"New Media"-compatible Audio-Visual Combination Model for Automobile

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The market for car navigation systems has been showing a rapid, healthy growth.
In August of 1996, we developed "new media"-compatible audio-visual (A/V) combination models,as forerunners, that have a wide 5.8 inch thin film transistor (TFT) LCD screen. We subsequently introduced models featuring multiplex FM, extended definition TV (EDTV), and other features.
Even with the multiple functions offered by these units, their front panels is designed to perfectly fit within the extremely small "2DIN" sized opening (10 x 18cm) of a car's instrument panel.
This paper primarily describes the technologies used, such as the mechanical structure, the heat dissipator, and digital-noise reduction methods for adjacent, circuits that permitted the co-existence of TV and audio in a single chassis.
Also covered are the circuit technologies that enhanced the on-screen readings and provided a higher definition, a newly developed TFT for a wider viewing range, and a power tilt function that enhances its controllability and appearance.

1. Introduction

The rapid evolution and expansion of car navigation systems for safer and more comfortable driving have brought numerous multimedia products into the market.

Since May of 1995, we have been manufacturing navigation-oriented audio-visual (A/V) combination models (incorporating AM, FM, TV, CD, and tape deck) equipped with a 5 inch thin film transistor (TFT) LCD. However, the market urgency needs audio visual units having functions intended for multimedia products. Accordingly, we have developed the built-in 2DIN "new media"-compatible A/V combination models (hear after called AVX combination model), jointly with Toyota Motor Corporation. This paper describes the outline, features, and design concept of the model.

2. Development objectives

As an upgraded version of traditional A/V combination models, the following functions have been included: a 5.8 inch wide display, an FM multiplex receiver (visual radio), an EDTV II automatic switching receiver, the power tilt function, and a dot-matrix graphics display function for the display screen. To emphasize system expandability, NAVI and VICS control by LAN for automobiles, a CD auto-changer feature, and an external VCR input have been supported with the aim of developing a multimedia-capable combination model all incorporated in a 2DIN sized body.

3. Outline of the system

For superior sound quality, a super live sound system (seven speakers: four door speakers, two tweeters, and one woofer) has been implemented by adopting a fixed equalizer built-in to an external amplifier system.

Visually excellent operation screens have been provided by a high-performance TV receiver (a diversity system also installed in FM) utilizing four antenna diversities, a 5.8 inch wide TFT display (with an aspect ratio of 16 to 9), and a function to display 16 of 260,000 colors on a 400 x 234 dot-matrix display.

For audio sources, AM/FM/TV broadcasting, FM multiplex broadcasting (visual radio), a CD (built-in and external changer systems), and a cassette tape are all supported.

The external system supports NAVI•VICS and can be manipulated by this device as the control center.

4. Product features

4.1 Basic configuration

Figure 1 shows the overall configuration.

4.2 Features

A 2DIN combination model having the following functions in addition to those of traditional A/V combination models (2DIN size, tuner, tape deck, CD, and TV).

- FM multiplex function
- 5.8 inch wide display
- Enhanced graphics function
- Power tilt function

4.2.1 External dimensions

The same 2DIN size as with car audio systems allows this product to be mounted in the dash to fit perfectly in the car instrument panel. The use of the display will not interfere with operating the air conditioner or other car components.

4.2.2 Built-in FM multiplex function

The FM character multiplex broadcasting enables the user to view the following character information sent with voice:

- Dependent information programs (program information channel)
- Independent information programs (news and weather report channels)

4.2.3 Improved visibility

As a display used in a car, its ease of visibility greatly influences the safety of driving. Accordingly, the visibility has been improved by the methods described below.

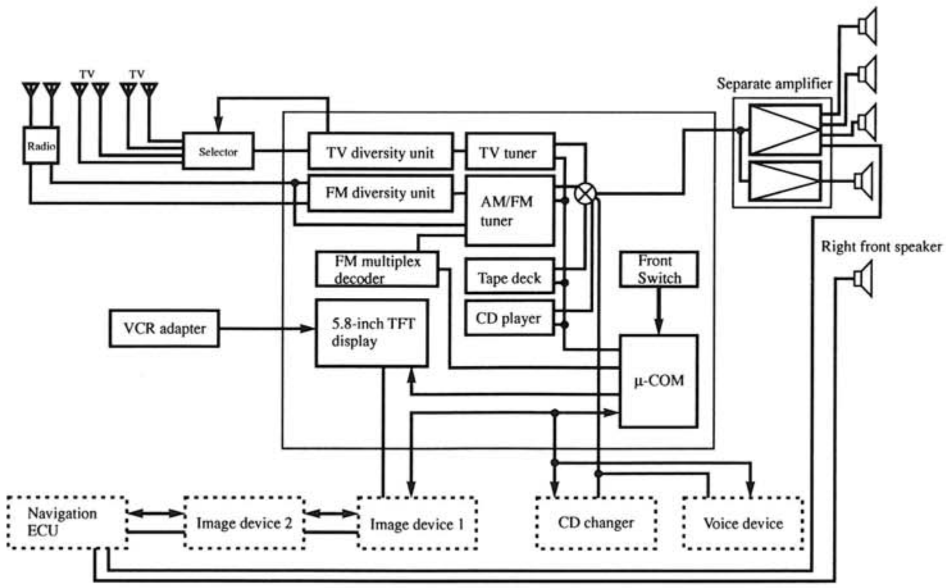


Figure 1. System block diagram of AVX

① The adoption of a 5.8 inch wide TFT-LCD to achieve a maximum screen size of up to 2DIN size (the first in the world)
② A wide TFT-LCD viewing range
③ Improved contrast
④ Improved screen intensity
⑤ The adoption of a display tilt feature (0°, 10°, 20°, 30°)

Feature ⑤ is especially useful to accommodate the differences in car mounting positions and viewing positions due to drivers' physiques.

4.2.4 Graphics function

To implement the advanced display functions and a graphics capability, a bit map graphic display has been newly adopted. This has increased the number of displayed colors to 260,000, presenting images closer to their natural colors.

4.2.5 Improved operability

The display adopts a motor driver method for the open, close, and tilt operations, improving operability and touch operations. The display can be opened and closed without protruding past the front (180 mm wide by 100 mm high) of the product to avoid interfering with other car controls (air conditioner, etc.).

5. Technological development

The following concerns the technical implementations:

5.1 The development of a 2DIN sized product (high density technology)

5.1.1 Board configuration and multilayering

1) Circuit configuration

Compared with traditional products (A/V combination models), the circuit scale is higher due to the improvements and an increase of specifications. Figure 2 shows an example of this.

In traditional products, control of the system was performed by one main CPU. The newly developed AVX combination model includes the functions corresponding to the traditional main CPU in the block configuration shown in Figure 2 (the dashed-line portions in Figure 2 have been increased). The ratio of the system control section to the entire system has been greatly increased. (See Table 1.)

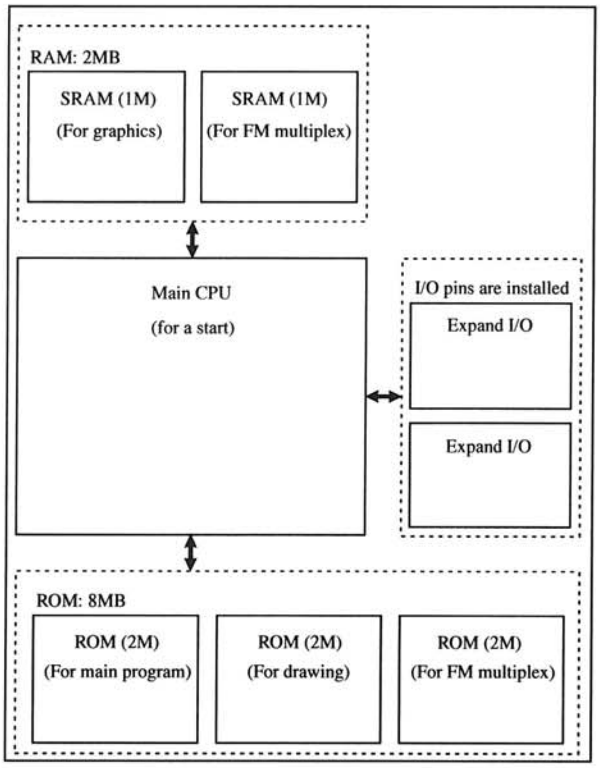


Figure 2. Block diagram of AVX system control

Table 1. Comparison of basic specifications

	Traditional (A/V combination model)	Current (AVX combination model)
Chip configuration	1	8
ROM capacity	64KB	8MB
RAM capacity	2KB	2MB
Clock frequency	5MHz	25MHz
Number of input/output pins	50	110

This is due to the improved graphics functions (the increased number of colors from 160,000 to 260,000), the support of FM multiplex function, and the increased number of input/output pins. This increase of circuit blocks has been accommodated by the allocation of board areas, the adoption of multilayered boards, and other technologies.

2) Decreasing receiver degradation due to noise

Improvements in the extended functions such as the FM multiplex and the graphics function require high-speed communications and increased communication clock frequencies. Also, the increased communication control circuits and the various circuit communication frequencies increase interference and exert a higher influence on radio and TV bands than do traditional products. The number of points that influence FM bands in particular have increased. (Figure 4)

Consequently, the improvements described below have been made.

① Board layout

A special consideration for this board configuration was separating the microcomputer and digital sections from the tuner section (radio/TV) to isolate noise sources systematically. (Figure 3 and Table 2.)

② Noise control

The filters and shields described below have been added.

Table 2. Main noise specifications

A. Main board		B. Microcomputer/ navigation board		C. Others	
Source	Clockdriver voltage	Source	Clockdriver voltage	Source	Frequencydriver voltage Generated voltage
① PLL system	7.2MHz/5V	① Microcomputer system	25 MHz divided by 2/ 5 V	① DC/DC converter system	70kHz to 100kHz /9V→ -16V, -5V, +13V, +7.5V
② FM multiplex decoder system	7.2 MHz divided by 2/5 V 12.5MHz max./ 5V	② Drawing system	14.3 MHz divided by 4/ 5 V		
③ S-RAM communication system	Integer multiple of 63.5 MHz (At 76 MHz, 0 to 8.5 V)	③ Address communication system	12.5MHz max./5V	② Inverter system	40kHz to 50kHz/5.5V →1.5kVrms
③ FM local system					

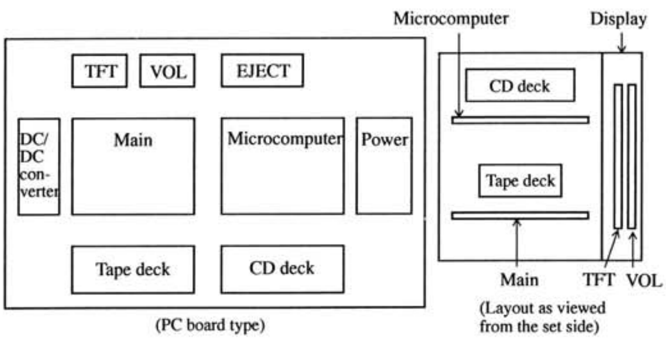
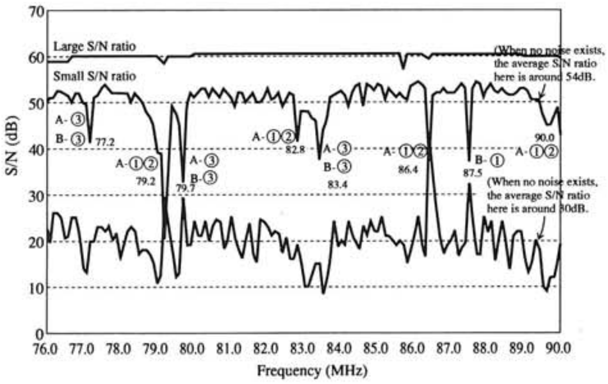


Figure 3. Layout of PC Board

- An EMI filter has been added between the microcomputer and the main board.
- GND has been enhanced by a multilayered microcomputer board (six layers) and main board (four layers), an enhanced pattern shield, and separated communication, signal, and power line layers.

(a) Initial stage of development



(b) After improvements

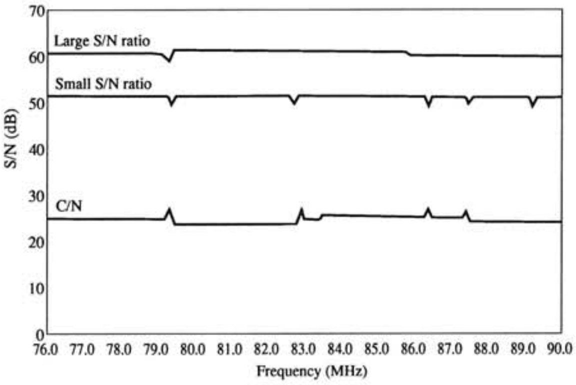


Figure 4. FM noise

- The addition of an EMI filter to the power line
- A different bypass capacitor for the power line
- An extra shield in addition to a shield plate (in the F/E, external connector, ANT, and microcomputer sections)
- The addition of a bypass capacitor to the address communication lines

As a result, improvements (a) to (b) in Figure 4 have been achieved.

5.1.2 Thin TFT-LCD unit

Traditionally, cold cathode tubes used as an LCD light source were placed directly below the LCD. By placing the TFT-LCD unit around the LCD and employing an illumination method (edge light type) that uses acrylic light conducting plates, the thickness of the TFT-LCD unit has been reduced by about 10 mm (Figure 5).

5.1.3 Measures taken for cooling

The heat emission from the power circuits that drive the 25 Watt, 4-channel power amplifier and the functions described earlier was an important consideration in achieving the 2DIN size.

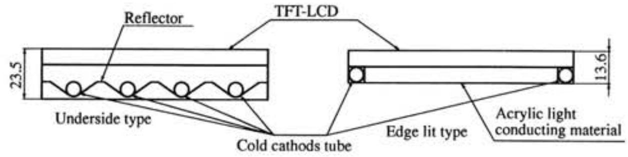


Figure 5. Structure of TFT-LCD assembly

This equipment has a heat emission volume of no more than about 80% that of the 1DIN combination model and emits 1.3 times as much heat. Therefore, we adopted a cooling fan to efficiently dispell heat. In the adoption of a cooling fan, two design concepts are possible. One is to forcibly expel the heat trapped inside. Another is to effectively cool the heat source with a cooling fan to prevent a buildup of the inside temperature.

This equipment was developed with the latter design concept because the limited space and the high density design make it difficult to provide air flow paths. Before designing the layout, we attached a fan to a flat aluminum plate and analyzed the air flow in a mock-up of the product. The results indicated that a concentrated placement of heat sources such as the power IC, the power supply IC, and the power regulator around a fan would efficiently dissipate heat through small aluminum heatsink plates. Experimental data revealed that the power supply IC section, the power IC section, the regulator section, and the cassette section were reduced to 24 °C, 25 °C, 23 °C, and 18 °C, respectively. Figure 6 shows the placement of the heat sources and the cooling fan.

5.2 Enhanced visibility

5.2.1 Improved LCD viewing characteristics

As the screen becomes larger, the view extends to more seat locations and a wider viewing range and higher contrast are required. However, the drawback of LCDs is that contrast varies with viewing locations because of the configuration properties. In extreme cases, images may be too difficult to view due to display reversal or other abnormal conditions. This is apt to occur with an increase in the

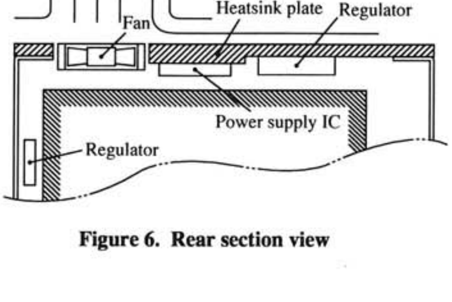


Figure 6. Rear section view

contrast, making a high contrast for a wide viewing range difficult to achieve. Accordingly, in a joint effort with a parts manufacturer, we reviewed polarization properties and succeeded in manufacturing a display-reversal-resistant screen having a wide viewing range.

Figure 7 shows the contrast characteristics.

5.2.2 Improved graphics function

Figure 8 shows the configuration of the graphics system.

The graphics function of the newly developed AVX combination model has been developed with the following four major objectives.

① The use of 260,000 display colors (16 colors displayed simultaneously)

② Superimposed display

③ Analog RGB output support

④ Color specification in dots

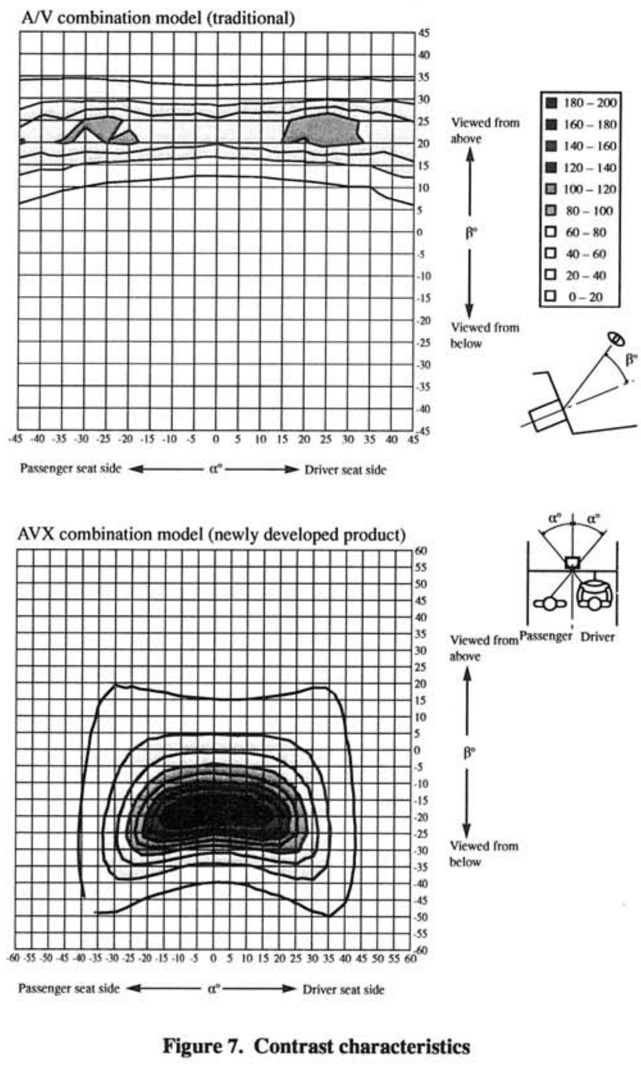


Figure 7. Contrast characteristics

These objectives could not be achieved for a graphic display based on the traditional character generation circuits.

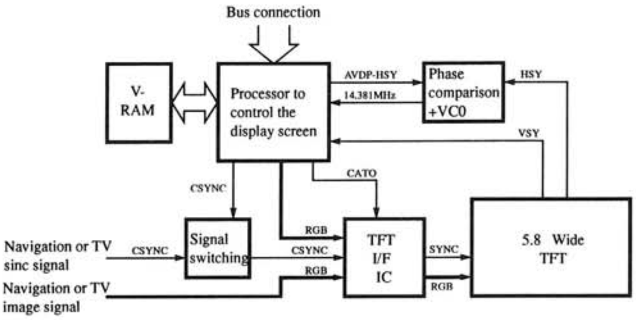


Figure 8. Block diagram of graphics system

These objectives have been achieved by methods (① to ⑦) as described below. ① A display screen control processor having an advanced display and graphics function that allows colors to be specified on a bit basis was adopted. ② A 4 Mbyte DRAM was included as external VRAM to help manage graphics data. ③ To access data at a high speed, an 8-bit parallel data path connection was employed for the CPU interface.

In addition, ④ two 4 Mbyte flash ROMs external to the main CPU were bus-connected to provide various types of graphics designs for operation, supporting graphics data, and holding level-2 kanji font data required to support the FM multiplex function.

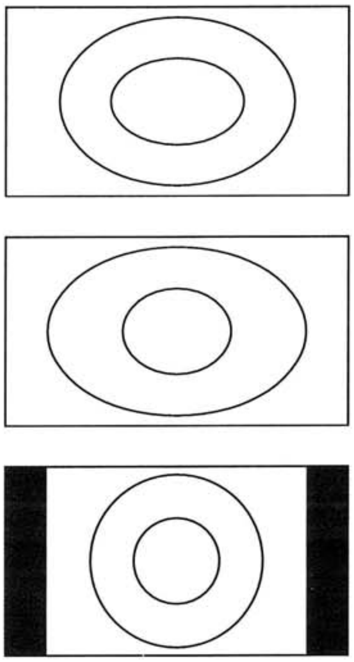
Moreover, ⑤ to provide a clear superimposed display for image input (television images, navigation images, etc.), a synchronous PLL circuit was configured separate from the display screen control processor to input a dot clock for the display screen control processor synchronously with the horizontal synchronous signal of the external image input signal. ⑥ In combination with a linear RGB output timing signal CATO for the color coding a stable display of image input signals was achieved.

In addition,

⑦ Three types of screen display modes were provided for the wide TFT, but the images may differ between the modes. (See Figure 9.)

Error were found to occur between the locations of the SW symbol and the actual SW. This occurred particularly, when the SW symbol was superimposed on the lower portion of the screen and external image input signals were being displayed in (3) narrow display mode or (2) uneven display mode.

To solve this problem, the linear RGB output timing signal CAT1 from the display screen control processor was used to forcibly align the TFT-LCD graphics display to the SW symbol .



(1) Full screen mode

(2) Wide 1 mode

(3) Normal mode

Figure 9. Three types of display modes

5.2.3 Improved FM multiplex display speed

1) Outline

The display of FM multiplex broadcasts is performed as described below. (See Figure 10.)

① Fetches required information from memory (database) and reads the character codes contained in it.

② Computes the data table address for kanji font ROM from the character codes and converts information into dot data.

③ Places the generated character data in a display area with 2.5 lines of 31 characters per line to create a display image.

④ Converts the display data into color data of 4 bits per dot, transfers it to the drawing IC, and displays it.

2) Improved display speed

Conventionally, character data is displayed by sending preregistered character codes to the graphics IC, or character generator. Now, however, a method of forming characters by sending color data one bit at a time is employed making it possible to freely display various characters and graphics.

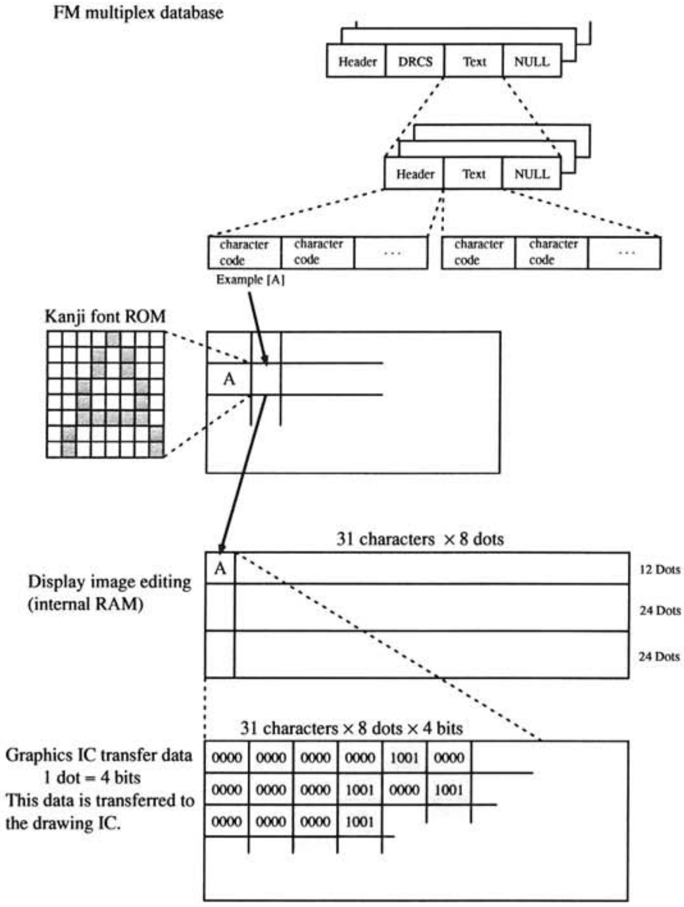


Figure 10. Sequence of displaying multiplex-FM characters

However, the disadvantage of this method is that the amount of data sent has increased 120 times or more which increases the processing time.

For the present model, we placed great emphasis on reducing the processing time.

Specifically, the program structure was modified to speedup processing as shown below. (See Figures 11 and 12)

① Since data transfer to and from memory involves calculating the transfer source and the destination addresses, calculation and branch processes requiring a long execution time were avoided when possible. Alternatively, addresses were specified by constant and absolute values to reduce execution time. (Figure 11)

② In conversion processing such as assigning color data to dot data, instead of performing processing on a per dot basis, four bits were collectively input as a unit and data was extracted from a data table consisting of 16 patterns. This reduced the number of process loops. (Figure 12)

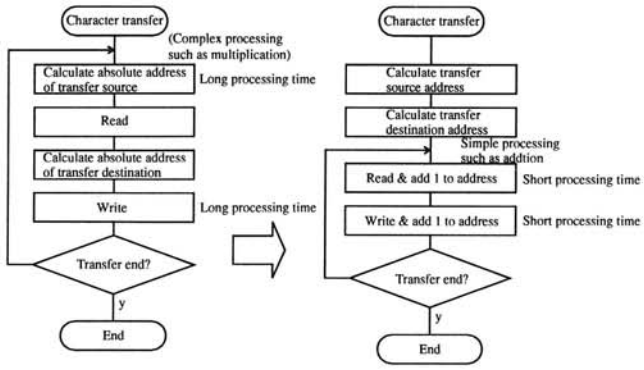


Figure 11. Transmission sequence

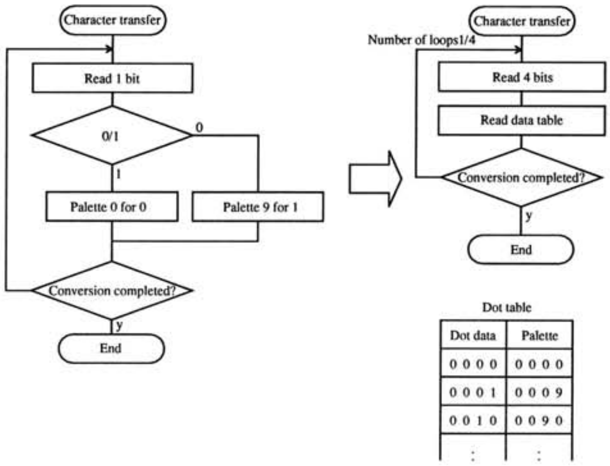


Figure 12. Conversion sequence

5.3 Development of the display driving feature

5.3.1 Adoption of the power open tilt function

This product is mounted in a car instrument panel or an appropriate place in the console (the position varies between vehicles). Viewers' eye positions and the display positions vary greatly depending on the vehicle and individual viewers.

The TFT-LCD, though having a wide view range, has a smaller optimum view range than a CRT. Therefore, as the visual angle to the screen increases, image distortion and reversal are liable to occur and images become more difficult to view.

To satisfy visibility in these conditions, the tilt feature of 30° in three steps, each being 10° upward, was adopted.

To accommodate as large a display as possible along with CD and cassette back insertion ports in the limited space of a 2DIN size, this product has been structured so that the display can be fully opened.

To facilitate the above operation and provide an upscale image, the operations are driven by a motor.

5.3.2 Tilt open

The display angle (hereafter called a tilt angle) changes in increments of 10° from 0° by pressing the tilt button, and the full tilt angle of 30° is returned to 0° by pressing the tilt button.

Pressing the open button levels the display from any tilt angle and reveals the CD and tape cassette openings appear. Pressing the open button again returns it to the original tilt angle (0 to 30°). (Figures 13 and 14)

5.3.3 Inner structure and operation

During tile operation, the motor A in Figure 15 rotates, the tray moves back and forth, and the display bottom moves. Since the upper roller of the display is controlled by the guide slot to move only vertically, the display angle changes.

when opened, the display is tilted up to 45° beyond the normal use tilt angle of 30°, then moves forward. After this, motor B rotates and lowers the lever downward via gears b1, b2, and b3, and tilts the display up to 90°.

This product is structured so that the open and tilt operations are driven by different motors. This has the following merits:

close

30° tile

Fully opened

Figure 13. Display (in working condition)

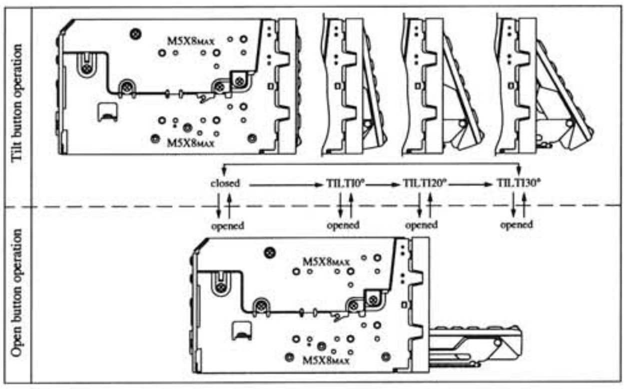


Figure 14 Tilt-to-open movement

① The link mechanism can be miniaturized, providing high reliability and efficiency.

② It provides an easy tradeoff between driving power and safety.

③ The display protrusion portion can be minimized when open.

5.3.4 Tilt angle control method

As previously described, display tile angles are determined by the position of tray. This product used a position sensor to detect the position of the tray. This method provides more precise control than the photo transistor method because a highly accurate detection can be made throughout the movable range of the tray. Also, the setting of the tilt angle can be changed flexibly.

5.3.5 Considerations for rattle

Since this product has eight direction switches (joy stick), the display sustains pressure from up and down, right to left, and back and forth directions. Since rattles in moving parts may reduce performance, the rattle prevention mechanism shown below is provided.

① Up/down direction

As shown in Figure 16, the tray is pressed downward by a spring, friction prevents rattles in the back and forth direction.

② Right to left direction

By using a cone shaped roller to control the right to left direction of the tray and by pressing the roller against the tray, rattle between the roller and tray is eliminated. (Figure 17)

5.4 Support of EDTV II function

A new television broadcasting method for widening the screen and achieving a high image quality while main-

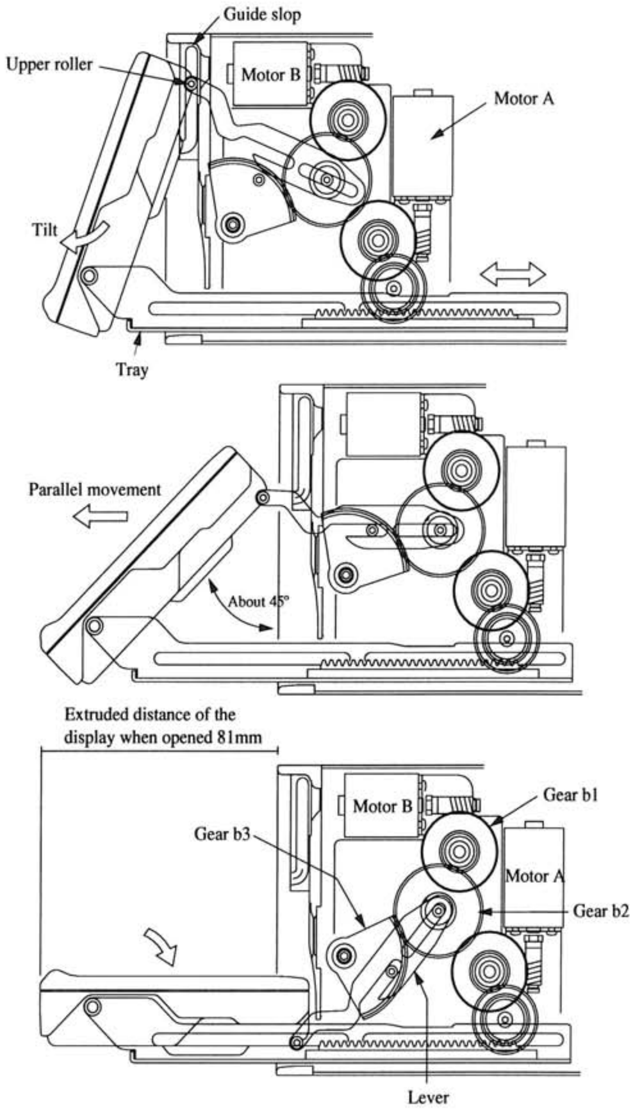


Figure 15. Inner structure of driving mechanism

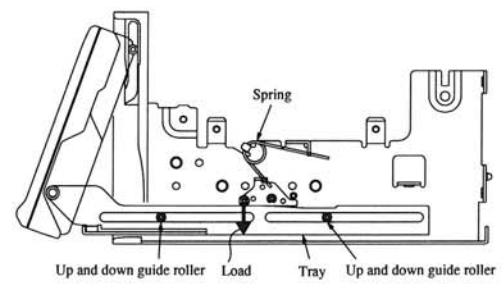


Figure 16. Rattle prevention mechanism (for up and down and back and forth vibrations)

taining compatibility with current systems is known as second generation EDTV (called broadcasting EDTV II). The AVX combination model has been partially provided with this new media function by widening the screen.

Second generation EDTV broadcasting in its full sense contains the following technologies:

① A maximum effective screen aspect ratio of 16:9

② Automatic aspect ratio switching by an identification control signal

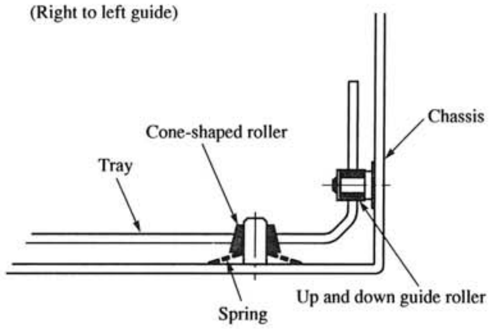


Figure 17. Rattle prevention mechanism (for right to left vibrations)

③ Supports all resolution reinforced signals (HH, VH, VT)

④ Sequential scanning

To satisfy these features, a wide, clear television receiver (level 1, full specification) is required. Of the technologies described above, this model supports ① the " maximum effective screen aspect ratio of 16:9" and ② the "Automatic aspect ratio switching by an identification control signal," which are collectively known as "wide television" (compatible with identification control signals)."

This model performs automatic aspect ratio switching by an identification control signal, as described below.

The signals of the second generation EDTV broadcasting method are used in such a way that identification signals and reference signals are multiplexed on two scanning lines (the 22nd and 285th scanning lines) with 27 bits of data multiplexed on each scanning line. The rectangular wave in the first to fifth bits of the data contains data indicating the difference between the EDTV II method and the NTD method. By decoding the data, EDTV II broadcasting is detected. However, for automobiles, a realtime response to changes in the field strength causes frequent screen size changes, which disturb watching the screen. Accordingly, we devised software detection logic for the main CPU which provides an EDTV II broadcasting screen frame upon detection, and releases it after a given period of time if detection becomes impossible. That is, an hysteresis operation has been added to satisfy the conditions inherent in automobile use.

6. Conclusion

This paper described the objectives, major technologies, and ideas regarding the AVX combination model which entered the market in August of 1996.

This product has enjoyed great popularity in the market, and we can state that the product development has satisfied our intent. We are considering tackling the development of additional products by taking full advantage of the precious experience and know-how gained in the development phases of this product for the development of next A/V combination system.

We wish to acknowledge the cooperation and assistance received from Toyota Motor Corporation, and the other organizations and individuals concerned in the development of this system.

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