Grounded-inductor employing Multi-output Current Controlled Conveyors

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Abstract —**The simulation of grounded inductor using two Multi-output Current Controlled Conveyors (MCCCIIs), a grounded capacitor and two grounded resistors is presented. Proper selection of the values of the passive elements can yield very large as well as very small of simulated inductances. The grounded inductor simulated can be used in the LCR passive filters. Thus, their advantages include low component sensitivities and the ability to utilize the extensive knowledge of LCR filter design. In addition, these filters are suitable for integration. Finally, a simple biquad filter is experimentally demonstrated. The experimental result of a RLC passive bandpass filter confirming the theory is included.**

Key words: differential-voltage current conveyor, inductor simulators, analog circuit design, active filters.

1. Introduction

Many sinusoidal oscillators, active filters and admittance simulating circuits using current conveyor (CCII), four-terminal active current conveyor (CFCCII) and differential-voltage current conveyor (DVCC) as building active elements have been reported in the literatures[1]~[30]. The multi-output current controlled conveyor (MCCCII) is also a versatile building block, because it can extend operating large signal bandwidth, great linearity, wide dynamic range, high input impedance and arithmetic operation capability. Recently, the MCCCIIs have been applied in the areas of simulation inductance design, filters, and cancellation of parasitic elements [31]~[39]. For example: Jiraseree-amornkun and Surakampontorn employed some MCCCIIs and some passive elements to synthesize the simulation of floating inductance and filters. Jiraseree-amornkun and Surakampontorn proposed a Butterworth lowpass filter, an elliptic lowpass filter and a Chebyshev bandpass filter again [31] ~ [33]. Zhijun used five MCCCIIs and two grounded capacitors to realize low-pass, high-pass, band-pass filter functions from the same topology simultaneously in 2009 [34]. Yin proposed a current-mode filter circuit which can realize either notch or all-pass or lowpass or highpass or bandpass filter using four MCCCIIs as active elements together with some passive components in 2011 [35]. Yin employed two MCCCIIs and some passive elements to synthesize current-mode notch, highpass, allpass, bandpass and lowpass filters in 2012 [36]. The required number of the active components for the above filters is quite large. Minimizing the number of the active component has the advantages of low cost and power dissipation. Yin and Liu used one MCCCII and some passive elements to construct the voltage-mode and current-mode configuration filter circuits, which can realize bandpass, lowpass, highpass, notch and allpass filters [37]~ [39]. From the above statement, the MCCCII-based grounded inductance-simulation circuit has never been presented apparently. In the area of active filter design, inductor simulation has attracted considerable interest, because the advantage of designing active filters by simulating the inductor of a passive LCR realization of the filter include low component sensitivities and the ability to utilize the extensive knowledge of LCR filter design. On the other hand, the grounded inductor is also frequently required for the design of analogue IC building blocks. For this reasons, it is, therefore, attractive to use MCCCII-based circuits for simulating grounded-inductor. In this paper, a grounded inductance simulator using two MCCCIIs, a grounded capacitor and two grounded resistors was constructed. This inductance simulator was used to RLC passive filters to enjoy the advantages of the RLC filters. Meanwhile, the use of the grounded capacitor simplifies the etching process for monolithic or hybrid fabrication. Therefore, these filters are suitable for monolithic implementation. Finally, a RLC passive filter using the proposed simulated inductor is given to confirm the afore mentioned theoretical analysis.

2. CIRCUIT DESCRIPTION

The circuit symbol for a MCCCII is shown in Fig.1. The port relations of a MCCCII can be characterized as $V_x = V_y + I_x R_x$, $I_y=0$, $I_{Z+}=I_x$ and $I_{Z-}=-I_x$. The '+' and '-' signs of the current i_z denote the non-inverting and inverting, respectively.

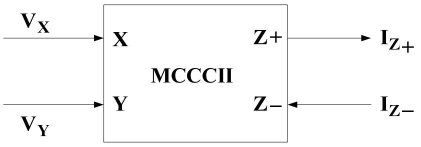


Fig.1. A MCCCII symbol.

The proposed simulation of grounded inductor circuit is shown in Fig. 2. Using the standard notations of ideal MCCCII, it is easy to show that the input impedance of the circuit of Fig. 2 can be expressed as

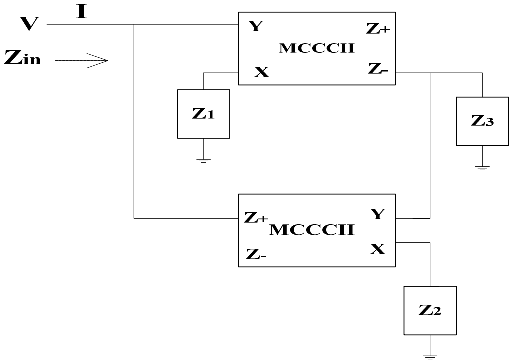


Fig.2 The proposed ground impedance simulator.

$$Z_{in}=\frac{Z_1 Z_2}{Z_3} \text{ ----------------(1)}$$

where Z_1, Z_2 and Z_3 are the impedances. If the impedances are chosen as $Z_1 = R_1$, $Z_2 = R_2$, and $Z_3 = 1/sC_3$ shown in Fig.3.

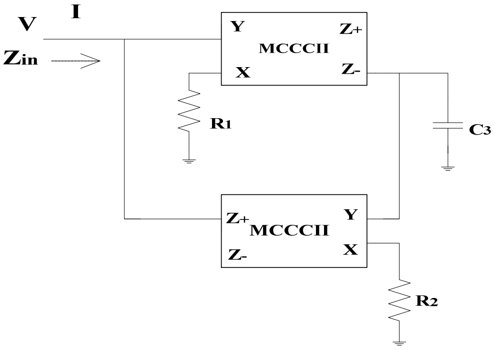


Fig.3. Grounded inductance simulator.

This is equivalent to an inductor with inductance L_{eq} given by

$$L_{eq} = R_1 R_2 C_3 \text{ ---------------------(2)}$$

From (2), it can be seen that by properly selecting values of the resistors R_1, R_2 and the capacitor C_3, very large as well as very small values of inductance can be easily obtained. Clearly, the grounded inductance simulator is constructed.

3. EXPERIMENTAL RESULTS

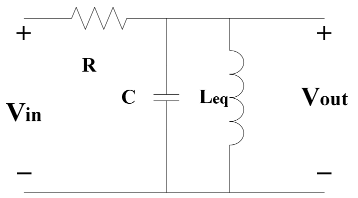
The MCCCII is implemented by three ICAD844s, three IC op-amps and five resistors. The proposed grounded inductor simulated was experimentally tested using $R_1=R_2=1K\Omega$, $C_3=1\mu F$ and AD844s, so this is equivalent to an inductor with $L_{eq} = 1H$. Then, this proposed grounded inductor simulated was used to replace the inductor of the RLC passive bandpass filter shown in the figure 4(a). The transfer function of the active filter has a biquadratic bandpass characteristic with

$$\frac{v_{out}}{v_{in}} = \frac{(\frac{1}{CR})s}{s^2 + s(\frac{1}{CR}) + \frac{1}{L_{eq}C}} \text{ ---------- (3)}$$

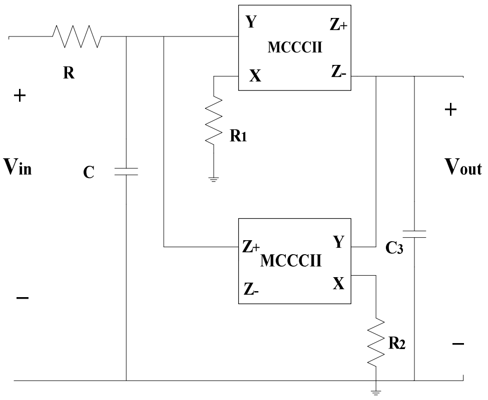
the central frequency: $\omega_o = (\frac{1}{L_{eq}C})^{1/2}$

the quality factor: $\vartheta = R(\frac{C}{L_{eq}})^{1/2}$

From the figure 4 (b), a biquadratic bandpass filter was constructed with $R = 10^3\Omega$, $C = 1\mu F$ and $L_{eq}=1H$. The resonance frequency was monitored and measured and the corresponding inductance value was calculated and compared with the theoretical value calculated using equation (2).



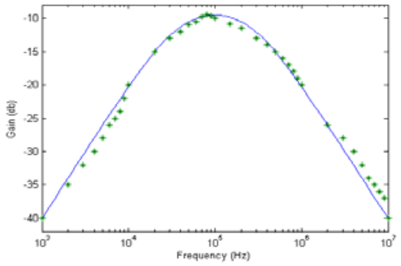
(a) The prototype passive RLC bandpass filter.



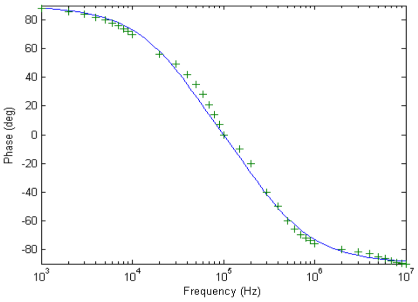
(b) Bandpass filter circuit used to test the inductor realized using circuit of Fig. 3.

Fig.4 (a) The prototype passive RLC bandpass filter.
(b) Bandpass filter circuit used to test the inductor. realized using circuit of Fig. 3.

The figure 5 (a) and (b) show the experimental results for the gain and phase responses. They showed a good agreement between theoretical calculations and practical measurements. The theoretical analysis correlated with the measured results with few errors which due to the errors of the use of passive elements.



(a) The gain response curve of the banspass filter using simulated inductor.



(b) The phase response curve of the banspass filter using simulated inductor.

Fig.5 (a): The gain response curve of the banspass filter using simulated inductor.
(b): The phase response curve of the banspass filter using simulated inductor.
*: Experimental result for banspass gain.
+: Experimental result for bandpass phase.
—: Ideal curve.

4. CONCLUSION

The realization of grounded inductor using two MCCCIIs, a grounded capacitor and two grounded resistors has been proposed. A proper selection of the values of the resistors and capacitor, of the figure 2, can yield very large as well as very small of simulated inductances. The advantages of designing active filters by simulating the inductors of a passive LCR realization of the filter include low component sensitivities and the ability to utilize the extensive knowledge of LCR filter design. Meanwhile, these filters are suitable for monolithic implementation. Finally, the experimental grounded inductors results of a LCR bandpass passive filter confirmed.

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