Development of 1DIN size HDD AVN (JUPITER) for Aftermarket Sales (2005 Fall)

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Abstract

The domestic car navigation market is steadily expanding, with factory genuine products being its motive force.

Since introducing AVN systems to the market in 1997, Fujitsu Ten has created and enlarged the AVN market through an extensive lineup and highly advanced functions (such as the incorporation of three [DVD/CD/MD] decks, adoption of touch panels, and adoption of film antennas) that other companies do not have.

In recent years, however, competition has intensified as one competitor after another has entered the market, and further improvement of product appeal is being sought.

In the midst of this situation, this paper introduces a 1DIN AVN (development code: Jupiter) which we have developed in order to make additional progress in AVN development.

1 Introduction

Having developed an all-in-one AVN ahead of other companies, Fujitsu Ten has been the leader in the car navigation market. Recently, other companies have launched "AVN" types as well, but as HDD AVN integrated units, each of the companies models have been 2DIN size only. None of the models were completed as 1DIN size. In the market (particularly overseas), there are still many vehicles that have only 1DIN size openings. Though this need for a 1DIN size HDD AVN system has existed for some time, there had been no products developed until now to meet this need, due to the technical issues associated with miniaturization.

In the midst of this situation, Fujitsu Ten, as an AVN pioneer, started developing a 1DIN size HDD AVN system in February 2004 under the project name "Jupiter," based on the catchphrase "No matter what, we must accomplish this before other companies do."

Then in the fall of 2005, we were able to release the world's first 1DIN HDD AVN system as a Fujitsu Ten aftermarket brand "ECLIPSE" to North America and Europe starting from release in Japan.

In this paper, we introduce its functions, principles, and technologies.

2 Overview of 1DIN size HDD AVN

In the fall of 2005, with the introduction of the world's first 1DIN size HDD AVN into the market as an ECLIPSE brand, Fujitsu Ten succeeded in proposing a new form of AVN as the second generation of AVN systems.

2.1 Product concept

In the summer of 2005, we engaged in planning and development based on the concept "New Evolution in AVN," and create high-performance navigation systems with a new operation system called "Active Wing (*1)" and an "Altima Engine (*2)".

During that fall, aiming for further evolvement of AVN, Fujitsu Ten proceeded with the planning and development of a new form of AVN system that went beyond previous boundaries, under the concept "NEXT STAGE AVN".

2.2 Product overview

The ability to "integrate audio, visual, and navigation into a 1DIN space without a hideaway unit" is the product's greatest feature. Moreover, despite miniaturizing to a 1DIN size, it has a 7.0-inch wide monitor, the largest class in the industry; a high-performance navigation CPU, the Altima Engine; a DVD/CD-compatible deck, and high-power amp. Thus, while featuring the stylishness of a 1DIN, it achieves performance that surpasses its size and is not inferior to that of a 2DIN size AVN.

Furthermore, when the 5.1-ch decoder unit (sold separately and exclusively for 1DIN AVN systems) is connected, it becomes possible to make high-accuracy corrections of vehicle interior sound, produce 5.1-ch playback through that system, and thus be improved in a manner that lives up to the name "sound flagship AVN".

With the intention of being distributed globally, including destinations such as Japan, North America, and Europe, the product has specifications and functions that correspond to the needs of each country. To say nothing of the radio frequencies and DVD-Video region codes that are set for each country, for example, Japanese models have a build-in TV tuner, MusicJuke function, and functions of FM de TITLE/FM de TITLE plus; North American models have support functions for digital radio such as IBOC and SIRIUS; and European models have a RDS-TMC function; to adapt to each regional service.

Fig.1 AVN 075HD

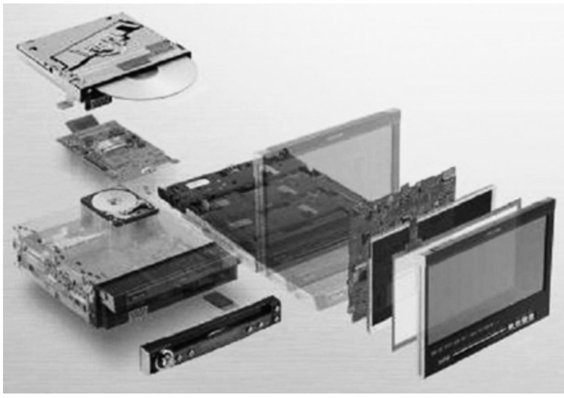

Fig.2 Internal structure of AVN 075HD

As described above, the 1DIN size HDD AVN was developed based on various new functions and new concepts. In the following sections, we focus on and explain the technologies that support the product's revolutionary miniaturization.

(＊1) Active Wing (movable operation panel)
A movable operation panel that has an operating unit for securing a drawing display range as efficiently as possible.

(＊2) Altima Engine (single-chip navigation core IC)
A navigation core IC unit that achieves drawing performance and processing speed exceeding that of conventional products by integrating the microcomputer, graphic CPU, peripheral circuits, and analog circuits into a single chip.

3 Efforts to develop 1DIN structure

In order to integrate the functions possessed by a conventional 2DIN-size model into a 1DIN size nearly as they are, it was necessary miniature the product and save space through a fundamental reexamination of each unit.

Structure comparison of 2DIN size and 1DIN size

The figure below (Fig. 3) shows a general structure and size of the main block and units in the conventional 2DIN product.

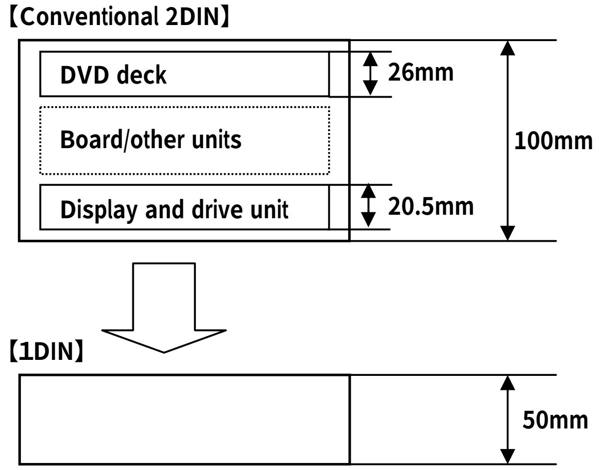

Fig.3 Unit structure dimensions of conventional model 2DIN

Needless to say, the largest difference compared to the conventional product is that the height will be reduced by half.

2DIN: 100 mm height ⇒ 1DIN: 50 mm height

Here, as you can see from the conventional structure in the figure,

TFT display/tilt units (height: 20.5 mm)
+
DVD deck unit (height: 26 mm)
↓
Total: 46.5 mm

In this case, just two units occupy a 1DIN size, leaving no room for other units to fit inside.

Thus, we first took steps to miniaturize the aforementioned two units.

TFT display/tilt units

As for the size of the TFT display, we made the display unit slimmer and reexamined the tilt unit while securing a 7-inch size.

By reexamining the tilt circuit and miniaturizing the motor, we were able to lay out the tilt unit to the rear of the TFT unit and to reduce the thickness by 2.8 mm (-14%).

DVD deck unit

As for the deck unit, we examined the size, interface, and control method (communication method); and while securing the optimum deck quality as a TEN system, we were able to achieve an 11 mm reduction in thickness (-42%).

In this way, starting with the miniaturization of the aforementioned two main units, we examined ways to lay out the other blocks.

In the next section, we explain various important issues that were involved.

4 Identification of technical issues

In the design of an AVN unit, which requires an extremely compact, advanced structural layout even with 2DIN, many issues must be addressed in order to successfully incorporate all of the AVN functions into a 1DIN space. First, as mentioned in the preceding section, we were able to find clues toward achieving a 1DIN size by miniaturizing the deck and display/tilt units. Next, we began to examine how to lay out the other blocks and how to address the issues that would result. Here, we explain those technical issues.

The explanation below will cover the following three technical issues:

- **Strategy for designing a high-density structure**
- **Efforts to counter the internal temperature rise caused by higher density**
- **Countermeasures for possible noise**

High-density structure

Issues involved in achieving a high-density structure include the following:

①Slimming of display/tilt units (compared to conventional product: 2.8 mm reduction, -14%)
②Slimming of DVD deck (compared to conventional product: 11 mm reduction, -42%)
③Integration of navigation processing board and audio processing board into a single board
④New development and adoption of MCM-PCB
⑤Development of compact AM/FM tuner (compared to conventional product: -44%)
⑥Development of compact power supply module
⑦Miniaturization of HDD
⑧Standardized design for four destinations (Japan, North America, Europe, and China)

For ① and ②, we were able to find clues toward achieving miniaturization as mentioned in the preceding section. Thus, top-priority was given to measures for and achieving of ③ thru ⑧.

Also, the following issues caused by the miniaturization and highly integrated circuit must be solved to realize 1DIN products.

Internal temperature rise

It is necessary to keep the temperature of internal parts (such as the HDDs, ICs, and electrolytic capacitors) from exceeding the parts' guaranteed values through the efficient heat dissipation from the inside of the product by fan operation.

Noise countermeasures

As a result of miniaturization, the circuit blocks became closer to each other. For this reason, there was a possibility that the noise from the clock and the high-frequency oscillating noise due to the miniaturization of the DC-DC converter might greatly effect on the performance compared to conventional 2DIN models, thus, it was necessary to consider preventive measures at the design stage.

5 Solutions to issues

5.1 High-density structure

1) Efforts in structure examination

Fig. 4 shows an exploded view created with 3D-CAD.

In regards to the display/tilt units and DVD deck in this figure, slimming and miniaturization were described in the preceding section. As for other miniaturization issues, an unconventional structure reexamination was conducted and a thorough design review at an early stage were implemented jointly with suppliers. In addition, a thorough benchmarks of competitors' products were also implemented.

As a new method for verifying high density design, we adopted a rapid prototype which utilizes 3D-CAD data to create mock-ups of circuit board, chassis, and all other structural parts. In the past, verification was implemented simply by using drawings created with 3D-CAD; thus, structural problems that could not be detected on drawings were sometimes discovered on the actual primary prototype. However, using rapid prototype mock-ups in this development, we were able to identify structural problems at initial design stage and establish design feasibility at early stage (Fig. 5).

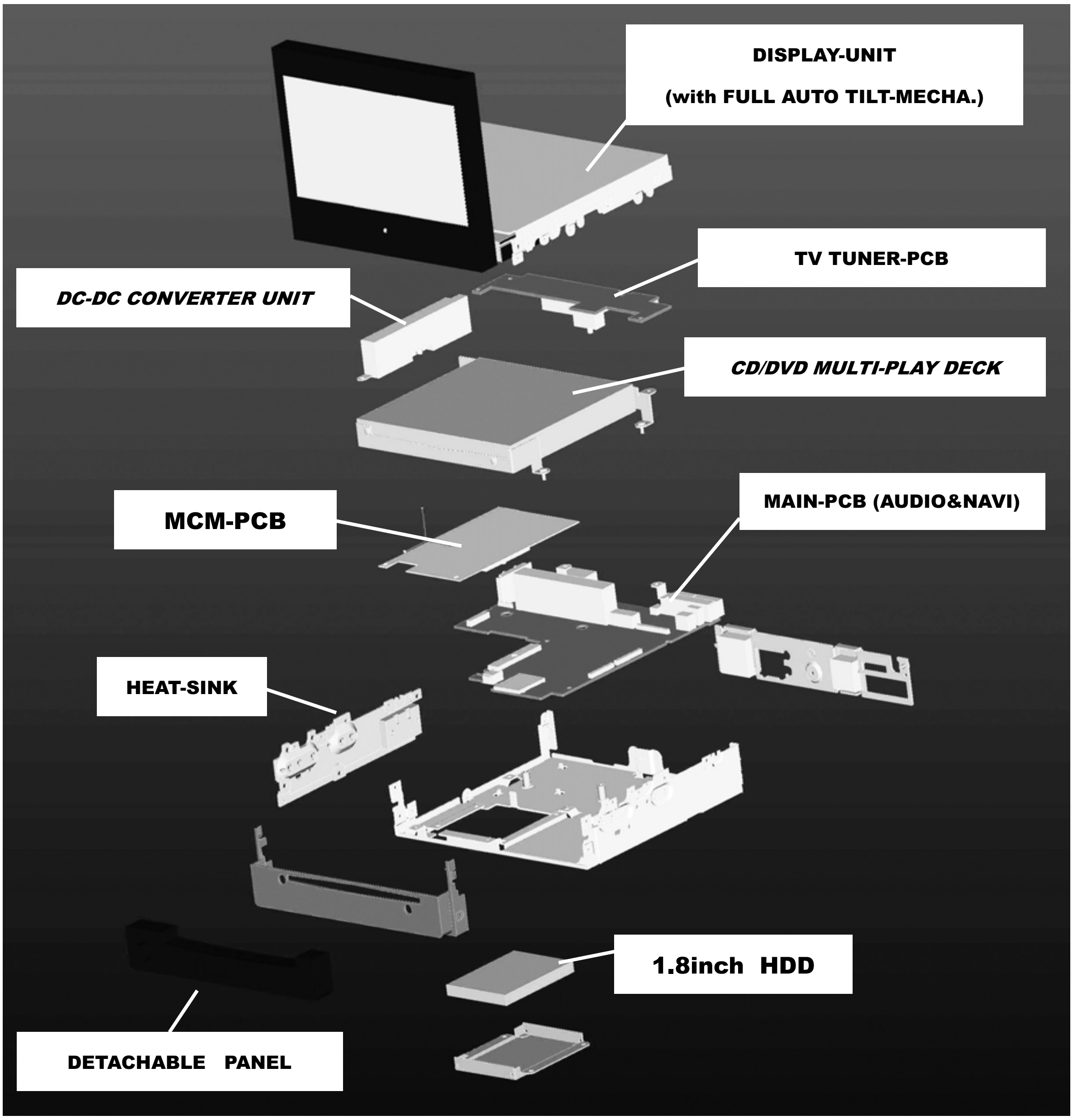

Fig.4 Exploded view of the structure

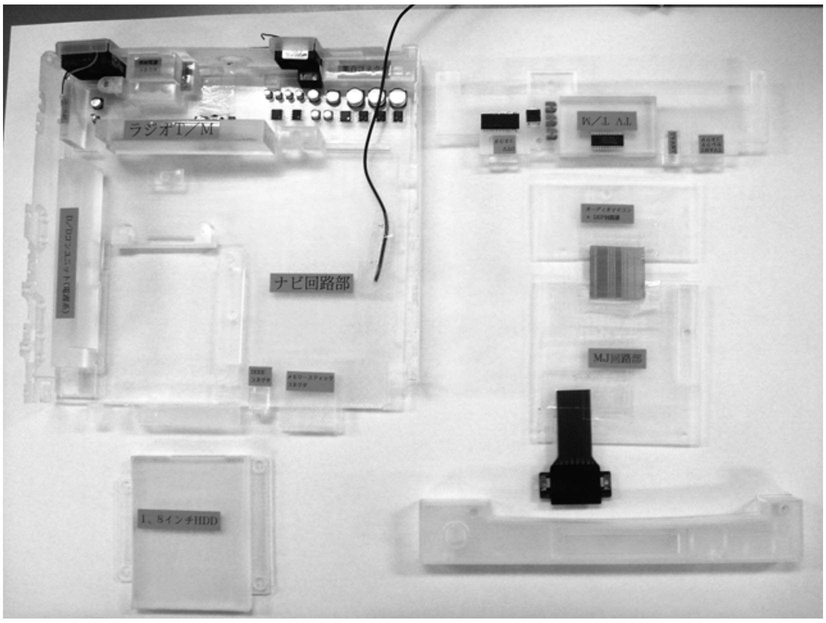

Fig.5 Physical verification with rapid prototype mock-up

The rapid prototype modeling makes it possible to create accurate full-size mock-ups for a short time; therefore, other full-size parts can be attached to a mock-up and checked.

Furthermore, utilizing a printed circuit board mounted with actual parts made it extremely useful in conducting visual verification and check.

Through an accumulation of such development and examination efforts, we were able to reduce the volume inside the product by approximately 35% compared to a conventional AVN unit.

Moreover, the structure design did not simply focus on high densification but also considered aspects such as assemblability and maintenance. That is, during the design of the overall structure, consideration was given to assemblability; and with respect to board-to-board connections, accumulation structure was adopted as much as possible using direct connectors between PCBs. In particular, with a view to replacing HDD in the field and implementing HDD assembly/build-up at customer locations, the structure was designed so that the HDD is attached from the bottom side.

Next, specific strategies for resolving each issue and its result are described below.

2) Strategies for addressing issues and results

Of the issues mentioned in the preceding section, the most important issues are:

③Integration of navigation processing board and audio processing board into a single board, and

④New development and adoption of MCM-PCB.

These are explained below.

As top-priority factors in realizing the 2DIN→1DIN change, the following points were kept in mind while space-saving was examined and the conventional board configuration was fundamentally reexamined.

Points

1. Miniaturization of parts to be adopted (adoption of BGA package)

2. Efficient circuit layout on each board

3. Integration of navigation part and audio (radio and power IC) part

With a conventional navigation board, only the navigation part circuit was constructed with a single board. But with the new board, this navigation part space was reduced and the navigation control microcomputer ASIC and drawing IC were integrated into a single chip, achieving significant space savings. As a result, space was obtained on the board that has the same area as the conventional navigation board, allowing to lay out the audio part in that space. Specifically, such audio part includes the AM/FM tuner module accessory circuits and power IC peripheral circuits. In this way, it became possible to create a shared board of the main part of the audio circuits (approximately 90% of the entire circuit, other than the DSP unit) and navigation part.

Next, where to lay out the board comprising the circuit's digital part and audio part (DSP unit) is described below. This is the most difficult point in this development and extreme efforts were required to make it achievable. In the initial stage of development, there was little space anywhere, and it was found that we had to lay out the board in a minimum of space between the DVD deck and HDD.

This space was on the top surface of the 1.8-inch HDD and had a height of 2 mm, which is almost the same size of the HDD. The area that was actually available for laying out the board was 122 mm × 79 mm.

Under such condition, we examined the structure to lay out the digital part and DSP part.

First, we reduced the space of multiple-pin devices such as digital part MJ (MusicJuke)-ASIC, MJ (MusicJuke) microcomputer, memory, audio microcomputer by using BGA type instead of QFP. In the same way, the space of DSP circuit part including some audio analog part was reduced using BGA type, resulting in a significant space saving.

In this way, we were able to establish design feasibility to lay out the parts in a space of 122 mm × 79 mm.

Next, with regard to height, all parts were thoroughly investigated and efforts were made to adopt low-height parts. Moreover, these parts were mounted on a single side, and a board thickness of 0.8 mm was adopted. In this way we made this achievable.

Also, with regard to connections with other boards, space and height requirements cannot be met with conventional board-to-board connectors. However this issue was solved by adopting a solder-press-fitting method for connecting a new slim type flexible cable to the board directly.

This type of board is called a multi-chip module board (MCM).

In MCM design and development, we made its design and mounting technology achievable using BGA devices through collaborative development with FDK CORPORATION having experience of cell phone design and its manufacturing,

Through the cooperation of FDK regarding:

- **Board pattern design,**
- **Prototype board production and its delivery, and**
- **Reliability testing for MCM boards,**

we were able to solve issues on the block layout, the most important issues in this development, and other development issues.

In Fig. 6 the left side shows the conventional board configuration (2004 model), while the right side shows the new board configuration.

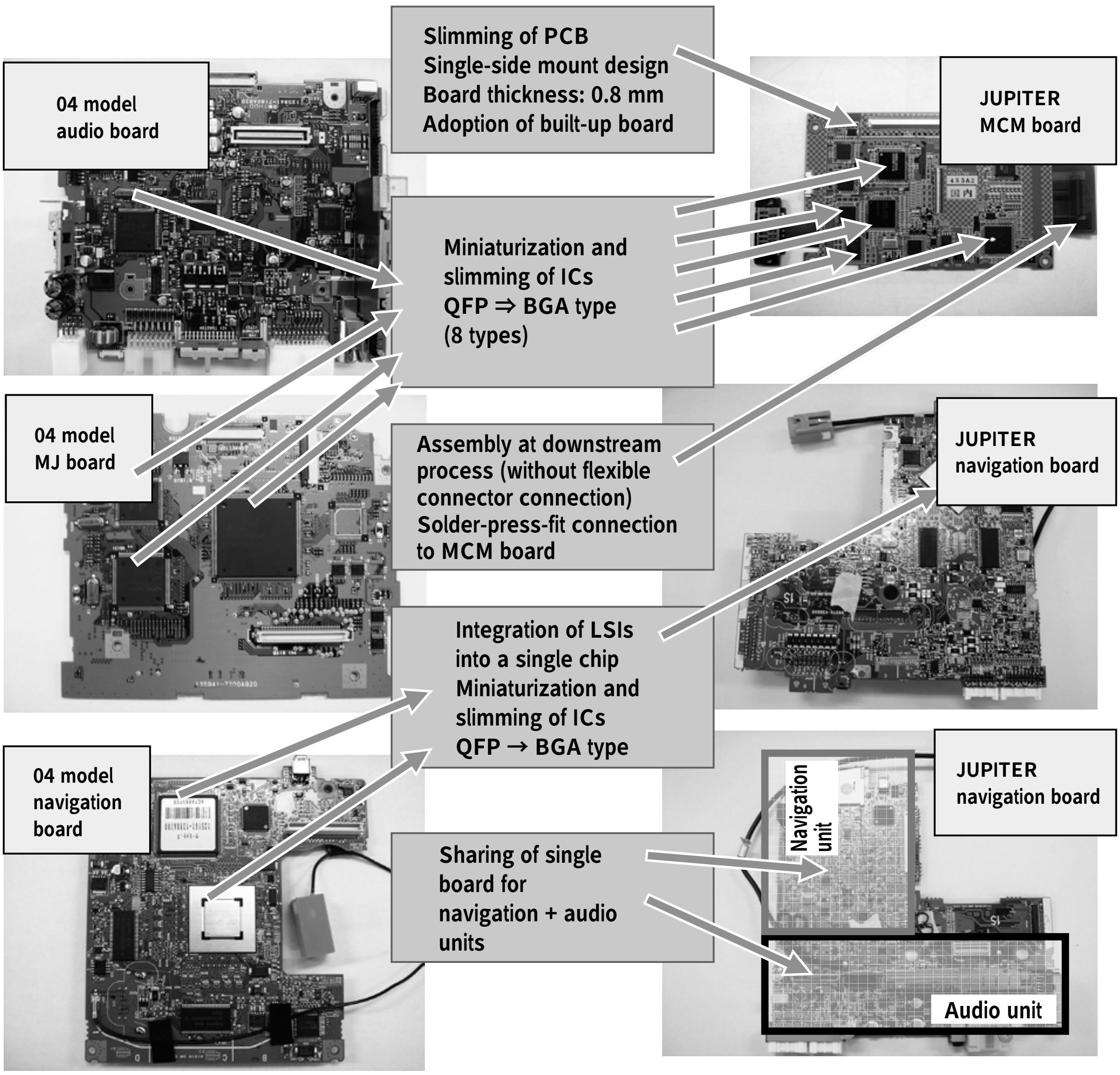

Fig.6 Board configuration (conventional 2DIN → 1DIN)

Consequently, as shown in the following table, significant board area saving was achieved, which greatly contributed to the design feasibility of this model.

Conventional model

Main board: 1 (170 × 145 mm = 24,500)
MJ board: 1 (140 × 140 mm = 19,600)
Navigation board: 1 (160 × 140 mm = 22,400)

New JUPITER model

MCM board: 1 (120 × 75 mm = 9,000)
Navigation + audio board: 1 (150 × 140 mm = 21,000)

(Units: mm²)

Board configuration	04 model (6604HD)	Target	Board configuration	New model
Main unit	24500	Approx. 50% reduction	MCM	9000
MJ	19600	→	Navigation unit	21000
Navigation unit	22400			
DC/DC converter	7250	Approx. 70% reduction →	DC/DC converter	5100
TV	6300	→	TV	6900
display	17500	→	display	17500

Fig. 7 shows the block diagram of the board.

In the conceptual design, particularly for the TV board (for Japanese market), RDS board (for Europe), and pre-out board (for North America), the board dies were completely standardized and only the pattern design was changed, achieving substantial improvements in cost and design efficiency.

The AM/FM tuner module also had to be laid out in a minimal amount of space with the new structure; thus, we newly developed an ultracompact module that is 44% smaller than the conventional module.

Next, we newly developed a compact power supply module (DC/DC converter) as well. In the past, DC/DC converters and regulator ICs were laid out throughout inside the product. But now they have been arranged as a module in a single location, making it possible to achieve a smaller size.

Additionally, regarding the HDD, which is the key part of the HDD model, we adopted a 1.8-inch-size HDD for the first time in the world as an in-vehicle AVN model (conventional size: 2.5 inches) to miniaturize.

Through above efforts to solve issues step by step, we overcame the size requirements that had not been met during the initial stage, and established design feasibility to fit the components into a 1DIN-size space.

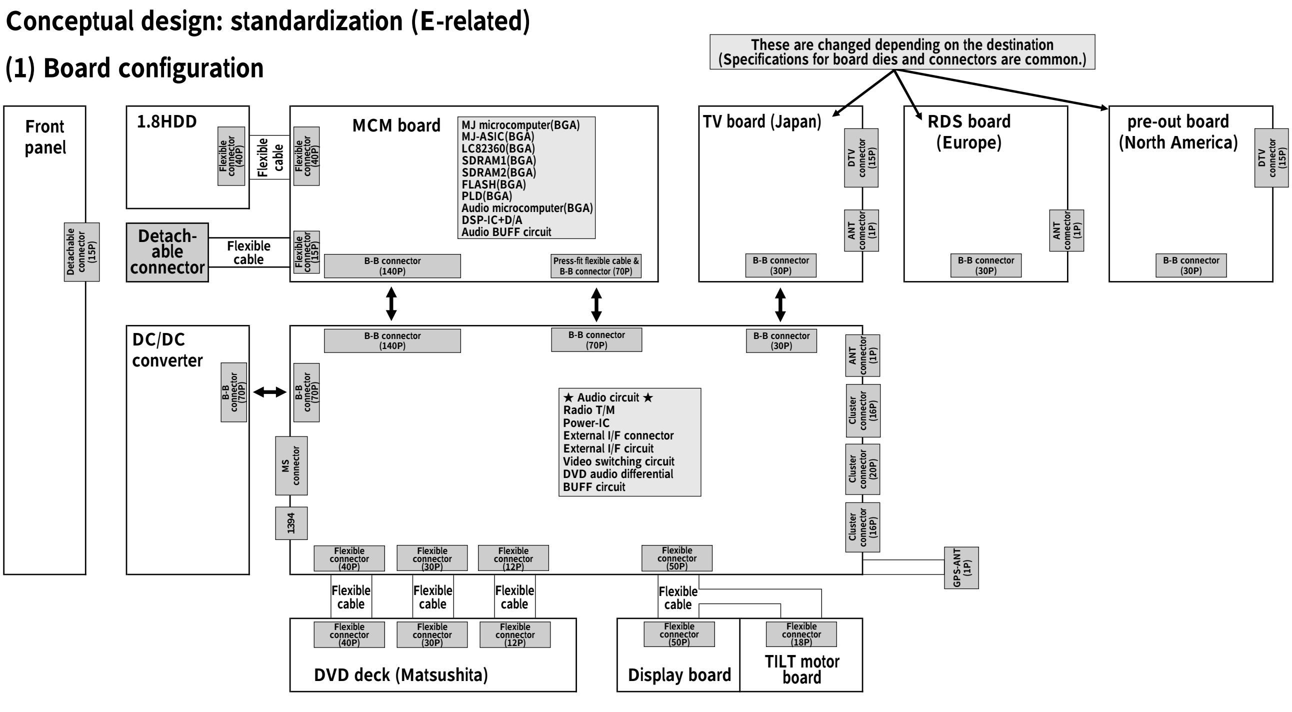

Fig.7 Board block diagram

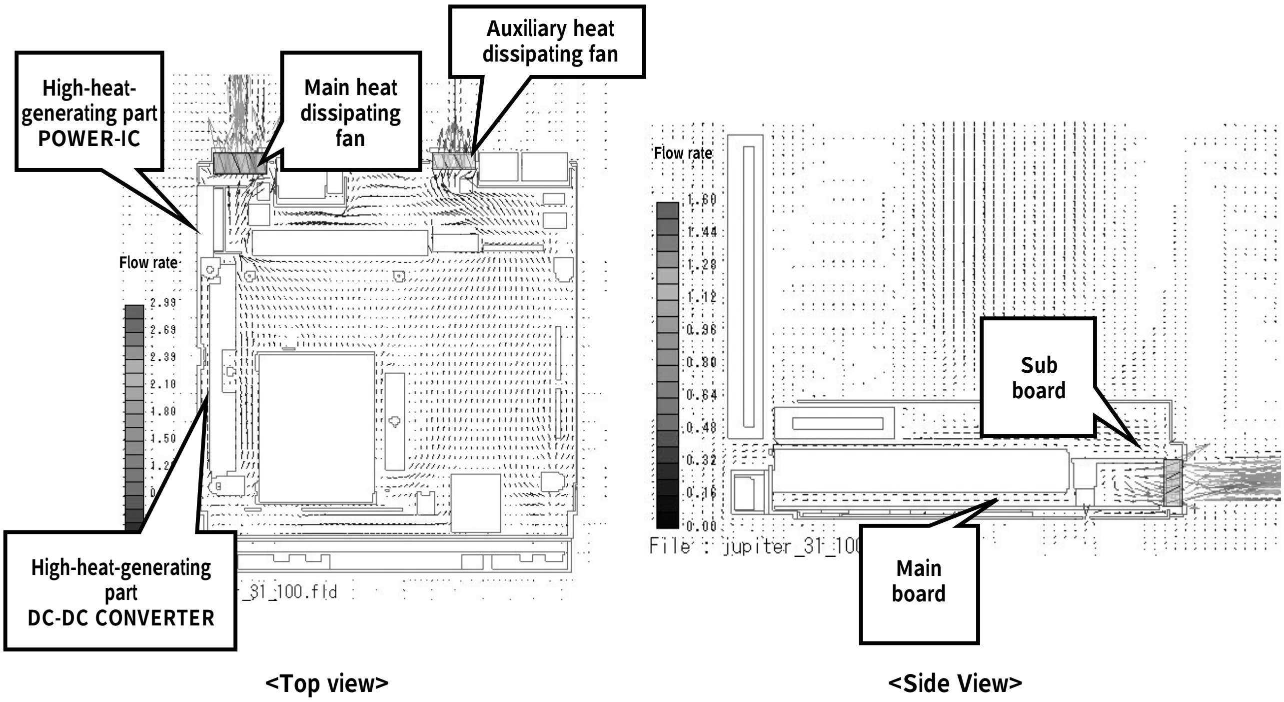

Fig.8 Heat dissipation analysis with CAE

5.2 Countermeasures for the rise in internal temperature

Efficient heat release from the inside by fan operation

Structurally, in order to efficiently dissipate the heat, parts that consume a particularly large amount of power, such as the power IC and DC-DC converter, were laid out on a direct line with the fan's airflow.

As a result, the cool air that is taken from the front of the product by the fan is expected to effectively cool parts that emit heat.

However, due to a lot of restrictions on the fan size within a 1DIN size; air flow amount is not still sufficient.

Accordingly, an auxiliary fan was mounted in the open space on the product rear surface. With this structure, the auxiliary fan dissipates heat that the first fan cannot dissipate,, particularly heat near the navigation CPU.

Also, the product's top half is the area in which the display is housed. When it is actually used, the display extends to the outside, creating a large space. If the heat dissipating fan takes air from this area, the internal temperature rise suppression becomes less effective, resulting in inefficient heat dissipation. Accordingly, by arranging the position and direction of the sub-board so that the internal airflow concentrates in the lower half, we were able to avoid making major structural changes and achieved efficient heat dissipating.

To confirm these conceptual designs prior to the prototype production, CAE analysis was utilized. Fig. 8 shows the results of an analysis of the internal air flow of the product.

From this figure you can see the DC-DC converter and power IC are on the left side of the product, and that their heat is efficiently dissipated by the main heat dissipating fan.

5.3 Noise countermeasures

1) Reexamination of power supply system

The conventional model has 5 DC-DC converters (5 systems) and 5 regulator ICs. But with this model, there is not enough space to lay out conventional-size regulator ICs., Therefore, we integrated 10 power supply systems into a single DC-DC converters to establish design feasibility.

To suppress DC-DC converter noise, we made the module shield, and strengthened the ground connection to the chassis during designing. Also, we reduced the AM-band noise by setting the switching frequency out of the AM band as 2 MHz.

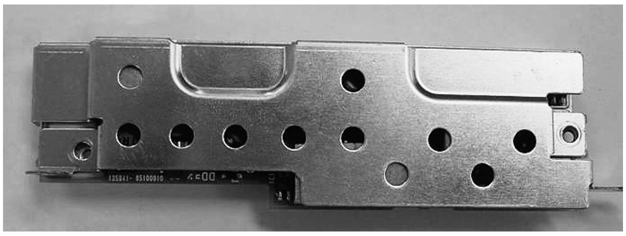

Fig.9 DCDC converter module

2) Pattern layout

In each development, the radiation noise or similar noise from the microcomputer system clock and its communication lines is produced as a high frequency noise (noise in all radio frequency range or all TV frequency range, and radiation noise due to terminal conduction), and making countermeasures for such noise is always difficult. However In this model, many BGA package parts are used in order to save space, making it easier to lay out the pattern from the BGA terminals to internal-layer pattern. To avoid effects on other circuits, the communication lines, etc. were routed as an internal-layer, and the surface layer was grounded. Consequently, we were able to improve patterns from the aspect of radiation noise.

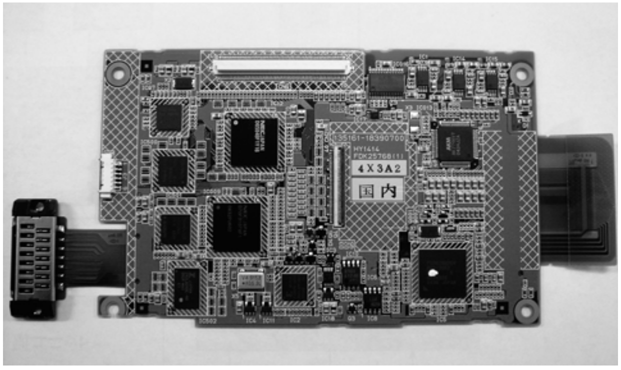

Fig.10 External view of MCM board

Moreover, to reduce board space as previously mentioned, the navigation part circuit and some audio circuits were integrated into a single board; however, it became necessary to also consider noise from the navigation part to the audio part.

To avoid such noise, we placed the navigation digital part at the front of the board and the audio analog part (such as the tuner and power IC) at the rear of the board, so that these are separated in the pattern layout aspect.

In addition, the grounding of this digital part and analog part was completely separated, which also helps to control noise coming around from the GND.

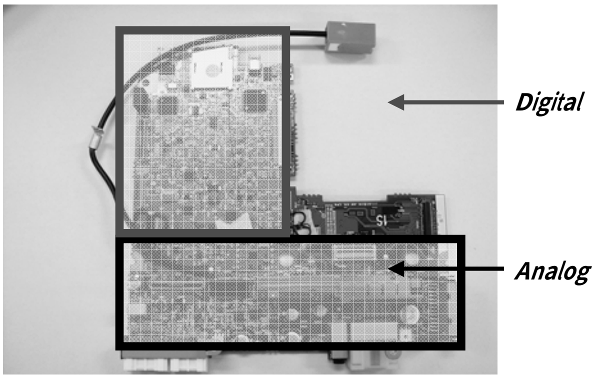

Fig.11 Status of digital/analog separation on the navigation-audio board

6 Conclusion

Several months have passed since, in October 2005, we began selling the Japanese model and then successively expanded sales to North America and Europe. In each market the product has been well received and sales have steadily grown.

From the market we have received many comments such as "We've been waiting for model like this." For the Design and the other relevant departments that pressed forward with the product's development as a united body without being set back, this has been an extremely joyous accomplishment.

In closing, through this publication, we would like to offer our deepest thanks to FDK CORPORATION, AISIN AW CO., LTD. and other companies that cooperated in the development of this 1DIN size AVN.

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