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ELECTRONICALLY TUNABLE SIGNAL PROCESSING CIRCUIT

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ABSTRACT

This paper presents a voltage mode universal filter using two multi-output operational transconductance amplifier (OTA). Proposed multi-input single output universal filter employs two capacitors only and realizes all the standard second order filtering functions from same configuration. Filter parameters namely pole frequency and quality factor can be tuned independently without affecting each other. Performance of proposed filter is verified by Tanner EDA tool at 180nm technology.

Keywords- Operational Transconductance Amplifier (OTA), Universal filter.

I. INTRODUCTION

In analog signal processing, active filter play a vital function in electronic circuit. It has wide area of application such as in communication, measurement, instrumentation, control systems and biomedical applications. Design of universal filter has gained considerable attention these days because of its ability to realize all the filter function from same configuration.

A challenging issue with the continuous time analog filter is RC time constant variation, which decides the filter parameters. Time constant of circuit varies with processing tolerance, humidity, environmental effects due to the drift in temperature and aging of components. This problem can be rectified with the tunability feature in the filter circuit. Thus, the interest is growing in designing of electronically tunable filters which can compensate the unwanted variation of RC time constant.

The progress of analog technology has grown many filters using various active elements such as operational transconductance amplifier (OTA), second generation current conveyor (CCII), current differentiation transconductance amplifier (CDTA), voltage differencing transconductance amplifier (VDTA), Current controlled conveyor differencing transconductance amplifier (CCCDTA), voltage differencing inverting buffered amplifier (VDIBA), Voltage differencing differential input buffered amplifier (VD-DIBA), voltage differencing buffered amplifier (VDBA) etc. These analog blocks are widely used because of their higher frequency operation, wide dynamic range, and current mode (CM) operation, high bandwidth and low power consumption.

Some of the active building blocks such as OTA, VDIBA, VDTA are providing more flexibility in analog circuit designing. These blocks offers tunability feature through their transconductance parameter and also filters based over it does not require resistor. Since the component count of filter based over these blocks are less it require less area on chip and results in more compact circuit. Literature survey shows that a lot of attention has been given in realization of tunable filters utilizing different active element. But, these reported circuits lack one or more of the following important features:

(1) Incapable of realizing all the five filter functions namely Low pass (LP), High Pass (HP), Band Pass (BP), Band Reject (BR), All Pass (AP) [1,2,3,5].
(2) Independent control of filter parameters.[4]
(3) Lesser sensitivity figures.[1,4]
(4) Cascadability [1]

The aim of this paper is to incorporate all these features in a single filter configuration. The proposed multi-input VM universal filter circuit consists of two OTA, one grounded and one conditionally grounded (for few filter functions) capacitor. It can realize all the filter functions by proper selection of input voltage levels. Filter parameters namely quality factor (Q) and pole frequency (ω_0) can be tuned independently. Simulation results using 180nm CMOS parameters are presented to to verify its performance.

The paper is organized as follows. Start with the introduction, section II briefly describes the active element OTA. Section III describes the realization of proposed universal filter. Section IV presents the simulation result of proposed filter Section V provides a comparison for proposed filter with available configurations. Finally, section VI holds the conclusion for the same.

II. OPERATIONAL TRANSCONDUCTANCE AMPLIFIER

Operational transconductance amplifier (OTA) is basically a voltage controlled current source (VCCS) device. It generates an output current by processing the input voltage differentially. The circuit symbol and schematic diagram is shown in Fig.1 and Fig.2 respectively. In this configuration $\boldsymbol{V_+}$ and $\boldsymbol{V_-}$ are the high impedence differential (voltage) input ports and output port is high impedance port yielding the current variable.

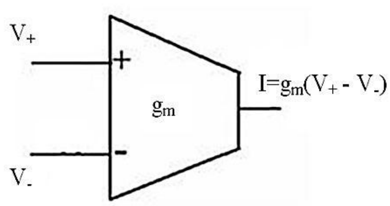

Fig. 1: Symbol of OTA

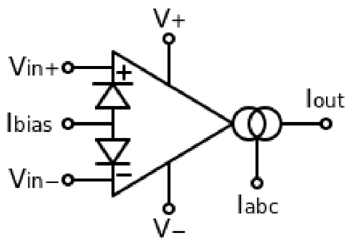

Fig. 2: Schematic diagram of OTA

The output current is a linear function of the differential input voltage. It is given by

$$I_{out} = (V_{in+} - V_{in-}) g_m \quad (1)$$

Where V_{in+} is the input voltage at the non-inverting terminal, V_{in-} is the input voltage at the inverting terminal and g_m is the transconductance of the amplifier.

The amplifier's output voltage is determined by its output current and associated load as

$$V_o = I_{out} R_{load} \quad (2)$$

Thus, the voltage of OTA can be obtained as

$$G_{voltage} = \frac{V_{out}}{V_{in+} - V_{in-}} = R_{load}\, g_m \quad (3)$$

The transconductance (g_m) parameters of OTA is controlled with the help of an input bias current (I_{abc}) shown in Fig. 2. The transconductance of the amplifier is directly proportional to the bias current. This feature makes it useful for electronic control of amplifier's gain.

III. PROPOSED UNIVERSAL FILTER

The proposed filter consist of two OTA block (one single output and one dual output) and two capacitors only. it is shown in Fig. 3.

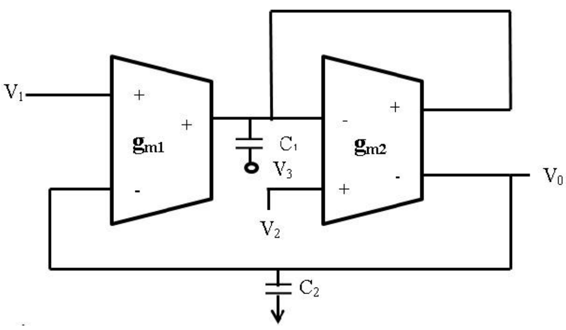

Fig. 3: Proposed VM universal filter

Output function of proposed universal filter is given as

$$V_0 = \frac{s^2 C_1 C_2 V_3 + s g_2 (C_1 V_3 - C_2 V_2) + g_1 g_2 V_1}{s^2 C_1 C_2 + s C_1 g_2 + g_1 g_2} \quad (3)$$

Second OTA block of proposed filter is required to have both inverting and non inverting output ports. Required current inversion is obtained by employing a current mirror circuit consisting of transistors M_{11}-M_{14} in OTA of [6]. Final transistor level schematic of dual output OTA is shown in Fig. 4.

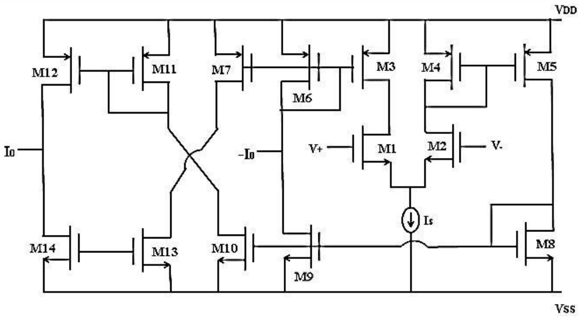

Fig. 4: Dual output OTA

From Eqn. 3, it is clear that all filter function can be realized with the same filter configuration without any change in the filter circuit which can be seen in table 1.

Table I: Input set for different filter functions

INPUT VOLTAGE	CONDITION	FILTER FUNCTION
V_2=V_3=0, V_1=V_{IN}	-	LP
V_1=0, V_2=V_3=V_{IN}	C_2=C_1, g_{m2} = g_{m1}	HP
V_1=V_3=0, V_2=V_{IN}	-	BP
V_1=V_2=V_3=V_{IN}	C_2=C_1	BR
V_1=V_2=V_3=V_{IN}	C_2=2C_1	AP

Bandwidth, pole frequency (ω_0) and quality factor (Q) can be expressed from the Eqn. 3 in Eqn. (a), (b) and (c) respectively.

$$BW = \frac{g_1}{C_2} \quad (4a)$$

$$\omega_0 = \sqrt{\frac{g_1 g_2}{C_1 C_2}} \quad (4b)$$

$$Q = \sqrt{\frac{g_2 C_2}{g_1 C_1}} \quad (4c)$$

It can be seen from (4) that the pole frequency (ω_0) and Q- factor can be tuned independently by equally varying transconductance and/or capacitances i.e g_1, g_2, and C_1, C_2

Sensitivity of pole frequency (ω_0) and Q-factor is given below:

$$(5a)\ {}_{2} = -S_{C1,C2}^{\omega_0} = \frac{1}{2}$$

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$$.(5b)_{2} = -S^{Q}_{g1,C1} = \frac{1}{2}$$

From Eqn. 5 it is clear that sensitivity of the proposed filter parameters with respect various active and passive element is always less than 1. So, it has less unwanted variation.

IV. SIMULATION RESULTS

Theoretical analysis of proposed filter is verified by simulating it on Tanner EDA tool using 180nm CMOS parameters. Supply voltage is set to 3V. Transistor dimension is given in Table II.

Table II: aspect ratio

M1-M2	W=7µm, L=0.7µm
M3-M7, M11 and M12	W=2.8µm, L=0.7µm
M8-M10, M13 and M14	W=5.6µm, L=0.7µm

The passive components C1 and C2 taken in accordance with the filter response requirement as given in Table I. The value of the capacitor C1 and C2 both are taken as 5pF. Tuning mechanism is depicted by varying the bias current (which varies its transconductance). Fig. 5,6 and 7 shows the simulated filter responses of LP, HP, BP, BR and AP at different values of bias current I_S.

At I_S=100µA, the frequency of the circuit is 16.12MHz.

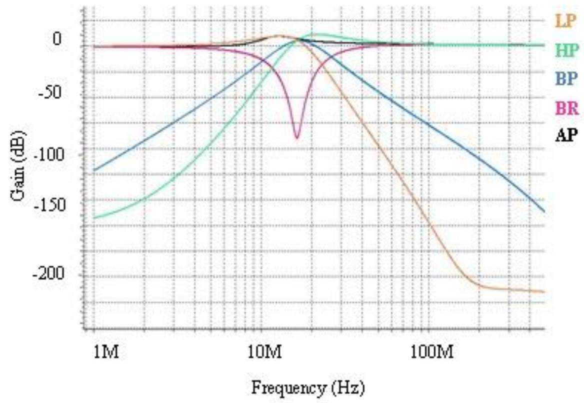

Fig. 5: Frequency response at I_s=100µA

At I_S=200µA, the frequency of the circuit is 20.93MHz.

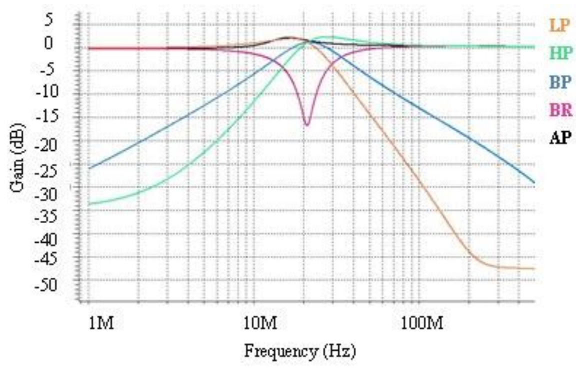

Fig. 6: Frequency response at I_s=200µA

At I_S=1.2mA, the frequency of the circuit is 34.43MHz.

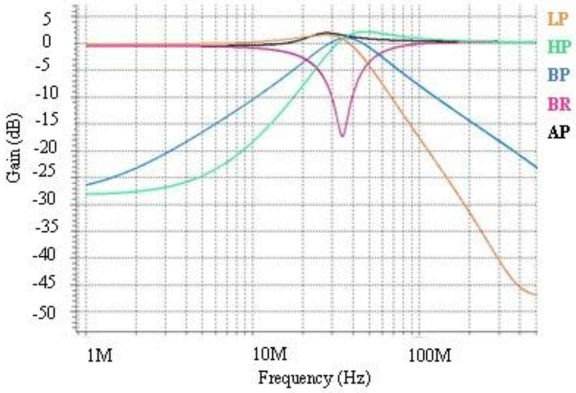

Fig. 7: Frequency response at I_s=1.2mA

From Fig 5, 6 and 7 it is clearly seen that the pole frequency of the filter increases with increase in the bias current.

Table III: Comparative study of universal Filters

Features/ References	1	2	3	4	5	6	7	8
[1]	Y	N	Y	0/0	2/0	2	CM	4(OTA)
[2]	Y	Y	N	3/1	2/0	4	VM	2(CC),1(OTA)
[3]	Y	Y	N	1/1	1/0	2	TAM	1(OA)
[4]	N	Y	N	0/0	2/0	5	TAM	5(OTA)
[5]	Y	Y	N	0/0	2/0	3	CM/VM	4(OTA)
Proposed	Y	Y	Y	0/0	1/1	5	VM	2(OTA)

V. COMPARISION

The proposed filter has been compared with a few existing filter in Table III on the basis of following important features such as (1) Independently tuned filter parameters (2) Cascadability (3) Component Matching constraints (4) No of resistors (Grounded/ floating) (5) No of capacitors (Grounded/ floating) (6) No of filter functions – Low pass, High pass, Band pass, Band stop, All pass (7) Mode of operation (CM/VM) (8) Number of active elements with name. The total power dissipation of the proposed biquad filter is approximately 1.212mW. It can be seen from Table III that the proposed filter provides more number of features compared to the reported filters.

VI. CONCLUSION

Paper proposes a VM universal filter using two OTAs, two capacitors only. It generates all five filter function without any change in the topology. It has also independently controlled parameters. Tunablity is depicted by varying the bias current (I_S). it consumes 1.212mW at 3V supply voltage. Moreover, the configuration requires component matching constraints in some filter functions i.e (HP), (BR) and (AP). It has low active and passive sensitivities. All the analysis is performed on Tanner EDA tool at 180nm technology.

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