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Implementation of Carlson Approximation-Based Fractional Order Universal Filter Using MO-CCCII

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ABSTRACT
In this paper, a new current mode fractional order filter is presented using multi-mode second generation current controlled current conveyors (MO-CCCII).in this method consists of two resistors and grounded capacitors using 3MO-CCCII. This is accomplished with a fractional-order capacitor, also known as a stationary phase element, to form a fractional-order filter. The proposed filter is designed as fractional 0.2, 0.4 orders. The fractional order capacitor was obtained using reduced integer-order models of fractional differentiators using the Carlson method[18] using third order Foster I RC network circuit. The filter is simulated using BJT-based MO-CCCII using LTSPICE Simulation for the filter to verify the theory and show its performance of it.
Keywords: Current-Mode Circuits, Fractional-Order Filters, MO-CCCII, Carlson Method.

I. INTRODUCTION

Active filters are one of the most used in the part of signal processing. When data is sent over a physical medium, it needs to first, convert into electromagnetic signals, data itself can be of two types; they are analog signals and digital signals. Digitals are discrete in type and represent a sequence of voltage pulses. An Analog signal is a continuous waveform in type and represented by continuous electromagnetic waves. Filter means an electrical filter is a circuit that can be designed to modify, reshape, or reject all the undesired frequencies of an electrical signal and pass only the desired signals. Filters are two types they are active and passive filters. Passive elements to design the passive filters like capacitors, resistors, and inductors. We use an active element to design the active filter like op-amp etc. active filters provide high gain and no loading effect. Filters are four types they are low pass filter, high pass filter, band pass filter, and band stop filter. Another type is an all-pass filter. It passes all the frequencies but the changes in the phase response. Filter specifications have passband ripple, stopband attenuation, and passband roll-off. If order increases, roll-off increases, and passband ripple and utmost roll-off. If order increases, roll-off increases, and passband ripples are more intense. Therefore, the exchange between passband ripple and roll-off rate is not easy to control them. So fractional-order system is applied to those filters called fractional order filters.

All disciplines like engineering and the natural sciences are mathematically based on the integer degree[1]. A subfield of mathematics known as fractional mathematics deals with the general circuit theory of integer degree derivatives and integrals. Fractional mathematics is used to create accurate models of real items and many natural events. Although the fundamentals of fractional mathematics were established over a long span of time, fractional order computations have shown recently that it has a growing potential for attention due to their improvement in design and modelling. Numerous applications have been made in a variety of domains, including electrical engineering[8-12], bioengineering[2], chaotic systems[3], electromagnetic Smith charts[3], biochemistry[4], medicine[5], materials science[6-7], agriculture, PV modelling, electronic filters, oscillators, and physics.

The use of fractional order calculations in interdisciplinary projects has given rise to the development of several emerging applications across numerous fields. Caputo's definition[11] given by fractional derivatives is as follows Eq. (1)

$$ {}_{\propto}D_{t}^{\propto} f(t) = \frac{1}{r(n-a)} \int_{a}^{t} (t-\tau)^{n-\propto-1} f^{(n)}(\tau) d\tau,\ n-1 < \propto < n \qquad (1)$$

Where' t' is used to determine the amount of time needed, 'a' is the starting time, and a is the fractional order. If Eq. (1) is transformed using the Laplace approach while Eq. (2) serves as the initial condition:

$$ L\{ {}_{\propto}D_{t}^{\propto} f(t)\} = S^{\propto}F(s) \qquad (2)$$

The fractional order integral and derivative affect how conventional capacitors and inductors are perceived, resulting in an additional degree of flexibility. Such an expression is referred to as a fractal device[12-13] in analogue. The fractal device described by its impedance4 is considered to be Eq (3) a special case of a more general circuit element:

$$ Z(s) = k_0 s^{\propto} = k_0\,(j\omega)^{\alpha} \qquad (3)$$

Where is fractional order and k0 is a constant. In Eq. (4), phase and size of Z are provided.

$$ |Z| = k_0 \omega^{\alpha} \ < Z = \frac{\propto\pi}{2} \qquad (4)$$

Due to its several advantages, including a wide dynamic range, wide bandwidth, high exchange rate, high linearity, lower power consumption, and a simple circuit construction, the current mode (CM) circuit approach is used in this study to design an analogue filter instead of a voltage mode (VM) circuit. In this study, a current mode fractional universal filter and a multimode second generation current controlled current conveyor (MO-CCCII) are introduced. Since current conveyors do not suffer from gain bandwidth multiplication like Op-Amps do, it is known that MO-CCCII performs much better. Additionally, Op-Amp has a more complicated circuit design than current conveyors and uses four times as much power. Accordingly, MO-CCCII is used as topologies providing low-pass (LP), high-pass (HP), band-pass (BP) and band-stop (BS) filter signals, which can simultaneously perform four standard filter functions.

This paper organised as follows. MO-CCCII is discussed in Section2. Details of fractional order universal filter and Carlson approximation is presented in section 3. Designing of MO-CCCII based fractional order universal filter is presented in section 4. Circuit simulation and results in section 5. Conclusion is given in section 6.

II. Multi-Output Second Generation Current Controlled Current Conveyor (MO-CCCII)

A variant of the second-generation current conveyor known as the second-generation current controlled current conveyor (CCCII) eliminates passive components by using parasitic resistors that are electrically adjustable. By substituting passive resistors used externally in analogue circuits, this parasitic resistor at the X-terminal of the CCCII reduces the number of passive parts in the circuits. Due to these benefits, it has found multiple uses in a variety of fields and is still doing so. In this work, a four-output second generation current controlled current conveyor (MOCCCII)[15-16] is created by multiplying the terminal Z outputs of the second-generation current controlled current conveyors by the available current mirrors. As a result, the circuit's necessary number of current conveyors is decreased. The MO-CCCII's symbol is shown in the figure 1, and Figure 2 shows the device's internal structure with BJT transistors. The following equations (5) and (6) provide the relationships between the general terminal currents and voltages of the second-generation current controlled current conveyors.

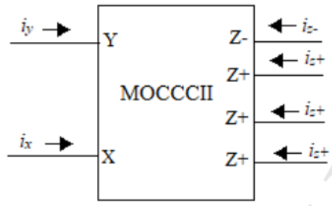
$$\begin{bmatrix} V_x \\ I_y \\ I_z \end{bmatrix} = \begin{bmatrix} 1 & R_x & 0 \\ 0 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_z \end{bmatrix}$$

$$I_Y = 0$$

$$V_X = V_Y + i_X |R_X(i_0)| \qquad (5)$$

$$I_{z\pm} = \pm I_X \qquad (6)$$

The block diagram representation of the MO-CCCII is shown in Fig.1. The BJT based implementation of the MOCCCII is shown in Fig.2.



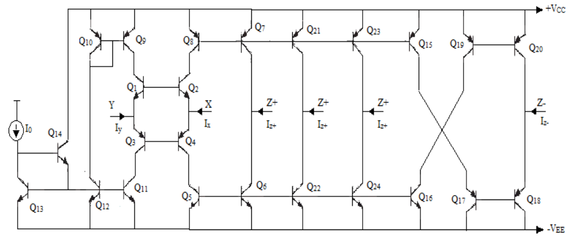


Fig.1. MO-CCCII Block Diagram

Fig.2. Internal structure of the MO-CCCII using BJT transistors

III. Fractional order Universal Filter

The general transfer function of the fractional order universal filter is given by

$$T(s) = \frac{ds^{1+\alpha} + es^{\alpha} + f}{s^{1+\alpha} + bs^{\alpha} + c} = \frac{N(s)}{s^{1+\alpha} + bs^{\alpha} + c}$$

Here, the fractional order α is the constant parameters $b = 1/C2R2$ and $c = 1/C1R1\ C2R2$.

first the Hankel singular values are found, as such respective energy of each state is known and the states to be eliminated are directly determined. The controllability and observability grammians are found. Then Schur balance truncation algorithm[19] is applied to obtain the reduced order model based on the states chosen to be eliminated. The additive error bound on the H∞ norm is taken as a measure of the transfer matrix and is a function of the discarded Hankel Singular Values. Carlson and Halijak proposed the approximation for approximating practice, $(\frac{1}{s})$, using regular Newton process. The general expression of the approximation is given by

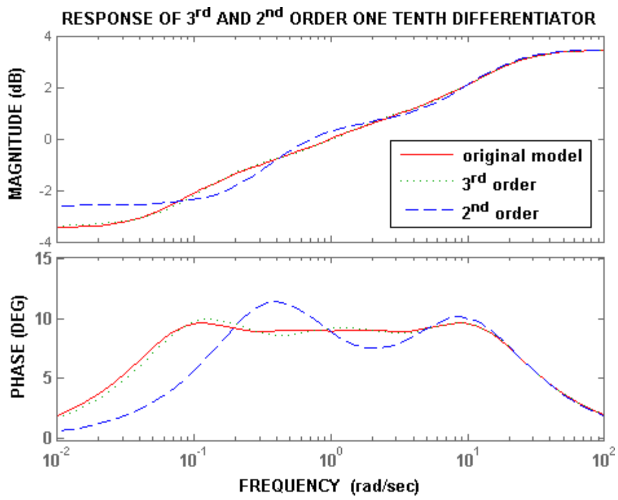
$$G_{k+1}(s) = G_k(s) \frac{(n-1)G_k^n + (n+1)H(s)}{(n-1)G_k^n + (n+1)H(s)} \qquad (7)$$

Where n is order of approximation and k is iteration number. The interval of frequencies where the approximation is valid is always centred at unity. We assume $G_0(s)=1$ in the rational approximation for

$$S^{0.2} = \frac{2.25S^3+21.96S^2+21.74S+1.66}{S^3+16.92S^2+26.07S+3.622} \quad (8)$$

$$S^{0.4} = \frac{2.25S^3+21.96S^2+21.74S+1.66}{S^3+20.28S^2+25.2S+2.626} \quad (9)$$

In this method, only even integer order approximations can be obtained for fractance device. Depending on the user requirement the order of approximation is chosen. But as the order increases, the realization would be complex and increases



hardware. The comparison of the ideal and Carlson approximation is shown in Fig.3

Fig.3. Frequency response of original and reduced 3rd and 2nd order models of one-tenth differentiator

IV. MO-CCCII BASES FRACTIOANLA ORDER UNIVERSAL FILTER DESIGN

The M0-CCCII based fractional order Universal filter using only one fractional order element is shown in Fig.4. Here Capacitor is of fractional order in nature. In this paper, the values chosen fractional order $\propto = 0.2$ *and* $\propto = 0.4$ For order $\propto = 0.2$, the transfer function given in Eqn.8 and For order $\propto = 0.4$, the transfer function given in Eqn.9 has been realized using network synthesis procedure in the form of Ladder network[20]. The proposed RC circuit is shown in below figure. The circuit can be realised by four resistors and three capacitors are placed in place of fractional capacitor for Universal filter design.

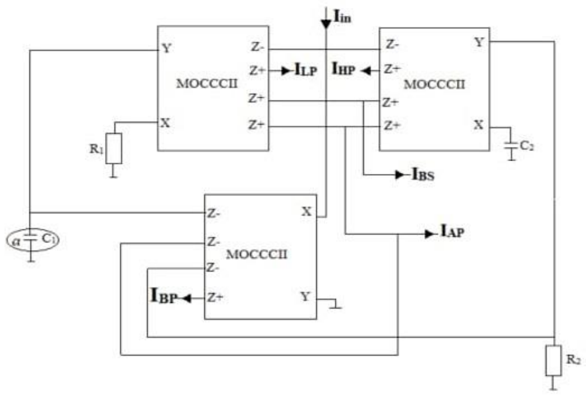


Fig. 4 Fractional Order Universal Filter Circuit

V. RESULTS AND DISCUSSION

MO-CCCII Based Universal Filer Circuit consists of C2=1nF and R1=R2=1k. In the Internal Circuit, MO-CCCII Values are Bias current I0=13ua and Source Voltage +VEE= -VCC =+2.5V and PNP and NPN Transistors in the Structure are Simulated Using NR100N and PR100N Bipolar Array Transistor. In addition, the cutting frequency of this filter is measured as 100 KHz.

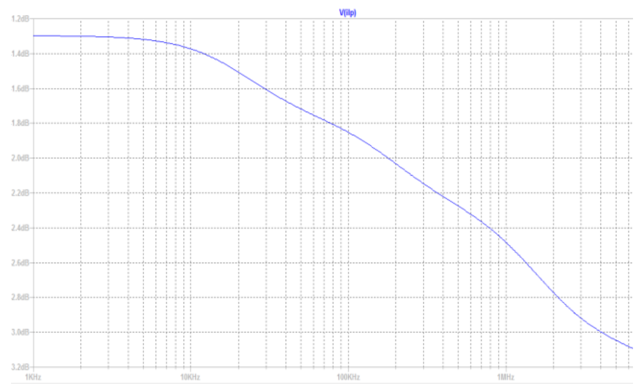


Fig. 5 Magnitude response of fractional Low-pass filter for (1+α) = 0.2

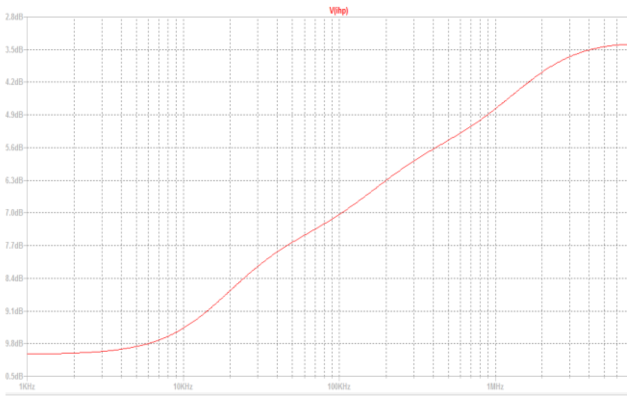


Fig. 6 Magnitude response of fractional High-pass filter for (1+α) = 0.2

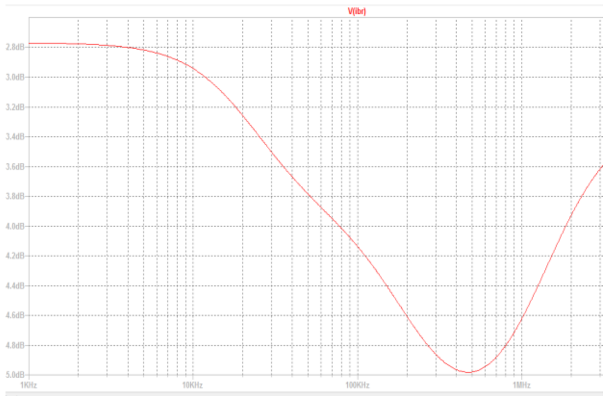


Fig. 7 Magnitude response of fractional Band-pass filter for (1+α) = 0.2

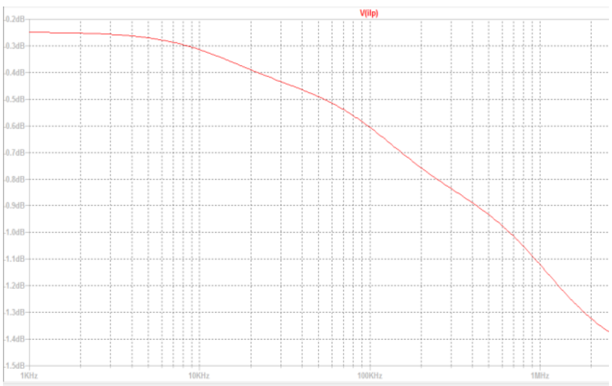


Fig. 8 Magnitude response of fractional Low-pass filter for (1+α) = 0.4

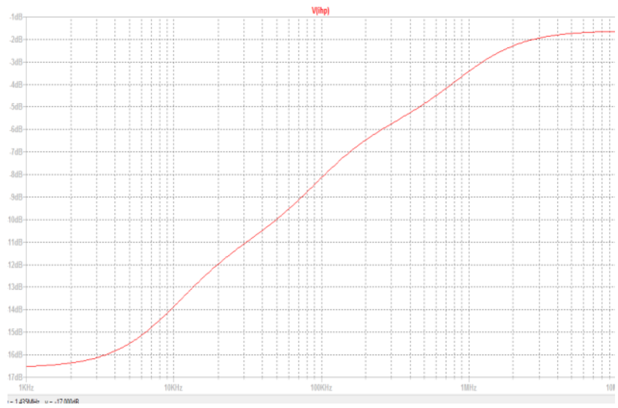


Fig. 9 Magnitude response of fractional High-pass filter for (1+α) = 0.4

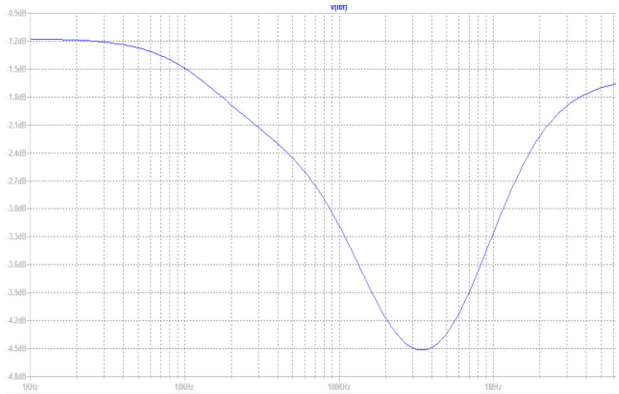


Fig. 10 Magnitude response of fractional Band-pass filter for (1+α) = 0.4

VI.CONCLUSION

In this Paper Balanced Truncation method applied and reduced order models developed. It is observed that the response of the model obtained using this Method match exactly with the response of the original model.

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