The Velox™ Platform

ABSTRACT

The development of a new chip and digital signal processing platform relies on dedicated and lengthy engineering efforts. Uniquely in Oticon, the development of both chip and platform takes place in the Research & Development department; from designing the multiple layers of the integrated circuits (chips) that need to conform to the very limited space and power consumption of the hearing instrument to coding the firmware and e-software that make up the audiological advancements of all the new features and capabilities. Keeping all development within the same house has pivotal importance for the quality of the final product.

The Velox chip is built for hearing aids and for the advanced digital signal processing used to give hearing aid users the best possible experience with hearing aid technology.

This tech paper will describe the Velox chip, its digital signal processing architecture, and the new wireless capabilities in TwinLink™.

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A hearing aid can only be as good as the digital processing chips and the platform architecture used for it. The chip defines the maximum speed, precision, type and amount of processing available. A hearing aid platform contains both hardware, firmware (what enables the software to communicate with the hardware), and embedded software.

The hardware is the physical component where the integrated circuits (ICs) are engraved on a piece of silicon. ICs are very compact and consist of several million transistors (the width of each conducting wire in a circuit can be made very thin). On the Velox chip, the engraving is only 65 nm thick and laid out in nine layers, resulting in 64,000,000 transistors.

The Velox platform consists of three ICs; one for the digital signal processing (DSP), one for the TwinLink 2.4 GHz radio connecting to external devices e.g. a smart phone, and a Front End (see Figure 1). The TwinLink Near-Field Magnetic Induction radio for exchanging information between the hearing aids is part of both DSP chip and Front End. The Front End chip works in the analogue domain, sampling the incoming signal from the microphones and surveilling battery level.

The high-speed Network-on-Chip (NoC) is the communication system that transfers data between the components. All the links on the network can operate simultaneously on different data packets. With complex processing, the NoC provides enhanced performance compared to previous communication architectures where connections were dedicated one-to-one signal wires or segmented buses. The DSP IC has 9 DSP cores, 7 for sound processing and 2 for wireless processes. The DSP chip runs the amp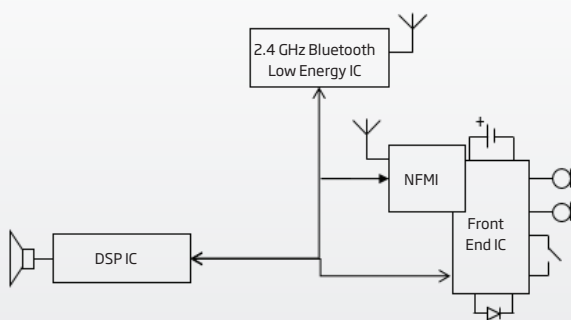lification, compression, different kinds of speech in noise processing, spectral shaping as well as the generation of internal sound (e.g. boot jingle, warning and notification tones).

The speed of processing on the chip is very fast. It can execute close to 500 million instructions per second (MIPS), which is 50 times more programmability than the Inium Sense platform, and it can perform 1,200 million operations per second (MOPS). MIPS and MOPS are measures of how many processing instructions and/or operations can be performed on the input.

> **What is an instruction?**
> A hearing aid typically samples the input with a 20 kHz (20,000 times per second) sample rate. Within one channel one gain is applied to the signal. This would take 20,000 instructions per second or 0.02 MIPS. Open Sound Navigator™ uses approximately 3 MIPS at all times.
>
> 500 MIPS enables very advanced input processing.

500 MIPS is equivalent to the processing power that once drove an Intel Pentium Pro processor. Now it is available in a small instrument powered by a 1.4 V 312 battery.

The chip is fully programmable and firmware updatable, which means that new developments in audiology can be coded onto the chip without changing the physical properties of the hearing aid.
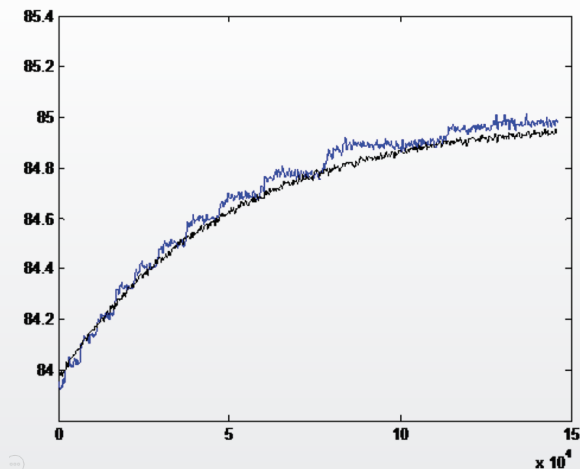

Figure 1: The Velox chip with three ICs and two radios making up the TwinLink

Figure 2: Block-floating point processing (in black) provides improved precision relative to conventional processing in 3/16 dB steps (in blue).

Processing

The Velox platform offers a wholly new market-leading DSP platform. It is the result of many years of intense engineering efforts. The processing on Velox is performed with block-floating point processing (Figure 2). This means higher resolution, enabling handling of a higher dynamic range with higher precision. 24 bit is used to encode dynamic range with the right level of precision. This also enables the extended 113 dB SPL upper limit input range achieved with Clear Dynamics.

Each microphone inputs to filter banks with 64 channels that are used for signal processing while 16 channels are used for the application of OpenSound Navigator™ and gain prescription. These 16 channels are approximating the auditory filters in the cochlea; in that they are narrower in the low frequencies than in the high frequencies. The fitting handles in our fitting software follows the same 16 frequency ranges.

Architecture – what happens as sound is processed?

The signal enters through two microphones on the instrument, through the Telecoil (TC), via the Direct Audio Input (DAI), or through a wireless (WL) connection to the instrument (Figure 3). Here the input adaptive gain control in Clear Dynamics adjusts gain to prepare the signal for the A/D-converter, and re-applies any gain reductions after the A/D-converter to ensure that a larger dynamic range is available for further processing. Thus, the full sound input range from 5 to 113 dB SPL comes into the instrument for processing without any initial, unnecessary compression.

Each input path (three in total – two microphones and an AUX input on each instrument) is associated with its own 64-channel filter bank. The three filter banks are in linear phase and with the same group delay, which keeps the interaural time differences (ITDs) from all four microphones in a binaural hearing aid fitting intact. From here the signal continues along the Signal Path. The three filter banks convert the time domain signal into 64 frequency bands, equally spaced with a bandwidth of 156.25 Hz. Converting to frequency domain enables more advanced mathematical processing.

The input calibration in 64 bands allows for precise compensation of head acoustics and preserves sound quality across styles. Just as it calibrates microphone sources and AUX sources separately.

Next the signal is analyzed, balanced and noise is attenuated with OpenSound Navigator (please refer to the Open Sound Navigator white paper for more details). Wind Noise Management enables, if needed, as an integrated part of the OpenSound Navigator before the two microphone signals are combined. After the two microphone signals are combined in the OpenSound Navigator, gain can be estimated and applied by VAC+ and Soft Speech Booster LX. This also determines the compression needed on the input, which Speech Guard™LX then applies, using its unique adaptive compression approach. Spatial Sound™ LX finally ensures that differences in level between the two instruments on the head are preserved for a better binaural balance.
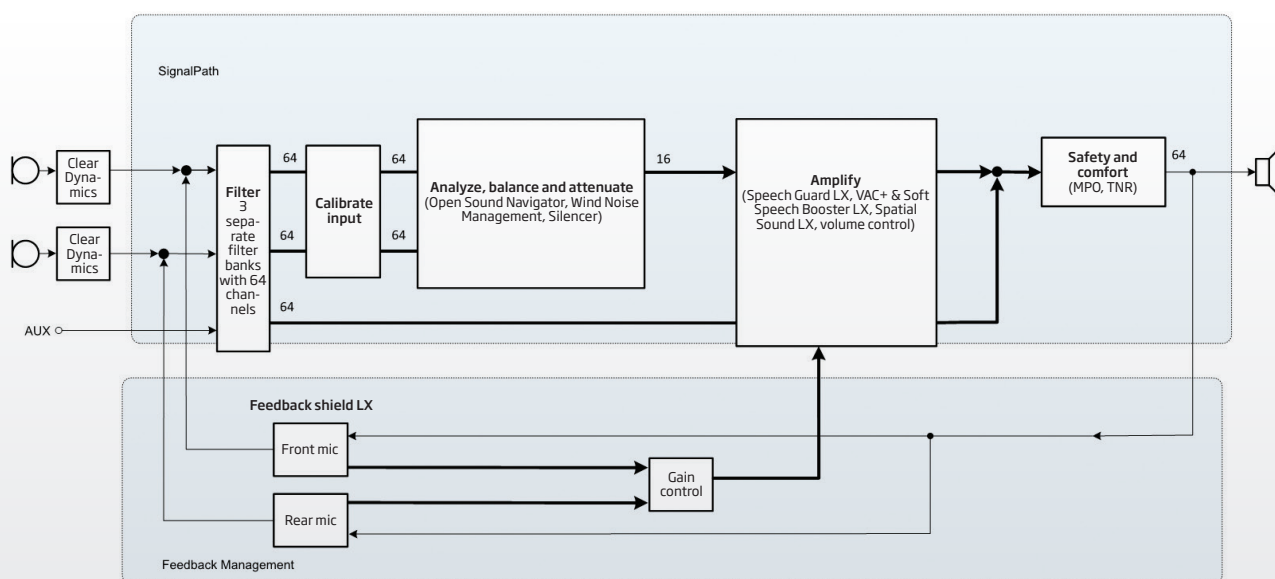

Figure 3: The platform architecture of Velox

The Maximum Power Output (MPO) and Transient Noise Reduction (TNR) modules act as "backstoppers" making sure that the output is safe and comfortable. This is done by ensuring that the output of the instrument will not exceed MPO and that loud, sudden transients have been sufficiently attenuated for user comfort. This way the full signal is processed and limitations to output are based only on audiometric concerns (hearing loss, uncomfortable loudness levels etc.) Lastly a filter bank summation (FBS) occurs where the signal from the 64 frequency channels are combined and transformed back to the time domain and delivered to the speaker.

The Anti-Feedback Management is a sub-system to counteract the acoustical feedback from receiver to microphone, in order to prevent whistling (please refer to the Feedback Shield LX white paper for more details).

TwinLink

TwinLink is the dual radio on the Velox platform. It features two separate radios for the distinct and different needs in wireless communication in hearing aids; both are built into the Velox chip.

For exchange of information between the instruments, TwinLink employs Near-Field Magnetic Induction (NFMI). This is highly energy-efficient, very low in battery consumption and travels very well around the head. The speed of data exchange is more than four times faster than on the Inium Sense platform, up from 5 times per second to 21 times per second. The exchange rate, i.e. the number of kbit per second, has also been improved and is more than 200% better than the rate on Inium Sense, up from 96 kbit/sec to 320 kbit/sec.

TwinLink powers the Spatial Sound LX feature on the Oticon Opn hearing aid. It does so by increasing the number of estimators from one to four. This provides the instruments with more precise information of the level on each instrument by using the four estimators in four equally distributed frequency channels, which is essential
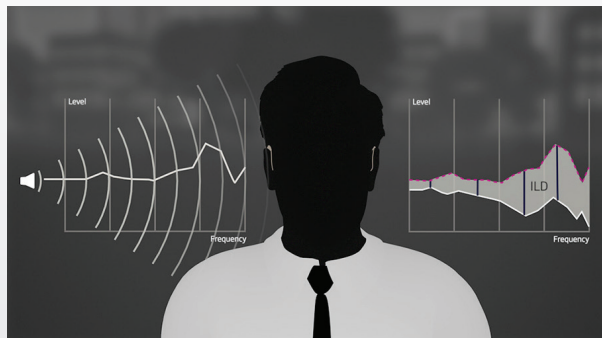
for keeping the important interaural level difference intact for accurate location and direction of sound. All this means fast updates in four individual frequency bands and improved preservation of the spatial ILD cues.

TwinLinks 2.4 GHz wireless capabilities makes it possible to connect the hearing aid directly to an array of wireless devices. The 2.4 GHz bandwidth is stable and holds its strength over longer ranges. Even still, at maximum performance including streaming capability, it runs on 1.8 mA max stable consumption.

Velox benefits
Faster, more precise and more powerful processing
Improved precision of the gain estimation and improved noise performance of the hardware (24 bit) along with a 50 times increase in programmability.

Catering for the state of the art OpenSound Navigator
Open Sound Navigator is the completely new way to use help systems and automatics, to decrease the cognitive load and facilitate cognitive processing when engaging in conversations in noise or in competing speech. For it to be efficient, fast adapting and fully transparent, a powerful and highly advanced platform is needed.

Full binaural capability
The Oticon dedication to improving binaural hearing as a natural component of BrainHearing™ is maintained. The platform secures binaural compression for exact preservation of interaural loudness cues as provided by Spatial Sound LX.

Intact interaural time differences
Filter bank processing in linear phase with constant group delay leaving the time differences occurring at each side of the head intact and unaltered by signal processing for natural timing in the output.

Integrated wireless abilities for all purposes
Integrated circuits for dedicated radios with Near-Field Magnetic Induction for ear-to-ear communication and 2.4 GHz Bluetooth Low Energy for communication to external devices. A combination of the best for low battery consumption and stable, reliable connections.

Figure 4: With TwinLink, the number of level estimators have been increased to four for improved ILD precision.

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