New CMOS VDTA Based Low power 8th Band-Pass LC Ladder Filter

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Abstract: In this paper, a new COMS Voltage Differencing Trans conductance Amplifier is presented. The proposed block has block has two voltage inputs and two kinds of current output, so it is functional for voltage- and transconductance-mode operation and by using VDTA the realization of a floating simulated inductance circuit has been presented. The realized floating inductance circuit uses single voltage differencing transconductance amplifier (VDTA) and only one grounded capacitor, results in simple and canonical structure as well as attractive for integration. The resulting equivalent A CMOS implementation of VDTA and a voltage-mode VDTA based filter are proposed and simulated. An application example of eight order elliptic band band-pass filter is given and the performance of the circuit is demonstrated by comparing the theory and simulation. PSPICE simulations of the proposed VDTA and its based band band-pass filter are given using 0.18µm CMOS technology from TMSC MOSIS and dual supply voltages ±0.6V.

Keywords: Voltage Differencing Transconductance Amplifier VDTA, Cauer band-pass ladder filter, CMOS integrated circuit, and PSPICE simulation.

1. Introduction:

Improved oil recovery processes broadly encompass all of the measures aimed towards increasing ultimate recovery from a petroleum reservoir. Most reservoirs are subjected to improved oil recovery (IOR) processes following primary recovery. Natural reservoir energies control the ultimate recovery of petroleum during primary production; such drive mechanisms include liquid and rock compressibility drive, solution gas drive, gas-cap drive, natural water influx, and combination drive processes[1]. Primary recovery from oil reservoirs is influenced by reservoir rock properties, fluid properties, and geologic Current-mode approach has received a considerable attention in the last few years for analog signal processing applications due to their low power consumption, large dynamic range, higher frequency ranges of operation, better accuracy, higher slew rate, and less complexity. As a result, 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 trans-conductance amplifier (CDTA), and voltage differencing transconductance amplifier (VDTA) are published. A literature review of such analog active block is presented in [1, 2].The VDTA is a recently proposed analog building block composed of two transconductance amplifiers and may be used to implement different analog processing application such as floating and grounded inductor simulation [3, 4], analog filter [5–7], and oscillators [8]. For the active simulation of higher-order LC ladder filter, mainly three methods exist, which are wave active method, topological simulation, and operational simulation.

In wave active approach, a wave equivalent is developed for inductor in series branch and then it is configured for other passive components by making suitable connection [9–11]. Large numbers of active blocks are used in this approach.

In the second method, topological simulation or element replacement method, the inductor of LC ladder structure is replaced by appropriate configured active elements.

The proposed operational simulation of LC ladder using VDTA has the following advantage over existing circuits:

(i) Lesser numbers of active blocks are used as compared to [12, 13].

(ii) There is no use of resistors in realization, while [13, 14] use both floating and grounded resistors and uses only grounded resistors.

(iii) Only grounded capacitors are used in proposed implementation, while [14- 16] use floating capacitors too.

As an example, an eight-order Cauer band-pass filter ladder filter is simulated by outlined approach and the workability of the filter is confirmed through PSPICE simulation using 0.18µm CMOS technology parameter.

2. CMOS Realization VDTA

The voltage differencing transconductance amplifier is consisting of two transconductance amplifiers [5]. Figure 1(a), (b) represent the symbolic representation and CMOS implementation of VDTA.

The port relationship of VDTA in matrix form is characterized by the following equation:

$$\begin{bmatrix} I_z \\ I_{x+} \\ I_{x-} \end{bmatrix} = \begin{bmatrix} g_{mz} & -g_{mz} & 0 \\ 0 & 0 & g_{mx} \\ 0 & 0 & -g_{mx} \end{bmatrix} \begin{bmatrix} V_p \\ V_n \\ V_z \end{bmatrix} \qquad (1)$$

where g_{mx} and g_{mz} are the input and output transconductance gain of VDTA. The input transconductance amplifier converts the input voltage difference ($V_p - V_n$) into current at z terminal and the voltage developed at z terminal is converted into current at I_{x+} and I_{x-} terminal by output transconductance amplifier.

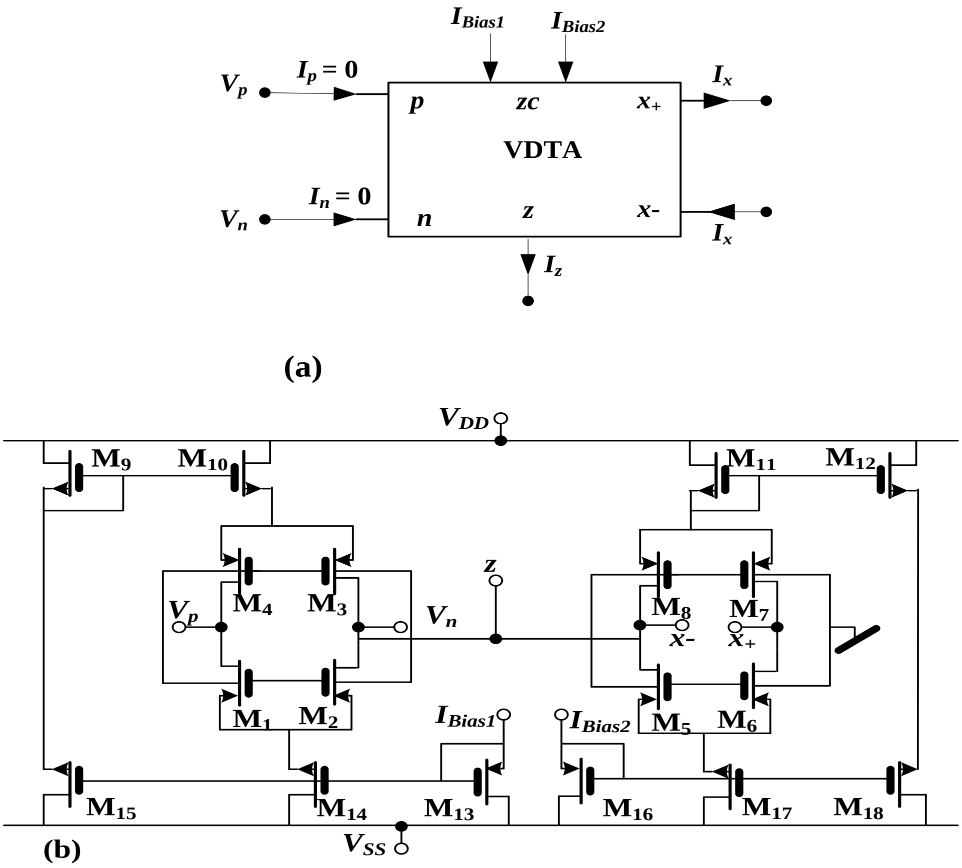

Fig. 1: (a) Symbol of the VDTA, (b) CMOS Implementation of VDTA

3. Floating and Grounded Inductor Based on VDTA

A floating and grounded inductor which employ one of voltage differencing transconductance amplifier (VDTA) in figure 2 which contains Differential Input Single Output OTA (DISO) and Single Input Differential Output OTA (SIDO), and one grounded capacitor C_L.

The process of transforming voltage difference ($V_P - V_n$) into current I_z of DISO OTA is described by the equation:

$$I_Z = g_{mz}(V_p - V_n) \qquad (2)$$

Current I_z causes voltage across the capacitor, and this voltage is transformed into current I_x.

$$V_C = \frac{I_Z}{sC_L} = \frac{g_{mz}(V_p - V_n)}{sC_L} \qquad (3)$$

$$I_x = g_{mx} V_C \qquad (4)$$

$$I_x = g_{mx} g_{mz} \frac{(V_p - V_n)}{sC_L} \qquad (5)$$

$$Z_{in} = \frac{I_X}{(V_p - V_n)} = \frac{g_{mx} g_{mz}}{sC_L} \qquad (6)$$

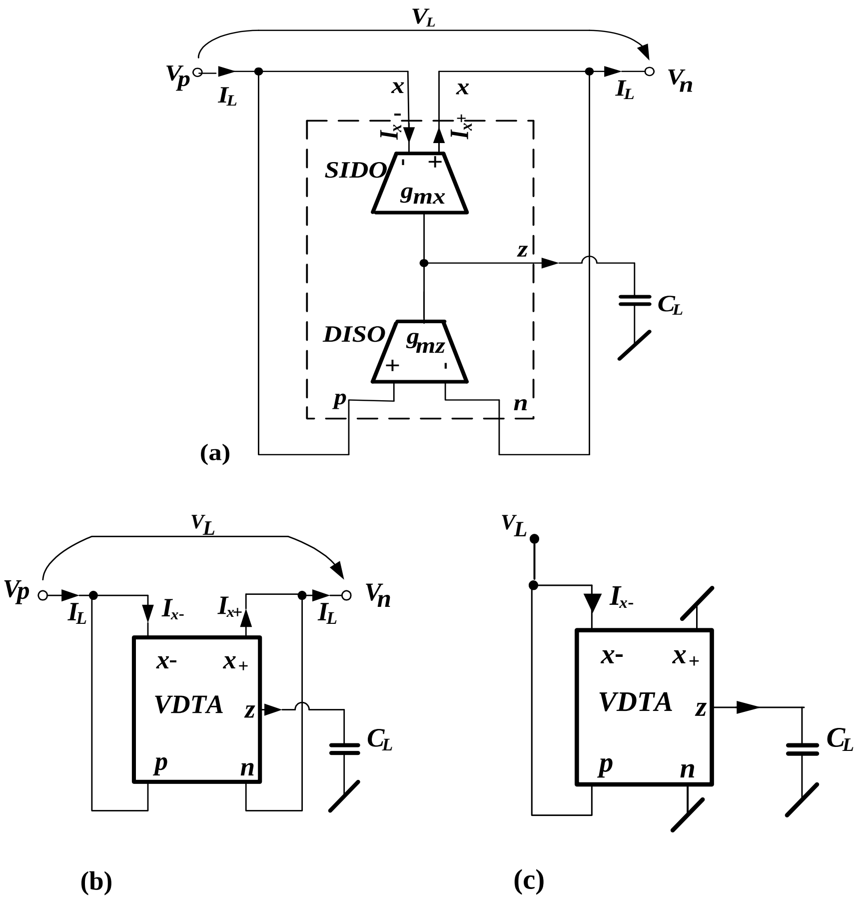

Fig. 2: (a) Synthetic inductor circuit employing DISO OTA and SIDO OTA, (b) simplified representation of the synthetic floating inductor by VDTA, (c) simplified representation of the synthetic grounded inductor by VDTA

The circuit, thus, simulates a floating inductor with the resulting inductance given by

$$L = \frac{g_{mx} g_{mz}}{C_L} \quad (7)$$

Figure 3 shows that the magnitudes of the impedances of an ideal inductor with value equal to 47.1mH which we used in LC ladder filter in our filter, and its simulator circuit by Voltage Differencing Transconductance Amplifier (VDTA) as shown in figure 2 with C_L equal to 441pF can be made very close for a set of selected values over many decades.

1. Band-Pass 8th Order Cauer LC Ladder Using VDTA

The VDTA is very flexible in different mode filter realizations. The advantages obtained are that the values of transconductance are adjusted by bias currents to realize these circuits without any requirement of external resistors .

Figure 4 shows the schematic of 8th order a band-pass LC ladder filter which has been designed according to Cauer approximation on the basis of the following specifications: 8th order, central frequency = 10 kHz, ripple 1 dB, 60 dB attenuation, B_1 = 5 KHz, B_2 = 20 KHz. The floating and grounded inductor circuit in figure 2 with R_{adj} equal to 10 kΩ and the ladder filter component values are given in Table1.

Table 1: Ladder filter component values

Component	Value Cauer filter	Component	Value Cauer filter
R_1, R_2	100KΩ	C_1	616pF
L_1	41H	C_2	5.88nF
L_2	43mH	C_3	372pF
L_3	177mH	C_4	1.43nF
L_4	679mH	C_5	3.07nF
L_5	82.4mH		

The active simulation of the passive LC ladder filter from figure 4 by means of Voltage Differencing Transconductance Amplifier (VDTA) is given in figure 5.

The proposed floating inductor circuit in figure 4 is realized with the following values: $g_{mx} = g_{mz}$ = 96.8 µS with R_{adj} equal to 10kΩ according to Table 2.

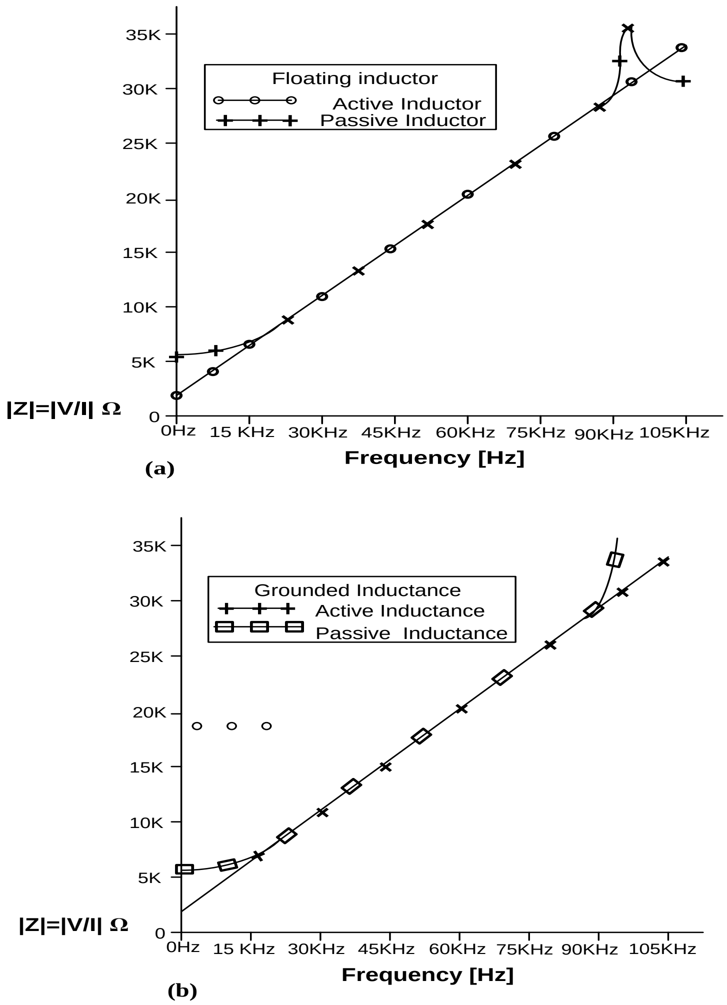

Fig. 3: (a) The impedance values relative to frequency of the ideal and simulated floating inductors, (b) impedance values relative to frequency of the ideal and simulated grounded inductors

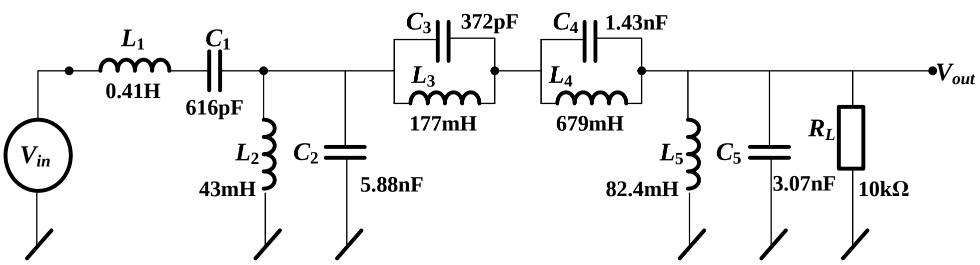

Fig. 4: Band-pass 8th order LC ladder filter

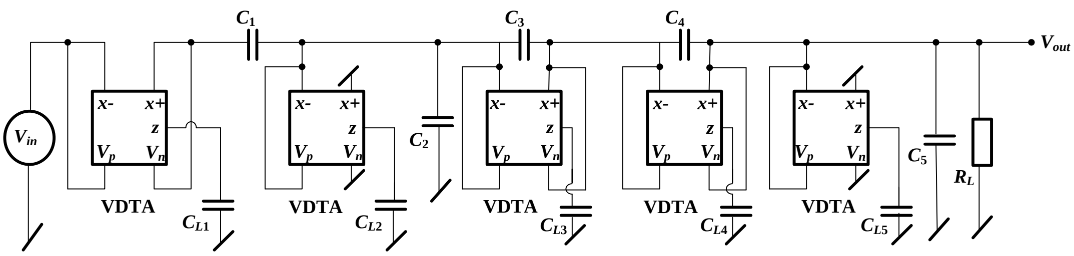

Fig. 5: Active imlementation of the filter from Fig. 4

It follows from equation (7) that

$$C_{L1} = L_1 g_{mz} g_{mx} = 3.85nF,$$
$$C_{L2} = L_2 g_{mz} g_{mx} = 403.7pF,$$
$$C_{L3} = L_3 g_{mz} g_{mx} = 1.662nF,$$
$$C_{L4} = L_4 g_{mz} g_{mx} = 6.375nF$$
$$C_{L5} = L_5 g_{mz} g_{mx} = 773.7pF$$

The active implementation of the filter component values and performance parameters are given in Table 2.

Table 2: VDTA filter component values and performance parameters

Component	Value Cauer filter
C_{L1}	3.85nF
C_{L2}	403.7pF
C_{L3}	1.662nF
C_{L4}	6.375nF
C_{L5}	773.7pF

2. Simulation Results

The simulations were performed by using PSPICE program with TSMC CMOS 0.18 µm process parameters. The aspect ratios of the transistors are given in Table 3. Supply voltages are taken as $V_{DD} = -V_{SS} = 0.6$ V and $I_{B1} = I_{B2} = 15$ µA biasing currents are used. Simulation results show that this choice yields transconductance values of VDTA as $g_{mx} = g_{mz} = 96.8$ µA/V. The DC transfer characteristic of I_{x+} and I_{x-} against V_z for output stage of proposed VDTA is shown in figure 6.

Table3: Transistors aspect ratios for the VDTA of Fig.2

Transistor	Length (µm)	Width (µm)
M_1,M_2,M_5,M_6	2	30
M_3,M_4,M_7,M_8	2	4
M_9,M_{10},M_{11},M_{12}	3	20
$M_{13},M_{14},M_{16},M_{17}$	2	16
M_{15},M_{18}	3	40

The frequency responses of the filter are shown in Figure 7. It can be seen that the simulation using the true inductor and its VDTA simulators are in good agreement

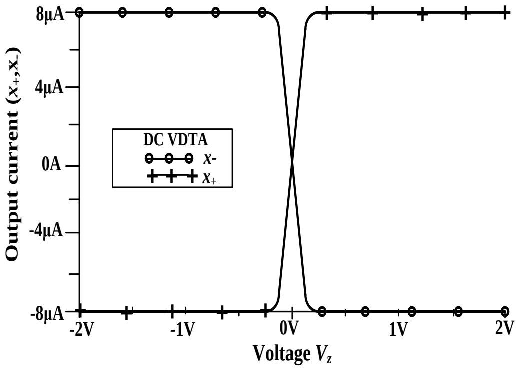

Fig. 6: The DC transfer characteristic of the VDTA

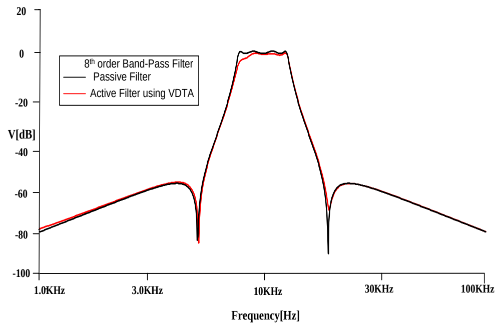

Fig. 7: The frequency responses of ideal LC ladder and VDTA-based active filter

3. Conclusion

New CMOS voltage differencing transconductance amplifier, VDTA is presented and implemented 8th order band-pass filter.

A new and simple CMOS realization of this element is given frequency response of this filter for the VDTA is suitable for high frequency applications. Besides, since supply voltages are ±0.6V, the circuit is suitable for low voltage applications. An application example of a voltage-mode filter employing the proposed CMOS VDTA realization has been presented, since the proposed filter is constructed employing only a single active element, VDTA, where the value of transconductances can be adjusted by biasing currents. Simulation results that are simulated using PSPICE confirm the theoretical results.

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