RESEARCHERID
THOMSON REUTERS

[Kumar* 7(4): April, 2020] ISSN 2349-4506
Impact Factor: 3.799

Global Journal of Engineering Science and Research Management

DESIGNING OF BIQUAD FILTER USING VDCC

Ajay Kumar*, Shatanjay Mishra
* Electronics Engineering Department, RR Institute of Modern Technology Lucknow, INDIA.

DOI: 10.5281/zenodo.3747338

KEYWORDS: VDCC, MOCCI, OTA, FILTERS (First order, second order, Biquad) etc.

ABSTRACT

It is widely accepted that all filters can be fabricated with the help of standard operational amplifiers. It is mainly used for audio application. For the creation of higher frequency ranges modern active functional blocks have been used. Recently, various kind of functional building blocks have been implemented, out of them only versatile and functional building blocks are useful for voltage differencing current conveyor (VDCC). VDCC based continuous time active RC filters have gained more attention in recent time. This branch of electronics having some useful advantages of the current conveyor filters and OTA filters, which is named as low supply voltages and power. Standard amplifiers are able to provide well developed IC topology and specific frequency ranges for signal processing. Since their inception, the VDCC have guided multiple of applications in signal processing circuits, for the development of many oscillators and filters. Sedra and Smith in 1968, first time introduced the principal of the current conveyor of first generation. After that multiple applications of current conveyors have been published by other people. After putting so much of efforts on research, current conveyors are still not available in the form of IC and, because of this reason this active block not being used in many analog circuit and system design applications by many developers. Some op-amps based applications on current conveyors are available, which can provide high speed and wide band, in the form of integrated circuits such as AD844, OPA660, and AD844. Analog VLSI can deal with nearly all real world issues and has extended its range of circuits (amplifier, filters, communication circuits, current comparators etc) for new information processing applications in numerous fields like integrated sensors, image processing, speech recognition, hand writing recognition etc.This lead to an increased interest in the evolution process of active elements which are used for analog signal processing.

INTRODUCTION

In analog circuit designing, current conveyor (CC) is one of the basic units in current mode techniques. Normally a semiconductor ideally used for basic analog signal processing functions with the support of proper circuitry. The current conveyor also simplifies the circuit design in multiple of ways like conventional operational amplifier do. New and useful implementations can be introduced by extending an alternate manner of removing complex circuit with the help of Current conveyor. Despite an active building blocks the current conveyor having a capacity to replace classical operational amplifier in the voltage mode applications [2]. This can add extra advantages to transform typical voltage mode applications into current mode. The working of current conveyor has gained attention of many researchers and thus many group of product of basic current conveyor have been implemented in the last two decades. In voltage-mode circuits, operational amplifier acts as a building block, which is used to add, amplify, subtract, filter, attenuate, and voltage signal. In current-mode circuit, the analogous building block is the current conveyor. The current conveyor introduced first was a three- terminal block in which x and y were input terminals and z was output terminal having following properties:

- Input terminal(x) potential is equal to the voltage applied towards the end of terminal(y).
- An input current applied at the terminal x results in flowing equal amount of current at node y.
- Input current which is flow between X node is conveyed to node z, which has the features of high output resistance current source.

When the external circuit connected to the input terminals of current conveyor is decoupled then the current is transferred from the input terminals to the output terminal.

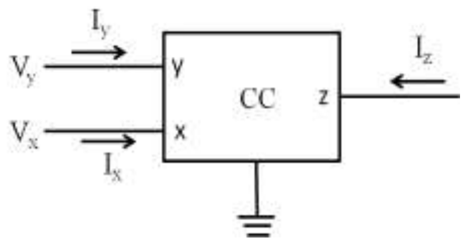

Figure 1: Current Conveyor Block Diagram

LITERATURE REVIEW

In 2013 paper "Positive/negative lossy/lossless grounded inductance simulators employing single VDCC and only two passive elements" published in International Journal of Electronics and Communications, Elsevier, written by Firat Kacar, Abdullah Yesil, Shahram Minaei and Hakan Kuntman [19] designed third order Butterworth high pass ladder filter circuit using VDCC based inductance simulators. Results of this paper are as follows:

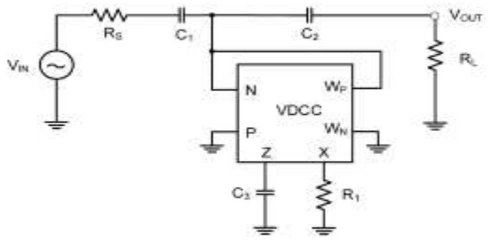

Figure 2: Block Diagram for High Pass Filter

A signal of 1MHz frequency having different amplitudes is applied to the high pass filter.This circuit works efficiently for amplitude lesser than 400 mV peak to peak.

In 2014 paper "Z-Copy Controlled-Gain Voltage Differencing Current Conveyor: Advanced Possibilities in Direct Electronic Control of First-Order Filter" published in ELEKTRONIKA IR ELEKTROTECHNIKA, written by R. Sotner, N. Herencsar, J. Jerabek2, R. Prokop, A. Kartci, T. Dostal, K. Vrba [20] designed reconfigurable reconnection less multifunction filter in which there is no need to change input or output terminal to change the transfer function.

In 2015 paper "A Voltage mode biquad with lowpass, bandpass and notch outputs using Voltage Differencing Current Conveyor" published in International Journal of Advanced Research in Computer and Communication Engineering, written by Mayank Rawat, Dr. Malti Bansal [21] designed voltage mode multifunction biquad filter which consists of gain blocks, summer and integrators.

In 2015 paper "Single Voltage Differencing Current Conveyor Based Second-Order Filter Realization" published in International Journal of Advanced Research in Electronics and Communication Engineering, written by Robin Jain [22] designed low pass, high pass and band pass filters using VDCC.

In 2014 paper "New Single VDCC-based Explicit Current-Mode SRCO Employing All Grounded Passive Components" published in ELECTRONICS, VOL. 18, NO. 2, written by Dinesh Prasad, D. R. Bhaskar and Mayank Srivastava [23] designed trans-admittance low pass and band pass filters using VDCC and minimum passive components.

PROPOSED WORK

VDCC transfers voltage and current in its correspondent terminals and provides trans-conductance gain which is electronically tunable. Different devices like filters, multipliers, simulators etc. can be designed efficiently using the VDCC. CMOS circuits for low pass, high pass and band pass filters are designed and simulated in PSpice tool using 180nm library. All the circuits and waveforms are included in this chapter. PSpice stands for *Personal Simulation Program with Integrated Circuit Emphasis*. It is a circuit simulator for the simulation and verification of analog as well as mixed signal circuits. PSpice was first introduced by MicroSim in 1984. A file with code or schematic diagram also called net list is analyzed and simulated in PSpice. It also includes waveform viewer and program analyzer. There are three analyzes which can be done in PSpice. These analyzes are as follows:

- **Transient Analysis:** This analysis is done when the circuits have time variant sources like sinusoidal sources or switched DC sources. In this analysis voltage at each node and current in each branch over a specific time interval are calculated and output is the instantaneous value.
- **DC Analysis:** This analysis is done when the circuits have time invariant sources like steady state DC sources. In this analysis voltage at each node and current in each branch over a specific range of values are calculated. Linear Sweep and Logarithmic Sweep are some examples of this analysis.
- **AC Analysis:** This analysis is done when the circuits have components with varying frequency for small signal. In this analysis magnitude and phase angle of voltage at each node and current in each branch over a specific range of frequencies are calculated.

VOLTAGE DIFFERENCING CURRENT CONVEYOR

Introduction

It is well known that precisely tailored frequency filters can be produced with standard operational amplifiers but for audio application only. In higher frequency range it is better to use some of modern active functional blocks. Recently, various active building blocks have been introduced in [1], in which versatile and powerful building blocks are the voltage differencing current conveyor (VDCC). Continuous-time active RC filters based on the VDCC have recently found attractive considerable attention. This stems from inherent advantages of the current conveyor circuits and OTA circuits, namely low supply voltages and power, current operational mode possibility, well-developed IC topology and particularly a frequency range of the signal processing which can be higher than with circuits with the standard operational amplifiers.

VDCC provides electronically tunable transconductance gain in addition to transferring both current and voltage in its relevant terminals; it is very suitable for the design of various active filters or inductor simulators.

Circuit Description

The circuit symbol of the proposed active element,VDCC, is shown in Fig. 4.2, where P and N are input terminals and Z, X, W_P and W_N are output terminals. Ideally, the VDCC is an active block which is the combination of OTA and MO-CCII as shown in Fig. 3.

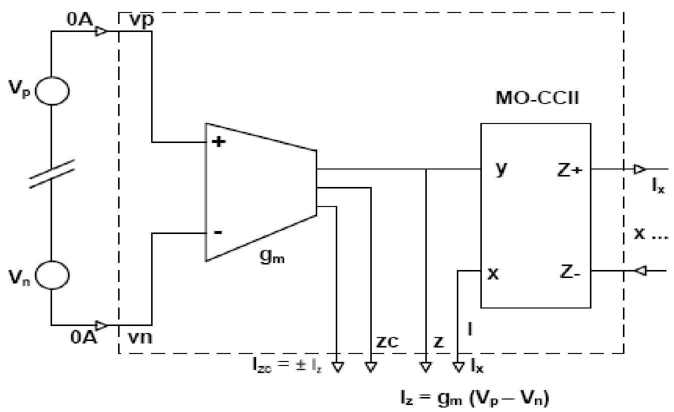

Figure 3: Internal structure of VDCC

All of the terminals exhibit high impedance, except the X terminal.Using standard notation the port of an ideal VDCC.

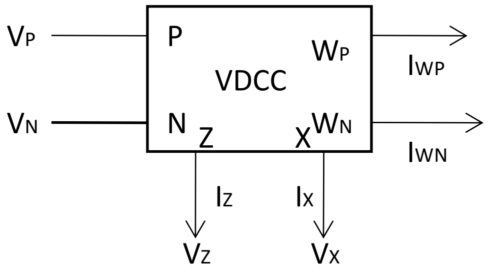

Figure 4: Voltage differencing current conveyor

Using standard notation, the port relations of an ideal VDCC can be characterized by

$$\begin{bmatrix} I_N \\ I_P \\ I_Z \\ V_X \\ I_{WP} \\ I_{WN} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ g_m & -g_m & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} V_P \\ V_N \\ V_Z \\ I_X \end{bmatrix}$$

Subheading According to the above matrix equation, the first stage can be realized by a balanced transconductance amplifier to convert the difference of the input voltages (V_p– V_n) into the output current (I_z) with transconductance gain of g_m and the second stage is a current conveyor used for transferring x-terminal current to W_p and W_n terminals. For a balanced CMOS transconductance amplifier, the parameter g_m can be given as.

$$g_m = \sqrt{I_{B1}\mu_n C_{ox}(W/L)}$$

where μ_n is the mobility of the carrier for NMOS transistors, C_{ox} is the gate-oxide capacitance per unit area, W is the effective channel width, L is the effective channel length and I_{B1} is bias current. In the VDCC block [2] in the input stage we have a trans-conductance amplifier and in the output stage we have a second generation current conveyor.

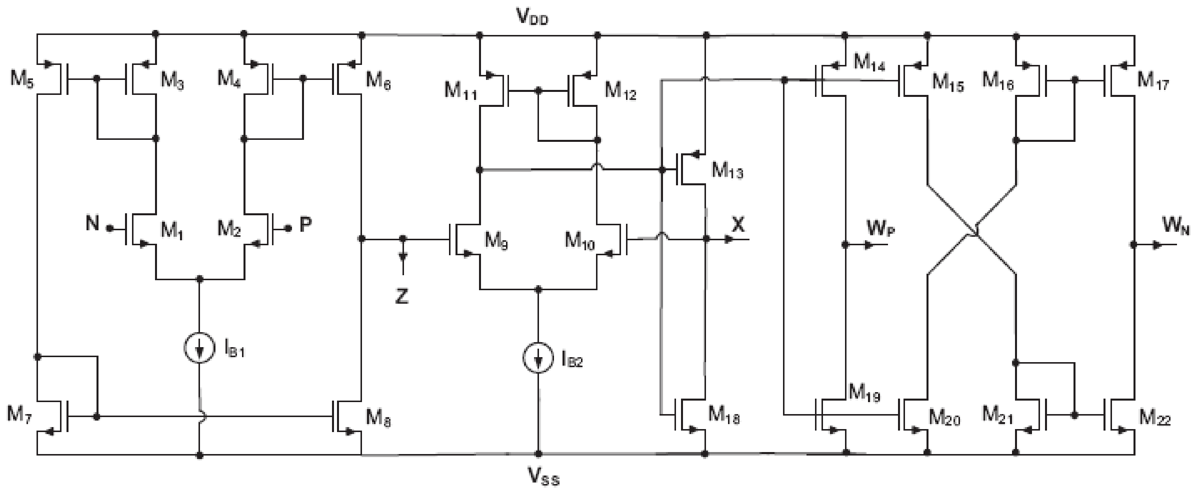

Figure 5: CMOS Realization of VDCC

Table: Transistors aspect ratios for the VDCC of Fig5.

Transistors	**W/L (μm)**
M1–M4	3.6/1.8
M5–M6	7.2/1.8
M7–M8	2.4/1.8
M9–M10	2.4/1.8
M11–M12	9/0.72
M13–M17	14.4/0.72
M18–M22	0.72/0.72

The CMOS schematic of VDCC shown in fig.4.3 was simulated in PSpice using TSMC CMOS 0.18µm model parameters [2]. The aspect ratios of the transistors used are given in Table 1. The supply voltages are chosen as V_{DD}=-V_{SS}= 0.9V, I_{B1} = 50µA and I_{B2} = -100µA. The following analysis has been carried out:

(i) DC sweep (to obtain the linear voltage for various current and voltage transfers),
(ii) AC sweep (to obtain the bandwidth of the device).
(iii) The following terminating impedances were used in characterization of the VDCC as Rz= 9kΩ, Rx= 100Ω, Rwp= 100Ω, Rwn= 100Ω. The input signal for AC sweep was taken as 3 mV with frequency 10MHz.
(iv) Different parameters obtained by PSpice
(v) Simulations of VDCC are listed as:
(vi) Transconductance g_m= 277µA/V
(vii) Power consumption = 0.90Mw

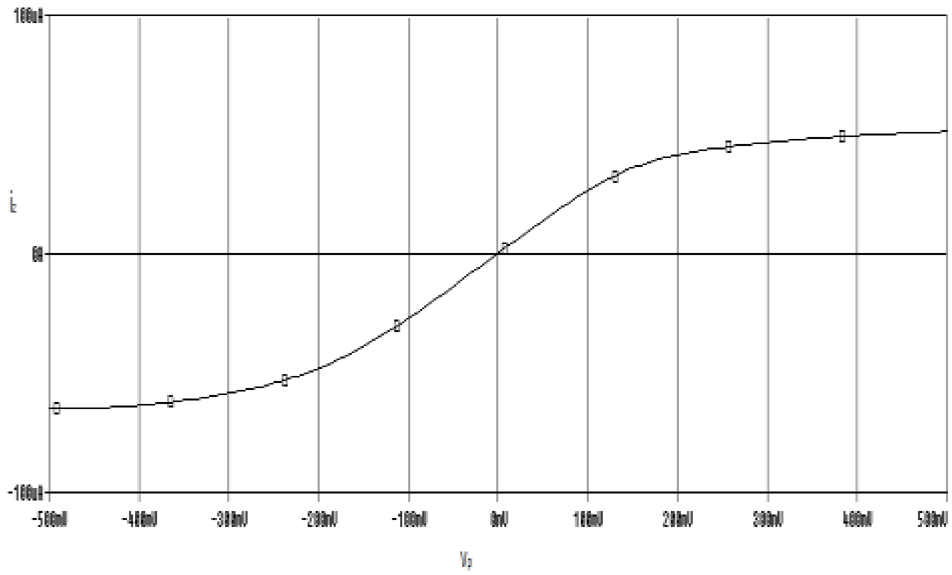

Figure 6: Input DC characteristic of VDCC

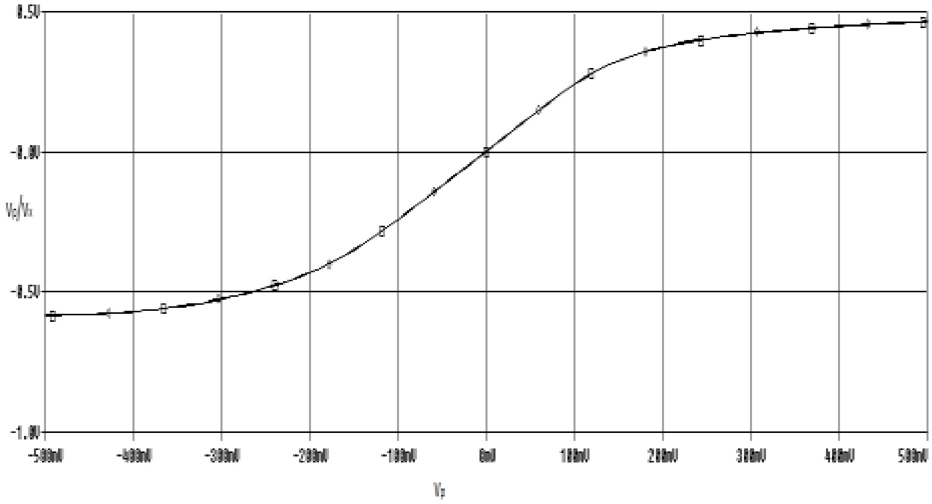

Figure 7: DC characteristic of Vz and Vx terminal of VDCC

Proposed Biquad using VDCC

Although many circuits for the simulation of grounded and floating inductance using different active building blocks such as operational amplifiers, current conveyors, current feedback amplifiers, current differencing buffered amplifiers, current differencing transconductance amplifiers, operational transconductance amplifiers, have been reported. In many active building blocks have been presented, and VDCC is one of them.

Here single voltage differencing current conveyor (VDCC) based second order filter is proposed. The proposed circuit employs one voltage differencing current conveyor (VDCC) as active elements together with capacitors and resistors as passive elements.

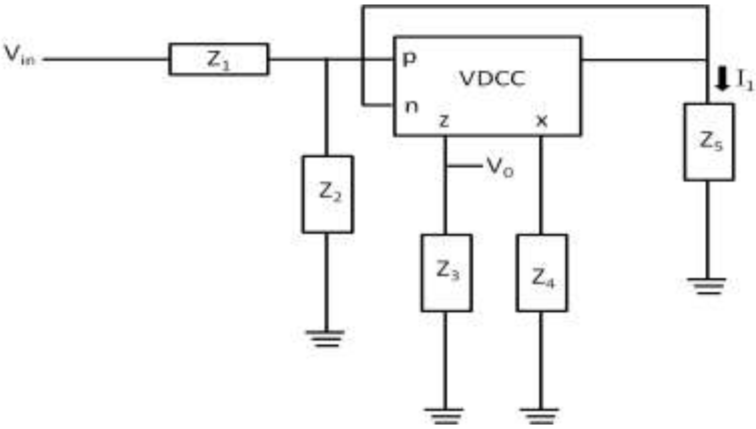

Figure 8: Circuit based on VDCC

SIMULATION RESULTS

Simulation was performed using a CMOS realization of VDCC given in fig 4.3. To prove the theoretical validity of single VDCC biquad filter of figure 4.10 for pole frequency (f_0) = 5MHz the filters were simulated with responses are shown in fig 4.11 to fig 4.13 respectively. The simulated center frequency of BPF was measured as 5.30 MHz. 3dB (cut-off) frequency of LPF and HPF were measured as 5MHz and 4.56MHz respectively.

To study the time-domain behavior of the proposed filter, an input sinusoidal signal of amplitude 10mV is applied. The transient response for low-pass, band-pass and high-pass are shown. To show the effectiveness of the proposed structure, sinusoidal signal of frequencies of 100 KHz, 100 MHz having amplitude of 10mV each is applied at the input of the low pass filter and high pass filter and sinusoidal signal of frequencies of 100 KHz, 5 MHz having amplitude of 10mV each is applied at the input of the band pass filter. The frequency spectrum of input and output are also given. It is clear that the 100 KHz signals is passed without attenuation and 100 MHz signal is significantly attenuated for low-pass response. There is appreciable reduction in amplitude of 100 KHz signal for both band-pass and high-pass responses. The sinusoidal signal of 5 MHz is passed through both band-pass and 100MHz through high-pass.

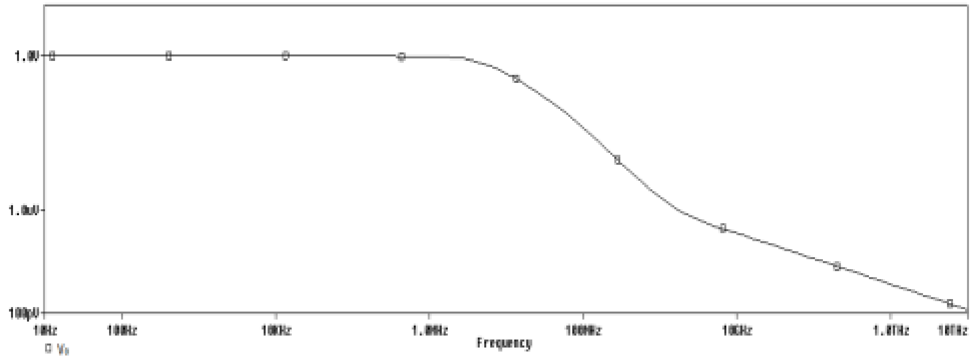

Figure 9: Frequency response of low pass filter

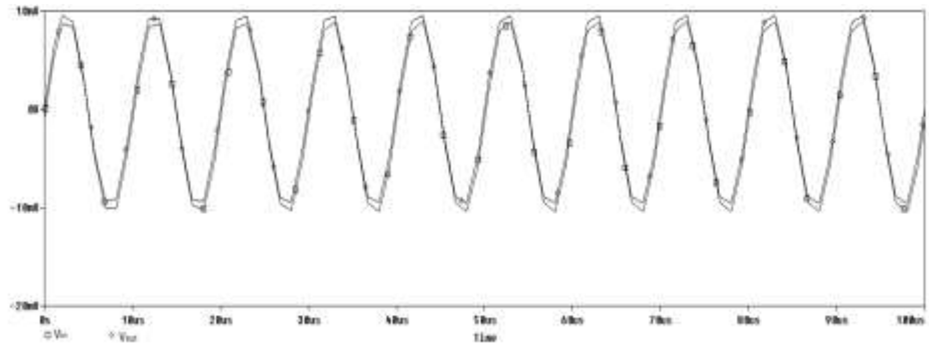

Figure 10: Transient response for low-pass output for frequency 100 KHz

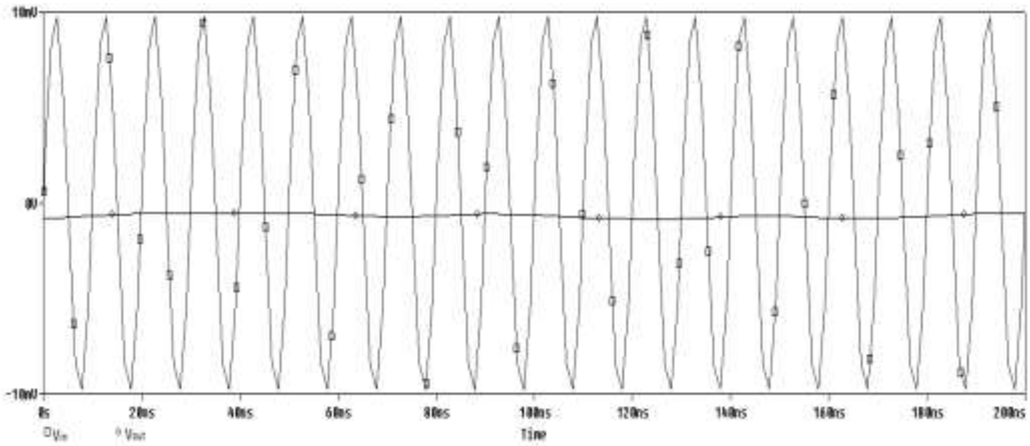

Figure 11: Transient response for low-pass output for frequency 100 MHz

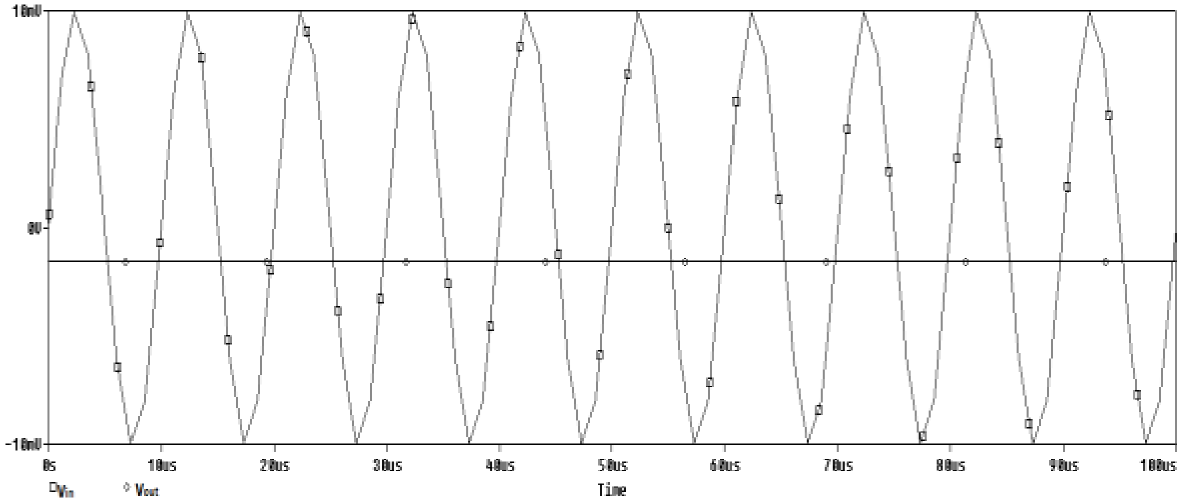

Figure 12: Transient response for high-pass output for frequency 100 KHz.

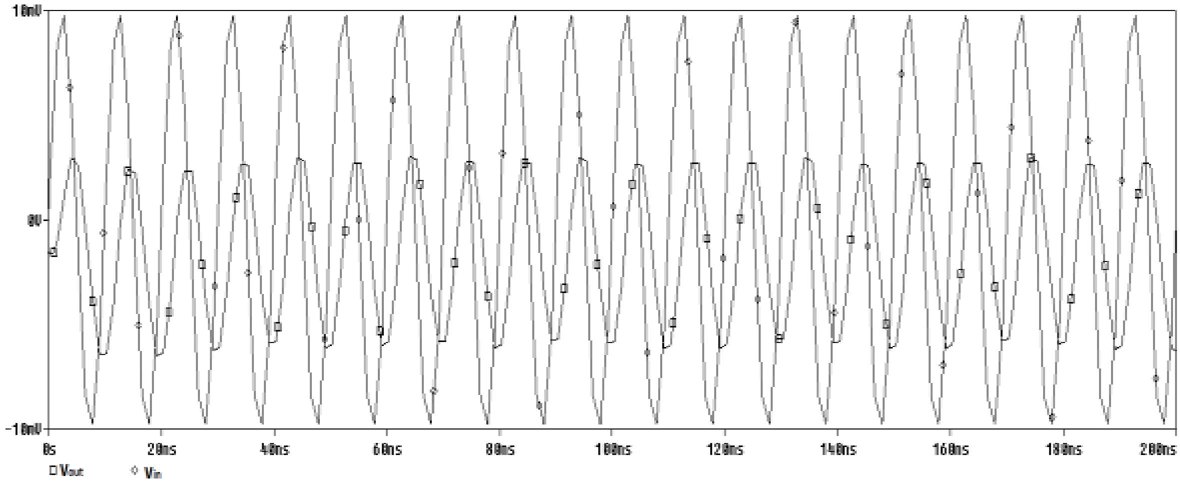

Figure 13: Transient response for high-pass output for frequency 100 MHz

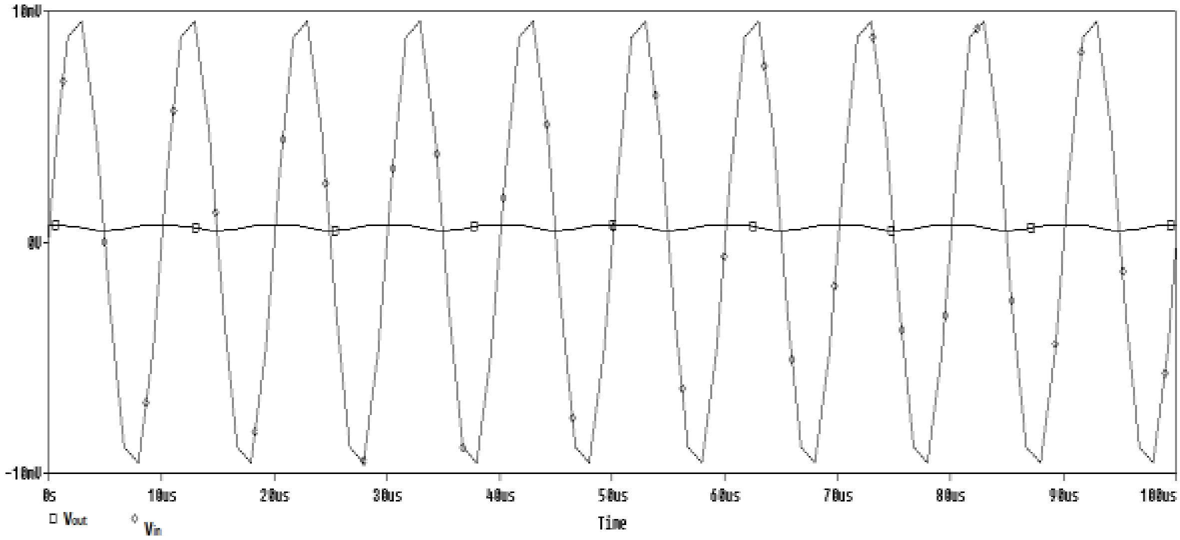

Figure 14: Transient response for band-pass output for frequency 100 KHz

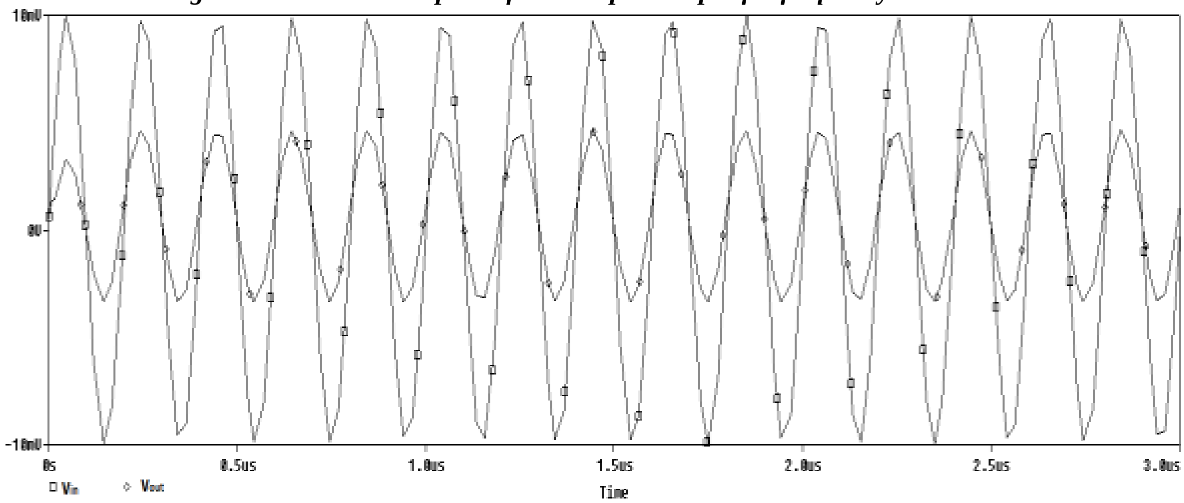

Figure 15: Transient response for band-pass output for frequency 5 MHz

CONCLUSION AND FUTURE SCOPE

In this paper, I have designed low pass, high pass and band pass filter circuits using voltage differencing current conveyor (VDCC). Each circuit structure has been simulated in PSpice simulator. All the circuits are made from CMOS transistors and analyzed using 180nm TSMC CMOS technology. These circuits work efficiently and consume less average power compared to other designs published in previous literatures.

In future more designs can be constructed and analyzed using different types of current conveyor with less number of CMOS transistors. We know that technology is getting advanced and delay time, average power consumption & chip area are the main concerns which we have to solve in less time. Therefore not only filters but other important devices can also be designed for particular application. Cost is also an important factor so circuits should be carefully designed.

REFERENCES

1. P. V. Ananda Mohan, “Current-Mode VLSI Analog Filters: Design and Applications”, Birkhäuser, Springer, 2003.
2. K. C. Smith and A.S. Sedra, “The current conveyor - a new circuit building block”, IEEE Proceedings, vol. 56 (8), pp. 1368-1369, August 1968.
3. R. Senani, D. R. Bhaskar and A. K. Singh, “Current Conveyors: Variants, Applications and Hardware Implementations”, Springer, 2014.
4. A. S. Sedra and K. C. Smith, “A second generation current conveyor and its application”, IEEE Trans Circuit Theory, pp. 132-134, 1970.
5. A. P. Naik, N. Devashrayee, “Cmos Second Generation Current Conveyors”, Lap Lambert Academic Publishing GmbH KG, 2012
6. J. W. Horng, Z. R. Wang, C.C. Liu, “Voltage- Mode Low pass, Band pass and Notch Filters Using Three Plus-Type CCIIs”, IEEE Journal on Circuits and Systems, pp. 34-37, 2011. [7] H. A. Kuntman, “New Advances and Possibilities in Active Circuit Design”, International Conference on Development and Application Systems, Romania, 2010.
7. A. Fabre, “Third Generation Current Conveyor: A New Helpful Active Element”, IEEE Electronics Letters, vol. 31(5), pp. 338-339, March 1995.
8. M. Yildiz, S. Minaei, S. Tiirkoz, H. Kuntman, “High Performance CMOS Realization of the Third Generation Current Conveyor (CCIII)”, IEEE Circuits and Systems 45th Midwest Symposium, vol. 1, pp. 307-310, August 2002.
9. A. M. Soliman, El-Adway, H. O. Elwan, “A Novel Fully Differential Current Conveyor and Its Application for Analog VLSI”, IEEE Transactions on Circuits and Systems, vol. 47 (4), pp. 306-313, April 2000.
10. S. Zhixing, W. Chunhua, L. Haiguang, “New CMOS Current-Controlled Second Generation Current Conveyors”, IEE Circuits and Systems for Communications 4th International Conference, pp. 333-337, may 2008.
11. Z. Qiujing, W. Chunhua, “Current Controlled Fully Balanced Current Conveyor”, IEEE Conference on Circuits and Systems, pp. 1062-1065, November 2008
12. H. Elwan, M. Ismail, H. A. Alzaher, “A CMOS Fully Balanced Second-Generation Current Conveyor”, IEEE Transactions on Circuits and Systems-II, vol. 50 (6), pp. 278-287, June 2003.
13. S. Minaei, E. Yuce, “ICCII-Based Universal Current- Mode Analog Filter Employing Only Grounded Passive Components”, Springer Analog Integrated Circuits and Signal Processing, vol. 58 (2) , pp. 161-169 , 2009. [15] Mohd. S. Ansari, S. Maheshwari, “Catalog of Realizations for DXCCII using Commercially Available ICs and Applications”, Radio engineering, vol. 21, pp. 281-289, April 2012.
14. E. Yüce ,S. Minaei , I. Myderrizi , “DXCCIIBased Grounded Inductance Simulators and Filter Applications”, Micro-electron Journal, 2011.
15. D. Biolek, R. Senani, V. Biolková , Z. Kolka, "Active Elements for Analog Signal Processing: Classification, Review, and New Proposals", Radio Engineering, vol. 17 (4), pp. 15- 32, December, 2008.