Phonak Insight

Bluetooth Classic for hearing aids? Good thing our engineers didn't hear that it was not possible!

Davina Omisore, March 2019

Introduction

Recently, Phonak hit an innovative milestone. It is the first hearing aid manufacturer to successfully use the universally available Bluetooth® Classic 2.4 GHz frequency technology to directly connect their hearing aids to everyday devices (e.g. iOS®, Android™ and other smartphones, televisions, computers, stereo systems, tablets, etc.) for streaming audio (music and phone calls). Other direct connectivity hearing aids utilize the proprietary Apple® Bluetooth Low Energy (LEA) technology for their Made for iPhone® (MFi) connectivity and can only be used with iPhones® and iPads®. This prevents clients using phones with other operating systems from being able to directly stream audio to their hearing aids. According to the 2016 eMarketer report[1], Apple iOS systems represent only 13% of the global market share. The largest market share is taken up by Android OS systems with 86%.

Marvel by Phonak is the latest generation of direct connectivity hearing aids that not only stream audio and phone calls binaurally but offer a full day of battery life on a rechargeable Lithium-ion battery. This is thanks to the low power consumption of the 3rd generation of the SWORD™ chip (Sonova Wireless One Radio Digital). This ultra-small wireless chip has improved radio sensitivity, which enables it to handle the power demands of Bluetooth Classic. It reduces the power consumption while maintaining excellent link distance and link stability. In order to overcome the Bluetooth limitation of being able to stream to one ear only, a dedicated algorithm was developed that extends the Bluetooth capabilities to allow streaming to both ears.

What is Bluetooth?

There are two main types of Bluetooth protocols used within the hearing aid industry, Bluetooth Classic and Bluetooth Low Energy (Bluetooth LE).

Bluetooth Classic

Bluetooth Classic is a short wavelength radio communication protocol that operates within the international standard of frequencies that is reserved for Industrial, Scientific and Medical (ISM) equipment.

Operating within the 2.4 GHz radio frequency band, Bluetooth Classic is a worldwide open wireless technology standard for exchanging continuous audio streams (e.g. voice and music exchange) over distances between two paired devices such as cell phones, headsets and stereos. Bluetooth Classic offers clients the advantage over Bluetooth LE of using the Advanced Audio Distribution Profile (A2DP) standard for audio streaming from all Bluetooth devices and supports hands-free phone calls using the standard Hands Free Profile (HFP). In fact, Bluetooth Classic is so widespread that even popular

Apple Bluetooth streaming devices like Apple AirPods® utilize it instead of their proprietary solution.

Bluetooth LE

Like Bluetooth Classic, Bluetooth LE also operates on the 2.4 GHz radio frequency band. It was developed to provide reduced energy consumption for control data but still have a similar communication range (up to 100 m/330 ft.) in free field. Bluetooth LE was originally introduced under the name Wibree by Nokia in 2006. It was merged into the main Bluetooth standard in 2010 with the adoption of Bluetooth v4.0. It is ideal for applications that only need to exchange a small amount of data periodically. Although it consumes less energy than Bluetooth Classic for small amounts of data, it was not designed for continuous streaming of data. Apple developed a modified version of Bluetooth LE that is utilized in MFi hearing aids. This allows the full capability of audio streaming directly from the iPhone to the hearing aids but without the ability to make hands-free phone calls.

The challenge of integrating Bluetooth Classic into hearing aids

There are two main challenges to overcome when integrating Bluetooth Classic into hearing aids. These challenges were considered insurmountable which is why other hearing aid manufacturers chose to use the proprietary Apple Bluetooth LE technology.

1. Power consumption

It is often noted that Bluetooth Classic is 'power hungry'. It was discounted as a technology for streaming audio by other hearing aid manufacturers because available chipsets consume significantly more power than the Made for iPhone technology. The hardware required for Bluetooth transmission can be designed to fit into a hearing aid, but the power requirements, unless addressed properly, would limit the battery life of a zinc-air battery below acceptable levels[2].

2. Streaming to two ears

Bluetooth Classic is capable of streaming stable, high quality stereo audio, but supports only one connection for streaming. To stream the same audio binaurally two connections are required. To design this, special proprietary shortcuts have to be developed. If not properly done, this can result in a significant imbalance in power consumption and one can notice this when streaming music with A2DP.

Solving the Bluetooth challenge with SWORD

Solving the Bluetooth Classic challenges of battery consumption and binaural streaming of music and phone calls, Phonak developed SWORD, a wireless chip that utilizes Bluetooth Classic but overcomes the battery life and audio streaming limitations.

1. Miniaturization of the wireless chip

In 1965, Gordon Moore observed that "processor speeds, or overall processing power for computers, will double every two years"[3]. This empirical statement became famously known as "Moore's law" and can also be applied to wireless digital hearing aid technology. Miniaturization of technology is one important key to unlocking universal wireless connectivity and complex algorithms without increasing the power consumption. As the size of the chip structure gets smaller, the power consumption can be reduced. With the transistors being smaller and more tightly packed, electrons don't have to travel so far when moving between them - saving both time and energy[4]. The smaller the transistor size, the more transistors can be added with more sophisticated features without increasing battery drain.

Phonak developed SWORD, an ultra small, ultra low power chip. The structure includes 42 million transistors placed on a 6.8 mm^2 size chip. Using 40 nm CMOS technology, SWORD is the only wireless chip that is capable of combining one radio chip with one antenna to power all applications. It is currently one of the lowest power consuming solutions for hearing aid applications. It offers more flexibility for sophisticated wireless applications such as binaural audio streaming using Bluetooth Classic, but also for proprietary audio links for ear to ear streaming, enabling unique functions like Binaural VoiceStream Technology™. These connections use the same antenna, thus allowing the size of the hearing aid to be further reduced. Binaural audio streaming is optimized for external devices using an extension of the Bluetooth Classic. SWORD has an increased robustness for a more stable Bluetooth connection with a new wireless antenna design, optimized for ear-to-ear and off-body performance, that is capable of transmitting audio around the head.

Fig. 1 shows the benchmarking of SWORD against other similar wireless chip technologies found in consumer wireless earbuds and 2.4 GHz MFi hearing aids from other manufacturers.

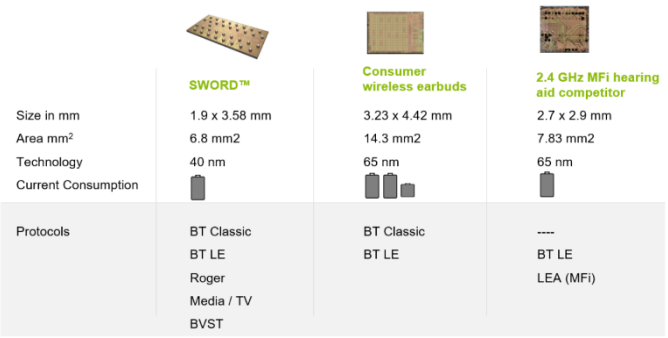

Figure 1: A comparison of the SWORD chip with other Bluetooth solutions. SWORD is by far the best in class in terms of size, area, smallest technology, current consumption and the number of protocols.

When comparing chip size and technology, Sword far outperforms both wireless consumer earbuds and MFI hearing aids. It is the only chip that is able to simultaneously use multiple protocols like Bluetooth Classic, Bluetooth LE and several proprietary protocols. SWORD current consumption is comparable to the competitor MFi hearing aids but far outperforms the consumer wireless earbuds.

2. Radio sensitivity and antenna design

To further optimize the power consumption, the sensitivity of the radio chip and of its antenna are also important. A good performing radio antenna helps to reduce power consumption especially on the transmitter side, without decreasing the link distance and stability. As the human body absorbs 2.4 GHz, it is very difficult for the signal to move around the body. Hearing aids traditionally relied on an inductive link that required duplication of radio and antennae. SWORD was designed to provide a sensitivity enabling binaural audio transmission. The radio antenna of SWORD was designed and optimized to allow stable back and forth streaming of external audio signals as well as communication around the head. It has the advantage of not being sensitive to the body proximity and thus does not suffer from a degraded performance when worn on the ear. In addition, the collective experience obtained from the introduction of Roger™ technology in 2013 was also of great benefit when developing the radio antenna.

SWORD is the only wireless chip available which requires only one radio antenna that can support short link distances for on-body ear-to-ear streaming with Binaural VoiceStream Technology, off-body long link distances like Bluetooth Classic and Bluetooth LE, and multiple protocols that are used for every day listening (fig. 2).

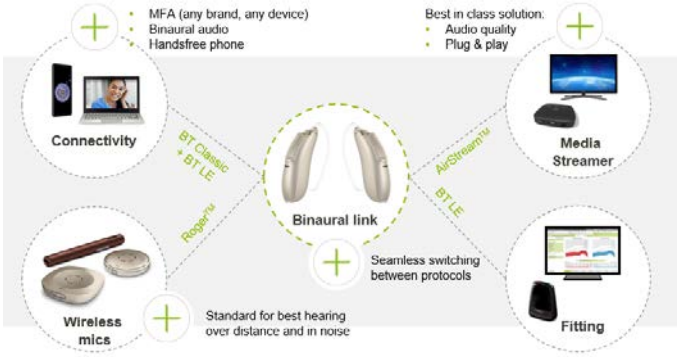

Figure 2: The multiple protocols that are integrated into the SWORD chip.

Power management and battery consumption

Without the above-mentioned improvements, integration of Bluetooth Classic would indeed result in significant drawbacks in power consumption. This is why MFi hearing aids opted to use the proprietary Apple Bluetooth LE (LEA) application instead. Using these protocols, the hearing aids can support two connections for binaural audio streaming. The disadvantage of these solutions is the limited connectivity to only Apple iPhones and iPads, no hands-free phone calls and no connectivity to other devices like Apple computers.

SWORD was designed for low power consumption. It´s power management system includes voltage converters which minimize the current consumed by Phonak hearing aids when using Bluetooth Classic to its full effect, without experiencing significant current consumption or battery drainage. This new power management system ensures that clients will experience comparable hearing aid battery time, when streaming music or phone calls compared to MFi hearing aids.

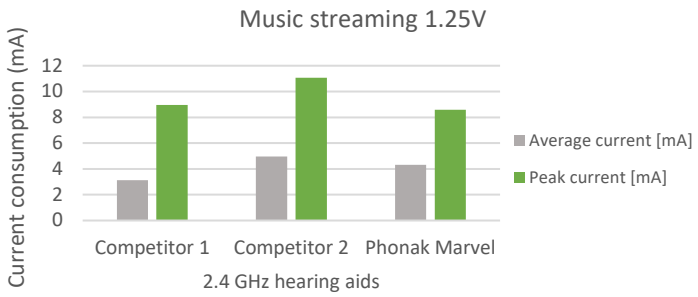

Figure 3: Peak and average current comparison of music streaming from RIC hearing aids that use 2.4GHz frequency technology. For comparable results the measurements were performed without a receiver.

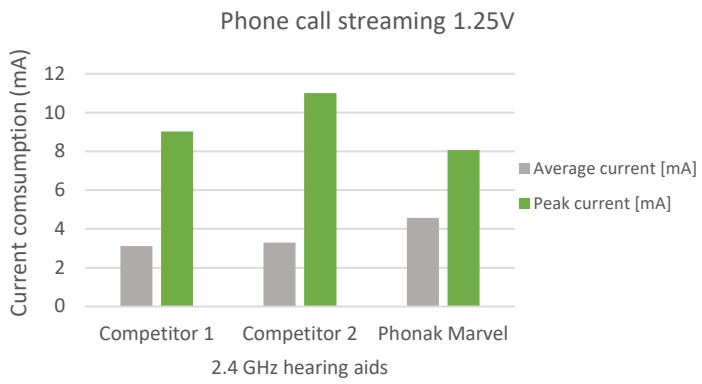

Figure 4: Peak and average current comparison of phone call streaming from RIC hearing aids that use 2.4GHz frequency technology. For comparable results the measurements were performed without a receiver.

Fig. 3 and 4 show a comparison of the peak and average current when streaming audio and phone calls, for Marvel hearing aids and two competitive MFi Receiver In Canal (RIC) hearing aids. The peak current indicates the current drawn when the radio is turned on and denotes the efficiency of the chip. For zinc-air batteries, the peak current is important as these batteries can only take in a limited amount of air to produce electricity, thus they can only provide a certain maximum current. If this amount is exceeded (which depends on the battery (10, 312, 13, 675)), the battery voltage decreases and the hearing aid shuts down, at least temporarily. This effect is called 'oxygen starvation', as the battery cannot breathe sufficiently anymore. The effect becomes more pronounced towards the end of the battery life and can prematurely end the life of a zinc-air battery, even though it has still the capacity to deliver lower currents. The aim is to reduce the peak current consumption in a device. This is not relevant for rechargeable Lithium-ion batteries, which can deliver much higher peak currents and don't require air.
Apart from the oxygen starvation effect, every battery has a certain capacity. The battery can also last longer if the hearing aid draws a lower average current.
During music streaming and phone calls, both Bluetooth Classic and Bluetooth LE radios are turned on and off at a regular interval. This results in a lower average current consumption. This effect is of course relevant for all kinds of batteries, Zinc air or Lithium-ion.

The graphs (fig 3 and 4) show that SWORD is capable of using Bluetooth Classic to stream audio in hearing aids without suffering high peak (and average) current consumption. The peak and average current response of SWORD when using Bluetooth Classic for streaming is very close to the two MFi hearing aids that use the energy efficient Bluetooth LE to save on power consumption. This refutes the argument against using Bluetooth Classic for audio or phone streaming in hearing aids.

Our experience with Lithium-ion rechargeable solutions and analysis of long-term performance data enabled us to further optimize the 2nd generation rechargeable solution. Based on internal data analysis, 98% of Phonak Audéo™ B-R wearers (n=12'239) utilize their rechargeable hearing aids for less than 17 hours per day. Datalogging data of more than 192'000 clients (wearing Phonak Belong) showed an average daily wearing time of 10.4 hours. Using this information, Phonak defined the battery life time of the rechargeable hearing aids as 16 hours' usage per day and consisting of

- 8 hours AutoSense OS™ 3.0 and Binaural VoiceStream Technology™ (50%)
- 4 hours Bluetooth streaming, phone call (HFP) and media (A2DP) (25%)
- 4 hours TV usage with TV Connector (AirStream™ technology) (25%).

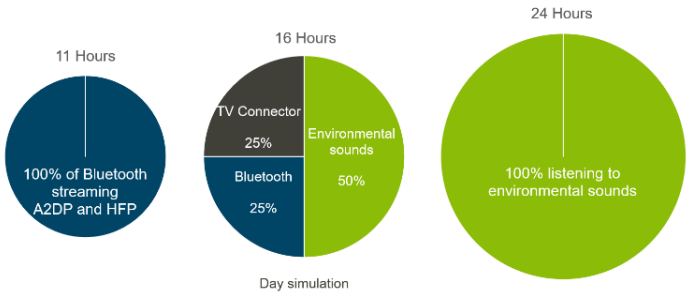

Figure 5: The calculated battery consumption when using Audéo Marvel hearing aids for audio streaming only, acoustic listening and audio streaming, and acoustic listening only.

Fig 5 shows the calculated battery consumption is based on preliminary tests, conducted by Phonak using preproduction Audéo Marvel. Battery life varies by use, configuration, and other factors; actual results will vary. The test sequence includes an acoustic stimulation with 16 hours "On" time/day. The test includes multiple, automatically activated streaming sequences with a total of 8 hours wireless streaming time. The hearing aids were fit with a typical, severe to profound hearing loss (N5) and P Receivers. Average loudness level in the box is 65-75 dB (variation of soft/moderate office environment, loud/heavy traffic and restaurant environment). This test has an extension for audio recording of the outputs of the receivers, to record the warning and notification signals.

Using the same conditions listed above, Audéo Marvel hearing aids with a size 13 zinc-air battery were found to

provide 100 hours of listening enjoyment including streaming.

Hearing aid	Battery life time
Audéo M-R	1 day / >16 hours
Audéo M-312T	60 hours
Audéo M-13T	100 hours

Figure 6: The average battery time of Phonak Audéo Marvel hearing aids that use rechargeable, 312 zinc-air and 13 zinc-air batteries.

Comparing Audéo Marvel rechargeable hearing aids to wireless earbuds, both using Lithium-ion rechargeable batteries, Audéo Marvel hearing aids can be used for 11 hours of phone calls or music streaming, while the wireless earbuds, which also use Bluetooth Classic, provides only up to 5 hours of listening time and 2 hours of talk time on a single charge[5].

Conclusion

Phonak has achieved a breakthrough with SWORD technology using Bluetooth Classic. By miniaturizing the wireless chip as well as improving the radio sensitivity and antenna design, only Phonak is able to harness the benefits of using Bluetooth Classic to stream audio and hands-free phone calls binaurally to hearing aids without jeopardizing power consumption. This is thanks to SWORD and it´s super small, power efficient 40 nm chip technology.

The latest generation of Phonak hearing aids are able to utilize multiple protocols including

- Bluetooth Classic for binaural phone connectivity and music streaming.
- Bluetooth LE for remote controls and wireless hearing aid fitting.
- Proprietary protocols for connecting to Roger technology, streaming from the TV Connector and binaural ear to ear data and audio exchange with Binaural VoiceStream Technology.

All this is possible with a battery consumption that is similar to or better than some MFi hearing aids that use a proprietary Bluetooth LE protocol and can only stream directly to an iPhone or iPad device.

With the high global market share of Android and iOS smartphones, SWORD can connect to a majority of devices and offers clients a full day of binaural music streaming and phone calls without having to worry about battery consumption.

References

1. Global Mobile Landscape 2016: A Country-by-Country Look at Mobile Phone and Smartphone Usage. eMarketer Report. (2016). Retrieved from https://www.emarketer.com/Report/Global-Mobile-Landscape-2016-Country-by-Country-Look-Mobile-Phone-Smartphone-Usage/2001859.

2. Galster, J. (2014 November/December). Making sense of modern wireless hearing aid technologies. *Ent and audiology news*, 23, 5.

3. Moore, G.E. (1965) Cramming More Components onto Integrated Circuits. *Electronics*, 38, 8.

4. Weste, N. & Harris, D. (2011). CMOS VLSI Design: A circuits and systems perspective, (4th ed.). Boston, MA: Addison-Wesley.

5. Charge your AirPods with charging case and learn about battery life. (2018). Retrieved from https://support.apple.com/en-us/HT207012, accessed February 27th, 2019.

Author

Davina is Audiology Manager for the Mild to Moderate Hearing Solutions team in Phonak HQ. She has been with Phonak since January 2006, specializing in audiology and hearing aid product training. She graduated with a MSc in Audiology from Dalhousie University, Halifax, Canada and previously worked in the UK.