6 Disc In-dash CD Changer Deck

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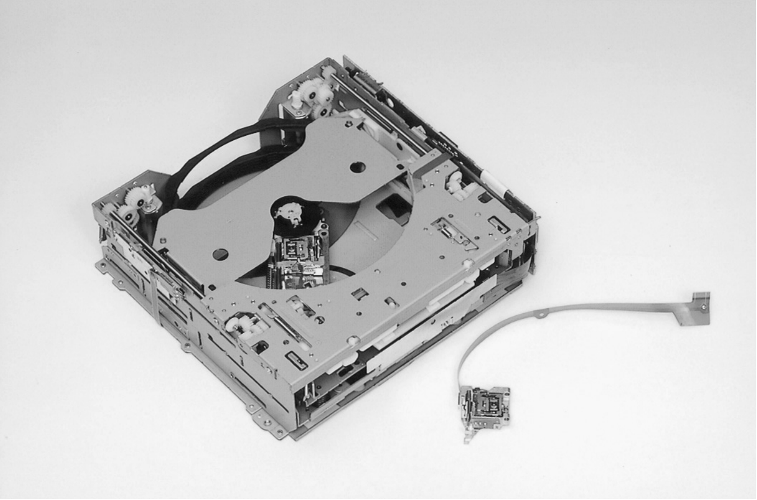

Abstract

In 1997, Fujitsu Ten was the first in the industry to introduce an in-dash CD changer deck (DA-26) featuring a 6-disc slot-in system. To meet user demand for smaller size, higher performance and lower price, we have now developed a second-generation in-dash CD changer deck. The following article describes the features of this new product.

1. Introduction

Recently, in the car audio market, the popularity of compact discs (CDs) that have replaced cassette tapes is at an all-time high. Users now take it for granted that the cabin dashboard has a CD or a CD-ROM player that can store one disc and that the trunk has a CD changer-player that can store multiple discs. There is even growing demand among users for a CD changer-player in the cabin dashboard, for enhanced operability. Fujitsu TEN was the first in the industry to develop a 1-DIN in-dash CD changer deck (the DA-26 model) that can store six discs. However, a CD player (product) that contained this CD changer deck could be installed into only a limited number of vehicle types, due to its considerable depth. Thus, we had to develop a CD changer deck compatible with a product that could be installed into more vehicle types. With this as a backdrop, we developed the CD changer deck DA-32, a second-generation product for Fujitsu TEN. This article describes the overview and features including functions and performance of the DA-32.

2. Basic Concepts in Development

We set the following development goals in developing the DA-32.

1) Smaller size: Less deck depth
2) Higher speed: Reduced access time
3) Better performance: Improved anti-vibration performance
4) Lower cost: Reduced number of models
5) Improved analysis capacity

Table 1 shows the methods and techniques employed to achieve these goals. We also defined specific target values to be used in the development process. Table 2 shows the major development specifications.

3. Overview of Deck

Roughly speaking, the DA-32 unit consists of the following six mechanisms:

1) Disc insert/eject mechanism
2) Stocker lift mechanism
3) Slide mechanism
4) Pickup drive mechanism
5) Stocker split mechanism
6) Anti-vibration mechanism
7) Deck controller

Table 3 shows the structure and mechanisms of the DA-32, the second-generation changer deck, compared with the DA-26, the first-generation for Fujitsu TEN.

The biggest difference lies in how discs are stored in a stocker. Six discs must be contained within the product height of 50 mm, and space for replacing and playing discs (including swing width) are required. Thus, a space of 2 to 3 mm exists per disc including the stocker. The biggest challenge in developing an in-dash changer deck is the stocker configuration as well as the storage method. Since the DA-26 had a disc-to-disc pitch of 2.5 mm and a disc was stored in 1.5 mm of space, a disc had to be inserted from the horizontal direction within this 1.5-mm clearance. Thus, we had to assure high accuracy for a stocker height, the disc height to be used when a disc is inserted, stocker form, etc. For the DA-32, we assumed disc loading via vertical instead of horizontal transport. We adopted a new mechanism that would move a disc horizontally while the stocker was split vertically, and then load the disc onto the stocker by raising it, then loading it horizontally. This mechanism eliminated the need of assuring high accuracy for a disc height and a stocker height to be used when a disc was inserted.

Table 1 Methods of achieving the goals

Item	Method and technique
1) Smaller size	Developing a compact pickup
2) Higher speed	Improving the access method
3) Better performance	Reduced floating unit weight
4) Lower cost	Sharing printed circuit boards
5) Improved analysis capacity	Subdividing the error codes

Table 2 Development specifications

Item	DA-32	DA-26
Deck outer dimensions: Width	154mm	155mm
Height	46mm	48mm
Depth	157mm	167.5mm
Time required to insert a disc	5.5 seconds	17 seconds
Time required to replace a disc	10 seconds	21 seconds
Time required to eject a disc	4.5 seconds	16 seconds

Table 3 Comparing the new and old changer decks

Item	DA-32	DA-26
Disc detection	Mechanical	Mechanical and optical
Disc transport	Roller + slide	Roller + pushing in
Disc loading	Vertical	Horizontal
Stocker lifting	Stage lever	Feeding screw
Stocker pitch	2mm	2.5mm
Floating	Pickup	Deck

4. Features

4.1 Disc Insert/Eject Mechanism

We have adopted a mechanical detection method in which a mechanism detects the location and status of a disc by coming into contact with it. The use of mechanical detection allows us to solve the problem of erroneous detection that occurs when the transparent part of a disc is read using the conventional optical detection method in which the mechanism does not come into contact with the disc.

We have adopted a two-stage method for inserting a disc into, and eject it from a stocker. In the first stage, an inserted disc is guided to the rubber rollers and taken further in as the rubber rollers rotate. When the unit detects that the disc has been transported to the specified location, the rubber rollers work in reverse (in the eject direction) to position the disc. In the second stage, the turntable that has been on standby rises and picks up the positioned disc. The turntable then moves into the stocker to complete the disc insertion operation. This method is effective in securely loading a disc onto the stocker and eliminating the need of a mechanism that only loads a disc, with the result that an effective mechanism is realized.

The first-generation DA-26 deck had a shutter mechanism that, while one disc was inserted, prevented another disc from being inserted by mistake. The second-generation DA-32 employs an internal component that performs the same function. As a result, it has the same type of shutter mechanism but doesn't require any additional components.

4.2 Stocker Split Function

A stocker used to store discs is provided for every disc. In the initial setting, the spring bias keeps all six stockers in close contact with each other. Stocker split refers to the splitting of the required stockers to eject or load the required disc.

The stocker in question, however, does not require a bias component to hold discs. More specifically, the use of a C-shape stocker instead of the conventional U-shape prevents a disc loaded in the stocker from falling off in the horizontal direction. Additionally, stacking another stocker or a cover on the stocker also prevents a disc from falling off in the vertical direction. Thus, the disc can be held in place simply by using the disc loading method and without the need of a bias component. Additionally, a disc can be inserted and removed simply by way of the vertical movement of a stocker.

The stockers are split as follows: Both ends of stacked stockers have projections used for splitting at both ends. The split levers with pointed edges are pushed in between the right and left projections simultaneously to push them open. First, all of the stockers are split into two and then split again in the same way until the target stocker is obtained. Since an inserted disc is transported to the clearance made by roughly splitting the target stockers, putting the stockers back in their original location completes the loading process. At this time, the unit inserts and extracts the turntable with the stocker closed in order to insert a disc into, or remove a disc from the stocker. Thus, a disc never falls off of a stocker due to any interference from external elements. Additionally, a holding lever positioned in the deck front presses against the deck rear a disc on a stocker in the lower group after splitting to prevent it from falling out toward the upper direction of the disc due to the stocker or the holding lever projections.

4.3 Reducing the Depth

The deck depth is determined roughly on the basis of the following three dimensions:

(1) Disc outer dimension: 120 mm
(2) Pickup dimension: X mm
Or turntable: 30 mm
(3) Swing width: 6 mm (±3 mm)

In other words, we need a pickup with the size of 24 mm to create a deck with a depth of 150 mm. A conventional pickup will not do because of its size of 30 mm, causing the calculated deck depth to be 156 mm. Thus, we developed a compact pickup described later. However, after the pickup size problem was solved, the next challenge we had to deal with involved the turntable. Since the turntable needed to be as large as possible owing to the precision required for disc support, we put some thought into where it should be installed. Instead of installing a disc and a turntable in the deck center as before, we installed the turntable off center in the horizontal direction to eliminate the effect it had on the deck depth. A turntable installed in the center needs to move in a straight line toward, and away from the deck center but an off-center turntable needs to rotate. Since the location of the turntable tends to be limited if all it does is rotate, we combined both the straight and rotational turntable movements to simplify the structure of the deck.

Additionally, automobile CD players require an anti-vibration feature. The swing width shown in (3) above is a factor that affects the deck size because it is supported by a spring and an oil-filled damper in the same way as with the earlier model. In the first generation model of the CD player, the entire deck floated, requiring more space in the product than that taken up by the deck. For the DA-32, we provide a floating space inside the deck, thereby making efficient use of the space inside the deck that would otherwise not be used. Thus, we were able to avoid increasing the deck depth when we added the swing width.

We also gave consideration to the locations of other components. For example, we installed a disc insert/eject motor and a splitting motor on both sides of the deck rear, reducing the amount of unused space and realizing the miniaturization of the deck, particularly in terms of depth.

4.4 Higher Speed

We assumed that the DA-32 must be able to replace a CD player that can store one disc. We naturally tried, during the development process, to speed up all of the functions in terms of the changer. However, we focused more reducing the amount of time required to insert one disc and play it, rather than the time required to insert all six discs.

5. Design Based on Component Sharing

The new DA-32 deck was targeted for use in various products. We intended for the deck to be installed not only in Fujitsu TEN products, but also sold to other companies as a separate product. Thus, to meet many of the requirements for installation and use in other products, including differences in vehicle types and communication methods as well as requests from non-Fujitsu TEN users, it was necessary that we provide a number of derivative models. To develop these functions using a limited number of labor-hours, we had to create a design based on component sharing wherever possible.

5.1 Component Sharing in Circuits

Due to the reasons described above, the DA-32 must meet or be able to meet numerous specifications, such as those shown in Table 4. To meet these specifications using a few types of circuit boards, we put some thought into software specifications and circuits and succeeded in enabling the deck to support the specifications by installing or not installing some electronic components.

Table 4 Variety of specifications

Specification	Selections
Communication	TAB2/AVC-LAN
Audio output	Analog/digital
Memory	4M/16M
Compression	No/Yes
Microcontroller power	Internally supplied/externally supplied
ILL control	No/Yes
Play speed	Standard/double-speed intermittent play

5.2 Component Sharing in Main Board Outer Dimensions

The DA-32 main board, installed on the side of the deck, needs to be clear of the screws inserted from outside the product. Thus, we must position the mounting screw holes in such a way that the deck can be installed in a vehicle with different mounting screw locations. Furthermore, we need to use common board outer dimensions so that the same board can be used for different products.

However, we would have to employ a large elliptic hole instead of the round hole (Fig. 1) used previously, presumably reducing the packaging area of the board and significantly restricting the layout of the components and patterns.

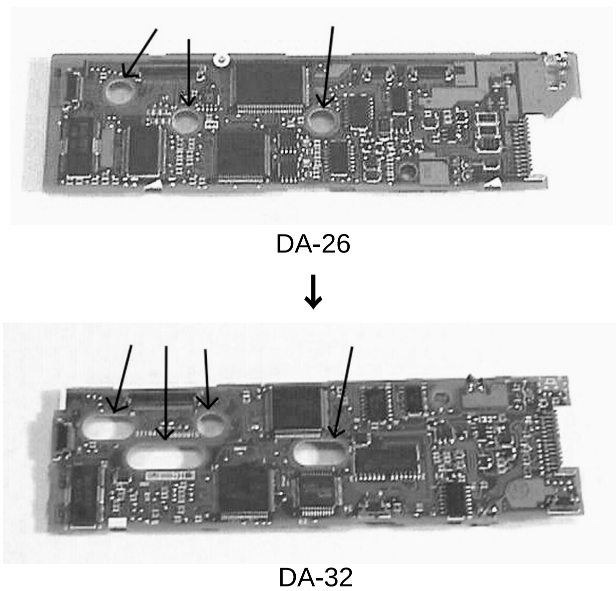

Fig. 1 Comparison of old and new PCB layouts

Thus, we have adopted:

(1) Smaller components

Adopting a shrink microcontroller and replacing a tantalum capacitor with a high-capacity ceramic capacitor

(2) Denser pattern design

Improving the pattern density by adopting fine patterns 0.15-mm in width and small-radius via holes

The adoption of these items allowed us to keep the types of boards we developed to a minimum, using the same outer dimensions and forms (die sharing). Thus, we made the DA-32 deck compatible to many products and vehicles and, at the same time, succeeded in reducing the development and evaluation labor-hours and die costs.

6. Reviewing the Interface with the Products

We examined the specifications thoroughly to meet the requirements of each product design department as well as to make it marketable outside our company. We improved the conventional interface specifications to make the deck independently marketable and succeeded in providing specifications enabling the deck to be used both with Fujitsu TEN products and the products of other companies.

7. Internalizing the Power Circuit

We internalized the power circuit conventionally provided outside the deck (in the product) and kept the power supply to the deck at 13 volts.

Thus, products hooked up to the deck do not require D+8, D+5, and B+5 power circuits for the deck.

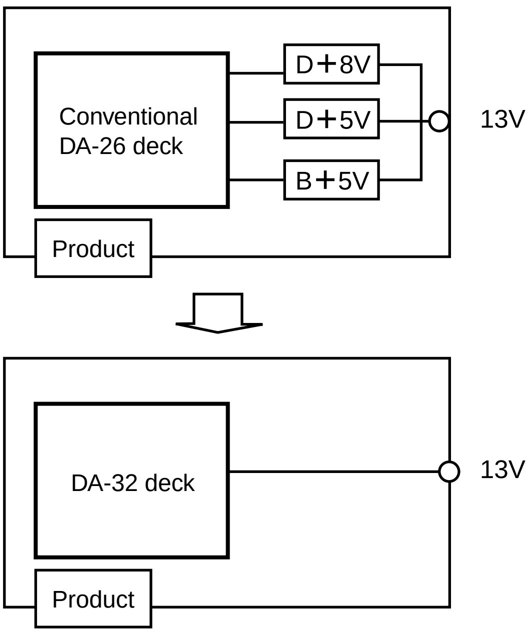

Fig. 2 Change of power supply method

8. Developing Control Firmware

8.1 Using the Deck Control Simulator

For this model, we used the deck control simulator for the first time to design control firmware (Fig. 3). The deck control simulator enables actual deck operations to be simulated on a personal computer, based on three-dimensional CAD data used in the design phase. We can design and evaluate firmware without having to using an actual unit if we connect it to the firmware development tool, because the simulator can output switch and sensor signals with the same timing as that of an actual unit. Previously, we were sometimes unable to develop firmware before a prototype deck could be completed. However, the simulator allows us to test the mechanism for normal operations or any design errors by having it run on the simulator as long as CAD design data is available (Fig. 4).

Thus, not only can we design the mechanism and firmware in parallel, we can also eliminate the chances of the costly destruction of a unit owing to software bugs. In the evaluation phase as well, the deck control simulator allows us to reproduce the timing and mechanism statuses that cannot be easily realized with an actual unit. Accordingly, the simulator contributes greatly to evaluating the fail-safe function provided by the firmware, contributing to making the design operation effective.

We intend to use the deck control simulator from now on because it can also be applied to the design of other cassette, CD, and MD decks.

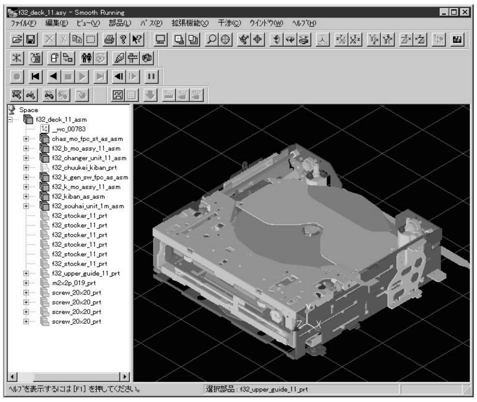

Fig. 3 Deck control simulator screen

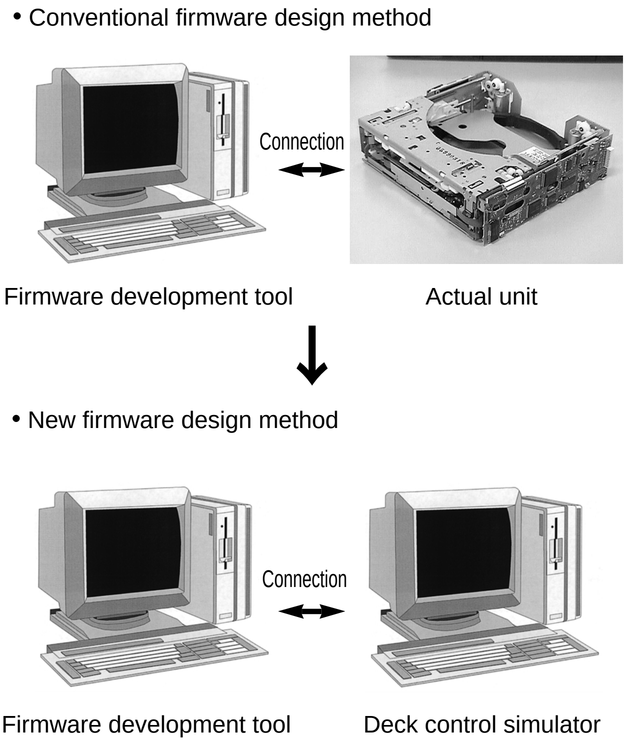

Fig. 4 Improvement of firmware design technique and its evaluation method

8.2 Error Codes Used for Abnormality Analysis

An error code described in this section is written to the E2PROM if an abnormality occurs in the DA-32, and used to analyze the abnormality. For the DA-32, more codes are provided than the conventional DA-26 deck. Moreover, the abnormality can be described in greater detail. Thus, the user can approximately identify the cause of the abnormal status simply by looking at the error code.

The DA-32 error codes are roughly classified into initial codes, CD replay codes, mechanical control codes, warnings, and others. They are further divided into subgroups, allowing the user to identify which SW or motor has encountered an abnormality during what kind of operation.

Table 5 Comparison of numbers of error codes

	DA-26	DA-32
Number of error codes	65	173

9. Developing a Compact Pickup

9.1 Points in downsizing a pickup

To reduce the deck depth, we needed a pickup about half the size of a conventional pickup. To realize this size reduction, we developed a new pickup by combining a short, object lens of a small diameter, a compact actuator housing this object lens, and an IC that modularizes the optical system (Fig. 5).

Fig. 6 shows the configuration of this pickup. An optics module IC (whose internal structure is described later) is an integral unit that includes a photo-detector that converts a laser beam or reflected light from a disc into electrical signals. A laser beam emitted from this IC is bent upward by a rising mirror, concentrated on a disc with an object lens, and then bounced back onto the photo-detector in the opposite direction. We first reduced the focus distance of the lens to cut the distance between the laser source and the disc. Then, we reduced the lens diameter to minimize the sizes of the lens holder and the coil bobbin. To miniaturize the pickup, we adopted a configuration integrating the actuator, lens holder, and coil bobbin.

9.2 Improving the Vibration Resistance Using a Smaller Actuator

A lens, together with a coil that drives it, is held by four suspension wires in a strong magnetic field generated by a neodymium magnet. Energizing this coil can optimally concentrate a laser beam on a disc by moving the position of a lens up and down and to the left and right with submicron accuracy (control using the focus servo and the track servo).

To maintain the optimal position while the vibration is applied to a vehicle-mounted deck, the servo circuit passes a current to the coil in such a way that a driving force always cancels out the vibration. To enhance the data read performance at this time (anti-vibration performance), one of the following two approaches can be taken:

-- reduce the weight of movable parts such as the lens or

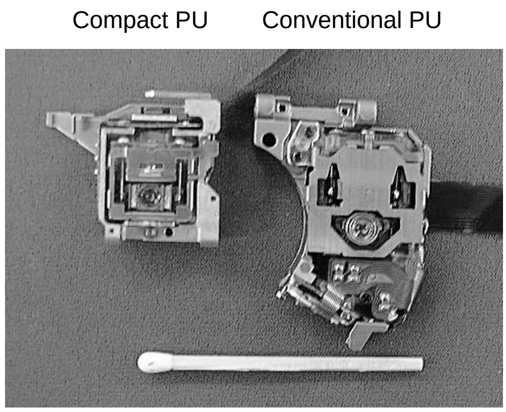

Fig. 5 Comparison of pickup external forms

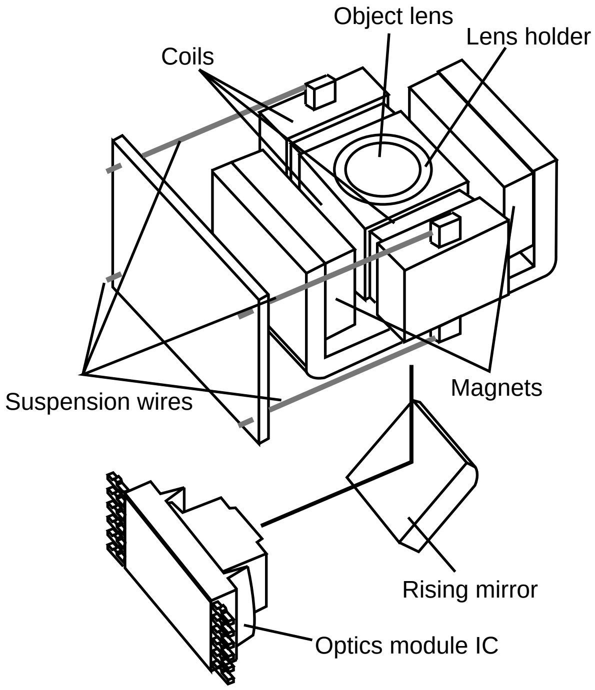

Fig. 6 Composition of optical system and small actuator

coil suspended by wires
-- increase the driving force by, for example, passing a larger amount of current, using a coil with more turns, or intensifying the magnetic force.

For this pickup, we adopted the former method because it is more advantageous in making the pickup smaller and reducing heat generation. We also adopted movable parts whose weight is one-fourth that of conventional ones. This arrangement improved the responsiveness by doubling anti-vibration and anti-dropout performance as well as reducing power consumption by 30%.

9.3 Improving the Environment Resistance by Adopting a Glass Lens and an Optical System Module

We adopted a glass lens instead of the conventional plastic lens. The adoption of a glass lens minimizes the deterioration and deviation of lens accuracy due to moisture absorption or high temperatures, leading to stabilized performance and improved margin.

We adopted an modularized IC as an optical component that must be put at accurate position and angle. Fig. 7 shows the internal structure of the optics module IC shown in Fig. 6. A laser beam emitted from the laser chip is bent upward by a mirror on a silicon substrate (a 45-degree plane obtained by etching a silicon crystalline plane and evaporating a metal on it). This

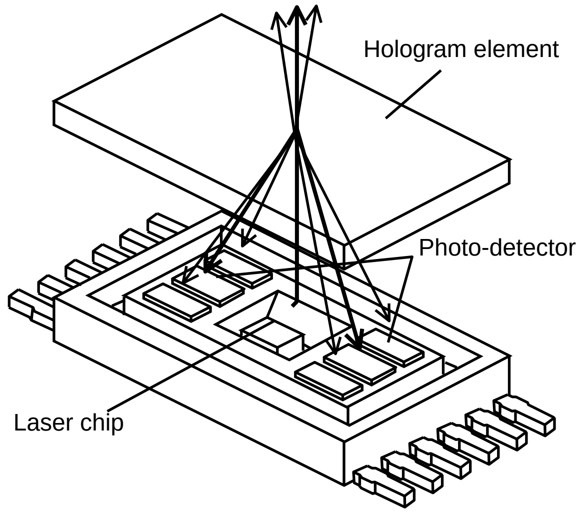

Fig. 7 Structure of optics module IC

laser beam is then split into three separate beams by a grating formed on the underside of a hologram element, and aimed at a disc. A beam reflected on the disc is sent by a hologram on the topside of an element to the right and left photo-detectors and used to generate a servo signal or read a signal recorded on the disc.

The light emitter (laser source), light receiver (photo-detector), and separator on the laser round-trip path (conventionally a half-mirror, or, in this module, a hologram) must generally be placed in an accurate position and angle. For this module, we have positioned the laser source on a silicon substrate that forms a detector, reduced the number of components involved in positioning from the conventional seven to one, and cut the distance between them to one-twentieth. The use of a hologram as the optical path separator has lowered the required angle accuracy as compared with the case where a conventional half-mirror is used. Compared with the conventional method that requires the positional accuracy in tens of microns and angle accuracy within a few minutes, this method can alleviate the accuracy requirements by one to two digits.

Thus, the adoption of this optics module IC and a glass lens that is extremely stable amid changes in temperature and humidity allowed us to improve the stability of vehicle-mounted decks, as exemplified by the improvement in the high-temperature limit from the conventional 95°C to 130°C.

10. Conclusion

This article gave an overview, and described the structure of the "DA-32" in-dash CD changer that we developed.

We succeeded in making the deck smaller and reducing the access time, consequently establishing it as the second-generation in-dash CD changer of Fujitsu TEN. In the future, we aim to further improve this deck to enhance its functions and performance and reduce its production costs.

Lastly, we would like to express our sincere thanks to all the people who provided us with cooperation and guidance in developing this product.

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