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A 4th Order Differential G_m-C Band-Pass Filter Using Improved Floating Current Source

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Abstract: Gm-C filters are the most popular technique used in implementing integrated continuous-time filters. In the study, we proposed a 4th order differential Gm-C band-pass filter using improved floating current sources. The improved current source structure is simple and includes fewer transistors. This provides an effective use of the chip area and brings simplicity to the design of circuits. Thus it reduces the investment cost. The proposed filter structure does not contain the resistor which is very important for integration. All capacitors in proposed filter are grounded which reduces the parasitic effects. The proposed filter is simulated using CMOS TSMC 0.18µm technology. Simulation results are given to confirm the theoretical analysis.

Keywords: Analogue filter, analogue signal processing, floating current source, MOS integrated circuits

Diferencialen G_m-C pasovno prehoden filter četrtega reda z uporabo izboljšanega plavajočega tokovnega vira

Izvleček: Pri uporabi integriranih časovno neomejenih filtrov se najbolj uporablja tehnika Gm-C filtrov. V članku predlagamo diferencialen Gm-C pasovno prehoden filter četrtega reda z uporabo izboljšanega plavajočega tokovnega vira. Struktura izboljšanega tokovnega vira je enostavna in uporablja manj tranzistorjev, kar prinaša efektivno izrabo prostora in enostavnost vezja. Istočasno tudi znižuje stroške. Predlagani filter ne vsebuje upora, ki je potreben za integracijo. Vsi kondenzatorji so ozemljeni, kar zmanjšuje parazitne vplive. Filter je simuliran v CMOS TSMC 0.18 µm tehnologiji. Podani so simulacijski rezultati, ki potrjujejo teorijo.

Ključne besede: analogni filter, analogna obdelava signalov, plavajoči tokovni vir, MOS integrirana vezja

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1 Introduction

A continuous time filter has been widely applied in video signal processing, hard disk drive, communication integrated circuit, CDMA, ultra-wideband wireless access technology, and etc. [1]. G_m-C filters are the most popular technique used in implementing integrated continuous-time filters [2]. Research and development in the microelectronic technology enable possibility to design filters with less number of active and passive components. It also brings versatility and simplicity to the design of circuits and systems while reducing the investment cost[3].

Mostly the desired radio frequency signal is narrowband and therefore most of the intermediate frequencies in a superheterodyne (superhet) receiver designed for applications are also narrowband. As a result of this important fact, band pass filters are very important building blocks in modern RF communication systems. Figure 1 shows the block diagram of a typical multistep superhet receiver with a digital back-end [4]. As the figure shows, a sequence of filter operations is used to convert the desired signal from radio frequency (RF), typically in the VHF (30 MHz to 300 MHz) range, down to one or more intermediate frequencies (IFs) and finally down to baseband, where the signal is digitized by an ADC [4].

The studies about the 4th order filters have been reported in the literature [1-2,5-9]. The comparison of 4th order filter circuits in terms of including active devices and passive components are shown in Table 1.

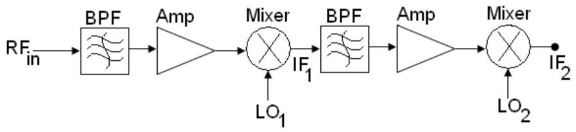

Figure 1: A typical superheterodyne receiver [4]

This paper proposes 4th order differential G_m-C band-pass filter using improved floating current sources. Improved floating current sources performance is better than the floating current sources at low frequencies, because of high output resistance. Compared with the studies that are shown in Table 1, the improved current source structure is simple and includes fewer transistors. Thus, we can use the chip area more effective and this brings simplicity to the design of circuits and reduces investment costs.

Table 1: The 4th order filter structures reported in literature

Active Device	Active Device Number	Passive Component Number	Reference
DVCC	4	8	[5]
OTA	6,8,8	4,4,8	[6-8]
OPAMP	2	20	[9]
Current Mirror	4	4	[1]
G_m cells	8	4	[2]

2 Proposed 4th order band-pass filter structure

The improved floating current source has very simple structure as shown in Figure 2. Having two different G_m and its frequent use in recent studies make the floating current source useful. Its G_m is electronically adjustable using bias current as OTA structures. Floating current source operation is similar to OTA. But, there is only one G_m for OTA and two different G_ms in floating current source. The output resistance of the improved floating current source is higher than the floating current source which is proposed by Arbel and Goldminz [10]. M5, M6, M7 and M8 transistors are added to the conventional floating current source to get high output resistance values as shown in Figure 2. The high output resistance is a necessity in current-mode structures and therefore the improved floating current source is preferred according to conventional improved floating current source. High output resistance provides better results at low frequency region. Output current of the improved floating current source is calculated by multiplying the voltage difference between P and N terminals with G_m. The G_m for P terminal is $(g_3/g_4)/2$ and the G_m of the n terminal is $-(g_1+g_2)/2$. The capacitors are connected to the structure without using resistance and this connection provides the desired transfer function in filter and oscillator applications [11-12]. In this study, we proposed G_m-C filter application.

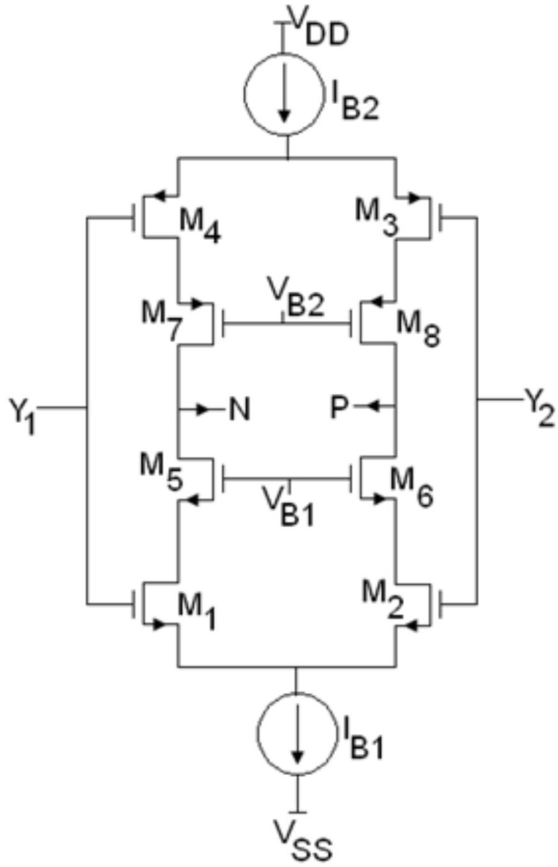

Figure 2: Schematic representation of improved floating current source [12]

W/L of transistors and DC values of the circuit are reported in Table 2 and Table 3, respectively. The functionality of the proposed circuit is demonstrated on a 4th order band pass ladder filter design which is illustrated in Figure 3 and the ladder filter component values are given in Table 4.

Table 2: Transistor dimensions

Transistors	W(µm)	L(µm)
M_1, M_2	18	0.18
M_3, M_4	72	0.18
M_5, M_6	27	0.18
M_7, M_8	90	0.18

Table 3: DC values of improved floating current source

Parameters	Value
V_{DD}, V_{SS}	±0.9V
I_{B1}, I_{B2}	300µA
V_{B1},V_{B2}	0.3V

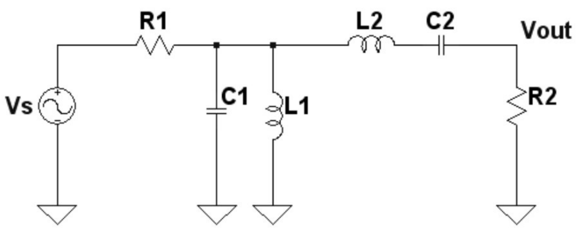

Figure 3: The LC Butterworth ladder filter

Table 4: Ladder filter component values

Component	Value
R1, R2	100Ω, 100Ω
C1, C2	225pF, 12.5pF
L1, L2	125nH, 2.251µH

The block diagram of the proposed 4th order G_m-C band-pass filter is presented in Figure 4. The proposed filter block diagram is the equivalent filter of the ladder filter in Figure 3 which consists of passive components. G_m-C filter component values and performance parameters are given in Table 5.

Table 5: G_m-c filter component values and performance parameters

Component	Value
C_1=C_1', C_2==C_2'	225pF, 12.5pF
C_{L1}=C_{L1}'=L_1.(G_m)^2	0,87pF
C_{L2}=C_{L2}'=L_2.(G_m)^2	15,71 pF
Parameter	
G_{m1}= G_{m3}= G_{m4}= G_{m5}= G_{m6}= G_{m7}= G_{m8}	2.642mA/V
G_{m2}= G_{m9}	0.99mA/V

Transfer function of the filter is given in Equation (1).

$$H(s)=\frac{s\frac{G_{m1}}{C_1}}{s^2+sC_{L1}\frac{G_{m2}}{C_1}+\frac{G_{m3}\cdot G_{m4}}{C_1\cdot C_{L1}}}\cdot\frac{s\frac{G_{m6}}{C_2}}{s^2+sC_{L2}\frac{G_{m9}}{C_2}+\frac{G_{m7}\cdot G_{m8}}{C_2\cdot C_{L2}}} \qquad (1)$$

Center frequency of the band pass filter is given in Equation (2).

$$\omega_0=\sqrt{\sqrt{\frac{G_{m3}\cdot G_{m4}}{C_1\cdot C_{L1}}\cdot\frac{G_{m7}\cdot G_{m8}}{C_2\cdot C_{L2}}}} \qquad (2)$$

3 Simulations

We perform the simulations by using LTSPICE program with TSMC CMOS 0.18 µm process parameters. The performance parameters of improved floating current source used in simulations are presented in Table 6.

Table 6: Performance parameters of IFCS G_m structure

Parameter	Value
V_{DD}, V_{SS}	±0.9V
I_{B1}, I_{B2}	300µA
V_{B1},V_{B2}	0.3V
G_{m1}= G_{m1}	2.445mA/V
Parasitic capacitances at p, n terminals	0.3pF, 15.6fF
Input offset voltage	0
Power dissipation	0.54mW

The output currents at n and p terminals of improved floating current source against input voltage (V_{Y1}-V_{Y2}) are shown in Figure 5. The output currents changes between ±300µA.

Figure 6 clearly shows that the G_m of improved floating current source operates well at frequencies close to 100MHz.

The ladder circuit in Figure 3 and the proposed circuit in Figure 4 are simulated with using the component values in Table 4 and Table 5. Figure 7 illustrates

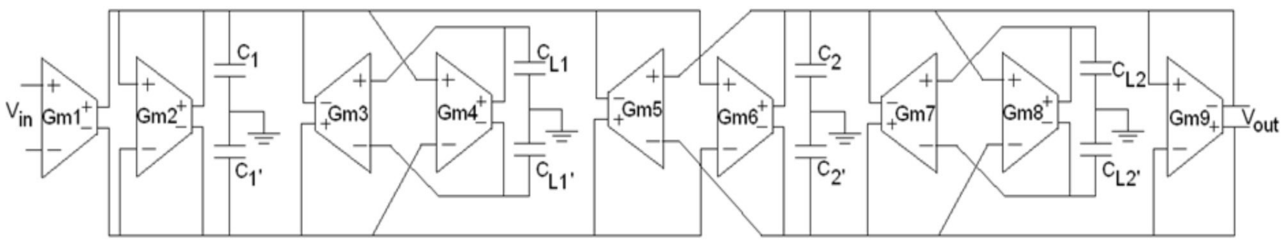

Figure 4: Block diagram of 4th order differential G_m-C band-pass filter

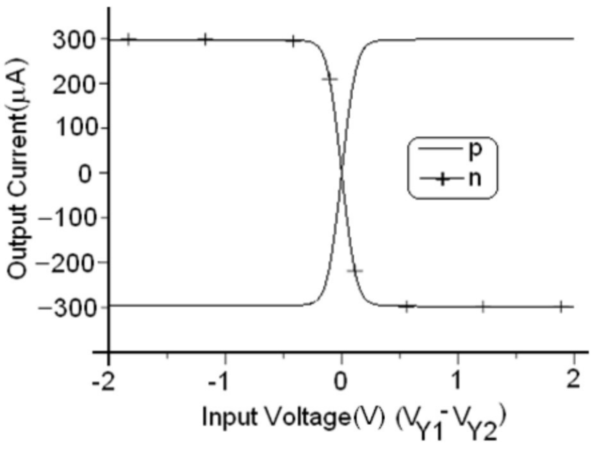

Figure 5: The DC transfer characteristic of improved floating current source

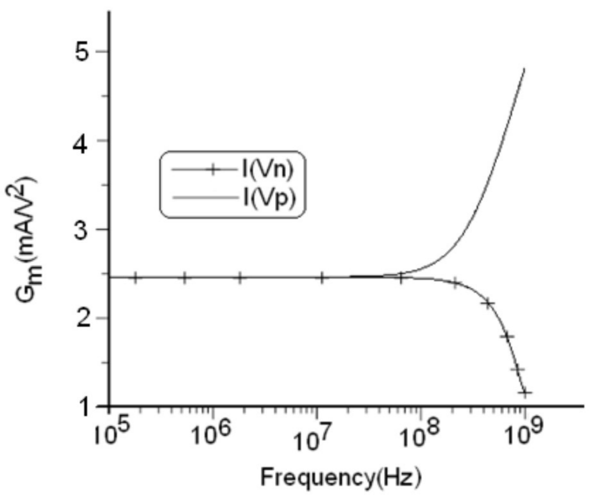

Figure 6: The AC transfer characteristic of improved floating current source G_m

the simulation results of ideal and proposed 4th order differential Gm-C band-pass filter. Center frequency is 30,11 MHz in LTSPICE simulation results of the filter responses. We calculated theoretical centre frequency using Equation 2 as $\omega_0 = 2\pi x30,05$ MHz using the values in Table 5. Simulations results obtained from our experiments show good match with the theoretical results.

Figure 7 shows that, the proposed filter can be used in modern RF communication circuits as the proposed filter operates intermediate frequencies in a superheterodyne (superhet) receiver. The large signal behavior of the proposed circuit band-pass filter was tested by applying a 10 MHz sinusoidal signal with different amplitudes to the input. The dependence of the output harmonic distortion of band-pass filter on input voltage amplitude is illustrated in Figure 8. The total harmonic distortion slowly increases (past tense olabilir bence) depending input voltage which is lower than 400mVp-

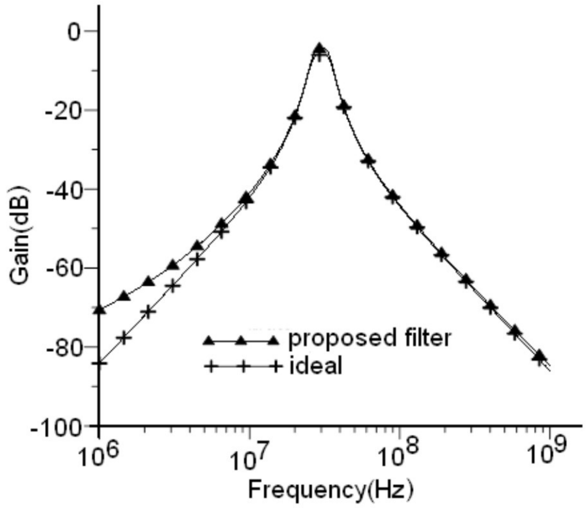

Figure 7: Ideal and simulation frequency responses of 4th order differential G_m-C band-pass filter

p. The THD remains in acceptable limits i.e. 3 %. Thus it confirming the practical utility of the proposed circuit shown in Figure 8.

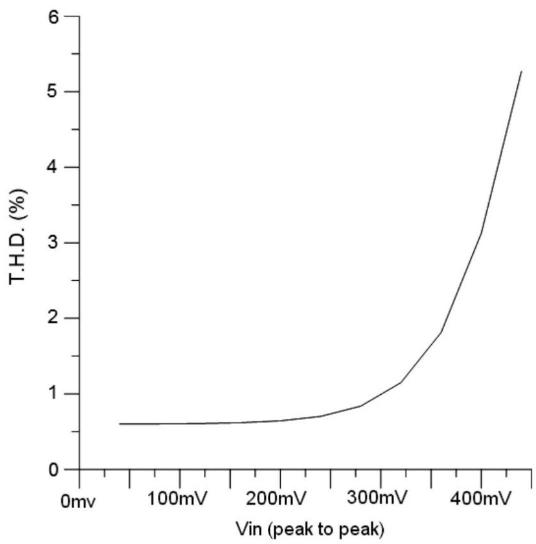

Figure 8: Total harmonic distortion (THD) values of band-pass filter for different frequency values terminals

4 Conclusion

In the study; a fourth order differential G_m-C band-pass filter using improved floating current sources is presented. Floating current source operation is similar to OTA. But, floating current source is superior to the OTA as it contains two different G_ms while there is only one in OTA. The improved floating current source has very simple structure. Its G_m is electronically adjustable using bias current. The filter centre frequency is about 30MHz. Simulations results show good match with the theoretical results. The proposed filter operates intermediate frequencies and can be used in modern RF communication circuits. The simulations obtained by LTSPICE indicate good functionality of the circuit, low total harmonic distortion. The improved current source structure is simple and includes fewer transistors. Thus, we can use the chip area effectively and also bring simplicity to the design of circuits and reduces the investment cost. The filter does not contain resistor and all capacitors are grounded. Therefore, it is suitable for integration and less effected from parasitic.

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