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# VOLTAGE MODE UNIVERSAL BIQUADRATIC FILTER USING FTFN AND OTA

**k KUMAR[1] k PAL[2]**

[1]Department of Applied Science, IMS Engineering College,
Ghaziabad Uttar Pradesh India.
[2]Department of Earthquake Engineering, IIT Roorkee, Roorkee, India.
Email: {kushalkumar75@gmail.com, kiratfeq@iitr.ernet.in}

## *ABSTRACT*

*A single input and five outputs voltage mode universal biquadratic filter using two four terminal floating nullor (FTFNs), two operational transconductance amplifiers (OTAs), four resistors and two grounded capacitors is presented. The circuit is capable of realizing the entire standard filters viz-low pass, high pass, band pass notch and all pass simultaneously. The circuit offers the advantageous feature of having high input impedance and the use of grounded capacitors makes the circuit suitable for cascading of higher order filter. The filter performance parameter resonance frequency $\omega_0$ and quality factor Q can be control orthogonally.*

***Keyword:*** *Voltage mode Circuits, OTA, FTFN, Analog filter, High input impedance.*

## 1. INTRODUCTION

The design of filters circuits employing active devices such as Four Terminal Floating Nullor (FTFNs) and operational transconductance amplifiers (OTAs) have been reported in the literature [1-4]. The FTFN is a versatile active circuit-building block, as it offers some potential advantages over conventional operational amplifiers (OA) and second-generation current conveyors (CCIIs). Also OTA is a differential voltage controlled current source. It offers highly linear electronic tenability and a wide tunable range of its transconductance gain $g_m$. The transconductance gain is adjustable over several decades through its bias current. A review of the literature reveals that not much attention has been paid towards the development of such circuits, which realize the entire standard filter simultaneously, and offers the advantage of high input impedance based on FTFNs and OTAs. Also the filters with high input imedance make the circuit suitable for cascading some cells to implements higher order filter circuits. Thus there has been growing interest to develop such analog filter circuits which offers high input impedance and realize all the standard filters simultaneously i.e. low pass, high pass, band pass, notch and all pass. Based on FTFNS and OTAs. As a sequel, a number of voltage mode filter circuits using FTFNs and OTAs have been reported in the literature [1-10]. One of the reported circuit [6] based on two FTFNs and five passive components has the limited scope of applicability as it can be configured to implement only one filtering function depending on the selection of passive components. Further the proposed circuit [7] of voltage mode universal biquadratic filter with single input and

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five outputs employing five OTAs for which o triple outputs and one dual outputs and capacitors realize all the standard fi simultaneously. In the contribution reported Shah et al [8] realize band pass and low filtering functions by employing two FTFNs , inverter, three resistors and two capacitors, circuit can be made to realize high pass and b pass filtering functions simultaneously as wel changing one admittance. In the recent work S et al [9] describe high input impeda multifunction filters with single input and t outputs employing two PFTFNs , one OTA resistors and two capacitors and realize t filtering functions simultaneously.

In this contribution we present a voltage m universal biquadratic filter circuit with single in and five outputs employing two FTFNs, two OT for which one is dual outputs OTA with additio passive components as four resistors and t grounded capacitors. The circuit realizes all t generic filter functions simultaneously from t same configuration.

## 2. CIRCUIT DESCRIPTION

The symbolic representation of FTF and OTA are shown in fig. 2 & 4 respectively. T positive FTFN can be characterized by the p relations with $v_x = v_y$, $i_x = i_y = 0$ and $i_w = i_z$. T characteristics of OTA are described $I_0 = g_m(V^+ - V^-)$ where $g_m$ is t transconductance gain of the OTA. The propos circuit of the voltage mode universal biquadrat filter is shown in fig. 1. A routine analysis of t circuit yields the voltage transfer function

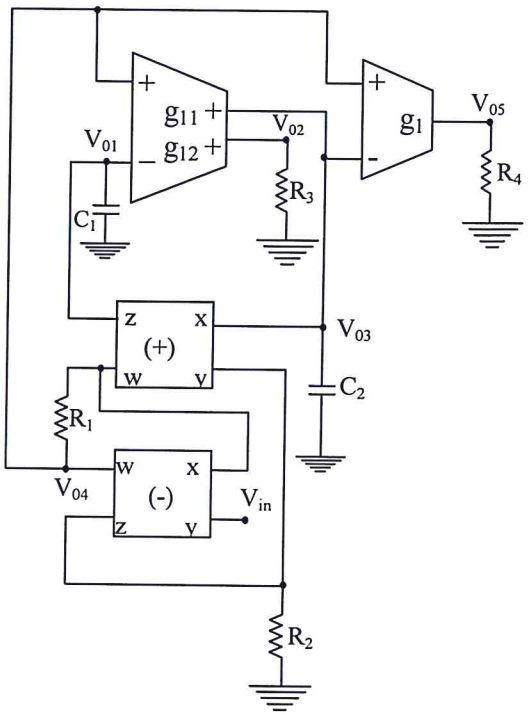


**Figure 1.** The proposed circuit of voltage mode universal biquadratic filter.

$$\frac{V_{01}}{V_i} = \frac{\frac{g_1}{R_1 R2}}{\frac{s^2 C_1 C_2}{R_1} + \frac{sC_1 g_1}{R_2} + \frac{g_1}{R_1 R2}} \quad (1)$$

$$\frac{V_{02}}{V_i} = \frac{\frac{s^2 C_1 C_2 g_1 R_3}{R_1}}{\frac{s^2 C_1 C_2}{R_1} + \frac{sC_1 g_1}{R_2} + \frac{g_1}{R_1 R2}} \quad (2)$$

$$\frac{V_{03}}{V_i} = \frac{\frac{sC_1 g_1}{R_1}}{\frac{s^2 C_1 C_2}{R_1} + \frac{sC_1 g_1}{R_2} + \frac{g_1}{R_1 R2}} \quad (3)$$

$$\frac{V_{04}}{V_i} = \frac{\frac{s^2 C_1 C_2}{R_1} + \frac{g_1}{R_1 R_2}}{\frac{s^2 C_1 C_2}{R_1} + \frac{sC_1 g_1}{R_2} + \frac{g_1}{R_1 R2}} \quad (4)$$

If $R_1 = R_2$

$$\frac{V_{05}}{V_i} = \frac{g_2 R_4 \left( \frac{s^2 C_1 C_2}{R_1} - \frac{s C_1 g_1}{R_2} + \frac{g_1}{R_1 R_2} \right)}{\frac{s^2 C_1 C_2}{R_1} + \frac{s C_1 g_1}{R_2} + \frac{g_1}{R_1 R2}} \quad (5)$$

The gain for BP filter is given by
$B_{BP} = R_2/R_1$
The gain for HP filter is given by
$B_{HP} = g_1 R_3$
The gain for AP filter is given by
$B_{AP} = g_2 R_4$
The symbolic representation of the negative FTFN is shown in fig. 2.

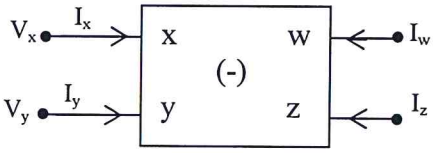


**Figure 2.** Symbol of the n FTFN.

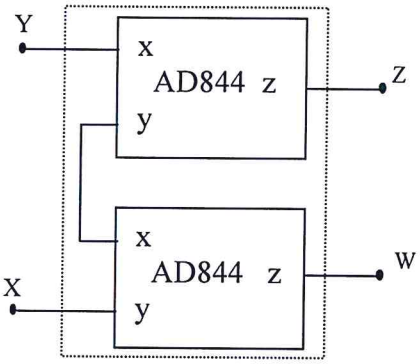


**Figure 3(a).** Implementation of negative FTFN.

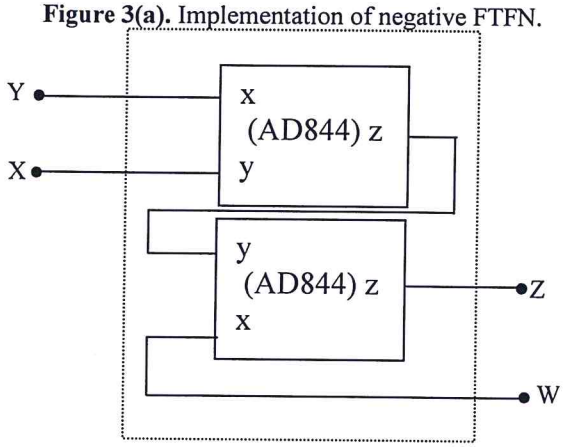


**Figure 3(b).** Implementation of positive FTFN.

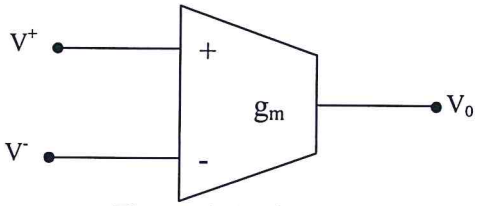


**Figure 4.** Symbol of the OTA.

The filter performance parameter $\omega_o$ and Q can expressed as

$$\omega_0 = \sqrt{\frac{g_1}{R_1 C_1 C_2}} \quad (6)$$

$$Q = \frac{1}{R_1}\sqrt{\frac{C_2 R_2}{C_1 g_1}} \quad (7)$$

It is obvious from equation (6) and (7) that filter performance parameters $\omega_o$ and Q can be controlled independently by the resistor R1 involved in Q. Both the parameters can be controlled electronically through the transconductance gain $g_1$ of the OTA.
The sensitivity performance are given by

$$S_{g_1}^{\omega_0} = 1/2, \qquad S_{R_1,C_1,C_2}^{\omega_0} = -1/2$$

$$S_{R_1}^{Q} = -1, S_{C_2,R_2}^{Q} = 1/2, S_{C_1,g_1}^{Q} = -1/2$$

Which reveals that the active and passive sensitivity performances are low.

## 3. EXPERIMENTAL RESULTS

To verify the functionality of the proposed circuit the experimental result were performed. In the experiment the positive and negative FTFN can be implemented by using two AD844 [13-14] from analog devices and is as shown in fig. 3 (a&b) respectively. He commercially available OTA IC CA3080 was used in the experiment and the dual output OTA was implemented by connecting two CA3080 in parallel. The proposed circuit was tested for the following components values $C_1=C_2=$ 4.5nF, $R_1=R_2$ =1KΩ and $g_1=g_2$=1mS(the values of $g_m$'s were taking by keeping the values of bias current $I_{b1}=I_{b2}$=53μA with center frequency $f_0$ =3.54x10$^4$Hz and Q=1. the experimental responses are shown in fig.5 & 6.

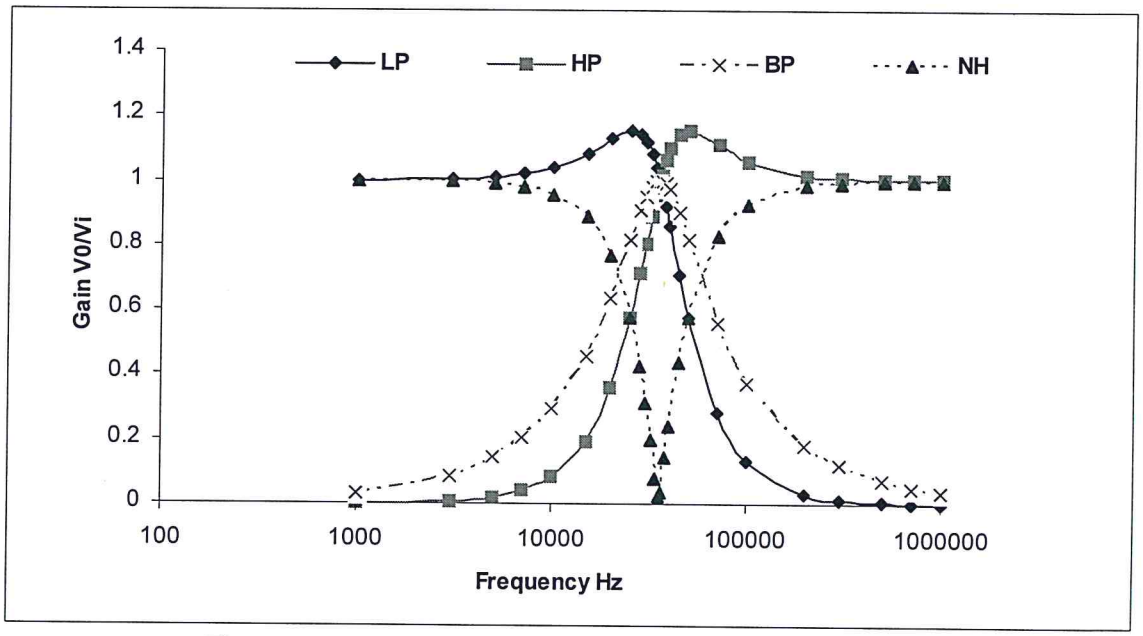


**Figure 5.** Frequencies responses of the LP, HP, BP and NH filters.

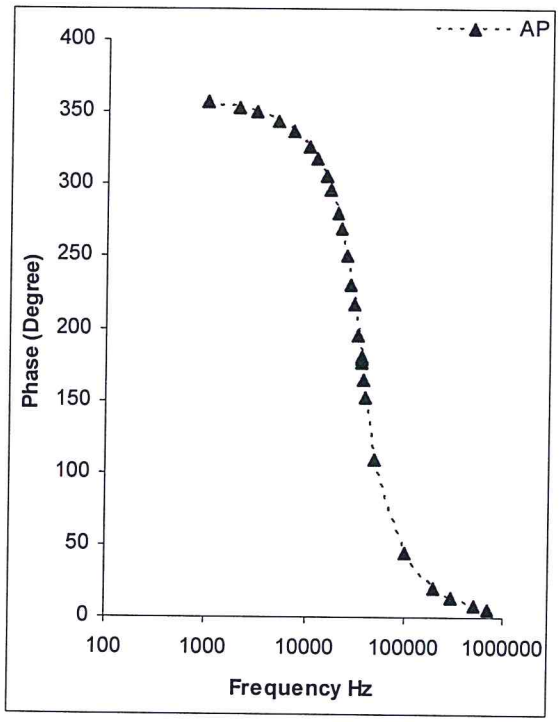


**Figure 6.** Frequencies responses of the AP filter

## 4. CONCLUSION

A new circuit of voltage mode universal biquadratic filter with single input and five outputs has been presented. The new circuit offers the several advantages, such as realize all the standard filters functions simultaneously, independent control of the filter performance parameter $\omega_0$ and Q, offer high input impedance and the use of grounded capacitors makes the circuit suitable for IC fabrication. The circuit can not requires matching conditions except all pass realization and have low active and passive sensitivity figures.

## References

[1] Abulma atti MT., Al-Zaher HA., "Universal two input two output current mode active biquad using FTFNs." Int. J Electron 1999 Vol 86, no 8, pp. 181.

[2] Cicekoglu O., "Current mode biquad with minimum number of passive elements." IEE Trans Circuits System II Analog Desital Signal Process 2002, Vol. 49, pp 783.

[3] Nawrocki,R. and Klein,U., "New OTA-capacitor realization of a universal biquad," Electronics Lett, vol.22, pp.50-51, 1986.

[4] Sun,Y. and Fidler,J.K.,"Novel OTA-C realization of biquadratic transfer functions", Int. J. Electronics, vol. 75, pp.333-340, 1993.

[5] Cam U., Kuntman H.,"A new CMOS realization ofa four terminal floating nuller (FTFN)" Int J Electron 2000 Vol 87,pp. 809-81`7.

[6] Liu, SI. Yang CY, "High input imedance filters usung FTFNs" Int J Electron 1998 Vol 84, pp.595-608.
[7] Horng,J.W., "Voltage-mode universal biquadratic filter with one input and five outputs five using OTAs," Int.J.Electronics, vol.89, No.9, pp.729-737, 2002.
[8] Shah, N.A., Malik,M.A. "High input impedance HP,BP, and LP filters using FTFNs" Indian Journal of Pure and Applied Physics, vol. 41, pp 967-969, Dec 2003.
[9] Shah,N.A., Malik,M.A. "High input impedance voltage and current mode multifunction filters" Int J Electron. Commu.(AEU), vol 59, pp 262-266, 2005.
[10] Liu SI, Lee JL, "Insensitive current/voltage mode filters using FTFNs" Ellectron Lett. 1996, vol. 32, pp. 1079-1080.
[11] Cam U., Cicekoglu o., Gulsoy M., Kuntman H., " New voltage and current mode first order all pass filters using single FTFN" Frequenz 2000,vol. 54, pp. 177-179.
[12] Cicekoglu, O., Ozcan s., Kuntman H., " Insesitive multifunction filter implemented with current conveyors and only grounded passive elements" Frequenz 1999,vol. 53, pp. 158-160.
[13] Liu SI, Hwang C-SII., "Realization of current mode filters using single FTFN." Int. J Electron 1997 Vol 82, pp. 499-502.
[14] Cam U, Cicekoglu O, Kuntman H. " Current mode single input three output SITO universal filter employing FTFNs and reduced number of passive components." Frequenz 2000 Vol 54, pp 94-106.

**Dr. K Kumar** received B.Sc degree from CCS University Meerut, M.Sc degree from CCS University Meerut, Ph.D. from HNB University Gharwal Shrinagar Uttarkhand, India. Dr. K Kumar held the positions of Project fellow in IIT Roorkee (April 2006–August 2008). He joined the Applied Science and Humanities Department (Physics) of IMS Engineering College Ghazaibal in October 2008 as a lecturer. Dr. K. Kumar's teaching and research interests are in the areas of CMOS Analog Integrated Circuits and Systems, Communication Systems and Electronic Instrumentation. He has authored or co-authored 27 research papers in various International, National journals and International and national conferences.