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A Study Comparing the Performance of Voltage-Mode and Current-Mode KHN Filters

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Abstract - The effectiveness of voltage-mode and current-mode Kerwin-Huelsman-Newcomb (KHN) filters, which make use of current feedback amplifiers (CFAs), is thoroughly examined in this work. For a wide range of signal processing needs, these filters may fulfill the usual low-pass, high-pass, and band-pass roles. The current-mode filter is multi-input and single-output (MISO) type, while the voltage-mode filter is single-input and multi-output (SIMO) type. The individual regulation of the natural angular frequency (ϋo) and quality factor (Q), made possible by CFAs, is an important aspect of the suggested filters. The two circuits are identical in that they both serve the low-pass, high-pass, and band-pass purposes. The suggested filter may regulate the quality factor (Q) and natural angular frequency (ωo) separately.

Keywords: - Circuit, Angular Frequency, Voltage, Quality factor, Functions

Introduction

Because of its adaptability and broad variety of frequency domains of application, the Kerwin-Huelsman-Newcomb (KHN) filter stands out among other filter topologies. Since its introduction a number of decades ago, the KHN filter has been extensively improved and adjusted to meet the needs of contemporary circuit design. The incorporation of current feedback amplifiers (CFAs) into the KHN filter architecture is one noteworthy advancement that has resulted in the creation of voltage-mode and current-mode implementations. When it comes to performance measures like bandwidth, linearity, and frequency response, these variants have their own set of benefits and drawbacks. The increasing need for flexible and efficient signal processing solutions in a wide range of electronic systems is driving research into voltage-mode and current-mode KHN filters. Different design needs and application circumstances call for different filter configurations, each of which has its own set of advantages. Applications requiring several filtered outputs from a single input signal are ideal for voltage-mode KHN filters due to its single-input and multi-output (SIMO) design. When processing several frequency components at once is crucial, like in biological signal analysis, picture processing, and audio equalization, these filters shine. However, systems that need multi-channel processing or intricate signal conditioning might benefit from current-mode KHN filters, which include a multi-input and single-output (MISO) architecture. Their single output capability and capacity to process several input signals make them ideal for use in instrumentation circuits, sensor arrays, and communication systems.

The control over the natural angular frequency (ωo) and quality factor (Q) is one of the principal factors impacting the performance of KHN filters. The bandwidth, selectivity, and transient response of the filter—among other frequency response characteristics—are defined by these parameters. The ability to independently modify ωo and Q is commonly missing in traditional KHN filter implementations, which limits their flexibility in meeting particular design goals. On the other hand, voltage-mode and current-mode KHN filters that include CFAs allow for fine-grained control over these parameters, making the filter more versatile and adaptable. Designers may enhance the filter's efficiency, fulfill demanding performance standards, and cater to various applications' specific needs by individually adjusting ωo and Q.

Several important criteria, such as frequency response characteristics, linearity, dynamic range, power consumption, and stability, are included in the performance assessment of voltage-mode and current-mode KHN filters. You may learn a lot about the filter's performance in various environments and evaluate it for potential uses with the assistance of these measurements.

I.Review Of Literature

Thakur, Rohit & Singh, Sangeeta (2021) Modern system-on-chip (SoC) designs rely heavily on complementary metal-oxide semiconductor (CMOS) circuits because of their low power consumption and good reliability, both of which enable efficient circuit design. In order to implement a Kerwin-Huelsman-Newcomb (KHN) filter, this paper details a novel method for creating voltage-tunable current differencing transconductance amplifiers (CDTAs). Through the use of the Cadence Virtuoso simulation tool and 0.18 [Formula: see text]m technological parameters, the suggested design has been tested. Gain and frequency of operation adjusting depending on input voltage is the basis of this design. It is possible to adjust the cutoff frequency in this filter design based on the input voltage rather than the input current, as previously described. The need that the iterative circuit adjustments operate within a certain frequency range is thereby relaxed. Since this method eliminates the requirement for iterative design and calibration, the reported CDTA design should be both resilient and provide more design freedom. As for the retained area requirement, it shows how the KHN filters compare to the state of the art. We have also tested the newly-designed CDTA-based KHN filter against the state-of-the-art KHN filters to ensure its performance.

Rana, Sandeep et al., (2016) A current mode universal biquad filter that makes use of voltage

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differencing current conveyor (VDCC) is presented in this communication. All grounded passive components are used in the filter that has been presented. In the current filter construction, the pole frequency (ω0) and quality factor (Q) may be changed individually via the use of tuning parameters. The correctness of the suggested biquad is validated by the use of PSPICE simulations, using 0.18µm TSMC CMOS technology characteristics.

Khatib, Nabhan & Biolek, Dalibor (2013) An innovative complementary metal-oxide semiconductor (CMOS) voltage-varying buffered amplifier (VDBA) with a structure well-suited for use in voltage-mode (VM) applications is presented in this work. We have developed a new second-order universal VM filter that takes use of the high/low input/output impedance and electrical tunability of the VDBA's transconductance value. This study includes enough simulated plots to demonstrate the proposed VDBA's simulation findings.

Kumar, A. et al., (2012) Numerous fields make use of second-order filter architectures. A higher order filter can also make advantage of them. When developing second-order filters with other active elements, the KHN (Kerwin, Huelsman, and Newcomb) filter is utilized as a reference. The authors of this work suggest a novel KHN filter that makes use of a pair of OTAs, a pair of ground capacitances, and a single resistance. With the suggested filters, you may adjust the cutoff frequency independently of the passive components, and the Q and cutoff frequency are orthogonal. The SPICE simulation confirmed the accuracy of this filter.

Rathore, Tejmal & Khot, Uday (2012) The purpose of this paper is to propose a method for converting a class of voltage mode circuits that are based on Op Amps, FTFNs, CCs, and CFAs into corresponding current mode circuits without the need for any additional circuit elements. Additionally, this method can be used to convert Op Amp-based voltage mode circuits into any of the FTFN, CC, or CFA current mode circuits. Compared to the earlier circuits, the subsequent ones have a higher frequency performance that is superior. PSPICE simulations of circuits have been used to analyze the transformation and determine whether or not it is legitimate.

Koton, Jaroslav et al., (2011) Analog circuit design frequently centers on creating frequency filters using various active components. This study introduces the universal voltage conveyor for designing KHN-equivalent filters operating in voltage-mode. Additional voltage inputs of the active components are utilized to minimize the quantity of unconnected admittances in the system. Both suggested designs are readily connectable in a series since the input impedances are theoretically endlessly large and the output impedances are zero. The filters' behavior has been confirmed using PSpice simulations and experimental tests.

Chantafong, Kessak et al., (2010) Based on a single current controlled conveyor transconductance amplifier (CC-CCTA), this paper introduces a current-mode KHN multifunction biquadratic filter that simultaneously performs low-pass, high-pass, and band-pass functions. The circuit's characteristics include the ability to electrically adjust the pole frequency and quality factor using the input bias currents. There is only one CC-CCTA and two grounded capacitors in the whole circuit. The suggested circuit is well-suited for future development into an integrated circuit as it uses just grounded parts and does not need any external resistance. Here are the findings of the PSPICE simulation. There is good agreement between the provided findings and the theoretical prediction. At voltages of around 1.5V

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from the power source, the maximum power usage is around 1.42mW.

II.Proposed Algorithm

The fact that it has a single input and three outputs makes it an ideal building block for the creation of cascade filters. It is capable of producing three fundamental transfer functions of the second order, namely low-pass, band-pass, and high-pass effects. Through the use of OA – CFA Transformation, the traditional KHN structure is converted into a voltage mode filter. This is accomplished by applying current feedback amplifier (CFA), as was discussed before. A KHN filter operating in voltage mode and using a current feedback amplifier is seen in Figure 2.

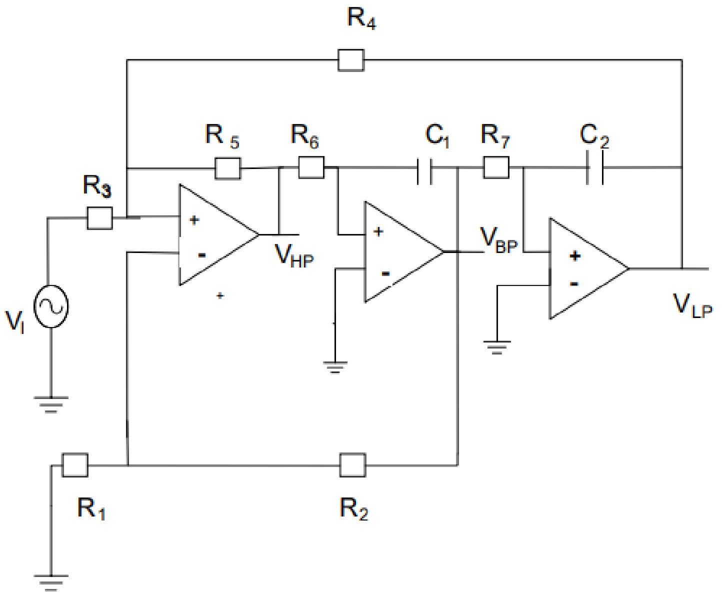

Figure 1: Implementation of KHN Filter by Operational Amplifier

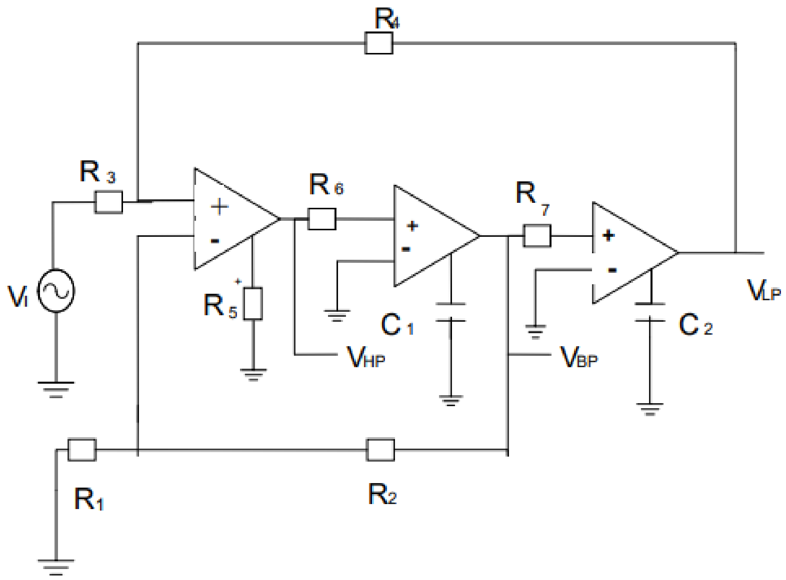

Figure 2: Voltage-Mode KHN Filter Utilizing CFAs

To tune this filter, change R3 to get the response magnitude you want, and then tune ω0 by adjusting R6 or R7 (c) To make Q sound better, change the R2/R1 ratio. You may change Q without affecting ω0 by modifying the value of R2. Since Q is proportional to the resistor

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ratio R2/R1, it is less affected by temperature drift and resistance tolerances. The adjoint principle allows for the construction of an inter-reciprocal network, which can transform a voltage-mode circuit into a current-mode circuit. This concept states that in order to implement a current response instead of a voltage response and an adjoint network Na in lieu of a network N, the two types of networks are switched. That is why N and Na, the two networks, have the same resultant transfer functions.

Therefore, it may be claimed that the networks N and Na are inter-reciprocal. In order for the two networks' transfer functions to be equal, the impedance levels at their nodes in the original network (N) and the adjoint network (Na) must be comparable. There is an inverse signal flow in the adjacent network since the voltage source and the current detecting device are both short circuits. Likewise, a component that detects voltage may be transformed into a source of current. Figure 3 shows the current-mode operation of the resulting circuit that achieves LP, BP, and HP transfer via input/output switching.

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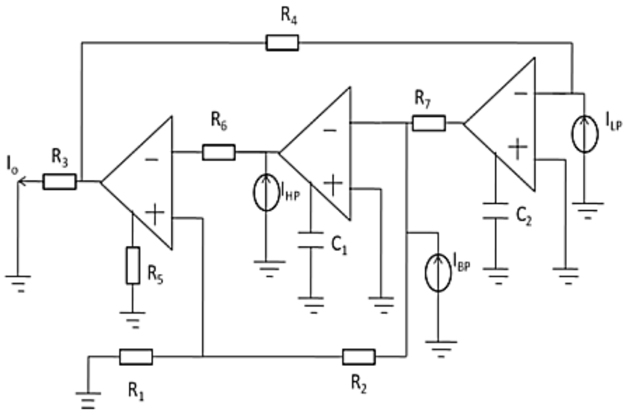

Figure 3: CFA based Current mode KHN Filter

III.Results And Discussion

The effectiveness of the suggested filters was shown via the use of PSPICE simulation. It was the AD-844 (CFA) IC that made the circuits possible. Figure 4 shows the responses of the suggested voltage mode filter's LP, BP, and HP as simulated using CFA. Results given by Figures 5, 6, and 7 shows the current mode filter that makes use of CFA. Clearly, the circuit architecture does not need to be changed in order for the voltage mode filter circuit to provide band-pass, low-pass, and high-pass responses all at once. One terminal at a time is used by the current mode filter to generate the corresponding answer. Capacitance values of +5 V were used for all simulations' DC supply voltages C1 = C2 = 0.1 nF, R6 = R7 = 15.9 KΩ and R3 = R4 = R5 = 10KΩ were chosen.

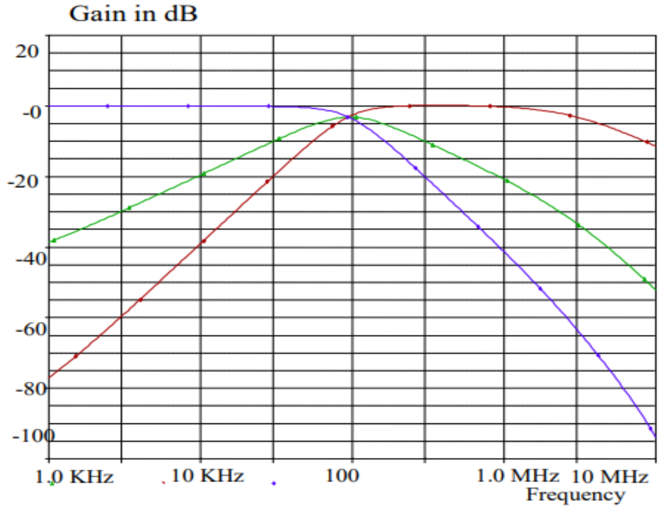

Figure 4: Results of BP, LP and HP voltage mode

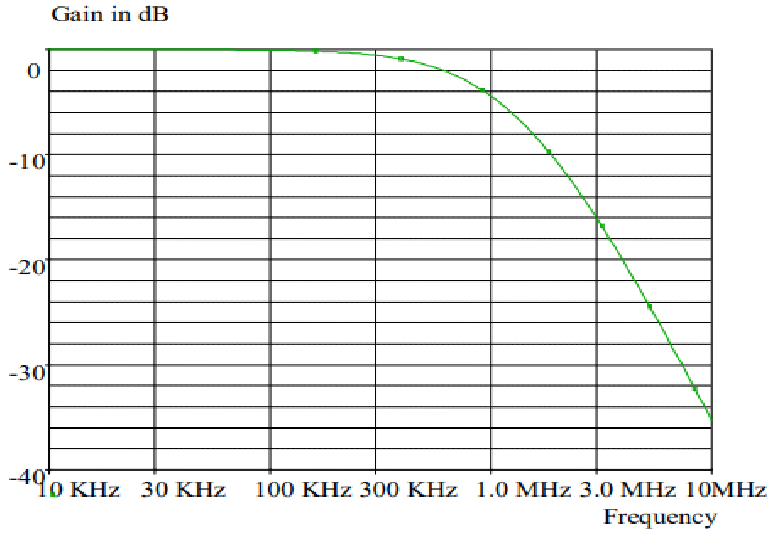

Figure 5: Results of LP current mode

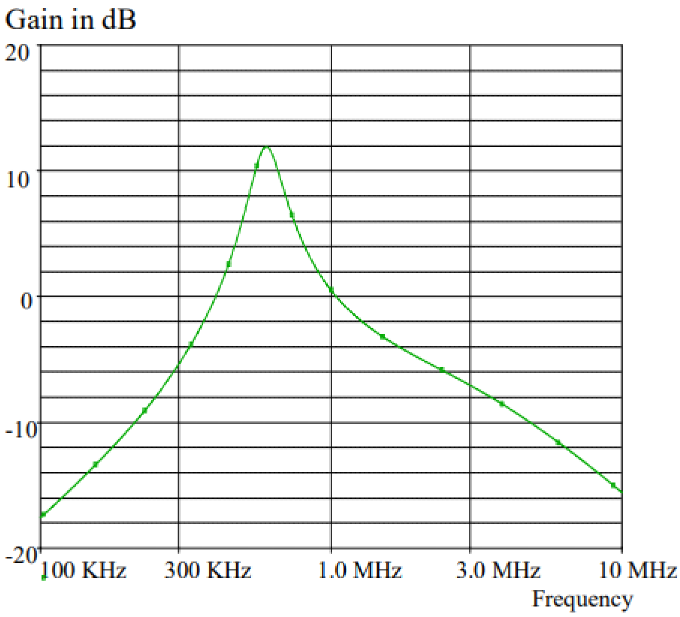

Figure 6: Results of BP current mode

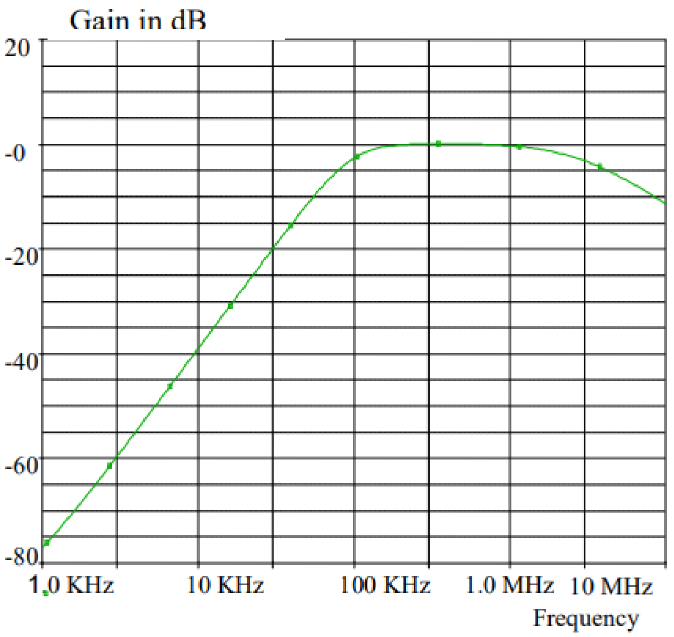

Figure 7: Results of HP current mode

IV.Conclusion

The area of electronic signal processing has made great strides and obtained valuable insights via the performance assessment of voltage-mode and current-mode KHN filters. Our research has shown that voltage-mode and current-mode KHN filters, when coupled with current feedback amplifiers (CFAs), give a great deal of flexibility and adaptability. In relation to the properties of frequency response, linearity, dynamic range, control over natural angular frequency (ωo), and quality factor (Q), these filters display clear benefits. Because of its SIMO design, voltage-mode KHN filters are great at handling situations when several frequency components need to be processed from a single input signal all at once. The current-mode KHN filters are ideal for uses that call for multi-channel processing or intricate signal conditioning because of their multi-input and single-output (MISO) architecture.

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