Development of an Audio Unit for Lexus Vehicles

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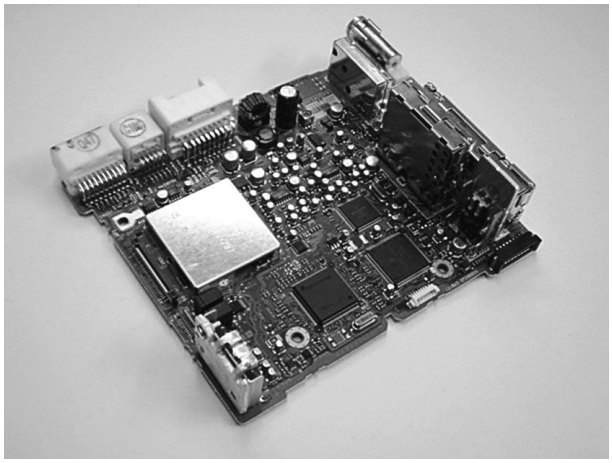

Abstract

In recent years, various Japanese car navigation manufacturers have begun introducing HDD audio units to the market that function with the HDD navigation unit and are capable of storing compressed music files on the HDD. This ability to store compressed music files in a memory medium and enjoy them anywhere, as in the case of the portable audio market, has permeated society.

As an HDD audio unit to be equipped on Lexus vehicles carries the Lexus brand name, it must be easy to use and preserve the luxurious ambience of the vehicle, as well as provide a full array of functions.

This essay introduces the enabling technology for HDD audio functions developed by Fujitsu Ten for the corresponding audio unit.

1 Introduction

The Japanese car navigation market continues to move away from navigation units using Digital Versatile Disks (DVDs) as a storage medium and towards navigation units that use Hard Disk Drives (HDDs) (referred to as HDD navigation units below). To accommodate this trend, various manufacturers are introducing HDD audio units to the market that function together with the HDD navigation unit and are capable of storing compressed music files on the HDD.

This ability to store compressed music files in a memory medium and enjoy them anywhere, as in the case of the portable audio market led by the iPod, has become more and more popular.

Fujitsu Ten has worked in collaboration with other related companies in the development of audio systems by participating, from the initial planning stages, in the development of HDD audio functions for audio units of Lexus vehicles with the goal of producing product functions that preserve the Lexus reputation for ease of use and luxury, as well as equaling or exceeding other commercially available products.

One major feature of the HDD audio unit is that, as the HDD navigation, audio and amp sections are all developed independently as single units by their respective manufacturers, the HDD audio unit must contain a function so that information such as music data can be communicated between units.

This essay introduces the enabling technology for HDD audio functions developed by Fujitsu Ten focused on the corresponding audio unit.

2 System Outline (HDD audio functions)

The audio unit for Lexus vehicles includes functions to record/play music data files that are shown in the system block diagram (Fig. 1 below).

A major characteristic of this system is that the HDD used for storing compressed music is a separate unit. For storing data on the HDD that is outside of the audio unit, the audio unit portion developed by Fujitsu Ten reads data from a CD disk and compresses it into the Advanced Audio Coding (AAC) format before sending the data to the HDD via the AVC-LAN plus communication.

The sending of data from the CD deck integrated into the audio unit for the HDD is controlled by the Re-configurable Automotive Processor (RAP) circuit board.

Reading of data from the CD can performed at a speed of 4X so that recording time can be reduced. The HDD navigation unit (Shown as EMVN in Fig. 1) decompresses recorded music into analog signals (parallel audio signals). These signals are input to the audio unit and output to the external amp when the selector is switched.

When recording at a speed of 1X, two digital signal systems are sent from the CD, with one sending music data to the HDD and the other one sending data to the Digital Sound Processor (DSP) so that the audio output can be used for both recording and listening at the same time.

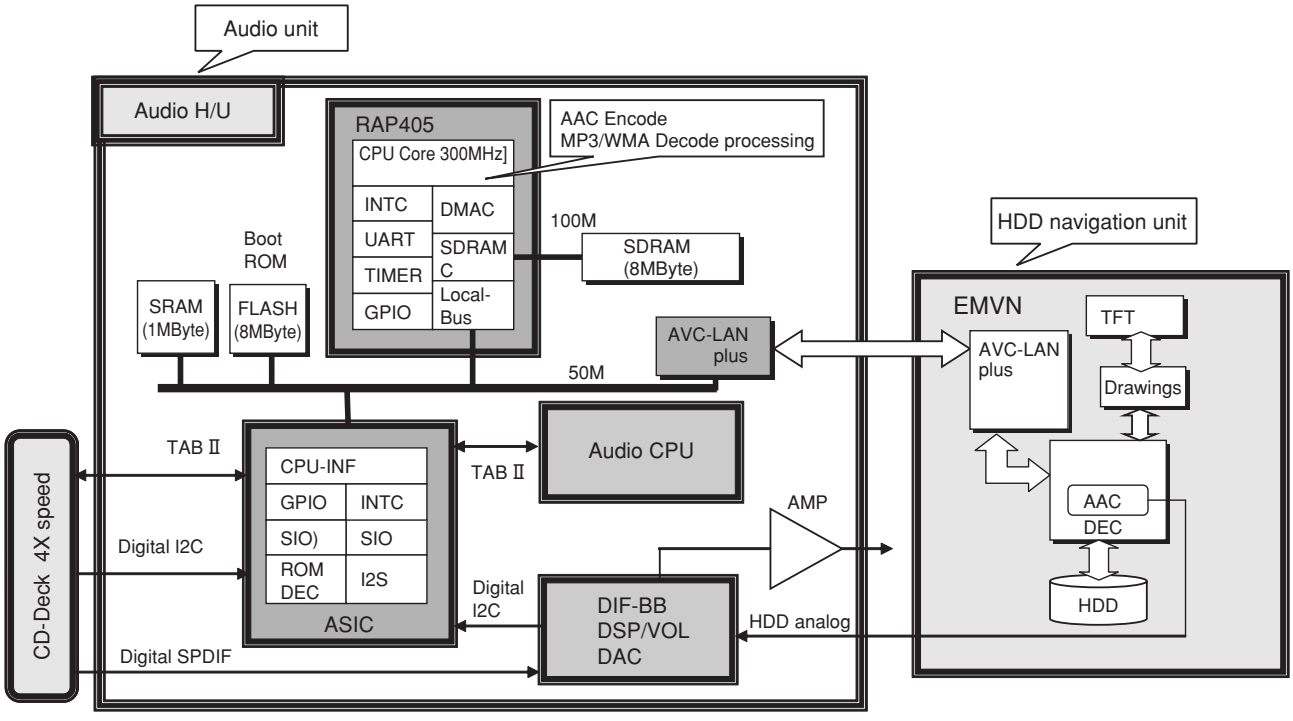

Fig.1 HDD audio system

3 Product Outline

The following provides an outline of the audio unit developed for Lexus vehicles.

Common components

External size: 2 DIN (W 178 × H 100 × D 155 mm)
Weight: 2.3 kg
Component decks
①CD deck: Fujitsu Ten DA-30 (Compatible with 4X)
②MD deck: Fujitsu Ten MS-06 (Compatible with group formatting)

AV components

Radio (AM/FM) reception function
Diversity antenna reception function
FM VICS component reception(1)
Specialized integrated tuner for VICS independent reception
CD-R/RW playing function
MP3/WMA playing function
MD-LP/MD group playing function
Function for digital recording of music from CD-DA to HDD (AAC encoding)
4X speed recording capability
Start -up music compatibility
Interrupted audio position control capability

4 Internal System Outline

This unit is equipped with a radio tuner, CD deck, and MD deck. The audio unit can receive AM/FM radio and VICS composite signals, and can play CD (CD-R/RW), MD (MD-LP/MD-group), and MP3/WMA(2) media. Additionally, a DSP has been integrated with the radio section and a variety of other functions are included such as an independent circuit configuration for interrupted audio paths.

DIF-IF and DIF-BB(3) with a radio noise-canceling function have been adopted for the DSP of the audio unit, and a RAP microcomputer that provides codecs for audio processing. A dedicated I/O ASIC has been adopted for communication between the RAP microcomputer and the surrounding memory ICs. Fig. 2 shows the system structure.

(Notes)
1. VICS：Vehicle Information and Communication System
2. WMA：Windows Media Audio
3. DIF-IF and DIF-BB are ICs that perform both noise and radio control. For details, see the Fujitsu Ten Technical Journal, No. 25.
   Refer to "Reception performance improvement of AM/FM tuner by digital signal processing technology".

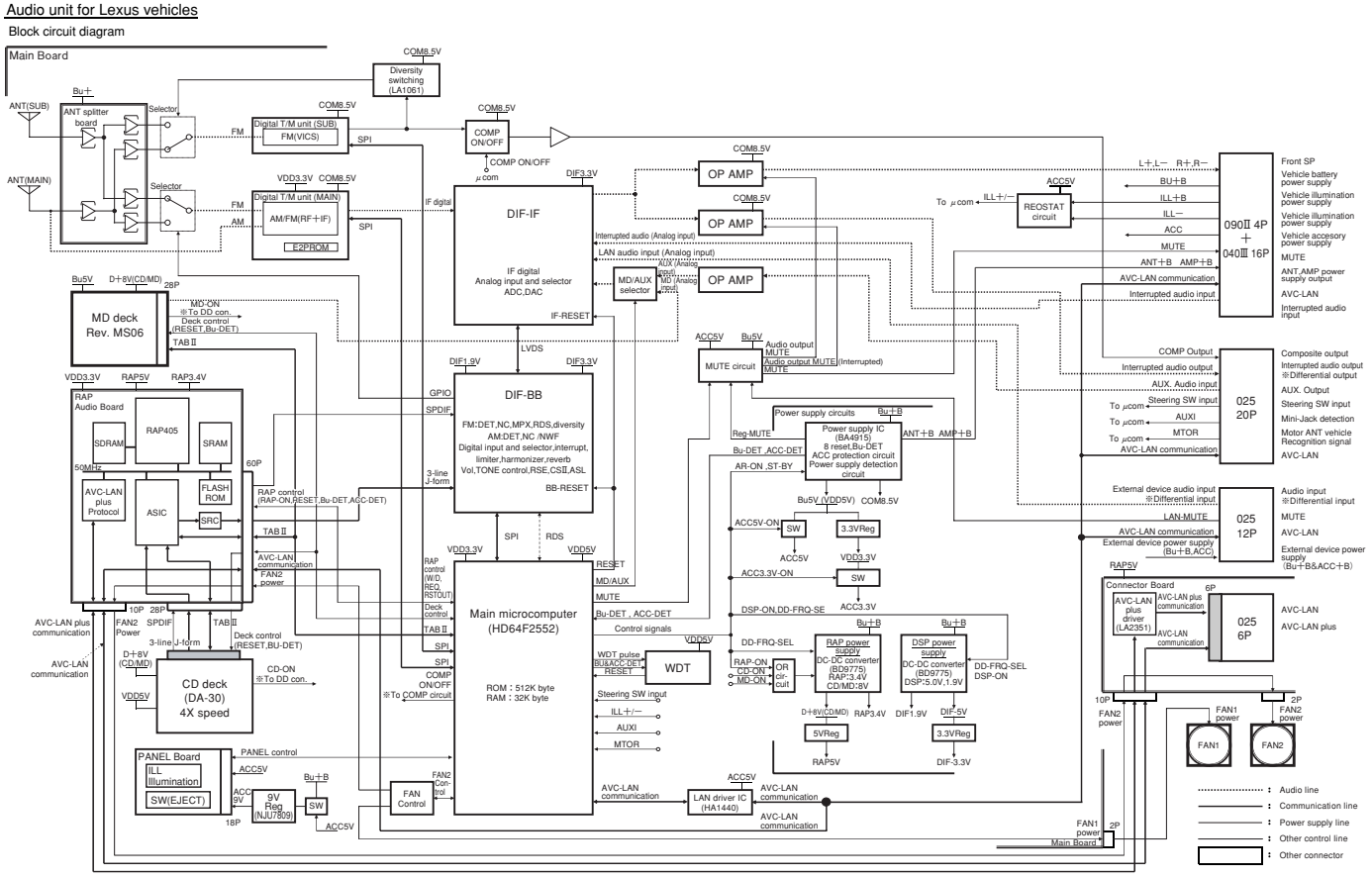

Fig.2 Audio unit for Lexus vehicles Internal circuit system

5 Technical Development Points

5.1 Adoption of RAP microcomputer

The Fujitsu-made RAP multimedia processor was adopted for this unit as the codec engine, an indispensable component of digital audio systems. The benefit of using codecs in the CPU is that software version upgrades after the product has left the factory can be performed easily and they provide a flexible measure for coping with compression technology that advances at a daily pace.

Additionally, RAP has a hardware configuration enriched with optimal media functions for image and digital AV processing so that it has sufficient functions for a general-purpose processor with a compact size.

In addition to music compression processing performed at a speed of 4X, this system has an optimal CPU for processing communication with the HDD containing unit (EMVN) or the audio CPU.

RAP405 Main Specifications

- Architecture: 2 parallel execution-type VLIW
- Core clock: 300 MHz (50 MHz × 6 using frequency multiplier)
- Bus clock: SDRAM 100 MHz, Local-bus 50 MHz
- Peak capabilities: 600 MIPS, 2,400 MOPS
- Integrated peripheral: SDRAM I/F, DMAC, TIMER, and others
- Power consumption: ≒ 0.6 W (typ.)
- Processor: 0.13 μm CMOS
- Package: 1.27 mm pitch PBGA-256

5.2 I/O-ASIC development

A dedicated I/O-ASIC was developed that integrates all I/O required by on-board devices in order to reduce the size and cost of the digital audio unit. This ASIC can be used to configure the CD deck interface, music data codec functions, and audio microcomputer interfaces by the combination of the CPU, memory, and ASIC. It fits on a 123 mm × 92 mm sized circuit board that includes a LAN (AVC-LAN plus) for communicating with the display unit (Fig. 3 below).

I/O-ASIC Main Specifications

- Peripheral: CPU I/F. INTC, CDROM-Decoder
- I/O function: I2S, TAB II × 2, SIO
- Circuit range: 380 kG (Including RAM)
- Power consumption: ≒ 0.5 W (typ.)
- Processor: 0.35 μm CMOS
- Package: 0.5 mm pitch LQFP-176

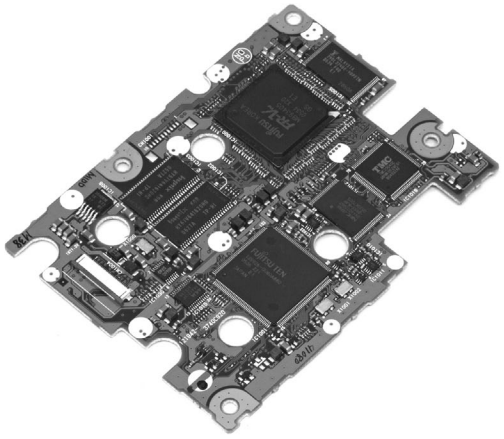

Fig.3 RAP circuit board

5.3 RAP circuit board

A general-use interface for on-board devices has been adopted. The interface contains circuit boards for all required digital audio processes such as TAB II, AVC-LAN plus, I2S, and SIO, as well as having a modular structure so that it can easily be developed for use with other devices.

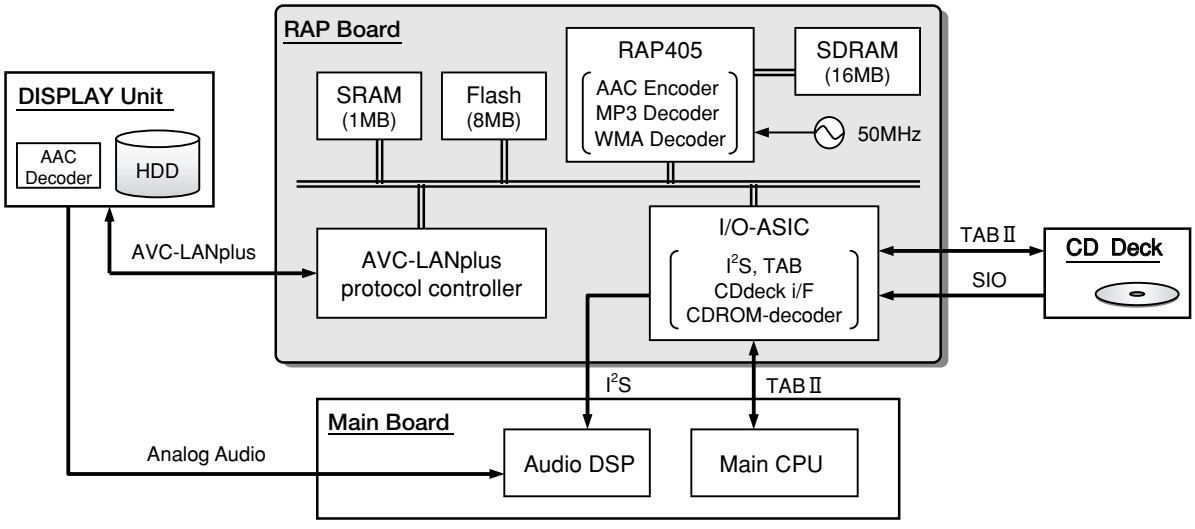

Fig.4 RAP circuit board block configuration

Table 1 RAP circuit board main specifications

No.	Item	Specification	
1	Principal external I/F	Between connector circuit boards	10-pin flexible (AVC-LAN plus)
		Between main circuit boards	50-pin flexible
		Between CD deck	28-pin flexible
2	CD-Deck I/F	3-wire digital line	LRCLK/BITCK/SDATA (Compatible with 1X, 2X, and 4X speeds)
3	Specified recording speed	4X recording/playing definition	Recording completed in 1/4 time when playing at normal (1X) speed* *(60 min. CD recording completed in 15 min. + α : α = seek time between songs x number of songs)
4	Encoding method	CD/MD/TV audio	MPEG2 AAC LC 256 kbps/128 kbps (44.1kHz or 48kHz sampling)
		AM/FM	MPEG2 AAC LC 128 kbps (44.1kHz or 48kHz sampling)
5	Decoding method	CD-ROM/R/RW	MP3 MPEG-1 Audio Layer 3 32k to 320 kbps
			MPEG-2 Audio Layer 3 8k to 160 kbps
			MPEG-2.5 8k to 160kbps
			VBR-compatible fs: 44.1kHz/48kHz
			WMA Ver. 7/Ver. 8 32k to 192kbps
			Ver. 9 High Profile 20k to 320 kbps, VBR
6	Failsafe	Sound skip during recording	1st time: Rewrite, Second time: Record as is and issue skip information
7	Env. Reqs. and other	Temp. assurance range	Assured performance range: −20℃ to (+65+⊿T*)℃
			Assured storage range: −40℃ to (+85+⊿T*)℃
8	Power consumption	4.2 W (Design value)	

Note) ⊿T refers to the portion of ambient circuit board temperature increase from (approx. 25℃)

5.4 Software development

The function layout of the logic units for the audio CPU and RAP are as shown in Fig. 5. The audio CPU implements AVC-LAN (STEP 1) communication control, and performs command SW control for audio functions of the whole system including the radio, CD, and MD within the H/U. The RAP CPU implements AVC-LAN plus (STEP 2) communication control and controls data transfer during CD ripping. Additionally, the interface was designed so that the AVC-LAN command status communication for CD and REC units mounted in the CPU is sent via internal TAB 2 communication acting as a gateway.

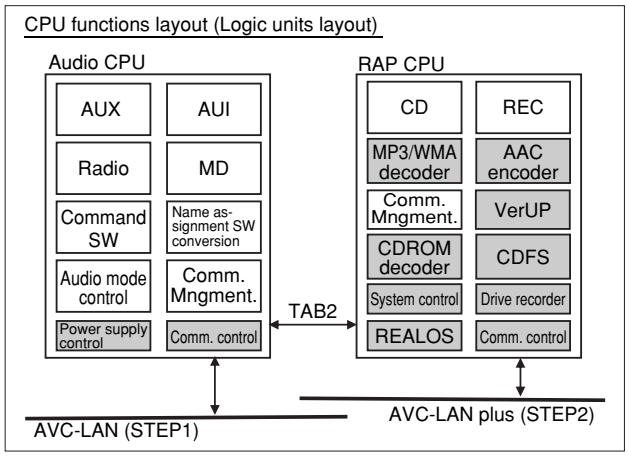

Fig.5 CPU function layout

The audio CPU incorporates carry-over software from existing audio and AVN, while the RAP CPU and interface were newly designed. The RAP CPU uses the REALOS (Real-time OS) manufactured by Fujitsu Ltd., AAC encoder library, and MP3/WMA decoder library, whereas system control, CD deck control, REC control, and communication control systems were all newly developed for this product.

The ripping performance requirements of the RAP CPU, as shown in Fig. 6, are as follows: PCM data is output from the CD deck at a 4X playing speed (approx. 1.4 Mbps) and undergoes realtime AAC encoding (256 or 128 kbps) before being sent via the AVC-LAN plus line to the HDD unit (max. of 1 Mbps). Extra consideration was given to the maximum load requirements of the corresponding CPU when an MP3 audio source (Lexus hospitality function = Background music played on start-up) is played using the above-mentioned flash memory.

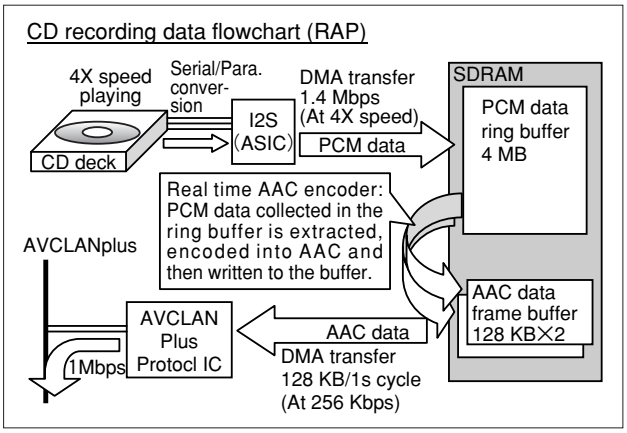

Fig.6 Data flow when recording

Power consumption for CPU processing is estimated on paper to be at 54 MHz for the AAC encoder library

and 35 MHz for the MP3 decoder library. The system was designed in a way such that, assuming the case of 4X speed ripping at the same time of MP3 playing, the excess 49 MHz (the core clock operation of 300 MHz minus 251 MHz power consumption for CPU performance) is used to perform other system control tasks. Performance verification of this unit was carried out under the maximum load conditions, with the buffer size optimized to where PCM data does not overflow and fail-safe operation (recording correction) is implemented if overflow occurs.

Finally, as measures to maintain the Lexus product quality level, a drive recorder function has been added for the first time and a CD-ROM software upgrade function has also been also included.

6 Audio Unit for Lexus Vehicles

As this audio unit is for Lexus vehicles, development was carried out under the concept of going above and beyond existing audio units and creating an even better product from the users" viewpoint. This essay presents a design overview and enabling technology for two items related to this design concept.

6.1 Heat radiation design

There are two major interfaces to consider regarding the mounting of audio units in vehicles. The first is the button/switches region on the front panel and the second is the CDs, MDs and other disk mediums. The first interface is exposed to the ambient environment as it is normally positioned on the vehicle console. It is hard to imagine that the temperature of that area would be greatly different from the temperature felt by the vehicle passengers. However, disk mediums operate completely within the H/U. Since there is a 4X speed recording function in the case of this HDD audio system, the electrical circuitry in the audio unit operates at maximum load during 4X recording. This causes the electrical power consumption to rise to approximately 1.3 times that during 1X speed recording.

For this reason, during development of this Lexus audio unit, heat management was considered an important part of the design process in order to ensure that the user would not sense a temperature difference when handling CDs, MDs or other disk media.

Basic design methods used during development included standard three-dimensional design as well as CAE analysis of model units.

CAE analysis was adopted in order to ensure design quality in a short amount of time. Basically this means that since simulation can be easily applied at the technical drawing stage, assessment can proceed without using prototypes. Therefore, a reliable assessment could be attained at the design development stage. Multiple simulations under different condition can be performed by adjusting the input data.

Additionally, due to heightened analytical accuracy, it is possible to achieve the same level of evaluation results without using tooled parts. From this aspect, CAE analysis helped to reduce development costs and shortening the development period.

The design methods used for this Lexus audio unit helped to achieve the design target of a 4 ℃ reduction to the current models without the need for repeated prototype assessment.

Comparison with current model:

4.7 °C reduction in the CD deck

6.4 °C reduction in the MD deck

Fig. 7 shows images from CAE analysis used for design of the Lexus audio unit. By performing simulation analysis from model A ⇒ model B, prototype expenses were reduced.

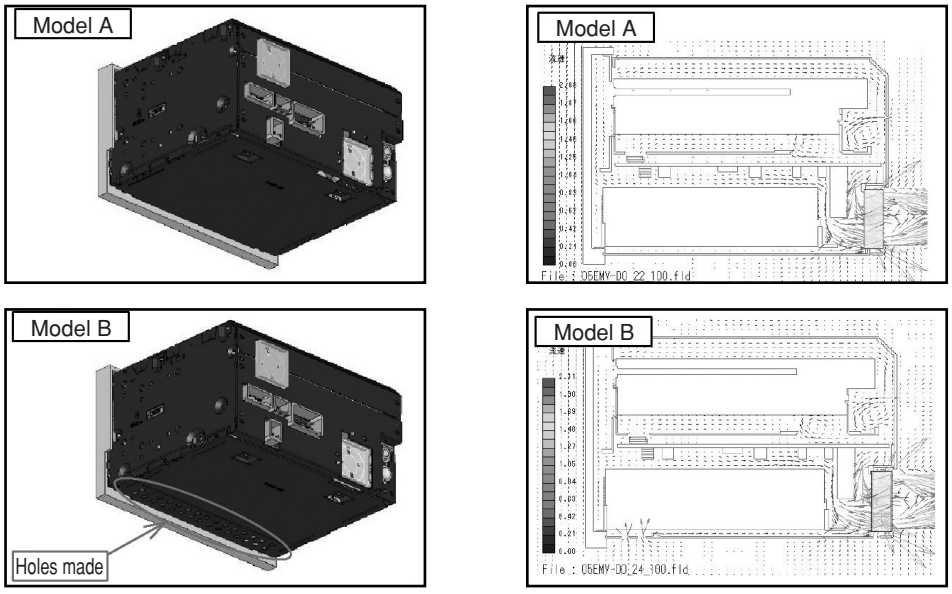

Fig.7 Fluid analysis images

6.2 High-quality sound design

The most important and basic function of an audio unit is to reproduce sound The design of this audio unit focused on achieving the highest quality audio as required for Lexus vehicles in regards to this most essential function.

This system for Lexus audio uses an exterior amp while the audio unit divides the CD and other audio sources into left and right signals and outputs through only two channels. Although the external amp is responsible for tuning frequency response and other elements for the sound, it is essential that this two-channel audio signal is of the highest quality in order for the system to also achieve the best possible sound quality. To this end, focus was placed on coupling condensers used for all power supply circuits related to the H/U. Coupling condensers (electrolysis condensers) from various manufacturers were repeatedly tested for the filter circuit of the H/U input power, and a final electrolysis condenser was chosen.

Table 2 Electrolysis condensers Listening test results

Sample	A	B	C	D
Points	10.5	12	9	13.5

* The grand total of three persons who carried out a five-point scale sound evaluation

7 Conclusion

This paper has discussed the development aims and technology for an audio system for Lexus vehicles that includes a recording system, and an HDD not integrated with the H/U.

In the future, we would like to see product development in which product quality attention is given, in greater proportion, to the users' point of view, as was done with the audio unit discussed here, in order to achieve even further cost reductions and carry out product development that continually strives to create the best possible audio products.

Profiles of Writers

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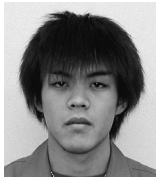

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