# Noise Curves

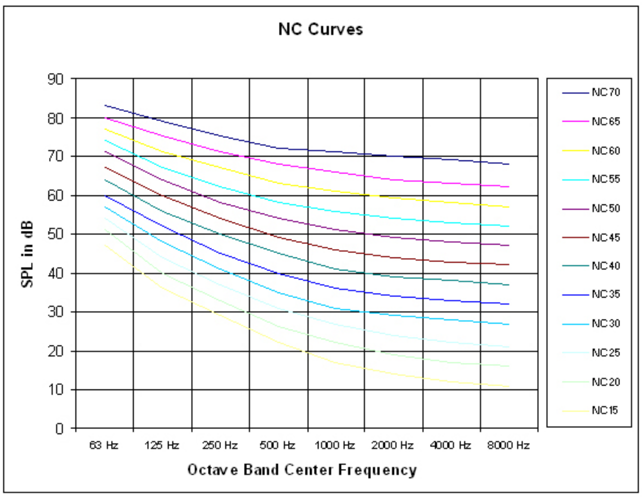
## Measurements with XL2


XL2 Audio and Acoustic Analyzer with M2211 Measurement Microphone

**Noise curves are a measure of the acoustic ambient (background) noise in an indoor environment. The unoccupied room is measured to produce a single maximum value across the complete sound spectrum. This value is used to determine if the ambient noise will be annoying to people occupying the room. The value also influences the intelligibility of speech.**

This application note describes how to interpret noise curves, and how to measure noise curves with the XL2 Audio and 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.

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 different 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. In other cases, background noise may be deliberately introduced to mask private conversations.




NC Noise Curves

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 as well as locations as diverse as target shooting ranges.

## 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. NC40, for example, means that the ambient noise in the room must not be higher than the Noise Criterion curve NC40 at any position in the audio spectrum.

Residual noise in buildings may be generated from both environmental sources (e.g. outside traffic) and systemic sources (e.g. heating, ventilating, and air-conditioning (HVAC) systems; or other machinery in use). It is also frequently necessary to measure residual noise curves prior to expected changes in advance of construction or prior to other expected environmental noise changes.

## How to Measure the Noise Curves with XL2 Audio and Acoustic Analyzer

- Connect the measurement microphone to the NTi Audio XL2 Audio and Acoustic Analyzer.
- Power up the XL2 and choose Noise Curves from the main menu (requires that the Spectral Limits option be installed on the XL2. See main menu, System - Information).
- 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 sounds during the measurements
- Press the XL2 start button to measure the ambient noise at typical room positions (30 seconds per measurement)
- Save each test result and a screenshot in the XL2 internal memory.

## Example - Estimating NC - Noise Criterion

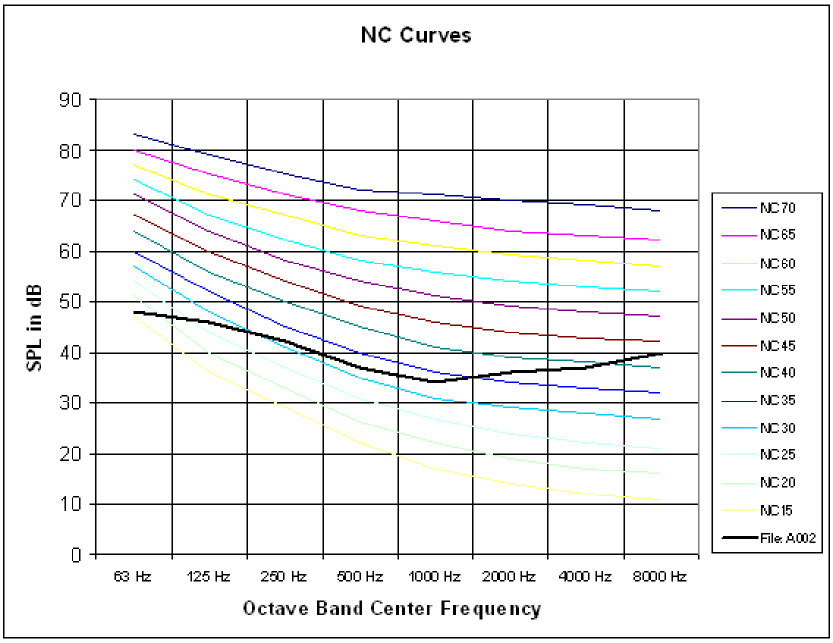
The rating is obtained by plotting the ambient noise spectrum onto the NC Curve graph. The lowest NC Curve that is higher than the entire noise spectrum determines the rating.

For example, the Noise Criterion - NC - of a noise spectrum like

- 63 Hz: 48 dB
- 125 Hz: 46 dB
- 250 Hz: 42 dB
- 500 Hz: 37 dB
- 1000 Hz: 34 dB
- 2000 Hz: 36 dB
- 4000 Hz: 37 dB
- 8000 Hz: 40 dB

indicated as the black line in the diagram below, is NC 45 in the 5 dB resolution chart because the NC 45 line is the first line from below that is not touched by the black line.

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.



## Measurement Range of NTi Audio Microphones

NTi Audio microphones are capable of measuring extremely quiet environments and are therefore suitable for most applications.

- M4260: NC27 upwards
- M2211: NC15 upwards
- M2230: NC15 upwards

For extraordinary measurements below these ranges, other microphones with higher sensitivity are required.

## 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 in the 600 to 1200, 1200 to 2400, and 2400 to 4800 Hz octave bands. 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 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 22 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).

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 lead 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.

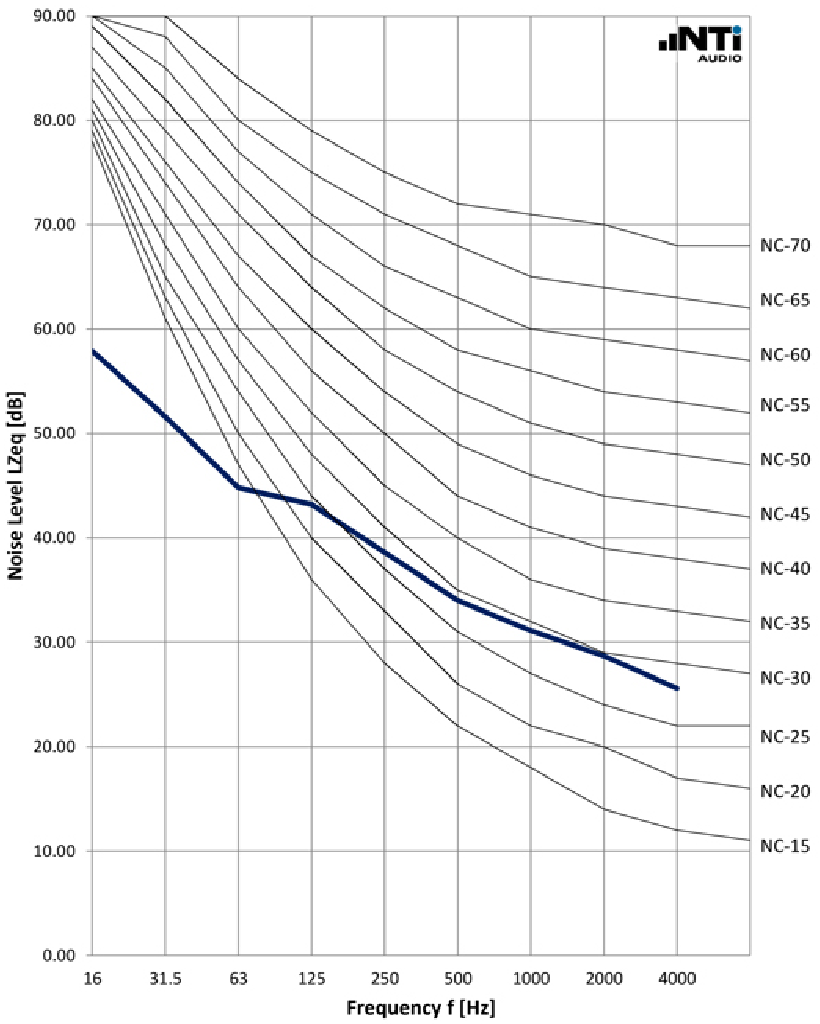
## Noise Curves Details

These five standardized noise curve types are the most widely used means for evaluating background sound in buildings, and other facilities such as transit facilities, as well as in other indoor/outdoor spaces. They are described in the following pages:

- Noise Criterion curves (NC)
- Noise Rating curves (NR)
- Room Noise Criteria curves (RNC)
- Preferred Noise Criterion curves (PNC)
- Room Criteria curves (RC)

## Noise Criterion Curves (NC)

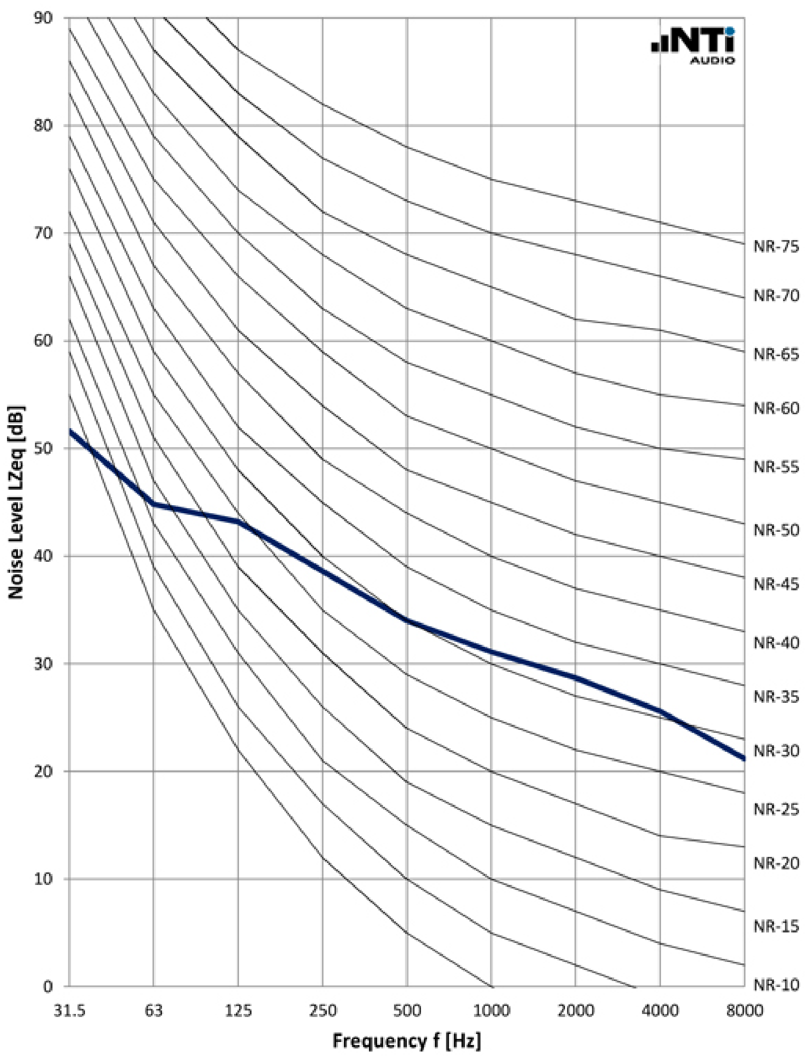
The American National Standards Institute (ANSI) defines the NC rating to describe the noise in a space by examining a range of frequencies. The NC rating of a spectrum is designated as the value of the lowest NC curve above the measured octave-band spectrum. The measured Noise Criteria, e.g. NC30, informs that the room performs better than that. The designating number for any NC curve is, approximately, its Speech Interference Level (SIL): the average of the levels in the 500, 1000, 2000 and 4000 Hz octave bands. SIL is a simple metric, which measures the effects of noise on speech intelligibility. The XL2 Analyzer includes the tangency method adaptation in accordance with the standard. The Noise Criteria NC are defined in the standards ANSI S12.2-2008 and 1995.




NC Noise Curves

## Noise Rating Curves (NR)

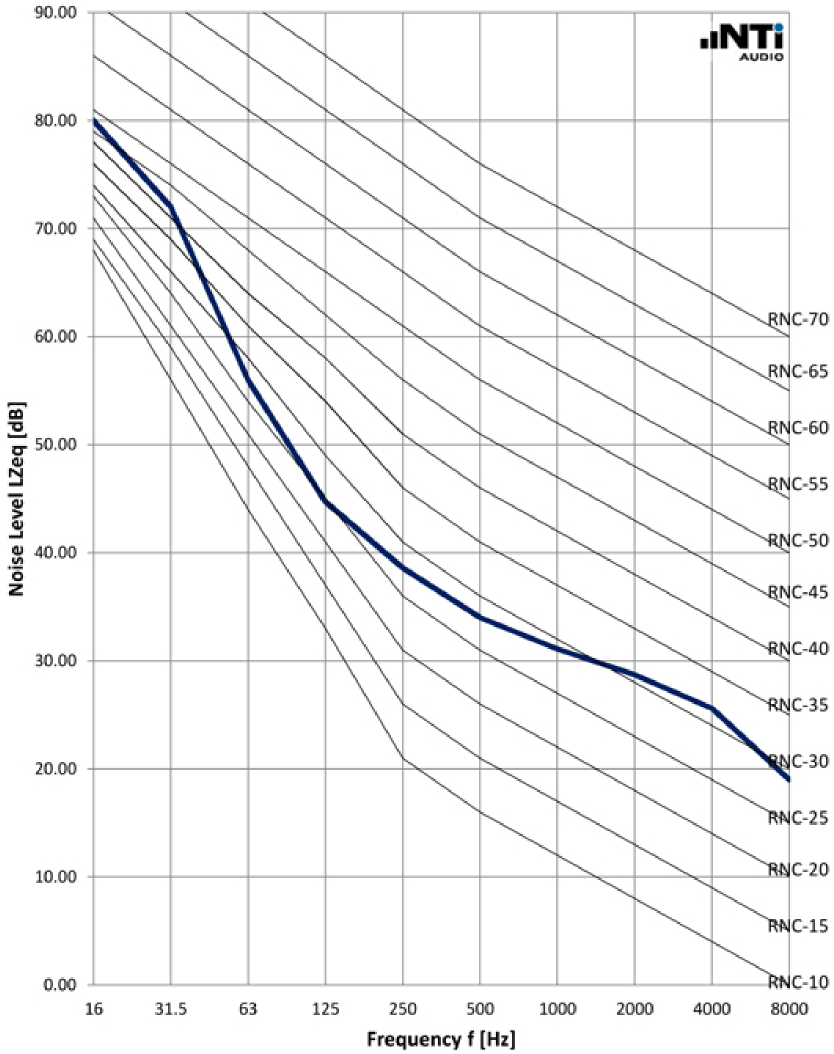
In Europe, the International Organization for Standardization (ISO) defines Noise Rating (NR) as a graphical method for assigning a single number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability 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. The NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum.




NR Noise Rating Curves

## Room Noise Criteria Curves (RNC)

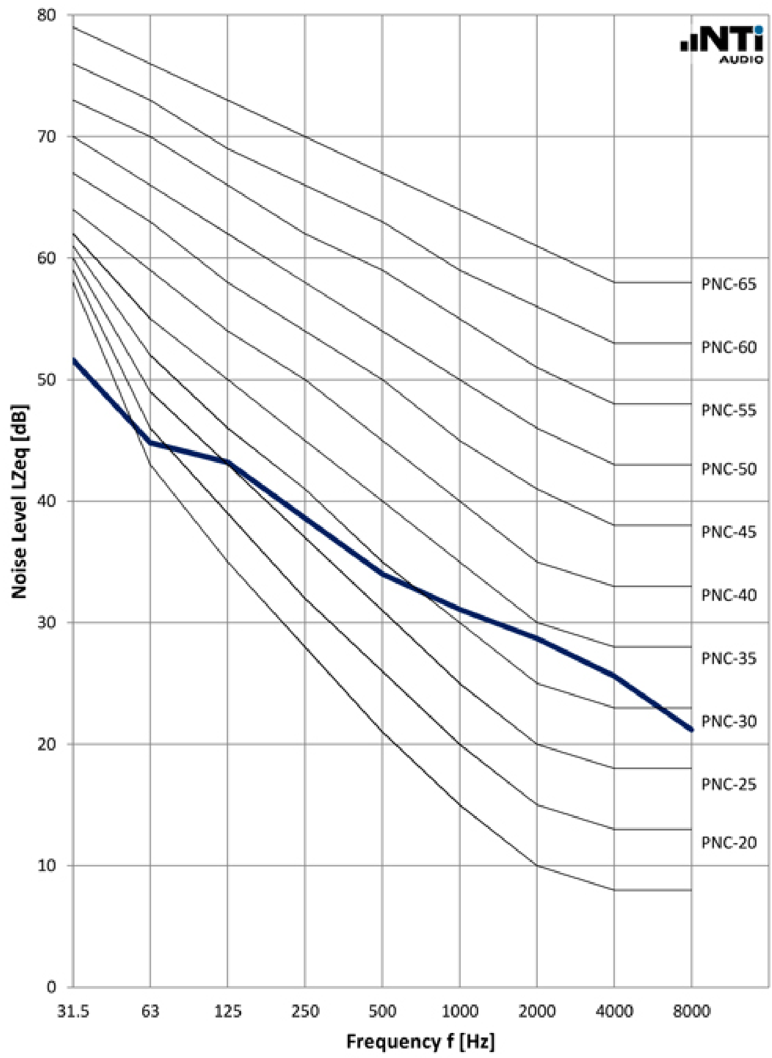
The RNC method is used to determine noise ratings when the noise from heating, ventilating and air-conditioning (HVAC) systems at low frequencies is high, and which is also suspected of containing sizeable fluctuations or surging. It essentially represents a rumble criterion. The RNC curves also provide 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 the standard ANSI S12.2-2008. The XL2 offers an RNC information page, which reports any large fluctuations or surging at low frequencies, e.g. caused by fans.




RNC Noise Curves

## 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 (2008) version of Noise Criteria curves includes an extended frequency range somewhat mitigating the original motivation for PNC.



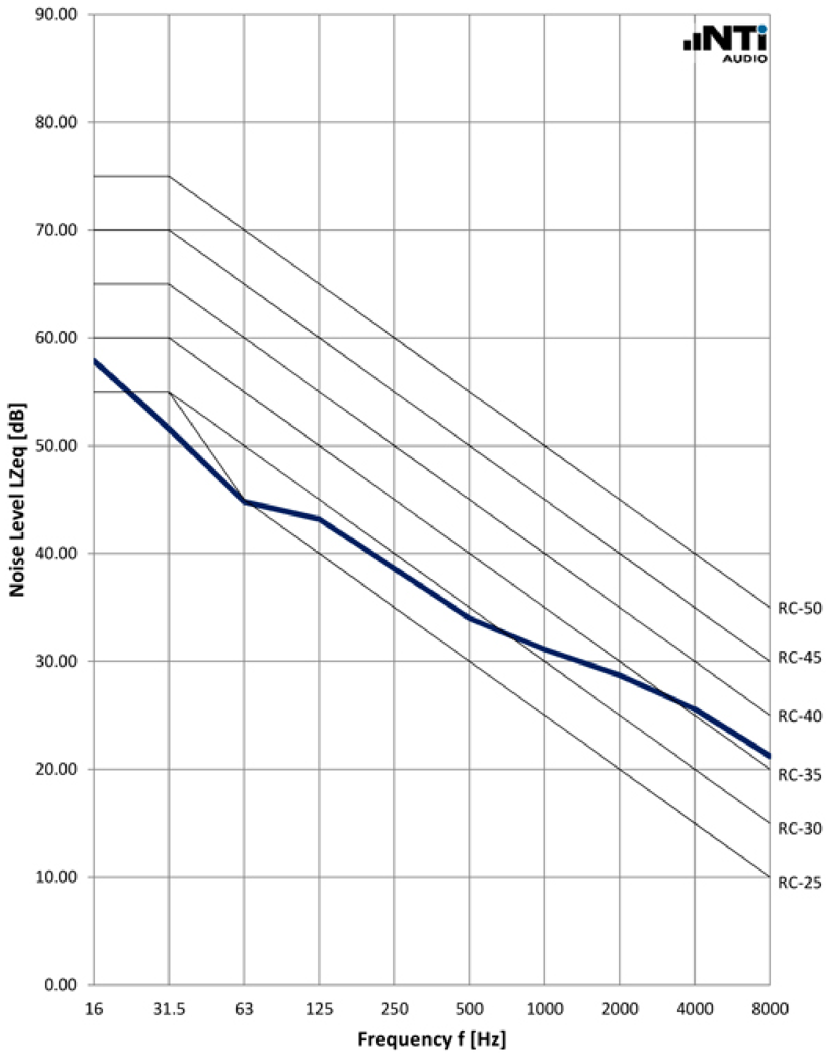

PNC Noise Curves

## Room Criteria Curves (RC)

The RC criterion curves are a system for use in 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 criterion curve bears a rating number equal to the level at 1000 Hz. The Room Criteria RC are defined in the standard ANSI S12.2-1995.

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.
- More classifications on the next page.




RC Noise Curves

- 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.

# Appendix:

## Recommended Noise Criterion - NC

Recommended noise level criteria for various occupied activity areas in accordance with ANSI/ASA S12.2-2008:

| Type of Room - Space Type | Recommended NC Level | Sound Level LAeq |
|---|---|---|
| | NC Curve | dBA |
| Recording Studios | 15-20 | 25-30 |
| Concert and recital halls | 15-20 | 25-30 |
| Small auditoriums (≤500 seats) | 25-30 | 35-39 |
| Large auditoriums (>500 seats) | 20-25 | 30-35 |
| TV and broadcast studios | 15-25 | 16-35 |
| Legitimate theaters | 20-25 | 30-35 |
| Movie theaters | 30-40 | 39-48 |
| Churches small | 30-35 | 39-44 |
| Churches large | 20-25 | 30-35 |
| Courtrooms | 30-40 | 39-44 |
| Libraries | 35-40 | 44-48 |
| Restaurants | 40-45 | 48-52 |
| | | |
| Private Residences | | |
| - Bedrooms | 25-30 | 35-39 |
| - Apartments | 30-40 | 39-48 |
| - Family rooms and living rooms | 30-40 | 39-48 |
| | | |
| Hotels/Motels | | |
| - Individual rooms or suites | 30-35 | 39-44 |
| - Meeting/banquet rooms | 25-35 | 35-44 |
| - Service support areas | 40-50 | 48-57 |
| | | |
| Offices | | |
| - Conference rooms large | 25-30 | 35-39 |
| - Open-plan areas | 35-40 | 44-48 |
| - Business machines/computers | 40-45 | 48-53 |
| | | |
| Hospitals and Clinics | | |
| - Private rooms | 25-30 | 35-39 |
| - Operating rooms | 25-35 | 35-44 |
| - Public areas | 40-45 | 48-52 |
| | | |

| | | |
|---|---|---|
| Schools | | |
| - Lecture and classrooms < 566 cu m | 25-30 | 35 |
| - Open-plan classrooms | 25-30 | 35 |

## Recommended Noise Rating - NR - Levels

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

| Noise Rating curve | 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.