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Design of 7th and 9th Order Low Pass Filter with Higher Cut-off Frequency Using 65nm CMOS Technology

Suman Nehra[a] and P.K. Ghosh[b]

[a]Department of Electronics and Communication, College of Engineering and Technology Mody University of Science and Technology Lakshmangarh, India

E-mail: nehra.sumanvlsi@gmail.com, pkghosh.ece@gmail.com

Abstract : 7th and 9th order low pass filter with higher cut-off frequency and less power consumption is introduced in this paper. The filters 7th and 9th order low-pass are synthesized using LC prototype and designed using ladder structure. Proposed floating inductor, and active load resistor is used for the implementation of the circuit. The differential floating active inductor is designed with CMOS and current sources. The floating inductor may be electronically tuned by varying external bias voltage as well as current. The simulations are obtained by using 65nm CMOS technology on Tanner EDA tool 13.0.

Keywords : *Complementary Metal Oxide Semiconductor (CMOS), low pass filter (LPF), active resistor, Power delay product (PDP).*

1. INTRODUCTION

Now a day's integrated circuit technology is mostly used for the integration of any electronic circuits. The improvement of scaled VLSI technologies, associated with the demand for signal processing integrated in a single chip, has extremely good ability for design of analog circuits [1]. Mostly the VLSI circuits in analog consist of amplifiers, filters, oscillators, digital to analog converters and analog to digital converter [2]. The key driving factor for any system is high gain, high packing density, low power dissipation, easy in designing etc. The most important part in analog circuit that should be integrated is analog filters [3]. The performance of general purposed processor and digital signal processing unit has been increased by scaling of CMOS technologies. Advanced and scalable CMOS technologies provide low cost, high integration and good reliability which form digital and analog circuit in a single chip [4].

Filters especially analog filters has a wide range of applications in different areas such as in control system, communication system, military, radar, medical instruments and industrial electronics [5] [6]. Filter is a circuit that transforms an electrical signal at input in such a manner so that the output signal has specified features which may be in terms of frequency or in time domain depending upon the application. Filter is the circuit that works on signal in a frequency dependent manner.

The fundamental nature of a filter can be described by evaluating the frequency dependent behavior of the impedance of inductor and capacitor [7] [8]. Filters can be made from passive components and from active components. Filters that are fabricated from active components have large number of advantages over filters fabricated with passive components. Passive inductor is large in size, unable to work at moderate frequency range; standard values are not very close to each other [9] [10]. So active inductor is preferred for the designing of filters.

In signal processing and in many other applications of analog circuits, low pass filters are mostly used as a basic element, the main function of low pass filter is to pass a band of frequency below a cutoff frequency and reject the band of frequencies above than the cutoff frequency. In this paper 7^{th} and 9^{th} order low pass filters are designed by using proposed differential floating inductor [11] [12].

Paper is organized as: In second part, we introduce filters. Third part presents the experimental results. Fourth part provides the conclusion of the paper.

2. FILTERS

In most of the applications of the filters they require higher order filters. As we increase the order of filter number of components required for the formation of the circuit also increases and the cut off frequency decreases [13] [14]. In stop band the roll off rate will changes at the rate of 20 db/decade for the first order filter, and for second order filter it was 40 db/decade, 60 de/decade for third order filter and so on.

Third order filter is designed by cascading a first order and a second order filter. In similar manner fourth order filter is designed by cascading the two second order filter [15] [16]. Similarly all other higher order filters were designed. Filters can be designed up to any limit, their designing will depend on its application in which it was used. But as we increase the order it will also increase the number of components used in it due to this size of the filter will also increase [17]. Therefore higher order filter are complex in designing and very expensive. For the design of seventh and ninth order fiter active floating inductor is used [18].

The schematic for seventh order RLC low pass filter is shown in fig.1. 7^{th} order low pass filter with proposed active inductor and active resistor is shown in fig.2.

Similarly in fig. 3 we show the RLC topology of ninth order low pass filter and ninth order filter using proposed active inductor and active resistor is shown in fig. 4.

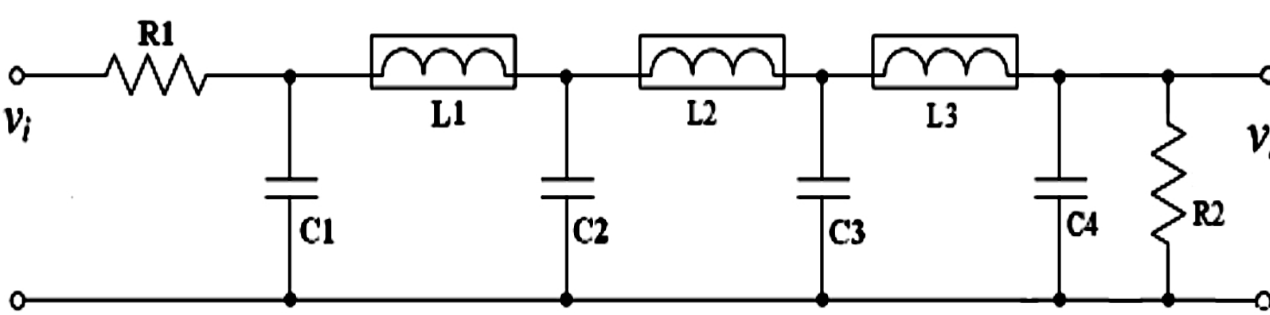

Figure 1: Seventh-order LPF topology

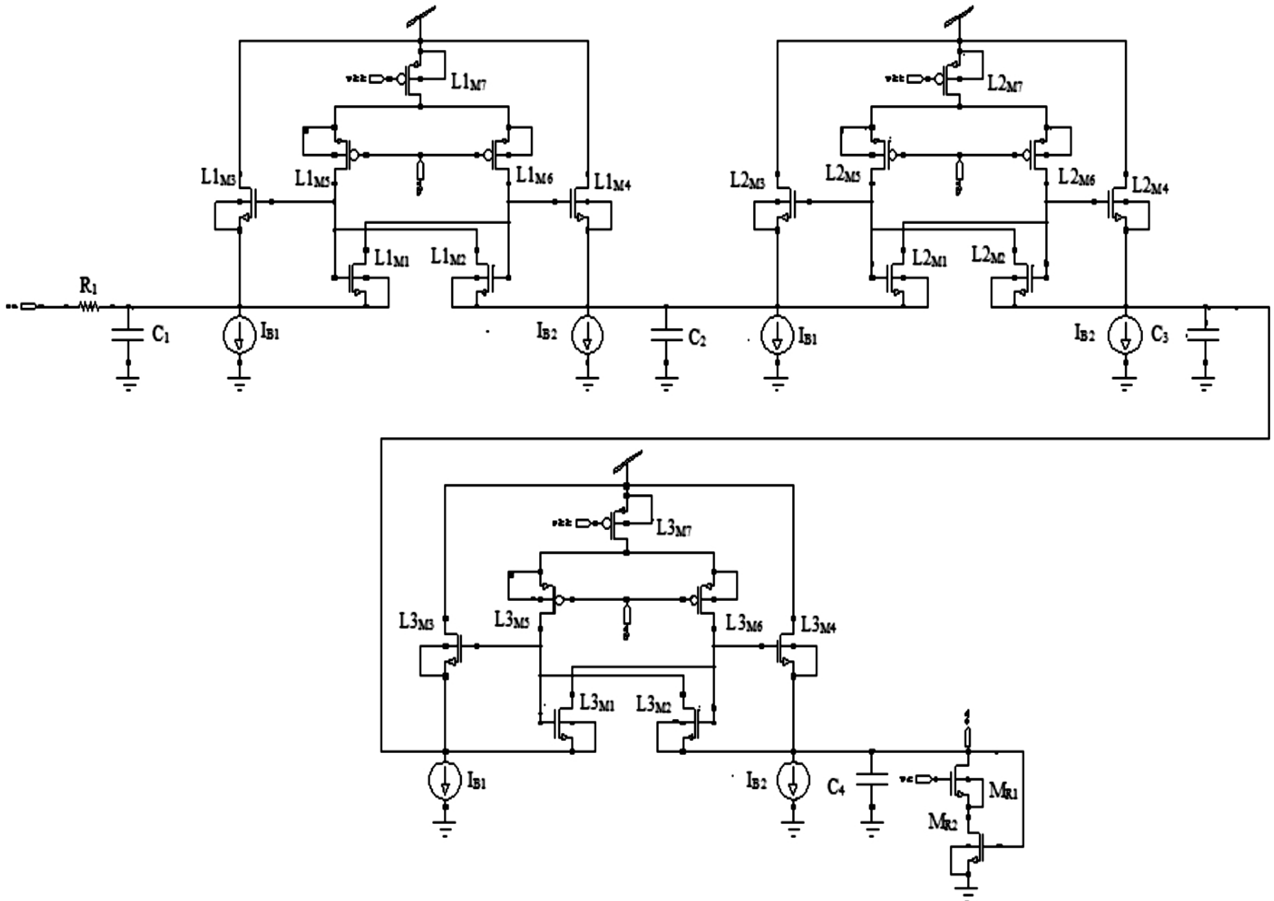

Figure 2: 7th Order LPF using active inductor

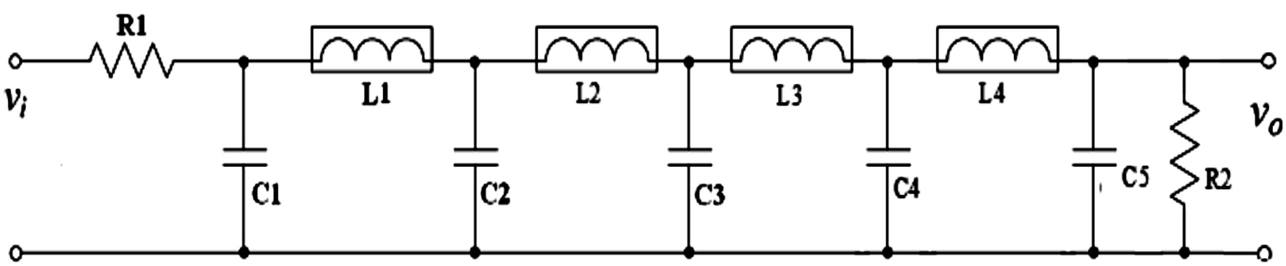

Figure 3: Ninth-order low pass filter topology

3. EXPERIMENTAL RESULTS

The proposed floating inductor and higher order active low pass filters was analyzed by the use TSPICE. 65nm technology is used for experimental result for the circuit implemented with CMOS. Fig. 5 shows response of seventh order active LPF. The variations in 3dB frequencies of seventh order LPF the bias voltage (Vb) is shown in fig. 6 and the variation of 3 dB frequency bias current (IB) shown in fig. 7. These figures reveal that as the filter designed with the proposed floating inductor shows better result than the conventional active inductor.

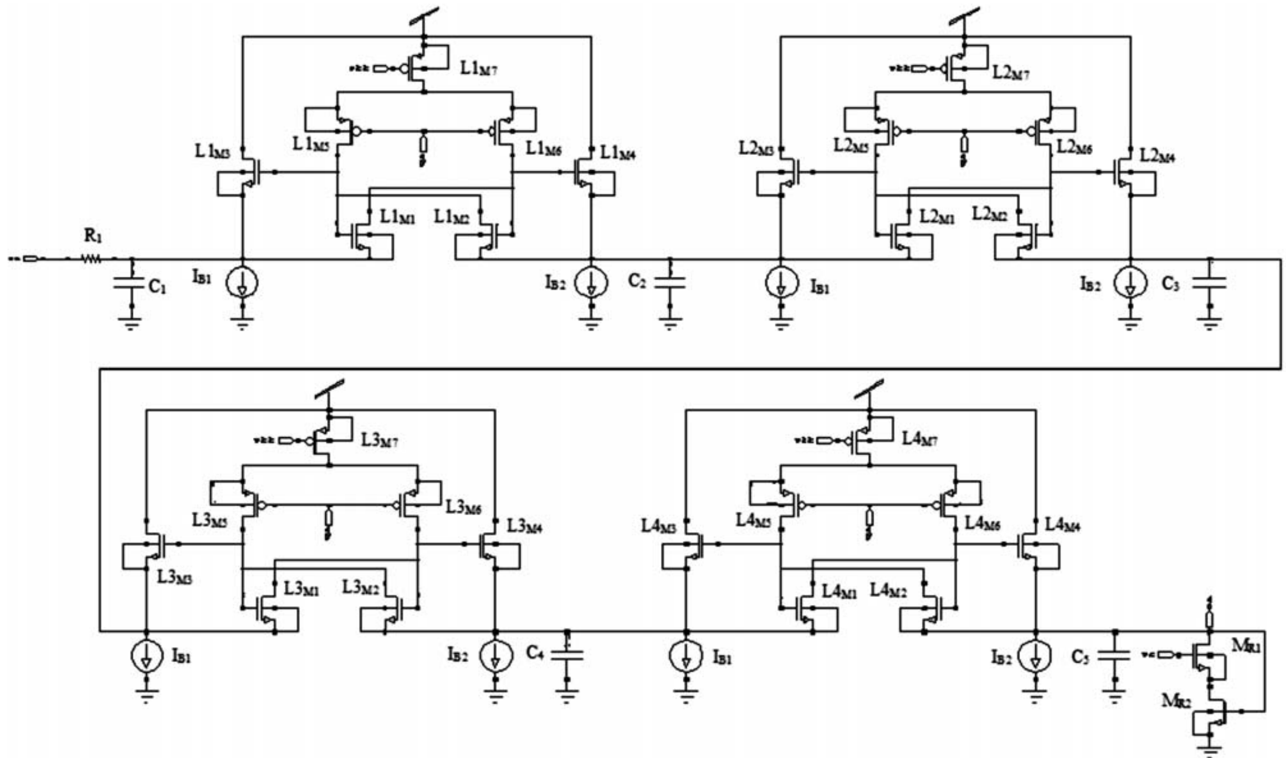

Figure 4: 9th Order LPF using active inductor

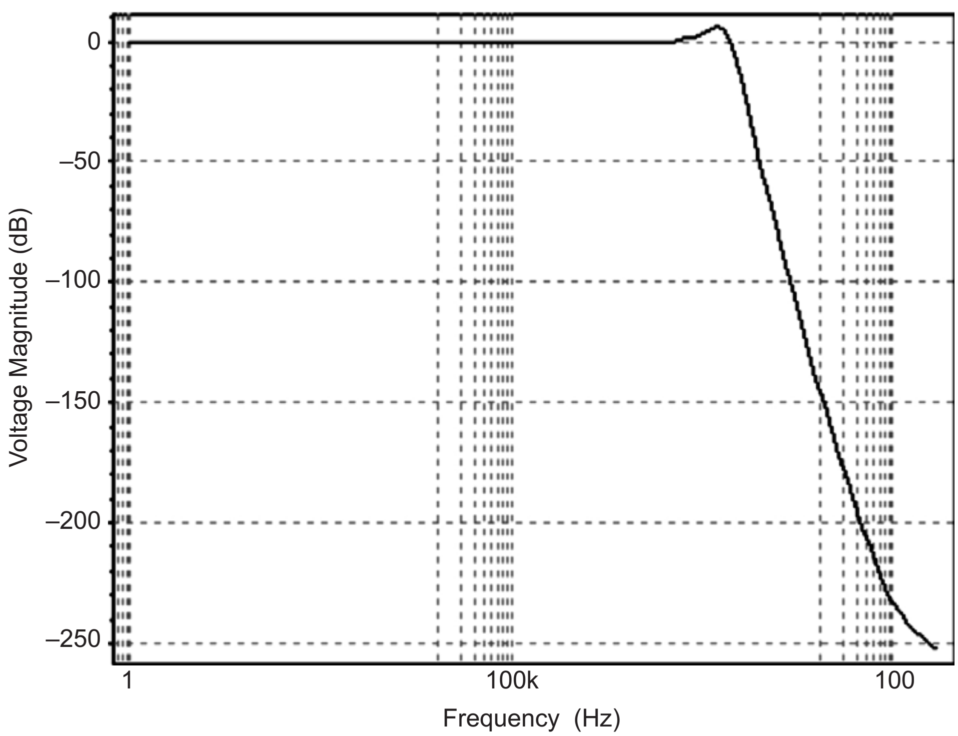

Figure 5: Response of 7th order LPF

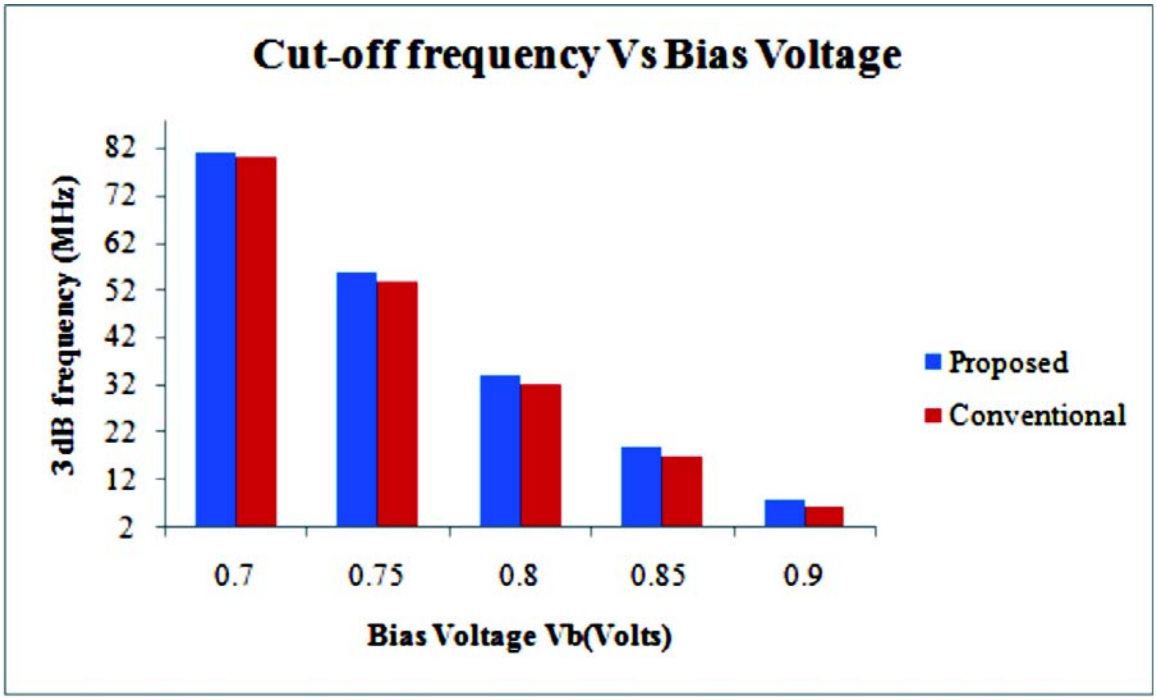

Figure 6: Variation in 3dB frequency with bias voltage for 7th order LPF

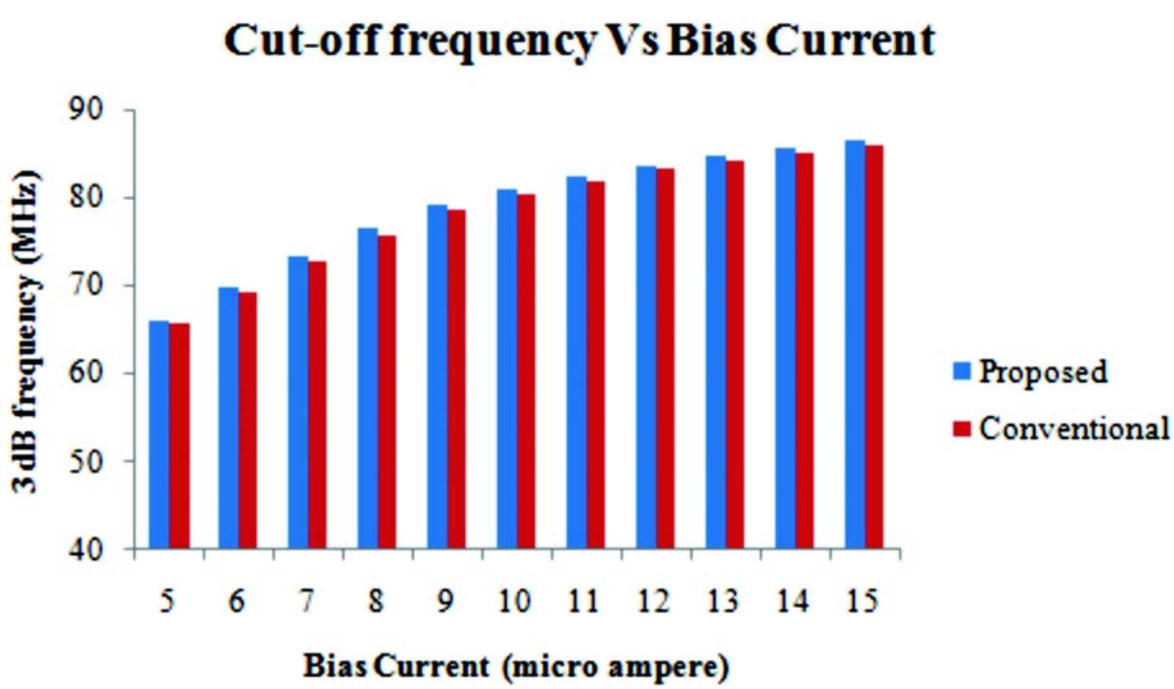

Figure 7: Variation in 3dB frequency with bias current for 7th order LPF

Fig. 8 and fig. 9 shows the variation in power consumption and power delay product with bias voltage for seventh order low pass filter. Filter with proposed inductor shows better results than the filter designed with conventional inductor.

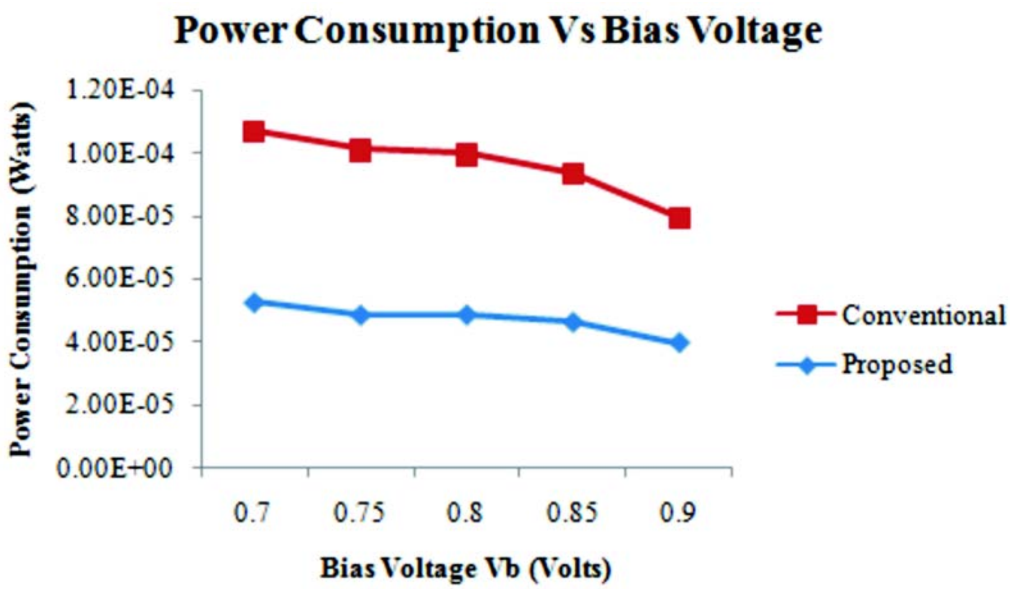

Figure 8: Variation in Power Consumption with Bias Voltage for 7th order LPF

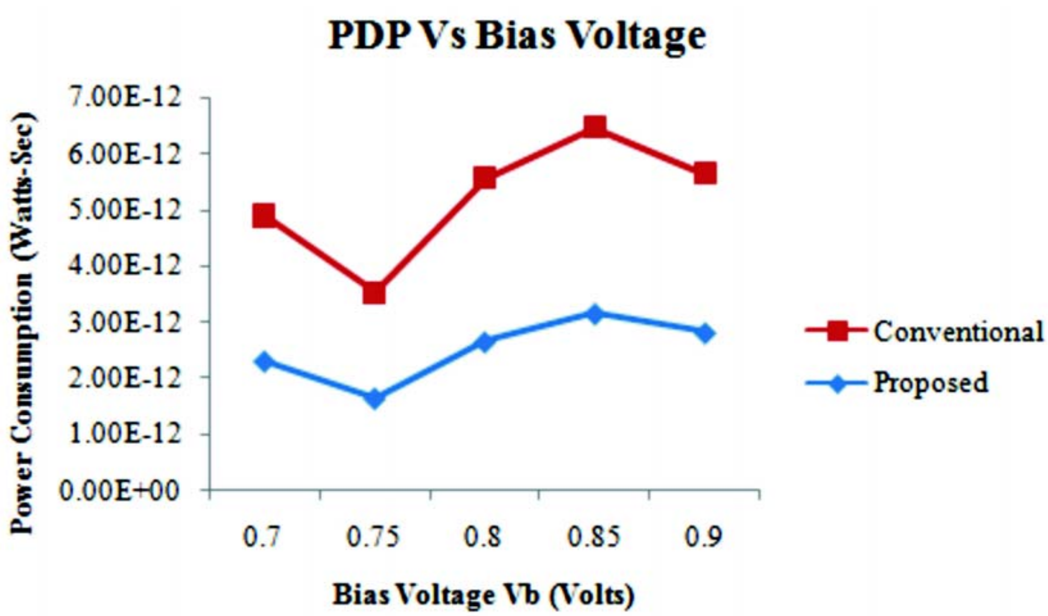

Figure 9: Variation in PDP with Bias Voltage for 7th order LPF

In active filter we can easily change the gain and frequency, they are easy to design and anlyze, they have low power dissipation than the passive filter. As we increase the order of filter number of components required for the formation of the circuit also increases and the cut off frequency decreases.

The response curve of frequency for ninth order low pass filter is shown in fig. 10. For ninth order low pass filter variation in cut off frequency with bias voltage was shown in fig. 11 and variation in 3 dB frequency with bias current was shown in fig. 12. The passband frequency decreases as we increase the order of the filter. So the stopband for the low pass filter approaches to the ideal curve i.e brick wall curve as we increase the order of the filter

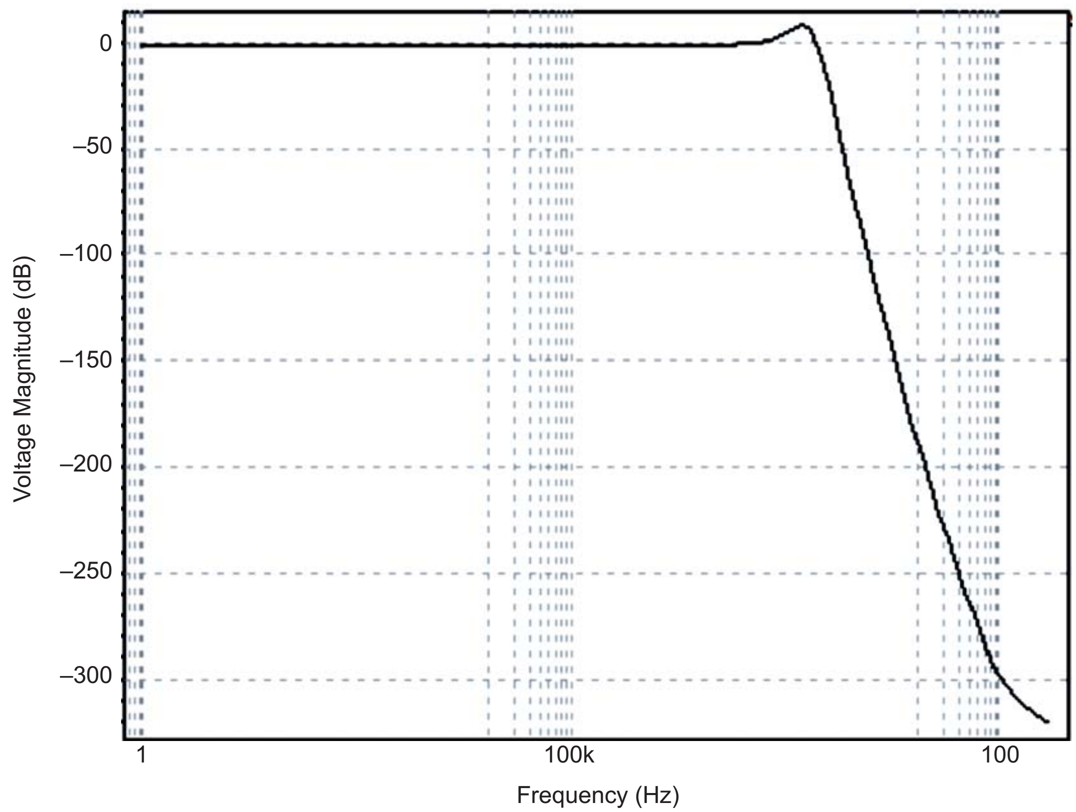

Figure 10: Response of 9th order LPF

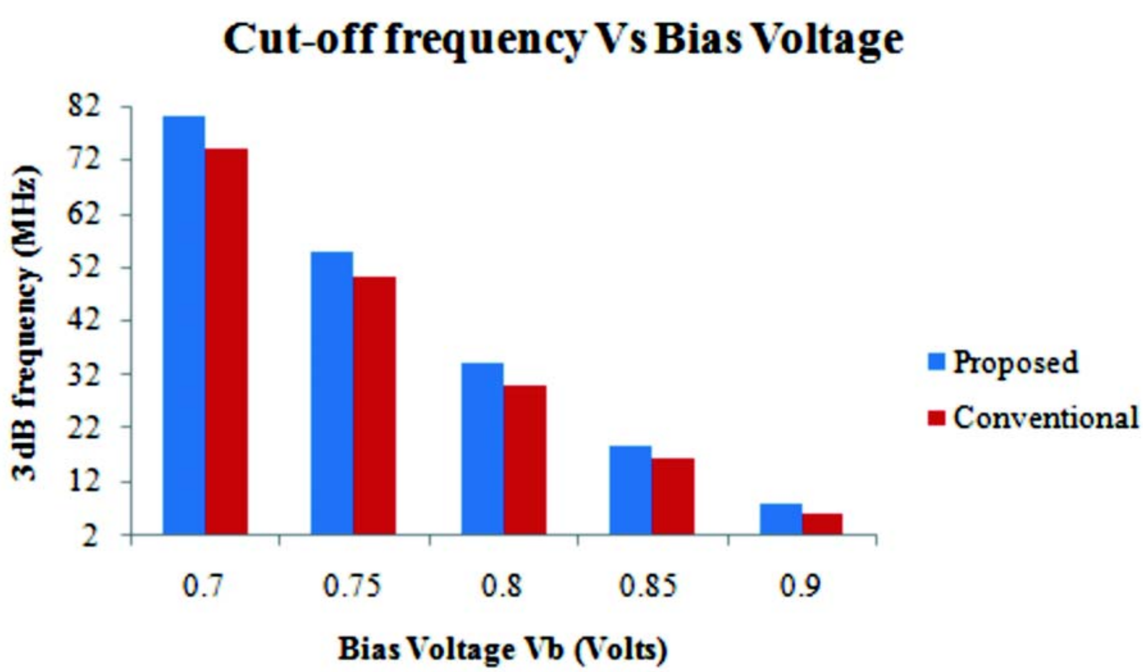

Figure 11: Variation in 3dB frequency with bias voltage for 9th order LPF

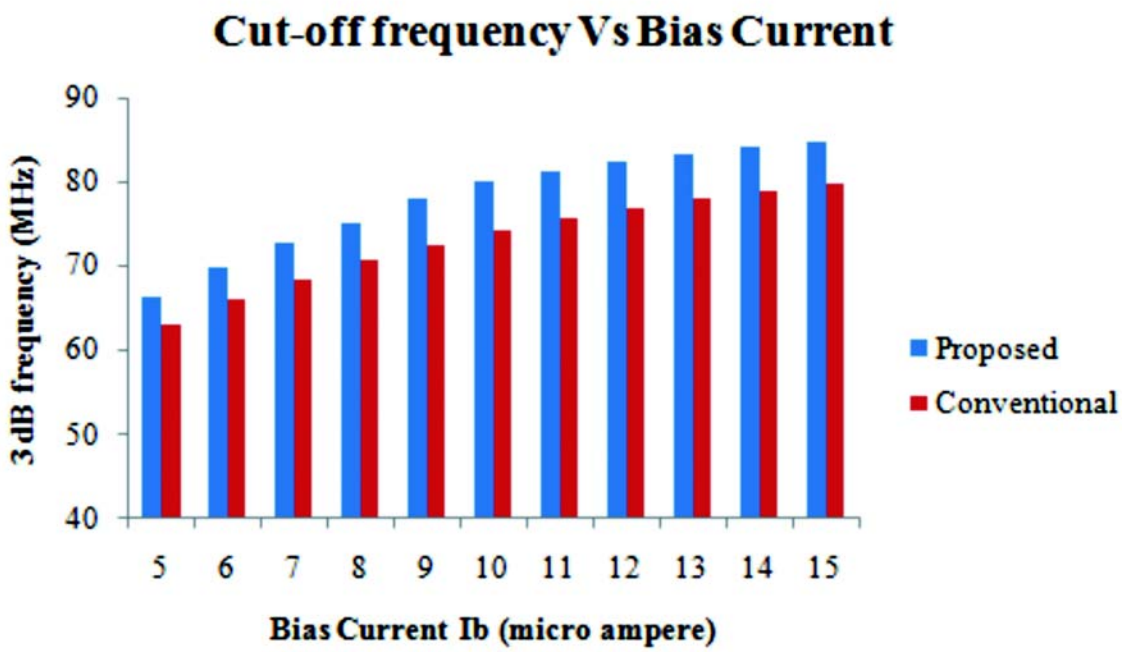

Figure 12: Variation in 3dB 3dB frequency with bias current for 9th order LPF

Variation in power consumption and power delay product with bias voltage was shown in fig. 13 and fig. 14. From these graphs, the conclusion we draw is that the filter with proposed active inductor shows better results than the conventional filter.

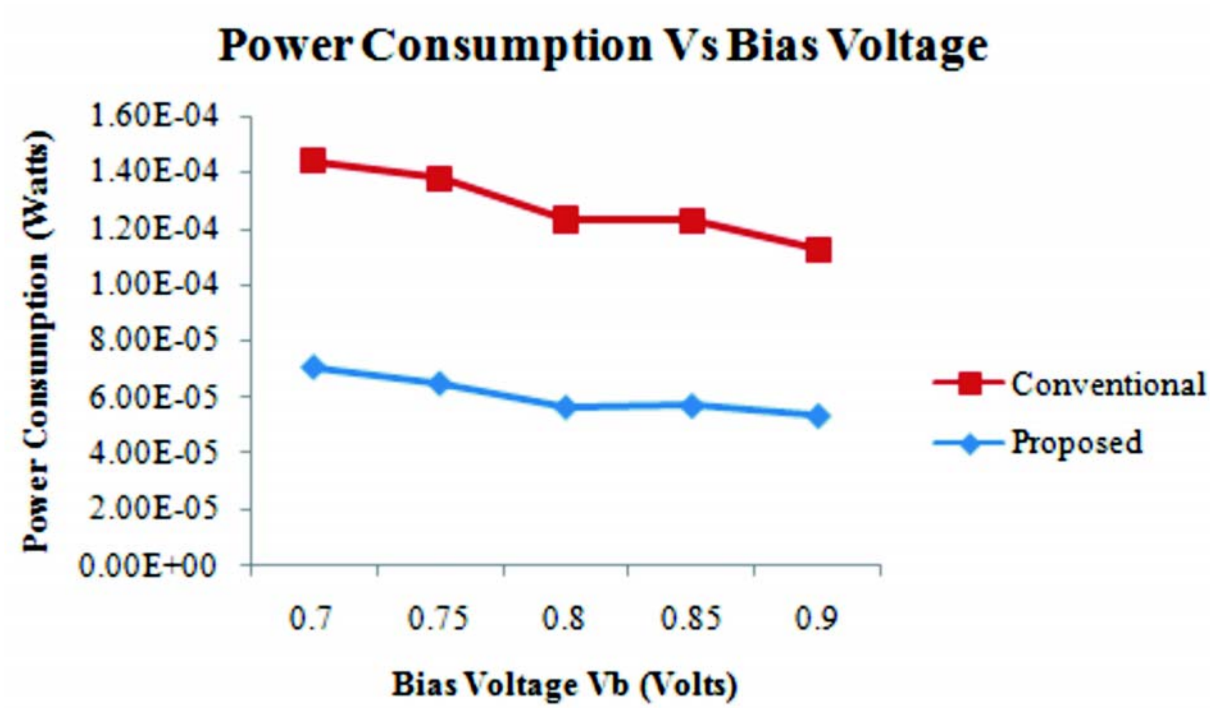

Figure 13: Variation in Power Consumption with bias voltage for 9th order LPF

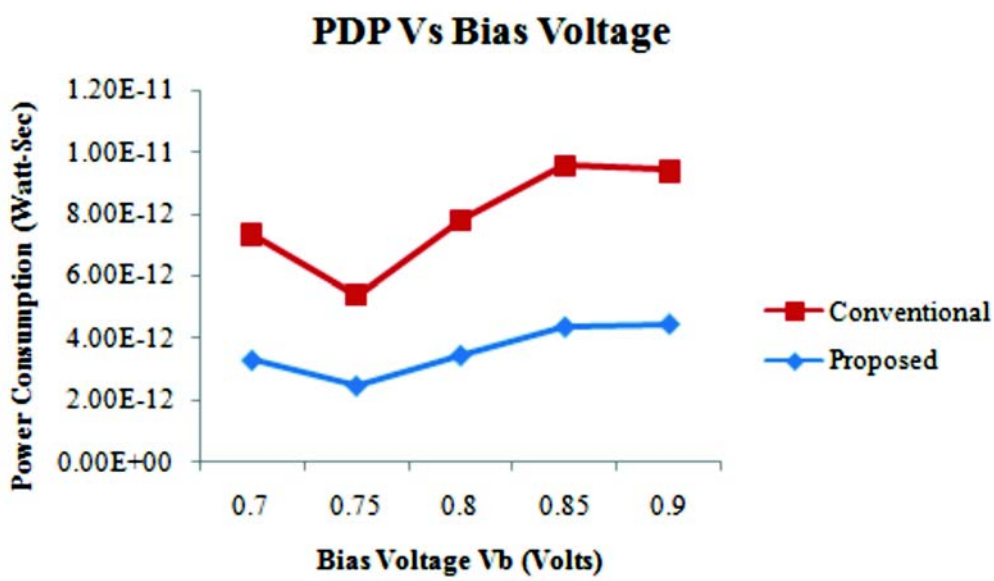

Figure 14: Variation in PDP with bias voltage for 9th order LPF

The response of low pass filter as a function of filter order for 7th and 9th is shown in fig.15.

Variation in cut off frequency with bias voltage and current according to the order of filter was shown in fig. 16 and fig. 17 respectively. The comparison result shows that passband frequency decreases as we increase the order of filter. Fig. 18 and fig. 19 shows the variation power consumption and power delay product with bias voltage according to the order of the filter

Fig. 18 shows that the filter with lowest order *i.e* 7th order has least power consumption than the 9th order low pass filter. There is a increase in the number of components used in the circuit as we increase the order of the filter due to this power consumption of the circuit is also increase. Table 1 provides the simulation results and design parameters used for 7th and 9th order low pass filter.

Figure 15: Response of low pass filter as a function of filter order

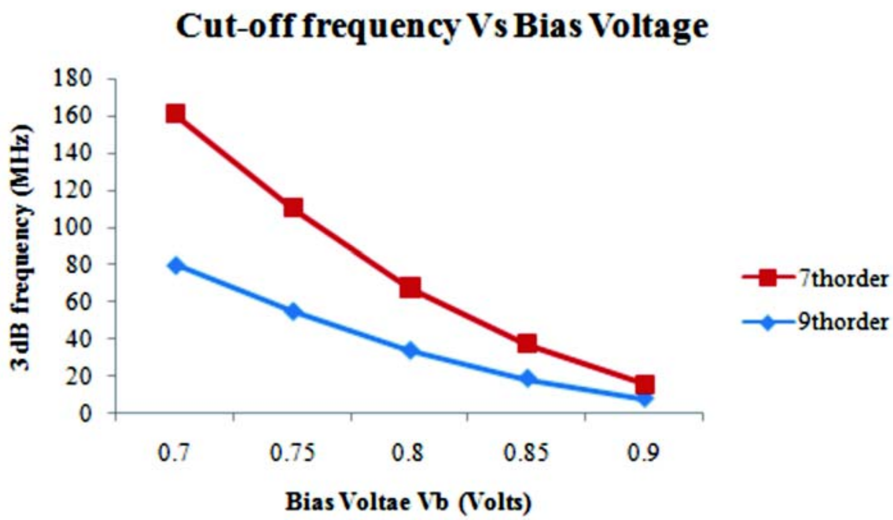

Figure 16: Variation in 3dB frequency with bias voltage according to the order of filter

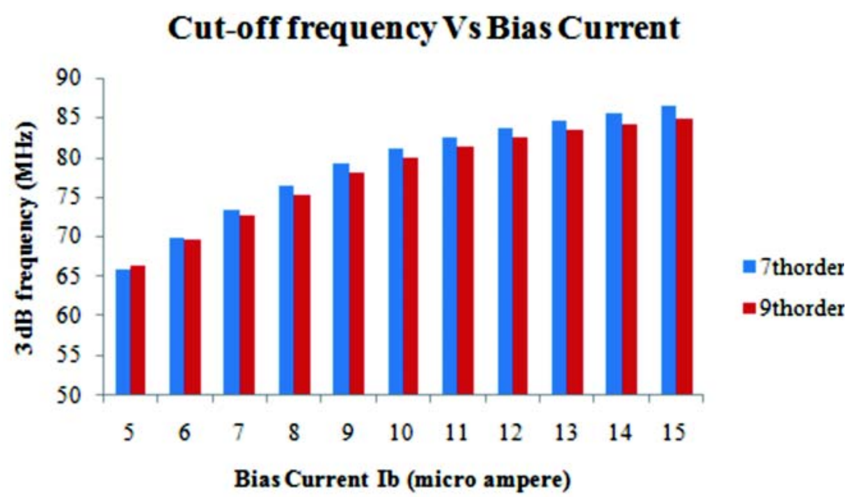

Figure 17: Variation in 3dB frequency with bias current according to the order of filter

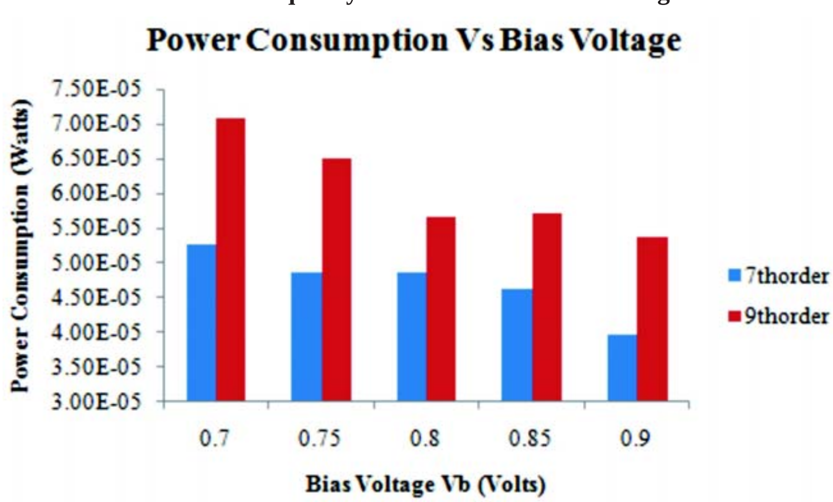

Figure 18: Variation in power consumption with bias voltage according to the order of filter

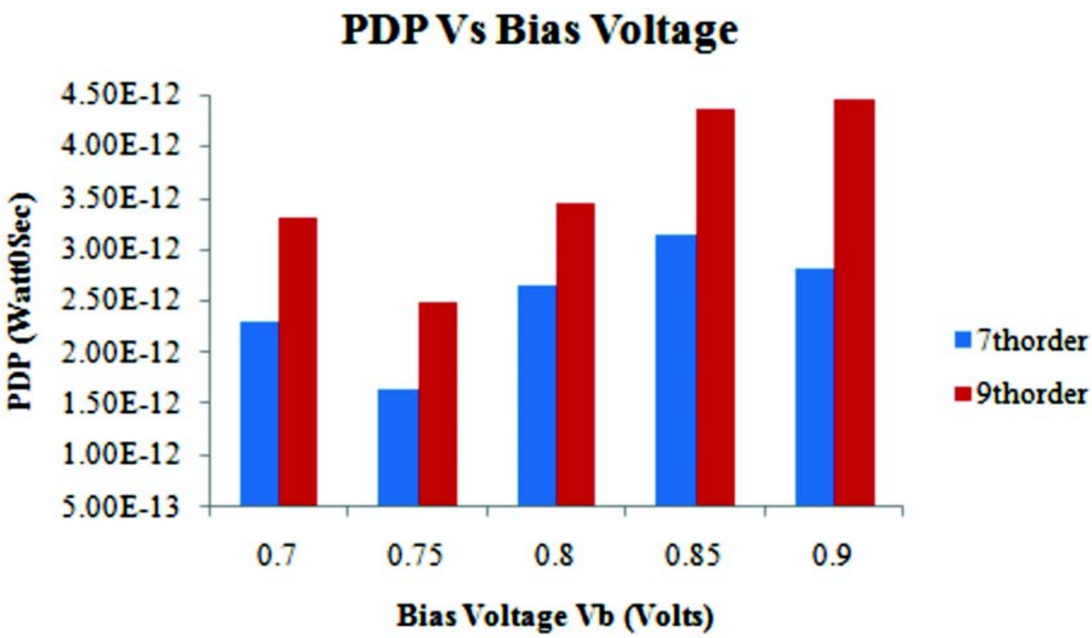

Figure 19: Variation in power delay product with bias voltage according to the order of filter

Table 1
Experimental Results of LPF With Design Parameters

S.No.	*Design Parameters*	*Values*
1.	Supply Voltage (VDD)	1V
2.	Bias Voltage (Vb)	0.7V
3.	Supply Voltage (Vbb)	0.5V
4.	C1 = C2 = C3	1p
5.	Current sources	10uA
6.	Resistance R1	1KΩ
7.	Cut off frequency for 7th order proposed LPF	81.04MHz
8.	Cut off frequency for 9th order proposed LPF	80.04 MHz

4. CONCULUSION

The key factor for the study and analysis of filter is its many application in different areas such as signal processing, medical instruments, control system, communication system, industrial electronics etc. Depending upon the application and given conditions there are various methods for the designing of a filter. A floating inductor using 7-CMOSs with two current sources has been proposed. In this paper 65nm CMOS technology is used. With the assist of external bias voltage and bias current the inductance of an inductor is regulate. It was analyzed that the proposed circuit provide enough accuracy due to this it is applicable for the designing of 7^{th},and 9^{th} order low pass filter. Experimental results shows that the higher order filter designed with proposed floating inductor shows better results than the convention filter.

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