Abstract—A new current-mode universal biquadratic filter with three inputs and one output employing only two current conveyors, two grounded capacitors and two grounded resistors is presented. The new circuit offers the following advantage features: using grounded capacitors and grounded resistors which is ideal for integrated circuit implementation, the versatility to synthesize any type of active filter transfer functions without requirements for critical component matching conditions and very high output impedance.

Keywords- universal biquad, current conveyor, current-mode

I. INTRODUCTION

There is a growing interest in designing current-mode current conveyor (CC) based active filters. This is attributed to their high signal bandwidths, greater linearity and larger dynamic range [1]. It is desirable for filters to employ grounded resistors. Once JFETs are used to replace them, an electronically tunable filter can be obtained. Also, if the filter employing grounded capacitors, it is attractive for monolithic IC implementation [2-4]. Several current-mode universal biquadratic filters with multi-inputs and single output were presented [5-9]. However, the active or passive components used in the design of these multi-inputs and single output current-mode universal filters [5-9] were not minimum.

Several current-mode universal biquadratic filters with five input terminals were presented [10-11]. However, these circuits either employ floating resistors or require passive component matching conditions. In this paper, a new current-mode universal biquadratic filter with three inputs and single output has a simpler structure, i.e. uses only two current conveyors, two grounded capacitors, and two grounded resistors is presented. The new circuit offers the following advantage features: using grounded capacitors and resistors, the versatility to synthesize any type of active filter transfer functions without requirements for critical passive component matching conditions and very high output impedance.

II. CIRCUIT DESCRIPTION

The port relations of a current conveyor can be characterized by $i_0 = a_{in}$, $v_0 = v_y$ and $i_{in} = \pm i_x$. For $a = 1$, the circuit is a first-generation current conveyor (CCI) [12]. For $a = 0$, the circuit is a second-generation current conveyor (CCII) [13]. It is called a third-generation current conveyor (CCIII) for $a = -1$ [14].

The proposed current-mode universal biquadratic filter is shown in Fig. 1. The circuit with three input terminals and one output terminal comprises one CCII, one CCIII, two grounded capacitors and two grounded resistors. The use of grounded capacitors and grounded resistors is particularly attractive for integrated circuit implementation [2-4].

Circuit analysis yields the following output current $i_{out}$ (see Fig. 1):

$$I_{out} = \frac{s^2C_1C_2I_1 - sC_1G_4I_2 + G_1G_4I_1}{s^2C_1C_2 + sC_1G_4 + G_1G_4}$$

Specializations of the numerator in (1) result in the following filter functions:

1. Highpass: $I_{out} = 0$, input current signal is $I_2$
2. Lowpass: $I_{out} = 0$, input current signal is $I_1$
3. Bandpass: $I_{out} = 0$, input current signal is $I_2$
4. Notch: $I_{out} = I_1 = I_3$, input current signal;
5. Allpass: $I_{out} = I_1 = I_3$, input current signal

Note that no critical component matching conditions is required for realization of the filter responses. The resonance angular frequency $\omega_0$ and the quality factor $Q$ are given by:

$$\omega_0 = \sqrt{\frac{G_1G_4}{C_1C_2}}$$

$$Q = \sqrt{\frac{C_1G_3}{C_2G_4}}$$

The resonance angular frequency $\omega_0$ can be controlled by the grounded resistor $R_3$ or $R_4$. By using a JFET as a voltage

Fig. 1 The proposed current-mode biquadratic filter.
controlled resistor to replace $R_3$ or $R_4$, we can obtain a programmable filter. Moreover, the quality factor $Q$ can be also controlled by the ratio of $G_3/G_4$ or $C_2/C_1$. Note that, for the notch and allpass realizations, a current follower is needed for providing multi-input current signals.

III. SIMULATION RESULTS

HSPICE simulations were carried out to demonstrate the feasibility of the proposed circuit in Fig. 1 using 0.35 µm, level 3 MOSFET from TSMC. The CCII was realized by the CMOS implementation in Fig. 2 [15]. The aspect ratios of the MOS transistors were chosen as in Table 1. The CCIII was realized by two CCII as shown in Fig. 3 [14]. Fig. 4 represent the simulated frequency responses for the allpass filter of Fig. 1 designed with $I_1 = I_2 = I_1o$, $C_1 = C_2 = 80pF$, $R_3 = 10k\Omega$ and $R_4 = 12.5k\Omega$. The supply voltages are $V_+ = +1.65$ V, $V_- = -1.65$ V and $V_b = -0.75$V. The non-idealities may be due to the ignored parasitic elements of the CCII and CCIII.

![Fig. 2 CMOS realization of the CCII.](image)

![Fig. 3 The implementation for the CCIII.](image)

![Fig. 4 The simulated frequency responses for the allpass filter of Fig. 1.](image)

### Table 1: Aspect ratios of the MOS in Fig. 2.

<table>
<thead>
<tr>
<th>MOS transistors</th>
<th>Aspect ratio (W/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_1$, $M_2$, $M_3$</td>
<td>14/0.7</td>
</tr>
<tr>
<td>$M_4$, $M_5$</td>
<td>16.8/0.7</td>
</tr>
<tr>
<td>$M_6$, $M_7$</td>
<td>56/0.7</td>
</tr>
<tr>
<td>$M$, $M_6$, $M_{10}$, $M_{11}$</td>
<td>154/0.7</td>
</tr>
<tr>
<td>$M_{12}$, $M_{13}$</td>
<td>56/0.7</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

In this paper, a new universal active current filter with three inputs and single output using only two current conveyors, two grounded capacitors and two grounded resistors is presented. The proposed circuit offers several advantages, such as the use of grounded capacitors and grounded resistors, the versatility to synthesize any type of filter transfer functions without requirement of component matching conditions and high output impedance.

REFERENCES