Phonak Insight

# Spice+ Signal Processing

## Hearing delight from the start

Once digital hearing systems became established at the end of the 1990s, the open-platform principle was introduced as an innovative concept, in contrast to the hard-wired systems (Latzel, 2001). Unlike the hard-wired systems, this concept makes use of freely programmable DSPs (digital signal processors) that offer more flexibility for hearing care professionals and manufacturers. Reprogramming the DSP made it possible not only to adapt the individual parameters of an algorithm to the individual requirements of a person hard of hearing, but also to rework the entire algorithm.
Earlier, the algorithms increased in line with the demands for new hardware, which meant that new algorithms also required new signal processors on which to operate them. This meant that the benefits of the open-platform system could never be fully brought into play.

For the first time, Spice+ Processing makes use of the open-platform principle in its true sense. By simply reprogramming the DSP and thus updating the hearing system, a new hearing system is created, based on algorithms that differ significantly from those of the original Spice generation. These changes involve far more than mere adaptation of the algorithm parameter, as the core of some algorithms has been revised. The technical and audiological background to Spice+ is outlined in detail below.

The Phonak processing philosophy has always involved natural response and good sound quality, with the best possible speech clarity.

In developing Spice, the engineers mainly focused on the performance of the hearing systems in acoustically difficult environments such as the classic cocktail party situation. This resulted in special features such as StereoZoom, auto ZoomControl and UltraZoom, which have proven to offer very good speech comprehensibility and impressive sound quality in a noisy environment.

The aim of the Spice+ research was to achieve a similarly high level, even in calm acoustic situations. The following scenarios, for example, would be placed in the "calm situations" category: A quiet conversation without any background noise, a quiet conversation in a slightly noisy environment (a hissing fan noise, such as from an air-conditioning unit, etc.), as might be experienced during a business meeting or a lecture, reading the newspaper with or without music from the radio or a ticking clock in the background in the living room, walking in the forest with the leaves gently fluttering.
It is easy to see that the "calm situations" category is far more heterogeneous than it might first appear. The idea behind the innovative algorithm that forms part of Spice+ Processing is to automatically provide the optimal setting and the best performance for the various "calm situations".

### Expansion

The response and thus the output of a hearing system are mainly characterised by their electro-acoustic components, the filter bank and the input/output gain curve. If the microphone, receiver and filter bank are regarded as given, it is the dynamic behaviour of the amplifier that mainly determines the perceived sound quality of the hearing aid. The dynamic behaviour of the amplifier is determined by the response curve (input/output curve) and the time constants of the system. As is widely known, the response curve can be divided into 4 ranges (Figure 1): Expansion, linear section, compression (AGC) and limitation.

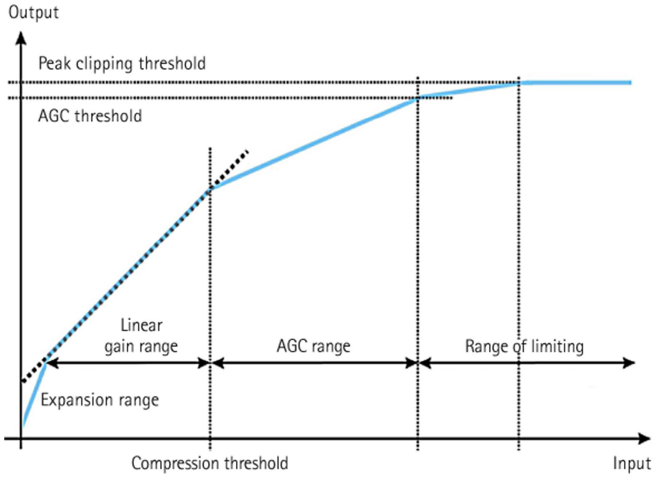


**Figure 1**: Response curve (output against input) for a typical amplifier with four ranges, integrated into a hearing system: Expansion, linear, compression, limitation (*Source* Hörakustik - Theorie und Praxis: Hoffmann and Ulrich, 2007)

It is mainly the expansion range that is relevant for processing calm situations; this also plays a special role in Spice+ signal processing.

Expansion is the opposite of compression, i.e. gain is reduced as the input drops. Expansion is also known as (soft) squelch and is, for example, used in radio technology to suppress constant background noise. Expansion is also very effectively used in many hearing aids to reduce the audibility of input signals at a very low level (Dillon, 2001). This generally relates to the internal noise of the hearing system, primarily caused by the installed electret microphone.

Three parameters can be used to adjust expansion: threshold kneepoint (TK), slope and time constants. The correct parameterisation of expansion represents a major challenge to the manufacturer, in endeavouring to ensure that only undesirable soft input signals are filtered out. Manufacturers, therefore, generally do not allow hearing care professionals to have access to the expansion parameters. The Phonak Target 2.0 fitting software, on the other hand, provides hearing care professionals with access to the expansion control threshold by changing the gain level when the input is low, as is explained in detail below. This is a popular means to have a direct effect upon the audibility of soft input signals. When using objective measuring methods, especially when the results are evaluated by means of percentile analysis, the influence of the expansion control level can be very easily detected, as the 30th percentile is directly related to the expansion threshold.

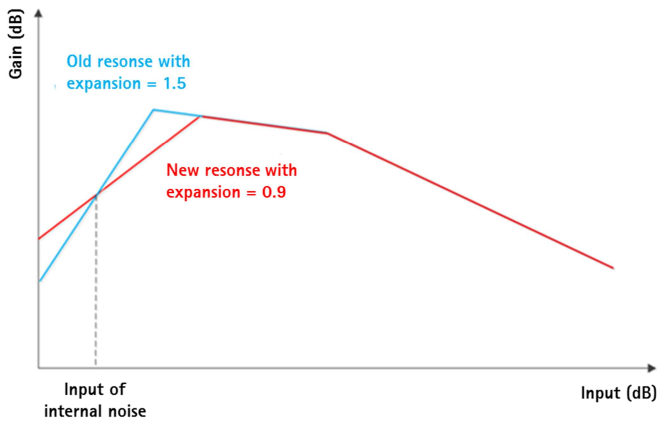


**Figure 2:** Comparison of response (gain against input) for the two hearing aid generations, Spice and Spice+. The input of internal noise is treated in the same way in both cases. However, the different compression ratios result in great differences as regards the TK control level, which is clearly higher for Spice+.

With Spice+ Processing, the response has been newly defined in the expansion range. Figure 2 shows the response (shown as gain against input) of Spice+ when compared with Spice. One can see that the curve is clearly flatter (a slope of 0.9 for Spice+, compared with 1.5 for Spice). This results in a clear reduction of the background and internal noise and the device becomes significantly quieter in calm environments with modulated noise (such as a ticking clock), without so-called noise floor. The time constants are another decisive factor when it comes to the perception of modulated noise at a level close to the expansion threshold ($T_K$). Consequently, the expansion time constants for Spice+ have been fundamentally changed: as a result, both the time constants for rising and falling input thresholds are very rapid, so that not only do soft speech components quickly become audible, but also soft noise components are rapidly reduced. The new time constants significantly affect sound perception, so that hearing aids with Spice+ sound clearly clearerthan Spice systems.

## Direct Sound Compensation

The Direct Sound Compensation algorithm is used for sound quality enhancement in the case of large vents and/or an entirely open fitting. In these cases, the direct sound components that pass through the vent into the ear canal are superimposed on to the amplified sound components (processed by the hearing system). If the phases are unfavourable, these results in comb filter effects, which are experienced by the hearing system user as an echoing sound. In order to counteract this effect, DSC (direct sound compensation) was already introduced in the Spice Generation. This algorithm estimates the proportion of direct and amplified sound in real time. If the calculation gives such an unfavourable ratio that it would result in unnatural sound, the gain of the hearing system is reduced, depending on the frequency and level.

In Spice+, the time constants for DSC have been adapted in such a way that the system does not respond too quickly, which would make it appear unsettled, but still kicks in quickly enough to ensure that the sound remains natural in all cases.

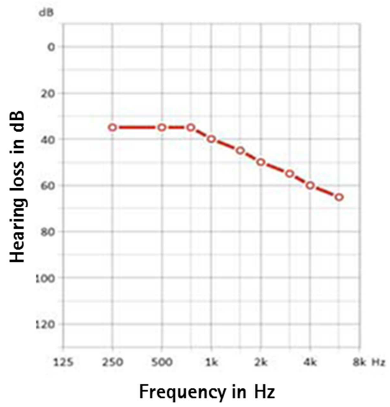


**Figure 3:** Example of hearing loss (mild to moderate)

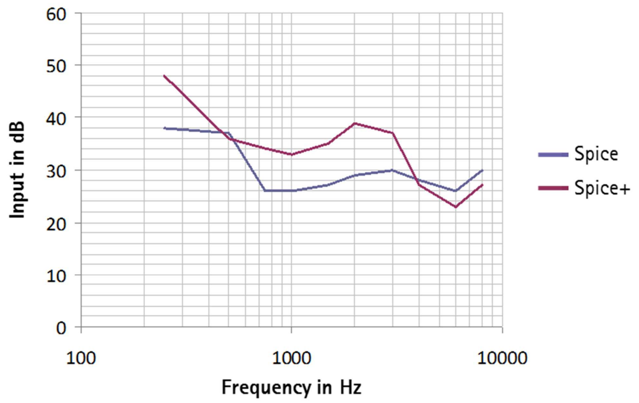


**Figure 4:** Diagram of the level values as a function of the frequency to which the TK control threshold has been preset in the event of hearing loss according to Figure 3.

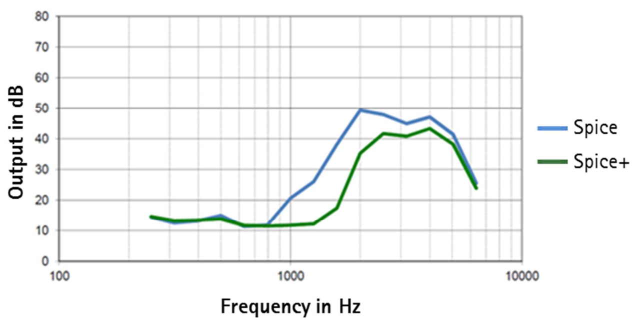


**Figure 5:** Output signal of a hearing system with Spice and Spice+, preset to the hearing loss as shown in Figure 3, without an input signal. The output signal is only determined by the internal noise of the hearing system. The output level of Spice+ is significantly lower at mid frequencies than with Spice

## Presetting

Phonak Target 2.0 offers the option to optimally adapt the system used in Spice+. Three main components have been further developed for this purpose:

**Presetting of the expansion control threshold (TK controller)**

Lowering the compression ratio results in a rise in the control threshold. Figure 4 shows a comparison of the control thresholds via the frequency for both Spice and Spice+. Within the 750 Hz to approx. 4 kHz frequency range, the control levels for Spice+ Processing are clearly above those of Spice. This measure considerably reduces the gain for low input levels, which has a positive effect upon the noise behaviour of the Spice+ hearing system. Figure 5 shows the output level of Spice and Spice+ when there is no input signal. The output signal is thus only determined by the internal noise of the hearing system. The figure shows that the changes in the control threshold mainly take effect in the case of medium frequencies, whilst the control threshold $T_K$ for Spice+ is higher. Precalculation of the individual hearing loss shown (Figure 3) thus reduces the output signal, i.e. the noise, by up to 20 dB for Spice+ signal processing.

$T_K$s can be set differently for the various programmes and are automatically adapted in SoundFlow.

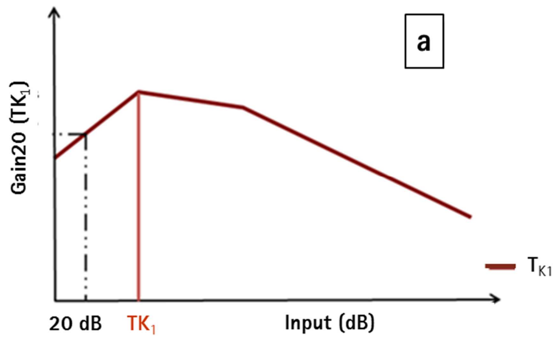


**Figure 6a:** Response curve for Spice+. An expansion threshold value TK1 results when low input levels at a specified value are amplified at a given rate (Gain20).

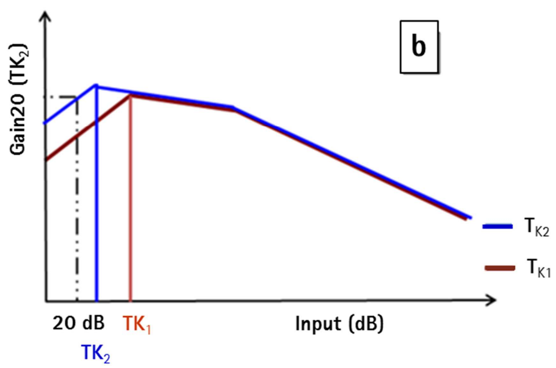


**Figure 6b:** Response curve for Spice+. The value of Gain20 is increased in comparison with the presentation in Figure 6a. As the incline of the expansion curve did not change, increasing this gain results in a reduction of the expansion control level to the value $T_{K2}$. TK and Gain20 are thus inversely proportional to one another.

*Note*: In Target 2.0, the $T_K$s can only be indirectly adapted individually to the requirements of the hearing system user by varying the gain level for low input levels (Gain20, i.e. gain at an input level of 20 dB). Figure 6a shows the response curve (gain of the input level) for a given Gain20. This results in $T_{K1}$. If the Gain20 is now increased (Figure 6b), a new $T_{K2}$, which is lower than $T_{K1}$, results from a constant incline of the curve. This shows that $T_K$ and Gain20 are inversely proportional to one another.

### Adapting the vent loss compensation

An open fitting means that gain can be poorly applied at low frequencies, thus - depending on the diameter of the vent - additional gain is required to compensate for the outflow. Depending on the choice of acoustic parameters, i.e. the receiver, vent size and tube length, in Target 1.2, the gain was corrected in such a way that the loss caused by the vent is compensated. For Spice+, Target 2.0 now determines the vent loss compensation not only on the basis of the acoustic parameters, but also takes into account the hearing loss. Where the hearing loss is mild, no gain is required and the loss is also not compensated by the vent. However, where the hearing loss is such that gains are also required for low frequencies, the vent loss is compensated up to 20 dB. Figure 7 shows a comparison of the vent loss compensation for Spice and Spice+, given the hearing loss shown in Figure 4 and an open fitting. The measuring difference for this hearing loss is up to 17 dB, with the values at the ear obviously not differing that much due to the superimposition of direct sound and amplified sound.

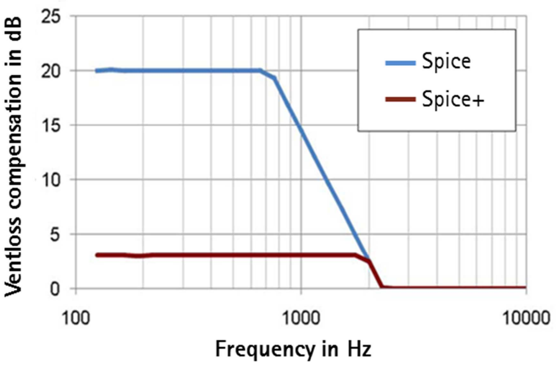


**Figure 7:** Diagram showing the effect of the vent loss compensation for Spice and Spice+ signal processing when entering the hearing loss given in Figure 3.

### MPO pre-settings

Phonak Target 1.x made direct use of discomfort level input, once it has been converted from a narrow-band to a broad-band value, in order to set the MPO. This has often resulted in MPO settings with very high input levels and - especially in the high frequency range - frequently results in MPO settings that are at the limit of the hearing aid. In Phonak Target 2.0, MPO and compression are scaled in a ratio between the measured and the estimated discomfort threshold, so that the remaining dynamic range is optimally used.

## Summary

The open-platform principle of the Phonak Spice generation makes it possible to create a new hearing aid generation (Spice+) by means of a simple firmware update. As a result, it has been possible to extend the development focus from understanding speech in particularly difficult environments to ensuring good performance in calm situations.

Spice+ Processing operates with a new expansion algorithm that softens the sound of the hearing aid and clearly calms its dynamic behaviour. The new first fit calculation, which shifts the control level for the new expansion ($T_K$) to higher input levels whilst also adapting the vent loss compensation to the hearing loss, guarantees a very high level of initial acceptance for Phonak's new generation of hearing aids.

## Literature reference

Dillon, H. (2001) *Hearing Aids*, Boomerang Press.

Latzel, M. (2001) *Kommunikationsprobleme von Hörgeräte-trägern bei der Telefonkommunikation - Ansätze zu deren Objektivierung und Lösung*, Dissertation Universität Gießen.

Ulrich J. and Hoffmann, E. (2007): *Hörakustik - Theorie und Praxis*, DOZ-Verlag.

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