EPSON

VC Evaluation Library
- Reference Manual

Notice of Document

Evaluation board/kit and development tool important notice

1. This evaluation board/kit or development tool is designed for use for engineering evaluation, demonstration, or development purposes only. Do not use it for other purposes. It is not intended to meet the requirements of design for finished products.
2. This evaluation board/kit or development tool is intended for use by an electronic engineer and is not a consumer product. The user should use it properly and in a safe manner. Seiko Epson does not assume any responsibility or liability of any kind of damage and/or fire caused by the use of it. The user should cease to use it when any abnormal issue occurs even during proper and safe use.
3. The part used for this evaluation board/kit or development tool may be changed without any notice.

NOTICE : PLEASE READ CAREFULLY BELOW BEFORE THE USE OF THIS DOCUMENT

The content of this document is subject to change without notice.

1. This document may not be copied, reproduced, or used for any other purposes, in whole or in part, without the consent of Seiko Epson Corporation("Epson").
2. Before purchasing or using Epson products, please contact with our sales representative for the latest information and be always sure to check the latest information published on Epson's official web sites and sources.
3. Information provided in this document such as application circuits, programs, usage, etc., are for reference purpose only. Please use the application circuits, programs, usage, etc. in the design of your equipment or systems at your own responsibility. Epson makes no guarantees against any infringements or damages to any third parties' intellectual property rights or any other rights resulting from the information. This document does not grant you any licenses, intellectual property rights or any other rights with respect to Epson products owned by Epson or any third parties.
4. Epson is committed to constantly improving quality and reliability, but semiconductor products in general are subject to malfunction and failure. In using Epson products, you shall be responsible for safe design in your products; your hardware, software and systems are designed enough to prevent any harm or damages to life, health or property even if any malfunction or failure might be caused by Epson products. In designing of your products with using Epson products, please be sure to check and comply with the latest information regarding Epson products (this document, specifications, data sheets, manuals, Epson's web site, etc.). When using the information included in the above materials such as product data, chart, technical contents, programs, algorithms and application circuit examples, you shall evaluate your products both in stand-alone basis and within your overall systems. You shall be solely responsible for deciding whether or not to adopt and use Epson products.
5. Epson has prepared this document and programs provided in this document carefully to be accurate and dependable, but Epson does not guarantee that the information and the programs are always accurate and complete. Epson assumes no responsibility for any damages which you incurred by due to misinformation in this document and the programs.
6. No dismantling, analysis, reverse engineering, modification, alteration, adaptation, reproduction, etc., of Epson products is allowed.
7. Epson products have been designed, developed and manufactured to be used in general electronic applications (office equipment, communications equipment, measuring instruments, home electronics, etc.) and applications individually listed in this document ("General Purpose"). Epson products are NOT intended for any use beyond the General Purpose that requires particular/higher quality or reliability in order to refrain from causing any malfunction or failure leading to harm to life, health or serious property damage or severe impact on society, including, but not limited to listed below. Therefore, you are advised to use Epson products only for the General Purpose. Should you desire to buy and use Epson products for the particular purpose other than the General Purpose, Epson makes no warranty and disclaims with respect to Epson products, whether express or implied, including without limitation any implied warranty of merchantability or fitness for any particular purpose.
   [Particular purpose]
   Space equipment (artificial satellites, rockets, etc.)
   Transportation vehicles and their control equipment (automobiles, aircraft, trains, ships, etc.)
   Medical equipment (other than applications individually listed in this document) / Relay equipment to be placed on sea floor
   Power station control equipment / Disaster or crime prevention equipment / Traffic control equipment / Financial equipment
   Other applications requiring similar levels of reliability as the above
8. Epson products listed in this document and our associated technologies shall not be used in any equipment or systems that laws and regulations in Japan or any other countries prohibit to manufacture, use or sell. Furthermore, Epson products and our associated technologies shall not be used for developing military weapons of mass destruction, military purpose use, or any other military applications. If exporting Epson products or our associated technologies, you shall comply with the Foreign Exchange and Foreign Trade Control Act in Japan, Export Administration Regulations in the U.S.A (EAR) and other export-related laws and regulations in Japan and any other countries and follow the required procedures as provided by the relevant laws and regulations.
9. Epson assumes no responsibility for any damages (whether direct or indirect) caused by or in relation with your non-compliance with the terms and conditions in this document.
10. Epson assumes no responsibility for any damages (whether direct or indirect) incurred by any third party that you assign, transfer, loan, etc., Epson products.
11. For more details or other concerns about this document, please contact our sales representative.
12. Company names and product names listed in this document are trademarks or registered trademarks of their respective companies.

2022.08

Trademark

- Epson is a registered trademark of Seiko Epson Corporation.
- Other product names are trademarks or registered trademarks of the respective companies.

Table of contents

Revision History

Rev. No.	Rev. Date	Page	Rev. Contents
20250221	2025/2/21	ALL	First edition Corresponding to the release of MSG004-001a_v1.0.0

1. Introduction

1.1. Overview

This library evaluates vibrations affecting precision equipment based on the paper concerning velocity response of precision instruments:

"Generic Vibration Criteria for Vibration-Sensitive Equipment"
by Colin G. Gordon, SPIE99, in accordance with ISO 2631.

It compresses input 3-axis acceleration data [G] into 1/n octave band frequency data (n = 3, 6, 12). The output can be selected as either acceleration [G] or velocity [mm/s]. The formulas for calculating the center, lower, and upper frequencies of each octave band are provided in **Appendix A: Frequency Settings for Each Octave Band**. The sum of FFT results within each frequency band (from lower to upper limit) is used as the intensity at the center frequency.

Additionally, the library converts acceleration to velocity and calculates the composite 3-axis velocity [mm/s]. It then performs VC (Vibration Criteria) evaluation for each 1/3 octave band based on the maximum velocity, outputting a result ranging from **“G”** to **“Over A"**.

- "Over A" indicates the evaluated velocity exceeds level A.
- "A" indicates the velocity is between level B and A.
- "B" through "F" follow the same logic.
- "G" indicates the velocity is below level G.

The VC evaluation thresholds for each 1/3 octave band are listed in **Appendix B: VC Evaluation Thresholds.**
For detailed interpretation of each VC level in relation to precision equipment, please refer to the research paper.

A tripartite chart of the evaluation levels is shown in **Figure 1-1** for reference.

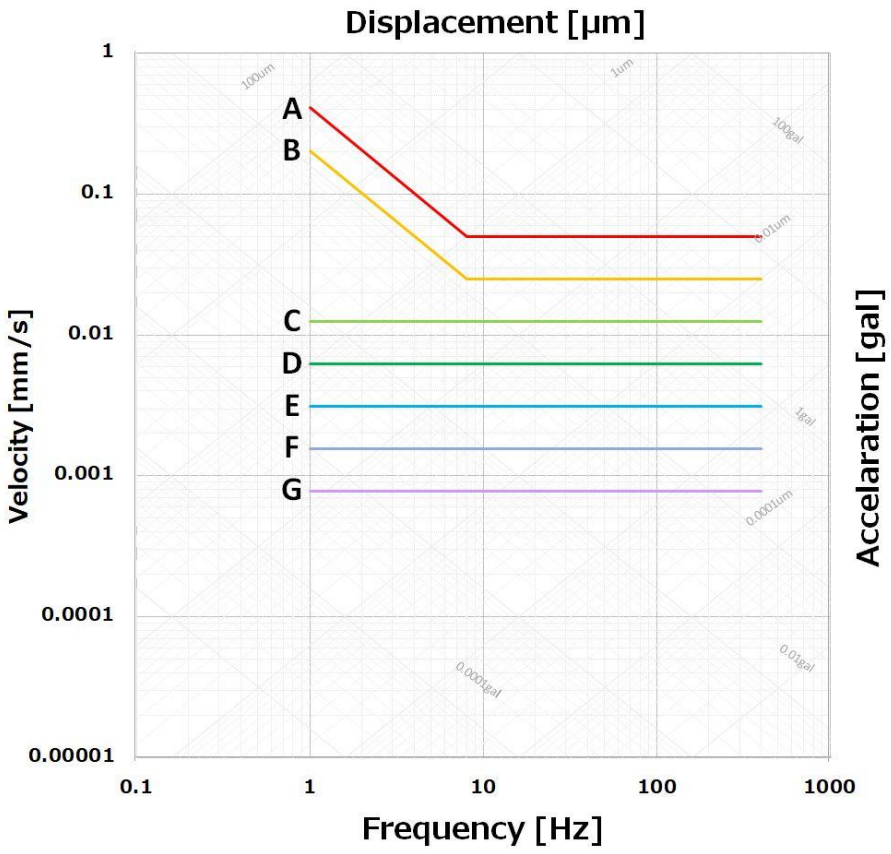

Figure1-1

1.2. License

License information is included in the header of each source file.

1.3. Recommended Execution Environment

Raspberry Pi 4B with 4GB RAM or higher CPU/memory specifications

(Operation confirmed on Raspberry Pi 4B 8GB)

2. Processing Algorithm Details

The computation follows the steps below:

2.1. Preparation of Input Data

1. Based on the configuration parameters, an octave band frequency table is generated.
2. Using the octave band frequency table and the FFT size, a table is created to indicate the boundary positions of each octave band in the FFT output.
3. For each input of data defined by `exec_size`, the library performs evaluation processes using accumulated data of the size defined by `fft_size`. These evaluation processes are both 1/n octave band frequency compression and VC evaluation.
   (Note: The first computation is performed only after `fft_size` worth of data has been accumulated.)

2.2. 1/n Octave Band Frequency Compression

1. The average bias of the target data is calculated.
2. The average bias is subtracted from each data point, and a Hanning window is applied.
3. FFT power spectrum is computed.
4. The power spectrum values are adjusted using Parseval's theorem.
5. For each 1/n octave band range, the power spectrum is integrated and the square root is taken.
6. If velocity output is selected, the data is converted from acceleration [G] to velocity [mm/s] at this stage.

2.3. Averaging and VC Evaluation

2.3.1. single_data

Outputs 1/n octave band frequency-compressed data.

The data output rate is calculated as: Output Rate = 1000 / `exec_size` [data/sec]

2.3.2. average_data

Outputs the average of 1/n octave band frequency-compressed data over `avr_size` executions.

The data output rate is calculated as: Output Rate = 1000 / (`exec_size` * `avr_size`) [data/sec]

2.3.3. VC Evaluation

VC evaluation is performed at the timing of `single_data` and `average_data` output.

1. The 3-axis 1/n octave band frequency-compressed data is synthesized.
2. If the output is in acceleration, it is converted to velocity [mm/s].
3. The maximum velocity and its corresponding center frequency are calculated.
4. The VC level is determined based on the evaluation value at the center frequency (1/3 octave band), and the result (VC level) is output.

3. API

3.1. File Structure

1. **vc_calc.py**： VC evaluation processing
2. **vc_constant.py**：Constant definitions used in VC evaluation
3. **vc_data.py**： Input/output data definitions for the VC evaluation library

3.2. Required Libraries

1. numpy ver.1.23.5

3.3. Class

1. VcCalc

3.4. Methods

3.4.1. Constructor

3.4.1.1. Constructor Usage Example

```
try:
   vc_calc = VcCalc(fft_size, exec_size, avr_size, data_type, oct_band, data_rate)
except ValueError as err:
   # [Error handling]
```

Figure 3-1

3.4.1.2. Parameters

Table 3-1

Parameter	Description	Default	Valid Range (*)
fft_size	Number of FFT points	10000	2000～40000 fft_size % 2 = 0
exec_size	Number of input acceleration data points per execution	1000	1000～fft_size fft_size % exec_size = 0
avr_size	Number of averages for VC output	30	10～50
oct_band	Type of octave band	1/3 octBand	1/3 octBand, 1/6 octBand, 1/12 octBand
data_type	Output data type	Velocity	Acceleration, Velocity
data_rate	Input data rate	1000 sps	Only 1000 sps supported

(*)If a parameter is out of range, a ValueError is raised with a specific message.

3.4.1.3. Recommended Settings

Compression error increases in the order: 1/3 octave > 1/6 octave > 1/12 octave. However, for frequencies below a few Hz, this order may reverse depending on `fft_size`. Larger `fft_size` increases CPU and memory load on Raspberry Pi.

Recommended combinations:

Table 3-2

oct_band	fft_size
1/3 octBand	10000
1/6 octBand	20000
1/12 octBand	40000

3.4.2. Calculation

3.4.2.1. Calculation Usage Example

```
measure_data = MeasureData()
# [Set acceleration sensor data to measure_data]
result_sgl, result_avr = vc_calc.calc(measure_data)
if result_sgl.done:
   # [Process single_data]
if result_avr.done:
   # [Process average_data]
```

Figure 3-2

3.4.2.2. Parameters

Table 3-3

Sensor Data: (dataclass) MeasureData

Parameter	Data Type	Data Type	Unit	Notes
index	int	(Unused)	–	–
count	int			
temperature	float			
x	float	Acceleration (X-axis)	G	Fixed at 1000 sps
y	float	Acceleration (Y-axis)		
z	float	Acceleration (Z-axis)		
flag	int	(Unused)	–	–

3.4.2.3. Return Values

- `single_data` result: (dataclass) VcCalcResult
- `average_data` result: (dataclass) VcCalcResult

(1) When `data_type` = Acceleration

Table 3-4

Parameter	Data Type	Description	Unit
c	List[float]	Combined 3-axis acceleration per 1/n octave band	G
x	List[float]	X-axis acceleration per 1/n octave band	G
y	List[float]	Y-axis acceleration per 1/n octave band	G
z	List[float]	Z-axis acceleration per 1/n octave band	G
max_v	float	Maximum acceleration (sum over 1/n octave band)	G
max_f	float	Center frequency of 1/n octave band at which max acceleration occurred	Hz
done	bool	Processing complete (data updated)	–
avr_num	int	Number of averaging iterations (always 0 in single mode)	–
vc_lvl	str	VC evaluation result ('OA' to 'G')	–

(2) When `data_type` = Velocity

Table 3-5

Parameter	Data Type	Description	Unit
c	List[float]	Combined 3-axis velocity per 1/n octave band	mm/s
x	List[float]	X-axis velocity per 1/n octave band	mm/s
y	List[float]	Y-axis velocity per 1/n octave band	mm/s
z	List[float]	Z-axis velocity per 1/n octave band	mm/s
max_v	float	Maximum velocity (sum over 1/n octave band)	mm/s
max_f	float	Center frequency of 1/n octave band at which max acceleration occurred	Hz
done	bool	Processing complete (data updated)	–
avr_num	int	Number of averaging iterations (always 0 in single mode)	–
vc_lvl	str	VC evaluation result ('OA' to 'G')	–

Appendix A: Frequency Settings for Each Octave Band

(1) 1/3 Octave Band

- fcenter = 2^(n/3)
- fmin = 2^((n-0.5)/3)
- fmax = 2^((n+0.5)/3)

  (n=0～26)

(2) 1/6 Octave Band

- fcenter = 2^(n/6)
- fmin = 2^((n-0.5)/6)
- fmax = 2^((n+0.5)/6)

  (n=0～53)

(3) 1/12 Octave Band

- fcenter = 2^(n/12)
- fmin = 2^((n-0.5)/12)
- fmax = 2^((n+0.5)/12)

  (n=0～107)

Appendix B: VC Evaluation Thresholds

1/3 octband	VC Threshold Velocities [mm/s]						
fcenter [Hz]	level A	level B	level C	level D	level E	level F	level G
1.000000	0.41	0.203	0.0125	0.00625	0.00313	0.00156	0.00078
1.259921	0.32	0.161	0.0125	0.00625	0.00313	0.00156	0.00078
1.587401	0.26	0.128	0.0125	0.00625	0.00313	0.00156	0.00078
2.000000	0.2	0.101	0.0125	0.00625	0.00313	0.00156	0.00078
2.519842	0.16	0.081	0.0125	0.00625	0.00313	0.00156	0.00078
3.174802	0.13	0.064	0.0125	0.00625	0.00313	0.00156	0.00078
4.000000	0.1	0.051	0.0125	0.00625	0.00313	0.00156	0.00078
5.039684	0.08	0.04	0.0125	0.00625	0.00313	0.00156	0.00078
6.349604	0.06	0.032	0.0125	0.00625	0.00313	0.00156	0.00078
8.000000	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
10.079368	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
12.699208	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
16.000000	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
20.158737	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
25.398417	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
32.000000	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
40.317474	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
50.796834	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
64.000000	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
80.634947	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
101.593667	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
128.000000	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
161.269894	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
203.187335	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
256.000000	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
322.539789	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078
406.374669	0.05	0.025	0.0125	0.00625	0.00313	0.00156	0.00078

Contact Information

Seiko Epson Corporation

Sales Headquarters MD Sales Department

Contact Information via the Internet

https://www.epsondevice.com/sensing/en/privacy/area-select-inquiry-contact.html