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DIN Type Audio System for Toyota '94 Models

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The in-car environment presents special challenges when designing audio systems with advanced features and high reliability. Every year, systems become more compact and have higher performance.

All industries have recently been under pressure to reduce costs. As part of this drive, we completely changed the DIN type audio system for Toyota '93 models sald in Japanese market. During this change, we reviewed the functions of component modules, and the performance and functions of parts.

This report mainly presents a tuner module developed for this redesigned system and describes its dramatically improved performance.

The turner is part of the new system for the Celica '94 model. We also present the complete system here.

1. Introduction

We completely revised the DIN type audio system for Toyota Motor Corporation. The new audio system meets current market needs. The previous model was based on the 1989 model, and its design is dated. The latest system is redesigned for higher performance and quality, and for lower cost.

2. Development aims and features

2.1 Minimum number of models

Our new models can be mounted on all cars that have DIN standard connections. The number of models was deliberately kept small for common use in future.

2.2 New design

The new design is simpler, to improve usability and to promote safe driving. Usability is also improved by a dot matrix LCD. (Figure 1)

2.3 Higher performance and quality

We improved performance with new technology and devices. In particular, we developed a new tuner and tape deck, which are the core of a car audio system.

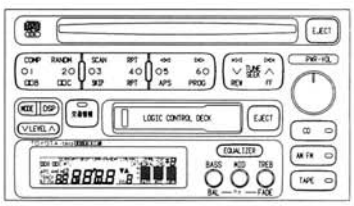
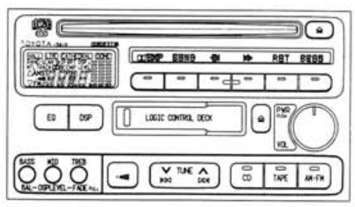
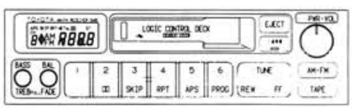
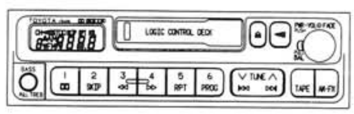
Function	Previous model	New model
Combination model with 2 DIN, AM/FM tuner, tape deck and CD player		
Combination model with 1 DIN, AM/FM tuner and tape deck		

Figure 1. Front panel design of previous and new models

2.4 Development policy

New designs took advantage of new technology and production processes to improve performance and quality of functional blocks, and to cut costs. Basic design concepts were as follows:

1 Improve the basic performance of functional blocks (develop functional modules)

2 Reduce the number of components (use ICs and combine devices into single chips)

3 Design without discrete wires for easy production

3. New technology development

3.1 Tuner module development

A new tuner module common to all models is used in the core of the AM/FM receiver of the new model.

New circuits and production process are used for this tuner module. Also, custom ICs are used for a compact standardized design, and receiver performance has been improved with only a small increase in cost.

We named this module the advanced tuner, and established a department to standardize circuit module development.

The features below make the advanced tuner module (ATM) compact with high performance.

3.1.1 Structure

Separate modules for front end circuit and FM demodulator

The recent trend is to integrate circuits into one module. In the ATM, a separate module houses functional circuits, to allow more product variations.

Each module uses surface-mount components for circuit integration, including custom ICs, high-frequency coil components, and crystal oscillators. This reduces module size. (Figure 2)

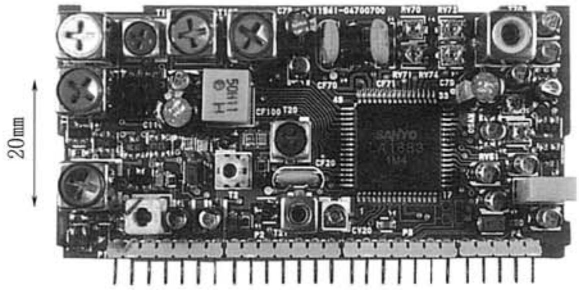
3.1.2 Improved receiver performance

The development aims of the ATM are described below.

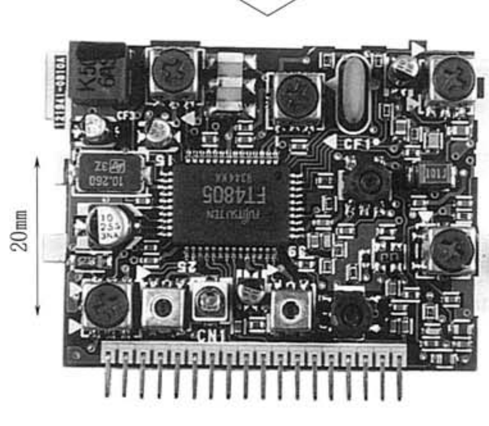
1 Extension of dynamic range of received signal
The dynamic range of the frequency conversion circuit must be extended so that circuits have no distortion when a strong signal is received. The ATM uses an emitter input type balanced mixer, until now only found in high-end communication equipment. This circuit is implemented as a custom IC at low cost and significantly improves characteristics when strong AM and FM signals are received. (Figure 3)

2 Improved reception sensitivity (FM)
The dynamic range of the mixer circuit has been extended, removing design restrictions on the high frequency circuit. As a result, the S/N ratio for 0 dB input is 20 dB. (Figure 4)

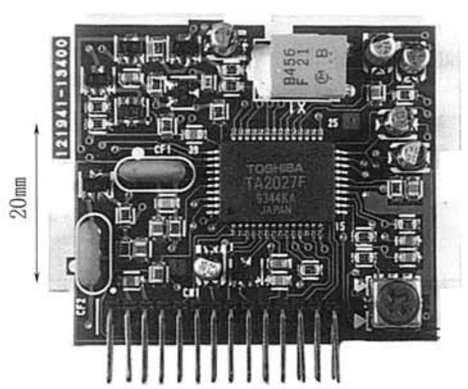
3 Reduced sensitivity variation (AM)
Because the dynamic range of the mixer has been extended, a tuning circuit is no longer needed in the high-frequency circuit. Because no tuning circuit is



(a) Previous tuner module (5 in 1)



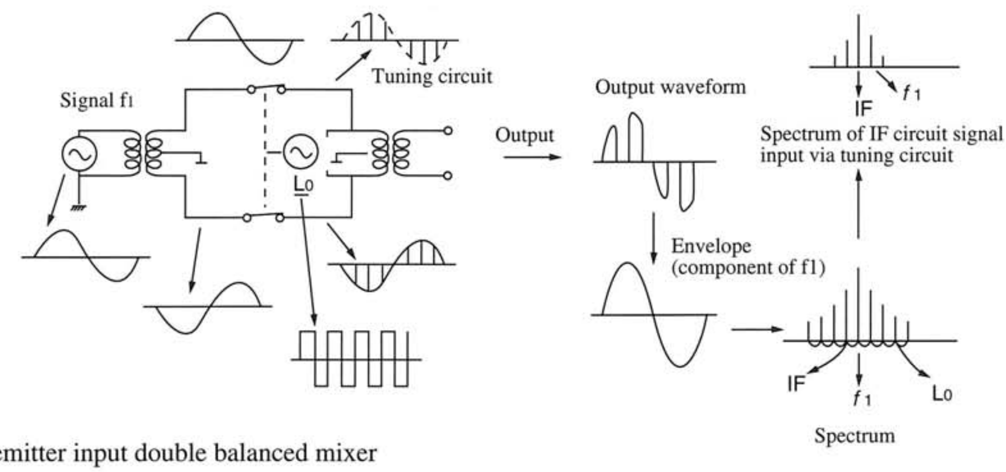
(b) New AM/FM module (ATM)



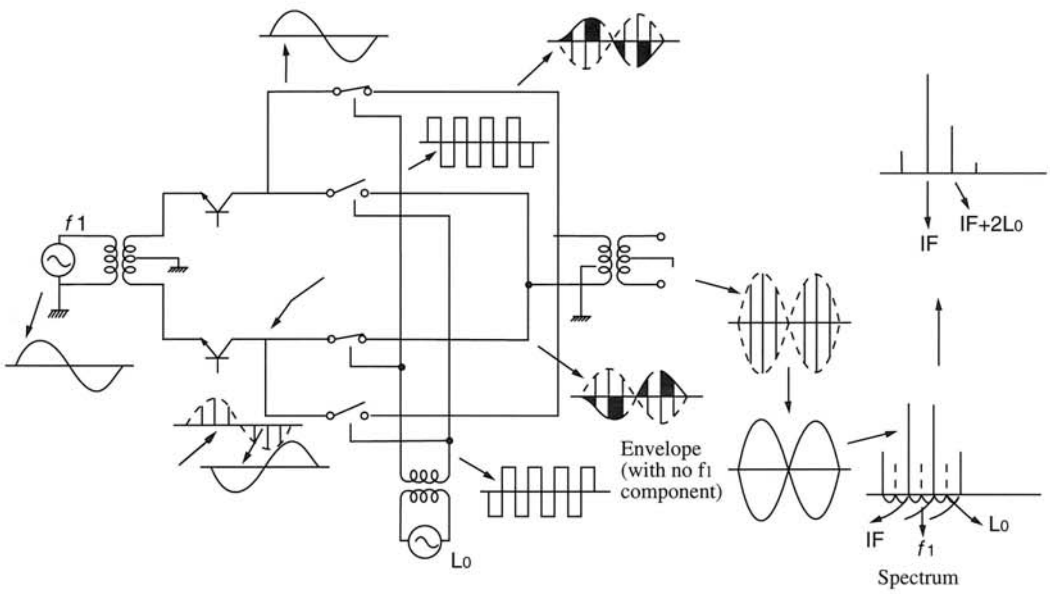
(c) New IF/NB/MPX Module (ATM)

Figure 2. Tuner modules of previous and new models

(a) Previous balanced mixer



(b) Newly developed emitter input double balanced mixer



(c) Improved interference rejection with strong AM interference

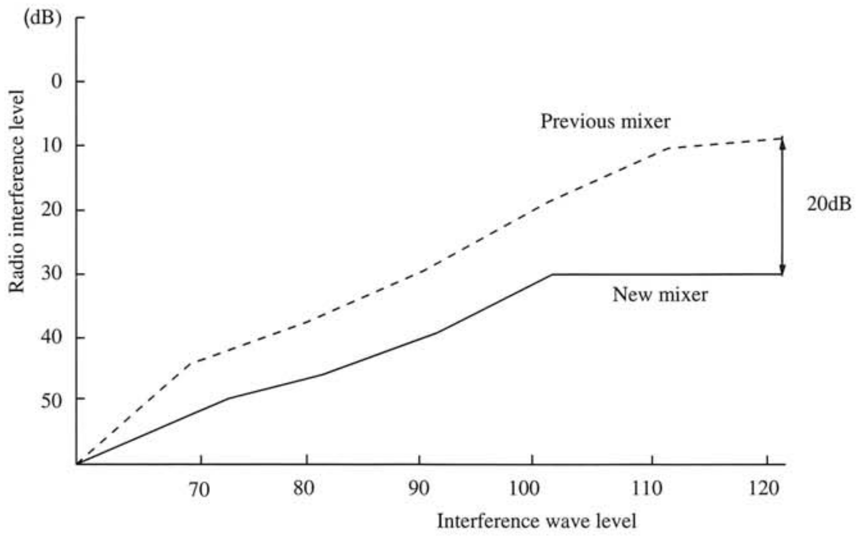


Figure 3. Operation principle and improvement of balanced mixer

used, sensitivity difference within the band is significantly lower, which improves reception sensitivity at 1620 to 1629 kHz, the band for broadcasting traffic information. (Figure 5)

4 Reduced FM multipath noise

A well known way to reduce multipath receive noise is to reduce the channel separation of FM stereo signals. Since 1987, Fujitsu TEN has incorporated a circuit that does this in all FM receivers.

The key feature of this technique is that multipath noise is detected separately from normal voice signals to minimize voice quality degradation.

The new model has a dedicated multipath noise detection circuit. The noise detection performance of the new model is therefore much higher than the previous noise detection circuit which was used also for the ignition noise blanker.

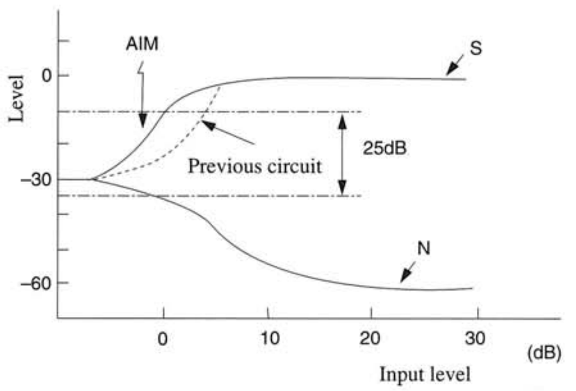


Figure 4. Improved FM signal sensitivity

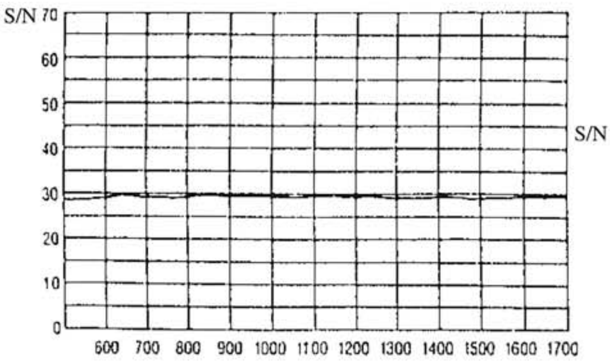


Figure 5. Reduced sensitivity variation in AM band

This method can detect multipath noise, regardless of the voice signal level. Channel separation can then be reduced for noise only, without lowering sound quality.

5 Upward frequency conversion

The frequency band will be extended in the future. For this reason, upward frequency conversion is used to add frequencies, particularly LW 150 to 280 kHz.

Upward frequency conversion is not a new technology. The mixer has two stages, causing insufficient dynamic range with the conventional technique. The limited performance of upward frequency conversion means it can only be used for middle or lower end models. Using ICs at this development stage gives us high performance mixers at low cost, and we use these mixers in models from the high to low end.

3.1.3 Other techniques

1 Automatic parts mounting

Except for four parts, all parts of the front end circuit module and IF circuit module are mounted on PC boards automatically. These four parts also were chosen so that they can be mounted automatically in the future. An automatic mounting machine for these parts is also being developed.

2 Automatic adjustment

Any part that requires adjustment was designed for automatic adjustment, so the entire product can be adjusted automatically.

For an IF circuit module, 99 percent of the land patterns is checked automatically. This prevents faulty parts from being delivered to the next process.

3 External setting

Circuit characteristic settings may be changed depending on the search sensitivity, the field-free noise convergence value (C/N), the product market, and the user.

Settings are made after the tuner is built into a product, so the tuner module can be used in models other than the new tuner.

This increase freedom to develop product variations. The difference in these set values is negligible between products, so the proportion of defective products is very low.

Table 1 and Figure 6 give the basic specifications and a block diagram of the tuner module.

Table 1. Tuner module specifications

Front end module		
Reception band	FM	76MHz to 90MHz
	AM	522 kHz to 1629 kHz
Reception method	AM	Double superheterodyne
	FM	Single superheterodyne
IF frequency	AM	10.7 MHz (1ST), 450 kHz (2ND)
	FM	10.70 MHz
Output	AM	Audio detection output, 450-kHz AM stereo output, IF count output, S meter output, SD output
	FM	10.7-MHz IF output
Built-in IF filter	AM	180-kHz type x 1
	FM	110-kHz or less type x 1, 8-kHz type x 1
PLL (1st) local oscillation frequency	AM	Reception frequency - 10.70 MHz
	FM	Reception frequency + 10.71 MHz
2nd local OSC. frequency		10.26 MHz (crystal)
AM station search		SD and IF count (450 kHz)
Performance guarantee power supply voltage		8.5 V±0.4 V
Maximum current consumption		F8.50mA, A8.90mA, Com8.70mA
Tuning voltage range		1.0 V to 7.8 V (MIN/MAX)
Number of tuning stages		2 for FM, 0 for AM
Module type		TA2034F
Dimensions		About 55 × 40 × 13
External adjustment		AM-AGC, keyed AGC, search sensitivity

F circuit module	
Input frequency	10.7 MHz
Detection method	Operation peak FM detection
Built-in IF filter	180-kHz type x 2
	Stereo audio output
	Composite output
	10.7-MHz output for IF count
	FM S level
	Stereo lamp
	Noise blanker gate pulse
External adjustment	Limiter, C/N, ANT, ASC, search sensitivity, separation, SD band
FM search	SD method (IF count possible)
Stereo decode	Nonadjusted PLL method (456 kHz)
Other functions	ASC, ATC, M-ASC, low cut ATC, noise blanker
Module type	TA2027F
Operating voltage	8.5 V±0.4 V
Current consumption	55 mA max.
Size	Vertical type, about 50 x 40 x 13

3.2 Development of a new tape

The DA-09 is used as the CD deck, and the DK-82 is used as the tape deck. The DK-82 tape deck was developed for this system. Its major features are improved initial quality, durability, and hardware quality. As vehicles

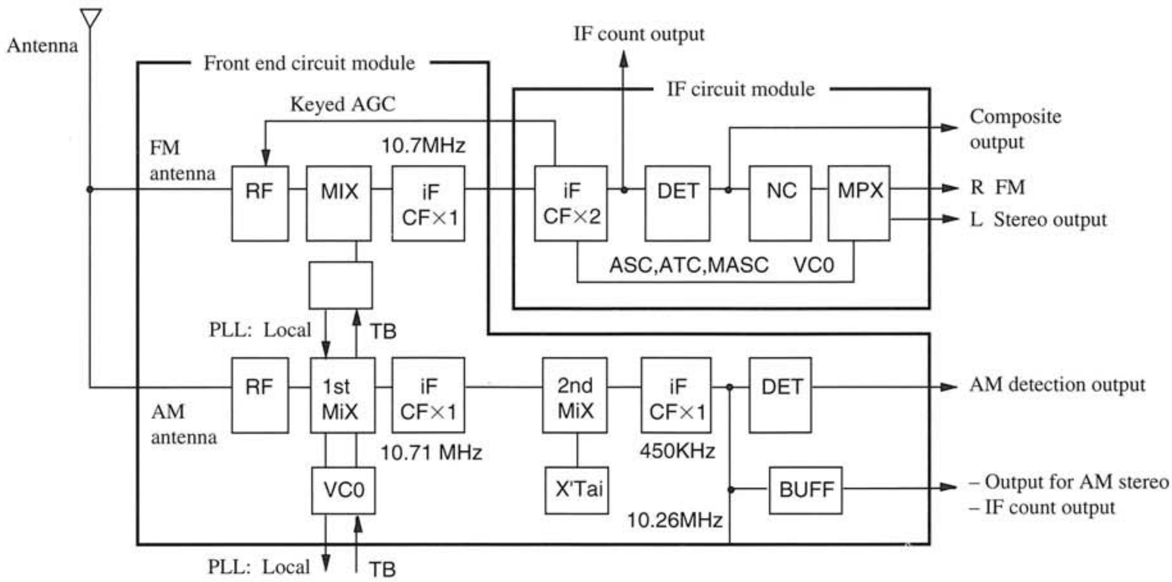


Figure 6. Block diagram of tuner modul

become quieter, the sound of a running tape and other mechanical noise becomes intrusive. The tape running sound of the new deck is 10 dB lower than the previous systems. This was achieved by improving the tape drive.

The new deck uses no plunger. This modification significantly reduces mechanical noise.

Parts are connected directly to greatly reduce the number of discrete wires (Figure 7). This increases assembly efficiency and improves quality.

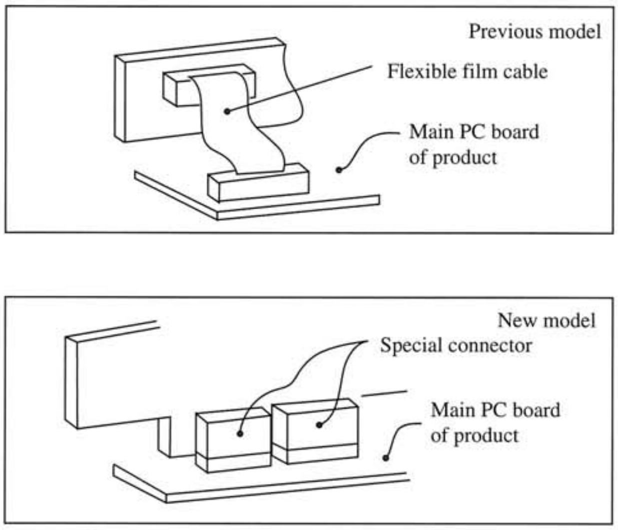


Figure 7. Cableless connection using special connector

3.3 Use of new parts

As car mounted TV sets, microdisks, and navigation systems become popular, the space available for an audio system becomes smaller.

On the other hand, the circuit scale of car audio systems tends to be large for safety because systems have many functions and because they must meet existing and future product liability laws.

Developing technology for more compact systems is now more important than ever before.

New ICs were developed to make products smaller. The major ICs are described below.

3.3.1 IC for audio system power supply

Figure 8 is a block diagram of the newly developed IC for the audio system power supply.

① This IC has all of the minimum required power circuits for a car audio system. For safety, an output current control circuit is added to each output. The IC is particularly suited to an audio system with an electronic tuner.

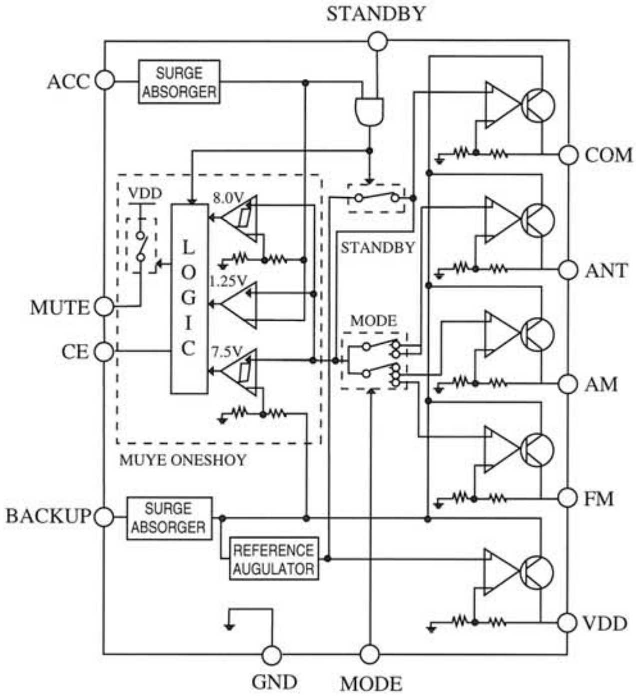


Figure 8. Block diagram of combined power supply IC

② The IC has voltage monitoring mute output for the +B power supply and the ACC power supply. This feature is included because cars are fitted with an increasing number of electronic and electrical devices, and the number increases every year. This feature prevents the sound from being adversely affected by power voltage variations.

③ The power IC is in a 12-pin package. This provides a large allowable loss for the IC, and requires 50 percent less space for the PC board than the previous power supply IC.

3.3.2 Sound volume control IC

Sound control ICs can be roughly classified into voltage-controlled attenuation (VCA) and resistance ladder types.

The VCA type requires no special control circuit because it is controlled by a DC voltage. Also, it can be directly connected to a variable resistor, requiring only a small space. However, the VCA type has the disadvantage that noise is larger than the resistance ladder type.

To solve this problem, we have developed a VCA sound control IC that generates as little noise as a resistance ladder type. As a result, we achieved both high sound quality and compact size. (Figure 9)

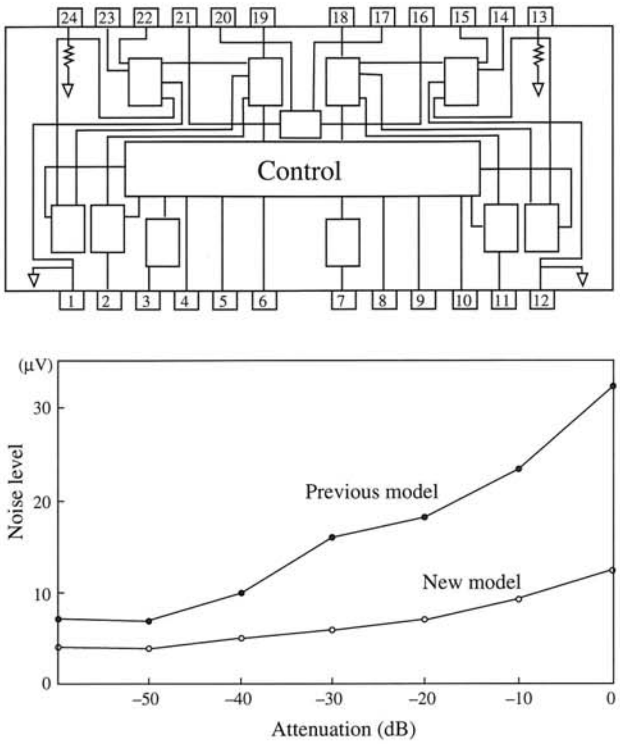


Figure 9. Block diagram of sound volume control IC and improved noise level

4. Celica superlive sound system

The new tuner and power amplifier are used in the Superlive sound system fitted in the new Celica. The loud speakers use a new material to provide the best overall system for the car. As well as providing powerful bass, sound quality has been improved. Figure 10 is a block diagram of the Celica Superlive sound system.

4.1 Compact power amplifier

The size of the power amplifier in the Superlive system for the new Celica had to be significantly reduced because it is installed in the console. To maintain the high quality sound of the Superlive system in the previous Celica, various new technologies were used in the circuits and system structure of the product.

First, the power supply circuit was simplified. In the previous models, a positive and negative power supply were formed by a DC-to-DC converter to provide amplifiers with discrete parts for a 50-W 4-ohm load. In the new model, the DC-to-DC converter has been removed from the power supply circuit by developing high sound quality 2-ohm speakers and by using a monolithic IC amplifier for a single voltage power supply to drive the speakers.

Second, a single-chip power IC is used for both channels. The new IC has almost the same performance as the previous single-chip IC for one channel. The number of parts has been roughly halved.

Third, a hybrid IC is used in the FIX equalizer circuit. A new low distortion chip capacitor gives the same sound quality as the previous film capacitor. The PC board space for this circuit has been reduced to about 1/10.

Device structure was also simplified. The digital circuit and the analog circuit were made into units, and now connect directly via a connector. This reduces wiring and improves work efficiency.

The above measures reduce the volume of the product by about 50 percent compared with previous products. Figure 11 compares the previous amplifier with the new amplifier.

4.2 Development of the new loud speaker system

We wanted to make the new Celica Superlive system sound better than the previous system. How we did this is described below.

Our aim was a powerful, wide ranging sound suited to the Celica, and a more natural quality. The best place to start is to improve the sound quality of the loud speaker units. We used a new kind of cone paper that contains cellulose of sea squirt.

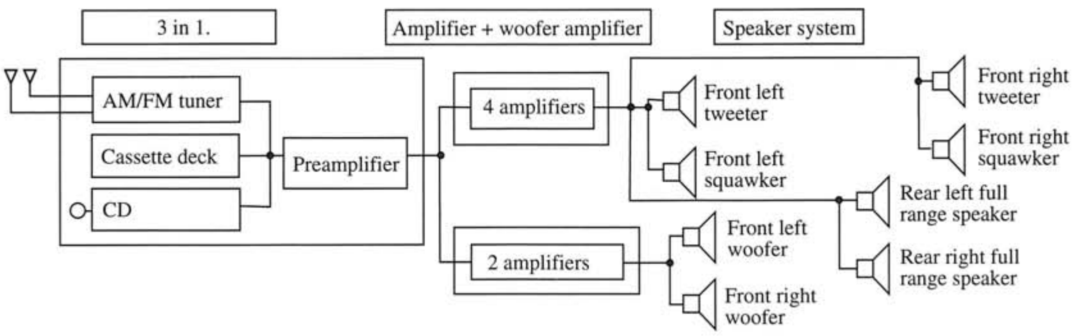
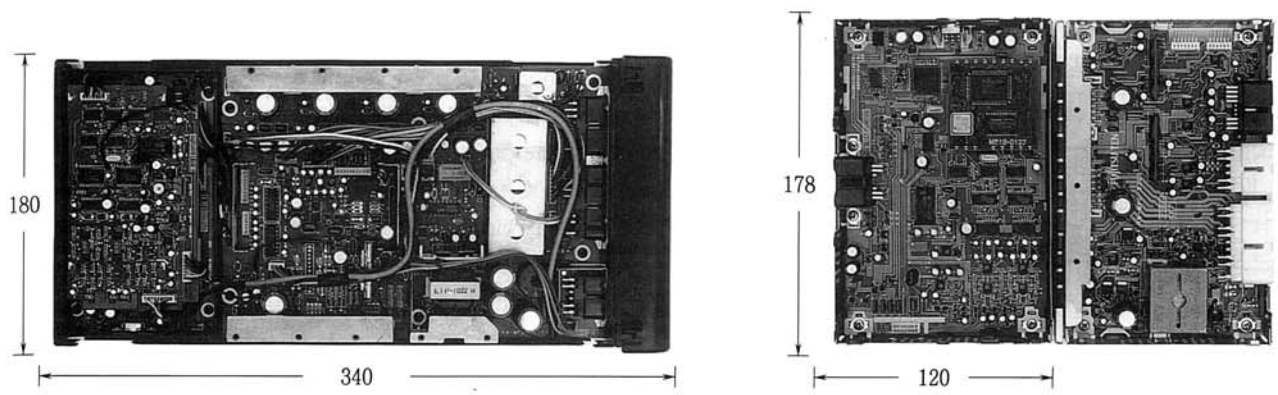


Figure 10. New Celica Superlive sound system



Previous amplifier　　　New amplifier

Figure 11. Previous and new power amplifiers

4.2.1 New cone paper containing cellulose of sea squirt

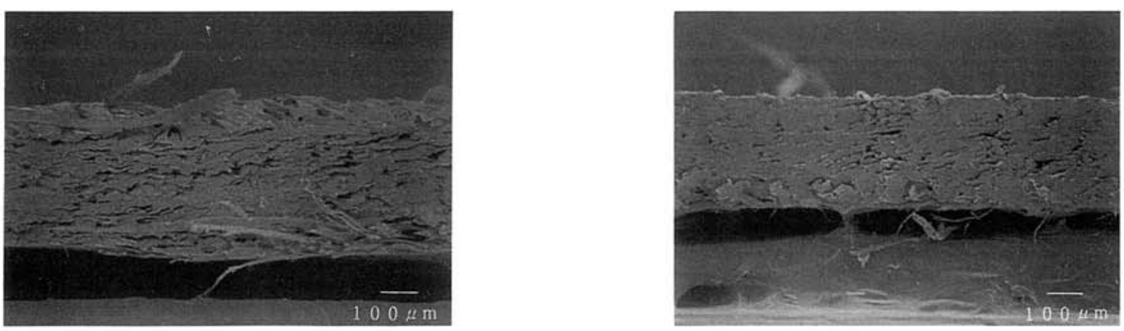
The requirements of a speaker diaphragm include light weight, high stiffness, and optimum energy loss. In conventional wooden pulp cones, these three requirements are well balanced. However, wooden pulp cones have poor stiffness compared with metallic metarials. A new cone paper containing cellulose of sea squirt overcomes this disadvantage. The new cone is made by mixing conventional wooden pulp and cellulose of a sea squirt to form fine paper layers (Fig.12). This improves stiffness and airtightness significantly (Table 2 compares conventional and new products).

A sea squirt is a creature that lives at the bottom of the sea. We use the cellulose from its outer skin in the speaker cones. This cellulose widens the high frequency reproduction, improves transient characteristics, and helps reproduce powerful medium and low frequency bands. Sound quality also improves (Table 3).

For balanced tone quality, sea squirt cellulose is used in all speakers in the new Celica Superlive system except for the semihard dome tweeter.

Table 2. Comparison of physical properties of cone paper

	Conventional pulp	Pulp containing sea squirt cellulose
Sound velocity	2600 m/s	3120 m/s
Energy loss factor	0.05	0.055
Air permeability	60 cc/s	1 to 10 cc/s



a: Diaphragm of wooden pulp　　　b: Diaphragm of wooden pulp containing cellulose of sea squirt

Figure 12. Diaphragm cross section

4.2.2 Sound improvement in the overall system

Figure 13 shows the layout of the new Celica Superlive system speakers.

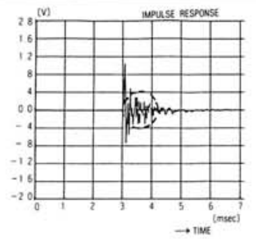
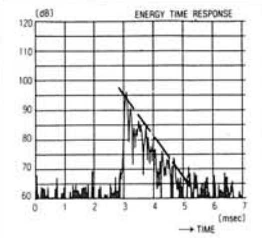
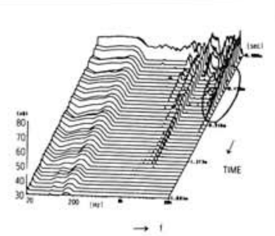
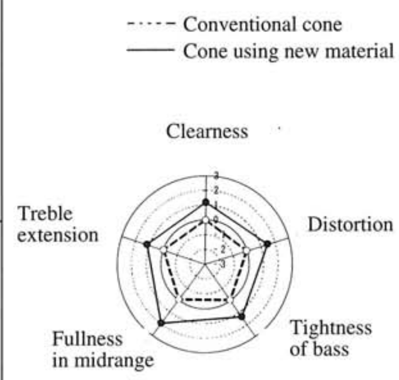
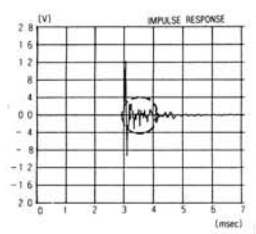
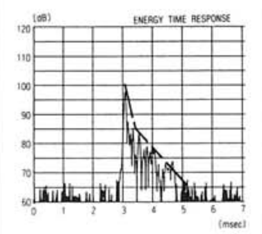
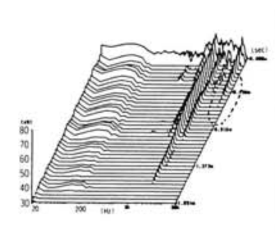
Front squawkers are placed at the top of the right and left door insides. The tweeters, squawkers, and woofers are therefore on the same plane (door). This arrangement reduces conventional unbalanced sound image positioning, and forms a sound field that extends right and left. Also, sound from the three speakers combines naturally, and sounds at low to high frequencies are reproduced smoothly.

The combined effect of the new speaker layout and new cone material enables the Celica Superlive sound system to reproduce the excitement of clear, powerful rock music and also soft vocals with great depth.

5. Conclusion

In this report, we presented the aims of the new sound system and the major technologies developed in 1993. At this stage of development, we did not significantly change specifications and functions, but we significantly improved

Table 3. Comparison of the new biocone speaker and a conventional speaker

	Impulse response	Energy time response	Falling edge accumulative spectra	Listening evaluation
Wooden pulp cone speaker				
Speaker with new cone material				Others - Improved crispness - Improved clarity
Improvement	Amplitude is small until 1 millisecond after impulses are input.	Energy attenuation characteristics are good.	Attenuation at high frequencies is steep.	

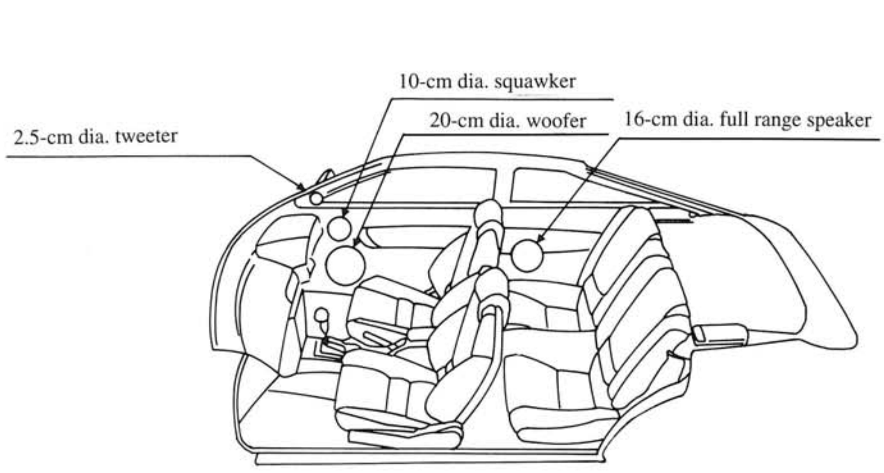


Figure 13. Layout of loudspeakers

reception and sound quality using new technologies and parts.

We reduced the number of parts and discrete wires, made parts compact, improved quality, and reduced costs. We will continue to build on what we have learned to develop technology that saves energy and to increase our experience.

Finally, we would like to thank Toyota Motor, Onkyo and the other organizations who supported the development of this new system.

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