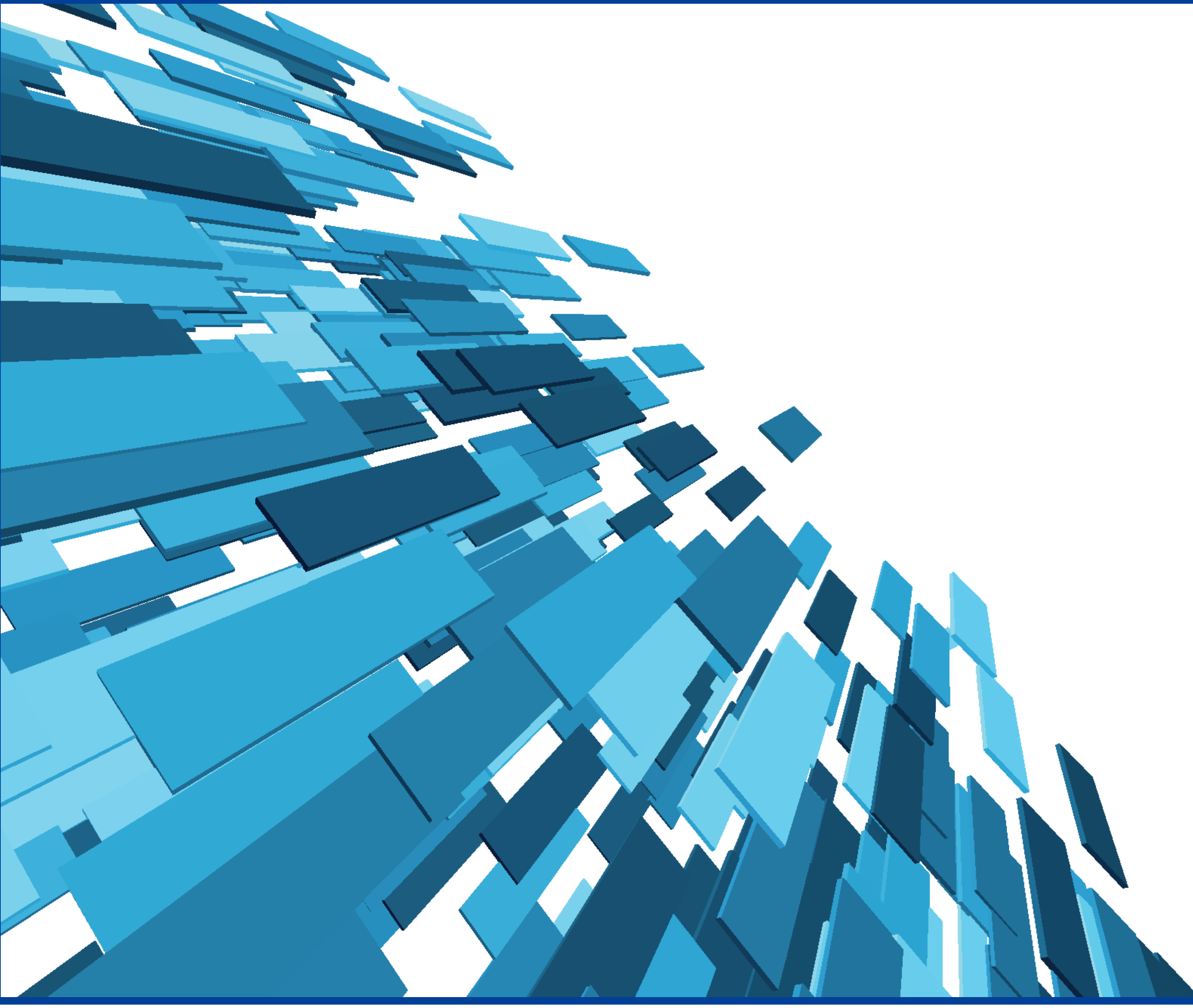
# Low Power Audio Subsystem of Samsung Exynos Processor



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## Contents

## Abstract

The demand for audio performance in mobile devices has been steadily increasing. For example, Mastering Quality Sound (MQS)[1] (192 KHz/24 bit) audio playback, advanced and realistic sound effect such as Dolby® DS1 and DTS® Headphone:X™, and voice recognition. However, increase in audio performance could be unfavorable news for the battery life of the device. One of the proposed solutions is to use a separate audio subsystem to increase the audio performance and battery life simultaneously. Samsung Exynos processor offers market-leading audio playback time with separate audio subsystem and strives to provide better performance and lower power consumption. This paper describes the efforts of Samsung and its preparation for high performance/low power audio for the future. It also includes:

- Procedure to play the audio file in mobile device
- Introduction on the operation principle of audio subsystem to implement low power audio
- Discussion on the procedure to support complex audio processing in the future

## Introduction

In mobile devices, audio is involved in most of usages such as audio playback, movie playback, gaming, and recording. Therefore, the audio processing is one of the most important functions of mobile device. Mobile users would wish to listen to music MP3 through the earphone and movie 6.1 channel sound through the Wi-Fi® display or HDMI®. Additionally, users require high quality audio with good sound effects. As playing music and watching movie is widely popular in mobile devices, high quality audio performance in mobile device has been increasing accordingly. Manufacturers of set and chip have made continuous efforts to improve the performance of audio and reduce the power consumption of audio simultaneously.

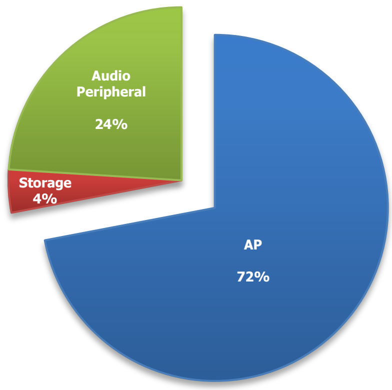


*Figure 1: Power Consumption Ratio during MP3 Playback [2]*

As illustrated in Figure 1, AP consumes 70 percent of system power during audio playback. Therefore, reduction in AP power consumption is the key to increase audio playback time in mobile devices.

## Understanding of the general audio playback

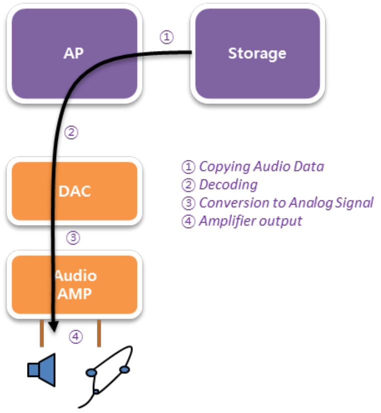


*Figure 2: Audio Processing Introduction*

Figure 2 illustrates the general audio playback system in mobile Application Processor (AP).

1) CPU copies the audio file (MP3, FLAC, AAC or WMA) from storage to Dynamic Random Access Memory (DRAM).

2) CPU decodes audio file and performs the post-processing such as equalization and providing sound effects. Audio stream data that has completed post-processing is transferred to the audio codec through the exclusive audio interface such as Integrated Interchip Sound ($I^2S$).

3) Audio codec performs additional post-processing such as Sample Rate Conversion (SRC), sound mixing, and sound compensation. Later, the audio codec converts digital audio stream data to analog data.

4) CPU transfers analog audio data to audio amplifier. Then, it creates a sound through the speaker, earphone, and headset.

Simple audio processing such as decoding and post-processing requires lesser CPU performance than playing movie, gaming, and other heavy user scenarios. However, even for the simple audio playback, the playing is not enough to satisfy the user expectation. This is because, in ordinary commercial AP, simple audio playback requires high performance CPU operation. You can save the power by scaling down the CPU frequency. However, it is not the solution.

## Methods to increase audio playback time

Audio processing is a low workload process and its power consumption depends on core type of processing and software audio codec. For example, MP3 decoding requires only 5~10 MHz and the power consumption of Cortex™-A5 is 0.12 mW/MHz[3]. Therefore, MP3 decoding consumes less than 2 mW. However, if main core manages audio playback, AP consumes more power than predefined power consumption of sub-core. This is because of turning on the main core, bus architecture, and memory block.

Dynamic Voltage and Frequency Scaling (DVFS) is the simplest method to increase the audio playback time. Audio playback is a light workload. It can operate with very low frequency. The system can drop the CPU frequency during audio playback by using DVFS. DVFS has an advantage because you need not change hardware architecture and OS. However, power efficiency lesser than that of a separate audio subsystem. This is because AP should turn on main core, memory block, and bus architecture during audio playback.

## Low power audio subsystem of Exynos Processor

Even with DVFS technology, AP consumes enough power during audio playback. This is because AP still turns On the main core, memory block, and bus architecture. Therefore, separate audio subsystem is required for to process low power audio. With the help of separate audio subsystem, you can perform the audio processing by using low power.

### Normal audio mode

Figure 3 illustrates the operational procedure of audio processing in normal AP.

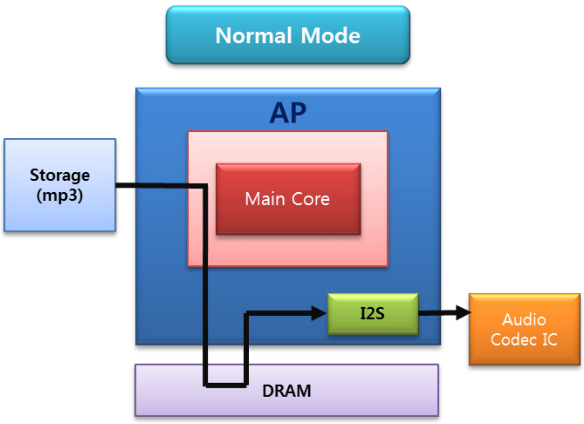


*Figure 3: Normal Audio Mode*

1) AP copies the audio file from storage to DRAM. The main core parses the audio file in DRAM to verify the basic information such as detailed encoding format, sampling rate, bit rate and so on.

2) The main core decodes the audio file. It also performs post-processing such as equalize.

3) CPU transfers the encoded audio stream to audio codec through the exclusive audio interface such as $I^2S$.

In normal audio mode, application processor should turn on all blocks such as main cores, memory module, and memory interface during the audio playback described in the steps.

### Low power audio mode of Exynos processor

Figure 4 illustrates the operational procedure of audio processing in the low power audio mode of Exynos Processor.

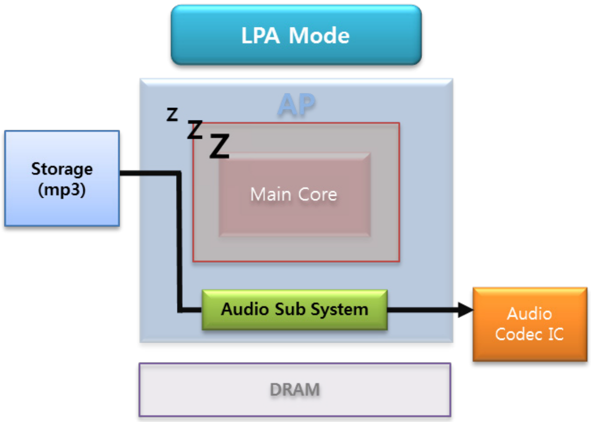


*Figure 4: Low Power Audio Mode*

1) AP copies the audio file from storage to DRAM. The main core pares the audio file. It is similar to normal audio mode until this step.

2) Main core transfers the audio file to audio subsystem. Then, the main core and memory block enter into to the sleep mode. It is known as Low Power Audio (LPA) mode.

3) Audio subsystem performs the remainder audio processing such as decoding.

4) Audio subsystem transfers the encoded audio stream to audio codec.

As described in the steps, when the system performs only audio playback without any other task, audio subsystem can take over audio work such as decoding and rendering. You can turn off the sub-blocks including main cores, memory interface, and memory module while music is being played except the audio subsystem.

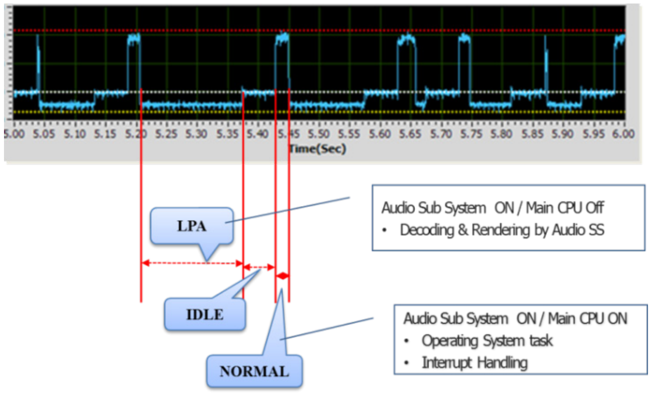


*Figure 5: Power measurement graph during audio playback [4]*

As illustrated in Figure 5, AP switches the power mode between normal mode and low power audio mode repeatedly. When you maintain low audio power mode, AP reduces power consumption. This is because there is gap of approximately nine times in the power consumption of AP between low power audio mode and normal mode.

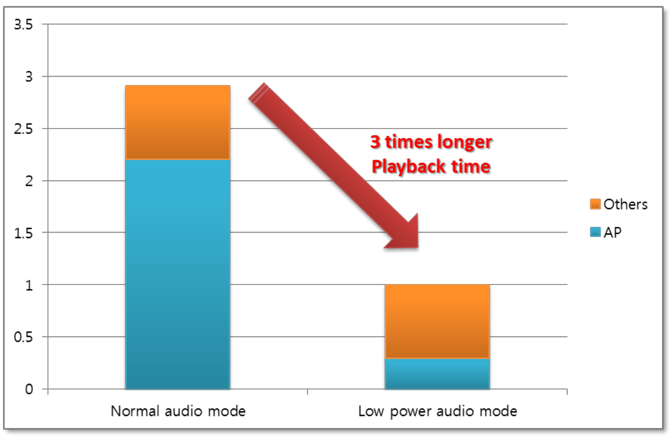


*Figure 6: Relative power comparison between low power audio mode and normal mode [5]*

When you consider other components such as audio codec, audio amp, and storage power consumption as same, the low power audio mode of Exynos processor can save 70 percent of total system power consumption. You can listen to MP3 three times longer than other devices that have no separate audio subsystem.

## Audio subsystem in the future

Audio processing in audio subsystem is sophisticated. There are three new audio demands in the mobile device market:

- Users wish to listen to high quality music like MQS. MQS is 24 bit and 192 kHz sampling rate and includes six times larger information than CD, which is 16 bit and 44.1 kHz.
- Users wish to watch high-quality movies through the TV by using HDMI or Wi-Fi display. Film producers tend to adopt advanced sound and realistic sound effects. Mobile device should support various post-processing tasks for the movie playback such as Dolby DS1 and DTS Headphone: X.
- Demands of voice recognition are increasing. Voice recognition enables user to hands-free commands. Voice recognition must be operating throughout unlike music and movie playback.

These tasks consume more power. As illustrated in Figure 7, advanced post-processing requires 18~30 times more performance. It affects the battery life largely.

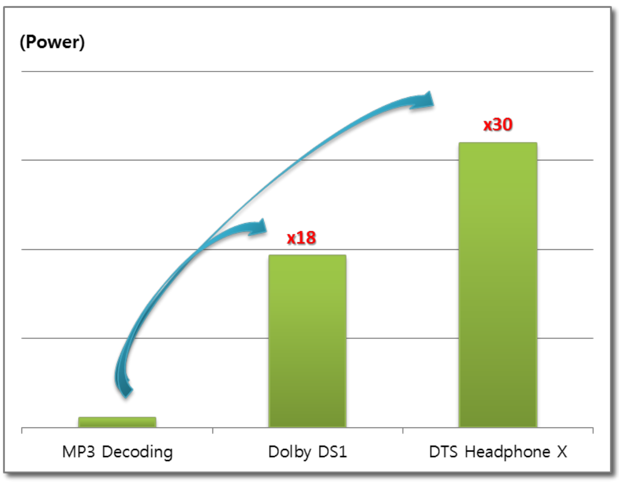


*Figure 7: Audio performance comparison [6]*

### Next generation of audio subsystem

The next generation of audio subsystem works on all audio processing that includes advanced post-processing, voice recognition, and high quality audio playback.

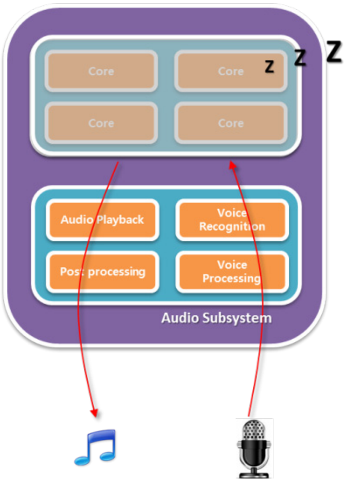


*Figure 8: The Concept of next generation audio subsystem*

The audio subsystem will perform all kinds of audio processing to reduce power consumption as illustrated in Figure 8.

In addition, a separate audio subsystem provides other benefits:

- Offers HD multi-channel audio processing such as Dolby DS1. This requires high performance and enough power. Separate audio subsystem secures power budget so that the performance of the system can be improved.
- Reduces total eBOM cost to perform additional functions such as voice trigger and noise reduction that is required for external components.

## Conclusion

This paper describes the principle of the general audio playback in the application processor and methods to increase audio playback time. Computational requirements of high-quality multimedia playback and various audio processing such as voice recognition continue to develop and evolve. Therefore, demand of low-power audio is increasing continuously.

Audio subsystem of Exynos processor is optimized for MP3 and assures longer audio playback time. In addition, Exynos will support multi-channel audio processing and sound effects that are required high performance with low power consumption.

## Reference


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