A 13-bit bandpass sigma delta modulator for 10.7MHz digital IF with a 40MHz sampling rate

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Abstract

This paper presents a sixth-order continuous-time bandpass sigma delta modulator (SDM) for analog-to-digital conversion of 10.7MHz intermediate frequency (IF) signals in AM/FM broadcast radio receivers. Sampled at 40MHz, the single-loop one-bit SDM achieves 67dB SNDR in 200kHz and 80dB in 9kHz. The third order intermodulation (IM3) is at -82dBc for a -10dBFS input level. The 0.5μm CMOS chip occupies 0.9x0.4mm² and consumes 60mW at 3.3V (digital) and 5.0V (analog). The sample frequency is variable and can be set from 30MHz to 80MHz.

1 Introduction

Due to scaling of the CMOS technology, more and more stages of (broadcast) radio receivers can be integrated onto a single die; adding intermediate frequency (IF) functionality to the baseband receiver IC [1]. Implementing (IF) signal processing stages in the digital domain takes full advantage of the increased speed, providing more flexibility, better noise immunity and potential improvements in performance and power by the technology scaling. The required analog-to-digital (A/D) conversion of the IF signal also alleviates problems due to DC-offset, flicker (1/f) noise and I/Q channel mismatch as occur in conventional analog heterodyne receivers [2].

Bandpass sigma-delta modulation [3–6] is well suited for A/D conversion of narrow band signals modulated on a carrier, as occur in AM/FM receivers. Through the use of oversampling and negative feedback, the quantization errors of a coarse quantizer are suppressed in a narrow signal band in the output of the modulator. Figure 1 shows an example of a single-loop multi-bit bandpass sigma delta A/D converter and the corresponding output frequency spectrum.

Figure 1: Example of a bandpass $\Sigma\Delta$ modulator (left) and a typical output spectrum (right).

A typical digital IF architecture for a radio receiver [7] using a sigma delta modulator (SDM) is shown in Fig. 2. The receiver consists of a low noise amplifier (LNA) followed by a wideband bandpass filter. Using a tunable local oscillator (LO) and a mixer, the FM signals (88-108MHz) are downconverted and the AM signals (520-1650kHz) are upconverted to the 10.7MHz IF frequency. This configuration allows a single (ceramic) SAW filter for channel selection for both AM and FM signals. The filter is followed by an automatic gain control (AGC) amplifier which feeds the signal to the SDM ADC. A digital signal processing (DSP) unit performs the demodulation, final channel selection and various baseband functions. A digital-to-analog converter (DAC) is used to output the baseband signal.

Figure 2: A typical digital IF radio receiver using a $\Sigma\Delta$ modulator.