Development of tuner IC units for the 2001 Model

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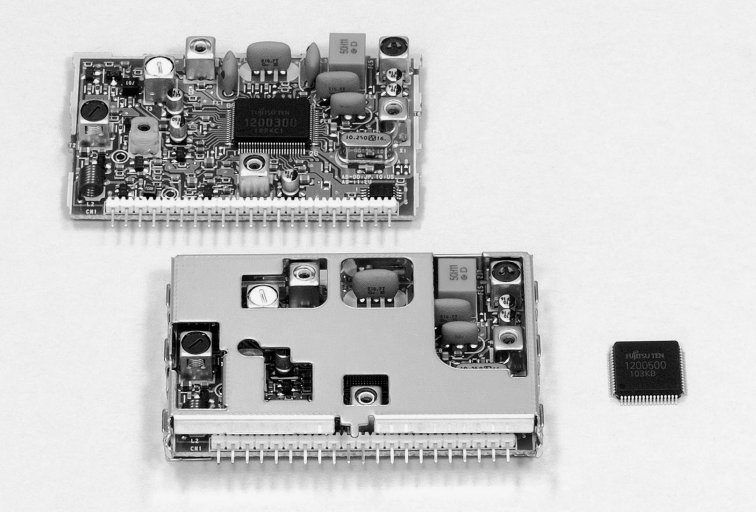

Abstract

With the development of digital technology, car AV products have become increasingly multi-functional with the advent of the CD, MD and the DVD. Additionally the increasing popularity of car navigation is resulting in intensified competition in the differentiation of features, miniaturization and prices.

In this environment, an urgent task in the development for future audio systems is to achieve groundbreaking cost performance by exploiting IC and key technologies.

The Tuner ICs introduced here were developed in conjunction with the Toshiba Corporation Semiconductor Company to meet the needs for 2001 model radios. The developed ICs provide productivity, multiple features and cost performance.

This paper presents the overview of functions and features in the newly-developed IC, together with the major technologies applied.

1 Introduction

Sales of navigation systems and other high-cost products have grown more than those of audio products in recent years. Given this situation, maintaining quality assurance and price competitiveness is a truly vital issue for the survival of audio products.

In order to achieve these goals, it became necessary to create products incorporating groundbreaking advanced technology in a short time frame, in a manner exemplified by the evolution of IC fabrication technology.

Considering that the same applies to development of the radio tuners that are a key component of audio products, we have begun with development of the IC's that are the tuner's core.

Despite difficulties concerning needs and technology for the tuner, as well as the difficulty of short time-frame development, we were able to develop IC's with high cost performance by utilizing past IC development know-how and collaborating an IC manufacturer. This development is presented below.

These IC's have been incorporated in our standard tuners since December 2000.

2 Objectives of development

The present IC's were developed with the following objectives:

①Improved performance

- Taking into consideration the increased distribution of multimedia equipment, to reduce emissions from local oscillators so that TV and navigation systems, etc., are not affected by radio frequency interference
- For sound quality improvement, to achieve both reduction of noise under FM adjacent channel interference and high sound quality at the same time (a longstanding difficulty with the tuner unit). And while incorporating the audio processing unit (electronic volume control) into the IC functions, to improve the S/N ratio, which is a basic performance factor.

②Miniaturization

- To employ IC's for fine processing, proceeding with further integration of functions, reducing the number of, and to miniaturize components (refer to Fig. 1).

③Improved quality

- To improve soldering quality via reduction in number of components
- To improve adjustment precision by automating all

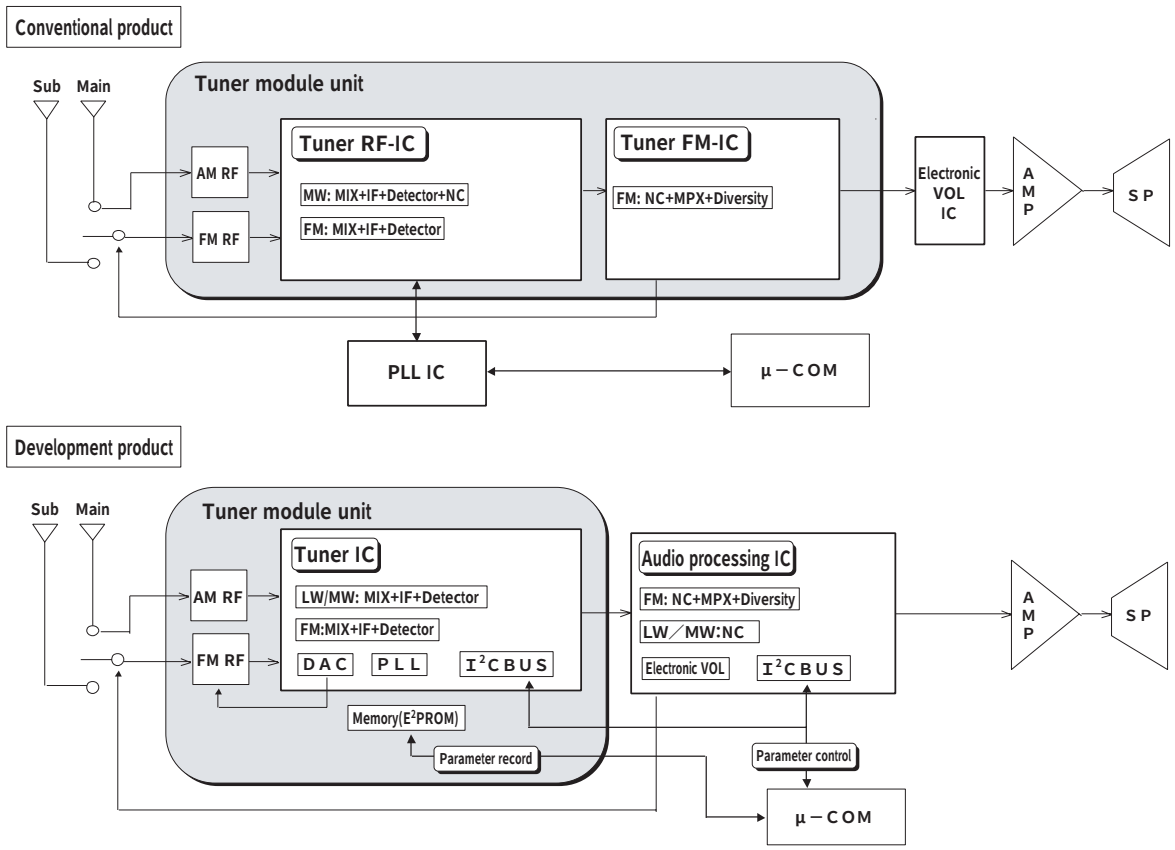

Fig.1 System block diagram (comparison versus conventional product)

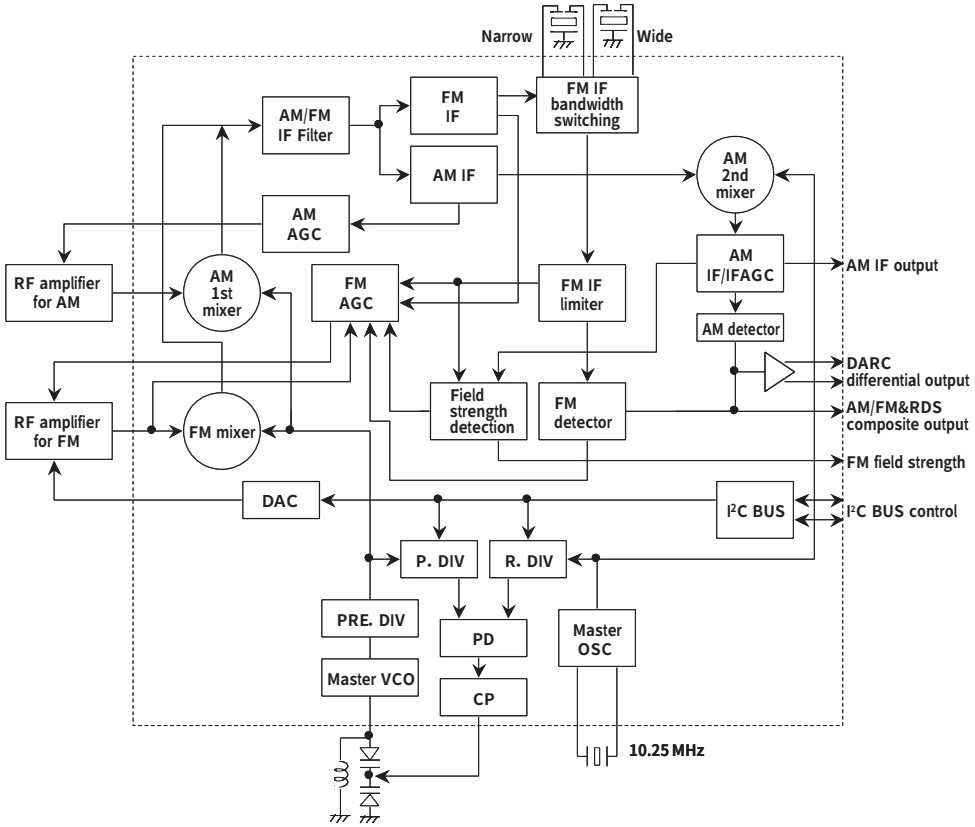

Fig.2 Tuner IC block diagram

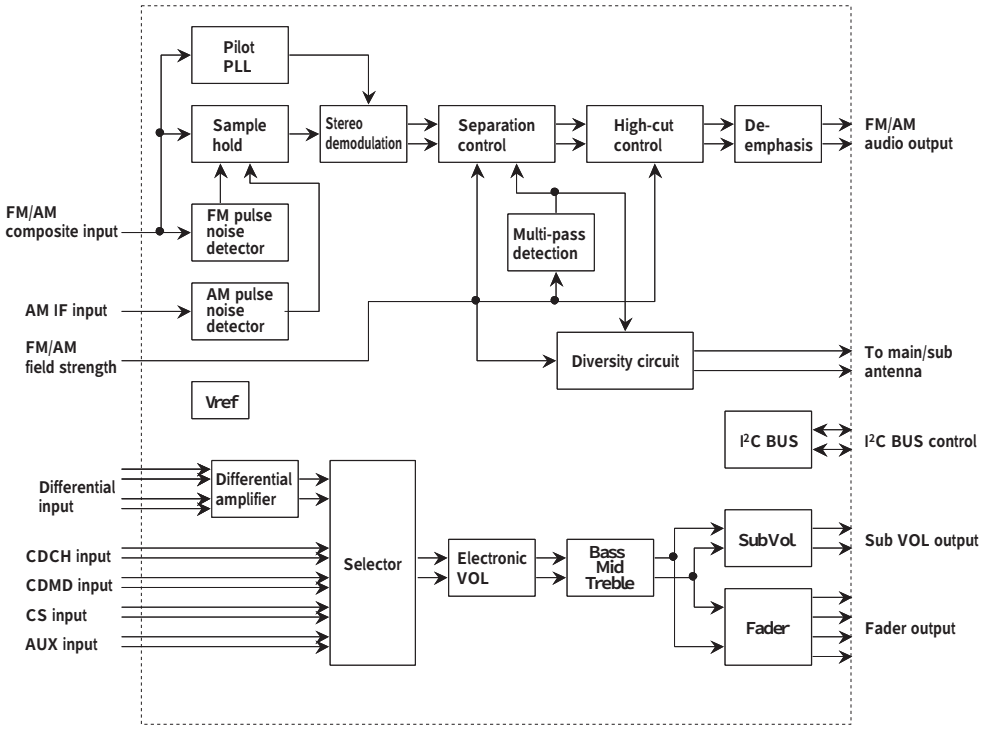

Fig.3 Audio processing IC block diagram

conventionally manual adjustments.

④Globally common design

・To standardize hardware for all tuner destinations worldwide

3 Overview of IC's

3.1 Block configuration

The four traditional IC's were the PLL IC, electronic variable resistor IC and 2 tuner IC's (for the RF and FM processors). By means of the 0.6 micron Bi-CMOS technology, these were integrated into 2 IC's: a tuner IC and an audio processing IC. The configuration took into account the following:

①Necessary number of pins

②Power dissipation

③Use of standard packaging

④In order to raise tuner and electronic volume control performance, an optimum split tuner IC's should:

・employ a heterodyne up-conversion for the AM tuner unit to match world-wide frequencies

・employ IF band width switching to improve susceptibility to adjacent channel interference in the FM tuner unit

・employ a medium-voltage process technology for the PLL units (AM/FM)

・employ I²C bus for serial bus control circuits (refer to Fig. 2).

The audio processing IC's should:

・have variable sample hold time for the FM noise canceller unit

・employ a switching type stereo demodulation unit

・employ multi-path detection and separation control for the automatic separation control unit

・employ multi-path comparison detection for the diversity unit

・have an AM noise canceller unit

・have an electronic variable resistor unit composed of a selector (5-channel), electronic volume control, Bass/Mid/Treble, SUB variable resistor and Fader

・employ I²C BUS for the serial bus control circuits (refer to Fig. 3).

3.2 Process Technology

The factors that have enabled the tuner and audio processing IC's to be rendered multi-functional can be cited as advances in semiconductor process technology and the partial adoption of a 12V medium-voltage CMOS transistors. In the present IC's, HV-BC-0.6M (high voltage Bi-CMOS processing technology 0.6 micron medium) is employed to provide optimal accommodation of mixed signals for audio applications. Details of this are described below.

①Realization of high-speed bipolar transistor

By keeping a 12V tolerance while achieving 9GHz, a substantial improvement over the conventional bipolar process of the PLAS-1S having ft(max)=1.8GHz@NPN, a world class speed and voltage tolerance (108GHz-V) was achieved (Fig.4).

②Mixed signal capability through the incorporation of CMOS transistors

In addition to the bipolar NPN and PNP transistors,

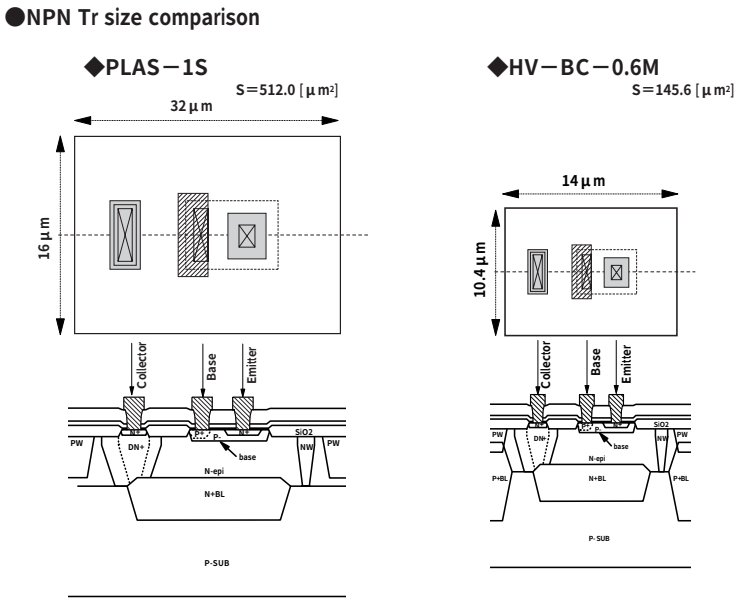

Fig.4 Comparison of NPN transistor sizes

5V spec CMOS transistors are also incorporated. This made it possible to realize high-speed mixed-signal IC's permitting communication with a microcomputer through a BUS, and various logic processing.

③Incorporation of medium voltage CMOS transistors

In addition to 5V spec CMOS transistors, 12V spec CMOS transistors can also be fitted. This permits optimum performance of the tuner system high-speed linear circuits requiring high intermodulation indices, audio system analog switches and also the charge pump for the PLL unit.

4 Development of new technology

New technology has been developed in order to achieve the development objectives, and they are described below.

4.1 FM IF band switching

This function switches the wide-bandwidth ceramic filter where the FM IF signals normally pass to the narrow band ceramic filter during adjacent channel interference, thus restricting the bandwidth and preventing adjacent interference (refer to Fig. 5).

Normally, a wide band ceramic filter of 150kHz or wider is used for the FM IF bandwidth.

If adjacent channel interference occurs, an interfering signal drops onto the IF passband. This interference element is sensed, and if it exceeds a certain level the ceramic filter is switched to the narrow-band filter. The noise generated by such switching is eliminated by implementing waveform shaping. In this way the IF signals are not adversely affected by adjacent-channel stations, and interference caused by poor adjacent channel selectivity are prevented.

A feature to prevent faulty operation during multipath and IF band width switching was provided to ensure high quality reception characteristics.

Fig. 6 shows the differences in performance depending on whether or not bandwidth switching is implemented when adjacent channel interference occurs. As can be seen, the range in which appropriate S/N can be obtained relative to the interference level is broad, so that good signal reception can be maintained even in areas subject to adjacent channel interference.

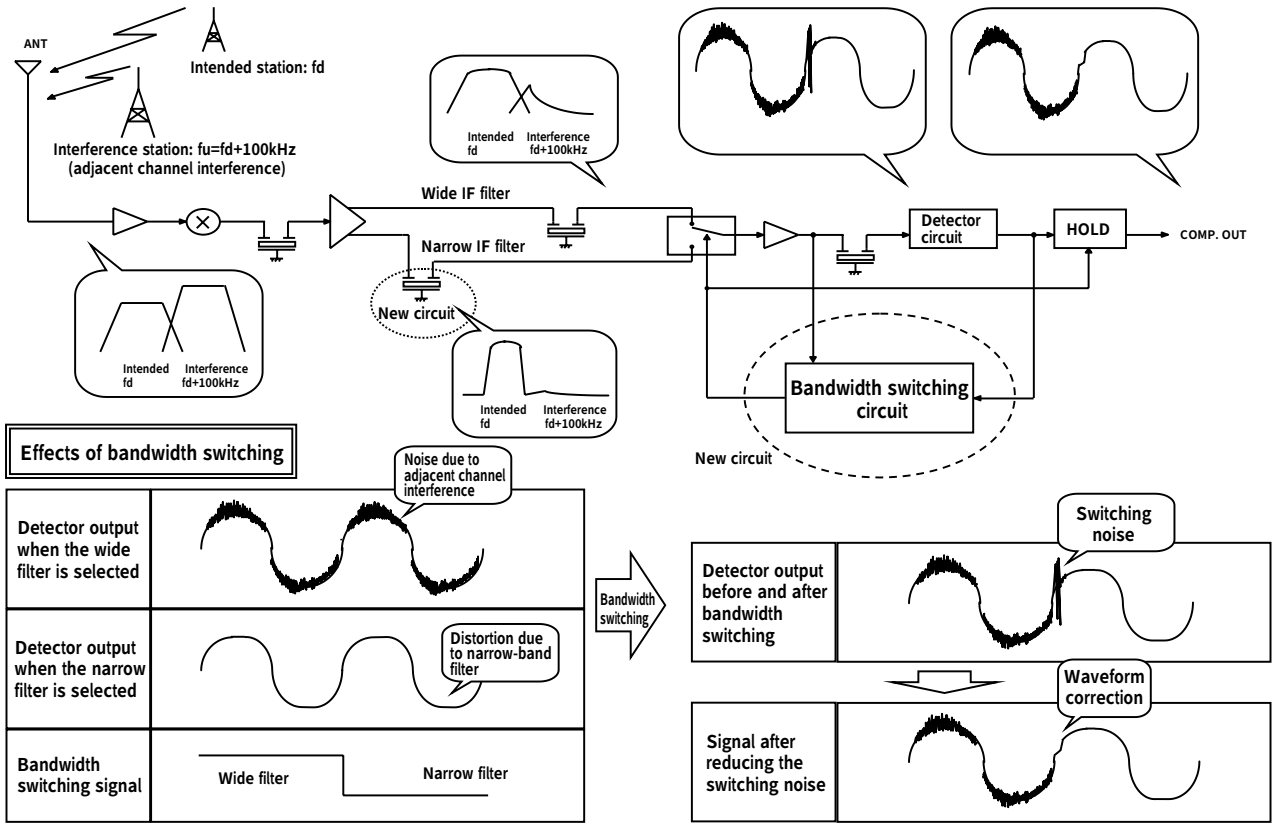

Fig.5 Schematic diagram of FM IF bandwidth switching operation

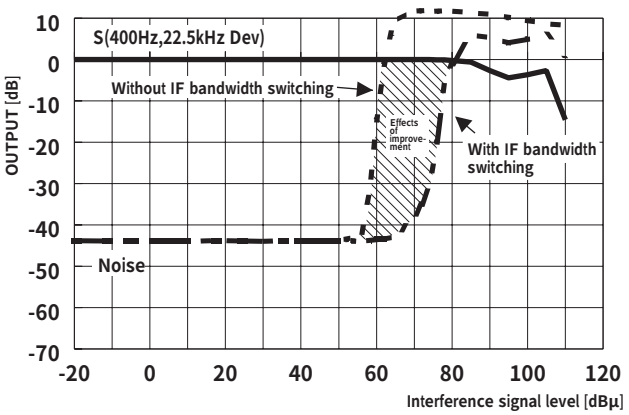

Fig.6 Effects of bandwidth switching on adjacent-channel interference immunity characteristics

4.2 Reduction of emission

As integration of TV receivers and GPS signal receivers proceeds, reduction of emissions that will have adverse effects on the reception quality of such and other equipment has become a required item for radio tuners intended to be installed in car audio-visual equipment.

Additionally, although progress in semiconductor process technology has drastically improved ft, permitting high-speed operation of circuits, this also poses risk of an increase in spurious noise from high-speed switching circuits. Innovations in the present IC technology have been made in the pin layouts (power supply, ground) and circuits etc., so as to reduce emissions compared with conventional products. The details of this are described below.

①IC pin layout

In tuner IC's the main circuit blocks causing emissions are the oscillator circuits (VCO), high-speed switching circuits (mixers) and PLL unit. By providing each of these blocks with a power source (4 pins) and ground terminals (4 pins) and creating a configuration in which the current is completed by short loops, each block is isolated and the level of radiation to the exterior is reduced.

Further, 28% (as opposed to 10% in conventional products) of all the terminals (84 pins) including the above-mentioned are assigned as power supply (8 pins) and ground (16 pins), thus reducing performance deterioration due to interference (spurious interference) between blocks.

②Measures via circuits

The output units of the VCO and mixer, which are major generators of spurious noise, were provided with LPF (low pass filters). Such provision took full account of the dynamic range and frequency characteristics. Additionally, 3 drive current patterns were provided for the VCO circuits, making possible tuning of the emission level in the installed condition (refer to Fig. 7).

③Dimension control of transistors

As stated above, although state of the art semiconductor processing technology has permitted high-speed circuit response, the downside is that this can also result in increased spurious noise in the high-speed switching

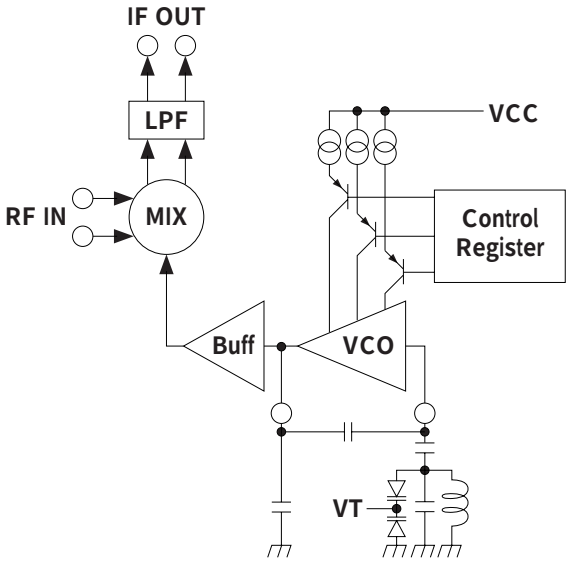

Fig.7 Emission reduction measures

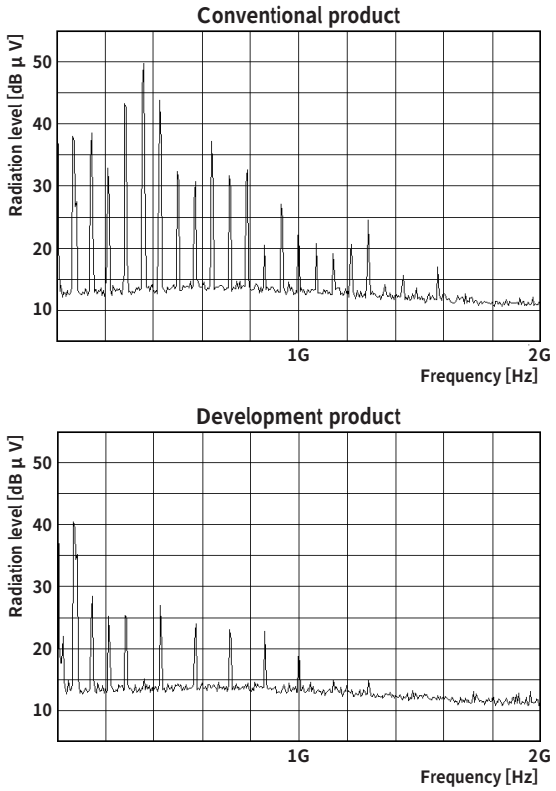

Fig.8 IC radiation level

circuits. Therefore for those switching circuits in the mixer block that use differential pairs, the transistor size (dimension) is controlled, thus securing necessary transition frequency and reducing spurious noise from undesired bands. The above measures have brought the improvement effects shown in Fig. 8.

Examples of emission interference

- With 79.2 MHz FM broadcasting station:
  68.5 (MHz)×3=205.5 (MHz)…TV channel 10 interference
- With 82.3 MHz FM broadcasting station:
  71.6 (MHz)×22=1575.2 (MHz)…GPS interference

4.3 Sharing of circuits

4.3.1 Reference oscillators

Tuners incorporating PLL for tuning require reference oscillators for generating reference frequency. And double conversion type AM tuners require a fixed-frequency local oscillator for their 2nd mixer. Accordingly in the present IC's, we contrived to integrate the reference oscillator and the local oscillator and enabled sharing of the resulting new 10.25 MHz master oscillator (refer to Fig. 9).

4.3.2 FM VCO and AM VCO

Generally speaking, FM and AM each require an independent local oscillator for their 1st mixer, since their reception frequencies differ by a great amount. In the present IC's, Bi-CMOS technology is utilized so that a pre-divider can be installed for the 1st AM local oscillator. This permits sharing of the oscillator as a new master VCO. (refer to Fig. 9).

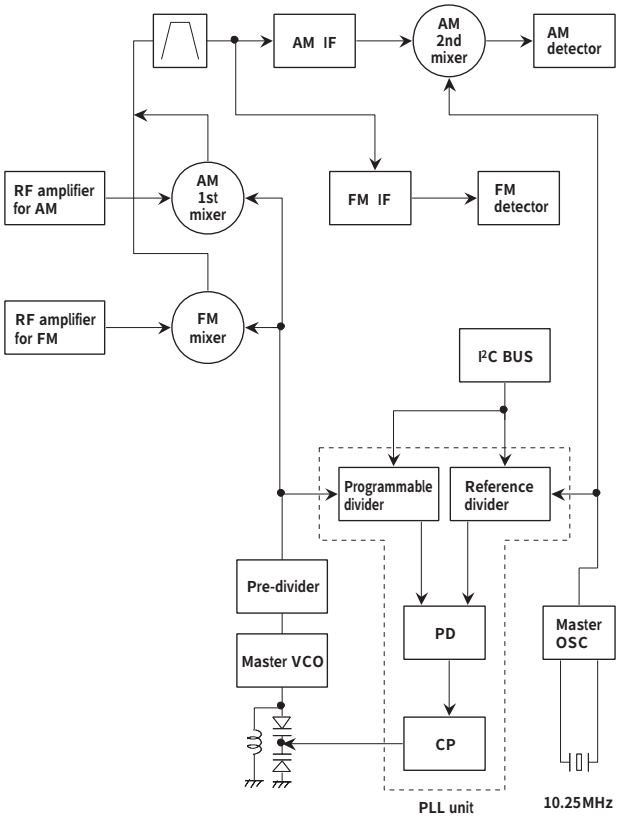

Fig.9 Block diagram of PLL unit and surroundings

4.4 Reference voltage regulator

The reference voltage unit for the audio processing IC's has a ripple filter configuration in which rapid charging circuits are added to a high ripple rejection type reference voltage regulator. Thanks to this it has been possible to shorten the time taken for charging of the capacitor when the power is turned on, and to stabilize the operational bias in a short time period (refer to Fig. 10). Further, the reference voltage is supplied to each block via buffers, thus eliminating adverse effects on the reference voltage, heightening isolation among the various function blocks, achieving low distortion and a high degree of separation (refer to Fig. 11).

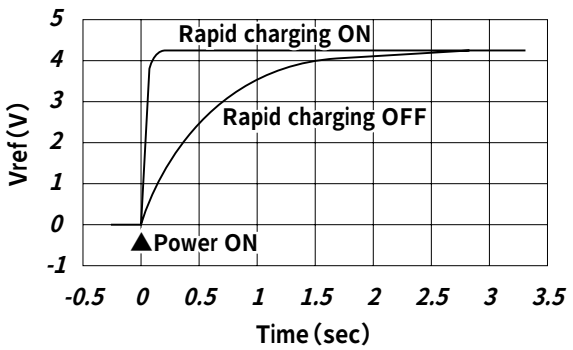

Fig.10 Vref rise time constants

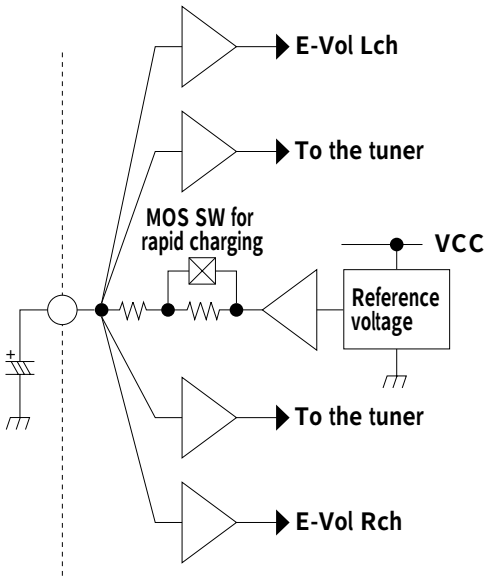

Fig.11 Block diagram of standard voltage regulator and surroundings

4.5 Control via bus communication

4.5.1 Characteristicswitching

In the present circuits, bus control can be used to switch the interfaces with the peripheral parts and to switch characteristics while using the same peripheral circuits (refer to Table 1). Fig. 12 presents an example of characteristicswitching. Though the A spec and B spec items both have the same IC peripheral circuits, their characteristics can be switched by means of bus control (refer to Table 2).

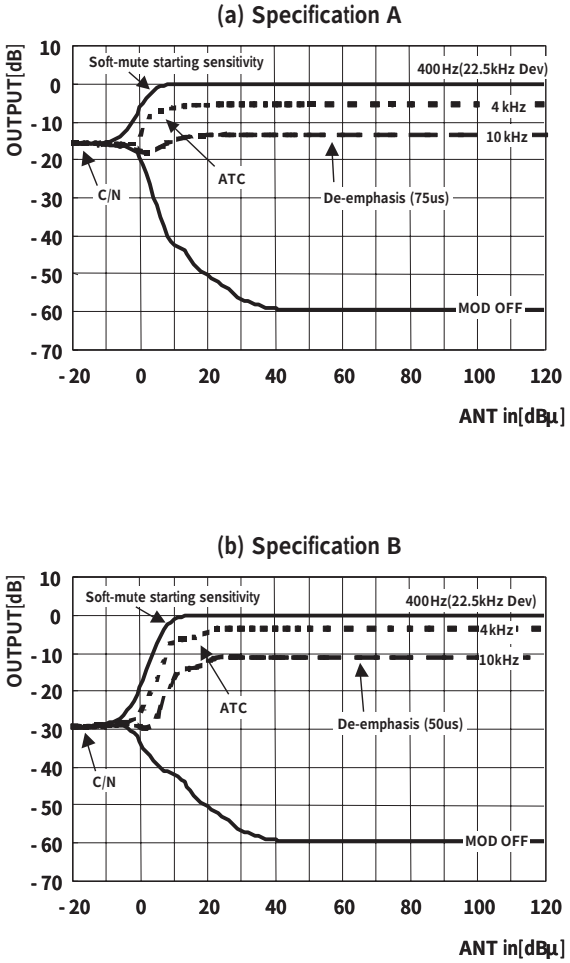

Fig.12 Example of characteristic switching via bus control (limiter curves)

Table 2 Points of changes in characteristics in Fig. 12

Changes	Spec. A	Spec. B
C/N	-15dB	-30dB
Soft-mute starting sensitivity	2dBμV	7dBμV
ATC	-4dB	-7dB
De-emphasis	75μs	50μs

4.5.2 Automated adjustment

Thanks to the adoption of bus control the adjustment that was traditionally performed via adjustment elements in the IC periphery is now automated. Further, whereas conventional products used transformer adjustments to compensate for irregularities in tracking unit peripheral components, the present IC's use DAC for this purpose, thereby allowing the transformers to be non-adjustable. Table 3 gives a comparison of the adjustment components of the tuner module developed using the present IC's versus that of conventional products.

Table 3 Comparison of adjustment points (newly-developed versus conventional product)

Adjustments		Development product	Conventional product
AM	RF1	—	×Transformer
	RF2	—	×Transformer
	OSC	—	×Transformer
	IFT1(1stMIX)	(sharable with FM)	×Transformer
	IFT2(2ndMIX)	△Transformer (robot)	—
	S meter	○	—
FM	ANT	○(DAC)	×Air-core coil
	RF	○(DAC)	×Transformer
	OSC	—	×Transformer
	IFT(1stMIX)	△Transformer (robot)	×Transformer
	DET	△Transformer (robot)	×Transformer
	S meter	○	×Preset resistor
	MPX	○	×Preset resistor

○ : Automatically adjustable
△ : Analog elements are adjusted by robots
× : Manual adjustment

Table 1 Major characteristics that can be switched.

IC	Switching type		Description	
Tuner IC	Interface		AM MIX1 in	Single ended or balanced
			AM IF filter	Ceramic or Crystal
			FM IF bandwidth switching	Yes or No
			DAC output	DAC or Charge pump
			M-OSC frequency	10.25MHz or 10.26MHz
	Spec.	AM	C/N, IF gain, interference detection sensitivity	
		FM	C/N, soft-mute starting sensitivity, IF gain, adjacent channel interference detection sensitivity, interference detection sensitivity	
Audio processing IC	Spec.		ATC, de-emphasis, multi-pass detection sensitivity, separation, noise canceler	

5 Effects of the development

As described above, by employing the industry's top-class process technologies, it was possible to integrate around 6 times as many elements as in conventional products. The PLL IC, electronic volume control IC and 2 tuner IC's were condensed to just a tuner IC and an audio processing IC (refer to Fig. 13). And by sharing circuits, a 42% reduction in the number of components compared with conventional products was achieved, thus contributing to miniaturization.

Also, 57 items of tuner IC and 52 items of audio processing controls were performed through BUS communication, allowing the reduction in the number of semi-fixed variable resistors and mechanical adjustment (from 11 items to 3 items), resulting in a 100% automatic adjustability.

And with the drastic reduction in the number of components, a 54% reduction was achieved in the time and labor required for the manufacture processing compared with conventional products (refer to Table 4).

Table 4 Effects of development

Item	Miniaturization		No. of process *	Performance
	No. of components	Installing area*		
Development	Approx. 150	80	46	◎
Conventional	Approx. 260	100	100	○
Improvement	▲42%	▲20%	▲54%	Bus control

＊ "Installing area" and the "No. of process" are shown in comparison to the prior model, which is considered 100%.

For reference, a comparison of the areas of the newly-developed and conventional products in the installed state is provided in Fig. 14.

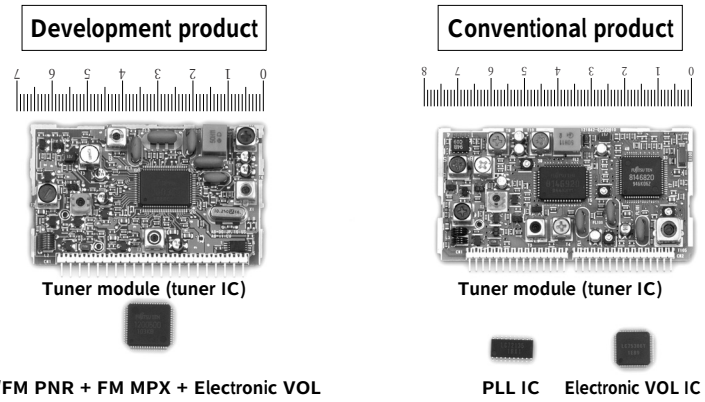

Fig.13 Comparison of newly-developed product versus conventional product (functions identical in both)

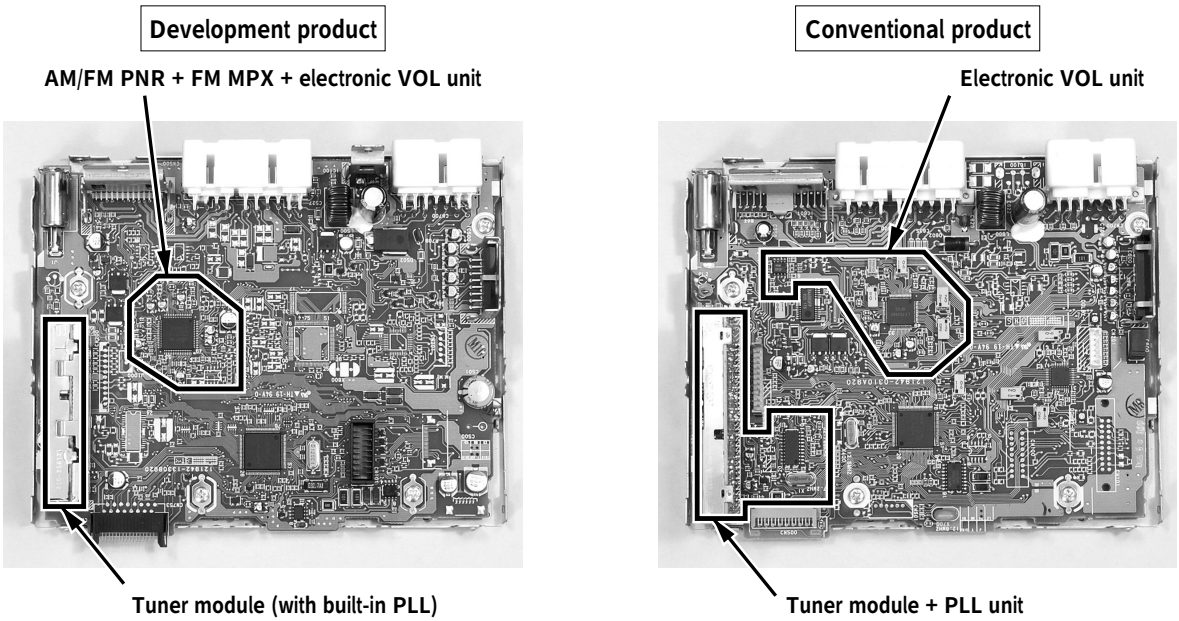

Fig.14 Comparison of areas on main circuit boards with the newly-developed product mounted, and with the conventional product mounted

The tuner module of the newly-developed product has built-in PLL IC's and has been miniaturized. Moreover in terms of performance the new product has realized emission reduction of 30 dB compared to conventional products, thanks to the built-in PLL and innovations in the circuits. And by means of effective utilization of bipolar and MOS input type operational amplifiers, high S/N ratio in the electronic volume control has been realized.

6 Conclusion

We believe that with the newly-developed radio tuner IC's (tuner and audio processing IC's) for the 2001 model we have made a significant contribution to miniaturization, performance enhancement and cost-cutting for product design. We would like here to thank the IC manufacturer and all of the others who were involved in the development.

Further miniaturization, performance enhancement and cost-cutting is expected to be required in the future, and synthesis with digital broadcasts will be an important task to that end. We intend to proceed with leading-edge IC development by utilizing the most advanced process technology and multi-chip packages (MCP) to move on to higher levels of circuit integration.

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