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A Review of Analytical Modeling and Designing of High Speed VDTA-Based Mimo Filter

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Abstract: *This paper presents the design of a universal active Multiple Input Multiple Output (MIMO) filter with the help of an active component known as Voltage Differencing Transconductance Amplifier (VDTA). Our research elaborates VDTA in detail and its various aspects, such as its concept, construction, parameters, advantages, application etc. The VDTA active block shall be utilized in the design of an active filter. The filter shall be designed in order to perform multiple filtering operations, such as low pass, high pass and bandpass without changing the circuit configuration and without need of an external passive resistor.*
Keywords: *Continuous time active filters, current controlled current conveyor, current controlled transconductance amplifier, current differencing transconductance amplifier, current follower transconductance amplifier, multiple input multiple output, voltage-differencing transconductance amplifier.*

I. Introduction

The applications, advantages and realizations of high performance continuous time (CT) active filters have been receiving considerable attention over the last few decades. Many attempts have been made to design a high speed transceiver circuit which would be able to perform multiple filtering functions without compromising the main circuit configuration. This lead to the advent of the MIMO concept and thus the term, Universal Filter comes into existence [1-3]. After the successful design of MIMO filters, two basic issues arose which needed to be tackled in order to achieve the ideal universal filter design. These issues are:-

- Power
- Complexity

The universal filter requires utilizing less area and hence, reduced complexity. Reduced complexity refers to the reduced requirement of components and thus makes the design simple and consumes less area thereby increasing its portability. The design issue of power actually consists of two issues:-

- Power efficiency
- Power dissipation

Power efficiency, as we all know, is the percentage of ratio of output power by input power. Thus, it depicts the performance reliability of the device. The efficiency is increased by either the decrease in input power, or the increase in output power. That is why, attempts are being continuously made to design a filter circuit which could produce maximum power output by taking minimum input power, thereby successfully increasing efficiency.

Power dissipation is the conversion of electric power of the components of the circuit to thermal power. This, though a natural phenomenon, is a form of loss which serves as one of the main reasons of improper performance of any device and thus efficiency is reduced. Though power dissipation cannot be completely removed from any circuit, it can be reduced by either the use of components with high thermal resistance or by utilizing components or designs specialized for reducing power dissipation.

Another critical issue with CT filter approach typically is the RC time constant variation problem where the RC time constant of the circuit varies due to process tolerance, environmental effects of temperature drift, humidity and aging of components.

This defect can be compensated by the use of tunable filters which electronically vary the time constant. Thus, there is a constant growing interest in designing of tunable electronic filters which can compensate for the RC time constant shifting problem [4-5].

During the last one decade and recent past, several electronically tunable MIMO type active filters have been proposed in the literature, using different active elements such as second generation current controlled current conveyor (CCCII), current differencing transconductance amplifier (CDTA), current follower transconductance amplifier (CFTA), voltage differencing transconductance amplifier(VDTA), current controlled transconductance amplifier (CCTA) and current controlled current conveyor transconductance amplifier (CCCCTA) etc.

In some new active building blocks providing the potentiality in analog circuit design are being introduced. Among these, the voltage differencing transconductance amplifier (VDTA) is a recently introduced active element. VDTA mainly comprises of a current source controlled by the difference of two input voltages and a transconductance amplifier, providing electronically tunable active circuit. Another advantageous feature of the use of VDTA as an active element is that in some applications, compact structures can be achieved easily.

In this paper, an electronically tunable universal MIMO filter is proposed. This filter will be designed using VDTA as active element. Our topic will mainly focus on VDTA and its various aspects, concept, design, working principle and how VDTA can be used to design a universal filter. The filter circuit proposed shall be able to realize all the standard filtering functions, namely lowpass (LP), highpass (HP) and bandpass (BP) from the same circuit configuration.

II. MIMO Filters

Due to the urgent need of design of devices which would not only perform multiple functions at once, but also has reduced complexity in terms of no. of components, area occupied by the device or circuit, device portability etc. MIMO filters and other devices are created.

MIMO filters are mainly realized in one of the two forms:-

• Multiple Input Single Output Filter, (MISO) or
• Single Input Multiple Output Filter (SIMO)

SIMO filters simultaneously realize different filtering functions at different outputs without changing the connection of the input signal. On the other hand, MISO filters can realize multifunction filter responses at single output terminal by altering the way in which multi-input signals are connected. The MISO configuration in comparison with SIMO configuration may lead to reduction in the number of active elements for circuit realization.

Hence, we can safely assume that realization of MISO filters seem more suitable than the realization of SIMO to realize all the standard filtering functions.

III. Literature Review

1. **Dinesh Prasad, Data Ram Bhaskar and Mayank Shrivastava** in their research proposed a voltage mode MISO biquad filter. Their filter employed one VDTA as the active element, two capacitors and a resistor. Their configuration realized all five filter operations without any matching condition. Their natural frequency (ω_0) and bandwidth were tunable.

2**. Jetsdaporn Satansup, Tattaya Pukkalanun and Worapong Tangsrirat** proposed an electronically tunable current mode universal filter with three inputs and one output employing two voltage differentiating transconductance amplifier with two grounded capacitors. The presented circuit can configure to realize all the five standard biquadratic filter functions; lowpass, bandpass, highpass and bandstop without changing the circuit configuration and needing an external passive resistor. The proposed filter is capable of providing an independent current-control of the natural angular frequency (ωo) and quality factor (Q) through the VDTA's transconductance and low incremental active and passive sensitivities.

3. **Witthaya Mekhum and Winai Jaikla** presents a voltage-mode bi-quadratic fillter performing completely standard functions: low-pass, high-pass, band-pass, band-reject and all-pass functions, based on single voltage differencing transconductance amplifer (VDTA). The proposed filter has three input voltage and a single output voltage. The features of the circuit are that; the quality factor and natural frequency can be tuned independently; the circuit description is very simple, consisting of merely one VDTA, one resistor and two capacitors; the pole frequency can be electronically adjusted. Additionally, each function response can be selected by suitably selecting input signals with digital method; the double input voltage is not required. Using only single active element, the proposed circuit is very suitable to further develop into an integrated circuit.

IV. Basic Concept Of VDTA

VDTA stands for Voltage Differencing Transconductance Amplifier. VDTA is a combination of Voltage Difference circuit and an Operational Transconductance Amplifier (OTA). The basic working principle of VDTA revolves around the transconductance characteristics of an amplifier. We know that transconductance of an amplifier is given by:-

$$g_m = i_{out} / V_{in} \quad (1)$$

i.e. the transconductance of a device is the ratio between its output current and input voltage. Now, in order to increase the transconductance, one can either increase the output current or decrease the input voltage. In the construction of VDTA, the main emphasis is given on obtaining the maximum output current using minimum input voltage. In VDTA, this is achieved by constructing the active element with two terminals. The input of the active element is the difference between the voltages of the two input terminals thus leading to a low voltage input. This low voltage is used to produce high output current at the output terminals.

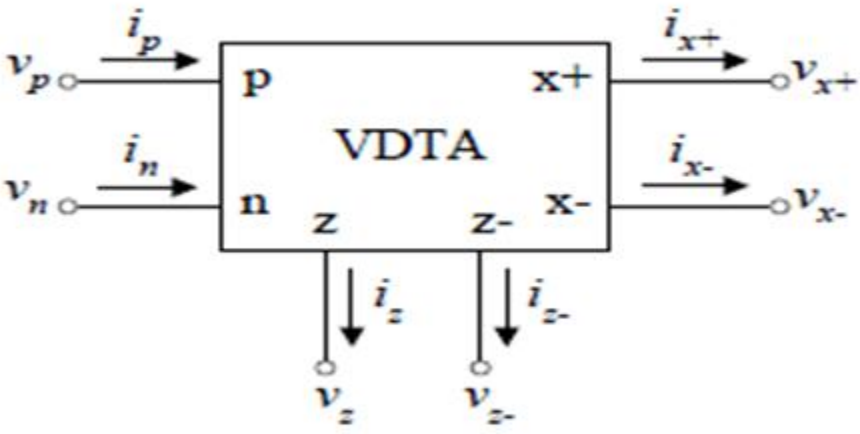

Fig. 1: Electrical symbol of the VDTA.

The above figure shows the simple block diagram of VDTA active element.
The characteristic equation for this block is given as:-

$$\begin{bmatrix} i_z \\ i_{z-} \\ i_{x+} \\ i_{x-} \end{bmatrix} = \begin{bmatrix} +g_{mF} & -g_{mF} & 0 & 0 \\ -g_{mF} & +g_{mF} & 0 & 0 \\ 0 & 0 & +g_{mS} & 0 \\ 0 & 0 & -g_{mS} & 0 \end{bmatrix} \begin{bmatrix} v_p \\ v_n \\ v_z \\ v_{z-} \end{bmatrix} \quad (2)$$

As we can see, there are two inputs vp and vn the input of the device is taken to be the difference between vp and vn, i.e. (vp-vn). This difference lead to the voltage in the output ports z- and z with by transconductance gmF. Then, with the help of transconductance gmS, the amplified output of the signal is obtained.

The relation between the output currents i_x- and i_{x+} can be obtained by solving matrix (2)

$$\begin{bmatrix} v_p g_{mF} + v_n(-g_{mF}) + 0 + 0 \\ -v_p g_{mF} + v_n g_{mF} + 0 + 0 \\ 0 + 0 - v_z g_{mS} + 0 \\ 0 + 0 - v_z g_{ms} + 0 \end{bmatrix} = \begin{bmatrix} i_z \\ i_{z-} \\ i_{x+} \\ i_{x-} \end{bmatrix}$$

$I_{z+} = v_p g_{mF} - v_n g_{mF} = g_{mF}(v_p - v_n)$ (3)

$I_z- = v_n g_{mF} - v_p g_{mF} = g_{mF}(v_n - v_p)$ (4)

$i_{x+} = v_z g_{mS}$ (5)

$i_{x-} = -v_z g_{mS}$ (6)

the voltage v_z occurs due to the offset due to the difference in v_p and v_n
thus, we can assume that,

$v_p - v_n = v_z$ (7)

so, (3) and (4) can be written as: -

$I_{z+} = v_z g_{mf}$ (8)

$i_z- = -v_z g_{mF}$ (9)

and $v_z = i_z/g_{mF}$ (10)

$-v_z = i_z-/g_{mF}$ (11)

Substitute (10) and (11) in (5) and (6), we get,

$I_{x+} = i_z g_{mS}/g_{mF}$ (12)

$i_{x-} = i_z-.g_{mS}/g_{mF}$ (13)

i_z and i_{z-} again are currents produced at ports z and z- due to the voltage produced by $(v_p - v_n)$ in ports pand n.
Thus, we can conclude that the output of VDTA is obtained with the help of differences in the input voltages and the transconductances produced during the operation.

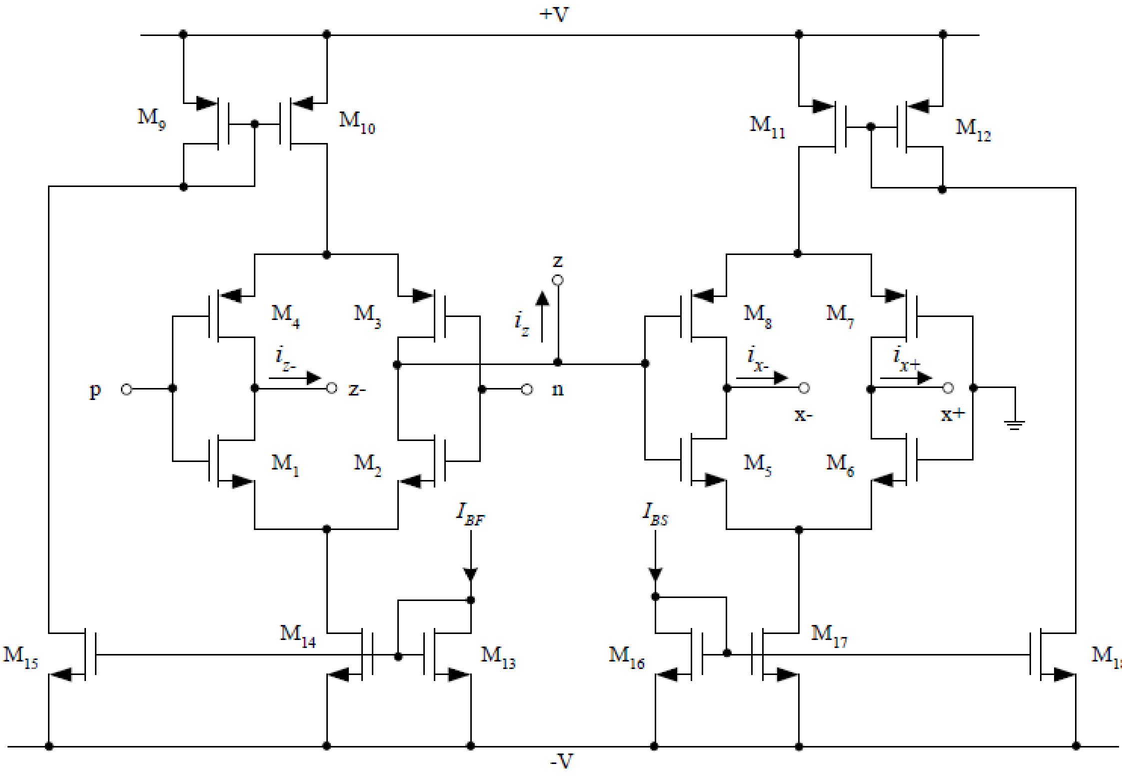

Fig.2: CMOS implementation of the VDTA.

The above figure shows the CMOS implementation of the VDTA block. nMOS M1and M2 and pMOS M3 and M4 form the first main active part of VDTA. M1, M4, and M3, M2 combine to form the primary CMOS differential amplifier. A similar differential amplifier is realized by using nMOS M5 and M6 and pMOS M7 and M8. pMOS M9, M10, M11 and M12 and nMOS M13, M14, M15, M16 ,M17, M18 all together form the transconductance amplifier. The circuit operation takes place as follows:

Due to the CMOS differential amplifier, the output obtained at port z is due to the difference between the input signals at port p and port n. the current is amplified in the first amplifier. The output V obtained at port z is fed into the secondary amplifier where one terminal is grounded, ensuring that no loss in signal occurs. Finally, the amplified output is obtained at port x+ and x-. With the help of differential input voltage, there is increase in the transconductance gain in the primary block i.e., g_{mF} is increased. The feeding of the increased output to the secondary block, due to the secondary transconductance g_{mS}, there is again increase in output current. Thereby, giving an overall gain and signal amplification. This low input amplification property of VDTA has been utilized in many applications. The most popular of them being their application in filters.

V. Conclusion

MIMO filter is descibed and analyzed here successfully. Our paper leads to the conclusion that VDTA is an active element of low power filter designing. The transconductance property ofdevices to perform power efficient signal amplification. VDTA offers better tunability than most of its contemporaries as its frequency and time constant errors can be easily removed by a minor change in the design parameter without having to design or add an additional matching component.

References

[1]. Biolek D, Senani R, Biolkova V, Kolka Z. Active elements for analog signal processing: classification, review, and new proposals. Radioengineering 2008;17:15–32.
[2]. Biolek D. CDTA-building block for current-mode analog signal processing. In: Proceeding of the ECCTD'03, Krakow, Poland, 2003;III: p. 397–400.
[3]. Prokop R, Musil V. New modern circuit block CCTA and some its applications. In: Proceedings of the 14th Int. Scientific andApplied Science Conf. Electronics (ET'2005), Sozopol, Bulgaria, 2005; p. 93–98.
[4]. Pandey N, Paul SK, Differential difference current conveyor transconductance amplifier: a new analog building block for signal processing, J. Electr.Comput. Eng. 2011 (2011) 10. Article ID 361384.
[5]. Yesil A, Kacar F, Kuntman H. New simple CMOS realization of voltage differencing transconductance amplifier and its RF filter application. Radioengineering 2011;632–7.