Development of Globally Compatible AVX Unit

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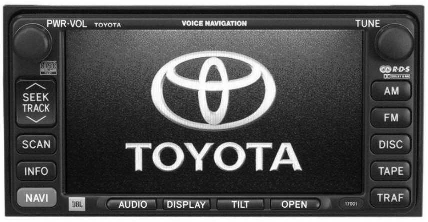
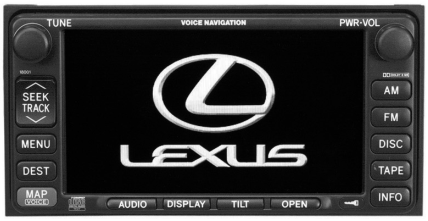




Abstract

In-car audio navigation systems have now been in the Japanese market for well over a decade. On the other hand, navigation systems were available only in a limited number of high-end vehicles in overseas markets until recent years. Therefore it is becoming necessary to develop a world-wide navigation system, to match the rapidly growing oversea market demand.

This paper introduces the features and principal technologies of an audio navigation system called the wide multi-AV system (AVX), which has display/audio functions and is being developed for the global market.

1 Introduction

In the Japanese market, navigation systems have seen steady growth and an increase in diffusion rate not only in the aftermarket but in the genuine parts market as well. In recent years, overseas demand has also grown rapidly.

But considering their high recognition capability, navigation systems with color map displays, which are popular in Japan, are limited to service as optional equipment in expensive high-end vehicles. (Toyota Motor Corp. utilizes them only in Lexus-brand vehicles.) Rather, simple navigation systems, such as arrow-display and voice-guided systems, are in the mainstream.

Reductions in price will be needed for future navigation systems. Map display navigation systems will also be expected to drop in price.

To promote the use of map display DVD navigation systems by Toyota and world markets (North America, Europe, Australia, and Japan), a wide multi-AV system (hereinafter referred to as the AVX unit) has been developed for the entire global market.

To expand sales throughout the entire global market, it is important to do the following:

①Simultaneously reduce costs and improve quality.
②Improve visibility and operability in all environments.
③Expand interchangeability (and reduce the development period) while meeting the specifications of each vehicle.

Here recently, through design activities implemented with Toyota, our company was able to establish specifications quickly and secure an ample planning/design period. We were also able to focus on concurrent development and reduce the development period while achieving the desired cost, quality, and performance in factor parts and products.

As a result, Toyota adopted the system for fifteen of its models, installing it in domestic vehicles starting in May 2001 and overseas vehicles in August 2001.

2 Development aim

This system was planned and developed for the purpose of offering a standard navigation service for the global market.

Principal aims include the following:

①Simultaneously reduce costs and improve quality.
→Circuit integration through development of new ASIC
→Adoption of high-density packaging/new construction method
→Adoption of new mechanism
②Improve visibility and operability in all environments.
→Adoption of touch switch operation
→Improvement of temperature characteristics of TFT display (hereinafter "display")
③Expand interchangeability while meeting the specifications of each vehicle.
→Symmetrical design with display screen in center
→Development of circuit block unit
④Environmental friendly.
→Simplified removal of TFT backlight containing mercury

Details of each will be introduced hereinafter.

3 System overview

Since the AVX unit is a system master, control is performed in connection with the following external systems:

NAVI, external amp (when not equipped with built-in amp), CD changer, MD changer, VTR, back guide monitor, vehicle information ECU, VICS, ETC, etc.

4 Product overview

4.1 Basic configuration

Figure 1 shows the overall configuration.

4.2 Functions

Major functions include the following:

- AM/FM (with diversity antenna support)
- CS or MD (with title display support)
- CD (with CD-TEXT support) ・
- TV (with stereo/bilingual broadcast support, 4 input antenna diversity control function: *for domestic market only)
- Back monitor input support
- VTR input support
- 35W(4-ch power amp (with built-in FIX-EQ)
- 6.5 wide display
- Touch switch
- Power tilt function

4.3 Features

The following changes were made to the conventional AVX unit:

- 16-color → 256-color production support

- 8-direction button → touch switch support
- Sharper character display
- Improved visibility at low temperature
- Reduced dark current (3 mA)
- ETC display support (when ETC is connected)
- External amp support
- Expansion of MD model setup (for domestic market)
- Overseas RDS/RBDS function support
- Exclusive color (silver) setup

5 New technology development items

5.1 Internal structure of main unit

5.1.1 Circuit board configuration and high-density design

(1) Development of single board for main primary circuit unit

In a conventional model, the primary circuit (excluding display unit) consisted of two circuit boards, one each for the audio circuit unit and main drawing control circuit unit. Two circuit boards were used to accommodate the size of the circuits and reduce noise by separating the analog and digital circuit boards.

With this product, however, a single circuit board was developed by creating units for essential circuits and by further integrating integrated circuits (ASICs). This enables the product to be globally compatible and clear hurdles associated with multiple models having differing functions (Figure 2).

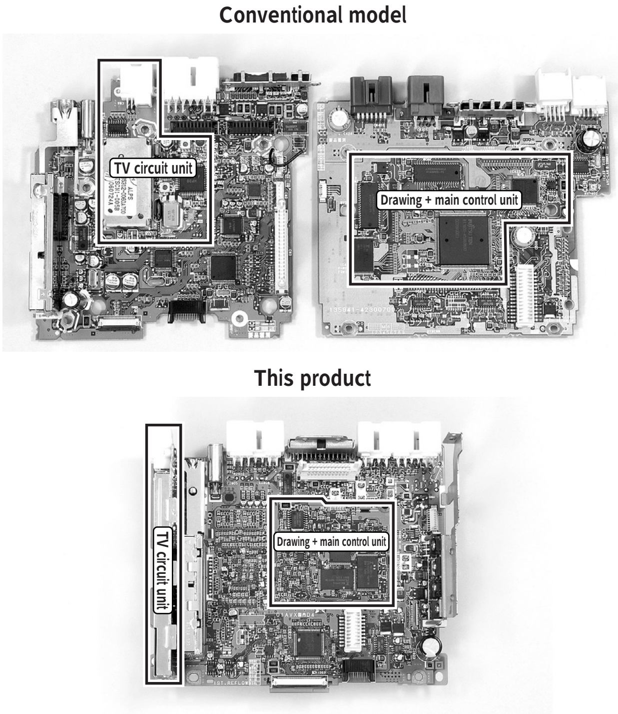


Fig.2 Comparison of board configurations of primary circuits

This product was designed to integrate the functions (circuits) of all models; and development easily expanded to fifteen types of derivative models, which was an important issue in the development of this product. As a result the main circuit board variations were also reduced to two types.

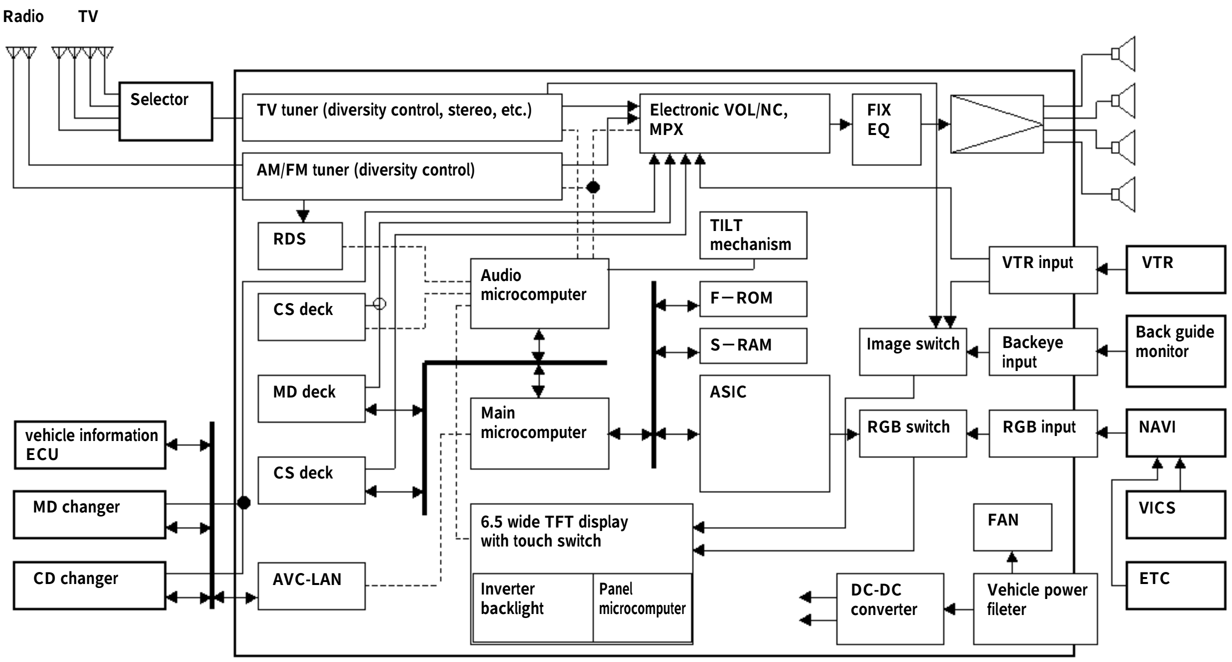


Fig.1 AVX unit block diagram

(2) Adoption of new soldering method (spot reflow)

For the soldering of conventional products, component-side reflow and solder-side dip methods were utilized. These techniques were used for circuit boards on which surface-mounted parts and parts with terminal leads were mixed. The conventional methods, however, greatly limited solder-side packaging and the realization of higher densification. Adoption of the spot reflow method for this product has enabled the solder side to have the same packaging limitations as the component side during circuit board design and has increased design densification.

5.1.2 Shield structure

Along with the development of a high-performance drawing function, it has become necessary to achieve higher communication speeds between components and higher communication clock speeds. And in equipment such as the AVX unit in which receivers such as radios and TVs coexist with drawing circuits (noise sources), measures for eliminating noise to such TVs and radios are essential. Furthermore, since the development of a single circuit board for the primary circuit unit placed noise sources and receivers adjacent to each other (as previously mentioned in 4-1-1), even greater noise reduction measures were necessary. To meet this requirement, the noise reduction measures introduced hereinafter were incorporated into the product.

(1) Measures for noise sources

①Drawing/main unit (effect on radio/TV bands)

・High densification and full shielding for targeted circuit units (Figure 3)

・Reduction in voltage of power supplies for targeted circuits (conversion to 3.3 V)

・Development of ASIC for drawing RAM (SDRAM)

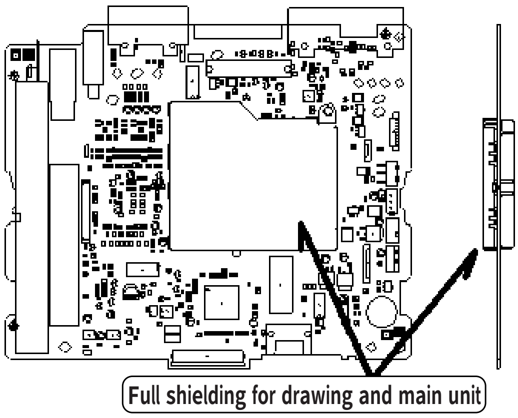


Fig.3 Full shield for main drawing circuit unit

②DC-DC converter circuit unit (effect on LW/MW bands)

・Separate units and full shielding for targeted circuit units

・Use of electromagnetic shielding coil for main power and output power

③Inverter circuit unit (effect on LW/MW bands and cassette head)

・Use of metal holder for shielding of unit back, since targeted circuit unit is on display unit side

④TV/radio tuner station frequency (effect on GPS band)

・Addition of filter to TV ANT line

・Adoption of TV tuner with feed-through capacitor

・Attenuation of high-frequency characteristics of radio mixing circuit unit

(2) Measures for receiver side

①Radio tuner and TV tuner units

・Development of units and full shielding

(3) Circuit board layout measures

・Development of six-layered circuit board and stronger GND

・Separation of noise circuit unit and receiving circuit unit

Use of the aforementioned techniques made it possible to reduce interference to GPS, as well as S/N and C/N of FM/AM/TV at all frequencies.

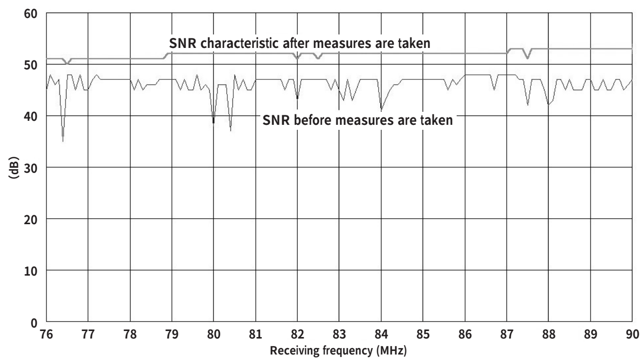


Fig.4 FM full-frequency Signal to noise ratio/SNR characteristics

5.1.3 Display drive equipment

For this product a drive equipment that opens, closes, and tilts the display was newly developed and installed.

(1) Structure of conventional drive equipment

As shown in Figure 5, the structure in conventional models was extremely complicated in order to lift the heavy display from a horizontal position.

(2) Structure of new drive equipment

The deck arrangement and other aspects of the inte-

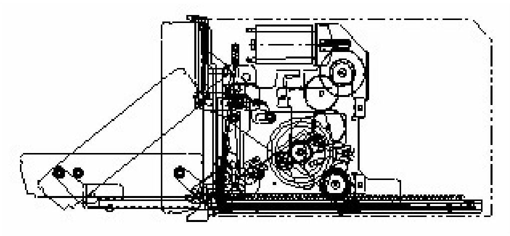


Fig.5 Tilt structure of conventional model

rior layout of this product were reexamined and the CS pack slot was oriented upward, thus eliminating the need to lay the display completely on its side when replacing the CS pack. Thus, the force required for operation was minimized, and it became possible to open/close the display by simply moving the bottom of the display forward or backward. As a result an extremely simple mechanism was created (Figure 6).

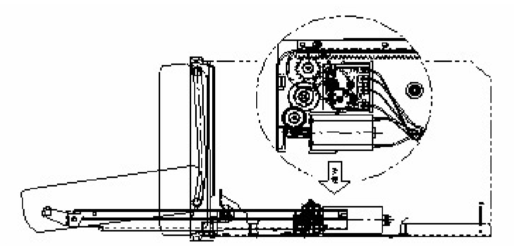


Fig.6 New Tilt structure

Features of the new drive mechanism include fewer parts (25% fewer than conventional models) and a large reduction in required space. Furthermore, power transmission loss is minimized and low-temperature operability is superior.

5.2 Touch switch display unit

5.2.1 Input system (touch switch)

In recent years, touch switches have become an indispensable part of improving display operability. Since the AVX unit is a standard product, it is necessary to configure the circuit in a 2DIN (100 mm (180 mm) or new standard size (104 mm (205 mm). For this reason it is necessary to arrange light-emitting diodes/photosensors around the display, making it impossible spacewise to use the "infrared system" that was in the mainstream until now. Thus, for this product a "pressure-sensitive system" with a proven performance record has been adopted for use from an in-car display.

A pressure-sensitive touch switch consists of two sheets of glass, which make contact when pressed by the user's fingertips. The switch is activated when the contact point is detected.

A problem with a pressure-sensitive touch switch is that light transmission is only 70%. This product alleviates the problem by increasing the brightness of the backlight. Furthermore, touch switches require microcomputers and peripheral circuits for detecting the position. And since the touch switch itself is somewhat thick, efforts have been made to make the circuits smaller and thinner than conventional models.

5.2.2 Sampling system

One display system that was adopted for many displays in the past is the "simultaneous sampling system." When viewed closely, however, characters were blurry and difficult to read at times. The reason, as shown in the diagram below (Figure 7), is that the navigation signals and TFT timing were not synchronized.

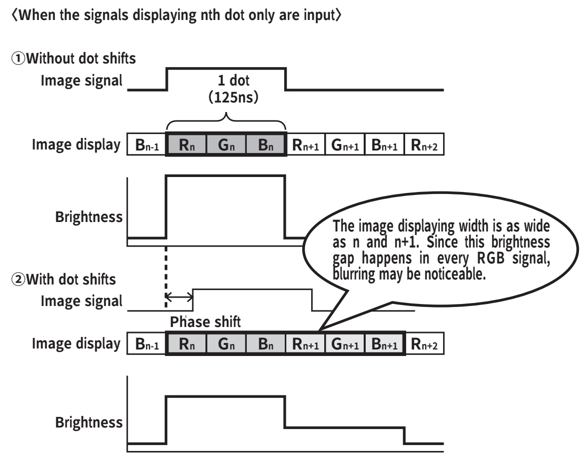


Fig.7 Simultaneous sampling system

In contrast the display system adopted for this product is called the "individual (sequential) sampling system." With this system the characters do not blur even if the navigation signals and TFT display timing are not

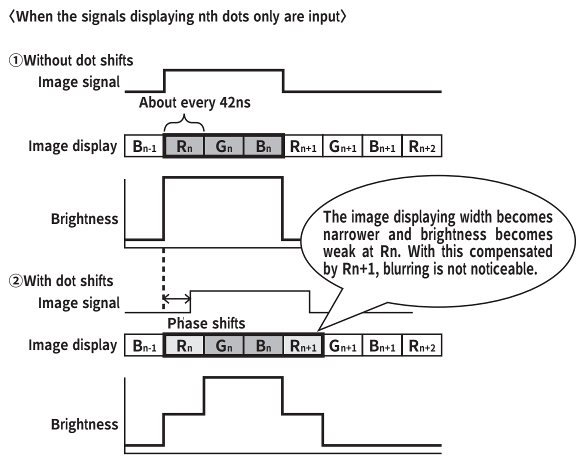


Fig.8 Sequential sampling system

synchronous.

The reason, as shown in the diagram below (Figure 8), is that the signals are sampled and displayed in RGB three times faster than "simultaneous." This provides improved character visibility compared to conventional models.

5.2.3 Light distribution characteristics

The brightness of the screen is an important element of visibility. Since the display position and seat position of an in-car display are fixed, the screen must always be viewed at an angle (approximately 30 degrees) from the driver's and front passenger's seats. Furthermore, from the rear seat, the screen viewing angle (angle of vision) is nearly frontal. Therefore, for high visibility from all seats, a high degree of screen brightness is needed within a 30-degree viewing angle both to the left and right.

In conventional models visibility from the front was assured by a high degree of brightness (viewing angle of 0˚); however, brightness was low in the vicinity of the actual viewing angle (30˚). For the new product, an optical sheet (sheet that changes the direction of the light) was adopted for the backlight unit. And by optimizing combinations of various sheets having different characteristics, flat light distribution characteristics were produced within a 30-degree range to the left and right, and visibility was improved within the entire actual viewing range.

As shown in the viewpoint-brightness characteristics diagram below (Figure 9), at a driver's seat viewing angle of 30˚, brightness is about 1.5 times better than that of conventional models.

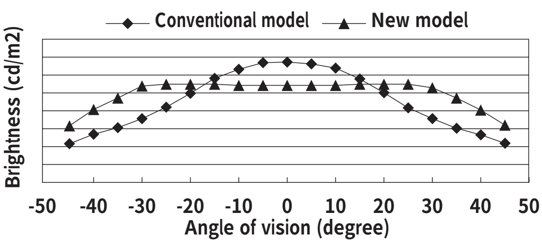


Fig.9 Viewing angle brightness characteristics diagram

5.2.4 Visibility at low temperatures

A cold-cathode tube is used for the in-car display backlight. With conventional models, it took time to attain sufficient visibility on cold winter mornings because the brightness did not improve due to the characteristics of the cold cathode. For the new product, however, the cold-cathode tube diameter, gas pressure, and gas component ratio were modified, making it possible for the brightness to rise extremely quickly even in cold temperatures through self-heating. This greatly improved cold-temperature visibility.

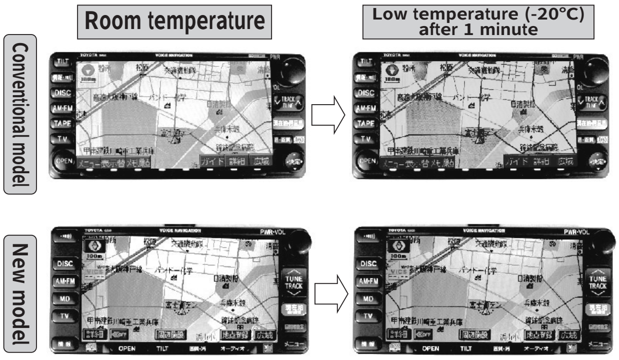


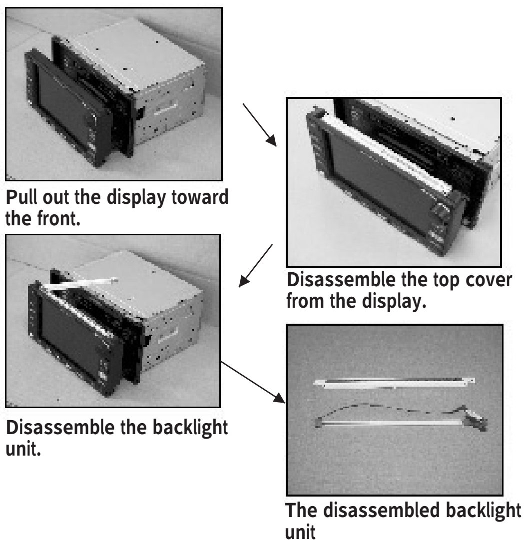
Fig.10 Comparison of low-temperature visibility

5.2.5 Structure

The cold-cathode tube that is used for display illumination contains mercury, an environmental load-generating substance. At the present time, lighting methods that do not use mercury are being examined, but such methods are not yet practical for in-car use. Thus, we are faced with the challenge of finding a way to easily separate and dispose of the substance.

To separate and dispose of a mercury-containing cold-cathode tube in a conventional model, the product had to be removed from the vehicle, and the display unit had to be completely disassembled. Only then could the cold-cathode tube be removed.

The cold-cathode tube in the new product is located

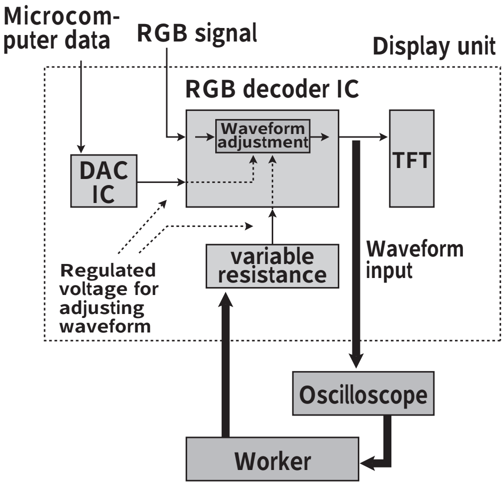


Simplified backlight disassembly
Fig.11 Cold-cathode tube disassembly structure

to one side at the top of the display unit. Also, the product viewing case has a split-threaded structure, making it possible to remove the cold-cathode tube by using the product tilt function, without having to remove the product from the vehicle. The time required to remove a cold-cathode tube has thus been reduced to about one tenth of the time required by conventional models.

5.2.6 Automatic adjustment

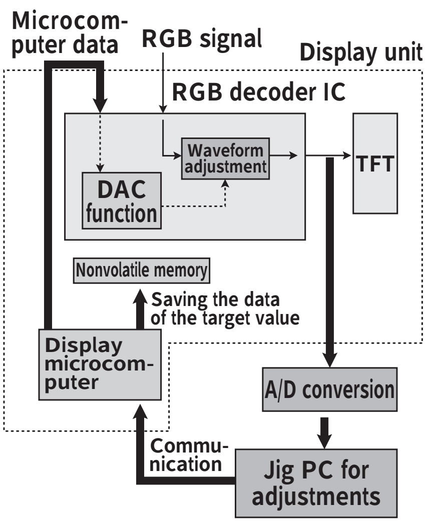
To ensure quality in the display, adjustment of the picture signal is required. With conventional display circuits, a worker would adjust the variable resistance while checking the picture waveform.



Manually adjusting while checking the oscilloscope

Fig.12 Display adjustment (conventional model)

With the new product, adjustments are made automatically by a personal computer rather than a worker, and nonvolatile memory is used in place of variable resistance.



While comparing with the target value, repeat till the target value is gained.

Fig.13 Display adjustment (this product)

This reduces the number of man-hours as well as human error.

5.3 Essential parts

5.3.1 ASIC

Developing ASICs for the drawing unit's peripheral circuits improved cost performance and reduced size.

The table below compares the features of the ASICs with those used in conventional models. The most significant features include a 62% reduction in area, made possible by having the display RAM built in and by reducing the voltage of the power supply; and a reduction in noise, made possible by having the RAM's bus connection built in.

Also, improved performance was achieved by providing display function support from simultaneous 16-color to simultaneous 256-color.

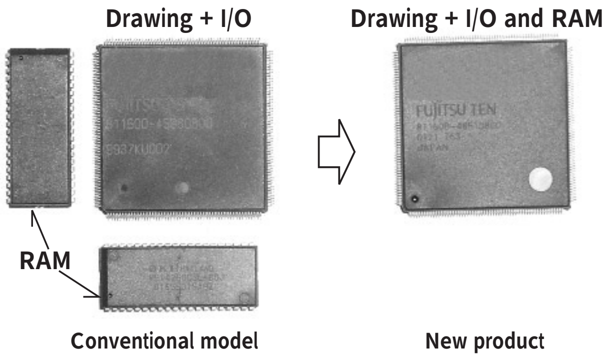


Fig.14 ASIC appearance (comparison with conventional model)

Table 1 Comparison of ASIC specifications

	Item	Conventional model	New model
Function	Color resolution	260,000 colors (16 simultaneous colors)	16,000,000 colors (256 simultaneous colors)
	Parallel I/O	24ch	24ch
	Flash memory control	Available	Available
	DRAM control	Available (external RAM)	Available (internal RAM)
	Power voltage	5V/3.3V	3.3V/2.5V
Size	Outside dimension	30mm×30mm	30mm×30mm
	Terminal pitch	0.5mm	0.4mm
	Number of pins	208 pins	256 pins
	Occupying area (including periphery)	1	62%

5.3.2 TV tuner module

In conventional models the TV circuit unit was placed on the main circuit board. But in order to expand to models across the globe, the existence of a TV function with the new product will depend on the customer. Thus, for effective utilization of the main circuit board, the TV circuit unit was modularized. Features of the TV tuner are explained hereinafter.

①Compactness through reexamination of component lineup

As shown in Figure 15, the entire component lineup was reexamined, resulting in a 50% reduction in parts packaging area.

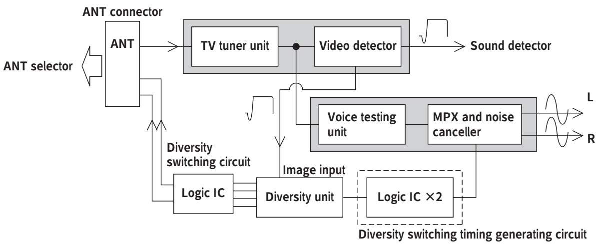
②Improvement of adjustment process

A large reduction in man-hours was achieved by incorporating the audio system adjustment process (conventionally performed during manufacturing by our company) into the manufacturer's module.

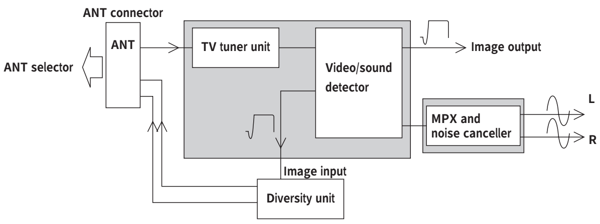
③New TV diversity function

In conventional models diver operations were constantly performed even when electric field stability existed. Consequently, flickering, though slight, occurred at times on the TV screen when the vehicle was stopped.

With the new product, an intermittent operation function (function that reduces diver operating speed when an electric field is stable) was adopted, reducing TV screen flickering when the vehicle is stopped.



Conventional model



New product

Fig.15 TV Tuner structure lineup comparison

Thus, development of the company's first internally manufactured TV tuner module helped to increase performance, improve maintainability, and broaden the range of use (expand to other models).

5.3.3 Radio tuner module

Even though the radio tuner used in this product is described in detail in this technical report (Smart T/M), distinctive items pertaining to the development of the AVX unit are briefly described here.

①Global compatibility (Japan, North America, Australia, and Europe)

Conventional tuners were not compatible with LW in Europe, so a worldwide standard design for the unit was not achieved. With Smart T/M, adoption of up-conversion made LW correspondence possible. Thus, achievement of tuner shape and interface compatibility made it possible to have a globally standardized circuit board for the AVX unit.

②Automatic adjustment

The greatest feature of the Smart T/M is that it can store adjustment values in nonvolatile memory and the adjustment process can be automated.

This product has a local serial communications line and has a function that rewrites the data of the nonvolatile memory in the radio tuner by external control. Utilizing such functions makes it possible to make adjustments automatically by remote communication, whereas the radio adjustment of a conventional product was accomplished by a person who would adjust the variable resistance.

5.3.4 Power supply module

With a conventional model, the power circuits that are required inside the product made use of multiple series regulators. A disadvantage of a series regulator is that it often emits heat when a large amount of current is consumed, causing the temperature inside the product to rise and other adverse effects. The new product, on the other hand, has one additional power supply system. With the increase in the calorific value inside the deck, a reduction in power circuit heat generation was sought.

As part of an effort to reduce heat generation, a small DC-DC converter was developed for double (8V, 3V) power supply output (Figure 16).

In order to use the 8-volt system to supply power to the display unit, and the 3-volt system to supply power to the CPP and ASIC peripheral digital circuits, the size was reduced (10×26×75 mm, excluding projecting areas), and a standby function (to reduce dark current) and output short protection circuit are built in.

Also, the product was designed to reduce the effects of noise on the radio (through the adoption of a metal casing and antimagnetic coil). Primary performance aspects of the converter are shown in Table 2.

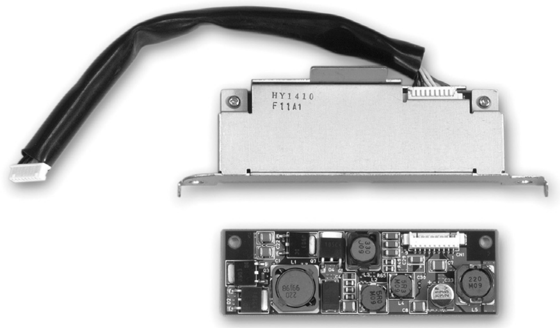


Fig.16 Appearance of DC-DC converter

Table 2 Specifications of DC-DC converter

Item		Specification
Power voltage		10.5～16V
Output voltage	Output A	8.0V
	Output B	3.5V
Output current	Output A	2.0A
	Output B	1.0A
Output ripple	Output A	50mVp−p
	Output B	50mVp−p
Input ripple	＋B	150mVp−p
Output voltage rise time		50ms
Standby current		100 μ A
Oscillating frequency		93kHz
Short protection		Available

5.4 Software

5.4.1 Software configuration

This product consists of three types of microcomputers whose roles are as shown in Table 3. Of these, the main microcomputer has a multichip configuration with built-in ROM and two types of external ROM.

Exclusive software from a standardized software library is compiled/assembled into a form that can be installed, and then stored in a microcomputer internal ROM or external ROM.

Table 3 Allocation of functions for microcomputers and storage ROM

Microcomputer type in use	Application	Allocation ROM
Main micro-computer	AVC-LAN communication control	Built-in ROM
	Screen drawing control	External program ROM
	Character font & drawing data	External font ROM
Audio micro-computer	Radio, TV, audio control units control	Built-in ROM (masking)
Panel micro-computer	Display board control	Built-in ROM (masking)

5.4.2 Compatibility for worldwide destinations

To accommodate fifteen types of function combinations, the individual parts of the main microcomputer are divided into two types: domestic and overseas. Corresponding display-use bit maps and data are also divided into domestic and overseas types. Furthermore, for the selection of functions for individual parts, a function enable/disable determination is made using model codes, which are stored in a designated area of the flash ROM. The model codes are written for each model in the production process.

Based on whether RDS/RBDS functions are available, two types of software are prepared for the audio microcomputer. As with the main microcomputer, function enable/disable selections are stored in the non-volatile memory inside the radio tuner and determinations are made by model code.

By dividing the software in this manner, it became possible to reduce ROM capacity by half during installation. Furthermore, assembling the software of each function and dividing by model code made it possible to achieve standardization in up to 60% of all software.

・Main microcomputer (5 types)

Common parts (destinations, model common parts:

storage in built-in ROM)
Individual parts (destinations, model individual functions: storage in external ROM)
For domestic use
For overseas
Display data unit
For domestic use
For overseas
・Audio microcomputer (2 types)
Without RDS/RBDS: (for Japan and Australia)
With RDS/RBDS: (for North America and Europe)
・Panel microcomputer (1 type)
No difference between model/destination
※These software combinations and classifications by "individual part" model codes make it possible to accommodate changes in the functions of all 15 types.

5.4.3 Writing tool

Exclusive hardware/software was prepared in order to write the aforementioned types of software into the applicable ROM (Figure 17).

A personal computer can be connected to a connector at the back of the display when the display is fully open, making it possible to upgrade software versions while attached to the vehicle. The exclusive software starts up on the personal computer, and a version upgrade is implemented only for the required parts of the software that are divided by address.

And since the audio microcomputer and panel microcomputer use a flash ROM built-in version during the prototype stage, commercially available special hardware from the device manufacturer is used, making it possible to write software with the same connections. This was utilized in experiments and tests during the development stage and achieved early quality.

5.4.4 Version display function

The product has a function that enables the user to view the divided software versions on the screen. It is used to check the version and confirm model functions after writing on the production line.

Fig.17 Software Writing tool

5.4.5 Flight recorder

Even conventional models have been equipped with diagnostic functions for diagnosing failures; however, it has been difficult to directly tie such to software problem solving. (The purpose of a diagnostic function is to record the results of a problem occurrence as a code and identify the failed piece of equipment.) Thus, a

Table 4 Purpose of the flight recorder introduction function (comparison with diagnostic function)

	Diagnosis	Flight recorder
Purpose	①Hardware trouble detection by sensor ②Identification of the affected devices upon communication trouble	①NTF *(Improved trouble analysis based on the software's operation history) ②Extraction of potential software error
Detection/ Recording system	When the trouble described in the specifications is detected, the applicable codes are recorded.	The software designers select the data necessary for the analysis and are collecting the history data regularly.
Relationship with clients	Notified as the clients required specifications	One of the ways to meet the quality required by the clients
First order analysis	Identifying the affected units by cross referencing the diagnosis results with the manual.	Selecting the data necessary for analysis from the trouble conditions. Analyzing the causes of trouble based on the data's time sequence changes.
Usage	Troubleshooting at the factories and dealers.	Engineering analysis of the trouble happening on site (only capable by the designers)

*NTF: No Trouble Found

"flight recorder" that analyzes software problems was incorporated into the new product. This device brings to mind a flight recorder installed in a passenger plane, as it records as data the process leading up to a software problem, collects data from the time that a problem occurs, and uses such data to analyze problem causes.

As shown in Table 5, the flight recorder is configured with seven types of functions. After analyzing the tendencies of problems that occurred during the development of the AVX unit, it selects and records the most effective six types of data as a means for analyzing problems.

Also, the error trace function of item 7 has a function that codifies and records when a software error occurs. Its purpose is to detect potential problems that do not appear as phenomena.

The figure below (Figure 18) shows the method by which the flight recorder records and collects data. As for connecting the interface jig for the data-collecting personal computer, the hardware is equivalent to the hardware used during software writing, and the method of connection is the same. The software used with the personal computer should be software that is exclusively used for data collection.

Table 5 General features of flight recorder

Function	Description	Analysis	Detection
①Power condition trace	Records power condition transition (about 2 months in normal usage)	○	—
②Mode control trace	Records sound/image mode transition (about 2 months in normal usage)	○	—
③TAB II trace	Records internal microcomputer communication data (about 7 minutes)	○	—
④AVC-LAN trace	Records external devices communication data (about 15 minutes)	○	—
⑤Task trace	Records the software that was processed before a forced reset (1 step only)	○	—
⑥ASIC trace	Records the communication data with the drawing ASIC (about 2 minutes)	○	—
⑦Error trace	Records the codes when trouble takes place while the software is being processed. (For about 2 years: once per day when trouble occurs)	—	○

Analysis: Trouble analysis support Extraction: Potential trouble extraction

Note: TAB II: Telecontrol Audio Bus II; adopted as a standard for communication between CPUs inside the product.

Furthermore, as an analysis support tool for collected data, software has been prepared that converts collected codes to a format that is easy to understand with an editor, and explains the meaning of the codes in Japanese.

As a measure for shoring up the capacity to collect data from actual vehicle tests and problems occurring in the field, flight recorder data that has accumulated in RAM is moved to flash memory and protected; then the battery or instrument is removed, and the equipment and data are recovered.

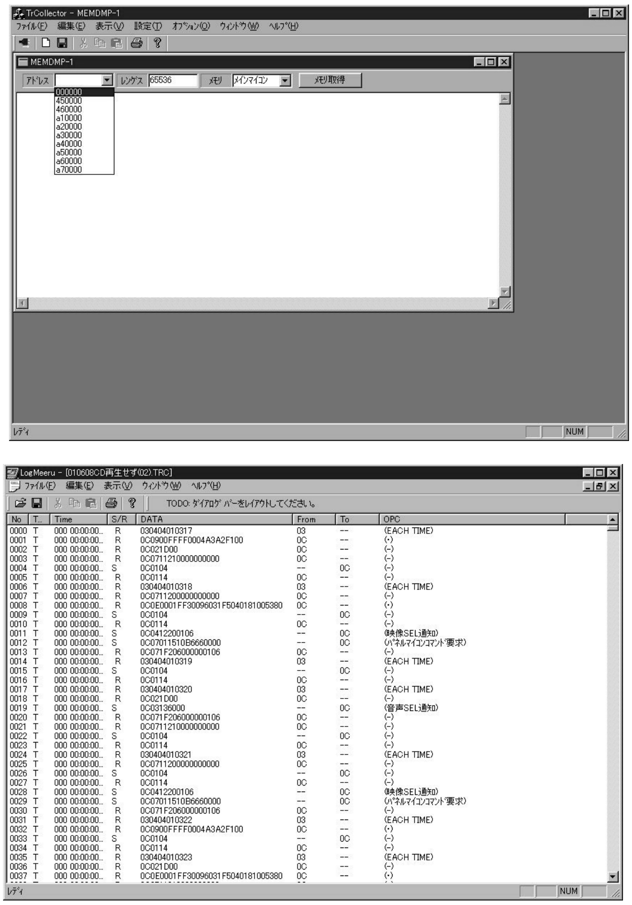


Fig.18 A screen example of data collection/analysis tool for the flight recorder

6 Conclusion

This report provided an overview of the recently developed AVX unit.

From the specifications stage, efforts were made to create a design with Toyota and establish the specifications early.

Furthermore, during the stage prior to mass production and with the cooperation of Toyota and the navigation system manufacturer, an evaluation was conducted with a large amount of monitor, which helped to establish quality at an early stage.

In the future as startling new developments take place in the "car infotainment" field, the AVX unit is also expected to add new functions (such as a telephone cooperative communication function, digital RGB display function, and multi-TV screen display).

Currently, we are planning and test-manufacturing the next model in cooperation with Toyota, and are making efforts to complete specifications early and establish quality.

In closing, we wish to extend our sincere thanks to those individuals from Toyota's Electronics Engineering Division I who have provided guidance during the making of the AVX unit.

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