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Presentation title: A Multi-standard RF Bandpass Sigma-Delta ADC

SHORT ABSTRACT OF PRESENTATION

Bandpass ΣΔ modulation is a very power-efficient technique to realize RF analog-to-digital converters (ADCs) [1]. To cover a wide frequency range, BP ΣΔ ADCs with tunable center frequencies have been proposed [2]. One important challenge in designing a tunable BP ΣΔ ADC relies in varying the modulator's feedback DAC coefficients to maintain the same signal transfer function (STF) and noise transfer function (NTF) for each center frequency, f0, in the complete tuning range, f0, of the ADC. The fact that the BP ΣΔ feedback DAC coefficients must be tuned for each center frequency has considerably complicated the modulator architecture. This resulted in a very large power consumption of 750 mW for a 1 GHz tuning range in [2], a rather low SNR of 40 dB with a bandwidth of 1 MHz for a 1.2 GHz tuning range in [3] or a very limited tuning range of 40 MHz in [4].

In a conventional BP ΣΔ architecture, the sampling frequency, fs, is fixed; so any variation in the center frequency, f0, leads to a variation in the normalized center frequency, f0/fs, and subsequently in the overall STF and NTF of the SD modulator. In this case, all the ΣΔ feedback DAC coefficients must be tuned to compensate for this f0/fs variation and maintain the same STF and NTF for all center frequencies. In this presentation, we present a tunable BP ΣΔ architecture, where the normalized center frequency, f0/fs, is fixed. In this case, any variation in the center frequency, f0, is tied to a variation in the sampling frequency, fs, to keep the normalized center frequency, f0/fs, equal to 1/4. Ideally in this case, all the ΣΔ feedback DAC coefficients can be fixed because f0/fs is fixed. Practically, varying the sampling frequency, fs = 1/Ts, changes the normalized loop delay, td/Ts, which leads to a modification of the modulator's NTF. To maintain the same NTF without tuning the feedback DAC coefficients, we propose to modify the loop delay, td, to compensate for any variation in the normalized loop delay td/Ts [5].

The proposed architecture is validated through the implementation of a second-order LC BP ΣΔ modulator in a 65 nm CMOS process. For an OSR of 64, the modulator achieves an Signal to Noise and Distortion Ratio (SNDR) of 37 dB over the entire tuning range, f0 = 1.5 GHz. This SNDR is achieved for a bandwidth BW = 47 MHz at f0 = 1.5 GHz and for a bandwidth BW = 93 MHz at f0 = 3.0 GHz. The fabricated chip consumes 13 mW and achieves the highest reported tuning range, f0, and the highest reported center frequency, f0, for a CMOS BP ΣΔ ADC.

In order to compare this circuit with the state of the art, we use not only the conventional ADC figure of merit, but we also use a figure of merit dedicated to RF circuits. In this case, the measured chip center frequency, noise figure, and non-linearity are also taken into account in the comparison.

KEYWORDS

Bandpass sigma-delta, CMOS, LC tanks, RF ADC, software-defined radio.

REFERENCES

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BIOGRAPHY

Hassan Aboushady received the B.Sc. degree in electrical engineering from Cairo University, Egypt, in 1993, and the M.Sc. and Ph.D. degrees in electrical engineering and computer science from Sorbonne University, Paris, France, in 1996 and 2002, respectively. He has been an associate professor, currently on-leave, at Sorbonne University since 2003.

Hassan Aboushady is the co-founder and CEO of Seamless Waves, a spin-off from Sorbonne University, specialized in highly digitized RF transceivers. Dr. Aboushady has 30 years of experience in the field of RF/analog, ADCs, and DACs. He is the author and co-author of more than 90 publications and several patents in these areas. He was a visiting researcher at NXP, The Netherlands and at STMicroelectronics, France, in 1999 and 2001, respectively. Dr. Aboushady was a visiting professor at the French University in Egypt, the Federal University of Rio Grande do Norte, Brazil, Tecnologico de Monterrey, Mexico, and Ecole Polytechnique, France, in 2007, 2011, 2012, and 2013, respectively. Dr. Aboushady is a senior IEEE member, an IEEE-CAS distinguished lecturer, and a member of the IEEE Circuits and Systems for Communications Committee (CASCOM). He also served as an associate editor of the IEEE Transactions on Circuits & Systems II.