UDC 681.84: 621.396.62: 629.113

Audio System for New Charade

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Recently in the field of car audio, quality equal to that of a home audio system has become a requirement for car component systems. Basic performance factors such as safety, electronic control mechanism for handling ease, and improved acoustic performance in the car interior are also required.

In the audio system that we have newly developed in conjunction with Daihatsu Motor Co., we concentrated our efforts on incorporating the design of the car body and improving the cost performance of the system. This has brought about the successful realization of electronic control for the system unit, as well as improved acoustic performance and visibility.

This report mainly describes the value engineering (VE) of the popular type AM electronic tuning radio, component system design emphasizing the sound quality, and improved visibility of the liquid crystal display.

1. Introduction

In 1977 when the Charade made its debut as the world's first 3-cylinder 1-liter car, the mainstream of car radios of this class was the pushbutton tuning system to serve only as an information source, not extending to listening pleasure.

Later on, in 1983 as FM broadcasting spread, car radios introduced the pushbutton tuner with FM receiver incorporated: a step forward to sound quality enjoyment.

More recently, in the car-audio field, there has been a stronger demand for sound quality equal to a home audio system. Moreover, greater importance is laid on a fashionable audio system as a car-interior item, as well as its handling ease for improved safety. The manufacturers are faced with the task of satisfying the diversified needs of users.

Under the circumstances, we set two main targets in developing the audio system for the new Charade. One point was an electronic tuning radio with emphasis on the basic performance of safety and operability. The other point was a component system with a variety to meet diversified needs. With these two aims, efforts have been concentrated on the following items in design:

1) Improved cost performance
2) Improved quality sound
3) Improved visibility of liquid crystal display

2. System outline

2.1 Basic structure of the system

Figure 1 shows the component systems of the newly developed units. The wide variety of units ranging from the popular type AM electronic tuner to the high sound quality digital compact disk player has been designed for a well-balanced and exclusive incorporation to the car body.

2.2 Features of the systems

1) Electronic tuning

Table 1 is a comparison between the pushbutton tuning radio and the electronic tuning radio in regard to operability, design, tuning performance, and other items. Figure 2 shows the two radios.

As is clearly seen from the table, the electronic tuning system excels the conventional pushbutton tuning radio in many respects. Further, these features ensure effective performance in the car, including the key point of driver safety.

The only drawback of the electronic tuning radio was the high cost. However, by a thorough VE design technique, we were able to reduce the cost of electronic tuning to the level of popular type of AM radios.

2) Sound quality emphasizing design

In designing this system with the AM/FM electronic tuning radio as the main component, the sound quality was treated preferentially, with due consideration given to the dynamic range and acoustic performance. Thus, a system was born with performance equivalent to home audio systems.

The following have been achieved in the new system:

a) Acoustic effects in the car interior have been fully studied to install the best-tuned loudspeakers.
b) A 4-loudspeaker system with 100 W high-power sound is used for enhanced dynamic range and presence.
c) Bass/treble control and a graphic equalizer are provided to help create the listener's favorite sound.
d) A bass/treble canceling circuit is provided for widening the dynamic range (when the graphic equalizer is installed).
e) A compact disk player with excellent sound

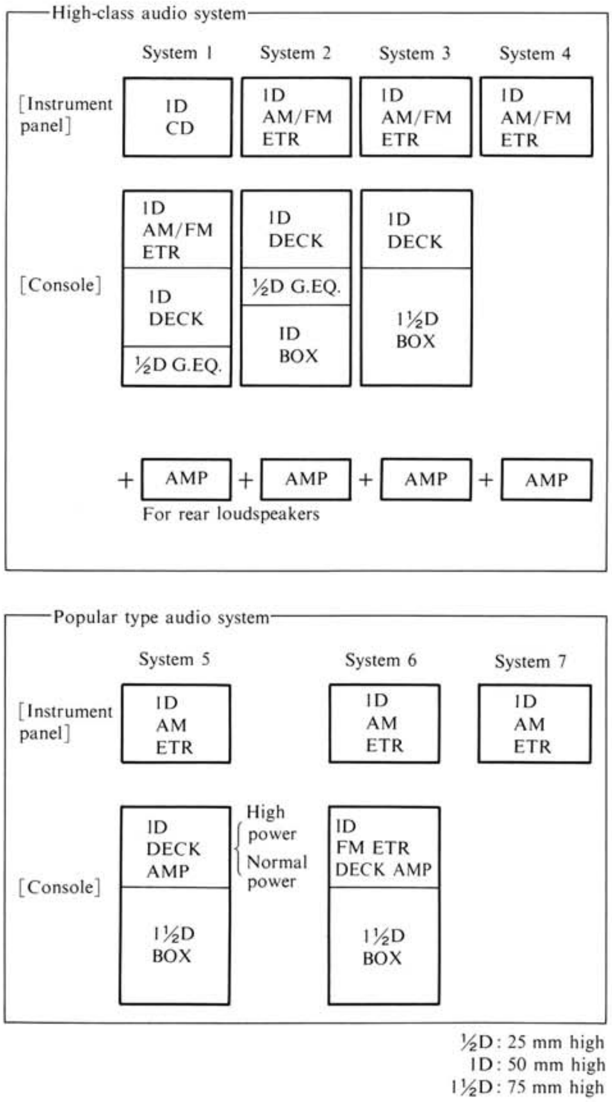


Figure 1. Audio systems for new Charade

Table 1. Comparison between pushbutton tuning radio and electronic tuning radio

Item		Pushbutton tuning radio	Electronic tuning radio
Operation	Feel of controls	Heavy (push and turn)	Light (push only)
	Tuning operation	Manual	Automatic
	Memory operation	Multiple operation (pull and push)	One-push operation
	Safety (for the driver)	Normal	High
Design	Frequency display (visibility)	Vague, guessing	Direct read: The tuned-in station is indicated by numeric display.
	Operation display	None. Unknown	Available: The pushed button is indicated.
	Front panel	Limited freedom	Great freedom
	Image impression	Cheap impression	High-grade
Tuning performance	Time for tuning	Long	Short
	Tuning precision	Poor: Fine tuning is difficult for many broadcasting stations.	Good: Any desired station can be tuned in correctly.
	Number of tuning memories	Limited	Many
Others	Possibility for additional functions	Difficult	Easy
	Cost	Low	Expensive

Figure 2. Pushbutton tuning radio and electronic tuning radio

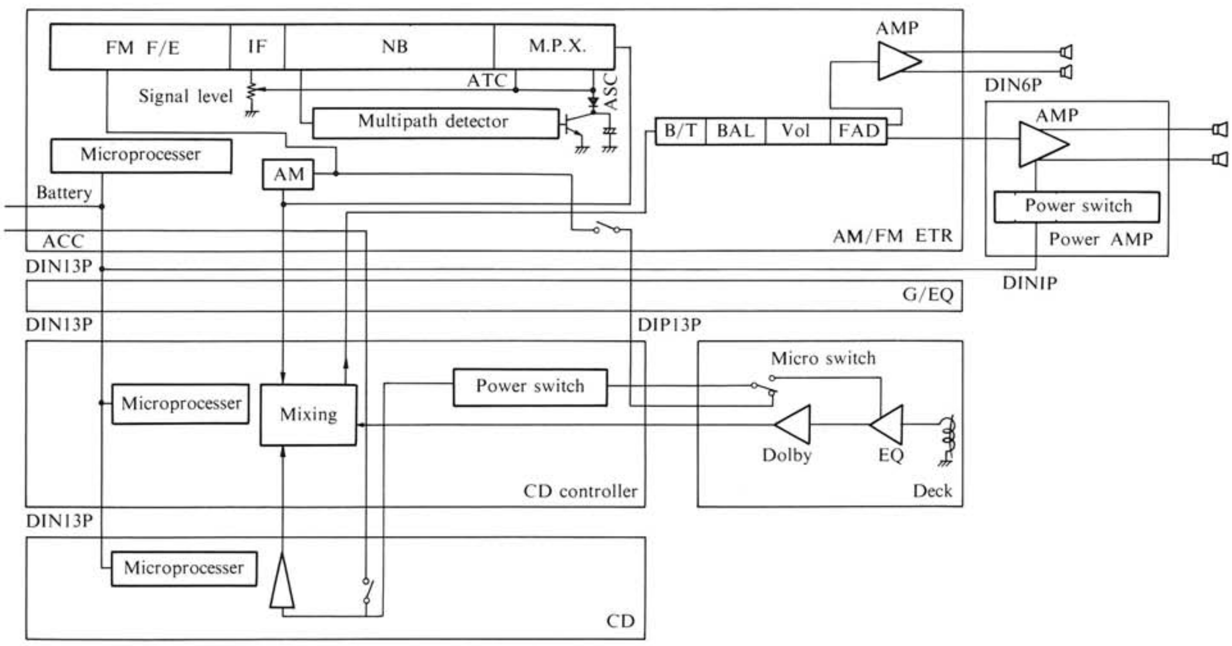


Figure 3. Block diagram of the audio system

quality is available.

f) Noise is reduced through improved performance of the FM tuner.

3) Facilitating system upgrading

Figure 3 is a block diagram of the component system. All connections between component units can be made with DIN connectors (13 p and 6 p), to facilitate system upgrading by eliminating extra harness.

4) Improved fashion and visibility

The radio and the compact disk player use large positive-type liquid crystal displays to improve the visibility. Function-displaying characters on the front panels are back-lighted when the headlights are turned on, and the visibility and fashionability are greatly improved. These effects are further enhanced by the light-blue surface lighting.

2.3 Specifications

Table 2 shows the specifications of this system.

Table 2. Specifications

Item			Specification	
AM/FM electronic tuner	Radio		AM	FM
		Receiving frequency	522 – 1629 kHz	76 – 90 MHz
		Usable sensitivity	26 dB	7 dB
		C/N ratio	–	25 dB
		Limiter sensitivity	–	7 dB
		Automatic tuning operation sensitivity	35 dB	35 dB
		AGC sensitivity	56 dB	–
	Amplifier			
		Bass	100 Hz : ±10 dB	
		Treble	10 kHz : ±10 dB	
		Frequency characteristics	50 Hz to 20 kHz	
		S/N	80 dB or more	
Cassette deck		Track type	4 tracks and 2 channels	
		S/N	50 dB	
		NR effect	8 dB	
		Wow and flutter	0.1%	
Graphic equalizer		Number of elements	9	
		Variable level range	±10 dB	
		Tape speed	4.76 cm/s	
Power amplifier		Frequency characteristics	20 Hz to 20 kHz	
		S/N	80 dB	
CD		S/N	80 dB	
		Separation	70 dB	
AM electronic tuner		Receiving frequency	522 – 1629 kHz	
		Usable sensitivity	26 dB	
		Automatic tuning operation sensitivity	35 dB	
		AGC sensitivity	56 dB	
Miscellaneous			Dimensions (W×H×D)	Weight
		AM/FM electronic tuner	180 × 50 × 130 mm	920 g
		Cassette deck	180 × 50 × 130 mm	1097 g
		Graphic equalizer	180 × 25 × 140 mm	620 g
		Power amplifier	189 × 35 × 97.6 mm	435 g
		CD	180 × 50 × 165 mm	1630 g
		AM electronic tunner	180 × 50 × 80 mm	445 g

3. Key techniques

3.1 Design on value engineering (VE)

To achieve electronic tuning in the popular type AM radio, efforts were concentrated on thorough value analysis. As a result, an AM electronic tuning radio with a built-in clock has been developed at the same cost of the pushbutton tuning AM radio and a built-in clock.

Table 3 shows the factors that greatly contributed to the VE designing of the popular type AM electronic tuning radio.

The detailed results are described below.

1) Simplified structure and cost reduction of component parts

Figure 4 compares the PC boards in the new and the conventional types of radio. By changing the arrangement of the parts and the circuits, the PC boards have been incorporated into one single-sided PC board.

Table 3. Main items of VE

Policy for VE	Items achieved
Study of low-cost circuits (reduction of number of component parts)	– Use of AM-dedicated microprocesser – Simplified low-pass circuit – Simplified power filter circuit
Reduced cost of component parts	Single-sided PC board
Combining circuits with the same function	Common use of power supply by RF section and low-pass circuit
Diversion of parts from other models	Diversion of mechanical parts (to reduce cost of molds)
Simplification of structure	Single PC board
Reduction of processing cost	Increase in automation ratio
Additional functions	Addition of clock function

2) Combining circuits with the same function

The regulators circuits for the tuner section and the PLL low-pass circuit were reduced to one. This was done because both circuits were 8 V regulators, and because this system was dedicated for AM band, interference between the circuits could be eliminated. Figure 5 is a block diagram.

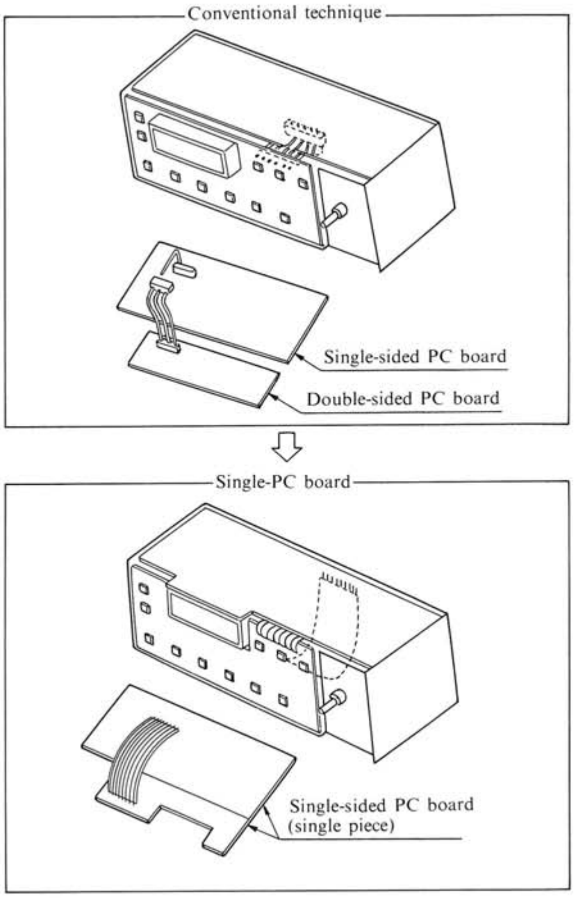


Figure 4. PC boards

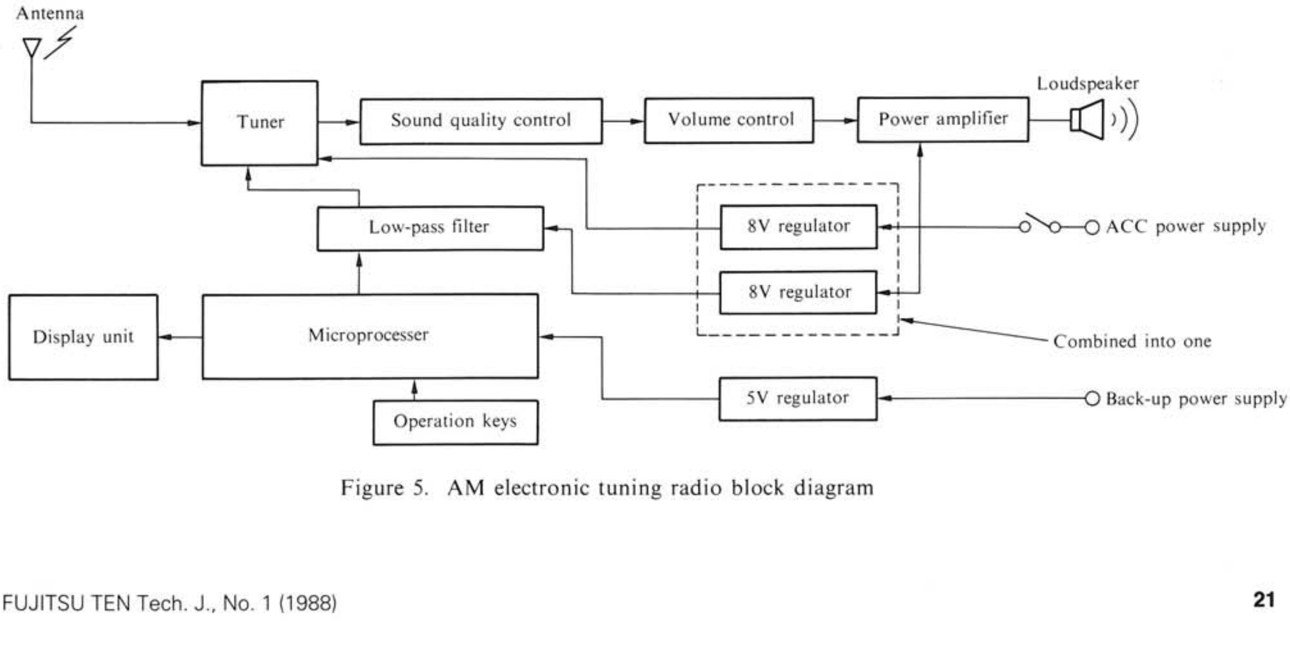


Figure 5. AM electronic tuning radio block diagram

3) Simplification of circuits

Figure 6 shows the illumination power line filter circuit. It consists of a high-frequency noise filter and a low-frequency noise filter.

This system has eliminated the low-frequency noise filter by arranging the illumination current separately from the signal current, as shown in Figure 7.

4) Processing cost reduction

As a result of several steps including unification into one PC board and simplification of circuits, the automation ratio has been increased through a reduction in the number of parts, and the processing cost has been greatly reduced.

5) Application of additional function

The electronic tuning radio performs accurate tuning through a microprocesser based on a high-precision quartz clock. For cost reduction, the same clock was used for displaying both the receiving frequency and the time by adding software for the clock.

3.2 Design emphasizing sound quality

To emphasize the sound quality of the new Charade system, FM receiving performance has been improved on the input side, and on the output side, sound quality of the loudspeaker has been improved, further providing a full-scale design of the sound field.

3.2.1 Improved reception

Compared with a home audio system, a car audio has an extremely fluctuating electric field which generates various types of noise. To reduce the noise, several functions dedicated to car installa-

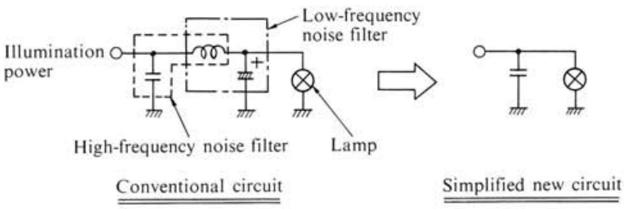


Figure 6. Illumination power line filter circuits

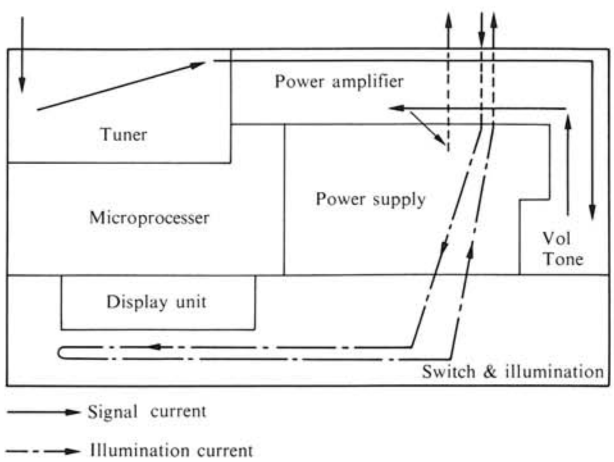


Figure 7. PC board layout

Table 4. Comparison of performance in car radios

	Function	Conventional type of radio	Electronic tuning radio
1	Soft muting	Output (dB) ↑; a; ANT input →	Soft-muting quantity : a>b; Output (dB) ↑; b; ANT input →
2	ATC function (automatic tone control)	Output (dB) ↑; a; ATC operation start level; A ANT input →	ATC quantity: a>b ATC start level: A>B; Output (dB) ↑; b; B ANT input →
3	ASC function (automatic separation control)	Separation (dB) ↑; ANT input →	Same as in the conventional radio
4	Noise blanker	Reduction of car noise	Same as in the conventional radio
5	M-ASC function (multi path automatic separation control)	———	IF NB MPX; Signal level; ATC; ASC; M-ASC; Multi-path detection circuit; C

tion have been applied, including a soft muting device, ATC, ASC, noise blanker, and M-ASC.

Table 4 compares special functions for use of the new type and the conventional type of radio installed in cars. In the new type, consideration has also been given to the sound quality while the car is being driven. A standard has been set for inhibition of sound flutter, not only noise reduction which was the main purpose of design in conventional radios. Further, an M-ASC function has been added to blank multipath noise.

Table 5. Loudspeaker setting specifications

	Diameter and type of loudspeaker	Mounting location
Front loud-speakers	10 cm dia. single-cone full-range type	Pointing upward at both ends of instrument panel
Rear loud-speakers	16 cm dia. double-cone full-range type	Pointing upward at rear package tray sides

3.2.2 Improvement of sound characteristics

In developing the previous models of Charade, attention was not directed to designing a well-localized sound field, as realized in the new model with a 4-loudspeaker system. Starting with adoption of large-diameter loudspeakers and selection of the optimum locations of loudspeakers, emphasis was laid on front sound localization and presence of the front loudspeakers. For the rear loudspeakers, the diameter and location were determined as shown in Table 5 to improve the radiation efficiency and bass sound range, and the resulting sound quality was evaluated.

The prototype had some problems with the interference peak sound at 1 to 2 kHz and insufficient level of bass sound. These were solved by changing the set coaxial lines and frequency characteristics of the loudspeakers. Figure 8 shows the car interior frequency characteristics obtained in the final production stage. Consequently, we have been able to achieve a sound quality and sound field

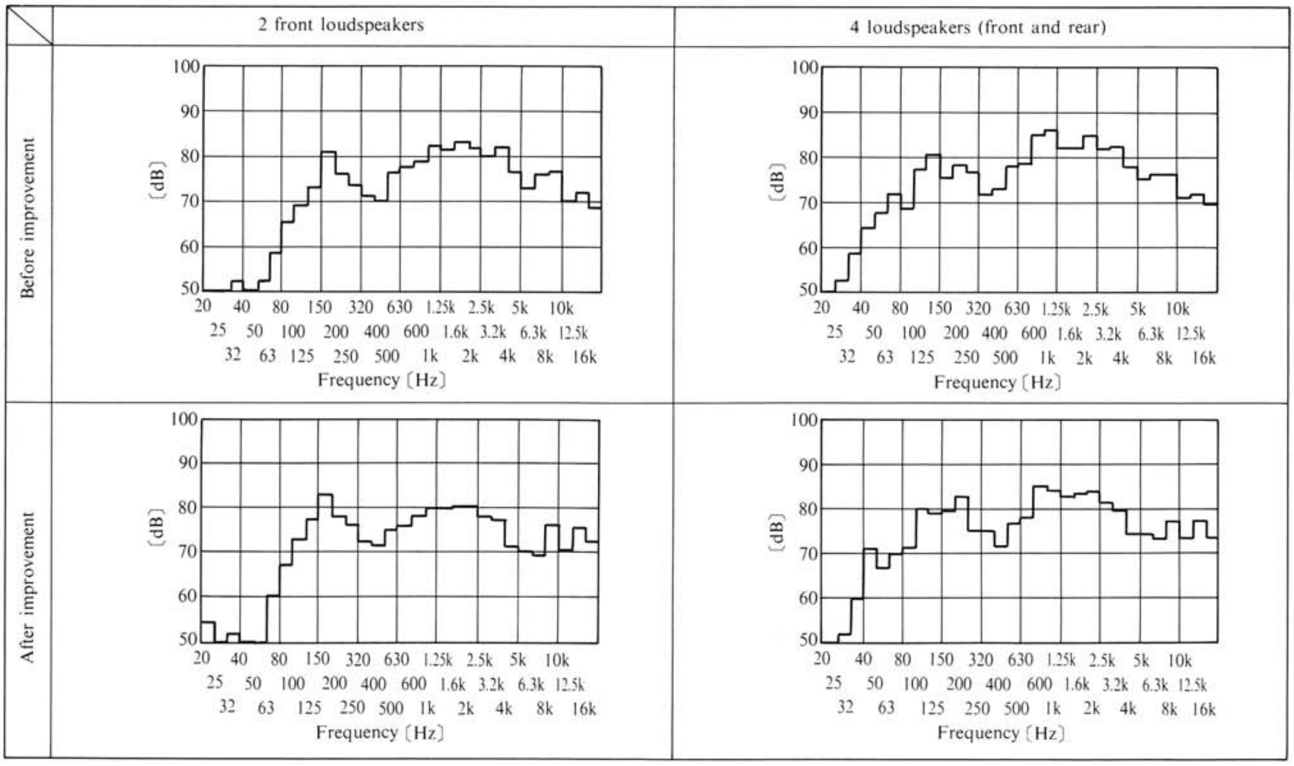


Figure 8. Carinterior frequency characteristics

characteristics that satisfy the digital sound of compact disk players.

3.3 Improved visibility of liquid crystal display

The newly developed electronic tuning radio uses liquidcrystal displays (LCD). For this system, a positive transmitted illumination type is adopted where the LCD is lit from the rear at night, and in the daytime, the operation mode is displayed by the light reflected from the reflector.

Visibility of the LCD depends on the contrast between the LCD character area and other areas. For the positive type of illumination, enhancing the lighting of areas other than the characters largely depends on the differences in the peripheral component parts as well as the environment and conditions for use.

In the present development, improved visibility was especially required by the factors shown in Table 6, for example, by the conditions of the car and the radio.

To improve the visibility, the points below have been studied and improved for brightening the area other than characters.

1) Improvement of reflection panel
2) Improvement of LCD polarizer plate

3.3.1 Improvement of reflection panel

The reflection panel at the rear of the LCD transmits rear light at night, and reflects natural light in the daytime. See Figure 9.

Usually the above functions are provided on a transparent resin plate by a special type of printing. In the new development, a whitening process has been applied from the beginning to the LCD holder itself (material coloring) to serve as a reflection panel at the same time. Although this presented no problem for transmittance, it lowered natural light reflectance in the daytime, requiring an improvement.

For this, two remedies have been applied: (1) roughening of the reflection panel gloss and (2) using an improved material (polycarbonate compound resin). This resulted in a brightness greater than the ordinary reflection panel in all reflecting directions. See Figure 10.

3.3.2 Examination of LCD polarizer plate

In an early stage of development, we evaluated visibility of the LCD and found that it differs according to the viewer's position. The visibility proved to be inferior when seen from the driver's seat rather than from the passenger's seat.

One of the factors causing this difference appears to be the polarizing characteristics of the reflection panel.

As is shown in Figure 11, incident light which oscillates in all directions will oscillate only in a fixed

Table 6. Factors affecting LCD visibility

No.	Factor	Reason
1	Vehicle conditions	When a front-seat passenger wears white clothes, the white reflection on the radio front prevents a clear display.
2	Color of LCD back light	The color is restricted to light-blue for uniformity of car-interior color at night, but the polarizing plate has a high orthogonal transmittance of light-blue, lightening the character area, which reduces the contrast.
3	Radio with a built-in clock	Frequent visual confirmation is required because the variable time information is supplied by the clock, not only the fixed information of radio frequency.

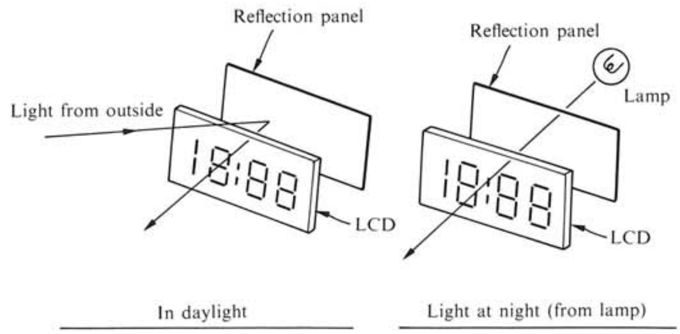


Figure 9. Semi-transmission type LCD

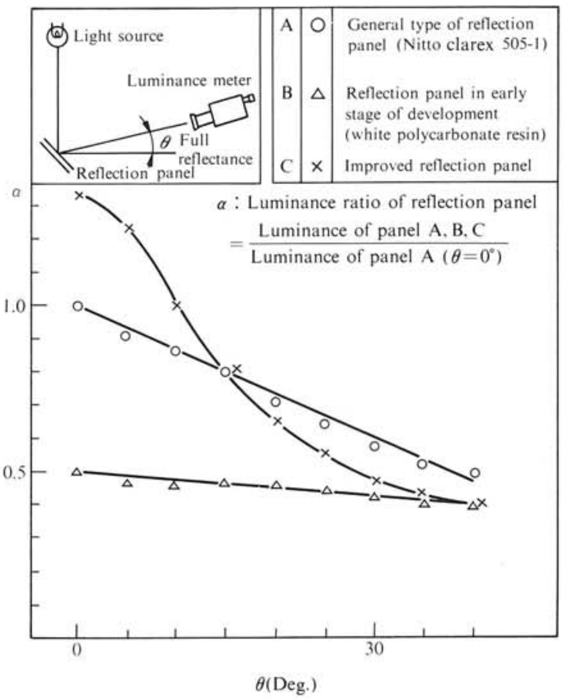


Figure 10. Comparison of reflectance

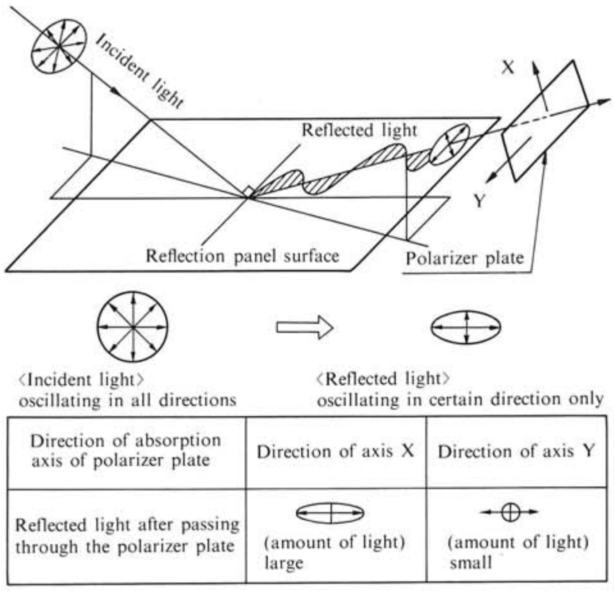


Figure 11. Reflection of light

direction after it is reflected. From this, when a polarizer plate is overlaid on the reflected light, light is largely reduced in the direction of axis Y when compared with the value on axis X.

This means that the light reflected from the LCD reflection panel is weakened in certain directions by the polarizer plate of the LCD.

As mentioned above, contrast of the positive type LCD depends on the reflectance from the reflection panel. To enhance the visibility from the driver's seat, it is necessary to minimize the absorption of reflected light by the polarizer plate in the direction from the driver's seat (direction of the absorption axis X in Figure 11).

Figure 13 is the comparison of reflectance from the reflector plate between the early stage of LCD development and after it was improved. Figure 12 shows the measurement method.

The result shows that the reflected light seen from the driver's seat has been almost doubled.

In the actual car, the visibility from the driver's seat has also been improved to satisfy the initial purpose, in spite of a slight reduction in visibility from the passenger's seat.

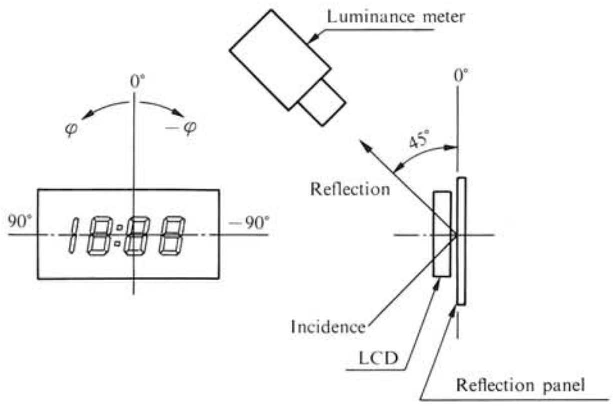
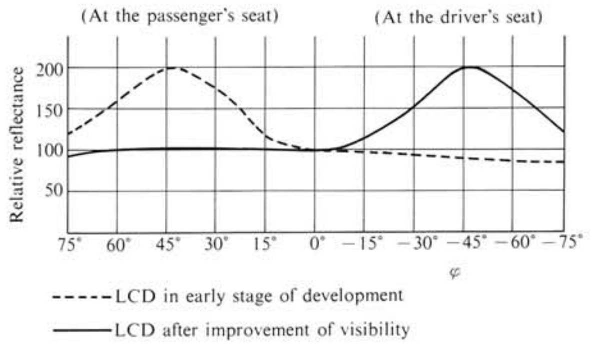


Figure 12. Method of reflectance measurement



The luminance of reflected light [Cd/m²] is set to 100 when φ=0° for the LCD at early development stage.

Figure 13. Measured reflectance

4. Conclusion

As outlined above, the newly developed audio system supports the functions required for being mounted in a car, with a sound quality equal to home audio systems.

However, in this age of rapid technical innovations, the user's needs will be more and more diversified and upgraded. We intend to continue developing new products to satisfy such needs. Especially for the new popular type of AM electronic tuning radio, we will treat it as a base for further advancing our VE activities in this line.

In closing, we wish to express our deep appreciation of the courtesies and support extended by those concerned in the development of this system.

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