

# *Development of DV-05: Miniaturized DVD Deck*

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## **Abstract**

Since we, at FUJITSU TEN LIMITED, commercialized the DVD-ROM deck for navigation systems in April 2000, we have mass-produced many types of DVD decks. With the recent AVN products equipped with DTV or other features, the interior space for DVD deck in AVN products has become less and less, and the deck itself is further required to be miniaturized and thinner. To accomplish this requirement, we redesigned the parts-layout significantly in conventional models, redesigned the PCB position, applied small damper and found other solutions. Besides, being environmentally responsible, we used resin parts instead of large sheet metal parts, saved weight by means such as downsizing the metal sheet parts, and applied POM (Polyacetal resin) with lower generation of formaldehyde. In this report, we introduce the DV-05: DVD deck, developed as outlined above.

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**Introduction**

Since the first DVD was introduced as a digital video media to the market in 1996, DVD began spreading, and today, it has completely taken over the job for which videotape was once responsible. The on-vehicle DVD market has spread for navigation purpose and has become established for entertainment (video) purposes, and has expanded rapidly from 11 million units in 2005 to 17.2 million units in 2010. Since Fujitsu Ten commercialized the DVD-ROM deck for navigation systems in April 2000, our production prospect in 2008 has now reached 2.5 million units. However, the worldwide DVD market is highly competitive, which requires meeting the needs of the market in terms of function, performance, as well as cost. Here, we would like to introduce our new DVD deck, DV-05, which we regard as the culmination of what we have achieved in the DVD deck technologies over all these years.

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**Development Objectives**

With the recent AVN products for Japanese market equipped with DTV or other features, the interior space for DVD deck in AVN products has become less and less, and the deck itself is required to be miniaturized and thinner. As environmental concerns are emphasized, fuel economy is an important task for auto manufacturers, and so the weight of decks must be reduced. Besides, reducing VOC (Volatile Organic Compounds) is now an urgent task, because some kinds of plastic include VOC harmful to human health, just as sick house syndrome has become a problem.

Set out below are our objectives for developing new DVD (DV-05), in order to satisfy the requirements from market / customers. These objectives were based on our research into major seven customers' required specifications and the benchmark evaluations conducted by five companies.

**Effort to thinning / weight saving**

- Deck height (for 8cmdisc): 26mm to 18.5mm

**Effort responding to environmental concerns**

- Weight: 570g to 350g
- Using low VOC resin material

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**Overview of System**

In DV-05, the same as DV-04 (mass production model), two types of models were developed. One is ROM dedicated model, and the other is ROM + VIDEO model equipped with video decoder. Both models follow DV-04 in the system configuration.

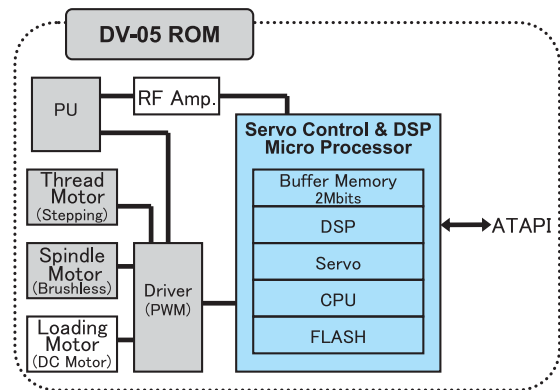


Fig.1 DV-05 ROM Block Diagram

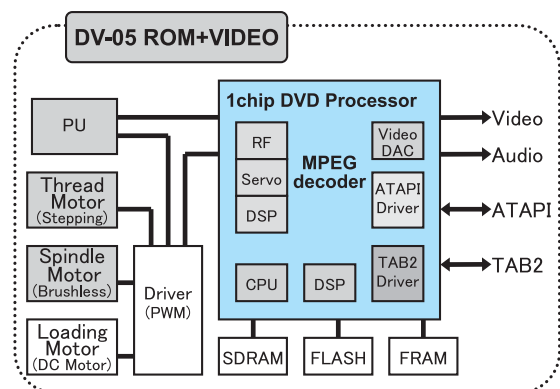


Fig.2 DV-05 ROM+VIDEO Block Diagram

The main PCB was to be downsized / changed in shape to achieve the development objective, "action to thin a deck" for DV-05.

For this action, by using a compact size driver IC and downsizing / reducing peripherals such as a capacitor, comprising of each circuit, the PCB was downsized in surface by approx. 30% and also responded to the change in shape.

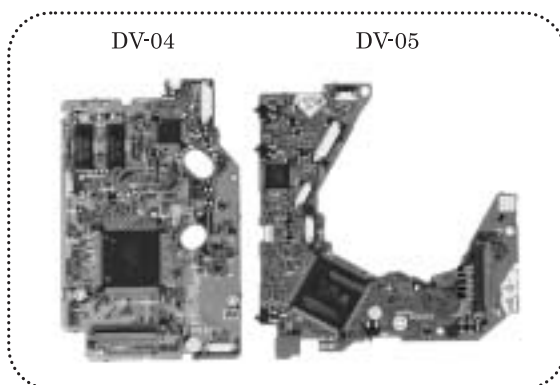


Fig.3 Comparison of Main PCBs

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**Downsizing / Weight Saving**

All DVD decks of Fujitsu Ten from the first DV-01 to DV-04 have been developed as thin type decks with the outer dimensions of all models in the size of W140 ×

D128 × H26. However further downsizing / lightening in weight have been required for the recent AVN products equipped with digital tuners.

Here are our achievements in the newly developed DV-05, such as how to make decks thinner, and decks lighter by using more plastic parts.

#### 4.1 Deck Thinning by Redesigning Large Part layout

The deck thickness depends largely on the key part dimensions and the layout. The key parts are hard to downsize because of the required functions and reliability, and besides, any change of the key part may cause cost increases. For this reason, we worked on deck thinning by redesigning layout. In particular, with keeping the positions of DISC / PU / SP MOTOR, moving the positions of LOAD MOTOR / PU feed motor to the outside of the DISC outer diameter, the deck PCB was set inside the deck by making the deck PCB into the shape with the portion for PU / SP MOTOR cut off.

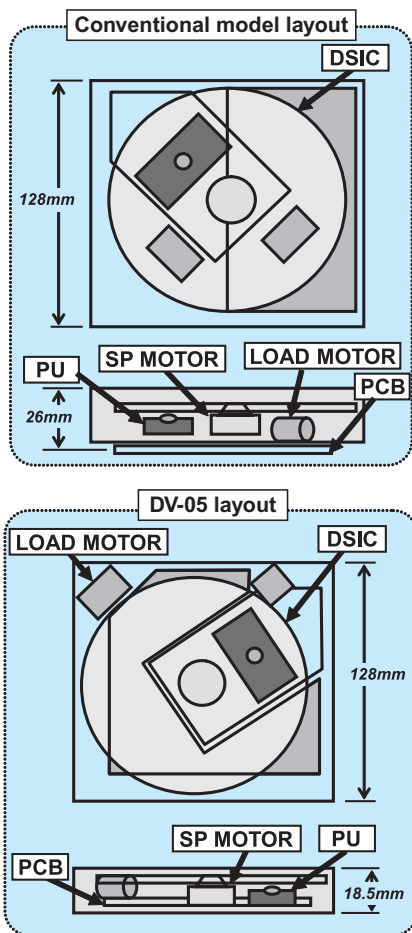


Fig.4 Comparison of Layouts

This layout change lead to the deck thinned to 70% (- 30%) compared to the previous models. Besides, this structure enabled the wiring inside the deck to be omitted and the number of the parts on PCB to be decreased, as the deck PCB is installed at the floating part,

#### 4.2 Weight Saving

DV-05 is a lighter product with plastic parts instead of sheet metal parts and miniaturized sheet metal parts. Here are the main examples.

##### Weight saving example by using plastic

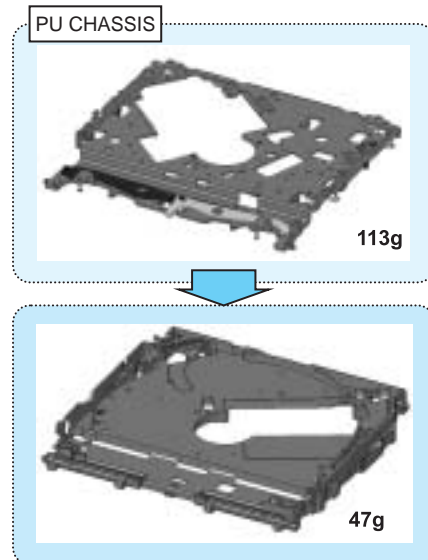


Fig.5 Comparison of PU Chassis

##### Weight saving example by using thinner board / cutting surface

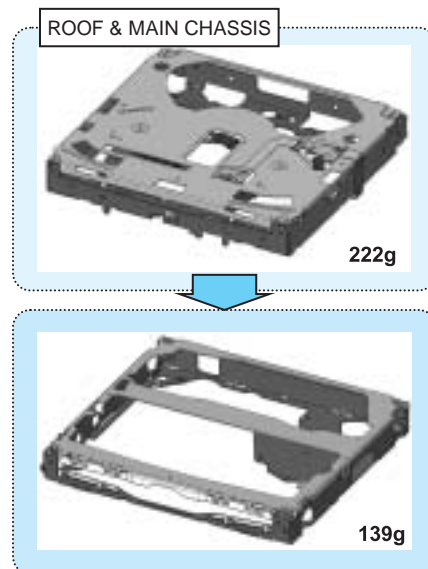


Fig.6 Comparison of Chassis

We made efforts to reduce the number of parts, especially on "Cutting shaft (rivet shaft)" or connecting parts, which was the primary factor of cost increases. (Refer to the examples of connecting method with reducing parts described in the next paragraph "Using plastic for PU chassis")

As the result of these design change, the deck became 63% (- 37%) in sum numbers of parts and 60% (- 40%) in weight compared to the previous model.

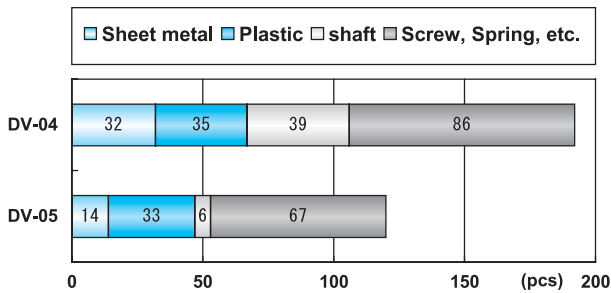


Fig.7 Comparison of Numbers of Parts in DV-04/DV-05

Moreover, with studying the POM with lower generation of formaldehyde as environment measures, by using selected material in view of QCD, low VOC deck was achieved.

### 5 Using Plastic for PU Chassis

In DV-05 development, we decided to use plastic for PU chassis, which is the base of DVD deck and a mechanical key part relating to almost all the mechanical operation.

Using plastic benefits largely on reduction of material cost / the number of rivet parts, cost-reduction due to more effective production, weight saving mentioned above and others. On the other hand, using plastic increases the number of fatal risks such as decrease of heat resistance / strength. Here is the explanation of how we overcame those risks while using plastic and achieved mass production.

First, we studied the measure of connecting parts with plastic to be used. By using plastic parts instead of sheet metal parts, it becomes easier to make a variety of shapes such as with a protrusion or portion cut off, but more difficult in connection by screws due to its becoming impossible to use connecting parts such as washers and E rings.

Fig. 8 shows the examples of gear installation, sliding-lever fit and fastening of holder fixed part,

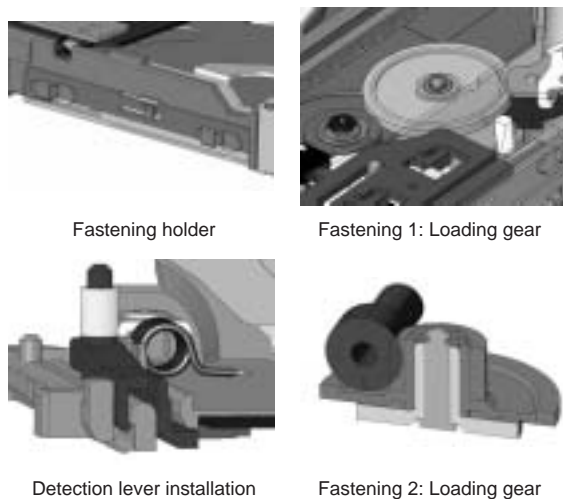


Fig.8 Examples of Part Fastening

Next, we studied moldability by flow analysis that is the same method used in the development of the past models.

Taking into account the possibility of bad filling to thinner part, warpage when molding, and other issues, the prototype mold with optimized GATE location / numbers was designed.

With the prototype mold, we studied the issues on demolding at the time of molding procedure and effects caused by variation in molding conditions, and designed mass-production tooling reflecting the results.

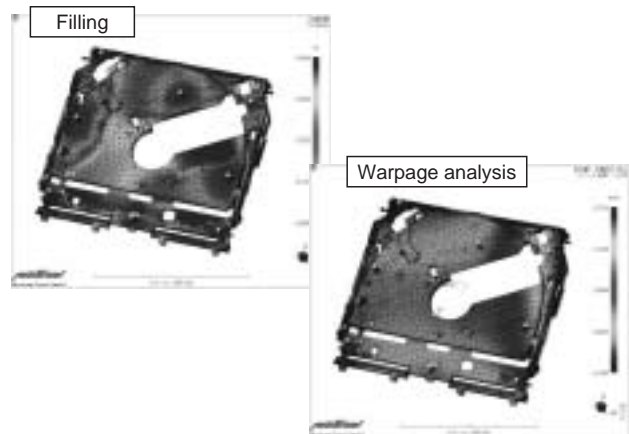


Fig.9 Flow Analysis of PU Chassis

To solve the warpage / deformation, the unavoidable issues at molding plastic parts, by finding more suitable shape and material, applying the specifications against warpage only for the required portion, the moldability was established on designing.

The locations with severe defects in the strength were at oil damper shaft and loading gear shaft, where fatigue breakdown were frequently caused at the time of vibration endurance test / insert-eject operation endurance test. For these locations, we found the shape that disperses the stress (cause of breakdown) concentrated in one location. With this result and by ensuring double or more safety of 31Mpa: fatigue breakdown stress, we achieved the required strength satisfying specifications in terms of endurance.

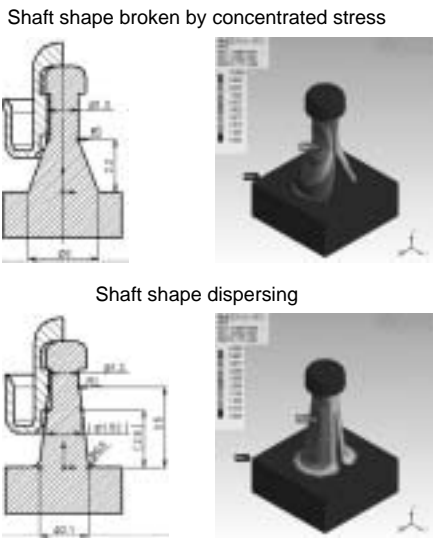


Fig.10 Stress Analysis of Oil Damper Shaft

## 6 Using Small Damper

On-vehicle DVD decks are required to have the playability without jumps even under vibration while driving. So far, DVD decks have been designed mechanically with vibration-proofing structure: which is a drive unit floated by oil damper.

This deck was required to have less vibration width of floating part than that the previous models do for achieving deck thinning. Besides, it was required to use the smaller damper. To maintain or improve the playability with less jumps even under severer conditions, and to secure the performance in early development stage, we optimized the damper feature at an early stage, asking our suppliers for help, by the new method of quality engineering.

### Quality Engineering Technique

The damper combinations were decided by selecting the damper specifications close to the target feature with the mass model resonance characteristic test conducted.

Table 1 Control Factor (Elastomer hardness, Oil viscosity)

Combination	Front damper		Rear damper	
	Hardness	Viscosity	Hardness	Viscosity
1		A		C
2		B		C
3		B		B
4		B		B
5		C		C
6		B		C

Table 2 Error Factor

Item	Temperature	PU location	Direction of vibration	Installation Angle
	Low	IN	Side to side	Flat
	Low	OUT	Front to back	Flat
	Low	OUT	Up and down	Front up
	Normal	IN	Front to back	Front up
	Normal	OUT	Up and down	Flat
	Normal	OUT	Side to side	Flat
	High	IN	Up and down	Flat
	High	OUT	Side to side	Front up
	High	OUT	Front to back	Flat

The most appropriate combination was selected with the result of the experiment conducted by the control factors and error factors based on orthogonal table L-9. With confirming the playability under vibration using the selected combination, the same level of performance as the conventional models was secured at an early development stage.

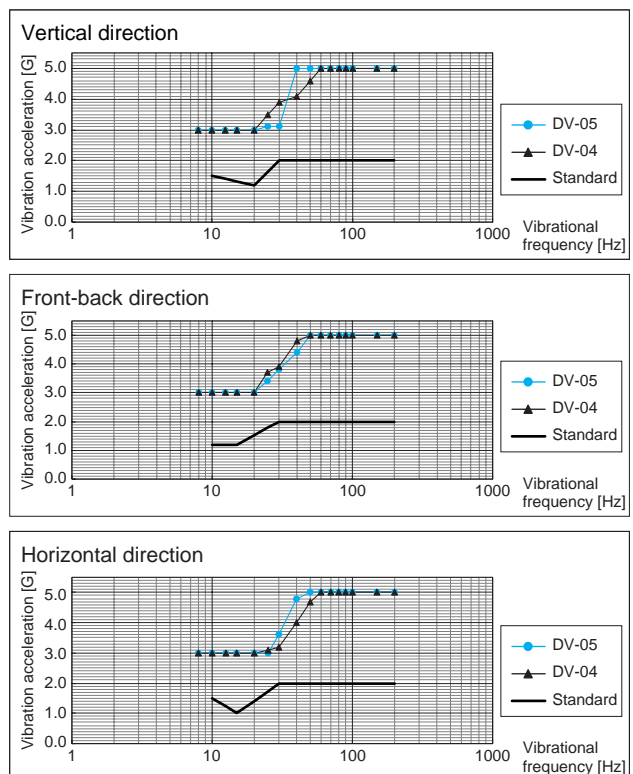


Fig.11 Comparison of Vibration Performance

## 7 Selecting pickup unit

First, to select pickup unit for DV-05, on-vehicle pickup units of five manufactures were compared in terms of quality, supply and other aspects. Then, the pickups narrowed-down into two suppliers' were compared in terms of the following performance for final selection.

- **Optical characteristics (comparison in general characteristics such as jitter characteristics)**
- **Vibration-proof performance (performance comparison under rigid conditions)**
- **Playability (Playability comparison by functionality assessment)**

We have selected the superior pickup in the following performance by the comparison results and the functionality assessment.

By the comparison results: Performance such as jitter temperature characteristics especially to a low-reflection disc, and stability in optical characteristics against scratches and contamination on discs.

By the functionality assessment: Eight factors affecting playability.

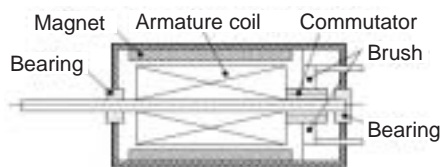
One of the advantages of this selected pickup is "switching function of output signal gain", which is added aiming for higher performance to low-reflection discs such as DVD-RW or CD-RW. This "gain switching function" seemed to be taken into consideration in this comparison between the last two companies.

## 8

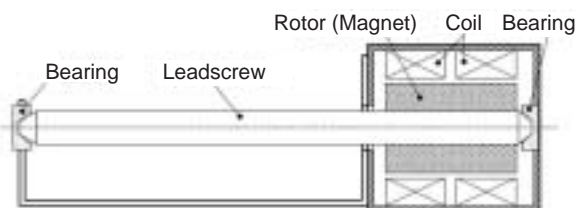
## Using Stepping Motor

This deck applies two-phase PM type stepping motor instead of DC motor used in the conventional models, as a motor for driving pick up. The two-phase PM type stepping motor is relatively low in price for a stepping motor, with two sets of windings and a rotor comprised of permanent magnet. To maximize the performance of a stepping motor, the cost used to be expensive due to the complicated driving circuit required. In recent years, since high-performance unified drivers have become available at low prices, we decided to use the stepping motor.

Here are the schematic cross sections of DC motor and stepping motor.



• DC motor



• Stepping motor

Fig.12 Comparison of Pickup Driving Motors

## 8.1 Stepping Motor Characteristics

### 8.1.1 Reliability / Durability

A stepping motor has higher reliability and longer life compared with a DC motor, as the stepping motor has no electrical contact / sliding part that the DC motor has.

### 8.1.2 Positioning

The control is easy as the setting location is possible with no need for feed back control.

## 8.2 Deck-thinning

If making the pickup guide shaft to be shared as a lead screw, it is possible to reduce the number of parts, but the stepping motor has to be set on the extended line from the pickup guide shaft. In this deck, while giving a priority to deck thinning, in consideration of other components arrangement, the pickup guide and driving lead screw were set separately.

## 8.3 Low Vibration / High Power Driving System

This deck applies bipolar / rated current microstepping driving system as a driving system.

The bipolar driving system in which current flows in two directions per one winding can gain higher torque due to the high use-efficiency of winding, compared to the unipolar system in which current flows in one direction.

The rated current driving system is the control system that keeps the current rated by using enough-higher power supply voltage than the rated voltage for motor. In this system, since it is possible to have current rise fast and produce less impact by back electromotive force even under high rotation, motors including mini motors can achieve high rotation / high torque.

The microstepping driving system achieves not only higher position resolution, but also smooth and low-vibration rotation, by controlling sinusoidal current, not by driving by general square wave.

Although all systems mentioned above are complicated in driver circuits, this deck has achieved a low price by using high-performance unified drivers that are widely used these days.

Besides, this deck was improved in operation speed by through up / through down control at the start up / stop of the stepping motor, using high-speed rotation area.

## 8.4 Control System Depending on the Environmental Changes

The environment in vehicle may be said to be severe as the temperature changes widely from  $-20$  to  $+80$ , and load changes a lot also. With the characteristics of stepping motor, when receiving a bigger load than the generated torque, operation defect, losing synchronism called step out, will occur. Solving this defect, generally, the torque is controlled so as to be bigger than the possible maximum load. On the other hand, if the driving torque is excessively big compared to the load, another

problem will arise with bigger noise and vibration generated. For this reason, the control conditions are changed so that the driving torque becomes appropriate to the load torque depending on the temperature environment.

In an optical disc device, it is possible to detect the operation defects such as step out by recognizing the pickup reading point on a disc. When the operation defect is detected, the condition is changed so as to recover from the operation defect to the state meeting the high load. So, in the normal state, it is possible to drive with the appropriate torque with no extra margin in case of defects, and this enables noiseless state.

## 9 Summary of Development Result

We achieved the targeted development in terms of deck height by redesigning the large components layout, and in terms of deck weight by using plastic parts instead of metal sheet parts and downsizing the metal sheet parts.

Table 3 Summary of Development Results

Item	Target	Result
Deck height	18.5mm	18.5mm
Mass	350g	350g

## 10 Conclusion

This report explained the outline and development technology for the DVD deck: DV-05. The AVN products equipped with this deck have been marketed as ECLIPSE brand in Japan since October 2007 and as DOP for automakers since April 2008. Besides, the deck itself has been in demand from several companies as OEM products. So, we deem this DVD development has been successful in achieving our purpose.

However, since the DVD will be improving in function, we continue efforts to develop the next DVD deck models aiming for lower cost / higher function / higher performance, utilizing the know-how accumulated through this development.

We have received cooperation from part suppliers / design companies for this deck development. We would like to express our sincere gratitude for guidance we received from the people who help us in technology including OEM customers.

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