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Enhancing BLE Audio in TWS Earbuds with Alif Semiconductor's Balletto™ Family of MCUs

The Bluetooth market is evolving at an astonishing pace, set to reach 7 billion units by 2026, according to research from Bluetooth SIG — 2 billion platform (central) devices and approximately 4.4 billion peripheral devices. According to the research, up to 95% of Bluetooth devices will incorporate Bluetooth Low Energy (BLE) by 2026.

Designed for low-power applications, BLE is highly energy-efficient, enabling longer battery life with faster connection times compared to Bluetooth Classic technology in wireless audio devices, like true wireless stereo (TWS) earbuds. The latest earbuds are designed to be compact, give off a modern aesthetic, and utilize low-power technologies to decode digital signals from a device and transform them into high-fidelity audio. The entire process unfolds remarkably quickly, all within the span of a few milliseconds as sound travels to our ears.

Classic Bluetooth Limitations in TWS Audio Devices

True wireless stereo, TWS earbuds, one of the most rapidly growing segments in the audio market, has historically relied on Bluetooth Classic technology, specifically utilizing advanced audio distribution profiles (A2DP) for audio streaming. But the classic technology struggles with several limitations when utilized in TWS earbuds.

These devices, being small and lightweight, offer limited space for batteries. Bluetooth Classic, with its relatively higher power consumption, leads to short battery life and more frequent charging in TWS devices. It also uses uni-directional audio streaming, making it difficult to handle smooth handovers between audio playback and voice applications. As a point-to-point technology, Bluetooth Classic has a difficult time maintaining high-fidelity audio while ensuring perfect synchronization between both earbuds.

Bluetooth LE: A Game-Changer for Wireless Audio Applications

BLE technology addresses several limitations of Bluetooth Classic in wireless audio devices — it significantly reduces power consumption, which extends the battery life in devices like hearing aids, cochlear implants, and TWS earbuds. BLE also improves the audio quality and supports multi-stream audio, enabling not only synchronization between individual earbuds, but also allowing multiple audio streams within a single device.

As Bluetooth technology evolves, more devices, like TWS earbuds, will incorporate Bluetooth Low Energy (BLE) in the future. Image credit: Shutterstock

With features like Auracast™ broadcast audio, BLE Audio allows for both public and private broadcasting, enhancing user experience in various environments like theaters, conferences, or public transport. BLE Audio also improves interoperability across different manufacturers and devices, a universal approach that breaks down proprietary barriers, allowing end users to enjoy a broader range of products without compatibility concerns.

Other key features of BLE shaping wireless audio includes isochronous channel support for synchronized data streams and efficient audio and data transfer and support for low complexity communication codec (LC3), which offers improved audio quality at reduced data rates.

Alif Semiconductor's Balletto family of MCUs: Powering Next-Gen TWS Earbuds

Alif Semiconductor is paving the way for a new generation of highly compact, AI-enhanced devices such as TWS earbuds with the introduction of its Balletto family of wireless MCUs, the first BLE and Matter wireless microcontroller featuring a neural co-processor.

At the heart of Balletto's architecture is a merging of DSP acceleration and a dedicated Neural Processing Unit (NPU), engineered to optimize AI and ML workloads in a small form factor. This integration is crucial for delivering high-performance audio and sensor fusion in the latest TWS earbuds.

Balletto's MCU design is encapsulated in a minimalistic WLCSP or BGA package, which addresses the space constraints of TWS earbuds in a sub 16 mm² design. Manufacturers can now integrate sophisticated AI/ML functions, e.g., real-time speech recognition and active noise cancellation without increasing the earbuds' size or reducing their battery life.

The Arm® Cortex®-M55 core delivers an EEMBC CoreMark® score of 704 at 160MHz. This impressive performance is largely attributed to the inclusion of the Arm® Helium™ M-profile vector extension (MVE), which achieves a 500% improvement in DSP performance.

Alif's Balletto MCUs also incorporate an Arm Ethos™-U55 Neural Processing Unit (NPU) capable of executing up to 46 GOPS and is backed by 2MB of tightly coupled memory (TCM). Compared to a Cortex-M4 processor, the neural network processing performance is up to 15 times superior. This exceptional performance yields outstanding results in audio encoding and decoding functions, including the high-bit rate, low-latency LC3 codec, which is the foundation of BLE Auracast™ broadcast audio technology.

Image Credit : https://alifsemi.com/products/balletto/

Ultra-low Power Wireless and High Security

In TWS earbuds, Alif Balletto MCUs achieve ultra-low power consumption by leveraging aiPM™ technology to dynamically power logic and memory in use, resulting in the lowest overall system power consumption possible. The aiPM power management unit implements four system level power modes including a Stop mode which draws just 700nA.

Bluetooth-enabled devices, including TWS earbuds, are vulnerable to various security risks such as eavesdropping, man-in-the-middle attacks, and unauthorized access. Eaves dropping occurs when third-party devices intercept Bluetooth signals within range, potentially exposing sensitive information like personal contacts and messages. Man-in-the-middle attacks involve a hacker posing as a legitimate device to access sensitive data by intercepting connections within range. Unauthorized access typically happens when devices are configured to be discoverable, making them visible to potential attackers.

Balletto addresses security concerns in TWS earbuds by incorporating an advanced secure enclave, which serves as the heart of the multi-layered security fabric. This enclave features its own dedicated processor and memory, ensuring that sensitive security functions are isolated from the rest of the system.

The security architecture of these MCUs includes device integrity protection, secure identity, secure lifecycle management, secure firmware updates, and secure key storage. These functions are built upon a solid foundation of trust established by generating and storing a unique key pair for each device during the manufacturing process. By generating the key pair internally, Alif ensures that it remains unknown to any external entity, including the company itself, further enhancing the security of the device.

Other security features include configurable firewalls that regulate access of each CPU to sections of memories and individual peripherals and extend the capabilities of the standard Arm TrustZone security partitioning. This holistic security suite is foundational for creating trusted, secure TWS devices. With Bluetooth LE 5.3 and the LC3 Codec support, Balletto MCUs are capable of broadcasting high-bitrate, low-latency audio efficiently.

Wireless earbuds are set to become more compact and energy efficient with Alif's Balletto MCUs. Image credit: Shutterstock

Learning more about Balletto ™

Addressing critical limitations of the older Bluetooth Classic technology, Bluetooth LE is not only enhancing the user experience through improved audio quality and battery life, but broadening the features of TWS audio devices, making them more accessible, versatile, and enjoyable for a wider range of users. With the introduction of its Balletto family MCUs, Alif Semiconductor is paving the way for a new generation of compact, AI-enhanced TWS earbuds. Their multi-protocol support, coupled with unparalleled AI/ML capabilities simplifies the creation of energy-efficient connected edge devices. As the BLE market continues to expand, technologies like Balletto will continue to drive innovation, ensuring secure, efficient, and high-quality wireless audio experiences.

Click here to learn more about Alif Semiconductor's Balletto MCUs.

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