Application Note

Sound Verification & Noise Analysis with RAPID-TEST + PureSound™

Verifying sound sequences (e.g. polyphonic ringer melodies) or monitoring stationary sounds (e.g. machinery noise) is very difficult. Transient steepness analysis is the first reliable method that fulfills this challenge. Actually, even the slightest defects such as single clicks, grinding noise or other anaomalies are detected accurately.

Contents

1. Introduction

Perfect sound quality is not only essential for countless consumer products, but also a key indicator for the correct operation or status of technical devices as e.g.:

- Polyphonic ringer melodies.
- Door chimes.
- Synthesized speech or music.
- Music replay devices (MP3, CD players).
- Intactness of manufactured parts (glass, moulded or welded parts etc.).
- Motors, gearboxes, bearings, hinges, guides, brakes, shock absorbers etc.

The integrity of these sounds directly correlates to the product quality. In the past, a number of more or less sophisticated acoustical test methods was applied:

a) "Golden ears", i.e. human testers who were listening to the sound.

b) Level, frequency or spectrum analysis (e.g. waterfall diagram).

c) Alternative methods for mechanical parts as e.g. ultrasound diagnosis.

Unfortunately, none of these approaches truly satisfied the high demands of a fully automated quality control.

The reasons for this lack of an applicable test are manifold. For instance, listening to the sound signal is not satisfactory because of several drawbacks:

- Poor reproducibility: every tester perceives a sound differently than other persons and provides different results depending on his daily form.
- Objective test specification not feasible.
- High price per test because of fixed employment costs.

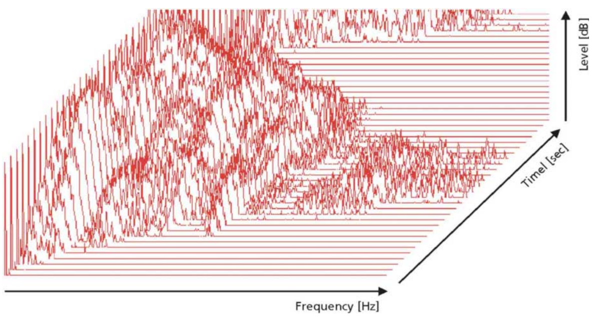

Fig.1 Waterfall diagram

Time-frequency analysis (e.g. *Fig.1*) is not helpful, since it is not sensitive enough to small signal degradations or short clicks with low energy content.

Finally, alternative test methods for detecting mechanical flaws (e.g. ultrasound or magnetic diagnosis) are either too complicated, costly or time consuming in a production line for high-volume QC.

Consequently, a simple & reliable method that provides a solution for the combination of these applications would be highly desirable.

2. The Leonhard Solution

Due to the known lacks of existing approaches, the search for a suitable sound quality test focused on following features:

- Sensitivity: the method must be able to detect slight signal defects or level shifts.
- Correlation to the human perception: the acquired results must represent the acuity of the human ear,
- Automized operation: the test has to be implemented on a technical test platform.

In the early 1990ies, Frank Leonhard - a highly innovative Danish scientist - succeded to find the path for a suitable solution. His patented approach is based on a sophisticated transient analysis in the time domain (please refer to the NTI Technical Note "Transient Steepness Analysis")

Briefely spoken, the algorithm extracts those components from the signal that are essential for its perceptual characteristic. The results not only visualize audible distortions, but also allow creating an individual 'fingerprint' of a recorded sound sample.

NTI has implemented this unique technology on its RAPID-TEST + PureSound™platform that supports two operation modes.

A) Sound verification: the test system records a sample (e.g. some beats of music) and compares it against a previously recorded 'golden sample' (refer to *chapter 3*).

B) Detecting irregularities in a continuous 'noise' signal: the test system records the noise of a device (e.g. a rotating machine) and checks it for irregularities, i.e. high transients that exceed an user-defined limit (refer to *chapter 4*).

3. Sound Verification

This features compares the 'fingerprints' of two sound samples, to determine their 'similarity'. In other words, the analysis quantifies how much the tested sound sequence correlates to a previously recorded reference signal (i.e. a 'golden sample').

NOTE ***Sound correlation measurements allow verifying for the correctness of a defined sound.***

A sound correlation analysis calculates three measurement results: sound correlation, level correction and overall RMS Level.

3.1 Sound Correlation

The results are expresssed in percent, ranging from 100% (identical) to 0% (completely different) and painting a clear picture to rate acquired samples with maximum significance. *Fig. 2* shows the time waveforms of 3 sound samples, whereby the individual percentage values indicate the sound correlation of the corresponding sample vs. the reference sequence, rated by PureSound™.

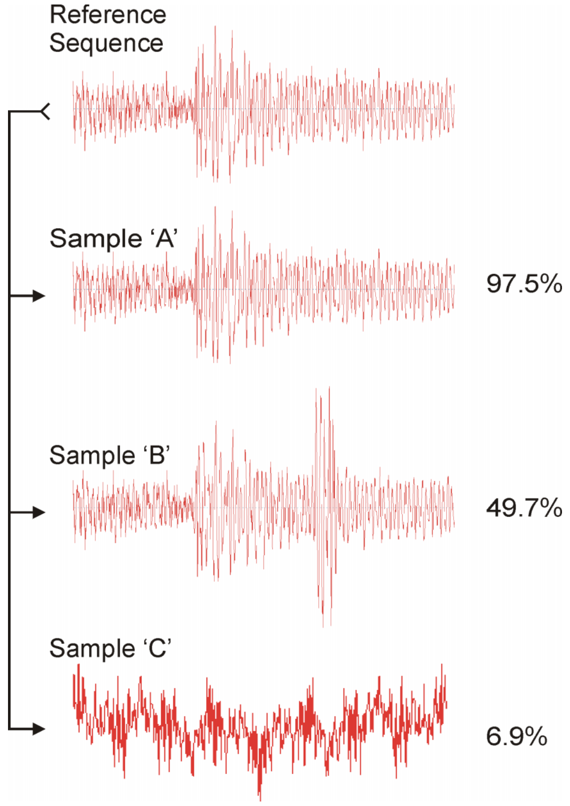

Fig.2 Samples with sound correlation results

- Sample 'A' is almost identical to the reference sequence.
- Sample 'B' suffers from a temporary increase of the signal level.
- Sample 'C' is a completely different signal.

3.2 Level Correction

A second possible defect occurs if the test signal shows a higher or a lower level than the reference signal.
RAPID-TEST returns this paramater as 'level correction', expressed in percent:

LevelCorr. [%] = (RefLevel / TestLevel) * 100

Examples

- Level correction result = 50%

  ⇒ test signal level = ½ of golden sample.
- Level correction result = 310%

  ⇒ test signal level = 3.1x higher than the golden sample level.

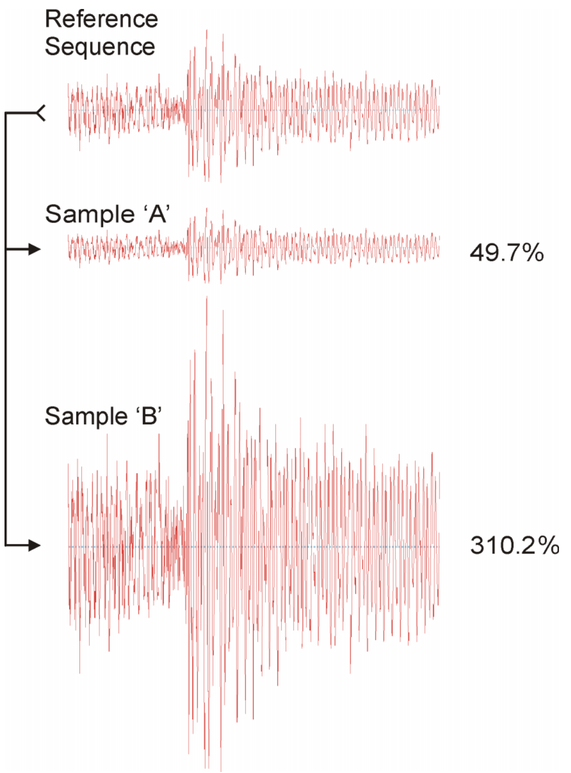

Fig.3 Samples with level correlation results

3.3 RMS Level

The third measurement function is the RMS Level that provides additional information on the tested signal.

3.4 Test Setup

Test signals are either recorded through a microphone an electrical sensor.

Fig.4 Signal verification setup

Fig. 4 shows the schematic setup of a typical sound correlation measurement, that checks the polyphonic ringer melodies of mobile phones.
The test setup is realized in two steps. First, RAPID-TEST records the reference signal ('golden sample') and stores it in one of its two internal memories. Second, it acquires the sound of the device under test (DUT) and calculates the correlation results.

1. The controlling PC sends a start command to the DUT and to the RAPID-TEST unit. Consequently, the DUT generates the sound and the test system starts sampling.
2. Next, RAPID-TEST calculates the sound correlation results.
3. The controlling PC queries the calculated results and takes the PASS / FAIL decision.

3.5 Triggering

An important part of the test is to properly synchronize the RT unit to the signal coming from the DUT. For this purpose, RAPID-TEST provides several operation modes:

a) <u>PC trigggers DUT and RAPID-TEST</u>. The PC sends the start commands to the DUT and the RT unit to initiate the signal generation & sampling. This mode is typically used in production environments.

b) <u>DUT generates the signal at an unknown time</u>. The PC arms the RT unit so that it automatically starts sampling as soon as it detects an incoming signal (typically used for evaluation).

4. Noise Analysis

There are countless products and processes that can be qualified by listening to the noise they are creating:

- rotating devices such as bearings, lathes, milling machines etc.
- turbines, motors, gearboxes etc.
- glassware, ceramics, welded parts etc.

Defective mechanical devices frequently create an irritating sound. Therefore, a test method is required that can reliably identify these sound components.

RAPID-TEST with PureSound™ is perfectly suited to satisfy this demand. In practice, the transient steepness analysis filters out the irritating sounds created by mechanical flaws, cracks, loose particles or other defects.

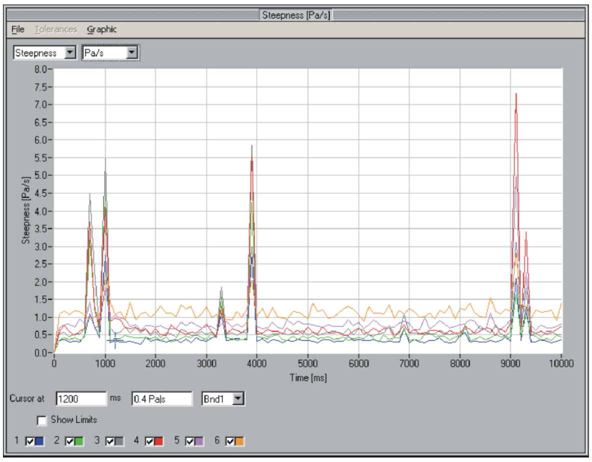

Fig.4 Machinery noise monitoring

Fig. 4 shows the recorded sound signal of a defective machine after processing with the PureSound™ algorithm. Due to loose particles in a bearing, clearly audible intermittent 'clicks' occur that are detected by the algorithm. Apparently, the analysis is perfectly suited to monitor the machine: the test system has to compare the results against an user-defined threshold limit. Thus, it can identify an audible defect as soon as it exceeds this limit.

NOTE Transient steepness analysis allows monitoring stationary, noise-emitting processes.

4.1 Test Setup

Noise signals from a DUT can be picked up through a microphone or other devices as e.g. a vibration sensor.

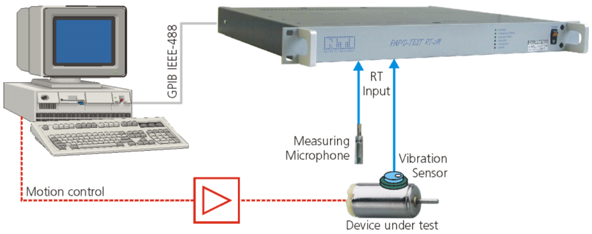

Fig.5 Noise monitoring setup

Make sure that the applied sensor is driven properly, e.g. with the internal microphone (Phantom) power supply of RAPID-TEST.

4.2 Triggering

RAPID-TEST must be programmed so that it acquires & analyzes the sensor signal in an endless loop, until it detects an error and reports to the host PC.

Appendix - Program Examples

The listings below refer to the test setups shown in *chapters 3.3* and *4.1*.

The code was automatically created by the code generator feature of RT-Eval. RAPID-TEST control commands are put in quotation marks.
Make sure that the channel-specific settings correspond to the actual wiring (i.e. microphone, sensor connected to input channel 1).

A1) Signal Verification

- The unit starts waiting for the incoming signal after it has received the start command "MEASUREMENT1:PURESOUND:START". Consequently, the device under test must be switched ON shortly after this command.
- RAPID-TEST returns the measurement results upon each query command (e.g. "MEAS:TRAN:STEEPNESS:CORRELATION?").

```
! REM  *************** INPUT SETTINGS ***************
SendToRT "INPUT1:RANGE -6.00 dBVp"
SendToRT "INPUT1:LINK OFF"
SendToRT "INPUT:SYNC INTNOHEADER"
SendToRT "INPUT:TRIGGER:TIMEOUT  500"
SendToRT "INPUT:SWFILTER OFF"
SendToRT "INPUT:DEEMPHASIS OFF"
SendToRT "INPUT1:MICSENSITIVITY  51.23"
SendToRT "INPUT1:IMPEDANCE PHANTOM"

! REM  *************** SOUND CORRELATION SETTINGS ***************
SendToRT "INOUT:PURESOUND:MODE CORRELATION"
SendToRT "MEAS:PURESOUND:STEEPNESS:REFERENCE:ACTIVE A"
SendToRT "MEAS:PURESOUND:LENGTH 2000"
SendToRT "MEAS:PURESOUND:STEEPNESS:UNIT  Pa|s"

! REM  -------------- SIGNAL VERIFICATION MEASUREMENT PART ------------------
! REM  Perform the measurment
SendToRT "INOUT:PURESOUND:MODE CORRELATION"
SendToRT "MEASUREMENT1:PURESOUND:START"

SendToRT "MEAS:PURESOUND:STEEPNESS:CORRELATION?"
ReadFromRT
! REM Parse the result string & check the Sound Correlation result

SendToRT "MEAS:PURESOUND:STEEPNESS:LEVELCORRECTION?"
ReadFromRT
! REM Parse the result string & check the Level Correction result

SendToRT "MEAS:PURESOUND:STEEPNESS:RMSLEVEL:UNIT dBV"
SendToRT "MEAS:PURESOUND:STEEPNESS:RMSLEVEL?"
ReadFromRT
! REM Parse the result string & check the RMS Level result

! REM  *************** ERROR QUERY ***************
SendToRT "SYSTEM:ERR?"
ReadFromRT
! REM Interpret the returned error messages
```

A2) Noise Monitoring

- The unit executes a PASSED/FAILED decision for every band, based on the transient steepness limits that are defined by the commands "`MEAS:PUR:STE:VARLIMIT:SET...`"
- The unit immediately starts sampling after it has received the start command "`MEASUREMENT1:PURESOUND:START`".
- RAPID-TEST returns the measurement results upon each query command (e.g. "`MEAS:TRAN:STEEPNESS1?`").

```
! REM  *************** INPUT SETTINGS ***************
SendToRT "INPUT1:RANGE -6.00 dBVp"
SendToRT "INPUT1:LINK OFF"
SendToRT "INPUT:SYNC INTNOHEADER"
SendToRT "INPUT:TRIGGER:TIMEOUT  500"
SendToRT "INPUT1:MICSENSITIVITY  51.23"
SendToRT "INPUT1:IMPEDANCE PHANTOM"

! REM  *************** TRANSIENT STEEPNESS ANALYSIS SETTINGS ***************
SendToRT "INOUT:PURESOUND:MODE RNB"
SendToRT "MEAS:PURESOUND:NRESULTS 100"
SendToRT "MEAS:PURESOUND:LENGTH 10000"
SendToRT "MEAS:PURESOUND:STEEPNESS:UNIT  Pa|s"
SendToRT "MEAS:PUR:STE:VARLIMIT:SET1 2 PA|S 0.0E00,1.0E02,3.0E01,3.0E01"
SendToRT "MEAS:PUR:STE:VARLIMIT:SET2 2 PA|S 0.0E00,1.0E02,3.0E01,3.0E01"
SendToRT "MEAS:PUR:STE:VARLIMIT:SET3 2 PA|S 0.0E00,1.0E02,3.0E01,3.0E01"
SendToRT "MEAS:PUR:STE:VARLIMIT:SET4 2 PA|S 0.0E00,1.0E02,3.0E01,3.0E01"
SendToRT "MEAS:PUR:STE:VARLIMIT:SET5 2 PA|S 0.0E00,1.0E02,3.0E01,3.0E01"
SendToRT "MEAS:PUR:STE:VARLIMIT:SET6 2 PA|S 0.0E00,1.0E02,3.0E01,3.0E01"

! REM  ----------------- TRANSIENT STEEPNESS MEASUREMENT PART ---------------
! REM  Perform the measurment
SendToRT "INOUT:PURESOUND:MODE RNB"
SendToRT "OUTPUT1:PURESOUND:CHIRP:START"

! REM  *************** MEASUREMENT Steepness [Pa/s] ***************
! REM --- Query and interpret the transient result string of band 1
SendToRT "MEAS:PURESOUND:STEEPNESS1?"
ReadFromRT

SendToRT "MEAS:PURESOUND:STEEPNESS2?"
ReadFromRT

SendToRT "MEAS:PURESOUND:STEEPNESS3?"
ReadFromRT

SendToRT "MEAS:PURESOUND:STEEPNESS4?"
ReadFromRT

SendToRT "MEAS:PURESOUND:STEEPNESS5?"
ReadFromRT

SendToRT "MEAS:PURESOUND:STEEPNESS6?"
ReadFromRT

! REM --- Check for errors.
SendToRT "SYSTEM:ERR?"
ReadFromRT
```