A COMPLETE SINGLE CHIP AM STEREO/FM STEREO RADIO IC

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Abstract

For the first time in the world, a complete single chip AM stereo/FM stereo radio IC which can be used for the portable radio has been developed. It has a PLL circuit for pilot detection that makes high quality AM stereo reception possible.

Introduction

Over the years, we have tried to develop the most suitable chip sets for car tuners, home tuners, portable radios, and other type of systems. All of them require high carrier-to-noise (C/N) ratio oscillator, less phase and level error of the IF signal, and high reliability on the pilot detection for high performance.

In Japan, almost every radio set has begun to apply AM stereo function. And at last, a complete single chip LSI for AM stereo/FM stereo radio has been developed.

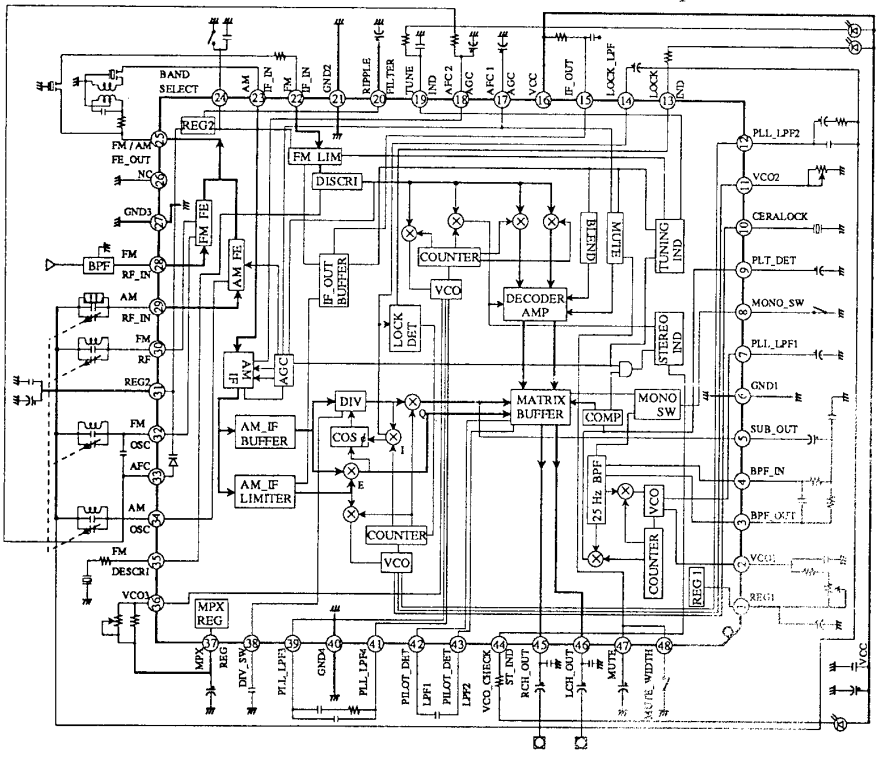

Fig.1 Block Diagram of the new LSI

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History of AM StereoDevice Development

In early 1980's, we have begun to develop the AM stereo decoder expecting the rapid growth of AM stereo service in the United States. It was a simple decoder composed of limiter, divider, PLL, lock detector, and I/Q mixer. It could decode any of the five different systems proposed then in the U.S.A. by changing the ratio of the divider. The pilot detector could then distinguish the five systems automatically. This chip set has been developed for use in car tuners and home tuners (Fig.2).

In 1991, we have developed the 2nd generation chip set (Fig.3) for portable radio preparing for the AM stereo service in Japan (March 1992). This chip set consists of five chips — FM/AM tuner, FM MPX, AM stereo decoder, pilot detector + matrix, and stereo power amplifier — housed in SSOP (Shrink Small Outline Package) and can operate at low voltage (Vcc=2.0V~). With this chip set, we could now enjoy both FM stereo and AM stereo broadcasts on a portable radio.

The 3rd generation chip set was planned at 1992 to realize the more compact set such as card radio. The single chip solution was the simplest way to make it. The separated four chips in the 2nd generation were combined and this has made easy and optimized the mutual control such as auto blend function (FM separation control function at low field strength), stereo indicator (FM/AM), and FM/AM IF out function for the D.T.S. (Digital Tuning System).

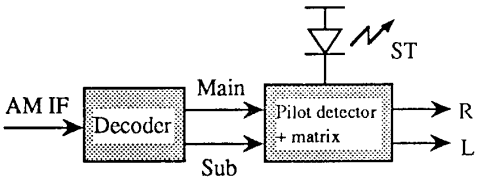

Fig.2 1st generation chip set

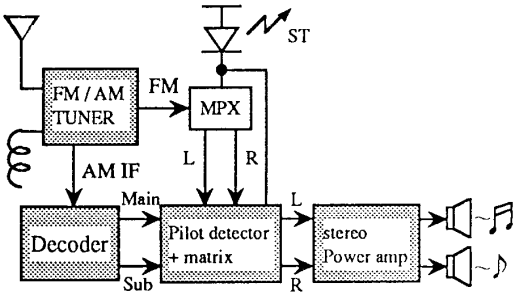

Fig.3 2nd generation chip set

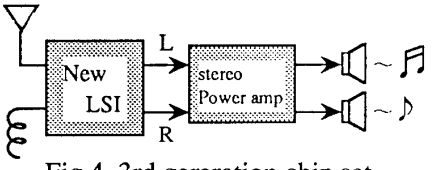

Fig.4 3rd gereration chip set

Outline of the new IC

Fig.1 is a block diagram of the new LSI. Most of the functional blocks are integrated: FM front end, FM IF limiter amplifier, FM stereo decoder with FM soft mute and auto blend function, AM front end, AM IF amplifier, AM IF limiter, AM IF buffer, divider, PLL for AM stereo decoder which has a loop gain control circuit for high quality reception, and PLL for AM stereo pilot detection. The control signal from the band select switch or a stereo signal makes the matrix + buffer block works like a signal selector. For the digital tuning system, the FM/AM IF buffer output which operate at the tuned state is useful.

AM Detector Section

The AM detector section in AM stereo radio is quite different from the conventional AM radio (monaural AM). The synchronous detector is required to detect PM (Phase Modulation) which contains the sub-ch information (L-R+pilot).

A high C/N ratio of the regenerated carrier is important to receive AM stereo broadcast in a high S/N ratio. By calculation, side band noise level of the carrier needs more than 79dB (at 10Hz bandwidth) to get over S/N 40dB (m=0.3).

The new PLL circuit is designed to achieve a high S/N and a high selectivity (Fig.5). The capture range of the PLL is about ±4KHz, but the loop gain controlled PLL (after PLL locks, loop gain is reduced to 1/100) can improve the selectivity and adjacent frequency interference characteristics. Fig.6 shows the improvement of the selectivity while Fig.7 and 8 show the spectrum indicating the effect of the loop gain control for the C/N ratio improvement. Fig.9 and 10 show the overall characteristics of the AM monaural and stereo auto mode. The separation at low frequency and the lock up time of the PLL is determined by the time constant of the PLL loop filter (Fig. 11).

To avoid the beat signal from being heard on a moment of lock up, the envelope detector is switched to the in−phase synchronous detector (I detector) and the IF clock signal. injected in I detector is cut off until PLL locks up.

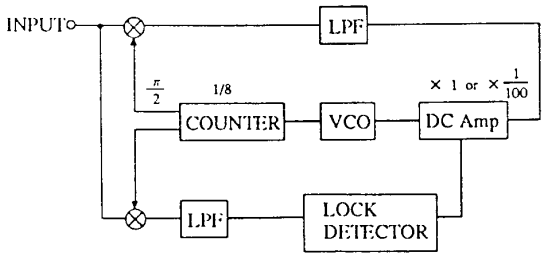

Fig.5 Loop Gain Control

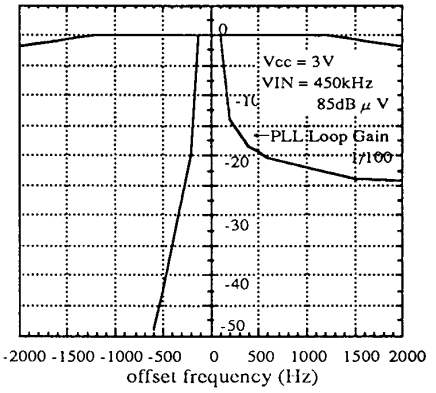

Fig.6 Selectivith of PLL

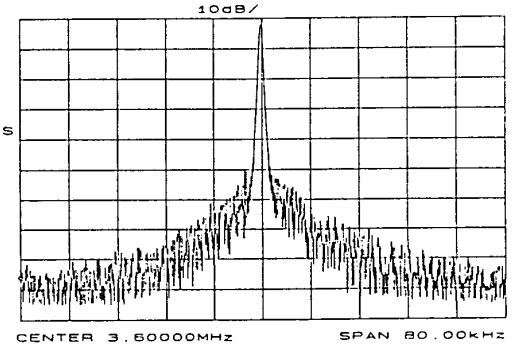

Fig.7 VCO spectrum (loop gain × 1)

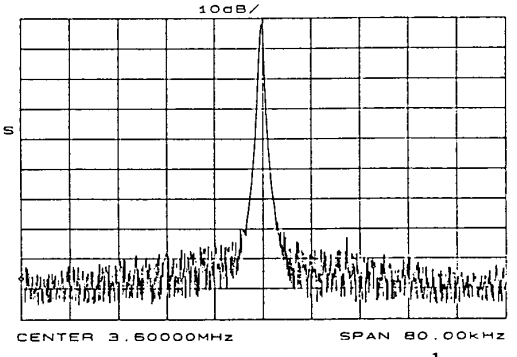

Fig.8 VCO spectrum (loop gain $\times\frac{1}{100}$)

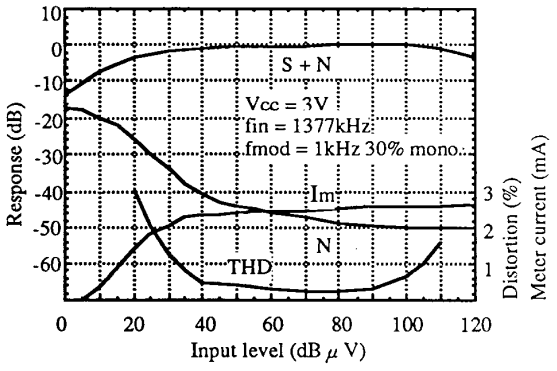

Fig.9 AM I/O Characteristics (AM mono)

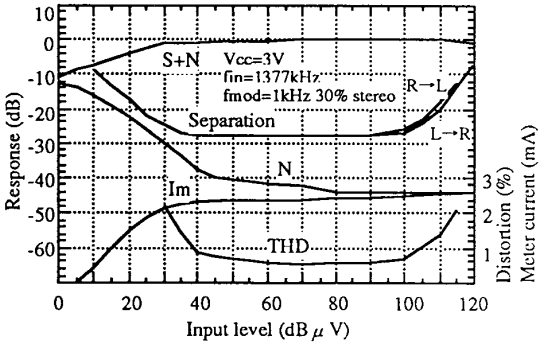

Fig. 10 AM I/O Characteristics (AM stereo)

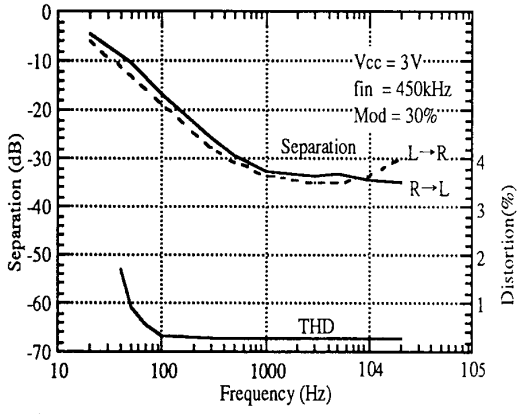

Fig.11 Frepuency Respose of Separation & Distortion (AM Stereo mode)

AM Stereo Pilot Detection

In detecting the pilot signal on sub-ch, the combination of BPF (Fig.13) and PLL circuit has a big advantage on reliability and stability compared with the conventional one. The 2nd ordered BPF is used to separate the pilot signal from the audio signal and the undesirable signal such as IPM (Incidental Phase Modulation) on Q detector.

The PLL for the pilot signal consists of I/Q detector, LPF, VCO, and counter (Fig.12). The dc output from I detector corresponds to the strength of the pilot signal. The dc output come from I detector for IF PLL controls the stereo indicator driver and the marix. Both PLL have a lock detector with hysteresis to improve the stability of the AM stereo reception at fringe area or excessive field strength change on mobile reception.

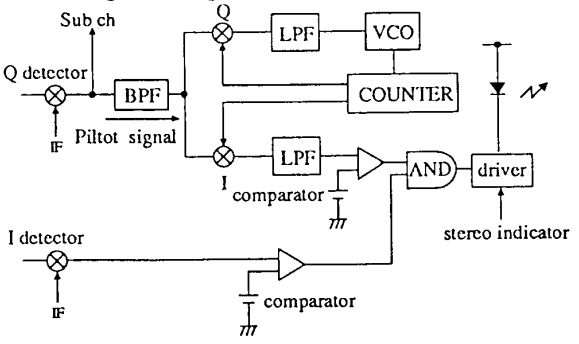

Fig.12 Block diagram of AM stereo pilot detector

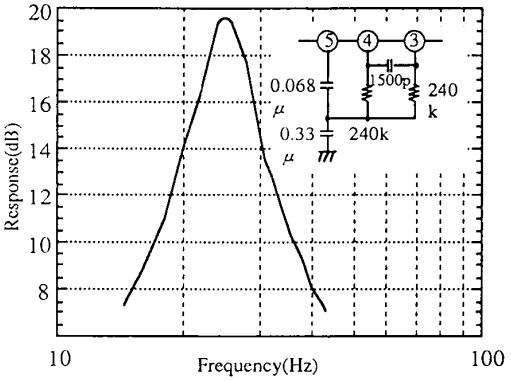

Fig.13 AM pilot detector BPF characteristic

Divider

The divider is required to compensate the phase error of the sub-ch signal. Fig.14 shows the effect of the divider function. Distortion and separation versus modulation factor is drastically improved by the divider function. In an actual design, the effect of AM-PM conversion should be also considered just like the phase error. Due to the finite gain of the AM IF limiter, the information as amplitude is converted to information as phase corresponding to the modulation factor. As a result, the total harmonic distortion becomes worse by the combined phase error. Thus, the compensation should consider both factors to reach the best characteristic in actual circuit design.

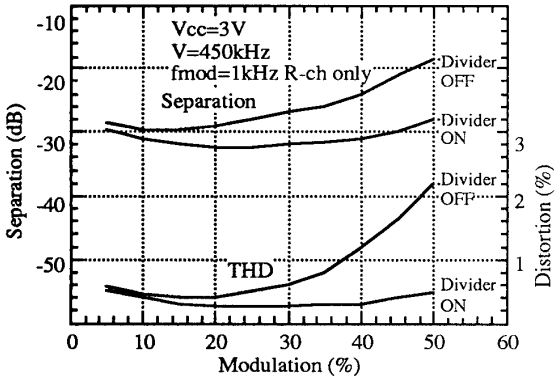

Fig.14 Separation & Distortion VS Modulation (AM stereo mode)

FM Section

The FM section consists of RF amplifier, oscillator, mixer, IF limiter, quadrature detector, tuning indicator driver, stereo multiplex decoder, stereo pilot detector, stereo indicator driver, and IF output buffer for DTS (Fig.1). To realize direct connection between quadrature detector and stereo multiplex decoder, dc offset cancellation circuit for the S curve is introduced. The FM mute function is useful at low field strength or detune status to reduce FM noise. And the auto blend function (separation control between monaural and stereo) is also preferable especially at mobile reception to avoid hearing the sudden change of the noise level.

Fig.15 and 16 show the overall characteristics of FM auto stereo and monaural while Fig.17 shows the frequency response of separation & distortion in FM.

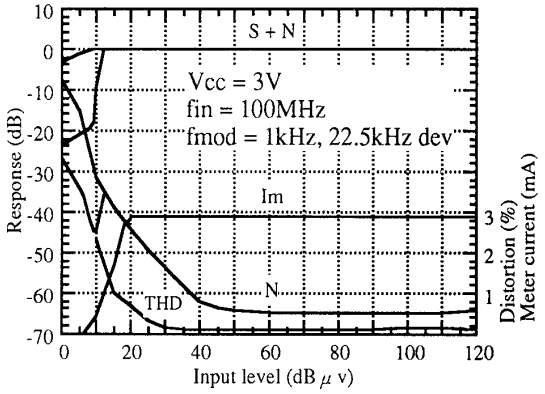

Fig.15 FM I/O characteristics (FM mono)

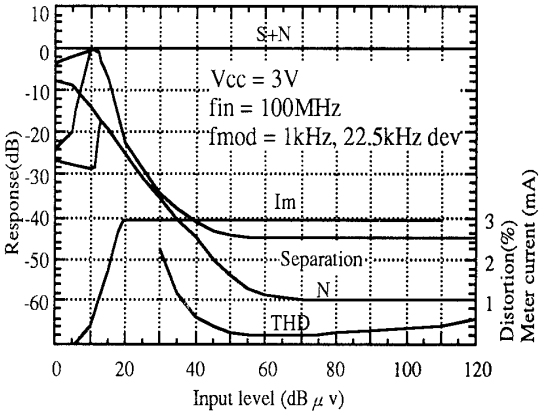

Fig.16 FM I/O characteristics (FM stereo)

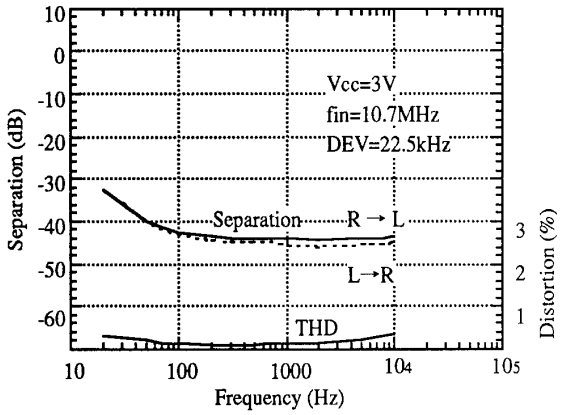

Fig.17 Frequency Response of Separation & Distortion (FM stereo)

Configuration of the LSI

This LSI is encased in the low profile quad flat L-leaded package (LQFP) and SDIP. Its photograph is shown in Fig.18. 2100 elements are integrated in a chip size of 3.36mm×4.00mm.

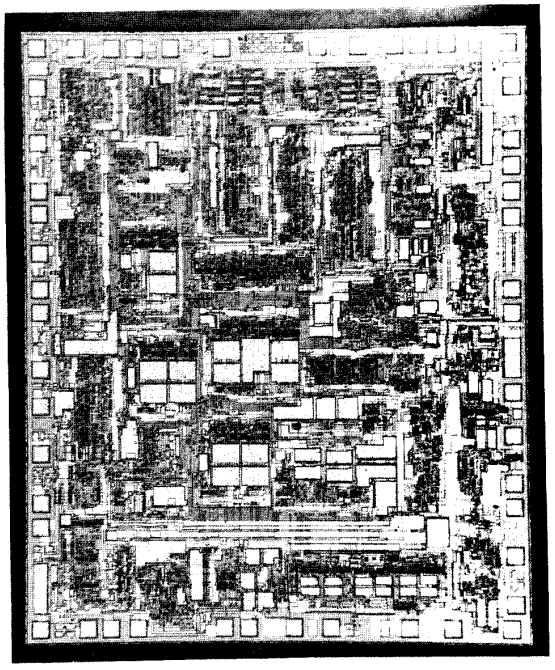

Fig.18 Photograph of the LSI

Conclusion

A complete single chip radio LSI that includes AM stereo and FM stereo function has been developed. Automatic identification logic by the new IF PLL and the pilot PLL has improved reliability of the pilot detection and the new LSI has realized high quality reception on AM stereo as shown in Table 1. Furthermore, we have managed to reduce the number of peripheral components, as well as the chip area and cost.

Table1. Performance of the new LSI

Supply voltage		2～12 V
Supply current	AM mode	14.8 mA
	FM mode	12.2 mA
FM det output level (mono)		38.8 mVrms
FM det output distortion (mono)		0.1%
FM IF knee level		25 dB μ v
FM det output level (stereo)		38.8 mVrms
FM det output distortion (stereo)		0.1%
FM stereo separation (fmod=1KHz)		40 dB
FM/AM IF buffer output level		500 mVpp
AM det output level (mono)		38.8 mVrms
AM det output distortion (mono)		0.3%
AM det output level (stereo)		38.8 mVrms
AM det output distortion (stereo)		0.3%
AM stereo separation (fmod=1KHz)		32 dB

All specifications were determined at Vcc=3V and all values are typical.

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