Development of 09CY Audio Platform

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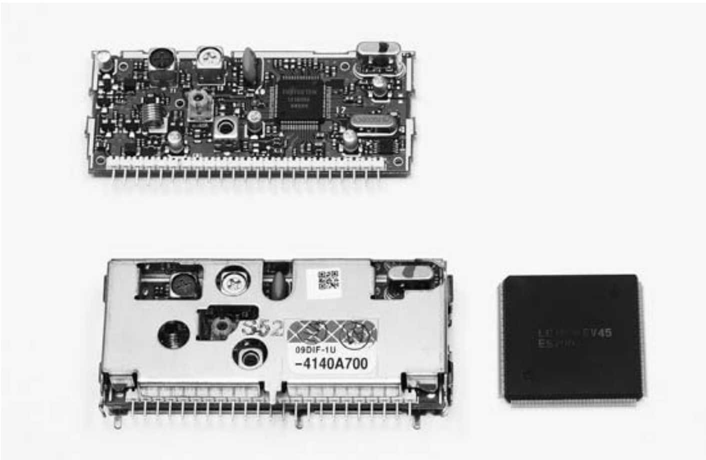

Abstract

With the development of digital technology, the mainstream digital media for use in car AV products has changed: from CD, DVD to HDD. In terms of broadcasting media, various types of digital broadcasting have begun in countries all over the world. While in AM / FM radios, further performance improvement is required.

Under these circumstances, from 2005CY we introduced the digital processing platform for the circuit blocks of AM / FM IF and thereafter. However it became relatively expensive for a low-grade CD-tuner, because it had too many various specifications.

Therefore, we developed a new platform with improved performance and optimized functions, dedicated to a CD-tuner. In this paper, we set out the function outline, characteristics and main technology involved.

1 Introduction

Conventional audio products as typified by CD-tuners are facing intense price competition. To win that competition among conventional audio manufacturers, drastic cost reduction and differentiated performance are both important. Also, machining cost reduction by sharing designs with other products is important.

This time, we have developed a new radio platform that can be shared across products for multiple OEM customers by downsizing, reducing its cost drastically and improving its receiving performance through optimizing the platform for our 09 model CD-tuner.

2 Aim of Development

2.1 Background

FUJITSU TEN DIF processing radio (Digital IF radio: radio with digital processing IF circuit block and thereafter) has been installed since our 05 model OEM car AV products. This 09 model is the third generation.

At the beginning of the development for the first-generation DIF processing radio, because there was no radio / audio integrated LSI (radio DSP + audio DSP) covering our entire OEM products, we had to adopt the most appropriate LSI depending on each customer's specifications. Thus, it was impossible to share the audio platforms.

During the development of the second-generation 07 model, we designed and developed an integrated LSI compatible with our customer specifications of all OEM products. With this platform development, the efficiency in development was improved and drastic cost reduction was achieved by using a unified audio platform.

However, the platform became relatively high in cost due to with various functions and extensibility.

So, we developed a new LSI conforming to our customer specifications specialized for a low-grade CD-tuner with higher performance in radio by building on the performance of the second-generation 07 model.

2.2 Aim of integration of radio / audio LSI and CD LSI

In accordance with the digitalization of radio BE part (Back end part: referring to the part of radio IF and thereafter), radio part and audio part were integrated. In this model, we aimed to reduce the number of parts, the space of printed boards and costs by integrating CD control part and compressed audio signal decode part into one package as a new approach, as well as improving receiving performance in radio.

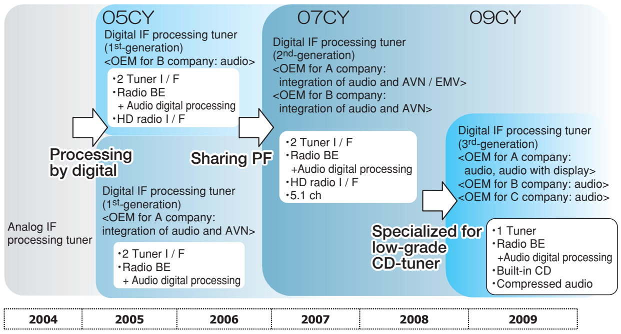

Fig.1 Roadmap of FUJITSU TEN DIF Processing Radio

3 Outline of Entire System

3.1 Improvement of Radio Reception Performance

We succeeded in improving further radio reception performance based upon the reception algorithm developed for the first- / second- generation DIF processing radio. In consideration of the vehicles equipped with antenna amplifiers, which have been increasing in number recently, we newly adopted the algorithm focusing on the noises generated at no signal situation.

3.2 Reducing Space

We succeeded in reducing the space required for a printed board by integrating the LSI for CD control and compressed audio (WMA, MP3, AAC) signal decode and the LSI for radio / audio processing into one package by Multi Chip Package technology. (20% reduction of LSI chip area)

3.3 Specialization of Function for Low-grade CD-tuner

We succeeded in reducing cost drastically by specializing functions for low-grade CD-tuners for OEMs and removing unnecessary functions (diversity combining function, HD function, 5.1ch reproducing function)

3.4 Others

We succeeded in reducing the load of the microcomputer system set by installing a built-in sub microcomputer (radio / audio / CD control).

The factors of radio reception performance for each destination and the sound field compensation conforming to each vehicle cabin configuration can be set by the microcomputer system in a set, thus controlling by hardware is unnecessary.

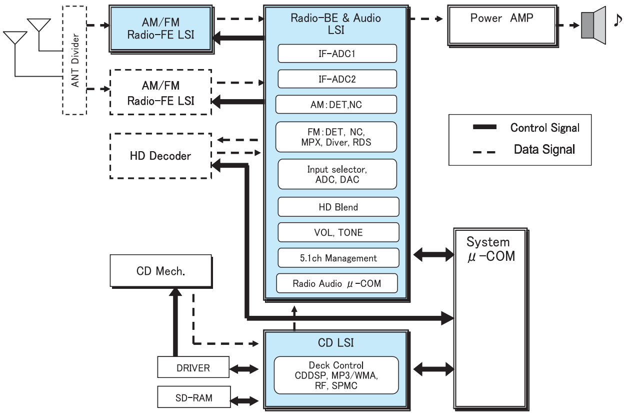

Fig.2 System Block Diagram of Conventional Product (07 model)

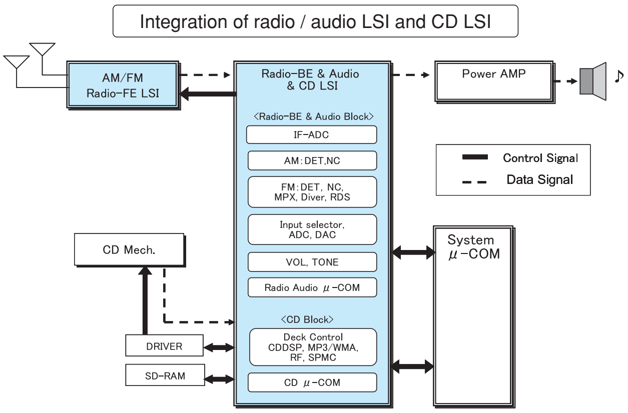

Fig.3 System Block Diagram of Developed Product (09 model)

4 Device Development

4.1 Device Configuration

The basic system of radio / audio / CD control is composed of two devices below. (**Fig. 4** shows this device configuration and skeleton block configuration inside the devices.)

a) Radio front-end LSI

b) Radio back-end & audio & CD LSI

(Integrated LSI of radio / audio / CD)

The integrated LSI mentioned in b) is composed of the following five blocks.

(1) System / Radio / Audio controller

(2) Radio back-end block

(3) Audio processing block

(4) CD controller

(5) CD & MP3 / WMA / AAC decoder block

Controller blocks mentioned in (1) and (4) are to be controlled by a built-in CPU. This system enables the microcomputer system to control the blocks by commands, and reduce the control load of microcomputer system. Each block of radio / audio / CD is composed of hardware processing and software processing (DSP).

Each throughput (bit width / operating cycle) of installed CPU / DSP is as follows.

- System / Radio / Audio controller CPU：
  32bit, 17.64MHz
  (decided conforming to multiple control and expandability for requirements)
- CD controller CPU：8bit, 17.64MHz
  (decided conforming to downsized scale and low power consumption)
- Radio / Audio / MP3, WMA, AAC decoder DSP：
  24bit, 135MHz
  (decided conforming arithmetic accuracy and arithmetic processing power)

4.2 Configuration of audio processing and functional specifications of I/O terminal

Fig. 5 shows the diagram of the audio processing block. **Table 1** shows specifications for I/O audio signals. This audio configuration enabled audio processing including mixing of multiple sound sources.

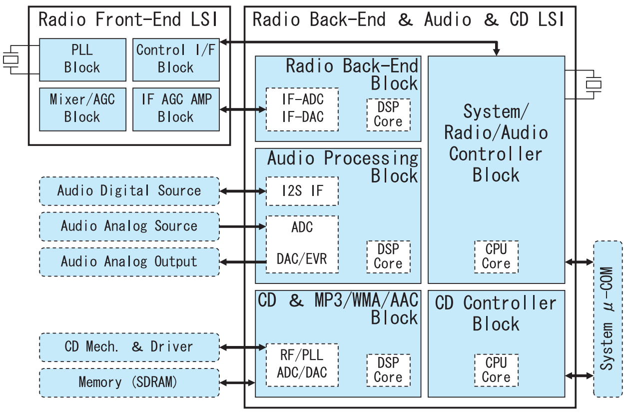

Fig.4 Device Configuration Diagram

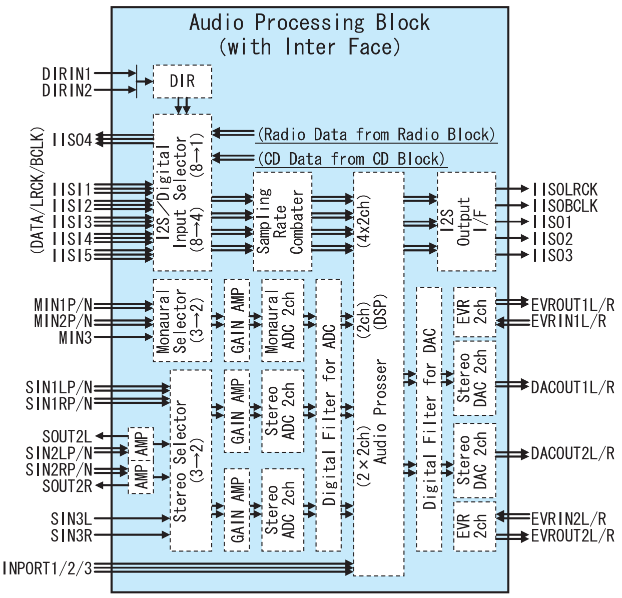

Fig.5 Diagram of Audio Processing Block

Table 1 Specifications for I / O Audio Signal

<table>
<tr><th>I/O</th><th colspan="3">Type</th><th>I/O system</th><th>Audio processable signal (DSP)</th></tr>
<tr><td rowspan="8">Input</td><td rowspan="4">Digital</td><td colspan="2">I2S PORT</td><td>5 sys</td><td rowspan="4">Max. 4 stereo signals selectable from 8 sys</td></tr>
<tr><td colspan="2">DIR PORT</td><td>2 sys (exclusion)</td></tr>
<tr><td colspan="2">(Radio Block)</td><td>1 sys</td></tr>
<tr><td colspan="2">(CD Block)</td><td>1 sys</td></tr>
<tr><td rowspan="4">Analog</td><td rowspan="2">monaural</td><td>Balanced PORT</td><td>2 sys</td><td rowspan="2">Max. 2 analog signals selectable from 3 sys</td></tr>
<tr><td>Single PORT</td><td>1 sys</td></tr>
<tr><td rowspan="2">Stereo</td><td>Balanced PORT</td><td>2 sys</td><td rowspan="2">Max. 2 stereo signals selectable from 3 sys</td></tr>
<tr><td>Single PORT</td><td>1 sys</td></tr>
<tr><td rowspan="4">Output</td><td rowspan="2">Digital</td><td colspan="2" rowspan="2">I2S PORT</td><td>1 sys</td><td>Non (Only selected output)</td></tr>
<tr><td>3 sys</td><td>Max. 3 stereo signal output possible</td></tr>
<tr><td rowspan="2">Analog</td><td colspan="2">DAC PORT</td><td>4 ch</td><td>Max. 2 stereo signal output possible</td></tr>
<tr><td colspan="2">EVR PORT</td><td>4 ch</td><td>Non (dedicated I/O)</td></tr>
</table>

4.3 Efforts toward integration (CD built-in)

We took the following measures as tasks for functional integration (Radio / Audio / CD).

a) Countermeasure against noise

b) Figuring maximum current flow and effort for low power consumption mode

c) Effort for fail safe

a) Countermeasure against noise

An integrated system is composed of multiple analog circuits (IF-ADC / DAC for radio, ADC / DAC / EVR for audio, RF / PLL and others for CD-Servo, and system clock forming network such as system PLL), digital circuits (block circuits of different operating frequencies), and multiple terminal pins. Aiming for integration, first, we optimized the layout (e.g. isolated position for interfering block) for respective analog circuits and terminals (group unit), and then, took the countermeasure for noise reduction by the method of optimum layout of power supply (LSI layout design method) and by enhanced power supply methods such as enlarging the capacity between power supplies in the LSI.

b) Figuring maximum current flow and effort for low power consumption mode

By estimating the current flow increment for each block caused by the integration, we read for consistency with heat resistance performance prior to designing.Also, using the estimated result of this current consumption by block for the block layout mentioned above, the block layout in consideration of the dispersion of power (current flow) is implemented. Further, building the low-power consumption mode by block (or by function unit) led to the circuit in which respective functions can work with the minimum current flow.

c) Effort for fail safe

Building fail safe processing function for each individual block by the multi-function system enables the respective recovery of radio / audio and CD function.

This processing outline is explained in Section **4.4**.

4.4 Fail Safe Function

As explained in the device configuration above, this device is equipped with various functions and multiple CPUs / DSPs. In case of malfunctions such as runaway of CPU / DSP, by building the fail safe processing (detecting malfunctions and recovering) by function, the load of the microcomputer system is reduced and prompt actions against malfunctions are possible.

The fail processing details are as follows.

- **To build the measure of giving notice when a malfunction is detected by a built-in controller (radio / audio system and CD system) in a device**

  For the notice of a case that the runaway of CPU / DSP is detected from the two blocks of radio / audio system and CD system, outputting respective error signals of watchdog timer is established. In this system, through the measure with notices by terminal output and respective runaway notices, prompt action against runaways and countermeasures by block are possible.

- **To build the measure of detecting malfunctions inside a device by built-in controller in a device (CPU), self-recovering and giving a message**

  Each built-in CPU processes for detecting malfunctions respectively by radio / audio system and CD system. A device itself can recover from some malfunctions.

  The malfunction results and self-recovering can be judged every time by the microcomputer system through communication, and besides, the action (recovering) by the microcomputer system can be added and changed.

  Further, by breaking up the judgments respectively, such as by system, radio and audio system in a radio / audio system, and by CD playback and compressed audio playback system in a CD system, in this system, respective recoveries by malfunction content are possible.

- **To detect malfunctions to command form (communication)**

  This device is controlled by a command base and the communication (judging the command contents) is judged in the device. In this system, communication result (normal / malfunction) by command can be checked by the microcomputer system, and recovery by command communication is possible.

5 Newly Developed Function

5.1 Prevention of Noise Converging Point Elevation (AM)

Recent years, for vehicle radio antennas, active antennas such as glass antenna and short-pole antenna are mainstream, replacing the conventional passive antennas.

In accordance with this change, noise level elevation under no-signal circumstances became problematic.

Signal strength was obtained by S-meter based on AGC signals controlled for detection. However, by preparing AGC for S-meter detection shown in **Fig. 6**, low-pass filter can be placed prior to the secondary AGC (for S-meter DC detection). This enabled preventing the noise level from being elevated under no-signal circumstances.

The characteristic of the one AM signal through the circuit with antenna amplifier for short pole combined is as follows.

Fig. 7 shows the graph of the conventional model, and **Fig. 8** shows the graph of the new model. Without antenna amplifier combined, both of the models output signals with the same characteristics.

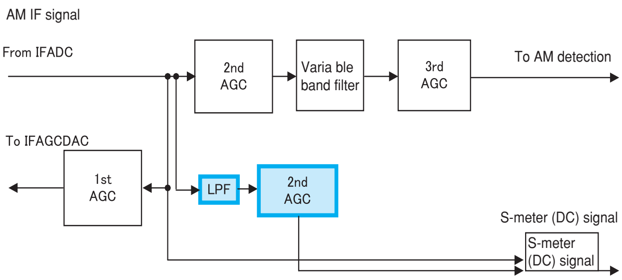

Fig.6 Block Circuit of DC Part S-meter

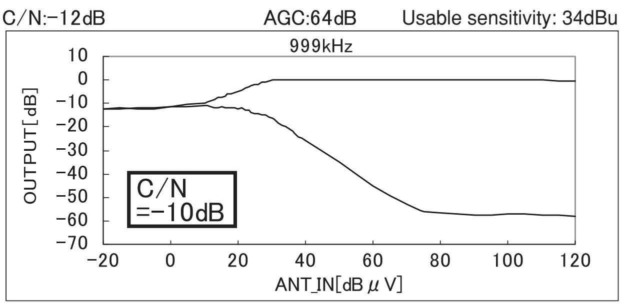

Fig.7 One Signal Characteristic of Conventional Model (07PF) with Antenna Amplifier for Short Pole Combined

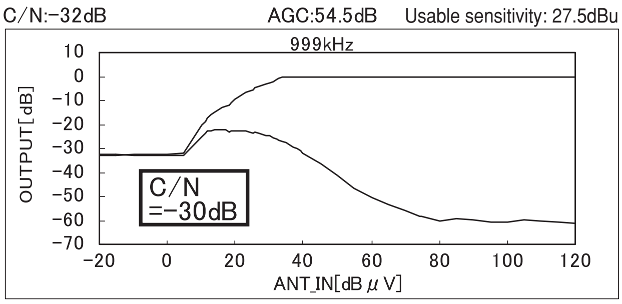

Fig.8 One Signal Characteristic of New Model (09PF) with Antenna Amplifier for Short Pole Combined

5.2 Prevention of Noise Converging Point Elevation (FM)

We saw the opportunity for detecting the repeating IF signal envelop drops as holes (circled in red); which are caused by random noises, to detect weak electric field without any influence by antenna amplifier. **Fig. 9** shows the image of the hole detection.

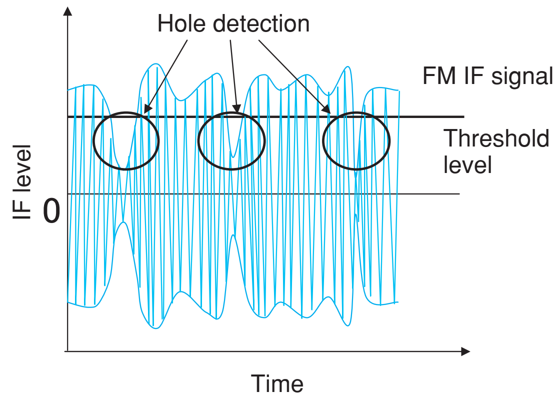

Fig.9 Detection Image of FM Weak Electric Field

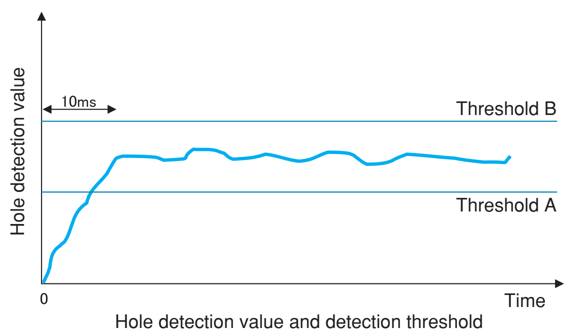

Fig.10 Relation between Hole Detection Amount and Threshold

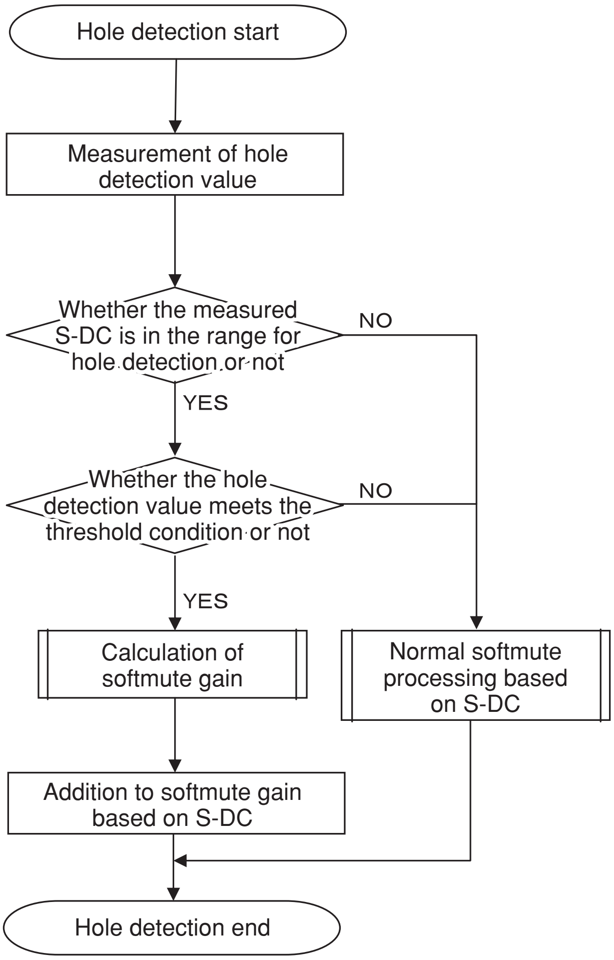

Fig.11 Soft-mute Processing following Hole Detection

As shown in **Fig. 10**, by setting two threshold levels to the hole detection values, the mute gain is to be controlled by following the algorism in **Fig. 11**.

a) When the measured S-DC value is above the threshold level range (the value is variable by parameter), hole detection is unnecessary.

b) When the hole detection value is above the threshold A (the value is variable by parameter), the softmute processing conforming to the hole detection is to be implemented.

c) When the hole detection value is under the threshold A, the hole detection result is not to be reflected to the S-mute. The softmute processing conforming to the normal S-DC is to be implemented.

By processing as above, we succeeded in preventing noise level elevation under no-signal circumstances.

5.3 CD sequencer

Here is the explanation of the CD part. In this newly developed system, to reduce the capacity of software and to accelerate the processing speed by reducing the load of software, various controls that were processed by software are now to be processed inside the LSI by sequencer (CPU) packed in a ROM. In the result, we succeeded in reducing CD control program capacity, integrating the dedicated CD control microcomputer into product control microcomputer, and operating CD playback function and RDS function concurrently. Besides, the sequencer packed in a ROM enabled the speed-up of processing and reduced the time required from disc insertion to playback start.

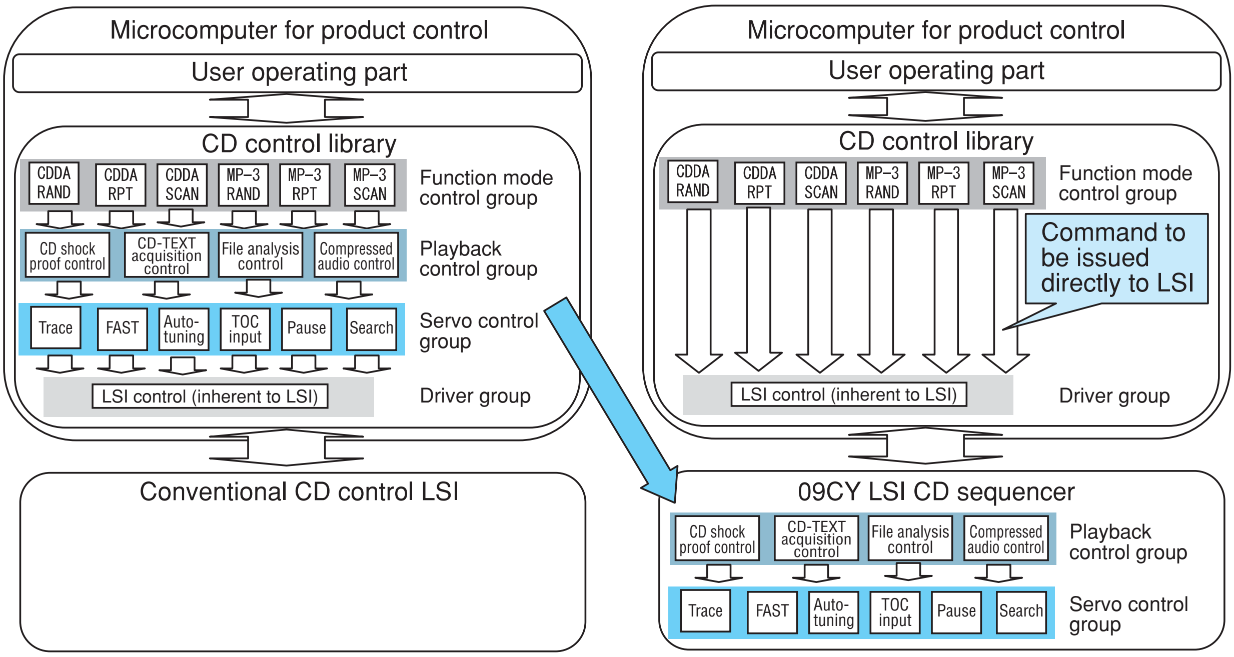

Fig.12 Block Diagram of CD Control Firmware

Table 2 Required Time from Insertion to Replay Start (Single CD)

	Conventional model (s)	09PF (s)
CDDA Disc	10.8	8.6
MP-3 Disc	13.7	9.7

As above, the CD sequencer was built in the LSI. However, the various know-hows in performance and function for an in-vehicle CD deck are incorporated in the conventional software controlling part.

We have been developing the CD sequencer so as to incorporate the following functions based on our consecutive ideal with repeating DR (Design Review) with LSI manufacturers from the beginning of the development.

- **Adding functions so as to make a retry suitable for the remaining amount of memory for shockproof function. Preventing noise generation and sound skips even under bad environment with vibrations. Taking measure that users are unaware of if any of sound skips occur.**
- **Incorporating function for playback of CCCD (copy control CD) and nonstandard CD**
- **Adding function for fail safe**
- **Enhancing function for retry**
- **Function for output of error code information**
- **Adding AGC function during playback**

5.4 Improving CD Read Performance

It is inevitable for in-vehicle devices to be used under bad environment with dust, sand, etc. in some countries and areas such as developing countries. We previously have taken some measures to prevent outside dusts from entering. However, it is difficult to seal up the in-vehicle devices because there are opening around the in-vehicle devices due to their slot-in mechanisms, and because the devices require spaces for heat release. These circumstances require a high playback capability even with dusts inevitably entering into lens.

In 09PF, by tripling the adjustable width of input gain, we achieved over 20% improvement in the dust resistance of the lens.

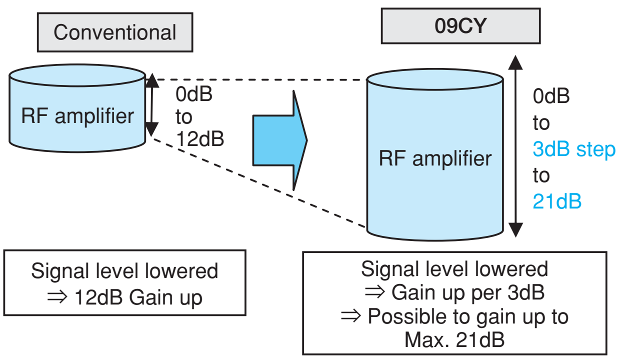

Fig.13 Variable Amount Expansion of Control Gain

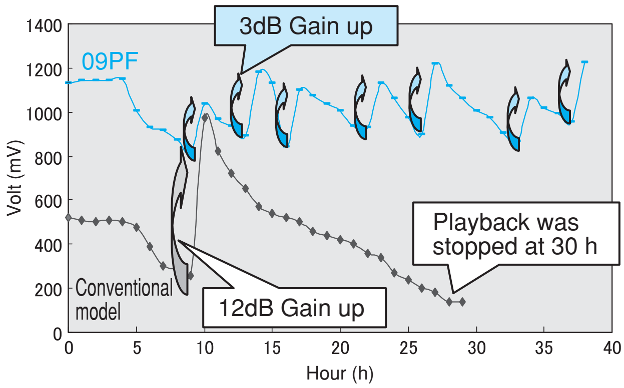

Fig.14 Comparative Efficacy with Dust Test

There are various discs in the market, which differ in reflectivity. Our new measure to make gain adjustment by 3 dB step method is effective in playback of these discs in their appropriate conditions, and the new model provides higher performance in playback than the conventional model.

5.5 Quality Improvement by Error Code

In-vehicle CD players are used under bad environment with outside vibrations and of high / low temperature. So, software in CD players incorporates high-power fail safe that provides recovery function from error status that users are unaware of. With the fail safe function, users can enjoy music as though at home. But in some cases, the fail safe makes the evaluation impossible due to its recovery function. Finding the way to reduce the cases of NTF (No Trouble Found) and low-frequency defects became our new task.

In this development, to eradicate NTF and low-frequency defects, we built a new function into the software, which plays a role in accumulating information into non-volatile memory for detecting abnormal operations including phenomena that users are unaware of and to identify the cause.

The following information is accumulated into non-volatile memory.

- **Abnormal state detected by software**
- **Details that fail safe ran**
- **Information about disc type / disc playback time (address)**
- **Result per disc adjusted by servo system**
- **Temperature information**

This system is beneficial not just to analyze defective products, but also to analyze products with no defects by reliability test such as for durability in operation, test with poor quality media collected from countries, and rough road driving test by actual vehicle using all error codes. This system enables detection of such control problems that do not come to the surface. We succeeded in solving all problems in the development step.

6 Effect

As above, with ensuring the higher radio performance and CD performance than the conventional platform, we achieved cost reduction and space reduction (20% reduction of LSI chip area) shown in **Fig. 15**.

This platform is the current main platform for our CD-tuner products, and is mass-produced for respective destinations for OEM customers.

7 Conclusion

In this development, we achieved development of platform with its performance and its cost optimized.

As mentioned in the abstract, various types of digital broadcasting have begun in countries and are becoming a major media.

We are pursuing the development of platform for other digital media while aiming for higher radio performance.

In conclusion, we appreciate the efforts of people of device manufactures and departments involved in this system development.

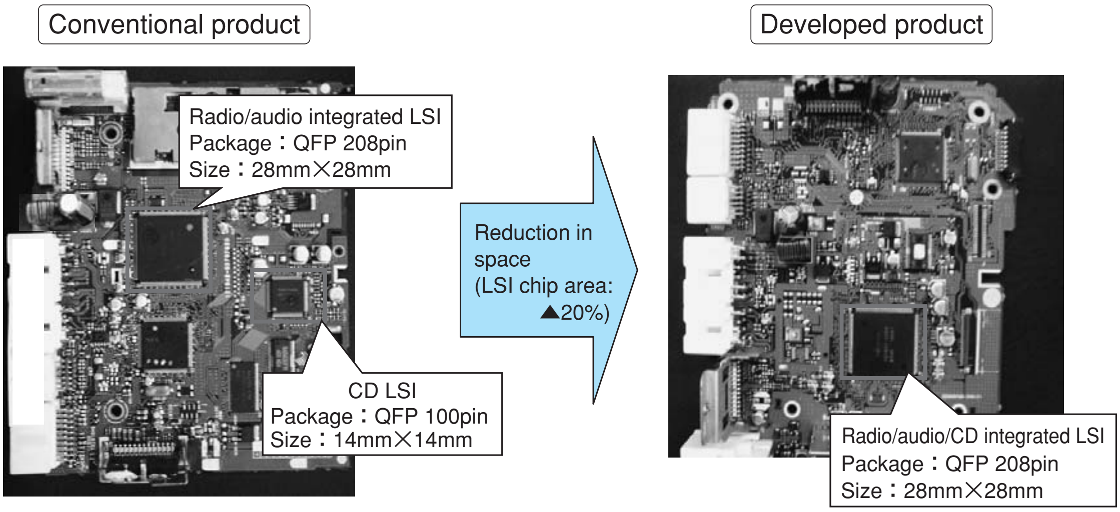

Fig.15 Comparison of Main Printed Boards in CD-tuners Equipped with Developed Product and Conventional Product

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