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Design of a Low Pass Filter for Wireless Applications

Mr. Chandra Shekar P[1] and Dr. L Basavaraj[2]
[1-2]Department of ECE, ATME College of Engineering, Mysuru, India
Email: chandrashekarp_ec@atme.edu.in, Basavaraj.atme@gmail.com

***Abstract*—Low Pass Filter (LPF) allows only low frequency signals to pass through and attenuates the high frequency signals. The aim is to design LPF that has pass band in order to provide more flexibility on the DAC/ADC clock frequency and also to provide excellent adjacent channel rejection in the receive chain. The active LPF simulations are carried out for the first and second order active low pass filter to operates with a cut-off frequency of 14 MHz, in Cadence tools using 45nm Generic Package Design Kit and also layout will be designed for the best order filter design. The designed LPF has an attenuation less than or equal to 55 dB which can be used for transceiver applications. The proposed LPF designed is for lower power consumption, small chip area and desired attenuation.**

***Index Terms*— Low Pass Filter, cut-ff frequency, cadence tools, transceiver, power consumption.**

I. INTRODUCTION

A low-pass filter (LPF) is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The exact frequency response of the filter depends on the filter design. A lowpass filter is the complement of a high-pass filter. Low-pass filters exist in many different forms, including electronic circuits such as a hiss filter used in audio, anti-aliasing filters for conditioning signals prior to analog-to-digital conversion, digital filters for smoothing sets of data, acoustic barriers, blurring of images, and so on. The moving average operation used in fields such as finance is a particular kind of low-pass filter, and can be analyzed with the same signal processing techniques as are used for other low-pass filters.

Low-pass filters provide a smoother form of a signal, removing the short-term fluctuations and leaving the longer-term trend. Filter designers will often use the low-pass form as a prototype filter. That is, a filter with unity bandwidth and impedance. The desired filter is obtained from the prototype by scaling for the desired bandwidth and impedance and transforming into the desired band form (that is low-pass, high-pass, band-pass or band-stop). Such a filter has a gain dependent on a signal's frequency over other parameters such as amplitude and phase. Considering a situation where the message signal is modulated on a carrier of frequency F1 and passed through a transmission line. Upon arrival of this modulated signal at the receiver end another signal 1 is found incorporated to it of frequency F2 which is usually noise. Passing this incoming signal possessing very low gain at F2 over F1 will result in removal of that frequency signal and message signal will remain. As long as noise is sufficiently attenuated when compared to the message signal, the performance of this filter is satisfactory. Low pass filters can be designed using two different ways; they are active low pass filter and passive low pass filter. Passive low pass filters consists of Resistors and Capacitors in their design where as active low pass filter is designed using opamp with Resistors and Capacitors in series. Active low pass filter has

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many advantages over passive low pass filter. Active low pass filter can be design using different approximation; such as Chebyshev, Butterworth, Bessel and Elliptic etc

II. LITERATURE SURVEY

In the paper "A 100 KHz – 20 MHz source follower continuous time filter for SDR applications" [1] authors S. Ramasamy, S. Kumaravel and Dr. B. Venkataramani have conferred about the source follower based filters used for wireless LAN applications and are preferred as they dissipate lower power compared to the filters using other architectures. To comply with multitude standards, filters with bandwidth programmable from 100 KHz – 20 MHz are required. In this paper, a second order, composite source follower based filter is made to work in weak inversion in order to achieve wide tuning range and to minimize power consumption. The centre frequency of this filter is varied using current steering DAC. The proposed filter is designed and implemented on TSMC-0.18μm CMOS process with 1.2V supply. The simulation results demonstrate the tunability of the center frequency from 100 KHz to 20MHz which meets the requirements of zero IF receivers for SDR applications. The third order input intercept point (IIP3) is found to be 15 Db. Vp for an input signal of 200mVp.The power dissipated by the filter is 1μW and 20μW at 100 KHz and 20 MHz respectively. The proposed filter consumes 14 times less power than that proposed in the literature at the cost of 1.5 times increase in the noise. A 55μ Vrms noise gives a dynamic range of 66dB.

In the paper "design and analysis of CMOS two stage opamp in 180nm and 45nm technology"[2] authors R Bharath Reddy and Shilpa K Gowda have presented the the buffered CMOS two stage opamp which uses 180nm and 45nm technology for the design and analysis of CMOS two stage opamp. Keeping 1.8V power supply, 20uA bias current, aspect ratio W/L, slew rate 20V/us, input common mode ration constant. The trade-off among various parameters such as open loop gain, phase margin, gain bandwidth product and power consumption are measured. It has been demonstrated that due to recent development through scaling the size of transistors decease power dissipation through the device also decreases. The design has been carried out using cadence design tool.

In the paper "implementation and simulation of CMOS two stage operational amplifier"[3] the authors D. Nageshwarrao, 2K. Suresh Kumar, 3Y. Rajasree Rao and 4G. Jyothi have explained the opamp as an integral part of many analog and mixed signal systems. As the demand for mixed mode integrated circuits increases, the design of analog circuits such as op-amp in CMOS technology becomes more critical. Opamp with moderate DC gain, high output swing and reasonable open loop gain bandwidth product are usually implemented with two stage structures. This paper presents the two stage CMOS opamp which has been designed, exhibits a unity gain frequency if 20Mhz and gain of 42dB with 50 degree phase margin. To increase the gain and phase margin new technique has been proposed. Simulation results are gain of 48dB unity gain frequency of 40Mhz, phase margin of 89 degree design has been carried out in cadence tool.

In the paper "Flexible baseband low pass filter and variable gain amplifier for software defined radio front end" [4] In the paper "A Low-power Programmable Low-Pass Switched Capacitor Filter Using Double Sampling Technique" [3] author's A. Zahabi, O.Shoaei, Y. Koolivand, Hossein Shamsi have explained. The fifth order low-pass chebyshev filter with cascaded biquad realized. The Switched-Capacitor (SC) approach has gained strong popularity for implementing precision filtering functions on monolithic integrated circuits. To operate at high clock rates and signal frequencies, these transients must settle quickly. Their settling time, however, is limited by finite bandwidth and slew-rate of op-amps and the nonzero resistance of the MOS transmission gates used in the filters.

In the paper "A Low-power Programmable Low-Pass Switched Capacitor Filter Using Double Sampling Technique" [5] author's Giannini, V., J. Craninckx, J. Compiet, B. Come, S. D'Amico, and A. Baschirotto have explained a novel technique to realize flexible analog circuits applicable to reconfigurable SDR front ends is reported and applied to a zero-IF LPF. The LPF provides a wide frequency tuning range between 0.35MHZ and 23.5 MHZ with an adaptive integrated noise level between 25u vrms and 163u vrms and a current consumption that moves from 1.2mA to 18mA. A network drives these baseband blocks on chip that is able to set performance like cut off frequency, selectivity noise and gain conveniently adapting the power consumption.

III. IMPLEMENTATION OF LOW PASS FILTER

A. Block diagram of Low Pass Filter

A Butterworth Filter is a type of Active Filter, where the frequency response of the across its pass band is relatively flat. Because of this frequent response, Butterworth Filters are also known as Maximally Flat Filters or Flat-Flat Filters. For maximum flat response the Butterworth filter is designed.
The amplitude response of nth order Butterworth filter is given as follows:

$$Vout / Vin = 1 / \sqrt{\{1 + (f / fc)\ 2n\}}$$

Where 'n' is the number of poles in the circuit. As the value of the 'n' increases the flatness of the filter response also increases, the 'f' = operating frequency of the circuit and 'fc' = center frequency or cut off frequency of the circuit.
The Butterworth LPF circuit basically consists of 2 major blocks. They are 1. RC components 2. Opamp

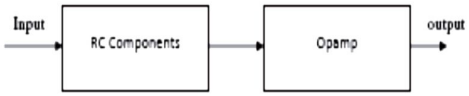

Fig: 1 Block diagram of Butterworth LPF

The block diagram of Butterworth low pass filter has 2 blocks as already stated. The input given to the RC components blocks will be then given to Op-amp block, which uses differential amplifier and common source amplifiers to amplify the input signal. Order of the filter varies with RC components connected to opamp. The block diagram of Opamp is given below

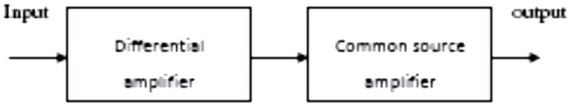

Fig:2 Block diagram of Opamp

As already stated op-amp has two main blocks named as differential amplifier and common source amplifier. These two blocks comprises Opamp. The input is given to non-inverting terminal.

B. First Order Butterworth LPF

Butterworth filter is a type of filter whose frequency response is flat over the pass band region. Low-pass filter (LPF) provides a constant output from DC up to a cutoff frequency f(H) and rejects all signals above that frequency. Circuit diagram shown below is a first-order low-pass Butterworth filter that uses RC network for filtering. Resistors R1 and R2 determine the gain of the filter.
The first order low-pass filter has a practical slope of -20 dB/decade. The low-pass filter has a constant gain Af from 0 to high cutoff frequency f (H). At f(H) the gain is 0.707Af and after f (H) it decreases at a constant rate of 20 dB/decade. The frequency f = f (H) is called the high cutoff frequency because the gain of the filter at this frequency is down by 3 dB (=20log(10) 0.707) from 0 Hz.

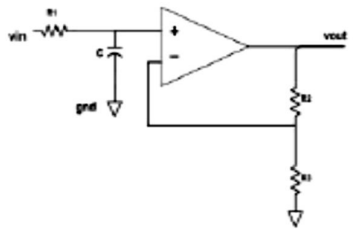

Fig:3 First Order Butterworth LPF

The RC values of the filter are designed as follows,
VO= [1+ (R1/R2)] Vi
Pass band gain is given by,
Af=Vo/Vi=1+ (R2/R3)

fc =1/2πRC
Assume R3=10KΩ, C=2PF,Av=6dB.
Substituting in equation 3.1, we get
R2=50KΩ
From the above equation we get R1=6KΩ

C. Second Order Butterworth Filter

A stop-band response having a 40-dB/decade at the cut-off frequency is obtained with the second-order low-pass filter. A first order low-pass filter can be converted into a second order low-pass filter by using an additional RC network as shown in the figure. The gain of the second order filter is set by R2 and R3.

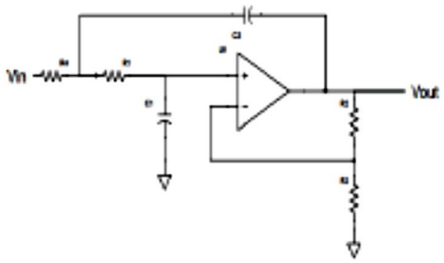

Fig: 4 Second Order Butterworth LPF

The RC values of the filter are designed as follows,
Assume R1=R4, C1=C2=2pF.
By substituting to above equation we get,
R1=R4=6kΩ and R2=50KΩ,R3=10KΩ.

IV. Results

The schematic and simulated waveforms of op-amp, first order Butterworth LPF and second order Butterworth LPF are shown.

A. Butterworth Low Pass Filter

Figure shows the Butterworth Low Pass Filter for single stage RCs. Resistors R3 and R4 are responsible for the gain of the filter. Gain is calculated using those two resistors and also the AC analysis for first order LPF is shown in fig 5 and 6. The second order butterworth LPF is shown in fig 7 along with the AC analysis in fig 8. The final layout of the Butterworth LPF is shown in fig 9.

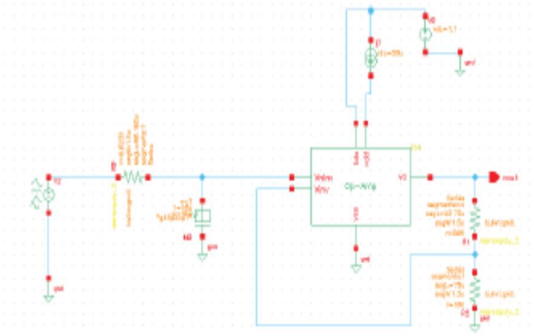

Fig:5 Single stage Butterworth LPF

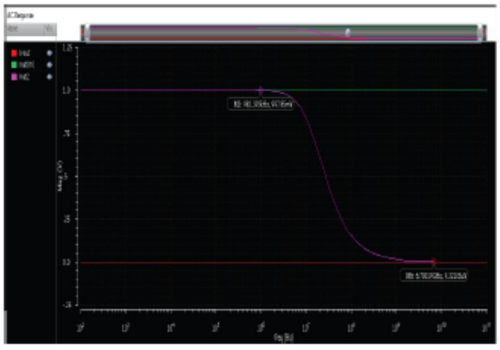

Fig:6 AC analysis for first order Butterworth LPF

V. Conclusion & Future Enhancements

A. Conclusion

A general approach for the design of active low pass filter using CMOS operational amplifier has been presented. The design circuit allows calculated performance to be closely in agreement with the simulated one. Design specification like W/L ratio is calculated and simulations are done. Calculation of profile parameter like

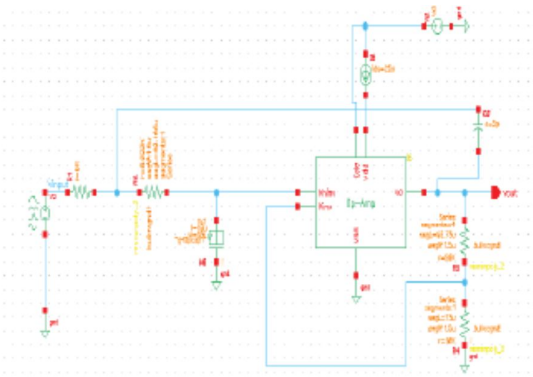

Fig:7 Schematic for second order Butterworth LPF

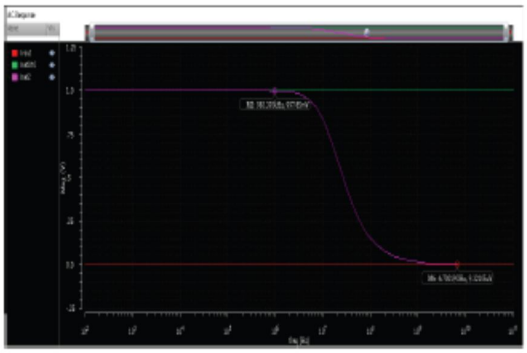

Fig: 8 AC analysis for second order Low Pass Filter

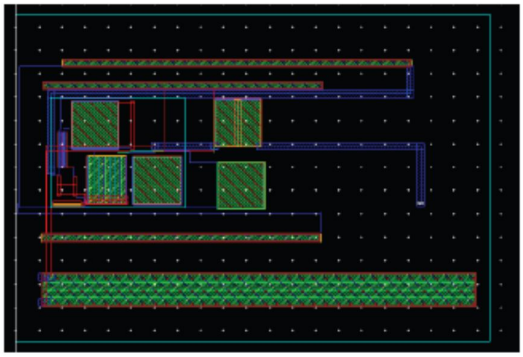

Fig: 9 Layout of the Butter Worth filter

open loop gain and cut-off frequency is done using ADE_L and the layout is done using cadence virtuoso layout XL tool, with no DRC and LVS errors.

B. Future Enhancement

The above-mentioned disadvantages of the active LPF and opamp can be overcome by using advanced cadence technology. The gain and higher operating frequency can be obtained by considering other design methodologies.

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