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Tuner Control CD Player "CD-1330,1331"

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The CD player released in fall 1982, has rapidly widespread, centering about the CD player for home use, and the digital audio age is getting into a full swing together with the digital audio tape recorder (DAT) put on the market last year.

In 1984, FUJITSU TEN released the CD player for automotive use, first in the industry, followed by the SD-1100 and SD-1101, which have gained public favor. Further, to meet market needs for combined functions, FUJITSU TEN released a high-grade tuner control CD player model CD-1330,1331 last fall. This new CD player is fully loaded with the latest technology, including the realization of data communication between microprocessors and diversified functions using ten-key operation as well as improved basic performance as CD player such as resistance to scratch on the disc and car vibration.

CD1330: For use in Japan.
CD1331: For use abroad.
In the USA, this is marketed as the ECD-110, ECLIPSE.

1. Introduction

The compact disc (hereinafter referred to as CD) was introduced to the home audio market in 1982, and has greatly contributed to the development of digital audio.

There was limited selection of titles to choose from in the beginning, and a player could cost over 100,000 yen (US $800). The CD had not yet become popular in the mass market. However, in 1984 CD portable players were put in the market including those for use in cars. In 1985, installing CD capability into minicomponents became standard and they were also included in cassette recorders with radio. CD players had increased in popularity by this time, and in 1987 the shipments in Japan exceeded three million units.

Naturally, the amount of available CD software increased, and from 1984 to 1986 the number of software titles quadrupled. As of 1987, there were over 15,000 titles published and 50 million discs in circulation.

The CD market for home use has grown due to parallel development of hardware and software. Conditions for CD players in cars were slightly different, however.

The price was the big problem. In 1984, home-use models around 60,000 were already being sold where as car CD players were available at prices starting from 90,000. Pricing of the players for home use kept falling, while CD players for cars were remained expensive. However, since 1987, models around 50,000 or 60,000 that may be considered inexpensive for car use have appeared in the market. The total market for car CD players has thus begun to expand, and it is forecast that unit sales will increase from 90,000 in 1987 to around 200,000 in 1988.

In August 1987, FUJITSU TEN developed an audio visual communication (AVC) system using CD-ROM. This was offered as a factory option for The Toyota Crown a top-of-the-line model.

This CD system is used as both an audio and visual information source. This kind of application will be further developed in the future, and sales of

the CD or data storage purposes may be expanded.

This installation space for the CD player is another problem. In Japan, most cars have an audio installation space of 100 mm by 180 mm. This is called the double-DIN size, and allows space for two standard units. The one-DIN size is 50 mm by 180 mm and allows space for only a single unit. This size is standard for most cars made outside Japan as well as in a few Japanese models.

The limitations of the one-DIN size have brought changes to the market, and models combining the functions of turners, amplifiers, and players have begun to replace the traditional single-function components.

The CD-1330 is based on this concept of combining function. It is a one-DIN size unit combining a CD player and tuner. (CD-1331 contains the tuner unit.)

The CD-1330/1331 are positioned as higher grade models in the [illegible] lineup, and will become the kernel of high-grade systems. This report describes the functions and performance that are required for such models, and also describes the design including ease of use that are important for high-grade models. The new techniques used to achieve the above requirement are also described.

2. Aim of development

Compact discs have the following features.

1) The sound quality is superior to that of records and cassette tapes.
2) The discs are small and light. They can easily be carried around.
3) The selections on the disc can be accessed directly and quickly.
4) In addition to the audio signal, it supports several control functions.

The CD-1330 and 1331 have been designed for ease of use and installation convenience in addition to good sound quality and quick access features. We made it a target to develop a sophisticated design that gives a sense of satisfaction as a high-grade machine. This model was developed based on the following concepts.

1) This unit must be able to fully represent audio response, and have flat frequency characteristics throughout the wide bandwidth, and the entire range.
2) This unit must have sophisticated functions that take advantage of direct access while featuring ease of operation and satisfying the requirements for car use.
3) The control panel will be designed for ease of use and an attractive appearance.

We decided to develop a unit based on the above concepts.

3. Product features

3.1 Function

Figure 1 shows the CD-1330 and its control functions.

The use of the ten-key pad on the control panel provides ease of use inside the car. The ten-key pad makes full use of the functions and is easy to operate. The functions are explained below.

1) Direct music selection

As explained previously, direct music selection enables much quicker access to music selections than cassette tape, which is a big CD feature, and is easy to operate while driving.

In the conventional car CD players, buttons must be pressed for each track to be skipped when selecting music. In ten-key direct music selection, it is necessary only to press the button corresponding to the music selection number. If the track number is higher than 9, two buttons must be pressed in sequence. It is also equipped with the conventional next/previous key.

2) Programmable music selection

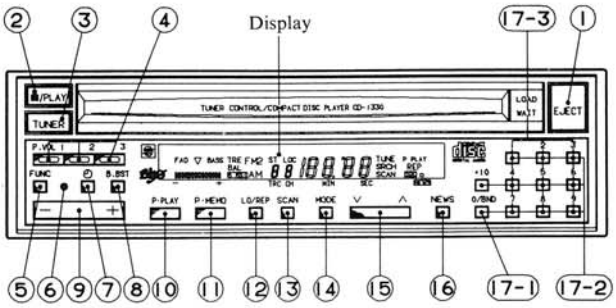
This function is to freely arrange order of selections to be played back.

In previous car CD players, music selection took longer. If a ten-key pad is used for this operation, it can be done quickly and accurately. If the next/previous keys are used together with the ten-key pad, the programming order can be modified.

This function has been tried in car CD players before, but was infrequently used because the programming was complicated and took time. Due to the simplification in operation, it should be more useful.

3) Preset station selection

This unit can be combined with a separately sold tuner (AE-3230). In the conventional electronic tuners, most of them had six preset buttons for



Button No.	Function CD mode	Tuner mode
1	Disc eject	
2	Stop/play switch	
3		Tuner on/off
4	Volume preset	
5	Adjsutment function select	
6	Clear	
7	Clock display	
8	Bass booster	
9	Function adjustments	
10	Programmed play	
11	Program memory	
12	Repeat	Automatic tuning sensitivity switch
13	Scanned music selection	Preset scan station selection
14	Music selection switch	Station selection switch
15	Music selection by track number, fast-forward/rewind	Automatic/manual station selection
16*		News function
17-1		AM/FM switch
-2	Track number entry	
-3		Preset station selection

* Button 16 is not used in the CD-1331.

Figure 1. The CD-1330 and its control functions

station selection. No more than six stations could be preset either for AM or FM. Japan has several AM stations but only a few on the FM band. Traffic information on expressways is recently being broadcast in Japan. Considering these facts, a total of 18 stations, nine for AM and nine for FM, can be preset in this unit by using buttons 1-9.

For the model CD-1331 which is sold outside Japan, a total of 27 stations, 9 for AM and 18 for FM, can be preset.

In addition to the above functions, the buttons 0-9 can be used to adjust the time of the clock.

Other functions for the unit are music scanning, and repeat play in the CD section, preset scanning in the tuner section, and electronic control and bass boost, in the audio section which are explained later.

3.2 Design

There are many factors by which a user decides to purchase a product. The design of the product is a major item. The same can be said for car audio products, especially for products like this CD player. The design was based on the following:

1) Flat panel design

In this unit, all controls are operated by electronic switches on the panel.

Too much unevenness of the front panel caused by protruding buttons and knobs does not give the appearance of a high-grade product.

2) Button layout

In car audio, one of the biggest problems in making a unit easy to use is in designing the button layout and how they function. In this unit, the problem was solved by considering the size, layout, and coloring of the buttons.

The basic operation buttons of the CD and tuner (eject, stop/play, tuner ON/OFF) were layed out on the both ends of the disc slot and crystal buttons were used. The buttons frequently used (volume control and buttons 0-9) were layed out on both ends of the indicator section, and translucent orange buttons were used. This made for easier operation while driving.

3) Visibility

The requirement for the control panel of a car audio devices that it is not obstructed by buttons, and that it can be read during the day or night. In a multifunctional model such as this unit, a lot of information is displayed. This information must be presented so that the driver can read it at a glance.

To satisfy these requirements, large tricolor fluorescent display tubes are used and layed out at the center of the front panel. When the visibility is optimized for daytime use, it is too bright for night. The indications were thus coupled with the parking lights of the car to reduce the brightness at night.

Fluorescent display tubes are often used in home audio components and are considered to make users

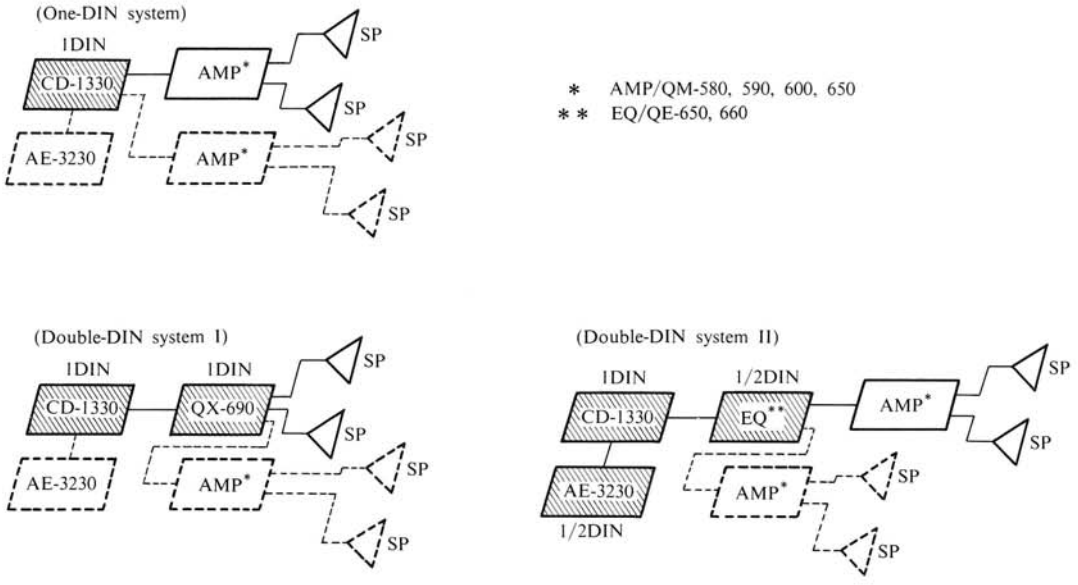


Figure 2. CD-1330 system configurations

conceive of the product as high grade and high quality.

4) Full illumination

The illumination is regarded as the most important for night time operation.

In this unit, the characters of all buttons are illuminated, and the front panel is fully illuminated at night. This improves both attractiveness and operability.

3.3 System configuration

Figure 2 shows the variety of systems in which this unit is used as a center device. The feature of this unit system is the system expansibility; in another word, the basic system which is composed of the CD deck, an amplifier, and loudspeakers can be expanded to configure a large system in which multisource units such as the CD deck, tuner, and cassette tape deck are connected to four amplifiers and four loudspeakers through a graphic equalizer. The latter especially, can be installed in the double-DIN space by combining the unit with a cassette tape player (QX-690) with an electronic graphic equalizer.

In consideration of the operability when this unit is combined with other unit with a volume control, a volume control pass switch is provided so that controls can be made with a single volume control and with a single audio control.

4. Techniques used

As previously explained, high density packaging and a highly reliable design were required for this unit to achieve multiple functions.

The front panel structure which integrated the indication and control sections and the fully electronic audio circuits to provide the feeling of high-grade are explained. The communication technique between microcomputers to smoothly process the enormous data transfer are also explained.

In car CD players, the greatest requirement to assure reliability is the resistance against vibration and scratches. A vibration-proof deck mechanism and disc loading mechanism are also described here.

4.1 Front panel structure

To make the high density operation panel and display PC board that are required to achieve multiple functions, the display section and the control section that processes the display signals

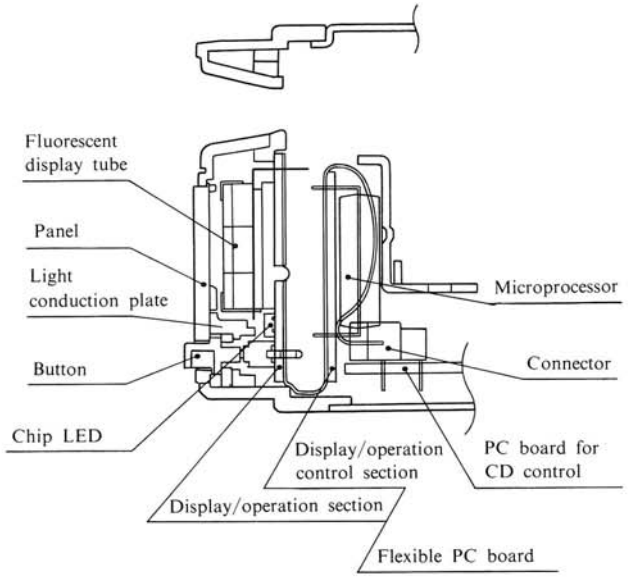


Figure 3. CD-1330 front panel structure

were divided as sown in Figure 3.

The display section consists of operation switches, display tubes for integrated display of the operation status, and space saving chip LEDs.

The control section consists of a microprocessor that processes the operation signals, peripheral circuits, and guide tone generation circuit.

The display and control sections are connected with a flexible PC board to simplify the connection with the CD control section.

4.2 Deck mechanism

1) Design targets

The deck was designed with the following targets.

(1) Down sizing of the deck mechanism for decreasing the depth of the unit.

(2) Improved vibration resistance

To improve the vibration resistance, a laser pickup (hereinafter referred to as PU) was fed diagonally. A thin PU unit and oil-enclosed damper were used. A new deck mechanism including the disc loading mechanism was developed.

2) Disc loading system

The main loading systems of the car CD players currently on the market are as follows:

(1) Disc-slot-in system I (both sides of the disc are pinched between rollers)

(2) Disc-slot-in system II (the disc is held by its edge)

(3) Cartridge system

The system (1) is the same as used in the current FUJITSU TEN model SD-1100. Discs are ejected sufficiently to provide good operability. However, the resistance against scratches is about the same for in system (2), and not as good as in (3).

In system (2), discs cannot be ejected sufficiently, thus providing less advantages than system (1).

System (3) is the best as for the resistance against scratches. However, the problem is that the users are forced to buy a cartridge.

Importance was thus attached to operability (disc ejection amount) in the deck mechanism, and the system (1) was adopted by modifying the roller to strengthen the resistance against scratches.

3) Disc loading mechanism

The deck mechanism of the current FUJITSU TEN products use two motors for disc loading/ejecting and disc clamping. The door open/close mechanism is mounted on the cabinet side. However, in this unit, the door open/close mechanism is mounted on the deck side, and the open/close plunger was also used for the switching of the loading mechanism drive. As a result of these modification, the number of motors was reduced and the space was saved.

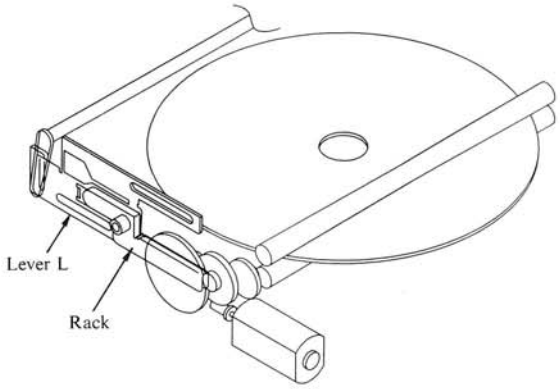


Figure 4. Disc loading/ejecting mechanism

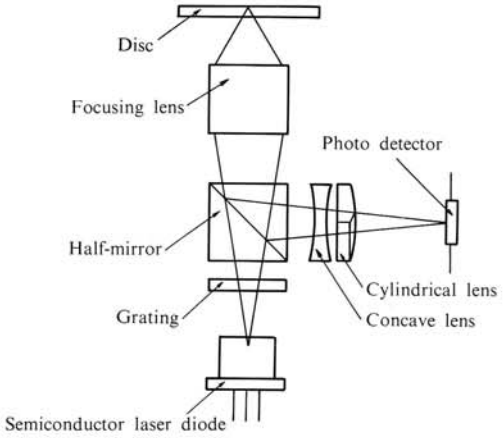


Figure 6. Principle of laser pickup

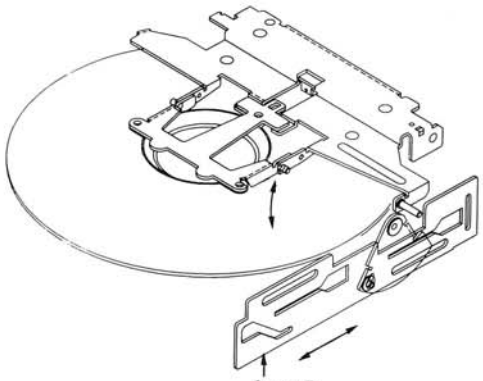


Figure 5. Disc hold mechnism

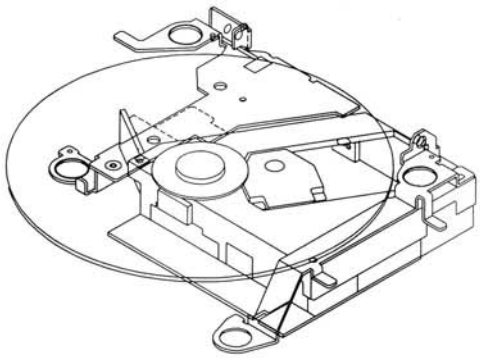


Figure 7. Pickup unit

To avoid being scratched during loading or ejecting, the disc is hold between a tapered rubber roller and a resin roller and is loaded or ejected by rotating the rubber roller.

The sensor used for controlling the loading and ejecting operation is made by combining a light-emitting diode and a phototransistor, which detects the disc without contacting it. Figures 4 and 5 show the disc loading mechanism.

4) Optical pickup unit

The pickup unit used in this model is a three-beam system which has advantages on circuit configuration and is used in most products in the market. We decided to use this type because of its compact size and because it is widely used for car use. Figures 6 and 7 show the pickup unit. The pickup feed mechanism is of a double gear structure to reduce backlash as much as possible. The chassis was made highly rigid and precise by using aluminum diecast while contributing to the improvement of resistance against scratches and vibration.

A highly reliable brushless motor was used for the disc drive to obtain high torque and low wow.

5) Shock-absorbing mechanism

To prevent the skipping of recorded sounds because of shock or vibration, the deck mechanism must be floated. In the current models of FUJITSU TEN, the shock was prevented by floating the entire deck with solid pieces of rubber.

In contrast, only the pickup mechanism is floated in this model. This construction has shut-out the vibration from the loading/ejecting mechanism,

and good shock-proof characteristics have been obtained.

A damper mechanism with silicone oil enclosed was used for the shock-absorbing rubber to improve the vibration damping performance. Figure 8 shows the two types of shock absorbing mechanisms.

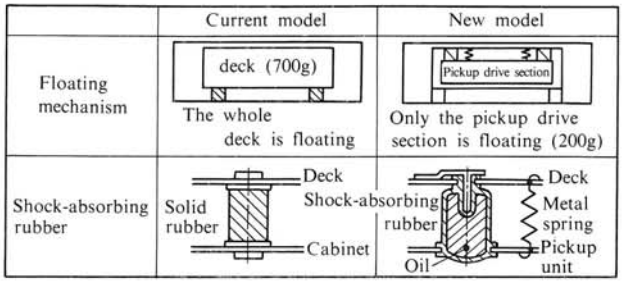


Figure 8. Shock-proof structure

By floating the pickup drive mechanism as described above, the deck dimensions were reduced to 140W × 130D × 33H mm, this is only 30% of the space (volume ratio) occupied by previous FUJITSU TEN models.

4.3 Microprocessors

Figure 9 shows the microprocessors contained in this unit. They include a main microprocessor that controls the user interface, a CD microprocessor that controls the distributed modules, and a tuner microprocessor.

The main microprocessor controls key-inputs and display outputs, and performs data communica-

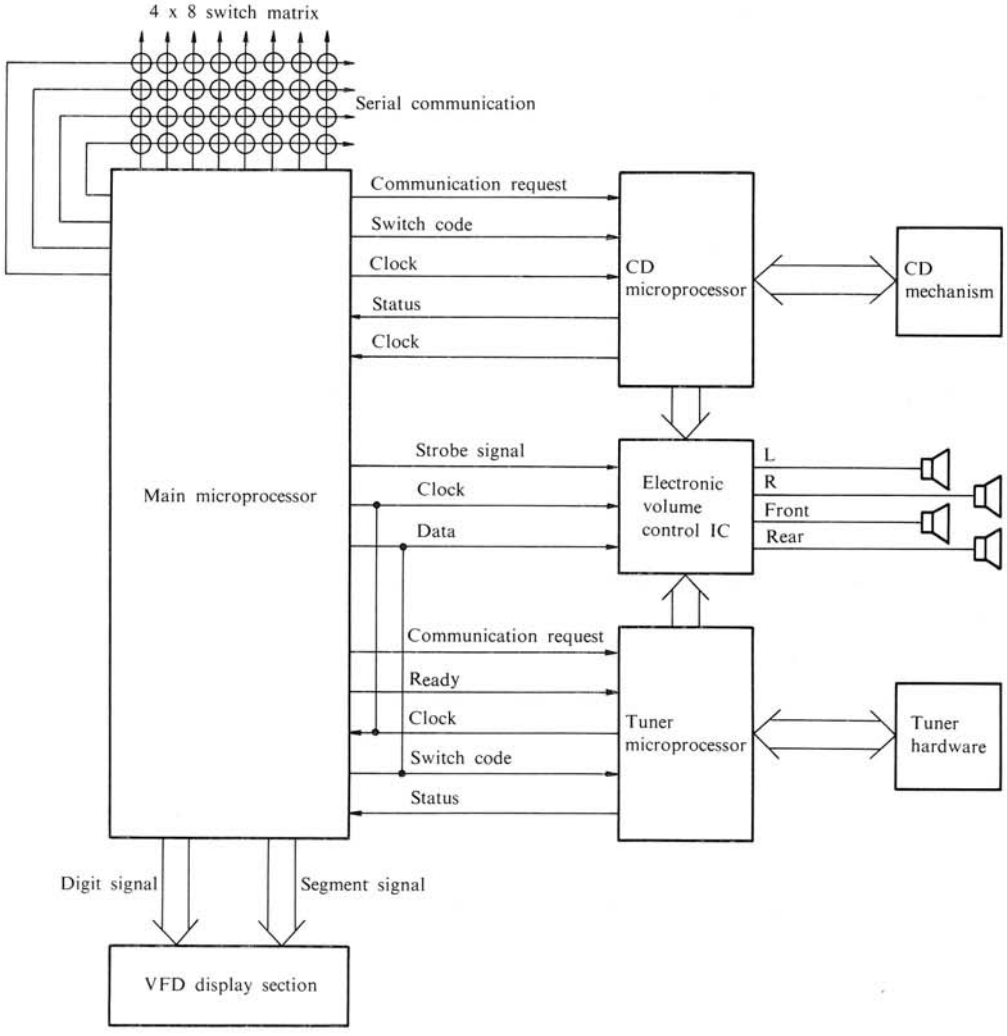


Figure 9. Communications between microprocessors

tions between the CD microprocessor, tuner microprocessor, and the electronic volume control IC for integrated information processing.

The communication in the unit was made efficient by simplifying the hardware connections between microprocessor, and by forming an interactive system between the modules while introducing software.

The data communication which is the kernel of this system is explained below.

1) Data communication between the main and the CD microprocessors

The CD microprocessor receives a switch code from the main microprocessor and controls the CD player. The operation state of the CD player is sent back to the main microprocessor.

As shown in Figure 10, communication starts with a request signal from the main microprocessor. A bidirectional synchronous serial transmission system that has a clock line and an information signal line for each transmission direction is used to form a response to the request system.

The information consists of twelve 4-bit words as shown in Tables 1 and 3.

The switch codes are transmitted twice, first in positive logic and then in negative logic and an exclusive-OR circuit is used for error detection.

As for the status signal, error detection is performed by comparing the block check characters (BCC) and by checking the exclusive-OR of TEXT 1 to TEXT 11 of the data.

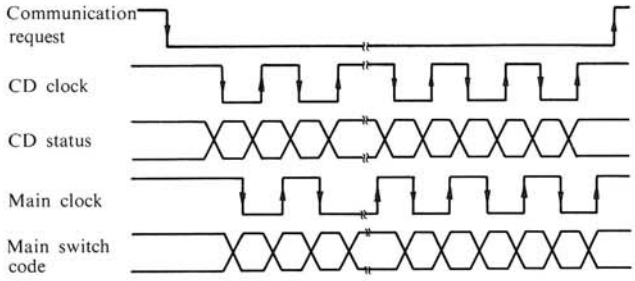


Figure 10. Communication between main and CD microprocessors

2) Data communication between the main and the tuner microprocessor

The tuner microprocessor receives a switch code from the main microprocessor and controls the tuner. It then sends back the tuner status including the frequency.

The communication starts with a request from the main microprocessor as shown in Figure 11. A bidirectional serial synchronous transaction system in which handshake transmission in units of 8 bits is performed is used.

The information consists of twelve 4-bit words as

Table 1. Status signal from CD microprocessor

TEXT No.	bit 3	bit 2	bit 1	bit 0
1	Track No. (×10 place)			
2	Track No. (×1 place)			
3	Minutes (×10 place)			
4	Minutes (×1 place)			
5	Seconds (×10 place)			
6	Seconds (×1 place)			
7	Disk ejection	Loading complete	TUNER was on previously	CD was on previously
8	REPEAT	SCAN	P.MEMP mode	PLAY/P·PLAY
9	+10	CD ON	Searching	Between selections
10	Electronic volume control ON	Deck is connected	Fader is ON	Loading or ejecting
11	DIMMER	NEWS ON	TUNER ON	Warning
12	BCC			

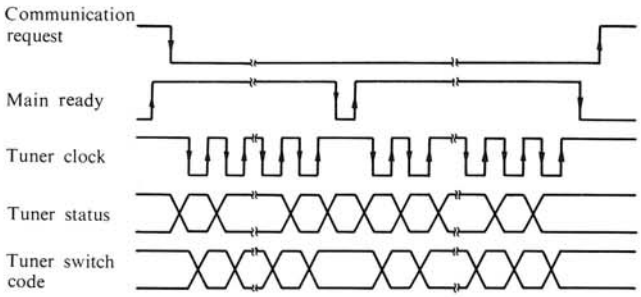


Figure 11. Communication between main and tuner microprocessors

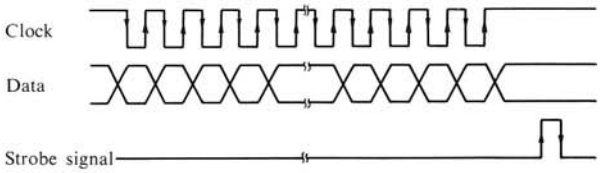


Figure 12. Communication between main microprocessor and electronic volume control IC

shown in Tables 2 and 3. The switch code is transmitted twice, first in positive logic and then in negative logic. The status signals are sent with the BCC for error detection.

The tuner is a separate module that can be mounted in this unit. In regards to whether the tuner is mounted, it is determined that there is no tuner if there is no response after several successive communications between the main and tuner microprocessors.

3) Data communication between the main microprocessor and electronic volume control IC

The electronic volume control IC operates with the data sent from the main microprocessor.

A unidirectional synchronous serial transmission system is used. In this system, a clock line and an information signal line output data from the main microprocessor, and a strobe signal is output when transmission is completed. This is shown in Figure 12.

Communication is executed only when the volume control is adjusted or when the system operation is switched.

The data supports the five functions volume, fade, bass, treble, and roundness. There are 16 bits used for each function. (Figure 13)

Table 2. Status signal from tuner microprocessor

TEXT No.	bit 3	bit 2	bit 1	bit 0
1	Japan	Australia	USA	Europe
2	Frequency (FM ×100 MHz, AM ×1000 kHz)			
3	Frequency (FM ×10 MHz, AM ×100 kHz)			
4	Frequency (FM ×1 MHz, AM ×10 kHz)			
5	Frequency (FM ×0.1 MHz, AM ×1 kHz)			
6	Frequency (FM ×0.01 MHz, AM 0)			
7	CH. NO			
8	SCAN	LOCAL	STEREO	TUNER ON
9	BEEP1	BEEP2	BAND1	BAND2
10	SK	DK	VF mode ON	Seeking
11	NEWS mode ON	Storing news	Receiving news	CD ON
12	BCC			

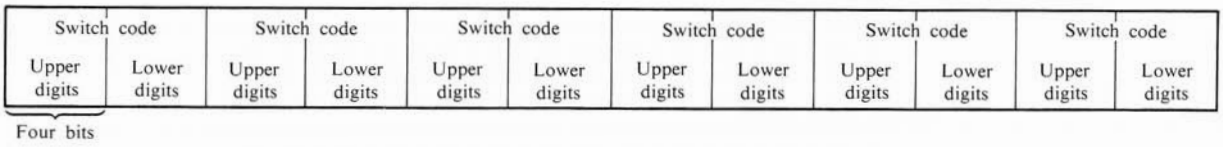


Figure 13. Switch code transmission from main microprocessor (three pairs of normal and inverted codes)

4.4 Analog audio circuit

1) Fully electronic audio control

In developing this unit, the audio control had to be made fully electronic for the following reasons.

First of all, it was to give more flexibility to the design. There were many restrictions in regard to the internal space when using the conventional rotary type or slide type controls.

Next, in order to hold down the increase of the number of buttons and knobs due to increasining functions, two or more functions had to be assigned to a single control key.

An LSI that supports the five functions of the volume, bass, treble, balance, and fade controls in the audio section is used in this unit. These functions are controlled by a microprocessor as shown in Figure 14. As a result of these improvements, the size and cost of this unit were reduced.

2) Bass booster circuit

The CD has made it possible to play back heavy bass sounds. However, the loudspeakers used in cars are at a disadvantage because of the limited car

Table 3. Switch code from main microprocessor (two 4-bit words)

Switch name	Switch code For CD	Switch code For tuner	Switch name	Switch code For CD	Switch code For tuner
EJECT	02		0	10	
CD OFF		A2	BAND		B0
CLOCK	03		1	11	B1
CD ON		A3	2	12	B2
NEWS INTERRUPT ON	04	A4	3	13	B3
NEWS INTERRUPT OFF	05	A5	4	14	B4
TUNER ON	06	A6	5	15	B5
TUNER OFF	07	A7	6	16	B6
STOP/PLAY	08		7	17	B7
NEWS, VF, MO/ST		A8	8	18	B8
P·PLAY	09		9	19	B9
P·MEMO	0A		+10	1A	
REPEAT	0B		SCAN	1F	
LOCAL		AB	P·SCAN		AF
TRACK UP	0C				
SEEK UP		AC			
TRACK DOWN	0D				
SEEK DOWN		AD			
FAST UP	0E				
MANUAL UP		AE			
FAST DOWN	0F				
MANUAL DOWN		AF			

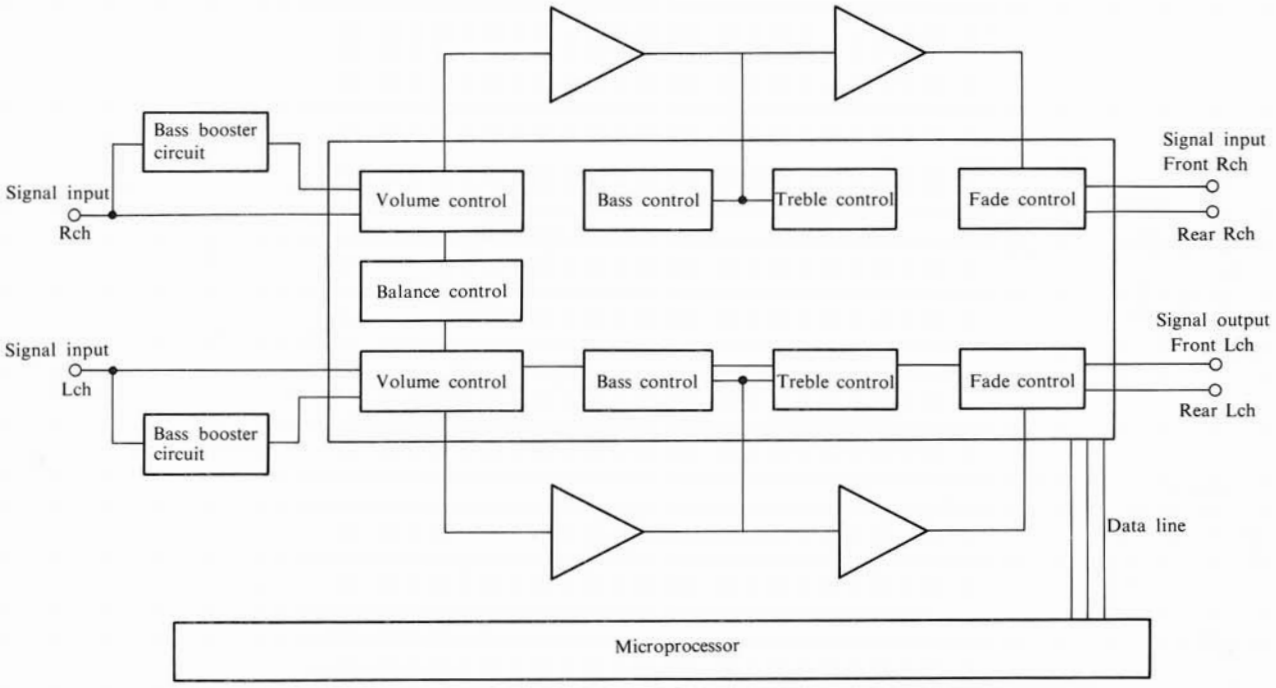


Figure 14. Audio control block diagram

space. That is, with the recessed type, the diameter is restricted, and with the box type, the internal volume is restricted. For these reasons it was difficult to reproduce low sounds. In car audio the tone is supplemented with a roundness control circuit when the sound volume is low.

Generally the acoustic propagation characteristics inside a car differ according to the shape of the room space and interior materials used. The distribution of the natural frequency shows that the peak is at about 100 Hz and this gives a confined feeling. Therefore when the low frequency sound is emphasized with a roundness control circuit, the low frequency sounds from about 100 to 300 Hz are emphasized and the confined feeling increases. For this reason, this unit uses a bass booster circuit to emphasize the frequency range lower than 100 Hz without emphasizing from 100 to 300 Hz. As a result, a heavy low sound was reproduced without a confined feeling. (See Figure 15.)

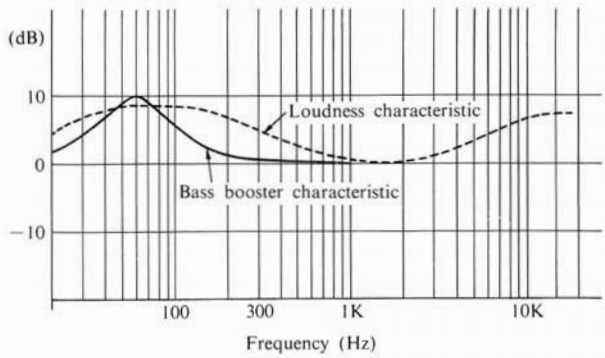


Figure 15. Bass booster circuit characteristics

5. Conclusion

The background, requirements, specifications, and techniques used for developing the CD-1330 have been introduced.

The CD player first appeared on the market five years ago, and from that time the use of digital for audio began to spread. Last year, the digital audio tape recorder was introduced. Since it is difficult to discriminate the sound quality of digital audio when compared to analog, competition of the added value

other than sound will probably be keener in the future.

Taking advantage of the development of this multifunctional CD player (CD-1330, 1331), we hope we can improve digital audio and continue to offer better products.

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Yoshinori Kayahara

Entered the company in 1984, where he has been engaged in car audio products. He is currently with the 2nd Audio Products Division's Engineering Department.

Yasuyuki Murakami

Entered the company in 1981, where he has been engaged in car audio R&D. He is currently with the 2nd Audio Products Division's Engineering Department.

Hideaki Kouzuki

Entered the company in 1984, where he has been engaged in car audio R&D. He is currently with the 2nd Audio Products Division's Engineering Department.