
Blasting: surface blasting requirements

(h) In all blasting operations, the maximum peak particle velocity may not exceed 2 inches per second at the location of any dwelling, public building, school, church or commercial or institutional building



VSS

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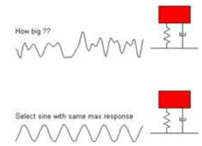
The criteria pointed to a response equivalent.
Sine frequency equal to
SDOF resonance frequency

Value is sine velocity peak.

"Response equivalent peak velocity spectrum". ISO TS-10811



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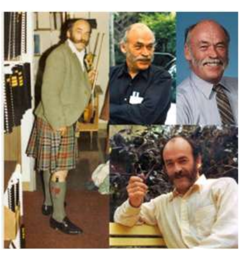
Colin Gordon was US member of the WG, but he never attended our meetings. So I put one meeting in his office, San Mateo, California ☺



INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
Technical Committee No. 108 • Mechanical Vibration and Shock

ISO/TC 108/SC 2/WG 16 N 78
11 May 1999
2 pages

Minutes

Meeting of ISO/TC 108/SC 2/WG 16, "Vibration and shock resistance of sensitive equipment"
San Mateo, 10-11 May 1999

1. **Opening of the meeting.** The meeting was held at Colin Gordon & Associates, San Mateo, California, 10-11 May 1999.
2. **Those present introduced themselves**, see attendance list (ISO/TC 108/SC 2/WG 16 N 77)
3. The **draft agenda** (ISO/TC 108/SC 2/WG 16 N 76) was approved.

谢拉林

SEES

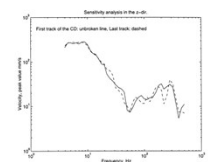
We did a field test with a student from KTH

Very nice vibration sensitive object.

Tested in many situations

40 stops, ALL compatible with VSS!

Method verified with experiments ☺



Portable CD Player

谢拉林

SEES

ISO/TS 10811-1:2000

Mechanical vibration and shock

Vibration and shock in buildings with sensitive equipment

Part 1: Measurement and evaluation

Status : Published

This standard was last reviewed and confirmed in 2024. Therefore this version remains current.

谢拉林

SEES

IEC Environmental Engineering

At IEC General Meeting in Durban 1995

IEC TC 50, Methods of Test

IEC TC 75, Environmental Conditions

Same people in both. There was a Joint WG to make a conversion table.

Many wanted the two TC to combine.

谢拉林 SEES

Some say there was a coup d'etat between SEK in Sweden and IEC General Office.
Anyway, the two TC combined into IEC TC 104, with Sweden having the secretariat.

First meeting with HP in Palo Alto, California.

There was a common feeling, that we missed a rational for the severities in the condition standards
WG 14, climate, and WG 15, mechanical, were formed

谢拉林 SEES

Maintenance teams, MT, were formed to maintain existing standards and for creating new ones.

MT 16 for climatical tests

MT 17 for mechanical tests

MT 18 for combined tests and special tests

I was member of WG 15 and MT 17 for many years.

I left 2003 when I became full time professor.

谢拉林 SEES

I was going to retire 2007. I got a phone call:
"Now when you retire, you can come back to IEC TC 104 and become chairman of TK 104 as you were before"

"No thanks, but wait a minute, where is next meeting?"

"Guangzhou, China", "OK, I come to that meeting"
I left IEC TC 104 year 2023!

谢拉林 SEES

These two ladies changed my life!

谢拉林 SEES

That was the beginning of my China life!

- Shanghai is my second home town
- So far, I have visited China 69 times
- I have worked as a consultant for a Chinese company, AAC Technologies
- I have been teaching at ten different Chinese universities, also supervising Chinese students

谢拉林 SEES

BEIHANG UNIVERSITY

Linyi Normal University

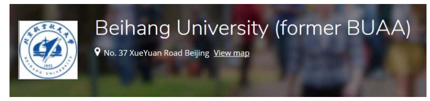
AAC Technologies

HUAWEI

AAC makes components to mobile phones

瑞声科技
AAC TECHNOLOGIES

HQ: Shenzhen
Factory: Changzhou
R&D: Nanjing

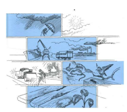


北京航空航天大学 běi jīng háng kōng háng tiān dà xué
north capital sail sky sail heaven big school

Seminars and courses in structural dynamics, environmental engineering and nonlinear systems

Made a course on demand:
"Reliablity and Environmental Engineering"
.

- Lecture 1 Reliability Definitions
- Lecture 2 Reliability Examples I
- Lecture 3 Reliability Examples II
- Lecture 4 Condition Monitoring
- Lecture 5 System Reliability and the Environment
- Lecture 6 Climate Classification
- Lecture 7 Climatic Testing
- Lecture 8 Chemical, Biological, Electrical Testing
- Lecture 9 Mechanical System Models
- Lecture 10 Mechanical Signals
- Lecture 11 Spectrum Analysis I
- Lecture 12 Spectrum Analysis II
- Lecture 13 Shock Response Spectrum
- Lecture 14 Shock Measurements, Fatigue
- Lecture 15 Fatigue Damage Spectrum
- Lecture 16 Vibration Measurements Techniques
- Lecture 17 Field Measurements, Data Quality
- Lecture 18 Test Specification from Field Data
- Lecture 19 Shock Test Specification
- Lecture 20 Test Specification from Standards
- Lecture 21 Accelerated Tests. HALT, HASS, ESS
- Lecture 22 Shock and Vibration Test Standards, Virtual Testing
- Lecture 23 Environmental Engineering Procedures
- Lecture 24 Design for Reliability Handbook

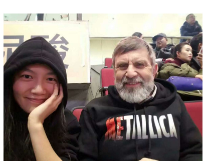


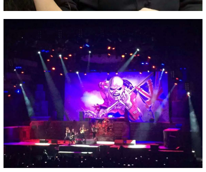
ALLIED ENVIRONMENTAL CONDITIONS AND TEST PUBLICATIONS

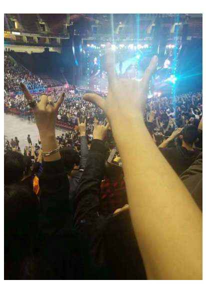
AECTP 200

ENVIRONMENTAL CONDITIONS

DEPARTMENT OF DEFENSE
TEST METHOD STANDARD







Guo Ying is now project leader for Xiaomi's AI development!

谢拉林 SEES

Li JiaXin, son of my professor
at Beihang, studied in Gothenburg

Golden Ridge Robotic AB

Information

Vice VD : Lei Zhu
VD , Styrelseordförande : Jiaxin Li
Bolagsform: Aktiebolag
F-Skatt: Registrerad Läs mer
Moms: Har aldrig varit registrerad i Momsregistret
Registreringsår: 2015

70 engineers under Li JiaXin in Chengdu

谢拉林 SEES

谢拉林 SEES

Before I left IEC TC 104, I was project leader for a new standard, multi-exciter and multi-axis vibration tests

At the same time, there was an ISO standard prepared for the equipment to use for those tests.

The people working with that were at CALT in Beijing.
China Academy of Launch Vehicle Technology
I visited them in January 2020

谢拉林 SEES

CASC 中国航天
W Wikipedia
China Aerospace Science and Tec...

Liujun

Long March 5B

谢拉林 SEES

The story of the Chinese booster rocket reentry
The booster was left after the big rocket lifted up the first part of the Chinese space station April 29 2021.

The booster was left in an uncontrolled orbit, and the whole world was watching, as it had a weight of some 20 tons, and the time and place of reentry was unknown.

We had great fun following the booster and predicting its orbits

It plunged into the ocean on my orbit #24

谢拉林 SEES

Orbit 20. Close to Shanghai

Orbit 26 was to pass Washington DC and NYC

I met him and his girlfriend in Beijing last year, and two weeks ago
I got this engagement photo.

谢拉林 SEES

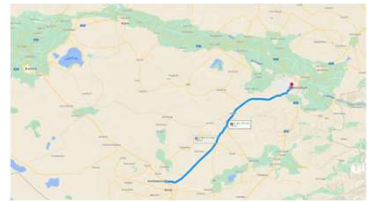
Now I am involved in a project funded by NSFC, National Science Foundation of China.
Method development for “self-driving vehicles on bad roads”.

- Develop road models, roads and test tracks
- Develop response calculation methods, faster and more accurate than commercial software
- Vehicle models may be nonlinear

谢拉林

I needed data from bad roads. My friends in Tashkent were happy to help me

'Survey date:,2014-03-30 '
'Survey time:,17:19:36 '
'Road name:,A378 '
'From:,0 km '
'To:,152 km '
'Direction:,Samarkand -Kashkhadarya'



I have tons of road data from Uzbekistan!

谢拉林 SEES

Project leader is Xu Fei, I supervised him for his PhD at Beihang.

Synthesis of Running RMS-induced Non-Gaussian Random Vibration Based on Weibull Distribution
Fei Xu[1], Chuanri Li[2], Tongmin Jiang[3], Kjell Ahlin[4]

I supervised Xia Jing:

On the research of establishing test spectrum of Non-Gaussian vibration signal with high kurtosis
Jing Xia, Hongjie Yuan and Kjell Ahlin

Simulation of non-stationary random excitation
B. Martin Olofsson
Ingemansson Technology AB, Sweden

谢拉林 SEES

Many of our road models contain the possibility of adding high kurtosis, making the road non-Gaussian.
Some examples of publications

On Vehicle Response under Non-Gaussian Road Profile Excitation
Kurtosis control of amplitude-modulated non-Gaussian signal for fatigue test purpose
Estimate Non-Gaussian Road Roughness from International Roughness Index
Research on vehicle vibration fatigue damage potential under non-Gaussian road profile excitation
Generation of amplitude modulated non-Gaussian signal considering kurtosis transmission and fatigue damage potential
A MATLAB GUI toolbox to generate non-Gaussian road profile

谢拉林 SEES

Last year I gave a course for Volvo CE, Braås.
Our example item was a self-driving dumper working at construction sites.

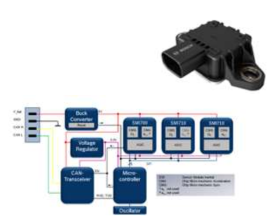
Sensor had shock and vibration specifications, random test PSD, sine sweeps, shock tests

We had measurements from service
Perfect example!

谢拉林

Inertial Measurement Unit MM7.10
Technical Customer Documentation

rexroth
A Bosch Company



Tested like this?

谢拉林 SEES

There is still A LOT to do, when it comes to method development!

We need new fresh ideas, and a lot of new people in standardization!

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谢拉林 SEES

Join ISO/IEC and see the world!

Kobe, Tokyo, Beijing, Guangzhou, Stockholm, Frankfurt, Munching, Berlin, Bergamo, Milan, Prague, Paris, Vienna, London, Geneva, Leuven, Dubrovnik, Sydney, Adelaide, Durban, Cairo, Gaithersburg, Washington DC, San Diego, San Mateo, Palo Alto, Oakridge, Minden, Orlando, The Keys, Detroit, Honolulu, Toronto

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谢拉林 SEES

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