Comb Filter Implementation using Voltage Differencing Transconductance Amplifier

Vipul Jee Verma, Vipul Dhasmana, Shubham Marathia, Saurabh Kaura

***Abstract*— This paper presents an implementation of active comb filter using Voltage differencing transconductance amplifier (VDTA). Comb filter is used to remove the signals of selected frequencies. The proposed realization of VDTA is resistorless and possesses electronic tunability. PSPICE simulation through 180nm CMOS technology parameter is carried out to verify the functionality of proposed comb filter.**

***Index Terms*— Comb filter, Notch filter, VDTA.**

I. Introduction

In the recent years, a large number of current mode active elements such as operational transconductance amplifier (OTA), current conveyor (CC), current controlled conveyor (CCC), current feedback amplifier (CFOA), operational transresistance amplifier (OTRA), differential voltage current conveyor (DVCC), current differencing buffered amplifier (CDBA), current differencing buffered amplifier (CDTA), voltage differencing transconductance amplifier (VDTA) etc. are published as current mode approach has gained a considerable attention due to their high bandwidth, low power consumption, high dynamic range, high slew rate and simple circuitry. A literature review of such analog active block is presented in [1-2]. The VDTA is a such a proposed analog building block, composed of two transconductance amplifier and may be used to implement different analog processing application such as analog filter [3-6], floating and grounded inductor simulation [7-9] and oscillators [10-12].

Among various kinds of noises, ac power line interference of 50Hz/60Hz and its harmonics in ECG signal are most common [13-21]. The elimination or reduction of power line interference is one of the most important problems in recording of biomedical signals. A filter which is designed to remove a series of selected frequencies with the spacing of all the frequencies at multiples of the lowest is named as a comb filter. Implementation of active comb filter using different analog building block like OTA [19-20], CC [21] is presented in literature.

In this paper, active realization of comb filter using VDTA is proposed. The proposed implementation is a resistorless structure and possesses electronic tunability via bias current of VDTA. Resistorless realization is suitable for IC implementation.

II. VDTA

Voltage Differencing Transconductance Amplifier [3] is a current mode active building block, consist of two transconductance amplifier. Presence of two transconductance circuit in VDTA eliminates the need of external resistors while implementing different circuits. Fig. 1 and Fig 2 represents the symbolic representation and CMOS implementation of VDTA respectively. The port relationship for VDTA can be defined through (1)

$$\begin{bmatrix} I_Z \\ I_{X+} \\ I_{X-} \end{bmatrix} = \begin{bmatrix} g_{mi} & -g_{mi} & 0 \\ 0 & 0 & g_{mo} \\ 0 & 0 & -g_{mo} \end{bmatrix} \begin{bmatrix} V_P \\ V_N \\ V_Z \end{bmatrix} \quad (1)$$

Where g_{mi} and g_{mo} are the input and output transconductance gain of VDTA.

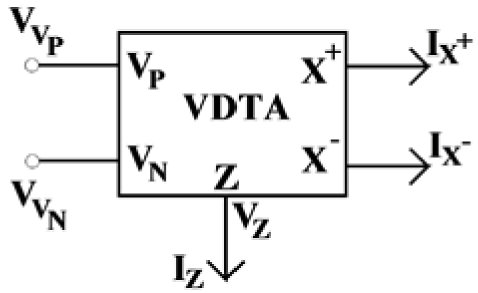

Fig.1 Symbolic representation of VDTA

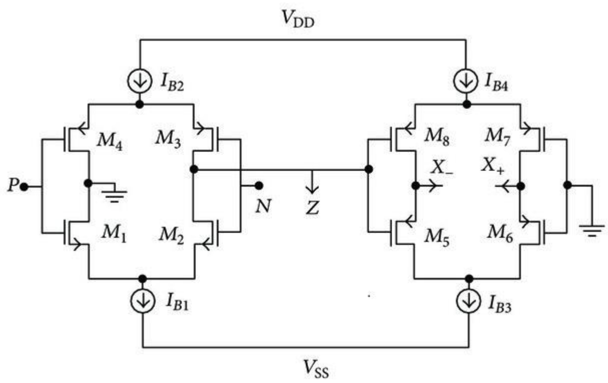

Fig.2 CMOS Implementation of VDTA [3]

III. Proposed Circuit

A. Passive comb Filter

Comb filter is used to remove the signal of selective frequencies. The basis of comb filter is notch filter. Fig. 3 shows a passive RLC notch filter. The transfer function of this circuit is expressed as-

$$T(s)=\frac{s^2+\frac{1}{LC}}{s^2+s(\frac{R}{L})+\frac{1}{LC}} \quad (2)$$

And the parameter of notch filter is expressed as-

$$f_0=\frac{1}{2\pi\sqrt{LC}} \quad (3)$$

$$Q=\frac{1}{R}\sqrt{\frac{L}{C}} \quad (4)$$

Where f_0 and Q are the notch frequency and quality factor respectively of the notch filter.

The extension of L-C section of Fig. 3 gives the comb filter circuit as shown in Fig. 4. The routine analysis of the circuit in Fig. 4 gives the voltage transfer function as-

$$T(s)=\frac{1}{R\sum_{i=1}^{n}(sC_i/(s^2L_iC_i+1))+1} \quad (5)$$

The i^{th} notch removes the i^{th} harmonic component from the input signal. The voltage transfer function of the i^{th} notch can be expressed as-

$$T^i(s)=\frac{1}{(sC_iR/(s^2L_iC_i+1))+1} \quad (6)$$

B. *VDTA Implementation of Comb Filter*

VDTA implementation of Fig.4 is obtained by replacing the passive resistor and inductor by their active realization using VDTA.

VDTA implementation of floating resistor is shown in Fig.5. By routine analysis the resistance value is calculated as-

$$R=\frac{1}{g_{mR}} \quad (7)$$

Where $g_{mi}=g_{mo}=g_{mR}$

And the VDTA implementation of grounded inductor is shown in Fig. 6 [9] and its inductance can be expressed as-

$$L=\frac{C_L}{g_{mL}{}^2} \quad (8)$$

Where $g_{mi}=g_{mo}=g_{mL}$ for the used VDTA.

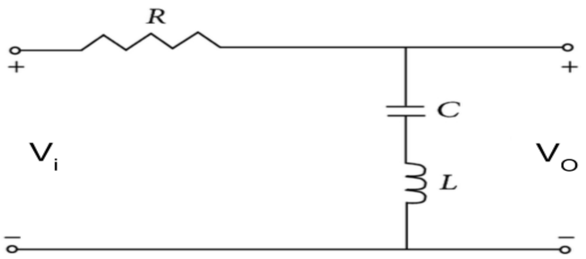

Fig. 3 RLC Notch Filter

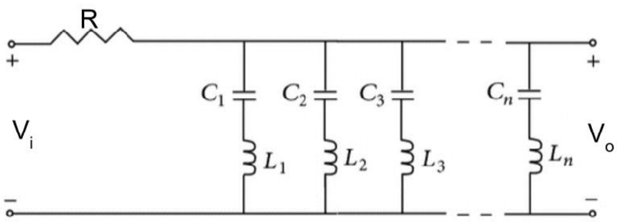

Fig. 4 Passive comb filter

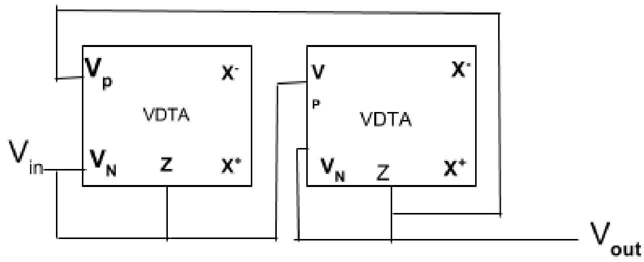

Fig. 5 VDTA implementation of floating resistor

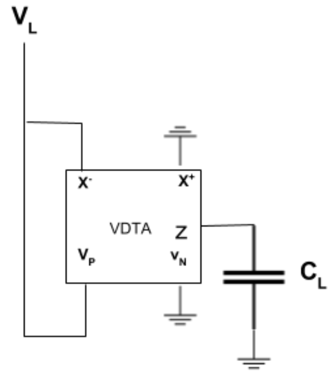

Fig. 6 VDTA implementation of grounded inductor [9]

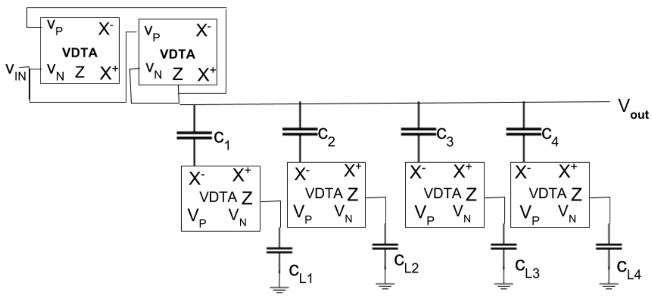

Fig.7 VDTA implementation of Comb filter for n=4 stages.

Here as an example, the comb filter is implemented for n= 4 stages. The complete VDTA implementation of comb filter for n=4 is shown in Fig. 7. The expression for notch frequency and quality factor for a single notch circuit is obtained as-

$$f_0=\frac{g_{mL}}{2\pi\sqrt{C_{Li}C_i}} \quad (9)$$

$$Q=\frac{g_{mR}}{g_{mL}}\sqrt{\frac{C_{Li}}{C_i}} \quad (10)$$

Here i=1, 2,3,4 and g_{mL} and g_{mR} are the transconductance of the VDTA used in implementation of floating resistor and grounded inductor respectively.

For $C_{Li}=C_i=C$ the expression of f_0 and Q becomes-

$$f_0=\frac{g_{mL}}{2\pi C} \quad (11)$$

And $Q=\frac{g_{mR}}{g_{mL}}$ (12)

It is clear from (11) and (12) that f_0 and Q can be tuned orthogonally. The f_0 and Q can also be tuned electronically via bias current of VDTA because g_{mR} and g_{mL} are the functions of bias current.

IV. SIMULATION

The aspect ratio of various transistor used in VDTA are given in Table 1 and the value of supply voltage used is V_{DD} = $-V_{SS}$ =0.9V. The circuit of Fig. 5 is simulated for bias current of I_{B1} =I_{B2} = I_{B3} = I_{B4} = 900µA and the simulated resistance curve is shown in Fig. 8. The simulated value of floating resistance is 842.35 ohms against theoretical values of 842.4 ohms. The grounded inductor of Fig. 6 is simulated for bias current of I_{B1} = I_{B2} = I_{B3} = I_{B4} = 10µA and C_L = 135nF, the simulated inductance value is obtained as 12.85 H against theoretical value of 12.97 H as shown in Fig. 9.

The proposed comb filter is designed for n =4 stages to remove the undesired power line signal of frequency 60Hz and its harmonic (180Hz, 300Hz and 420Hz). To eliminate the signals of these frequencies, the circuit of Fig. 7 is simulated using C_{L1} = C_1 = 270.7nF, C_{L2} = C_2 = 90.24nF, C_{L3} = C_3 = 54.14nF, and C_{L4} = C_4 = 38.67nF. The bias current of I_{B1} =I_{B2} = I_{B3} = I_{B4} = 900µA is used for VDTA 1, VDTA2 and 10µA is used for VDTA3, VDTA4, VDTA5, VDTA6 respectively. The simulated magnitude response of comb filter is shown in Fig. 10, which shows that the signal is significantly attenuated at desired frequencies. The total power dissipation for the proposed circuit is 6.62mW. The proposed circuit is also tested for total harmonic distortion in its pass band. For an input signal of 100Hz, the % THD is within acceptable limit of 2.7% up to 2V p-p input as shown in Fig. 11.

The effect of noise on the proposed circuit has been analyzed through simulation. The noise of the circuit for an input signal of 100 KHz is obtained as 4 nV/√Hz at the input and 3.9 nV/√Hz at output. However, when it is tested with input signal of 60Hz, the input noise is obtained as 61.2 nV/√Hz and output noise of 13.1 nV/√Hz. This shows the significant attenuation in stop band.

V. CONCLUSION

In this paper active realization of comb filter using VDTA is presented. Floating resistance and grounded inductors in passive RLC comb filter are replaced by VDTA implemented floating resistance and grounded inductor to obtain active realization of comb filter. To verify the functionality of the proposed circuit of active comb filter, PSPICE simulation using 180nm TSMC CMOS technology parameter is carried out for power line frequency (60Hz) and its harmonic of frequencies of 180Hz, 300Hz and 420Hz. The simulated results agree well with the theory.

Table 1 Aspect ratio of used transistor in VDTA

Transistors	Aspect ratio, W(µm)/L(µm)
M_1, M_2, M_5, M_6	3.6/.36
M_3, M_4, M_7, M_8	16.64/.36

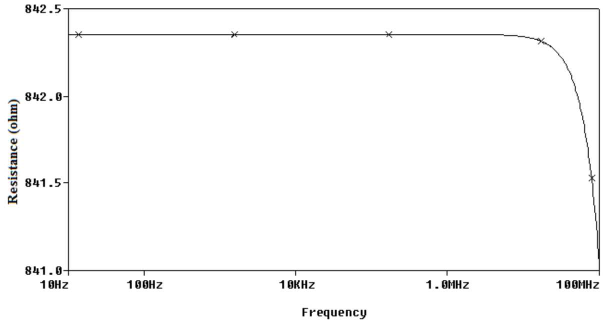

Fig. 8 Simulated response of floating resistor

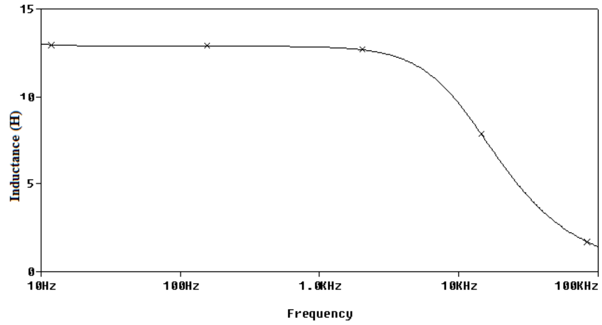

Fig. 9 Simulated response of grounded inductor

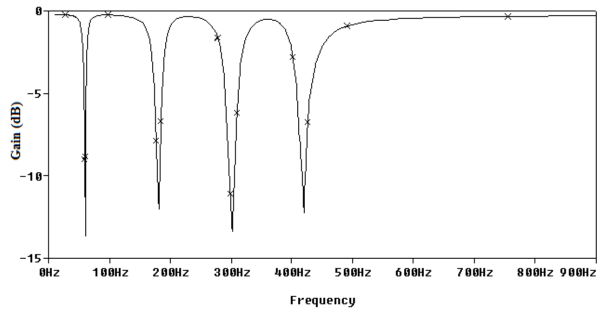

Fig. 10 Magnitude response of proposed active comb filter for n=4 stages

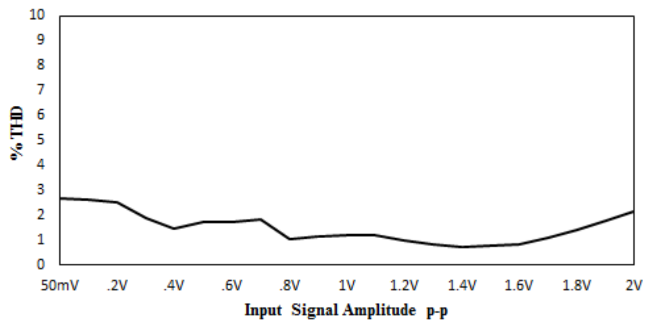

Fig. 11 % THD variation with input signal amplitude (p-p)

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