AN AM/TV/FM STEREO RADIO IC INCLUDING IF FILTERS FOR A DTS

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ABSTRACT

A single-chip AM/TV/FM stereo radio IC including IF (Intermediate Frequency) filters for a digital tuning system has been developed. The IF filter center frequency is controlled by new low-noise, low-distortion equivalent resistor circuits. Even though the value of resistors varies naturally, the center frequency can be fixed. Consequently, a radio IC including IF filters can be used for a DTS (digital tuning system), and peripheral components and production costs are reduced.

INTRODUCTION

Recently, FM/AM radio analog tuning systems are being replaced by Digital Tuning Systems (local oscillator frequency-controlled system by PLL frequency synthesis). A prior radio IC [1] including IF filter could not be used easily for a DTS because IF filter center frequency varied naturally . Therefore in order to compensate the frequency error, an *equivalent resistor circuit* is realized in this new IC.

In this prior radio IC , the advanced low IF DCR (Direct Conversion Receiver) architecture was realized . A DCR has been investigated in the aim of lowering power consumption and reducing number of components . We think that the low IF DCR is a practical technology for a low cost portable radio[2] .

This paper describes a technology in order to realize analog active C-R IF filter which uses bipolar process for low IF DCR and two technologies which are useful for DTS as follows .

1) IF filters comprising equivalent resistor circuits
2) A dual IF amplifier system for DTS scanning .
3) FM / TV dual mode front-end using a single local oscillator .

A PRIOR RADIO IC

In order to achieve low IF DCR , image canceling circuit is needed .

Fig. 1 is a block diagram of image canceling circuit. Two 90 degrees phase-shifted signals LO1 and LO2 are fed to Mixer Q and Mixer I, respectively. These two signals are made by 1/2counter which divide local oscillator signal. Received signal (DSR or IMG) is down converted to IF1 and IF2 by these mixers. And next, IF2 is converted to IF2' which relative phase is increased 90 degrees by PSN (Phase Shift Network) . After these signals (IF1 and IF2') are added, desired signal appears and image signal is canceled.

Fig. 2 and Fig. 3 describe magnitude and phase of these signals to explain these signal relationship . Fig. 2 shows a desired received signal diagram and Fig. 3 shows an image signal diagram.

Initially , assume that mixer input signal is an image signal , shown in Fig. 3 , as a frequency of an image signal IMG is higher than that of LO2 , signal IF2, mixed by LO2 and IMG , is 90 degrees lead to signal IF1 . Because IF2' is 90 degrees lead to signal IF2 through PSN, IF1 and IF2' are contrary signals. In this way , IF signal , which is an addition of IF1 and IF2' is canceled .

On the other hand , shown in Fig.2, when mixer input signal is a desired signal DSR , IF signal is doubled (IF1 and IF2' is identical) .

In 1992 , low IF DCR with image canceling circuit was realized as a single chip radio IC [1] . The IC had all functions for FM and AM radio and stereo decoder, and operated only at a supply voltage of 0.95 volt . As IF (Intermediate Frequency) filters were included, which was made up of active R-C filters, no off-chip filter was needed. Image canceling circuit for low IF DCR is included in the IC and overall characteristics (sensitivity, selectivity) were adequate for a portable radio.

Due to center frequency variations of IF filters caused by a process variation (resistor changes +/-20%) , this IC was used mainly for an analog tuning radio.

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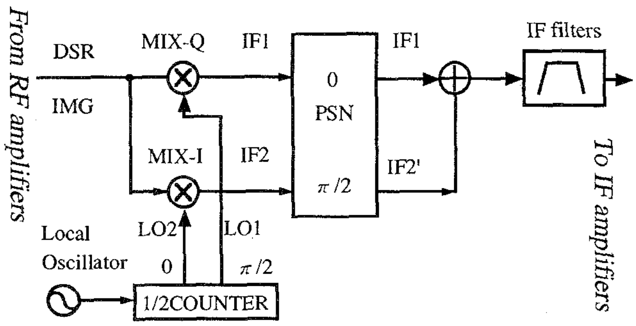

Fig. 1 Image canceling circuit

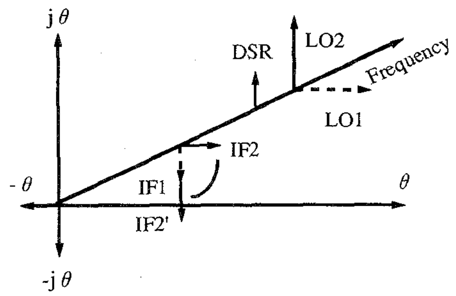

Fig. 2 Phase of desired signal

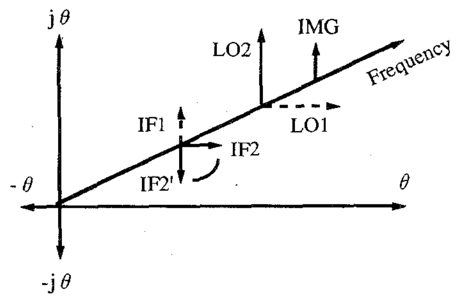

Fig.3 Phase of image signal

NEW TECHNOLOGIES

IF filters using equivalent resistor circuits

In order to use a radio IC including IF filters for DTS, a center frequency of the filter must be fixed to a constant frequency. Therefore, IF filters of a new radio IC should be center-frequency-controllable filters, which comprise equivalent resistor circuits.

Here A performance specifications of AM IF filter of a portable radio are, the selectivity is 30dB (+/-10kHz), the S/N ratio is 50dB, Total Harmonic Distortion is below 1%. Furthermore the filter chip size must be small for cost efficiency and the consumption power must be low.

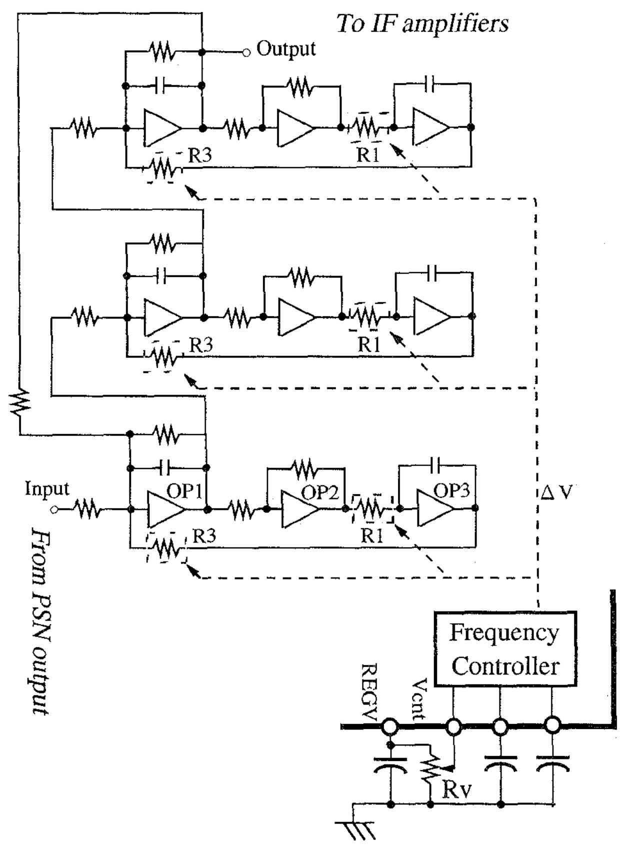

Fig. 4 AM IF filter

To make a stable active filter which has adequate selectivity, the IF filter consists of triple stages second order Biquad band pass filter shown in Fig.4 . The resistor R1 , R3 are made of equivalent resistor circuits , which value is adjusted by an external voltage Vcnt.

Fig. 5 shows an equivalent resistor circuit which has low noise and low distortion enough for the mentioned specification. This circuit can be divided into , voltage-current converter circuit (Qe) , and current separating circuit (Qa and Qb) .

Shown in Fig.5 , an input signal of this equivalent resistor circuit is vin and the output current is i3. First the vin is converted into a current i1, and then the current is separated by differential amplifiers Qa and Qb. Assuming that γ is a ratio of the separation, an output current i3 is obtained by subtracting $\gamma \cdot$ i1 from i2.

In this way, Req is controlled by γ, which depends on ΔV , a voltage between a base of Qa and a base of Qb . Since ΔV is an output of Frequency Controller Block shown in Fig. 4 , a center frequency of IF filter can be controlled by the block input voltage Vcnt .

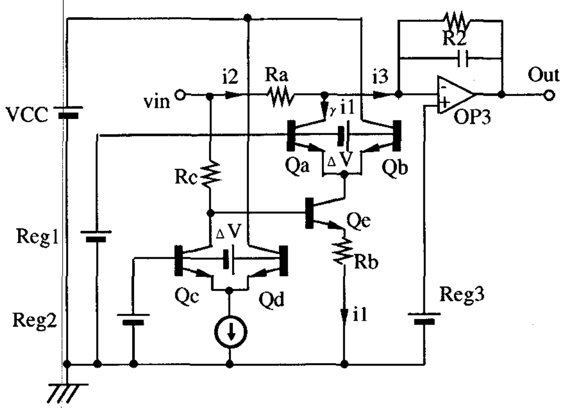

Fig. 5 Equivalent resistor circuit

In terms of equations :

$$i_3 = i_2 - \gamma \cdot i_1$$

$$= \left(\frac{R_b - \gamma \cdot R_a}{R_a R_b} \right) \cdot v_{in}$$

$$R_{eq} = \frac{v_{in}}{i_3} = \frac{R_a R_b}{R_b - \gamma \cdot R_a}$$

As a result , the characteristics of the AM IF filter shown in Fig.4 , are the center frequency is 45kHz, the selectivity is 30dB, the output noise level is 1μV/$\sqrt{}$Hz, A maximum output level is 150mVp, the consumption current is 1.8mA. A selectivity of the filter is shown in Fig. 6 .

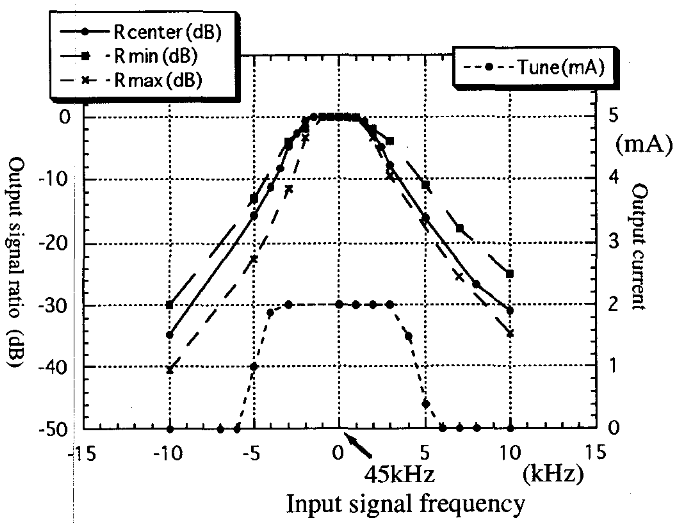

Fig. 6 A characteristic of AM IF filter

These graphs are the characteristics which have been adjusted by Frequency Controller Block to have same center frequency. Rcenter is no process variation . Rmax is when resistor changes by +20 percent, and Rmin is when resistor changes by -20 percent , caused by process-related variations .

Dual IF amplifiers system

One of the convenient feature of a digital tuning radio is *scanning* (tuning in a station automatically) . For precise AM radio scanning, not only received signal strength , but also the frequency must be detected.

Dual amplifiers system is shown in Fig.7, AGC (Automatic Gain Control) amplifier performs as AM IF amplifier and FM signal level detector. And limiter amplifier performs as FM IF amplifier , and as frequency detector at AM scanning.

In this new IC an AM IF signal frequency can be detected by FM detector circuit block, which center frequency is adjusted to the AM IF center frequency at AM receiving mode . It can be achieved because AM IF (45kHz) is similar to FM IF (150kHz) , while at a conventional radio its AM IF (450kHz) and FM IF (10.7MHz) is entirely different . Shown in Fig. 6 , when a received signal frequency is an adjacent channel (+/10kHz) , tuning current doesn't occur. Therefore precise scanning can be achieved at AM receiving mode .

This FM detector circuit consists of pulse count circuit shown in Fig. 9 . Since a slope and a center frequency in the detector characteristic can be changed by a *charge current* . This pulse count circuit detects IF signal both at AM and FM receiving mode . Fig.8 shows output characteristics of a pulse count circuit. At AM mode center frequency is 45kHz and at FM mode center frequency is 150kHz .

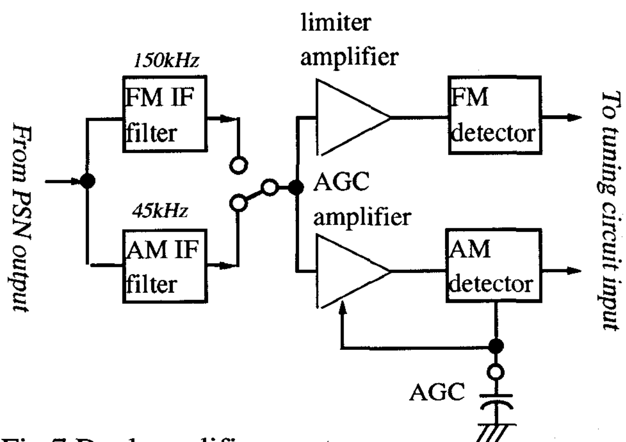

Fig.7 Dual amplifiers system

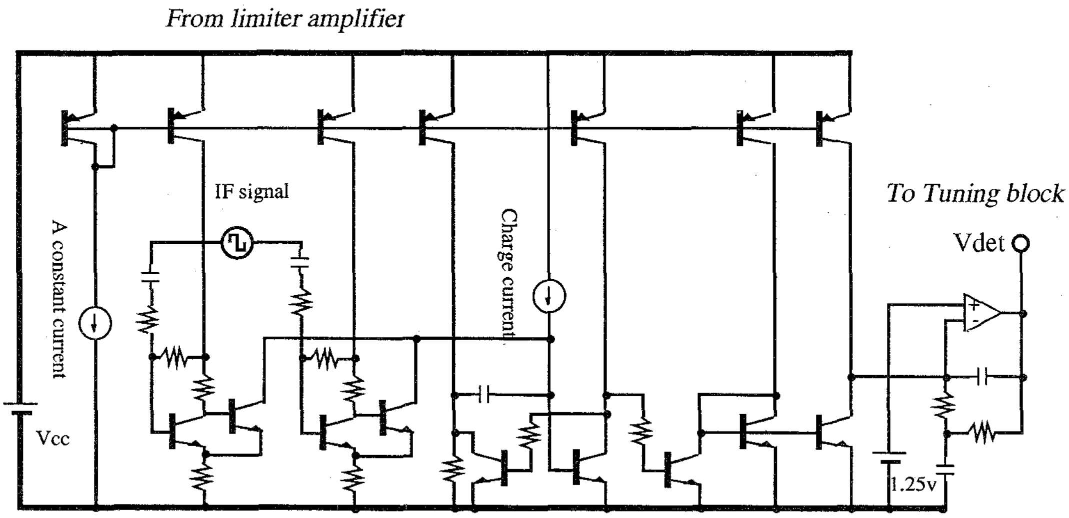

Fig. 9 Pulse count circuit

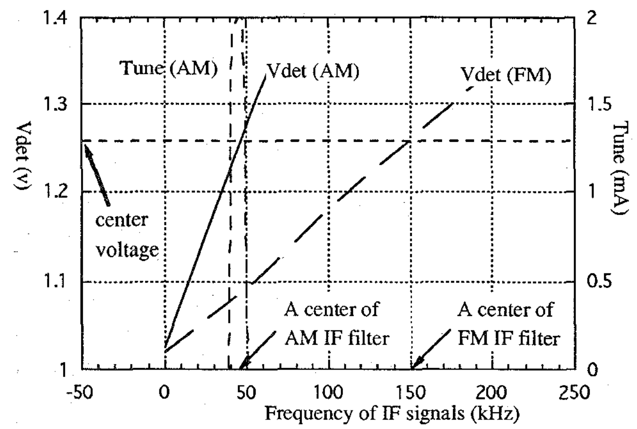

Fig. 8
Output characteristics of a pulse count circuit

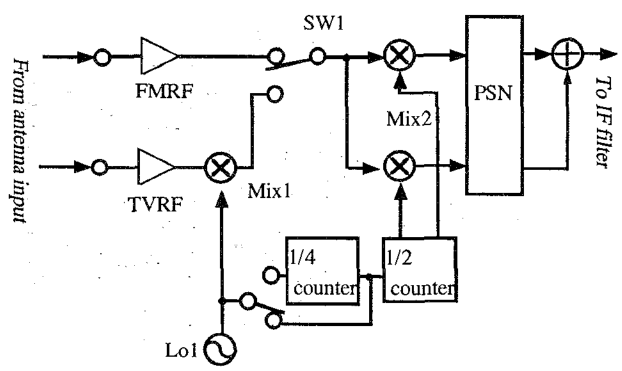

Fig. 10 FM/TV dual mode front-end

FM/TV dual mode front-end using a single local oscillator

Recently a radio receives not only FM broadcasting but TV sound broadcasting . In Japan FM broadcasting station frequency is from 76MHz to 90MHz and TV low channel broadcasting station frequency is from 90MHz to 108MHz and TV high channel broadcasting station frequency is from 170MHz to 220MHz .

At a conventional radio, FM IF is 10.7MHz . In order to receive both FM and TV high channel , two local oscillators are needed. In this new IC, low IF DCR architecture and double conversion receiver using a single oscillator make it possible that a dual mode front-end works only by a single oscillator.

The block diagram is shown in Fig. 10 . At FM and TV low channel receiving mode, RF signal entering from antenna input is amplified in FM RF and converted into IF signal (150kHz) at mix2. Two 90 degrees phase shift signals are made by dividing local oscillator signal using 1/2 counter.

At TV high channel sound receiving mode, RF signal is converted by mix1 at first, then converted by mix2. As first local oscillator is controlled from 156 MHz to 197 MHz , and the second mixer switching signals are made by dividing local oscillator using 1/8 counter. Its first IF is from 19.4 MHz to 24.5 MHz , and the second IF is about 150kHz .

Fig. 11 shows a received signal frequency and local oscillator frequency of FM receiving mode and TV receiving mode.

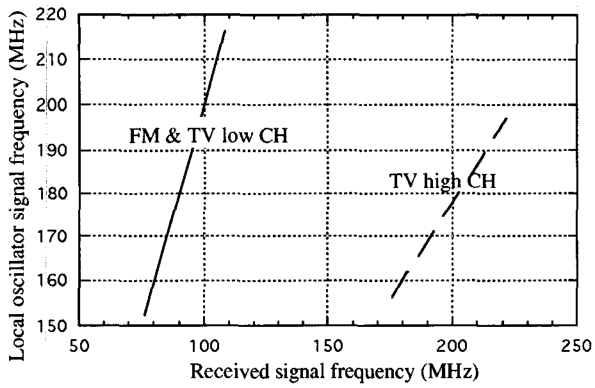

Fig. 11 Local oscillator frequency

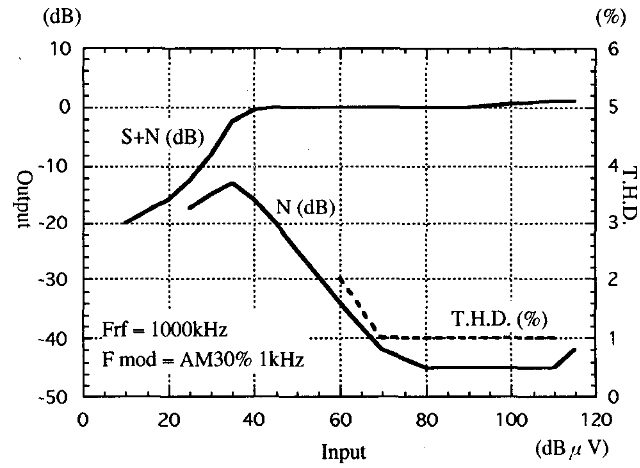

Fig. 12 AM I/O characteristic

Digital Tuning System

As described previously , this new IC has such functions useful for DTS . Fig. 16 shows DTS which consists of the IC and a micro computer including a PLL circuit .

At *scanning* mode , a local oscillator frequency is increased (or decreased) by the PLL . And when a tuning current flows from external pin TUNE , the micro computer ceases to change the local oscillator frequency , and then a radio station can be found . As a tuning current at AM mode depends both on a received signal strength and on the signal frequency , the precise scanning is achieved .

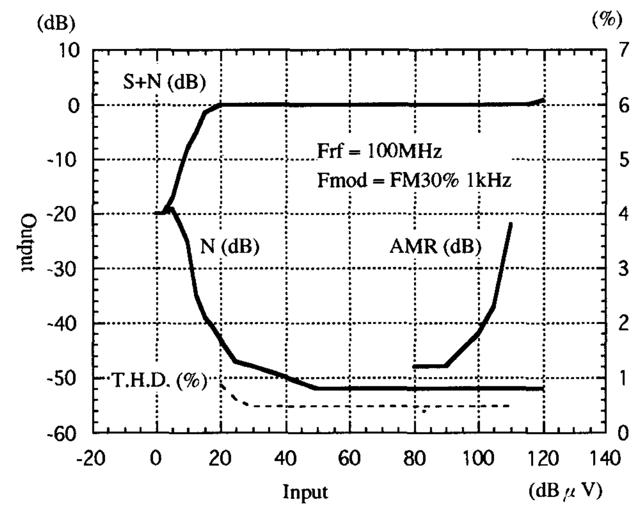

Fig. 13 FM I/O characteristic

OVER ALL CHARACTERISTICS

As shown in Fig. 16 , This radio IC has all functions from antenna input to audio output for FM , TV , AM radio and FMstereo decoder .

At AM receiving mode , frequencies of the AM IF filter and FM detector circuit are adjusted through Frequency Controller circuit by the external variable resistor Rv . An AM over all input/output characteristic is shown in Fig.12 .

At FM receiving mode , FM IF filter is a ninth order low pass filter with 300kHz cutoff frequency . As shown in Fig.15 FM effective selectivity , an adjacent channel suppression is over than 40dB and an image signal +300kHz away from center frequency is 35dB attenuated . An FM over all input /output characteristic is shown in Fig . 13 .

An audio signal is decoded to Lch output and Rch output in this STEREO MPX decoder . Fig.14 shows a separation and T.H.D. frequency characteristics of a Lch / Rch output .

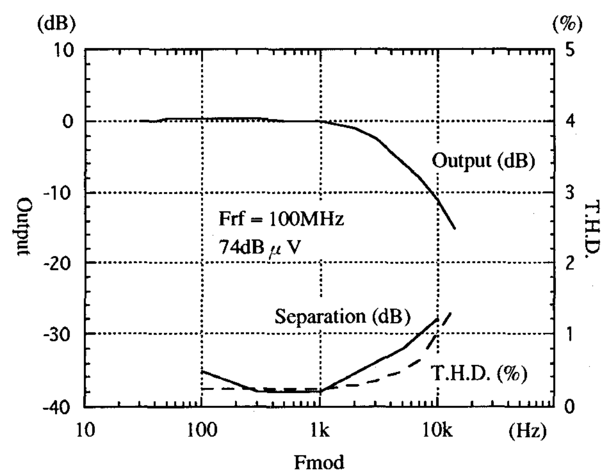

Fig. 14 FM stereo characteristic

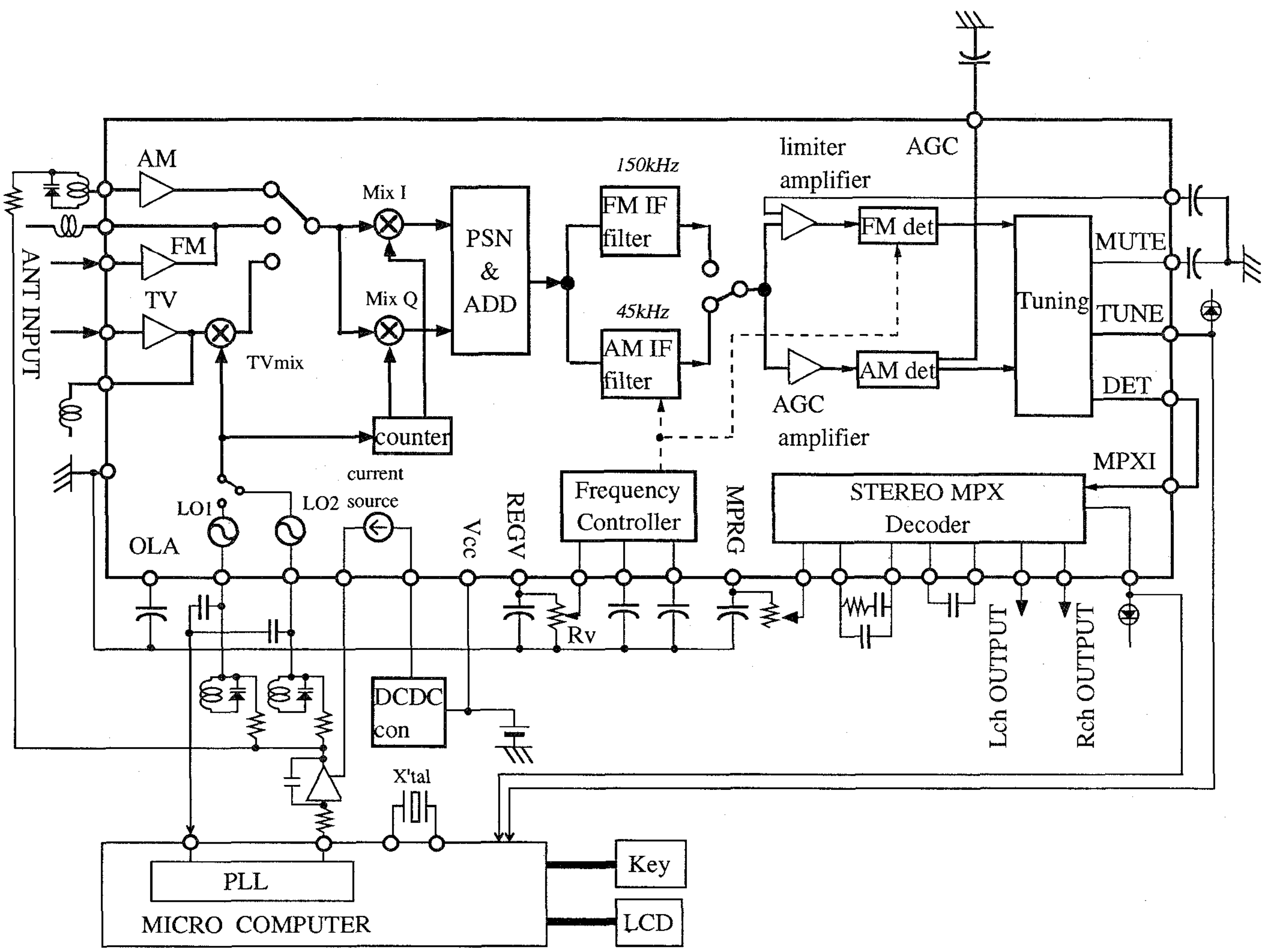

Fig. 16 DTS and Block diagram of a new IC

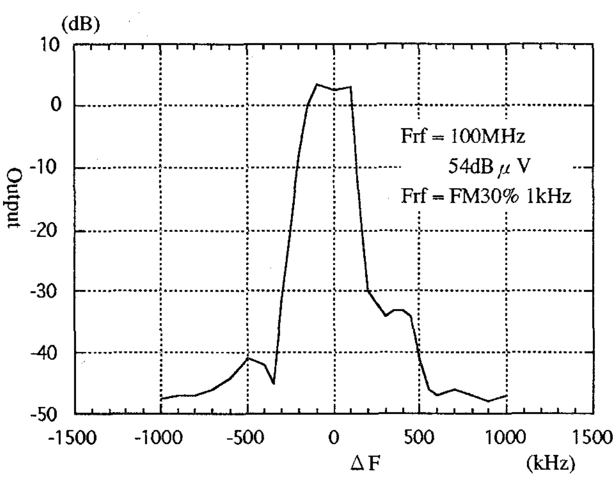

Fig. 15 FM effective selectivity

Operating Voltage	1.8v~4.5v
Current Consumption(AM)	9.1mA
Current Consumption(FM)	13.2mA
Current Consumption(TV)	15.4mA

Table 1 Static Characteristics

AM S/N6dB sense (Rsig=20kΩ)	25dB μ V
FM S/N 30dB quieting sense	12dB μ V
AM selectivity	30dB
FM selectivity	45dB

Table 2 Dynamic Characteristics

Chip size	2960 μ m × 4020 μ m
Elements	2000
Process	Bipolar

Table 3 Chip Characteristics

CONCLUSION

In conclusion the technology controlling center frequency of analog active filters has been discussed . Using this technology , low IF DCR radio IC is used not only for an analog tuning radio but for digital tuning radio .

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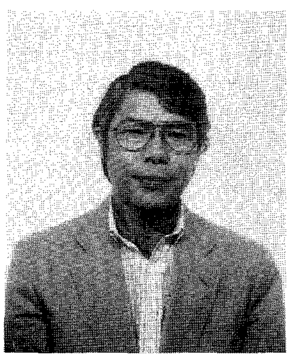
BIOGRAPHIES



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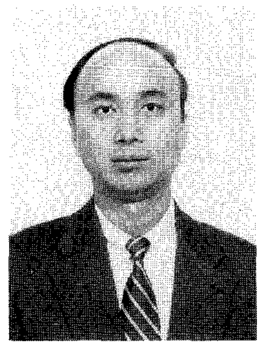

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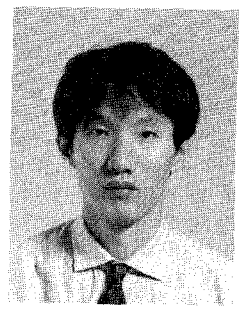

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