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Sub-Hertz Low Pass Filter

Dolly Patle, Prof. G. N. Wazurkar, Dr. N.N. Mhala

M.Tech (Electronics), Bapurao Deshmukh College of Engineering, Sevagram, India

Bapurao Deshmukh College of Engineering, Sevagram, India

Bapurao Deshmukh College of Engineering, Sevagram, India

ABSTRACT: Low-pass filters have many applications in biomedical signal processing units. Biomedical signals are usually in the 10-mHz to 100-Hz frequency range and hence require sub-hertz frequency filters to condition the signal before processing. The performance of passive filters degrades at high frequencies and the required values of resistances and inductances are very difficult to meet from the market. To achieve the low frequency cut-off the filter based around the use of clocked transconductor which provides a low transconductance while using a relatively high bias current level. The aim of this work is to determine values of the design parameters that optimize an objective feature whereas satisfying specifications or constraints. This fourth order filter is implemented in a 0.25-μm technology. In terms of power consumption and cut-off frequency this filter performs better than previous filters from the literature. This circuit is used with low frequency signal and low power portable medical equipment.

KEYWORDS: Analog filtering, Clocked transconductor, Low power, Biomedical and signal conditioning.

I. INTRODUCTION

An electrical filter is a circuit that can be designed to modify, reshape or reject all unwanted frequencies of an electrical signal and accept or pass only those signals wanted by the circuit designer. In other words they "filter-out" unwanted signals and an ideal filter will separate and pass sinusoidal input signals based upon their frequency. Filter are network that process signals in a frequency-dependent manner. The basic concept of a filter can be explained by examining the frequency dependent nature of the impedance of capacitors and inductors. Consider a voltage divider where the shunt leg is reactive impedance. As the frequency is changed, the value of the reactive impedance changes as a result voltage divider ratio changes. This mechanism yields the frequency dependent change in the input/output transfer function that is defined as the frequency response. Filters have many practical applications. A simple, single pole, low-pass filter (the integrator) is often used to stabilize amplifiers by rolling off the gain at higher frequencies where excessive phase shift may cause oscillations. The higher the filter order the steeper the cut-off slope is, but proportional to the order it results in a more complex circuit. This trade-off must be kept in view. In this circuit, power consumption is a critical factor thus the complexity of the filter and the steepness must be kept at an optimal value. The filters employed in biomedical systems are used for sensing bioelectrical signals which are typically in the range of 10mHz –100Hz at the input, a low-pass filter is usually employed in order to limit the frequency band. The Design of very low-frequency filters (10 Hz) is not straightforward, especially for integrated circuit implementation. However, despite their utility, creating large time constant low-pass filters on-chip is a challenging problem. To implement large time constants, switched-capacitor-based topologies require large capacitor ratios, and a sufficiently high power supply must be used to achieve an acceptably low switch on-resistance.

Switched-capacitor filter has been successfully applied to many voice band applications. It has good accuracy of time constants and good temperature characteristics; whereas the problem of clock feed-through is difficult to be solved and it also needs continuous-time filters as anti-aliasing filters. Another alternative is to use gm-c filters which do not have the aliasing problem of sampled-data systems. Due to the dependence of the cut-off frequency of the filter on the absolute values of monolithic components such as capacitors and transistors transconductances, which are both process and temperature dependent, feedback and cancellation techniques are required to control the cut-off frequency of this type of filters. And it also needs a small transconductance in order to avoid using large area capacitors at low frequency. This work describes a low cut-off frequency CMOS low pass filter which utilizes a cross-coupled input structure to cancel the deviation of the cut-off frequency under the influence of different temperature and produce an appropriate transconductance with four auxiliary amplifiers to keep the gain. It is a monolithic filter with low power consumption and low-voltage.

II. BASIC OPERATION

A. *Principle of operation*

The basic principle of operation of proposed low-pass filter is shown in fig. 1 is based on clocking of the output of a transconductor element. A transconductor is placed in a feedback loop with a capacitor forming a first-order *gm/C* low-pass filter, and a switch is then added between the output of the transconductor and the capacitor. This switch allows the output of the transconductor to be connected to and disconnected from the capacitor and the feedback loop.

When the switch is closed, the output current from the transconductor I1, flows only though the capacitor, so that the average current that flows into the capacitor, I2 is reduced.

When the switch is open, the output current of transconductor has no path to flow. This would cause the output of the transconductor to saturate at the supply rails as no output current could be provided.

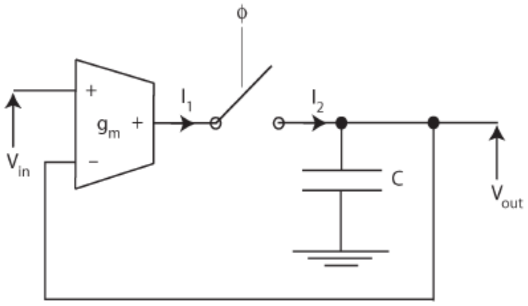


Fig1: Principle of operation of the proposed low-pass filter

To overcome this, two buffer cells are introduced, as shown in Fig2. The first buffer is placed between the capacitor and the output node Vout to isolate the capacitor node from the load. The second buffer is then placed between the output of the filter transconductor *gm*1 and the capacitor via a second switch in opposite phase to the main switch. This second buffer thus provides a path for the output current of *gm*1 when the *φ* switch is open.

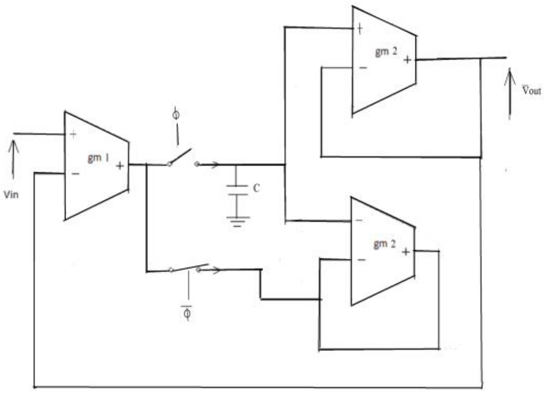


Fig2: The block diagram of low-pass filter with two buffers for low power application

B. The complete low pass filter

In reality the simplistic diagram of Fig. 1 does not obey Kirchoff’s current law: when the switch is open the transconductor’s output current has nowhere to flow. This would cause the output of the transconductor to saturate at (or near) the supply rails as no output current could be provided. To overcome this two buffer cells are introduced as shown in Fig. 2. The first buffer is placed between the capacitor and the output/feedback node, Vout, to isolate the capacitor node from the load.

The second buffer is then placed between the output of the filter transconductor $gm1$ and the capacitor via a second switch in opposite phase to the main switch. This second buffer thus provides a path for the output current of $gm1$ when the φ switch is open. When φ is open, second switch is closed, and the output of $gm1$ is fixed to the same voltage as the capacitor but without any current from $gm1$ flowing into the capacitor. Thus, the voltage at the output of $gm1$ stays approximately constant regardless of whether the current from it is flowing into the capacitor or not, preventing the output of the transconductor changing between the supply rail voltages and the voltage at the capacitor each time the switch is toggled.

This topology also reduces the effects of charge injected through the switches. When φ switches, charge is predominately injected into capacitor C because it offers the lowest impedance. For low-frequency operation, C is generally large. This results very small voltage spikes. When switches, charge is predominately injected into a buffer connected in negative feedback. The load capacitance seen is thus both the buffer output capacitance and the input capacitance of the negative input, increasing the total capacitance present. Additionally, both switches can operate at frequencies much higher than the bandwidth of the filter, and therefore, the remaining voltage ripple can be easily removed if required.

III. IMPLEMENTATION

In order to control the input-stage transconductance more precisely, and combined with the characteristics of the small value, the transistors in cross-coupled differential pair are biased in the sub-threshold area. The transconductance and the bias current have a linear relationship in a wide range.

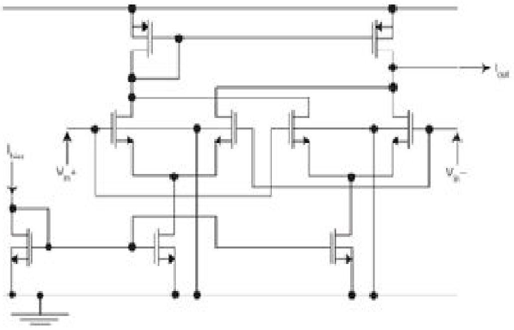


Fig3: Filter having transconductance $gm1$ schematic implemented in CMOS

The $gm2$ transconductors are buffers, as shown in Fig4. It consists of basic differential pairs with their outputs connected to the negative inputs for unity voltage gain. Since these buffers operate well below their bandwidth, their inputs are approximately equal and they contribute very little to distortion in the overall filter.

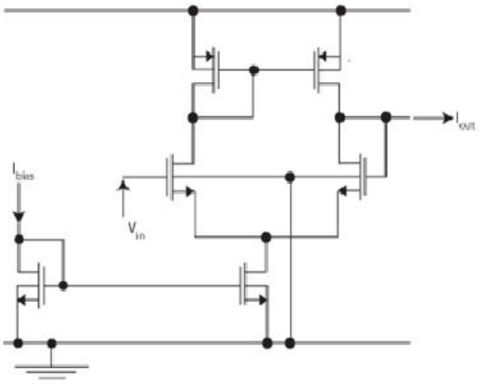
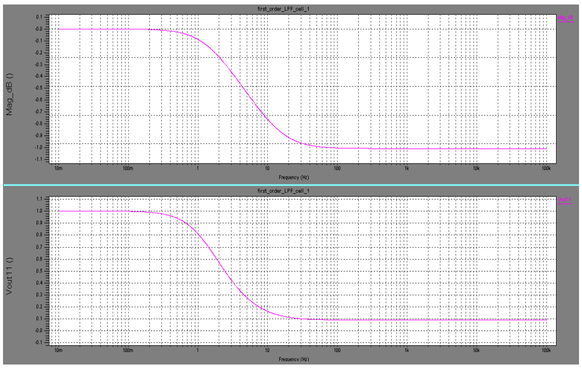
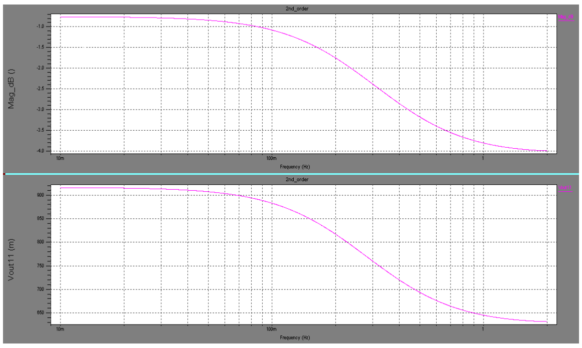


Fig4: Buffer Filter having transconductance *gm*2 schematic implemented in CMOS

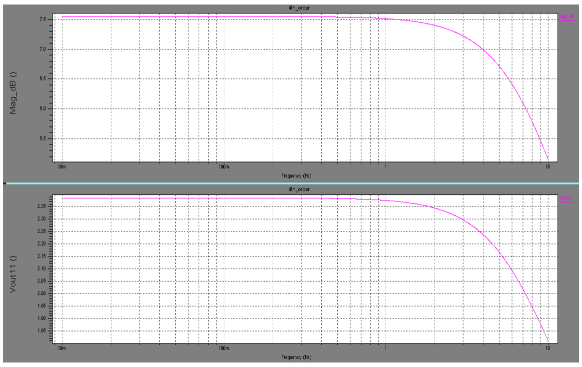
IV. SIMULATION RESULTS



(a)



(b)



(C)

FIG.5: GAIN CHARACTERISTIC OF PROPOSED LOW-PASS FILTER (A) FIRST ORDER (B) SECOND ORDER (C) FOURTH ORDER

This circuit is connected in unity gain configuration hence gain of the transistor is unity i.e -0db. And Cut-off frequency is 130 mHz as shown in gain curve of filter shown in fig. 5(a).
This circuit is connected in unity gain configuration hence gain of the transistor is unity i.e -0.8db. And Cut-off frequency is 100 mHz as shown in gain curve of filter shown in fig. 5(b).
This circuit is connected in unity gain configuration hence gain of the transistor is unity i.e 7.5db. And Cut-off frequency is 1 Hz as shown in gain curve of filter shown in fig. 5(c).

V. CONCLUSION

There is a great demand of low frequency low pass filter in biomedical and sensor technology at the same time low power consumption is great challenge. The device designed collects cardiac data and monitors heart and circulation activity. It is built into the human body. The device is therefore must be realized as an integrated circuit. A very low frequency low-pass filter for power ranges of nW has been designed. Operation is based on using a switch at the output of a transconductor in a *gm/C* filter to decrease the value of the transconductance and to increase the output resistance. In comparison to previous low-pass filters from the literature, the proposed topology provides the lowest power consumption, in addition to a very wide tuning range. In this, the proposed filter circuit has been designed at 0.25µm Technology.

VI. FUTURE SCOPE

This work can be extended to designing of low pass filter with low frequency and low power in the future. The proposed clocked transconductor topology is thus highly suitable for use in low power, low-voltage sensor interfaces and in portable medical instrumentation. This can further be used for lower cut-off frequency and power. And since it is 1st order filter so for improved performances higher order filters for few nW power can be designed using this topology.

TABLE I
COMPARISON OF PROPOSED TOPOLOGY PERFORMANCE WITH OTHER REPORTED LOW FREQUENCY LOW PASS FILTERS

Parameter	Reference[1]	First Order	Reference[2]	Second Order	Fourth Order
Technology	0.35 µm	0.25 µm	8µm	0.25µm	0.25µm
Supply Voltage	1V	1V	25V	910mV	2.38V
Dynamic Range	63.8db	~0db	-0.12db	-0.8db	7.5db
Cut-off frequency	002mHz	130mHz	-	100mHz	1Hz
Load Capacitance	40pf	1 µf	15pf	1µf	1µf
Power Consumption	5nW	45.93860nW	3.7mW	35.28778nW	0.00484542nW

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BIOGRAPHY

Dolly Khetsingh Patle is a Research in the Electronics Engineering Department, Bapurao Deshmukh College of Engineering, Sewagram, Nagpur University. She received Bachelor of Engineering (BE) degree in 2013 from Madhukarrao Pandao College Of Engineering, Bhandara, Nagpur University (India). Her research interests are Computer Networks, Control System etc.