

# CMOS Implementation Of VDBA To Design Symmetric Filters

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**Abstract**—This research paper presents the design of a new kind of biquad filter using an exceptional active element, Known as Voltage Differencing Buffered Amplifier (VDBA). The suggested block holds high and low input impedances which provides a unique advantages at voltage mode circuit. Furthermore, VDBA's Transconductance gain enforced the circuit to ignore the external resistance. The paper states and emphasizes that, the most suitable way to devise such an energetic VDBA filter is fulfilled using both active and passive elements. The main idea of this paper is designing a filter application based on Multi Inputs Single Output (MISO) connection principle. The devised biquad filter employs two active elements represented by (VDBA) and two passive elements represented by two (capacitors). The proposed filter realize voltage mode (LP, BP, HP, BS, AP) filter functions. The low output impedance of the proposed filter, increases the Cascabilities of voltage mode circuit, and neglects the matching conditions of the decisive elements. Finally, the results are presented to obey the theoretical analysis and simulated using LTSPICE simulator.

**Keywords**—Voltage Differencing Buffered Amplifier; CMOS Circuits, voltage mode filter; biquad filters; Multi Inputs Single Output blocks

## I. INTRODUCTION

The active elements provide grate properties lead to design filters realize most of typical filter functions. The element named voltage differencing buffered amplifier denoted as VDBA plays an ultimate role specially if designed based on the specifying the number of inputs and outputs that most filters allow in the field of this work. Identifying the number of inputs and outputs means that whether the filter is SIMO (Single Input Multi Outputs) or MISO (Multi Inputs Single Output) biquad filter. In this research paper, the proposed filter based on MISO which realizes all filter functions. The proposed filter employs both active and passive elements such as two VDBAs and Two capacitors respectively. Furthermore, Analog signal processing circuits are also created using such elements. These elements demonstrate large compatibilities specially, if employed as Operational Transconductance Amplifier (OTA) [1]. In addition, a great role is performed by Current Differencing

Transconductance Amplifier (CDTA) [2] particularly the Operational Transresistance Amplifier (OTRA) [3] also the Current Differencing Buffered Amplifier (CDBA) [4] and the first generation of Current Conveyor (CCI) [5], as a final point, the Fully Balanced Voltage Differencing Buffered Amplifier (FB-VDBA) [6]. The circuit principle is named (Voltage Differencing Buffered Amplifier) VDBA and (Current Differencing Buffered Amplifier) as presented in [7]. The inputs of VDBA are voltage whereas the inputs of CDBA are current. Hence, VDBA and CDBA have difference points according to their structures.

Voltage Differencing Buffered Amplifier (VDBA) and (OPAMP) give considerable similar features such as high input and low output impedances. The input voltage of the circuit is switched to current at side (z), that will be mirrored to different impedance zone identified as side (w) by using Transconductance gain and voltage drop. Moreover, Voltage Differencing Buffered Amplifier (VDBA) presents excellent behaviors in current mode circuits comparing to (OPAMP) such as wide linearity, power consumption, high slew rate and greater bandwidth [8,9]. VDBA element make use of the Transconductance properties such as Transconductance rate that can be altered electronically. In addition of the difference between VDBA and OTA that presented recently, the lower output impedance makes VDBA adaptable more than voltage mode circuit due to the effect of the loading that is entirely eradicated. The main topic of this paper is highly dependent on the work presented in [10], but the main difference is that the entire filter functions are realized using unique and exceptional application circuit. Voltage mode Transconductance based on MISO filter application demonstrated by this research paper, does not concentrate on adjusting the natural frequency and the quality factor as [11,12] depending on the voltage and current. The most important challenge in the paper is realizing whole filter functions with an excellent superiority without using external resistors. On the other hand, the proposed filter exhibits the following disadvantages:-

- 1) Larger number of active elements are required.
- 2) Two types of active elements are employed.
- 3) The filters need the matching condition in some cases.

- 4) Not good for voltage mode filter due to the high output impedances.
- 5) The quality factor is not adjusted as the natural frequency.

An exceptional CMOS satisfaction of VDBA is applied in this paper. The application circuit is connected based on MISO filter scheme (allow three inputs and single output). Moreover, the application circuit holds two VDBAs and two passive elements identified as two capacitors to produce all filter functions (High Pass (HP), Low Pass (LP), All Pass (AP), Band Pass (BP), Band Stop (BS)). Besides, the input signal in all pass (AP) of the proposed biquad filter should be inverted type.

As a result, the proper way to design a filter is fulfilled by adding a few numbers of active and passive elements to the proposed application. Hereby, the selection of element conditions to identify filter performance is not required, then the sensitivity is reduced accordingly. Last but not least, the Transconductance gain of VDBA played a big role to realize the pure frequency and the quality factor.

## II. CMOS REALIZATION OF VDBA

The symbol of the circuit that recently demonstrated active element (VDBA) is shown in Fig.1, where P and N are input terminals, Z and W are output terminals.

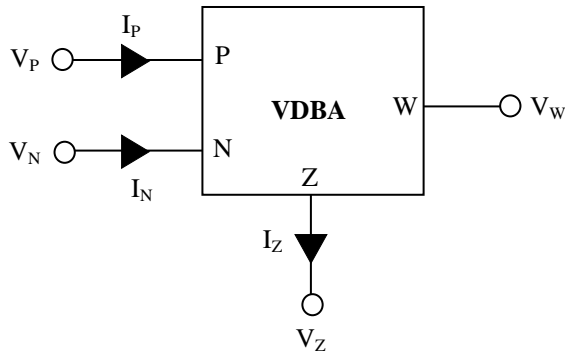


Fig. 1. The circuit symbol of VDBA

The model of the circuit is expressed as shown in the following equations:

$$\begin{bmatrix} I_P \\ I_N \\ I_Z \\ V_W \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ g_m & -g_m & 0 \\ 0 & 0 & \alpha \end{bmatrix} \begin{bmatrix} V_P \\ V_N \\ V_Z \end{bmatrix} \quad (1)$$

\$\alpha\$ is the voltage ratio of VDBA where, \$\alpha = 1 - \epsilon\_v\$. Furthermore, \$\epsilon\_v\$ represents voltage tracking error of VDBA. The value of voltage tracking error does not exceed a unity.

As illustrated above, it is obvious that Voltage Differencing Buffered Amplifier consists of two high impedance voltage inputs denoted as \$V\_P\$ and \$V\_N\$, high

impedance current outputs \$I\_Z\$ and low impedance voltage outputs \$V\_W\$.

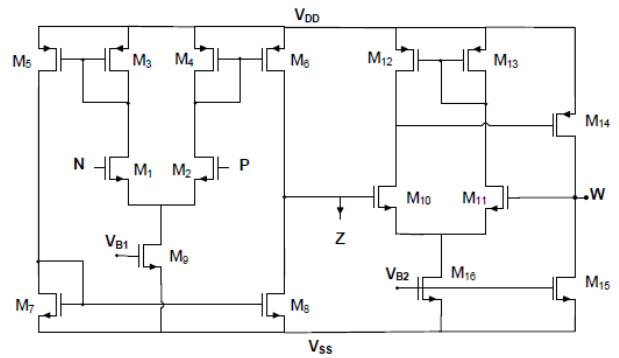


Fig. 2. CMOS Implementation of VDBA

The circuit diagram in Fig.2. demonstrates VDBA circuit structure. The voltage buffer is employed by \$M\_{10} - M\_{16}\$ as [13], and OTA circuit by \$M\_1 - M\_9\$ as [14]. OTA is put in charge to work as the input of VDBA. The voltage buffer is linked to the current output of OTA. Furthermore, OTA is an amplifier whose differential voltage generates an output current identified as Voltage Controlled Current Source (VCCS). Usually, there is an extra current input used to organize the amplifier of Transconductance. The key of similarity that makes OTA considerably similar to the ordinary operational amplifier is that both have high impedance input and appropriate for negative feedback. The amplifier that allows electrical impedance to be switched over between two circuits is known as Buffer Amplifier.

## III. PROPOSED VDBA APPLICATION EXAMPLE

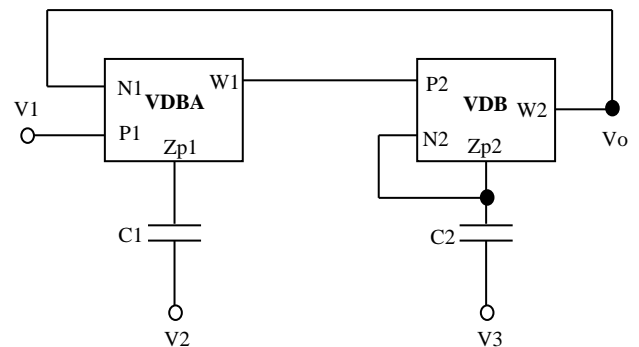


Fig. 3. The proposed Biquad Filter

The proposed filter in Fig.3. shows Multi inputs single output voltage mode circuit. The transfer function of the proposed biquad filter is given as follows:

$$V_o = \frac{V_1 g_{m1} g_{m2} + V_2 g_{m2} s C_1 + V_3 s^2 C_1 C_2}{g_{m1} g_{m2} + g_{m2} s C_1 + s^2 C_1 C_2} \quad (2)$$

The condition of the numerator coefficients \$V\_1\$, \$V\_2\$ and \$V\_3\$ shown in equation (2) are considered the most valuable parts that realize the following five filter functions presented in Table (1):

TABLE I. THE REALIZED FILTER FUNCTIONS

Filter Type	V1	V2	V3
Low Pass Filter	$V_{IN}$	0	0
Band Pass Filter	0	$V_{IN}$	0
High Pass Filter	0	0	$V_{IN}$
Band Stop Filter	$V_{IN}$	0	$V_{IN}$
All Pass Filter	$V_{IN}$	$-V_{IN}$	$V_{IN}$

The quality factor ( $Q$ ) and the pole frequency ( $\omega_0$ ) of the proposed biquad filter are given by using a specific passive elements as follows:

$$Q = \sqrt{\frac{g_{m1}C_2}{g_{m2}C_1}} \quad (3)$$

$$\omega_0 = \sqrt{\frac{g_{m1}g_{m2}}{C_1C_2}} \quad (4)$$

The sensitivity examination with respect to both passive and active elements are given as follows:

$$S_{g_{m1}}^{\omega_0} = S_{g_{m2}}^{\omega_0} = -S_{C_1}^{\omega_0} = -S_{C_2}^{\omega_0} = \frac{1}{2} \quad (5)$$

$$S_{g_{m1}}^Q = -S_{g_{m2}}^Q = -S_{C_1}^Q = S_{C_2}^Q = \frac{1}{2} \quad (6)$$

For more clarity, it is obvious from sensitivity equations (5), (6) that the active and passive elements values of the pole frequency and the quality factor are chosen in the range of 0.5 (almost do not exceed a unity).

#### IV. SIMULATIONS AND RESULTS

The theoretical expectations of the proposed biquad MISO filter is proved in collaboration with CMOS realization of VDBA element in Fig.2. The results and simulations are achieved by using LTSPICE program with TSMC CMOS 0.3  $\mu\text{m}$  technology and (Golden Software Grapher V8.4.696). The parameters of the proposed filter are chosen as follows:

- Passive elements values  $C_1 = C_2 = 0.1\text{nF}$ .
- VDBA supply voltage  $V_{DD} = 1.5$  and  $V_{SS} = -1.5$ .
- The power consumption of the VDBA = 0.97mW.
- The biasing current  $I_B = 10\mu\text{A}$  and  $I_{SS} = 100\mu\text{A}$ .
- The Transconductance value of  $g_m = 730.7\mu\text{A/V}$ .
- The value of the pole frequency  $\omega_0 = 1.16\text{MHz}$ .
- Finally, the value of the quality factor  $Q = 1$ .

The simulation results of the paper are almost similar to the work presented in [10]. However in this paper, the application based on the biquad filter in

Fig.3. is considered unique and exclusive. The parameters based on the transistors employed in VDBA realization circuit are chosen as shown in Table(2).

TABLE II. TRANSISTORS ASPECT RATIOS FOR THE VDBA

Transistors	W( $\mu\text{m}$ )	L( $\mu\text{m}$ )
M1-M4-M10-M11-M15-M16	7	0.35
M5-M6	21	0.7
M7-M8	7	0.7
M9	3.5	0.7
M12-M14	14	0.35

The application filter realizes (LP, BP, HP, BS, AP) filter functions as shown in Fig.4. and Fig.5. by applying the parameters presented above in simulations and results section.

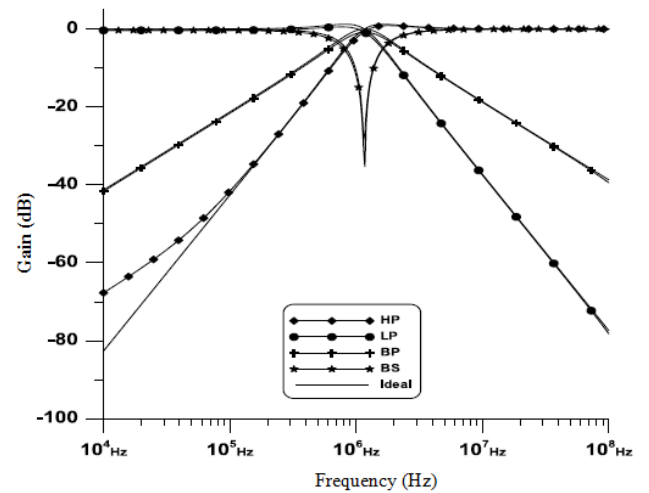


Fig. 4. The gain-frequency response simulation results

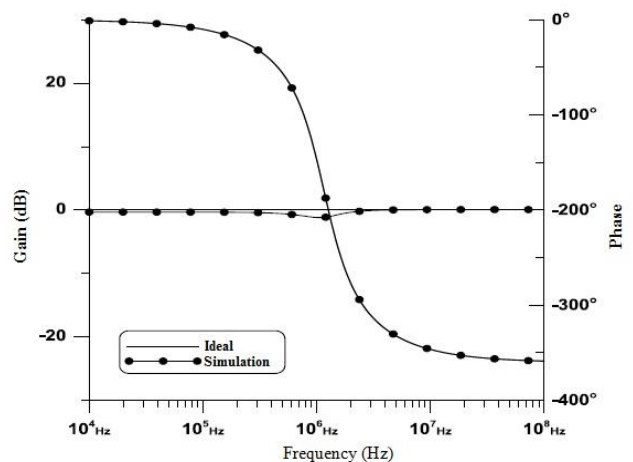


Fig. 5. The gain-phase frequency response of all pass filter

The curve in Fig.6. shows the distortion performance of the proposed band pass filter such that for input less than 1.2 Vp-p, the harmonic distortion increases slowly based on input voltage. It is clear that total harmonic distortion THD stay in the range of (1%). Hence, verifying the practical utility of the second circuit exposed in following THD curve.

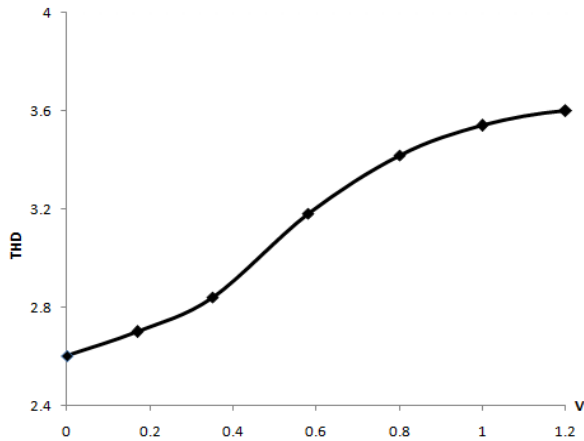


Fig. 6. The Total Harmonic Distortion

#### V. CONCLUSION

The paper demonstrates a new generation of CMOS implementation based VDBA element by using voltage mode Multi Input Single Output (MISO) biquad filter application that possesses two active (VDBA) elements and two capacitors. The proposed filter realizes the entire filter functions (LP, BP, HP, BS, AP). Moreover, the proposed filter can electronically control the natural frequency. The application provides output voltage signal with low impedance. Finally, the proposed biquad filter uses a few number of active elements, tolerable THD and low sensitivity.

#### REFERENCES

[1] R. L. GEIGER, E. S. SINENCIO, "Active Filter Design Using Operational Transconductance Amplifiers": A Tutorial, IEEE Circuits and Devices Magazine, 1985, vol. 1, p.20-32.

[2] D. BIOLEK, "CDTA–Building Block for Current-Mode Analog Signal Processing", In Proceedings of the ECCTD03. Krakow (Poland), 2003, vol. III, p. 397-400.

[3] S. KILINÇ, U. CAM, "Operational Transresistance Amplifier Based First-Order Allpass Filter with an Application Example", Circuits and Systems, 2004. MWSCAS '04. The 2004 47th Midwest Symposium on, 2004, vol.1 p.165-168.

[4] C. ACAR, S. OZOGUZ, "A new versatile building block: current differencing buffered amplifier", Microelectronics Journal, 1999, vol. 30, p. 157-160.

[5] F. KACAR, "New Voltage Mode Biquad Filters Employing Single Current Conveyor (CCI)". Frez Journal of Telecommunication, 2010, vol.64, no.1-2, p.26-29.

[6] V. BIOLKOVÁ, Z. KOLKA, D. BIOLEK, "Fully Balanced Voltage Differencing Buffered Amplifier and its Applications". In Midwest Symposium on Circuits and Systems Conference Proceedings. Cancún, Mexico: IEEE, 2009. p. 45-48. ISBN: 978-1-4244-4479-3.

[7] D. BIOLEK, R. SENANI, V. BIOLKOVÁ, KOLKA Z., "Active Elements for Analog Signal Processing": Classification, Review, and New Proposals, Radioengineering, 2008, vol. 17, no. 4, p.15-32.

[8] G. FERRI, N. C. GUERRINI, "Low-voltage low-power CMOS current conveyors", London: Kluwer, 2003.

[9] G. PALMISANO, G. PALUMBO, S. PENNISI, "CMOS Current Amplifiers", Boston, MA: Kluwer, 1999.

[10] F. KAÇAR, A. YEŞİL, A. NOORI, "New CMOS Realization Of Voltage Differencing Buffered Amplifier And Its Biquad Filter Applications", Radioengineering, 2009, vol.18, no.1, p.1-7.

[11] J-W. HORNG, "Voltage-Mode Universal Biquadratic Filter Using Two OTAs", Active and Passive Elec. Comp., 2004, vol. 27, p. 85–89.

[12] W. TANGSRIRAT, "Novel Current-mode and voltage-mode universal biquad filters using single CFTA", Indian Journal of Engineering & Materials Sciences, 2010, vol.17, p.99-104.

[13] B. METIN, O. CICEKOGLU, K. PAL, "Voltage mode all-pass filter with a single current differencing buffered amplifier", Circuits and Systems, 2008. MWSCAS 2008. 51st Midwest Symposium on, 2008, p. 734 – 737.

[14] H. KUNTMAN, A. OZPINAR, "On the realization of DO-OTA-C oscillators", Microelectronics Journal, 1998, vol. 29, p. 991-997.

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