REALIZATION OF CCII BASED GENERALIZED IMPEDANCE CONVERTER AND ITS APPLICATION IN BI-QUADRATIC FILTER AS FDNR SUBSTITUTION

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ABSTRACT

This paper presents a new versatile active circuit for the realization of Generalized Impedance Converter (GIC), using CCII and grounded passive elements, which makes it suitable for IC implementation. This circuit can be used as Ideal Grounded Inductance, Ideal Grounded FDNR, R & C multipliers through appropriate selection of passive elements. As an application the proposed GIC is used to realize Ideal Grounded FDNR simulator that is used to make a Bi-quadratic multifunctional filter, which gives Low Pass (LP), Band Pass (BP) and High Pass (HP) responses. The circuit enjoys attractive features, such as high Quality Factor (Q), independent tuning of Q and Pole Frequency (f_o), low voltage, low component count, low sensitivities. Simulation results show excellent performance at a low bias voltage of ±0.75 volts.

Keywords: Generalized Impedance Converter (GIC), Ideal Grounded FDNR, Second Generation Current Conveyor (CCII).

I. INTRODUCTION

Immittance simulation has been a standard research topic since it can be used in the design of oscillators, active filters and cancellation of parasitic elements. The arrival of integrated circuit has encouraged the design of simulated inductance [1, 2], FDNR [3, 4] that can be used instead of the bulky grounded and floating inductors in passive filters. Component multipliers [5] are popular in the fabrication of large R and C values in ICs, as well as, for convenient tuning of filters and oscillators. Among all current mode devices, Second Generation Current Conveyor (CCII) is the most popular one. It is widely considered as the op-amp equivalent in current mode signal processing. Commercially available IC AD844 implements the salient feature of CCII. Its performance is characterized by the voltage and current following behaviors. The need of low voltage analog circuit is well established for portable battery operated devices. In such applications, the use of current mode approach can be favorable for both dynamic range and operating speed point of view. The signal in current mode approach can achieve a higher dynamic range [6]. This feature is particularly suited in VLSI circuits where the trend is that of shrinking the power supply.

In this paper, we present a low voltage realization of Generalized Impedance Converter (GIC), using CCII and passive elements that can implement an impedance converter, ideal grounded inductance, FDNR, and R & C multipliers through appropriate selection of passive components. The proposed GIC simulator is realized using grounded passive components without any matching constraints. As an application, the proposed Frequency Dependent Negative Resistor (FDNR) is used to construct a multifunctional filter, which provides Low Pass (LP), Band Pass (BP) & High Pass (HP) responses. The proposed circuit is superior over earlier circuits [1-5] in terms of the number of components, versatility, supply voltage requirement and functionality. The frequency performance of the circuit is critically studied and verified through PSpice simulation with TSMC 0.18µm parameter using low supply voltage of ±0.75 volts.

II. CIRCUIT DESCRIPTION

Fig.1 shows the circuit for the realization of a generalizeimpedance converter that can implement ideal grounded inductance, FDNR, and R & C multipliers. It consists of two CCIIs along with three grounded passive components. The CCII characteristics can be defined by the following matrix equation (1) [7].

$$\begin{bmatrix} i_Y \\ v_X \\ i_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} . \begin{bmatrix} v_Y \\ i_X \\ v_Z \end{bmatrix} \quad (1)$$

Where, the voltage output at X terminal follows the voltage input at Y terminal and current output at Z terminal follows (or inverter) the current input at X terminal.

Routine analysis of the proposed circuit yields the input impedance as:

$$Z_{in}(s) = \frac{Z_1 Z_2}{Z_3} \quad (2)$$

If $Z_1 = R_1$, $Z_3 = R_3$ and $Z_2 = Z(s)$ are selected in equation (2), then an impedance multiplier is realized whose input impedance is given by following equation:

$$Z_{in}(s) = \frac{R_1 Z(s)}{R_3} \quad (3)$$

Where, $K = R_1/R_3$ is multiplication factor.

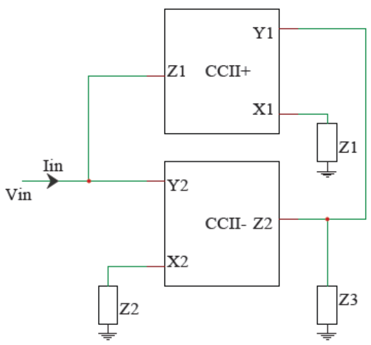

Fig.1 The Proposed CCII Based Generalized Impedance Converter

2.1. Grounded FDNR Simulator

If $Z_1 = 1/sC_1$, $Z_2 = 1/sC_2$ and $Z_3 = R_3$, are selected in equation (2) then an input impedance is given by equation (4).

$$Z_{in}(s) = \frac{1}{s^2 C_1 C_2 R_3} = \frac{1}{s^2 D_{eq}} \quad (4)$$

Where,

$$D_{eq} = C_1 C_2 R_3 \quad (5)$$

Thus an Ideal Grounded FDNR is implemented with only grounded passive components and CCIIs. Here it can be seen that the Ideal Grounded FDNR realized is without any matching constraints.

2.2. Grounded Inductance Simulator

If $Z_1 = R_1$, $Z_2 = R_2$ and $Z_3 = 1/sC_3$, are selected in equation (2), then the input impedance is given by equation (6).

$$Z_{in}(s) = sR_1R_2C_3 = sL_{eq} \tag{6}$$

Where,

$$L_{eq} = R_1R_2C_3 \tag{7}$$

Thus the circuit realizes an ideal active inductance (L_{eq}). It can be seen that Ideal Grounded Inductance is realized, without any matching constraints, using only grounded passive components along with CCIIs.

2.3. Grounded R- Multiplier

If Z1 = R1, Z2 = R2 and Z3 = R3, are selected in equation (2), then the input impedance is given by equation (8).

$$Z_{in}(s) = \frac{R_1R_2}{R_3} = K_rR_2 = R_{eq} \tag{8}$$

Where, the Resistance Multiplication Factor (K_r) is given by equation (9).

$$K_r = \frac{R_1}{R_3} \tag{9}$$

2.4. Grounded C- Multiplier

If $Z_1 = R_1$, $Z_2 = 1/sC_2$ and $Z_3 = R_3$, are selected in equation (2) then the input impedance given by the equation (10).

$$Z_{in}(s) = \frac{R_1}{sC_2R_3} = \frac{1}{sC_{eq}} \tag{10}$$

Where,

$$C_{eq} = \frac{R_1C_2}{R_3} = K_cC_2 \tag{11}$$

Where, the Capacitance Multiplication Factor (K_c) is given by equation (12).

$$K_c = \frac{R_1}{R_3} \tag{12}$$

Thus the proposed circuit can realize ideal grounded inductance, FDNR, and R & C multipliers through appropriate selection of grounded passive elements.

III. NON IDEAL EFFECTS

The non-ideal CCII is characterized by namely $v_X = \beta v_Y$, $i_Z = \alpha i_X$. Where $\alpha = 1-\varepsilon_i$ (ε_i denotes the current tracking error at the high impedance output terminal Z) and $\beta = 1-\varepsilon_v$ (ε_v denotes the voltage tracking error at the low impedance terminal X from the high impedance terminal Y). If α & β are considered in the analysis of proposed circuit of Fig. 1, the input impedance is then given by equation (13).

$$Z_{in}(s) = \frac{Z_1Z_2}{\alpha\beta_1\beta_2Z_3} \tag{13}$$

For ideal CCIIs, $\alpha_1=\beta_1=\beta_2= 1$ thus the input impedance becomes same as equation (2).

$$Z_{in}(s) = \frac{Z_1 Z_2}{Z_3}.$$

The non-ideal Grounded Inductance (L_{eq}), Grounded FDNR (D_{eq}), resistance (R_{eq}) and capacitance (C_{eq}) are given by:

$$D_{eq} = \alpha\beta_1\beta_2 C_1 C_2 R_3 \quad (14)$$

$$L_{eq} = \frac{R_1 R_2 C_3}{\alpha\beta_1\beta_2} \quad (15)$$

$$R_{eq} = \frac{R_1 R_2}{\alpha\beta_1\beta_2 R_3} \quad (16)$$

$$C_{eq} = \frac{\alpha\beta_1\beta_2 R_1 C_2}{R_3} \quad (17)$$

For ideal CCIIs, $\alpha_1=\beta_1=\beta_2= 1$ then the equations (14), (15), (16) &(17) are same as in (5), (7), (8)& (11) respectively, as realized for ideal case.

IV. APPLICATION OF PROPOSED GIC

As an application, the proposed GIC is used as Grounded FDNR Simulator to realize the Bi-quadratic filter shown in Fig.2. It has been obtained by replacing the FDNR of a CRD transformed version of a passive RLC prototype Band Pass filter by ideal grounded FDNR simulator. The filter gives High Pass and Band Pass filter responses at nodes (1) and node (2) respectively. Simple analysis of the circuit gives Band Pass and High Pass equation (18) and (19) respectively.

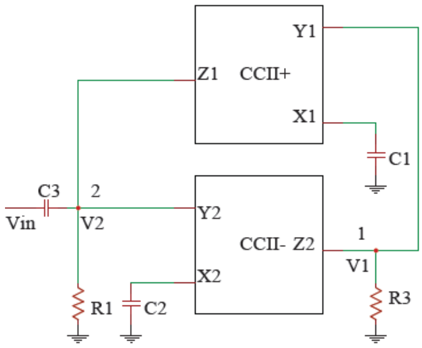

Fig. 2. CCII based Bi-quadratic filter using Ideal Grounded FDNR realized by proposed GIC.

$$\frac{V_1}{V_{in}} = \frac{\frac{s^2 C_3}{C_1}}{s^2 + \frac{sC_3}{C_1 C_2 R_2} + \frac{1}{R_1 R_3 C_1 C_2}} \quad (18)$$

$$\frac{V_2}{V_{in}} = \frac{\frac{sC_3}{C_1 C_2 R_3}}{s^2 + \frac{sC_3}{C_1 C_2 R_2} + \frac{1}{R_1 R_3 C_1 C_2}} \quad (19)$$

If the input and ground terminal of the resistor (R_1) are interchanged, then Band Pass and Low Pass filters will be realized at node (1) and (2) respectively. The Band Pass and Low Pass transfer functions are given by equation (20) & (21) respectively.

$$\frac{V_1}{V_{in}} = \frac{\frac{s}{R_1 C_1}}{s^2 + \frac{sC_3}{C_1 C_2 R_2} + \frac{1}{R_1 R_3 C_1 C_2}} \quad (20)$$

$$\frac{V_2}{V_{in}} = \frac{\frac{1}{C_1 C_2 R_1 R_3}}{s^2 + \frac{sC_3}{C_1 C_2 R_2} + \frac{1}{R_1 R_3 C_1 C_2}} \quad (21)$$

The bi-quadratic filter parameters, Pole Frequency (ω_o) and Quality Factor (Q) of the multi-functional filters are given as:

$$\omega_o = \sqrt{\frac{1}{R_1 R_3 C_1 C_2}} \quad (22)$$

$$Q = \frac{1}{C_3}\sqrt{\frac{C_1 C_2 R_3}{R_1}} \quad (23)$$

For $C_1 = C_2 = C \ and \ R_1 = R_3 = R$

$$\omega_o = \frac{1}{RC} \quad (24)$$

$$Q = \frac{C}{C_3} \quad (25)$$

It may be seen that the proposed circuit realizes Low Pass, Band Pass and High Pass responses without requirement of component matching. The quality factor of the filter can be tuned independently by varying C_3 without disturbing the Pole Frequency. The passive sensitivities of the filter parameters ω_o and Q against the component is given by equations (26-29).

$$S^{\omega_o}_{C_1 C_2 R_1 R_3} = -\frac{1}{2} \quad (26)$$

$$S^{Q}_{R_1} = -\frac{1}{2} \quad (27)$$

$$S^{Q}_{C_3} = -1 \quad (28)$$

$$S^{Q}_{C_1 C_2 R_3} = \frac{1}{2} \quad (29)$$

The sensitivities are found to be low, that is comparable to passive filter sensitivity.

V. SIMULATION RESULTS

The performance of the Bi-quadratic filter is verified through PSpice simulation. The CCII [8] is simulated with TSMC 0.18µm parameter using low supply voltage of ±0.75 volts. The filter circuit is designed for Low Pass, Band Pass and High Pass responses with quality factor of 0.707 and f_o= 300 KHz. Preselecting $C_1 = C_2 = C = 0.25$nF, $R_1 = R_3 = R$ is found to be of 2.123KΩ. This gives the value of $C_3 = 0.3536$nF. The simulation results are shown in Fig.3. These are found to be in conformity with the design.

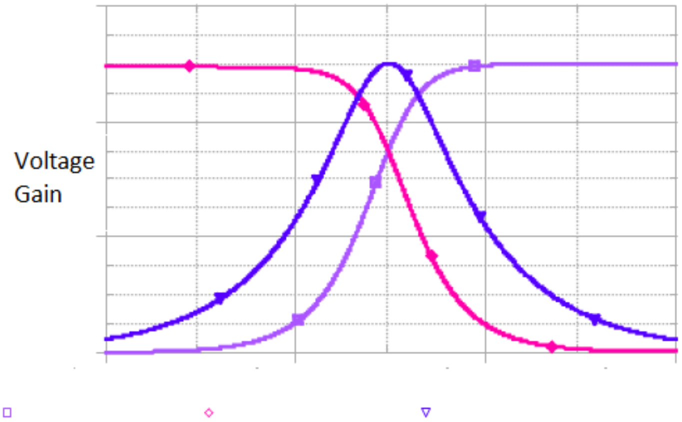

Fig. 3. Frequency response of CCII based LP, BP and HP filters at f_o= 300 KHz.

The Independent tuning of Q is demonstrated by designing the BP filter at f_o= 500 KHz and changing its Q through C_3. The corresponding capacitances for Q of 2, 4 and 7 are obtained to be 0.125nF, 0.0625nF & 0.0357nF respectively. The fig.4 shows the Q-tuning of band pass filter, which is in conformity with design.

he independent tuning *of* f_o of the Band Pass filter is achieved by varying the resistor value. Selecting $R_1 = R_3$ and C1 = C2 = C3= C, gives Q=1 and ω_o will be given by equation (24). Preselecting C= 0.15nF to tune f_o at 165KHz, 330KHz & 645KHz, the value of R is found to be 6.430K, 3.215K & 1.645K respectively. The response curves in Fig.5 obtained by simulation verify the design. Here the tuning of f_o over wide range achieved which is independent of Q-Factor.

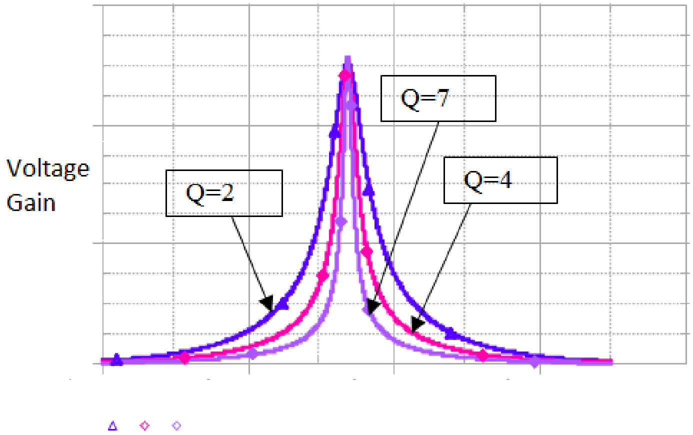

Fig. 4. Tuning of Q at constant f_o= 500 KHz (i) Q = 2 (ii) Q = 4 (iii) Q = 7.

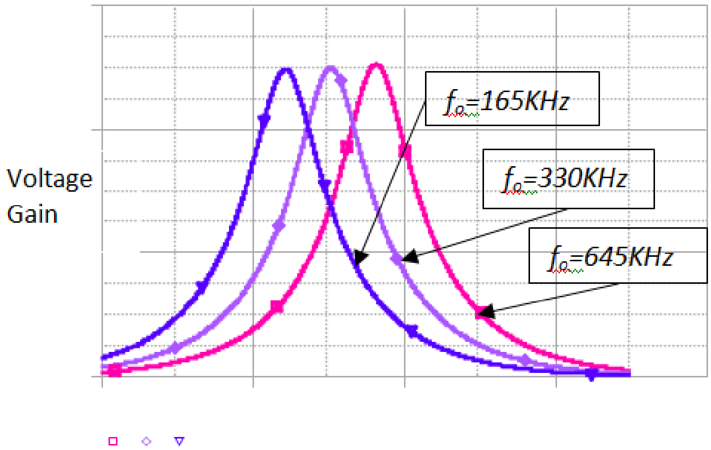

Fig. 5. Frequency tuning of BPF (f_o) at constant Q = 1 (i) f_o = 165KHz (ii) f_o = 330 KHz (iii) f_o = 645 KHz.

VI. CONCLUSION

In this paper a novel versatile circuit is proposed for the realization of Generalized Impedance Converter that can simulate Ideal Grounded Inductance, Ideal Grounded FDNR, and R & C multipliers through appropriate selection of passive elements**.** The proposed circuit is realized using ±0.75 volts CMOS Second Generation Current Conveyor [8] and feasible valued grounded passive components without any matching constraints. These features make it attractive for integration on monolithic IC. As an application, the proposed Generalized Impedance Converter simulator is used as a FDNR to construct a multifunctional filter, which provides Low Pass, Band Pass and High Pass responses. This filter have the attractive features such as, low component count, low bias voltage, low sensitivity of components, high Q, independent Q-tuning of the filter without affecting its Pole Frequency and hence suitable for monolithic IC fabrication.

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