Integrated Circuit (IC) for Multi Function Tuner

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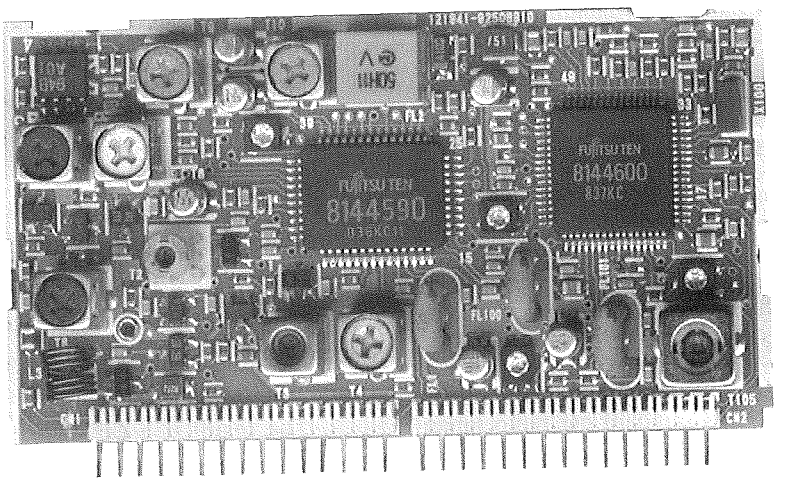


Abstract

In the last several years, as car audio continues developing into a multi-functional, multimedia technology, manufacturers have increasingly been called upon to achieve sophisticated, highly integrated system design and cost reduction in the product planning stage.

With the demand for greater integration as the backdrop, Fujitsu Ten has been moving to combine the various functions of circuits - components of car audio products -- into IC chips. In one area, our car radio tuner R&D effort, the major challenge has been development of an IC that can bring multiple functions together on a more compact, cost-effective chip than the conventional tuner IC.

Capitalizing on Fujitsu Ten design expertise, we have recently developed such a multi-function tuner IC. Equipped with a keyless entry reception function, the new IC is an added feature to the Fujitsu Ten car radio tuner, which already includes such peripheral functions as FM diversity reception and an AM noise canceller.

1. Introduction

The market for car-mounted AV equipment has grown lately because of increased demand for systems integrating a car navigation unit, TV set, CD unit, and MD unit.

As a result, the requirements for car radio tuners have become diverse. Not only must they receive radio broadcasts, they must also receive the following information:

(1) Weather and sports information (e.g., via FM teletext)
(2) Road traffic information (e.g., via VICS)
(3) Car control information (e.g., via keyless entry signal reception)

There has also been a great need to improve sound quality. In particular, car radio tuner manufacturers need to find a low-cost way to reduce the multipath noise and electromagnetic noise specific to mobile communication equipment.

In response to the demand for the reception of various kinds of information and for improved sound quality at low cost, Fujitsu TEN has developed an original integrated circuit (IC) for a multifunction tuner in cooperation with Toshiba Corporation Semiconductor Company.

The new IC, which is already in use in the Hyper Tuner Module, Fujitsu TEN's standard car radio tuner, has been on the market since December 1998.

2. Design Objective

Every conventional radio tuner model has been equipped with diversity reception, multipath detection automatic separation control (M-ASC), and AM noise canceler circuits separate from the tuner module to suit the user's needs.

This method of manufacturing has resulted in additional costs due to increased labor for circuit board design and more parts. It may have also caused wiring, parts layout, and product performance to vary depending on the circuit designer.

We developed the new tuner IC with the following ideas in mind:

(1) Reducing the cost for functional circuits by mounting the diversity reception, M-ASC, and AM noise canceler circuits on the IC
(2) Significantly reducing the labor for circuit board design and the extra cost of materials that have been required separately for each model by mounting the circuits listed above in a conventional size tuner module and by improving product quality through standardized design

With a goal of developing original products, we incorporated a keyless entry signal reception function in the tuner IC so that it would be a multiplex product both vehicle electronics and audio-visual features.

The result is a car audio product with a keyless entry signal reception function that should create a new market.

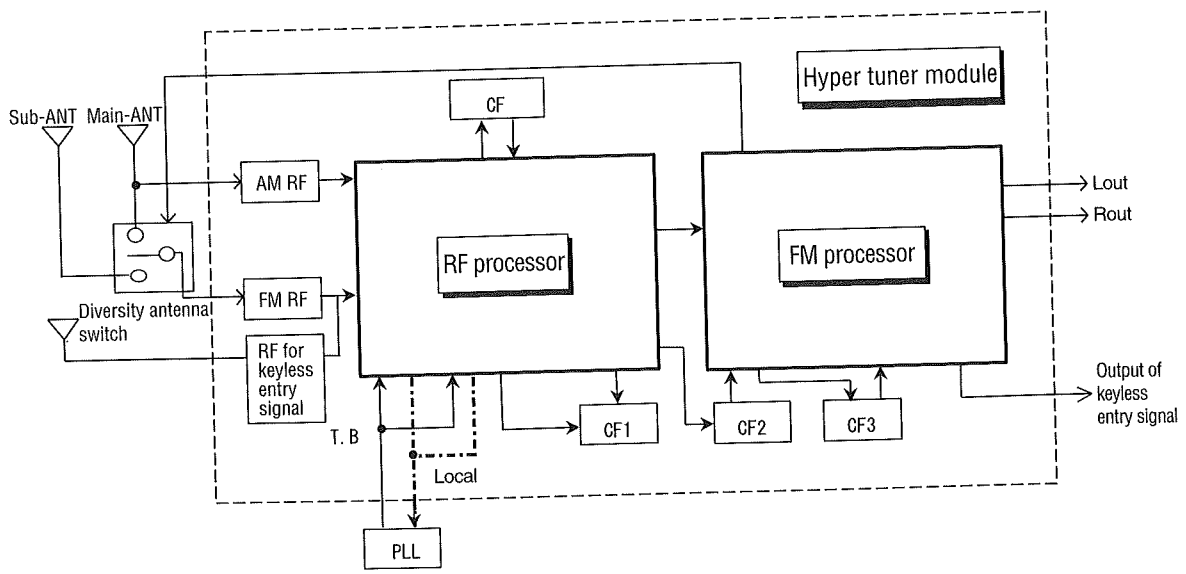


Fig.1 Schemematic wiring diagram of tuner module

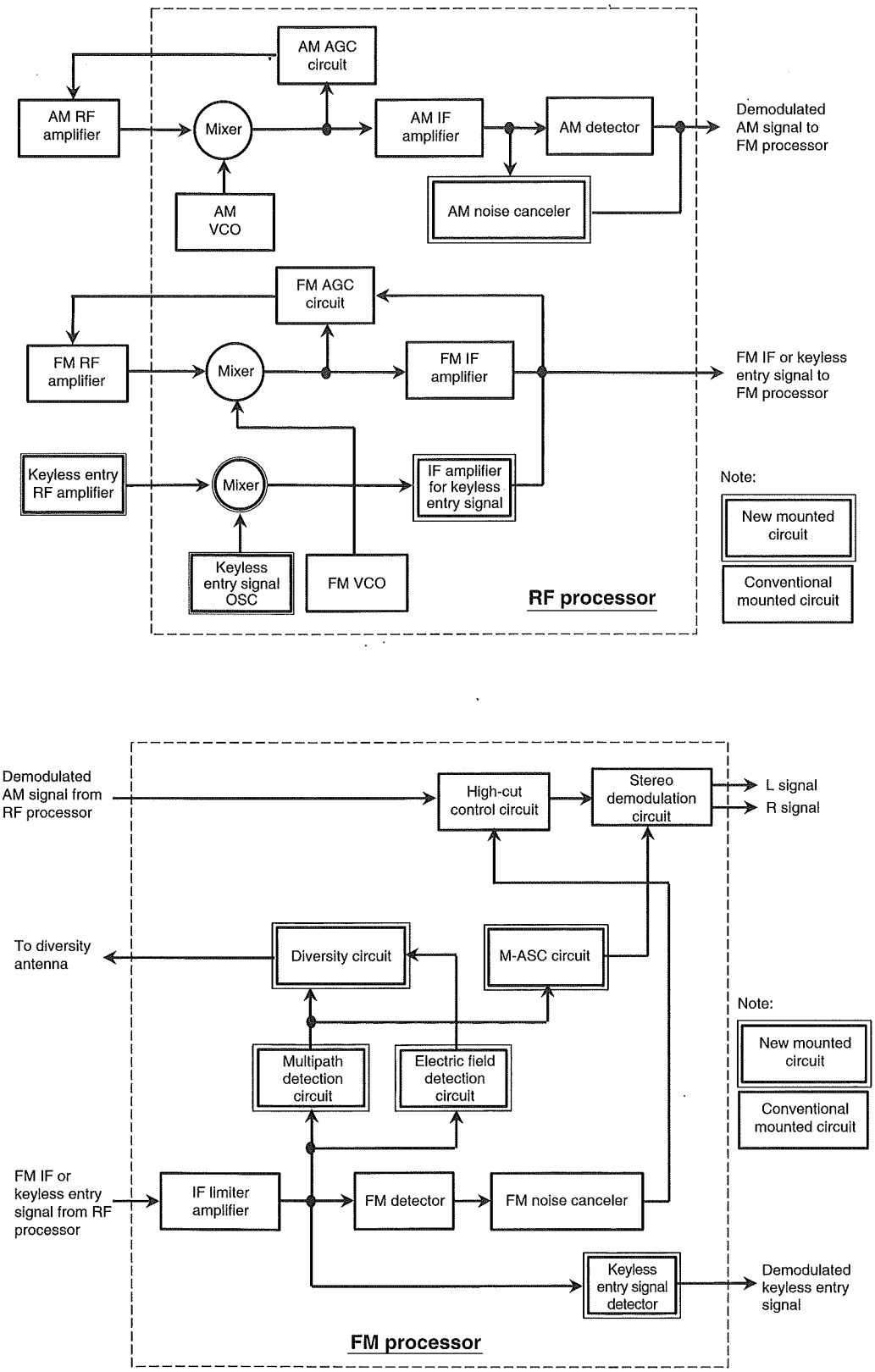


Fig.2 Block diagram of RF processor and FM processor

3. Overview of Tuner IC

The new tuner IC consists of two IC chips (RF and FM processors) that integrate in one module four functions: AM/FM tuner, AM noise canceler, FM diversity reception, and keyless entry signal reception. We based our design on the following considerations:

(1) Number of pins required
(2) Power consumption.
(3) Use of general-purpose package
(4) Convenience of application to the tuner module

The RF processor consists of the following sections:

(1) AM tuner section: VCO, converter (mixer), AGC, IF amplifier, detector, and noise canceler
(2) FM front-end section: VCO, converter (mixer), AGC, and IF amplifier
(3) Keyless entry signal reception section: VCO, converter (mixer), and IF amplifier

The FM processor consists of the following sections:

(1) IF limiter amplifier section: IF detector and IF limiter amplifier
(2) FM noise canceler section
(3) Stereo demodulation section
(4) Diversity reception section
(5) M-ASC section
(6) Keyless entry signal reception section: Keyless entry signal detector

These two IC chips enable the tuner to receive keyless entry signals in addition to AM and FM broadcasts.

3.1 Block Configuration

Figure 2 on the previous page shows the block configurations of the RF and FM processors.

3.2 Manufacturing Process Used

The multifunction tuner IC owes its existence to the progress in fine pattern process technology for semiconductors.

We used the high-performance bipolar LSI process for analog systems -- 1 shrink (PLAS-1S) for our tuner IC.

PLAS-1S is based on self-aligned technology (*1), which has been improved to enable semiconductor devices to be integrated.

PLAS-1S allows more devices to be mounted in the same chip area than can be mounted with the conventional process. It also increases the operating speed of the IC. The following compares the transition

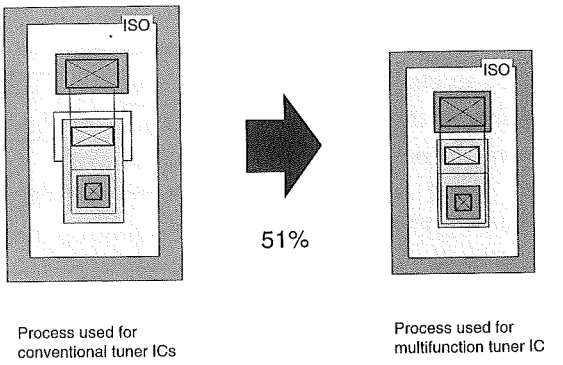


Fig.3 Size comparison of basic NPN transistors

frequency of the conventional process and the new process:

<Comparison of transition frequency(f_T)>

(1) Conventional process: (f_T) = 1.0 GHz
(2) New process: (f_T) = 1.8 GHz

The new process enabled us to incorporate in the tuner IC the diversity reception, AM noise canceler, and keyless entry signal reception circuits that previously had been mounted as external circuits.

*1 Self-aligned technology: Technology which produces a self-aligned transistor structure that greatly reduces the repetition of pattern lithography and the errors in mask alignment and which makes fine pattern processing possible.

4. New Mounted Functions

4.1 Multipath Detection Automatic Separation Control (M-ASC) Function

The multifunction tuner IC has a new diversity reception function and a multipath detection automatic separation control (M-ASC) function that eliminate multipath noise.

First, we will present an explanation of the M-ASC function.

When multipath reception occurs, a lot of high-frequency noise is generated. Especially for FM stereo broadcasting that uses the pilot tone system, the subchannel signal is easily affected by multipath noise.

Figure 4 shows the spectra of the composite signal and multipath noise components in FM stereo broadcast signals.

The M-ASC circuit detects the multipath noise components generated in the pilot signal (19 kHz, 10 % modulated with FM) and controls the stereo separation circuit to remove the noise. The circuit controls the

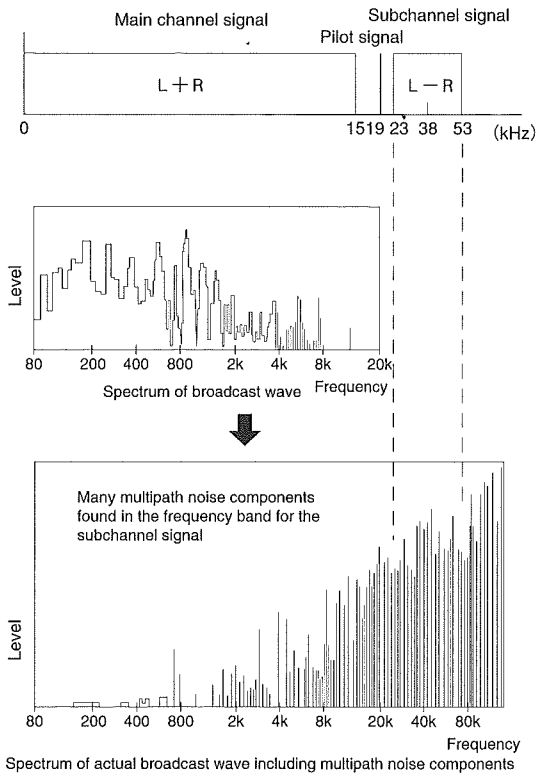


Fig.4 Multipass noise and composite signal

stereo separation circuit to switch to monaural output (main channel signal alone) to exclude the multipath noise, much of which is usually laid over the subchannel signal from the composite output.

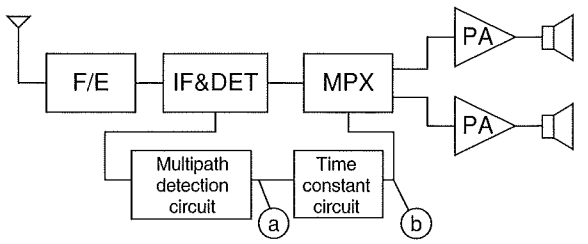


Fig.5 Block diagram of M-ASC

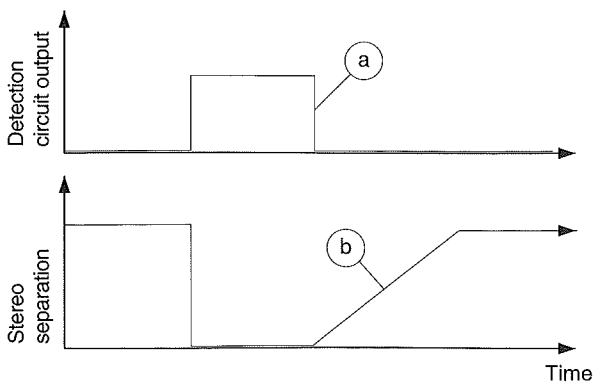


Fig.6 Conventional operation of M-ASC

In general, the M-ASC circuit has faced a conflict. If too much importance is given to the removal of noise, the stereo effect of the output will be poor. On the other hand, if too much importance is given to the stereo effect, the removal of noise will be poor.

We resolved this conflict by dividing the time constant circuit into two systems and controlling the two systems as follows:

(1) For light multipath noise, only the fast system (whose response is fast) operates to reduce the degree of separation to about 40 percent.

(2) For heavy multipath noise, both the fast system and the slow system (whose response is slow) operate to reduce the degree of separation by 100 percent.

When we perceived a lessening of the stereo effect

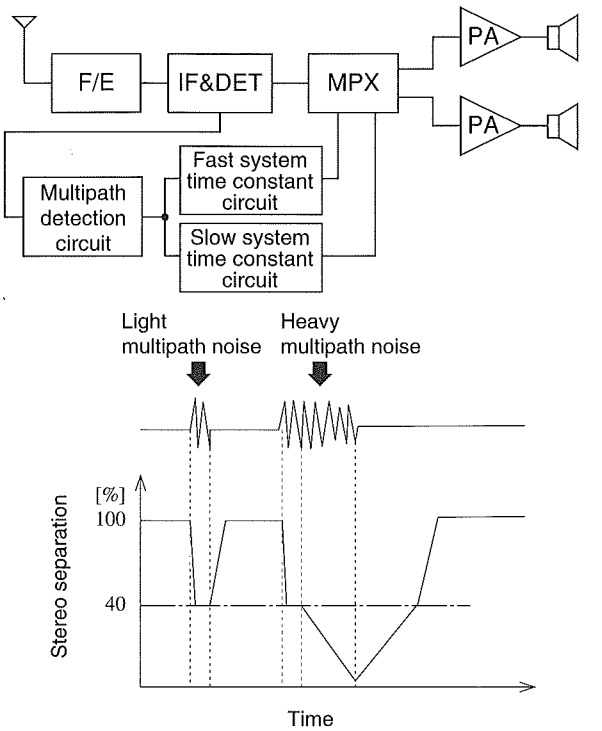


Fig.7 Block diagram and timing chart of new IC

as the level of modulation dropped, we also developed a new function to control stereo separation according to the level of modulation and included it in the tuner IC.

(3) When modulation dropped below a certain level, the degree of stereo separation is reduced linearly in proportion to the level of modulation to enhance the removal of noise.

We were therefore able to resolve the conflict by improving both noise reduction and stereo effect.

4.2 Diversity Reception Function

The diversity reception function is effective for

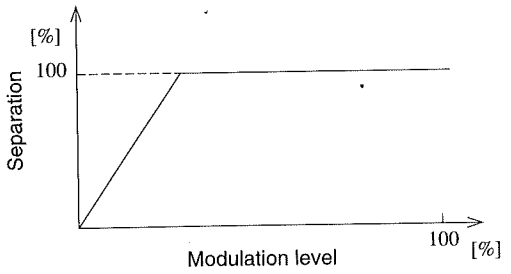


Fig.8 Separation control based on modulation factor

multipath noise reduction during FM broadcast reception. The diversity reception function has been used in an increasing number of intermediate-class cars, as well as luxury cars, as antennas built into the windshield have become popular.

The diversity reception function uses two antennas, and switches to the other antenna if one of the antennas

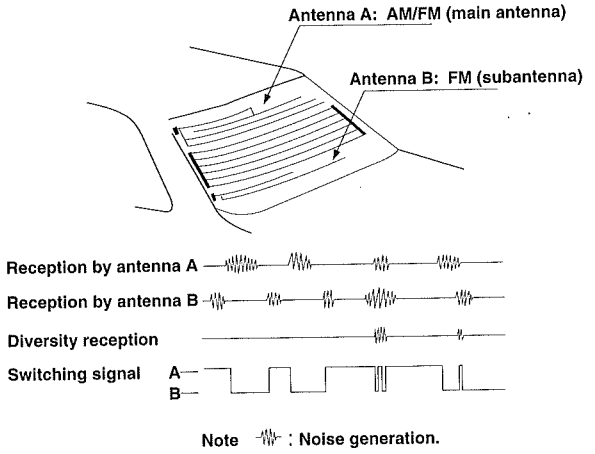


Fig.9 Basic operation of diversity reception system

receives a signal affected by multipath noise while the car is running. There are two typical systems of diversity reception:

(1) In a selection system, a separate tuner is prepared for each antenna. The signals received by two antennas are always input to both tuners, and the signal containing the less noise is selected.

(2) In a scanning system, only one tuner is prepared. An antenna input switching circuit is used to switch the antenna input according to a control signal from the multipath detection circuit.

The scanning system costs less than the selection system, and is currently the mainstream system.

We developed a logic circuit for a high-speed comparison operation that compares the field strengths of the two antennas for optimum switching and included the circuit in the diversity reception function that uses the scanning system.

The logic circuit monitors the voltage on the S meter for the FM wave, and switches antenna input between the main antenna and the subantenna at a rate of 19 kHz when the voltage falls below a specified level. The circuit then reads the voltage on the S meter when each antenna is selected, compares the readings for both antennas, and selects the one that indicating a higher voltage.

The diversity reception function is therefore able to switch antenna input according to both the detection of

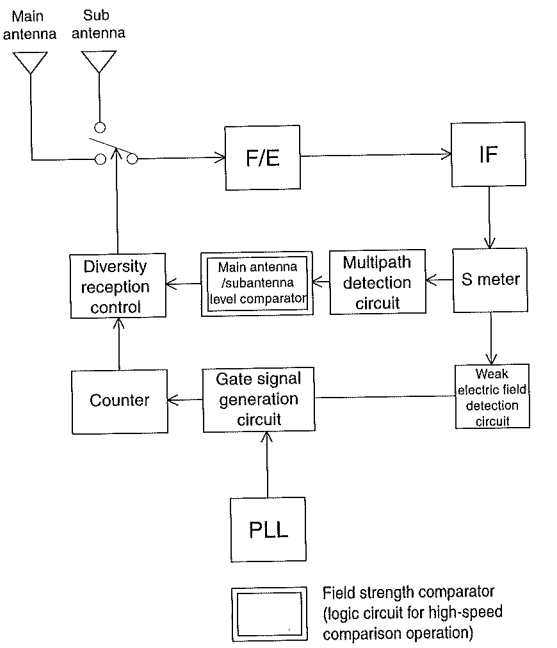


Fig.10 Block diagram of diversity reception system

multipath noise and the difference in field strength.

As an added benefit, the diversity reception system can share the multipath detection system with the M-ASC circuit, resulting in fewer externally mounted parts and improved total cost-effectiveness.

4.3 AM Noise Canceler

We incorporated an AM noise canceler (AM-PNR) in the multifunction tuner IC to meet increasing demand for noise elimination during the reception of AM radio broadcasts.

Keeping an eye on the cost of the AM-PNR without compromising performance, we narrowed down the target performance and studied how to simplify the circuit for mounting on the tuner IC.

(1) Narrowing down the target performance
We narrowed down the target performance to the elimination of the pulse noise in weak electric fields, which is the most offensive to the ear while listening to AM radio broadcasts.

(2) Determining how to simplify the circuit
A. Because the target performance was narrowed down to the performance of noise elimination in weak electric fields, the AM-PNR could be controlled only by the carrier AGC. For this reason, unlike the other maker's IC dedicated to AM noise cancellation, our AM-PNR did not require multiple AGC circuits such as noise AGC, carrier AGC, and audio signal AGC circuits.
B. With regard to the simplification of the signal interpolation system, we confirmed that the double-point interpolation system(*1) used for the other maker's dedicated IC and the single-point interpolation system(*2) result in no aural differences. We used a breadboard construction for confirmation.

*1 Double-point interpolation system: This system interpolates signals at two points before and after the generation of noise, and eliminates noise from the signals, which are delayed by a delay circuit.

*2 Single-point interpolation system: This system retains the signal detected before the generation of noise for a specified period of time to eliminate noise.

We designed the AM-PNR circuit on the basis of the above study. Our AM-PNR could achieve the signal-to-noise (S/N) ratio in weak electric fields equivalent to the one achieved by the other maker's dedicated IC. It also has the advantage of many fewer circuits for mounting in the tuner IC.

The AM-PNR circuit uses a sample hold system with IF band detection.

The AM-PNR consists of the following circuits:

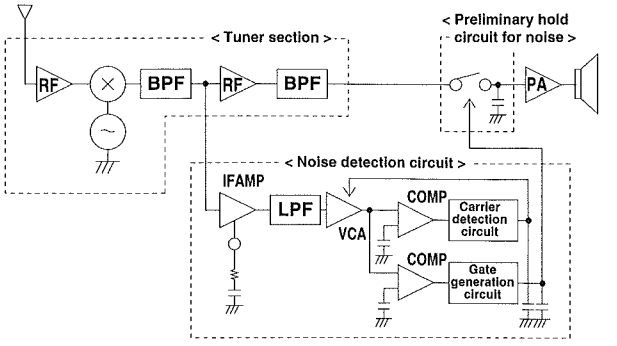


Fig.11 Block diagram of AM noise canceler

(1) IF amplifier for noise detection
(2) Carrier AGC circuit to prevent tuner malfunction from sound
(3) Sample hold circuit for signal interpolation

When compared with the other maker's dedicated IC, the AM-PNR was designed to have a simplified structure, allowing a reduction in pins for external parts to perhaps as little as one-fourth.

The following explains the measures taken for the noise radiation to the AM tuner that is caused as a side effect of the AM-PNR switching operation.

Because the AM tuner and AM-PNR are mounted on a single chip, the switching noise produced by the AM-PNR may radiate to the AM tuner and lower the reception performance of the AM tuner.

The measures we took to counteract this effect are as follows:

(1) In the mask layout, an independent ground (GND) line was connected to the AM-PNR block to separate the AM-PNR block from the tuner block in terms of impedance.
(2) The voltage amplitude of the carrier AGC was minimized in the circuit design to reduce any switching noise that might radiated to the tuner.

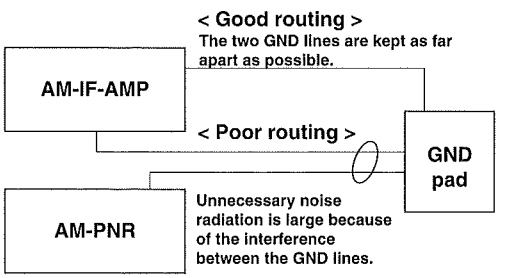


Fig.12 Schematic diagram of mask layout

These measures eliminated the influence of AN-PNR operation on the reception performance of

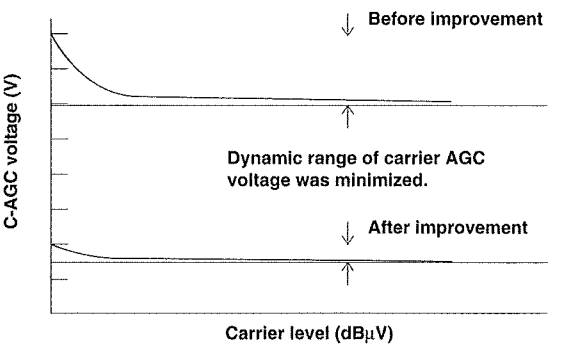


Fig.13 Improvement of carrier AGC voltage

the tuner.

Table 1 Comparison with other maker's dedicated IC

The above table compares the performance and cost of our AM-PNR and other maker's dedicated IC.

Judgment: ◎ : Superior ○ : Average

	Number of parts	Required area on board	Noise elimination performance
Our AM-PNR	30%	1cm^2	○
Other maker's dedicated IC	100%	9cm^2	◎

The AM-PNR does not exceed the other maker's dedicated IC in noise elimination performance because the AM-PNR circuit was simplified. On the other hand, the AM-PNR gets high marks in terms of a reduction in the number of parts and required area on board. We expect that an AM-PNR whose performance is not lower than the other maker's dedicated IC can be mounted on the tuner IC if semiconductor integration is increased further.

4.4 Keyless Entry Signal Reception Function

There are two modulation methods available for keyless entry signal. One is frequency shift keying (FSK), and the other is amplitude shift keying (ASK). A separate conventional keyless entry signal tuner had to be designed for each modulation method.

For the multifunction tuner IC, we designed the keyless entry signal reception system on the basis of the comparison described below to enable the tuner to receive keyless entry signals regardless of the modulation method.

First, we compared receiving frequencies, data transmission methods, and IF amplifiers as follows:

<Receiving frequencies>

(1) FM broadcasting: 76 to 90 MHz (in Japan)

(2) AM broadcasting: 0.522 to 1.629 MHz (in Japan)

(3) Keyless entry signal: 304.3 MHz (in Japan)

<Methods of transmitting door lock/unlock codes>

(1) FSK method: Difference in level of frequency

(2) ASK method: Difference in level of amplitude (that

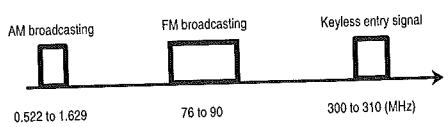


Fig.14 Receiving frequency bands

is, turning the carrier on and off)

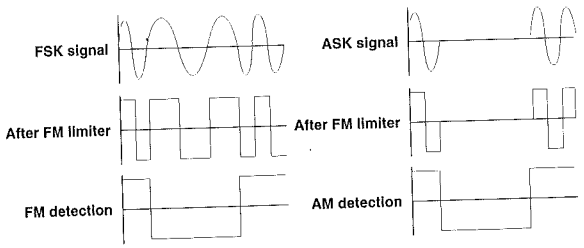


Fig.15 FSK and ASK waveforms

<IF amplifiers for FM and AM tuners>

(1) FM tuner: Dedicated IF limiter amplifier prior to the FM detection circuit

(2) AM tuner: Dedicated IF amplifier with AGC function prior to the AM detection circuit

We paid attention to the manner of transmission (data transmission by turning the carrier on and off) in the ASK method.

The ASK method does not require the AGC function, which is needed to receive amplitude-modulated signals without distortion. The ASK method only requires the IF signal to be amplified up to the level where the existence of the carrier can be confirmed.

We found that the IF limiter amplifier used for the FM tuner can generate a higher gain and be much more advantageous in comparison with the IF amplifier with AGC function that is used for the AM tuner. We decided to place the FM tuner circuits, including externally mounted parts, after the mixer so that they can be shared by both the ASK and FSK methods.

We created the special circuits for the keyless entry reception system with only an externally mounted RF amplifier, oscillation circuit (OSC), and selector circuit (for mode switching). Thus, the number of parts would be much fewer when compared with conventional

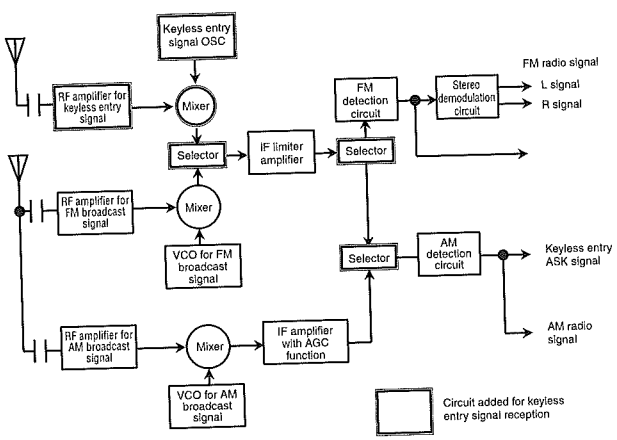


Fig.16 Block diagram of radio tuner with keyless entry reception function

keyless entry signal reception systems.

The table below compares the cost, convenience in mounting, and receiving sensitivity of our IC and a conventional receiver dedicated to the keyless entry signal.

Table 2 Comparison with dedicated receiver

Judgment: ◎ : Superior ○ : Average

Item	Cost	Convenience in mounting	Receiving
Our IC	50%	◎	○
Dedicated receiver	100%	○	◎

Our IC is superior to the conventional receiver dedicated to the keyless entry signal in terms of the cost and convenience in mounting. We expect that the receiving sensitivity can be increased up to a level equivalent to that of the dedicated receiver through improvements to the externally mounted RF amplifier.

Development of a keyless entry signal reception system would have the following three benefits:

(1) The need for a dedicated keyless entry signal receiver is eliminated, and the costs for the cabinet, wiring, and parts can be greatly reduced.

(2) Keyless entry signals can be received regardless of the modulation method (FSK or ASK) of the keyless entry signal transmitter. The keyless entry signal reception systems that have been designed conventionally as separate systems for each modulation method can be made common, and the labor for their design can also be greatly reduced.

(3) Possibilities exist for developing new products that combine car audio equipment with the keyless entry reception system.

4.5 Concurrent Reception of AM and FM

As FM teletext, which supplies traffic information and news, D-GPS, which increases the accuracy of car navigation, and VICS, which supplies road traffic information, become popular, there is greater need for handling FM information by car audio equipment. Reception of FM signals is necessary not only for receiving FM radio broadcasts but also for receiving FM signals during reception of AM radio broadcasts.

Presently, general AM/FM tuner ICs cannot operate their AM and FM tuners at the same time because of the interference between circuits and heat generation. To receive FM signals while receiving AM signals, another FM tuner module must be prepared or the AM/FM tuner must use separate ICs for AM signal reception functions and FM signal reception functions.

The multifunction tuner IC makes possible the concurrent reception of AM and FM signals because of the following special circuit designs and mask layout it uses:

(1) Rearrangement of the layout of the AM tuner and FM tuner blocks

(2) New switching functions, including the switching of the block power in concurrent reception mode, in addition to the conventional AM/FM mode switching

(3) Full reduction of power consumption by the AM tuner and FM tuner blocks

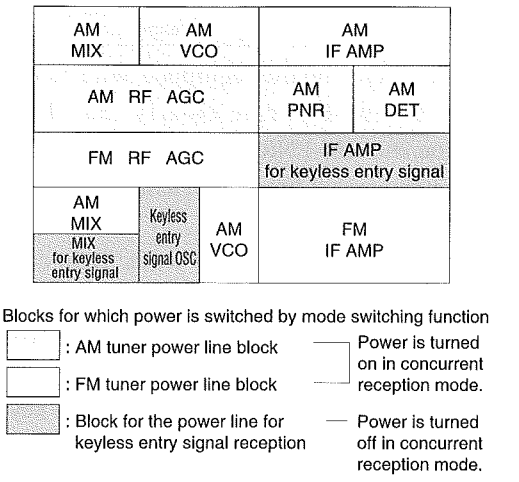


Fig.17 Layout of RF processor

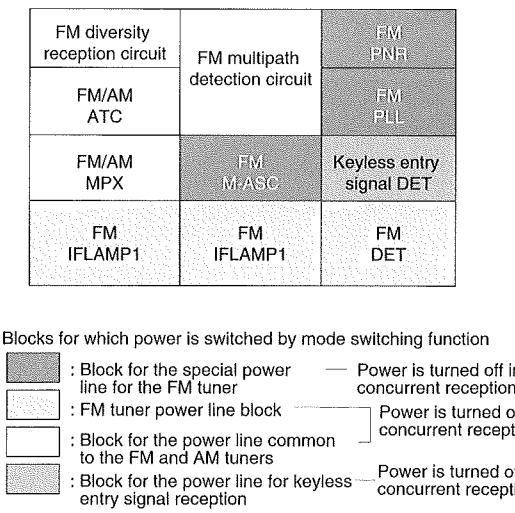


Fig.18 Layout of FM processor

With PLL circuits for both the AM and FM tuners, the hyper tuner module containing the multifunction tuner IC enables us to receive FM signals even while we are receiving an AM radio broadcast.

5. Advantages of the Multifunction tuner IC

The multifunction tuner IC integrates in the tuner module the diversity reception circuit, M-ASC, and AM-PNR, which up to now have been mounted as external circuits for optional tuner functions. As a result, the labor and cost of materials normally required for the board design for each tuner model are greatly reduced, and the efficiency of product design and the standardization of tuner modules are improved.

Table 3 Advantages of the multifunction tuner IC

Item	Number of parts	Mounting area	Reception performance
New product	About 170	60%	○
Conventional product	About 220	100%	○
Effect	▲50	▲40%	Equivalent

The circuit boards equipped with tuner modules shown below illustrate clearly that the diversity reception and AM-PNR circuits conventionally mounted on the audio circuit board are included in the hyper tuner module.

For reference, the figures on the right compare four conventional system ICs and two new ICs and illustrate the size of the hyper module in comparison with a cigarette lighter.

Other features of the new tuner IC are keyless entry signal reception and the reception of FM teletext information and traffic information (from RDS) during the reception of an AM radio broadcast. These features cannot be found in conventional car audio products.

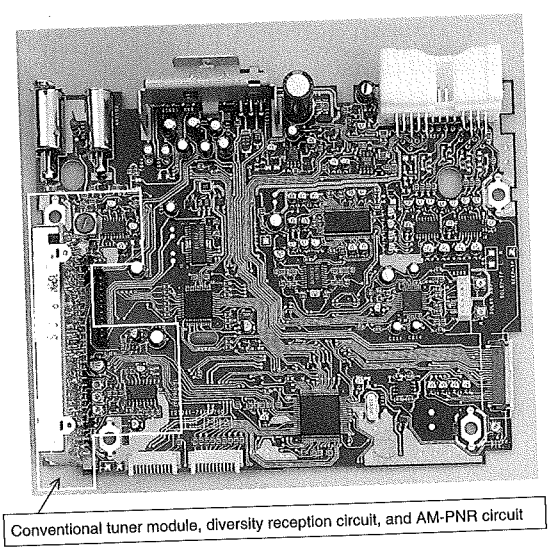
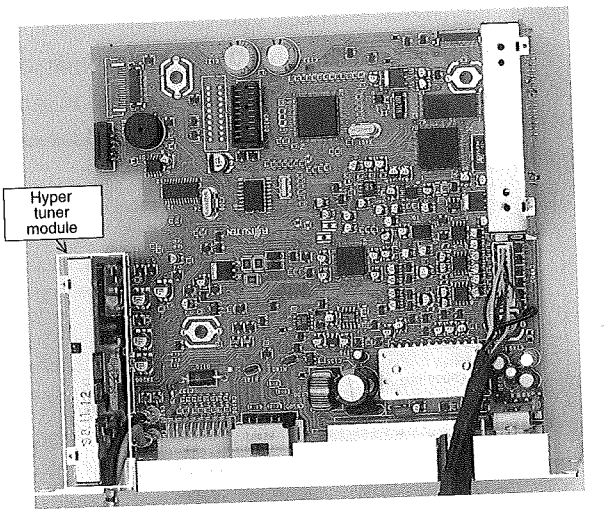


Fig.19 Tuner section with conventional ICs



(The mounting area is nearly halved.)

Fig.20 Tuner section with new IC

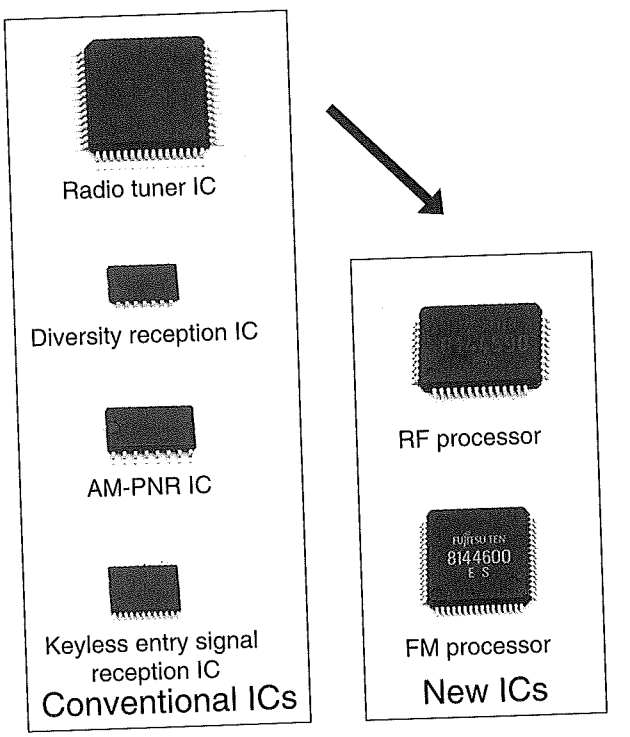


Fig.21 Comparison of conventional IC and new IC

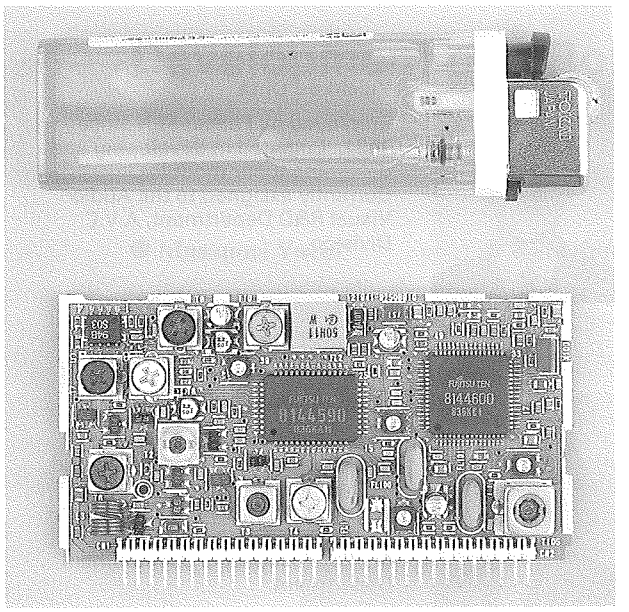


Fig.22 Tuner module with new IC

6. Direction of Future Development

We have been able to incorporate nearly all the required functions of a car radio tuner on a multifunction tuner IC. We will continue our development work, our goal being the production of low-priced car radio tuners with high sound quality.

Car audio systems are currently being replaced by multimedia systems. Market demand for car radio tuners will become even more diverse, and future tuners will have to be capable of also receiving non-audio information, such as keyless entry signals. We will continue to work aggressively to meet whatever the market demands.

7. Conclusion

We have presented an overview of the multifunction tuner IC we developed.

The multifunction tuner IC is appropriate for almost all car radio tuners, from the low-end to high-end models. We believe that this product will lead to more efficient product design, better product standardization, and lower costs.

With the cooperation of an IC maker for circuit design and other development work, we have been able to acquire a wealth of technical design knowledge and have had many opportunities to review current and future development issues. We would like to express our gratitude to all those who have participated in this development work.

The market for tuner ICs will undergo many changes as the digitization of the infrastructure for broadcasting progresses. By taking full advantage of the technical knowledge we have obtained, we will strive to develop new ICs that are ahead of their time.

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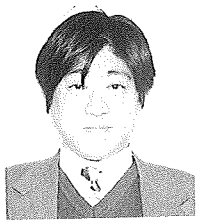

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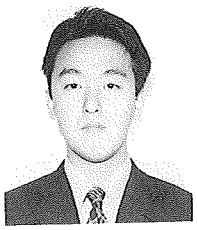

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