

Analyzing keyboard noises

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Introduction

Noise emitted by a computer (desktop PC or laptop) has many sources. First of all, fans are required to dissipate heat generated by the computer; they generate noise. Furthermore, the hard disk drive emits noise both in idle mode and when reading or writing data, which may lead in some cases to complaints by customers. Other sources of noise from computers are input devices, such as the keyboard and mouse. These noises, too, can be found very annoying by the user or other persons nearby.

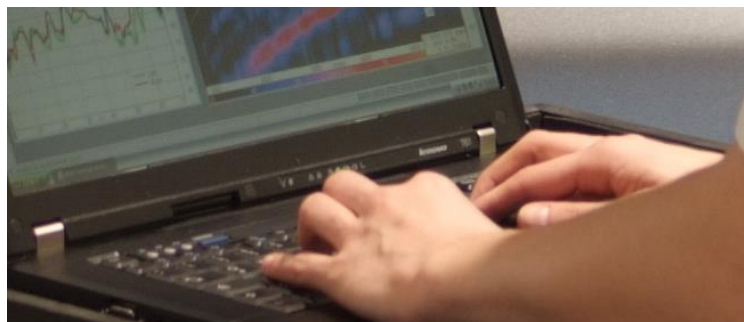
For the user, the tactile characteristics of a keyboard are the foremost aspect when assessing its quality. To ensure precise handling (e.g., to avoid accidental double key presses or slurring adjacent keys), the key actuation pressure and the key drop both to the contact depth and later in the travel to the end-of-travel point or pressure point must be optimally matched. Furthermore, the keys should have a distinct pressure point (end-of-travel). The total key drop is strongly affected by the type of keyboard. The slim design and limited space of a laptop only allows for a short key drop. Desktop keyboards, on the other hand, can be built with a longer key drop. The user's individual preferences regarding key drop and pressure point are also influenced by the area of application. People writing a lot of text often prefer a different type of keyboard than people using their computers mostly for gaming.

Besides the individual preferences regarding the tactile characteristics, users also pay attention to the sound of a keyboard. By no means should it be too loud, in order for the noise not to be perceived as annoying. However, since the user deliberately triggers the action that causes the noise, he or she is initially less likely to perceive the noise as unpleasant as an uninvolved person (e.g., on a plane or train, where some people are working, i.e., typing, while other passengers wish to relax). Likewise, in an open-plan office where several people are typing simultaneously, an unnecessary high noise level can be generated, which could be avoided by using low-noise keyboards with a good sound quality.

The noise from a keyboard is influenced, for example, by its type. A keyboard with a long key drop and a hard pressure point will usually produce a "harder" sound ("clattering") than a laptop keyboard with a short key drop and a soft pressure point. To provide users with the desired acoustic feedback, laptops with special keyboards for frequent writers are offered. While not having a very long key drop, they feature a very distinct pressure point. Such keyboards can produce a comparatively loud noise.

Besides the type of keyboard, the materials used to build it also affect the resulting noise.

This Application Note presents suitable recording methods and analysis functions for examining keyboard noise.



Recording keyboard noises

For recording keyboard noises, several approaches are possible. A simple and cost-effective possibility is to record the sound with a single measurement microphone. Such a setup can be easily reproduced, making it easy to compare the sounds from different keyboard models.

Another method, which better adapts the human hearing sensation, is to record the noise with an artificial head measurement system. With suitable specifications for the measurement setup, an artificial head can be positioned quickly and reproducibly as well.



Figure 1: Artificial head measurement system HMS IV

Furthermore, this kind of recording allows the sounds to be archived in a way that allows them to be played back in an aurally accurate way at any time. Even when the keyboard is no longer at hand, its sound can still be retrieved and compared with other recordings at any time. In addition, sounds recorded with an artificial head can also be used to define target sounds. This is done by applying digital filters to the recorded sounds in order to develop new keyboard sounds. These sounds can then be played back binaurally and authentically in jury tests in order to determine the perceived sound quality and to validate target sounds.

With both recording methods, it is important to select a sufficient measurement range in order to make full use of the dynamic range of the recording system, thus ensuring that the keyboard sound is not covered by the inherent noise of the recording system. Furthermore, the distance between the keyboard and the microphones of the artificial head must always be identical in order to be sure that different signal levels are caused by differences between the keyboards and not by variations in the measurement setup.

Keyboards have very different types of keys. Besides the keys for letters and numbers, there are also large keys such as the space bar or the return key. These keys have different mechanics adapted to their larger area and therefore produce a different sound. In addition, these special keys are usually pressed in a different way by the user. For example, unlike other keys, the space bar is often pressed with the thumb, and the return key is sometimes pressed with several fingers. Both can cause louder noise when typing. In order to analyze the keyboard noise properly, the way the keys are struck must be reproducible.

Of course, all other measurement conditions (e.g., the size and acoustic properties of the room, background noise) must be identical as well. Only if all relevant conditions are consistent, it can be assured that during the subsequent playback the differences between the keyboards are evaluated rather than different measurement conditions.

Analyzing keyboard noises

In the example shown below, the sound of three laptop keyboards from different manufacturers have been compared. In addition, the sound of an older desktop keyboard with a relatively long key drop was recorded for comparison. The recordings were made with an HMS IV artificial head measurement system from HEAD acoustics.

This Application Note focuses on the analysis of individual keystrokes on one letter key per keyboard. However, the analysis results should not be generalized, as in real life, more than a single key is pressed. Besides single letter keystrokes as in this example, a comprehensive examination of keyboard noises must also include the analysis of multiple keystrokes as well as special keys such as the space bar or the return key. But to allow for an easy comparison of the analysis results and to facilitate their interpretation, the following diagrams show useful analysis functions and configurations for individual keystrokes only.

Furthermore, for a better overview, only one channel of the artificial head measurement is examined. For an aurally accurate playback, it is of course necessary to play both channels.

Sound pressure level vs. time analysis

The sound pressure level vs. time analysis in figure 2 shows that, as expected, the desktop keyboard (blue) produces a much higher sound pressure level than the laptop keyboards. But there are differences between the laptop keyboards, too. The second laptop (red) produces a lower level compared to the two other keyboards. Furthermore, it can be seen that all keys produce a second level peak approximately 0.1 s after the maximum level. This second peak is caused by the key returning to its idle position. However, the second peak only becomes visible if a sufficiently short time constant is used for the time weighting of the analysis (the default **Fast** time weighting, 125 milliseconds, is inappropriate). For the calculation shown in figure 2, a time constant of 2 ms has been selected. This is roughly the time resolution of human hearing.

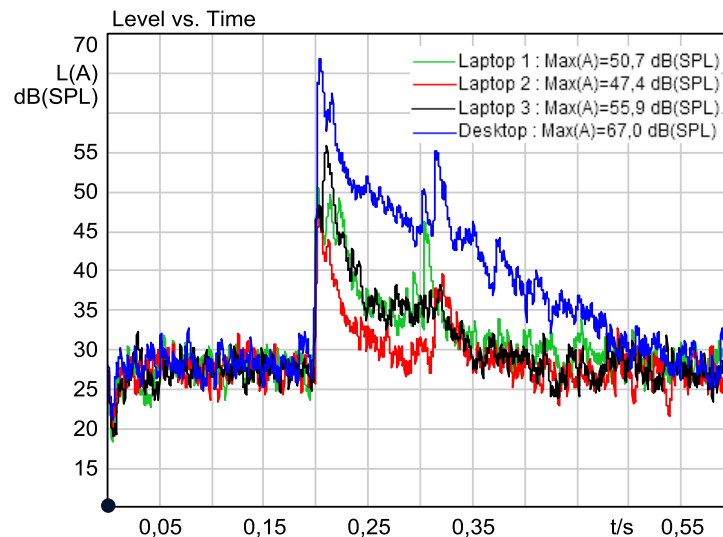


Figure 2: Sound pressure level analysis of keyboard noises (time weighting: 2 ms)

The second level peak is different for each keyboard. On the first laptop (green), it is almost as high as the first peak (due to a hard return stop). On the second laptop (red), the second peak is about 5 dB lower, whereas on the third laptop (black), the secondary peak is hardly recognizable at all (soft return stop).

Loudness vs. time

Another analysis suitable for examining keyboard noises is the loudness vs. time analysis. This analysis shows the psychoacoustic quantity called loudness as a function of time. Loudness represents the human perception of sound volume on a linear scale, i.e., a doubled loudness value means that a person would perceive the sound as twice as loud.

The diagram in figure 3 shows the results of the loudness calculations of the four keyboards. The loudness analysis illustrates that the noise of the desktop keyboard is perceived as more than twice as loud as that of the other keyboards.

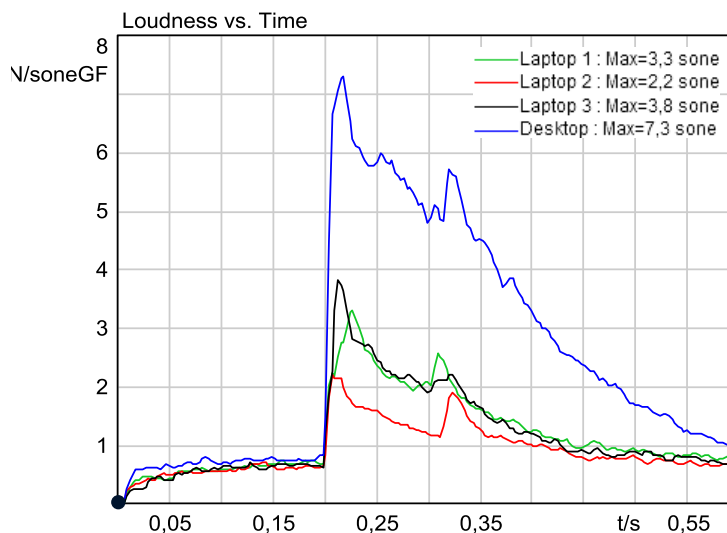


Figure 3: Loudness analysis of keyboard noises

Sharpness vs. time

The keyboard noises not only differ in their loudness, but also in other acoustic characteristics. The sharpness analysis determines the ratio between the loudness of high-frequency signal components and the total loudness of the signal. Sounds with a high sharpness contain a large portion of high frequencies and are usually perceived as unpleasant. Figure 4 shows the sharpness curve of the four keyboard noises versus time.

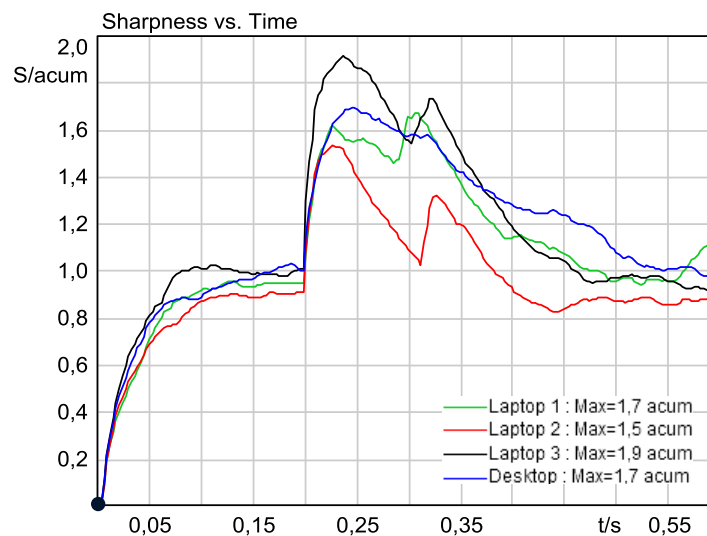


Figure 4: Sharpness curves of keyboard noises

The analysis shows that the third laptop keyboard and the desktop keyboard produce higher sharpness values than the two other keyboards. It can also be seen that the keyboards 1 and 3, while having similar loudness values, strongly differ in their sharpness. This delivers a possible explanation as to why the sound of the third keyboard, as revealed by a jury test, is perceived as more unpleasant than the first keyboard, even though both keyboards have almost the same loudness value. The difference in the subjects' judgments may be caused by the different spectral distribution that makes the third keyboard sound sharper than the first one.

Sound design by means of Playback Filters

The Playback Filters in the Mark Analyzer of ArtemiS SUITE¹ allows recorded sounds to be modified in order to obtain a better, or the desired, sound impression. Since the modifications can be heard immediately and are also visualized in the diagram, the effect can be verified directly. This allows modifications to be performed virtually at first, so the new sound can be assessed in a jury test before making expensive and time-consuming hardware modifications to the actual keyboard.

Several analyses can be used as a basis for such sound design. In the following example, the time-dependent wavelet analysis is used, since it examines the signal both in the time domain and the frequency domain simultaneously and with a high resolution. This is particularly essential for fast-changing signals such as keyboard noises.

Once the Mark Analyzer has calculated the desired analysis, the Playback Filters can be activated by clicking on the  button (see figure 5).

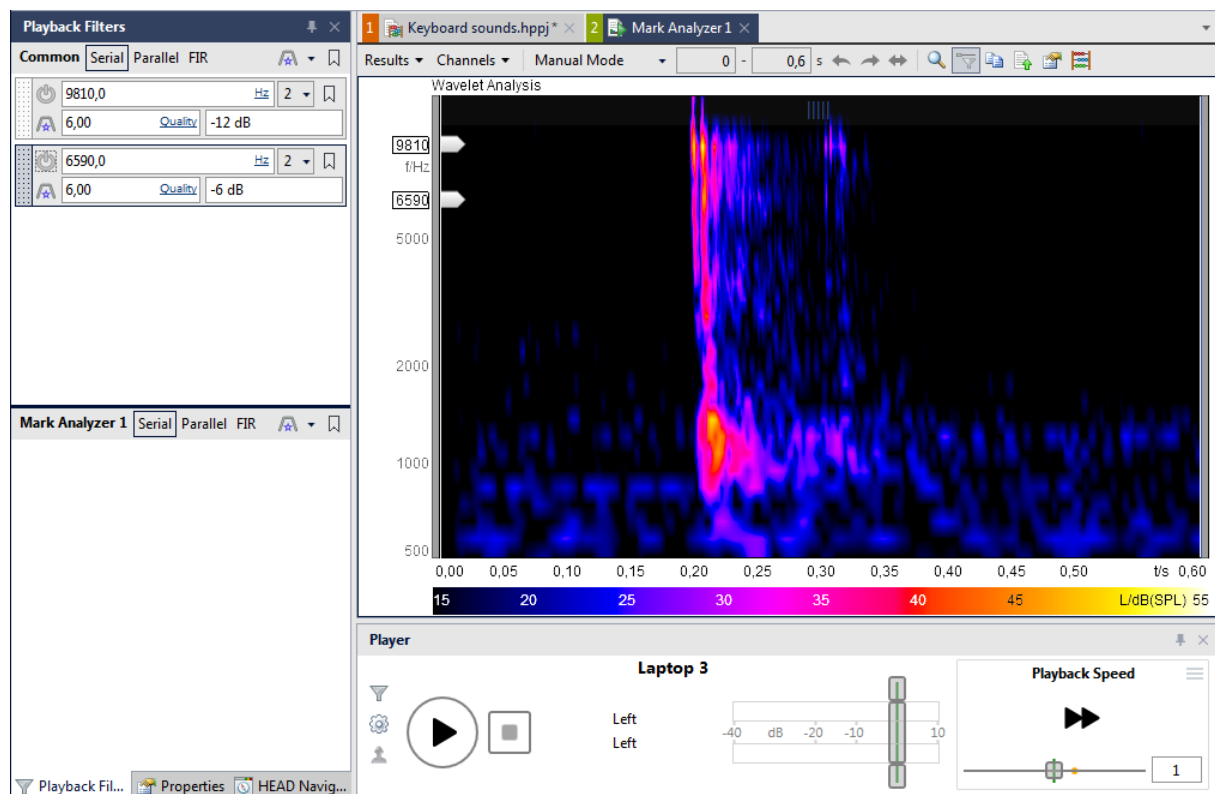


Figure 5: User interface of ArtemiS SUITE with Playback Filters and activated filter cursor

¹ The descriptions in this Application Note refer to ArtemiS SUITE 9.0. The general procedures also apply to other versions. However, the scope of functionality and the user interface may differ.

Subsequently, the sound of the third laptop is optimized via filters. As determined in the previous section, this sound has a higher sharpness value than the other laptop keyboards, i.e., the sound is dominated by high frequencies.

With the Playback Filters, the high frequencies can be reduced. The attenuation of the filters can be adjusted in the properties window. Different degrees of attenuation can be tested, allowing the enhancement of the sound characteristics to be assessed in relation to the effort required to modify the hardware accordingly.

Figure 6 shows the wavelet analysis of the left channel of the third laptop keyboard. The left diagram shows the unfiltered sound, the right one shows the filtered sound. Two filters were applied: a parametric band-stop at 9807 Hz with an attenuation of 12 dB and another parametric band-stop at 6592 Hz with an attenuation of 6 dB.

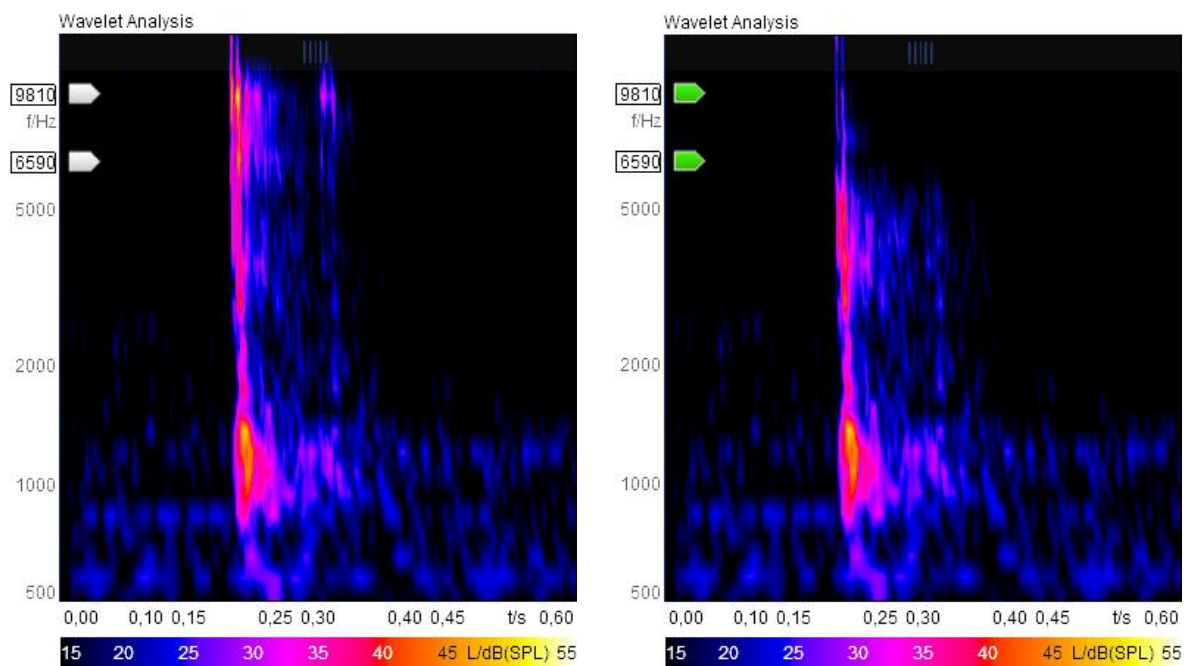


Figure 6: Wavelet analysis of the unfiltered (left) and the filtered (right) left channel of the third laptop sound

The sound quality is improved by the attenuation of high frequencies. This is clearly shown by the differences in the sharpness analysis in figure 7 (black: unfiltered signal, magenta: filtered signal).

Instead of the Playback Filtering you can also use the Sound Engineering Project of ArtemiS SUITE for improving the sound quality. This project provides you with an even more extensive toolkit for filtering your recordings interactively, optimizing the sound quality of your sounds and for creating target sounds, e.g. for jury testing. You can find a detailed description of the possible applications in the Help System of ArtemiS SUITE.

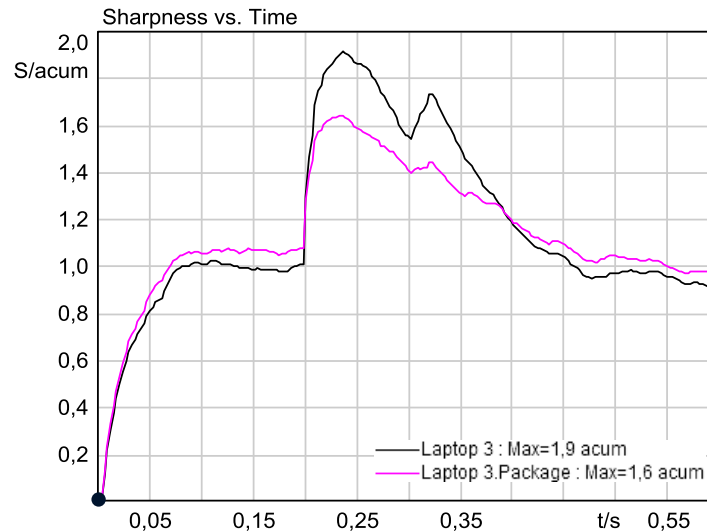


Figure 7: Sharpness analysis of the unfiltered (blue) and filtered (magenta) left channel of the third laptop sound

Summary

ArtemiS SUITE offers analyses and tools that allow the sound quality of keyboard noises to be examined and optimized. Even basic analyses, such as **Level vs. Time**, **Loudness vs. Time** and **Sharpness vs. Time**, already deliver valuable hints as to what is good about a sound and what can be improved. Furthermore, the analysis and sound design functions employing real-time filters or the Sound Engineering Project allow the required optimization measures to be narrowed down and quantified (e.g., which reduction of high frequencies leads to which improvement of the sound).

Note

ArtemiS SUITE is a modular application. Thus you only need to purchase the modules you really require for your individual tasks. For calculating the analyses presented in this Application Note by means of a Pool Project, you need the following ArtemiS SUITE modules: **ASM 00** Basic Framework (code 5000), **ASM 01** Basic Analysis Module (code 5001). Moreover, you will need **ASM 11** Advanced Playback Module (Code 5011) for employing Playback Filters, **ASM 12** Psychoacoustics Module (Code 5012) for The analyses *Loudness vs. Time* and *Sharpness vs. Time*, **ASM 17** Advanced Analysis Module (Code 5017) for the Wavelet analysis and **ASM 19** Advanced Filters Module (Code 5019), if you want to execute the sound optimization by means of the Sound Engineering Project. If you want to calculate other analyses, you may need other modules. Your HEAD acoustics representative will gladly provide you with further information.

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We look forward to receiving your response!