

Loudness measurement in sone (DIN 45631 ISO 532B)

Sound can be described with various physical parameters e.g. intensity, pressure or energy. These parameters are very limited to describe the perception of the human ear. A first approach is to take into account that the ear is less sensitive at lower and higher frequencies. The research work around 1920 from Barkhausen result into the well known A,B,C weighting curves. The frequency response of the ear depends on the sound level, that is the reason for different curves, which are valid for a certain level only. A pure sine at lower levels e.g. 40dB(A) has the same subjective loudness over the complete frequency range. However, in practice sine tones are not very common. For complex sounds and noise, this simple model is not valid anymore.

In most sound pressure meters available today you will find these techniques, because they can be easily derived from the physical parameters.

Loudness (Sone)

A wideband noise has a different subjective loudness than a pure tone at the same level measured in dB(A). Therefore, dB(A) is very limited in its usage although widely used. Zwicker analyzed various psychoacoustics effects thoroughly. A result was a model for the human hearing. A famous psychoacoustics effect is acoustical masking. A loud tone hides quiet tones. Nobody would expect to hear the sound of a mouse during a symphonic orchestra, although the mouse would audible in quiet phases. A very famous application of this and other effects are audio compression techniques like MP3. Only parts of the signal, which are audible according to a model, are stored.

Based on its countless hearing tests, Zwicker developed a model for loudness measured in sone. For stationary signals you will achieve much better results than the traditional dB(A). In contrast to dB(A), sone is a linear parameter. Two sone has double loudness compared to one sone. The reference level is one sone, which is equivalent to a tone with 1kHz at a level of 40dB.

As mentioned previously, sone is valid for stationary signals, only. It is ideally for the judgment of air conditioners or typical PC noise like hard disks or fans.

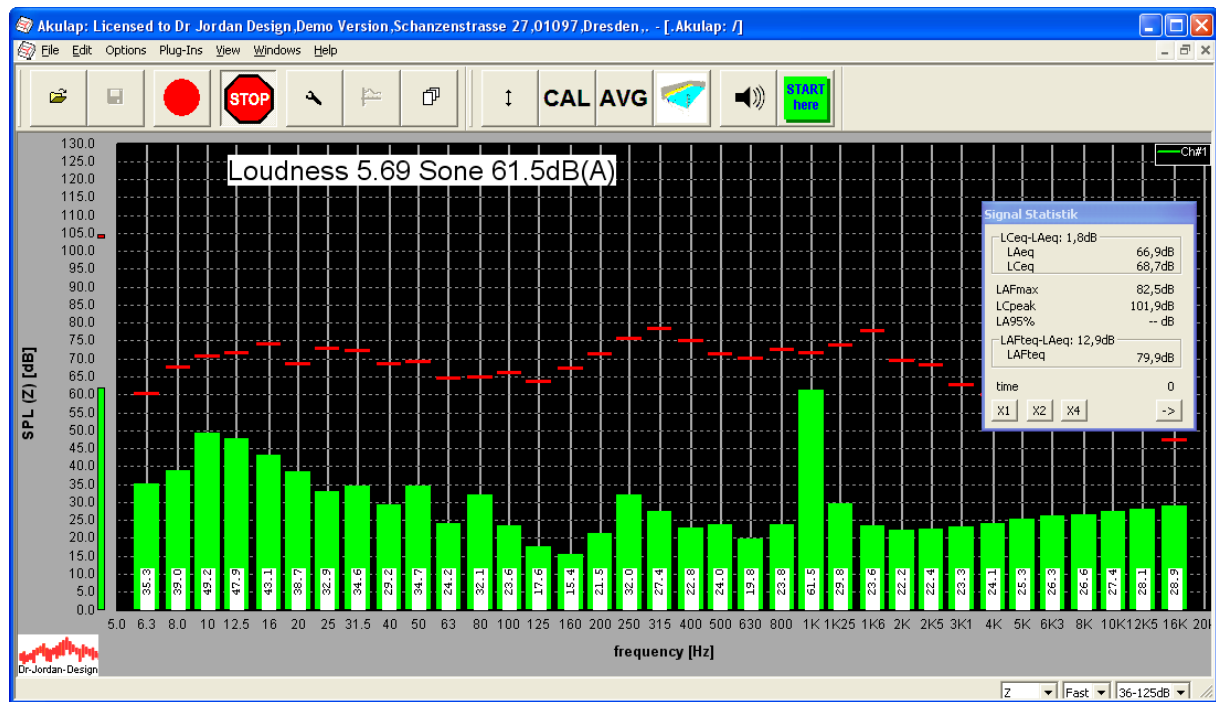
This measurement describes the subjective loudness. However, it does not allow distinguishing between “nice” or “annoying” tones. Most people will agree, that the sound of a flute is much nicer than a drill used by a dentist, although they both might have the same loudness.

The measurement of the loudness is based on the 1/3 octave analyzer. All psycho acoustic analysis requires absolute sound levels. This can be achieved with a sound calibrator or a sound pressure meter.

A complete measurement system for sone contains the following components:

- PC/Laptop running Microsoft Windows
- Software Akulap module noise
- USB Measurement microphone
- Optional Sound-level calibrator
- Tripod





Akulap with Sone/Loudness live measurement. All values are displayed in real-time.

Overview of typical sound level in dB and sone

Situation and sound source	Sound pressure p Pascal	Sound pressure L_p dB re 20 μPa	Loudness sone
Pain threshold	100 Pa	134 dB	~ 676 sone
Hearing damage even at short-term exposition	20 Pa	>120 dB	~ 250 sone
Jet engine at 100 m	6,3 - 200 Pa	110 - 140 dB	~ 125 - 1024 sone
Pneumatic hammer, at 1m, discotheque	2 Pa	~ 100 dB	~ 60 sone
Hearing damage at long-term exposition	0,63 Pa	>90 dB	~ 32 sone
Main road at 10m	0,2 - 0,63 Pa	80 - 90 dB	~ 16 - 32 sone
Car at 10m	0,02 - 0,2 Pa	60 - 80 dB	~ 4 - 16 sone
TV at 1m normal loudness	0,02 Pa	~ 60 dB	~ 4 sone
Normal conversation at 1m	$2 \cdot 10^{-3}$ - $6,3 \cdot 10^{-3}$ Pa	40 - 50 dB	~ 1 - 2 sone
Quiet room	$2 \cdot 10^{-4}$ - $6,3 \cdot 10^{-4}$ Pa	20 - 30 dB	~ 0,15 - 0,4 sone
Silent breathing	$6,3 \cdot 10^{-5}$ Pa	10 dB	~ 0,02 sone
Hearing threshold at 2 kHz	$2 \cdot 10^{-5}$ Pa	0 dB	0 sone

Measurements with low noise devices

Many some measurements include analysis of low noise devices (e.g. beamer, notebooks etc.). The normal measurement distance is 1m. You can only perform a reliable measurement if the signal level is above the noise. The noise includes acoustic noise from the environment and noise in the measurement chain from the microphone or preamplifier. In a normal office environment at a quiet noise level of 45dBA it is impossible to analyze a fan with 25dBA. Since the human ear is very sensitive, such measurements require high quality measurement equipment.

For every measurement, we strongly recommend to measure the quiet noise first. Simply switch off the measurement device. The optimum measurement environment is a special anechoic chamber, which reduces reflections and noise from outside. We strongly recommend switching off noise sources if possible (windows, air-condition, computers etc.)

Many measurement microphones have a sensitivity of 30dB, which defines the lower bound for measurements. We offer USB measurement microphones down to 16dB(A). Our Lab is equipped with an ultra low noise measurement system from G.R.A.S. which goes down to 6dB(A). You can improve the measurement sensitivity by reducing the measurement distance from 1m to e.g. 25cm. This increases the signal level by 12dB. This offset can be corrected with a different calibration factor, which allows Akulap to show the measurements results with respect to 1m.

We will explain this with an example.

By reducing the distance to the half, the level increases by 6dB. With a distance of 25cm the correction factor is 12dB. If you use a sound level calibrator with 94dB, the reference level has to set to 82dB. A sound level of 82dB will be displayed as 94dB. This approximation is only valid in the far-field with spherical radiation. In the near-field you will encounter e.g. diffraction, which has significant influence on the signal level. Therefore, we strongly recommend documenting this different measurement distance clearly, because it is difficult to compare different measurement distances.

Procedure

With Akulap you can perform a loudness measurements in three different modes.

1. Live mode: all measurement values are displayed in real-time
2. Analysis mode: Calculate the loudness from manual selections of an Akulap noise measurement
3. Report mode: Create an loudness report automatically.

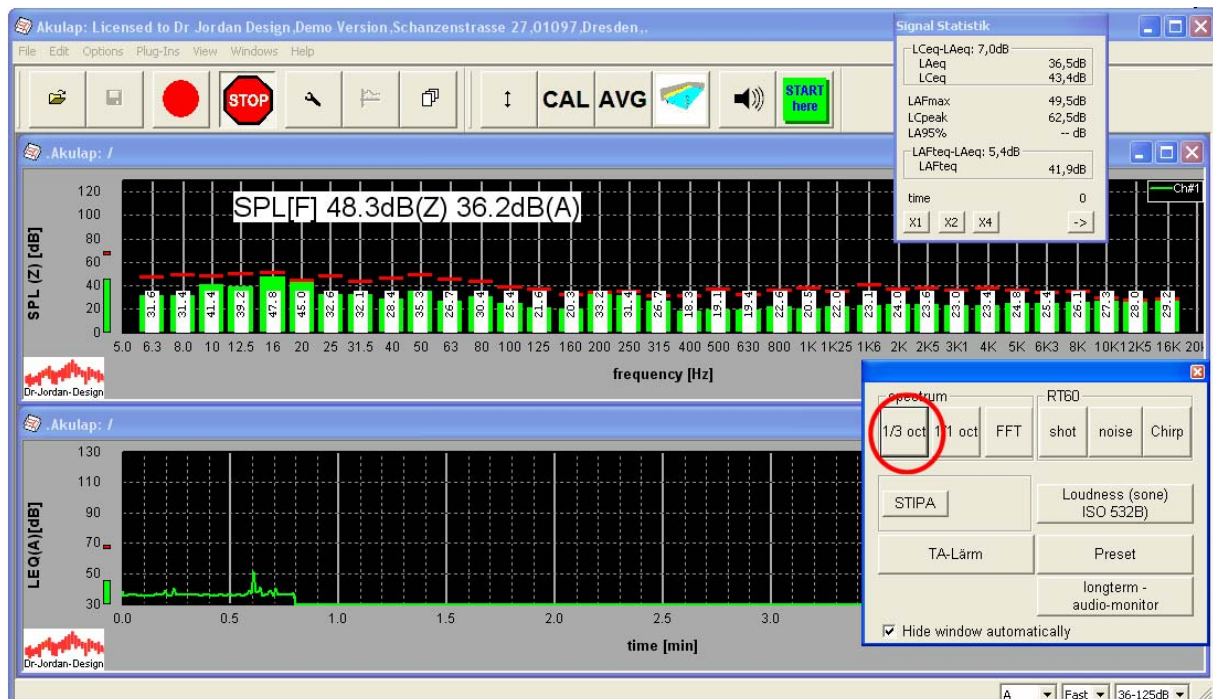
With the automatic measurement many parameters are checked for plausibility to reduce possible sources of error. In addition, you can enter a reduced measurement distance directly. We recommend using the live measurement, if the setup is already verified and optimized and you need a quick measurement.

Live measurement

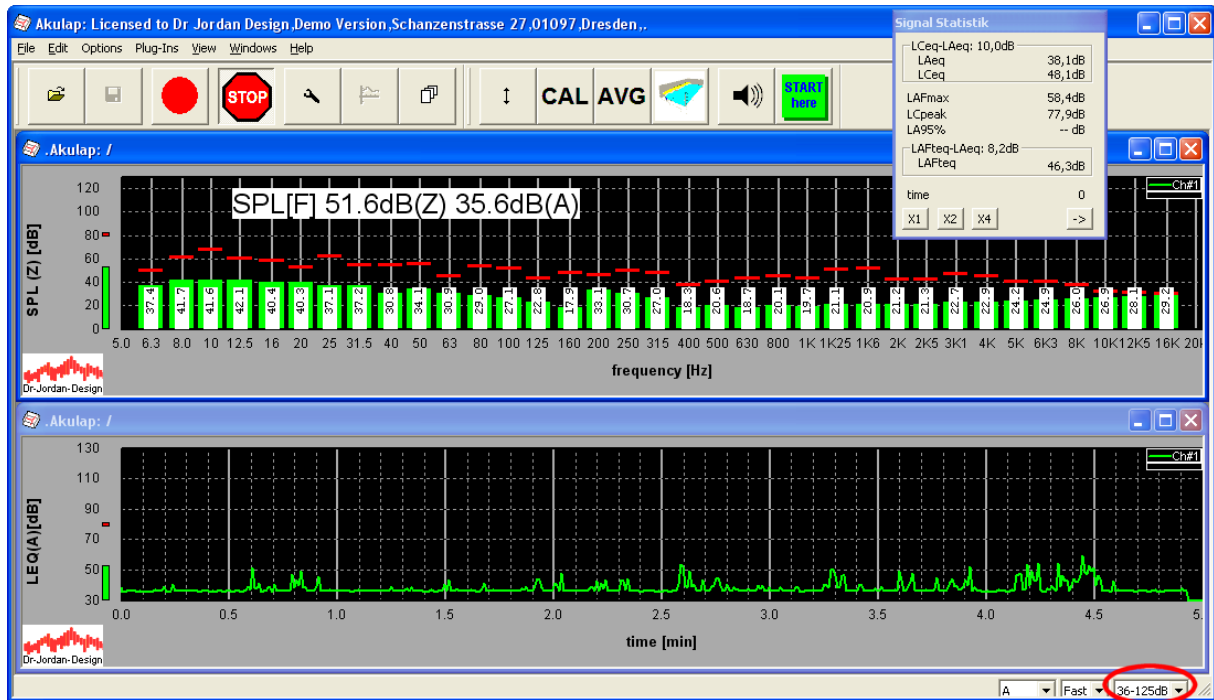
For a live measurement you have to perform the following steps

- Start the 1/3-octave RTA
- Activate the sone measurement
- Apply the measurement microphone to the device under test.

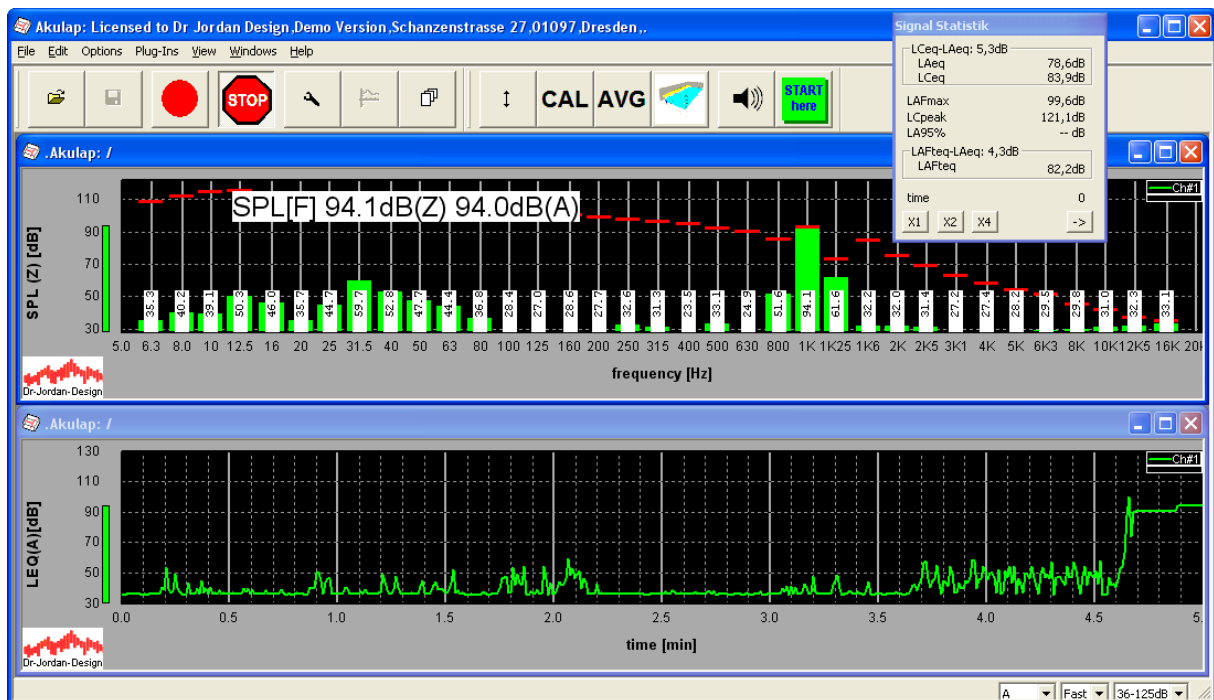
Start Akulap with its default settings and activate the 1/3 octave RTA.



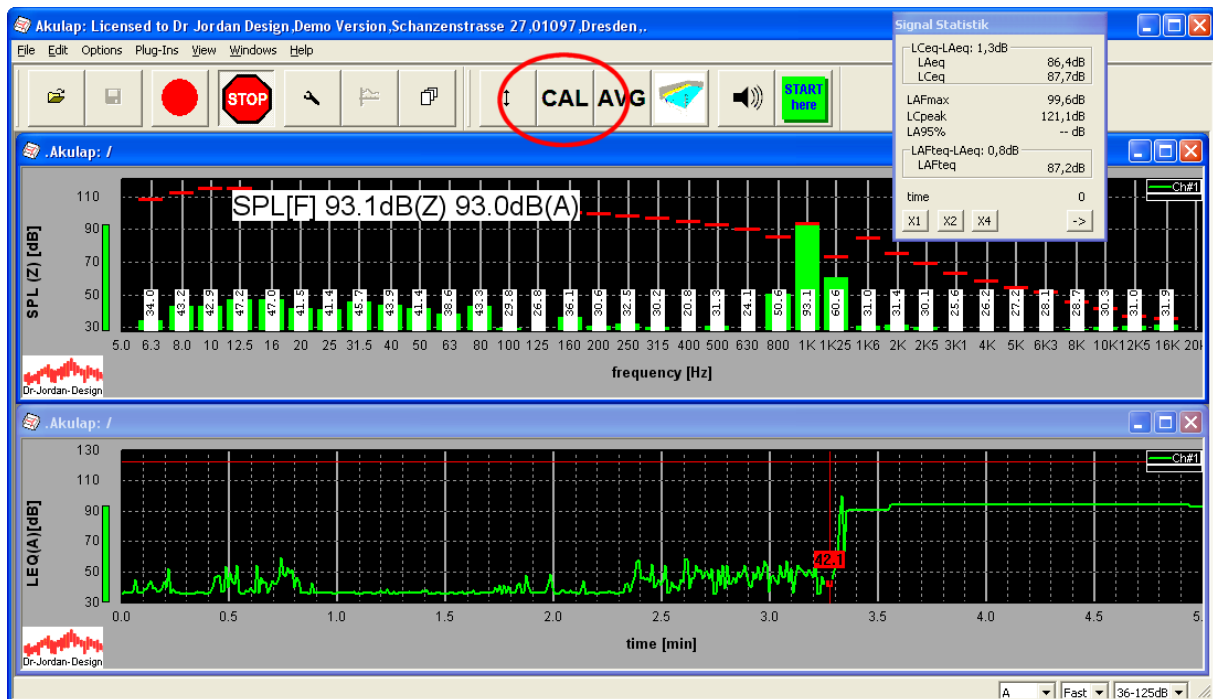
First, select an appropriate measurement range.



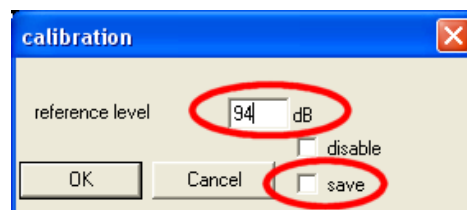
Verify the calibration by putting a sound level calibrator on top of the microphone. In this example, we use a calibrator with 94dB.



If you see a different level, please use the calibration feature.

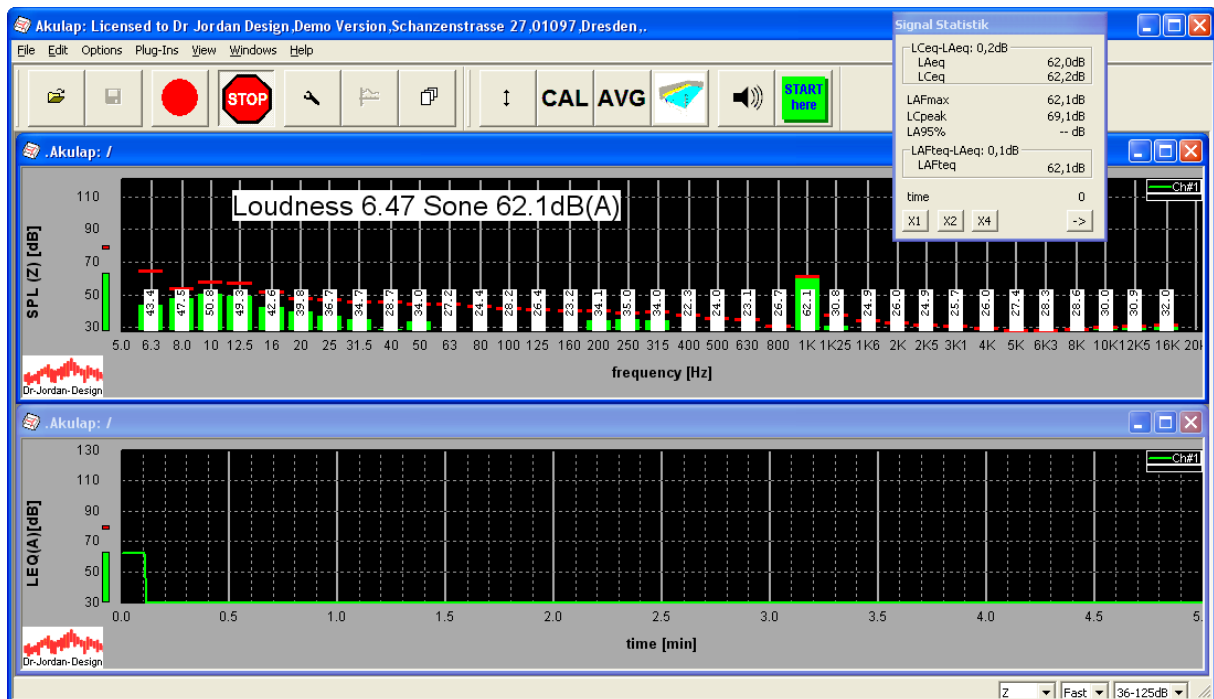


If the level difference is more than 2dB, please check your setup. Such a large level difference is very rare.

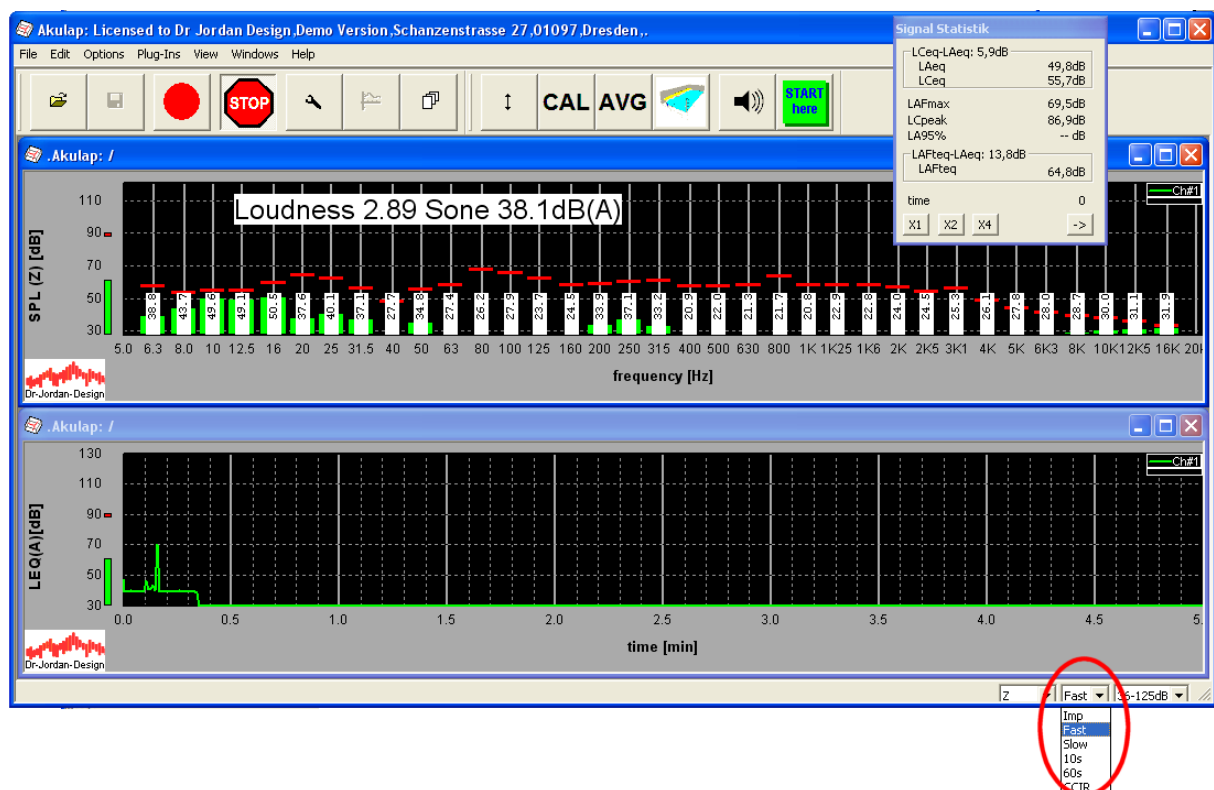


Enter the reference level of your calibrator (typically 94 or 114dB). If the calibration looks reasonable, you can save the calibration permanently.

Finally, start the sone measurement with plug-ins->loudness (Sone) from the menu.



Place the microphone near the device under test. The default measurement distance is 1m. Please ensure that the signal level is significantly above the noise level.

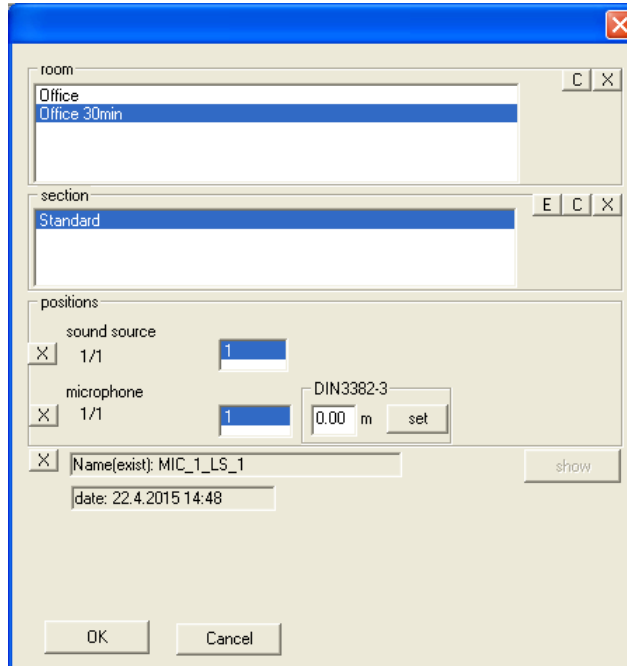


If the signal shows strong fluctuations, you can apply averaging. Simply select a different time constant.

Analysis mode

First you need to perform a calibrated noise measurement. Please refer to the Akulap noise measurement user manual.

In this example we load a 30 minutes measurement. The upper windows shows the average 1/3 octave level. The bottom window shows the sound level versus time.



room

Office
Office 30min

section

Standard

positions

sound source
1/1 1

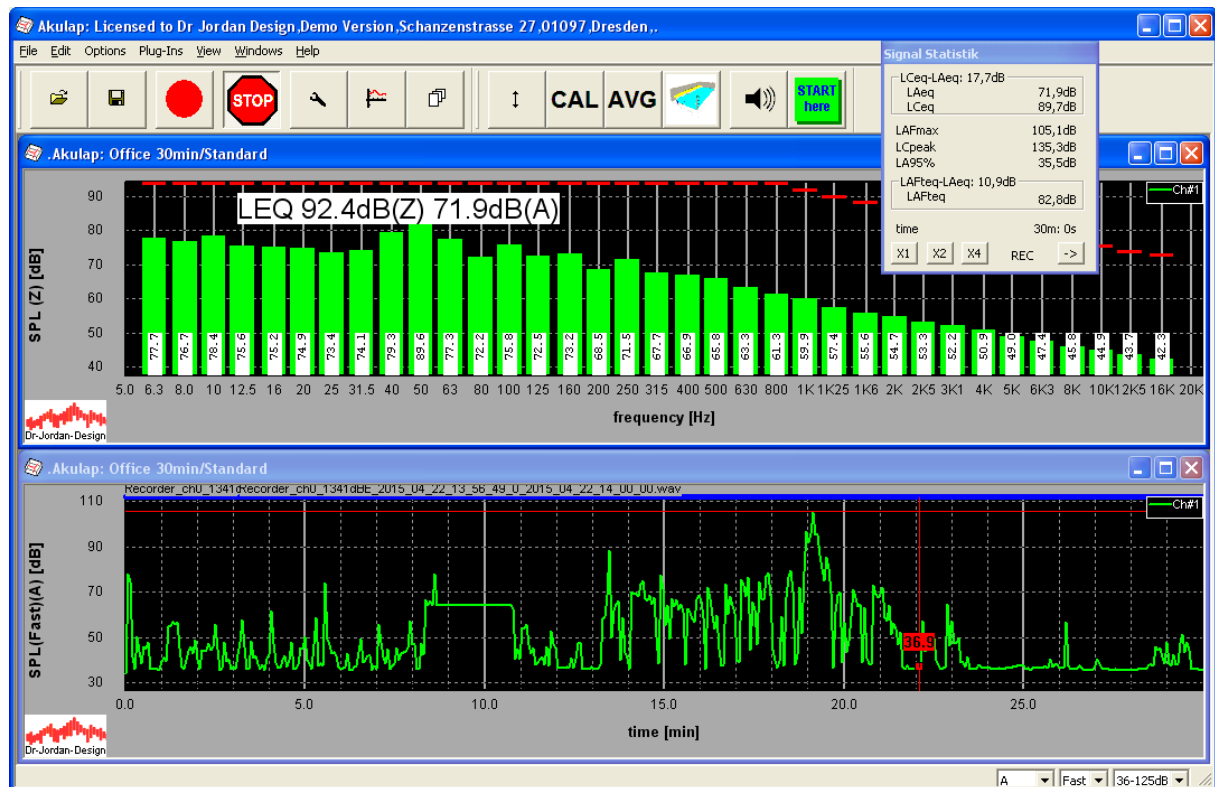
microphone
1/1 1

DIN3382-3
0.00 m set

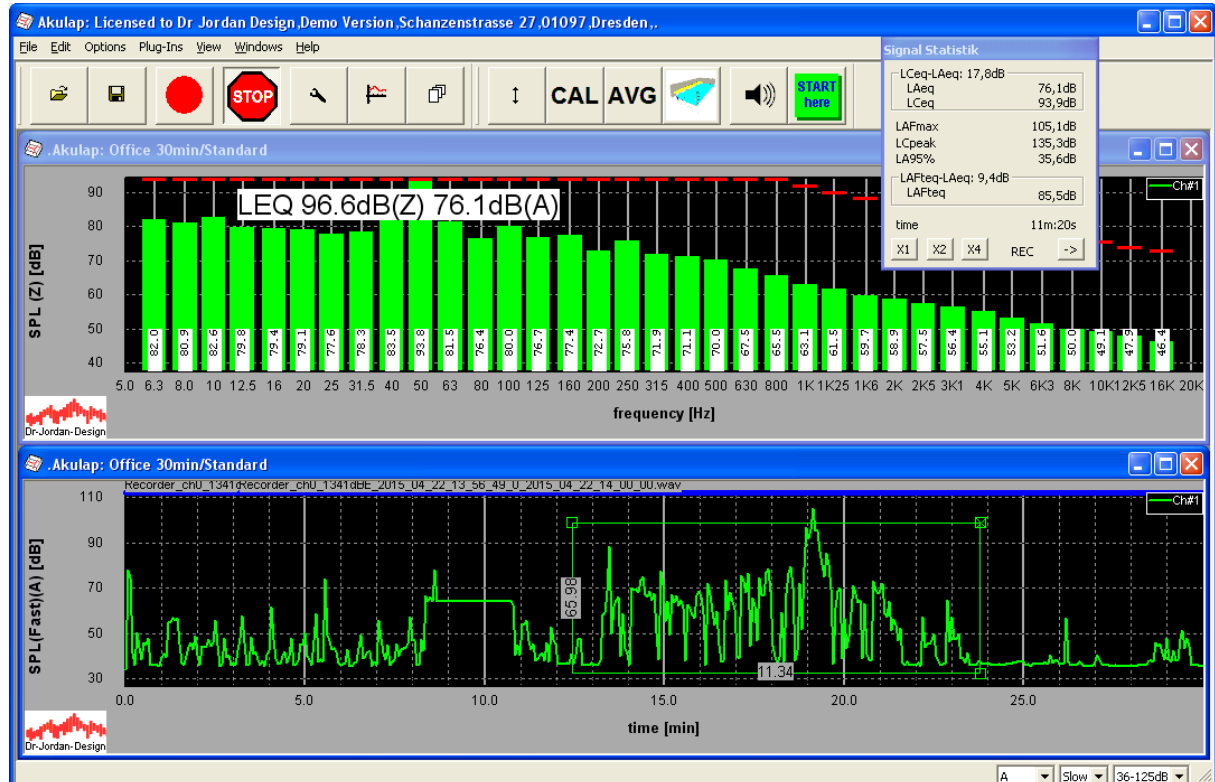
Name(exist): MIC_1_LS_1 show

date: 22.4.2015 14:48

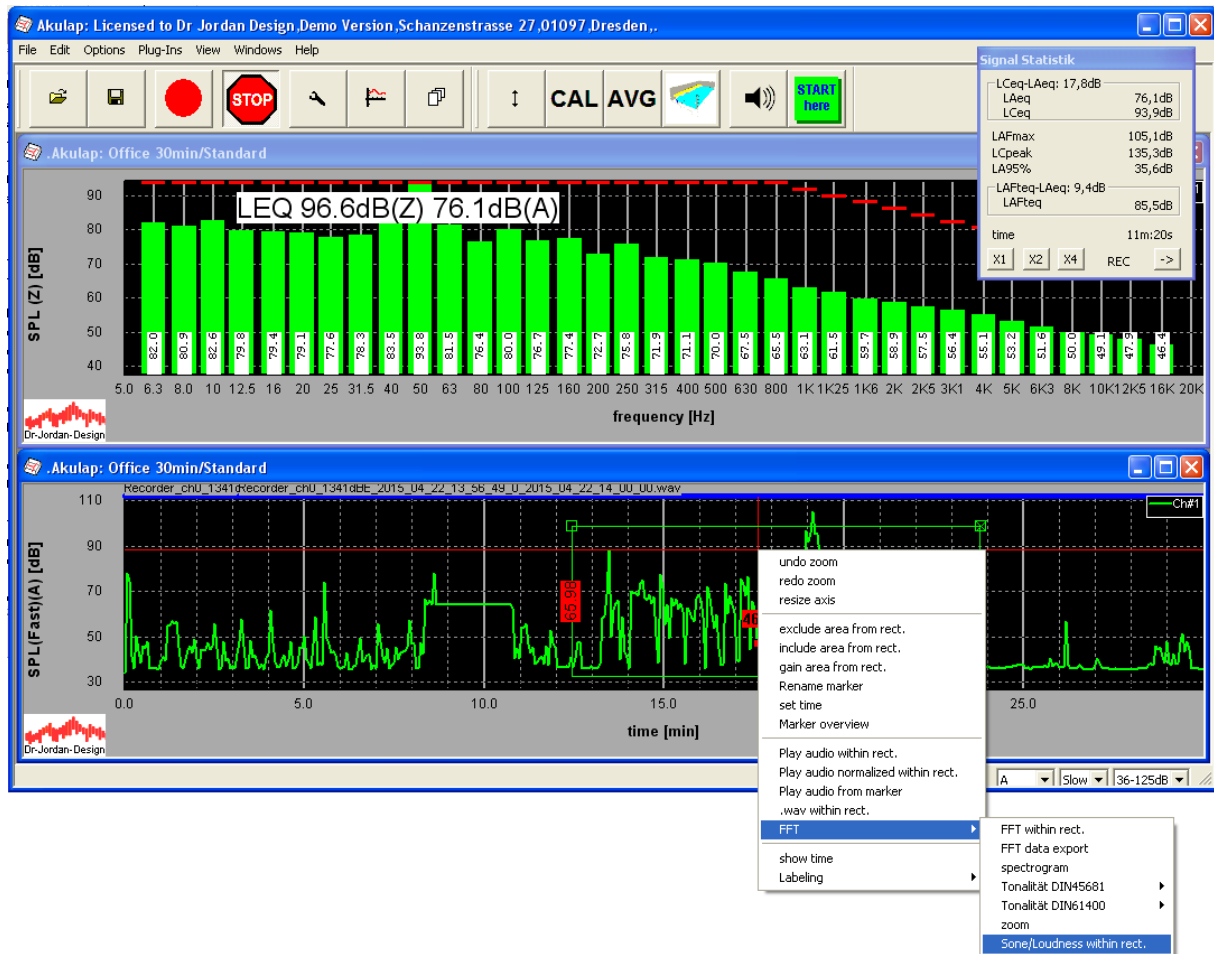
OK Cancel



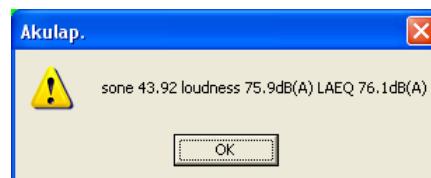
In the bottom window double click left with the mouse to set a measurement rectangle.



Resize it with the small squares to the desired position and duration. In this example we set a selection of 11min and 34s. Right click with the mouse to open the context menu.



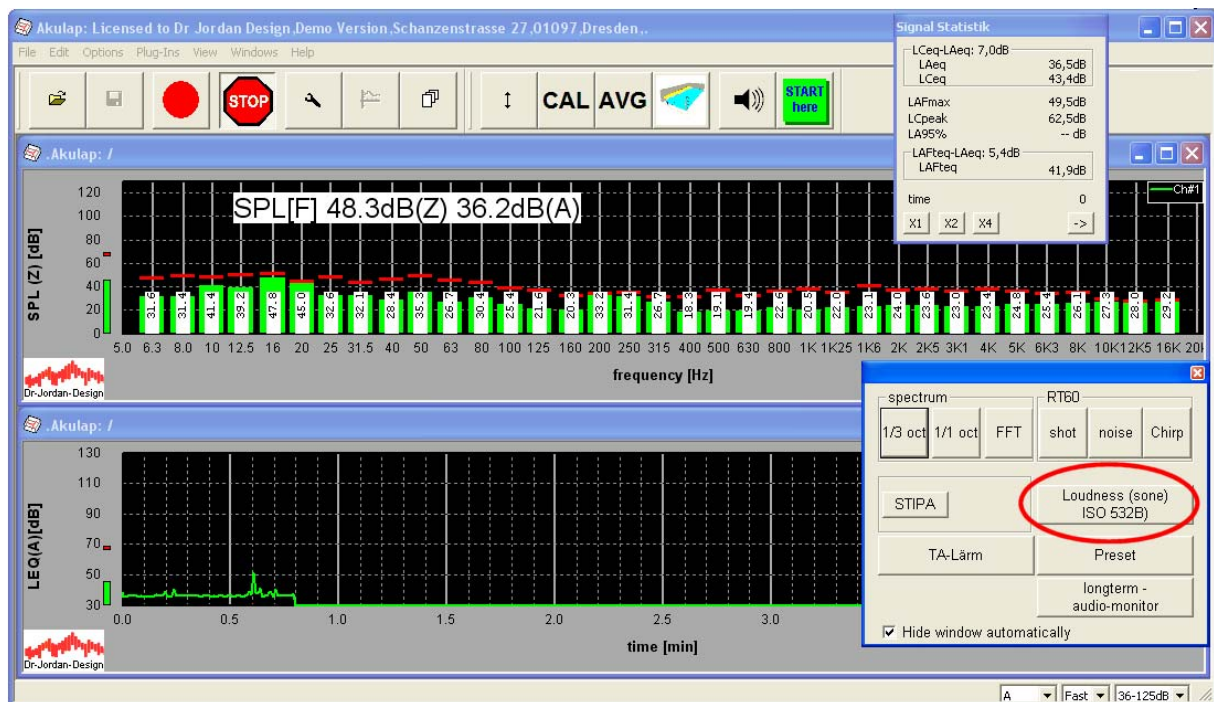
This window shows the average loudness of the selection.

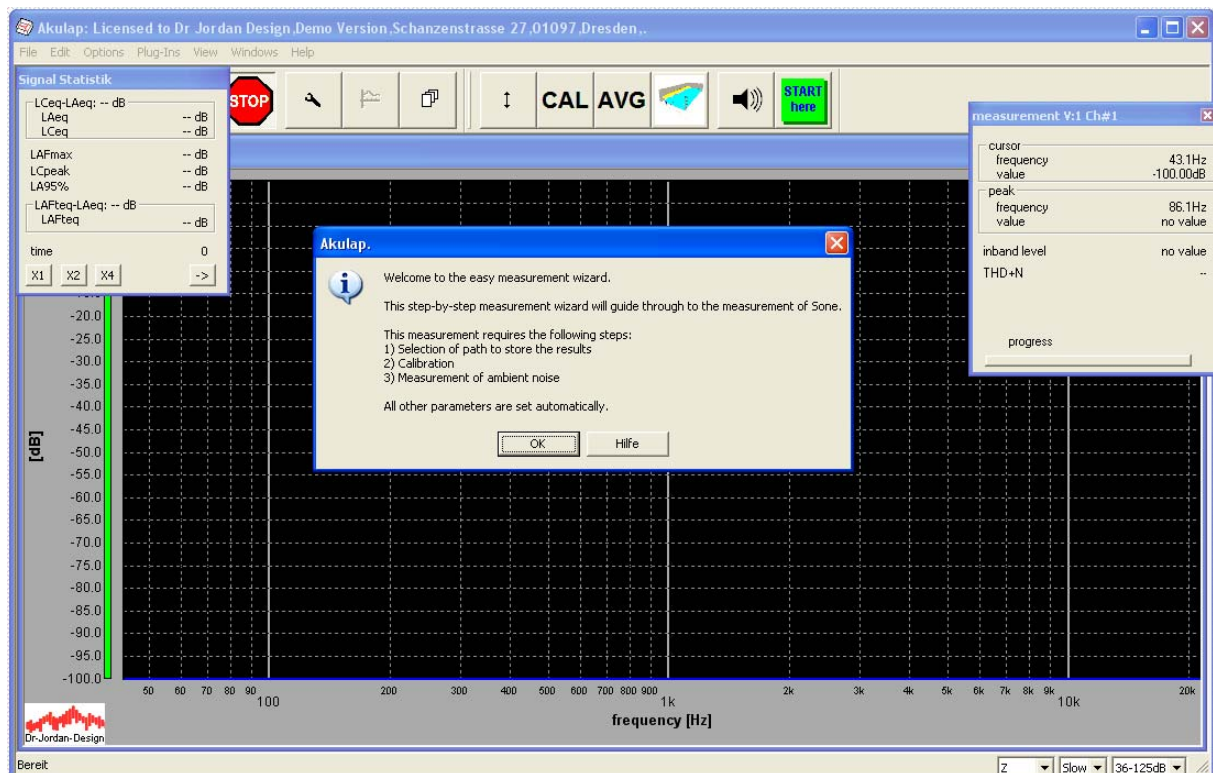


Automatic measurement

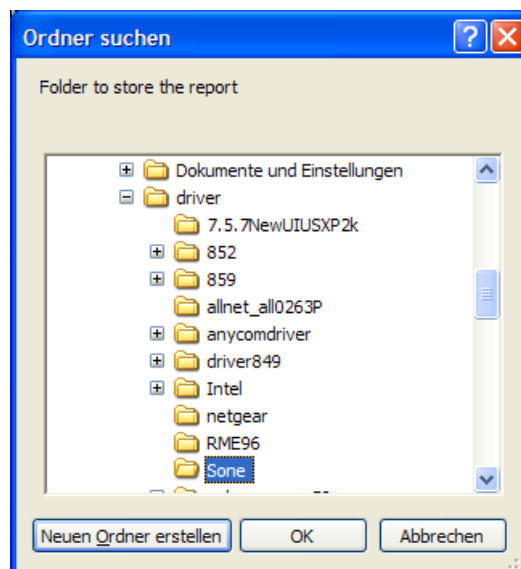
The automatic measurement wizard guides you through all steps. The final results are stored in a comprehensive report.

Start the measurement with Easy Measurements->Sone/Loudness from the menu.

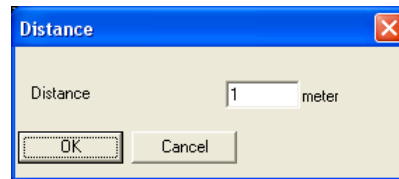




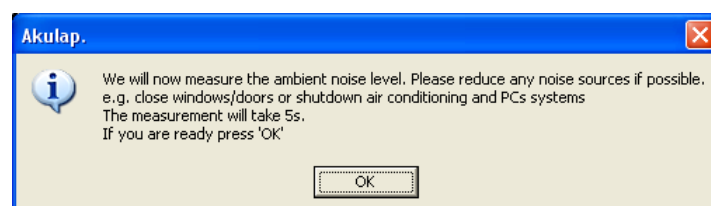
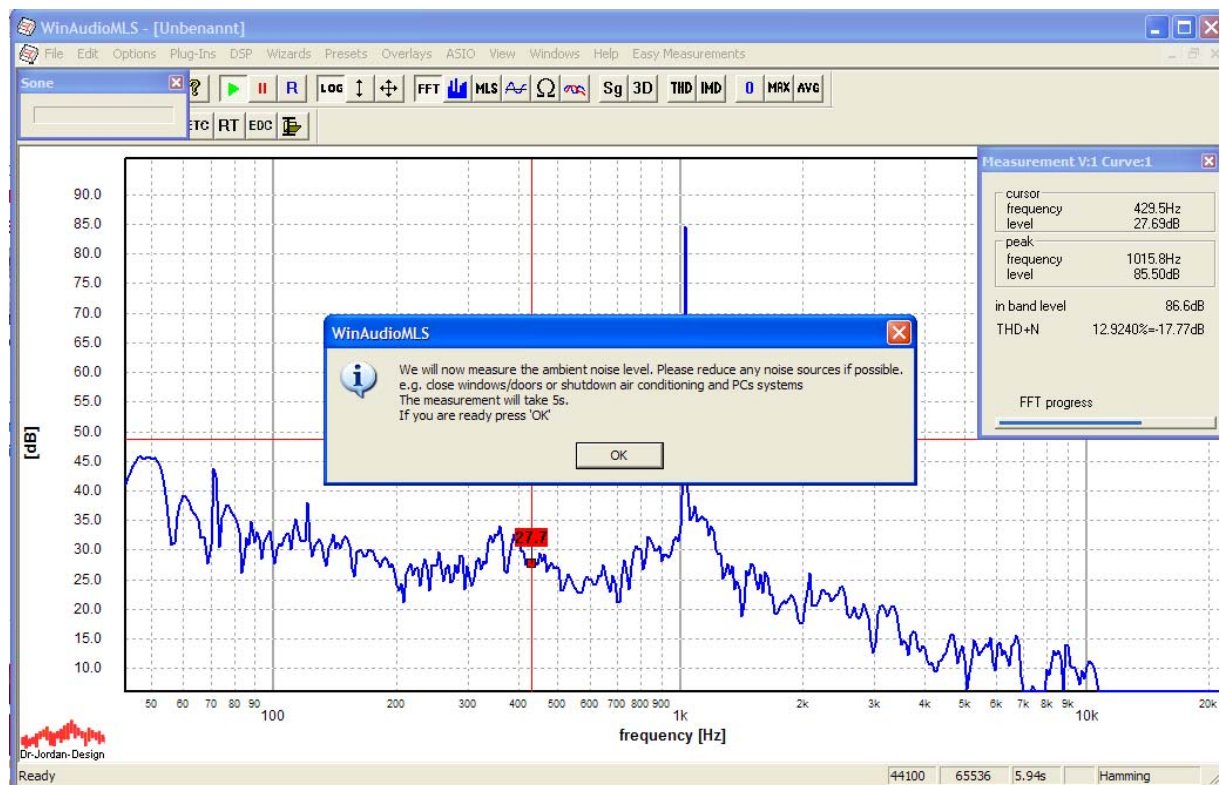
Select a folder, where the results will be stored.



In the next step enter the measurement distance. All results are converted to a reference distance of 1m.



By using the automatic measurement, Akulap automatically measures the quiet noise. This ensures that the signal level is significantly above the quiet level. Switch off the calibrator, any noise sources and the device under test.



In the final step, switch on the device under test and confirm it in the dialog box.



All measurement results are written to a HTML-report. You can view it with any browser, print it or convert it to PDF. If the measurement has finished, your default browser will open the report automatically.

The following screenshots show an example of such report.

