Measurement of reverberation time (RT60) and absorption coefficient (alpha)

DEWESoft®

SOFTWARE USER MANUAL

RT 60 plugin V21-1

1. Table of contents

2. About this document

This is the users manual for Measurement of reverberation time (RT60) and absorption coefficient (alpha) module.

2.1. Legend

The following symbols and formats will be used throughout the document.

Important
It gives you important information about the subject.
Please read carefully!

Hint
It gives you a hint or provides additional information about a subject.

Example
Gives you an example of a specific subject.

3. Reverberation time

Reverberation time is a time required for sound to decay 60 decibels from its initial level.

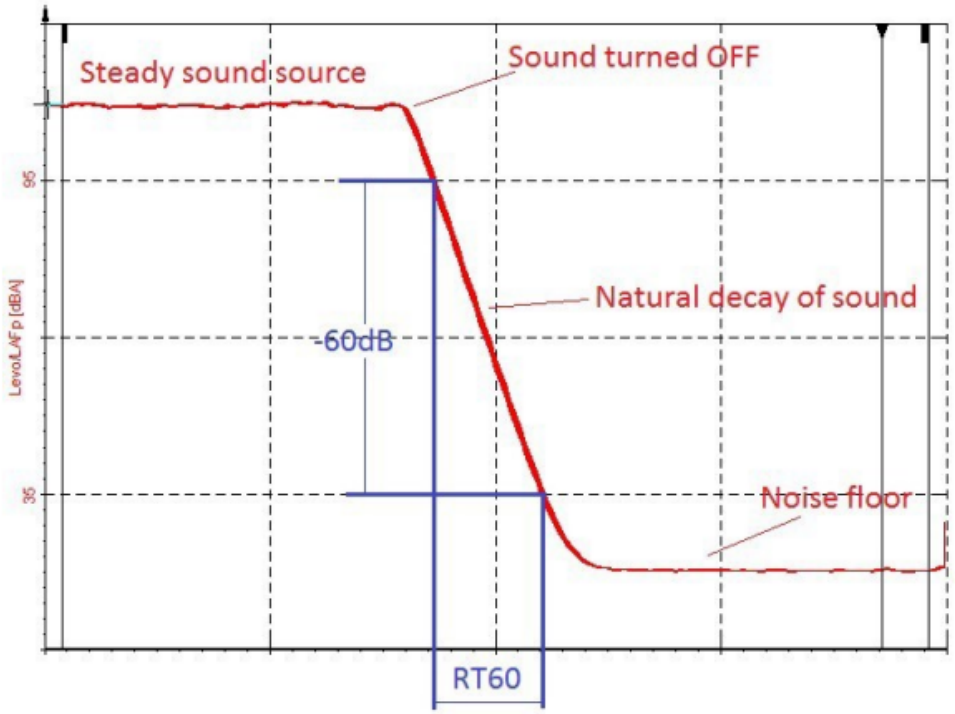


Illustration 1: Reverberation time

Reverberation time is measured in narrow bands and differs depending on the frequency band being measured. For precision, it is important to know what ranges of frequencies are being described by a reverberation time measurement.

Rooms used for speech typically need a shorter reverberation time so that speech can be understood more clearly. If on the other hand, the reverberation time is too short, tonal balance and loudness may suffer
.
Reverberation effects are often used in studios to add depth to sounds. Reverberation changes the perceived spectral structure of a sound, but does not alter the pitch.

Basic factors that affect a room's reverberation time include the size and shape of the enclosure as well as the materials used in the construction of the room. Every object placed within the enclosure can also affect the reverberation time.

4. Sabine equipment

In the late 19th century, Wallace Clement Sabine started to investigate the impact of absorption on the reverberation time. Using a portable wind chest and organ pipes as a sound source, a stopwatch and his ears, he measured the time from interruption source to inaudibility (a difference of roughly 60 dB). He found that the reverberation time is proportional to room dimensions and inversely proportional to the amount of absorption present.

$$RT_{60} = \frac{24ln10^{1}}{c_{20}} \frac{V}{S_a} \approx 0.1611\, sm^{-1} \frac{V}{S_a}$$

- C_{20} is the speed
- V is the volume
- S is the total surface
- α is the average
- The product Sα

The total absorption (and reverberation time) generally changes depending on frequency (which is defined by the acoustic properties of the space). The equation does not take into account room shape or losses from the sound travelling through the air (which is important in larger spaces). Most rooms absorb less sound energy in the lower frequency ranges resulting in longer reverberation times at lower frequencies.

Sabine concluded that the reverberation time depends upon the reflectivity of sound from various surfaces available inside the hall. If the reflection is coherent, the reverberation time of the hall will be longer; the sound will take more time to die out.

The reverberation time RT60 and the volume V of the room have great influence on the critical distance dc. Critical distance is the distance at which the sound pressure level of the direct sound and the reverberant sound are equal:

$$d_c \approx 0.057 \sqrt{\frac{V}{RT_{60}}}$$

5. Eyring formula

The Sabine and Eyring equations were derived under different assumptions. The Sabine equation assumes that as a sound wave travels around a room it encounters surfaces “one after another.” The Eyring equation assumes that all the surfaces are simultaneously impacted by the initial sound wave, and that successive simultaneous impacts, each diminished by the average room absorption coefficient, are separated by mean free paths.

$$T = \frac{0.161V}{-S\ ln(1-\overline{a})}$$

Sabine and Eyring converge at low absorption, but diverge when the absorption is high, in which case Eyring is more appropriate. The Eyring absorption (and its more accurate reverberation formula) takes into account that the decay of sound is not a continuous process, but is instead a stepwise reduction of sound energy whenever a sound wave is incident on a surface, with reflections and absorptions resulting from that surface interaction.

6. Comparison of Eyring and Sabine absorption coefficients

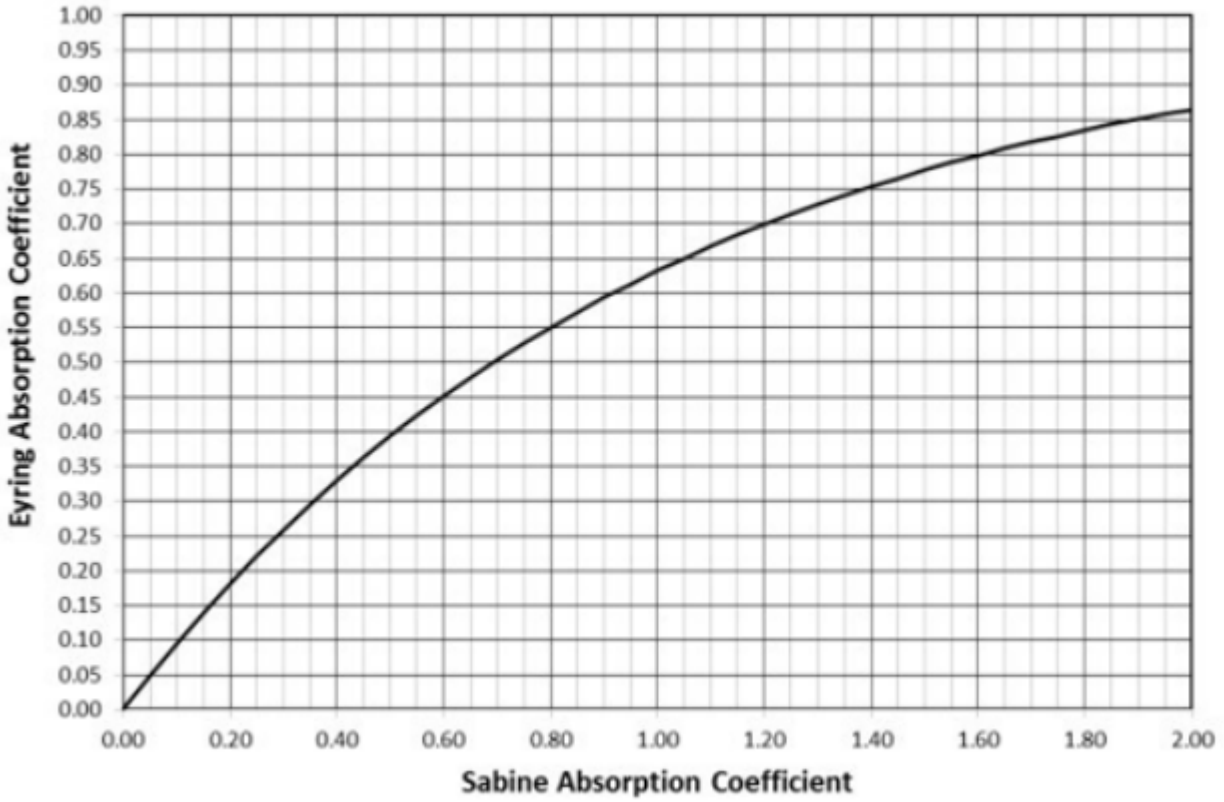


Illustration 2: Comparison of Eyring and Sabine absorption coefficients

7. Absorption coefficient (alpha)

The absorption coefficient of a material indicates the proportion of sound which is absorbed by the surface compared to the proportion which is reflected back into the room.

8. Measurements of reverberation time

The average reverberation time in the reverberation room is measured with and without the test specimen mounted. From these reverberation times, the equivalent sound absorption area of the test specimen is calculated.

According to the standard, the volume of the reverberation room should be at least 150 m3 . When the volume of the room is greater than about 500 m3 , it may not be possible to measure sound absorption accurately at high frequencies because of air absorption. Changes in temperature and relative humidity during the course of a measurement can have a large effect on the measured reverberation time, especially at high frequencies and at low relative humidity.

Measurement should be performed in the empty room and in the room containing the test specimen under conditions of temperature and relative humidity that are almost the same. For all measurements, the corrections for the change in air absorption have to be taken into account.Standard prescribes two methods for measuring decay curves:

- The interrupted noise method (the excitation signal shall be sufficiently long to produce a steady-state sound pressure level in all frequency bands before it is switched off. In order to obtain steady-state conditions, the excitation time shall be at least half of the estimate of the expected reverberation time).
- The integrated impulse response method (the impulse response may be measured directly by using an impulse source such as a pistol shot, balloon burst, spark gap or any other sound source that produces an impulse with sufficient bandwidth and energy). This is the preferred method.

The decay curve measured with the interrupted noise method is the result of a statistical process, and averaging several decay curves or reverberation times measured at one microphone/loudspeaker position is mandatory in order to obtain a suitable repeatability. The integrated impulse response of a room is a deterministic function and not prone to statistical deviations, so no averaging is necessary.

The directivity characteristic of the microphones used for the measurement shall be omnidirectional. The measurements shall be made with different microphone positions which are at least 1,5 m apart, 2 m from any sound source and 1 m from any room surface and the test specimen.

The sound in the reverberation room shall be generated by a sound source with an omnidirectional radiation pattern. The signals from different microphones shall not be averaged together

9. RT60 plugin setup in DEWESoft

RT60 plugin can be found in DEWESoft under Plugins section. Add a plugin with the click on it.

The following window and setup appears when you add the plugin. First select the input channels (microphones).

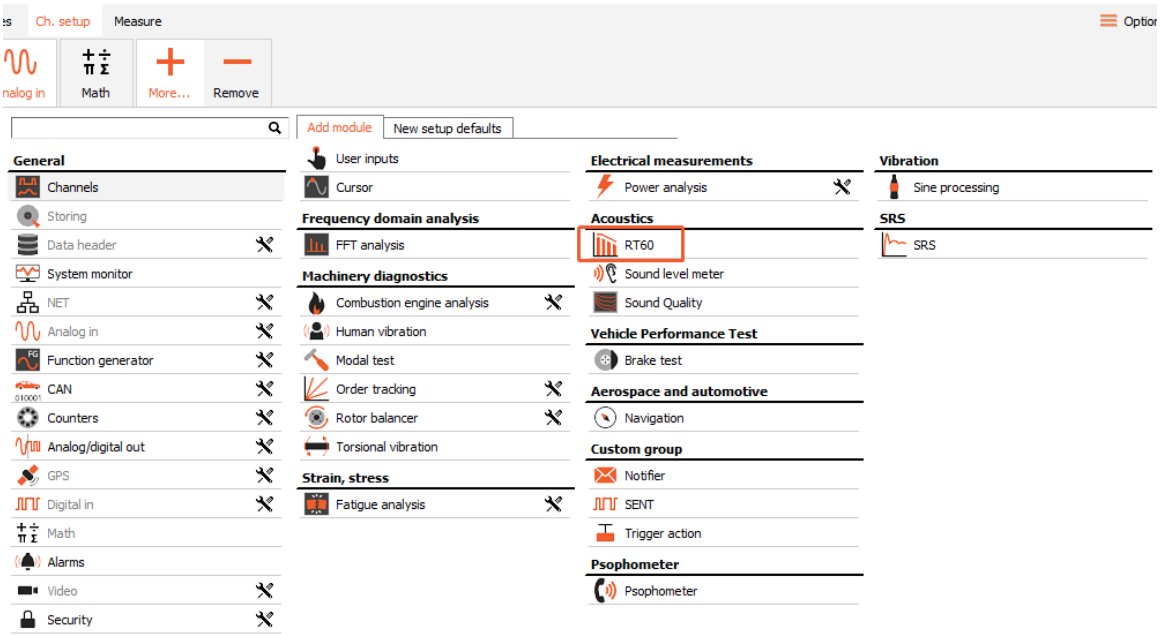


Illustration 3: RT60 plugin in Dewesoft

The following window and setup appears when you add the plugin. First select the input channels (microphones).

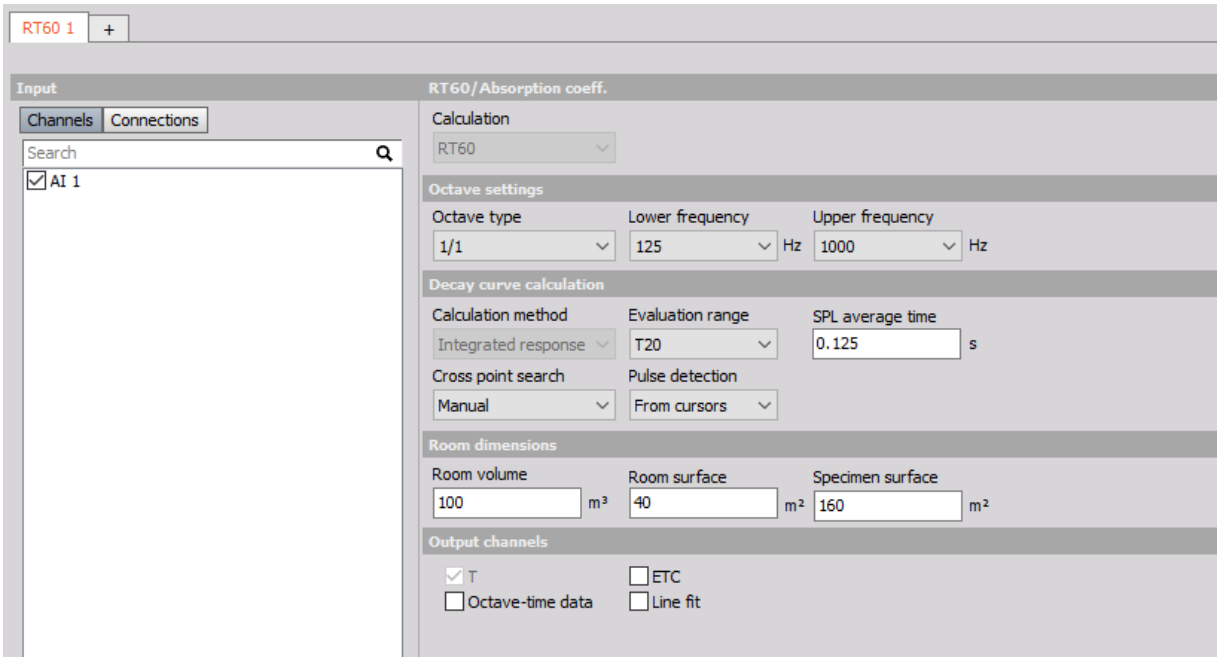
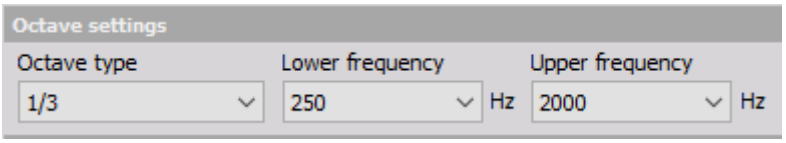


Illustration 4: RT60 plugin settings

9.1. Octave settings

Octave analysis type can be selected from 1/1 or 1/3 octave. The difference is in the centre frequency and bandwidth of the bands. When defining the Lower frequency, we have to be careful, because of the

longer wavelength of the sound with low frequency (the longest wavelength is conditioned with the room's dimensions).



9.2. Decay curve calculation

Decay curve is a graphical representation of the decay of the sound pressure level in a room as a function of time after the sound source has stopped. Integrated impulse response method is a method of obtaining decay curves by reverse-time integration of the squared impulse responses.

9.3. Evaluation range

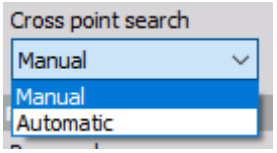
Reverberation time can be evaluated based on a smaller dynamic range than 60 dB and extrapolated to a decay time of 60 dB. The evaluation of the decay curve for each frequency band shall start at 5 dB below the initial sound pressure level. The bottom of the evaluation range should be at least 10 dB above the overall background noise of the measuring system.

- T10 is a time derived from the time at which the decay curve first reaches 5 dB and 15 dB below the initial level
- T15 is a time derived from the time at which the decay curve first reaches 5 dB and 20 dB below the initial level
- T20 is a time derived from the time at which the decay curve first reaches 5 dB and 25 dB below the initial level.
- T30 is a time derived from the time at which the decay curve first reaches 5 dB and 35 dB below the initial level.
- T60 is a time derived from the time at which the decay curve first reaches 5 dB and 65 dB below the initial level.

9.4. SPL averaging type

Average time is a constant of an exponential averaging device and shall be less than 1/30 of the reverberation time.

9.5. Cross point search



Option **manual** will calculate the reverberation time from the first to the second locked cursor.

Automatic search uses the improved algorithm for reverberation time estimation (Lundby algorithm). It is important to place the first cursor on the right position, and the position of the second cursor will be found automatically.

9.6. Output channels

- T – measured reverberation time
- ETC – energy time curve
- Octave-time data
- Line fit – makes a fitted curve on an energy time curve

10. Measurement

First, we measure the RT60 of an empty room. Connect and calibrate the microphones. Add the RT60 plugin, select the input channels (microphones) and adjust the setup.

Record and store the impulse noise signal with the microphone. An example of an impulse signal is shown in the picture below (i.e. popping a balloon).

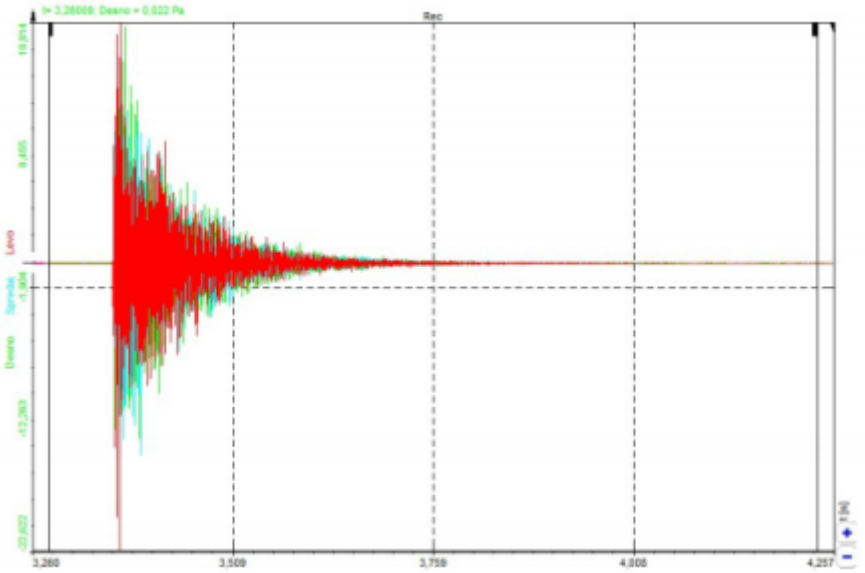
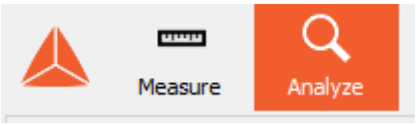


Illustration 5: Impulse signal

The reverberation time DEWESoft calculated in Analyze mode, only the SPL is shown online (live during measurement in the Acquisition mode). Switch to Analyze mode.



11. Placing of the cursors

Open the recorded data file and place the cursor I on the beginning of the impulse and cursor II on the place, where signal has already fallen on the noise floor level (for help, take a look at the orange rectangular). It is important to place the cursors right, otherwise you don't get enough of the difference in dB fall to get the right calculation.

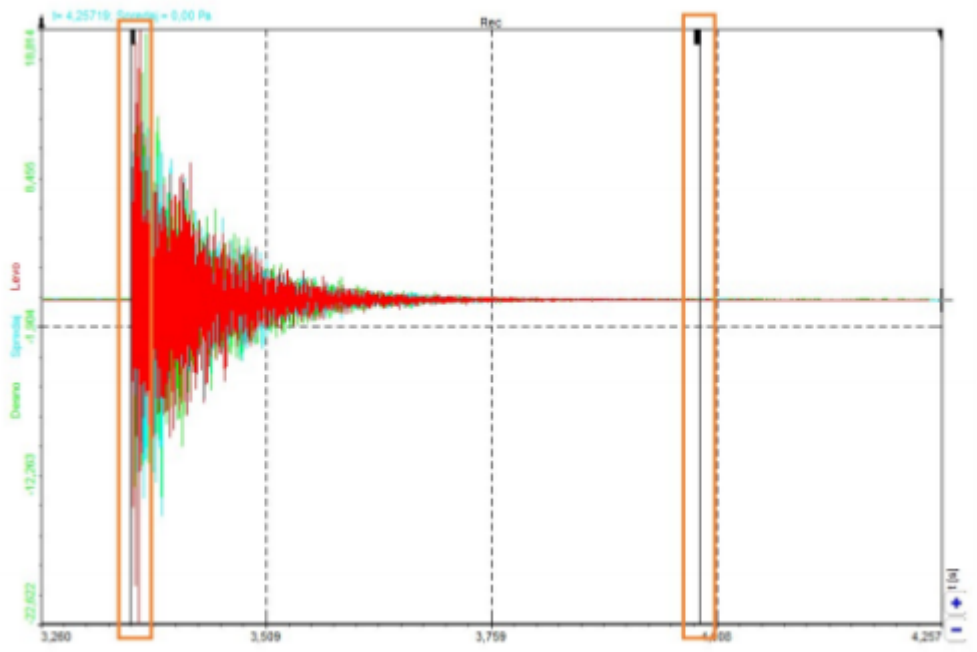
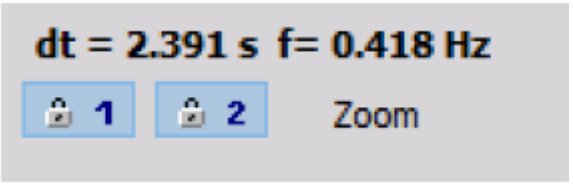
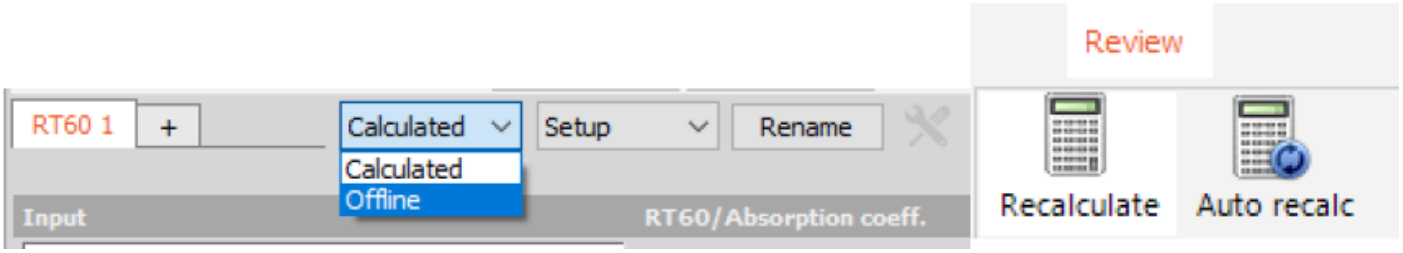


Illustration 6: Placing the cursors

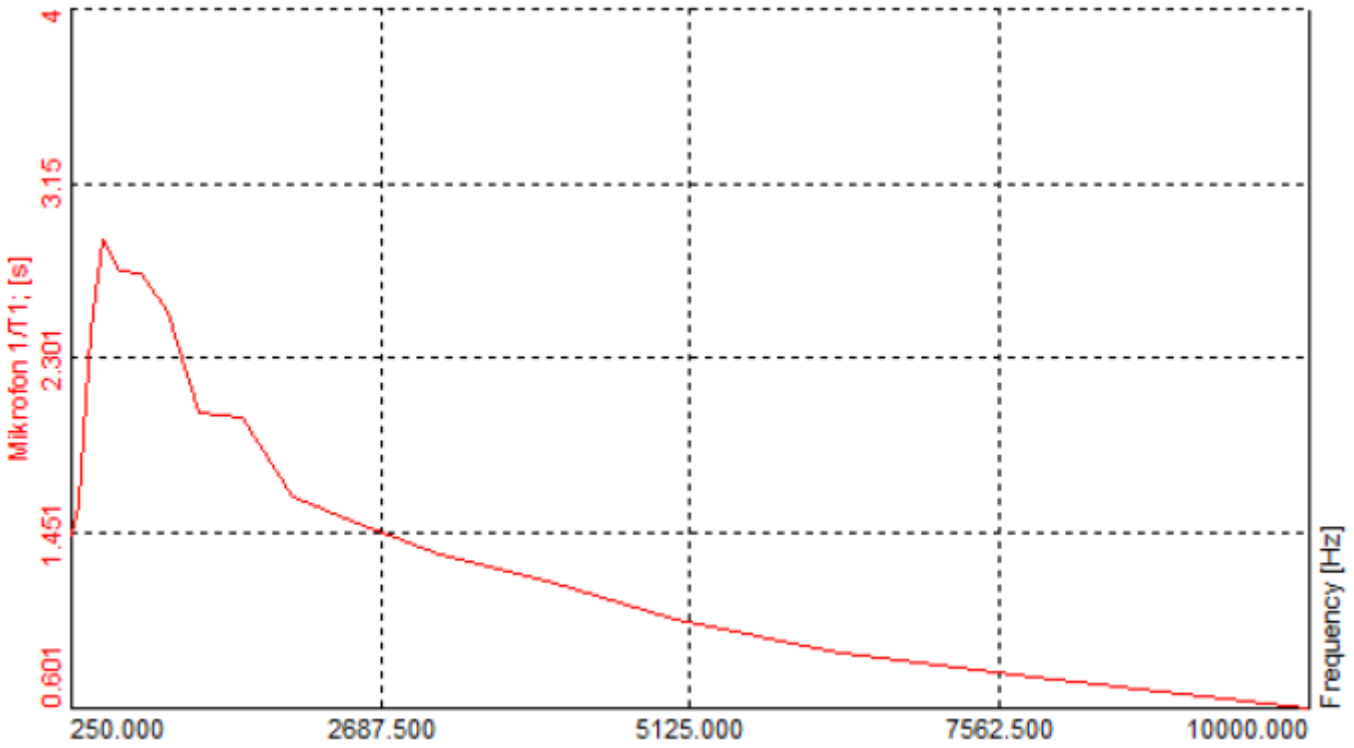
Lock the position of the cursors with the click on two locks in the bottom left corner.



After the cursors are locked on the right positions, we have to Recalculate the data. Go back to Math and change the channel to Offline. Recalculate function will again do the calculation of the selected data (area between the locked cursors).



The results for the reverberation time can be shown on a 2D graph.

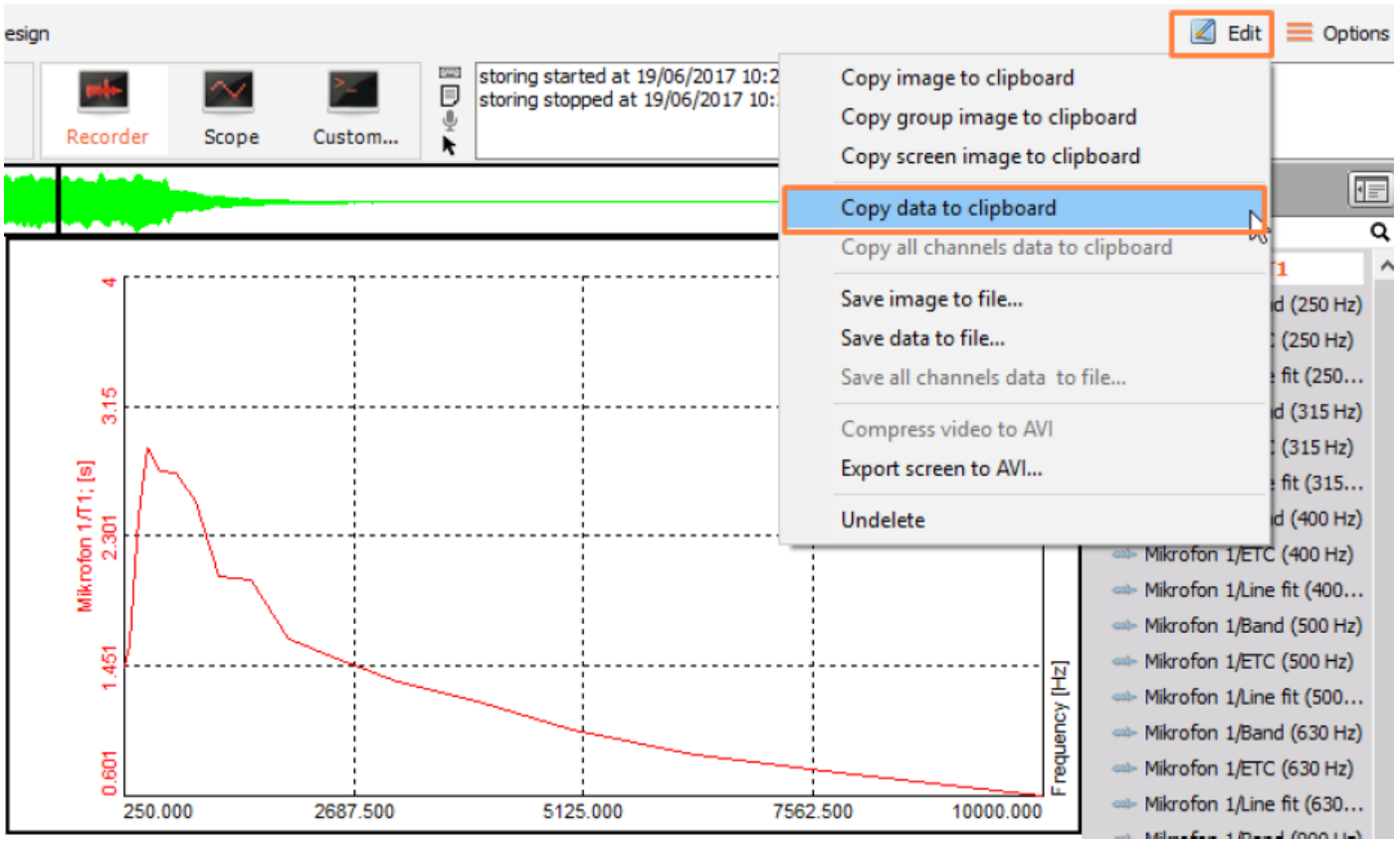


12. Alpha coefficient calculation

Alpha coefficient is calculated with a formula, where both reverberation times are important parameters.

The provided Excel template RT60_AlphaTemplate_v1_0 contains formulas for averaging and calculation of absorption (alpha) coefficient.

Open the template and copy the RT60 data to Excel.



Enter the parameters about the room conditions and dimensions (temperature, humidity, volume, surface). The important parameter is the surface area of a test specimen.

Conditions - empty room	
Temparature [°C]	22
Humidity [%]	20
Attenuation coefficient [dB/m]	
Speed of sound [m/s]	344.60248

Room	
Length [m]	
Width [m]	
Height [m]	
Volume [m^3]	16
Area [m^2]	38

Conditions - room with specimen	
Temparature [°C]	22
Humidity [%]	20
Attenuation coefficient [dB/m]	
Speed of sound [m/s]	344.60248
Deviation [%]	2

Tested specimen	
Specimen area [m^2]	1.2

Data for reverberation time T1 (in an empty room) are copied into Excel template. It is recommended that the measurement of the reverberation time is repeated multiple times to ensure the right data. Reverberation times in the same frequency band are averaged.

Microphone 1 - empty room - T1						
Frequency [Hz]	Average T1 [s]	Microphone 1/T1 [s] - test 1	Microphone 1/T1 [s] - test 2	Microphone 1/T1 [s] - test 3	Microphone 1/T1 [s] - test 4	Microphone 1/T1 [s] - test 5
125	-					
160	-					
200	-					
250	1.63	1.60	1.61	1.63	1.66	1.62
315	1.68	1.67	1.70	1.64	1.73	1.63
400	2.74	2.88	2.76	2.72	2.60	2.58
500	3.77	3.74	3.74	3.93	3.67	3.51
630	3.77	3.75	3.74	3.81	3.77	3.83
800	4.26	4.13	4.16	4.45	4.31	4.24
1000	4.30	4.38	4.43	4.18	4.20	4.52
1250	4.46	4.48	4.46	4.49	4.39	4.60
1600	4.35	4.40	4.41	4.23	4.35	4.35
2000	3.76	3.80	3.75	3.73	3.74	3.77
2500	3.32	3.30	3.30	3.34	3.35	3.41
3150	2.95	2.95	2.94	2.93	2.96	2.90
4000	2.46	2.45	2.41	2.57	2.41	2.36
5000	1.97	2.02	1.99	1.93	1.93	2.00
6300	1.47	1.48	1.45	1.49	1.48	1.47
8000	1.12	1.14	1.11	1.10	1.13	1.13
10000	0.84	0.85	0.83	0.85	0.84	0.84

The measurement with the test specimen in the alpha chamber should also be done multiple times. The frequency band data of reverberation times are being averaged in the template.

Microphone 1 - with specimen - T2						
Frequency [Hz]	Average T2 [s]	Microphone 1/T2 [s] - test 1	Microphone 1/T2 [s] - test 2	Microphone 1/T2 [s] - test 3	Microphone 1/T2 [s] - test 4	Microphone 1/T2 [s] - test 5
250	1.45	1.45	1.39	1.44	1.62	1.45
315	1.55	1.59	1.51	1.56	1.69	1.49
400	2.58	2.43	2.76	2.59	2.63	2.53
500	2.77	2.88	2.74	2.76	2.80	2.76
630	2.86	2.73	2.85	2.85	2.90	2.88
800	2.70	2.72	3.00	2.70	2.69	2.69
1000	2.35	2.53	2.55	2.23	2.30	2.21
1250	2.01	2.03	1.97	2.01	2.11	2.00
1600	1.94	2.02	1.96	1.88	1.97	1.88
2000	1.64	1.63	1.69	1.64	1.63	1.64
2500	1.45	1.50	1.43	1.44	1.47	1.46
3150	1.28	1.35	1.22	1.25	1.33	1.27
4000	1.20	1.23	1.23	1.19	1.18	1.19
5000	1.02	1.04	1.01	0.99	1.03	1.03
6300	0.88	0.87	0.88	0.90	0.87	0.91
8000	0.74	0.75	0.71	0.74	0.75	0.74
10000	0.62	0.60	0.66	0.61	0.62	0.62

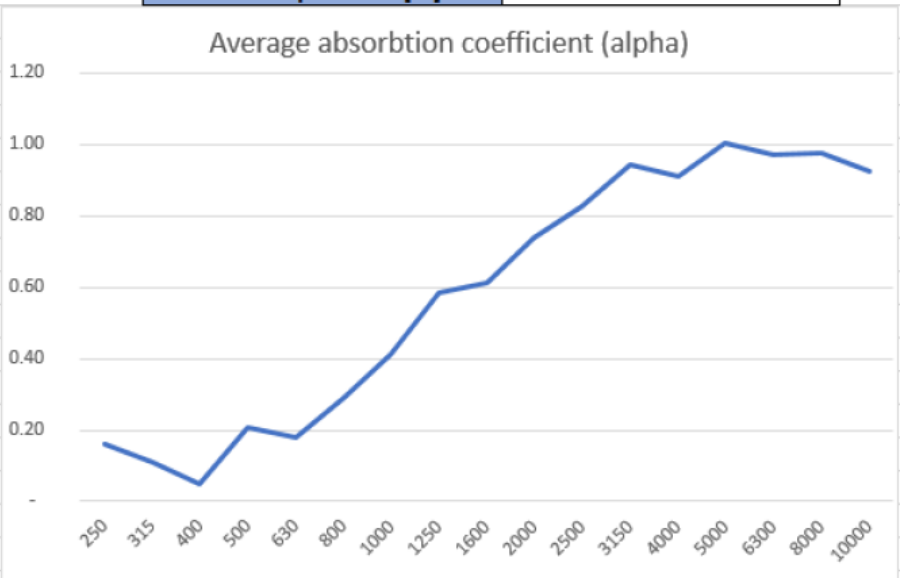
13. Report and analysis

Section in Excel template is dedicated to report. Alpha coefficient is calculated from reverberation times (T1, T2) and other parameters, that have to be entered (surface area of a test specimen, speed of sound, ...).

DEWESoft®
measurement innovation

Testing labaratory:	DEWESoft
Report number:	524
Date of test:	21.07.2017
Tested by:	DEWESoft
Test ordered by:	DEWESoft
Product:	
Manufacturer:	
Purpose of test:	
Place of test:	
Standard:	
Ambirent humidity [%]	20
Ambient temperature [°C]	22

Frequency [Hz]	Average alpha
250	0.16
315	0.11
400	0.05
500	0.20
630	0.18
800	0.29
1000	0.41
1250	0.58
1600	0.61
2000	0.74
2500	0.83
3150	0.94
4000	0.91
5000	1.01
6300	0.97
8000	0.97
10000	0.92



The result shown in the Excel template is the alpha coefficient for each frequency band and a graph of the alpha coefficient.

14. Warranty information

Notice
The information contained in this document is subject to change without notice.

Note:
Dewesoft d.o.o. shall not be liable for any errors contained in this document. Dewesoft MAKES NO WARRANTIES OF ANY KIND WITH REGARD TO THIS DOCUMENT, WHETHER EXPRESS OR IMPLIED. DEWESOFT SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Dewesoft shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory, in connection with the furnishing of this document or the use of the information in this document.

The copy of the specific warranty terms applicable to your Dewesoft product and replacement parts can be obtained from your local sales and service office. To find a local dealer for your country, please visit https://dewesoft.com/support/distributors.

12.1. Calibration

Every instrument needs to be calibrated at regular intervals. The standard norm across nearly every industry is annual calibration. Before your Dewesoft data acquisition system is delivered, it is calibrated. Detailed calibration reports for your Dewesoft system can be requested. We retain them for at least one year, after system delivery.

12.2. Support

Dewesoft has a team of people ready to assist you if you have any questions or any technical difficulties regarding the system. For any support please contact your local distributor first or Dewesoft directly.

Dewesoft d.o.o.
Gabrsko 11a
1420 Trbovlje Slovenia

Europe Tel.: +386 356 25 300
Web: http://www.dewesoft.com
Email: Support@dewesoft.com
The telephone hotline is available Monday to Friday from 07:00 to 16:00 CET (GMT +1:00)

12.3. Service/repair

The team of Dewesoft also performs any kinds of repairs to your system to assure a safe and proper operation in the future. For information regarding service and repairs please contact your local distributor first or Dewesoft directly on https://dewesoft.com/support/rma-service.

12.4. Restricted Rights

Use Slovenian law for duplication or disclosure. Dewesoft d.o.o. Gabrsko 11a, 1420 Trbovlje, Slovenia / Europe.

12.5. Printing History

Version 2.0.0, Revision 217 Released 2015 Last changed: 23. July 2018 at 16:54.

12.6. Copyright

12.7. Trademarks

We take pride in our products and we take care that all key products and technologies are registered as trademarks all over the world. The Dewesoft name is a registered trademark. Product families (KRYPTON, SIRIUS, DSI, DS-NET) and technologies (DualCoreADC, SuperCounter, GrandView) are registered trademarks as well. When used as the logo or as part of any graphic material, the registered trademark sign is used as a part of the logo. When used in text representing the company, product or technology name, the ® sign is not used. The Dewesoft triangle logo is a registered trademark but the ® sign is not used in the visual representation of the triangle logo.

13. Safety instructions

Your safety is our primary concern! Please be safe!

13.1. Safety symbols in the manual

Warning
Calls attention to a procedure, practice, or condition that could cause the body injury or death

Caution
Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

13.2. General Safety Instructions

Warning

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. Dewesoft GmbH assumes no liability for the customer's failure to comply with these requirements.

All accessories shown in this document are available as an option and will not be shipped as standard parts.

12.2.1. Environmental Considerations

Information about the environmental impact of the product.

12.2.2. Product End-of-Life Handling

Observe the following guidelines when recycling a Dewesoft system:

12.2.3. System and Components Recycling

Production of these components required the extraction and use of natural resources. The substances contained in the system could be harmful to your health and to the environment if the system is improperly handled at its end of life! Please recycle this product in an appropriate way to avoid unnecessary pollution of the environment and to keep natural resources.

This symbol indicates that this system complies with the European Union's requirements according to Directive 2002/96/EC on waste electrical and electronic equipment (WEEE). Please find further information about recycling on the Dewesoft web site www.dewesoft.com

Restriction of Hazardous Substances
This product has been classified as Monitoring and Control equipment and is outside the scope of the 2002/95/EC RoHS Directive. However, we take care of our environment and the product is lead-free.

12.2.4. General safety and hazard warnings for all Dewesoft systems

Safety of the operator and the unit depend on following these rules.

- Use this system under the terms of the specifications only to avoid any possible danger.
- Read your manual before operating the system.
- Observe local laws when using the instrument.
- DO NOT touch internal wiring!
- DO NOT use higher supply voltage than specified!
- Use only original plugs and cables for harnessing.
- You may not connect higher voltages than rated to any connectors.
- The power cable and connector serve as Power-Breaker. The cable must not exceed 3 meters, the disconnect function must be possible without tools.
- Maintenance must be executed by qualified staff only.
- During the use of the system, it might be possible to access other parts of a more comprehensive system. Please read and follow the safety instructions provided in the manuals of all other components regarding warning and security advice for using the system.
- With this product, only use the power cable delivered or defined for the host country.
- DO NOT connect or disconnect sensors, probes or test leads, as these parts are connected to a voltage supply unit.
- Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), a non-interruptible safety earth ground must be provided from the mains power source to the product input wiring terminals.
- Please note the characteristics and indicators on the system to avoid fire or electric shocks. Before connecting the system, please read the corresponding specifications in the product manual carefully.

- The inputs must not, unless otherwise noted (CATx identification), be connected to the main circuit of category II, III and IV.
- The power cord separates the system from the power supply. Do not block the power cord, since it has to be accessible for the users.
- DO NOT use the system if equipment covers or shields are removed.
- If you assume the system is damaged, get it examined by authorized personnel only.
- Adverse environmental conditions are Moisture or high humidity Dust, flammable gases, fumes or dissolver Thunderstorm or thunderstorm conditions (except assembly PNA) Electrostatic fields, etc.
- The measurement category can be adjusted depending on module configuration.
- Any other use than described above may damage your system and is attended with dangers like short-circuiting, fire or electric shocks.
- The whole system must not be changed, rebuilt or opened.
- DO NOT operate damaged equipment: Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the product until the safe operation can be verified by service-trained personnel. If necessary, return the product to Dewesoft sales and service office for service and repair to ensure that safety features are maintained.
- If you assume a more riskless use is not provided anymore, the system has to be rendered inoperative and should be protected against inadvertent operation. It is assumed that a more riskless operation is not possible anymore if the system is damaged obviously or causes strange noises. The system does not work anymore. The system has been exposed to long storage in adverse environments. The system has been exposed to heavy shipment strain.
- Warranty void if damages caused by disregarding this manual. For consequential damages, NO liability will be assumed!
- Warranty void if damage to property or persons caused by improper use or disregarding the safety instructions.
- Unauthorized changing or rebuilding the system is prohibited due to safety and permission reasons (CE).
- Be careful with voltages >25 VAC or >35 VDC! These voltages are already high enough in order to get a perilous electric shock by touching the wiring.
- The product heats during operation. Make sure there is adequate ventilation. Ventilation slots must not be covered!
- Only fuses of the specified type and nominal current may be used. The use of patched fuses is prohibited.
- Prevent using metal bare wires! Risk of short circuit and fire hazard!
- DO NOT use the system before, during or shortly after a thunderstorm (risk of lightning and high energy over-voltage). An advanced range of application under certain conditions is allowed with therefore designed products only. For details please refer to the specifications.
- Make sure that your hands, shoes, clothes, the floor, the system or measuring leads, integrated circuits and so on, are dry.
- DO NOT use the system in rooms with flammable gases, fumes or dust or in adverse environmental conditions.
- Avoid operation in the immediate vicinity of high magnetic or electromagnetic fields, transmitting antennas or high-frequency generators, for exact values please refer to enclosed specifications.
- Use measurement leads or measurement accessories aligned with the specification of the system only. Fire hazard in case of overload!

- Do not switch on the system after transporting it from a cold into a warm room and vice versa. The thereby created condensation may damage your system. Acclimatise the system unpowered to room temperature.
- Do not disassemble the system! There is a high risk of getting a perilous electric shock. Capacitors still might be charged, even if the system has been removed from the power supply.
- The electrical installations and equipment in industrial facilities must be observed by the security regulations and insurance institutions.
- The use of the measuring system in schools and other training facilities must be observed by skilled personnel.
- The measuring systems are not designed for use in humans and animals.
- Please contact a professional if you have doubts about the method of operation, safety or the connection of the system.
- Please be careful with the product. Shocks, hits and dropping it from already- lower level may damage your system.
- Please also consider the detailed technical reference manual as well as the security advice of the connected systems.
- This product has left the factory in safety-related flawlessness and in proper condition. In order to maintain this condition and guarantee safety use, the user has to consider the security advice and warnings in this manual.

EN 61326-3-1:2008
IEC 61326-1 applies to this part of IEC 61326 but is limited to systems and equipment for industrial applications intended to perform safety functions as defined in IEC 61508 with SIL 1-3.

The electromagnetic environments encompassed by this product family standard are industrial, both indoor and outdoor, as described for industrial locations in IEC 61000-6-2 or defined in 3.7 of IEC 61326-1.

Equipment and systems intended for use in other electromagnetic environments, for example, in the process industry or in environments with potentially explosive atmospheres, are excluded from the scope of this product family standard, IEC 61326-3-1.

Devices and systems according to IEC 61508 or IEC 61511 which are considered as “operationally well-tried”, are excluded from the scope of IEC 61326-3-1.

Fire-alarm and safety-alarm systems, intended for the protection of buildings, are excluded from the scope of IEC 61326-3-1.

13.3. Documentation version history

Version	Date	Notes
V20-1	17.8.2020	New Template
V21-1	22.3.2021	Added chapter 12 and chapter 13