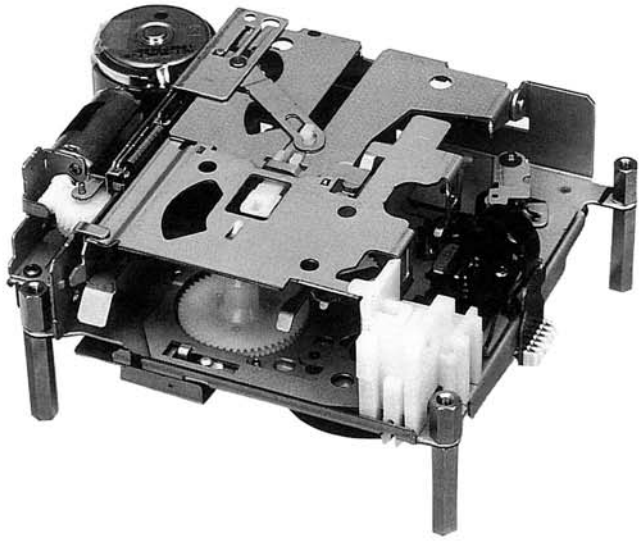
Tape Deck DK-90

- 40% reduction in the number of parts -

● Tsutomu Goto ● Tsukasa Ueda ● Yasuma Yonetani

● Masanao Takata



Fujitsu TEN has been developing cassette tape decks for cars since 1968. For over three decades, we have made every effort to design new decks and make improvements in sound quality and other features. Our production activities have aimed at making reliable audio equipment for cars that meet market demands. Accordingly, our newest tape deck, the DK-90, was just released. The design and features of the DK-90 were developed by improving existing models based on our latest expertise. Quality improvements, including better sound, quieter mechanisms, and higher reliability, have been made. Another advantage is its low cost, owing to a simplified structure and other factors. This paper outlines the features of the DK-90 and details the technologies that were used in its development process.

1. Introduction

Two types of new audio media have been introduced into the market: MD (mini-disc) and DVD (digital video disc). MD is anticipated to dominate the car audio market. However, total sales of MD units is still slow, while CD player sales, including those units with the auto-changer feature, is increasing. However, as indicated in Figure 1, sales of CD players account for about 30% of total soles. This is nearly equal to the number of compact cassette tape players sold including the 3-in-1 type (a cassette tape deck, CD player, and radio are combined in one product)

Thus, we feel that the compact cassette players will certainly dominate the car audio market in the future.

Another development factor is that the needs of tape deck users are changing, as follows:

1) Improved sound quality — clearer sound
   Car audio sets are required to produce sound quality comparable to stand-alone audio equipment (for home use). These audio sets often have a CD player. These units must playback higher sound quality.
2) Lower mechanical noise — to match reduced vehicle noise
   Since vehicle NVH (noise, vibration, and harshness) has been greatly reduced, noise from a car's audio equipment must also be reduced.
3) Smoother cassette insertion and ejection
   Since passenger compartment features have improved, users want equal comfort and ease in operating their car audio equipment.
4) Higher reliability and quality
   Reliability requirements are higher than ever.
5) Better cost-performance
   Any car audio equipment, high- or low-end, must have high cost-performance in this now highly competitive, global market. To meet the competition, supplying products with high cost-performance while maintaining or improving quality is necessary.

2. Purpose of Development

Fujitsu TEN added two new models of logic decks to its highly-reliable, tape deck lineup. These are the DK-80 and DK-82. The DK-80 is for low-end audio systems, while the DK-82 is for high-end.

The DK-80 is a logic tape deck that handles all operations in a motor-driven way, except cassette insertion. This was a popular model of car audio equipment, but is beginning to become outdated. Customers are demanding higher quality operations. Consequently, low-end audio set sales are dropping.

The DK-82 is a full-logic tape deck that has all motor-driven operations. Similar to the DK-76, the DK-82 operates better than the DK-80. The preamplifier and control circuits are built into the DK-82's deck. The resulting full-logic tape deck is reliable and its audio performance is equal to high-end car and home audio systems.

However, demand for higher competitive advantages is at its highest. Since the high-end deck DK-82 is designed to have peripheral functions, the unit itself can be simply evaluated. However, the deck can still be improved in cost-performance terms. For example, a printed circuit board dedicated to the preamplifier and control circuits is necessary

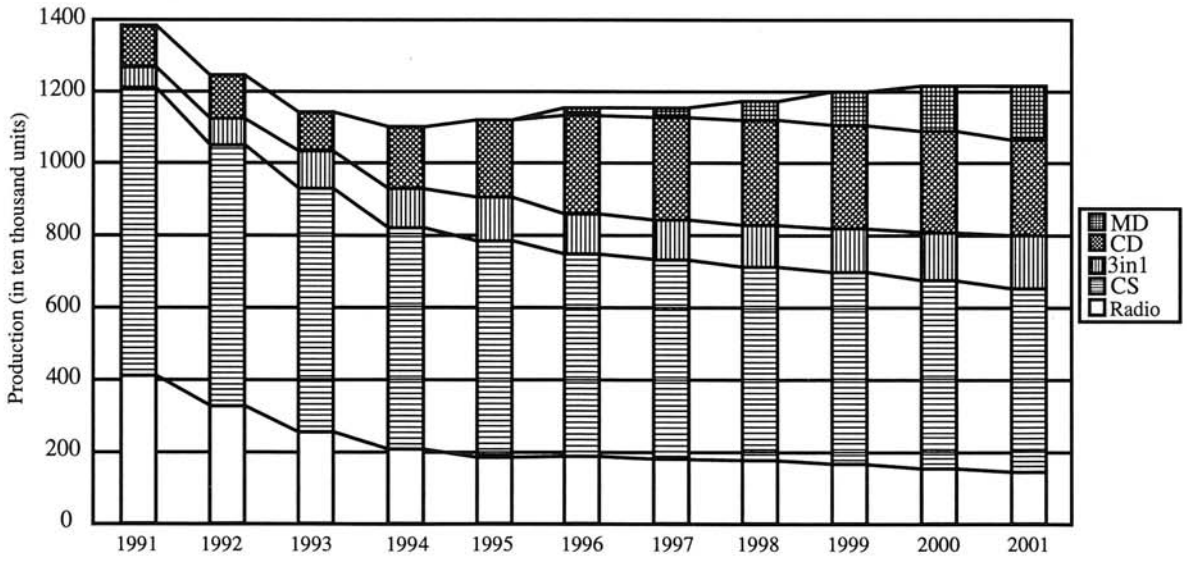


Fig.1 Sales quantity of car audio in Japan

because these circuits are attached to the deck.

We began to develop a new tape deck, the DK-90, considering these conditions and changes in the market functions as an audio product.

As the successor to the DK-80 and DK-82, the DK-90 was generally designed to serve the following three. It should be equal or superior to the DK-82 in sound quality, quiet mechanisms, and reliability.

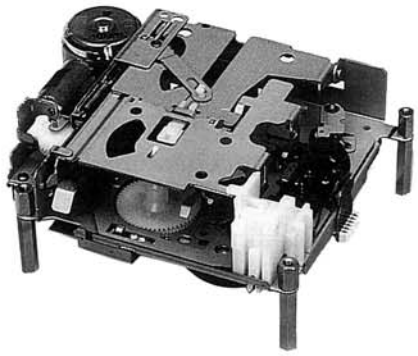
parts integration.

3. Design Concept

The DK-90 is a cassette deck designed to perform all the basic functions required of a tape deck, as shown in Figure 2.

A method of parts integration is to reduce the number of parts. However, competitive advantage is lost if functions or performance degrades when the number of parts is reduced.

The rest of this section discusses the design concept used to develop the DK-90 tape deck. The design maintains competitive advantage, while having fewer parts.



<Basic functions>
- Power loading and ejecting
- Fast forward and rewind
- Tape running direction switch option

<Functions that can be supported>
- Automatic channel selection
- Repeat
- Blank skip
- Scan
- Auto tape selector

Figure2. Outline drawing and function of DK-90

3.1 Appropriate Design of Functions

Prior to Japan's current recession, product emphasis was on increasing value added features. At whatever cost, companies were committed to make improvements in the functions, performance, and reliability. The aim was to add value to their products to surpass competitors' products. When Japan's bubble economy collapsed and market demands changed, companies had to find ways to reduce costs while keeping functions, abilities, and other performance-related factors at present levels.

When our development activities were started, we divided the basic functions of a tape deck into the following blocks and rearranged the functions in each block:

1) Cassette pack loading and ejecting
2) Tape feed
3) Tape take-up
4) Selection
5) Head movement
6) Connection

Function rearrangement is a process to study the purpose of and restrictions on each function block and lay out the functions in a hierarchy. This hierarchy consists of primary, secondary, and subsequent functions to achieve the intended purpose more efficiently.

Next, we studied and devised means to accomplish the intended purpose of each function block and compared our products to competitors' products. In this way, our products were redesigned to match market trends. In addition, we evaluated the efficiency and importance of each devised means, extracted the most suitable functions, and used these functions as design guidelines.

3.2 Structure Optimization

As stated above, the functions were rearranged to find the best method of implementing their intended purposes. In addition, they were designed to be more suitable to this rearrangement. During this process, we optimized structures by redesigning such suitable means into the actual mechanical structures. Structure optimization is a process of dividing the parts involved in each function into key and auxiliary parts. Then, calculating the minimum number of parts required to perform the desired function. Key parts refer to the indispensable parts in implementing a function. For example, the key parts of the tape feed function are the pinch roller and DC servo motor. The pinch roller feeds the tape, while the DC servo motor is the feed driver. Auxiliary parts are parts that interconnect key parts in an well-organized way to implement a required function. Examples

of auxiliary parts include fasteners (such as screws and washers), and holders and shafts, which support parts.

We designed the mechanism to allow the required functions to be implemented with as few parts as possible,calculated for each function block.

Table 1 lists the calculated ideal number of parts to implement each function.

Table 1 Ideal number of parts

	Number of key parts	Minimum number of parts needed to implement the function	Target number of parts
Tape pack loading/ ejecting mechanism	15	26	30
Tape feed mechanism	25	31	30
Tape winding mechanism	15	36	40
Direction selecting mechanism	2	9	10
Head support mechanism	6	8	10
Total	63	110	120

3.3 Quality Maintenance and Improvement

Quality improvement is Fujitsu TEN's primary aim. We make every effort to improve quality.

When developing the DK-90, we added to the high reliability of DK-82 and adopted other key parts.

The items listed below illustrate this and detail the methods that were used to improve the DK-82.

1) Quiet mechanism

Gear meshing causes principal mechanical noise, which occurs during music playback. We reduced the level of this noise by driving only the capstan and reel with a DC servo motor to minimize the number of turning gears. In addition, another type of mechanical noise exists. This noise occurs when mode switching is performed mechanically. We tried to reduce this noise by using a motor dedicated to mode selection for all mode switching operations. This has totally eliminated the clicking and cracking sounds. The clicking sound was caused by the plunger, while the cracking sound occurred when the spring-loaded lever changed position.

2) Inner-shield head

Magnetic heads in cars must be shielded from external magnetic noise, unlike home-use magnetic heads. The wire harnesses within the car generate magnetic noise. To protect against magnetic noise, an inner-shield head with a shielded structure was used within the head. This head helps prevent ejection errors for out of standard cassettes because it is smaller than outer-shield heads. (See Figure 3.)

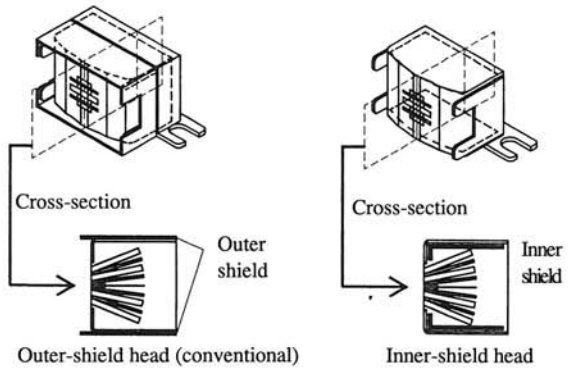


Figure 3. Comparison of magnetic head appearance

3) Measures to keep the head clean

The portion of the head surface that contacts the tape is structured to prevent the exposure of any resin and to reduce the dirt that sticks to the head surface. Dirt that sticks to the head surface increases spacing loss, resulting in poor treble playback. Dirt tends to stick to the resin on the head surface and accumulate. There is no exposed resin in our heads. Thus, our heads stay clean.

4) Handling out of standard cassettes

Compact cassettes, including pirated versions from overseas, may have dimensions out of standards. The DK-90 has been designed to include the following measures to have a broader allowance for the following out of standard cassette:

① Smaller reel caps
② Optimized guide pin diameter
③ Cassette half horizontal drop mechanism

These measures increase the deck's allowance for out of standard cassette and reduce the probability for a cassette insertion error to occur.

5) Magnet slip mechanism

The slip mechanism provides the tape with constant torque to prevent tape breakage resulting from excessive tension. The slip occurs when the tape is

rewound during playback and what fast forwarding or rewinding at the end of a tape. In contrast to conventional slip mechanisms that use felt, the slip mechanism in the DK-90 uses a magnet. Therefore, the DK-90 is able to stabilize performance longer in especially hot or humid environment. Figure 4 shows the structure of the slip mechanism.

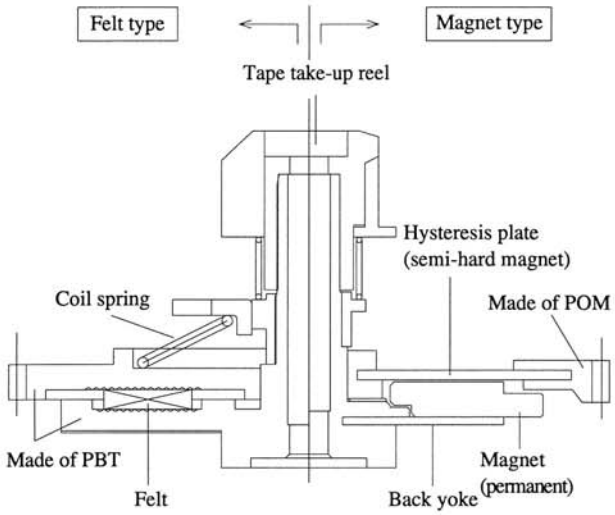


Figure 4. Comparison of ship-mechanism structure

6) Bias mechanism on the elevator for cassette
This mechanism supports the elevator with spring force so that elevator position is flexible. The mechanism helps prevent the cassette loading and ejecting mechanism from being damaged.

7) Enclosed low-current switches
Enclosed switches are used to prevent dust and other debris in a car from sticking to the switch contacts, which may cause the switches to malfunction. This makes the DK-90 durable to whatever adverse conditions in a car.

4. Mechanism

The characteristics of the DK-90 mechanism are explained below. Figure 5 is a sketch of the DK-90 tape deck.

4.1 Quieter Mechanisms

Unnecessary gears in the tape player do not run while music is playing, as shown in Figure 5. Gears are used only to rotate the reel via the flywheel, connected by a belt that is driven by the DC servo motor.

The mechanisms are connected to two cam gears and a deck mode is determined according to the rotational positions of the cam gears. This allows for only a mode selection motor to perform all operations. Almost no mechanical noise is heard during mode selection because all operations are carried out by only cam gears and a lever linked to them. Positioning in each mode is performed using a mode switch, which is engaged with the cam gear. Furthermore, normal operation can be easily restored even if the mechanism abnormally stops since all operations are linked to each together, regardless of when the mechanism stops.

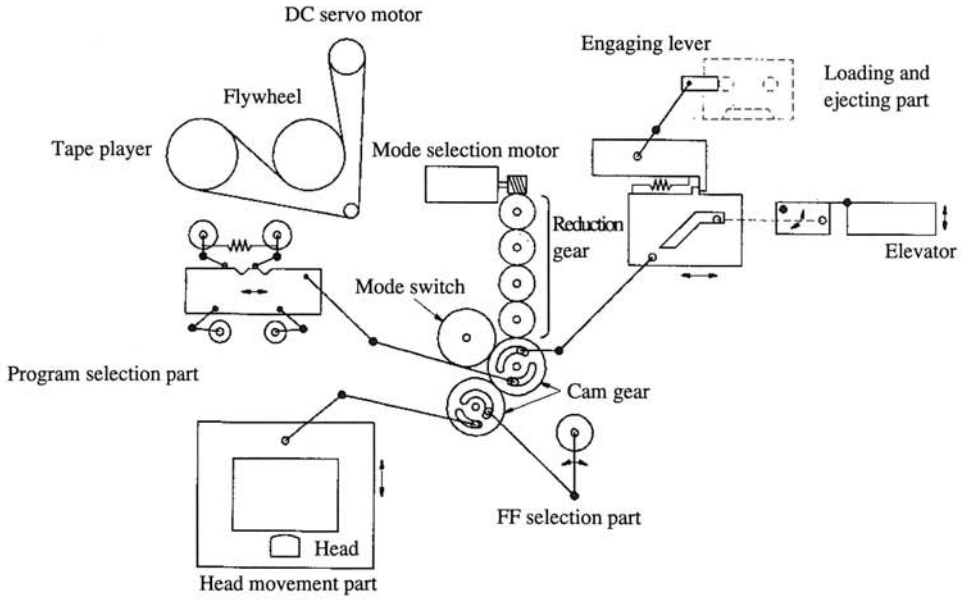


Figure 5. Mechanism outline chart of DK-90

4.2 Reducing Parts

As stated above, the key to reducing parts is to design the mechanism to allow the minimum number of auxiliary parts to implement all the required functions. As this was attempted, reducing shafts that support parts and fasteners, which secure parts, was vital.

To reduce the number of parts in the DK-90, the following techniques were used:

① A press shaft mold was used, instead of the cutting shaft

② A burring riveting was used, instead of the cutting shaft

③ Fasteners were eliminated by using a press-fit shaft

Techniques ① and ② were already implemented with Fujitsu TEN's CD deck DA-22 and CD auto-change deck DA-19/23. For details, refer to the ##Fujitsu TEN Technical Report, Vol. 13, No. 2 (1996)##.

The use of technique ③ was first used in the DK-90 among Fujitsu TEN's audio decks for cars. In general, gears are secured using washers or other fasteners (see Figure 6). In the DK-90, each gear is inserted into a shaft, which is one-piece molded with a plastic lever. The collar of the shaft prevents the gear from coming off the shaft. Thus, gears are secured without using washers. This method eliminates washers and cutting shafts and is called press fitting. This securing method takes advantage of the elasticity of the plastic materials .

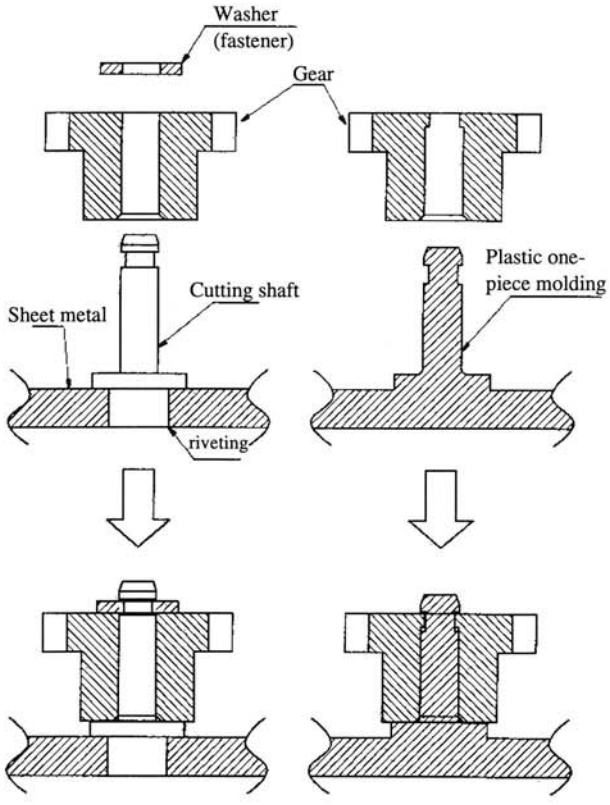


Figure 6. Shaft deletion by a press fit

5. High-Quality Key Parts

To make the tape deck highly reliable, the quality of each of the key parts must be high. The following key parts were used:

5.1 Non-Azimuth Head

Using the tape running mechanism of general auto-reverse decks, the tape running angle slightly deviates each time the playback direction changes. This gives rise to loss in azimuth and results in lower quality treble playback. To solve this problem, conventional decks use a dual azimuth mechanism. This mechanism has an adjustable head angle for each tape run. As shown in Figure 7, performing separate adjustments for different tape running directions optimizes the head azimuth angle.

However, the dual azimuth mechanism is complex and requires many parts because the head angle must be adjusted for each tape run. In addition, this mechanism requires adjustment for each tape run and performance tends to depend on the experience of the worker who makes it.

Furthermore, the deck mechanism may distort if the dimensions of the car's console do not match the corresponding dimensions of the deck housing unit, which is attached to the console. In addition, such distortion could

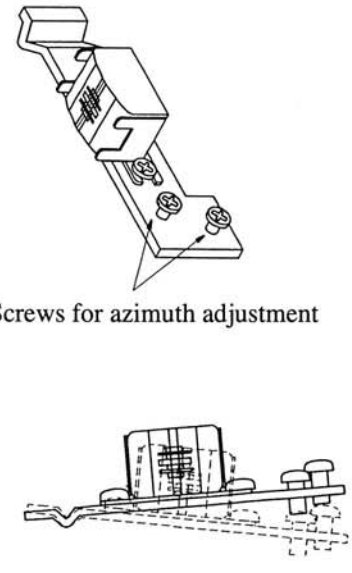


Figure 7. Mechanism of dual azimuth

occur if the body of the car distorts due to adverse road conditions. Also, this distortion may slightly disturb the tape player, resulting in a deviation in the tape running angle.

The dual azimuth mechanisms may deviated due to the optimum azimuth angle.

The DK-90 uses a non-azimuth head to ensure that the head and tape player angles always match.

As indicated in Figure 8, which shows the exterior of the non-azimuth head, two guides are provided on each side of the head (four guides in total). This keeps the tape running angle always constant and avoids azimuth loss.

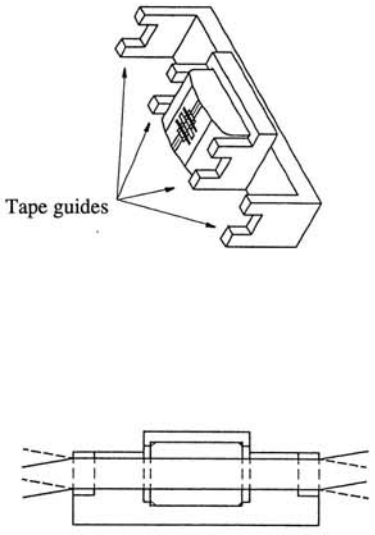


Figure 8. non azimuth head

Use of this non-azimuth head has many benefits. For instance, sound quality deterioration is reduced, even in the above-mentioned condition; head angle adjustment is unnecessary; and processing is more efficient.

In addition, outer guides always contact the tape during playback and scrape dirt off the tape surface. Thus, the non-azimuth head also prevents head contamination.

5.2 Mode Switch

Logic decks require that the appropriate sensor inform the microcomputer of the detection mode of each operation. The DK-82 uses reflection-type optical sensors for this purpose. This sensor projects light onto the object to be sensed and detects the light reflected from that object. This method may bring a sense error if the intensity of the reflected light is too low because the surface of the object being sensed could be contaminated.

The DK-90 uses rotary switches instead of optical sensors. A rotary switch, also called a mode switch, changes the circuit connection mode according to the position of a brush. This brush is attached to the gear rotating on the base. The mode switch of the DK-90 has three output logic circuits of this type. Therefore, the DK-90 can detect up to eight modes.

Optical sensors can only output the ON and OFF status. Sensing that uses optical sensors is relative. The pulses are counted beginning with the mechanical position determined by another switch. However, sensing that uses mode switches is absolute based on 3-bit codes. Even if the deck malfunctions, normal operation can be quickly restored. The absolute position can be determined without moving the mechanism. In addition, aging-induced deterioration, which is unavoidable with optical sensors, is considerably small because the contacts are physical. Thus, high reliability is achieved.

Also, preventing foreign matter from entering the contact area was considered. Projections are provided on both sides of the base and gear to shield the contact area.

6. Conclusion

In developing the DK-90, we succeeded in reducing the number of parts in the conventional DK-82 by about 45% (see Figure 9). We believe that the DK-90 has the smallest number of parts of all cassette tape decks now in this market.

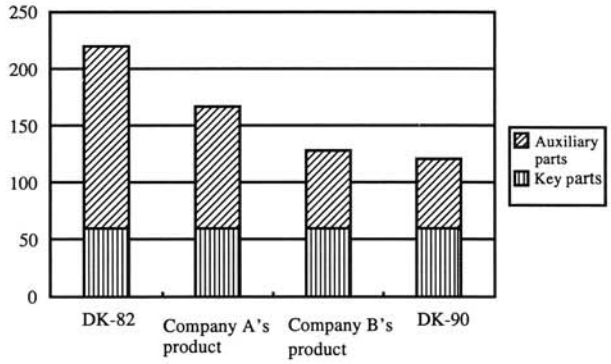


Figure 9. Comparison of number of parts

The advantages of the DK-90 are not limited to this aspect. As listed in Table 2, the panel of the organoleptic evaluation concluded that the organoleptic properties of the DK-90 rank first among the tested cassette decks. Users can comfortably handle the DK-90 and enjoy music without any annoying noises. In addition, the noise when a cassette is loaded is low level.

Table 2 Results of organoleptic evaluation

		Cassette tape decks for cars						Remarks
		Fujitsu TEN's products			Other companies' products			
		DK-90	DK-82	DK-80	Company A's product	Company B's product	Company C's product	
Required time	Cassette loading	○	○	△	X	△	○	○ Short or small △ Medium X Long or large
	Time required from when a cassette is loaded to when the music starts	○	○	○	○	○	○	
Mechanical noise	Program selection	○	○	△	△	△	△	
	Tape running noise	○	○	○	○	○	△	
	Loading/unloading noise	○	○	△	△	△	△	

We also studied and devised a variety of ways to improve the quality, as listed in Table 3. The DK-90 conventional tape deck assures high customer satisfaction.

Table 3 Comparison in quality improvement among products

			Fujitsu TEN's products			Other companies' products			Remarks
			DK-90	DK-82	DK-80	Company A's product	Company B's product	Company C's product	
Sound quality improvement	Head loading		○	○	△	△	△	○	△ Partial outer shield ○ Outer or inner shield
	Azimuth mechanism		None	Dual	Dual	None	Dual	Dual	
Quiet mechanism	Mechanical mode switching made only by the motor		○	○	X	○	X	X	
Reliability improvement	Head contamination prevention	Elimination of exposed resin	○	○	X	X	○	X	
	Handling of non-standard cassettes	Reduction in the guide pin diameter	○	○	○	○	○	○	
		Horizontal drop mechanism	○	○	X	○	X	○	
		Relief for the label area	○	○	△	○	X	○	
	Slip mechanism (torque stabilization)		○ Magnet type	○ Magnet type	△ Felt type	△ Felt type	△ Felt type	△ Felt type	○ : Yes X : No
	Measure to prevent tape from being caught	Slackening prevention	○	○	○	X	○	X	
		Reel lock	○	○	X	X	X	X	

7. Afterword

This paper outlines the DK-90 cassette deck that was recently developed. To expand Fujitsu TEN's current cassette deck lineup, the DK-90 was designed. This tape deck provides many functions to fulfill customer needs, while the number of parts has been reduced. We succeeded in reducing the number of parts to 40% conventional decks, while maintaining and even improving quality, in some cases.

Tsutomu Goto

Employed by Fujitsu TEN since 1986; engaged in developing cassette tape decks; currently in the Deck Mechanism Engineering Department, A.V.C. Products Group

Yasuma Yonetani

Employed by Fujitsu TEN since 1988; engaged in developing cassette tape decks; currently in the Deck Mechanism Engineering Department, A.V.C. Products Group

Tsukasa Ueda

Employed by Fujitsu TEN since 1987; engaged in designing the circuits of cassette tape decks; currently in the Deck Mechanism Engineering Department, A.V.C. Products Group

Masanao Takata

Employed by Fujitsu TEN since 1980; engaged in developing cassette tape deck mechanisms; currently a Manager of Mechanism Engineering Department, A.V.C. Products Group