Performance Analysis of Low Frequency Filters Design Based on Frequency Dependent Negative Resistance

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Abstract: *An important concern for LPF with switchable attributes at baseband is to select a appropriate filter structure. Among the different approaches three approaches are prominently used named Frequency dependent negative register (FDNR), LC-ladder simulation biquad cascade and multiple-loop feedback (MLF). This study aimed at comparative analysis of three different low pass filter approaches. The filters are realized using Biquad Technique and FDNR and MLF approach. Simulations are done using different CMOS technology. In this paper a comparison is made using different parameters. In general, the results prove that a good agreement between the two approaches usng SPICE simulations.*

Keywords: *Biquad filter, FDNR, Low Pass Filter, GIC and gyrator.*

1. Introduction

Filters serve a critical role in many common applications. Such applications include power supplies, audio electronics, and radio communications. Filters can be active or passive, and the four main types of filters are low-pass, high-pass, band-pass, and notch/band-reject. A filter is a frequency-selective device that makes certain frequency components of a signal pass and greatly attenuates other frequency components. In the test device, the interference noise can be filtered or the spectrum analysis can be carried out by using the frequency selection function of the filter. Although digital filtering technology has been widely used, analog filtering is still widely used in automatic detection, automatic control and electronic measurement instruments.
Filters could be classified on behalf of frequency response as Low Pass Filter, High Pass Filter, Band Pass Filter and Band Reject Filter (Notch filter). On behalf of mathematical approximation, they can be classified as Butterworth approximation, Chebyshev approximation, Elliptic approximation and Bessel approximation. On behalf of signal domain they can be classified as Analog (Active and Passive) filters and Digital (FIR and IIR) filters. On behalf of implementation they can be classified as State Variable approach (Tow Thomas and KHN filters), Sallen Key structure, Gm-C based Filters and Active RC filters (Op-Amp based).

2. Analog Filter Classification and Design Aspects

A passive LPF filter is shown in figure 1 using R and C.

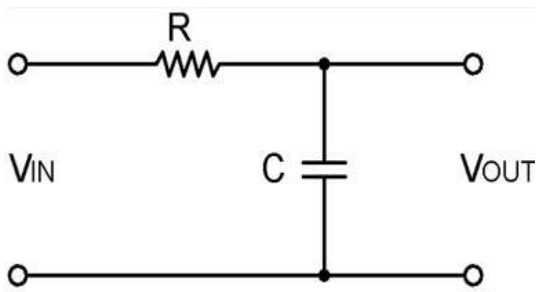

Figure 1: Passive Low Pass Filter

$V_{OUT}/V_{IN} = 1/1+sCR$ …(1)

Active filters can be used to design Low-order filters without the use of inductors; this is important because inductors are problematic in the context of integrated-circuit manufacturing techniques. Active filters are capable of dealing with very low frequencies (approaching 0 Hz), and they can provide voltage gain (passive filters cannot). There is a wide variety of analogue integrated filters in the literature, but there are only two operating principles behind the majority of these filters. Figure 2 shows the active Low Pass Filter.

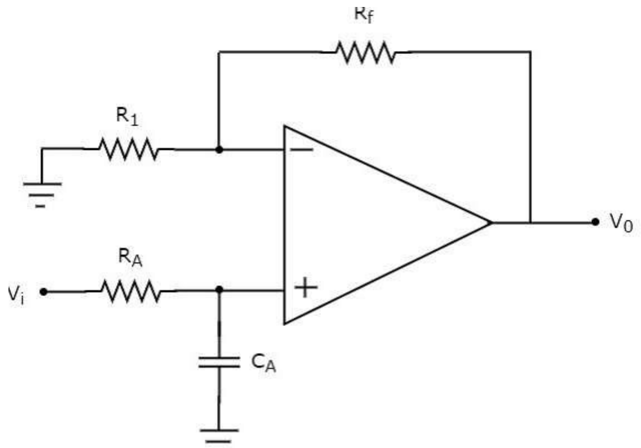

Figure 2: Active Low Pass Filter

Complex poles are either achieved by implementing RLC filters without using actual inductors, or by building an analogue computer that is capable of forming differences of rational expressions with real poles.
Integrator filters is one approach to form such differences is to build loops containing integrators; such filters are known as integrator connected filters, state-space filters, and under other names.
They are often implemented as Gm–C filters or as log-domain filters, although different integrators are sometimes used when special filter properties are needed. From a mathematical point of view, such filters can produce complex poles because two or more interlinked loops give the transfer function a denominator with three or more difference terms of polynomials having real zeros.
Single-amplifier biquadratic filters: Integrator-connected filters always require at least two amplifiers to generate one complex pole pair. In contrast, single-amplifier biquadratic filters form a difference of two second-order rational expressions with real poles. This is achieved by putting a second-order RC network in the feedback path of an amplifier. Figure 3 shows a typical Biquad filter namely Tow-Thomas biquad.

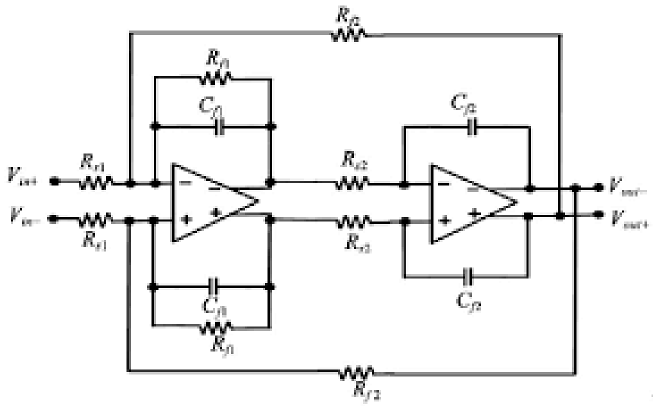

Figure 3: Biquad (Tow Thomas) Filter [3]

Gyrator filters: There are also two different ways of implementing RLC filters. One is to simulate every inductor using a gyrator circuit. Although gyrators are often built using op-amps, they can also be built with OTAs, in which case the resulting filter again isa Gm–C filter. Such gyrator filters are mainly used because of their good sensitivity properties and good noise behaviour.

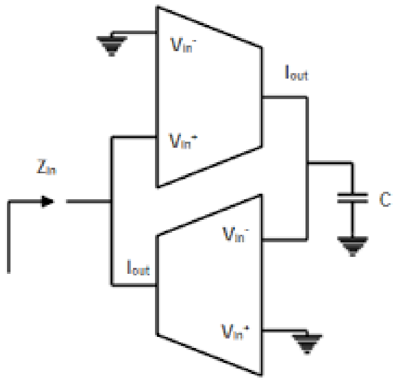

Figure 4: Gyrator Circuit [4]

FDNR Filters: The other way of simulating RLC filters is the so-called FDNR (frequency-dependent negative resistor) synthesis, where the impedances of all elements in the RLC prototype are scaled by the factor ω_0/s, where s is the complex frequency of the Laplace domain. This transformation maintains the transfer function of the filter, but not its terminal impedances: all resistors are transformed into capacitors, the inductors into resistors, and the capacitors into so-called FDNRs. Since many gyrator implementations can also be used as FDNRs, there is not much difference between FDNR and gyrator filters. In fact, if it is not a problem whether the port impedances are transformed or not, the decisive question is whether the RLC prototype has more inductors or capacitors. In the latter case, the gyrator filter should be used, in the former case it is the FDNR filter.

However, RLC simulations also require at least two amplifiers per pole pair, so the single-amplifier biquads (SABs) that were already a good way to build cheaper discrete-component filters are also promising candidates for power-efficient, small integrated filters.

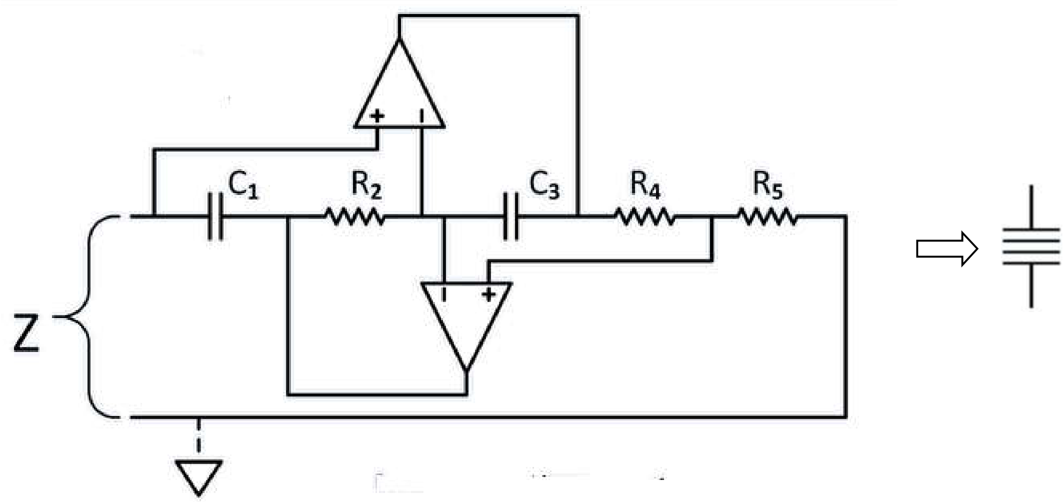

Figure 5: FDNR Circuit

Volatge at point 5 is V_{in} same as non-inverting voltage for Opamp A_1 which is equal to V_- of A_1 (voltage at pin-3 and V_- of A_2) equal to V_+ of A_2. Because of virtual ground concept. Now voltage at different point are

$$V_5 = V_{in} = V_3 = V_1 \quad (2)$$
$$V_2 = V_{oA1} \quad (3)$$
$$V_4 = V_{oA2} \quad (4)$$
$$Z_{in} = V_{in} / I_5 = V_{in} / I_{in} \quad (5)$$
$$Z_{in} = R_5 / s^2 C_1 C_3 R_2 R_4 \quad (6)$$

Since s= j ω, So

$$Z_{in} = - R_5 / \omega^2 C_1 C_3 R_2 R_4 \quad (7)$$
$$\mathbf{Z_{in} = 1 / \omega^2 D} \quad (8)$$
$$\mathbf{D = - R_5 / C_1 C_3 R_2 R_4} \quad (9)$$

Equation 7 shows negative sign due to $j^2 = -1$, $\omega = 2\pi f$

Because of this reason circuit in figure 5 called frequency dependent negative resistor.

3. Challenges to Analog Filter Design

Conventional VLSI design challenges: Area, Power and speed

Active Filter specific:

- Quality factor
- Center frequency (application specific)
- Linearity in the Passband
- Supply sensitivity
- Technological compatibility

In order to proceed towards the desired aim, the work will mainly focus on two primary aspects of Integrated Circuit design.

4. Low Pass Filter Synthesis Using FDNR

The low pass filter LCR basic circuit is shown in figure 6.

The problem of the low pass filter is the floating inductor therefore is difficult to realized, the alternative to that is to use a frequency dependent resistance (FDNR) as simulator elements without using inductor.

To realize this low pass filter can be accomplished by dividing each element by jω and transforms resistances into capacitances,

inductances into resistances and capacitances into D element as following equations, and the new transformed network is shown in figure 7.

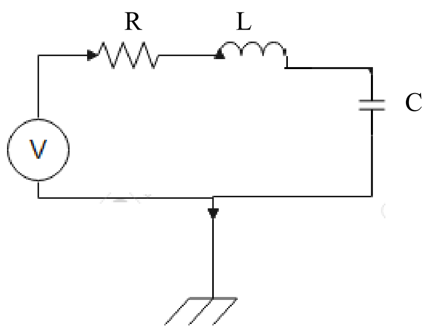

Figure 6: Basic LCR low pass filter

$$V- I (R + sL + 1/sC) = 0 \quad (10)$$
$$V- I (R + sL + 1/sC) = 0 \quad (11)$$
$$I= V_o sC \quad (12)$$ V_o is output voltage across C

$$Z_{in} = V/I = (R + sL + 1/sC) \quad (13)$$

$$\left.\begin{array}{ll} R/j\omega = 1/j\omega R^{-1} & \text{Capacitance value } R^{-1} \\ j\omega L/j\omega = L & \text{Resistance value L} \\ (1/j\omega C)/ j\omega = -1/\omega^2 C = D & \text{D element value C} \end{array}\right\} \quad (14)$$

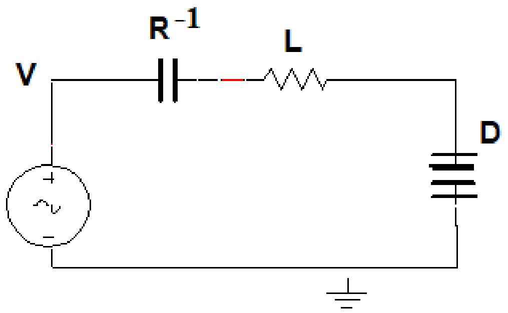

Figure 7: Transformed low pass filter network

5. Conclusion

In this paper, a Low Pass Filter was proposed to overcome the problem raised due to inductor realization. The equivalent circuit realized by frequency dependent negative resistance, resistance and capacitance in place of RLC. The results obtained showed that the filter in very low frequency could be realized without using inductance. PSPICE free package simulator accomplishes the simulation and the results conform the theoretical analysis. This expected filter can be useful in analog filter especially at low frequency. In addition, the components used easily built-in integrated circuits as chips. These filters could be easily use in medical application, which need low frequency signals processing.

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