25-mm-High MD Playback Mechanism (MD-02)

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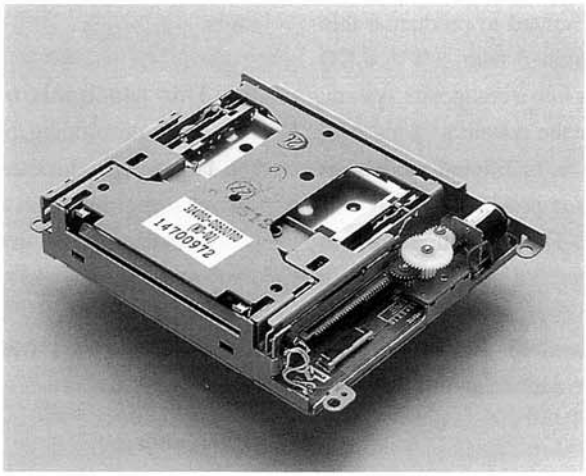


Mini disc (MD) decks first appeared in November 1992 and achieved widespread popularity in 1996. The shipment of MD decks in Japan reached five million units in 1997. We are currently aiming to produce lighter MD decks that can be used more easily than ever. In April 1995, we marketed a 1-DIN sized model that features a four-MD carousel changer in a single unit.

The single MD deck MD-02 was developed with two targets in mind: (1) We wanted a thin model that could easily be combined with a TV, a CD player, navigational systems, and other such units into a composite system. (2) We also wanted an operational response comparable to that of CD decks. The second target arose in response to a strong demand for improving traditional models in this respect. This paper discusses the techniques and procedures involved in achieving these targets.

1. Introduction

A mini disc (MD) is a storage medium that is unequaled in portability, vibration resistance, simplicity, random accessibility, and repeated recording/playback performance. In November 1992, three types of MD decks were introduced: those for use in automobiles, and the portable and stationary types. In Japan, the MD market began to expand in 1996, and the number of units shipped reached 5,000,000 in 1997. Because of their increased popularity, in April 1995 we developed a 1-DIN sized model, which features a four-disc MD changer in a single unit.

The single-deck MD-02 described here was conceived with two targets in mind. We wanted to produce a thin model that could be easily combined with, a TV, a CD player, and navigational systems into a composite system. Secondly, we wished to improve the system's operational response, which has been weak in traditional models, as noted by a strong demand for its improvement.

The MD-02 is available in a 1-DIN sized model, which is combined with an MD changer and was introduced in April 1997. It also is available as a so-called "AVN composite unit", which is a combination of a TV, a navigational system, a CD player, a tuner, and an amplifier in a 2-DIN sized compact model.

2. Features

The MD-02 is Fujitsu TEN's first single-MD deck product. It has the following features.

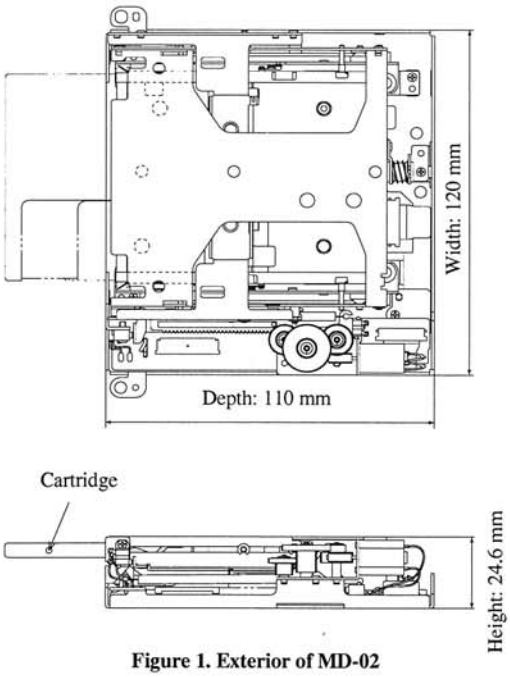


Figure 1. Exterior of MD-02

① Thin construct

A deck thickness of 25 mm, or 1/2-DIN size, was targeted so that other media add-ons (such as TVs and CDs) could be accommodated in a 1-DIN sized unit. (See Figure 1.)

② Improved operational response

Traditional models needed longer delays times between MD insertion and the start of playback and when switching from radio to MD mode and the start of CD playback. In short, traditional MD decks responded more slowly to users than CD units. When developing the MD-02, we set the goal of achieving a response comparable to that of CD units.

3. Thin Mechanism

When developing the MD-02, we considered not only the target deck thickness discussed above, but also its interchangeability with a cassette deck.

Specifically, we designed the MD-02 to be thinner than our cassette decks and have a projected area equal to that of a cassette deck. The resulting unit would measure 120 mm wide (W), 110 mm deep (D), and 25 mm high (H). (See Figure 2.)

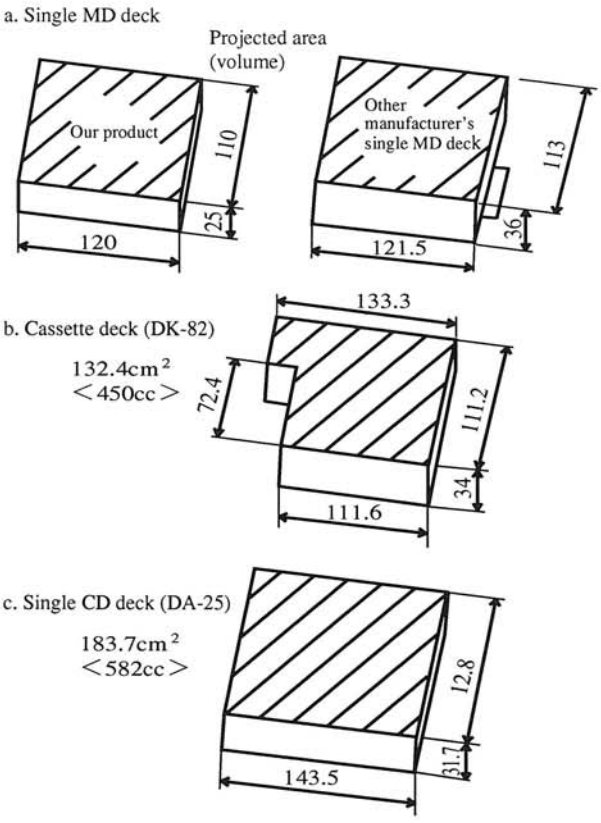


Figure 2. Sizes of MD, CD, and CS decks

We kept the above two targets in mind when developing the MD-02. Both goals were met in the successful production of a quality MD deck.

We focused on two targets to achieve a thin mechanism.

① The creation of an insertion/ejection mechanism best suited for thin decks. The components required for this mechanism should, as far as possible, be positioned peripheral to instead of on the drive unit because of the severe height requirements.

② This drive mechanism is manufactured within the company so that the components are of compatible sizes to make the drive mechanism as thin as possible, as well as to minimize the total thickness, which includes that of the deck control printed wiring board.

Our development efforts led not only to incorporating a 1-DIN sized, single MD deck with an MD changer into a single unit, but also to the development of a product equivalent to our 3-in-1 model (a 2-DIN sized CD-CS deck). This latter is included in our main composite product family, with the exception that the cassette deck is replaced by an MD deck.

In addition, we opened the way to manufacturing an MD deck substitute version of the AVN composite product, which is the 3-in-1 model with a navigation feature and is expected to be one of our mainstream products.

3.1 Insertion/ejection mechanism

The MD-02 consists of a drive unit, which plays back the disc, and an insertion/ejection mechanism, which accepts the cartridge the user inserts, places it in the drive unit, and ejects the cartridge.

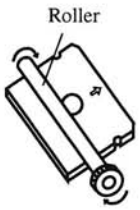
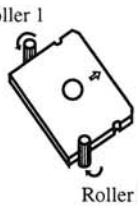
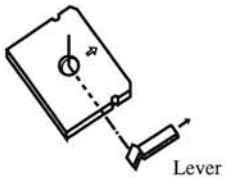
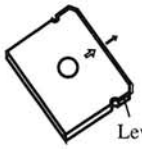
We selected a currently available cartridge mechanism while giving special consideration to its suitability for use in a thin-structured unit.

Table 1 lists the available acceptor mechanisms.

We considered the following methods as viable candidates. Method A, which is used for CD decks, method B, which is based on a roller and is used for our MD changer-combined decks, and methods C and D, which are latch based and used for cassette decks.

Roller-based methods make it difficult to thin the entire mechanism and seem to require a complex mechanism.

Table 1. Cartridge mechanisms

Method	Method A	Method B	Method C	Method D
	Roller-based	Roller-based	Latch-based	Latch-based
Illustration				
Advantages	- The disc is inserted/ejected straight even when the roller is driven only on one side (a relatively simple structure). - Since a disc insertion/ ejection stroke is utilized, there is no need for a mechanism to prevent vibrations in the roller.	- This method allows for thinner designs than those in which the roller is positioned on the upper side do.	- The shape is simple because the lever is hooked only at one place near the center.	- Since the latch mechanism is pulled at two places, the cartridge holding force and insertion/ejection operations are stable.
Disadvantages	- Thin designs are difficult to achieve if the roller is positioned on the upper side. - Because of the friction drive, the drive force is unlikely to remain stable during environmental changes.	- A straight insertion/ejection cannot be assured without the use of two rollers. - The structure is complex because two rollers must be driven. - Because of the friction drive, the drive force is unlikely to remain stabile during environmental changes.	- When the cartridge is set in the drive unit, a mechanism for disengaging the lever is necessary.	- This structure is slightly more complex than those in which the lever is hooked only at one place are.

Method C needs an latch mechanism under the cartridge; therefore, a lever mechanism is needed to disengage the lever when the cartridge is set in the drive unit, making the mechanism more complex. In contrast, method D is suitable for thin designs because the latch lever works within the thickness of the cartridge. In addition, since the cartridge latch mechanism is pulled at two points, the insertion/ejection operation is stable. We therefore selected method D.

We compared two possible methods when designing our mechanism for accepting the latched cartridge. One method is to convert the rotation of the lever into a translation by means of a cam groove, and the other uses a rack-and-pinion assembly for cartridge translation.

We rejected the first method because the rotating lever entails greater thickness, and so chose the rack-and-pinion method.

When designing the deck to be thin, we had to focus on the drive unit, because it is the component having the greatest thickness. To achieve the target thickness, it was necessary to avoid placing the insertion/ejection components on the drive unit.

Specifically, we positioned the loading motor at the right rear of the deck and designed the lever so that it translates on the right side by means of a rack-and-pinion assembly. The translating lever pulls the holder engaged with the cartridge in order to accept the cartridge. (See Figure 3.)

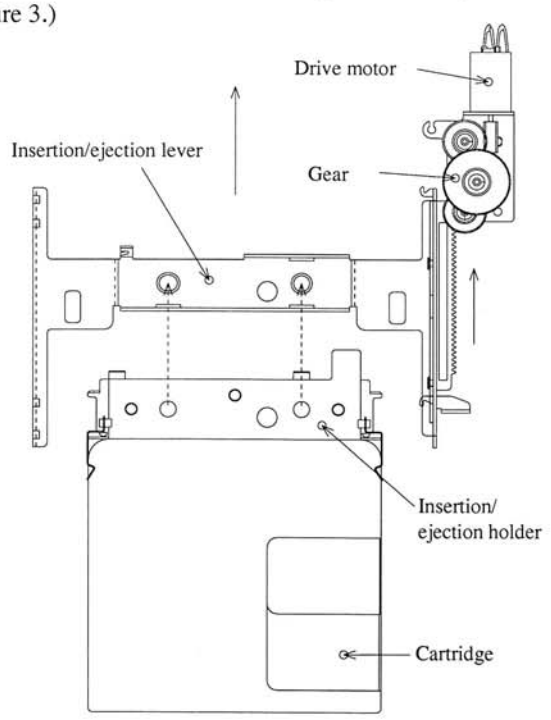


Figure 3. Insertion/ejection mechanism

3.2 Drive unit

The drive unit, which is the heart of the deck, plays back the contents of the disc. We first tried to manufacture the drive mechanism ourselves instead of relying on an outside supplier.

The true purpose for manufacturing the drive unit within the company was to gain a foothold in this field. We used components (such as a thread motor) that are smaller than their counterparts in conventional drive units and reduced the height of the gear train. With these efforts, we succeeded in designing a very thin deck. (Figures 4 and 5.)

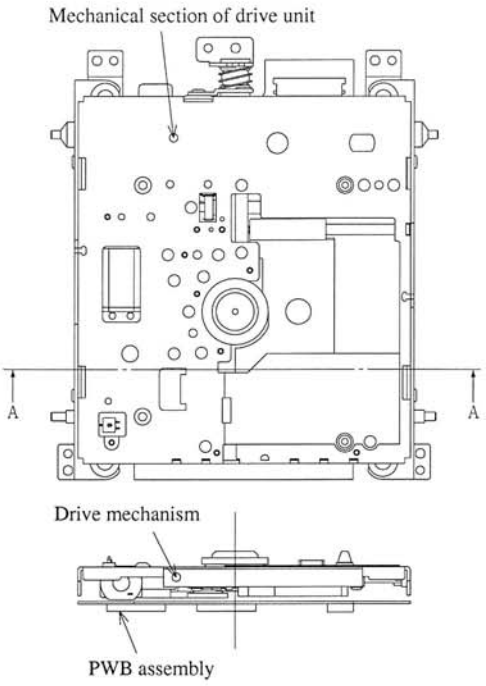


Figure 4. Exterior of drive unit

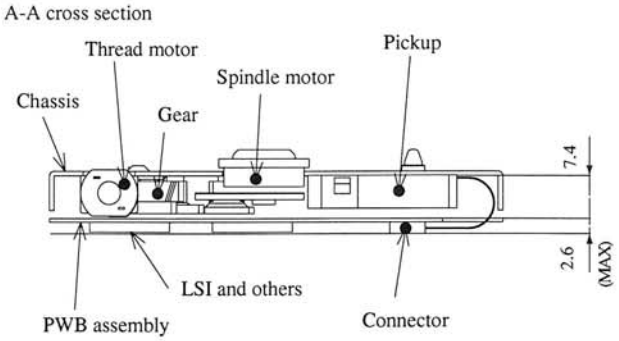


Figure 5. Cross section of drive unit

In addition, we arranged the components on the control printed wiring board so that tall components, such as the electrolytic capacitor, were positioned where the drive mechanism did not require much room. This arrangement helped reduce the total thickness of the deck.

Each component must satisfy very precise design requirements. A technique for fulfilling this need is to use outserts for the pickup chassis.

Outserts are plastic supports that hold the shaft used for sliding the pickup or for securing the spindle motor. The use of outserts can reduce variations that would otherwise add to the overall dimensions when the components are assembled.

Combining several components into a single unit makes it possible to specify precise requirements for component dimensions as they are actually used. It is thus assured that individual components can be assembled with the highest possible precision.

We plan to continue studying methods to further improve the precision and pickup performance.

4. Quick Playback Control

One of the MD-02 design targets was to shorten the playback start time. This chapter discusses the method used for this purpose.

4.1 Outline

Figure 6 compares the playback start times of our MD and CD products. In this figure, "recordable disc" means a disc on which users can record sounds and "premastered disc" indicates a playback-only disc.

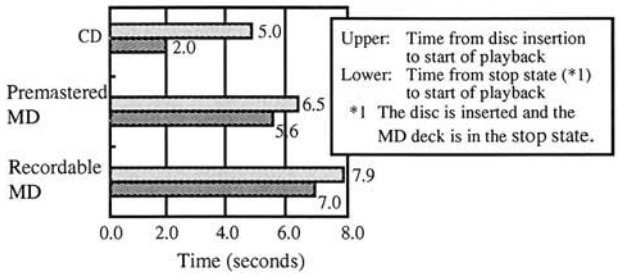


Figure 6. Comparison of playback start times (conventional type)

This figure indicates the following:

① The MD is slower in playback start than the CD.

② With an MD, there is no significant difference between the time from disc insertion to start of playback and the time from the stop state to restarting the playback.

The reason for this and our method for shortening the playback start time are discussed below.

Table 2 outlines the processes involved during the period from the time a recordable disc is inserted to the time playback starts. Table 3 indicates the differences in the processes involved in starting playback between the CD and the MD. These tables demonstrate that the process differences just mentioned and the type of disc used influence the playback start time. Note the differences between the CD and the MD in Table 3.

Table 2. Processes involved from disc insertion to start of playback

Process No.	Process	Outline of purpose
①	Disc setup	Inserted disc is placed in the deck
②	Pickup moves to the innermost track	Pickup moves to the innermost track because the TOC and UTOC to be read first are on that track
③	Disk rotation start	Start disc rotation and achieve the desired speed after the focus is taken
④	Focusing	Initiate control for maintaining a constant distance between the object lens and the disc
⑤	Servo adjustment (pits)	Optimize the focus and tracking servo for the pits
⑥	TOC data read	Read the recording time and titles for a premastered disc or the recordable time and UTOC position for a recordable disc
⑦	Move to the grooves	Move the pickup to the grooves because the UTOC to be read next is on the grooves
⑧	Servo adjustment (grooves)	Optimize the groove focus and tracking servo
⑨	UTOC data read	Read information (such as recording time and title) concerning the user's recording
⑩	Move to the track to be played back	Move the pickup to the sound data to be played back - typically the first one if the disc has just been inserted
⑪	Storage of sound data	Because one track may be recorded at different locations on the disc, inhibit playback until a certain amount of sound data is stored in memory
⑫	Playback start	Start playback when a certain amount of sound data is stored in memory

Table applies to a recordable disc

① For playback restart from the stop state, either the TOC or the TOC and UTOC are read.

② For recordable discs, both the TOC and UTOC must be read.

③ For recordable discs, an automatic servo adjustment is performed twice.

④ Playback start time depends on the position of the pickup in the stop state. (When the pickup is farther from the center, the playback start is slower, because the times for processes ② and ⑩ will vary.)

Table 3. Comparison between the number of processes for playback start in a CD and an MD

Process No.	From disc insertion to playback start					From stop state to playback restart (disc already inserted)				
	Conventional MD		CD	Conventional MD-02		Conventional MD		CD	Conventional MD-02	
	Premastered	Recordable		Premastered	Recordable	Premastered	Recordable		Premastered	Recordable
①	○	○	○	○	○	×	×	×	×	×
②	○	○	○	○	○	○	○	× (*1)	×	×
③	○	○	○	○	○	○	○	○	○	○
④	○	○	○	○	○	○	○	○	○	○
⑤	○	○	○	○	○	○	○	○	○	×
⑥	○	○	○	○	○	○	○	×	×	×
⑦	×	○	×	×	○	×	○	×	×	×
⑧	×	○	×	×	○	×	○	×	×	○
⑨	×	×	×	×	○	×	○	×	×	×
⑩	○	○	○	○	○	○	○	○	○	○
⑪	○	○	×	○	○	○	○	×	○	○
⑫	○	○	○	○	○	○	○	○	○	○
Total number of processes	9	12	8	9	12	8	11	5	6	6

Process numbers in this table correspond to those in Table 2.
Symbols: ○ - used; × - not used

Considering the above differences, we decided to apply the following two techniques to shorten the playback start time:

① Speed up the TOC and UTOC read processing
② Shorten the automatic adjustment time

These methods are discussed in detail below.

4.2 Speeding up the TOC and UTOC read processing

The TOC and UTOC are explained first below.

The innermost track of a premastered disc has an area containing a record called a TOC (Table of Contents). The TOC contains information such as the starting and ending locations and titles of the recorded tracks. A recordable disc has an area for a UTOC (User Table of Contents), which contains information about tracks recorded by users, since it is recordable/erasable.

For a recordable MD, the number of recorded tracks and the time required to play back the tracks are calculated by using information from the TOC and UTOC. Therefore, these tables must be read from the disc first.

The TOC of a CD is about 300 bytes, whereas that of an MD can be up to 10 kilobytes. In the case of a CD, the TOC data read from the disc is stored in the random access memory (RAM) of the microcomputer. Since the microcomputer is always supplied with power, the contents of the RAM are nonvolatile even when the player is in the stop state. This is why the CD's TOC is not read when playback restarts from the stop state (denoted by mark *1 in Table 3.)

The built-in RAM of conventional microcomputers has a capacity of about 2 kilobytes, too small for storing MD TOC data. Therefore, the TOC data is stored in dynamic random access memory (DRAM). Conventional MD decks introduce another problem. When the MD stops, the power to the MD control circuit, which includes the DRAM, must be turned off to reduce current consumption and digital noise. For this reason, TOC data could not be retained in DRAM. It was therefore always necessary to reread the TOC each time a playback started.

The MD-02 uses a new one-chip microcomputer with built-in RAM having a large capacity of 10 kilobytes. This makes it possible to store and manage TOC data in this built-in RAM, which is always supplied with power. As a result, the time from the stop state to the restart of playback has been greatly reduced: from 2.8 seconds to 400 milliseconds.

With the use of a large-capacity RAM, the processes for starting playback start of an MD have become comparable to those of a CD. (See the three right columns of Table 3.)

Since process numbers 2 and 10 are no longer necessary, they have no impact on the playback start time.

As explained above, the use of a microcomputer's RAM has greatly reduced playback start time from the stop state. However, this is completely separate from starting a playback after a disk insertion. Instead, RAM prolongs playback start time (by about 600 milliseconds) because additional processing is needed to transfer TOC data from the DRAM to the microcomputer's built-in RAM. The MD-02 is designed to minimize the amount of TOC data transferred to the internal RAM (by transferring only the control data) in order to reduce the impact of this transfer on playback start time.

The side effects of using a microcomputer's built-in RAM are twofold, as follows.

① Increased shock-proof memory
The DRAM area that has been used to hold TOC data is used as shock-proof memory after the TOC data is transferred to the built-in RAM. The memory increase is nine sectors, which is equivalent to about 600 milliseconds of sound.

② Support for various applications related to title display
With conventional models, disc and track titles were displayed only when the MD player was working. With the MD-02, they can be displayed regardless of the operating status of the MD player because stored TOC data is always energized a microcomputer's built-in RAM. This feature may be useful when users want to display MD track titles while listening to a CD in order to select which titles they like to play back next. In this and other ways, the MD-02 supports a variety of applications that more fully exploit the title display facility.

4.3 Shortening the automatic adjustment time

The entire surface of a premastered disc and the TOC area of a recordable disk use a recording method based on the intensity of light reflected by the disc. (The area where this recording method is used is referred to as the pits.) On the other hand, the UTOC and voice-recorded areas of a recordable disc use a magneto-optical recording method. (The area where this recording method is used is referred to as the grooves.) (See Figure 7.)

An optical pickup reads data from both types of discs. A focus servo and a tracking servo control the objective lens of the optical pickup.

The focus servo is responsible for maintaining a constant distance between the objective and the disc and for focusing the laser (control in the direction perpendicular to the disc). The tracking servo is responsible for keeping the objective on the target track in spite of track fluctuations due to disc eccentricities (control in the radial direction of the disc).

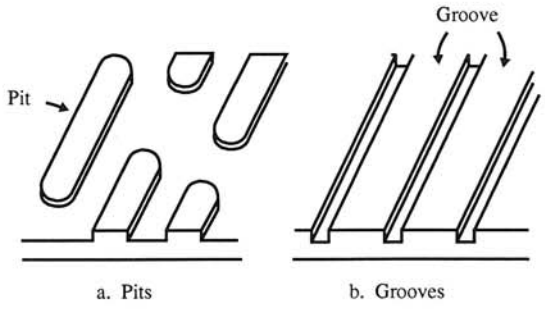


Figure 7. Disc structure

The automatic adjustment is used to stabilize the servos. The index of reflection and other optical characteristics vary from one disc to another. Such variations, if present, could cause instabilities in the focus and tracking servos. An unstable servo might result in slow track searches, a high probability of skips due to disc flaws or vibrations, and other problems. In addition to variations between different discs as discussed above, there are other variations in optical characteristics as well. These include variations arising from different recording methods (whether using pits or grooves).

To accommodate these variations, the MD-02 performs an automatic adjustment on each disc and, on recordable discs, on the pits and grooves. Three parameters for the pits and four for the grooves are automatically adjusted.

The following schemes are used to shorten the automatic adjustment time:

① Omitting adjustments
② Reducing the number of parameters to be adjusted
③ Shortening the adjustment time

The first two schemes cannot be adopted at present because of the great variations in optical characteristics among discs, as discussed above. We decided to adopt scheme ③.

Figure 8 shows the flow of an actual adjustment procedure.

When designing the MD-02, we used the following three approaches for shortening the automatic adjustment time:

① The averages of measured values are calculated by a microcomputer.
With conventional methods, a low-pass filter was used to stabilize the measured values. This involved the

need of a certain period of time for measured values to converge because the use of a low-pass filter degraded the response performance. To solve this problem, we used the following method. Parameters are directly measured at the necessary points at shorter intervals, a microcomputer calculates the averages of multiple measured values, and well-converged measurement values can thus be obtained in a shorter period of time. (See Figure 9.)

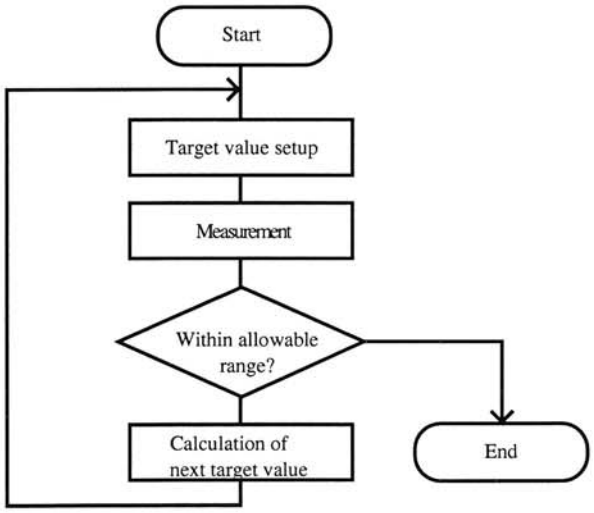


Figure 8. Adjustment flow

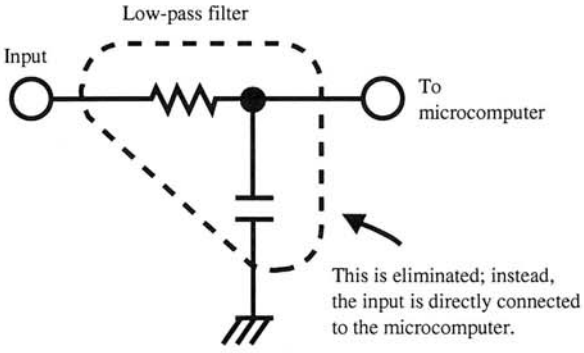


Figure 9. Measurement circuit

② Appropriate preset values are chosen. This increases the likelihood that the first measurement attempt will fall within the target range.

③ If a measured value falls outside of the target range, an adjustment is performed to increase the likelihood the next measurement attempt will be successful.

To make ② and ③ feasible, we examined the variations in pickups and discs. Accordingly, we chose preset values so that the measured values would be likely to fall within target ranges and selected target value calculation methods to increase the probability of subsequent adjustment attempt to fall within the target ranges.

4.4 Effect of new approaches

Figure 10 reveals the effect of our method on reducing the playback start time. In comparison with conventional models, the time from disc insertion to the start of playback has been reduced by 45% (3.6 seconds). What is more, the time from the stop state to a playback restart has been reduced by no less than 61% (4.3 seconds), which is comparable to that of CDs. In this respect, the MD-02 is faster than any MD deck offered by another manufacturer.

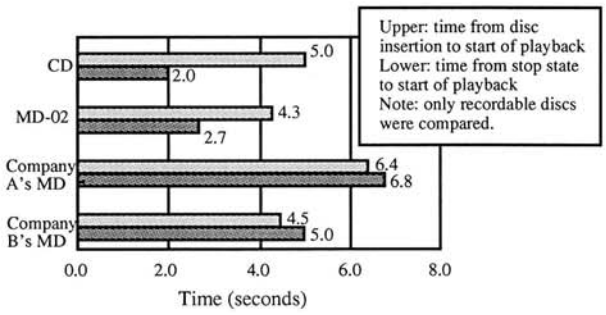


Figure 10. Effect of our method for shortening the playback start time

5. Conclusion

This paper gave a brief description of the MD-02; a thin, single-MD deck we have recently developed.

We achieved the goals we set of ① producing a thin deck and ② providing a good operational response. We also demonstrated the MD-02 to be ideal for automotive MD decks.

As stated in the beginning of this paper, the MD market is ever expanding and promises continued growth in the future. We plan to further our efforts in developing new MD decks by taking advantage of the know-how we accumulated while developing the MD-02.

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