ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

Passband Gain and Q Factor Enhancement Scheme of Opamp Based Band Pass Filters

Abhishek Dwivedi[1], Vijayprakash Singh[2]

PG Student [VLSI], Dept. of ECE, School of Engineering, Sri Satya Sai University of Technology and Medical Sciences Sehore, M.P., India[1]

Assistant Professor, Dept. of ECE, School of Engineering, Sri Satya Sai University of Technology and Medical Sciences Sehore, M.P., India[2]

ABSTRACT: Operational Amplifier is a basic building block of many Analog circuits like Amplifiers, Filters, Integrators, Oscillators, etc. This paper presents a design of an active band pass filter using single stage operational amplifier in 45nm CMOS technology and also presents a techniques to enhance the pass band gain and Q factor of active band pass filter. Proposed active band pass filter exhibits the pass band gain, Q factor and power dissipation as 22db, 12.64 and 450 micro watts respectively. Proposed active band pass filter is dedicated for the applications where high selective band pass filters are required. Design and simulation work has been carried out on cadence virtuoso 6.1 tool.

KEYWORDS: OPAMP, OTA, Active Band Pass Filter, Pass band gain and Q factor.

I.INTRODUCTION

Operational Amplifier is a versatile device which is used to amplify dc as well as ac input signals and was originally designed for mathematical operations. Modern day OPAMP has variety of applications such as ac and dc signal amplification, Active filters, Oscillators, Comparators, Regulators, etc[1]. This paper illustrates an application of OPAMP as an active band pass filter and also proposes techniques to enhance the pass band gain and Q factor of active band pass filters. Active filters unlike Passive filters not only filter the input signal but also amplify it and also they are easier to tune and adjust as compare to passive filters.

Active low pass filter is designed using a biquad design methodology for a wireless and wire line applications with a reconfigurable frequency response, selectable order, continuously tunable frequency and adjustable power consumption [2]. Chebyshev high pass filter of fourth order is designed with programmable gain and corner frequency is designed to support for ADSL and VDSL applications [3]. For high frequency applications filters are realized through operational trans conductance amplifiers. Tunable Sub Hertz operational transconductance amplifier-capacitor filter with very low transconductance is designed using single ended and differential operational transconductance amplifiers configurations biased with MOSFET interface trap charge pumping current generators [4]. Fully differential intermediate frequency filter with 6th order butterworth bandpass characteristic is designed using operational transconductance amplifier [5]. Resonators having high quality factor which are used in active filters are designed using operational transconductance amplifiers [6]. New higher order current mode filter is designed using OTA-C Filter. Current mode filter designed is having minimum number of active and passive components, uses only single ended OTAs and uses only grounded capacitors for integration and also new method is proposed for specification based parametric fault detection of higher order linear analog circuits [7].

Second order filter provides sharper frequency response as compare to first order filters. Second order linear and log domain filter synthesis from state space representation is done using operational tranconductance amplifier. 3db bandwidth and Q factor can be adjusted using transconductance of operational transconductance amplifier [8]. CMOS tunable versatile filter can be implemented through current conveyor. Filter realized through this technique is suitable for Low pass, High Pass, Band pass and Elliptical Notch filter. Current Conveyor is the basic building block that can be

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

implemented in analog circuit design .Current conveyors have wide range of applications ranging from universal and multifunction filters, Oscillators, etc. Current conveyors can provide larger Bandwidth and are suitable for the low voltage applications. Filters realized through current conveyors are suitable for high frequency applications while filters realized through OPAMP are suitable for low frequency applications and this is because no feedback is present in current conveyor [9]. Universal Filters are the filters which can be made to behave as a low pass, high pass, band pass and band reject filters by simply changing the input connections and not modifying the circuit of filter [10].

Floating active inductor is realized using 3 stage operational transconductance amplifier and this floating active inductor is used to realize a low frequency based active band pass filter [11]. Active band pass filter is designed using single stage operational amplifier with a positive feedback. Q factor and pass band gain gets boosted up in band pass filter realized with positive feedback applied single stage OPAMP [12]. In this paper an active band pass filter is proposed which uses two stage OPAMP with a positive feedback. By using the two stage OPAMP and positive feedback topologies open loop gain of an OPAMP gets boosted a lot hence the pass band gain and Q factor of active band pass filter.

Single stage OPAMP which is used to realize a conventional active band pass filter contains the basic differential pair with the active current mirror load. Two NMOS transistors (Nm0 and Nm1), forms the basic differential pair and two PMOS transistors (Pm0 and Pm1) forms the active current mirror load. Active current mirror load provides the gain and also converts the differential output into single ended output. Bias current source of 100 micro ampere in bottom is used to bias all transistors of single stage OPAMP in saturation region. The two transistors in a differential pair provide a simple means of steering the tail current to one of the two destinations and the small signal gain of the circuit is the function of tail current. The small signal gain of the differential pair with the current source loads is in the range of 10 to 20 in submicron technologies. The voltage gain of single stage OPAMP is given by the expression

$$A_v = G_m . R_{out} \qquad 1.$$

Here G_m is the trans conductance of an OPAMP and .R_{out} is the output impedance. to the varying available spectrum. Using a Trust-Worthy algorithm, it improves the trustworthiness of the Spectrum sensing in CR-Networks.

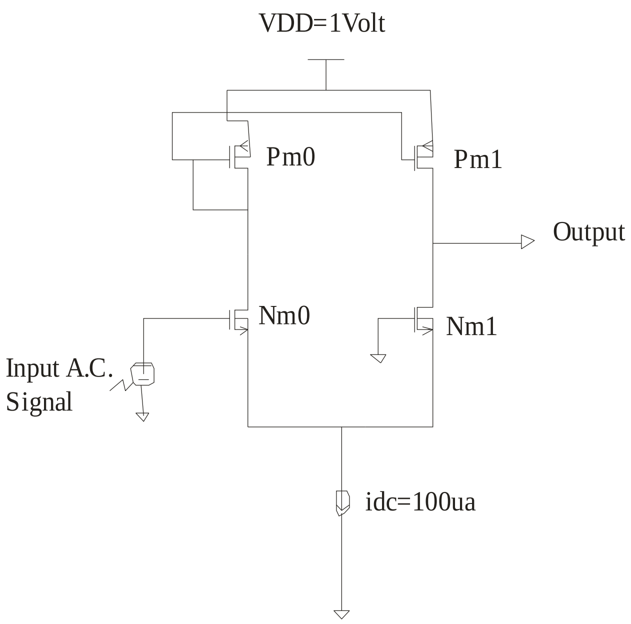

Figure 1. Single Stage CMOS Operational Amplifier.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

II. MATERIALS AND METHODS

A. Conventional Active Band pass Filters using OP-AMPs.

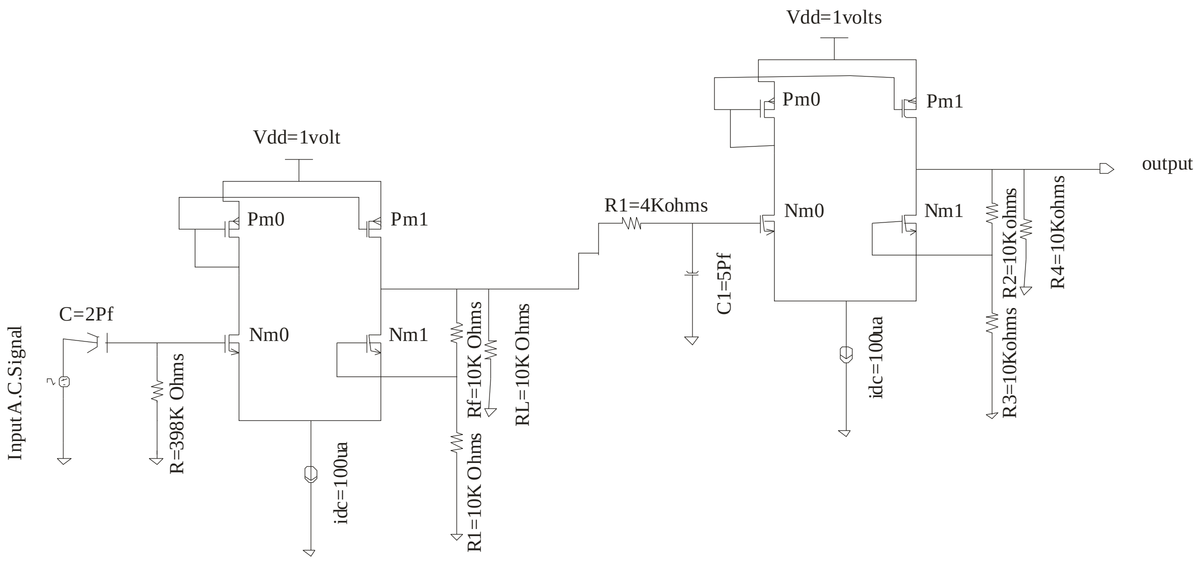

Figure 2. Conventional Active Band Pass Filter.

In the above mentioned figure the sinusoidal signal of frequency 1 MHZ varying between -0.8 to 0.8 volts is applied at the input of Active band pass filter and finally filtered output is obtained at the output terminal . Designing equations used for the calculation of center frequency, 3 db bandwidth and Q factor of active band pass filter are mentioned as below.

f_l is the low cutoff frequency of the active low pass filter and its expression is given as below.

$$f_l = \frac{1}{2\pi RC} \qquad 2.$$

Here C is the capacitance and its value used in the circuit is 2 PF and value of R is 398 K Ohms. From the value of R and C the low cutoff frequency of the filter is calculated as 200 HZ.

f_h is the high cutoff frequency of the active low pass filter, and its expression is given as below.

$$f_h = \frac{1}{2\pi RC} \qquad 3.$$

Here C is the capacitance and its value used in the circuit is 5 PF and value of R is 4 K ohms. From the values of R and C high cutoff frequency of the filter is calculated as 8 KHZ.

Bandwidth of band pass filter is given by the following expression.

$$\text{Bandwidth} = (f_h - f_l) = 7.8 \text{ KHZ.} \qquad 4.$$

Centre frequency of band pass filter is given by the following expression.

$$f_0 = \sqrt{(f_h \cdot f_l)} = 1.26 \text{ KHZ.} \qquad 5.$$

Where f_h and f_l are cut off frequencies of active low pass and high pass filters respectively.

Selectivity is an important parameter of band pass filter and is denoted by Q and its expression is given by.

$$Q = \frac{f_0}{B} = \frac{1.26\,KHZ}{7.8\,KHZ} = 0.16 \qquad 6.$$

B. Active Band Pass filter employing an OPAMP with the Positive Feedback.

Output impedance of single stage operational amplifier is increased by applying positive feedback in it and this in turn increases its open loop gain. Gain boosted OPAMP is designed using a positive feedback for enhancement of its gain [13]. Noise performance and transconductance of Bulk driven OPAMP is improved by using positive feedback in

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

it [14]. Positive feedback is applied to the folded cascode OPAMP for its DC gain enhancement [15]. Positive feedback applied single stage OPAMP is used for designing of active band pass filter. Q factor and pass band gain are obtained for the active band pass filter and found higher as compare to that of conventional band pass filter. Value of resistances, capacitances, supply voltage and bias current source in active band pass filter are same as that of conventional active band pass filter.

C. Proposed Active Band Pass filter.

Two stage OPAMP is a topology of OPAMP which provides high gain, medium output swing and high power dissipation. Low power two stage CMOS OPAMP is designed using a current buffer compensation strategy for providing better stability to it [16]. Two stage CMOS OPAMP is designed using particle swarm optimization algorithm for getting required functionality and performance specifications [17]. Two stage OPAMP design is proposed for a balance between its noise performance and power consumption [18]. Proposed active band pass filter is designed using an OPAMP which incorporates the two stage OPAMP topology and positive feedback topology which is discussed above. Open loop gain of an OPAMP increased a lot due to both of these topologies and hence the Q factor and pass band gain of active band pass filter designed using this OPAMP. Q factor and pass band gain obtained for this active band pass filter is found higher as compare to the active band pass filter designed using positive feedback applied OPAMP. Values of resistance, capacitance, voltage supply and Bias current source is same as in conventional active band pass filter. Circuit diagram of two stage OPAMP with positive feedback is mentioned as below.

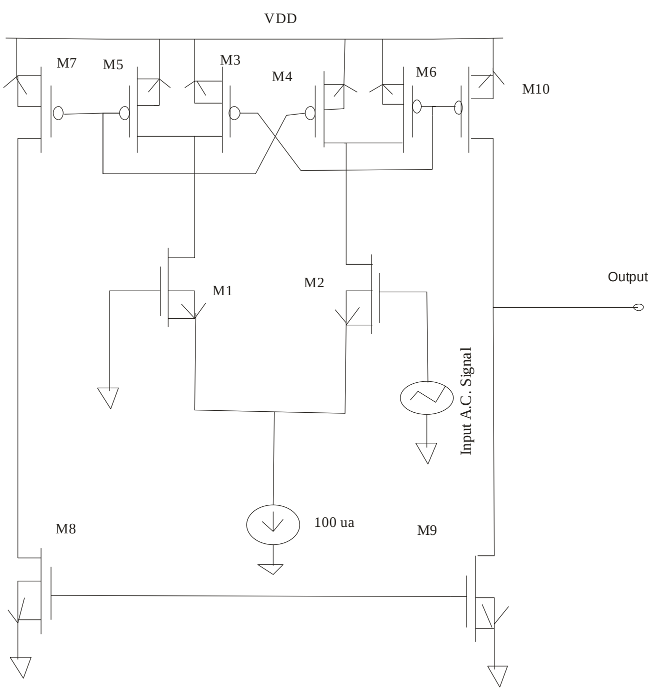

Figure 3. Two Stage OPAMP with Positive Feedback.

Cross coupled transistors M3, M4, M5 and M6 generates the positive feedback in two stage OPAMP mentioned above.

III. RESULT AND DISCUSSION

Simulation results shows frequency response of the conventional active band pass filter, active band pass filter employing positive feedback OPAMP and proposed active band pass filters and the input signal applied to them.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

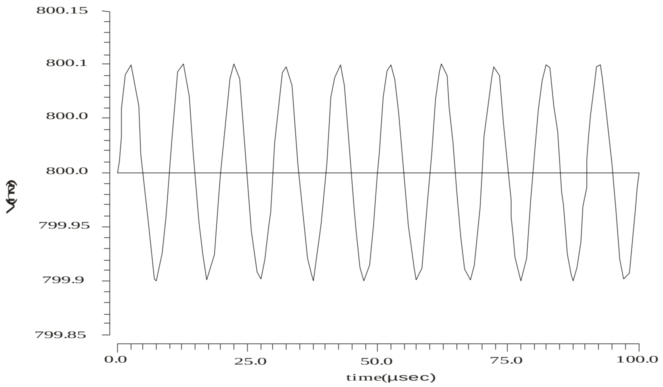

Figure 4. Input Voltage Swing of Input Signal applied to Active Band Pass Filters.

The input AC signal of 100 micro volt with dc level of 0.8 volts is applied between the start time of 0 micro seconds and stop time of 100 micro seconds.

a) Conventional active band pass filter.

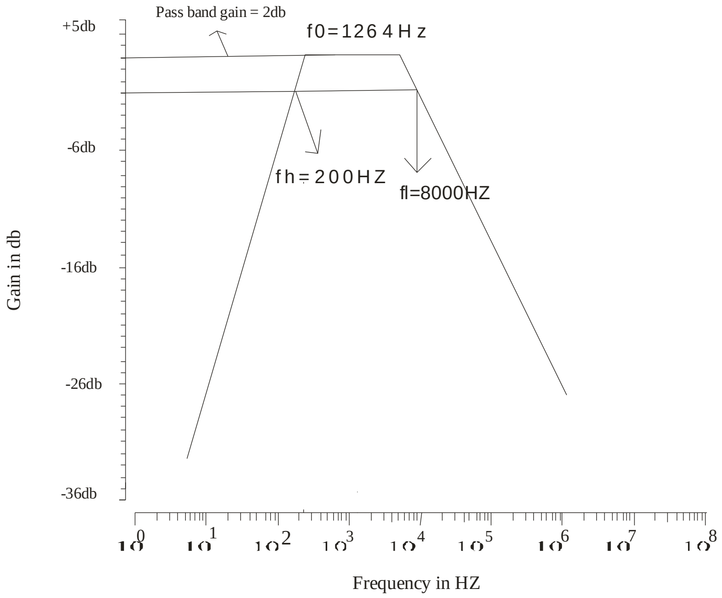

Figure 5. Frequency Response of Conventional Active Band Pass filter.

From the above graph it can be seen that frequency response is obtained between the start frequency of 1 HZ and stop frequency of 100 MHZ. Cut off frequency of active high pass filter is obtained as 200 HZ and cut off frequency for active low pass filter is obtained as 8 . It is also clear from the figure that center frequency of active band pass filter is obtained as 1264 HZ, pass band gain, 3db bandwidth and Q factor of the active band pass filter is obtained as 2 db, 7.8 KHZ and 0.16 respectively.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

b) Active band pass filter employing an OPAMP with the Positive Feedback.

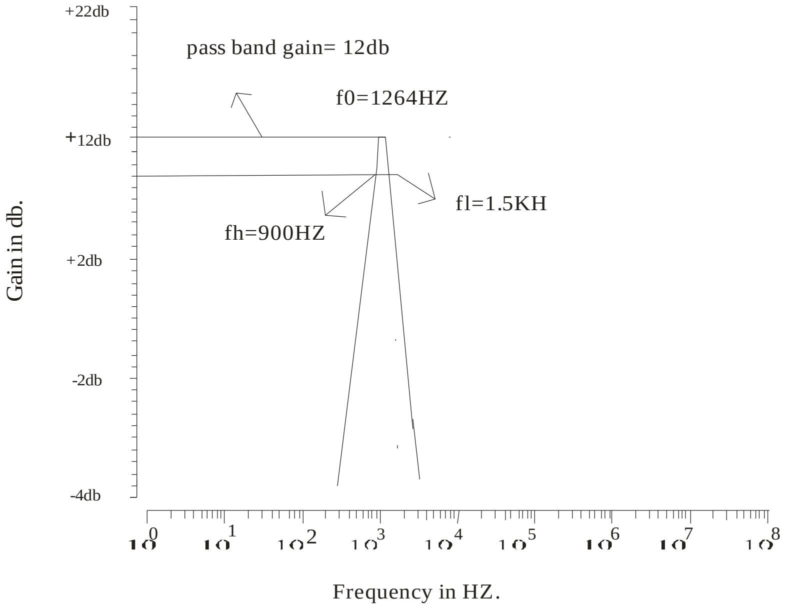

Figure 6. Frequency Response of Active Band Pass filter employing Positive Feedback.

From the above mentioned figure it is clear that 3 db bandwidth of active band pass employing single stage OPAMP with positive feedback filter is reduced to 0.6 KHZ from 7.8 KHZ, pass band gain is increased from 2db to 12db and this leads to the increase in Q factor from 0.16 to 2.10.

c) Proposed active band pass filter employing two stage OPAMP with the positive feedback .

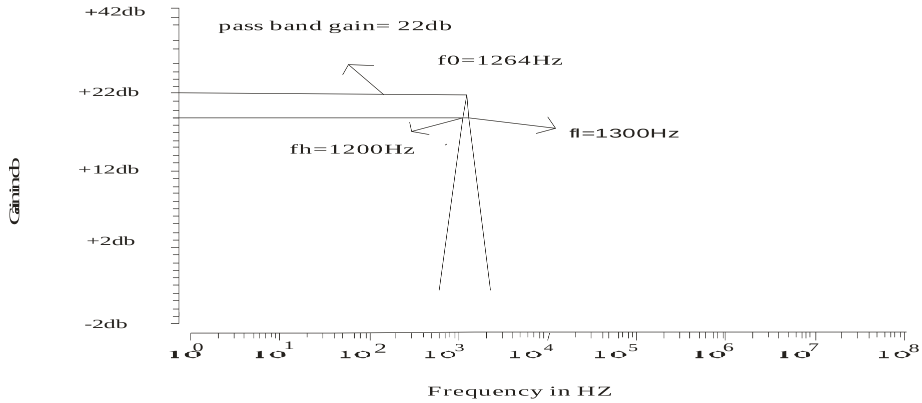

Figure 7. Frequency Response of Proposed Active Band Pass Filter.

From the above mentioned figure it is clear that Pass band gain of proposed active band pass filter is boosted from 2 db to 22 db, 3db bandwidth is reduced from 7.8 KHZ to 0.1 KHZ and this leads to the boosting in Q factor from 0.16 to 12.64. Besides the pass band gain and Q factor noise and power dissipation is also calculated for active band pass filters.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

Table mentioned below shows the comparison of parameters like Pass band gain, Q factor, noise and power dissipation of conventional active band pass filter, active band pass filter employing positive feedback applied single stage OPAMP and proposed active band pass filter.

Table 1. Comparison of the Parameters of Active Band Pass Filters.

Conventional active band pass filter.				Active band pass filter employing positive feedback OPAMP.				Proposed active band pass filter employing two stage OPAMP with positive feedback.			
Pass Band Gain.	Q factor	Noise	P_d	Pass band Gain	Q factor	Noise	P_d	Pass band Gain	Q factor	Noise	P_d
+ 2db	0.16	1.20e -11	300u watt	+12db	2.10	1.25e-10	400u watt	+22db	12.64	1.21e -11	450u watt

IV.CONCLUSION

This paper gives insight into the application of an operational amplifier as an active band pass filter. Selectivity and Pass band gain both are very important parameters for checking the performance of any band pass filter. From the above table it can be concluded that proposed active band pass filter exhibits a high pass band , high Q factor and low power consumption. Proposed active band pass filter is dedicated for superhetrodyne communication receivers. Highly selective band pass filter improves the performance of superhetrodyne receivers.

REFERENCES

[1] Behzad Razavi, "Design of Analog CMOS and Integrated Circuits," Tata McGraw Hill edition, 2002.
[2] Hesam Amir-Aslanzadeh, Erik J.Pankratz, Edgar Sanchez Sinencio, "A 1-V +31 dbm IIP3 Reconfigurable, Continuously Tunable Power Adjustable Active- RC Low Pass Filter," IEEE Journal of Solid State Circuits, vol.44, no.2, pp.495-508, 2009.
[3] Fang Lin, Xinyu Yu, Sumant Ranganathan, Tom Kwan, "A 70 dB MTPR Integrated Programmable Gain/Bandwidth Fourth-Order Chebyshev High-Pass Filter for ADSL/VDSL Receivers in 65 nm CMOS," IEEE Journal of Solid State Circuits, vol.44, no.4, pp.1290-1297, 2009.
[4] A. Becker-Gomez, U.Cilingiroglu, J. Silva Martinez, "Compact Sub-Hertz OTA-C filter Design with Interface-Trap Charge Pump," IEEE Journal of Solid State Circuits, vol.38, no.6, pp.929-934, 2003.
[5] Christoph TZschoppe, Alexander Richter, Markus Schulz, Corrado Carta, Frank Ellinger, "A 60MHz OTA-based IF filter for wireless wake-up receivers with 115 ns settling time," Microwave Conference, 2016, Germany.
[6] Saeed Ghamari, Gabriele Taseelii, Cyril Boterron, Pierre – Andre Farine, "Design Methodology for Controlled Q Resonators in OTA based Filters," Radio Frequency Integrated circuit Symposium, 2015.
[7] K. Ghosh, B.N. Ray, "Design of New High Order OTA-C Filter Structure and its Specification based Testing," International Symposium on VLSI Design and Test, 2014.
[8] Kasturi Ghosh, Mousmi Bhanja , "Realization of Second Order Log filter with OTA using State Space Representation," International Conference on Informatics, Electronics and Vision, 2012.
[9] Vijay Kumar, Pardeep Kumar, Dharam Vir, "Design of Tunable Versatile Filter Using Operational Transconductance Amplifier," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol.4, no.3, pp.1323-1334, 2015.
[10] Rahul Kumar, D.S.Ajnar, P.K.Jain, "Design of Biquad Universal Filter Using Operational Transconductance Amplifier in 180 nm Technology," International Journal of Engineering Research and Applications, vol.5, no.5, pp.120-125, 2014.
[11] Arnab Pramanik, A.K. Gupta, "Implementation of Low Frequency Band Pass Filter by 3 Stage OTA based Floating Active Inductor," Communication, Control and Intelligent Systems, 2015.
[12] Mezyad M. Amourah, Randall L.Gieger, "Gain and Bandwidth boosting Techniques for High Speed Operational Amplifiers," International Symposium on Circuits and Systems, 2001.
[13] Subhra Chakraborty, Abhishek Pandey, Vijay Nath, "A Novel 116db Operational Amplifier design using Positive Feedback," International Conference on Electricals, Electronics, Signals, Communication and Optimization, 2015.
[14] Abhishek Tiwari, Sheetal U. Bhandari, "Improvement in Noise Performance and Transconductance using Positive Feedback in Bulk Driven Operational Amplifier," International Conference on Computing Communication Control and Automation, 2015.
[15] Sina Farahmand, Hossein Shamsi, "Positive Feedback Technique for DC Gain Enhancement of Folded Cascode OPAMP," International New Circuits and Systems Conference, 2012.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

[16] Sachin K. Rajput , B.K. Hemant, "Two Stage High Gain Low Power OPAMP with Current Buffer Compensation," Global High Tech Congress in Electronics, 2013.
[17] Pankaj P. Prajapati, Mihir V. Shah, "Two Stage CMOS Operational Amplifier Design using Particle Swarm Optimization Algorithm," IEEE UP Section Conference on Eectrical, Computer and Electronics, 2015.
[18] J.Mahattanakul, J.Chutichatuporn, "Design Procedure for Two Stage CMOS OPAMP with Flexible Noise Power Balancing Scheme," IEEE Transactions on Circuits and Systems, vol.52, no.8, pp.1508-1514, 2005.