# Rub & Buzz Detection with Golden Unit     **AN 23**

Application Note to the KLIPPEL R&D SYSTEM

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.
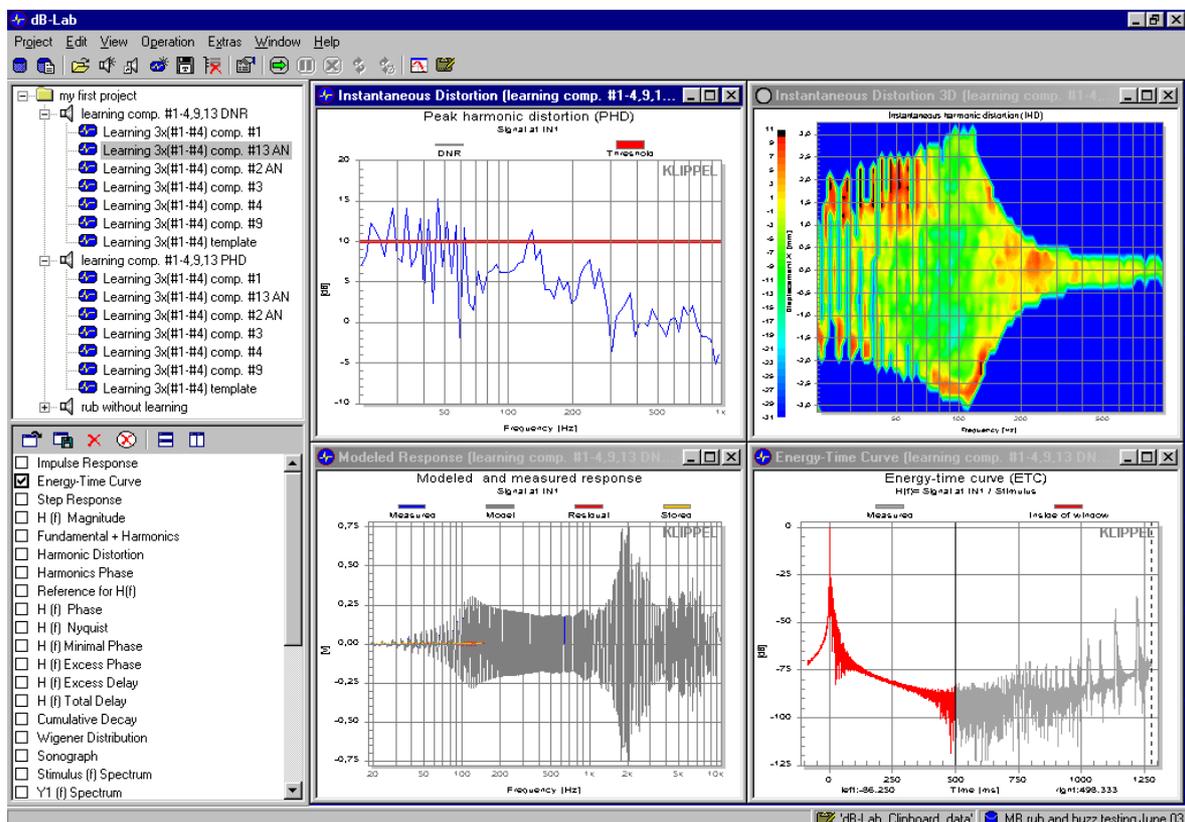


## CONTENTS:

# Theory

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| ***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 speaker. 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. Distortion **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 |
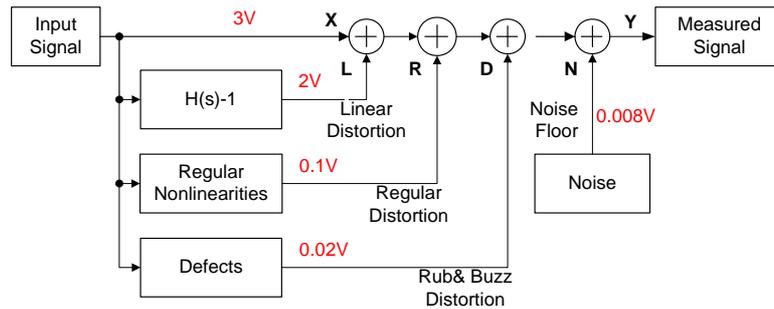
present in the measured signal. Noise has no correlation with the input signal but can be characterized as a distribution of energy (noise floor). Rub & buzz effects **D** are usually masked by linear and regular distortion **L+R** and can therefore not be measured with traditional measurement technique assessing the overall output signal **Y**.

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| ***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.<br><br>An adaptive nonlinear model predicts the linear and regular distortion **L+R** and is subtracted from the output signal **Y**. The residual information are the distortion **D** and noise **N**. |
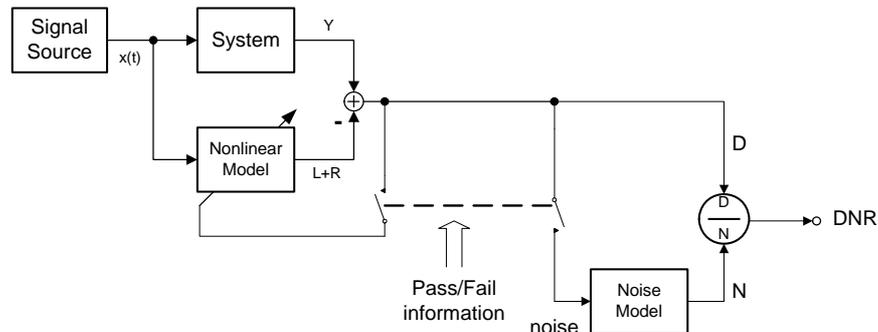
The reference model consists of a nonlinear model and of a noise model. Assuming the reference model has been learned, in case of a good unit without defects the residual signal **D=Y-(L+R)** is noise only. Therefore is the Distortion Noise Ratio DNR is about 0 dB. In this case the nonlinear model and the noise model may be updated by user interaction. This continuous learning process improves the robustness of the 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.

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| ***Frequency – Time mapping*** | 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 an accurate time delay information. |

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| ***Distortion Noise Ratio DNR*** | The ratio of distortion **D** to noise **N** is a characteristic measure that indicates driver defects. |

| DNR | Interpretation |
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| $\approx$ **0 dB** | Typical for good drivers. The output **D** comprises mainly noise and the DNR varies around 0 dB. |
| **> 10 dB** | DNR above 10 dB indicates driver defects. 10 dB may be used as a **Threshold** for separating Good and bad drivers. |

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| ***Rub and Buzz without golden unit*** <br><br> → ***AN22*** | 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. |

# Performing the Measurement

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| ***Requirements*** | The following hardware and software is required:<br>- Distortion Analyzer<br>- Laser Sensor, Microphone<br>- One or more reference loudspeakers (Golden Unit)<br>- PC<br>- Software modules (TRF-Pro, dB-Lab)<br>- **No** anechoic chamber needed |

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| ***Setup*** | - 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 *Mode* to *Deviation Rub & Buzz* and *Measure* to *IHD* (instantaneous harmonic 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 amplitude levels, where possibly rub & buzz effects are occurring. Note, that at high levels some defects may be mask, so try intermediate levels also. |
| | - 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 distortion are calculated up to 1kHz only. The 10 kHz bandwidth is needed to measure the harmonics at least up to the 10th-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 also the laser. |

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| ***Measurement*** | 1. Connect a good ("golden") driver and start the measurement.<br>2. Adjust the excitation level if required and repeat the measurement. Defects occur not necessarily at highest levels.<br>3. Open the result windows *Energy-Time Curve*, *Instantaneous Distortion* and *Instantaneous Distortion 3D*. This 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).<br>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.<br>5. Open property page *I-Dist* and press the *Learn* button.<br>6. Connect different (if possible) golden drives 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 also. It is also good practice to use different golden drivers and to measure each driver several times.<br>7. Now the model is ready for checking other drivers with possible defects. Connect the drivers and restart the TRF measurement. |
| ***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, result window *Instantaneous Distortion 3D* shows the displacement on the Y-axis, sweep frequency on the X-axis while color coding the DNR in the 3$^{rd}$ dimension. This allows to identify 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.<br><br>Select *vs. X* on property page *I-Dist* to get this mapping.<br><br>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 accelaration the distortion appear phase inverted (e.g. positive sound pressure corresonds with negative displacement).<br><br>Select *vs. IN1* onproperty page *I-Dist* to get this mapping.<br><br>3. The **color code of the 3D graph** can be controlled by the parameter *Thresh* on property page *I-Dist*. Black color indicate distortion that exceeding 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. |

# Example

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| | 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** |   Crest harmonic distortion (CHD), Signal at IN1 |

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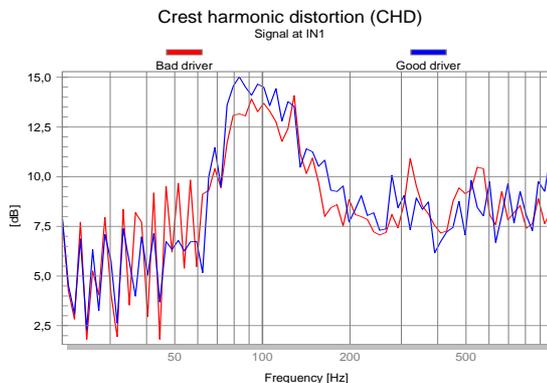
Open the result window *Instantaneous Distortion* and set *Measure* to *CHD* (Crest Harmonic Distortion) on property page *I-Dist*. Two drivers, one good and one bad sample are analyzed for comparison.

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 show for both the good and the bad driver peaky distortion.

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| **DNR 2D** | Activate now the checkbox *Show distortion to noise ratio* on property page *I-Dist*. |



Peak harmonic distortion (PHD)
Signal at IN1
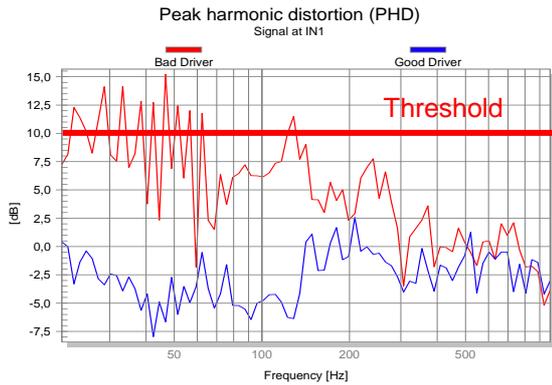
**With learning:**

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 signifficantly suppressed by the adaptive compensation technique.

Finally a 6th driver with an hardly audible defect is measured. At low frequencies there is a clear deviation from the trained driver model indicating an defect. The effective DNR is well above 10 dB, exceeding the threshold clearly.

| Good Speaker (Gold en Unit) | Bad driver (Rub & Buzz effects) |
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| **DNR 3D**  |  |
| The 3D representation allows to identify 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 at the displacement limits a defect is visible (both in and out). This may be caused by staggering. At around 100 Hz the defect occurs only if the voice coil is inside. |

# 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. |

updated April 4, 2012