Dolby

Integrating Dolby Technologies into automotive platforms

A collaborative White Paper by Dolby and Qualcomm Technologies, Inc.

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Notices

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Scope

This White Paper can be used as a step-by-step guideline for integrating a Dolby Car Experience product into Qualcomm® automotive platforms.

The learning objectives are:

- Understanding the features and the value of a Dolby Car Experience product.
- Understanding the relevant parts of the Qualcomm automotive platforms with a focus on the Android Automotive operating system.
- Understanding how developers of music applications interface with the Dolby Car Experience functionality.
- Understanding how the Dolby Car Experience Implementation interacts with non-Android components such as Qualcomm's AudioReach or DSP Concepts's Audio Weaver signal processing frameworks, or Apple CarPlay supporting phone connectivity.
- Understanding that in contrast to stereo, music content mixed in Dolby Atmos contains separate center, rear and height content. The goal is to create a comprehensive and detailed three-dimensional sound stage across the entire car cabin. See section *Dolby Atmos* for an overview about the key features.

  It is important to understand that any speaker in the car, including the speakers in the back as well as the height speakers, contributes to this specific experience. To preserve the artistic intent of a Dolby Atmos mix, it is essential that all speaker levels and speaker frequency responses are carefully aligned and that no back- or height-specific signal processing, such as additional reverb, is applied.

The target audience for this documentation are technical product owners and decision makers of car original equipment manufacturer (OEM)s and Tier-1 suppliers.

References

For details about Dolby Car Experience, refer to the following kits provided by Dolby through the Dolby Customer portal (these are external links that require authorized account login):

- *Dolby Car Experience System Development Kit*
- *Dolby Car Experience Tuning Kit*

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Contacting Dolby

Support services are available to address any questions and to provide advice about integrating Dolby technology into your product.

For product design or testing, contact Dolby at systemsupport@dolby.com. By utilizing Dolby expertise, especially during the design process, many problems that might require design revisions before a product is approved can be prevented.

Dolby is also available to review product plans, including preliminary design information, markings, displays, and control and menu layouts, with the goal of preventing problems early in the product development cycle.

If you have comments or feedback about this documentation, send us an email at documentation@dolby.com.

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Introduction

Dolby Car Experience has been widely implemented in vehicles worldwide for several years.

Dolby Car Experience is a technology that is provided by Dolby in the form of an Implementation Kit which contains several software packages compatible with multi-core processors and other platforms.

This White Paper aims to:

- Explain the key steps for integrating a Dolby Car Experience Implementation into Qualcomm's automotive platforms, such as the Qualcomm® Snapdragon® Cockpit Platforms.
- Describe necessary modifications to the Android Automotive operating system that must be considered.
- Describe how to implement Dolby Atmos cabin tuning on one of the Snapdragon® Cockpit Platform DSPs using DSP Concept's Audio Weaver or Qualcomm's AudioReach software as an example.
- Outline the process for creating a Dolby Atmos experience in vehicles when content reaches the Dolby Car Experience Implementation via phone projection technology, specifically through Apple CarPlay.
- Provide guidance for music service application developers such as TIDAL or Apple Music on how to identify and properly utilize the Dolby Car Experience functionality.

Note: This documentation also provides links to documentation from Dolby and Qualcomm. To access those links, additional agreements are required.

Dolby Atmos

Dolby Atmos is an object-based audio technology for creating and reproducing spatial audio. The Dolby Atmos platform encompasses products, services, and technologies and includes authoring, distribution, and playback tools for both linear and nonlinear content.

Rather than requiring a content creator to downmix the elements (objects) of an audio scene to a fixed number of output channels prior to transmission and rendering, Dolby Atmos audio objects can be individually preserved, transmitted, and rendered. Key features of Dolby Atmos include:

- The ability to encode object-based audio metadata in the audio bitstream
- Three-dimensional audio rendering
- Device-independent audio bitstreams that can be faithfully rendered by any Dolby Atmos playback device
- A flexible rendering engine for Dolby Atmos playback devices that supports a wide range of loudspeaker layouts and room characteristics
- New speaker positions and designs

Tip: For more information about Dolby Atmos, refer to dolby-atmos.dolby.com.

For more information regarding Dolby Atmos Music, refer to music.dolby.com.

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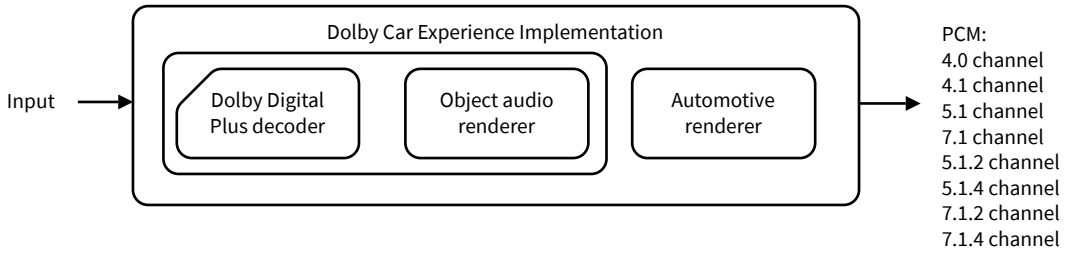
Dolby Car Experience product overview and Implementation overview

The main components of a Dolby Car Experience Implementation are a Dolby Digital Plus decoder, an object audio renderer, and an automotive renderer.

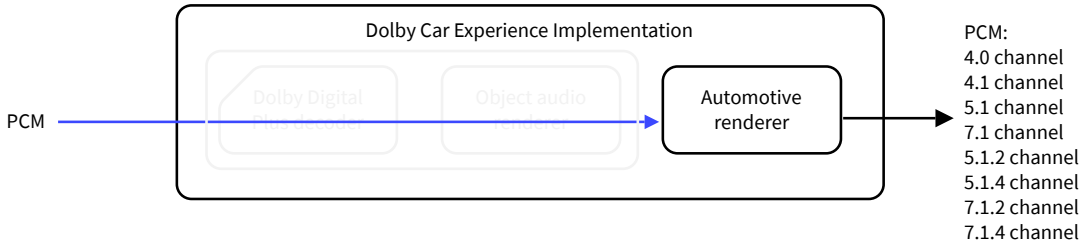
Figure 1: Dolby Car Experience Implementation overview



The Dolby Car Experience receives Dolby Digital Plus bitstreams as input from a streaming service provider. The input bitstream is decoded by the Dolby Digital Plus decoder and then rendered to a desired channel representation by the object audio renderer. The data rate of a typical bitstream is 768 kbps. The signal processing reproduces the acoustical behavior of physical speakers, for example, in case of missing height speakers or a missing center speaker.

Pulse code modulation (PCM) input, arriving from phone projection applications such as Apple CarPlay, is directly fed to the automotive renderer component.

Figure 2: Dolby Car Experience Implementation overview for PCM input signals



PCM Input data types

The Dolby Car Experience Implementation requires the input of PCM signals with a sample rate of 48 kHz. The following PCM data types are supported:

- `short`: 16-bit integer linear PCM
- `int`: Left-aligned integer linear PCM (usually 32 bits)
- `float`: Single-precision floating point

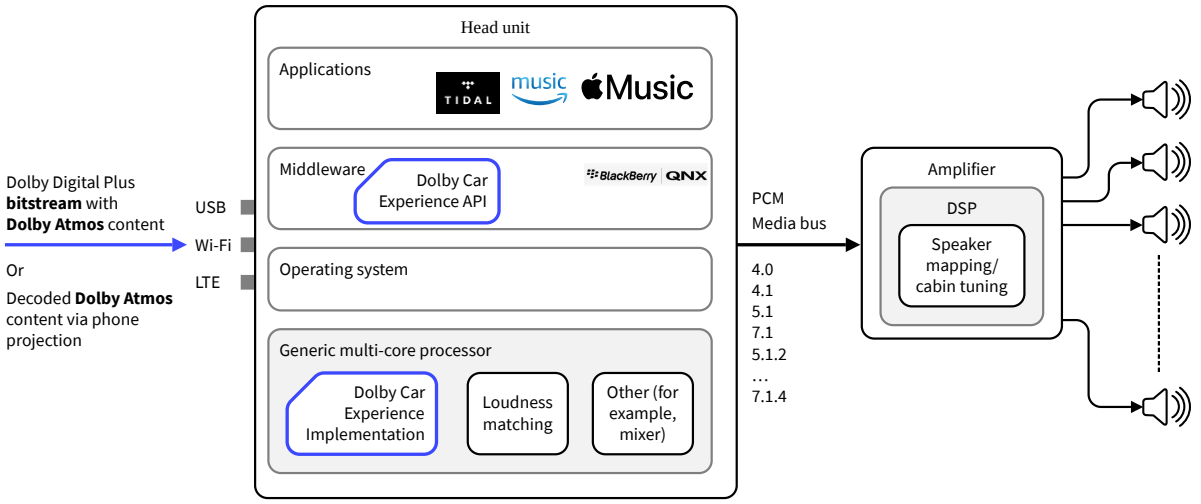
Note: Other PCM data formats or bit depths from the integration layer must be converted to one of the supported data formats before they can be provided to the Dolby Car Experience Implementation.

- Traditional functional integration of Dolby Car Experience in car audio systems
- Functional integration of Dolby Car Experience in a head unit running on Snapdragon® Cockpit Platforms

4.1 Traditional functional integration of Dolby Car Experience in car audio systems

The Dolby Car Experience Implementation is typically integrated in the head unit of the car.

Figure 3: Dolby Car Experience Implementation integrated in the head unit on a generic multi-core processor



- The input to the head unit is either a Dolby Digital Plus bitstream with Dolby Atmos content via a streaming music service, or decoded Dolby Atmos content via phone projection.

  The Dolby Car Experience Implementation typically operates on an multi-core processor. The output of the Dolby Car Experience Implementation is PCM rendered to one of these output channel configurations:

  - 4.0
  - 4.1
  - 5.1
  - 7.1
  - 5.1.2
  - 5.1.4
  - 7.1.2
  - 7.1.4
- A loudness matching component ensures that different sources of content are leveled to an equivalent loudness reference level so that, for example, a mixed playlist of Dolby Atmos Music items and stereo items are played back at the same loudness level. A mixing component performs, for example, the mixing of system sounds, blending or leveling with other sources such as navigation systems or phone calls.

  One possible approach for music content is that the playback levels of several streaming service providers are adjusted to the lowest loudness level, which in this case is Dolby Atmos at -20 loudness K-weighted relative to full scale (LKFS) and the Dolby Car Experience Implementation configured in RF mode.

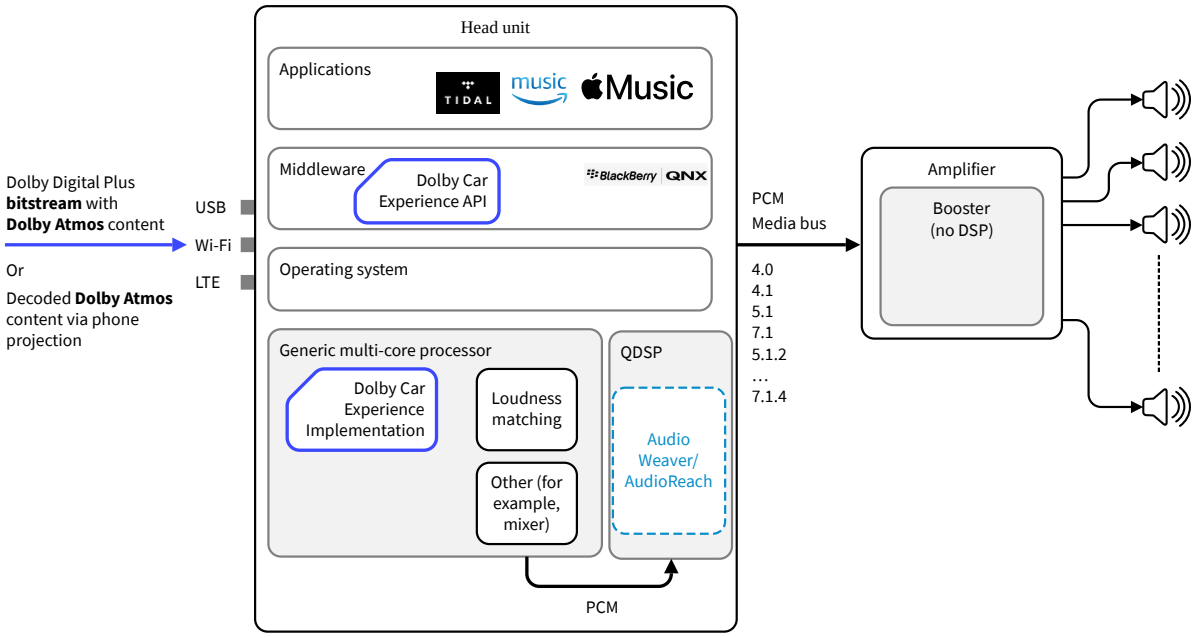
  Dolby Atmos Music has a target loudness level of -18 LKFS; therefore, a common target reference level of -20 LKFS maintains its dynamic range. This solution also works for other types of content, as the dynamic range control stage of the Dolby Car Experience Implementation will ensure that peaks are limited to 20 loudness units above the reference level. This is the recommended solution for the playback of Dolby Atmos Music in a car and the recommended dynamic range control setting of the Dolby Car Experience Implementation.
- The media bus carries PCM to an external (smart) amplifier at a minimum of 16 bits.
  - The amplifier includes a DSP and booster DSP

    Could be also located in the SoC of the head unit
  - The PCM is typically mapped to more speakers than there are immersive channels.

4.2 Functional integration of Dolby Car Experience in a head unit running on Snapdragon® Cockpit Platforms

As for the traditional integration, the easiest and most straight forward approach for a head unit running on a Snapdragon® Cockpit Platform is to integrate the Dolby Car Experience Implementation on the multi-core central processing unit (CPU).

Figure 4: Dolby Car Experience Implementation integrated in the head unit running on a multi-core CPU (Snapdragon® Cockpit Platform)



- The Dolby Car Experience Implementation receives and processes the input bitstream or content received via phone projection and outputs PCM.
- The intelligent amplifier is replaced by a booster.
- Cabin tuning/equalization processing is moved to one of the Qualcomm® DSPs using AudioReach from Qualcomm or Audio Weaver software from DSP Concepts as an example in addition to loudness, mixing, leveling, etc.
- Loudness matching and mixing could still reside on the generic multi-core CPUs as individual components.

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Dolby Car Experience running on generic multi-core processors

Precompiled libraries of the Dolby Car Experience Implementation

Dolby provides precompiled libraries of the Dolby Car Experience Implementation for all supported Android Automotive operating system variants using the default compiler flags. Builds with customer-specific compiler flags might be available on request.

Integrating Dolby Car Experience into Android Automotive operating system

Dolby Digital Plus bitstreams with Dolby Atmos content are automatically identified by the Android Automotive operating system as `AUDIO_FORMAT_E_AC3_JOC`.

However, by default the Android Automotive operating system does not know how to decode the bitstreams and therefore will not play them back. As a result, the Android Automotive operating system needs to be extended to correctly to handle bitstreams with `AUDIO_FORMAT_E_AC3_JOC`.

Dolby provides detailed documentation and sample code in the *Dolby Car Experience System Development Kit* for how to extend the Android Automotive operating system to include a Dolby Digital Plus decoder capable of processing Dolby Atmos content. All extensions follow Google's standard for the Android Automotive operating system.

Although the Dolby Car Experience consists of a decoder and a renderer, from an Android Automotive operating system perspective, it operates as a regular decoder that receives bitstream input and outputs PCM.

Two methods can be used to enable additional audio technologies such as Dolby Car Experience; MediaCodec and Pass-through, also referred to as Offload. Pass-through offloads the decoding process to the HAL. Because the Android Automotive operating system supports MP3, AAC or Opus using MediaCodec, and application support for MediaCodec is more widespread than for pass-through integration, the MediaCodec integration is strongly recommended. This documentation focuses on MediaCodec only.

A Dolby Car Experience Implementation can be integrated into a `MediaCodec` decoder for bitstream inputs and a `MediaCodec` pulse code modulation (PCM) decoder for PCM inputs in system-on-chip (SoC) and OEM devices.

The Dolby Car Experience Implementation can be integrated as a `MediaCodec` decoder using either an `OpenMAX` component or as custom media codec that uses the `Codec 2.0` interface.

A Dolby Car Experience Implementation supports 4.0, 5.1, 7.1, 5.1.2, 5.1.4, 7.1.2, and 7.1.4 output channel configurations. Additionally, the Implementation also supports active output channel metadata that depends on the input format and the output channel configuration.

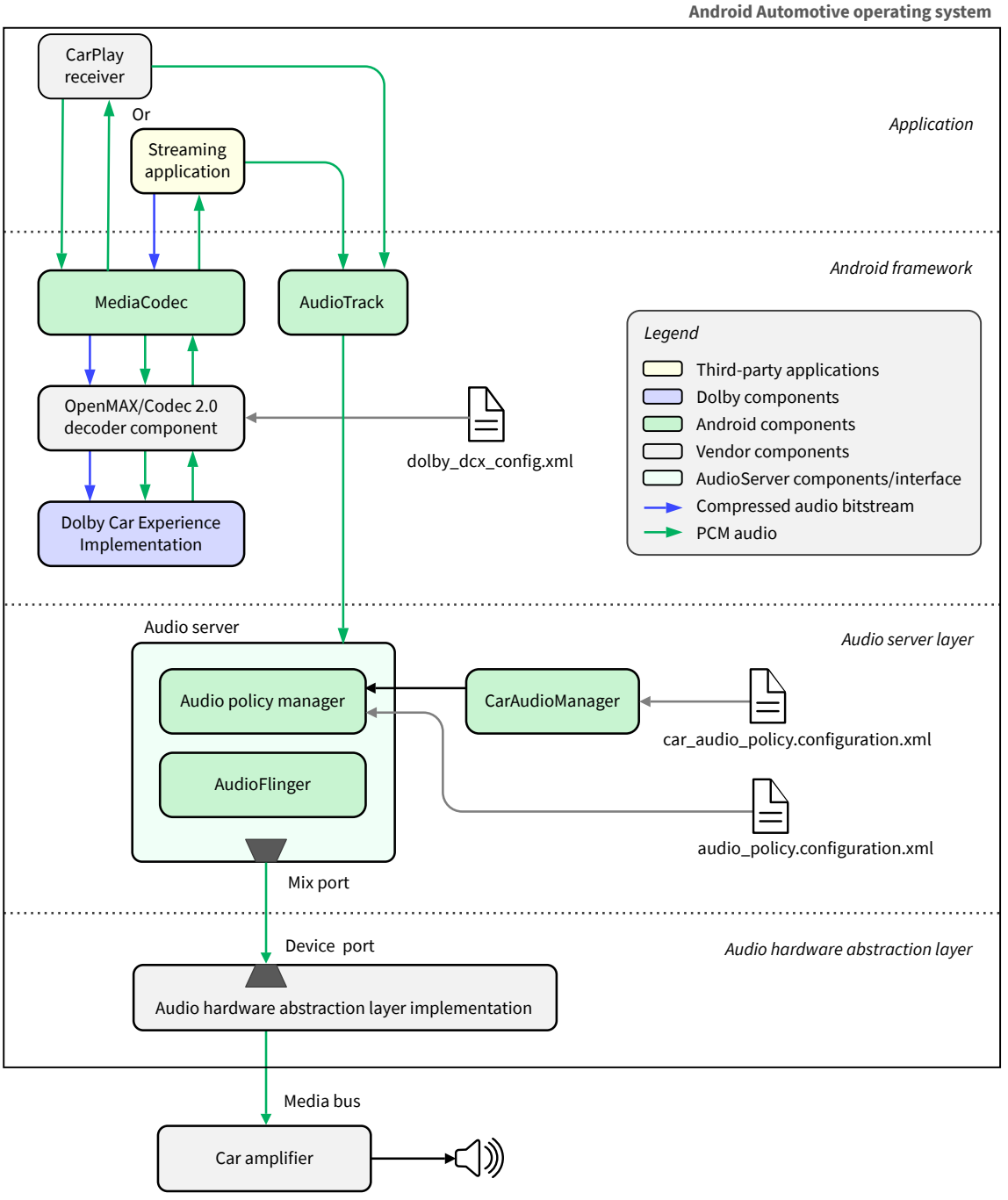
In Android Automotive 11, the Android Automotive audio server is limited to output of up to eight-channel PCM, both for mixed outputs as well as for direct outputs. This is because, for mixed outputs, the Android Automotive audio mixer only supports a maximum of eight output channels, and that for direct outputs, the default audio policy only supports channel-mask parsing for up to eight-channel masks. In Android Automotive 11, the output-channel count of a `MediaCodec` codec that includes a Dolby Car Experience Implementation should be configured to output a maximum of eight channels, which corresponds to an output channel configuration of either 7.1 or 5.1.2.

In Android Automotive 12 and above, the Android Automotive audio mixer supports up to 12-channel output, and the default audio policy supports channel-mask parsing of 24-channel masks. The output-channel count of a `MediaCodec` codec that includes a Dolby Car Experience Implementation can be

configured to any of the supported output channel configurations of the Dolby Car Experience Implementation (up to 7.1.4).

The following diagram shows the `MediaCodec`-based architecture and the possibilities for integrating a Dolby Car Experience Implementation, as well as the two approaches for creating a multichannel PCM audio path from the music application to the audio hardware abstraction layer (HAL).

Figure 5: Dolby Car Experience MediaCodec-based architecture



For detailed information about the integration of the Dolby Car Experience Implementation into Android Automotive operating system, refer to the documentation delivered with the *Dolby Car Experience System Development Kit* (Dolby Car Experience System Development Kit, Chapter Android Automotive Integration).

Phone projection

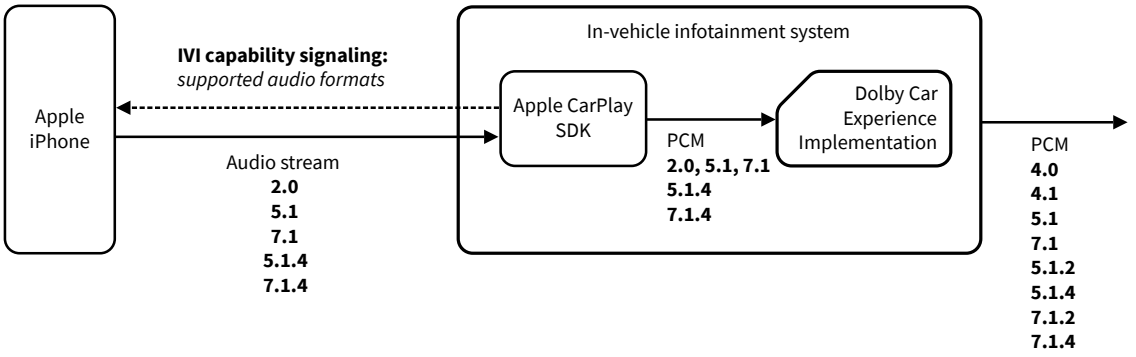
Apple CarPlay technology allows for audio projection from iPhone to the Apple CarPlay-enabled in-vehicle infotainment (IVI) system.

The solution consists of the source device supporting Apple CarPlay (iPhone) and receiver device (IVI) that integrates the Apple CarPlay SDK. The integrator or integrators of the IVI system are responsible for the integration of the Apple CarPlay SDK and Dolby Car Experience implementation.

Apple CarPlay supports various channel configurations, from stereo to spatial audio. It supports the Dolby Atmos audio format and allows Dolby Atmos content to be deliverd to the car. Audio is transmitted from the source device using format specific to CarPlay technology. The Apple CarPlay SDK decodes this format to PCM and outputs this PCM audio to the IVI system.

In the following block diagram, you can see how phone projection using Apple CarPlay works.

Figure 6: Phone projection using Apple CarPlay



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Cabin tuning on DSPs

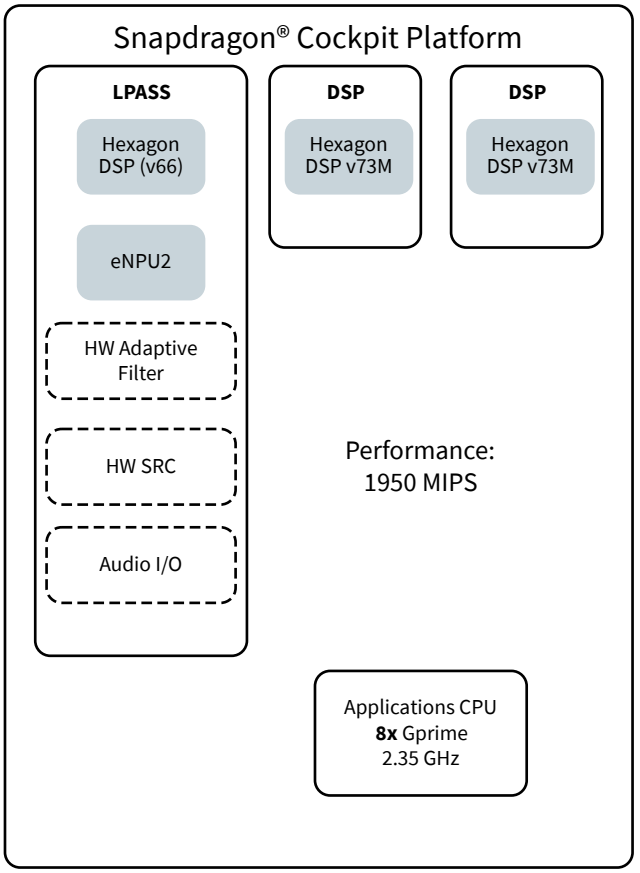
Modern cabin tuning in the automotive industry predominantly relies on a block-diagram paradigm, utilizing sophisticated software tools designed specifically for in-vehicle audio systems. These tools enable audio engineers to optimize sound quality and create immersive listening experiences tailored to each vehicle's unique acoustic environment.

Audio Weaver by DSP Concepts and AudioReach™ Signal Processing Framework by Qualcomm Innovation Center provide intuitive interfaces and powerful algorithms that allow for precise adjustment of various audio parameters, ensuring that the IVI system delivers superior sound performance across different seating positions and driving conditions.

Basic blocks include various types of filters, biquads, multiplexers, demultiplexers, and other signal processing functions executing on the Qualcomm DSPs. After finalizing the tuning, the software stores the corresponding parameter set in flash memory.

Dolby provides a *Dolby Car Experience Tuning Kit* to Licensees. The Tuning Kit provides comprehensive guidelines for optimizing Dolby Atmos audio experiences in vehicle cabins. The kit includes tools and specifications for different speaker configurations and supports multiple input formats including Dolby Digital Plus with Dolby Atmos content. Through careful speaker alignment and optimization, the tuning process enables creation of an immersive three-dimensional soundstage while preserving artistic intent.

Figure 7: Snapdragon® Cockpit Platform SoC



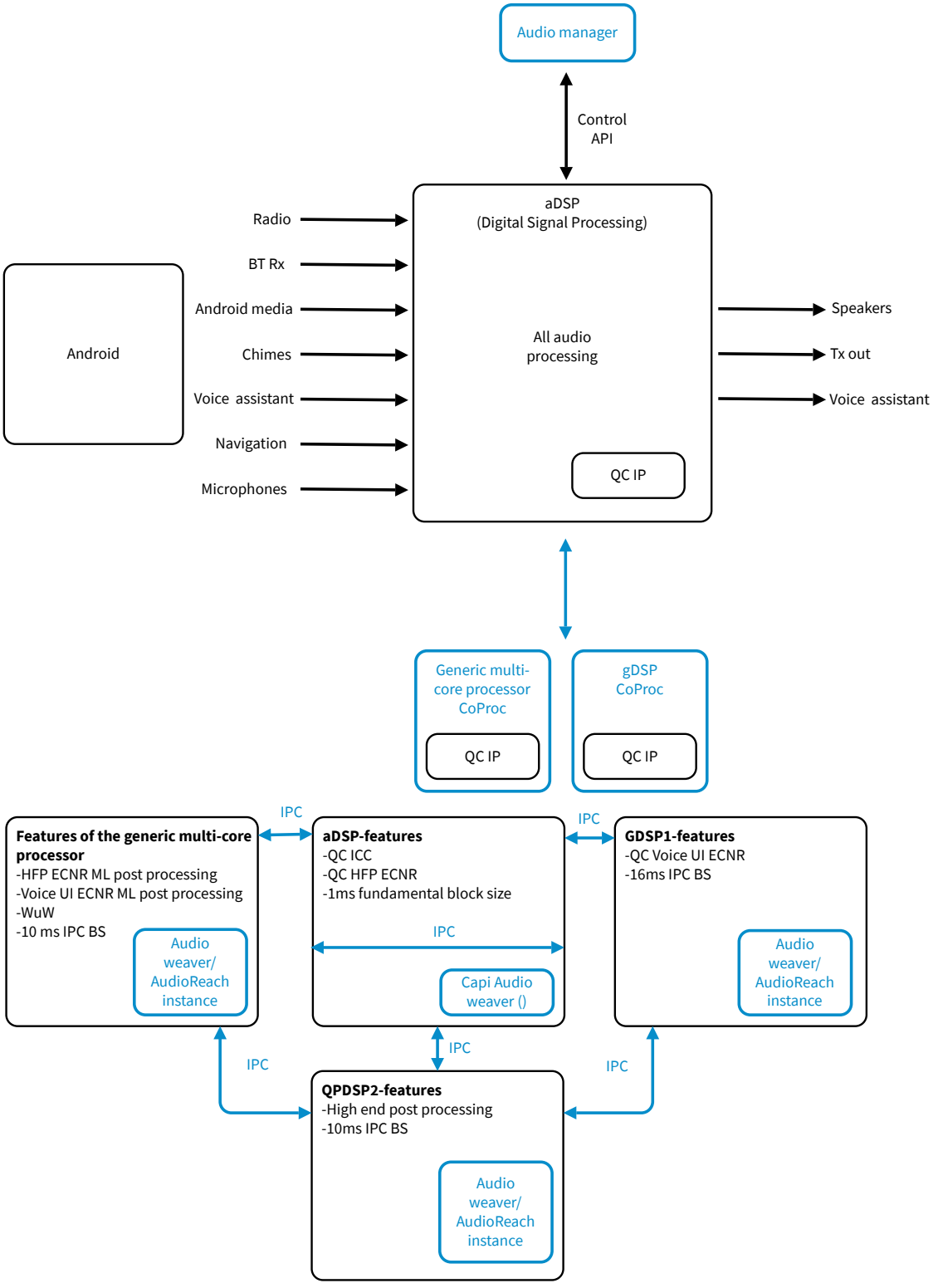
The Snapdragon® Cockpit Platform SoC delivers robust processing power through its three DSPs (providing approximately 1,950 MPPS) and eight Qualcomm® Kryo™ CPU cores. This computational capability enables the SoC to meet the audio and voice processing requirements for premium vehicles equipped with 28 or more speakers.

Audio Weaver or AudioReach audio frameworks extend across all three DSPs and CPUs, enabling data processing across all cores. This setup, with a single processing graph spanning all cores, ensures efficient data handling for activities such as voice pickup and rendering from various seating positions. Decoded Dolby Atmos content PCM samples can be seamlessly consumed by the frameworks.

Using either Audio Weaver or AudioReach, you can implement as-needed postprocessing on these decoded samples to match the vehicle's speaker configuration. Even in premium vehicles with more than 28 speakers, a single DSP, such as the versatile gDSP, can execute these audio postprocessing workloads. For example, Dolby Atmos technologies and algorithms such as , Bose CP 360, and Bose 3DX, which offer immersive audio experiences and seat-centric rendering, have been efficiently integrated within a single gDSP. This leaves the other two DSPs available for additional voice processing tasks. The Snapdragon® Cockpit Platform SoC also include neural processing units and an eNPU for hardware-accelerated AI processing, further enhancing its capabilities.

The following figure illustrates how audio and voice features can be distributed across the three DSP cores of the Snapdragon® Cockpit Platform SoC: the audio Digital Signal Processor (aDSP), two general-purpose Digital Signal Processors (gDSP0 and gDSP1), and the CPU. This architecture enables efficient implementation of advanced audio technologies, including Dolby Atmos and other postprocessing functions, showcasing the versatility and power of the Snapdragon® Cockpit Platform SoC for premium automotive audio applications.

Figure 8: Capabilities of the Snapdragon® Cockpit Platform SoC



- I/O specification

6.1 I/O specification

Qualcomm Snapdragon® Cockpit Platforms offer a complete audio solution.

The solution includes these components:

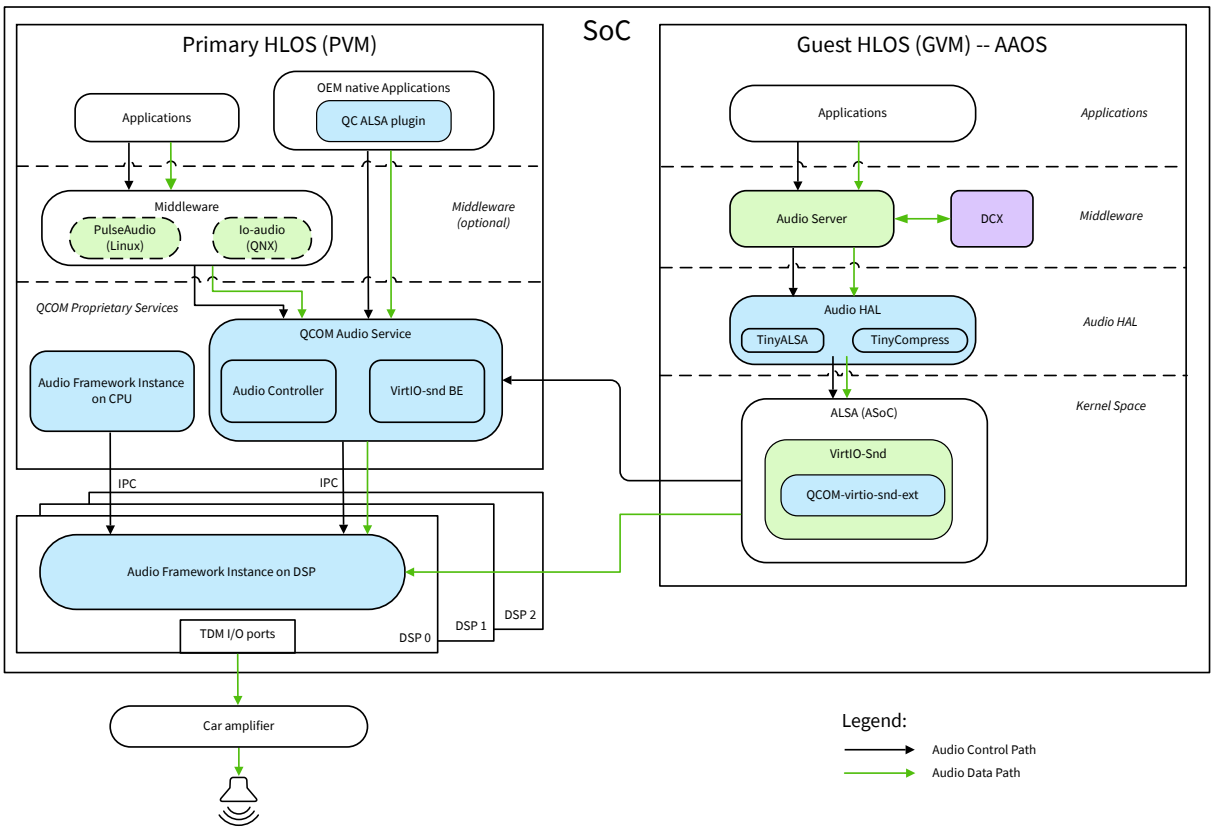
- Audio Framework Instance (AudioReach or Audio Weaver) on digital signal processor (DSP) and CPU

  Hosts a block diagram-based “drag & drop” approach which allows customers to design, configure and execute signal-processing modules in automotive products.
- Qualcomm® Audio Service running on Primary High-Level Operating System (Primary HLOS) on a Physical Virtual Machine (PVM):
  - Interacts with audio framework instances from different DSP or CPUs.
  - Maintains the overall system initialization, audio streams management and pre- and postprocessing controls.
- Android Audio HAL and VirtIO-Snd running on Guest High-Level Operating System (Guest HLOS) on a Guest Virtual Machine (GVM)

  Provide seamless integration with the Android framework to support various Android-based applications.

Throughout the system design, a Qualcomm SoC uses an effective interprocess (IPC) message scheme for the audio control path and direct shared memory for the audio data path. This approach minimizes the overall audio latency from applications to the processing modules and renders components to cabin speakers.

Figure 9: Qualcomm SoC audio architecture



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Extending music applications to support Dolby Atmos

Music applications running on AAOS that currently offer only stereo playback require updates to utilize Dolby Car Experience capabilities integrated into a typical vehicle head unit.

While this document primarily targets technical product owners and decision makers who may not be responsible for developing or extending a music application, understanding the music service integration process is valuable for all stakeholders.

For most music application developers, this extension is relatively straightforward. For detailed information on how applications can implement decoding of Dolby Digital Plus bitstreams with Dolby Atmos content on AAOS platforms, refer to Enabling Dolby Atmos in Android Automotive OS media apps.

Testing music applications that support Dolby Atmos does not require physical vehicle access. Instead, Dolby provides an AAOS image that includes a Dolby Car Experience Implementation to be operated on the standard Android emulator included with the respective Android Automotive SDK.

From a music application perspective, the emulator environment behaves identically to a physical AAOS device, including the internet-based access to the respective music application. The AAOS image with integrated Dolby Car Experience Implementation is available for Dolby customers. Contact Dolby for more information.

Glossary

codec
A system consisting of an encoder and decoder.

CPU
Central processing unit.

DSP
Digital signal processor. A specialized microprocessor optimized for digital signal processing.

HAL
Hardware abstraction layer. A layer of programming that allows a computer operating system to interact with a hardware device at a general or abstract level rather than at a detailed hardware level.

head unit
In automobiles, a central module that provides a unified hardware interface for the system, including screens, buttons, and system controls for integrated information and entertainment functions.

I/O
Input/output. The communication between a system and an entity outside the system, such as another system or a human being.

Implementation
An implementation is a realization of a technology as an integrated circuit (IC), a hardware component (subsystem), or a software module that runs on a general-purpose microprocessor. An Approved Implementation is one that has been tested and approved by Dolby and can be used to build consumer products.

IVI
In-vehicle infotainment. A system in automobiles consisting of hardware and software that provides audio and video entertainment and information.

LKFS
Loudness K-weighted relative to full scale. A unit of loudness measurement, standardized in ITU BS.1770 and designed to enable normalization of audio levels for delivery of broadcast content, providing a gated average loudness measurement over an audio program. For long-term measurements, LKFS is equivalent to LUFS as defined by EBU Tech-3341.

object-based audio
Consists of one or more audio signals and associated metadata. Object-based audio can contain bed objects (channel-based audio) with a fixed nominal playback position, dynamic objects with explicit positional metadata that can change with time, and intermediate spatial format objects. Object-based audio is closely linked to auditory image position rather than assumed loudspeaker positions.

OEM
Original equipment manufacturer. A manufacturer that provides a complete hardware and software system to the consumer.

output channel configuration
channel configuration present at the output of the decoder

PCM
Pulse code modulation. A digital representation of an analog signal where the amplitude of the signal is sampled at uniform intervals.

RF mode
A dynamic range control mode that applies metadata with a target dialogue level of -20 dBFS.

SoC

System-on-chip. An integrated circuit that integrates all components of an electronic system into a single chip.

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