

## LETTER

# A Reduction of the Number of Components Included in Direct Simulation Type Active Complex Filter

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**SUMMARY** In this paper, a reduction of the number of components included in direct simulation type active complex filter is proposed. The proposed method is achieved by sharing NIC's (Negative Impedance Converters) which satisfy some conditions. Compared with the conventional method, the proposed one has wide generality. As an example, a third-order complex elliptic filter is designed. The validity of the proposed method is confirmed through experiment.

**key words:** complex, active, filter, NIC

## 1. Introduction

In recent years, many techniques concerned with the complex signal processing have been presented, not only in the field of digital circuits but also in the field of analog circuits. The complex filters are important for the Low-IF radio systems [1], [2], SSB (Single Side Band) communication systems [3] and so on.

It is known that the direct simulation method [4]–[6] offers the advantage of a simple design. The authors have proposed a complex filter using NIV's (Negative Imittance Inverters) [4]. Compared with the conventional circuits [5], the complex filter using NIV's can be realized with fewer active components. However, it is difficult to apply this technique [4] to the complex filters with finite transmission zeros.

In this paper, a reduction of the number of components included in direct simulation type active complex filter is proposed. The proposed method is achieved by sharing NIC's (Negative Impedance Converters). As an example, a third-order complex elliptic filter is designed. The validity of the proposed method is confirmed through experiment. The number of the required components of the proposed circuit is compared with that of the conventional one.

## 2. Proposed Method

In many cases, complex prototype filters include not only resistors and capacitors but also imaginary resistors and inductors. The imaginary resistors and inductors can be realized by using gyrators. Therefore, the complex filters can be realized by using resistors, capacitors and gyrators. When

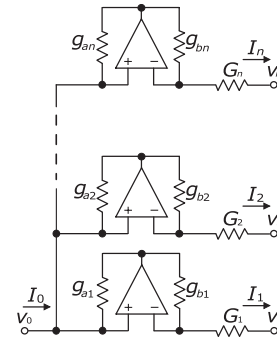


Fig. 1 Several NIC's connected to the same node.

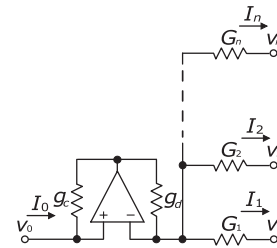


Fig. 2 An NIC and resistors.

the complex filter is realized directly by using operational amplifiers, gyrators are realized by using NIC's [5]. Except for special case [7], complex filters composed of resistors, capacitors, and gyrators are realized as circuits including two or more NIC's connected to the same nodes.

In this section, a method for sharing NIC's is proposed. First, when  $(I_0, I_1, \dots, I_n)^t = \mathbf{Y}_a(V_0, V_1, \dots, V_n)^t$ , a  $Y$ -matrix of the circuit shown in Fig. 1 has the following form.

$$\mathbf{Y}_a = \begin{pmatrix} Y_{a0} & (g_{a1}G_1)/g_{b1} & (g_{a2}G_2)/g_{b2} & \dots & (g_{an}G_n)/g_{bn} \\ -G_1 & G_1 & 0 & \dots & 0 \\ -G_2 & 0 & G_2 & \dots & \vdots \\ \vdots & \vdots & \ddots & \ddots & 0 \\ -G_n & 0 & \dots & 0 & G_n \end{pmatrix}, \quad (1)$$

where  $Y_{a0} = -\{(g_{a1}G_1)/g_{b1} + (g_{a2}G_2)/g_{b2} + \dots + (g_{an}G_n)/g_{bn}\}$ .

Secondly, the  $Y$ -matrix of the circuit shown in Fig. 2 becomes as follows. When  $(I_0, I_1, \dots, I_n)^t = \mathbf{Y}_b(V_0, V_1, \dots, V_n)^t$ .

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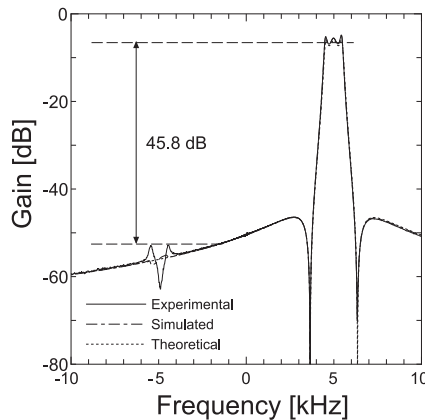
a) E-mail: shouno@cs.tsukuba.ac.jp  
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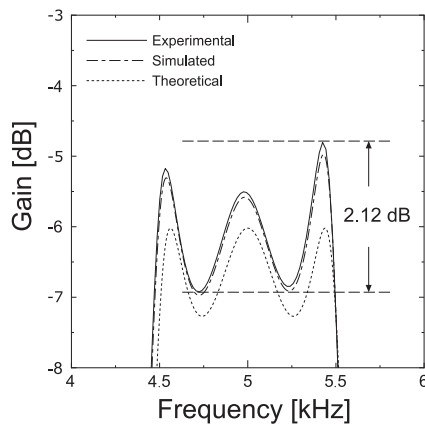
**Table 1** Element values of the experimental circuit shown in Fig. 4.

Element	Value	Element	Value	Element	Value
$R_S$	20	$R_{gy}$	20	$R_1$	0.8930
$R'_1$	0.9173	$R''_1$	1.010	$R_2$	2.323
$R_{2C}$	12.55	$R_3$	0.8930	$R'_3$	0.9614
$r_1$	0.8930	$r_2$	1.010	$r_3$	2.323
$r_4$	2.323	$r_5$	0.8930	$r_6$	0.9614
$C_1$	33.11	$C_{2L}$	13.70	$C_{2C}$	2.537
$C_3$	33.11				

R's in k $\Omega$ , C's in nF



**Fig. 5** Experiment result (overall).



**Fig. 6** Experiment result (near passband).

ideal operational amplifiers with GB products of 5 MHz. The experimental results show that the proposed filter exhibits a complex elliptic response and an image rejection of 45.8 dB.

The number of the required components are summarized in Table 2 and Table 3. From Table 2, it is found that the components required in the proposed circuit are fewer than those in the conventional complex filter with finite transmission zeros. From Table 3, it is found that the required components are not reduced when the proposed method is applied to the complex filter without finite transmission zeros [4]. Although it is difficult that the conventional method [4] is applied to the complex filter with finite transmission

**Table 2** The number of the required components for complex filter with finite transmission zeros.

Order	Proposed			Conventional [5], [6]		
	OA	C	R	OA	C	R
3rd	6	8	29	14	8	49
5th	10	14	49	26	14	87
(2k + 1)th	4k + 2	6k + 2	20k + 9	12k + 2	6k + 2	38k + 11

OA: Operational Amplifier

**Table 3** The number of the required components for complex filter without finite transmission zeros.

Order	Proposed			Conventional [4]		
	OA	C	R	OA	C	R
3rd	6	6	27	6	6	27
5th	10	10	44	10	10	44
(2k + 1)th	4k + 2	4k + 2	17k + 10	4k + 2	4k + 2	17k + 10

OA: Operational Amplifier

zeros, the proposed one can applied to the filters with or without finite transmission zeros.

#### 4. Conclusion

In this paper, a reduction of the number of components included in direct simulation type active complex filter is proposed. The validity of the proposed method is confirmed through experiment. Compared with the conventional method, the proposed method has wide generality.

The further investigation is required to compensate GB product of the operational amplifiers.

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