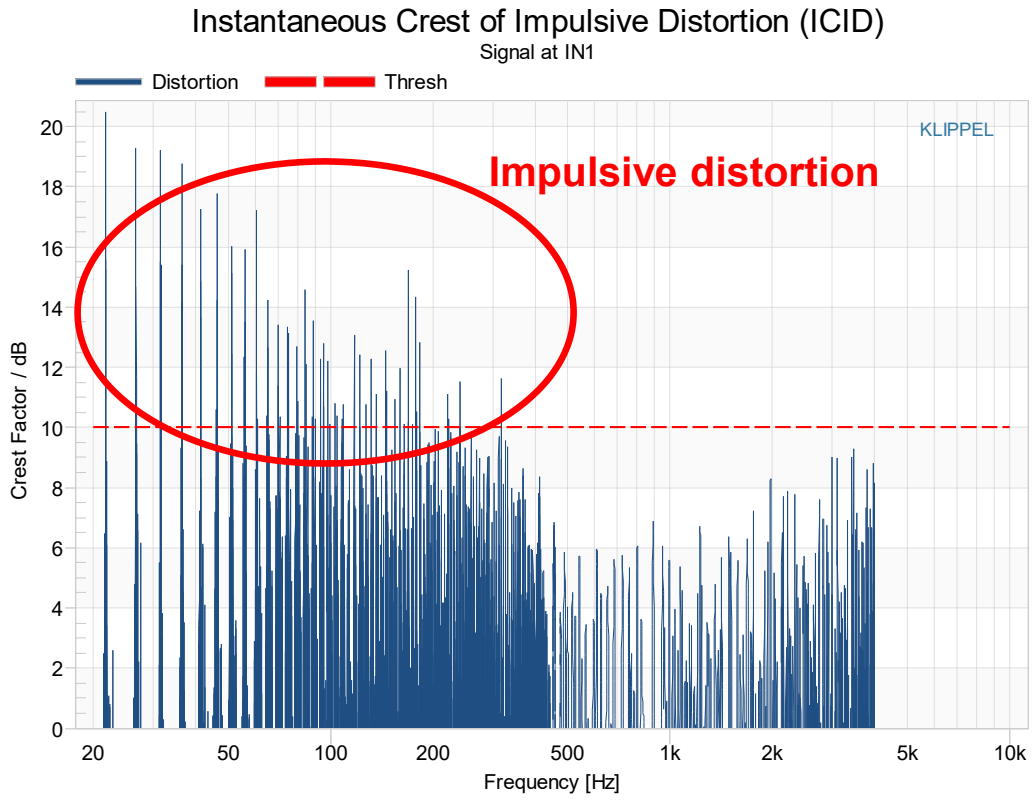
Defect (Rub & Buzz) Detection with TRF AN22

Application Note to the KLIPPEL R&D (Document Revision 1.2)

DESCRIPTION

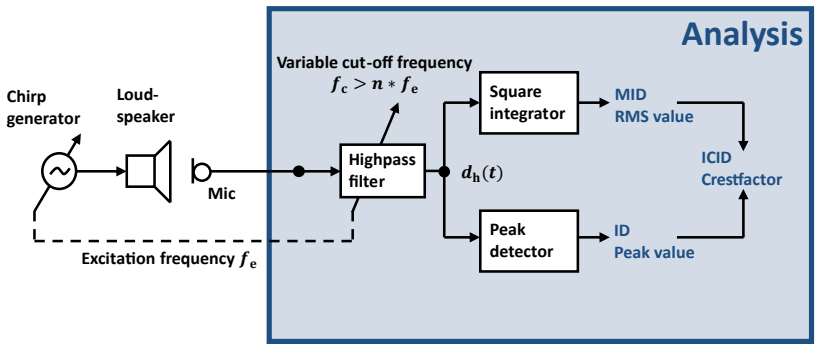
Loudspeaker defects generate signal distortions that are low in amplitude, but still have a significant impact on perceived sound quality. The symptoms associated with these defects are typically more impulsive than distortion produced by regular nonlinearities (motor, suspension, etc.) and are commonly grouped under the category Rub & Buzz.

This application note focuses on detecting such loudspeaker defects in an R&D context. The Transfer Function Pro (TRF) module is used, which provides detailed insights and diagnostic information. The module evaluates the crest factor and the peak values of higher-order harmonic distortion, which are reliable indicators for the defect behaviour. Plotting the crest factor against voice-coil displacement reveals the position of the voice coil when the impulsive distortion is generated, giving further indications of the physical cause.



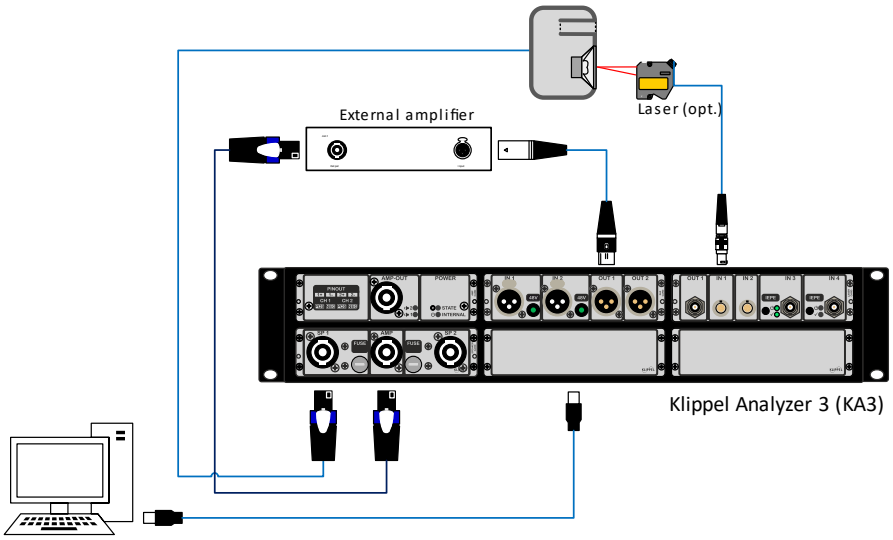
CONTENTS:

1 Limits of Voice Coil Displacement

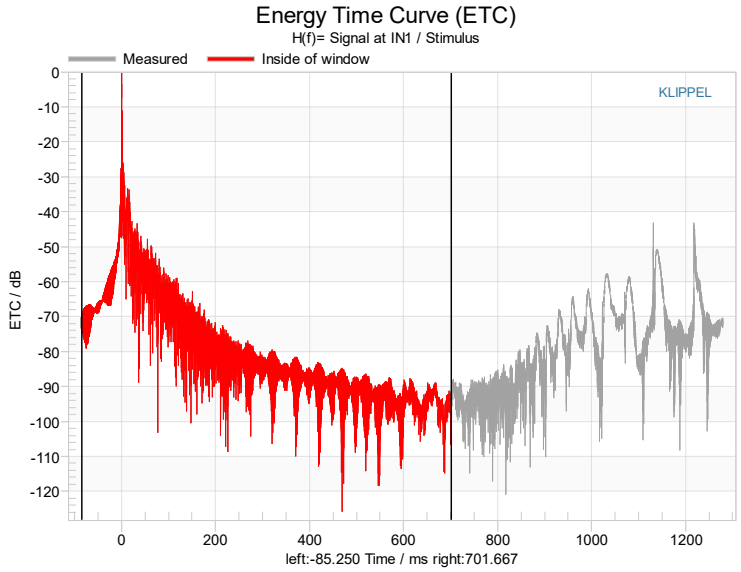
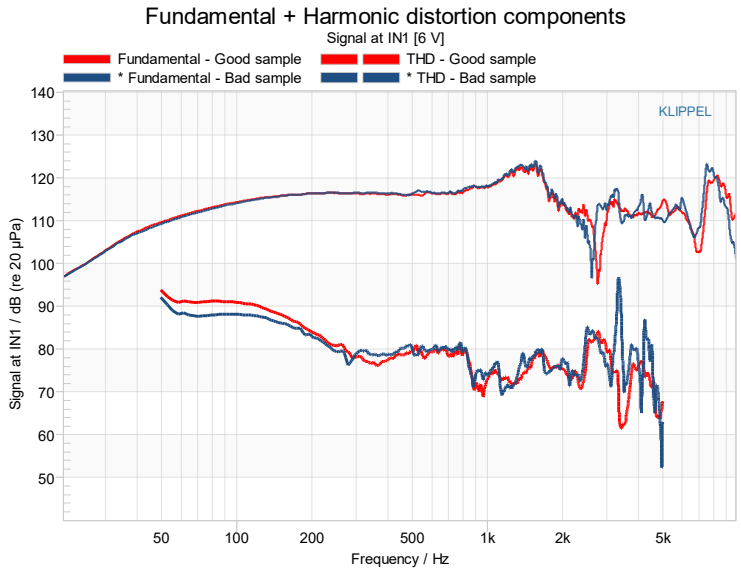
What is Rub & Buzz?	The term Rub & Buzz refers to a class of irregular, impulsive disturbances that are not generated by the driver's inherent nonlinearities. Such effects arise from defects including a rubbing voice coil, buzzing loose parts, hard limiting of the voice-coil former, loose particles in the gap and other loudspeaker defects. From a physical standpoint, these phenomena often involve a resonant system exhibiting strong nonlinearity. A typical case is a wire lead that intermittently interacts with the diaphragm. This auxiliary vibrating structure produces disturbances only under specific operating conditions, such as particular frequency ranges or critical excitation amplitudes.
Audability of Rub & Buzz	Rub & Buzz are high-frequency distortion effects, which are especially audible due to several characteristic properties: • The distortion components appear as separated tones from the fundamental with a high frequency difference (3 octaves or more). • The human ear is most sensitive around the frequency f = 1 kHz. Because Rub & Buzz effects arise primarily at large displacements near the driver's resonance frequency, the resulting high-order components (often above the 10th-20th harmonic) fall directly into this frequency range. The peak auditory sensitivity makes them more noticeable than many regular nonlinear distortions that may even exhibit higher amplitude • Lower harmonic distortion components (2nd, 3rd) may be masked by the psychoacoustic masking effect. The human ear can't detect tones located narrow frequency around a dominant single tone • Usually Rub & Buzz effects are not pure harmonics of the fundamental. There are resonance effects that are excited by the coil's motion and vibrate at their own natural frequencies
Rub & Buzz and THD	The commonly used THD metric is not suitable for detecting Rub & Buzz defects. The distortion components associated with these defects are typically 20–40 dB below the fundamental and therefore overshadowed by the unavoidable low-order harmonic distortion generated by the loudspeaker's inherent nonlinearities. As a result, the relevant symptoms contribute only marginally to the overall THD value. In addition, Rub & Buzz phenomena often manifest as brief, localized glitches in the time domain. THD, however, is a purely frequency-based measure and disregards phase information. When a Fourier transform is applied to the entire signal, these short-duration disturbances are effectively obscured by the transformation's integrating nature, making them difficult to detect.
Time domain analysis	The Rub & Buzz detection algorithm is based on a time domain analysis to overcome the disadvantages of the THD measure and to show impulsive distortion at high temporal resolution. 

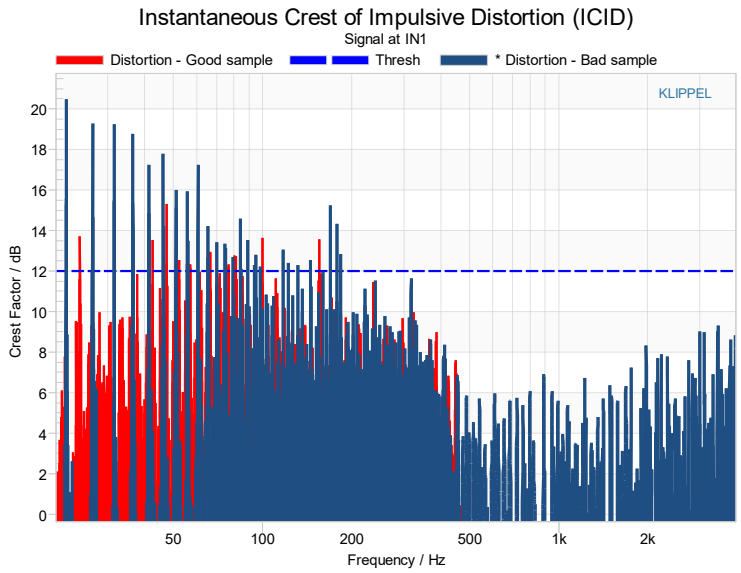
	The measurement principle is also specified in IEC 60268-21. A sinusoidal chirp is used to excite the loudspeaker under test. The instantaneous excitation frequency f_e of the chirp is used to control the high-pass cutoff frequency f_c of a tracking filter. This enables the extraction of all distortion components $d_h(t)$ above the n[th]-order of the fundamental. The high-pass factor suppresses the regular distortion produced by the motor and suspension as well as the fundamental. Several important parameters are derived from the distortion signal $d_h(t)$ at the output of the tracking filter: • Peak Impulsive distortion (ID) • Instantaneous crest of impulsive distortion (ICID) The TRF uses a logarithmic chirp or sweep, so the linear time scale corresponds to a logarithmic frequency scale. Since a sine sweep is used for exciting the driver, the measurement time can be mapped uniquely to the instantaneous excitation frequency. Hence each distortion measure can either be plotted versus time or frequency, as long as the dependency is known. Both measures exploit both magnitude and phase information of the high-frequency distortion components.
Peak value of Impulsive Distortion (ID)	The peak value of Impulsive Distortion (ID) is a relative metric derived from the distortion signal $d_h(t)$ and the RMS value of the microphone signal $y_{RMS}(f)$. It provides a useful description of the magnitude of impulsive distortion and its quantitative impact on sound quality. $ID(f) = \frac{d_{h,peak}(f)}{y_{RMS}(f)}$ with $y_{RMS}(f) = \sqrt{\frac{1}{t_{k+1}-t_k}\int_{t_k}^{t_{k+1}} y^2(t)dt}$
Instantaneous Crest of impulsive distortion (ICID)	The traditional metric for quantifying the peaky-ness of a signal is the crest factor. To preserve the fine structure of the distortion, an "instantaneous" crest factor is employed. The Instantaneous Crest of Impulsive Distortion (ICID) is defined as the ratio between the instantaneous impulsive distortion (ID) value and the mean impulsive distortion (MID) value: $ICID(f) = \frac{ID(f)}{MID(f)}$ with $MID = \sqrt{\frac{1}{t_{k+1}-t_k}\int_{t_k}^{t_{k+1}} d_h{}^2(t)dt}$ The ICID is independent of the amplitude of the distortion but exploits the phase information of all distortion components. Rub & Buzz defects cause components that are strongly related to their phase response and produce a distinct impulse in the time domain. In contrast, measurement noise will produce a lower crest factor. Typically, a crest factor higher than 12-14 dB indicates impulsive distortion. Mapping the ICID over displacement makes it a powerful diagnostic metric for revealing the physical origins of Rub & Buzz defects.
Impact on sound quality	There is no clear definition of audibility for defect symptoms. However, a useful indication is the combined analysis of ICID and ID. This provides structural information (peakiness, ICID) and level information relative to the fundamental (ID) of critical defect symptoms. This combination can be checked in two steps: • Search for frequencies where crest factor ICID is higher than about 12-14 dB (value can be set on the property page "I-DIST" of TRF module) • At those frequencies, search for ID values above ID Limit. (Limit depends on application and can be set on property page "I-DIST" of TRF module, typical value is -40 dB) If both criteria apply at the same frequencies, an impact on sound quality is likely. The higher those symptoms are, the higher the impact is.

2 Using the KLIPPEL R&D System

Requirements	• Klippel Analyzer (KA3 or DA2) + PC • Microphone + Laser sensor (optional) • dB-Lab Software + TRF Pro module
Setup	• Connect external power amplifier or use internal AMP-Card of KA3 • Mount DUT and connect terminals with speaker output of Klippel Analyzer • Connect microphone with microphone input of Klippel Analyzer and place it in near-field of loudspeaker • Connect laser with laser input of Klippel Analyzer and adjust beam to diaphragm of the speaker 
Object Template	Create new object based on the object template “TRF Defect Detection with TRF (for Woofer) AN22” Note: Alternatively, the template for microspeakers can be used.
TRF Pro measurement	The following describes how loudspeaker defects can be determined manually using the TRF Pro module. Alternatively, the TRF Voltage Stepping (STEP) module provides an automated processing of the defined sequence: 1. Start measurement 2. After measurement, open window “Instantaneous Distortion”. If the instantaneous crest factor “ICID” is below the limit “Thresh”, no distinct impulsive distortion is generated. Consequently, the window “Instantaneous Distortion 3D” will exhibit no black dots, provided the system is operating with a connected laser sensor. In this case, the measurement must be repeated with a higher stimulus voltage 3. If significant and reproducible impulsive distortion is detected, the window “Fundamental + Harmonic Distortion“ should be examined. If the “ID” curve exceeds the “ID Limit” within the same frequency range as the ICID, the Rub & Buzz effect must be considered critical Note: Ambient noise, vibrating cables or loudspeaker stands, as well as loose connectors at the loudspeaker terminals, may also introduce impulsive distortion. It is therefore strongly recommended to use a vibration-free fixture. To minimize any parasitic Rub & Buzz effects during the measurement, the driver may be placed on a piece of foam.

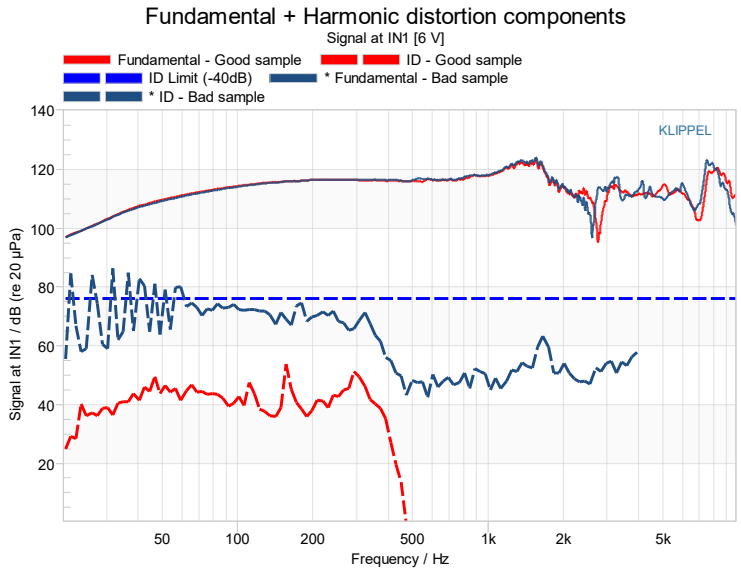
3 Example

Energy Time Curve (ETC)	In the window “Energy Time Curve (ETC)” you can select a region of analysis by shifting the black markers. The exact range is not critical as long as the main impulse lies within the selected window, since this is important for the time-delay calculation. To achieve a proper separation between the linear and nonlinear responses, it is recommended to place the left marker at the beginning and the right marker at the first minimum of ETC. 
THD	The THD curves of a good and a defective driver are shown in the window “Fundamental + Harmonic distortion components”. It becomes evident that THD is not a reliable metric for characterizing or detecting Rub & Buzz phenomena. The regular distortion dominating the THD, originating from motor and suspension nonlinearities, masks the much smaller Rub & Buzz components. 
Instantaneous Crest of Impulsive Distortion (ICID)	The window “Instantaneous Crest of Impulsive Distortion (ICID)” represents the instantaneous crest factor of the high-passed microphone signal $d_h(t)$. The bad sample exhibits pronounced peaks in the range of 20–200 Hz, with ICID values exceeding 12 dB. Such peaks are characteristic indicators of Rub & Buzz symptoms. By contrast, the good sample generally shows ICID values below this threshold. Although a few isolated frequency bins exceed the limit, the corresponding ID levels at those frequencies remain well below the threshold.



Peak Impulsive distortion (ID)

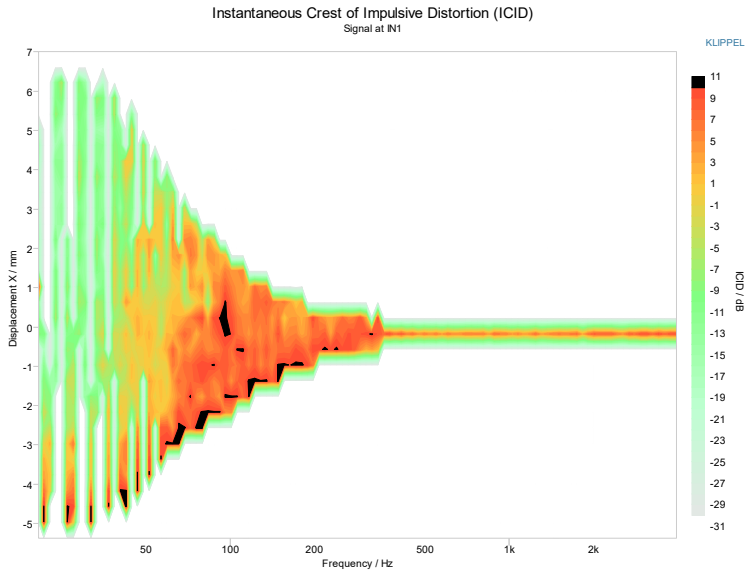
The window “Fundamental + Harmonic distortion components “displays also the peak ID value of the harmonic distortion and the ID Limit set in the property page. For the faulty driver, the ID value exceeds the permissible limit at low frequencies below 60 Hz, where the crest factor also surpasses the threshold. As a result, impulsive distortion has a significant negative impact on the sound quality.

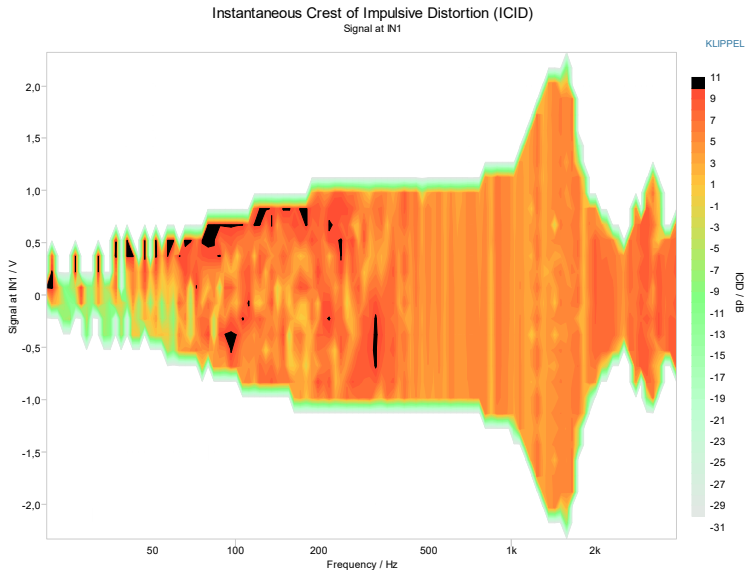


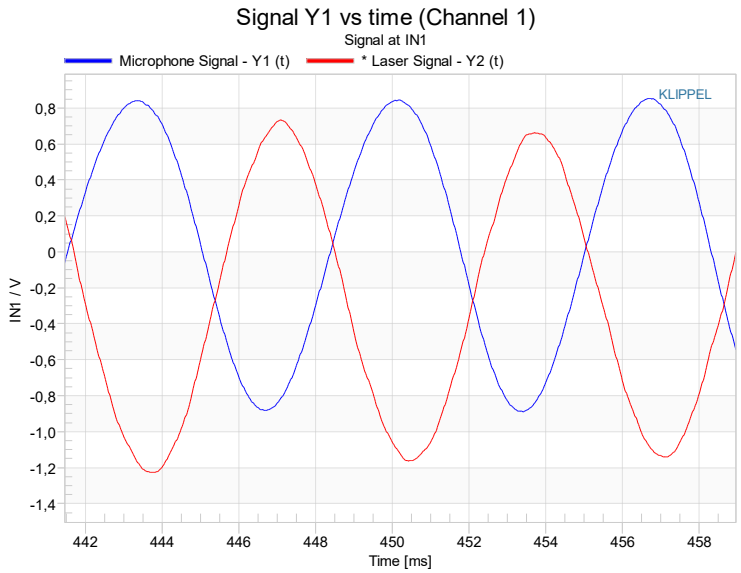
3D-representation

The window “Instantaneous Distortion 3D” results window displays the crest factor (ICID) as a color map, plotted against voice-coil displacement (y-axis) and frequency (x-axis). This visualization provides valuable insight into the location of R&B defects. Dark areas between 20–200 Hz, particularly at negative voice-coil displacements, indicate voice-coil rubbing, which may be the result of a tilted voice coil.

By adjusting the settings on the property page “I-Dist”, you can display the ICID values relative to the microphone signal instead of the displacement. This view is also available when no laser sensor is connected. There is a 180° phase shift between the displacement and the microphone signal when a loudspeaker is measured in free air. You can verify this by comparing the displacement and microphone waveforms in the windows “y1(t) Input Waveform” and “y2(t) Input Waveform”. In this example, the black spots indicating high ICID values will appear at the positive peak of the microphone signal, corresponding to the negative peak in displacement


Instantaneous Crest of Impulsive Distortion (ICID)
Signal at IN1
KLIPPEL
Displacement X / mm
Frequency / Hz
dB / ICI


Instantaneous Crest of Impulsive Distortion (ICID)
Signal at IN1
KLIPPEL
Signal at IN1 / V
Frequency / Hz
dB / ICI


Signal Y1 vs time (Channel 1)
Signal at IN1
Microphone Signal - Y1 (t)
* Laser Signal - Y2 (t)
KLIPPEL
IN1 / V
Time [ms]

4 Hints

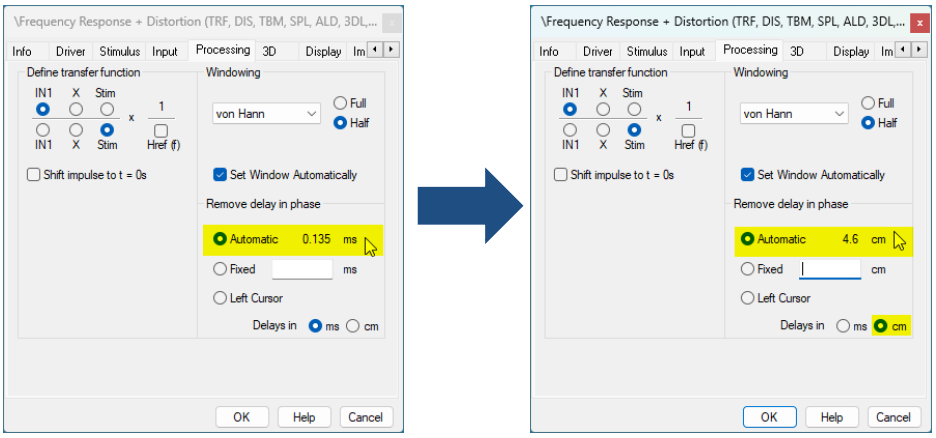
Compensate Laser sensor delay

Lasers have built-in digital signal processing, which introduces a significant time delay compared to the microphone signal. Proper time-delay compensation is essential, otherwise the black spots in the 3D graph may appear at incorrect displacement values. For transducers with higher resonance frequencies (full-range drivers or micro-speakers) and for input filters causing dominant displacement above 100 Hz, delay compensation is recommended. Applying compensation significantly improves the accuracy of the 3D result mapping. For woofers and mid-woofers with a low resonance frequency (below 100 Hz) the following delay compensation could be ignored. Time delay values for Keyence laser series are listed as follows:

Laser	LK-H052/22/82	LK-G32/82/152 (f_{max} =10 kHz)	LK-G32/82/152 (f_{max} =25 kHz)
Delay in seconds	580 +/- 10 µs	120 µs	300 µs

Procedure:

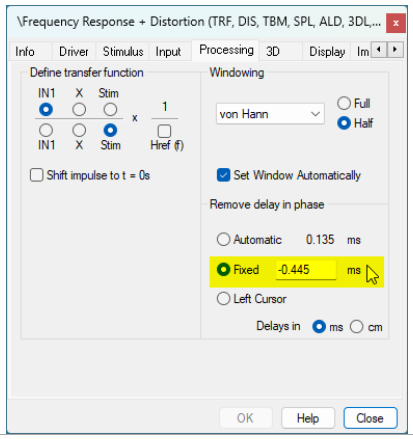
1. Check measured microphone signal time delay in property page “Processing” (Can be verified by switching to distance and checking real microphone distance to diaphragm)



2. Determine the difference between mic and laser signal input delay
(In this example LK-H052 laser is used and microphone distance is 4.6cm)

$$t_{\mathrm{mic}} = 0.135\ \mathrm{ms};\ t_{\mathrm{laser}} = 0.58\ \mathrm{ms}$$
$$\Delta t = t_{\mathrm{mic}} - t_{\mathrm{laser}} = -0.445\ ms$$

3. Both input signals must be time-aligned. The microphone signal should be delayed by the difference between the microphone and laser signal input delays

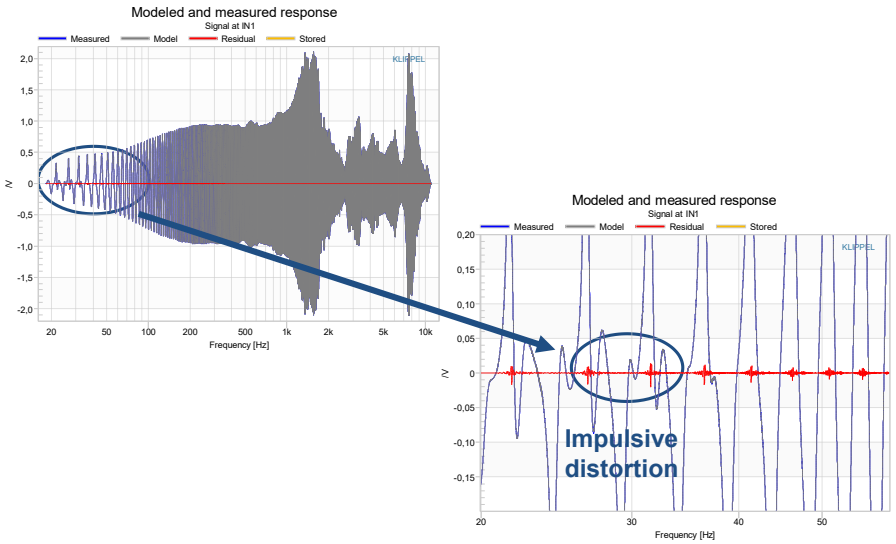


***t*mic < *t*laser :** the mic input signal has to be delayed by the difference of both
(Typical for Rub & Buzz measurements performed in the near-field of DUT)

***t*mic > *t*laser:** the difference of both has to be removed from the mic input signal

***t*mic = *t*laser,:** no delay compensation is needed
(For LK-Hxx2 laser sensors in default laser controller configuration, this is given for a mic distance of about 20 cm)

More Information

Instantaneous Distortion	The "Residual" curve in the window "y(f) Modeled Response" represents the instantaneous distortion $d_h(t)$ measured in the time-domain signal. The impulsive distortions occur only within a small fraction of the fundamental period and exhibit a clearly defined structure (see picture). Noise-corrupted measurements can also introduce parasitic effects that interfere with Rub & Buzz analysis. The "Residual" curve provides a means to assess whether the signal contains impulsive distortion or merely exhibits stochastic noise fluctuations. 

5 More Information

Standards	IEC 60268-21
Paper	W. Klippel, U. Seidel: Measurement of Impulsive Distortion, Rub and Buzz and other Disturbances, Presented at the 114th AES Convention 2003 March, Amsterdam.
Related Specification	Transfer Function Pro (TRF Pro), Specification S8 TRF Voltage Stepping (STEP), Specification S71 Klippel Analyzer 3 (KA3), Specification H3 Distortion Analyzer, Specification H1 Laser displacement sensor, Specification A2 Microphones, Specification A4
Manuals	User Manual TRF - Transfer Function Measurement

Find explanations for symbols at:

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

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