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CD Auto-Changer Decks "DA-11," "DA-13"

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The car CD player market is constantly changing; manufacturers must anticipate these changes and supply what customers want. This paper introduces FUJITSU TEN's two latest CD auto-changer decks designed to be smaller, lighter, and to target multiple markets. FUJITSU TEN has developed a novel disc changer using an elevator transport method and a pantograph lever. We describe these and the functions and subassemblies of our new decks.

1. Introduction

The popularity of the compact disc medium, CD for short, means people want CD players in their cars. Demand for CD auto-changer decks which can hold and play more than one disc is increasing rapidly. Fujitsu Ten has responded by developing two compact and light CD auto-changer decks, models DA-11 and DA-13; units which can be installed in a wide variety of car models with their individual restrictions on installation position and space. The decks have the following features: they are half the size of existing decks, they are 40% lighter than existing decks, they have two magazine insertion directions (crosswise and longitudinal), two deck installation positions (horizontal and vertical), and a disc storage capacity of 1 to 12 discs. This paper outlines the functions and performance of the DA-11 and DA-13.

2. Basic development concept

2.1 Market trends

Figure 1 shows car CD player shipment growth in the domestic market. As you can see, since their release for cars in 1988, shipment of auto-changers has steadily

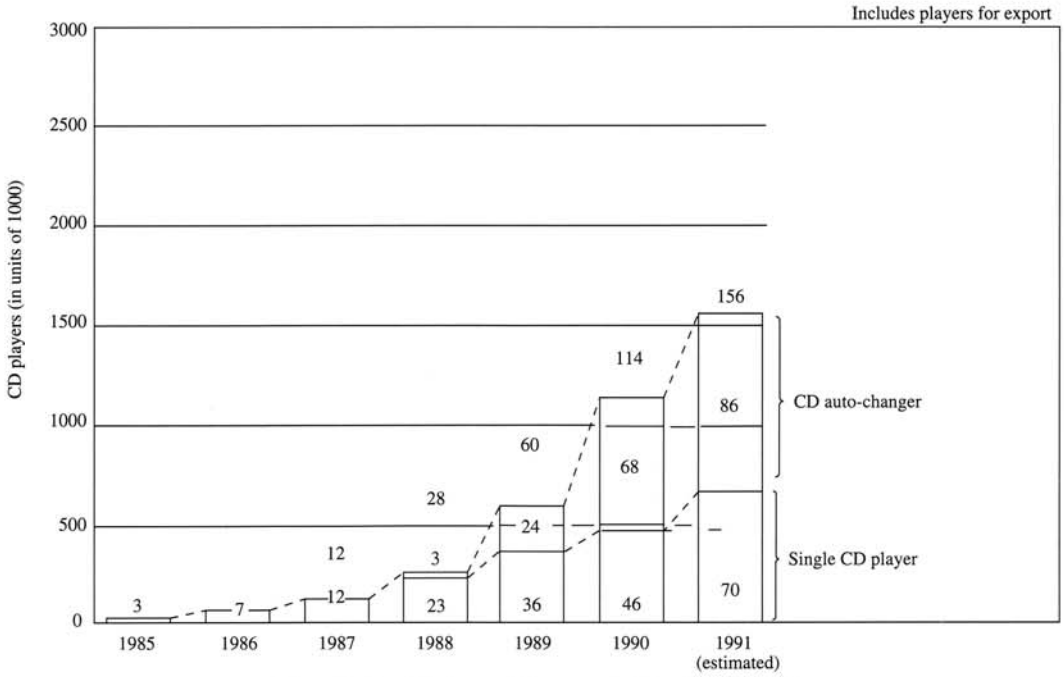

Figure 1. Car CD players shipment growth in domestic market

increased and, in 1990, overtook the shipment of single CD players. It is clear they are taking the largest share of the car CD player market.

2.2 Development aims

Our development targets were for CD auto-changer decks which will generally be installed in car factories. We also wanted to make them available as after-market audio equipment for domestic or export models or as an option which a car manufacturer can offer.

Table 1 lists the specifications we decided on before development.

① Small and light: Easy to mount making it suitable for a wide range of cars, large and small.

Table 1. Development Specification

Aim of Development	Parameter		Exisiting Model	Models Developed This Time	
			DA-07	DA-11	DA-13
		Wmm	162	152	
		Dmm	295	262	
		Hmm	126	78	
	Weight (kg)		2.8	1.6	
	CD control circuit		Additional	Built-in	
Applicability expansion	Magazine insertion direction		Crosswise	Longitudinal	Crosswise
	Number of discs that can be loaded		12	12	
	Compatibility with 8 and 12 cm discs		Six 12-cm discs and six 8-cm discs, or a dedicated magazine for twelue 12-cm discs	Presence of trays dedicated to 8 cm discs and trays dedicated to 12 cm discs allows random disc loading in the magazine.	
	Deck installation position		Horizontal	Horizontal	Horizontal/ vertical
Improvement of performance		Damage (width in mm)	0.5	1.0	
		Black spot (diameter in mm)	0.5	1.0	
		Fingerprint (diameter in mm)	65	75	
	Access time	1st to 12th disc (s)	16	13	
		1st to 2nd disc(s)	13	8 s or less	

② Multiple markets: We aimed our CD auto-changer decks at various markets: —Installation at car factories, availability as after-market audio equipment, and an option offered by a car manufacturer. Having a wide range of markets ensures a competitive advantage.

The DA-11 is designed primarily for installation at car factories, so for a given car, it will have only one specific position.

Therefore, it is always installed horizontal, and its magazine is always inserted longitudinally.

The DA-13 is also designed as an after-market audio product or option, so it can be installed in both horizontal and vertical positions as well having crosswise and longitudinal magazine insertion directions. This frees the DA-13 of restrictions on car models and installation positions with the idea of giving it a competitive advantage.

③ Improvement of performance: Resistance to mechanical damage has been increased and the mechanical drive speed has been increased.

3. Outline of The DA-11 and DA-13

3.1 Structure of the DA-11 and DA-13

Figure 2 and 3 show the DA-11 and the magazine. Figure 4 shows the components of the DA-11 and DA-13.

The function and theory of operation of each mechanism are outlined below.

1) Magazine mechanism

The magazine mechanism consists of a magazine unit and trays to prevent discs being damaged. The DA-11 and DA-13 use different magazine mechanism designs because they have different magazine insert and eject

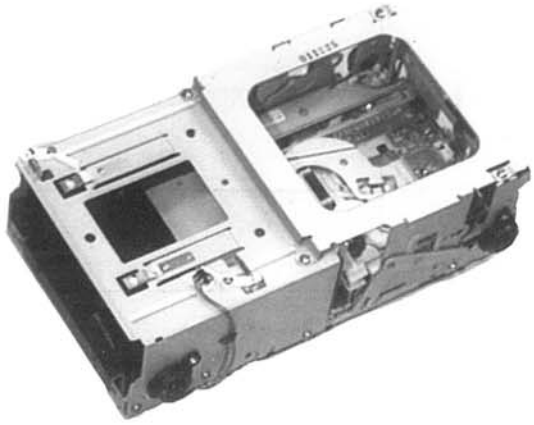

Figure 2. DA-11

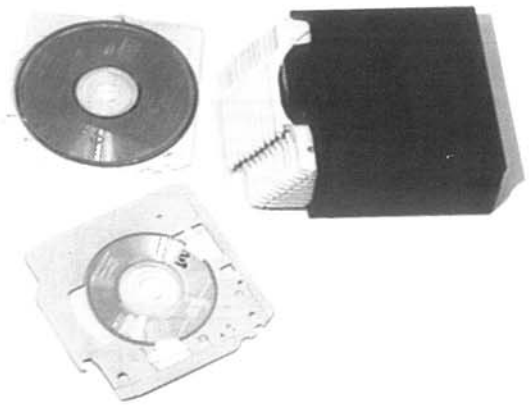

Figure 3. Magazine

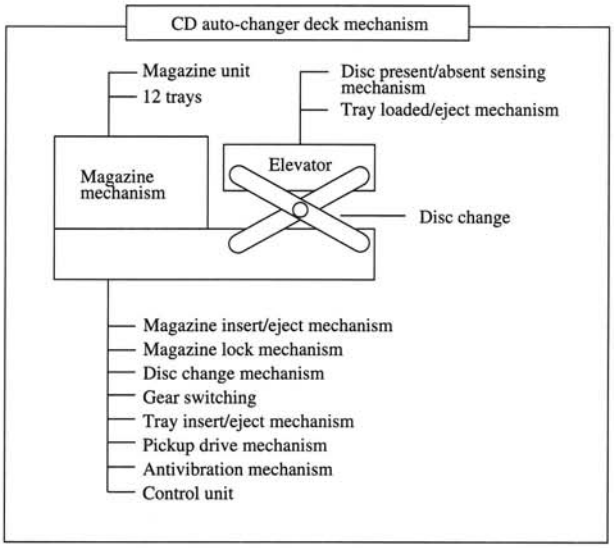

Figure 4. CD deck mechanism

directions. Other components are common to both. Dedicated trays are provided for 8 cm and 12 cm discs so that discs can be loaded into the magazine at random (Figure 5).

When the magazine is not in the deck, the tray is held in the magazine by tray lock claws to stop the tray being ejected. When the magazine is inserted into the deck, the tray lock is released and trays can be loaded and ejected.

2) Magazine insert/eject mechanism

The magazine is inserted manually, but it is power-ejected by driving the ejection lever from the motor via gearing (Figure 6).

3) Magazine lock mechanism

This mechanism holds the magazine in position in the deck. It locks the magazine in place when the magazine engages with the lock lever.

Lock is released by the cam on the cam gear which drives the ejection levers (Figure 6).

4) Disc change mechanism

The disc change mechanism moves the elevator up and down between tray positions (1st to 12th) to place the tray in the pickup drive position. The elevator is moved by the pantagraph lever driven by the motor via gearing (Figure 6).

5) Gear switching mechanism

The gear switching mechanism uses one motor to both eject the magazine and change discs. It switches between magazine ejection and disc change using planetary gearing (Figure 6).

6) Tray load/eject mechanism

The tray load/eject mechanism loads trays from the magazine into the elevator and removes them from the elevator. The tray is moved by driving the tray ejection lever from the motor installed in the elevator via gearing (Figure 7).

7) Disc present/absent sensing mechanism

This mechanism uses a photorensor to sense whether there is a disc in the tray or not when the tray is loaded into the elevator (Figure 7).

8) Pickup drive mechanism

The pickup drive mechanism rotates a disc using the disc motor so the disc can be read. Pickup feed drive from the drive motor via gearing rotates and drives the pickup feed screw (Figure 6).

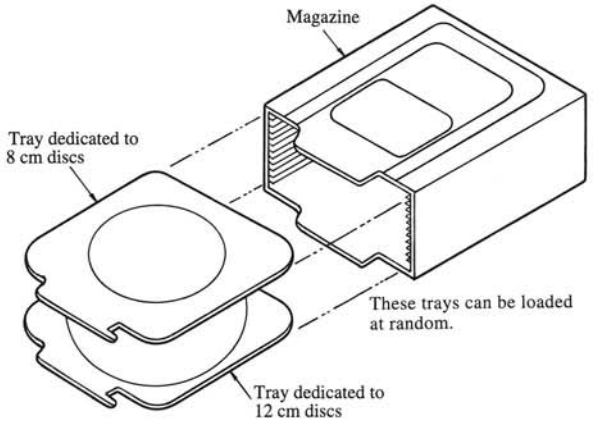

Figure 5. Magazine mechanism

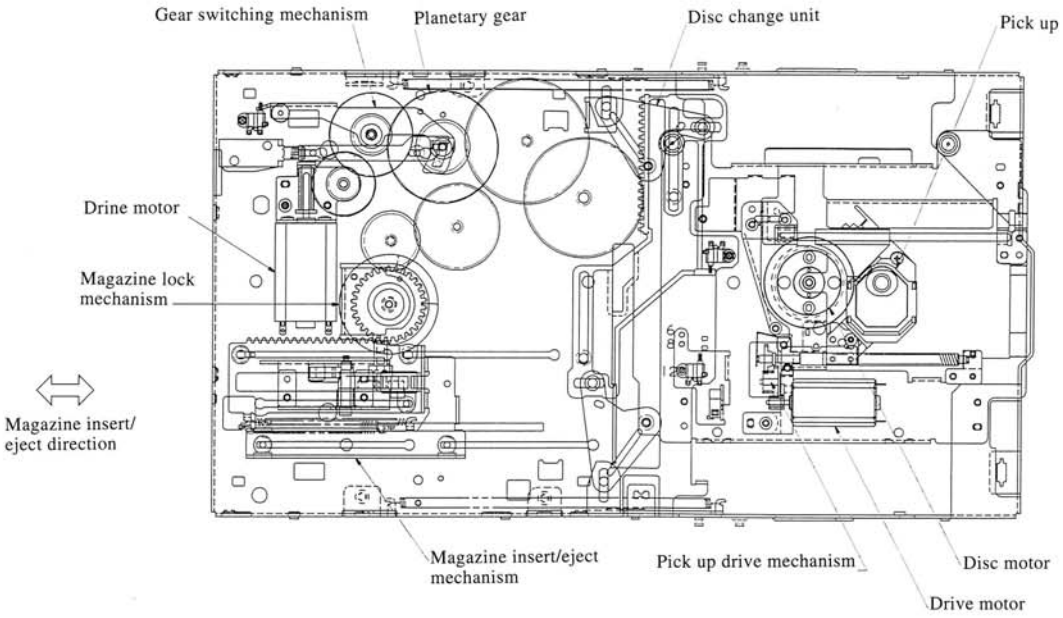

Figure 6. Detailed DA-11 deck mechanism

9) Antivibration mechanism

The antivibration mechanism lifts the entire deck from the CD changer enclosure using an oil damper and a spring. This reduces the vibration transmitted from the car to the deck through the enclosure.

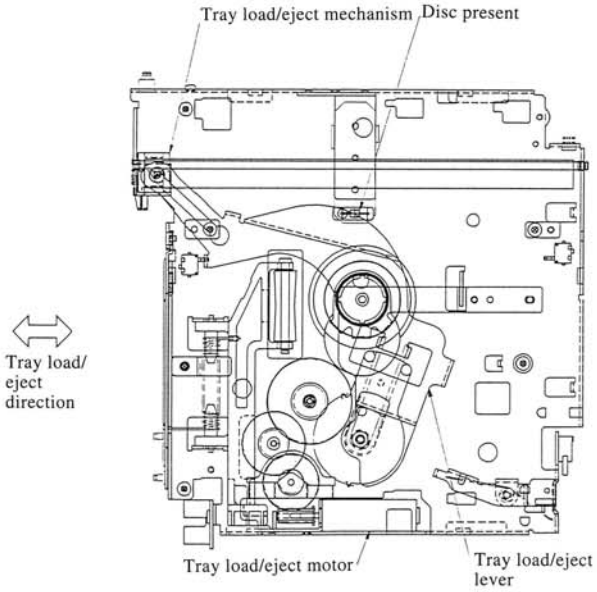

Figure 7. Elevator structure

10) Control unit

The control unit controls actions of all mechanisms of the deck, including inserting and ejecting magazines, changing discs, and playing music. It also manipulates data read from the disc and provides audio signal outputs.

11) CD CRAFT disc playback function

The DA-11 has functions which can play back audio and CD ROMs and has two digital data output systems, for audio signal output and display output.

4. Features

4.1 Small size and light weight

A car has a limited number of installation positions and limited space. There are also needs for low fuel and power consumption which all means smaller and lighter car components, including car audio units.

We used new structures and dedicated components to make our decks smaller and lighter than conventional products. The following measures achieved a 40% reduction in weight and 50% reduction in volume compared with conventional products:

① A dedicated load/eject mechanism and pickup drive mechanism.

② The disc load/eject mechanism moves inside the disc change mechanism.

The way we designed each subassembly to make DA-11 and DA-13 small and light is explained below.

4.1.1 Disc load/eject mechanism

The DA-11 and DA-13 use trays to load and eject discs. Trays can be changed by moving the tray load/eject lever and can center the disc. This simplifies the disc load and eject mechanism and makes the deck small and light.

Because of the restricted deck dimensions, we used a small motor to load and eject trays and reduced volume by 30%. However, the small motor has low torque. To compensate for this, we increased the reduction ratio of the worm gear and improved the gearing layout.

The high reduction ratio of the worm gear causes a bite at either stroke end of the tray load/eject lever when the worm gear is reversed. To solve this problem, the DA-11 and DA-13 use a spring which absorbs impact at the stroke ends. The spring is between the last reduction gear and the tray insertion/ejection lever.

4.1.2 Disc change mechanism

The disc change mechanism in conventional players moves the magazine and the disc load and eject mechanism stays fixed (Figure 8). The deck must be twice as high or more as the magazine (126 mm) because the vertical travel, including the magazine height, is large. The disk change mechanism in the DA-11 and DA-13 moves the disc load and eject mechanism and the magazine stays fixed (Figure 9), so the deck height is approximately equal to the height of the magazine plus the height of the load and eject mechanism (78 mm).

The magazine is of course heavy, especially when all discs are loaded, making it difficult to move. Furthermore, the weight varies depending on the number of discs in the magazine, so the operating load varies. The disc load and eject mechanism in our decks has a light moving part, much lighter than the mechanism in conventional disk.

The lower and constant weight means a small drive motor can be used and placed below the chassis. This improvement together with a smaller control board makes the deck height small, resulting in a small enclosure.

4.1.3 Pickup drive mechanism

Conventional decks use a pickup drive subassembly containing both the pickup and drive mechanisms. Our decks separate the drive mechanism and pickup chassis and achieve a small and thin pickup drive without sacrificing any features. Our decks include 8/12 cm tray indicator switches and a tray positioning guide shaft.

4.2 Applicability to different car models

One of our development aims was to make our decks suitable for different car models.

Although existing decks can be adapted to some extent, their versatility is limited. Only partial mechanical or electrical changes can be made to a deck selected as a base model. For example, a single CD player supporting 8 and 12 cm discs can have its disc sensing mechanism and control circuit changed so for 12 cm discs only. However, any changes will make installation or operation or both more difficult. We designed our decks for true versatility by adding the specialized mechanisms described below to the basic mechanisms.

4.2.1 Supporting two magazine insert and eject directions

Our deck structures support both crosswise and longitudinal directions for magazine insertion and ejection.

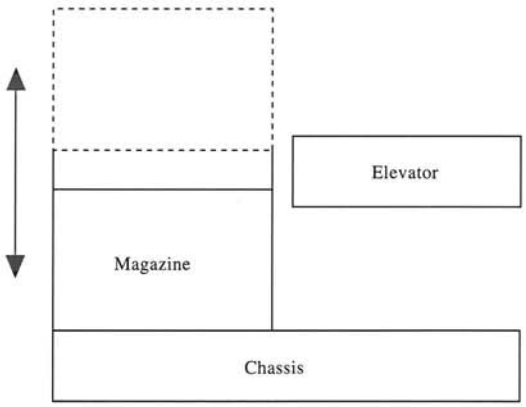

Figure 8. Movable magazine disc loading

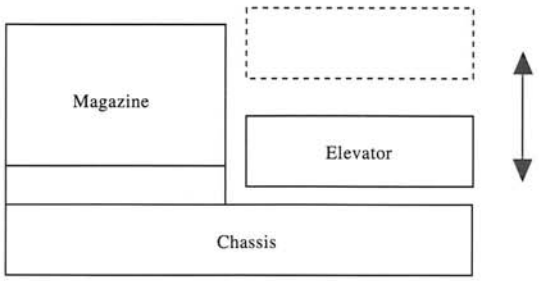

Figure 9. Fixed-magazine disc loading

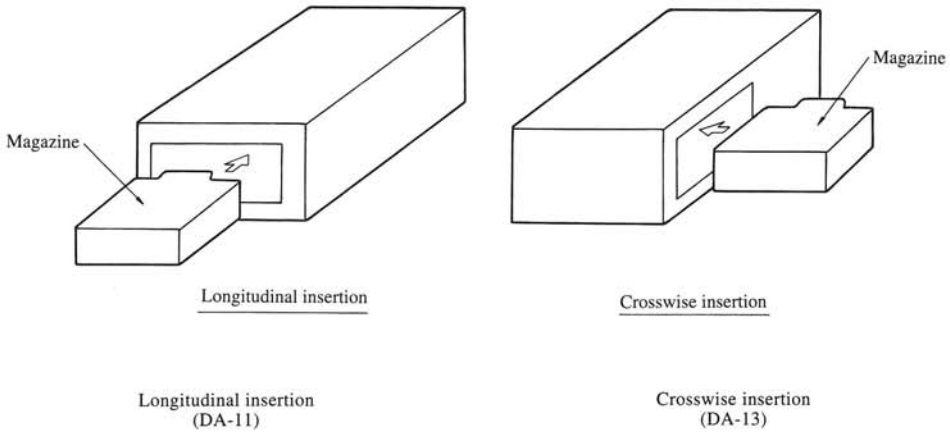

Figure 10. Magazine insertion

We did this because longitudinal insertion and ejection is preferred by car factories, and crosswise insertion and ejection is preferred for after-market audio products and options (Figure 10).

1) Magazine insert and eject mechanism

The magazine insert and eject mechanism locks the magazine after inserting it into the deck mechanism and ejects it after releasing the lock.

Two magazine insert and eject mechanisms are set up by setting two insert and eject directions. When the magazine is locked, the positional relationship of the magazine and tray load and eject mechanism are the same for both. The only difference is the insert and eject direction of 90 degrees for both mechanisms. This process has the following layout:

The cam gear, which is linked to the magazine lock mechanism, transmits motor drive to the magazine eject lever. This cam is at the bottom center of the magazine. Then, the magazine insert and eject mechanism (the magazine eject gear lever and the eject lever) and the magazine lock mechanism are rotated 90 degrees about the cam gear. This allows magazines to be inserted and ejected in two different directions without changing the basic drive mechanism (Figure 11).

2) Magazine with two insert and eject directions

Guide grooves and lock holes enable the magazine to be inserted in two different ways. The width and depth of the left and right grooves differ to ensure insertion in the correct direction.

The design of the top of the magazine for the DA-11 and DA-13 differ because of their design requirements. The two are, however, interchangeable.

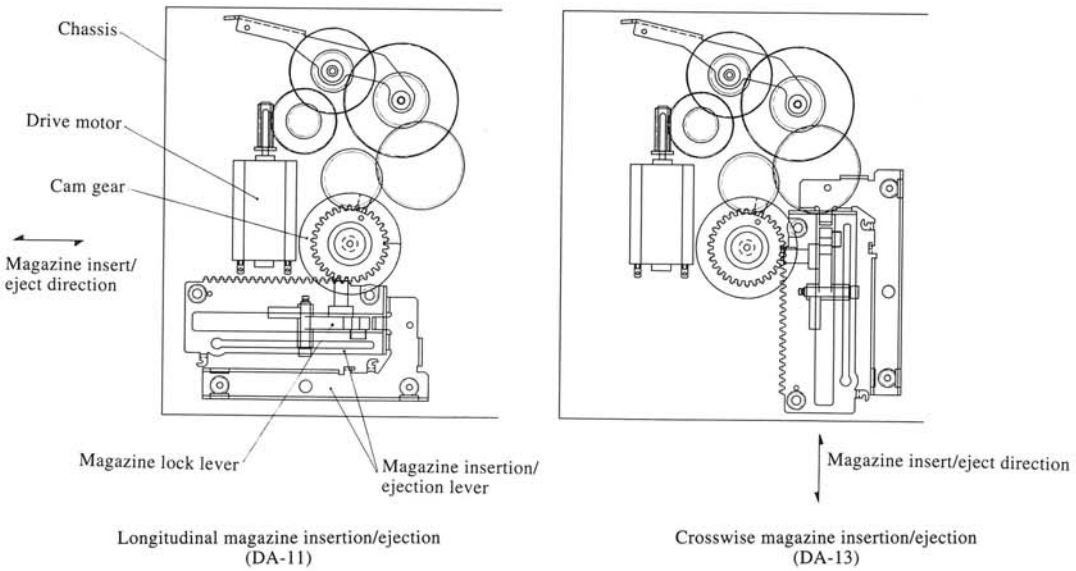

Figure 11. Insertion mechanism

4.2.2 Supporting a change in the number of discs

The disc change mechanism has an elevator which contains the tray load and eject mechanism. The elevator is moved up and down by a pantograph lever.

The drive mechanism does not have to be changed to adapt to different numbers of discs (e.g., six discs). In contrast, the feed screw method used in conventional models requires a small change to its drive system. Since the vertical travel of the elevator determines the number of discs, the number is changed by changing the stroke of the rack lever linked with the pantograph lever at the switch position.

4.2.3 Supporting two deck installation positions (DA-13)

The main drawback of auto-changers is that they are difficult to install because they are much larger than single CD players. Because of their size, they are usually installed in the trunk. It is more difficult to install them in a passenger compartment. The DA-13 solves this problem because it can be installed horizontally as well as vertically and use the space available in the passenger compartment.

The following measures make two installation positions possible:

① A motor drive is used together with springs to eject the magazine. This stabilizes ejection and minimizes the influence of the changing weight when the number of discs in the magazine changes.

② We chose the magazine insertion and ejection directions so the structure supporting the pickup lens doesn't deteriorate.

③ Changing where the floating spring is placed assures that the deck is always in the specified position with respect to the enclosure. This makes mechanical operation stable regardless of where the deck is installed and gives the deck its immunity to vibration.

④ There is a bias mechanism for the trays and discs which prevents them dropping when the disc is changed in a vibrating environment. This ensures stable ejection.

4.3 Improving performance

4.3.1 Improving resistance to mechanical damage

A damaged disc may cause sound skip when it is played back. The causes of sound skip are:

① Damage to the disc prevents correct error signals for servo control.

② If the servo circuit is on and the optics move according to the incorrect signal, servo control may fail.

To solve this problem, CD auto changers use a disc defect detection circuit which turns the servo off in condition ②.

In the disc defect detection circuit of a conventional model, transitional charging and discharging currents and circuit stabilization takes a long time.

We improved the disc defect detection circuit in the DA-11/13 and improved immunity to the mechanical damage of the disc. Figure 12 shows the disc defect detection circuits of conventional models and of the DA-11/13.

There may still be noise even when defects do not cause sound skip. Audio signals become noise when an error caused by contamination of a large area (such as a fingerprint) is too severe to be handled by error correction.

With the DA-11/13, error correction has been greatly improved (Figure 13). In conventional models, double

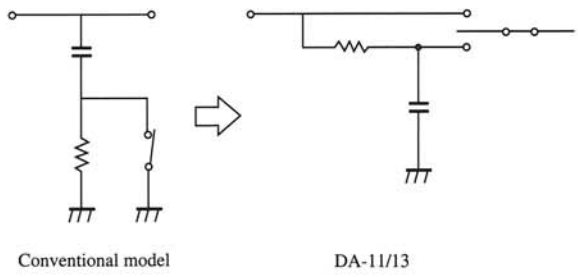

Figure 12. Disc defect detection circuit

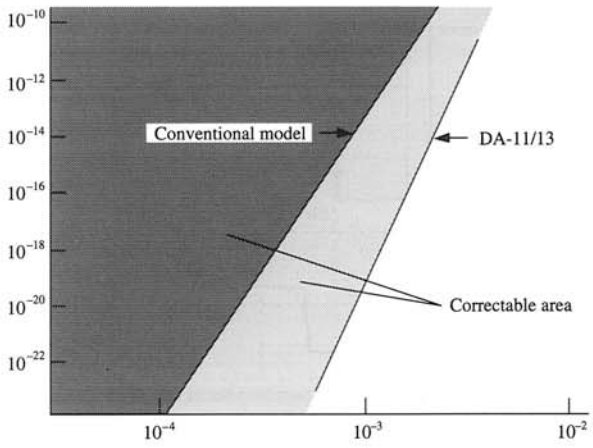

Figure 13. Error correction capability

correction is used for C1 codes and C2 codes. In the DA-11/13, quadruple correction is used for C2 codes. This error correction exploits the CD format to the full. Theoretically, continuous defects in up to 16 frames can be completely corrected. In addition, because we expanded RAM from 16K bits to 32K bits, the frame jitter margin increased seven fold from +4 to +28 frames. This greatly reduced the effect of rolling on variations in disc speed (Figure 14).

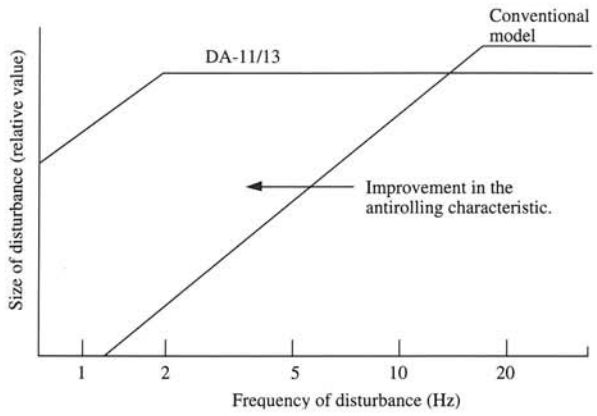

Figure 14. Antirolling characteristics

4.3.2 Moving the elevator vertically

The DA-11/13 uses a pantograph in the mechanism to move the elevator up and down for high-speed vertical movement. The elevator may overshoot the target position if the brake is applied after the target tray stop position is detected.

Our deck controls the stop position as follows: The tray just before the target tray is detected as the elevator is moving in the vertical direction. The motor drive voltage is reduced by about 40%. Braking is applied to the motor when the target position is detected, stopping the elevator at the center of the target slit. This helps reduce the disc change time.

4.3.3 Counting tray slit position

When a disc is changed while the car's engine is running, chattering may cause noise around the edge of the tray count pulse because the elevator holding the tray count sensor is vibrating. When the elevator is moving up or down, this noise may be mistaken for a count pulse and cause the search for a requested disc to fail.

The DA-11/13 masks the count pulse input for a specified period after the slits are counted. It counts only regular pulses and ignores noise in the count pulse caused by chattering. These techniques prevent count errors (Figure 15) and stabilize operation when the car is moving over an uneven surface.

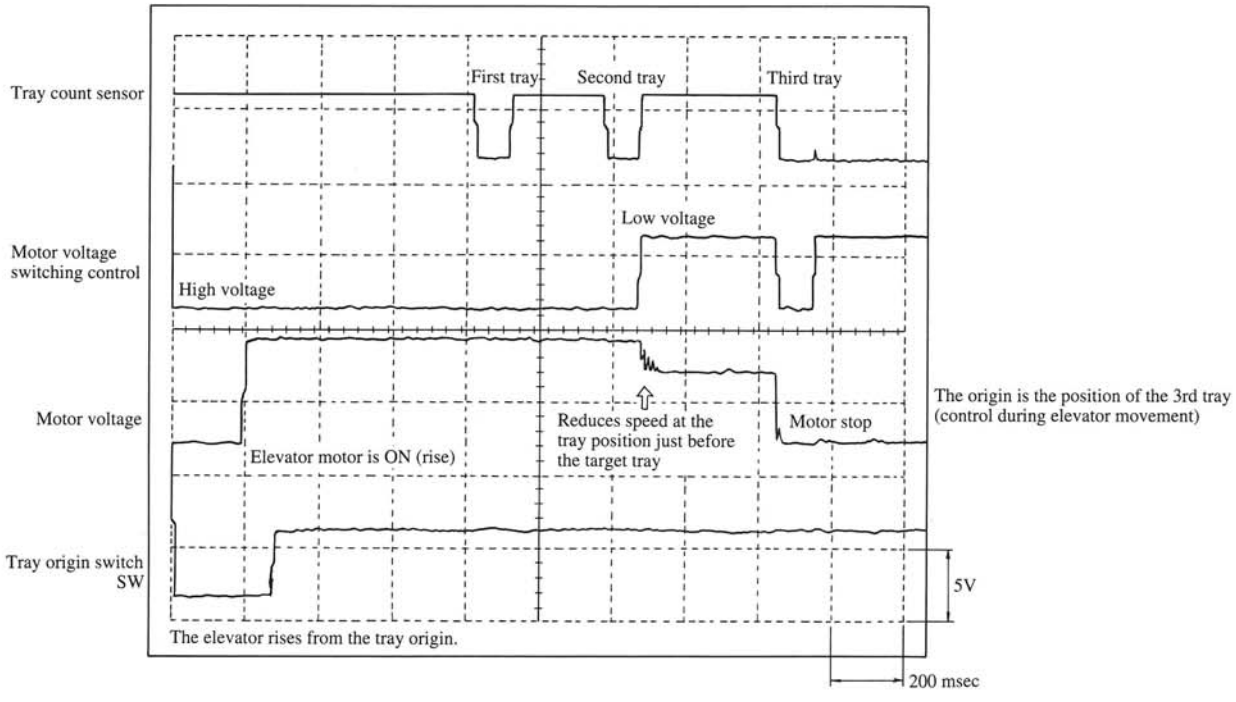

Figure 15. Motor control of disc change operation

4.3.4 Preventing disc damage

If, during disc change, the elevator rises before the disc stops rotating, the tray and outer track of the disc may scratch each other. To prevent this, a stop signal is sent to the disc motor and the elevator waits until the disc stops.

The elevator rises after disc stop has been confirmed, the discs are then changed and the magazine is ejected.

4.4 CD CRAFT Disc playback function

The DA-11 also has a ROM disc (CD CRAFT disc) playback function. This function is under the control of the LCRT. One deck changes discs, plays back music, and reads ROM disc data. When music mode restarts, music starts from the position where it stopped.

When "CD ROM mode" is selected, the CD auto-changer records the number of the last disc being played and, replaces that disc with the specified ROM disc. When an instruction to access the ROM disc is issued, the deck returns the ROM data at the specified address.

When "music CD playback mode" is reselected, the auto-changer retrieves the music disc which was playing just before the CD ROM started. Music performance then restarts at the beginning of the last track number being played.

5. Conclusion

We have described our latest CD auto-changer decks, models DA-11 and DA-13.

Toyota Motor Corporation has decided to use the DA-13 as an option and the DA-11 in factory-installation. This suggests that our aim of "multiple markets" has been met.

We plan to further improve the design technology using what we have learned during this work. We will continue to seek higher quality and performance, to make compact machines with long life and low cost.

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