
Overcoming the design challenges of wearables and hearables:

# Implementing health monitoring and other advanced capabilities

EN www.infineon.com/wearables

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## Abstract

The rapid commoditization of wearables and hearables has put tremendous pressure on manufacturers to introduce new capabilities that can command a higher price and increase profitability. Advanced health monitoring, such as atrial fibrillation or blood pressure, is a differentiating feature that enables a manufacturer to turn a $60 smartwatch into a premium product that sells for a much higher MSRP.

While innovative features improve the user experience and increase the value of these products, they add significant complexity. Consider the challenge of enabling blood pressure sensing in a wearable form factor. Using existing photoplethysmography (PPG) sensor technology and advanced algorithms might be implemented to cancel out motion and other artifacts. These advanced devices provide capabilities needed to reduce the dependency on a traditional blood pressure cuff.

Further complicating design is the need for a compact architecture that minimizes the system footprint. This must be achieved with the lowest power consumption possible to maximize battery operating life. Given the high volume of these markets, reliability helps minimize return losses. Finally, developers must meet all of these requirements while driving costs down.

These aren't issues just for smartwatches. The pressure to differentiate through new capabilities impacts all wearables, especially hearable applications. This article explores how adding new features impacts design and the role non-volatile memory plays in enabling developers to meet increasingly challenging size, performance, power, reliability, and time-to-market requirements.

# 1. The cost of delivering a superior user experience

Adding innovative features to a system can substantially increase code size. Features like vital sign monitoring also require significantly more data memory to implement. Security continues to become an increasingly critical capability for every connected device. Maintaining user privacy is essential to many customers, and data protection is essential for health-related data that is being tracked by more and more wearable devices.

Security is a constantly moving target, so connected devices require ongoing security updates. The volatility of communications protocols means drivers need to be updatable to ensure that devices can continue connecting to other devices such as users' phones and computers with each new OS update.

For wireless devices like smartwatches, these updates are increasingly implemented using over-the-air (OTA) mechanisms. With OTA in place, developers also have the opportunity to upgrade functionality and fix bugs, even after sale. However, implementing OTA reliably requires sufficient memory to maintain a second code image. This enables a system to download the update then verify and authenticate it before transferring control over to the new code. A failed download could overwrite critical code without this step, potentially rendering the device useless if the updated code is corrupted. Many devices are beginning to implement data logging as well. The impact of data logging on the user experience is just starting to be explored and will enable a whole new range of customization capabilities. Devices that currently track users, such as health monitors, will employ more sensors and, consequently, capture more data.

Looking at next-generation devices, artificial intelligence at the edge will become a disruptive trend, improving algorithms' accuracy for health monitoring. MCUs will deploy dedicated cores for parallelized processing in resource constraint embedded devices enabling machine learning models to be run and optimized on the device itself. This will lead to an increase in the density and memory size required on wearable devices.

Also, data logging can capture more than just sensor data. In terms of performance and reliability, devices can monitor and analyze their operation to predict and preempt system maintenance and failure. Features like voice recognition will benefit from data logging to improve accuracy. Data logging can also be used to track user behaviors so that devices can accurately anticipate what users want before they know it themselves.

## 2. Memory as the foundation for differentiation

All of these new capabilities drive the need for more non-volatile memory. And given that many wearables and hearables are battery-operated, NOR Flash is often the memory of choice given its fast read access, endurance, and reliability.
It's not surprising then that the market for NOR Flash for smartwatches, wireless earbuds, and other IoT body-worn devices is expected to grow from $90M in 2019 to more than $265M by 2024 (Source: Gartner, ABI, and internal Infineon estimates). At the same time, increasing density requirements are anticipated as well, moving from lower density 64 Mb memories to mid-density 256 Mb devices.

Physical size is arguably the most crucial aspect of these memories as die size directly determines the cost. It also impacts the final device footprint, and ultimately the form factor of the end product. One of the unique requirements of hearables and wearables is that the height or profile of a memory device matters. Thus, the depth of the memory die must also be optimized.

Memory manufacturers continue to develop innovative technologies and new architectures that improve die size and power consumption. For example, the SEMPER™ NOR Flash family from Infineon utilizes their proprietary MIRRORBIT™ technology that stores two data bits per cell. This doubles the density in the memory portion of the device, making it possible to pack higher-density memory into a smaller footprint. The difference is substantial. A typical 256 Mb NOR Flash has a die size on the order of 18 mm2. Using MIRRORBIT, 256 Mb can fit on a 13.6 mm2 die.

The memory also needs to be available to manufacturers as a die. Consider that a standard approach for wearables is to use tailored packaging such as a chip-scale package. In short, manufacturers use their package to integrate multiple processors – such as a CPU + DSP – with the memory die of their choice in a single package (see Figure 1). This, in turn, leads to the need for higher-density memory devices since they now need to store the application code and data of two processors.

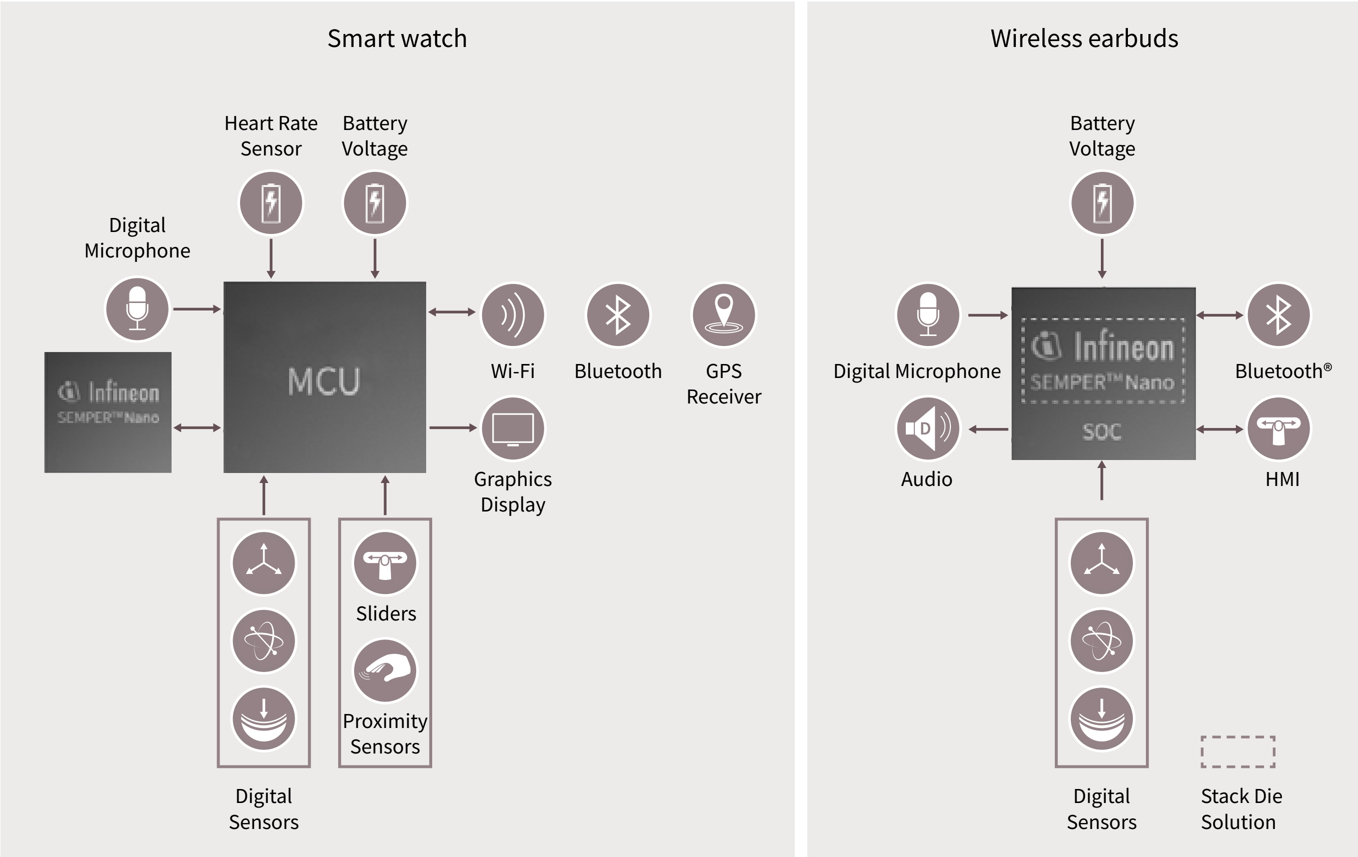



Figure 1: (a) Traditional hearables and wearables need external NOR Flash to store code, data, and data logs. (b) Applications with an extremely tight footprint, such as wireless earbuds with True Wireless Stereo capabilities, utilize a high density stacked-die architecture that combines an MCU + DSP with memory in a single chip-scale package.

To facilitate this high level of integration, memory must be accompanied by design resources that accelerate overall development. For example, production-grade drivers eliminate the need for engineers to write their own drivers or customize generic drivers. This not only saves development time, but it also increases reliability since the chip vendor has proven out the drivers over time. The availability of C-models makes it possible to evaluate designs using simulators before hardware is ready. Verilog and/or IBIS models of memory are essential for applications where an application-specific processor is being created.

The availability of starter kits and off-the-shelf memory modules enables immediate prototyping of designs out-of-the-box. Reference designs and application code examples provide a foundation upon which customized designs can be quickly developed. A hardware abstraction layer (HAL) separates application software and hardware firmware in terms of integration with an application. Developers can then access memory functionality through an API rather than code directly to specific registers. This not only speeds initial development, it enables developers to utilize different parts within a memory family without having to rewrite application code. Finally, because memory can be used with a wide range of processors, these resources need to be platform- and OS-agnostic so developers can select the processor and development tools of their choice.

## 3. Power and reliability

Traditionally, memory devices are commodity items designed to serve a wide range of applications. However, the tight constraints of the hearables and wearables markets require the use of memory explicitly optimized for size, power, and reliability. For example, SEMPER™ Nano NOR Flash takes the capabilities of SEMPER NOR Flash and optimizes it for applications like wearables.

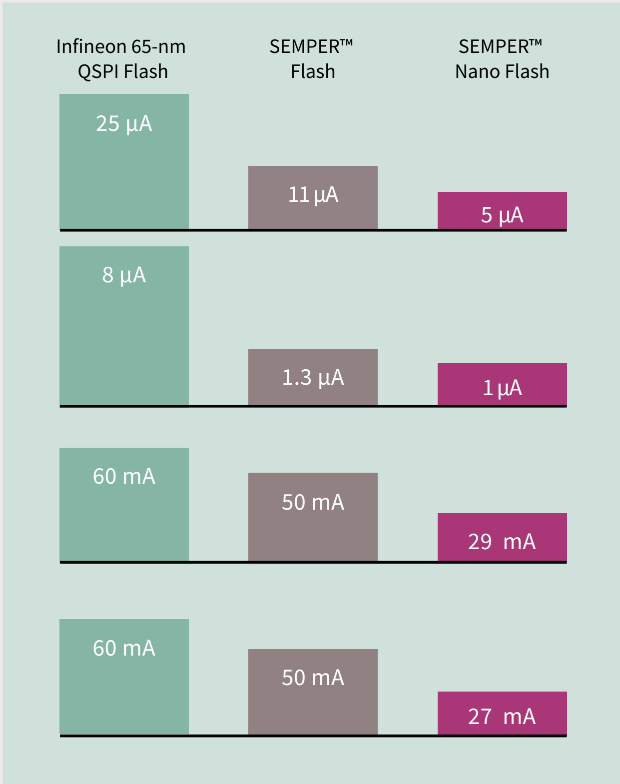
There are several ways NOR Flash can be optimized to minimize power consumption. Traditionally, low power is achieved by lowering standby current and active read current. Deep power down mode can significantly extend battery operating life to improve power efficiency further. To put this in perspective, SEMPER Nano NOR Flash has a typical standby current of 5.0 uA, which is 54% lower than SEMPER™ NOR Flash, and typical deep power-down mode drops to 1 uA, 23% lower than SEMPER NOR Flash (see Figure 2).

54% LOWER — **Standby current**
5 µA standby current*

23% LOWER — **Deep power down current**
1 µA deep-power-down current*

42% LOWER — **Program current**
29 mA program current*

46% LOWER — **Erase current**
27 mA erase current*




*Extends battery life for battery-powered applications

Figure 2: SEMPER™ Nano NOR Flash power consumption compared to SEMPER™ NOR Flash

The key to lower power consumption is minimizing the time of memory in active mode. Specifically, the time it takes to transition from active to standby mode is effectively wasted power. Thus, to maximize power savings, the memory needs to be able to drop into standby mode immediately (no delay standby).

Since SEMPER™ Flash was designed for the automotive market, SEMPER Nano has a foundation built on reliability. Even though hearables and wearables are consumer devices, increasing code size and data storage make reliability a growing concern for manufacturers. While a user may not perceive any error in an audio stream, a single bit error in driver or critical application code could render earbuds unusable. In addition, these devices tend to be used daily, often for a substantial amount of time. Thus, high endurance is required, so NOR Flash with an endurance of 100K write cycles is the memory of choice.

Because Flash wears, error correction code (ECC) technology is needed to protect devices. ECC integrated into the memory speeds processing by offloading this task from the CPU. It also ensures that every bit of memory is appropriately protected. Devices like SEMPER Nano that support a configurable sector architecture enable developers to segment code and data storage individually. This allows each segment to be configured with appropriate endurance and data retention levels, thus optimizing for both workloads in a single device.

It's important for manufacturers not to underestimate the importance of reliability. Ultimately, reliability directly impacts customer satisfaction and profitability, which are extremely important in high-volume markets, given that every returned device erodes profit.

Furthermore, with the prevalence of social media, an increasing concern is brand protection. In short, a single posting of a "crashed" wearable can impact the purchasing decisions of a great many potential customers. To minimize this risk, manufacturers need a memory partner with years of experience in the market. Expertise from a high-reliability industry such as automotive, medical, and industrial applications as well is best.

## 4. A superior user experience

Today's memory is more intelligent than ever before. SEMPER Nano, for example, has an integrated ARM Cortex M0 to handle low-power and reliability processing (see Figure 3).

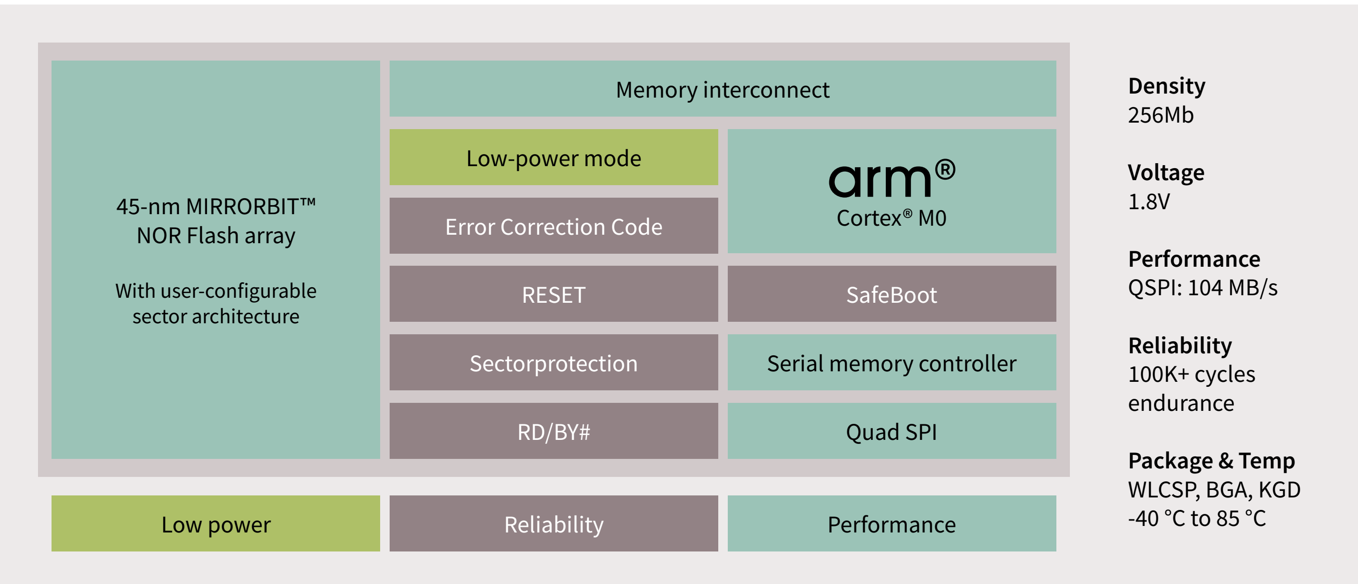



Figure 3: Smarter memory like SEMPER Nano NOR Flash integrates a processor such as an ARM® Cortex M0 to offload low power and reliability processing from the application CPU.

Fast read access is essential for features like “Instant On”. Many consumers expect electronic devices to turn on immediately; no one wants to wait for their earbuds to boot. Instant On is another one of the reasons NOR Flash is the non-volatile memory of choice for hearables and wearables. NOR Flash utilizes a parallel memory array interface, which allows for speedy read times, and makes it possible to boot up larger programs quickly.

Another aspect of Instant On is the use of NOR Flash as a unified memory architecture. Traditionally, program code is downloaded from Flash into RAM before execution. The fast access and low power of memory like SEMPER™ Nano make it possible to run code directly from Flash, known as Execute-in-Place (XiP). This further reduces the time for a device to turn on.

Effectively, a unified memory approach combines code, data, and logs in a single memory. This significantly reduces the overall physical memory footprint by eliminating RAM for code and data storage. Also, it enhances overall reliability, lowers power consumption, shrinks form factor, and simplifies design.

The key to success and profitability in the wearables and hearables markets is differentiating products with innovative features like advanced health monitoring to deliver a superior user experience. These features increase the need for higher density NOR Flash optimized for size, low power, and reliability. The integrated reliability capabilities of NOR Flash – with the ability to store code, data, and logs in a single unified memory – simplifies and accelerates designs while enabling developers to meet the tight design constraints of these applications. The final result is building better products, leading to higher profitability even in highly competitive markets.

For more information, visit Infineon’s wearables offering.

www.infineon.com

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