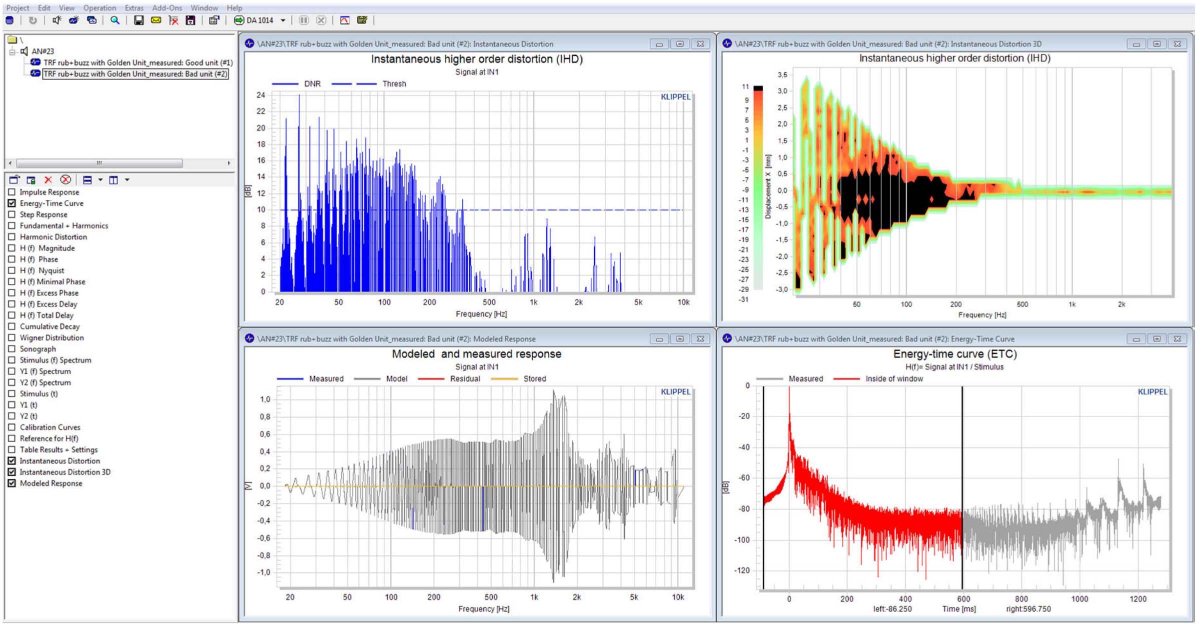
Rub & buzz Detection with Golden Unit AN23

Application Note to the KLIPPEL ANALYZER SYSTEM (Document Revision 2.0)

Rub & buzz effects are unwanted, irregular nonlinear distortion effects. They are caused by mechanical or structural defects such as filings in the gap, scraping of the voice coil at the pole pieces or even lack of adhesive. Some disturbances are clearly audible while other effects may be detected only by trained listeners. However, there is a high need to detect these effects not only in the production process but also during the prototyping and development phase.

The TRF-Pro module provides several possibilities to detect rub & buzz effects. In this Application Note a test is described for a series of drivers, for which a "golden unit" is available. Using the information of a "golden unit" the system knows about the defined "good" properties of the reference driver(s). This includes linear as well as regular (expected) distortion and also a specific noise distribution. All this information is efficiently used to separate good from bad drivers.

The result is a measure called "distortion to noise ratio" (DNR) that shows the deviation from the expected model behavior. To this measure a constant threshold value may be applied to detect defective drivers.



CONTENT

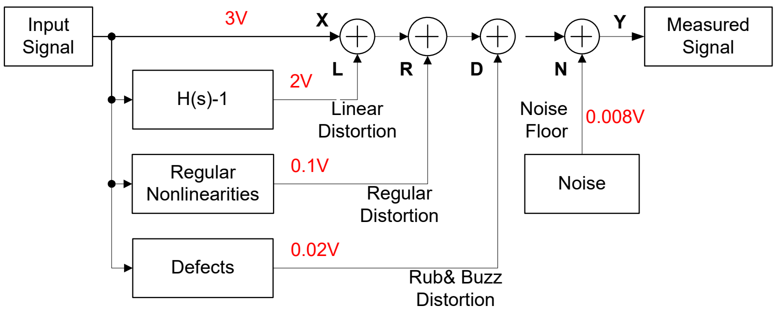
1 Theory

What is rub & buzz

Rub & buzz effects are a class of unwanted disturbances due to constructional or material defects. Physical causes and audibility of rub & buzz effects are explained in AN22.

Isolating rub & buzz distortion

Several distortion components contribute to the measured output signal of a loudspeaker. As illustrated below, the components contribute at different levels. Linear distortion **L** caused by the amplitude and phase response are much higher than regular distortion **R** caused by motor and suspension nonlinearities.

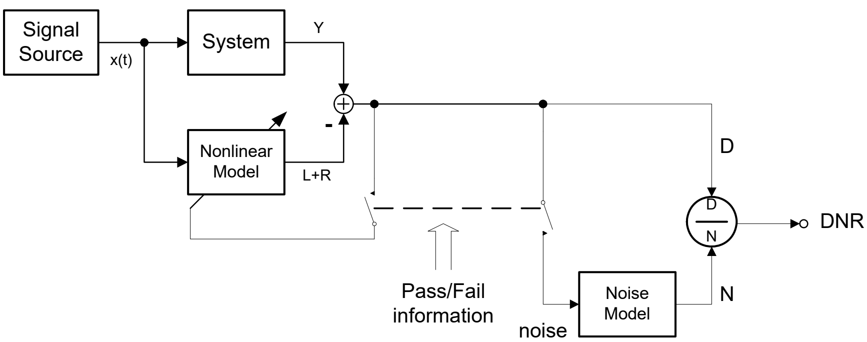


Distortions **D** caused by loudspeaker defects are even lower and are the subject of this application note. After all a certain level of noise **N** is always present in the measured signal. Noise has no correlation with the input signal but can be characterized as a distribution of energy (noise floor). Rub & buzz effects **D** are usually masked by linear and regular distortion **L+R** and can therefore not be measured with traditional measurement technique assessing the overall output signal **Y**.

Active Compensation of Regular Distortion

To reveal the distortion **D** the dominant linear and regular distortion **L+R** must be removed from the output signal **Y** by an active compensation technique.

An adaptive nonlinear model predicts the linear and regular distortion **L+R** which is subtracted from the output signal **Y**. The residual information consists of the distortion **D** and noise **N**.



The reference model consists of a nonlinear model and of a noise model. Assuming the reference model has been learned, in case of a good unit without defects the residual signal D=Y-(L+R) is noise only. Therefore the Distortion to Noise Ratio DNR is about 0 dB. In this case the nonlinear model and the noise model may be updated by user interaction. This continuous learning process improves the robustness of the

<table>
<tr><td></td><td colspan="2">detection.
In case of a bad driver the residual signal is distortion D which is considerably above the noise floor N predicted by the Noise Model. Hence it follows that the DNR is much higher than 0dB. A limit value of about 10 dB can be used to separate good from bad drivers.</td></tr>
<tr><td>Frequency – Time mapping</td><td colspan="2">If a sine sweep is used for exciting the driver, any measurement instant t can be mapped uniquely to the instantaneous excitation frequency f. Hence it follows that each distortion measure can either be plotted versus time t or frequency f, as long as the dependency is known. The TRF uses a logarithmic sweep, so the linear time scale corresponds to a logarithmic frequency scale.
The mapping requires accurate time delay information.</td></tr>
<tr><td rowspan="4">Distortion to Noise Ratio DNR</td><td colspan="2">The ratio of distortion D to noise N is a characteristic measure that indicates driver defects.</td></tr>
<tr><td>DNR</td><td>Interpretation</td></tr>
<tr><td>≈ 0 dB</td><td>Typical for good drivers. The output D comprises mainly noise and the DNR varies around 0 dB.</td></tr>
<tr><td>> 10 dB</td><td>DNR above 10 dB indicates driver defects. 10 dB may be used as a Threshold for separating good and bad drivers.</td></tr>
<tr><td>Rub and Buzz without golden unit
→ AN22</td><td colspan="2">In Application Note 22 “Rub & buzz detection without golden unit” an example is presented, where no reference (Golden Unit) is available. A different configuration of the structure presented here is used for suppressing L+R contributions. However, it is strongly recommended to read both Application Notes since they are written as a complement to each other.</td></tr>
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2 Performing the Measurement

<table>
<tr><td>Requirements</td><td>The following hardware and software is required:
Klippel Analyzer hardware (either DA1 / 2 or KA3)
Microphone
[optional] Laser Sensor
One or more reference loudspeakers (Golden Unit)
Software (dB-Lab with “TRF-Pro” License)
PC
No anechoic chamber needed</td></tr>
<tr><td>Setup</td><td>The TRF setup needed for the rub & buzz test can be loaded using the operation template labeled TRF Rub+Buzz with Golden Unit.
All settings related to the rub & buzz measurement are specified at the property page I-DIST (stands for Instantaneous Distortion). If you don’t use the template, set the parameter Mode to Deviation Rub & buzz and the parameter Measure to IHD (instantaneous higher-order distortion). Set Thresh to 10-20 dB and select vs. X. Select also the Show Distortion to Noise ratio checkmark.
The excitation level (group Voltage on property page STIMULUS) should be adjusted to your specific driver. You should operate the driver at different</td></tr>
</table>

	amplitude levels, where possibly rub & buzz effects are occurring. Note, that at high levels some defects may be masked, so try intermediate levels too. • The **bandwidth** (property page *STIMULUS*) can be specified according to the user specific test demands. Set 20 Hz to 10 kHz for F_{min} and F_{max}, respectively. Note, that instantaneous distortions are calculated up to 1 kHz in this case only. The 10 kHz bandwidth is needed to measure the harmonics at least up to the 10^{th}-order. • Select a **resolution** (parameter *Resolution* on property page *STIMULUS*) that gives a FFT length of (at least) 16384 points. • Select on property page *INPUT* the signals *(Mic) IN1* and *X (Displacement)*. Connect the microphone to input *IN1* and adjust it to the near field of the driver. Connect and adjust the laser too (if available).
Measurement	1. Connect a good ("golden") driver and start the measurement. 2. Adjust the excitation level if required and repeat the measurement. Defects occur not necessarily at highest levels. 3. Open the result windows *Energy-Time Curve*, *Instantaneous Distortion* and *Instantaneous Distortion 3D*. These are the default windows of the operation template and are opened if you double click on operation name. *Instantaneous Distortion* shows the rub & buzz measure vs. excitation frequency while *Instantaneous Distortion 3D* presents a 3D plot of the distortion measure (see section *Post processing* below). 4. Set the left cursor in result windows *Energy-Time Curve* to the very left end and the right cursor to the minimum of the ETC. 5. Open property page *I-DIST* and press the *Learn* button. 6. Connect different golden units (if possible) and repeat steps 1-5 at least three times. Press the *Learn* button after each measurement. After the initial learning (three measurements) the DNR curve will be displayed. It is recommended to use different drivers to improve robustness. However, measuring one single golden driver will work too. It is also good practice to use different golden drivers and to measure each driver several times. 7. Now the model is ready for checking other drivers with possible defects. Connect the drivers and restart the TRF measurement. Don't press the *Learn* button again.
Post processing	1. **3D representation with displacement**: The DNR measure can be mapped to the actual voice coil position since the TRF measures displacement and SPL in parallel. Correlating the signals from laser and microphone, the result window *Instantaneous Distortion 3D* shows the displacement on the Y-axis, sweep frequency on the X-axis and the DNR color coded in the 3^{rd} dimension. This allows identifying the voice coil position, where rub & buzz effects are generated. Typically one direction of displacement will generate rub & buzz while the other direction does not show any defect (e.g. bottoming of the voice coil). Select *vs. X* on property page *I-DIST* to get this mapping.

Please also note the hints at the end of AN22 about adjusting the delay between microphone and laser signal correctly. Otherwise you may get wrong displacement overlay in the 3D plot due to the time delay between the two signals.

2. **3D representation with sound pressure**: If no laser is available the distortion may be mapped versus frequency and sound pressure signal. Since the sound pressure is proportional to the voice coil acceleration the distortion appear phase inverted (e.g. positive sound pressure corresponds with negative displacement).

   Select *vs. IN1* on property page *I-DIST* to get this mapping.

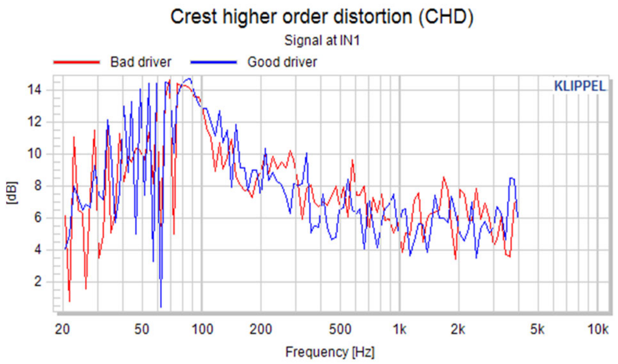
3. The **color code of the 3D graph** can be controlled by the parameter *Thresh* on property page *I-DIST*. Black color indicates distortions that exceed the defined threshold. A threshold of 10-12 dB is a good choice. You may also modify the threshold to make the check more or less strict.

3 Example

The driver investigated was an oval driver with f_s=100 Hz. The sensitivity is about 86 dB/W/m. Typical for this driver are some regular peaky distortion at 40-150 Hz. The defect of this driver is hardly audible.

CHD

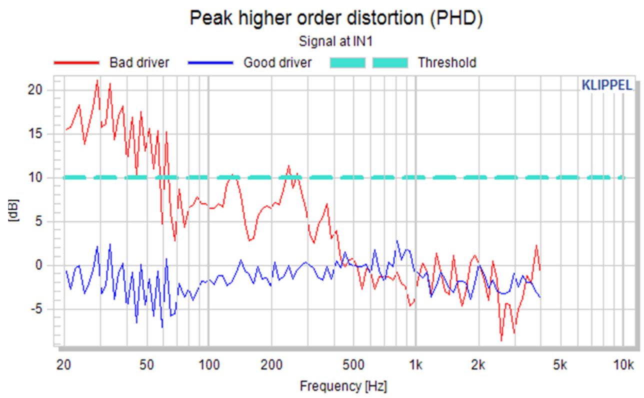
Open the result window *Instantaneous Distortion* and set the parameter *Measure* to *CHD* (Crest Higher-Order Distortion) on property page *I-DIST*. Two drivers - one good and one bad sample - are analyzed for comparison.



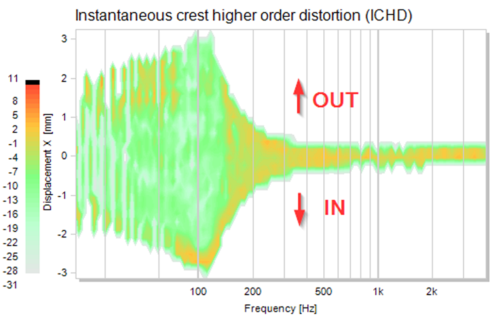
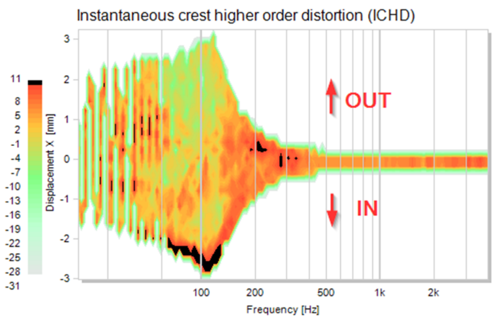
No learning:
First we check the rub & buzz detection without learning according to AN22. This shows, that the CHD measure can't reveal the defect of the bad unit since they are masked by regular distortion.

Note the high crest factor at 40-100 Hz which shows peaky distortion for both the good and the bad driver.

DNR 2D



Activate now the checkbox *Show distortion to noise ratio* on property page *I-DIST*.
With learning:
Four different golden units have been learned, each sample three times, so the total number of learning runs is 12. A 5th good driver has been tested with the trained model. Here the DNR (blue curve) is around zero indicating that for the good sample the residual signal corresponds to the modeled noise shape very well.

	As mentioned above all of the golden units have some regular (peaky) distortion at 40-100 Hz which is typical for this driver. However, this regular distortion is significantly suppressed by the adaptive compensation technique. Finally a 6th driver with a hardly audible defect is measured. At low frequencies there is a clear deviation from the trained driver model indicating a defect. The effective DNR is well above 10 dB, exceeding the threshold clearly.	
	Good Speaker (Golden Unit)	Bad driver (Rub & buzz effects)
DNR 3D	 The 3D representation allows identifying the position of the defect. The good driver does not show DNR values above 10 dB. All regular distortion including the peaky behaviour at 40-100 Hz has been compensated.	 Two defects can be detected for this driver. At low frequencies a defect is visible in the whole displacement area. This may be caused by coil rubbing or loose particles. At around 100 Hz the defect occurs only if the voice coil is inside.

4 More Information

Documents	AN22 – Rub & buzz Detection without Golden Unit W. Klippel, U. Seidel: Measurement of Impulsive Distortion, Rub and Buzz and other Disturbances, Presented at the 114th AES Convention 2003 March, Amsterdam.
Software	User Manual for the KLIPPEL R&D SYSTEM.

Find explanations for symbols at:

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

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