Realization of voltage-mode CCII-based allpass filter and its inverse version

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A voltage-mode (VM) filter implementing first-order allpass (AP) function and its inverse signal is presented. The proposed circuit with one input and one output employs a single CCII, two resistors and one grounded capacitor. The circuit respectively implements allpass (AP) signal and its inverse function by using inverting CCII and non-inverting CCII without requiring change in the circuit topology. The phase angle is adjustable through frequency of the applied signal and/or grounded capacitor without disturbing the realizibility condition. The Personal computer simulation program with integrated circuit emphasis (PSPICE) simulation results are included.

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The employment of inverse filters is inevitable to recover the signal which has been distorted by a processing or transmission system. This pull through is possible through inverse filter building block as its frequency response is reciprocal of the frequency response of the system that caused the distortion. Thus, inverse filters are unavoidable building blocks in the construction of signal processing and conditioning systems like communication, control and instrumentation. The functions performed by first and higher-order allpass filters are: (1) for shifting the phase of a signal from 0 to \( \pi \) at constant amplitude over the frequency range of interest; (2) for implementing various types of filtering characteristics and oscillators, and (3) for realizing the high-\( Q \) frequency selective circuits.

Several circuits implementing allpass function operating either in current-mode or in voltage-mode using either OTA or FTFN or CCII have been reported\(^{1-9}\). However, it seems that no such topology is available which can be used to implement both allpass and its inverse function through reversal of the polarity of the device used. The proposed configuration uses a single CCII, two resistors and a grounded capacitor. By using inverting and non-inverting CCII, the circuit respectively yields AP function and its inverse signal. In both the cases, the phase can be controlled by adjusting frequency of the input signal and/or grounded capacitor which is preferred in IC design.

Circuit analysis—The ideal CCII can be characterized by the following port relations:

\[
V_X = V_Y, \quad I_Y = 0 \quad \text{and} \quad I_Z = \pm I_X
\]

where the \( \pm \) 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:

\[
\frac{V_0}{V_{in}} = \frac{1}{1 - sRC} \quad \text{and} \quad \frac{1 + sRC}{1 - sRC}
\]  

By reversing the polarity of the CCII, Eq. (1) takes the form of first order AP signal as given by:

\[
\frac{V_0}{V_{in}} = \frac{1 + sRC}{1 - sRC}
\]

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 in IC 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

![Fig. 1—Proposed voltage-mode filter](image-url)
respectively has the following phase responses corresponding to inverse AP and AP:

\[ \phi(\omega, R, C) = 2 \arctan(\omega RC) \quad \cdots (3) \]

\[ \phi(\omega, R, C) = -2 \arctan(\omega RC) \quad \cdots (4) \]

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

**Tracking error analysis** — The non-ideal port relations of CCII are given by \( I_x = \alpha I_x \), where \( \alpha = 1 - \psi_1 \); \( \psi_1 \ll 1 \), denotes the current tracking error; \( V_x = \beta V_x \), where \( \beta = 1 - \psi_2 \); \( \psi_2 \ll 1 \), 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:

\[ \frac{V_0}{V_{IN}} = \frac{1}{1 - \alpha \beta sRC / (1 + \alpha \beta sRC)} \quad \cdots (5) \]

\[ \frac{V_0}{V_{IN}} = \frac{1 - \alpha \beta sRC}{1 + \alpha \beta sRC} \quad \cdots (6) \]

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

\[ S_x^F = \frac{x \partial F}{F \partial x} \]

where \( F \) is the networks function and \( x \) is the element of variation. Using this definition, the sensitivities of \( \alpha \) with respect to active and passive components are given by:

\[ S_{\alpha,b,R,C} = -1 \]

which are no more than unity.

**Simulation 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 implemented by using two AD844s supported by Analog Devices, Inc. The circuit in Fig.1 was built with \( C = 1 \text{mF} \) and \( R = R = 1 \text{k}\Omega \) for realizing allpass and its inverse function with a phase shift for \( 90^\circ \) at \( f_0 = 159 \text{ kHz} \). 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 the active device, the magnitude response varies with the theoretical calculations.

**Conclusion** — 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.
References