Development of Blu-ray Deck Mechanism for Vehicle

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Abstract

Since the TV broadcasting system has transitioned from analog broadcast to high-definition digital broadcast, thin hi-resolution digital televisions are now widely used at home. After having been used to watch high-definition images, a user is hardly satisfied with the image quality provided from a DVD disc. Therefore, the sales of high-resolution contents, Blu-ray discs, have been steadily increasing since the discs have been released in 2006. It is safe to assume that Blu-ray will be sold in the higher rate exceeding 30% among the image media sold in 2012, and will become the main image medium in the future. This paper introduces the in-vehicle deck mechanism that supports the Blu-ray discs for replay.

1 Introduction

FUJITSU TEN, as follows, has early started developing in-vehicle deck mechanisms for optical discs; CDs, MDs and DVDs, to put them into the market.

- **1983: World-first CD deck mechanism**
- **1997: World-first in-dash changer deck mechanism**
  MD deck mechanism
- **2000: DVD-ROM deck mechanism**
- **2002: DVD-VIDEO deck mechanism**
- **2005: In-dash DVD changer deck mechanism**

Especially, the DVD deck mechanisms have been adopted by many customers, and more than 2.5 million DVD decks have been manufactured annually in 2011. Now, we can see the vehicles equipped with our DVD decks all over the world.

A Blu-ray disc, a candidate of the next-generation medium that replaces a DVD disc, has been increasing in sales since its release in 2006, and will account for more than 50% of the entire video disc sales in 2015. Therefore, the demand for playing Blu-ray discs in a vehicle will grow. It is assumed that in-vehicle larger displays will become common in accordance with the spread of tablet information terminals, and that the demand for the in-vehicle decks replaying high-definition Blu-ray discs will grow. This paper introduces our new Blu-ray deck BD-01 that we have developed by utilizing the accumulated know-how obtained through optical disc deck development.

2 Purpose of Development

Here is the concept for developing the Blu-ray deck, BD-01.

2.1 Compatibility

The product equipped with the Blu-ray deck is developed based on the product equipped with a DVD deck. We have set prospective models as follows: a standard model equipped with a DVD deck, and a premium model equipped with a Blu-ray deck. For easier replacement of the DVD deck with the Blu-ray deck, we have designed the structure of DVD deck product compatible with the prospective Blu-ray deck from the beginning of the planning step of designing the DVD mechanism.

2.2 Approaches to Various Disc Media

We have set a goal for designing the deck that supports all types of 8cm/12cm optical discs currently available in the world, including DVD high-definition record format of AVCREC and AVCHD, as well as BD, BD-R and BD-RE.

2.3 Challenge to develop mechanism available in vehicle

In order to develop an in-vehicle Blu-ray deck, we have extracted tasks based on Blu-ray standards and the operation benchmark on consumer products, and have set target values before the start of designing. Aiming at stress-free operation in a vehicle cabin where the deck is assumed to be used, as well as considering the items relevant to the vehicle environment, such as heat and vibrations, we have improved the usability: for example, to shorten the start-up time, and to improve the resume feature (replay from the next part of the contents).

3 Ensuring Compatibility

We have set our development concept for the Blu-ray deck BD-01 (**Fig. 1**) to installation compatibility so that the DVD deck DV-05 (**Fig. 2**) can be easily replaced with BD-01. Concretely, we have developed BD-01 so that BD-01 and DV-05 have a common mechanical interface regarding such as a deck outer shape (some portions vertically higher), a height of deck opening, and ease of installation to the product. We have tried hard to adopt common parts for the purpose of quality stability. As a result, the common parts accounts for 85%, and especially the common parts of an ejection-insertion mechanism accounts for 100%.

Fig.1 BD-01

Fig.2 DV-05

3.1 Method for Achieving Installation Compatibility

A Blu-ray pickup with right and left objective lenses is wider in the outer shape than a DVD pickup. Therefore, if the feed angle of the Blu-ray pickup is set at the same angle as DV-05, the outer part of the pickup protrudes from the deck outer shape (**Fig. 3**). Setting the pickup of BD-01 at optimized angle (40° instead of 29°) allows the Blu-ray deck to be compatible with the DVD deck (**Fig. 4**). Moreover, the changes in the vicinity of a pickup drive are minimized.

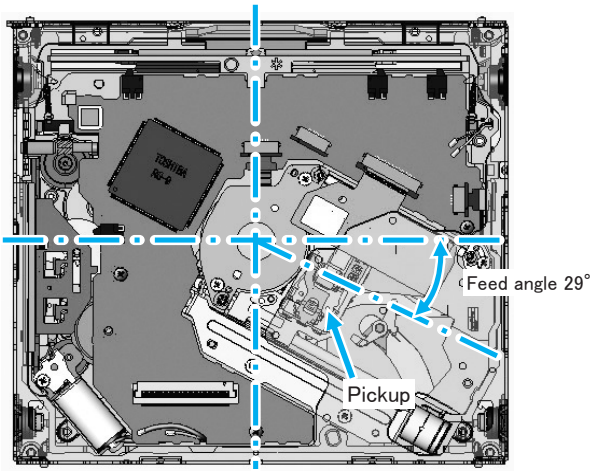

Fig.3 Pickup Layout on DV-05

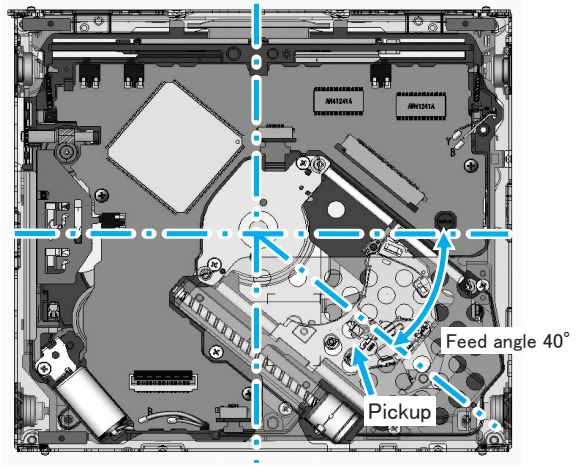

Fig.4 Pickup Layout on BD-01

4 Overview of System

Setting our concept for developing BD-01 to have compatibility in system configuration with our DVD decks, we have developed two types of decks; ROM deck and ROM+VIDEO deck, both of which adopt the same mechanism but different electric circuit boards.

The ROM deck adopts Serial-ATA as communication interface unlike the DVD decks adopting Parallel-ATA, in order to support high-speed data transmission. Besides, the ROM deck adopts pattern designing, shielded FFC (Flexible Flat Cable) and connectors for impedance matching in signal path, in order to ensure communication quality and EMC performance.

The ROM+VIDEO deck provides functions in combination of the ROM deck described above, and the newly-developed AV decode circuit and its software that provide an AV decoding function and application functions equivalent to the conventional deck functions. The ROM+VIDEO deck has compatibility with the conventional DVD ROM+VIDEO deck through ATA bridge (Serial-ATA<->Parallel-ATA) on the AV decoder board and adjustment of the signal array of interface connector. The deck is newly equipped with full HD analog component video output and 7.1 digital audio output. Taking into consideration the installation on the various types of existing products, we have developed the system that has the audio video output equivalent to the conventional quality, and that can be adopted in the various products from a high-end product that provides high-quality images and sounds to a low-end product that has only to support Blu-ray discs for playing. In addition, the ROM+VIDEO deck is already prepared for prospective installation of a digital video interface for digital video output in conformity with the ban on analog video output of Blu-ray contents, starting from 2014.

Both of the ROM deck and the ROM+VIDEO deck are designed to have upper compatibility with the existing DVD deck specifications regarding the command interface

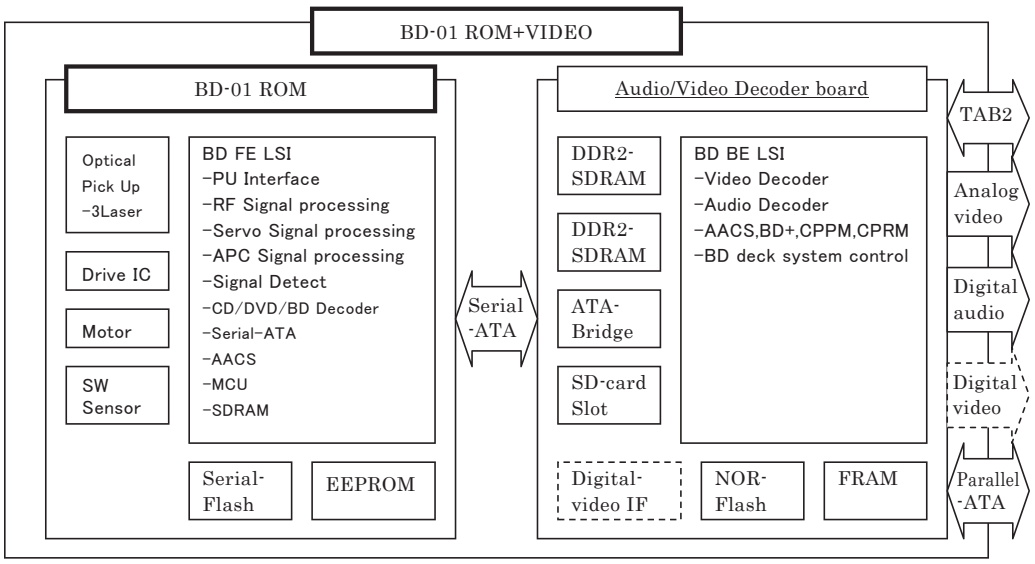

Fig.5 System Block Diagram

with a host microcomputer. This helps to reduce the resources in designing the deck control software that is installed in the host microcomputer and that is designed both for the DVD deck compatible with Blu-ray and for the newly-developed DVD & Blu-ray model.

5 Challenge to Develop Deck Available in Vehicle

5.1 Shortening of Start-up Time

Consumer Blu-ray players normally take time for start-up, from application of power to video/audio output (approx. 1 minute from application of power to start of playing).

This period of time is absolutely long compared to the periods taken by the existing in-vehicle DVD deck (DV-05) or others. In the situation where a user has to wait for approx. a minute before the start of playing every time an engine is started, usability is lowered, which is the largest issue to be solved for developing the deck available in a vehicle.

Although the first thing we have to do to solve this issue is to set the target value for the start-up time, there has been no Blu-ray deck as a product at the time. Competitors also had no appropriate in-vehicle products available for benchmarks. Therefore, we conducted in-house survey of usability, as well as benchmarking consumer products and competitors' in-vehicle DVD models. Based on those results, we have set respective target values for BD-01 as follows: 9 seconds as the target value for CD, 10 seconds as the target value for DVD (these two values are equivalent to the existing DVD decks), 23 seconds as the target value for Blu-ray (the limit value that a user can tolerate). Then, we have taken the following measures to achieve these target values.

- **Change of system configuration**
- **Optimization of Linux start-up processing**
- **Optimization of disc judgment processing**

5.1.1 Change of System Configuration

The deck that plays Blu-ray discs requires Linux as an OS, to satisfy standards and conform to the size of software. Since the Linux takes longer period of time for start-up, the deck naturally takes longer period of time to provide videos/audios.

The new BD-01 has the LSI including two CPUs inside: the one including Linux as an OS; the other including μiTron as an OS. The μiTron-installed CPU that is superior in real-time response and that takes shorter period of time for start-up controls the entire system and playing of CD/DVD. The Linux-installed CPU controls playing of BD. This system configuration for playing CD/DVD allows for audio/video within the period of time equivalent to the existing DVD decks.

In the conventional system configuration, only the Linux-installed CPU controls two start-ups in the order: system start-up⇒Linux start-up. However, in the new system configuration, the μiTron-installed CPU controls the system start-up, and concurrently the Linux-installed CPU controls the Linux start-up. Therefore, this system configuration also speeds up the Linux start-up time by approx. 9 seconds.

5.1.2 Optimization of Linux Start-up Processing

Speeding up the Linux start-up time relevant to playing of Blu-ray discs is further required. Since the base software has been designed for home use, we optimized the software for use in a vehicle. Concretely, we analyzed the details of the various kinds of processing conducted at the Linux start-up, such as network connection, mounted various file systems and log output at the start-up, redesigned wait time, and omitted unnecessary processing. As a result, we succeeded in shortening the Linux start-up time by approx. 14 seconds, which used to take approx. 19 seconds.

5.1.3 Optimization of Disc Judgment Processing

We have optimized the disc judgment processing conducted after the Linux start-up, as well. Concretely, we omitted the processing for confirming whether the files not targeted for playing (files for use on PC) are included, and redesigned the disc-read process in AACS license processing that is required specially for playing Blu-ray discs. As a result, we also succeeded in shortening the start-up time by approx. 12 seconds.

At last, we have succeeded in speeding up the start-up time regarding playing Blu-ray discs by approx. 35 seconds in total [(i). approx. 9 seconds, (ii). approx. 14 seconds, (iii). approx. 12 seconds)], and achieved the target values respectively for CDs and DVDs. This eventually gained an advantage of our products over competitors' products.

Table 1 Target Start-up Time and Current Time

Medium	Test disc	Start-up time (sec)		
		Target	Before	Current
Blu-ray	ABD-520	23.0	52.0	17.5
DVD	TDV-520C	10.0	32.0	9.2
CD	TCD-785	9.0	30.0	8.5

Table 2 Start-up Time Comparison with Other Companies

Medium	Test disc	Start-up time (sec)	
		Competitors' in-vehicle products	FUJITSU TEN
Blu-ray	ABD-520	18.3	17.5
DVD	TDV-520C	17.0	9.2
CD	TCD-785	14.9	8.5

5.1.4 Shortening of ROM Drive Start-up Time

Along with the shortening of AV decoder start-up time described above, we also challenged speeding up ROM drive start-up.

Control relevant to the characteristic variation of the discs and the decks (mechanisms and circuits) is required to read the data stored in the disc correctly. Conventionally, this control is conducted when a disc is inserted or when power is turned on. This time, the control due to the deck part is conducted in advance in production process, and the result is stored in the non-volatile memory installed in a deck. This enables accurate control in a stable condition as well as shortening the control time since secondary control can start at the vicinity of the optimum value.

5.2 Resume Function for BD-Java Application Disc

There is a Blu-ray specific standard called BD-Java, unlike the conventional DVD standard. The BD-Java is the playing method first introduced in the Blu-ray standard. Executing the program written in a Java language (hereinafter, referred to as BD-Java application) downloaded from the disc into the deck control software provides more interactive operation (e.g. elaborate menu, games and internet connection) than the conventional DVDs. The Resume function is capable of starting playing from the point last-time stopped during playing because of ACC turned off or on, or transition of a mode to another such as to a radio mode.

The deck control software installed in a conventional DVD deck controls the order of the contents to be played and others based on the control information stored in the disc. When ACC is turned off, the deck control software stores the control information in the non-volatile memory. Then, when ACC is turned on, the deck control software reads out the stored control information to provide a resume function. In the BD-Java, the playing order and others are controlled by the BD-Java application, not by the deck control software. The BD-Java application, unlike on the DVD deck, does not have the control information to be stored in the non-volatile memory. The capacity of the non-volatile memory is too small to store the operation condition as is of the BD-Java application (hundreds of megabytes required at maximum).

However, the resume function is mandatory for in-vehicle products that are restarted every time the engine is started. After examination of various methods, we have achieved the function capable of playing videos/audios from the stopped point on the main part of a movie (**Fig. 6**).

Playing the part other than the main part of a movie by use of the resume function may cause a functional problem during playing. Thus, the important point for developing the resume function is whether the function can identify the video having been played as being in the main part of the movie.

We have developed the algorithm for the identification based on the combination consisting of various parameters of database file stored in the disc (playlist, number of point marks of chapters, time information, user operation setting, etc.). Thus, the main part of the movie can be played by a pseudo resume function without the BD-Java application being run when ACC is turned on, which provides only the videos/audios of the main part (not providing the menu or others controlled by the BD-Java application).

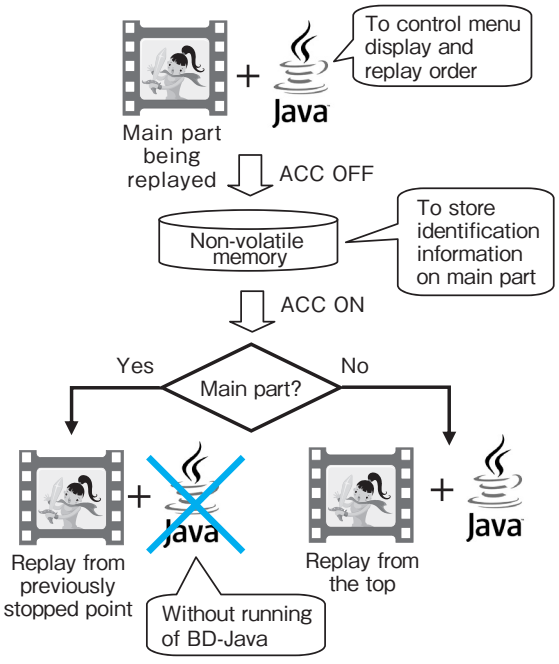

Fig.6 Pseudo Resume Processing Image

5.3 Operation under High-temperature

The pickup itself of the Blu-ray deck generates more heat due to its configuration where the pickup reads three-wavelength lasers and includes a laser drive circuit inside. In this reason, the pickup is subjected to higher temperatures than the conventional DVD deck. The Blu-ray lens installed in the pickup is made of the optical plastic material that tolerates Blu-ray wavelength close to ultraviolet rays. Thus, the heat resistance performance of the Blu-ray lens degrades relatively easily. To solve this problem, heat release around the pickup is necessary. To release more heat around the pickup, vent holes are set respectively on a main chassis and on a PU chassis (**Fig. 7** and **Fig. 8**).

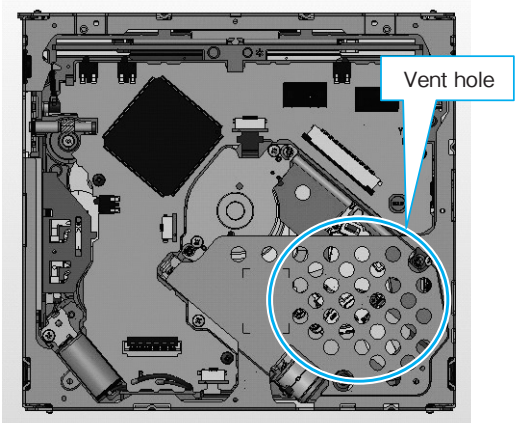

Fig.7 Heat Release Hole of Deck Chassis

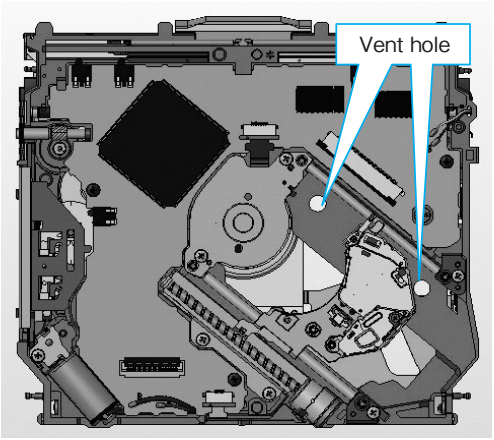

Fig.8 Heat Release Hole of Pickup Chassis

When a laser diode is subjected to the environment heated above its temperature limit, thermal runaway may occur on the laser diode due to the positive feedback relevant to the current increase, which may result in destruction of the pickup for playing. On the conventional DVD decks, the thermistor set on a printed board detects temperature to protect the pickup by stopping the operation before reaching the temperature limit. However, Blu-ray decks had less accuracy in temperature measurement. This is because the temperature is measured at the point on the printed board set far from the pickup itself generating higher heat, and the generated heat narrows the temperature margin up to the temperature limit. On the BD-01, the accuracy of temperature measurement is improved by use of the pickup itself equipped with the thermistor. Therefore, the BD-01 is capable of surely stopping operation for protection before reaching the temperature limit.

5.4 Improvement of Vibration Performance

The Blu-ray deck requires more a precise follow-up servo than the DVD deck because of a smaller optical spot size and a shorter track pitch. To conform to the size and the pitch, we have redesigned the servo for Blu-ray deck based on calculation (**Table 3**).

Table 3 Redesigned values for servo due to differences of discs

Optical spot size		Track pitch	
DVD	Blu-ray	DVD	Blu-ray
1.32μm	0.58μm	0.74mm	0.32mm
Focus detection width		Tracking detection width	
DVD	Blu-ray	DVD	Blu-ray
9μm	2.6μm	0.37μm	0.16μm
11dB Gain Up		7.3dB Gain Up	

While improvement of the vibration performance has been expected at a design phase, we found, at an evaluation phase, the problem of the vibration performance falling at the rage between 90Hz and 100Hz. A 12cm-disc medium has resonance point normally in the range from 90Hz to 100Hz. In addition, the pickup equipped with two lenses for reading Blu-ray discs weighs more and its weight balance becomes worse, resulting in the resonance point of a tilt actuator (ACT) falling to the range from 90Hz to 100Hz (**Fig. 9**). This causes the ACT rolling, which becomes an obstacle to normal playing.

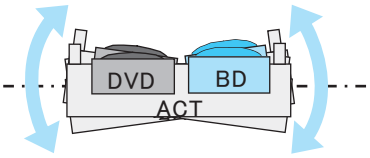

Fig.9 Rolling of TILT Actuator

As a primary solution method, sliding the resonance point of ACT tilting or rebalancing the weight is taken. However, while we try to lower the price of the deck by designing the pickup utilizing the one of the consumer products, it becomes hard to achieve our price target if we take these methods for customizing the pickup design only for in-vehicle decks. What we took for improving the performance is to insert in the BD-01 the circuit for correcting rolling of the PU lens (**Fig. 10**).

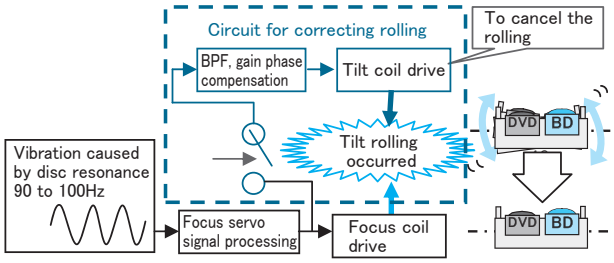

Fig.10 Block Diagram of Rolling Correction Circuit

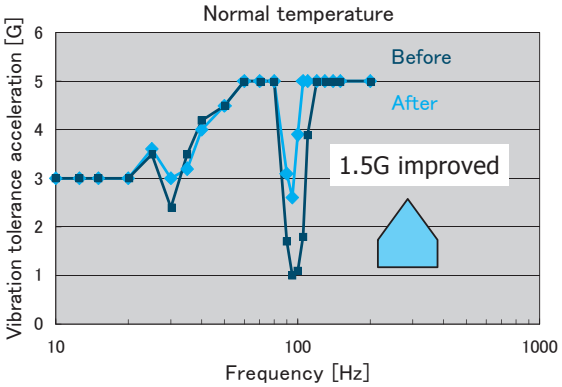

Fig.11 Rolling Correction Circuit Effect

6 Challenge in Quality

6.1 Self-check/Self-diagnosis Function

The important point to improve deck mechanism quality in the market is how to detect problematic mechanisms at a production process to prevent those mechanisms from being offered for sale. So far, in accordance with functional addition from CD function to DVD function, we have been building up our checking system for detecting the problematic deck mechanisms at the production process, by adding checking items and measurement devices. However, the complicated checking system and the abrasion occurred in accordance with increased production produce quality destabilizing factors in the checking system. Naturally, we have been taking time to maintain the checking system to provide stable checking

(Fig. 12).

In the new simple process we have developed for improving quality, the developed Blu-ray deck itself is capable of conducting required checking without checking/measuring instrument (Fig. 13). Eliminating the unstable part of the process, not mending the unstable part, provides us with more reliable checking process.

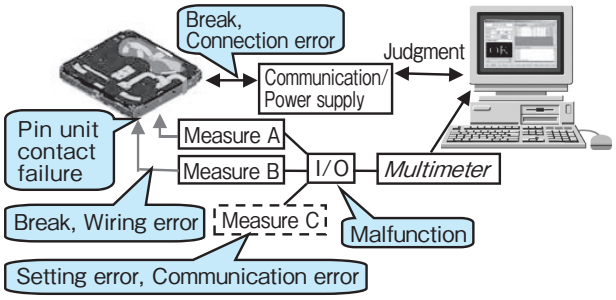

Fig.12 Conventional Process

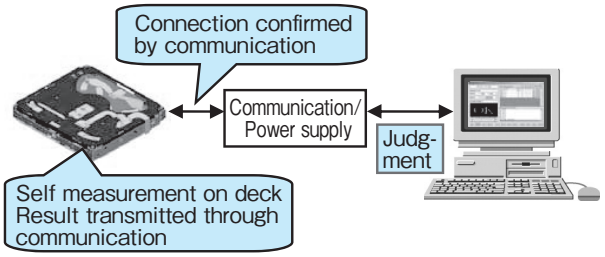

Fig.13 Simplified Process with Self-Check

Since LSI is highly integrated and upgraded, and its internal processing is digitalized, it is harder than before for the person other than the designer in charge to analyze the problematic product, and also, it takes time to find out the cause. And besides that, since the manufacturing factories are located outside Japan, it is impossible for the designer in charge promptly to be present at the scene of analysis. Moreover, the problem may not be found on the working deck even if the deck itself has a problematic part, which is because the deck controller includes a potent fail-safe/controller function. Therefore, checking only OK/NG response for each function is not proper measure to find out the problematic part.

The newly developed deck including the self-diagnosis function diagnoses whether the deck itself behaves properly, so as to detect the problematic mechanism that is not found through the functional checking. For example, the newly developed deck is capable of detecting sensor/SW malfunction and an abnormal motor/mechanism load based on the detection on whether the voltage value or transition/timing of the sensor voltage value conforms to the design value on the installed working deck. This allows the analysts even who do not have specialized design knowledge to narrow down the problematic part.

Moreover, we use these self-check / self-diagnosis functions as a product diagnosis function. The function that is capable of determining whether the product behaves properly or whether the disc is defective or not on the in-vehicle deck as is without being taken off from the vehicle is demanded by market service field. We have developed the function that satisfies these demands by use of the measurement function included in the deck.

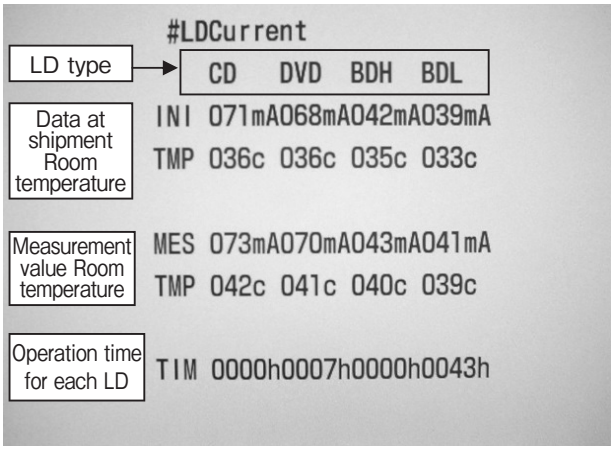

Fig.14 Sample Display of Diagnosis Result regarding Laser Current Value

There is a failure mode where the playing function on the disc player having been used by a user for long time does not work because the current value increases due to the deteriorated laser diode. The BD-01 has the function by which an analyst or others can check on a display whether the laser deteriorates or not based on the data measured at present and the data stored in EEPROM as the measurement data at the process check, regarding respective CD, DVD and BD lasers (Fig. 14). The function can also store and display accumulated operation time for respective lasers.

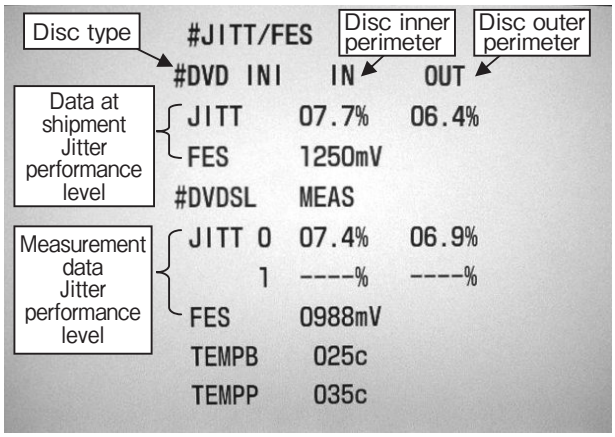

Fig.15 Sample Display of Diagnosis Result regarding Jitter Performance

As another index for playing performance regarding the deck and the disc, jitter performance is used. The jitter performance used to be measured on the condition of the deck alone by a specific measurement device. However, the BD-01 is equipped with the self-diagnosis function capable of displaying the jitter performance measured on a finished product by use of self-check function (Fig. 15). Whether the deck behaves properly can be judged through the comparison between the data stored in EEPROM as the data measured at the process checking and the data measured by use of a test disc.

Moreover, carrying out the measurement by use of the customer disc with which the deck has a problem in playing, whether the disc is defective can be judged through the comparison between the measured data and the values measured by use of a test disc.

6.2 Response to Irregular Disc

The analysis on failures occurred at market on the conventional DVD decks revealed that 90% of causes relates to irregular discs.

Looking back our responses to the irregular discs on our previous models, we have taken a so-called "follow-up method" where the responses are made every time the failures are pointed by users, to upgrade quality. However, the number of the Blu-ray standard issues is simply triple the number of the DVD standard issues (**Table 4**). Taking the conventional development method, the number of the Blu-ray-relevant failures received from the market will be simply triple the number of the DVD-relevant failures.

Table 4 Item Number Comparison between Blu-ray Standard and CD/DVD Standard

Blu-ray (New medium)

Medium	No. of standard issues
BDAV	550
BDMV	720
BD-J	2,208
Total	3,478

CD/DVD (Existing medium)

Medium	No. of standard issues
CD	258
DVD	884
Total	1,142

Therefore, based on our new policy, we have designed the BD-01 with the fail-safe function, unlike the conventional follow-up method, in its specifications regarding all of the standard issues covering irregular discs at the design phase.

We have developed the specifications based on the following concepts:

①Even irregular discs are played as much as possible

e.g.) Error string in file identifier

↓Before	↓Improved
Replay stopped upon detection of outlier	Replay continued despite error

②Playing is normally terminated even at failure part. (Disc ejected without freezing)

e.g.) Data length error (Value defined by standard)

↓Before	↓Improved
Runaway with memory destroyed due to outlier	Replay continued by use of fixed value

③Replay continued by skipping failure part

The deck with the specifications developed based on the concepts above has gone through problematic parts (approx. 150 parts). The BD-01 is our first but successful Blu-ray deck that is capable of adapting first-time irregular discs.

7 Conclusion

This paper described the overview of our newly-developed Blu-ray deck BD-01, and the technology for its development. The deck as an OEM product has been shipped since March 2012, and has been introduced to Japanese market since June. In addition, we have received nominations from some OEM Tier 1 customers. We are confident that the Blu-ray deck has been successfully developed as intended, as shown by these mostly positive responses.

We have been developing this deck, cooperating with part suppliers and design companies. We would like to express our heartfelt thanks to everyone involved including the OEM customers, for their technical cooperation and guidance for this development.

※ Blu-Ray Disc is a trademark.

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