UDC 681.84: 621.396.62: 629.113

DIN-Size Component Stereo 650 Series

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The DIN-size audio aperture has predominated since 1982 when it was first adopted in Toyota cars. Our D-550 Series marketed in autumn 1984 and its upgraded version, the 580 Series, released in the spring of 1985, have been praised in the market. The D Crystal Version 650 Series was marketed in July 1986 as a completely new version of the 550 Series. The QE-660 was added to the lineup in November 1986; it embodies the "Graphic Sound Flavor" technique, a new sound field control technique. This paper discusses the total system for sound production, the method for implementing the design concept of the QE-660, and new technologies and devices embodied in the QE-660, focusing on the QD-650 which is the component deck serving as the core of the system. It also discusses the 200 W high-power loudspeaker system introduced at the same time as the QE-660.

1. Introduction

Over the years, the total shipment of car audio equipment in Japan has grown steadily because of increasing needs for car audio equipment by car manufacturers stimulated by favorable business in the automobile industry. However, the sales of car audio equipment on the general market tend to be less because of the increase in car manufacturers' sales, although an increase of no less than 10% was registered in 1985.

According to the records of sales of each type of equipment, the sales of component types have remarkably decreased in recent years. This tendency is outstanding in middle and lower class component types. This is because single-unit types are beginning to be favored. However, the rate of decrease in component types is not so acute these days.

Recently, the emphasis in user evaluation is shifting from functions to sensitive factors, including sound and appearance. Also, the introduction of built-in CD players has caused people to look for high-quality sound in tape audio equipment.

Under these circumstances, Fujitsu TEN has tried to develop a variety of products under the "sound and light" philosophy and has continued the approach of manufacturing component types as the base and other car audio equipment with emphasis on sound quality. Fujitsu TEN has also adopted new-type illumination to improve the appearance of the equipment at night, with the result that Fujitsu TEN's products are highly appraised in the market.

The D Crystal Version features a total system for sound production based on a deepened "sound and light" philosophy and a refreshing appearance including the "Graphic Sound Flavor" technique.*1 Outlined below are the features of the 650 Series and its design objectives.

2. Design objectives

When the development of the 650 Series started, the following objectives in sound, appearance, and handling were established:

1) A total system, from the head unit to the loudspeaker, for sound production
2) Fully flat design of buttons and classy appear-

*1 Graphic Sound Flavor is a sound field control device that has a parametric function permitting the dip frequency of the equalizing characteristic to be varied, and an acoustic flavor function allowing the desired tone to be preset with a one-touch action. It is also equipped with a graphic display that can display the preset equalizing pattern and can be switched to a spectrum analyzer to display the sound level in nine steps.

ance with crystal buttons. Also, four-way illumination is adopted; it allows one of four combinations to be selected to match the instrument panel of the car.

3) All buttons are feather-tough action, and main buttons are large. Therefore, the equipment is very easy to use.

The "sound and light" philosophy embodied in the eclio D-500 Series with a DIN size is deepened in the 650 Series, which therefore appears more classy. The functions and appearance of the 650 Series are intended to attract a wider range of users.

3. The 650 series

3.1 Outline of the system

The 650 Series consists of a tuner, a cassette deck, a graphic equalizer, a main amplifier, and loudspeakers. See the system block diagram in Figure 1.

3.2 Features of the system

The features of this component system are described below.

1) The component deck is designed with emphasis on sound quality using narrow-gap head and dual-azimuth adjustment system.
2) The quality of sound in the passenger compartment is adjusted using a nine-step graphic equalizer and a newly developed Graphic Sound Flavor which allows one of eight equalizing patterns to be selected with one touch. The Graphic Sound Flavor has a parametric function which permits the 10 to 20 dB peak sound at 100 to 300 Hz to be adjusted with a middle dip frequency control.
3) The basic performance of each component is improved. Such improvements include a hi-fi loudspeaker that can handle high input power and reproduces high-quality digital source sound with high power and high fidelity. The sound is adjusted considering conditions in the passenger compartment. The quality of sound is thus totally improved.

3.3 Four-way illumination

The highly evaluated two-way illumination adopted in the 500 Series is upgraded in the 650 Series.

The center panel block and left and right switch groups are illuminated separately. Orange or green illumination can be selected with selector buttons.

Figure 2 shows four-way illumination patterns that can be selected.

Power for illumination is supplied from the source for lights of the car. When the light control switch is turned on at night, the illumination also goes on to embellish the equipment and environment inside the car.

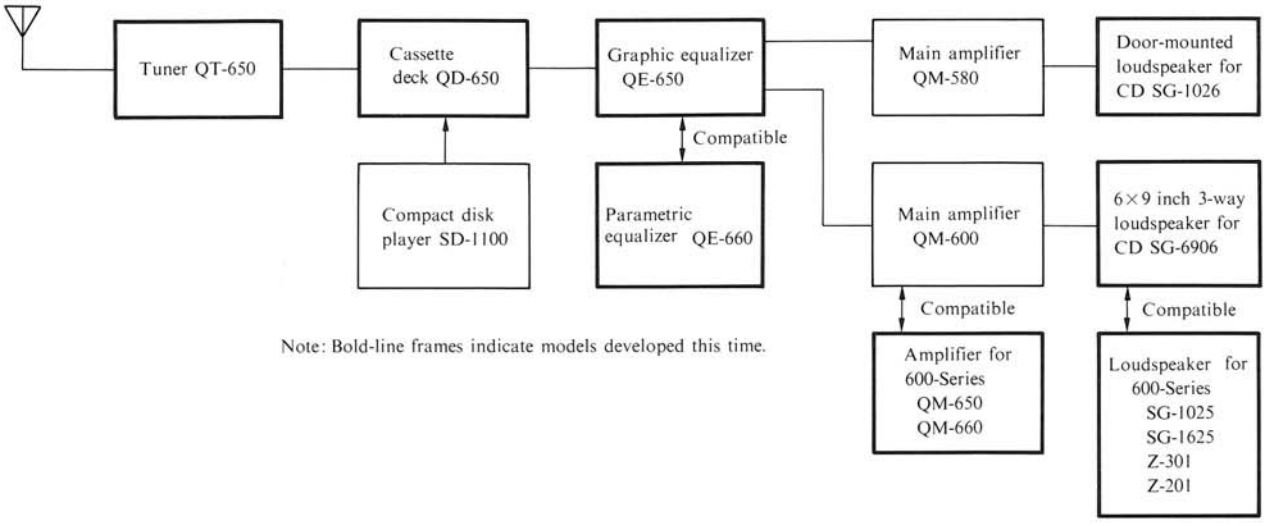


Figure 1. System block diagram

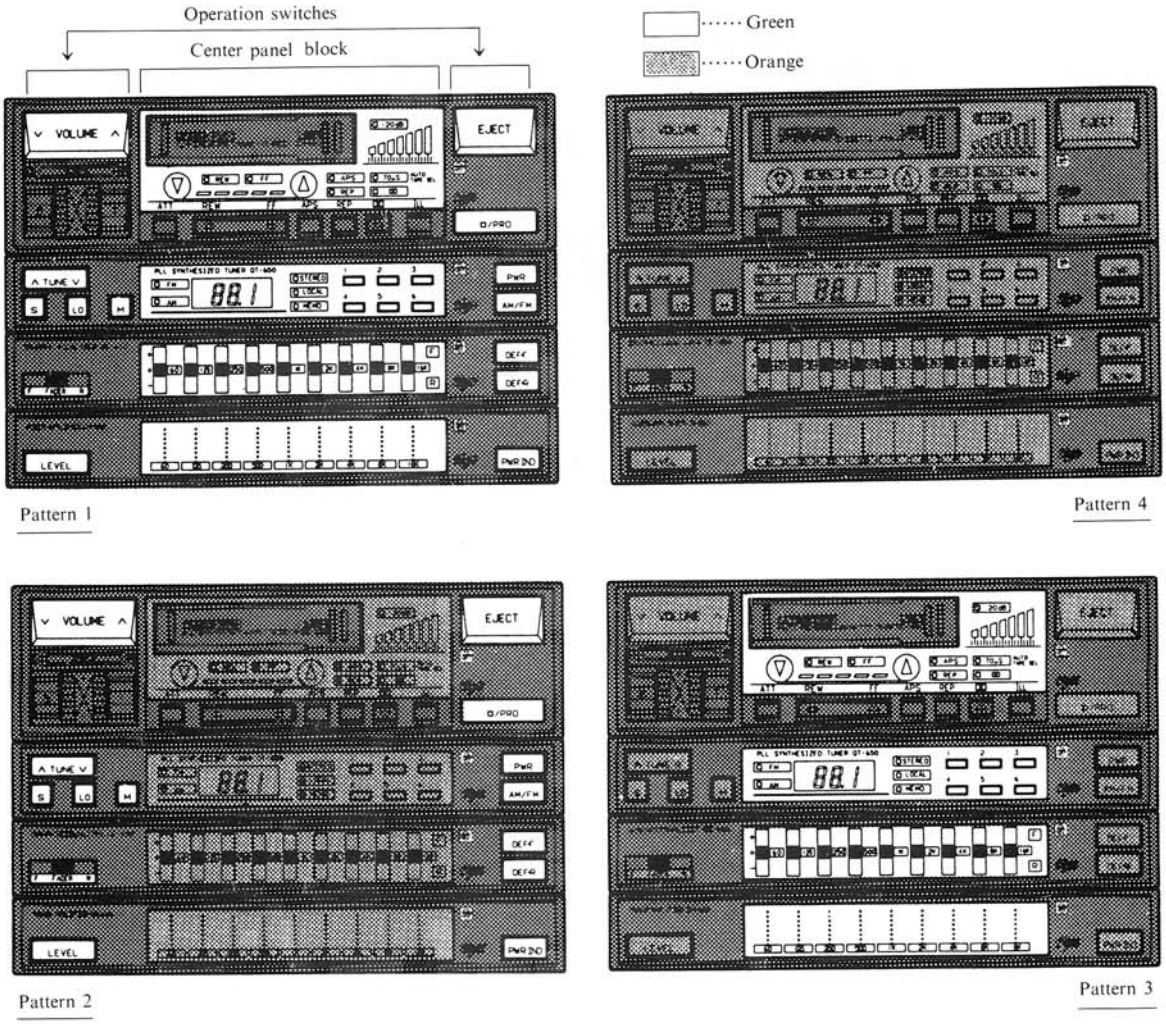


Figure 2. Four-way illumination patterns

4. Component deck QD-650

4.1 Outline

The component deck QD-650 mainly consists of (1) a tape mechanism, (2) a volume and tone controller, and (3) a four-way illumination color selector panel.

4.2 Principal functions

4.2.1 Tape mechanism

1) The tape mechanism incorporates a dual-azimuth adjustment system to assure stable high-frequency characteristics.
2) Since power ejection is adopted, any operation for controlling the tape can be performed by a feather-touch action. All buttons are flat.
3) Automatic tape selection is adopted; this function is to identify the type of tape automatically.
4) A key-off eject function is adopted; the tape cassette is automatically ejected when the engine is turned off during tape playback.
5) A trouble standby function is adopted; when an abnormality occurs, this function protects the deck mechanism.
6) Functions for selecting a piece of music, including APS (Automatic Program Selector) and repeat functions, are adopted.

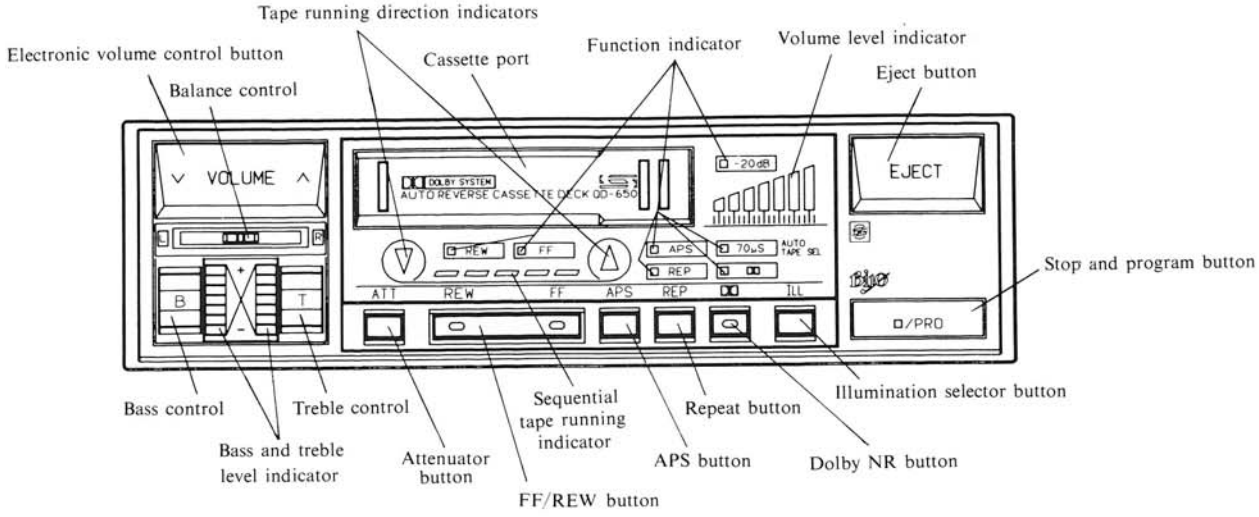


Figure 3. QD-650 major functions

4.2.2 Functions for adjusting volume and tone

1) Because of electronic control, volume can be adjusted with a feather touch, and buttons are flat.
2) Bass and treble controls are in steps with a one-push action.
3) An ATT function is adopted; volume can be lowered by about 20 dB with one touch.

4.2.3 Display functions

1) Seven LEDs are used as volume indicators.
2) Red and orange LEDs are used to display APS, repeat, tape selector, and Dolby functions.
3) A red LED is used to indicate ATT operation.
4) The tape running direction is indicated by green LEDs. Five red LEDs in a horizontal row are used as a sequential tape running indicator.

4.2.4 Control functions

Four-way panel illumination is adopted; one of four illumination patterns can be selected. See Table 1 for the above functions.

Table 1. Principal functions of the QD-650

Item		Description
Tape running control		Automatic reverse
Playback head		Hard permalloy
Wow and flutter		0.08% (WRMS)
Tape speed		4.76 cm/s
Frequency characteristic		30 Hz – 18 kHz
S/N (IHF-A network)		61 dB (Dolby B)
Cross talk		60 dB
Tone control	Bass	±10 dB
	Treble	±10 dB
Rated output level		100 mV
Applicable load impedance		5 – 20 kΩ
Current		0.6 A
Dimensions		178(W)×50(H)×148(D) mm
Weight		1.5 kg
Operating voltage		10.5 to 15.8 (rated: 13.2 V)
Remarks		Automatic loading and power eject Dolby B noise reduction incorporated Function for access to the beginning of a piece of music Repeat function Automatic tape selection Attenuator function

4.3 New deck DK-62

4.3.1 Outline

This deck was developed to be mounted on the QD-650. The development objectives are as follows (see Table 2):

1) Classy multifunction design
2) Small size and light weight
3) Low cost

In addition to the narrow-gap head and dual-azimuth adjustment system described in Section 4.2, the DK-62 has a function for return to side A after the cassette is ejected with side B just played back.

Table 2. Principal functions of the DK-62

Item	Description
Rating	
Type of deck	Vertical insertion and automatic reverse
Operation	Feather-touch action
Loading and eject	Mechanical automatic loading and power eject
Outside dimensions	115(W)×32(H)×110(D) mm
Weight	420 g
Playback	Four tracks, two channels
Applicable tape	Philips-standard compact cassette
Tape speed	4.76 cm/s
Power supply voltage	Performance
Performance	
Wow and flutter	0.1% or less (WRMS)
Frequency response	0 dB at 1 kHz; within −4 dB at 17 kHz
Take-up torque	55 − 70 g·cm
FF/REW torque	55 g·cm or more
Tape driving force	100 g or more
FF/REW time	110 s or less (C60)

This feature is an example of the classy and multi-function design implemented in the DK-62.

Many components are made up of resin, and large electric components, such as a plunger, are eliminated. As a result, the DK-62 is light and small: The weight is 420 grams, and the width of the tape drive mechanism is 7 millimeters. Also, components are integrated to be used for different functions and are simplified in structure. The number of components is 26% less than in the DK-61, contributing to low cost.

Conventional tape drive mechanisms use two independent drives for playback and fast-forward (FF)/rewind (REW). In contrast, the DK-62 uses one integrated drive fitted with a gear for switching between playback and FF/REW in synchronism with head base movement. As a result, only one stage of flywheel gearing is required, reducing the number of components and the thickness.

4.3.2 Dual azimuth adjustment system

Like the DK-61 mounted on the high-grade QD-580, the DK-62 incorporates a dual-azimuth

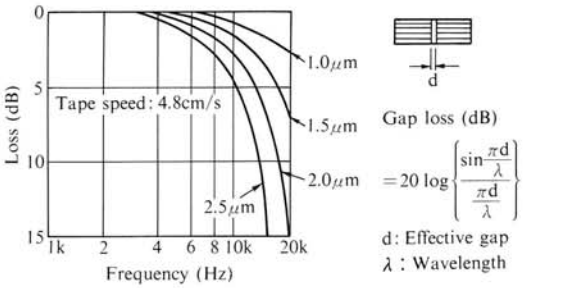


Figure 4(a). Gap loss

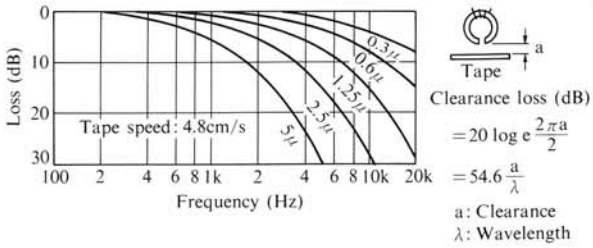


Figure 4(b). Clearance loss

adjutment system. This feature eliminates variations in frequency characteristics involved in forward and reverse running of the tape on the automatic reverse deck, thus assuring stable reproduction of high-frequency sound. This is done as follows: The contact faces in contact with the azimuth adjusting screw are switched according to the running direction of the tape. Optimum azimuth adjustment is assured for either tape running direction.

4.3.3 Narrow-gap head

The following losses are involved in playback on a tape deck; they increase with the frequency:

1) Gap loss
2) Angular deviation loss (azimuth loss)
3) Clearance loss

The azimuth loss is minimized because the deck incorporates a dual-azimuth adjustment system as described in Section 4.3.2. A narrow-gap head is adopted to reduce the loss due to head gap.

The head gap in the DK-62 is 1 μm. When compared with conventional heads with a 1.5 μm gap, the head greatly contributes to improved frequency response because of the narrow gap and the dual-azimuth adjustment system as shown in Figure 4 (a). However, treble characteristics may deteriorate because of the clearance loss caused by dirt on the head. The surface of the head is finished and shaped so that it does not collect so many

magnetic particles from the tape. However, the head surface should be kept clean by caring for the head after a long playback. The deck will maintain its functions for a long time.

For reference, Figure 4 (b) shows the clearance loss caused by magnetic particles or other dirt on the head.

4.4 Front unit

4.4.1 Illuminated buttons

Requirements for illumination were as follows:

1) Crystal feeling according to the design concept
2) Four-way illumination allowing two colors to be selected for button illumination
3) Quiet and simple, rather than showy and bright, illumination

To match the above requirements, the illuminated buttons are designed as follows: The material is transparent acrylic resin. Characters and edges are emphasized by illumination in contrast to the previous series in which the entire surface was luminous. Also, luminous elements are two-color LEDs rather than pilot lamps. This helps reduce heat dissipation. Chip LEDs that can be mounted automatically are adopted for the first time.

As shown in Figure 5, the front unit consists of the following:

1) Illuminated buttons made of transparent acrylic resin
2) Light guide filter on which characters are printed
3) White spacer for both light diffusion and button release
4) Transparent holder for retaining the unit
5) Front panel PC board on which LEDs are mounted

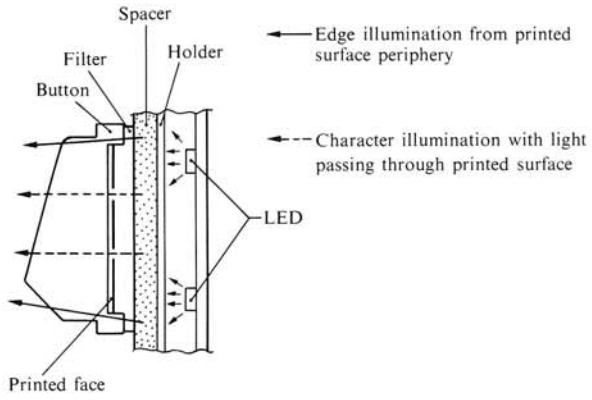


Figure 5. Button illumination mechanism

4.4.2 Front panel PC board

The front unit contains a panel PC board on which chip LEDs for illuminating buttons in one of two colors are mounted. This PC board has about 90 chip LEDs.

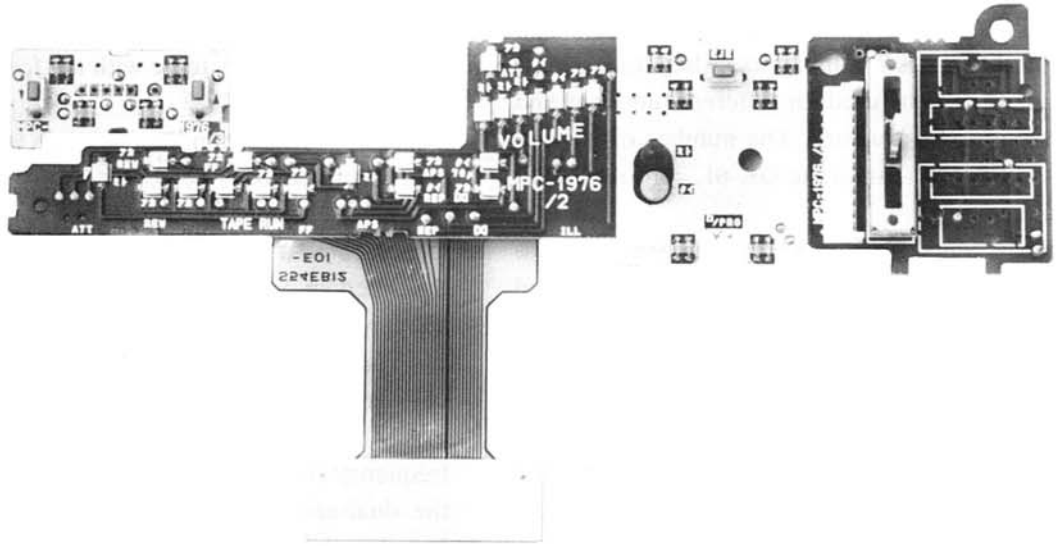


Figure 6. Panel PC board

The chip LEDs are mounted through reflow soldering. This technique was first attempted and established in cooperation with the Production Engineering Department.

Figure 6 shows the panel PC board fabricated using the above technique.

5. Graphic Sound Flavor

5.1 Outline

The acoustic transmission frequency characteristic (hereafter referred to as the transmission characteristic) in the passenger compartment varies with the shape of the car and the interior material. The transmission peak frequency lies between 100 and 300 Hz depending on the distribution of resonant frequencies of the passenger compartment. Fujitsu TEN has already adopted an equalizing system to flatten the frequency characteristic in the peak frequency band using an equalizer dedicated to a particular car model. Examples of this equalizing system are those in the Big-Bose audio system and new Celica audio system. However, it was difficult to employ dedicated equalizers in audio equipment to be sold in the general market because car models, types of loudspeaker, and mounting positions cannot be designated. To overcome this difficulty, the QE-660 (see Table 3) adopts a parametric function which allows the dip center frequency of the equalizing curve to be varied according to the peak of the transmission frequency characteristic determined by the particular condition, including the car model. Therefore, an optimum sound field is assured in a wide range of car models. Also, this equalizer incorporates a Sound Flavor function which enables the user to select the desired tone with one touch, thus improving the operability of the equipment.

The display using LEDs can be switched between equalizing curve display mode in which the equalizing curve preset by switch operation is displayed and spectrum analyzer mode in which the frequency distribution of the music source is displayed.

5.2 Features of transmission characteristics in the passenger compartment

In the passenger compartment, unlike an ordinary listening room, the transmission frequency characteristic is complex because of the following:

1) Low resonant frequencies which occur in narrow acoustic space are extended up to several hundred Hertz.
2) The passenger compartment is enclosed by sound reflecting objects (glass) and sound absorbing objects (seats).
3) Loudspeakers are installed asymmetrically.

These factors cause peaks and dips in the transmission frequency characteristic curve.

Figure 7 shows an example of the transmission frequency characteristic of a box loudspeaker system using 12 cm diameter units mounted on the rear parcel tray.

The graph in Figure 7 shows that the sound pressure near 200 Hz is about 10 dB higher than the sound pressure at 100 Hz. This leads to a 10 to 20 dB

Table 3. Specifications of the QE-660

Item		Specification
Frequency characteristic		20 Hz – 40 kHz
S/N (IHF-A network)		90 dB
Parametric equalizer	Variable range of center frequency	100 – 300 Hz
	Selectivity (Q)	4
Rated input level		100 mV
Rated output level		50 mV
Applicable load impedance		10 kΩ – 20 kΩ
Outside dimensions		178(W)×25(H) ×140(D) mm
Weight		0.8 kg
Operating voltage		10.5 – 15.8 V

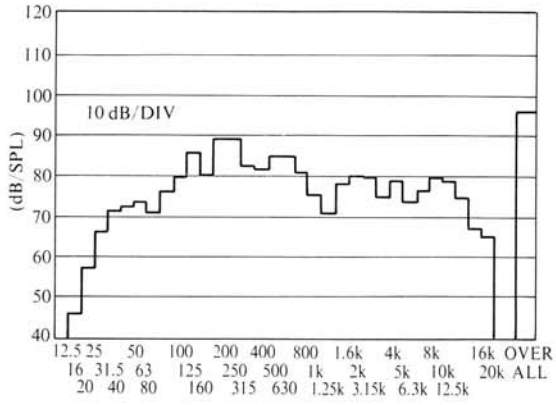


Figure 7. Transmission frequency characteristics

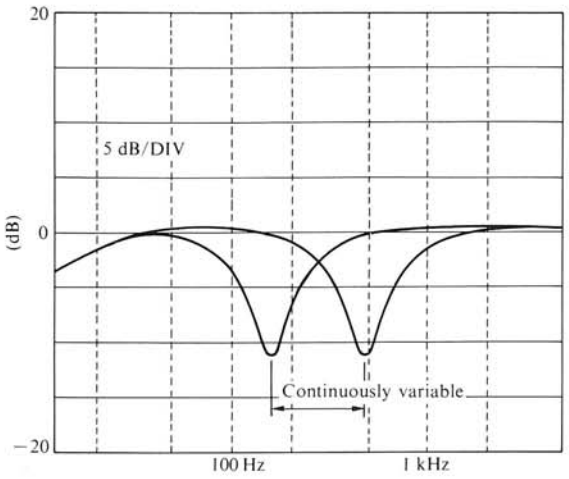


Figure 8. Frequency characteristics of the parametric equalizer

peak in the range between 100 and 300 Hz when the car model, type of loudspeaker, or mounting position is changed. The sound is muffled on auditory perception.

5.3 Parametric function

The newly developed car audio equipment incorporates a parametric equalizer which allows the dip frequency of the equalizer curve to be varied according to the peak frequency of the transmission characteristic. Figure 8 shows the frequency characteristics of the parametric equalizer.

Considering the transmission characteristics in the passenger compartment, the variable range of the dip center frequency is between 100 and 300 Hz on the parametric equalizer. A switch is provided to select a dip level of −6 or −12 dB.

5.4 Equalizing characteristic

The Graphic Sound Flavor enables the user to select one of eight equalizing curves according to the music source or the user's taste.

The eight equalizing curves were determined after sound inspectors repeatedly evaluated sound with characteristics adjusted by a sound field controller which allowed the center frequency, level, and Q in the passenger compartment to be varied independently. Figure 9 shows typical equalizing curves.

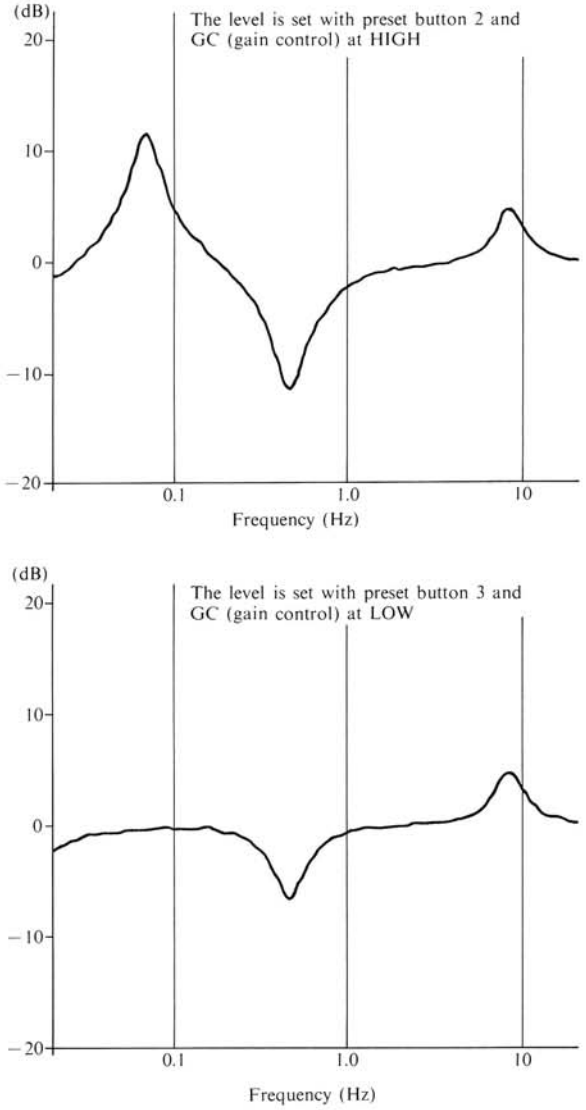


Figure 9. Typical equalizing curves

The dip frequency in the middle frequency range can be continuously varied between 100 and 300 Hz with the parametric equalizer discussed in Section 5.3.

5.5 Circuit construction

Figure 10 is a block diagram of the newly developed car audio equipment. This section describes the Sound Flavor, parametric equalizer, and control circuits specific to the QE-660.

The sound flavor circuit consists of plural band-pass filters and ten analog switches. One of the eight equalizing curves is selected according to the setting of these analog switches.

The parametric equalizer incorporates a state-

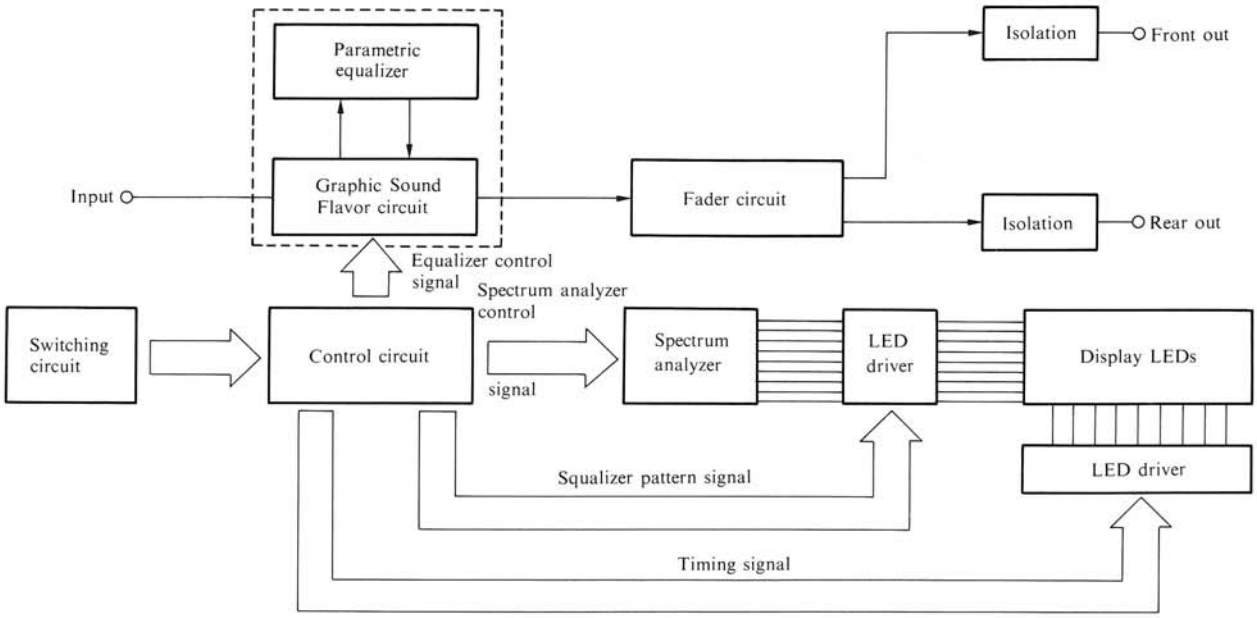


Figure 10. Block diagram

variable filter; only the center frequency can be varied using a sliding control, while Q is kept constant.

The control circuit supplies control signals to the other blocks in response to operation of the switches. At the initial stage of development, the control circuit was composed of multiple digital ICs and two hybrid ICs. However, this construction occupied a large area on the PC board and was expensive. Therefore, a new gate array IC was developed to reduce the size and cost of the circuit.

Figure 11 shows the newly-developed gate array IC and the circuit components used at the initial stage of development.

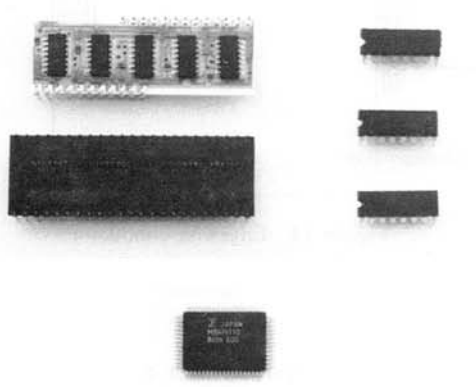


Figure 11. Gate ICs

6. High power HI-FI loudspeakers

6.1 Outline

The following targets were established when we began to develop loudspeakers that could handle a digital source:

1) High power handling ability and high efficiency
2) Improvement of heavy bass reproduction
3) Improvement of directivity
4) Reduced distortion

Described below are the features and performance of the loudspeaker system and points in design.

The loudspeaker system consists of a 10 cm diameter two-way loudspeaker (SG-1026) for the front door and a 6 × 9 inch three-way loudspeaker (SG-6906) for the rear. These component loudspeakers were developed under the same design philosophy. Often, loudspeakers produce different sounds although their frequency characteristics are identical. This is due to the difference between the loudspeakers in dynamic characteristics, including transient response; it occurs because the loudspeakers differ in the material necessary to convert electric signals to sound, including the diaphragm, edges, voice coils, and dampers.

The SG-1026 and SG-6906 developed this time use the same material for the woofer cone and edges. The middle and high frequency loudspeakers

are integrated into a single unit to match the quality of sound of both frequency ranges. Also, film capacitors featuring low variations in the quality of sound are used for network elements interconnecting the woofer and the squawker/tweeter. The loudspeaker system is thus designed with emphasis on the quality of sound. Its components are the SG-1026 and SG-6906: The SG-1026 is a two-way system consisting of a dome tweeter with a 1.1 cm diameter polyimide resin diaphragm and a woofer arranged on the same axis as the tweeter; the SG-6906 is a three-way system consisting of a 2.5 cm diameter dome squawker and a 1.1 cm diameter dome tweeter with the same diaphragms. Die-cast aluminum is used for the grill and spacers.

Figure 12 shows the construction of the SG-6906.

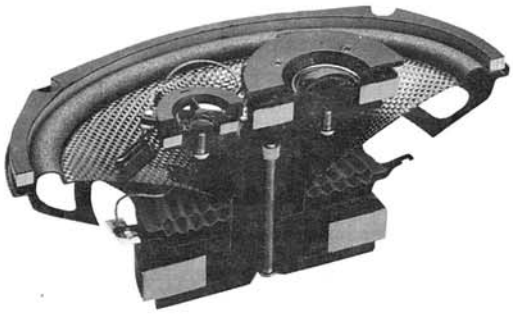


Figure 12. SG-6906 construction

6.3 Key points in design

6.3.1 High input power handling capacity (200 W maximum)

Playing back the wide dynamic range of compact-disk records with high fidelity requires a loudspeaker system that can handle the output of a high-power amplifier with adequate margin.

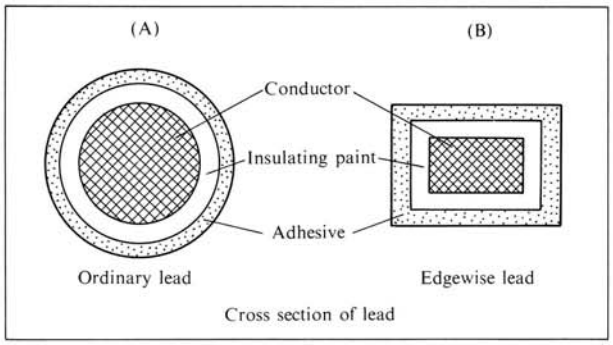
In the woofer, we introduce a lightweight but highly rigid cross-woven carbon fiber cone*2 to prevent bad effects at low frequencies caused by cone breakup. We also adopted a long voice coil to play back the sound with good linearity over the long range of piston motion that takes place due to high power input, and used an aluminum bobbin for its good heat-radiation characteristics.

For the damper that suspends the vibrating section, we introduce a twin-damper structure to improve the linearity. For the spacer that fixes the loudspeaker unit and for the grille, we used die-cast aluminum to prevent unwanted vibration, achieving high input power handling capacity.

6.3.2 Design for high efficiency

Loudspeakers satisfying the requirement for handling high input power cannot reproduce sound in a wide dynamic range if their efficiency is low. The light, rigid cloth carbon cone is driven by a large strontium magnet with a diameter of 120 mm and a magnetic flux density of 11,500 gauss, and an edgewise voice coil with a flat wire wound in four layers. This construction helps raise the efficiency (93 dB 1 W (m)) while maintaining the high input power handling capacity.

Figure 13 shows the edgewise conductor for the voice coil.



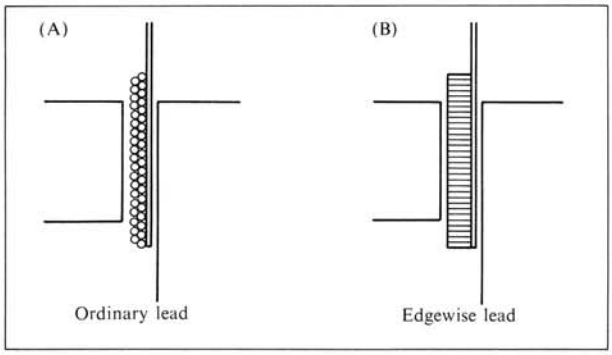


Figure 13. Edgewise conductor

*2 The cross-woven carbon fiber cone is a cone fabricated by weaving carbon fiber into sheet cloth and pressing the cloth by heat treatment.

6.3.3 Design with emphasis on the quality of sound

The means adopted to improve the quality of sound are as follows: Cloth Carbon Cones now attracting attention in home hi-fi equipment are used as the diaphragms, and film capacitors are used as network components interconnecting the units. In general, electrolytic capacitors are used in flush mount loudspeakers; however, they are placed in series with squawkers/tweeters, thus influencing the quality of sound. Therefore, film capacitors superior in distortion suppression characteristics are employed in this equipment. Figure 14 compares the cross-modulation distortion involved in the two types of capacitor. The components are thus chosen on the basis of design philosophy placing emphasis on the quality of sound. The middle and high frequency units are of a dome type superior in directivity. Satisfactory characteristics in the middle to high frequency range are thus assured in the car.

Figure 15 compares the directivity of a dome loudspeaker and that of a cone loudspeaker. In the newly developed loudspeaker system, the overall

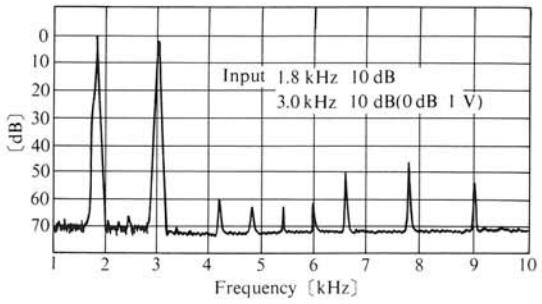


Figure 14(a). Electrolytic capacitor distortion

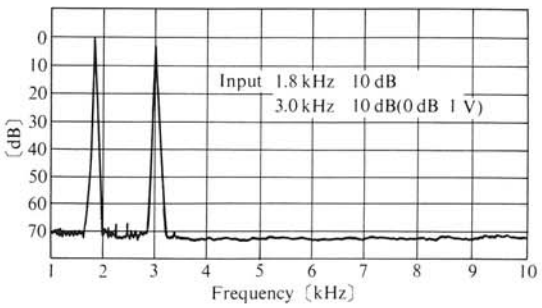


Figure 14(b). Film capacitor distortion

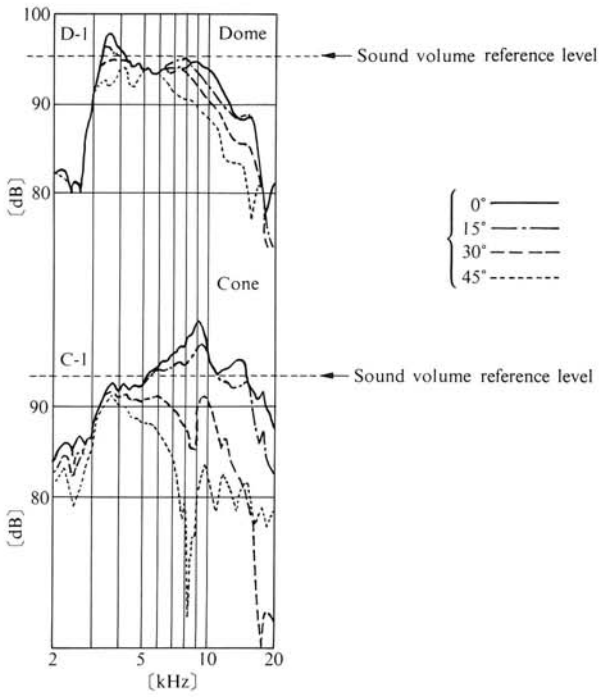
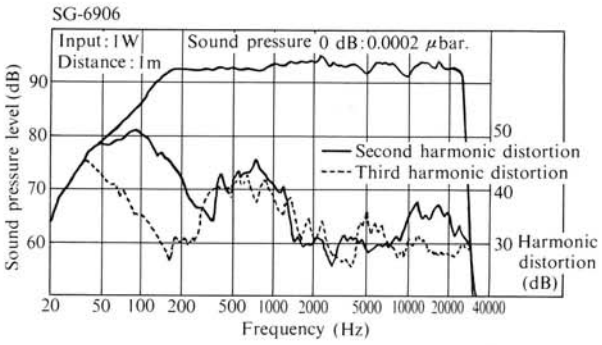


Figure 15. Directional characteristics



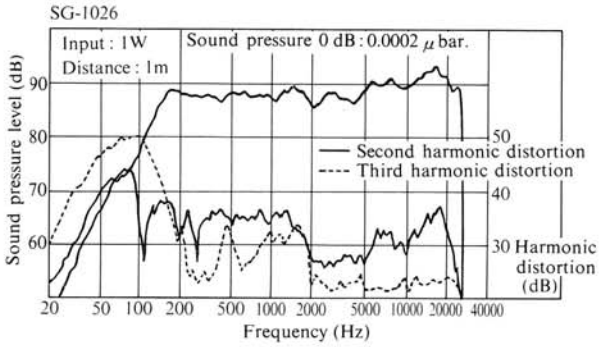


Figure 16. Overall frequency characteristics

frequency characteristics of the front and rear loudspeakers is flattened throughout the frequency band. See Figure 16.

With the SG-6906, the reproduction frequency range is wide, i.e., from 30 Hz to 28 kHz, and the minimum resonant frequency (f_0) is about 50 Hz. Bass reproduction is thus improved.

In the loudspeaker system, oxygen-free-copper (OFC) loudspeaker cords featuring a high transmission efficiency are used. This is another example of the development effort made to improve the quality of sound by choosing materials even for attachments.

7. Conclusion

The features and key points in design of the DIN-size 650-Series have been discussed above.

The system has proved to be satisfactory in the light of the design philosophy of "total sound production from input to output". The other concept, "light", is embodied in the form of four-way illumination, crystal buttons, and edge lighting, all of which provide classy, comfortable illumination at night.

Targets for the future are to advance technology for controlling the sound field in the car and to develop systems that can reproduce high-quality sound in the most favorable condition.

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