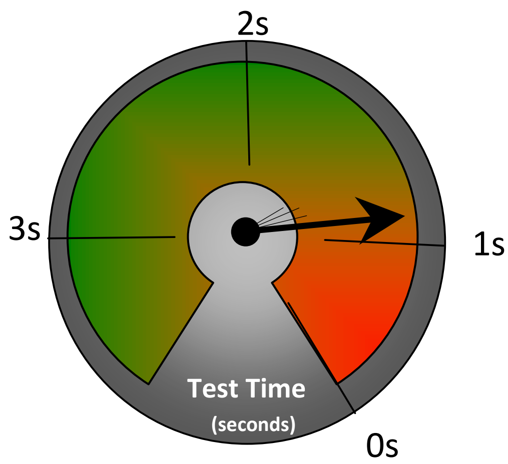
Optimal QC setup for fixed measurement time

AN 45

Application Note to the QC SYSTEM (v4.0)

In automated production environments the testing time is defined by the cycle time which includes the actual measurement time, the calculation of results, the output and storage of results and the mechanical handling of the DUT (moving, connecting). Some processes can be done in parallel (moving parts, processing results) while others cannot (mechanical action and testing).

In this Application Note it is discussed how to fill the available testing time in a most efficient way. There is no single solution for all applications, but the interaction of measurement system and time restrictions are explained and can be applied to similar problems.



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updated May 11, 2015

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Task

Test Setup	**Timing:** In an automated production line a measurement time t_{meas} = 1.4 is specified in which the DUT can be tested and measurement signals can be applied to the DUT. The start impulse could be set earlier as well as the final result (verdict) can be available after this specified pure measurement time. The overall cycle time t_{cycle} is about 4s and includes movement of the DUT, connecting the DUT, opening and closing of shielding and other mechanical actions. The calculation of the PASS/FAIL result can be in parallel to the mechanical actions and is not necessarily included in the measurement time t_{meas}. **Frequency Range:** The SPL response of the DUT shall be tested over the full frequency range from 30Hz to 20kHz. The critical frequency range for potential Rub&Buzz defects are defined by the manufacturer from 30Hz – 200Hz. In this range most of the test time should be spent to reliably excite parasitic resonances.
Test Object (DUT)	The DUT is a woofer driver with the following specification: ○ Re = 8 Ohm ○ fs = 70 Hz ○ Qts = 0.6
Test Environment	The DUT is measured in a test enclosure. Although the test box attenuates most production noise, high impulsive disturbances may have sufficient level (easily >90dB) to corrupt the Rub&Buzz measurement. Using a second Production Noise microphone this corruption can be reliably detected and signalized to the automated line. In this case the DUT can be retested or sorted out to a pool of DUTs which need a retest at a later time. It is recommended to use a well shielded test box with an attenuation of >25dB above 1kHz. Optionally, a hood or cover to fully shield the DUT can be used.
Measurements	It is assumed that the following measurements shall be executed: ○ Frequency Response ○ Harmonic Distortion (THD, 2nd, 3rd harmonics separated) ○ Rub&Buzz ○ Polarity ○ Level in stated band (or average) ○ Impedance curve ○ Re, fs, Qts. All measures have user definable limits.

Timing Considerations

Required timing headroom

Fading the signal

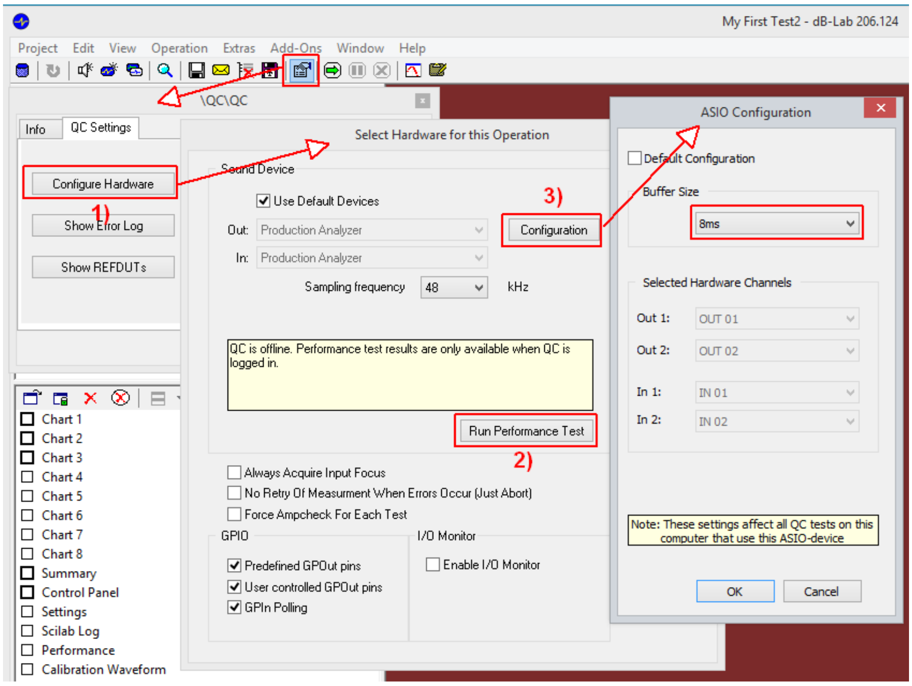
To prevent from switching noise, the sweeps are faded in and out. For sine sweep tests 10% of the sweep time is added to provide a click less measurement. For multi-tone testing a partial pre-loop of the test signal is required avoiding transient effects. Fading and pre-loop is considered automatically and cannot be customized by user.

Audio Interface Latency

The audio interface to the Production Analyzer hardware unit inherently has latency, which increases the total measurement time. Basically, this delay is caused by filling data buffers that allow robust operation when using a non-real time hardware (computer) configuration. By default the buffers are defined to provide robust but not time efficient operation. Depending on particular computer configuration and performance, smaller buffer sizes may be used without any problem.

The buffer sizes can be modified using the *Hardware Configuration* setup (off-line). With the QC software a *Performance Test* program is provided to find the fastest configuration:

From QC-Start use the View button and select the property page QC Settings.



1) Press *Configure Hardware* button.

2) Run the Performance Test, select the *Find fastest Configuration* mode. Find the minimal buffer size from the test. Run the test for at least 8h, better over a weekend.

3) Enter the minimal buffer size value in the Device Configuration menu.

Switching time	Switching the routing of the PA hardware requires additional time. All control access is done via USB. Consequently keep the number of tasks minimal avoiding switching time. When testing multi-channel systems (stereo or coax transducer) the switching of power relays can be minimized using a task specific routing setup. Contact Klippel for individual suggestions.

Variation of Measurement Time

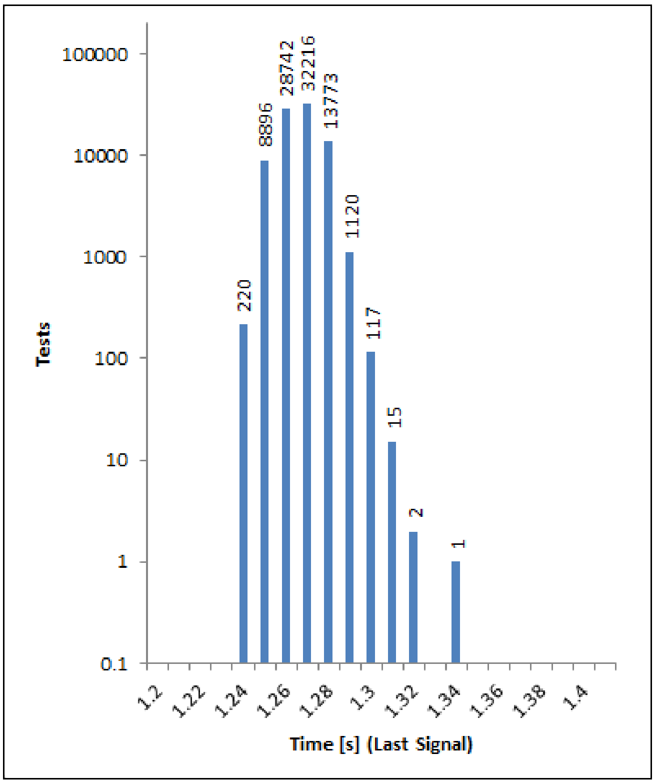
Causes of variation	A fixed duration of each test without deviation is aimed in automated test environments. However, using a PC without running a real time operating system and using USB as communication channel for control commands, there are several sources of variation of measurement time. The following list is not complete but lists the major contributions: o USB communication. The speed of a transaction depends on the load of the USB bus (other devices), the used protocol and potential errors (repeating of transactions). o Call of windows system functions depends on the performance of the PC and other concurrently running programs. For QC, examples are hotkey handling for starting the test and organizing windows (restoring the arrangement in operator mode). o Thread handling within windows. The KLIPPEL QC software consists of more than 10 threads. Despite having priorities and timing properties each, they are not scheduled in a defined order, and a real timing sequence cannot be guaranteed. o Hard disc access. Windows file management, especially on the saving process of databases and log file, may vary considerably. o 3rd party software running on the computer (e.g. anti-virus software scanning the log files each time) o Automatic scheduled services of the windows system / 3rd party software (Defragmenting the hard disk, periodic network access for update scanning) High effort was undertaken to keep the summed variation below 100ms in an optimized system. A normal non-optimized system may show variations up to seconds easily.

Example

Based on the suggested two-step measurement (Setup 1), the variation of the measurement time (measured from start impulse to finish of complete measurement) of >75.000 DUTs was checked. The final processing time incl. storage of data is not included in this time. Note the logarithmic axis of tests.

See two step measurement setup 1 for details below.

100% of the tests were performed in the defined 1.4s time frame.



A 8ms buffer time was used for this example. See section Audio Interface Latency. The distribution chart above was made using the performance log data stored by the QC-system and post processed by MS Excel®.

Solution

Using one or two tasks?

Number of channels:

The KLIPPEL QC Production Analyzer is a two-channel system; so only two states of the test can be measured at the same time. For accurate impedance and SPL testing 3 states must be measured: Voltage, Current and near field SPL. If tested with two channels, constant voltage driving of the test can be exploited. Using a standard audio amplifier giving a constant voltage, the output of the amplifier is relatively independent on the load caused by the DUT. Consequently, it is possible to measure the voltage once for the whole batch because the impedance change between DUTs will not change the voltage considerably. However, this is a compromise in accuracy.

Common Level of test:

If measured with one test step, all measurements must be tested at the same excitation level. Usually, the impedance shall be measured at lower (linear) level than SPL (at high power in non-linear range). So even if the system could provide more than 2 channels, this restriction can require a two-step measurement.

Bandwidth:

The same restriction also applies to the bandwidth of the test. Using one test, all measurements must be measured using the same bandwidth. For impedance curve fitting an optimal setup with the resonance fairly centered in the frequency range cannot be provided. This is usually a minor drawback.

Pause between tests:

A minimal pause between a two-test setup is required by design. It is mostly defined by the audio interface buffer size.

Noise Robustness:

While SPL tests are highly sensitive against ambient noise corruption (especially Rub&Buzz tests), the impedance test is extremely robust. Further optimization may be possible if the impedance test is done even in presence of mechanical action, and for the SPL task only a low noise environment is provided.

A two-step setup allows measuring voltage and current for impedance test and test microphone and production noise microphone for the acoustic test step. Thus, corruption by production noise can safely detected an the DUTs can be sorted out accordingly and fed back to a re-test.

Using Speed Profile

The Speed Profile allows concentrating measurement time at specific frequency ranges. Especially Rub&Buzz testing is very time dependent. Defects need a defined time to develop their symptom. Such defects can be modeled as a “parasitic” resonance that must be excited by the measurement stimulus. Critical defects may have very small bandwidth and a high Q-factor of the parasitic resonance. Such defects are mostly generated at frequencies with high excursion from low to about twice the resonance frequency. So it is important to concentrate the energy and hence the time per octave in this range.

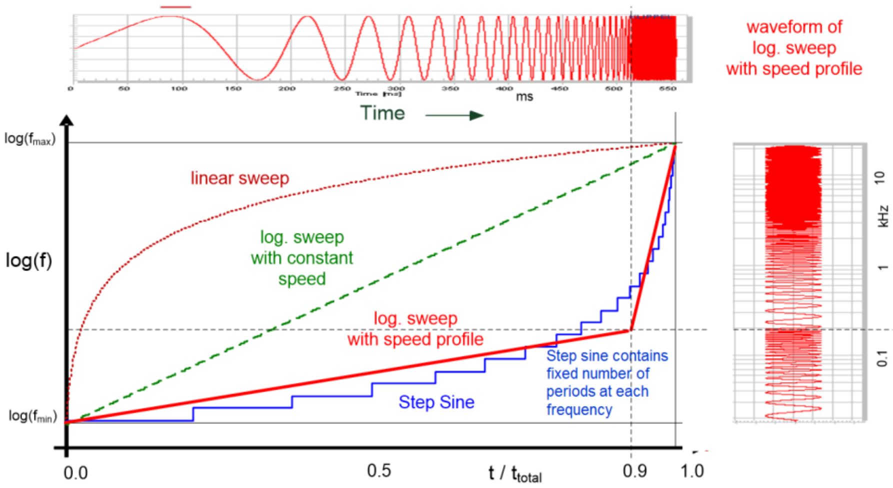
A logarithmic sweep is defined by the time frequency mapping: log *f* ~ *t*.

The sweep speed *q* characterizes the relative bandwidth

$B = \left|\log(f_{stop} / f_{start})\right|$ which is swept in a time *t*:

$$q = B / t \qquad \text{(eqn. 1)}$$

If the complete measurement is split up into multiple (at least 2) ranges with different speed, the energy can be concentrated in critical regions, e.g. for optimal Rub&Buzz detection. For comparison other typical frequency – time mappings are added:



To calculate the time spent in a certain bandwidth of the simple case with 2 sections, the following formula can be derived:

$$X_q = q_2 / q_1$$ (Speed ratio of sweep speed in two sections)

$$t_1 / t_2 = B_1 / B_2 \cdot X_q$$ (eqn. 2) and with $t_{total} = t_1 + t_2$ follows

$$t_1 = t_{total} \cdot \frac{1}{1 + \frac{B_2}{B_1} \cdot \frac{1}{X_q}}$$ (eqn. 3)

Eqn. 2 says that the time ratio t_1/t_2 can be changed by defining *Xq*. eqn. 3 is used to calculate the time spent at low frequencies as a function of the total time and the selected bandwidth.

The time of an equivalent log sweep without speed profile but the same speed at low frequencies which dominates the Rub&Buzz detection rate, is

$$t_{equ} = t_1 \cdot \frac{B_1 + B_2}{B_1}$$ (eqn. 4)

The equivalent time divided by the actual measurement time t_{total} using a sweep provides the gain of measurement time using a speed profile.

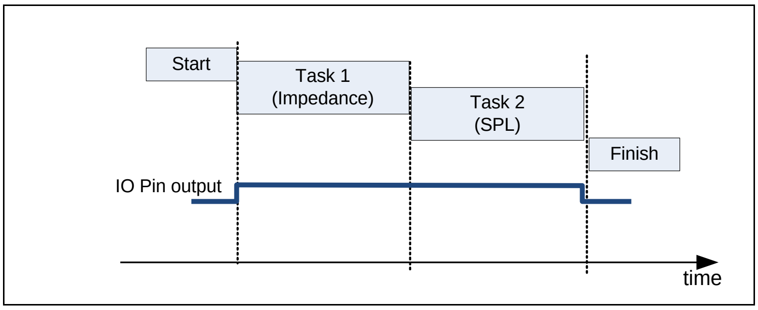
$$\frac{t_{equ}}{t_{total}} = \frac{1 + \frac{B_2}{B_1}}{1 + \frac{B_2}{B_1} \cdot \frac{1}{X_q}}$$ (eqn. 5)

For the examples below this ratio is calculated and compared in a chart.

Theoretically using *Xq* the energy can be arbitrary distributed over frequency. However, the value of *Xq* is limited if harmonics shall be calculated at the same time. The cause of this is the discrimination of harmonics in the impulse response of the test (using Farina post-processing).

IO Scheme

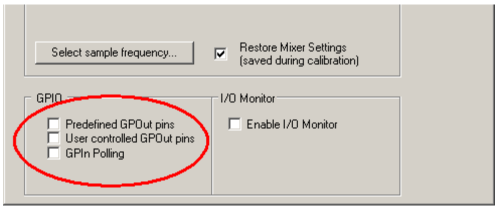
The actual measurement time is signalized by an output pin to the line automation. Using the IO Scheme (customizable parameter in the Start task), a pin can be set to signalize the actual testing time where all mechanical actions shall be minimized.



Disable unused functions

Disabling of not required functionality could shorten the measurement time. Check the hardware settings of the test (available from QC Software version 2.7 and higher):

Task Property Page | Menu | Configure Hardware…



Predefined GPIO pins: All status information is represented at the GPIO port (required for IO Scheme, Logged in Status etc., see User Manual | Hardware | IO Connector).

User controlled GPIO pins: All outputs defined by user setup (IO Task, Routing section in measurement tasks, Pass/Fail verdict information from the control task)

GPIn Polling: Required to start the test using an external switch or logic and to query input pins using the I/O Task or custom scripts.

Enable I/O Monitor: Required for software interaction with other software components (control of Klippel QC, control of 3rd party software)

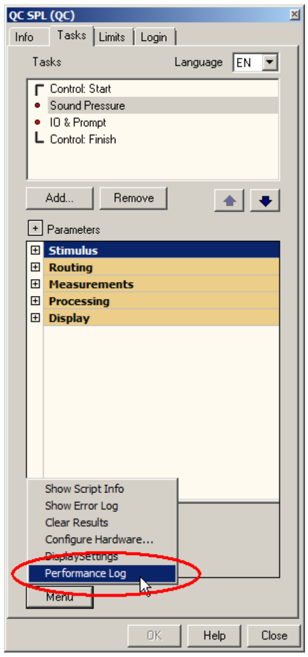
Performance Data Logging

Performance Log File

If enabled (toggle this menu item to en/disable), a log file containing detailed timing information is written to the hard disc. The log file is stored in a subfolder relative to the database file:

{current folder}\{test database}.kdbx
{current folder}\{perflog\{timestamp}.perflog

Using Excel® or other spread sheet software the timing charts similar to those in this note can be made easily.

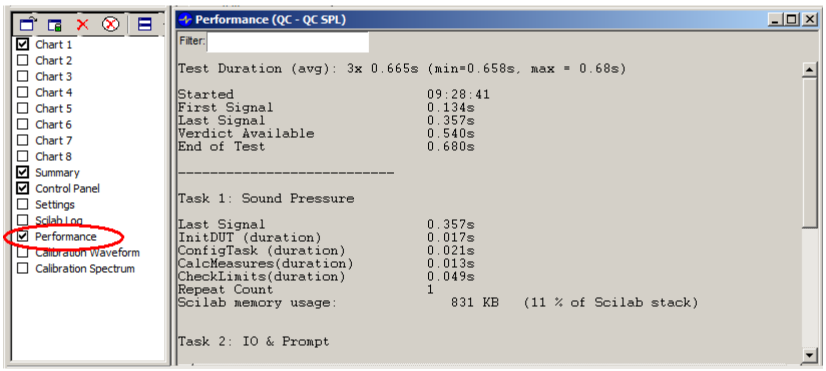


Performance Chart

In the chart list the *Performance* window can be enabled and provides detailed analysis of the timing within one test. Especially for customized scripts using the programmable option this diagnostics helps to find performance problems.

Note, that in Engineer mode an additional amplifier test is done on user request. For QC version 4 and higher, there is no difference in timing between Engineer and Operator login mode.

The chart must be opened in Engineer mode and the window configuration must be stored (second left icon above the chart list ) to be used in Operator mode.



Examples

One Step Measurement Setup

Tasks

The combined task **SPL+IMP** is the choice for testing all of the requested tests in one single measurement. Using one single sine sweep, the input current and the near-field SPL is recorded.

In a pre-measurement (which is executed only at the very first test of the batch) a voltage reference is measured. In an automated environment the first test must be handled in a special mode allowing twice the time of all following tests in a batch.

Setup 1

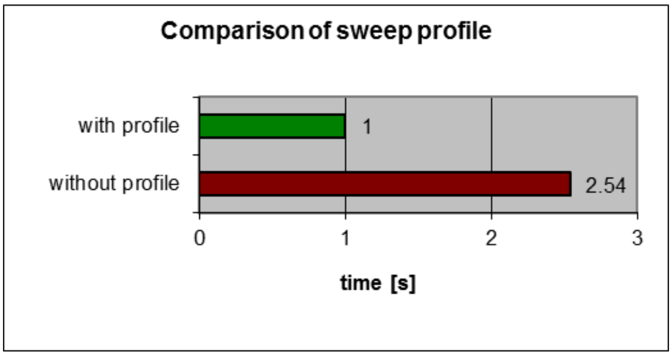
Measurement time: 1.0s (Rub&Buzz time: 750ms)

Advantage: Minimal testing time, no additional task.

Using the Sweep Profile, the time spent at low frequencies up to about 3-4 times the resonance frequency can be extended. The maximum which can be set, if at the same time harmonics shall be measured, is 7 times faster sweep speed above 200 Hz than below. So, consequently, according to equation (3) above, the time, which is used for Rub&Buzz testing, is about **750ms**. You may increase this ratio to even higher values, but harmonics cannot be calculated anymore.

A comparison chart is given with the duration of an equivalent log sweep with same sweep speed at low frequencies (which are important for Rub&Buzz detection) but without speed profile. This equivalent sweep needs much more time due to the (unnecessary) low speed at high frequencies (based on eqn. 4).

Consequently, the gain of using speed profile is more than **2.5**, in other words the time can be reduced by 60%:



Drawbacks:

- Pre-measurement of voltage required to calculate the impedance. Accuracy of the test depends on the validity of the measured voltage for all measured DUTs. If the impedance of the DUTs varies, the voltage will also vary (according to the ratio of source impedance by the amplifier output and the load impedance of the DUT), and the accuracy will suffer.
- Same level and frequency range for all measurements required. The level is more or less defined by the SPL test to excite all potential defects for Rub&Buzz defects. Consequently, the driver is operated in the nonlinear range, and the impedance will show typical nonlinear artifacts, which could degrade the fitting accuracy. Note that the T/S parameter (f_s and Q_{TS}, even R_e due to self-heating) may considerably change with level, so they may not be comparable to small signal tests. In most cases in a QC application this is not as critical since the reproducibility is more important than the absolute values.

Two Step Measurement Setup

Tasks

IMP Task (using sine sweep excitation) and

SPL Task will be executed after each other. It is recommended to start with the low level impedance task since a preceding high level test would influence the T/S parameter (see AN 43).

Setup 1
2nd, 3rd

Measurement time: 0.2s + 0.7s (Rub&Buzz time: 520ms)

Advantage:

***Impedance**:*

200ms is a very short time for impedance testing. All impedance tests are FFT based, so the frequency resolution corresponds to the measurement time. 200ms yields a resolution of 5 Hz, which is already a bit coarse for a woofer (fs=70Hz). A fitting method ensures an accurate estimation of f_s anyway. However, 200ms are enough to get the required T/S parameter in a reproducible way. The level should be chosen so high that nonlinear artifacts are hardly visible in the impedance curve to ensure optimal SNR. The level of impedance test can be chosen independently from the SPL test.

***SPL**:*

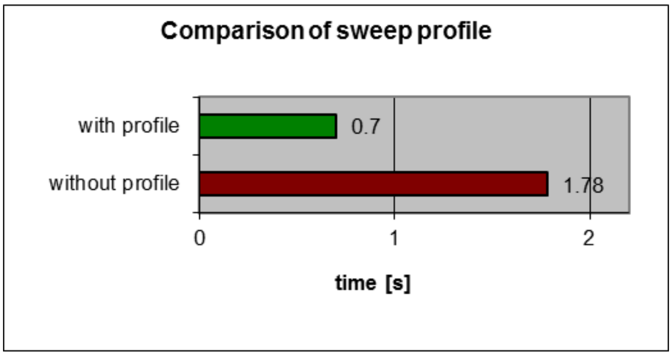
The level shall be chosen as high as possible to excite most defects while also protecting the driver. Here it can be set independent from impedance test.

The speed profile here was set to split the bandwidth at 200Hz. The maximum speed factor *Xq* is 7 if harmonics shall also be measured. This yields an absolute time for the 30-200Hz range of 520ms.

Eqn. 3 yield: **t1=520ms**; t2 = 180ms

A comparison chart is given with the duration of an equivalent log sweep with same sweep speed at low frequencies (which are important for Rub&Buzz detection) but without speed profile. This equivalent sweep needs much more time due to the (unnecessary) low speed at high frequencies (eqn. 4).

Consequently, the gain of using speed profile is more than **2.5**, in other words the time can be reduced by 60%:



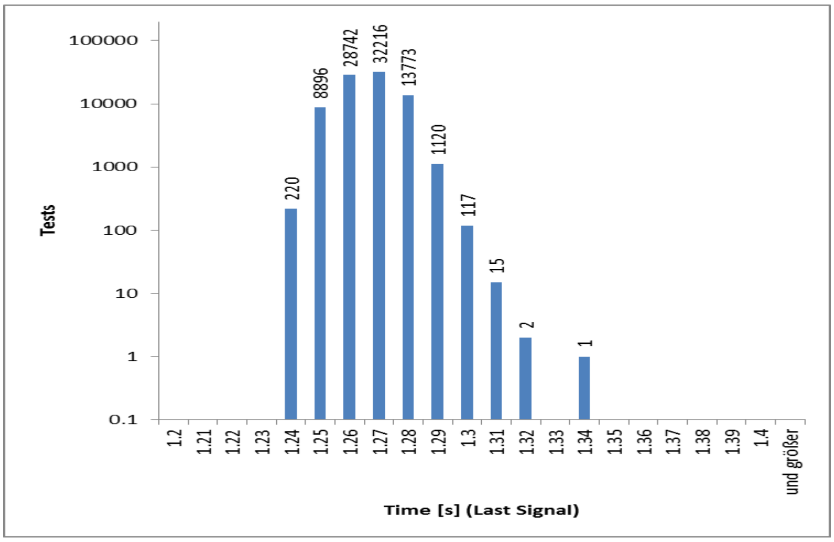
Drawback:

The two step test sequence, even if shaped with speed profile, provides 200ms less time in the critical band than the 1s one step measurement.

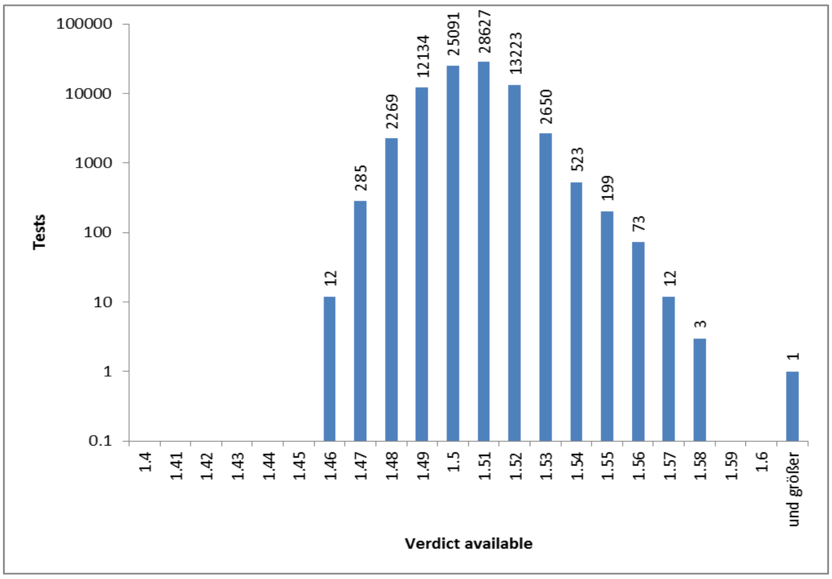
Timing results

Using a digital oscilloscope the timing from the rising edge of the start impulse until the edge of the finished capture (last sample) as well as the availability of the final verdict was measured for more than 75.000 DUTs.

The tests were triggered using an external signal generator with a TTL like output signal and a cycle time of 4s.



Note the extremely small spread of timing.



Note that the “Verdict available” timing includes the storage of test data to the hard disc and shows a bit higher spread and on outlier (0.165s) due to a non real time operating system.

Setup 2 Multitone Imp.	**Measurement time**: 0.2s + 0.5s (Rub&Buzz time: 370ms) **Advantage:** In this setup for the impedance test a multitone excitation has been selected. The main advantage of multi-tone testing is the lower frequency for R_e detection. Consequently, the R_e in most cases (especially if the fs is lower than in the example) is more stable and more accurate. **Drawback:** However, multi-tone excitation needs considerably more pre-excitation than a sine sweep stimulus. The pre-loop requires 50% of the test time, meaning 100ms are used for pre-excitation and cannot be used for SPL testing. SPL test time must therefore be reduced to 500ms instead of 700ms in Setup 1. The time for impedance testing cannot be further reduced since the resolution will get worse, and, consequently, the number of points around resonance impedance will go down and fitting accuracy drops. Note that this is not a problem for tweeters.

Conclusions

Test in 1 second	Testing just for the most important properties of a typical woofer to be used in cars or smaller boxes can be done in about 1 second. However, the time must be used in an optimal way to excite potential defects to be detected by the measurement. Using a speed profile, the measurement time for the acoustical test can be greatly reduced by more than 60%.
Extensions	The tests can be extended with other tasks to check e.g. ○ **Motor and Suspension (MSC)**: The MSC test may replace the small signal impedance task in a time critical application. In addition to the T/S parameter measured at high level, also the voice coil position as well as the properties of the driver stiffness (spider and surround) can be checked and kept under control. The minimal measurement time is 750ms. ○ **Air Leakage Detection (ALD)** option can be added. The standard SPL task (no additional task is required!) can be used to detect small leaks in boxes or enclosures (in transducers, multi-media boxed systems, vented car sub-woofer systems etc.) with high sensitivity. ○ **Meta Hearing (MHT)** option can be added. The Rub&Buzz method implemented in the standard SPL task is improved to provide even higher sensitivity for tiniest parasitic and irregular defects (such as loose particles). ○ **Multiplexer / Automation Control:** The IO Task is dedicated to control external devices and to start / control the sequence using input pins. Note that all tasks can be setup to control the output pins for external device control (such as routing of multiplexing hardware).

Software

Database	The tests discussed in the Application Note are available as a KLIPPEL QC database or template.
QC Version	The Application Note was made using QC version 4.0.
Specifications	• C3 - QC Set • S13 - QC MSC • S18 - QC Air Leak Detection • S20 - QC Meta hearing

updated May 11, 2015

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