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OTA Model Used in Active-Passive Filter for Lowering Power Consumption

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Abstract

Biomedical signals are usually of 10-mHz to 100-Hz frequency range. Designing of these low power consumption filters has many applications in biomedical signal processing and their interfacing with sensors. The performance of these filters designed by the use of passive components degrades at audio frequencies and the required resistance and inductance values calculated from the mathematical expression are very difficult to meet from the market. In this we study the realization of Passive Filters into Active Filters using Operational Trans-conductance to solve the problem of power consumption.

Keywords: Filters, OTA, Power Consumption, Sensors.

Introduction

An electrical filter is "filter-out" unwanted signals and an ideal filter will separate and pass sinusoidal input signals based upon their frequency. Filters are networks which 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 inductance [3]. It has 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 [5]. A simple, single pole, high pass filter can be used to block DC offset in high gain amplifiers or single supply circuits. Filters can be used to separate signals, passing those of interest and unwanted frequencies.

Filter Types

Filters can be divided into two distinct ways:
A. Active Filters **B.** Passive Filters.

Active filters contain amplifying devices to increase signal strength while passive do not contain amplifying devices to strengthen the signal. Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input. As, there are two passive components in passive filter design and the output signal has smaller amplitude [2]. In low frequency applications (up to 100 kHz), passive filters are usually made from simple RC (Resistor-Capacitor) contain amplifying devices to strengthen the signal. However, higher frequency filters (above 100 kHz) are usually made from RLC (Resistor-Inductor-Capacitor) components [1]. Hence, filters can be divided into various categories on the basis of frequency of signals to which they allow to pass through them.

A. Low Pass Filter: Allow only low frequency signals to pass through where, **f_c** is cut off frequency

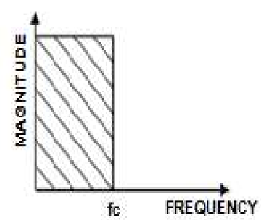

Fig 1.1 Low pass filter

B. High-Pass Filters: Allow only high frequency signals to pass through.

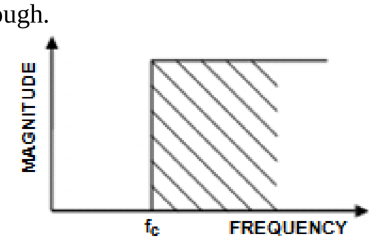

Fig 1.2 High pass filter

C. Band-Pass Filters: Allow passing only the range of frequency (band of frequency).

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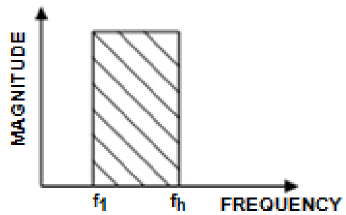

Fig 1.3 Band pass filter

D. Band Reject Filter: Passes most frequencies unaltered but attenuate those in a specific range to very low level.

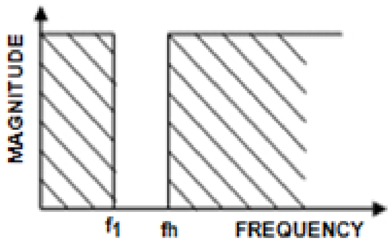

Fig 1.4 Band reject filter

Another complement to the band pass filter is the band reject, or notch filter. Here, the pass bands include frequencies below $\mathbf{f}_{l}$ (lower cut-off frequency) and above $\mathbf{f}_{h}$ (upper cut-off frequency). The band from $\mathbf{f}_{l}$ to $\mathbf{f}_{h}$ is in the stop-band. It allows signals falling within a certain frequency range to pass through. If a high-pass transfer function can be realized using a Cauer-1 form. The $\mathbf{k}^{th}$ element is given by: filter and a low-pass filter are cascaded; a band pass filter is created. The band pass filter passes a band of frequencies between a lower cut-off frequency, $\mathbf{f}_{l}$ and an upper cut-off frequency, $\mathbf{f}_{h}$. Frequencies below $\mathbf{f}_{l}$ and above $\mathbf{f}_{h}$ are in the stop-band.

Filter Parameter

The idealized filter unfortunately cannot be easily built. The transition from pass band to stop-band will not be instantaneous, but instead there will be a transition region. Stop band attenuation will not be infinite.

Filter Topologies

Two main topologies are available to implement a linear analog filter.

A. Cauer Topology

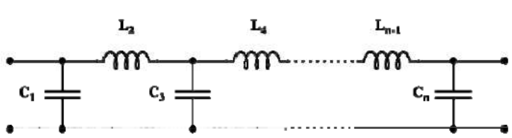

Fig 1.5 Cauer Topology

The Cauer topology uses passive components (shunt capacitors and series inductors) to implement a linear analog filter.

B. Sallen-Key Topology

The Sallen-Key topology uses active and passive components (operational amplifiers, resistors and capacitors) to implement a linear analog filter.

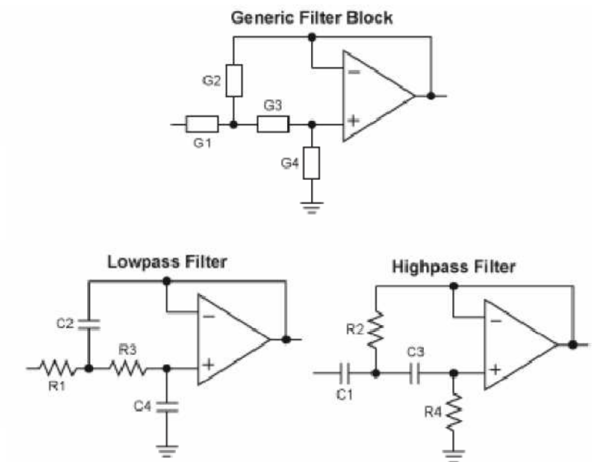

Fig 1.6 Sallen Key Topology

OTA Based Low-Pass Filters

The conventional operational amplifier (op-amp) is used as the active device in the vast majority of the active filter literature. A host of practical filter designs have evolved this approach [4]. It has also become apparent, however, the operational amplifier limitations preclude the use of these filters at high frequencies, attempts to integrate these filters have been unsuccessful (with the exception of a few non demanding applications), and convenient voltage or current control schemes for externally adjusting the filter characteristics which do not exist [6]. In this case, basic first, second and higher-order structures using the trans-conductance amplifier.

OTA Model

The trans-conductance gain, gm, is assumed proportional to Ib. The proportionality constant h is dependent upon temperature, device geometry and the process.

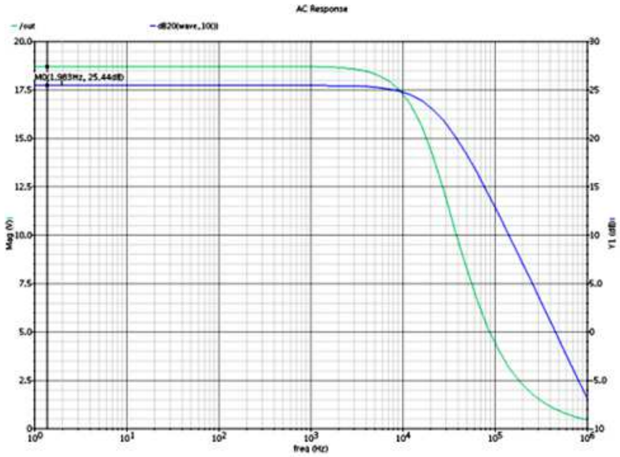

Fig 1.7 Gain plot of basic OTA structure

This OTA is designed for 5μW and 25 dB with 1.8 V power supply in 0.18μm UMC technology [10]. Then following characteristic has been obtained shown in Fig 1.7 where, obtained gain is 25.44 dB and power consumed is 4.88 μW of above differential OTA.

Balanced Differential OTA

In a balanced OTA there are three current mirrors and a single output. The complexity of differential OTA structures is also provide an improvement in offset reduction and robustness, but not necessarily with an improvement for high-frequency applications. Thus, trade-offs between speed and accuracy should be established for each particular application.

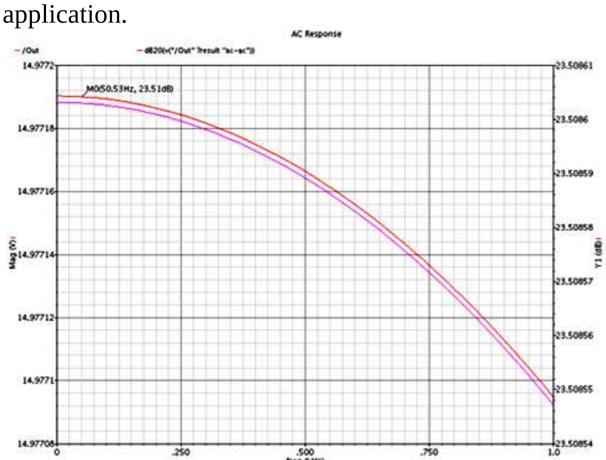

Fig 1.8 Gain characteristic of balanced OTA

Applications

a) Typical data acquisition system for Signal is shown in Fig 1.9. The preamplifier must amplify the input signal to a higher level with low distortion and low noise.

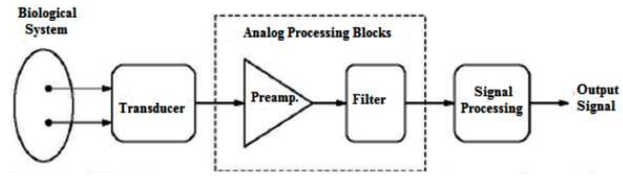

Fig1.9 Block diagram of a general purpose bioelectric signal acquisition system

b) 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.

c) A simple, single pole, high-pass filter can be used to block DC offset in high gain amplifiers or single supply circuits. Filters can be used to separate signals, passing those of interest, and attenuating the unwanted frequencies.

d) In integrated wireless receivers.

e) The electrical activity within living organisms,.

f) Butterworth LPF for aerospace extreme environment applications is implemented in SiGe BiCMOS technology.

g) COGNITIVE radio.

Conclusion

There is a great demand for low frequency low pass filter in biomedical & sensor technology and at the same time low power consumption is great challenge. The designed device can collect cardiac data and monitors hearth and circulation activity. It is built-in device (can be placed inside the body), therefore, must be realized as an integrated circuit. This work can be extended for designing of low pass filter with low frequency and low power in the future. However, the basic need in order to design low pass filter for low power is to minimize the power of OTA.

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