

Optimum Design of a Mostly-Digital Fleischer-Laker Switched-Capacitor Bilinear Bandpass Filter in Standard CMOS Technology

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EXTENDED ABSTRACT

This paper presents a Fleischer-Laker switched-capacitor (SC) bilinear bandpass filter implemented using an inverter-based amplifier. Due to the generalized scaling used in advanced deep-submicron CMOS technology over the past decades, it is becoming increasingly more difficult to design high-gain high-bandwidth opamps, due to the reduction of the supply voltage and of the intrinsic gain of the transistors. Since the amplifier used is implemented using inverters, it can take advantage of the improved transistor performance in smaller nodes, which is mainly exploited by digital circuits.

A. Bilinear Bandpass Fleischer-Laker SC filter

The bilinear bandpass SC filter circuit, shown in Fig. 1, is based on the Fleischer-Laker architecture [1].

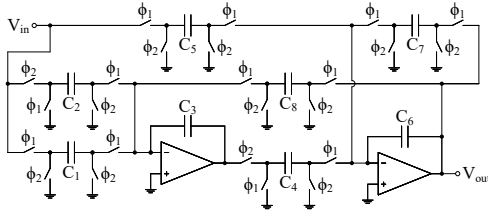


Fig. 1. Bilinear bandpass Fleischer-Laker SC filter.

Considering that the output signal is sampled at the end of clock phase ϕ_2 , that the input signal only changes value once per clock period ($1/F_s$) and if $C_1 = C_2 = C_5$ and $C_3 = C_4 = C_6$, the Fleischer-Laker SC filter's transfer function is given by (1) and have a bilinear type response.

$$H_{bp}^{\phi_2}(z) = \frac{C_1(z+1)(z-1)}{C_3(z-1)^2 + (C_7(z-1) + C_8)z} \quad (1)$$

B. Inverter-based Amplifier

The amplifiers used in the Fleischer-Laker SC filter have been implemented using a three-stage inverter-based architecture [2], [3], which is shown in Fig. 2.

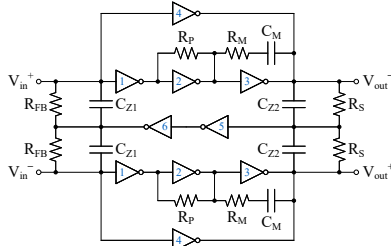


Fig. 2. Three-stage pseudo-differential inverter-based amplifier [2], [3].

C. Simulation Results

The filter circuit was designed in a 28-nm bulk-CMOS technology, using a supply voltage of 0.9 V and a clock frequency of 100 MHz. Simulation results show that the filter's central frequency is approximately 10 MHz, with a gain of 0 dB, and a quality factor of 10/3. The amplifiers have a typical gain of 42.5 dB, the SC filter has a SNR of 54.4 dB, an IM3 of -63.6 dB, and the circuit's total power dissipation is 2.5 mW.

The resulting frequency response and output spectrum of the bilinear bandpass SC filter are shown in Fig. 3. Results from the filter's impulse response show a notch depth at $F_s/2$ of -59.3 dB, while the transient simulation using an input signal with two 100 mV tones has a depth of -52.8 dB.

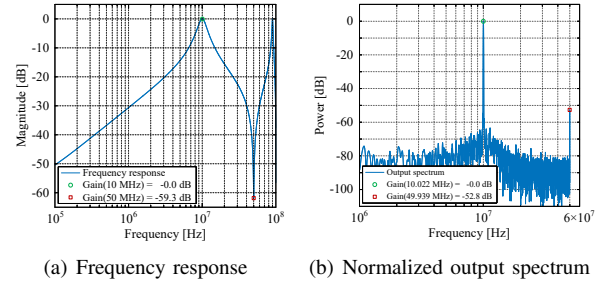


Fig. 3. Bilinear bandpass Fleischer-Laker SC filter: (a) Frequency response, (b) Normalized output spectrum for an input with two 100 mV tones.

The bilinear bandpass SC filter was also tested under 12 different process, voltage, and temperature (PVT) corners (TT/FF/SS, $V_{DD} \pm 5\% V_{DD}$, $0^\circ/85^\circ$) and under 100 Monte Carlo (MC) cases of mismatch variations, the performance obtained from these two tests is summarized in Table I.

TABLE I
PERFORMANCE UNDER PVT CORNERS AND MISMATCH VARIATIONS.

		Impulse response performance				Transient performance			
		f_c [MHz]	$G_{f_{sl}}$ [dB]	G_{f_c} [dB]	$G_{f_{sh}}$ [dB]	SNR [dB]	THD [dB]	IM3 [dB]	$G_{f_{sh}}$ [dB]
Nom.	Nom.	10.00	-50.89	0.03	-59.16	54.38	-80.56	-63.58	-52.75
	μ	9.97	-49.70	0.01	-60.81	53.74	-77.14	-63.53	-52.81
	σ	0.03	1.42	0.04	1.38	0.08	3.21	2.49	0.13
PVT	μ	9.94	-50.27	-0.02	-60.02	53.91	-72.71	-57.46	-52.41
	σ	0.16	0.65	0.59	4.28	0.97	11.35	12.78	4.64

f_{sl} – lower stopband frequency (0.1 MHz), f_{sh} – higher stopband frequency (49.939 MHz)

REFERENCES

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