CURRENT-MODE UNIVERSAL BIQUAD

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Abstract: A procedure for universal filter design using generalized current conveyors is described. The proposed network can be realized with the aid of so-called universal current conveyors. It can therefore be easily transformed from the current mode into the voltage mode and vice versa.

Indexing terms: current conveyor, universal filter

1. INTRODUCTION

Our idea was to design a four-port network that can be employed as a lowpass, highpass or bandpass filter but also as a notch filter or allpass filter. The filter should operate in the current mode and it should be possible to load the output ports with arbitrary one-port networks. A similar network has recently been described in [1]. We are going to describe another proposed solution of the problem. The structure to start from in the design is a suitable autonomous circuit with general circuit elements (see Fig.1). In the Figure, the symbol GCC refers to a generalized three-port current conveyor defined by the following equations: $V_x = a_1 V_{y1}$, $I_{y1} = b_1 I_x$, $I_{z1} = d_1 I_x$, where I_x is the independent current and the conveyance coefficients a_1 and $d_1 \in \{+1, -1\}$ but $b_1 \in \{0, +1, -1\}$.

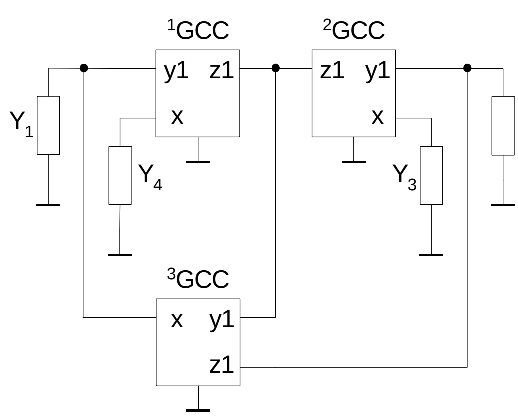

Fig.1. General autonomous circuit with generalized three-port current conveyors

2. DESIGN PROCEDURE

In the first step of the design we calculate the characteristic equation (CE) of a chosen autonomous circuit:

$$a_{13}\{\, Y_3 Y_4 a_{11} a_{12} (b_{11} b_{12} b_{13} + b_{11} d_{12} d_{13} + b_{12}) + \\ + Y_2 Y_4 a_{11} (b_{11} b_{13} - d_{11}) + Y_1 Y_3 a_{12} (b_{12} b_{13} - d_{12} d_{13}) - \\ - Y_1 Y_2 b_{13} \,\} = 0$$

The second digit of the conveyance coefficients relates to the serial number of the current conveyor in the circuit diagram.

This CE will be simplified if choosing

$$b_{11} = b_{12} = 0\,. \tag{1}$$

Both the first and second conveyor is of *class zero*, which is defined by Eq. (1). Obviously, conveyance coefficient a_{13} can be either +1 or –1.

Let us choose

$$a_{13} = +1\,. \tag{2}$$

The polynomial of CE is then simplified to the form

$$D(p) = -a_{11} d_{11} Y_2 Y_4 - a_{12} d_{12} d_{13} Y_1 Y_3 - b_{13} Y_1 Y_2\,. \tag{3}$$

For the sake of stability of the circuit under consideration all members in Eq. (3) must have identical signs. Let us choose:

$$b_{13} = a_{11} d_{11} = a_{12} d_{12} d_{13} = -1\,. \tag{4}$$

If in relation (3) we choose $Y_1 = pC_1$, $Y_3 = pC_2$, $Y_2 = G_2$, $Y_4 = G_1$, we obtain the characteristic polynomial in the required form:

$$D(p) = p^2 C_1 C_2 + pC_1 G_2 + G_1 G_2\,. \tag{5}$$

We want to design a network that works in the current mode. We therefore add to each conveyor an output port, which will be the output port of the resultant filter. Generalized three-port current conveyors will thus change to four-port current conveyors. The generalized four-port current conveyor of the *first kind* (it has only one voltage port y_1) is described by these equations:

$$V_x = a_1 V_{y1}\,, \quad I_{y1} = b_1 I_x\,, \quad I_{z1} = d_1 I_x\,, \quad I_{z2} = d_2 I_x\,.$$

In the next step we calculate all possible current transfers from potential grounded ports to the added output ports. From the results obtained we have chosen a convenient variant as a prototype, which is shown in Fig. 2.

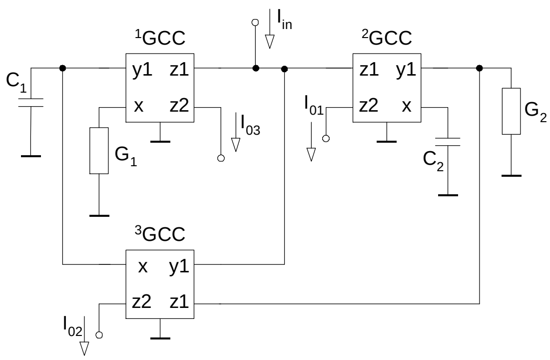

Fig.2. Prototype of universal filter.

For the prototype the following current transfers have been calculated:

$$\frac{I_{o1}}{I_{in}} = \frac{p^2 a_{12} d_{22} a_{13} d_{13} C_1 C_2}{D(p)}\,, \tag{6}$$

$$\frac{I_{o2}}{I_{in}} = \frac{p a_{13} d_{23} C_1 G_2}{D(p)}\,, \tag{7}$$

$$\frac{I_{o3}}{I_{in}} = \frac{a_{11} d_{21} a_{13} G_1 G_2}{D(p)}\,. \tag{8}$$

From relations (6) to (8) we determine the last conditions that must be satisfied for the realization of universal filter:

$$a_{12} d_{22} a_{13} d_{13} = +1,\; a_{13} d_{23} = -1,\; a_{11} d_{21} a_{13} = +1\,. \tag{9}$$

Conditions (1), (2), (4) and (9) are then used to determine the values of conveyance coefficients of four-port conveyors:

a_{11}	b_{11}	d_{11}	d_{21}	a_{12}	b_{12}	d_{12}	d_{21}	a_{13}	b_{13}	d_{13}	d_{23}
+1	0	1	+1	+1	0	1	+1	+1	1	+1	1

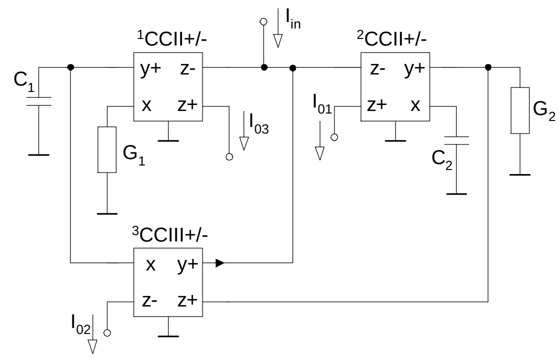

Fig.3. The designed universal filter with CCII+/- and CCIII+/- elements

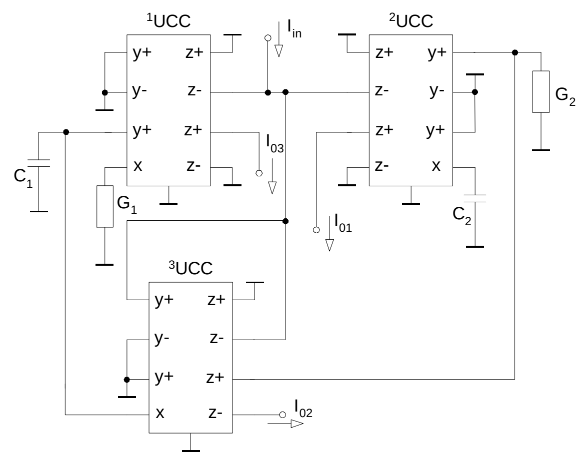

Fig.4. Realization of universal filter using a universal current conveyor

The designed filter with CCII+/- and CCIII+/- conveyors is shown in Fig.3. Its current transfers are:

$$\frac{I_{o1}}{I_{in}} = \frac{p^2 C_1 C_2}{D(p)}\,, \tag{10}$$

$$\frac{I_{o2}}{I_{in}} = \frac{-pC_1 G_2}{D(p)}\,, \tag{11}$$

$$\frac{I_{o3}}{I_{in}} = \frac{G_1 G_2}{D(p)}\,. \tag{12}$$

Equations (10) to (12) describe the highpass, bandpass and lowpass filter, respectively. The notch filter will result if

$$\frac{I_{out}}{I_{in}} = \frac{I_{o1} + I_{o3}}{I_{in}} \tag{13}.$$

The allpass filter if obtained if

$$\frac{I_{out}}{I_{in}} = \frac{I_{o1} + I_{o2} + I_{o3}}{I_{in}}. \qquad (14)$$

The designed filter can be realized, for example, using the universal current conveyor UCC [3]. The schematic diagram of the connection of designed filter is given in Fig.4. Here, the conveyor of class one given in Fig.3 has been realized by a class-zero conveyor [4].

3. CONCLUSION

Even if there exists just one suitable prototype, several solutions can be proposed as described above since there are only six equations for determining ten transfer coefficients. In each solution the capacitor and the resistor can be mutually exchanged.

An advantage of the network in Fig.4 is that its adjoint network can be created. Thus a network is obtained that operates in the *voltage* mode. The transformation process is very simple. The input current port changes to the output voltage port. Driving voltage sources are connected to output current ports. Finally, in universal current conveyors (UCC) the terminals $y+ \leftrightarrow$ z- and $y- \leftrightarrow z+$ are mutually replaced. Here the symbol $\leftrightarrow$ denotes replacement.

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