Noise Curves

CRITERIA FOR EVALUATING ROOM NOISE

Noise curves specify the acoustic ambient noise in an indoor environment. Typical disturbing noises are the background noise caused by an air conditioning system as well as noises from heating or ventilation systems (HVAC).

This application note describes how to interpret noise curves, and how to measure noise curves with the XL2 Acoustic Analyzer. We also detail why it is necessary to measure, give a history of the development and finally describe the major types of noise curves.

XL2

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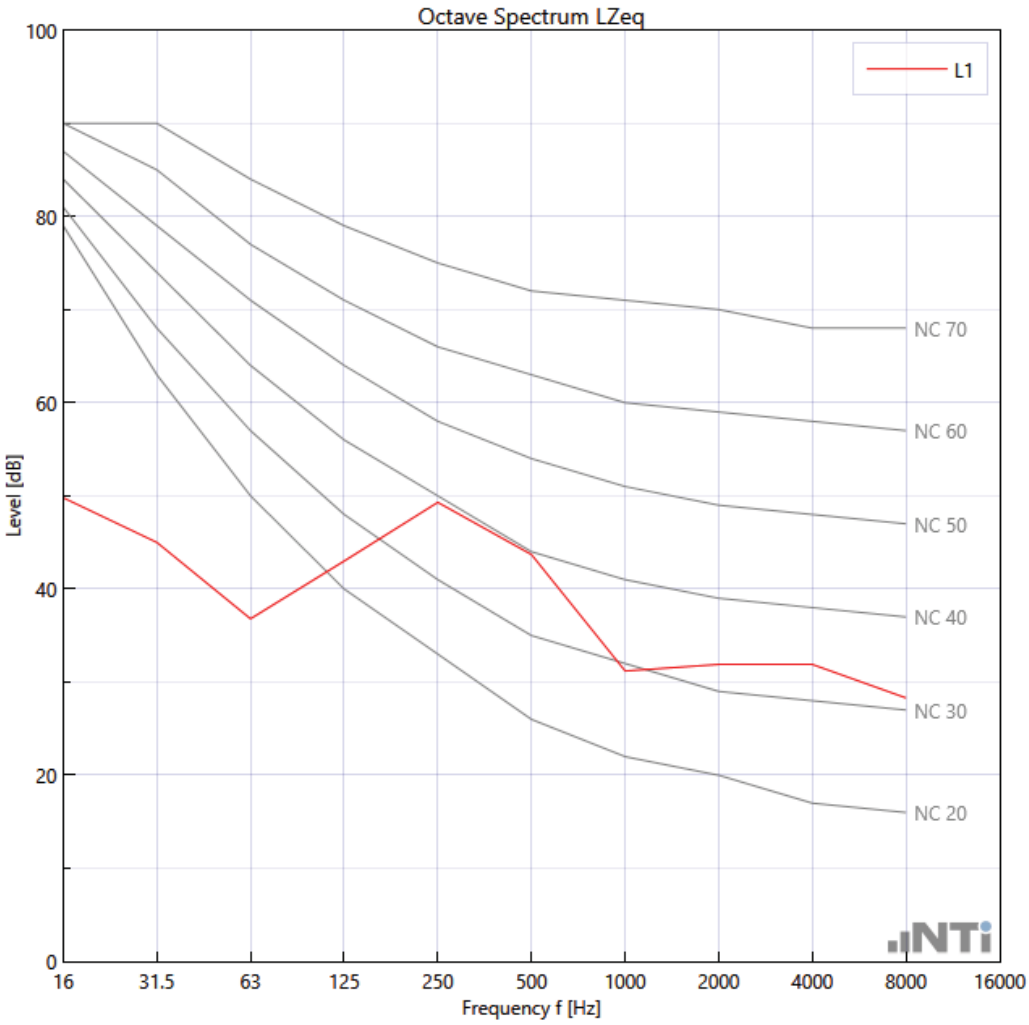
Background noise that is annoying creates fatigue and can negatively affect productivity and safety. Too much noise also affects the ability to communicate. Therefore, standard methodologies for quantifying such noise have been developed. Different rooms, locations, regulations and applications may allow individual acceptable noise ratings. In most cases, the goal is that background noise should not interfere with the purpose of the room, e.g. the noise of an office air-conditioning system should not interfere with telephone calls or conversations. Such residual noise may be caused from outside road traffic noise, HVAC systems (heating, ventilating, air-conditioning) or other sources. Background noise may also be deliberately introduced to mask private conversations.



NC Noise Curves - Screenshot Room Acoustics Reporter

Noise curves provide a uniform measuring standard and are referred to by several noise regulations covering a variety of common locations including manufacturing environments, concert halls, schools and lecture theatres, hospitals and offices.

REQUIREMENTS

- XL2 Acoustic Analyzer
- M4261 Measurement Microphone (Class 2) or better
  Typical measurement range of measurement microphones
  - M4261: NC27
  - M2211: NC20
  - M2230: NC15
  - M2340: NC15
- Spectral Limits Option installed on XL2 for onboard noise curve reading
- Room Acoustics Reporter PC Software available as
  - Room Acoustics Reporter 365 (annual subscription service)
  - XL2 Room Acoustics Option
    (permanently installed option in XL2 Sound Level Meter)

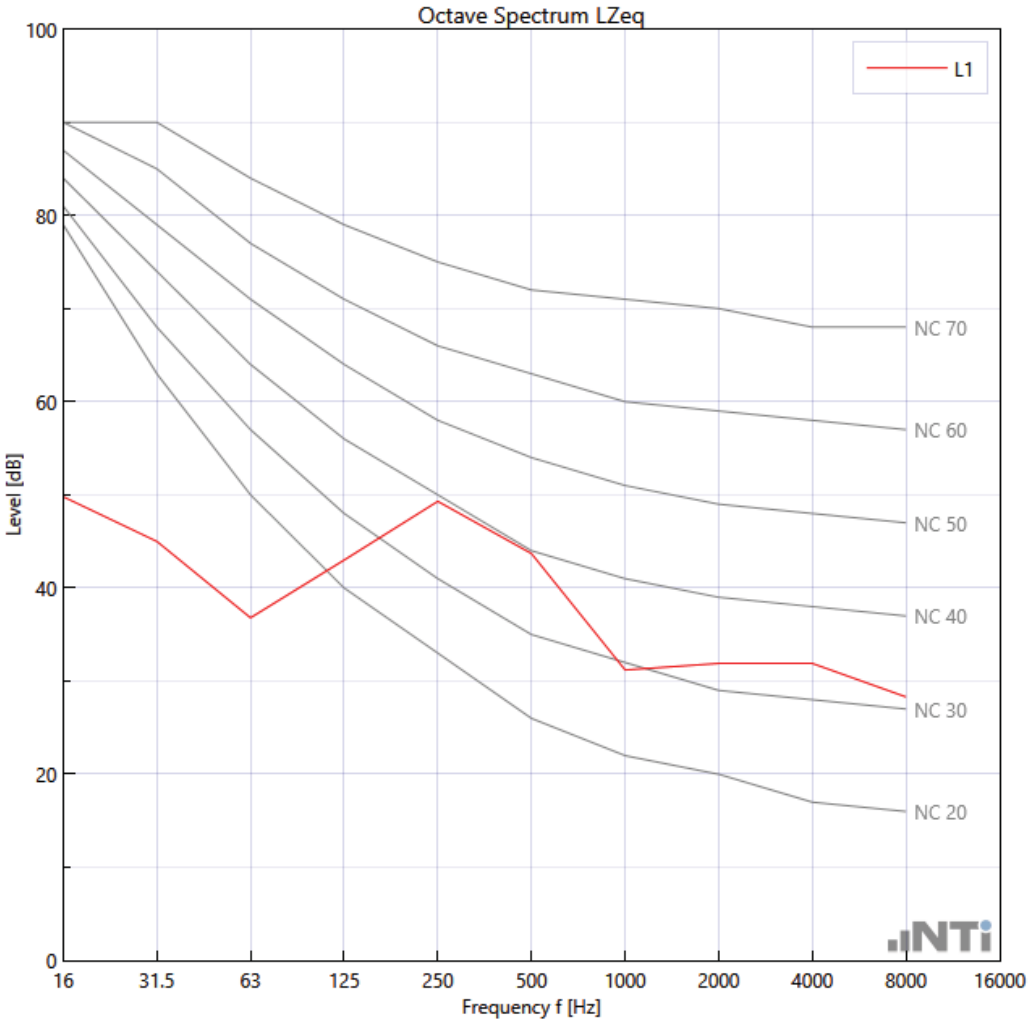
HOW TO MEASURE THE NOISE CURVES

The XL2 Acoustic Analyzer measures the background noise spectrum of the unoccupied room in accordance with the standard. The resulting frequency spectrum gets classified by the Noise Curves.

- Power up the XL2 Acoustic Analyzer.
- Choose the measurement function Noise Curves. This requires the Spectral Limits Option be installed on the XL2. Alternatively, select the LZeq spectrum within the function SLMeter.
- Ensure that the level of background noise in the room is typical for the room when it is unoccupied i.e., nobody should be talking and there should be no extraordinary noise during the measurements.
- Start the measurement.
- Move the microphone slowly (not more than 0.5 m/s) around the entire room for at least 20 seconds. Alternatively, use multiple fixed microphone positions randomly distributed in the room.
- Save the reading(s).
- Load the data into the software Room Acoustics Reporter and generate the measurement report.

HOW TO INTERPRET NOISE CURVES

A noise curve may be used to characterize room noise or other environments. In the design documentation of a building the noise curve may be specified for each room. The noise rating is designated as the value of the highest noise curve “touched” by the measured noise spectrum. When all the noise levels fall on or below a noise rating curve, that noise rating is attributed to the room. For example, the Noise Criterion (NC) of the sample noise spectrum below is NC40. This means, that the ambient noise in the room must be on or lower than the Noise Criterion curve NC40 at any position in the frequency spectrum.



NC Noise Curves - Screenshot Room Acoustics Reporter

The standards list the noise criteria in 5 dB steps. The XL2 measures the noise criteria’s more precisely in 1 dB steps, which are calculated by linear interpolation between the standardized 5 dB levels.

HISTORY

Fully describing the tonal and temporal characteristics of acoustic sound in buildings is a complex undertaking. Throughout the history of acoustic measurement, therefore, there have been many attempts to simplify by create single-number rating methods.

SIL: To evaluate the interference of noise upon speech communication in passenger aircraft, Leo Beranek (1947) introduced the Speech Interference Level (SIL). The SIL was defined as the arithmetic average of the sound pressure levels measured in the octave bands 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. It also served as a convenient single-number rating for evaluating the interference of noise on speech communication in enclosed spaces and outdoors.

SC: The Sound Communication (SC) curves were first introduced in 1953 (Beranek et al., 1953 and 1954). The SC curves were defined in 10 dB increments, but later interpolated to 5 dB and 1 dB increments.

NC: The Noise Criteria curves were first published in 1957 by Beranek, and, like the SC curves that preceded them, are curves of approximate equal loudness. They were developed from a table of Speech Interference Level (SIL) values found to be acceptable in a survey of a person's working in a wide variety of office environments. The curve shapes were set to be monotonic in shape and to have loudness levels in phons that are 23 units above the corresponding SIL values. It is to be noted that the NC curves are not intended to be the most desirable noise spectrum shapes, but rather they are intended to be octave band noise levels that just permit satisfactory speech communication without being annoying (Beranek, 2000). The NC curves have been revised in 1960 and extended in 2004.

It was originally presumed that an octave band spectrum that generally follows an NC curve shape would be perceived as equally balanced in low, mid, and high frequency energy. Although this was shown not quite to be the case, this led to the development of other curve sets.

SI: Leo Beranek developed the originals for Speech Interference (SI) rating in aircraft for face-to-face communication. These curves were found reasonable for noise annoyance as well.

RC: Warren Blazier sought "a simpler and more apt" straight-line version for heating, ventilating and air-conditioning (HVAC) mechanical noise equipment design purposes, sloping at the rate of 5 dB/octave and down to 31 Hz.

NR: The common understanding stemming from the 1970s was that NR curves were intended for external environmental application, as distinct to NC curves etc. that were derived for assessing/rating/design in the context of internal spaces.

MEASUREMENT POSITIONS

The microphone locations shall be near the average normal standing or seated height of human ears in the space in accordance with ANSI/ASA S12.2-2019

- Height of 1.6 m for standing and 1.2 m for seated adults
- Height of 1.1 m standing and 0.75 m for seated children
- Minimum microphone distances
  - to any sound reflecting surface is 0.6 m
  - to any room edge is 1.2 m
  - to any room corner is 2.4 m

SUPPORTED NOISE CURVES TYPES

The XL2 Acoustic Analyzer support the five the most widely used standardized noise curve types for evaluating background noise in rooms.

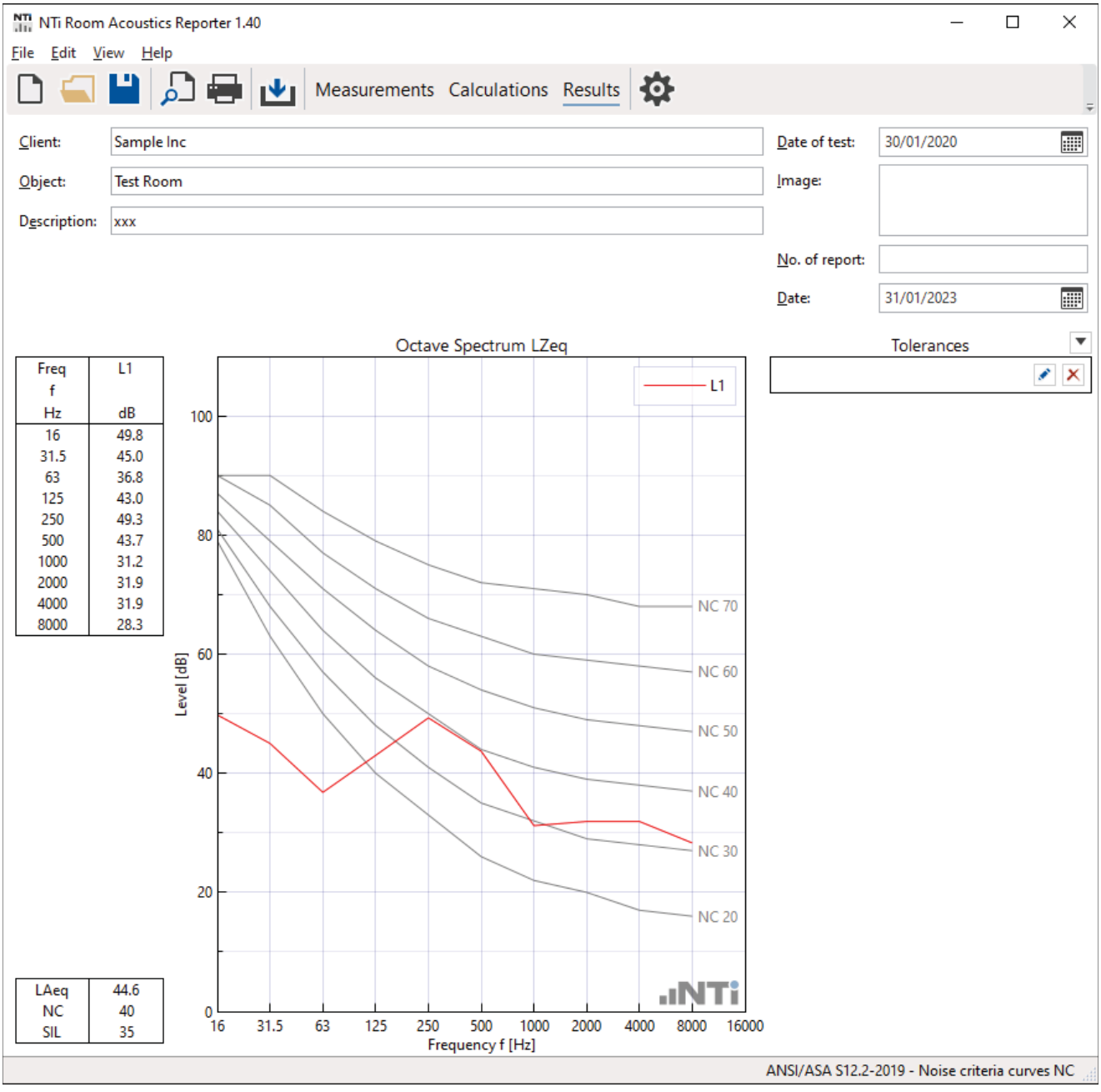
- ANSI/ASA S12.2-2019 - Noise criteria curves NC
- ANSI/ASA S12.2-2019 - Room noise criterion RNC
- ISO R 1996-1971 - Noise rating curves NR
- Preferred Noise Criterion curves (PNC)
- Room Criteria curves (RC)

Room Acoustics Reporter offers a dedicated solution for generating standardized noise curve reports. The software calculates the average background noise spectrum in the room. This may be compared with the target range - based on the usage of the room. The measurement data of the following XL2 functions can be imported: SLMeter, Noise Curves, 1/12 Octave and Cinema Meter. The software supports the following Noise Curve standards.

- ANSI/ASA S12.2-2019 - Noise criteria curves NC
- ANSI/ASA S12.2-2019 - Room noise criterion RNC
- DIN 15996:2020 - Grenzkurven GK
- ISO/R 1996-1971 - Noise rating curves NR

Noise Criterion Curves (NC)

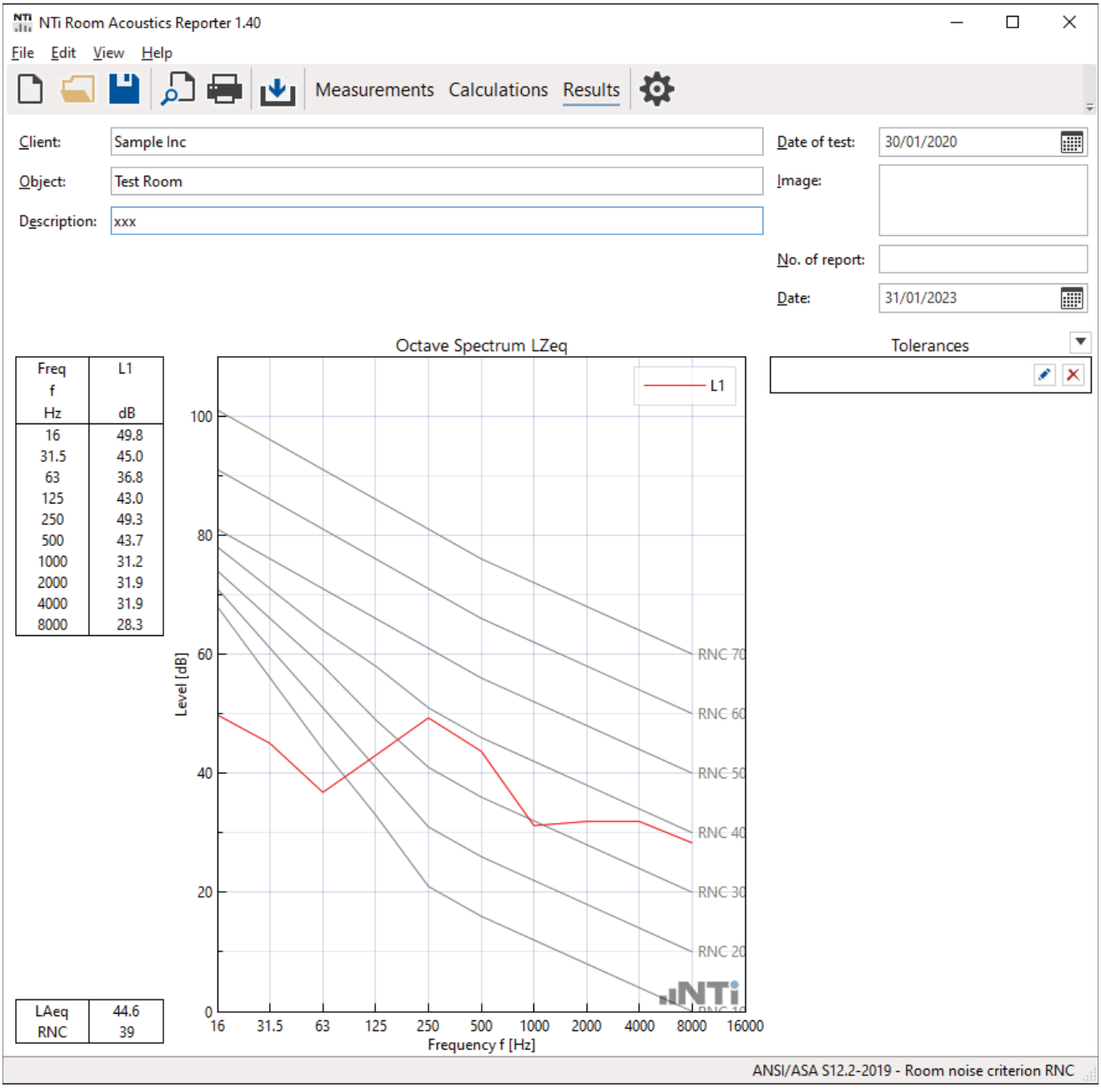
The American National Standards Institute (ANSI) specifies the NC rating in ANSI/ASA S12.2-2019. The XL2 Analyzer reports the NC curves using the specified tangency method adaptation in accordance with the standard. Additionally, the Speech Interference Level (SIL) is presented on the screen. This is calculated by the linear average of the measured sound pressure level in the octave bands 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The designating number for any NC curve is, approximately, its speech interference level, which measures the effects of noise on speech intelligibility.



NC Noise Curves - Screenshot Room Acoustics Reporter

Room Noise Criteria Curves (RNC)

The RNC method is used to determine noise ratings when the noise from heating, ventilating and air-conditioning (HVAC) systems at low frequencies is high, and which is also suspected of containing sizeable fluctuations or surging. It essentially represents a rumble criterion. The RNC curves also provide a procedure that reduces the result essentially back to the NC curves when systems are well designed and acoustically well-behaved. The Room Noise Criteria RNC are defined in ANSI/ASA S12.2-2019. The XL2 Analyzer measures the RNC and reports any large fluctuations or surging at low frequencies, e.g. caused by fans.



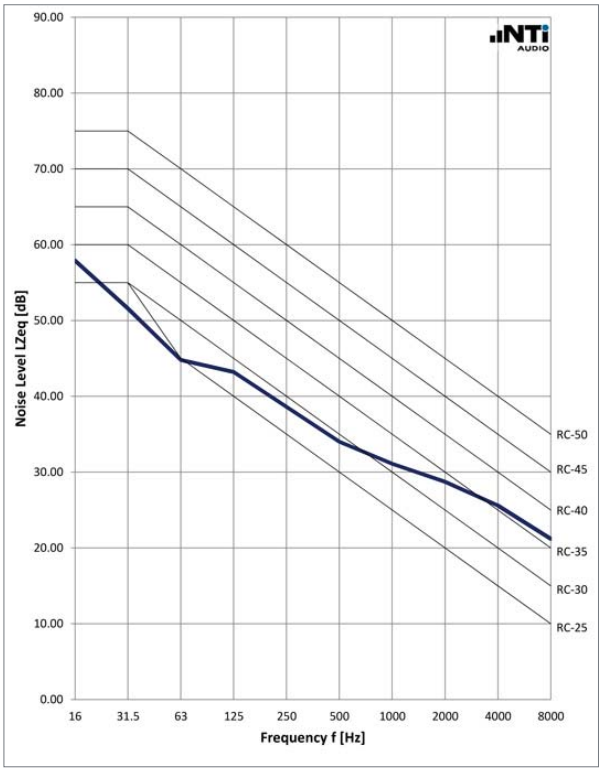
RNC Rating Curves - Screenshot Room Acoustics Reporter

Room Criteria Curves (RC)

The Room Criteria RC Mark II are defined in the informative Annex of the standard ANSI/ASA S12.2-2019. The RC Mark II criterion curves are used for the design of heating, ventilating and air-conditioning (HVAC) systems in office buildings, dwelling units, etc., where the desired mid-frequency levels are in the range of 25 to 50 dB. Each RC curve bears a rating number equal to the level at 1000 Hz.

Spectrum classification

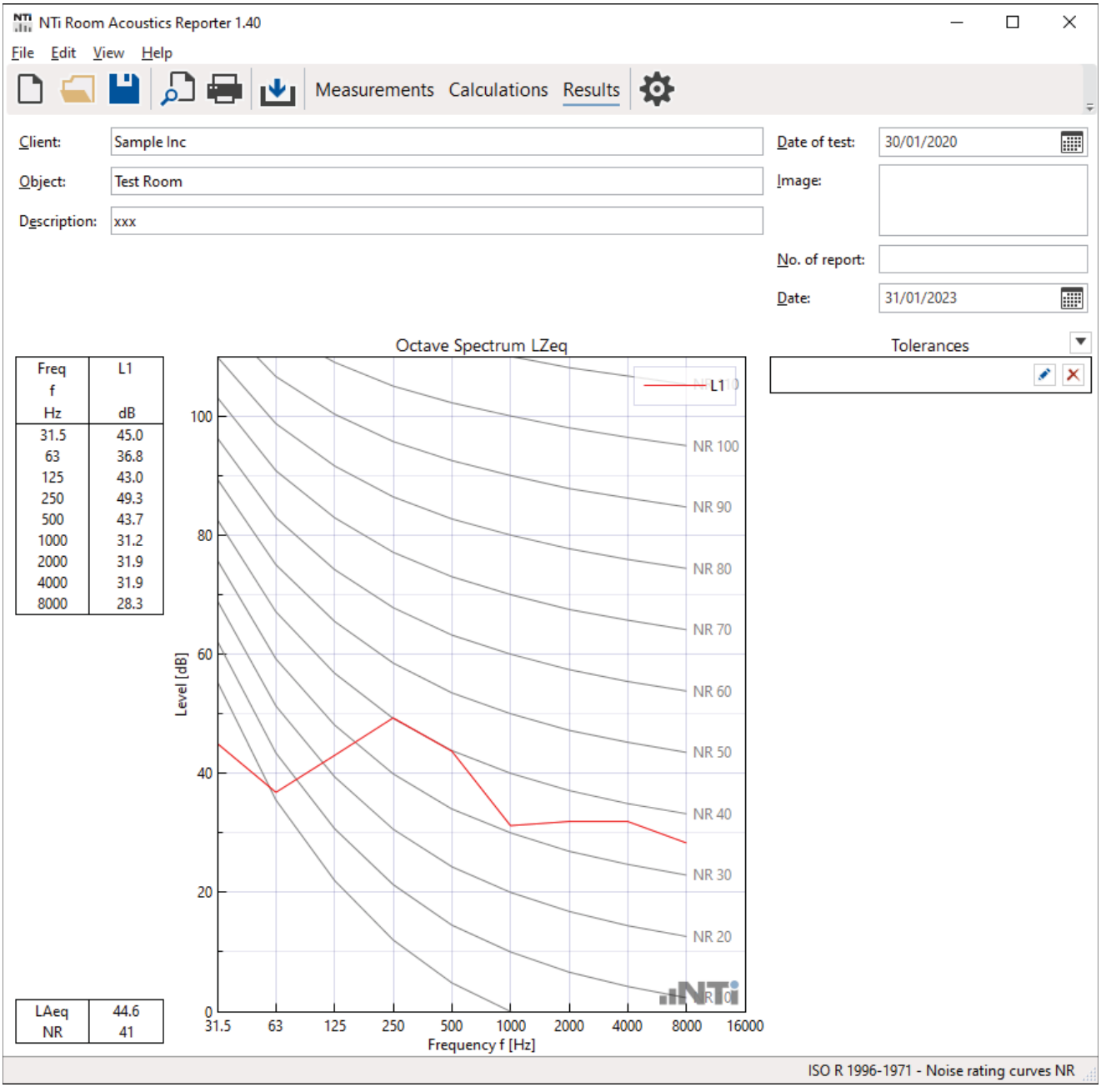
- Neutral spectrum (N): The levels at 500 Hz and below do not exceed the RC curve corresponding to a sound level spectrum by more than 5 dB; and the spectrum levels in Band 1000 Hz and higher do not exceed the corresponding RC curve by more than 3 dB.
- Rumble (R): Excessive noise in low-frequency band. The level in one or more of the octave bands at and below 500 Hz exceeds the RC curve corresponding to a spectrum by more than 5 dB.
- Hiss (H): Excessive noise in high-frequency bands. The level in one or more of the octave bands at and above 1000 Hz exceeds the RC curve corresponding to a spectrum by more than 3 dB.
- Rattle and Vibration (RV): The level in one or more of the octave bands from 16 Hz through 63 Hz exceeds the criterion for moderately noticeable rattle.



RC Noise Curves

Noise Rating Curves (NR)

The Noise Rating Curves (NR) are defined in the old standard ISO/R 1996-1971. This standard has been revised; today's edition does no longer contain the NR curves - still some local standards refer to the NR curves. The NR curves offer a graphical method for assigning a single number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but it is now used frequently for describing noise from mechanical ventilation systems in buildings.

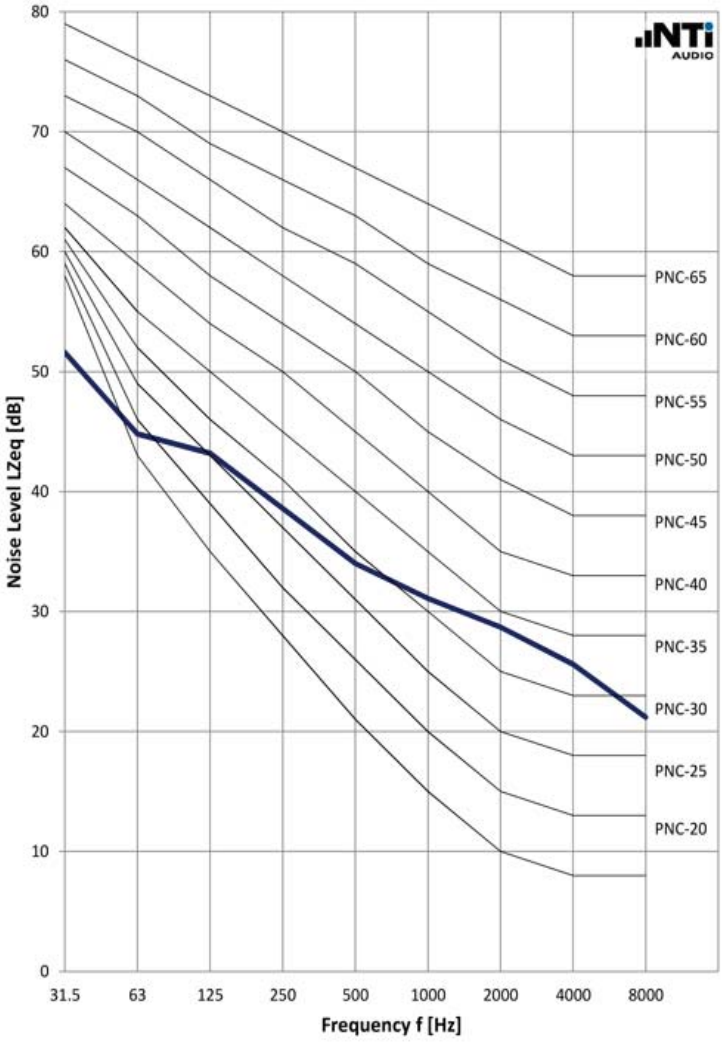


NR Noise Rating Curves - Screenshot Room Acoustics Reporter

Preferred Noise Criterion Curves (PNC)

The American Statistical Association (ASA) defines the PNC curves as an extension of the basic Noise Criteria system. They have been used in the past to judge the acceptability of ventilation and other background broadband noise. PNC curves are considered superior to NC curves for critical uses such as in studios, concert & lecture theatres.

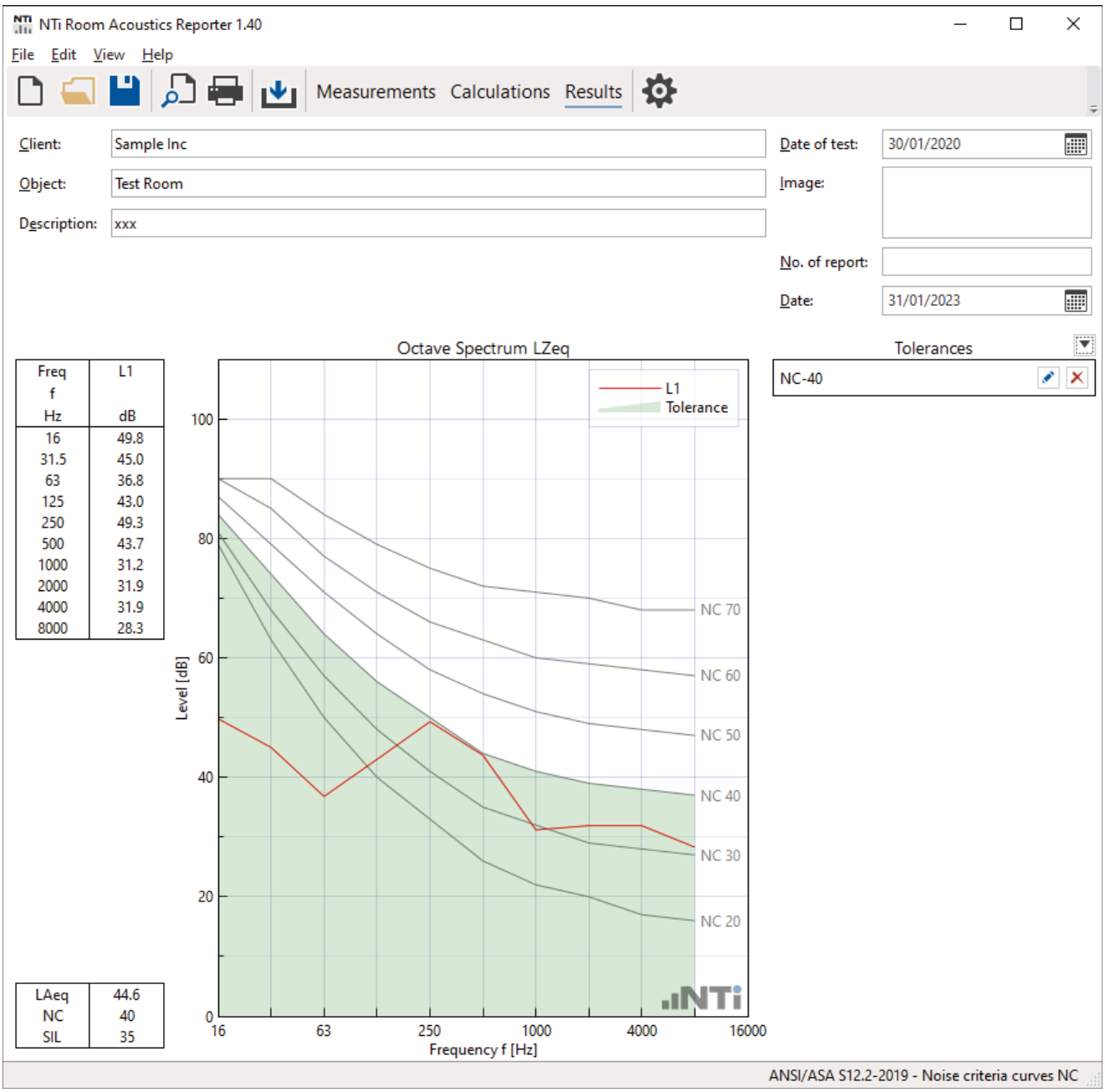
These curves are less steep in the low frequencies and steeper in the high frequencies than the NC curves. PNC curves are less often used than Noise Criteria curves because they are more stringent at lower frequencies than the Noise Criteria curves, and also because the latest (2019) version of Noise Criteria curves includes an extended frequency range somewhat mitigating the original motivation for PNC.



PNC Noise Rating Curves

TOLERANCES

A tolerance may be added in the report visualizing the specified maximum noise curve. This allows a quick verification if the background noise in the room under test meets the requirements and shall not annoy people occupying the room.



NC Noise Curves with NC40 Tolerance - Screenshot Room Acoustics Reporter

The set of noise curve tolerances is available for download at the XL2 Support Page upon registration of the XL2 Analyzer.

RECOMMENDATIONS

The standard ANSI/ASA S12.2-2019 provides three primary methods for evaluating room noise:

- a survey method that employs the A-weighted sound level with Slow time-weighting measured at a point (or average of points) in the space under test
- an engineering method that employs expanded noise criteria (NC) curves
- a method for evaluating low-frequency fluctuating noise using room noise criterion (RNC) curves.

These are the recommended criteria for various unoccupied rooms:

Type of Room	Sound Level LAeq	NC and RNC Curve	RC Mark Criteria
Concert and recital halls	-	15-18	-
Small auditoriums (≤500 seats)	35-39	25-30	-
Large auditoriums (>500 seats)	30-35	20-25	-
TV and broadcast studios	16-35	15-25	-
Live performance theaters	25-30	20-25	-
Premier movie theaters	25-30	20-25	-
Normal theater	30	25	-
Private residences			
• Bedrooms	35-39	25-30	25-30(N)
• Apartments	39-48	30-40	30-35 (N)
• Family rooms and living rooms	39-48	30-40	30-35 (N)
Hotels/Motels			
• Individual rooms or suites	39-44	30-35	25-35 (N)
• Meeting/banquet rooms	35-44	25-35	25-35 (N)
• Service support areas	48-57	40-50	35-45 (N)
Office buildings			
• Offices executive	35-44	25-35	25-35 (N)

Type of Room	Sound Level LAeq	NC and RNC Curve	RC Mark Criteria
• Offices small	44-48	35-40	25-35 (N)
• Offices large	39-44	30-35	-
• Conference rooms large	35-39	25-30	25-35 (N)
• Conference rooms small	39-44	30-35	25-35 (N)
• Open-plan areas	44-48	35-40	30-40 (N)
• Business machines/computers	48-53	40-45	-
• Public circulation	48-57	40-50	40-45 (N)
Hospitals and clinics			
• Private rooms	35-39	25-30	25-35 (N)
• Wards	39-44	30-35	30-40 (N)
• Operating rooms	40-50	40-50	40-45 (N)
• Laboratories	44-53	35-45	35-45 (N)
• Corridors	44-53	35-45	35-45 (N)
• Public areas	48-52	40-45	40-50 (N)
Schools			
• Lecture and classrooms < 566 m^3 (20,000 ft^3)	35	25-30	25-30 (N)
• Lecture and classrooms > 566 m^3 (20,000 ft^3)	40	30-35	35-40 (N)
• Open-plan classrooms	35	25-30	-
Churches small	39-44	30-35	25-35 (N)
Courtrooms	39-44	30-35	25-35 (N)
Libraries	44-48	35-40	30-40 (N)
Restaurants	48-52	40-45	-
Control rooms, kitchens, and laundries	52-62	45-55	-
Shops and garages	57-67	50-60	-

The Noise Rating level should not exceed the levels indicated in the table below:

Noise Rating	Application
NR 25	Concert halls, broadcasting and recording studios, churches
NR 30	Private dwellings, hospitals, theatres, cinemas, conference rooms
NR 35	Libraries, museums, court rooms, schools, hospitals operating theaters and wards, apartments, hotels, offices
NR 40	Halls, corridors, cloakrooms, restaurants, night clubs, offices, shops
NR 45	Department stores, supermarkets, canteens, general offices
NR 50	Typing pools, offices with business machines
NR 60	Light engineering works
NR 70	Foundries, heavy engineering works

PRIVACY MASKING

Sound masking for privacy is the addition of sound, created by a sound generator, to an indoor environment in order to mask conversations. In a simple form, a broadband spectrum sound similar to a pink noise may be introduced to a corridor outside a meeting room to mask the conversations within the room from anybody standing in the corridor. Sound masking is used in homes, commercial offices, medical facilities, court rooms, and in secure facilities to provide secrecy.

REFERENCES

- ANSI/ASA S12.2-2019, Criteria for Evaluating Room Noise
- ISO-R-1996-1971, Assessment of Noise with respect to community response
- Beranek, L.L., “Revised criteria for noise in buildings.” Noise Control 3, 19-27 (1957)
- Beranek, L.L., Noise Reduction, McGraw-Hill Book Co., p. 519 (1960)