Nor838 Measuring System for Hearing-Protection Devices

Features:

• Complete system with 4 uncorrelated signal generators, amplifiers and speakers.
• Very flexible test sequence set up
• Built-in database for
  - test subjects
  - measurement organization
  - report generation from a large number of individual measurements
  - handles several parallel studies
• Calibration tool and sound field control using a sound level meter

Applications

• Determination of the sound attenuation of hearing protectors using subjective methods
• Finding the hearing thresholds using the Békésy or JND methods
• Pure tone Audiometer measurements

Standards applicable

• ISO 4869-1
• ANSI ASA S12.6
• ISO 8253-1
• ISO 8253-2
Hearing Protector Test System Nor838 is used for the determination of the sound attenuation of hearing protectors using the subjective method (ISO 4869 part 1) and is performed by two measurements of hearing thresholds.

The sound attenuation of the hearing protector is the difference, in decibels, between the thresholds of hearing with and without the hearing protector in place for a test subject. The threshold of hearing with open ears and with hearing protector in place must be measured once for each test subject in accordance with ISO 8253 part 2.

The software Nor4869 in combination with the instrument Nor838 and a room with reproduction devices provides two methods to determine hearing thresholds. The Békésy method and the method of “just noticeable differences”. In addition several methods to process the data are selectable by the operator.

The measurements are conducted in a diffuse sound field which is generated by four loudspeakers placed in the corners of a (virtual) tetrahedron. The loudspeakers are fed by four uncorrelated noise sources. The test signal is one-third octave band-filtered random noise with centre frequencies 63 Hz (optional), 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz.

**Operator selectable**

Apart from the measurement of the sound attenuation of hearing protectors, the instrument can be used for the determination of the diffuse or free field hearing threshold using both ears. A pure tone audiometer tool for headphone presentation is also included thus providing the possibility of measuring the left / right ear hearing threshold independently. Measurements of hearing thresholds are described in the standard ISO 8253.

Specific information on the requirements of different sound field conditions is given in the standard ISO 8253-2 §5.1 (free field), §5.2 (diffuse field) and §5.3 (quasi diffuse field).

**System Hardware Nor838**

To achieve the best possible performance for audiometric tests two aspects must be met that are difficult to handle with general purpose PC technologies:

- The dynamic range of the audio signal output must be very high, which can not be achieved by the typical PC sound system.
- The timing of the system requires an accuracy of about 10 ms, which again is difficult to maintain with PC-ports.

Therefore a special hardware, designed for measuring purpose, is used offering the highest possible DA-converter precision available today and providing an input with a jitter free timing accuracy for the external events. The hardware communicates with the PC using general purpose RS 232 COM-port.

All test-signals are software generated (24 bit PCM) signals. There are no hardware or software (DSP) generators used to create the signal in real-time. All signals are stored on the fixed disc drive in the PC and are fed to the hardware using AES/EBU digital audio interface.

The Nor838 front-end is an external device in a commercial, shielded 19” rack-mountable case which contains all hardware required for timing and DA-conversion. It is connected to the PC using two cables and provides at its front 4 outlets for the signals and a jack-connector for the “answer-button”. A display provides all required information during operation and setup. Different buttons can be used to navigate through the internal menu for setup-purpose only. In general the hardware must not be touched during normal operation and therefore can be placed remotely in a rack. Cables of up to 10 m length should not induce any problems.

**The Nor838 system hardware**

The digital audio front-end contains the micro-controller as a base-unit for interfacing to the PC, two sets of dual channel DA-converter cards (Nor838 1) and a input for the hand switch. The unit uses a standard 19”, 3 unit high case with a sturdy aluminium diecast frame. Due to the AES/EBU digital audio interface and the RS 232 controller interface all connections to the PC may be as long as needed.

**Performance data Nor838-1:**

- **Audio interface:** AES/EBU symmetrical
- **Audio out:** +20 dBu symmetrical, XLR connectors
- **Signal processing:** 1 Motorola DSP56009 for one card used for levelling, noise shaping, and ramp generation. Controlled by the system µC and
- **Sampling rates:** 32 kHz, 44.1 kHz, 48 kHz
- **Data format:** 24 bit linear audio quantisation
- **DA-Converter:** 20 bit R2R-converters, with selected linearity < 0.001 % THD
- **Signal to noise:** > 110 dB full scale
- **Level adaptation:** -20 dB output attenuation relays to maintain ultra low noise and highest linearity even at very low levels.

**Highly integrated system**

Full integration between the HW and SW offers the highest standard of measurement quality while still retaining user friendliness. The dynamic range of the system has been designed to be of the superior quality needed for this application in contrast to using a standard soundcard.

The system generates optimum timing precision down to sample accuracy. This means that the responses of the test subject correlates directly to the output from the loud-speakers.
Measuring Software Nor4869
The Nor4869 software is used to determine the hearing threshold of persons (subjects) either in a free field, a diffuse field or under headphones. Using these measurements the sound attenuation of hearing protectors worn by people can be evaluated. Even if other “threshold of hearing” measurements are possible, this evaluation is the main target of this application. The measurement procedure is based on the examination of the threshold of hearing of subjects without and with the hearing protectors in place. The attenuation of the protector is calculated from the difference of both measurements (open ear versus occluded ear thresholds). Since the variance of the results is rather large an average with at least 16 subjects is required to calculate the final protection value following ISO 4869.

There are 2 measurement modes of operation with the Nor838 system:

- American Version: According to the ANSI Standard ASA S12.6 a reverberant room is used in combination with three loudspeakers to create a diffuse field condition. Likewise only 3 channels can be calibrated with that configuration. The Békésy method is used by default.

- European Version: According to the ISO 4869 §4 ff., 4 Channels are used in an anechoic chamber to create a diffuse field at a single area around the test subject. This uses the so called “method of just noticeable differences” (JND) as default.

Besides different measuring techniques for the examination of the threshold of hearing, the software includes valuable tools to ease the handling of the gathered data. For this purpose the handling of different database files containing all relevant information on the subjects, all measuring sessions and the individual projects is provided. The software has a user friendly graphical user interface (GUI).

For each operation an individual program dialogue window is used. Database structure for storage eases the administration of all data. The data can be exported to Excel for further calculations.

Basically the system consist of two main programs providing the following features:

- Sound-field calibration software
  - Calibration of the sound field to maintain equal level of the different channels.
  - Reproduction of different test signals (broad-band noise, music samples etc.).
- Measuring system for the derivation of the threshold of hearing
  - Personal database for the storage and administration of the test subjects.
  - Project database for the storage of the manufacturer and measured data related to one particular hearing protector.
  - Main database as a collective storage of all data (for safety purpose).
  - Software for the investigation of the hearing threshold level providing different methods (G.v.Békésy, Bracke, Ascending) and different signals in accordance with ISO standards.
  - Audiometer test with head phones and pure tone signals for the individual testing of the threshold of hearing for each ear separately.
  - Calculation software for the derivation of the attenuation for the protectors.
  - Graphics for the display of frequency response curves (Threshold curve, attenuation curve etc.).
- Derivation of the hearing threshold.

Principle of operation
The automatic test program uses either pulse method or continuous signal presentation.

Békésy Method
The second method uses uninterrupted signal presentation (of either constant amplitude or modulated with a certain level variation) and the test person is asked to press the answer button, when the test signal is audible and to release the button if not. In each case the level of the signal is changed with time: If the button is depressed the level is lowered, if the button is released, the level is raised. Each time when the status of the answer button changes the current timer count and the current level is returned to the PC and the software displays the range and mean value of the running test.

Pulse and timing specifications according to IEC 645 and user defined. Most of the parameters can be changed to the laboratory requirements.

The displayed hearing threshold level is the relative level with respect to the reference equivalent hearing threshold sound pressure level (RETSPL). The standardised curve of the RETSPL is stored into a file. All data gathered during one test procedure is stored into a file that contains several additional information on the test person, the hearing situation, etc. From the measured curves of the RETSPL without and with protector the frequency dependant attenuation of the protection device can be calculated as well as the SNR single number rating.
Since the reproduction of sound via loudspeaker systems is affected by several uncertainties (like loudspeaker frequency response, or amplifier gain etc.) the sound field has to be checked from time to time. For this purpose a sound field may be generated that can be measured using a normal sound level meter. Each loudspeaker can be operated individually for each 1/3rd octave band and the measured SPL is entered into a file that precisely reports the achieved SPL.

All measured values are stored for each channel individually. For the reproduction these measured values are used to re-calculate the gain factor to reproduce the sound field with the correct SPL. The level information is recorded individually for each frequency and each channel.

This operation mode allows a reproduction of a steady state sound field as required. The sound field is generated by the continuous reproduction of a stored wave file. Therefore the signal basically can be of any kind. However, with the supplied narrow-band signal files all 1/3rd octave band, octave band and wide band noise signals with a defined level may be used for excitation. The reproduction level therefore can be adjusted in dB SPL for a calibrated reproduction chain. Any of the channels may be operated solo or together with other channels. As well the modulation of reproduction level as is used for the Békésy-Method may be superimposed.