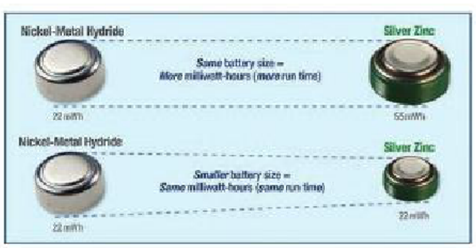
The role of ASICs in hearing aid development

The hearing aid market demands high energy density in a small size as devices become smaller and less obtrusive. Traditionally, primary zinc-air (ZnO2) button cells have been used which need replacement on a regular basis. However, as Carl Hudson of Swindon Silicon explains, by using high energy density, silver-zinc (AgZn) rechargeable batteries, modern hearing aids with wireless features can run all day on a single charge

Manufacturers constantly seek to shrink the size of hearing aids to make them discrete. Small, disposable, ZnO2 button cells are used that are difficult to handle, especially for those with poor eyesight or dexterity. Hearing aids also experience increasing current drains in new 'made for iPhone' designs with wireless streaming. These higher loads increase the frequency of changing these tiny batteries.



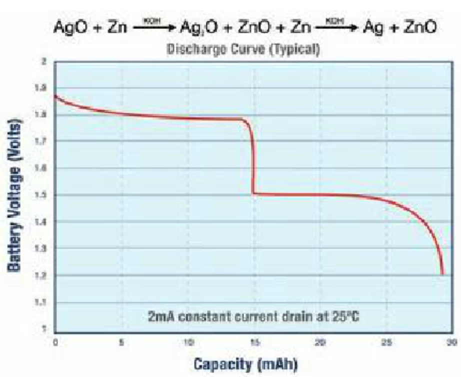
Some hearing aid manufacturers offer rechargeable nickel-metal hydride button cells but the energy density doesn't meet the demands of new wireless streaming. A successful rechargeable button cell must power the hearing aid for at least 18 hours, meet the higher current drain requirements and last at least one year before replacement.

Developments in rechargeable AgZn button cell technology now meet these requirements and make it an excellent design choice. The AgZn battery voltage of 1.8V is, however, slightly higher than the maximum ratings for most current hearing aid DSPs. Designing an ASIC to lower the voltage to match the ZnO2 chemistry would make silver-zinc compatible with existing hearing aids. The ASIC had to be efficient and small, and available in a bumped die, so a suitable partner had to have the right design skills and the ability to deliver the tested dies.

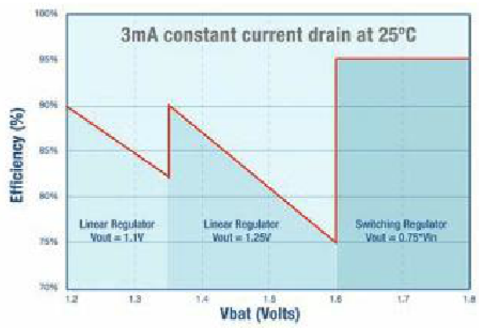
AgZn battery solution

Hearing aids are designed for ZnO2 voltages in the range 1.1-1.45V with a 1.6V maximum. When the battery falls below 1.1V, the hearing aid emits a tone to warn the wearer of an impending shut-down. Depending on the level of hearing loss and the sound environment, continuous current drain is up to 3mA with transients up to 40mA for several milliseconds. During wireless streaming, 2.4GHz radios increase the current drain up to 5mA.

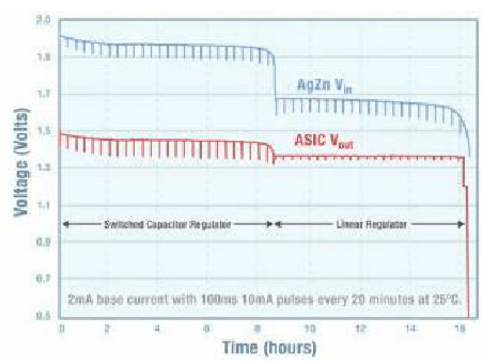
Combining a new battery technology with unique hearing aid power supply requirements meant an ASIC with voltage regulation capability was necessary. The ASIC needed to efficiently down convert the AgZn voltage to an optimum output voltage of 1.2-1.4V. Hearing aid designers also wanted the flexibility to operate with either AgZn or ZnO2, requiring a supply voltage from 0.9-1.85V. Additionally, when AgZn reaches its low battery warning level, the output voltage must be lowered to the ZnO2 low battery warning level to trigger a warning tone in the hearing aid. Lastly, the ASIC must sense when the hearing aid is in the charger and disable the output voltage.



AgZn has a two-step voltage profile, operating above 1.6V for about half of the discharge capacity. The transition between voltage steps is fast, typically within five minutes. The unique discharge curve allows different voltage regulation architectures for the two voltage levels. Three candidate architectures were considered - linear, switched capacitor and an inductive switcher. While an inductive switcher offers good efficiency, the relatively large inductor footprint and potential for resonance due to magnetic coupling ruled it out for this application.



Because of the input/output voltage conversion ratio, the switched capacitor regulator is a good choice for the upper voltage step. For this switched capacitor regulator, a 4:3 Dickson topology was selected. This topology generates an output voltage as a fixed ratio of the input voltage and for the upper voltage step generates an output voltage of 1.2-1.4V. Three external flying capacitors and one decoupling capacitor gives an efficiency up to 96%.



An output voltage ripple requirement of less than 5mVp-p drives selection of the flying capacitors and switching frequency. For low ripple, high value, low ESR capacitors and a high switching frequency are desirable. The flying capacitors are limited to a 0201 footprint and 470nF is selected for the best combination of performance and size. Switch impedances in the range of 2Ω are required for efficient operation. Since higher switching frequencies lead to higher losses, 250kHz is used to achieve low ripple and high efficiency while staying clear of audio frequencies and ISM bands.

The lower voltage step is below 1.6V and the switched capacitor regulator would generate an output voltage below 1.2V. For the lower voltage step, a linear regulator is a better choice due to its stable output voltage and low impedance. The linear regulator is designed for an output voltage of 1.25V to provide supply voltage margin for high transient loads. Linear regulator efficiency is defined by the simple relationship Vout/Vbat (ignoring control circuitry power consumption). When the ASIC detects a ZnO2 battery, the linear regulator's pass transistor bypasses the regulator minimising the voltage drop.

Conclusions

In order for the hearing aid industry to transition to rechargeable designs, new higher energy density, battery technologies are required. Due to the unique requirements of current hearing aids, a custom ASIC is required to take full advantage of the new AgZn chemistry. Combining the AgZn battery with a small form factor, ASIC provides manufacturers a 'drop-in' solution. As with many applications, an ASIC approach was fundamental in enabling this solution.