Implementation of a Voltage-Mode All-Pass Filter Using CCII and Its Inverse Configuration

Rimpi Datta[1],Koushick Mathur[2],P. Venkateswaran[3], R Nandi[3]

[1]Meghnad Saha Institute Of Technology,DepartmentofElectronicsand Communication Engineering,Kolkata.

[2] University Institute of Technology, Burdwan University, Department of Electronics and Communication Engineering, Burdwan

[3]Jadavpur University, Department of Electronics & Telecommunication Engineering, Kolkata

Abstract: *This work presents a voltage-mode (VM) filter capable of performing a first-order all-pass (AP) function as well as generating its inverse signal. The proposed design features a single input and output and utilizes one CCII, two resistors, and a grounded capacitor. By employing either an inverting or non-inverting CCII, the circuit can achieve both AP and inverse AP responses without altering the circuit topology. The phase angle can be adjusted by varying the frequency of the input signal or by modifying the grounded capacitor, maintaining the circuit's reliability condition. Simulation results using the PSPICE software confirm the circuit's performance.*

Keywords: Voltage mode Circuit, All Pass Filter, Inverse Function, CCII

I. Introduction

The application of inverse filters is indispensable for recovering signals that have been distorted by a processing or transmission system. This recovery is achievable using an inverse filter block, whose frequency response is the reciprocal of the system that caused the distortion. Therefore, inverse filters are essential components in the design of signal processing and conditioning systems, such as those used in communication, control, and instrumentation. First- and higher-order all-pass filters serve several key functions, including: (1) shifting the phase of a signal from 0 to π while maintaining a constant amplitude over the target frequency range; (2) enabling various filtering characteristics and oscillator designs; and (3) facilitating the realization of high-Q frequency-selective circuits. Numerous circuits implementing all-pass functions in either current-mode or voltage-mode have been reported, utilizing components such as OTAs, FTFNs, or CCIIs [1-9]. However, no existing topology appears to offer the capability to realize both the all-pass function and its inverse simply by reversing the polarity of the active device, without requiring modifications to the circuit structure. To address this, we propose a voltage-mode (VM) filter that achieves both a first-order all-pass (AP) response and its inverse by reversing the polarity of the active device. The proposed design requires only a single CCII, two resistors, and a grounded capacitor. By employing either an inverting or non-inverting CCII, the circuit provides the AP function and its inverse signal, respectively. In both configurations, the phase can be adjusted by varying the input signal frequency or the grounded capacitor, an approach well-suited to integrated circuit (IC) design.

II. Proposed Design

The ideal CCII can be characterized by the following port relations:
$V_X = V_Y$, $I_Y = 0$ and $I_Z = \pm Ix$

where the ± sign depicts the polarity of the CCII.

By using non-inverting CCII, the analysis of the circuit in Fig. 1 yields the first-order inverse AP VM transfer function given by:

$V_0/V_{IN} = (1/\ 1 - sRC)/\ 1 + sRC$ ....(1)

By reversing the polarity of the CCII, Eqn 1 takes the form of first order AP signal as given by

$V_0/V_{IN} = (1 - sRC)/\ (1 + sRC)$ ....(2)

The realizibility condition for both the versions of the circuit is $R_1 = R_2$ which is simple and temperature invariant being resistor ratio and therefore desirable inIC fabrication.

The circuit respectively yields phase shifts from 0 to 180 and 0 to –180 for inverse AP function and corresponding AP signal. For an ideal case, the filter respectively has the following phase responsescorresponding to inverse AP and AP:

$\phi(\omega, R, C) = 2\arctan(\omega RC)$ ….(3)

$\phi(\omega, R, C) = -2\arctan(\omega RC)$ ….(4)

Eqs (3) and (4) reveal that the phase can be controlledby adjusting the frequency of the input signal and/or C without influencing the realizibility condition.

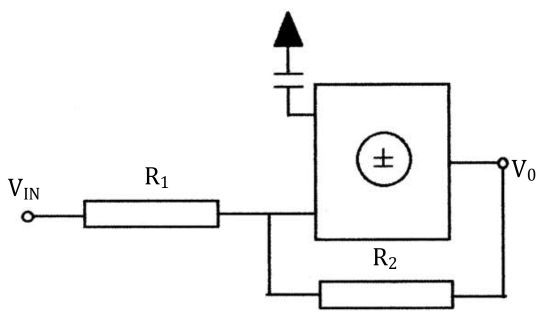

Figure1. Proposed voltage-mode filter

III. Error Analysis

Tracking—The non-ideal port relations of CCII are given by $I_z = \alpha I_x$, where $\alpha = 1-\psi_1$; $\psi_1 << 1$, denotes the current tracking error; $V_x = \beta V_y$, where $\beta = 1-\psi_2$; $\psi_2 << 1$, denotes the input voltage tracking error.

The re-analysis of the circuit based on the non-idealities of the device employed yield the following voltage-transfer functions:

$V_0/V_{IN} = 1/[(1 - \alpha\beta sRC)/\ (1 + sRC)]$ ...(5)

$V_0/V_{IN} = (1 - \alpha\beta sRC)/\ (1 + \alpha\beta sRC)$ ...(6)

IV. Sensitivity

The study of sensitivities forms an important index of the performance of any active network. The formal definition of sensitivity is:

$$S^{r}_{x} = X\delta F / F\delta X$$

where *F* is the networks function and *x* is the elementof variation. Using this definition, the sensitivities of ω_0 with respect to active and passive components aregiven by:

$$S^{w0}\ \alpha,\beta,R,C=-1$$

which are no more than unity.

V. Experimental Results

PSPICE simulations were performed to verify the feasibility of the circuit yielding responses represented by Eqs (1) and (2). The negative CCII shown in Fig. 2 can be implemented14 by using two AD844s supported by Analog Devices, Inc. The circuit in Fig.1 was built with C=1nF and $R_1=R_2=1K\Omega$ for realizing allpass and its inverse function with a phase shift of 90^0 at f_0=159KHz

Figs 3 and 4 depict the magnitude responses and the phase response for the two filtering functions, respectively. The phase simulation results obtained agree with the theoretical calculations. However, owing to the non-ideal behaviour of theactive device, the magnitude response varies with the theoretical calculations.

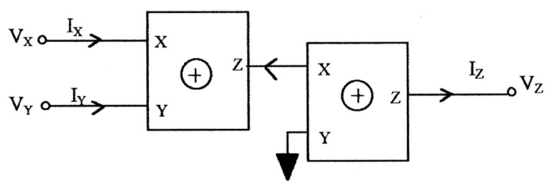

Figure 2. Implementation of inverting CCII using two AD844

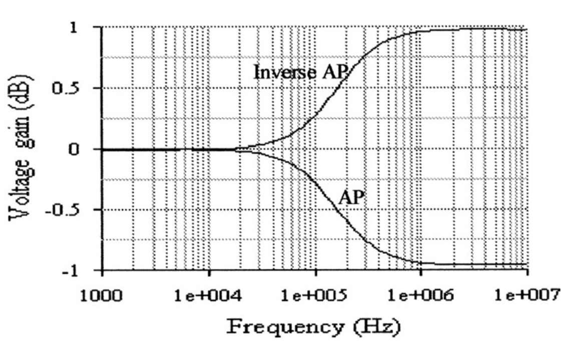

Figure 3. Magnitude responses of AP and inverse AP functions

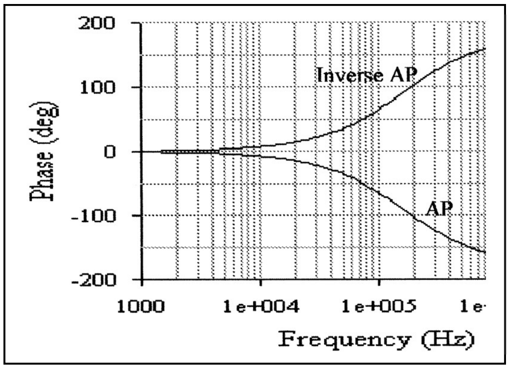

Figure 4. Phase response of AP and inverse AP functions

VI. Conclusions

A novel generic circuit implementing first-order allpass and its inverse function has been presented. The circuit is based on low component count and has simple realizibility condition being in the ratio of resistors, which remains insensitive to environmental changes. By using inverting CCII, the circuit permits implementation of AP function while inverse AP function can be realized by changing the polarity of the device. Both the filtering signals have been implemented without inducing change in the circuit topology or affecting rotation of components or using additional components.

VII. References

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About Author

Rimpi Datta is an Assistant Professor at the ECE Department of Meghnad Saha Institute of Technology under MAKAUT. She has teaching experiences of 11 years. She had completed her B.Tech and M. Tech Degree during 2008 and 2012 respectively. She is now pursuing PhD (Signal. Processing) at the ETCE Department of Jadavpur University. She is a member of IEEE CAS. Her research areas are Signal Processing and Communication Engineering.

Koushick Mathur received the B.E and M.Tech degrees, both from Burdwan University, in 2004 and 2007 respectively and PhD from Jadavpur University in 2020. He is currently serving as an Assistant Professor in Department of Electronics & Communication Engg., University Institute of Technology, Burdwan University, Burdwan, W.B. His research interests include electronic communications, analog circuits and signal Processing

Palaniandavar Venkateswaran (MIETE) has been an Associate Professor with the Department of Electronics and Tele-Communication Engineering (ETCE), Jadavpur University, Kolkata, India, since 2001, and was promoted to Professor in 2009, and served as the Head of the Department of ETCE during April 2016 to April 2018. .He has authored over 100 papers in various national/international journals and conference proceedings. His fields of interest are computer communication, microcomputer systems, and digital signal processing. He is also the Senior Member of IEEE, and served as the Treasurer of the IEEE Communications Society Calcutta Chapter from 2003 to 2009, and as the Secretary from 2009 to 2012. He also served as the Secretary of the IEEE Circuits and Systems Society Calcutta Chapter from 2007 to 2011.

Rabindranath Nandi is a senior professor and UGC-emeritus fellow at the department of Electronics & Telecommunication Engg. Dept., Jadavpur University, Kolkata. He served as the Head of the Department during 1999-2001. His research interest includes topics on analog/ digital signal processing and computer communication. He served as visiting faculty in various universities abroad. He is a member of IEICE and Senior member of IEEE.