



State Variable based Tow Thomas Biquad filter using Gm-C Universal design using 180nm CMOS Technology

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ABSTRACT

Filters, especially analog filters, are employed in many different systems that electrical engineers embark upon to design. Even many signal processing systems that are apparently digital, often contain one or more analog continuous-time filters either internally or as interface with the real-time world, which is analog in nature. In this paper we are working on 180nm CMOS technology approaching state variable filter with Tow Thomas biquad filter. "State variable filters" treat both the signal and its derivatives as variables. This configuration offers the most precise implementation, at the expense of many more circuit elements. All three major parameters (gain, Q & ω_0) can be adjusted independently, and low-pass, high-pass, and band-pass outputs are available simultaneously.

Key words: Thomas biquad filter, Low Pass, High Pass, Gain.

1. INTRODUCTION

The natural international is analog. In a wide form of sign processing programs there are still unavoidable deployments of analog sign processing strategies and circuits, that too in spite of the dominance of Digital Signal Processing inside the gift system design eventualities. The reality of digital dominance however, several analog capabilities/circuits; along with amplification, rectification, continuous time filtering, A/D and D/A conversion, are impossible to get replaced by virtual machine strategies no matter their advances.

Analog circuits are, thus, conclusively quintessential in lots of programs consisting of; processing of natural alerts, digital communicate, disk pressure circuitry, processing of sign from acoustic/optical sensors and optical/wi-fi receivers [4-6]. In yet few extra areas along with synthetic neurons and neural community, beneficial in packages like picture processing and speech reputation, are better made by using VLSI (or by blended signal VLSI) wherein analog circuit design strategies play very critical role. In reality, excessive speed digital gadget design will become in large part an analog layout, consequently, all designs are, greater or less, in a manner analog. Hence, the surprising fulfillment of digital method cannot render the analog layout strategies

out of date; as an alternative it can only create infinite possibilities and new challenges for analog circuit designers. Historically, the primary analog signal processing standards developed, advanced and grew with involvement of tube devices. Later it in addition evolved its smaller circuit configuration variations with bipolar devices up till center of twentieth century. Then, after the arrival of integrated circuit production centers the most trendy excessive-benefit differential amplifier came in to lifestyles and the complete domain of analog circuit analysis/synthesis were given transformed. Analog design were given completely ruled by the Integrated Circuit (Op-Amp), henceforth referred as voltage mode Op-Amp or in brief VOA. It is widely recognized that during analog circuit layout the overall purpose Op-Amp like 741, that is characterised via excessive enter impedance, low output impedance, excessive voltage advantage & excessive CMRR (Common Mode Rejection Ratio), can be used to carry out almost any given analog characteristic. However, the internal structure of ordinary Op-Amp, mainly the 2 level architecture, imposes basic restrict at the overall performance of resulting circuit. Since, with the bad comments, the near loop configuration has a finite advantage bandwidth product, consequently, there is an unavoidable battle between benefit and bandwidth. Also the finite benefit bandwidth product restricts the usable frequency range of conventional Op-Amp primarily based circuit to typically approximately 1% of the benefit bandwidth manufactured from the op-amp hired. Although there are strategies by using which this trouble may be overcome inclusive of lively repayment or the so called active-R design, these methods have their very own barriers [7]. For example, within the first approach, the full numbers of additives required are doubled for any given function whereas inside the 2nd approach the signal level has to be necessarily stored low otherwise the finite slew rate of the Op-amp outcomes in the slew prompted distortion at the output. Besides the above points, there are a number of primary functions which includes recognition of non-inverting differentiator /integrator, non-inverting /inverting voltage managed modern-day source and variable gain instrumentation amplifier wherein case traditional Op-amp based totally circuits rent more than the minimum variety of energetic and passive additives. In addition, these kinds of referred to programs compulsorily require using a

number of matched resistors. Thus, these circuits additionally be afflicted by the drawback that any mismatch inside the thing values may not simplest result in degradation of the meant feature however might also lead to instability. Because of the above stated barriers and downsides of VOA primarily based circuit, the designers have frequently toiled with the thoughts of introducing or searching new type of energetic building blocks to triumph over these difficulties.

The basic concept of modern-conveying and its embodiment as modern conveyor1 changed into brought via Smith and Sedra in 1968 [1]. Subsequently, this became called the primary technology cutting-edge conveyor (CCI) and afterward, in 1970, they introduced a more flexible modern conveyor, named as 2d era modern-day conveyor (CCII) [2].

2. RELATED WORK

A 3-enter and single-output voltage-mode everyday biquadratic filter out with high enter impedance, the usage of nice operational transconductance amplifiers (OTAs), one plus-kind 2nd-technology contemporary conveyor (CCII) and two capacitors, is supplied thru Jiun-Wei Horng (2003)[1]. The proposed circuit can recognise all the same old filter out responses, this is, highpass, bandpass, lowpass, notch and allpass filters, from the equal configuration. The proposed circuit has no requirements for thing matching situations.

In this paper, a new voltage-mode famous biquadratic filter configuration with 3 inputs and a single output has been supplied. The new circuit offers numerous advantages together with excessive enter impedance, using simplest OTAs, one plus-kind CCII and capacitors, the versatility to synthesize lowpass, bandpass, highpass, notch and allpass responses from the identical configuration without problem-matching conditions.

A novel electronically tunable flexible voltage-mode time-commemorated biquad clear out via the use of two single-output-operational transconductance amplifiers (OTAs), one differential difference modern-day-day conveyor (DDCC) and two capacitors is proposed. Hua-Pin Chen *et. Al.* (2008) [2], proposed circuit, which can be used as both a 4-input unmarried-output not unusual clear out or a single-input 3-output multifunction clean out with the identical topology. Besides, the modern day circuit offers the subsequent quality capabilities: popularity of all the non-inverting and inverting biquadratic clear out signs from the identical configuration, no want to rent inverting-type enter indicators, no need to thing-matching situations and espresso passive sensitivity universal overall performance.

A new flexible typical voltage-mode filter with four inputs and three outputs has been furnished. The proposed circuit may be acted as each a multifunction voltage-mode clear out with a single input and three outputs and a regular voltage-mode filter with four inputs and a single output. Therefore, the voltage-mode clean out proposed on this paper is extra versatile than the normal one with a single enter and 3 outputs or the commonplace one with multiple inputs and a

single output. The proposed configuration does not employ outside resistors thus is an active-C filter. Moreover, the new circuit still offers the following blessings: (i) no want to problem-matching situations, (ii) no want to hire inverting-kind enter indicators and (iii) all the non-inverting and inverting popular clean out functions can be obtained with out converting circuit topology.

Roman Šotner *et. Al.* (2009) [3], dealt with RC energetic biquad jogging inside the so-referred to as present day mode (CM). The layout approach uses best three transconductors (OTA) with the minimal essential extensive variety of outputs and with simplest three passive grounded elements. The proposed clear out has easy circuit configuration imparting all wellknown transfer features consisting of immoderate-bypass (HP), band-pass (BP), low-bypass (LP), band-reject (BR) and all-pass (AP). Electronic tuning and unbiased adjusting of the first-class trouble and bandwidth of BP clear out is feasible. The provided circuits are confirmed through PSpice simulations the usage of OTAs on transistor stage of abstraction. The linear parasitic consequences of the actual lively factors in every endorsed circuit are in short stated. Experimental verification is also given. Designed networks may be utilized in masses of packages such as antialiasing filters, in excessive-speed statistics telecommunication structures, for sign processing inside the cable modems, in regulation and dimension strategies and so on.

In this paper the format of multifunctional biquad became supplied using OTAs with unmarried enter and 3 outputs because the active devices. For PSpice simulation models of OTAs on transistor degree of abstraction with rapid bipolar generation had been used. Simple circuit form (only three energetic and passive factors), smooth digital tuning of the cutoff frequency and opportunity of fixing of the BP clean out bandwidth can be considered as essential blessings of this multifunctional biquad. It is shown that 3 active blocks with three cutting-edge outputs are sufficient for common filtering circuit. Experimental effects hinted that the clear out is appropriate for operating in video band frequency variety. Resistance R can be smooth discovered out via OTA, simply so focus of this form in covered form (IC-s) is viable. Mentioned results showed theoretical assumptions.

3. METHODOLOGY

Electrical filters permeate present day electronic structures a lot that it is vital for an electronic circuit or system designer to have at the least some primary knowledge of these filters. The electronic systems that employ filtering technique are varied, including communications, radar, patron electronics, army, medical instrumentation, and area exploration. An electrical clear out is a community that transforms an electrical sign implemented to its enter such that the signal on the output has distinctive traits, which can be said within the frequency or the time area, relying upon the utility. Thus, in some instances the filter out reveals a frequency-selective property, which include passing some frequency additives inside the enter sign, even as rejecting (preventing) indicators at different frequencies [8]. The traits of filters started round 1915 with the advent of the electric wave filter

by using Campbell and Wagner, in reference to cellphone communication. The early design advanced with the aid of Campbell, Zobel, and others made use of passive lumped factors, namely, resistors, inductors, and capacitors, and become based totally on picture parameters (see as an instance, Ruston and Bordogna, 1971). This is known as the classical filter idea and it yields fairly right filters with out very state-of-the-art mathematical techniques.

Modern clear out principle owes its foundation to Cauer, Darlington, and others, and the improvement of the concept commenced in the Thirties. Major advancements in clear out idea passed off in the 1930s and Nineteen Forties. However, the filters have been still passive systems the use of R, L, and C elements. One of the maximum critical applications of passive filters has been within the design of channel financial institution filters in frequency department multiplex cellphone systems. Introduction of silicon incorporated circuit (IC) era collectively with the improvement of operational amplifiers (OAs) shifted the point of interest of filter out designers in the 1960s to realise inductorless filters for low-frequency (voice band three hundred–3400 Hz) programs. Thus ensued the technology of active-RC filters, with OA being the active element. With computer-managed laser trimming, the values of the resistances in thick and thin movie technologies might be managed appropriately and this led to giant use of such low-frequency (up to approximately 4 kHz) lively-RC filters in the pulse code modulation (PCM) gadget in telephonic conversation. Owing to the difficulty in fabricating huge-valued resistors inside the equal [9-11] manner as the OA, low-frequency filters couldn't be constructed as monolithic gadgets. However, the remark that positive configurations of capacitors and periodically operated switches ought to function approximately as resistors caused the introduction of completely monolithic low-frequency filters. The creation of complementary metallic-oxide semiconductor (CMOS) transistors facilitated this alternative with monolithic capacitors, CMOS OAs, and CMOS transistor switches. The switched-capacitor (SC) filters have been soon recognized as being in the magnificence of sampled-statistics filters, because the switching brought sampling of the indicators. In comparison, the active-RC filters are within the category of continuous-time filters, since the sign processed should theoretically take on any viable value at a given time [12].

In the SC method, sign voltages sampled and held on capacitors are processed via voltage amplifiers and integrators. Following the SC filters, researchers quickly invented the complementary method where present day signals sampled and transferred directly to parasitic capacitances at the terminals of metallic-oxide semiconductor (MOS) transistors could be processed similarly via cutting-edge mirrors and dynamic memory garage (to provide the impact of integration). This caused switched-contemporary (SI) filtering strategies, which have turn out to be popular in all-virtual CMOS era, in which no capacitors are wanted for the filtering method. In recent instances, several microelectronic technology (which includes Bipolar, CMOS, and BiCMOS) [13], filter out architectures, and design techniques have emerged leading to superb absolutely integrated lively filters. Moreover,

sophisticated digital and analog functions (inclusive of filtering) can coexist on the identical very massive-scale incorporated (VLSI) circuit chip. An instance of the life of numerous integrated energetic filters in a VLSI chip is illustrated in Figure 1. This depicts the ground plan of an ordinary PCM codec chip [14].

Together with the development in semiconductor era, new kinds of semiconductor amplifiers, which include the operational transconductance amplifier (OTA), and modern conveyor (CC) have become realizable within the past due Nineteen Seventies and onwards. This opened up the possibility for implementation of high-frequency filters (50 kHz to ~three hundred MHz) in monolithic IC era. An OTA may be effectively configured to produce the characteristic of a resistor and an inductor, so that normal excessive-frequency passive LCR filters can be without problems changed via appropriate combos of monolithic OTAs and capacitors leading to operational transconductance amplifier capacitor (OTA-C) (or gm-C) filters. Introduction of CCs within the 1990s endorsed researchers to investigate signal processing in phrases of signal currents in preference to sign voltages. This initiated sports inside the place of current-mode (CM) sign processing and as a result CM filtering, even though the idea of realizing modern transfer features is going lower back to the past due Fifties and the 1960s (Thomas, 1959; Hakim, 1965; Bobrow, 1965; Mitra, 1967, 1969; Daggett and Vlach, 1969). In reality, a very easy and direct approach of acquiring a current switch function consciousness from that of a voltage transfer feature employing the concept of transposition turned into advanced as early as 1971 via Bhattacharyya and Swamy (1971). Since for CM signal processing, the impedances on the input and output ports are presupposed to be very low, the attendant bandwidth can be very big. Modern CMOS gadgets can operate at very low voltages (around 1V direct cutting-edge (DC)) with small currents (0.1mA or less). Thus, CM sign processing the use of CMOS era entails low-voltage high-frequency operation. The intermediate frequency (IF) ($f_o \sim$ one hundred MHz) filter out in a modern cell communication (worldwide system cell, GSM) gadget has normal specifications as presented in Table 1.1. The required filters can be implemented as monolithic IC filters within the CM, using several CC building blocks and included capacitors [16].

Considering packages in extremely wideband ($\sim 10\text{--}30\text{GHz}$) communique systems, monolithic inductors ($\sim 1\text{--}10\text{ nH}$) can be without problems found out in present day submicron CMOS technology [17]. Thus, passive LCR filter structures can be applied for absolutely monolithic very wideband digital filters. Advances in IC generation have additionally brought about the introduction of several varieties of virtual ICs. These might be used to process an analog sign after sampling and quantization. This has led to virtual techniques for implementing an electronic clear out (i.e., virtual filters), and the region falls below the overall class of digital signal processing (DSP).

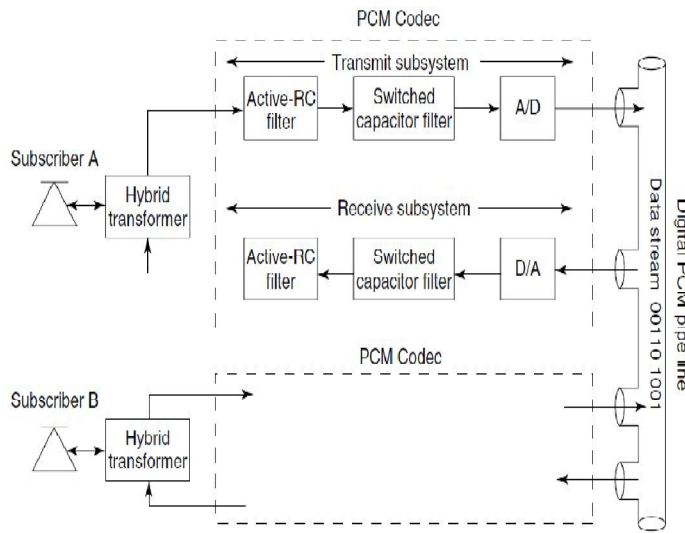


Figure 1: A typical VLSI analog/digital system floor plan

“state variable filters” treat both the signal and its derivatives as variables. This configuration offers the most precise implementation, at the expense of many more circuit elements. All three major parameters (gain, Q & ω_0) can be adjusted independently, and low-pass, high-pass, and band-pass outputs are available simultaneously. Note that the low-pass and high-pass outputs are inverted in phase while the band-pass output maintains the phase [19]. The gain of each of the outputs of the filter is also independently variable. With an added amplifier section summing the low-pass and high-pass sections the notch function can also be synthesized.

We are using analog CMOS IC Design for approaching State Variable Filter with Tow Thomas Biquad filter. Implementation Topology used is Gm-C based (OTA-C) on 180nm CMOS technology for this we are using SPICE (TANNER-EDA: TSPICE) toll.

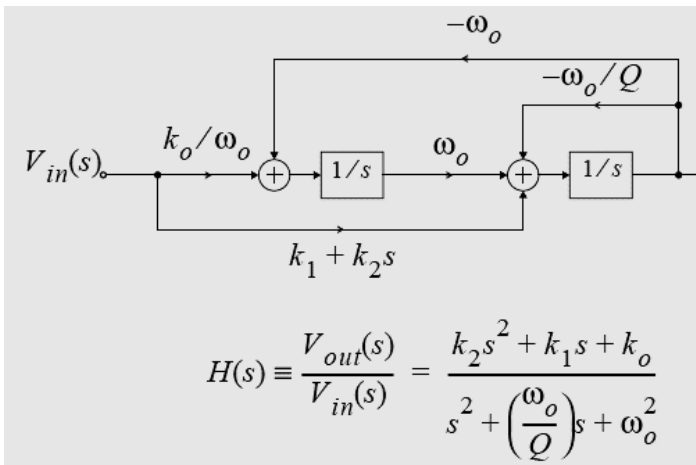


Figure 2: Proposed work

$$\omega_0 = \sqrt{\frac{G_{m1} \cdot G_{m2}}{C_1 \cdot C_2}} \quad \text{and} \quad Q_0 = \frac{\sqrt{G_{m1} \cdot G_{m2} \cdot C_1}}{G_{m3}^2 \cdot C_2}$$

Where G_{m1} , G_{m2} and G_{m3} are obtained by OTAs as integrator and kept in negative feedback loop. For $C_1 = C_2 = 100\text{pF}$ in 180 nm CMOS, G_m required for target frequency of 1.3 MHz would be around 800 μS (from above equation).

4. RESULT AND DISCUSSION

In this work we have focused on low Cost-Compact Design which achieved using minimum order and OTAs (II order here). We also achieved linear Operation by using dual power supply mode ($\pm 1.8 \text{ V}$) and Universal Operation achieved at least three responses from a single design. Technological Compatibility achieved using conventional CMOS also target frequency is 1.3 MHz with nominal Quality (Qo) factor of value 1. Fig 3 shows the Circuitual design of OTA being employed in filter

Multiple output current driving OTA Design (for Filter applications)

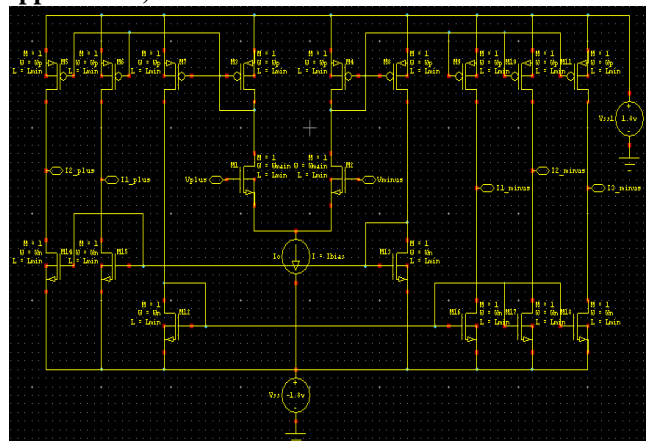


Figure 3: Circuitual design of OTA being employed in filter

We have done Dc analysis found $G_m = 861 \mu\text{S}$ at $V_{dd} = \pm 1.8 \text{ V}$.

Verifying OTA performing Integration (First Order Filter)

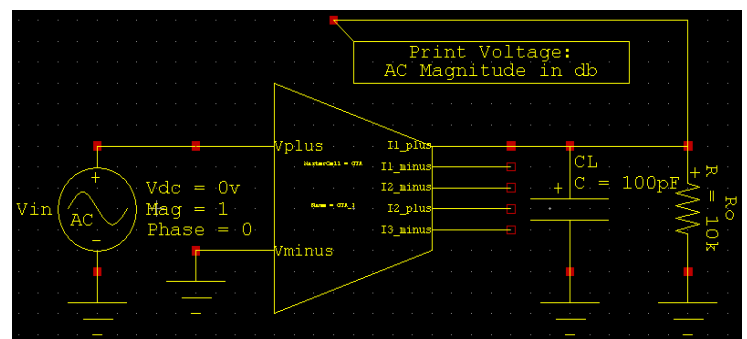


Figure 4: AC simulation setup for OTA performance evaluation

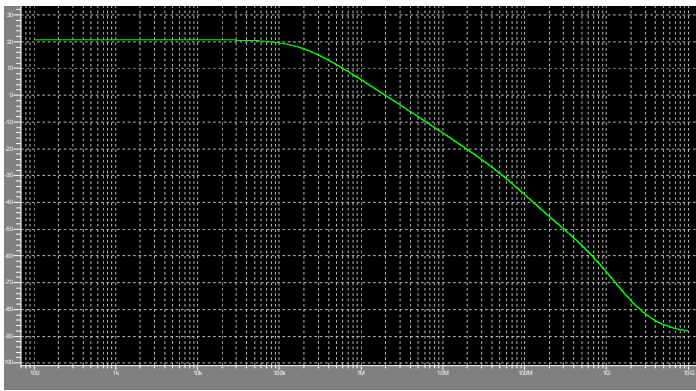


Figure 5: Frequency response of OTA indicating high gain

Fig 4 shows the AC simulation setup for OTA performance evaluation. In this fig 5 Integrator simulation confirms the cut off frequency of 1.28 MHz for the designed OTA. Hence now we can proceed for filter implementation.

Filter Design and simulation results:

We are working on Gm-C based Second Order Universal KHN Filter (Voltage mode operation) on Low Paas, Band Paas and High Paas shown in fig 6.

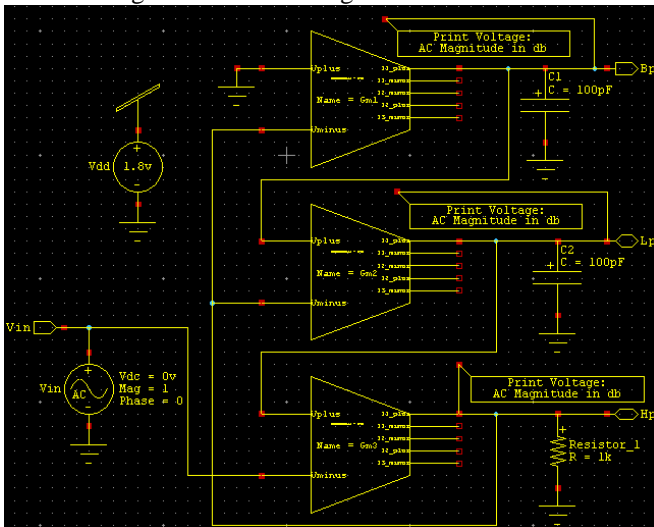


Figure 6: Proposed biquad filter design and simulation setup for LP, HP and BP responses

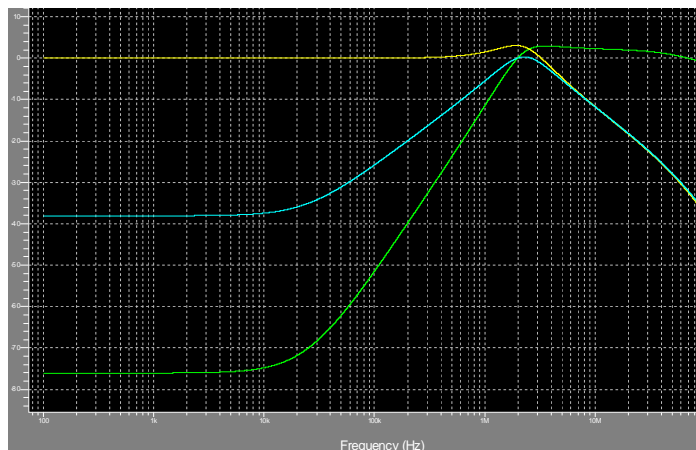


Figure 7: Frequency response validation of filter setup (fig. 6)

For all three responses indicated in fig 7 with $C1= C2= 100\text{pF}$ and $Gm1= Gm2= Gm3$, $f_0 = 1.28 \text{ MHz}$ hence $\omega_0= 8 \text{ M rad/s}$ due to similar components, we found $Q_0 = 1$ (unity) as $BW= 1.28 \text{ MHz}$ and Power dissipation is 1867 uWatt

Now we are working on Gm-C based Second Order Universal KHN Filter (Current mode operation) on Low paas, Band Paas and Band Reject shows in fig 8.

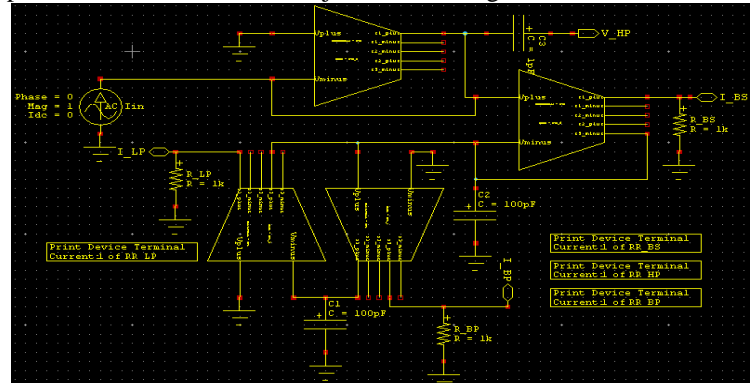


Figure 8: Proposed biquad filter design and simulation setup for LP, Notch and BP responses

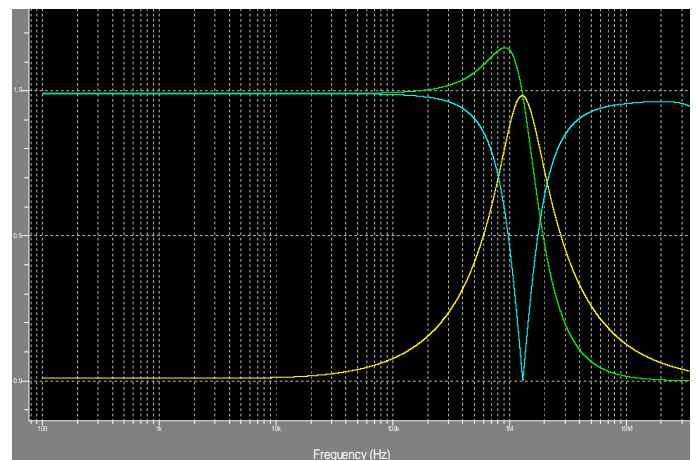


Figure 9: Frequency response validation of filter setup (fig. 8)

We found for all three responses shown in fig 9 with $c1= C2= 100\text{pF}$ and $Gm1= Gm2= Gm3= Gm4$ and $f_0 = 1.28 \text{ MHz}$ hence $\omega_0= 8 \text{ M rad/s}$ due to similar components $Q_0 = 1$ (unity) as $BW= 1.28 \text{ MHz}$ Power dissipation: 980 uWatt .

5. CONCLUSION

An OTA based active filter design was implemented in 180nm CMOS technology, targeting Medium Frequency range (1-2 MHz). The topology was based on State variable approach, hence minimum number of integrators kept in negative feedback were employed to achieve multiple frequency responses with a quality factor of 1. The choice of quality factor is almost arbitrary and has only been envisaged in order to make use of symmetrical stages, which reduces the mathematical complication to a greater extent.

REFERENCES

- [1] Jiun-Wei Horng, " High input impedance voltage-mode universal biquadratic filter using two OTAs and one CCII " *Int. J. Electronics*, 2003, Vol. 90, NO. 3, 185–191.
<https://doi.org/10.1080/00207210310001595365>
- [2] Hua-Pin Chen et. al., "Electronically tunable versatile voltage-mode universal filter", *Int. J. Electron. Commun. (AEU)* 62 (2008) 316 – 319.
<https://doi.org/10.1016/j.aeue.2007.04.008>
- [3] Roman Šotner et. al., " Current-Controlled Current-Mode Universal Biquad Employing Multi-Output Transconductors", *Radioengineering*, vol. 18, no. 3, September 2009.
- [4] Lee, Chen-Nong. "Multiple-mode OTA-C universal biquad filters." *Circuits, Systems and Signal Processing* vol. 29, no. 2, 2010, pp. 263-274.
- [5] Kumngern, Montree, Boonying Knobnob, and Kobchai Dejhan. "Electronically tunable high-input impedance voltage-mode universal biquadratic filter based on simple CMOS OTAs." *AEU-International Journal of Electronics and Communications*, vol. 64, no. 10, 2010, pp. 934-939.
- [6] Wu, Jie, and Chang-Yan Xie. "New multifunction active filter using OTAs." *International Journal of Electronics* vol. 74, no. 2, 1993, pp. 235-239.
<https://doi.org/10.1080/00207219308925830>
- [7] Chen, Hua-Pin, Yi-Zhen Liao, and Wen-Ta Lee. "Tunable mixedmode OTA-C universal filter." *Analog Integrated Circuits and Signal Processing* vol. 58, no. 2, 2009, pp. 135-141.
- [8] Kumngern, Montree, Pichai Suksaibul, and Boonying Knobnob. "High-input impedance four-input one-output voltage-mode universal filter using OTAs." In *Information and Communication Technology, Electronic and Electrical Engineering (JICTEE)*, 2014 4th Joint International Conference on, pp. 1-4. IEEE, 2014
- [9] Abuelma'atti*, Muhammad Taher, and Abdulwahab Bentrchia. "A novel mixed-mode OTA-C universal filter." *International Journal of Electronics* vol. 92, no. 7, 2005, pp. 375-383.
- [10] Lee, Chen-Nong, and Chun-Ming Chang. "High-order mixed-mode OTA-C universal filter." *AEU-International Journal of Electronics and Communications* vol. 63, no. 6, 2009, pp. 517-521.
<https://doi.org/10.1016/j.aeue.2008.04.004>
- [11] JIE, WU EZZ I. "Universal voltage-and current-mode OTAs based biquads." *International Journal of Electronics* vol. 85, no. 5, 1998, pp. 553-560.
- [12] Sanchez-Sinencio, Edgar, Randall L. Geiger, and H. Nevarez-Lozano. "Generation of continuous-time two integrator loop OTA filter structures." *IEEE Transactions on Circuits and Systems* vol. 35, no. 8, 1988, pp. 936-946.
- [13] R. Sharma, Anurag, " Detect Skin Defects by Modern Image Segmentation Approach, Volume 20, Issue 1, 2020.
- [14] Anurag, R. Sharma, " Modern Trends on Image Segmentation for Data Analysis- A Review", *International Journal of Research and Development in Applied Science and Engineering*, Volume 20, Issue 1, 2020.
- [15] Sun, Yichuang. "Second-order OTA-C filters derived from Nawrocki-Klein biquad." *Electronics letters* vol. 34, no. 15, 1998, pp. 1449-1450.
<https://doi.org/10.1049/el:19981036>
- [16] Wattikornsirikul, Natchayathorn, and Montree Kumngern. "Threeinput one-output voltage-mode universal filter using simple OTAs." In *ICT and Knowledge Engineering (ICT and Knowledge Engineering)*, 2014 12th International Conference on, pp. 28-31. IEEE, 2014.
- [17] Safari, Leila, Shahram Minaei, and Bilgin Metin. "A low power current controllable single-input three-output current-mode filter using MOS transistors only." *AEU-International Journal of Electronics and Communications* vol. 68, no. 12, 2014, pp. 1205- 1213.
<https://doi.org/10.1016/j.aeue.2014.06.011>
- [18] Young Soo Jang et. al., "Development of the cost-effective, miniaturized vein imaging system with enhanced noise reduction", *International Journal of Advanced Trends in Computer Science and Engineering*, Volume 8, No.6, November – December 2019.
<https://doi.org/10.30534/ijatcse/2019/80862019>
- [19] Irma T. Plata1, et. al., "Development and Testing of Embedded System for Smart Detection and Recognition of Witches' Broom Disease on Cassava Plants using Enhanced Viola-Jones and Template Matching Algorithm", *International Journal of Advanced Trends in Computer Science and Engineering*, Volume 8, No.6, Volume 8, No.5, September - October 2019.