A LOW-VOLTAGE LOW *Q* SECOND ORDER BANDPASS FILTER REALIZATION THROUGH FGMOS BASED CCII

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ABSTRACT

A second order low *Q*, low voltage, bandpass filter based on a single CCII and four grounded passive components imparting the ease in chip implementation is presented. The proposed filter structure can easily be cascaded to get enhanced *Q*. Theoretical results have been validated by PSpice simulations for 0.5µm technology at ± 0.75 V.

I. INTRODUCTION

The low voltage (LV) analog circuits are well established due to the mobility in applications and the filters form an integral part of any LV modern communication and instrumentation equipment [1-3]. Current conveyor type II (CCII) has been used in almost all linear and non-linear current mode applications exhibiting performance superiority over the conventional op amps [4]. LV CCII can be designed by employing LV circuit design techniques [1-3]. Floating gate MOSFET (FGMOS) is one such LV design technique where threshold voltage can be tailored without device scaling [5-7].

There are many CCII based filter structures but most of them use either number of CCIIs or number of passive components [8-15]. Some structures, however, use floating components which complicate their implementation in chip form [15]. In this paper, we present a low *Q* bandpass filter realized using a low voltage CCII+. Low *Q* filters are more or less insensitive to component variations [16]. The *Q* of the bandpass filter can be enhanced by cascading identical stages. The operation of these circuits has been verified by using PSpice in 0.5 µm technology at supply voltage of ± 0.75 V.

II. CIRCUIT DESCRIPTION

The circuit for the voltage-mode bandpass filter is shown in Fig. 1.

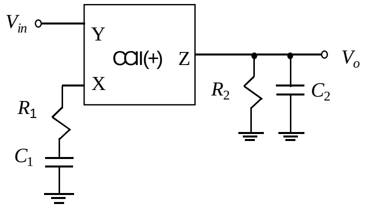

Fig.1 Voltage-mode bandpass filter

The transfer function is given as

$$\frac{V_o}{V_{in}} = \frac{sC_1R_2}{s^2C_1C_2R_1R_2 + s(C_1R_1 + C_2R_2) + 1} \qquad (1)$$

which gives Center frequency $\omega_0 = \frac{1}{\sqrt{C_1C_2R_1R_2}}$, Quality factor $Q = \frac{\sqrt{C_1C_2R_1R_2}}{C_1R_1 + C_2R_2}$ and Passband gain $k = \frac{C_1R_2}{C_1R_1 + C_2R_2}$.

This circuit when realized with current controlled current conveyor (CCCCII+), intrinsic resistance R_X and R_1 come in series. Since R_X depends on the biasing current flowing through CCCCII+, the structure can provide tunability or *Q* factor adjustment.

III. FILTER DESIGN

The band-pass filter can be designed to yield different results depending upon the relationship between various components as shown:

Design I

A: For equal valued components as $R_1 = R_2 = R$ & $C_1 = C_2 = C$, Eqn. (1) gives $f_0 = \frac{1}{2\pi RC}$, *Q* = 0.5 and *k* = 0.5.

B: For $R_1 = R$, $R_2 = 2R$ & $C_1 = 2C$ $C_2 = C$, we get $f_0 = \frac{1}{4\pi RC}$, *Q* = 0.5 and *k* = 1.

C: For $R_1 = R, R_2 = 4R \,\&\, C_1 = 4C\ C_2 = C$, we have $f_0 = \frac{1}{8\pi RC}$, Q = 0.5 and k = 2.

D: For $R_1 = R, R_2 = 6R \,\&\, C_1 = 6C\ C_2 = C$, we have $f_0 = \frac{1}{12\pi RC}$, Q = 0.5 and k = 3.

Hence, pass band gain can be increased at the expense of center frequency while retaining the quality factor.

Design II

Now for $C_1 = C_2 = C$ and $R_2 = KR_1$, we have the transfer function as

$$\frac{V_o}{V_{in}} = \frac{sKCR}{s^2KC^2R^2 + s(K+1)CR + 1} \tag{2}$$

which gives $\omega_0 = \frac{1}{CR\sqrt{K}}, Q = \frac{\sqrt{K}}{1+K}$ and $k = \frac{K}{1+K}$.

Here, Q can be varied between 0.5 and lower while resonant frequency decreases and passband gain increases with increase in the value of resistance scaling factor K.

IV. SIMULATION RESULTS

CCII (+) used for realizing bandpass filter is taken from reference [3] wherein FGMOS current mirrors [6] have been used. It has been simulated using PSpice for 0.5µm technology with supply voltage of ± 0.75 V. Simulation results show that it offers an input resistance of 2.53 Ω at port X, 10^{20} Ω at port Y and output resistance of 119.8 MΩ at port Z. The power consumed by the circuit is 1.62 mW. Current and voltage transfer ratios are almost unity with an error less than ± 0.2 %. The bandwidth for both current and voltage transfer has been found to be 100 MHz.

The filter circuit for design I is simulated by choosing C = 500 pF and R = 0.5 kΩ. The simulated magnitude and phase responses are shown in Figs 2(a) & 2(b) respectively. The simulated filter response for design II for different values of K is shown in Fig. 3(a) & 3(b). The simulated results agree well with the results of theoretical analysis (Tables 1 & 2). The effect of cascading on the enhancement of Q has also been observed. The cascaded filters are simulated for identical values of components and it has been found that Q increases to 0.732 for two-stage filter and to 0.914 for three-stage filter from 0.495 for a single-stage filter.

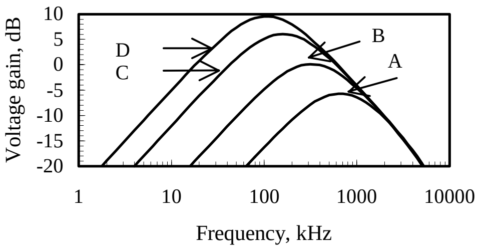

Fig. 2(a) Magnitude response of design I

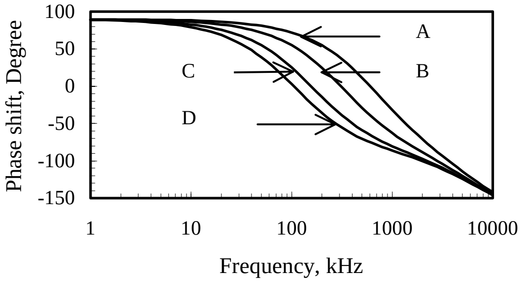

Fig. 2(b) Phase response of design I

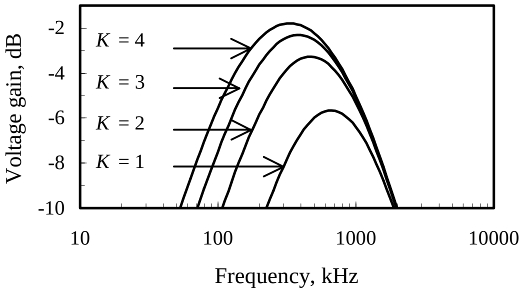

Fig. 3(a) Magnitude response of design II

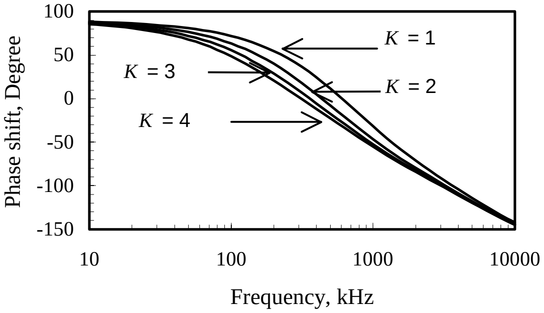

Fig. 3(b) Phase response of design II

Table1-Performance of Filter design I (Q = 0.5)

Filter parameters		Type of filter design			
		A	B	C	D
f_0 (kHz)	Cal.	636	318	159	106
	Simu.	631	316	159	100
k (dB)	Cal.	-6	0	6.02	9.54
	Simu.	-5.66	0.15	6.08	9.55

Table 2-Performance of Filter design II

Filter parameters		Type of filter design			
		K=1	*K*=2	*K*=3	*K*=4
f_0 (kHz)	Cal.	636	449.79	367.2	318
	Simu.	631	501	398	316
k (dB)	Cal.	-6	-3.48	-2.50	-1.94
	Simu.	-5.66	-3.28	-2.31	-1.79
Q	Cal.	0.5	0.471	0.433	0.40
	Simu.	0.495	0.464	0.423	0.389

V. CURRENT-MODE BANDPASS FILTER

The filter structure can be modified to yield the current-mode bandpass filter as shown in Fig.4. The analysis shows that the characteristics of this structure are similar to those derived for the voltage mode structure

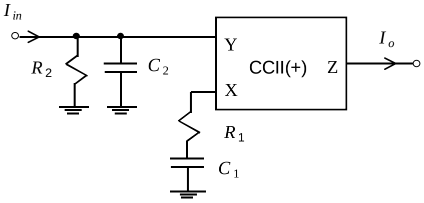

Fig.4 Current-mode bandpass filter

When this circuit has been simulated for the same design values (as have been used in voltage-mode bandpass filter) the resultant characteristics resembles to the voltage mode structure. However, in this case input impedance decreases to the maximum R_2, which further decreases as the input signal frequency increases.

VI. CONCLUSION

The low Q, CCII+ based voltage-mode bandpass filter uses only four grounded passive components, which are desirable for integration on a chip. The low Q filter presented is useful for cascading active filters. A current-mode version of bandpass filter also has similar characteristics. When the CCII+ is replaced by a CCCCII+, electronic tunability can be achieved. All these circuit structures operate with at ± 0.75 V.

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