Less noise • More sound

Application Note

RAPID-TEST + PureSound™

A revolutionary test system for electroacoustic transducers that includes 100% reliable Rub & Buzz detection

RAPID-TEST with PureSound™ is a fast and flexible audio test instrument for a comprehensive QC of transducers, drivers, loudspeakers, capsules etc.
The system provides a revolutionary new solution for Rub & Buzz detection that is 100% reliable. Thus, it allows cutting down production costs and increasing the quality of shipped goods.

Contents

1. Introduction

Defective transducers, drivers and speakers are annoying to the customer and costly for the supplier. Consequently, a test system that separates good from bad samples with 100% reliability would be of great value for manufacturers to cut down failure costs and to increase product quality.

In practice, a suitable QC tester has to meet the following requirements:

- Thorough sample characterization (frequency & impedance response, f0, SPL, polarity).
- 100% reliable Rub & Buzz detection.
- Minimum test cycle time.
- Maximum noise immunity.
- Sophisticated test result processing.

The most challenging demand is a fast and accurate Rub & Buzz detector that operates reliably in noisy environments. However, no test method so far succeeded to meet this requirement, due to the lack of reliability (e.g. golden ears) or the inability of truly detecting all types of Rub & Buzz defects (e.g. FFT or distortion analyzers).

2. Rub & Buzz

Rub & Buzz is the collective term for audible defects of electroacoustic transducers, drivers, tweeters, woofers, loudspeakers, headphone capsules, microphones etc.

Actually, various defects are responsible for Rub & Buzz effects:

- Mis-centered, cocked, or out-of-round voice coils.
- Foreign matter in the gaps.
- Faulty glue joints.
- Air leakage.
- Slit or torn cones or spiders.
- Improper lead-wire dress.
- Other causes.

All of these defects have in common that human ears would hear them. However, it was not possible to reproduce the human perception with test instruments, especially not for the subtle - but still audible - Rub & Buzz effects as e.g. air leakage.

Consequently, a suitable Rub & Buzz test instrument must be able to:

- Modeling the human ear,
- Detecting all audible defects,
- Clustering samples in quality groups (e.g. excellent, good, faulty),
- Executing a test at a high resolution within a minimum of test time,
- Filtering out ambient noise.

The solution for this demand is the use of a proper test signal and signal analysis.

The test signal

A suitable test signal must be applied on the device under test (DUT) to make the potential Rub & Buzz defects audible.

- The test signal has to comprise all potential resonance frequencies that are typically very sharp for most Rub & Buzz defects.
- The DUT must be stimulated at the maximum allowed power, because some Rub & Buzz defects occur only at a high driving voltage.
- The stimulus should not stay stable at any frequency, since some Rub & Buzz defects occur only at the very beginning of a new test frequency.

The only test signal that meets these requirements is a chirp, i.e. a gliding sweep that continuously increases (or decreases) the signal frequency through the band of interest. Only this way one can make sure that all potential Rub & Buzz defects of a transducer are audible.

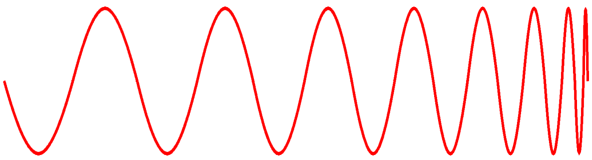

Figure 1 Chirp (i.e. gliding sweep)

Figure 1 shows the time signal of a chirp. Do not mix up this signal with a stepped sweep, which is a sequence of consecutive sine tones with discrete frequencies.

Rub & Buzz analysis

The other core requirement for a reliable Rub & Buzz detection is an appropriate signal analysis. In the past, two approaches were used:

- Human testers (i.e. „golden ears“)
- Test instruments that analyzed the harmonics or the distortion of the returned test signal.

Unfortunately, both approaches suffer from inherent lacks that prevent them from ever becoming truly reliable.

Golden ears, i.e. human employees who listen to the samples are basically able to detect all audible Rub & Buzz effects. They are thus the best available solution to assure a maximum product quality.
However, human testers also have several drawbacks:

- The aural perception varies from day to day and is compromized e.g. by illness or atmospheric changes.
- The perception of single humans can not be correlated to others.
- A quality control executed by human beings cannot be quantified and is neither measurable nor traceable.
- Exposing employees to loud noise harms their health and is therefore forbidden by legal regulations.

On the other side, conventional test instruments failed as well since they are not able to detect all kinds of Rub & Buzz. This is mainly because they are based on the assumption that Rub & Buzz defects would generate harmonics, which can be detected by a *spectral analysis*.
Unfortunately, the reality is different. For instance, a driver with an air leakage creates a pink-noise signal that can be impossibly detected by analyzing the harmonics of the test signal in which way so ever.
All the worse, spectral analysis methods (e.g. FFT or tracking filters) comprise of an averaging or settling process that filters out short pulses, which are typical for several kinds of Rub & Buzz.

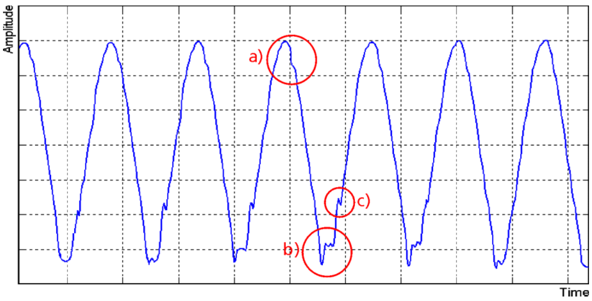

Figure 2 Sweep signal with Rub & Buzz

A spectrum analysis can not detect 100% Rub & Buzz because some slight defects are too short with an energy content that is too low.

The solution

The answer to the question, how can a Rub & Buzz test method be comprehensively realized, is surprisingly simple: analyze the test signal in the *time domain*.
A noticeable proof for this is how the human hearing system works: It processes sound signals via an array of sensory hairs that send out short electric pulses to the brain.

For this reason, a Rub & Buzz detector with comparable behavior has to emulate the psychoacoustic processes of the human hearing system.
So far, only the approach invented by Frank Leonhard of Denmark has successfully reached this goal. The patented solution is best described as the *detection of changes in the instantaneous energy by means of transient analysis*. It detects the slightest speaker failures and allows even identifying the type of the defect.

This new principle has been implemented exclusively for NTI's RAPID-TEST platform in the form of the PureSound™ option.
The system stimulates the DUT with a *chirp* (i.e. *gliding sweep*) from 5 Hz - 6 kHz to cause possible Rub & Buzz defects.
Simultaneously, the analyzer samples the output signal of the DUT, splits it into 6 bands and calculates the steepness of its transients. This procedure reflects the human brain's hearing perception, thus enabling the detection of any Rub & Buzz effects.

The system supports the following standard analysis functions:

- Frequency response (level)
- Impedance vs. frequency.
- Resonance frequency (f0).
- Rub & Buzz.
- Sound Pressure Level (dB_{SPL}).
- Polarity.
- Thiele / Small parameters.
- Statistics (e.g. histogram, trends).
- Statistical Process Control (SPC).

3. Test procedure

A complete device test with RAPID-TEST and PureSound™ consists of two parts:

- A stepped sweep analysis, measuring the frequency response, impedance vs. frequency, f_0, SPL and polarity.
- A chirp transmission for Rub & Buzz detection.

The stepped sweep can be defined in the frequency range from 20 Hz - 20 kHz with a resolution of up to 500 points and the possibility to shape (i.e. equalize) the DUT's input level. Sophisticated settling and noise immunity procedures allow making the test rugged against ambient noise.

The PureSound™ Rub & Buzz analysis uses a very short chirp as test signal (*chapter 2*).
A powerful noise cancellation procedure (patent pending) cancels out ambient noise.

There are many advantages of using two specialized test signals instead of a single stimulus (e.g. a stepped sweep):

- A stepped sweep necessarily is a compromise between resolution and speed. For instance, a typical sweep with 250 frequencies definitely lacks the resolution for a thorough Rub & Buzz analysis. On the other hand, increasing the number of test points for the sake of a better Rub & Buzz detection results in an unacceptably long sweep duration.
- The frequency response usually has to be acquired at the standard driver voltage. However, a Rub & Buzz test has to be executed close to or at the maximum allowed driver voltage (*chapter 2*) so that the two tests cannot be combined.
- An individual test signal is generally better to optimize to the demands of a measurement. This allows achieving maximum speed without compromising on the accuracy.

4. System setup

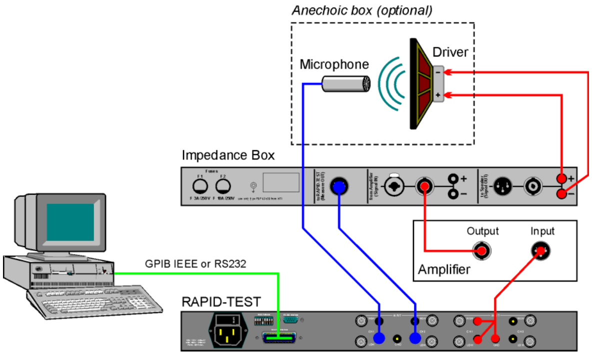

Figure 3 Test setup

Figure 3 shows a typical setup that is required to test transducers, drivers, woofers, tweeters, loudspeakers etc.

The feedback connection between the impedance box and RAPID-TEST allows weighting the test signal in a way that it equalizes the characteristics of the amplifier and the impedance box.

If the test stand is located in a very noisy environment, it is recommended to protect the driver and microphone with a sound absorbing baffle or an anechoic box.

Stepped sweep

The stepped sweep allows measuring the frequency and impedance response, the resonance frequency f_0 and the sound pressure level. The following parameters need to be defined:

- The sweep's start- & stop-frequency (e.g. 20 kHz - 20 Hz or 300 Hz - 3 kHz) should be adjusted in compliance to the bandwidth of the DUT.
- The number of steps (i.e. sweep frequencies) gives the resolution. A typical value is 124 - 250.
- The sweep settling is an automated procedure that lets the test signal stabilize at every frequency before it is measured. This is only required in case of unstable measurement results.
- The noise immunity is activated if the driver & microphone are exposed to ambient noise, In this case a tracking filter is applied to reject ambient noise.

Chirp (gliding sweep)

The fast continuous sweep is solely used for Rub & Buzz analysis. It is defined in a similar way as the stepped sweep:

- Adjust the start- & stop-frequency of the chirp (available range: 5 Hz - 6 kHz). Select these values in compliance with the band where the DUT typically shows Rub & Buzz defects (e.g. from 20 Hz to 800 Hz).
- Determine the minimum required chirp duration by evaluating bad samples.
- The chirp level should be equal to the maximum allowed driver voltage.
- The six steepness bands should be enabled to allow characterizing possible Rub & Buzz defects.
- The steepness limits represent individual acceptance criteria for the six bands. The best way to define them is by measuring several good reference drivers („golden samples“) and adding a user-defined offset to the results. Please refer to the RT-Speaker operation instructions for further details.
- The number of steepness results can be high for the setup procedure but should be reduced for production. Thereby, it is important to know that a low number of results has no effect on the resolution of the internal Rub & Buzz analysis of RAPID-TEST.

Noise cancellation

The noise cancellation is an extremely powerful feature to avoid false alarms (i.e. good samples that are rejected due to ambient noise). If the system detects a defective sample, it repeats the test for a user-defined number of times and compares the returned results.

Consequently, the system rejects the sample only in case that the comparison shows a systematic fault, whereby random noise is cancelled out.

Production software

In practical use, it is essential that the system meets the following requirements:

- Straightforward operation: easy system setup; suited for operation by unskilled people etc.
- Quick setup: minimum time required to get the system running; easy and quick adaptation to new driver types etc.
- Flexibility: simple amendment of setup parameters to changing environmental conditions; user-defined access levels etc.
- Comprehensiveness: all relevant measurement functions supported; statistical result analysis; simple data export etc.

RT-Speaker, NTI's production software for the PureSound™ option has been especially designed to fullfill these demands.

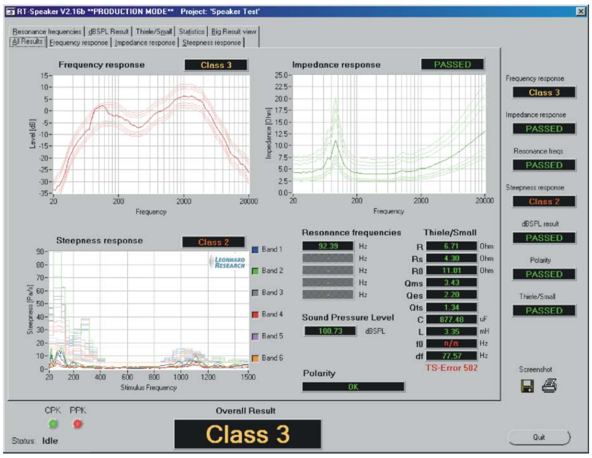

Figure 4 RT-Speaker (production mode)

An unexperienced operator typically needs less than 30 minutes to set up the complete system from scratch to the point where it is ready for production testing.
If the production process changes (e.g. new DUT), the system setup can be adapted quickly to the new conditions.
The SW allows analyzing virtually all measurement functions that are required for production QC, such as frequency and impedance response, resonance frequency, phase, SPL, Thiele-Small parameters, Cpk and Ppk analysis, trends and histograms etc.

5. Advanced topics

Speed omptimization

In a high volume production every fraction of a second counts. Therefore, all parts of a transducer test must be executed as fast as possible.
RAPID-TEST + PureSound™ fully complies with this demand by executing a complete transducer test within a typical test cycle time of 2.5 seconds.

The following list provides useful hints on how to optimize the test speed.

Stepped sweep

- Reduce the number of sweep steps (i.e. test frequencies).
- Avoid low frequencies unless they must be tested.
- Disable the sweep settling. If this is not possible, let the sweep start at the higher and stop at the lower end of the frequency band.

Chirp (gliding sweep)

- Reduce the chirp length (e.g. 500 ms).

If the chirp length is too short, very narrow-banded Rub & Buzz effects do no longer appear.

- Restrict the chirp bandwidth to the frequencies where Rub & Buzz can occur. Examine some faulty samples to find out the optimum bandwidth (typically 20 Hz - 800 Hz).
- Reduce the impact of ambient noise on the test stand, e.g. by using an anechoic box. Adjust the „number of runs if failed" to 2 or disable the noise immunity at all in case of a very good shielding against ambient noise.

Test feedback

By watching the transient steepness graphs of defective drivers it becomes obvious that certain defect types can be grouped into a restricted number of classes. For instance, identical defects show a specific resonance frequency or a typical shape of the transient steepness graph. Thus, it becomes possible to pinpoint the cause behind the Rub & Buzz distortion:

1. Select some driver samples that suffer under specific defects.
2. Record the transient steepness graphs of those drivers with related defects.
3. Investigate the graphs to find out the typical characteristics of the defect classes.

The following pictures show three classes of defects. The graphs have been acquired by using several faulty samples of the same driver type.

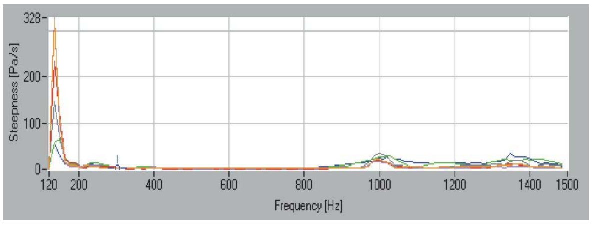

Figure 5 Defect a: foreign matter in gap

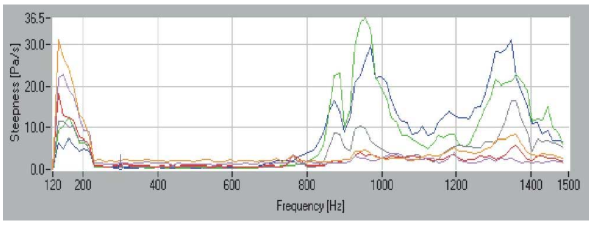

Figure 6 Defect b: rubbing coil

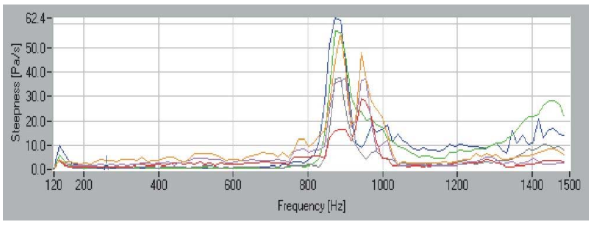

Figure 7 Defect c: cocked coil

Appendix - FAQs

Q: What types of speakers can be tested?

A: All kinds of transducers, drivers, speakers, tweeters, subwoofers etc. There are no restrictions on the size, shape, frequency band etc. However, all applications require an amplifier to drive the speaker.

Q: Is it possible to test a tweeter behind a crossover?

A: In most cases the chirp can pass the crossover (maximum frequency = 6 kHz). If not, you have to directly link the RAPID-TEST output to the tweeter.

Q: Is it mandatory to transmit a stepped sweep and a chirp?

A: Not necessarily. The chirp is required to detect Rub & Buzz distortion, whereby the stepped sweep is used to measure the frequency & impedance response, f_0 and sound pressure level.

Q: Why does a Rub & Buzz test provide 6 different result curves?

A: These 6 bands reflect the psychoacoustic perception of the human ear (*Figure 5*), thus maximizing the evidence of the acquired Rub & Buzz test results.

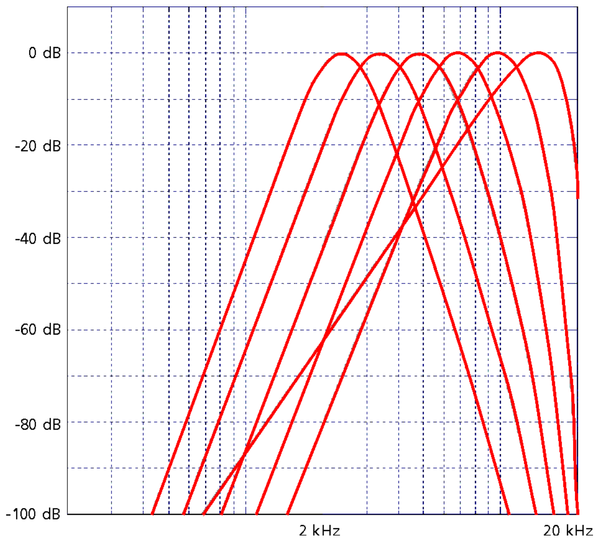

Figure 8 R&B bandpass filters