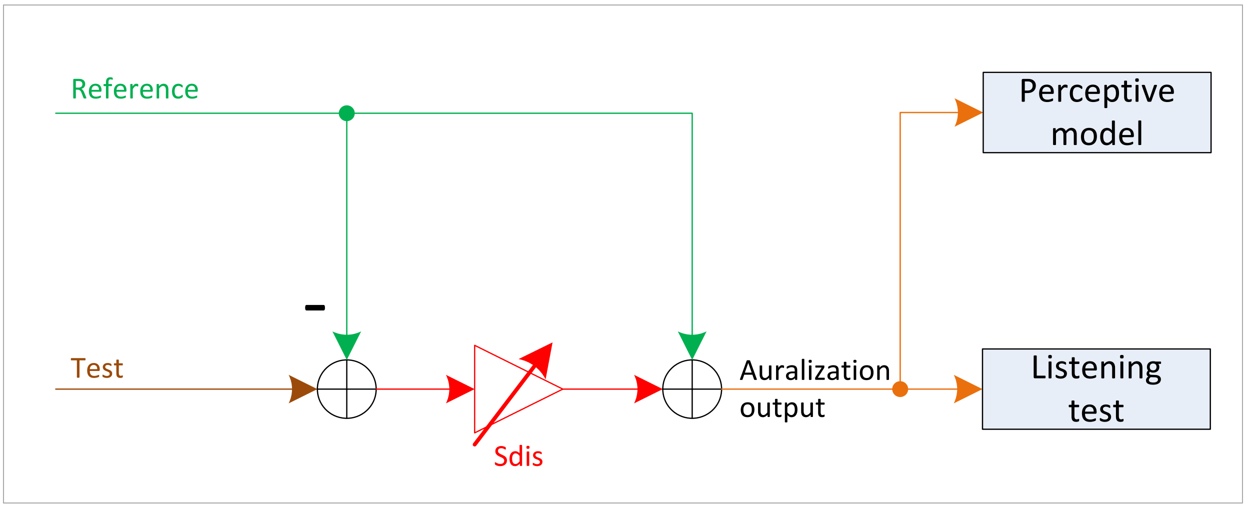
Difference Auralization v 2.0 S22

Specification to the KLIPPEL ANALYZER SYSTEM (Document Revision 1.0)

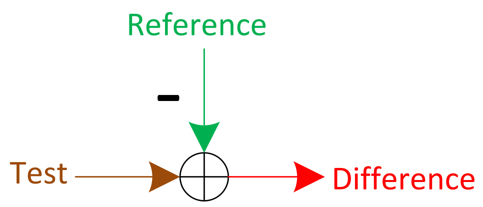
FEATURES	BENEFITS
• Automatic alignment of input signals in time • Isolation of difference signal (no model is employed) • Scaling of difference signal to enhance or attenuate distortion • Automatic leveling of auralization output • Export of auralization output to WAVE files • Distortion analysis and frequency domain analysis	• Combines subjective and objective evaluation • Isolates all kinds of regular and irregular distortion (also rub & buzz) • Exported files may be used for listening tests or perceptual simulation • Sensitization of listeners to defect symptom • Communication of sound quality to nontechnical colleagues to define target performance • Determine critical test signals

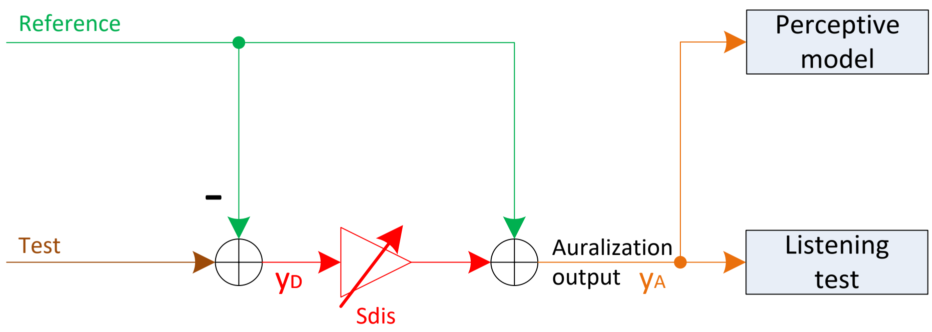


Article Number:	1001-104

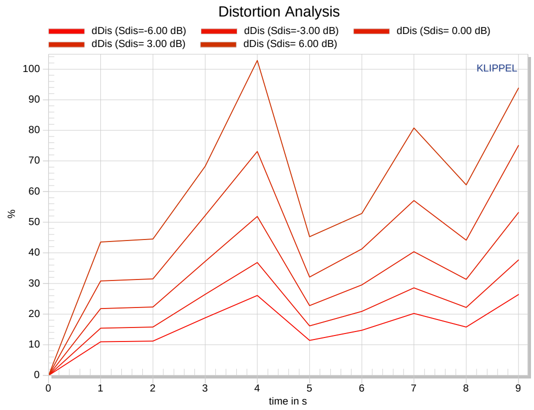
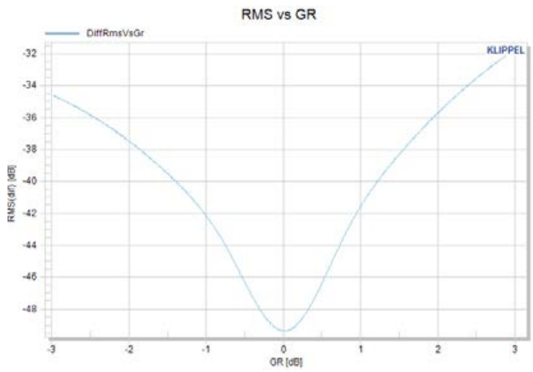
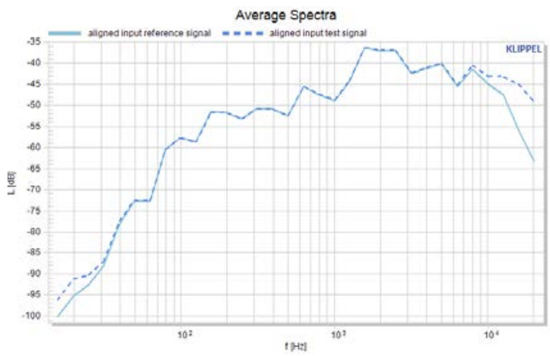
CONTENTS:

1 Overview

<table>
<tr><td>Introduction</td><td>
Auralization techniques are used to enhance or attenuate distortion components to communicate symptoms (e.g. of defects) that influence the sound quality.
This module uses a difference decomposition technique to isolate the distortion signal. Two input signals (a reference input signal and a test input signal) are used to calculate the difference signal.


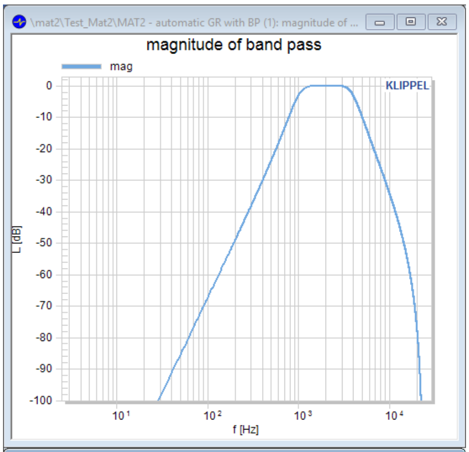
The input signals have to be aligned in time and level before the subtraction. The time alignment is performed automatically by the module, thus providing synchronous signals.
Depending on the containing distortion components, the difference signal contains these components that are in the test input signal, but not in the reference input signal.
The difference signal is then scaled with the distortion scaling factor S_{dis} resulting one auralization output signal for each distortion scaling. The signals are exported to WAVE files and may be used in listening tests or a perceptual model.


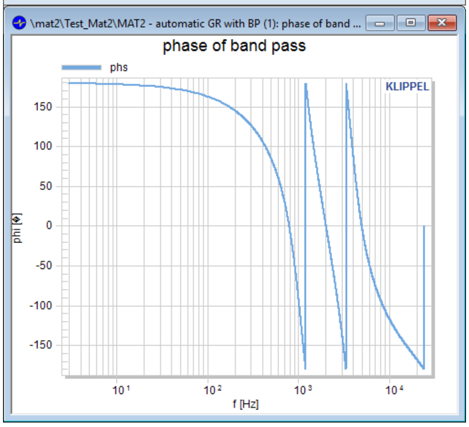
</td></tr>
<tr><td>Requirements</td><td>This module is a licensed CAL module. A license and a dongle or distortion analyzer is required.</td></tr>
<tr><td>Input Signals</td><td>WAVE data and vector formats are supported as input signals. All kind of audio signal (music, sweep, noise, …) is supported.</td></tr>
</table>

Distortion Analysis	The distortion analysis indicates the amount of contained distortion in the auralization output it's defined as the ratio of scaled difference signal to auralization output within a certain time frame: $$d_{\mathrm{dis},S_{\mathrm{dis}}} = \frac{10^{\frac{S_{\mathrm{dis}}}{20}} \hat{y}_{\mathrm{D}}(t)}{\hat{y}_{\mathrm{A},S_{\mathrm{dis}}}(t)}$$ The time frame is set to 1 s to be comparable to the AUR module. 
RMS vs GR	This window shows the overall RMS value of the difference signal versus GR. An optimal GR shows a defined minimum in the RMS. 
Average spectra	This window shows the average spectra of the aligned input signal in third octave bands. 

Magnitude and phase of band pass filter

The windows show the magnitude and phase of the FIR filter for the difference





signal

Signals

The single value results comprise signal characteristics of the following signals (please refer to the signal flow plan for explanation of symbols):

- Exported signals

	Output (Wave)	Symbol	Level$_{RMS}$	Level$_{Peak}$	Level$_{A}$
	Reference	w_R	-42.6 dB	-20.4 dB	-42.8 dB(A)
	Auralized (S_{dis}=-6 dB)	$w_{A,S_{dis}=-6\,dB}$	-42.7 dB	-20.5 dB	-42.9 dB(A)
	Auralized (S_{dis}=-3 dB)	$w_{A,S_{dis}=-3\,dB}$	-42.7 dB	-20.5 dB	-42.9 dB(A)
	Auralized (S_{dis}=0 dB)	$w_{A,S_{dis}=0\,dB}$	-42.7 dB	-20.6 dB	-42.9 dB(A)
	Auralized (S_{dis}=3 dB)	$w_{A,S_{dis}=3\,dB}$	-42.7 dB	-20.6 dB	-42.9 dB(A)
	Auralized (S_{dis}=6 dB)	$w_{A,S_{dis}=6\,dB}$	-42.8 dB	-20.8 dB	-43.0 dB(A)
	Difference	w_D	-61.1 dB	-33.0 dB	-63.3 dB(A)
*	Calibration	w_C	-14.0 dB	-1.3 dB	-13.9 dB(A)

- Signals in the pressure domain*

The exported signals are mapped to the pressure domain at the receiving position (using playback gain G_P). Only visible in advanced mode.

	Signal Name	Symbol	SPL$_{RMS}$	SPL$_{Peak}$	SPL$_{A}$
*	Reference	p_R	51.3 dB	73.6 dB	51.1 dB(A)
*	Auralized (S_{dis}=-6 dB)	$p_{A,S_{dis}=-6\,dB}$	51.3 dB	73.5 dB	51.1 dB(A)
*	Auralized (S_{dis}=-3 dB)	$p_{A,S_{dis}=-3\,dB}$	51.3 dB	73.5 dB	51.1 dB(A)
*	Auralized (S_{dis}=0 dB)	$p_{A,S_{dis}=0\,dB}$	51.3 dB	73.4 dB	51.0 dB(A)

*	Auralized (S_{dis}=3 dB)	$p_{A,S_{dis}=3\text{ dB}}$	51.2 dB	73.3 dB	51.0 dB(A)
*	Auralized (S_{dis}=6 dB)	$p_{A,S_{dis}=6\text{ dB}}$	51.2 dB	73.2 dB	50.9 dB(A)
*	Difference	p_D	32.9 dB	61.0 dB	30.8 dB(A)
*	Calibration	p_C	80.0 dB	92.7 dB	80.1 dB(A)

- Gain settings

This table shows an overview of gain settings.

	Name	Symbol	Gain
	Reference Gain	G_R	0 dB
*	Auralization Gain*	G_A	0 dB
*	Level Equalization Gain (S_{dis}=-6 dB)	$G_{L,S_{dis}=-6\text{ dB}}$	-.04 dB
*	Level Equalization Gain (S_{dis}=-3 dB)	$G_{L,S_{dis}=-3\text{ dB}}$	-.07 dB
*	Level Equalization Gain (S_{dis}=0 dB)	$G_{L,S_{dis}=0\text{ dB}}$	-.11 dB
*	Level Equalization Gain (S_{dis}=3 dB)	$G_{L,S_{dis}=3\text{ dB}}$	-.19 dB
*	Level Equalization Gain (S_{dis}=6 dB)	$G_{L,S_{dis}=6\text{ dB}}$	-.32 dB
	Export Gain	G_E	0 dB

- Input signal information

Information on the input signals are provided for determining problems due to input headroom and temporal alignment.

Symbol	Signal Name	f_s	Headroom	Length	Delay
x_R	Reference input signal	48000.00 Hz	20.42 dB	9.34 s	-
x_T	Test input signal	48000.00 Hz	20.44 dB	9.34 s	-0.00 s (-10.00 samples)

Items with asterisk (*) are only shown, if an absolute relation is calculated. Please refer to the advanced parameter playback gain G_R.

Exported audio files	The difference auralization exports the following signals to one channel WAVE files: • Calibration signal The calibration signal is a noise signal with one octave bandwidth centered at 1 kHz. The wave file is used to calibrate the audio playback system in order to realize the sound pressure levels of the signals in pressure domain. Please refer to the section calibration of playback system. • Reference signal This represents the reference signal used for the auralization. It represents the best sound quality without any distortion ($S_{\mathrm{dis}} = -\infty\ \mathrm{dB}$) and may be used as the reference signal in listening tests or perceptual models. • Auralized signals The auralization output represents the signals with differently scaled distortions. For each defined distortion scaling factor S_{dis} an auralized signal is calculated. • Difference signal The difference signal is exported to provide the possibility for manually checking the isolated difference. The mono signals are available as file link in the signal characteristics table of the exported signals. In addition to the mono files, stereo files are generated that consists of reference and auralized signals in separate channels. Files in the folder stereo_ref+auralized have a fixed channel assignment: the reference signal is the 1st channel, the auralized signals for different distortion scaling factors are in the 2nd channel. Files in the folder stereo_ref+auralized_random have a random channel assignment and may be used for listening tests directly. The file solutions_distorted_channel.txt contains the channel assignment for the distorted signal.

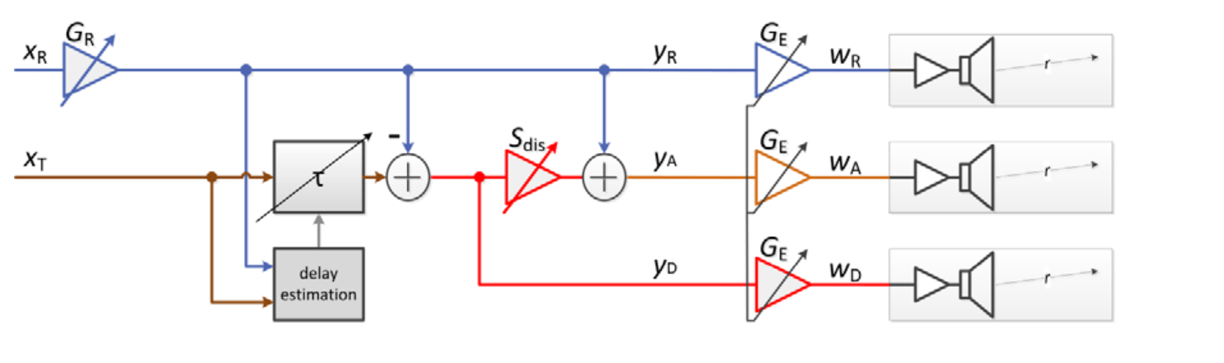
2 Basic Signal Flow Plan

The basic signal flow plan shows all major input and output signals for operating the DIF-AUR. The minimal set of input parameters allows a fast execution of the auralization:

- Reference and test input signals (vector or wave file)
- G_R – if necessary, set to 0 dB if not defined
- S_{dis} – defines the scaling of isolated distortion, set to 0 dB if not defined

Available, yet optional parameters are:

- Delay, determined automatically by maximum of cross correlation
- G_E – determined automatically to ensure efficient headroom for exported wave files



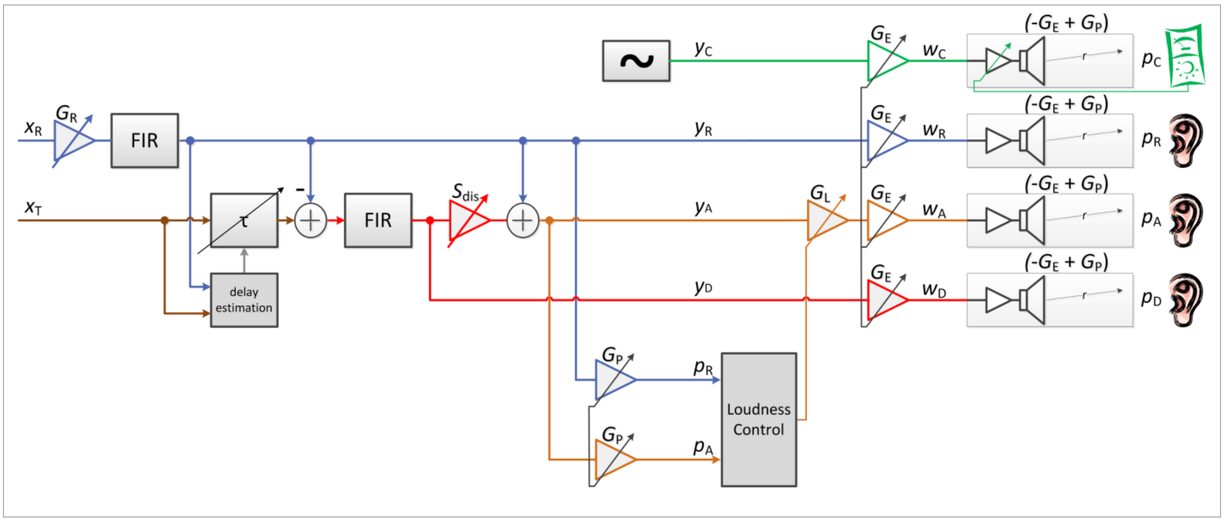
3 Advanced Signal Flow Plan

Additional advanced parameters allow the fine-tuning of the exported wave files.

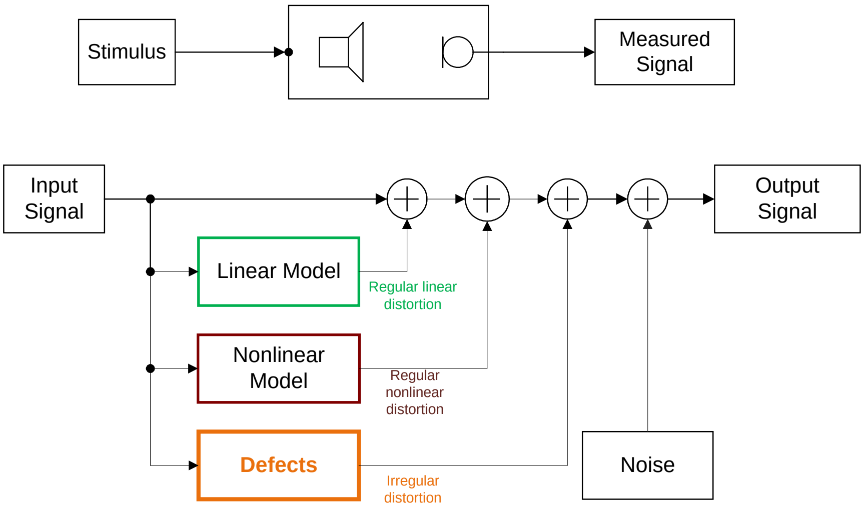
Overview:

- FIR filters: The available FIR filters allow manipulating the
  - **reference input signal** by loading an impulse response (VEC or WAV) and convolving the original input signal.
  - difference signal by applying a band-pass filter and reducing the signal components of the difference signal to the desired frequency range.
- Playback gain G_P: allows the specification of an absolute pressure definition (please also refer to the section *Calibration of playback equipment*) by defining a playback gain and thus the sound pressure level in the listening experiment.
  - It may be specified as a relative gain ({number}) or
  - as the target sound pressure level of the reference output signal.

  An absolute pressure definition is necessary to apply the psycho-acoustical model for the level alignment and to calculate the sound pressure levels at the receiving position.
- G_L – allows the level alignment of the exported wave files. It may be defined as a gain (in dB) or set to ‘level’ or ‘loud’. Please note that ‘loud’ requires an absolute pressure reference. The module applies the given gain to all auralization output signals.
  - {number} applies the gain in dB to all auralization signals.
  - ‘level’ applies an individual gain to all auralization signals (multiple signals, if multiple distortion scaling factors S_{dis} are defined) to realize wave files with the same level as the reference output signal.
  - ‘loud’ applies a psycho-acoustical model to calculate the necessary gain for each auralized signal to be perceived as loud as the reference output signal.



4 Distortion components

Signal flow plan	The distortion components of audio products may be modeled with the following signal flow plan. 
Modeling distortion components	The regular linear distortion can be predicted by lumped or distributed parameters of the linear transducer model. The linear distortion generation is optimized during the design process. The regular nonlinear distortion can be predicted by lumped parameters of the nonlinear transducer model, the generation of this distortion component is optimized during the design process as well. The irregular nonlinear distortion are generated by defects (rub&buzz) in manufacturing and can usually not be modeled or predicted. Noise is caused by external factors, e.g. environmental noise, production noise, noise in a typical application (tire and air noise for automobiles). This component is independent of the stimulus.
Auralization of distortion components	Traditional auralization techniques are able to auralize distortion components with models of the transducer. Irregular nonlinear distortions cannot be modeled due

to their random characteristics. The difference auralization may auralize all components (including irregular nonlinear distortion), since it does not employ a model.

The definition which distortion components are isolated lies solely with the choice of input signals. All components that are included in the test input signal, but not in the reference input signal are defined as distortion and reflected in the difference signal. The following table provides an overview of possible choices.

Difference Signal	Test signal	Reference signal
Regular Linear Distortion	Transducer output at small amplitudes (amplitude adjusted to listening level)	Stimulus (time delay and amplitude adjusted to test signal)
Regular Nonlinear Distortion	Total output (linear + distortion) of the AUR module (digital model in DA using nonlinear parameters)	Linear output of the AUR module (digital model in DA using nonlinear parameters)
Irregular Nonlinear Distortion	Transducer output at high amplitudes	Total output (linear + distortion) of the AUR module (amplitude and time delay adjusted)
Regular Linear + Regular Nonlinear Distortion	Total output (linear + distortion) of the AUR module (digital model in DA using nonlinear parameters)	Stimulus (time delay and amplitude adjusted to test signal)
Regular + Irregular Nonlinear Distortion	Transducer output at high amplitudes	Transducer output at small amplitudes
All Distortion (Regular Linear +Regular Nonlinear + Irregular)	Transducer output at high amplitudes	Stimulus (time delay and amplitude adjusted to test signal)

Please refer to the section application for selected examples in greater detail.

Note that the signals that are used for subtraction are aligned automatically in time. The level must be aligned manually in order to obtain a physically sensible subtraction (e.g. comparing transcuder output at high and small amplitudes).

5 Calibration of playback equipment

Background	All signals to be exported are defined as pressure signals. To meet the required headroom for the WAVE export (signals must be in range -1..+1), the export gain can be applied. If an absolute pressure reference is given, the wave files may be calibrated to the displayed sound pressure levels. All signals are exported with the same export gain, thus keeping the exported signals relatively aligned. If different output signals of other DIF-AUR runs shall be used, a common export gain is beneficial.
Calibration	The exported calibration signal is played back in loop mode by the sound reproduction system of the listening experiment. The resulting sound pressure level at the receiving positions can be measured with a SPL meter. By providing a steady-state calibration signal, the measurement result is stable.

	The gain of the sound equipment is adjusted until the resulting SPL equals the defined sound pressure level of the calibration signal, thus compensating for the export gain G_E and realizing the necessary playback gain G_P. When the playback equipment is calibrated all signals (that where exported with the same export gain) result in the calculated sound pressure level.

6 Input Parameters

Type of input signal	Defines of wave of vector data are used for processing
Reference signal	Path to wave file or vector data for reference input signal
Test signal	Path to wave file or vector data for test input signal
Distortion scaling factor	Definition of distortion scaling factor, available options: • Single (single value) • Range (range definition) • Matrix (arbitrary matrix definition)
GR	[dB] Reference gain, if empty G_R = 0 dB are applied
Advanced parameters	Delay Manual definition of delay between reference and test signal Reference gain Manual definition of reference gain G_R Export gain Manual definition of export gain G_E Playback sound pressure level Manual definition of sound pressure level of reference signal or playback gain G_P Level equalization Activation and definition of level equalization method for auralized signals. BP for difference signal Definition of band pass filter for difference signal

7 Patents

USA	8,964,996

Find explanations for symbols at:

http://www.klippel.de/know-how/literature.html

Last updated: Juni 28, 2017