DESIGN AND NOISE ANALYSIS OF BIQUAD GIC NOTCH FILTER IN 0.18 μM CMOS TECHNOLOGY

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ABSTRACT

In design of analog circuits not only the gain and speed are important but power dissipation, supply voltage, linearity, noise and maximum voltage swing are also important. Noise limits the minimum signal level that a circuit can process with acceptable quality. Today analog designers constantly deal with the problem of noise because it trades with power dissipation, speed, and linearity. So in this paper a biquad GIC notch filter is design which provides low noise linearity. In this research, the design and VLSI implementation of active analog filter, based on the Generalized Impedance Converter (GIC) circuit, are presented. The analog features include the filter type (band pass, high pass, low pass or notch), the centre or cut off frequency, and the quality factor. The circuit is then modeled and simulated using the Cadence Design Tools software package. Active filters are implemented using a combination of passive and active (amplifying) components, and require an outside power source. Operational amplifiers are frequently used in active filter designs. These can have high Q factor, and can achieve resonance without the use of inductors. This paper presents a new biquad GIC notch filter topology for image rejection in heterodyne receivers and Front End receiver applications. The circuit contains two op-amp, resistors, and capacitor topology for testing purposes. It is implemented with standard CMOS 0.18μm technology. The circuit consumes 0.54 mW of power with a open loop gain 0dB, 1 dB compression point the linear gain obtained +7.5dBm at 1.1 kHz and 105 degree phase response , from a 1.8V power supply optimum.

KEYWORDS

Op-amp, GIC, Notch filter, linearity, low noise.

1. INTRODUCTION

In concern of noise, noise is a concern because it sets a fundamental limit on the normal operation of all electronic Circuits and systems. Traditionally, it is stated that noise is important whenever we are dealing with weak signal. That's true, but perhaps a more appropriate statement would be that noise is important whenever the amplitudes of the processed signals are similar to those of the existing noise. Clearly, if we refer exclusively to the intrinsic noise, only very weak signals risk losing their information content in a noisy environment. The information carried by signals with high amplitudes is not corrupted.

The design of analog circuits itself has evolved together with the technology and the performance requirements. As the device dimension shrink, the supply voltage of integrated circuit drops, and the analog and digital circuit are fabricated on one chip, many design issues arise that were unimportant only few decade ago. In design of analog circuits not only the gain and speed are important but also supply voltage, linearity, noise and maximum voltage swing. Noise limits the minimum signal level that a circuit can process with acceptable quality. Today analog designers constantly deal with the problem of noise because it trades with power dissipation, speed, and linearity. Real circuit, of course, is never immune from small, "random" fluctuations in voltage and current levels. So in this work a biquad GIC notch filter is design which provides linearity with low noise. [1]

Linearity: Active RF devices are ultimately non-linear in operation. When driven with a large enough RF signal the device will generate undesirable spurious signals. How much spurious generated by the device is dependent on the linearity of the device? If an amplifier is driven hard enough the output power will begin to roll off resulting in a drop of gain known as gain compression. The measurement of gain compression is given by the 1dB gain compression point

1dB Compression Point: This parameter is another measure of the linearity of a device and is defined as the input power that causes a 1dB drop in the linear gain due to device saturation. An example of the 1dB compression point is shown in figure 5. [4]

Third-order input intercept point (IIP3): In telecommunications, a third-order intercept point (IP_3 or TOI) is a measure for weakly nonlinear systems and devices, for example receivers, linear amplifiers and mixers. It is based on the idea that the device nonlinearity can be modeled using a low-order polynomial, derived by means of Taylor series expansion. The third-order intercept point relates nonlinear products caused by the third-order nonlinear term to the linearly amplified signal. As shown figure 4 the intercept point is obtained graphically by plotting the output power versus the input power both on logarithmic scales (decibels). [8]

Noise figure (**NF**) is a measure of degradation of the signal-to-noise ratio (SNR), caused by components in a radio frequency (RF) signal chain. The noise figure is defined as the ratio of the output noise power of a device to the portion thereof attributable to thermal noise in the input termination at standard noise temperature T_0 (usually 290 K). The noise figure is thus the ratio of actual output noise to that which would remain if the device itself did not introduce noise. It is a number by which the performance of a radio receiver can be specified The noise figure is the difference in decibels (dB) between the noise output of the actual receiver to the noise output of an “ideal” receiver with the same overall gain and bandwidth when the receivers are connected to sources at the standard noise temperature T_0 (usually 290 K). The noise power from a simple load is equal to KTB, where k is Boltzmann's constant, T is the absolute temperature of the load (for example a resistor), and B is the measurement bandwidth

2. GIC TOPOLOGY

The integrated circuit manufacturing of resistors and inductors is wrought with difficulty, exhibits poor tolerances, is prohibitively expensive, and is, as a result, not suitable for large scale implementation. The use of active components, the General Impedance Converter (GIC) design will allow for the elimination of resistors and inductors by simulating their respective impedances.

The generalized impedance converter (GIC) is highly insensitive to component variation. The GIC filter design was introduced by Mikhail and Bhattacharya and proved to be very insensitive to non–ideal component characteristics and variations in component values. Figure 10 shows the general topology of the GIC filter. GIC Biquads are two op–amp biquads with good high frequency performance. All but the even notch stages are tuneable. The high pass, low pass and band pass stages are gain adjustable. The notch and all pass stages have a fixed gain of unity. All GIC stages have equal capacitor values, unless a capacitor is required to adjust the gain. Notch stages do not rely on element value subtractions for notch quality and are thus immune from degradations in notch quality due to element value errors. Analog circuits such as audio and radio amplifiers have carry the signals in the form of physical variables such as voltages, currents, or charges, which are continuous functions of time. The manipulation of these variables must often be carried out with high accuracy.

Analog systems On the other hand, in digital systems the link of the variables with the physical world is indirect, since each signal is represented by a sequence of numbers. Clearly, the types of electrical performance that must be achieved by analog and digital electronic circuits are quite different.

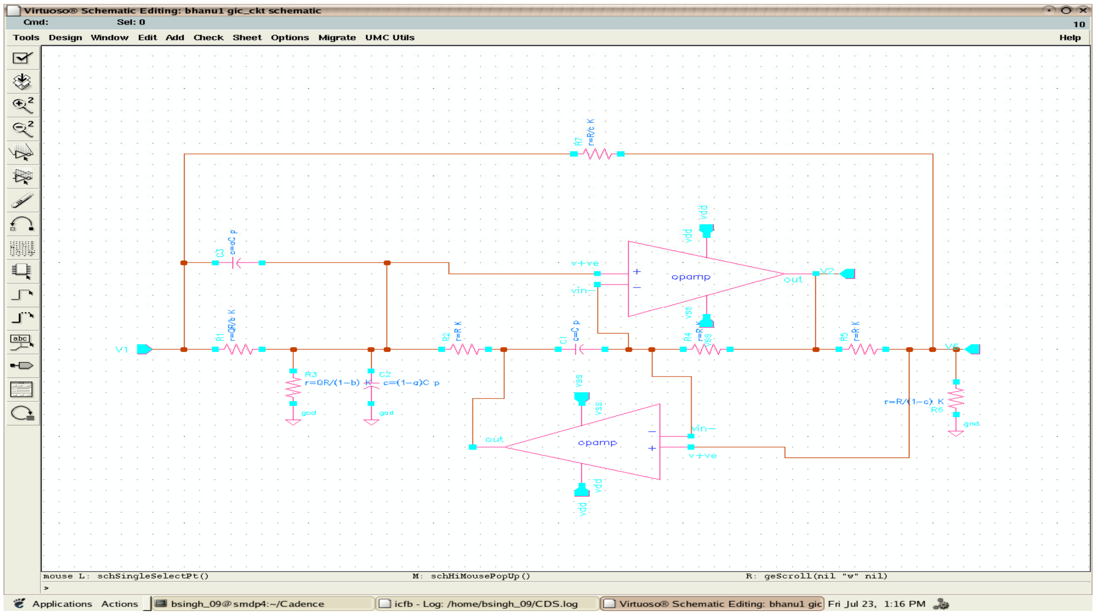

Fig.1 Generalized Biquad GIC Schematic

Nowadays, analog circuits continue to be used for direct signal processing in some very-high-frequency or specialized applications, but their main use is in interfacing computers to the analog world. The development of the very-large-scale-integration (VLSI) technology has led to computers being pervasive in telecommunications, consumer electronics, biomedicine, robotics, the automotive industry, etc. As a consequence, the analog circuits needed around them are also pervasive. Interfacing computers or digital signal processors to the analog world requires various analog functions, among them amplification, filtering, sampling, (de)multiplexing, and analog-to-digital (A/D) and digital-to-analog (D/A) conversions. Since analog circuits are needed together with digital ones in almost any complex chip and the technology for VLSI is the complementary metal–oxide–semiconductor (CMOS), most of the current analog circuits are CMOS circuits. [5]

3. DESIGN OF BIQUAD GIC NOTCH FILTER

The generalized impedance converter (GIC) is highly insensitive to component variation. The GIC filter design was introduced by Mikhael and Bhattachararyya and proved to be very insensitive to non–ideal component characteristics and variations in component values. Figure 1 shows the general topology of the GIC filter. GIC Biquads are two op–amp biquads with good high frequency performance. All but the even notch stages are tunable. The high pass, low pass and band pass stages are gain adjustable. The notch and all pass stages have a fixed gain of unity. All GIC stages have equal capacitor values, unless a capacitor is required to adjust the gain. Notch stages do not rely on element value subtractions for notch quality and are thus immune from degradations in notch quality due to element value errors.

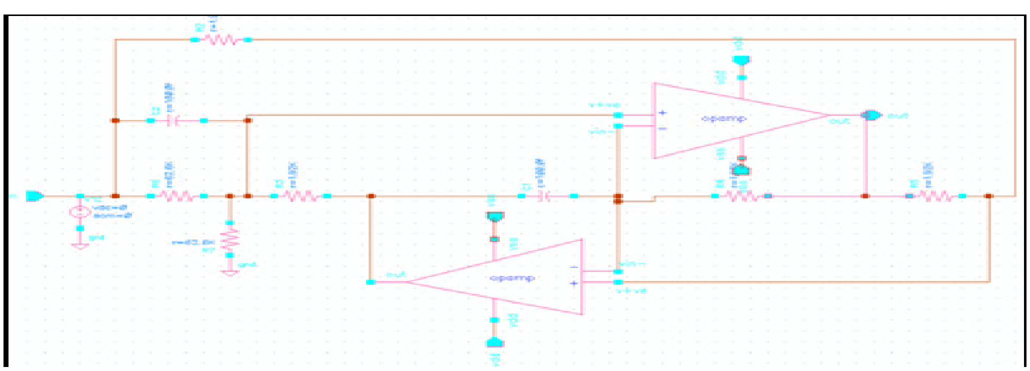

Fig.2 schematic of biquad GIC notch filter

It has been shown that in order to implement all possible filter types using passive components a circuit network must contain resistors, capacitors, and inductors. Modern IC manufacturing techniques allow for the accurate construction of capacitors, and a method for the elimination of resistors by using switched capacitors. However, we are still left with the problem of inductors. Discrete inductors of suitable impedance values are available for use in circuits. However, these inductors tend to be large and costly. Additionally, the focus of modern electronics on fully integrated circuits. Integrated circuit manufacture of suitable inductors is very difficult, if not possible. IC inductors take up vast quantities of valuable chip area, and suffer from terrible tolerances. How then can we develop the full range of filter types in light of the problems involving inductors? It was recognized in the 1950s that size and cost reductions, along with performance increases, could be achieved by replacing the large costly inductors used in circuits with active networks. This is not to say that the need for inductive impedance was obviated. Rather a suitable replacement, or means simulation was necessary. A variety of methods for the simulation of inductances have been developed. One of the most important and useful of these methods is the Generalized Impedance Converter (GIC) developed by Antoniou et al.

Design the notch filter with the GIC biquad of figure 2. To be eliminated is the frequency component at f_0 = 1 kHz from a signal. The low and high frequency gains must be 0 dB and the attenuation must not be larger than 1 dB in a band of width 100 Hz around f_0. The transfer function of this filter is

$$T(s) = \frac{s^2 + \omega_0^2}{s^2 + s\,\omega_0/Q}$$

To design schematic of notch filter, we have chose C = 0.1µF, R = 1/(ω_0C) = 1.918 kΩ, and Q = 16.3 It is the schematic of CMOS biquad GIC notch filter using the AM biquad topology. The design of this CMOS biquad GIC notch filter is done using Cadence Tool. The Simulation results are found using Cadence Spectre environment with UMC 0.18 µm CMOS technology.

4. EQUATIONS

The first goal will be to develop the transfer function of the circuit in terms of the generic admittance values. Then we can substitute in values for the admittances in order to realize the various filter types. Note that two output nodes are specified in the circuit. To analyze the circuit write Kirchhoff's current law at the node labeled V5, V4, and V6 and assume ideal op-amps so that V4 = V5 = V6. We obtain

$$2GV6 = cGV1 + GV2$$

$$(G + sC)\,V4 = GV2 + sCV3$$

$$(G + G/Q + sC)\,V5 = (bG/Q + asC)\,V1 + GV3$$

Calling again $\omega_0 = 1/(CR)$, and using that V4 = V5 = V6, these equations become

$$2V4 = cV1 + V2$$

$$(\omega_0 + s)V4 = \omega_0 V2 + sV3$$

$$[\omega_0 (1 + 1/Q) + s]\,V4 = (b\,\omega_0/Q + as)\,V1 + \omega_0 V3$$

Solving for the transfer function T(s) = V2/V1 results in

$$T(s) = V2/V1 = \frac{s^2 (2a - c) + s\,(\omega_0/Q)\,(2b - c) + c\omega_0^2}{S^2 + s\omega_0/Q + \omega_0^2}$$

We observe that above equation can realize an arbitrary transfer function with zeros anywhere the s-plane.

5. SIMULATION RESULT OF GIC NOTCH FILTER

The open Loop Gain obtained 0dB which confirm to the design parameters we took at the starting of the design. This simulation result shows the phase response of the given filter, its gives 105 degree. Its value obtains by adjusting the value of capacitances. (fig.3)

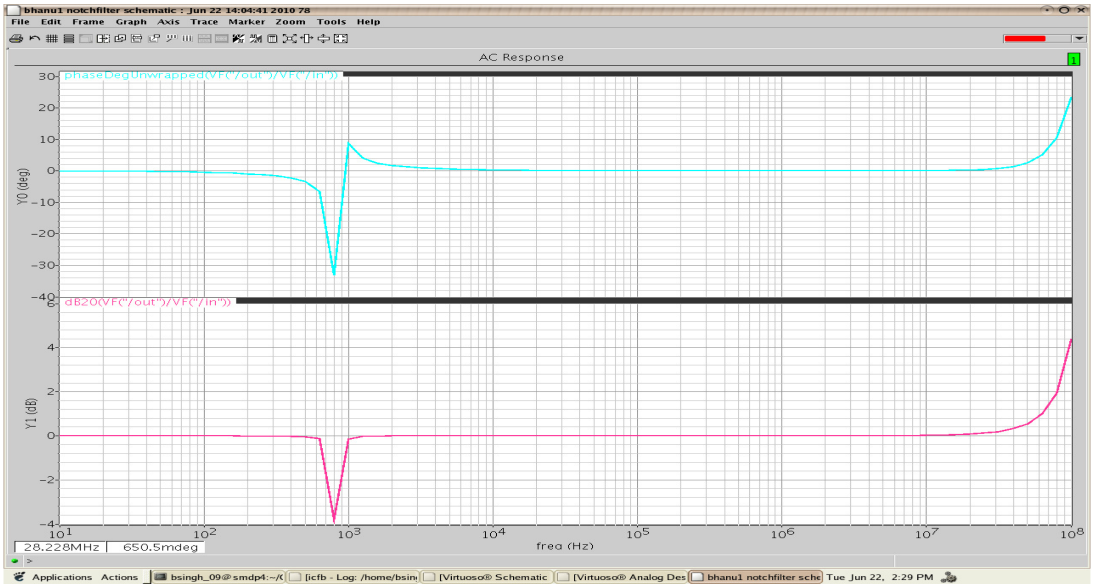

Fig.3 Simulation result of Gain and Phase response

This parameter to measure the linearity of a device and is defined as the input power that causes a 1dB drop in the linear gain due to device saturation. At 1dB Compression Point the linear gain is obtained + 7.5 dBm at 1.1 kHz. (fig.5)

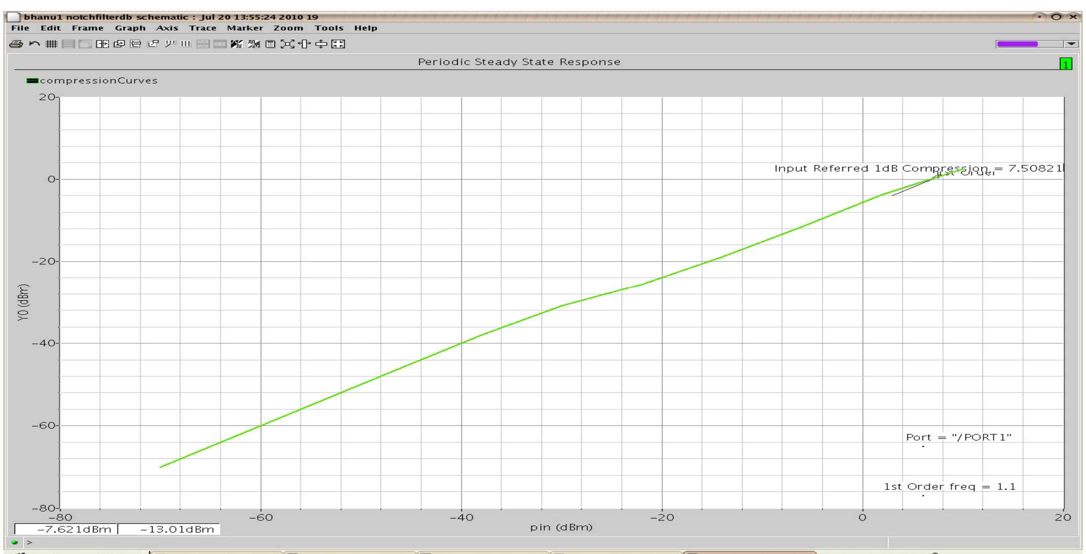

Fig.5 Simulation result of 1dB Compression Point response

The following figure is third- order input intercept point (IIP3). A two-tone test is used to measure an IIP3 curve where the two input tones are ω1 and ω2. Since the first-order components grow linearly and third-order components grow cubically, they eventually intercept as the input power level increases. The IP3 is defined as the cross point of the power for the 1st order tones, ω1 and ω2, and the power for the 3rd order tones, ω1 and ω2 & two ω2 and ω1 on the load side. The input intercept point (IIP3) was found to be 22 dBm on choosing the 1st order frequency and 3rd order frequency are 1.1 kHz & 3.3 kHz respectively

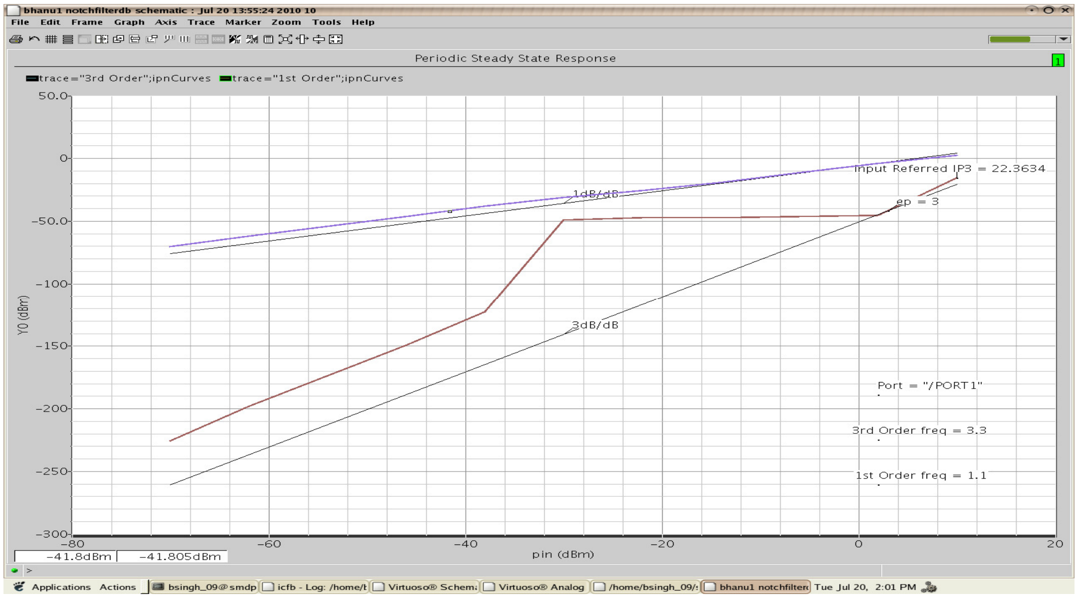

Fig. 4 Simulation results of Third-order input intercept point (IIP3)

The noise figure is the difference in decibels (dB) between the noise output of the actual receiver to the noise output of an “ideal” receiver with the same overall gain and bandwidth when the receivers are connected to sources at the standard noise temperature T_0 (usually 290 K). This notch filters having 80 dB noise figures. (fig.6)

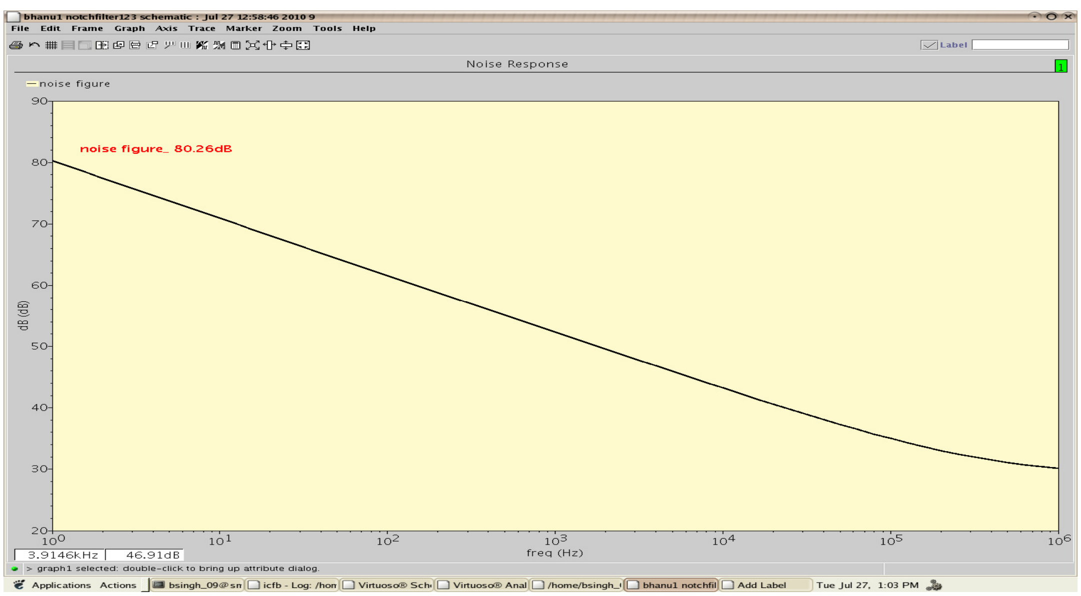

Fig.6 Simulation result of noise figure

6. CONCLUSION

This design, a low-voltage CMOS biquad GIC notch filter is designed using a Generalized Impedance Converter topology. A new frequency does not require peak detectors, which are also proposed for low-voltage active filters that are high-performance fully integrated telecom transceivers. The proposed techniques can be used to design low-voltage and low-power biquad GIC notch filter in a standard CMOS process. To demonstrate the proposed techniques, a ±1.8V, second-order filter implemented in a standard 0.18µm CMOS process. In this designing mainly work on linearity and low noise. By the experiment analysis we obtain the open loop gain 0dB and 105 deg phase, the 1dB Compression Point the linear gain is obtained + 7.5 dBm at 1.1 kHz. And this notch filters having 80 dB noise figures the required high linearity, IIP3 22 dBm and low-noise specifications are achieved.

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