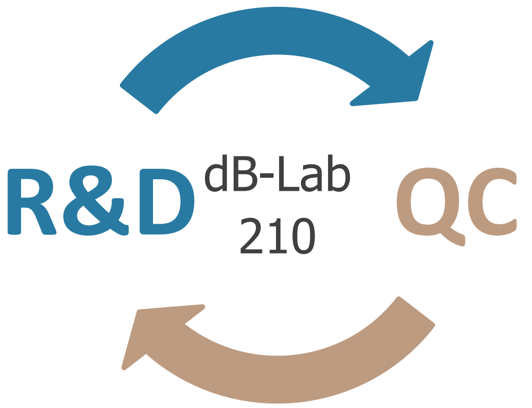
KLIPPEL ANALYZER SYSTEM



Unified Framework for R&D and QC Application

dB-Lab Version 210 ↔ QC Version 6.1

Features

- Modular hardware platform *KLIPPEL Analyzer 3* (*KA3*)
- Combined software dedicated to R&D and end-of-line application
- New software (*LSI3, CRC, QC 6.1*) exploiting *KA3* capabilities
- Multi-channel measurements
- Supports existing hardware (*DA2, PA, PM8*)
- Full compatibility with existing data and test setups
- Linked with *Klippel Controlled Sound*

Benefits

- Cost-effective and flexible hardware solution tuned to your application
- Same software from prototyping to mass production
- More functionality - simple to use by experts and operators
- Satisfying particularities of EOL testing (fast, sensitive, robust)
- Safe investment for reliable, long-term test solutions
- Easy exchange of setups and data
- Suite of tools for design, measurement and DSP

Feature Overview

Updates in Existing Products

- dB-Lab – frame software
    - Supports KLIPPEL Analyzer 3
    - Support for KLIPPEL Dongle
    - Database stability update (for more information see TN10)
- LSI2 – changed definition of $R_e(T_v = 0\text{ K})$. The temperature is displayed referenced to the imported (cold) R_e using an additional curve. The temperature limit remains based on the determined R_e from the "Linear Mode"
- MSPM:
    - new distortion measures:
        - E_{lin}: Represents the error in between measured and identified linear model at excitation lines (replaces E_f).
        - Model Performance: This value in dB is intended to give an easy to understand dB value on how well the nonlinear model performs. Higher values are more preferable, whereas fitting is good if bigger than 6 dB to 9 dB. Replaces E_{Model}.
    - Excitation frequencies for MSPM Pro are now based on small signal parameters (customization is possible).
- SIM2 – Simulation
    - add fade-in for the simulated excitation signal to improve reaching steady state for certain enclosure configurations
    - auto-symmetrize peak/bottom-window around 0 value of the y-axis

New Klippel Software Modules

- ISC – In-Situ Room Compensation:
  Correction filter for compensating room influence in standard measurements
- LSI3 Woofer – Large Signal Identification Woofer (for KA3)
    - Advanced nonlinear model
    - Dedicated to electro-dynamical transducer (f_s < 500 Hz)
    - Driver in free air, vented, sealed enclosure
    - Start with given small signal voltage
    - Import custom voice coil material coefficient
    - Improved excitation noise generation
        - Less heating by band-pass boost around resonance
        - Adjusted frequency range for excitation band-pass
    - Switch speaker polarity when viewing data
- LSI3 Micro-Speaker (for KA3)
    - Advanced nonlinear model
    - Dedicated to headphones drivers and micro-speakers (f_s < 2 kHz)
    - Optimized signal crest factor using multi-tone excitation
- HMA – Higher Order Modal Analysis (Beta):
  Automatic extraction of modal parameters from SCN measurements and FEA simulations
- SIM-AUR – Simulation-Auralization:
  Nonlinear and thermal simulation and auralization of speaker performance with music
- STAT – Statistics (Beta)

    - Statistical overview of measurement data (curves + single values)
    - Visualization of variances and fast comparison between batches
    - Intuitive calculation of limits (parameter-based or interactive)
    - Quick grouping of test objects in pools (e.g. “good”, “bad”, “borderline”) manually or automatic via thresholds (limits)
- The QC framework module is now available as a general dB-Lab measurement module (KA3 required); the following QC Tasks are available (operation templates are available):
    - ALD Air Leak Detection / ALS Air Leak Stethoscope
    - BAC Balanced Armature Check
    - MSC Motor + Suspension Check
    - LST Linear Suspension Test
    - IMP Impedance
    - SPL Sound Pressure
    - EQA Equalization & Alignment
    - EXD External Devices

  →Close the gap between R&D specifications and end-of-line test results

QC 6.1 Features in dB-Lab 210

Hardware Support

- Supports KLIPPEL Analyzer 3 (see *Support of New KLIPPEL Analyzer 3 (KA3)* below)
- Multichannel measurement: up to 8 input channels (4 input channels + voltage and current for 2 speaker channels)
- Supports multichannel 3rd party soundcards with up to 4 input channels
- Last version supporting *Production Analyzer* with Firewire Interface (hardware upgrade available)

Workflow

- Batch processing of multiple QC operations; may also be combined with R&D operations
- Complex testing of systems like smart speakers or digital headsets (various sample rates, audio devices, long test sequences)
- Summary verdict collector and overall verdict for batch processing
- Activate/deactivate tasks in the test sequence with just a click
- New access to calibration routines from dB-Lab menu *Tools*
- New feature option: conditional skip/repeat option for a task (*Sequence Control*)
- Improved feature option *Serial Number Validation*: validation of serial number length

Infrastructure

- Wave file export of Rub&Buzz time signal for monitoring and diagnostics
- Sparse wave export for PASSed test objects
- Wave file import is independent of the used measurement device
- Easy migration of customized scripts / software to main QC software version
- Easy case studies by reprocessing wave files of multiple test objects, e.g. reprocess data with a different Rub&Buzz filter setting - how does the yield change?
- Signal sharing: high speed testing by sharing measurement data with other tasks. Multiple and multi-channel analysis available based on single measurements.
- Update of hotkey management, smooth interaction with 3rd party software
- Manual Sweep: dialog is not exclusive (modal) anymore. Zoom and other customization supported.

Results and Signal Processing

- Standardized/preferred/user defined result frequencies (ISO)

- On-line monitoring of Rub&Buzz audio signal using standard PC soundcard (for SPL task and manual sweep)
- Higher Order Harmonic Distortion (HOHD)
- HI-2 distortion
- Distortion measures relative to frequency response or average level (in dB or %)
- Normalized frequency response relative to Golden DUT, reference DUT pool average or average level
- Manual Sweep: Rub&Buzz waveform added, live audio monitoring
- New feature option: *Step Sine* stimulus for comparison purpose

New & Updated Modules

- Impedance (IMP): new *TSX* add-on – full TS parameter set based on laser displacement measurement (Hx(f), Bl, Mms, Rms, Cms, Vas); KA3 hardware required
- Sound Pressure + Impedance (SPL-IMP): measure U, I, Mic 1 & 2 simultaneously with KA3 hardware - measurement of impedance, sound pressure and ambient noise at the same time for up to two DUTs (e.g. headphone)
- Sound Pressure (SPL): laser measurement for checking dynamic shift of coil position (DCX)
- Equalization & Alignment (EQA):
    - measurement and control of displacement (AC and DC)
    - Single value results (e.g. average level) can be used as alignment target for sweep signal
- Linear Suspension Test (LST): now supports MSPM Bench for small diaphragm measurement

Accessories

- New USB temperature and humidity sensor

Support of New KLIPPEL Analyzer 3 (KA3)

- Adaptable, modular hardware concept
- Wider frequency range ($f_s \leq$ 192 kHz)
- Excellent sensitivity, SNR and distortion
- Sturdy, compact hardware at high performance
- Flexible speaker channels with switchable current sensitivity (controlled by software)
    - standard (e.g. woofer)
    - high-sensitivity (e.g. micro-speaker)
- Comes with a second laser-input in standard configuration
- Internal power amplifier (50 W)
- New measurement modules for evolving needs

Main Features Explained

KLIPPEL has released a new software update for the *KLIPPEL Analyzer System* unifying both R&D and QC applications that have been formerly available as separate hard- and software system packages.

KLIPPEL dB-Lab has been the base platform for all software modules so far, but the unified release and common hardware platform provides completely new application opportunities and improved work flow in product development and manufacturing.

Additionally, new software modules and major features in existing modules have been added as listed above. The most important ones are introduced in the following article.

Unified Hard- and Software Framework for R&D and QC

In modern audio system manufacturing, research and development (R&D) should be closely connected to quality control (QC) in pre-production and end-of-line testing for optimal product performance, maximal yield and lasting customer satisfaction.

The new unified release of the *dB-Lab* framework software benefits from the latest modular *KLIPPEL Analyzer 3* hardware, which can be tailored to the particular requirement of the application while supporting the full range of KLIPPEL software modules. Extension cards like *Laser* (incl. microphone), *XLR*, *Speaker* and *Amplifier Card* provide a high level of scalability and flexibility.

Figure 1: The KLIPPEL Analyzer System – the comprehensive testing tool from lab to production

KLIPPEL R&D modules like *LSI* or *TRF* and *Tasks* of the *QC* module like *Air Leak Detection* can now be used with the same analyzer hardware platform and even used in the same batch run sequence, extending the capabilities the test system. Since the requirements in end-of line testing are still different from lab applications, the software comes in two dedicated distributions that are fully compatible but include different tools like *QC Start* for operator-oriented EOL test management. Test results, templates, settings and limits can easily be exchanged for optimal communication and comparability between design and manufacturing. Therefore, the same tests can be run on prototypes in the lab as well as in pre- and mass production.

Since compatibility with earlier software releases and existing analyzers is ensured, long-time users of the KLIPPEL systems will feel completely familiar with the look and feel of the software while benefiting from the new capabilities. Please note that a software update requires a new USB license dongle. Please contact info@klippel.de or visit www.klippel.de for more information.

New Features for Complex QC Tests

Modern audio devices like smart speakers, sound bars or wireless headsets are getting more and more complex through high integration, multi-channel in- and output, wireless signal transmission and extensive signal processing (e.g. virtualization, beam steering, active noise cancelation). Consequently, the test system needs to provide a high flexibility in order to reflect those capabilities in quality control.

In combination with the KLIPPEL analyzer hardware, the QC framework module handles all kinds of audio devices (*ASIO* or *Windows Direct Sound*), either as device under test (e.g. USB headset) or test interface (e.g. sound card). Multiple QC operations can be run in a test batch covering different input and output devices, transmission channels, sample rates, codecs and so on.

Using the capabilities of the KA3 hardware, up to eight channels (4 x microphone + 2 x impedance channels) can be measured simultaneously. This speeds up testing of passive stereo systems (e.g. headphones) or multi-microphone setups (e.g. speaker cabinet air leak detection) significantly.

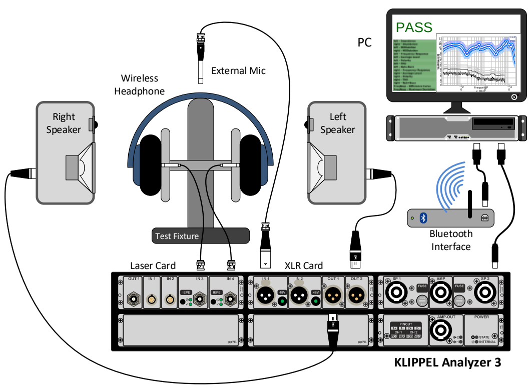


Figure 2: Hardware setup sketch of a complex QC test for Bluetooth headphones with ANC

To simplify the test setup of complex sequences, single test steps in the QC test sequence may be activated/deactivated as needed. The new, free sequence control add-on feature allows repeating or skipping individual test steps dynamically, based on test verdicts or user interaction.

To get a practical insight into those capabilities, the new [Application Note 73](#) dedicated to quality control of passive, digital and wireless headphones and headsets provides some good examples. Figure 2 shows an exemplary hardware setup sketch for a *Bluetooth* headphone test based on KA3 hardware, a Bluetooth interface and additional, speakers for *ANC* (active noise cancellation) performance check. All application notes can be downloaded from http://www.klippel.de/know-how.

New Chirp Results and Normalization Modes

The continuous sine sweep (chirp) is a very versatile and efficient test signal for acoustical tests providing optimal frequency resolution even for ultra-fast tests in EOL testing. The sweep-based *QC Sound Pressure Task* has been extended with additional results and processing options.

The *Rub&Buzz* analysis relies on a highly customizable band-pass tracking filter that provides optimal sensitivity for detecting random impulsive defects like loose particles in time domain. A new mode has been added that only focuses on high-order harmonic distortion (*HOHD*). The orders of analyzed harmonics can be customized with high flexibility to focus on very specific defect symptoms. Additional calculation modes have been added to display Rub&Buzz distortion relative to the fundamental response or average level.

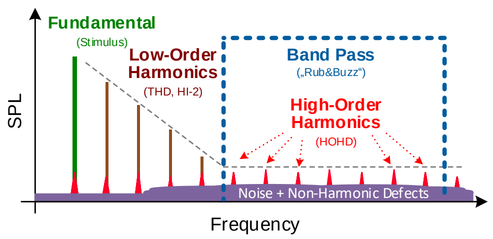


Figure 3: Sound pressure response spectrum of an audio system excited with a single tone.

Furthermore, HI-2 ("blat") distortion has been added as an optional feature providing a special weighted harmonic distortion measurement. It mainly focuses on medium-order (<11) harmonic distortion that is primarily caused by hard limiting or significant asymmetries in the motor and suspension assembly. *KLIPPEL Application Note 7* provides more information about this topic.

Extended by three new normalization modes, the fundamental frequency response may now be displayed relative to the average level (sensitivity), a "golden unit" or even the reference pool average curve in a separate result chart. This improves monitoring drifts and variations and it supplements floating limit modes and on-line limit calibration perfectly.

Large Signal Identification 3

One of the most popular software modules of the *KLIPPEL Analyzer System*, the *Large Signal Identification (LSI)*, has received a major update in *dB-Lab* version 210. The *LSI3* is dedicated for operation with the *KA3* hardware. In the new version, the nonlinear speaker model, identification algorithms and accuracy have been improved. A wider nonlinear range (larger displacement) can be identified without thermal limiting due to improved stimulus shaping. It is now easier and more transparent to control the small signal measurement level.

Due to the increased importance of micro-speakers, *LSI3 Micro-speaker* is the successor of the *LSI2 Tweeter*. This new variant uses a multi-tone stimulus instead of noise to drive the speaker to its mechanical limits. The *LSI3 Micro-Speaker* also identifies linear and nonlinear tweeter parameters (maximum resonance frequency is 1.5 kHz). Furthermore, the identification time for a micro-speaker has been halved.

Laser-Based Test Options for QC

Typical end-of-line tests of loudspeaker transducers rely on electrical and acoustical measurements in order to check small and large signal parameters as well as acoustical output. In R&D tests, the additional measurement of voice coil and diaphragm displacement is very common for measuring Thiele/Small parameters, evaluating stability or analyzing cone vibration. Laser sensors for loudspeaker applications are sensitive equipment and are less easy to handle compared to a microphone. However, in some cases it is also desirable to exploit the information provided by displacement measurement in quality control.

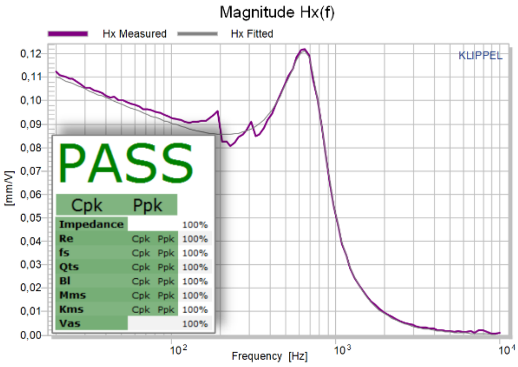


Figure 4: Laser-based displacement transfer function $H_x(f)$ and new test results provided by the TSX add-on for the QC Impedance Task

Using the capabilities of the *KA3* hardware, the *TSX* add-on enhances the *QC Impedance Task* with laser input providing additional *Thiele-Small* parameters such as *Bl*, M_{ms} or C_{ms} that quantify problems of mass, suspension or magnetization directly. The state-of-the-art speaker modeling technology easily handles suspension creep, complex inductance behavior and vented box (4th order) systems in order to yield accurate result parameters at very high speed.

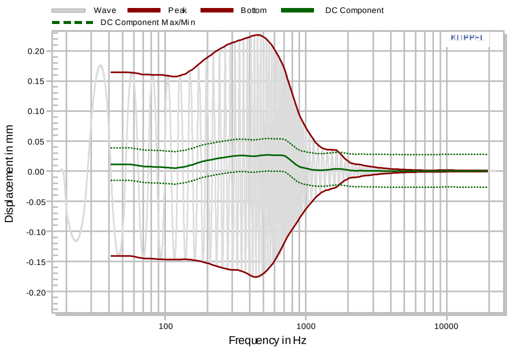


Figure 5: Chirp displacement response waveform, envelope and dynamic DC component (incl. limits) of a micro-speaker measured with DCX add-on for QC SPL Task

For the chirp-based *Sound Pressure Task*, the *DCX* option unlocks measurement and control of displacement in addition to the acoustical response. Based on displacement waveform, the envelope and dynamic shift of voice coil center position (DC displacement), which is related to asymmetries in the suspension or the motor, is measured directly. An example response plot is shown in Figure 5. This ensures maximal working range and stability for critical pure tone excitation in every tested device, especially for micro-speakers.

In-Situ Room Compensation

Most acoustical standard measurements shall be performed on a single reference point (e.g. 1 m distance, on-axis) without assessing the full directivity of the loudspeaker. Still, according to standard conditions, an anechoic environment is required to exclude impact of the room on the test results. Anechoic chambers are often not available for everyday testing tasks or they highly increase testing effort.

The *In-Situ Room Compensation* (ISC) module copes with the imperfections of the acoustical environment (room, positioning, test box). Based on anechoic reference data, it automatically generates a complex compensation function $H_c(f)$ that is used in a pre-filter to transform the microphone signal $p_{test}(\mathbf{r}_t)$ measured at a convenient position (e.g. near field) into a simulated free-field signal $p_{free}(\mathbf{r}_f)$ at the desired observation point $\mathbf{r}_r$ (e.g. in the far field).

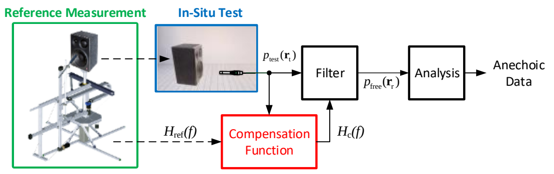


Figure 6: Overview and signal flow of ISC module

The inverse filtering is applied prior to the signal analysis; thus, it ensures accurate measurement of nonlinear distortion and transient behavior (burst testing). The *ISC* module uses reference data H_{ref} provided by the *Near Field Scanner* (*NFS*) or by conventional measurements performed under standard conditions (free field).

Nonlinear & Thermal Simulation (SIM-AUR)

KLIPPEL provides various tools for measurement (e.g. *LSI*) and simulation of large signal and thermal parameters (*SIM2*) of electrodynamic loudspeakers. For transducer engineering, the provided parameters and simulated responses for single and two-tone signals are highly valuable for optimizing design. Even the heat flow and mean temperature of the voice coil, pole plates and magnet/frame structure are simulated accurately for steady-state conditions in thermal equilibrium.

However, it is desirable to simulate the heating and cooling process under more realistic, dynamic conditions for real music signals. The novel *SIM-AUR* module reveals the thermal dynamics for any input signal at full temporal resolution.

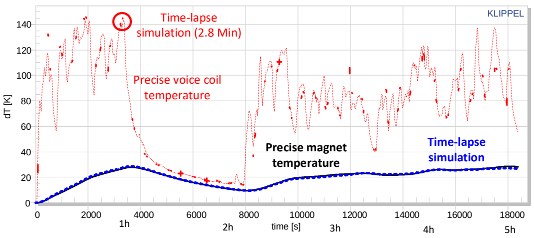


Figure 7: Simulated voice coil and magnet temperature for a 5-hour music signal. Both fast and full resolution simulation data is compared.

The long-term performance is simulated for your selected music signal in order to assess the large signal performance under virtual target conditions.

This gives you the opportunity to simulate and optimize the nonlinear as well as the thermal behavior of your speaker design in the target environment (e.g. music concerts, speech), before even building the first prototype. The simulation assists you in identifying critical sections of the test signal, without the need to run time-consuming durability tests. Additionally, the simulated sound pressure output is auralized for assessing nonlinear distortion and for creating listening tests to find the optimal performance/cost ratio.

The mass of the iron parts, magnet and frame generate thermal time constants that exceed minutes or even 1 hour in large loudspeakers. However, the *SIM-AUR* calculates all states at full temporal resolution, faster than in real-time. For even faster simulation of long music signals, a time-lapse technique provides accurate thermal results within very short time. An example is given in Figure 7 comparing full resolution and time lapse simulation results.

New Statistics Module (STAT)

The *Statistics* (*STAT*) module is a powerful tool for statistical analysis of your KLIPPEL test data (single value or curve data). It may be applied for comparing prototype data in R&D or for large scale statistics of EOL test data.

The data sets (test objects) are easily organized in pools (e.g. “good”, “bad”, “borderline”, …), assigned manually or based on user defined thresholds (limits).

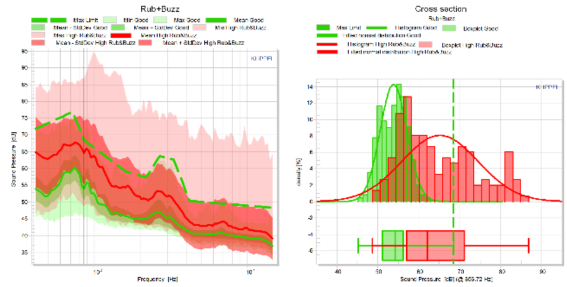


Figure 8: Rub&Buzz statistics for two data pools; left: curve statistics (mean, standard deviation, min/max, limit); right: histogram, boxplot, fitted normal distribution and limit for selected frequency point (cross section)

As shown in the example in Figure 8, the statistical data is presented in charts (curve plots as well as histograms for single values and cross section view of curves) and overview tables. Variances of measurement data and relationships between pools can be visualized with advanced normalization features.

Limits can either be defined by entering the numerical limit definition or by using the intuitive point & click feature, directly in the charts. They can be used to create new pools or exported and transferred to the QC software for an optimal ratio of quality and yield. Furthermore, the advanced golden unit detecion algorithm provides a ranking of representative units based on user-selected parameters.

Rub & Buzz Auralization and Diagnostics

Automated test systems have widely replaced listening tests at the end of the production line providing objective means for acoustic Rub&Buzz detection with high sensitivity and speed as well as at high SPL. Using isolated test chambers, the operator is protected while the DUT can be driven to the specified limits. However, for diagnostics, it is difficult to listen to what is going on inside the test box.

For this reason, the QC software framework provides playback of the recorded microphone signals through headphones at reasonable levels during the test or manual sweep. Additionally, each device’s response can be stored as an audio file for off-line evaluation, listening tests or in-depth signal analysis.

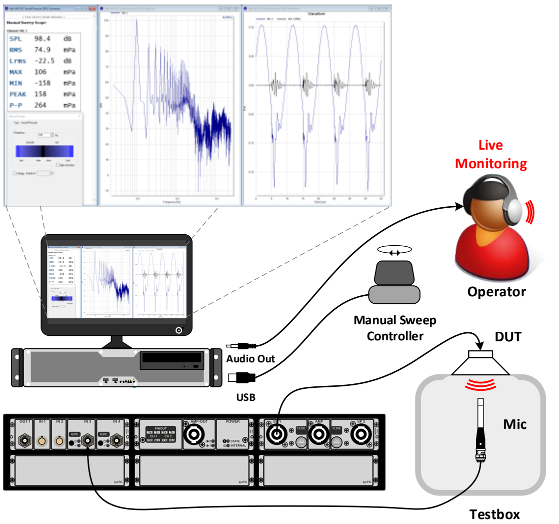


Figure 9: Manual sweep - live scope and headphone monitoring of defect distortion at EOL test station

In addition to the full response signal, only the isolated high-order distortion (*Rub&Buzz*) can be monitored and exported in order to focus on subtle defect symptoms without masking of the stimulus signal and low-order harmonic distortion. In combination with the manual sweep generator and live scope, this is a powerful diagnostics tool for defect analysis or debugging vibration problems of the test station.

In addition to off-line listening tests and operator training, the WAVE file export is very useful for in-depth time-frequency analysis as performed by the *TFA* module (see next section). For sweep-based tests, the frequency content of defect distortion can be analyzed over the excitation frequency in order to optimize *Rub&Buzz* filter settings (harmonic order, filter bandwidth) for optimal sensitivity.

Time-Frequency Analysis

The *Time-Frequency Analysis* module *TFA* is a powerful tool for investigating the spectral content of audio signals over time. Both, arbitrary WAVE files or signals recorded by KLIPPEL measurement modules may be analyzed. For this purpose, the tool provides wavelet analysis, auditive filter bands or short-time Fourier transform (*STFT*). The results may be displayed in 3D plots (time slices), waterfall diagrams or sonographs with high temporal resolution due to interlaced analysis.

A useful application is the analysis of the impulse response and nonlinear distortion generated by an audio system. The sonograph reveals nonlinear signal components generated by the test stimulus that are at much higher frequencies than the excitation frequency.

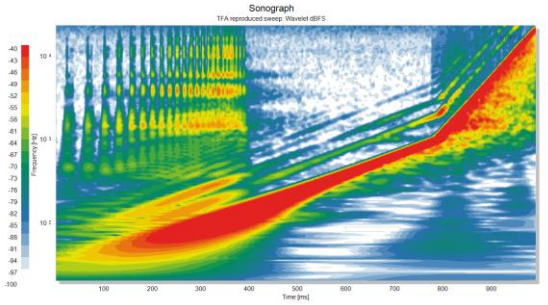


Figure 10: Wavelet analysis plot of a chirp sound pressure response of a defective speaker. The x-axis represents time, while the y-axis refers to the frequency. The sound energy is coded by the color scale.

For defect analysis, the TFA allows for the investigation of temporal and spectral fine structure in the chirp sound pressure response of a bad speaker as shown in Figure 10. While deterministic defects (e.g. coil bottoming) result in higher order harmonics, random defects cause impulsive sounds - the energy is distributed over the whole frequency band for a very short time. The information provided by the TFA is very helpful in optimally setting Rub&Buzz filters (harmonic order, bandwidth, …) for the EOL test.