

Review on CMOS based Low Pass Filters for Biomedical Applications

Arunendra Nath Tripathi¹, Raj Kumar Tiwari²

¹Research Scholar, Department of Physics & Electronics, Dr. Rammanohar Lohiya Avadh University, Ayodhya.

² Professor, Department of Physics & Electronics, Dr. Rammanohar Lohia Avadh University, Ayodhya.

Abstract- In this paper, survey has been done on low pass filter used in biomedical devices having low power consumption, low weight and good linearity. Different types of low pass filters with their respective technologies have been described in this paper. It is found that low pass filter with low noise low power consumption and low weight is necessary part of portable biomedical instrument. Our future work will be based on the implementation of RKTG pair in low pass filter circuits by changing aspect ratio of MOSFETs at 45nm, 90nm and 180nm technologies.

Key words- Low pass filter, Biomedical devices, RKTG pair, CMOS, Low power

1. Introduction:-

The shrinking feature size has always attracted the circuit designers to look forwards to the overlapping future of semiconductor technology [1]. Continuous Technology feature size scaling has enabled denser and faster digital circuit reduces successively with the supply voltage, which has been driven the digital industry to move forwards low supply voltage [2]. In the recent years due to growing market of the portable and wearable biomedical devices to low voltage and low power supply need archiving a long battery life and light weight of the devices [3]. The necessary requirement in portable biomedical devices for achieving the low cut-off frequency at the same time of low power consumptions and low area [4]. LPFs with very low cut-off frequencies are heart of biomedical signal processing[4]-[5]. Modification of already existing technology to achieve the needed target of low voltage operation means saving in cost as well as resecures [6]. Digital and Analog circuit coexist of SOC circuit, power consumed by digital circuit is required quadratically with a low voltage and capture this advantage are forced to design Analog circuit operating at low supply [7]. MOSFETs provided better option for above requirement because MOSFET are usually biased in the weak inversion as they must conducted current in the ranged of few nanoampere [8]. A feasible solution for designing low power circuit is to operate MOS devices in SUB-Threshold

region [9]. Metal oxide semiconductor (MOS) devices biased in the sub-threshold region are exploited to maximize power efficiency and achieve very low power consumption, and a switched resistor approach is used to keep the silicon area [10].

Mostly systems mentioned above have pre-processing blocks such as low noise preamplifier and filters for the possession of low frequency signals are employed [31]. These blocks should not have any type of distortion that can explode the necessary signal. To meet these requirements, the pre-processing blocks must have present high performance over the gain and frequency for low frequency signal processing. To achieve the required parameters for signal processing, different topology-based filters like: Switched-Capacitor Based Topology for Voice Band Applications, gm-c Filters, Feedback and Cancellation topology has been designed. But these offers some disadvantages like clock feed-through, aliasing problem, temperature dependent etc. To avoid the above problems, we have designed a high frequency range at low frequency second order active low pass filter using complementary compound pair [32]-[40]. It provides very high current gain in case of BJT (Bipolar Junction Transistor) and very high voltage gain in case of MOS (Metal Oxide Semiconductor) to avoid the dependency of temperature and provide low frequency signal amplifications with low power consumption. It is a monolithic filter for IC fabrication.

2. Results & Discussion

2.1. Low Pass Filter- If an ideal low pass filter existed, it would completely block or eliminate signals above the cut-off frequency, and perfectly pass signal below the cut-off frequency .in an ideal filter various trades offs are made to gate optimum performance for given application[10] The design of very low frequency filter (10Hz) is not straight forward especially for integrated circuit implementations where chip realization of larger time constant are needed [4].Low pass filter with very cut-off frequencies are key blocks in biomedical devices[11].[12] Filter are networks

that prepares small signals in a frequency dependant way, Filter can be making use to separate signal, passing the one of intrigued and put by terns the unwanted frequencies. In the design of analog filters the number of active devices used are reduces because of the concerns like power consumptions and noise distribution[13].Integrated LPF are basic building blocks for analog signals processing while they are typically implemented using either an active RC or a $g_m c$ architecture. The performance of such filters depends on the OTA (operational transconductance amplifier)[14]. Operational Transconductance Amplifier is used for low power analog filtering application, because of its linear input-output characteristics. IN analog circuit application OTA is fundamental block. The function of OTA is same as OP-AMP because both contain differential input but they are vary as in OTA where the output is difference in current but in OP-AMP is in voltage.[15]

2.2. Types of Filter Circuits- Four types of low pass filter were examined during the design phase of the circuit

- Butterworth type
- Chebyshev, I type
- Chebyshev II type
- Elliptical type

2.2.1. Butterworth filters: Butterworth filters in 1930 it was first designed by British engineer and Physicist Stephen Butterworth in his paper entitled "On the theory of filter Amplifiers". Butterworth filter is a type of filter designed to have a frequency response that is as possible in pass band. Butterworth filters stays maximally flat in pass band with the expanses much slower real of at cut-off frequency as shown in fig.1

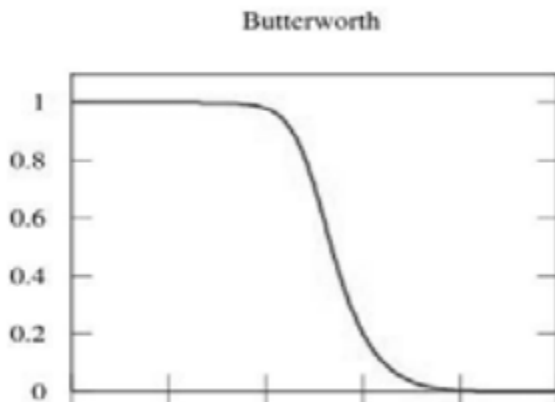


Fig. 1 - Butterworth frequency curve

2.2.2. Chebyshev I: Chebyshev filters are mostly used to separate one band frequencies from another. Chebyshev filter type I have equal ripple in pass band and monotonic in stopband but its rolls off very fast but at expense of grater pass band ripple i.e. It has ripples in pass band but its rolls off very fast as shown in fig. 2.

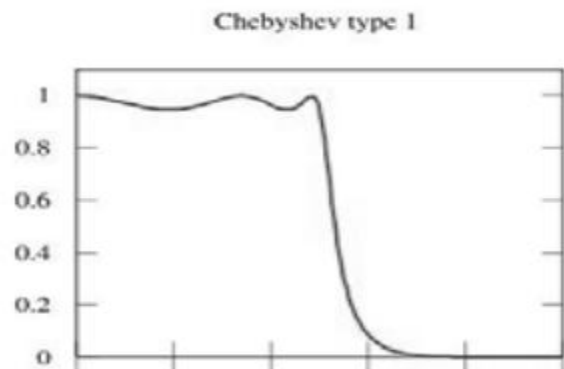


Fig. 2 - Chebyshev I type filter frequency curve

2.2.3. Chebyshev II: Chebyshev II types filter is maximally flat in the passband and has an equal amplitude ripple in stopband. In the Chebyshev II filter specify the frequencies at which the stopband begins and the maximum ripple amplitude. Chebyshev II types filter has in ripple stop band has the same roll off as type I and has no ripple in pass band as shown in below figure i.e.It has ripple stop band has the same roll off as type I and has no ripple in pass band as shown in below figure 3.

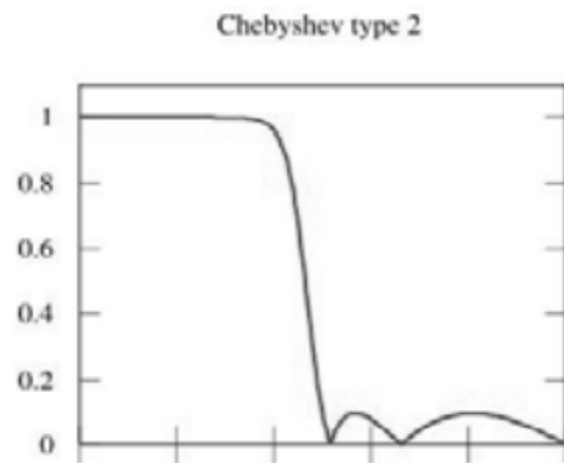


Fig. 3 - frequency response curve Chebyshev Type II filter

2.2.4. Elliptic filter: The elliptic filters mix by Chebyshev I and Chebyshev II it has ripples in both stop band and pass band but has the steepest roll off at cut- off frequency as shown in fig. 4. The elliptic filter can achieve a sharper cut off than the Chebyshev but has a reduced stopband performance. This filter type is best used where the PA has to work over a wide frequency range and therefore there is a requirement for a filter that cuts off sharply above the maximum operating frequency to give good rejection of the harmonics of the minimum operating frequency. The other application where an elliptic filter may be suitable is as a simple filter to reduce the second and third harmonics of a PA stage that already has a fair degree of harmonic filtering produced by a high *Q* output matching circuit. The design method is similar to that of the Chebyshev being based on standard curves and tables of normalized values.

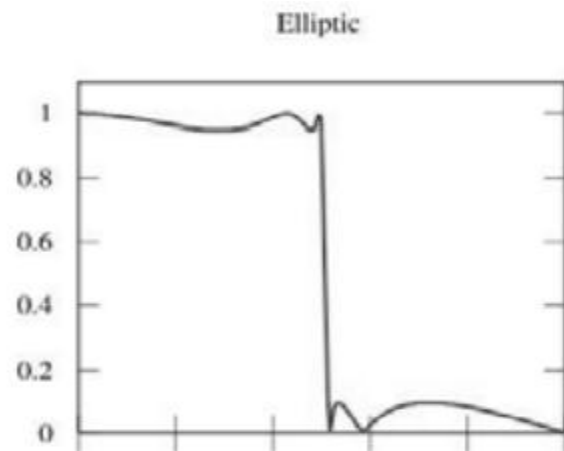


Fig. 4 - frequency response curve by elliptic filter

2.3. Comparison table of low pass filter in use of biomedical devices – Table 1 summarizes the different work done on low pass filters with their respective parameters.

Table 1: Comparative Table of different types of low pass filters

Year	Reference	Types of filers	Technology	Order	Power supply	Band width	Power consumption	Dynamic rang	Active area
2000	[4]	Elliptical	0.18 μm	6th	1.5v	2.4 Hz	10 μw	>60dB	1mm ²
2005	[17]	Mix mode	0.35 μm	-	3-4v	175 Hz	0.3mv	-	-
2006	[18]	SC	0.35 μm		1.5v	15 Hz	90.6 nW	-3dB	-
2009	[19]	Chebyshev I	0.5 μm	3rd	5v	1.75 Hz	30mW	-70dB	1.5 mm ²
2010	[20]	Chebyshev II	0.18 μm	6th	1.8v	95 Hz	-	30dB	-
2012	[21]	-	65 nm	-	1.2v	15 Hz	-	37dB	0.01
2012	[1]	Butterworth	0.18 μm	4th	0.5v	1.7 Hz	36 μw		-
2012	[22]	Butterworth	0.25 μm	5th	0.8v	17 Hz	26 μw	53.5 dB	-
2013	[23]	-	0.18 μm		1.8v	88 Hz	594 μw		0.042
2014	[24]	Differential	0.13 μm	5th		47.7Hz	125 μw	44.7dB	
2014	[5]	Real pols	65 nm	7th	1.2v	142 Hz		>100dB	0.42
2015	[6]	Butterworth	180 nm	2nd	0.5v	100Hz	225 nw	70dB	
2016	[14]	Chebyshev	0.18 μm	4th		37 Hz		30.8dB	0.1 mm ²
2017	[25]	Butterworth	90 nm	4th	0.6v	98 Hz	2 nw	51 dB	
2020	[12]	Chebyshev	0.35	4th	1.5v	7 Hz	5.2 nw		13 nm
2020	[3]	Chebyshev	90 nm	2nd	0.35v	58 Hz	13.46nw		
2020	[13]	Chebyshev	90nm	4th	0.2 v	90 Hz		-53.7dB	
2021	[26]	Papoulis	22 nm	10	1v	72 Hz	0.35 nw		0.1816 mm ²
2022	[34]	Chebyshev	0.18 μm	5th	0.5v	250 Hz	50-60nw	57.6-60.4 dB	0.036 mm ²

3. Conclusion

In the literature survey, it is clear that low pass filter with low noise low power consumption and low weight is necessary part of portable biomedical instrument. CMOS low pass filter gm-c based provided better opportunity to researcher to work on it.

Our future work will be based on the implementation of RKTG pair (Complementary compound pair) in low pass filter circuits by changing aspect ratio of MOSFETs at 45nm, 90nm and 180nm technologies. This pair is combination of two CMOS inverter connected in the form of darlington pair and behave as a complementary compound pair. This RKTG pair (Complementary Compound Pair) has become a popular pair for different applications like delay system, amplifier designing, filter designing, etc. due to wide band frequency, low power consumption, low output noise, large current /voltage gain.

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