
What is Sound Quality?

The sound quality of the noise from a product is of ever increasing importance when assessing the total quality of the product. For products such as sports cars and hand tools, not only the level, but also the quality of the noise it makes are part of what attracts or repels the customer. The right sound can lead to increased sales.

Many factors come into play in the sound quality evaluation process. Traditional objective measuring and analysis methods such as A-weighted sound pressure and FFT analysis are not enough for analysing product sound. Customer expectations and jury testing are also important factors for determining acceptable sound quality because, in the end, only the human ear can tell the designer whether he is producing the right sound.

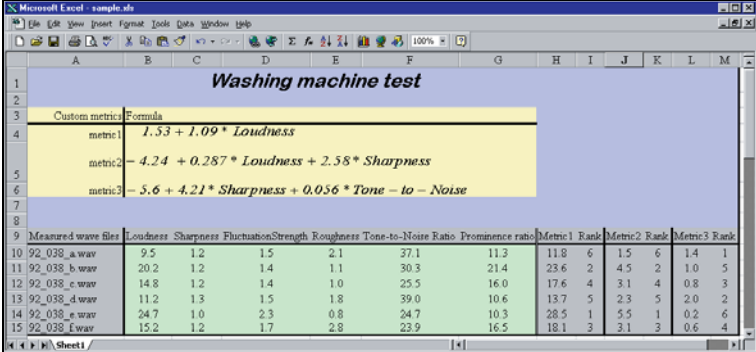
PULSE Sound Quality software allows you to perform objective analysis based on Zwicker Loudness. It analyses sound much closer to the way the human ear experiences sounds. Many parameters of sound, or metrics, can be defined and quantified with these tools to show whether aspects of sound such as roughness and sharpness fall within an acceptable range. Used carefully, combinations of these objective results can show good correlation with the subjective results of jury test, although they can never completely replace them. This can save a tremendous amount of time and money in the development process.

This new version of the program runs even faster and easier, and consequently saves time. It also provides a direct interface with the new Psychoacoustic Test Bench tool, thus ensuring a complete sound quality solution.

The Complete Sound Quality System

Besides offering powerful tools for both objective and subjective analysis of sound quality, PULSE Sound Quality software provides complete facilities for every other step of the sound quality evaluation and optimisation process. From calibration, recording, and playback to editing and display, PULSE Sound Quality software does it all.

Fig. 1
Creating reports for
Microsoft® Excel with
OLE Automation



Washing machine test											
Custom metric Formula											
metric1	$1.53 + 1.09 * Loudness$										
metric2	$-4.24 + 0.287 * Loudness + 2.58 * Sharpness$										
metric3	$-5.6 + 4.21 * Sharpness + 0.056 * Tone - to - Noise$										
Measured wave files	Loudness	Sharpness	FluctuationStrength	Roughness	Tone-to-Noise Ratio	Prominence ratio	Metric1 Rank	Metric2 Rank	Metric3 Rank		
10 92_038_a.wav	9.5	1.2	1.5	2.1	37.1	11.3	11.8	6	1.5	6	1.4
11 92_038_b.wav	20.2	1.2	1.4	1.1	30.3	21.4	23.6	2	4.5	2	1.0
12 92_038_c.wav	14.8	1.2	1.4	1.0	25.5	16.0	17.6	4	3.1	4	0.8
13 92_038_d.wav	11.2	1.3	1.5	1.8	39.0	10.6	13.7	5	2.3	5	2.0
14 92_038_e.wav	24.7	1.0	2.3	0.8	24.7	10.3	28.5	1	5.5	1	0.2
15 92_038_f.wav	15.2	1.2	1.7	2.8	23.9	16.5	18.1	3	3.1	3	0.6

You can even customise the software to automatically execute operations with its extensive OLE programmability, or with VBScript or JavaScript. These are especially useful for automating long or involved tasks for a large batch of measurements or files or for creating reports containing Zwicker Loudness and user-defined metrics for display in a Microsoft® Excel spreadsheet. Since PULSE Sound Quality now controls and imports data from

the base PULSE software, you have easy access to PULSE's multichannel recording capabilities. You can also pre-analyse your data in real time with any of PULSE analyzers in parallel to exporting it to PULSE Sound Quality. OLE automation allows Sound Quality to be controlled from other applications and completely integrates Sound Quality software with the Psychoacoustic Test Bench software.

Calibration and Equalisation

In order to compare sounds recorded at different times or under different conditions and to repeat as accurately as possible the psychoacoustic effect of a sound, it is important that you work with calibrated signals. Type 7698 allows you to calibrate the input by using acoustic calibration signals.

When binaural signals are to be presented to listeners, the output needs to be calibrated as well. PULSE Sound Quality software lets you adjust the output signal level for playback via headphones by placing headphones on the Sound Quality Head and Torso Simulator Type 4100 or 4100-D. The software also includes a weighting curve correction at both the input and the output. This has a number of fixed weightings and also allows user-defined weightings. Using this, you can, for example, apply a frequency weighting to the input to correct the diffuse- or free-field response of Type 4100 to a flat response, or correct the frequency response for a specific set of headphones, e.g., Sennheiser HD 650. The audio quality is improved using FIR filters. You can also define your own headphone correction filters.

Charge Injection Calibration (CIC)

The Sound Quality Program also allows you to use Brüel & Kjær's patented CIC technique for calibration checks and fault diagnosis. This method uses an electrical signal directed back to the microphone preamplifier junction via a third cable. Information on the condition of the recording system can be obtained by monitoring the stability of the response to this signal. If the response is unchanged the acoustic calibration can be considered intact. Various other responses can indicate microphone diaphragm damage, short circuits, leakage in the microphone or disconnected or broken cables.

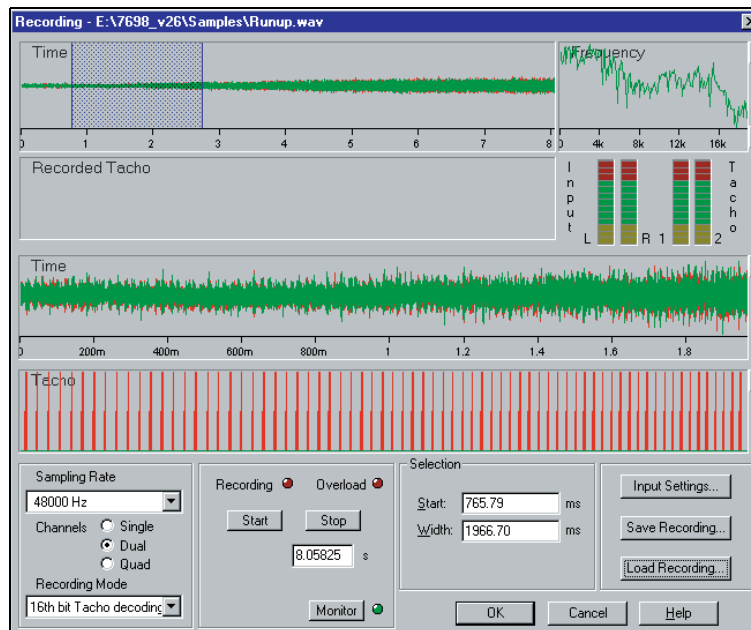
Psychoacoustic Correction

Once you have calibrated your system, you may discover that the sound played back through headphones is not realistic compared to the real-life situation. This can arise from the sense of the room, vibration, or even the simple fact that you can no longer see the object making the sound. To overcome this, PULSE Sound Quality software contains a psychoacoustic correction filter on top of the normal corrections that allows you to alter the amplitude of the signal over the frequency range 20 Hz to 20 kHz. You can then save your user-defined filter specification when you are satisfied with the results.

Recording Sounds

Sound Quality supports four channel recording – two audio signals and two tacho signals. Using two ZE-0770 sound cards interconnected with a synchronisation cable (included with the sound card), you can record four channels (one binaural signal and two tacho signals). ZE-0770 A is a high-quality, 2-channel Notebook sound card.

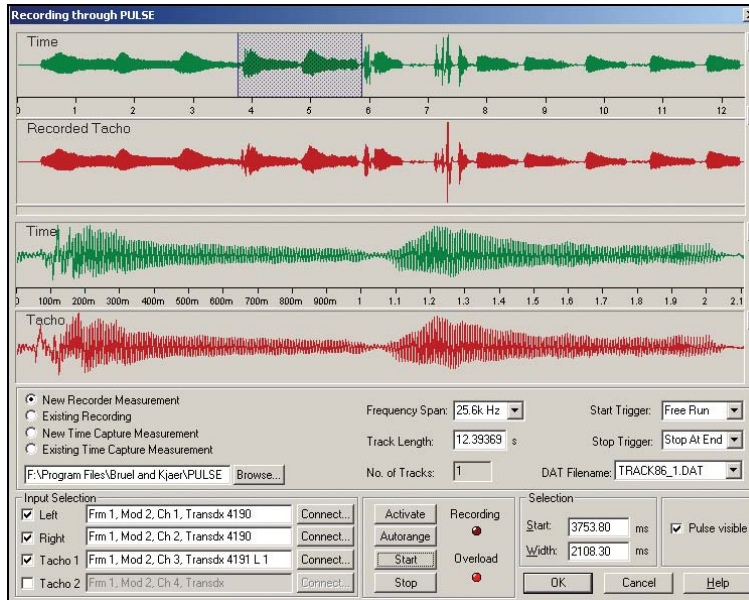
Fig. 2
Selecting a part of the original recording for editing and analysis. You do this by either entering the number of seconds or by selecting a section of the signal using cursors



As you are recording a sound, the time signal is displayed on screen as the recording proceeds. The sound is recorded in a temporary .wav file on your PC's hard disk allowing you to save longer time records than would otherwise be available if you were recording to RAM. After recording, you can select the part of the signal of interest. The selected sound sample can then be saved, including calibration data, ready for further editing, analysis, etc. When ready, the part of the signal selected for further processing is displayed in a playback monitor in the toolbar area. When you play the signal, the display shows your progress and indicates the level at every point on a bar graph.

Recording with PULSE

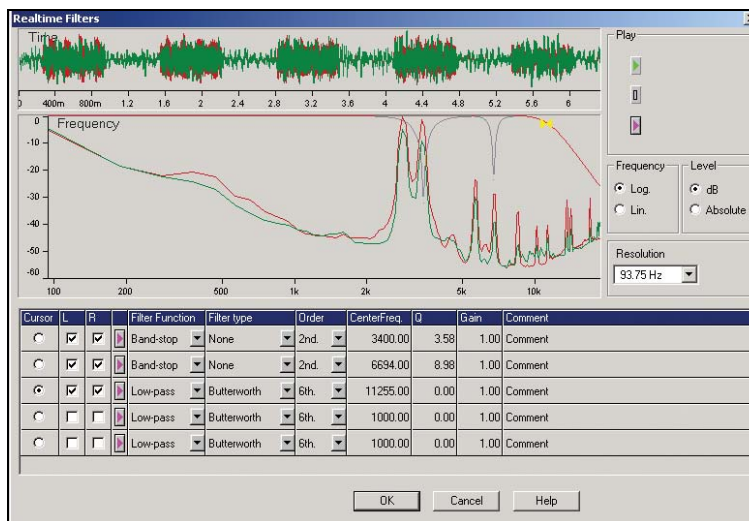
Fig. 3
Recording with PULSE



Sound Quality supports recording using PULSE. With Data Recorder Type 7701 or Time Capture Type 7705, it is possible to record data from Portable Data Acquisition Unit Type 2827. Type 7698 automatically controls the PULSE system and records and retrieves data. Time data can also be retrieved from existing recordings. In Sound Quality, you can pick the signals from the HATS and one or two tacho signals and select the portion of the time signal that you want to use for analysis. Calibration information from PULSE is saved with the signal in Sound Quality.

Editing Sounds

Fig. 4
The Real-time Filter editing tool



Sound quality is normally used interactively, for example in the product design phase, to carry out time and frequency filtering before the signal is played back for listening. This allows the localisation of signal components that are important for the subjective impression of the sound, or the simulation of proposed modifications to a test piece.

Both time and frequency domain editing are available, as is real-time editing (see Fig. 4). Using Type 7698 and its advanced, time, and frequency cursors you can apply the following edits:

- Peak Limit
- Time Attenuation
- Level Edit
- Demodulation
- Frequency Attenuate
- Frequency Shift
- Passband
- Peak Limit Frequency
- Harmonic Frequency Attenuate
- Harmonic Frequency Shift
- Harmonic Passband
- Generator
- Mixer
- Order Attenuation
- Order Passband
- Real-time Filter
- Frequency Response Filter
- User-defined Filter

The edits can be applied to a signal sequentially in any combination. Each edit sequence is displayed in the project view as a branch of the signal tree. Within the limits imposed by your PC's RAM, you can have any number of signals in a project, and any number and combination of edits for each signal. You can also create your own using Visual Basic® or Visual C++®.

The cursor readings can be customised using ActiveX™. Metrics, special calculations or combinations of standard metrics can easily be tested and require only minor coding in Visual Basic.

Real-time Editing

The Real-time Filter lets you change filter parameters while listening to the result. This makes it easy to find characteristics of the sound and alter it.

Analysing Sound Quality

Subjective Listening Tests

Subjective listening tests are vital for assessing a product's competitiveness. The final evaluation of the sound quality of a product is normally made using a group, or jury, representing the targeted customer group, in a listening test.

For example, for a jury to listen to the sound in a car prototype, ideally, each jury member would have to drive in the car and then report on the sound quality – a time consuming and expensive process. To overcome this, a binaural head, such as the Brüel & Kjær Head and Torso Simulator Type 4100 can be used as a stand-in for a human being to make a high-quality binaural recording of the specified product sounds directly to the hard disk of a computer or a DAT recorder. Headphones are then used to present the recording in parallel to all members of the jury off-site. The new Psychoacoustic Test Bench option makes the setup and control of these subjective jury tests very easy.

Control of the Jury Test tool is fast and easy. It allows you to design and execute jury tests by arranging wave files in a play list. You can create two specific types of tests. One is the Semantic Differential test, in which each recording is rated on an absolute scale. The other is a Paired Comparison test (Fig. 5). Delays may be inserted before and after the recordings to allow the jury time to form an opinion. There is full and automatic integration with Psychoacoustic Test Bench with dedicated user interfaces.

Fig. 5
PULSE Sound Quality software's Play List allows you to design and execute jury tests

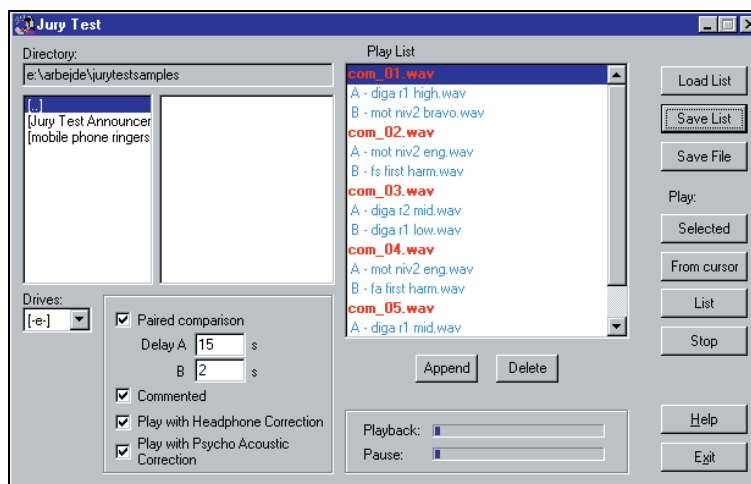
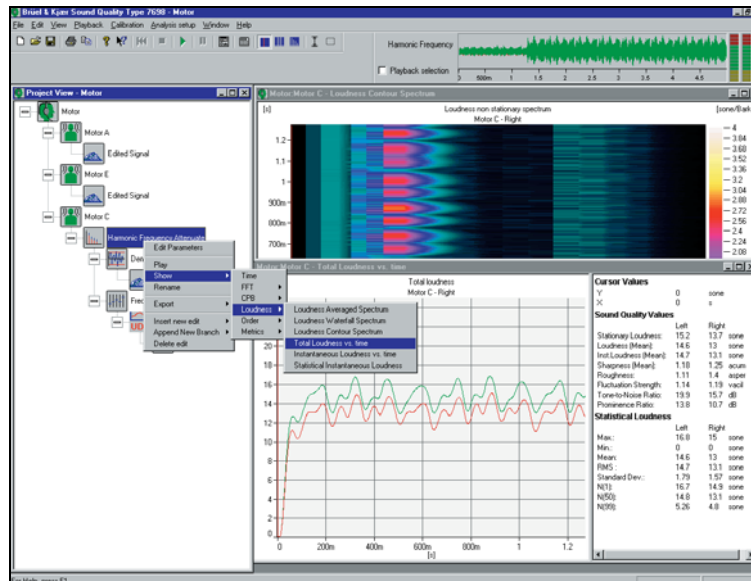


Fig. 5 is an example of a Paired Comparison test, in which recordings are paired together. The jury decides which sound it prefers of the two. Announcements may be inserted between the pairs to announce, for example, test object identification or number.

Fig. 6
The PULSE Sound Quality software's Zwicker Loudness option BZ-5265 adds the ability to calculate and analyse Loudness-based metrics



Zwicker Loudness is the most important tool for objectively determining sound quality parameters, or metrics.

It attempts to understand how the human ear experiences sounds by properly weighting the different parts of the sound signal. Sound Quality's Zwicker Loudness option calculates metrics for both stationary and non-stationary sounds.

The Zwicker Loudness-based options include:

- Loudness Averaged Spectrum
- Loudness Waterfall Spectrum
- Loudness Contour Spectrum
- Total Loudness vs. Time
- Instantaneous Loudness vs. Time
- Statistical Instantaneous Loudness
- Sharpness vs. Time
- Specific Roughness
- Specific Fluctuation Strength

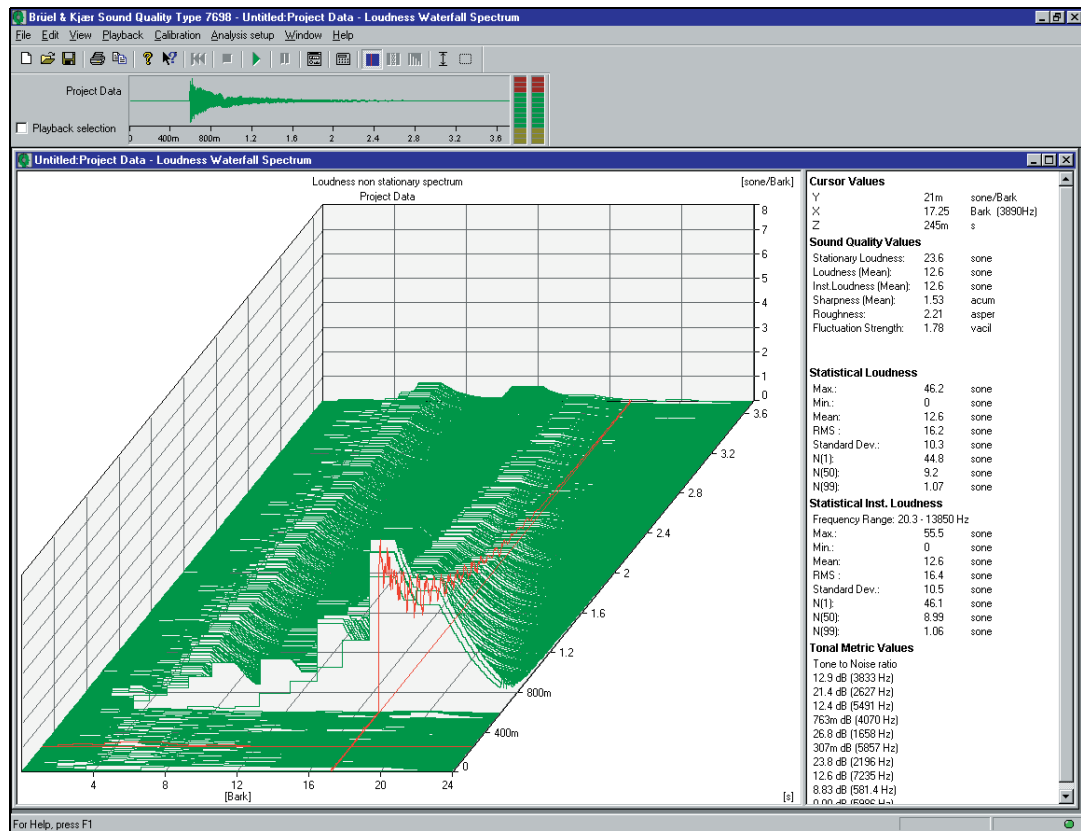
All of the above can also be displayed for binaural loudness.

Other sound quality parameters can be determined through FFT analysis. These include the tone-to-noise ratio, prominence ratio and RMS of time and frequency data.

Viewing the Results

You can choose to display a signal as a time graph, a spectrum or multispectrum on a frequency scale or psychoacoustic Bark scale. Multispectra can be displayed as contour plots, 3D plots, slices and envelopes. All of these can be displayed simultaneously. PULSE Sound Quality software offers a huge range of axis settings and cursor values for display with graphs.

Fig. 7
Specific Loudness waterfall graph with read-out of sound quality parameters. Note the list of cursor values to the right of the display. PULSE Sound Quality software has a very extensive set of cursor values to choose from



You can also display a multiple graph to allow easy comparison of data. The graph could, for example, display the FFT of all signals in a project or the results of different edits applied to the same signal.

Exporting Data

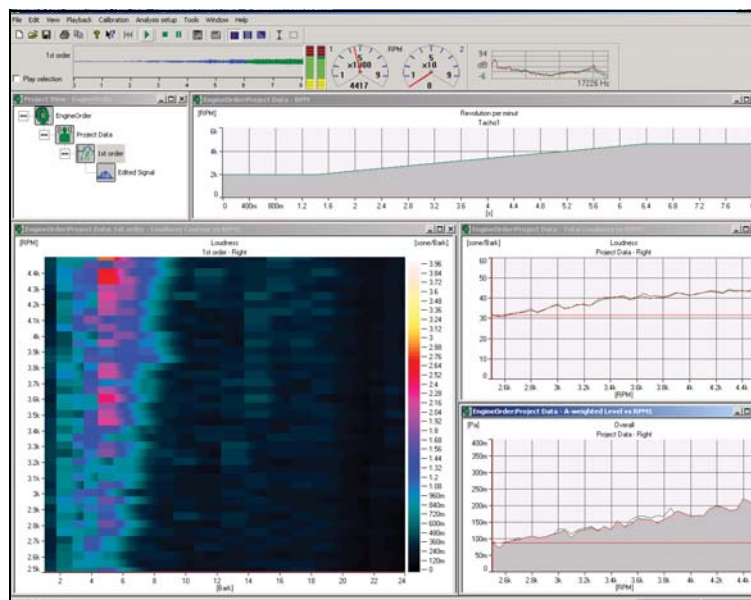
For report generation or further post-processing using a word processor or spreadsheet, data can be exported in ASCII format or via the clipboard. Sound signals can be exported with all calibration information as Windows®-compatible .wav files. You can also export data to other analysis applications in Universal File Format (UFF), HDF/DAT, MATLAB® or TEAC-GX1.

On-line Help

The software is fully documented with both context-sensitive help, an on-line manual and a glossary.

Sound Quality on Rotating Machinery – Order Analysis Option BZ-5277

Fig. 8
Plots of A-weighted Level, Specific Loudness and Total Loudness as functions of RPM



The Order Analysis Option for PULSE Sound Quality software lets you perform sound quality-based order analysis on rotating machinery, even when the speed is not constant.

The order analysis option adds two tacho channels to supplement the two existing sound channels. Data for the tacho channels may either be directly measured, transferred from a digital recorder or imported from files, for example, from the base PULSE software. When transferred from a two channel digital recorder, the tacho signal may either be taken from one of the channels leaving

the other for acoustic input. The software can also read signals with the 16th bit of one or both acoustic channels as a digital tacho. If the file format permits (for example UFF or multitrack wave), two sound channels and two tacho channels may be selected.

The order analysis option also adds order-related display and analysis functions to allow detection and quantification of order related signals from the sound channels. Order edits attenuate or filter out specific orders or sets of orders for troubleshooting or simulation of design changes.

Combined with Zwicker Loudness Option BZ-5265, the order analysis option lets you display Loudness, Roughness, Fluctuation Strength, and A-weighted and Linear levels as functions of RPM.

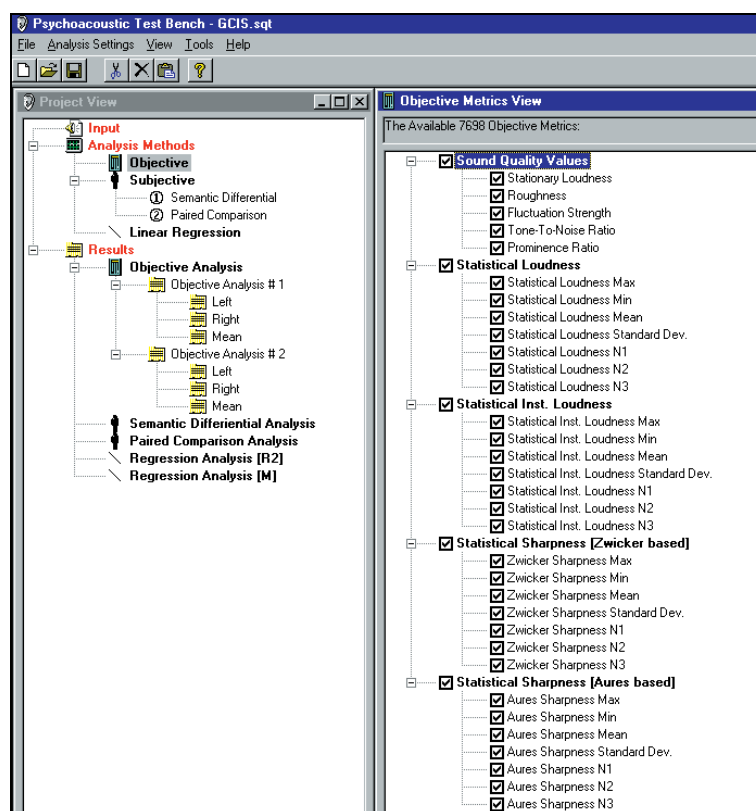
Psychoacoustic Test Bench Option BZ-5301

Psychoacoustic Test Bench is an advanced option which can be run as an addition to Sound Quality. It controls the specific objective tests (metrics) carried out by Sound Quality and also implements the two subjective test methods – Paired Comparison and Semantic Differential. For a set of sound files in .wav format, Psychoacoustic Test Bench will calculate a sound model (a formula for a combination metric) using regression analysis by correlating the subjective and objective tests, thus completing the sound quality solution.

Subjective Tests

For each subjective test session a corresponding user-defined playlist and jury answer form are produced. Multiple jury preference/voting can be collected using the Internet/Intranet and then saved in an Excel worksheet. The program provides a fully detailed report score sheet for each jury session and saves the HTMLs, playlists and Excel worksheets. The user can carry out as many subjective tests as required and new worksheets are assigned to each.

Fig. 9
Project view and user
selected metrics
options



Objective Tests

The objective test tool calculates the user selected metrics for specified wave files in the project input view. The loudness analysis parameters are set from Type 7698.

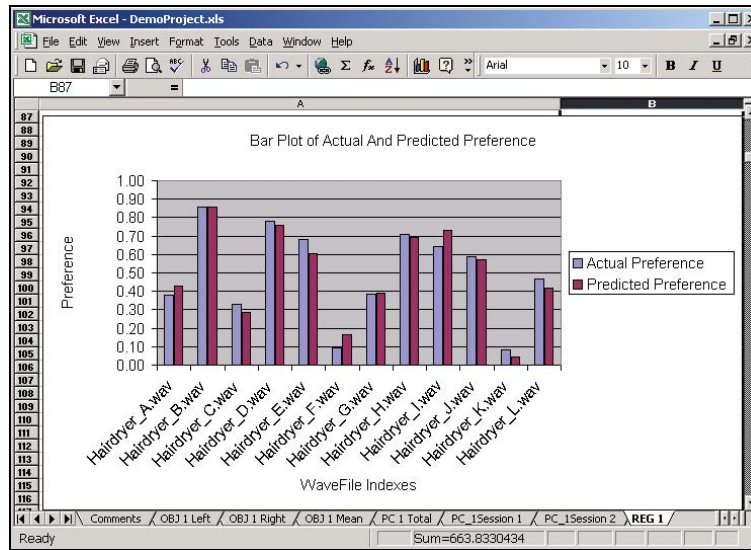
The test results are placed in an Excel worksheet. The saved data includes wave file and metrics names, loudness settings, and the objective metric values. If the sound is binaural, both left and right channel values can be calculated, and displayed both individually and as a mean, and saved.

Statistical Analysis

The statistical analysis function calculates the correlation between the objective and subjective tests. It is carried out by an advanced Excel function which calculates the optimal straight line estimate for a given set of input and output values.

Fig. 10

The statistical analysis calculation showing the plots and graphs displayed in an Excel worksheet



The statistical analysis calculation provides an automatic search facility using regression analysis to find and calculate the test model – the final combination metric – based on the preselected number of metrics. It compares the predicted values from the model to the actual results from the subjective listening tests. The final combination metric can be used as a user-defined cursor reading in the Sound Quality program, making it possible to evaluate any signal against the model very quickly.

Specifications – PULSE Sound Quality Software Type 7698

SIGNAL INPUT/OUTPUT

- 2 channels (+ 2 tachometer channels with BZ-5277)
- Analog or Digital
- Tacho can be read from a 16th-bit encoding or normal encoded
- Direct recording with PULSE and Time Capture or Data Recorder options
- Loading of time data from existing PULSE projects and recorder files

ANALYSIS

- Overall Levels: RMS, Statistics, Metric Statistics
- FFT
- Statistical Regression Analysis (with BZ-5301)
- Envelope

ZWICKER LOUDNESS ANALYSIS (WITH BZ-5265)

- Stationary Loudness (according to DIN 45 631/ISO 532B)
- Non-stationary Loudness (according to Zwicker Loudness)
- Binaural Loudness

ZWICKER LOUDNESS METRICS (WITH BZ-5265)

- Loudness
- Sharpness
- Roughness
- Fluctuation Strength

OTHER METRICS

- Tone-to-noise ratio (according to ANSI S1.13–1995)
- Prominence ratio (according to ANSI S1.13–1995)
- A, B, C, D weighting
- User-defined cursor readings

EDITS

- Peak Limit
- Time Attenuate
- Level Edit, +/- 20 dB
- Demodulation
- Frequency Attenuate
- Frequency Shift
- Passband
- Peak Limit Frequency
- Harmonic Frequency Attenuate
- Harmonic Frequency Shift
- Harmonic Passband
- Generator
- Mixer
- Real-time Filter
- Frequency Response Filter
- User-defined Filter

DISPLAYS

- Real-time playback monitor
- Time (Lin/Lin, Log/Lin, Lin/Log, Log/Log, Waterfall, Contour)
- Single Signal or Multiple Signal Graphs

ORDER ANALYSIS (WITH BZ-5277)

- Schmitt trigger of tacho signals
- RPM extraction from tacho signals
- FFT analysis of sound signal using RPM signal to determine orders

ORDER-RELATED EDITS (WITH BZ-5277)

- Order Attenuate
position specified by order start and width attenuation in dB or absolute
- Order Passband
position specified by order start and width stop-band gain in dB or absolute

ORDER-RELATED DISPLAYS (WITH BZ-5277)

- Time graphs:
 - Tacho
 - Schmitt triggered tacho
 - RPM
- FFT Contour versus RPM
- FFT Waterfall versus RPM with Zwicker Loudness Metrics (with BZ-5265)
- Loudness versus RPM
- Roughness versus RPM
- Fluctuation Strength versus RPM

PSYCHOACOUSTIC TEST BENCH (WITH BZ-5301)

- Controls Type 7698 from an Excel spreadsheet
- Set up of calculation of objective metrics for wave signals
- Set up of subjective tests and evaluation of results from jury members
- Remote jury tests using Internet
- Regression analysis for calculation of combination metrics

WEIGHTING CURVE CORRECTIONS

- Input (Flat, 4100 diffuse-field, 4100 free-field or user-defined)
- Output (Flat, HT 0012, HT 0017 or user-defined)

CALIBRATION

- Input level
- Output level
- Charge Injection Calibration

AUTOMATION

- OLE 2 interface
- Programmable from e.g., Visual Basic®, Visual C++®, Microsoft® Excel, Microsoft® Word
- VBScript, JavaScript

DATA IMPORT AND EXPORT

Import and export of multichannel external file formats: HDF/DAT – HEAD Acoustics ArtemiS format. Support for both 16- and 24-bit data (Note: In 16-bit format, the tachometer information is embedded in the LSB of the left channel). MATLAB time format – contains no calibration information

Data Export

- .WAV (wave file)
- .TXT (ASCII text file)
- Universal File Format (UFF)
- HDF/DAT
- MATLAB
- TEAC GX-1

Data Import

- .WAV (wave file)
- Universal File Format (UFF)
- HDF/DAT
- MATLAB
- TEAC GX-1
- Import from base PULSE software – requires that either Data Recorder Type 7701 or Time Capture Type 7705 is installed on PULSE computer. Support of 24-bit DAT files from Type 7701

PLAYBACK

- Single or repeated
- Calibrated or uncalibrated
- Synchronised (original vs. edited)

JURY TEST

- Test methods supported: Paired Comparison, Semantic Differential
- Voice annotation
- User-defined delays
- Play List

ON-LINE DOCUMENTATION

- On-line, context-sensitive Help and User Manual

Specifications – Power Amplifier ZE-0769 (optional headphone amplifier)

INPUTS

Type: bridging, balanced/unbalanced, transformerless

Input Impedance: 10 k Ω each leg

Maximum Input Level: +18 dBu

Connector: 3-conductor ¼" (tip-ring-sleeve)

INDICATORS

Power: yellow LED indicates power "on"

AUDIO PERFORMANCE

Frequency Response: 20 Hz to 20 kHz, +0 dB, –1 dB

THD: 0.01% (1 kHz, 0 dBm, 600 Ω)

0.02% (1 kHz, +24 dBm, 600 Ω)

Signal-to-Noise Ratio: 95 dB

Gain: –30 to 0 dB in 6 dB steps

OUTPUTS:

Type: low-Z

Output Impedance: 60 Ω

Maximum Output Level: >50 V p-p into 2000 Ω

Connectors: ¼" (×4)

POWER REQUIREMENTS

16 V AC, 200 mA (power supply, included)

Specifications – Headphones HT- 0017 (optional)

Nominal Impedance: 300 Ω

Contact Pressure: approximately 2.5 N

Weight (without cable): approximately 260 g (9 oz.)

Jack Plug: 6.5/3.5 mm stereo

Transducer Principle: open, dynamic

Ear Coupling: Circumaural

Cable Length: 3 m (10 ft.)

Frequency Response: 10 to 39500 Hz

Sound Pressure Level: 103 dB (1 V RMS)

THD: 0.05%

Ordering Information

Type 7698-X*	PULSE Sound Quality
BZ-5265-X	PULSE Sound Quality Zwicker Loudness
BZ-5277-X	PULSE Sound Quality Order Analysis
BZ-5301-X	PULSE Sound Quality Psychoacoustic Test Bench

FOR DATA RECORDING USING TIME DATA RECORDER

Type 3050-A-040	4-ch. Input Module LAN-XI 51.2 kHz (Mic, CCLD, V)
Type 7708-X	PULSE Time Data Recorder
Type 7698-X	PULSE Sound Quality
BZ-5265	PULSE Sound Quality Zwicker Loudness

OPTIONAL SOFTWARE†

- Type 7700-X2 PULSE FFT & CPB Analysis, 2-channel License:
- Gives you the possibility to control the recording from inside Type 7698 using the PULSE Recorder
 - Gives you the possibility to analyse the recordings in PULSE LabShop

System Requirements

RECOMMENDED PC

- Gen Intel® Core™ i7 3 GHz processor, or better
- 8 GB RAM
- 250 GB Solid State Drive (SSD) with 20 GB free space, or better
- DVD-RW drive

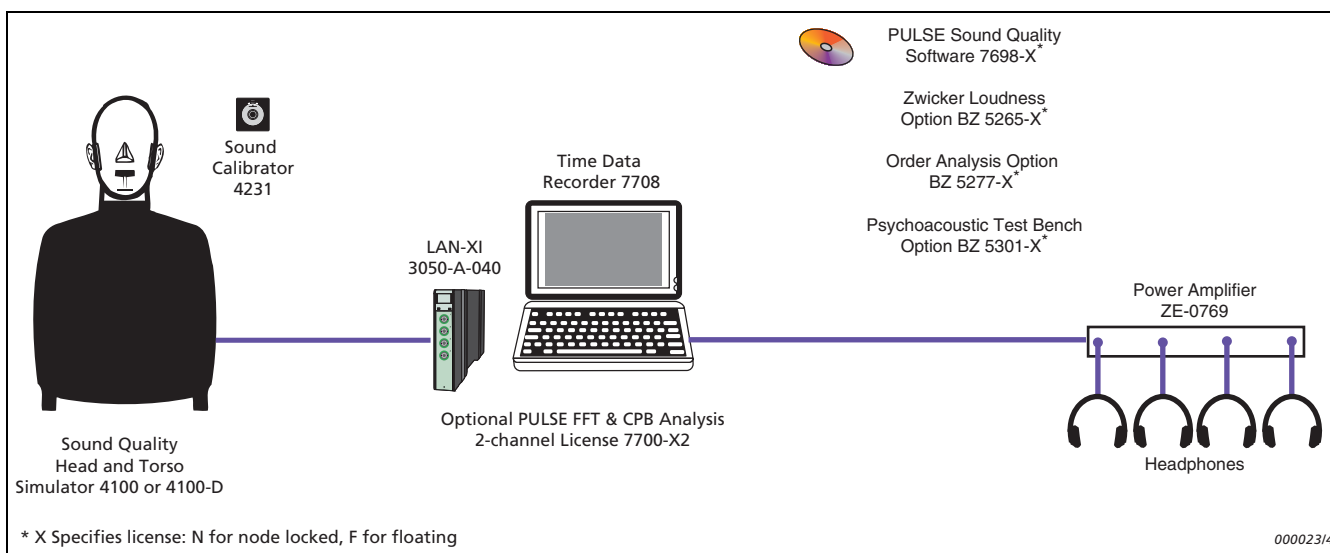
* X Specifies license: N for node locked, F for floating

† Optional to the ordering information FOR DATA RECORDING USING TIME DATA RECORDER

- 1 Gbit Ethernet network
- Microsoft® Windows® 8.1 Pro (x64), Windows® 7 SP1 (x32 and x64) or Windows® XP Professional (SP3)
- Microsoft® Office 2007 (SP2), Office 2010 (SP2) (x32) or Office 2013 (x32)
- Adobe® Reader® 11.0 (US version included on DVD)
- Microsoft® SQL Server® 2008 R2 Express Edition (SP 1) (included with PULSE)
- Sound Card (see Optional Accessories)

Optional Accessories

Type 4100	Sound Quality Head and Torso Simulator (Preamplifiers: Type 2669-L with charge injection calibration facility)
Type 4100-D	Sound Quality Head and Torso Simulator (Preamplifiers: DeltaTron® Type 2671)
Type 2672	Sound Quality Conditioning Amplifier
UA-1324	Positioning Frame for Types 4100 (D) and 2672
HT-0017	Sennheiser HD 650 Headphones
ZE-0769-004	Headphone Amplifier, including JP 0352 and 2 × AO-1459
ZE-0770-A-001	PCMCIA Sound Card
AO-1458	Stereo Jack Plug – 2 × BNC male cable (1 m)
AO-1459	Mono Jack Plug – BNC male cable (1 m)
JP-0352	Stereo Jack Plug – Stereo Minijack Adaptor
Type 4101	Binaural Microphone
Type 4101-A	Binaural Microphone with TEDS



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HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 7741 2000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com

Local representatives and service organisations worldwide

Brüel & Kjær 

