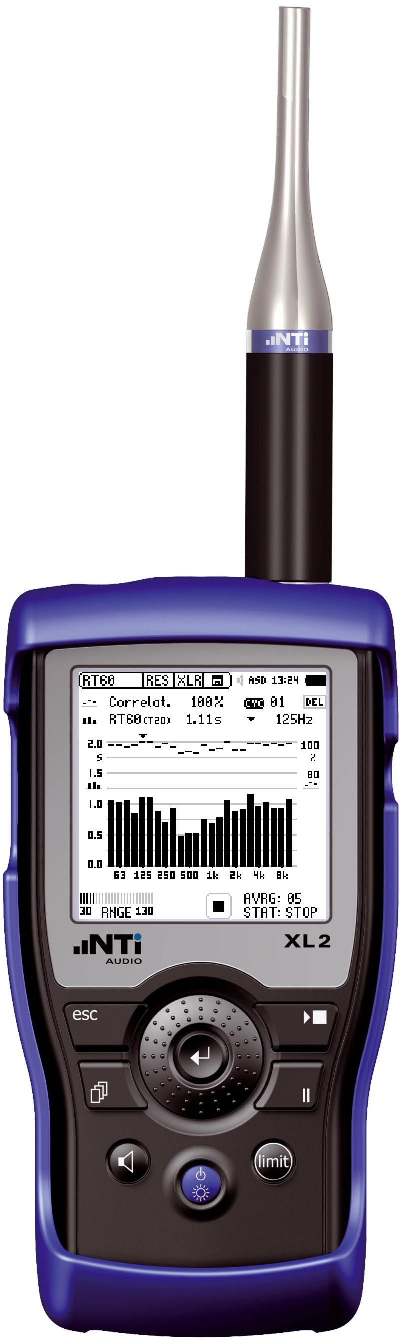
RT60 Reverberation Time



XL2 Acoustic Analyzer
with M4261 Measurement Microphone

The XL2 Audio and Acoustic Analyzer measures RT60 reverberation time in octave and 1/3rd octave band resolution. This application note describes the technical details of reverberation time measurements.

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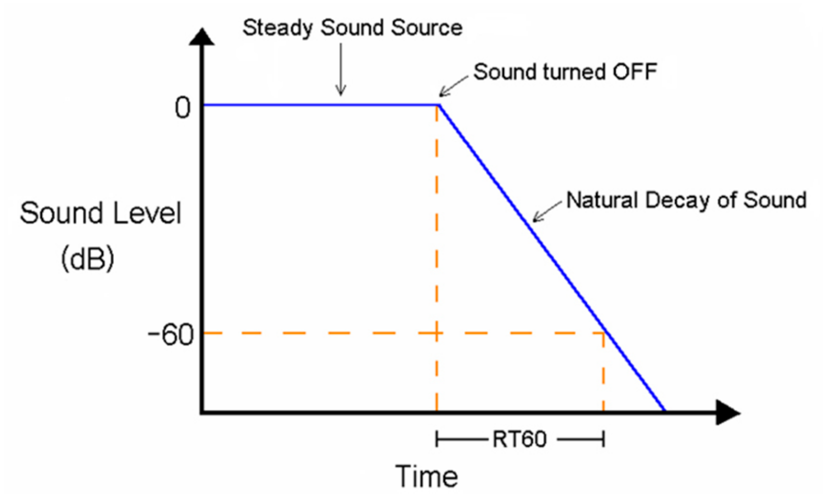
What is Reverberation Time?

Reverberation time is the time required for sound to "fade away" in a room. Sound waves will repeatedly bounce off reflective surfaces such as the floor, walls, ceiling, windows or tables and return to the listener position. This is particularly noticeable in a church, for example, where the sound may be heard for several seconds while it fades away.

In principle, RT60 reverberation time is the time required for the sound pressure level to decrease by 60 dB after the sound stimulus signal abruptly stops. The sketch below visualizes this basic principle of an RT60 measurement.



The RT60 reverberation time measurement is defined in the following standards

- ISO 3382-1 for performance spaces
- ISO 3382-2 for ordinary rooms
- ASTM E2235

The actual measurements span across 63 Hz to 8 kHz in octave band resolution and 50 Hz to 10 kHz in 1/3rd octave band resolution. Rooms have individual absorption capabilities for each frequency, so the RT60 values within each frequency band will vary.

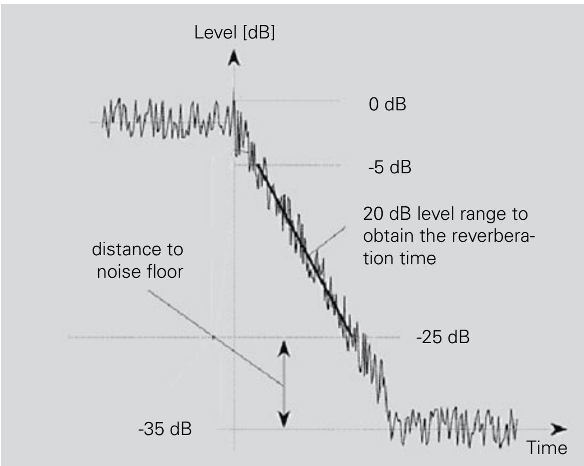
Why do we Measure Reverberation?

Reverberation is a key parameter when qualifying the acoustic status of a room. Particularly, too much reverberation may have a negative impact on the intelligibility of speech. Also, the sound pressure level from noise sources can be enhanced while the privacy of a room can be decreased by reverberation in a room. Furthermore, reverberation time is measured to determine the room absorption correction value required in many acoustic measurements, such as sound insulation and sound power.

T20 and T30 Methods

By way of example, say the ambient noise floor in a room is 45 dB. To measure a linear decay of 60 dB, we need to ensure that the decay measurement ends 10 dB above this noise floor (so the linearity of the sound decay is not significantly influenced by the ambient noise). An additional 5 dB headroom is required to detect the start of the decay. Adding these levels together, we require a test signal level of 45 + 60 + 10 + 5 = 120 dB across the whole frequency spectrum. This is technically often not feasible, particularly at low frequencies.

In practice, therefore, we measure the time taken for the reflections to decay by 20 dB or 30 dB in accordance with the ISO 3382 standard. If the decay is acceptably linear, these readings can then be linearly extrapolated to a decay of 60 dB. The reverberation time measurement method used is identified as T20 or T30 respectively.



RT60 Measurement with T20 method

- T20
  - The measurement requires a relatively small dynamic measurement range of ~35 dB above the noise floor for each frequency band.
  - RT60 (T20) = 3 x time measured for a 20 dB decay
- T30
  - The measurement requires a dynamic measurement range of ~45 dB above the noise floor for each frequency band.
  - RT60 (T30) = 2 x time measured for a 30 dB decay

Generally it is better to choose T30 over T20, as the measurement uncertainty will be lower. However, if the background noise is too high and/or the sound source is not loud enough to create 45 dB above the noise floor, then T20 may be your best option.

Mathematically, RT60 is calculated from a linear least-squares regression of the measured decay curve.

- If the overall RT60 is short (e.g. < 0.3 seconds) the room acoustic is referred to as being "dead". For example, a room with thick carpets, curtains and upholstered furniture may have such an acoustic character.
- If the overall RT60 is long (say more than 2 seconds) the room acoustic is referred to as being "live" or "echoic". For example, a large empty room with painted plaster walls and a tiled floor may have such an acoustic character.

Accuracy of Reverberation Time Measurement

The ISO 3382 standard specifies three levels of measurement accuracy (3 methods). The main difference concerns the choice of signal source and the number of measurement positions.

Survey method

- There are no directivity requirements on the signal source.
- Measurements typically carried out in octave band resolution.
- The frequency range should cover at least 250 Hz to 2 000 Hz.
- The nominal measurement accuracy is assumed to be better than 10 % for octave bands.
- A short excitation or an impulse signal may be used as an alternative to the interrupted noise signal. Pink noise provides a better measurement accuracy than an impulse signal.

Engineering method

- For measurements in performance spaces: An omnidirectional speaker with identical radiation characteristics in all directions is required.
- For measurements in ordinary rooms: There are no directivity requirements on the signal source.
- Measurements may be carried out in octave band resolution or the optional 1/3rd octave band resolution (part of the XL2 Extended Acoustic Pack).
- The frequency range should cover at least 125 Hz to 4 000 Hz in octave bands, or 100 Hz to 5 000 Hz in 1/3rd octave bands.
- The recommended duration of excitation of the room equals the measured reverberation time in each frequency band.
- The nominal measurement accuracy is assumed to be better than
  - 5 % in octave bands
  - 10 % in 1/3rd octave bands

Precision method

- For measurements in performance spaces: An omnidirectional speaker with identical radiation characteristics in all directions is required.
- For measurements in ordinary rooms: Requires an omnidirectional speaker.
- Measurements may be carried out in octave band resolution or the optional 1/3rd octave band resolution (part of the XL2 Extended Acoustic Pack).
- The frequency range should cover at least 125 Hz to 4 000 Hz in octave bands, or 100 Hz to 5 000 Hz in 1/3rd octave bands.
- The duration of excitation of the room needs to be sufficient for the sound field to have achieved a steady state before the source is switched off.
- The RT60 measurement accuracy is assumed to be better than
  - 2.5 % in octave bands
  - 5 % in 1/3rd octave bands

Sound Source

RT60 measurements require a diffuse sound field in the room. This means that the sound energy of the test signal has to be distributed uniformly. A speaker with an omnidirectional radiation characteristic should be used for accurate measurements using a gated pink noise test signal. The recommended signal source set consists of the DS3 Dodecahedron Speaker and the PA3 Power Amplifier. Survey method measurements may be performed with an existing installed speaker system using the Minirator MR-PRO as the signal source. Alternatively, an impulsive sound source may be used in accordance with ISO 3382-1. The ASTM E2235 standard does not allow impulsive sound sources.

DS3 Dodecahedron Speaker Set


DS3 Dodecahdron Speaker

The PA3 Power Amplifier includes a pink noise signal generator. This test signal is played through the DS3 Dodecahedron Speaker into the room under test. The test signal may be switched on and off by remote control. The test signal should be played for a long enough time period to ensure that a balance between injected and absorbed acoustic energy has been reached. i.e. the sound should be given enough time to reach all reflective surfaces in the room. The duration of the pink noise test signal should thus be at least equal to or longer than half of the measured reverberation time for each frequency band. As the room can never be "over-saturated" with sound for an RT60 measurement, to be on the safe side, play the noise for least the time period of the estimated RT60 test result. Each time the test signal stops, the XL2 recognizes this interruption, measures the decay time, and calculates the reverberation time automatically.

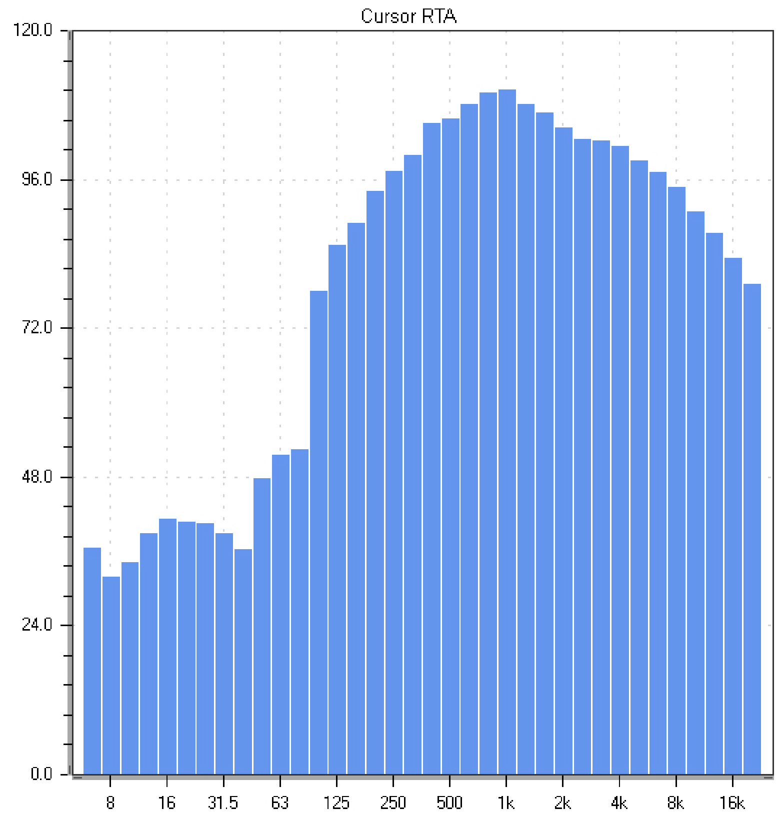
The DS3 Dodecahedron Speaker is a powerful sound source with omnidirectional radiation characteristics. It consists of 12 loudspeakers of the same type, mounted to a dodecahedron-shaped chassis. The optimized frequency spectrum delivers a high level of equalized sound energy for precise reverberation time measurements. The emitted sound power is constant throughout the measurement and for several consecutive hours.

Impulse Sound Sources

Typical impulse sound sources are, for example, a starter pistol, starter clapper board or bursting balloon. Such sound sources may be used for survey method measurements in performance spaces. The XL2 measures the decay time and calculates the reverberation time automatically.

Various starter pistols may be used to generate an impulse in the room and trigger the reverberation time measurement. For example, customers may use the following models, both shooting blank or gas using a 9 mm caliber:

- HW37, manufacturer Weihrauch
- Chiefs Special, manufacturer Smith & Wesson



Sample Gun Shot Spectrum

WARNING: Using such a pistol in a closed room with approx. 800 m^3 may generate an impulse sound pressure level LZI_{max} of up to 125 dB.

Advantage

- lightweight and portable

Disadvantages

- may be inappropriate in the presence of children or in a church
- may not be permitted on airplanes
- may leave a smell of gunpowder residue in the room
- may unsettle dust in the room; e.g. requires cleaning after the measurements

Alternative impulse sound sources are, for example, balloons, a clapper board or hand clapping. The challenge is that these sound sources typically generate insufficient sound energy in the lower frequency bands. Thus the reverberation time cannot be measured in these bands.

The larger the balloon, the deeper frequencies it will cover, and the more sound energy it can produce. Make sure you use higher-quality balloons that are fit for purpose. Cheap children party balloons can be difficult to blow up, and may burst prematurely (at worst, in front of your client!). Also allow sufficient time, as a balloon of 1 meter diameter could take up to 5 minutes to inflate with an electric balloon inflator.

Hand clapping is often used for a quick initial indication of the reverberation time in the room. Take a look at the following videos of handclapping in different rooms:

https://www.nti-audio.com/en/support/know-how/how-to-get-a-feeling-for-rt60-value

Minirator MR-PRO

Minirator MR-PRO

The Minirator MR-PRO is a test signal generator that can be used for survey method measurements. The generated audio signal may be played through an existing speaker system. The MR-PRO generates a gated pink noise with a low crest factor. The on/off cycle time is adjustable from 1 to 10 seconds. The MR-PRO connects to the installed power amplifier and the test signal is played through the installed speakers. In addition, the MR-PRO offers a Glide Sweep signal with editable cycle time (< 1.5 seconds for RT60 measurements using the XL2 Acoustic Analyzer).

Sound Source Position

The omnidirectional DS3 Dodecahedron Speaker should be positioned at the typical sound source locations for the room e.g. for classrooms, at the front from where the teacher normally speaks. In performance spaces a minimum of two speaker positions shall be used at a height of 1.5 m above the floor.

For small rooms or in case there is no typical sound source location, one source position should be in a room corner.

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Measure with the XL2 Acoustic Analyzer

The XL2 measures the energy decay spanned across 63 Hz to 8 kHz using the Schroeder method in octave resolution. The optional Extended Acoustic Pack enables 1/3rd octave band resolution from 50 Hz to 10 kHz.

Pink Noise Source

Using a pink noise signal source, we recommend an excitation of the room equaling the measured reverberation time in each frequency band. This is a simplified guide. In detail the ISO 3382-1 standard states that the sound has to radiate at least half of the measured reverberation time for the engineering and precise methods. Due to the randomness of the pink noise, it is recommended to average over at least three decays at each position in order to achieve an acceptably low measurement uncertainty. The XL2 averages the readings of all cycles automatically.

Impulsive Sound Source

Using an impulsive sound source, the XL2 has a feature that discards RT60 results when a level overload condition occurs. This is in accordance with the ISO 3382 standard. Sometimes you might not be able to reduce the level of an impulse sound source; e.g. in a small room using a starter gun. In order to still get an RT60 result in such a situation, this overload feature can be disabled by loading a empty file with the name "RT60allowOVLD.txt" in the root directory of the XL2. Note that such an overload condition may affect the RT60 result.

Minimum Microphone to Speaker Distance

The measurement shall not be strongly influenced by the direct sound from the speaker. Therefore the formula below defines the minimum distance between the omnidirectional sound source and the measurement microphone.

Minimum Distance $D = 2 * \sqrt{(V/(c*T))}$

with V = Volume of the room [m^3]
c = Speed of sound [m/s] (at temperature of the room)
T = Reverberation time of the room [s]

For example, in a small hall, 10 meters by 10 meters with a height of 5 meters, and an expected RT60 of 3 seconds, the microphone must be at least 1.4 meters away from the sound source.

$D = 2 * \sqrt{((10*10*5)/(342*3))} = 1.4$ m

Microphone Position

In performance spaces the measurement microphones shall be positioned at the typical listener locations in the room, e.g. 1.2 m above the floor is the typical ear height of seated persons. The selected positions shall represent the entire space in the room. Symmetric microphone positions should be avoided.

The minimum distance to the nearest reflecting surface, such as a floor, wall or ceiling, shall be at least a quarter of a wavelength of the lowest frequency measured. e.g. 1 m to measure down to 100 Hz. For measurements down to 50 Hz, use a minimum distance of 2 m to the nearest reflecting surface.

Distance between Microphones

The microphone positions shall be at least 2 m apart for measurements down to 100 Hz. Use at least a distance of 4 m between microphone positions for measurements down to 50 Hz. This recommendation is based on at least a half wavelength of the lowest frequency measured.

Number of Speaker/Microphone Positions

The minimum number of speaker positions, microphone positions and measurements in a box-shaped room, using the interrupted noise measurement method, depends on the required accuracy.

	Survey	Engineering	Precision
Speaker Positions	1	2	2
Microphone Positions	2	2	3
Measurements	2	6	12
Decays per Measurement	1	2	3

More positions should be used in case of a more complicated room geometry. The measurement starts by pressing the start/stop button on the XL2 Acoustic Analyzer and ends by pressing the start/stop button. It is recommended to measure at least three decays at each position; this reduces the statistical measurement uncertainty in the XL2 report.

Reporting

The XL2 stores all data on an SD card for direct transfer to a computer. Data reports and log files are stored in plain text format, which can be opened with any text editor (Notepad, Wordpad, etc). The data is tab-delimited, so dropping the .txt file into a spreadsheet application will conveniently show the results in columns.

Alternatively, an excellent reporting tool is provided by NTi Audio. The Room Acoustics Reporter is a PC software for the generation of professional reverberation time measurement reports. The software supports acousticians and experts in the visualization and detailed evaluation of measurement data recorded with the XL2 Acoustic Analyzer.

Reverberation Time RT60 in accordance with ISO 3382-2
Measurement of reverberation time in ordinary rooms

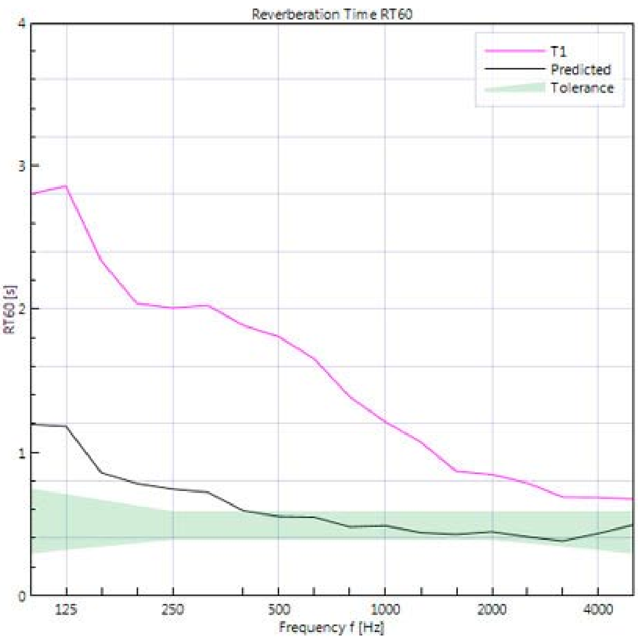
Client: Sample Inc
Object: Office with wooden floor
Date of test: 15/02/2019

empty room w/o furniture

XL2 Sound Level Meter: A2A-10929-E0 (M2230: 5742)
Room Volume: 50 m³ Room Surface: 70 m²

Freq f Hz	T1 RT60 s	Pred RT60 s
100	2.81	1.20
125	2.86	1.18
160	2.34	0.86
200	2.04	0.78
250	2.01	0.75
315	2.03	0.72
400	1.89	0.59
500	1.81	0.55
630	1.65	0.55
800	1.39	0.48
1000	1.21	0.49
1250	1.07	0.44
1600	0.87	0.43
2000	0.85	0.45
2500	0.79	0.41
3150	0.69	0.38
4000	0.69	0.43
5000	0.68	0.49

Mid		
400 - 1250	1.50	0.52



No. of test report: 1234
Date: 22/05/2019
Name: NTi Audio Inc.
Signature:

The reverberation time is reported for each frequency band in octave or 1/3rd octave resolution. For simplification, a single figure reverberation time can be calculated by averaging the following bands:

- Octave band: 500 Hz, 1000 Hz
- 1/3rd octave band: 400 Hz - 1250 Hz

Typical Expected RT60 Results

These are typical RT60 measurement results:

Location	Volume	Recommended RT60
Recording Studio	< 50 m^3	0.3 s
Classroom	< 200 m^3	0.4 - 0.6 s
Office	< 1'000 m^3	0.5 - 1.1 s
Lecture Hall	< 5'000 m^3	1.0 - 1.5 s
Concert/Opera Hall	< 20'000 m^3	1.4 - 2.0 s
Church		2 - 10 s

Typically reverberation times can be reduced with the introduction of absorbing materials such as thick carpets, curtains, upholstered furniture, or dedicated sound-absorbing panels. Furthermore, the presence of people in a room reduces the reverberation, and therefore produces a lower RT60 value compared to the unoccupied room.

More Measurement Tips

- There should be a maximum of two people in the room during the measurements, neither of whom positioned within 1 meter of the microphone.
- In very large rooms (e.g. concert halls) you may operate several Dodecahedron loudspeakers in parallel.