

# Current-mode universal biquadratic filter with five inputs and one output using three ICCIIs

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A current-mode universal biquadratic filter with five inputs and one output employing three inverting second-generation current conveyors (ICCIIs), two grounded capacitors and two resistors is presented. The new circuit offers the following advantage features: very low active and passive sensitivities, using of grounded capacitors that is ideal for integrated circuit implementation, the versatility to synthesize any type of active filter transfer functions without requirements for critical component matching conditions, very high output impedance and needs not another current follower to duplicate the input current signal for the realization of notch or allpass responses.

**Keywords:** Active filter, Analog signal processing, Current-mode, Current conveyors

## 1 Introduction

There is a growing interest in designing current-mode current conveyor based active filters. This is attributed to their high signal bandwidths, greater linearity and larger dynamic range<sup>1</sup>. Several current-mode universal biquadratic filters with multi-inputs and single output were presented<sup>2-7</sup>. In 1991, Chang and Chen<sup>2</sup> proposed a current-mode universal biquadratic filter with three inputs and single output using five second-generation current conveyors (CCIIIs), two grounded capacitors and six grounded resistors. In 1994, Chang *et al.*<sup>3</sup> proposed the second current-mode universal biquadratic filter with three inputs and single output using four current conveyors (two first-generation current conveyors (CCIs) and two CCIIIs), two grounded capacitors and two grounded resistors<sup>3</sup>. Chang<sup>4</sup> proposed the third current-mode universal biquadratic filter with three inputs and single output using five plus-type CCIIIs, two grounded capacitors and four resistors. Chang and Tu<sup>5</sup> proposed the fourth current-mode universal biquadratic filter with three inputs and single output using four multiple output CCIIIs, two grounded capacitors and four grounded resistors. Gunes *et al.*<sup>6</sup> proposed a current-mode universal biquadratic filter with four inputs and single output using three multi-output CCIIIs, two grounded capacitors and two grounded resistors. In 2004, Abuelma'atti *et al.*<sup>7</sup> proposed a mixed-mode universal biquadratic filter. This mixed-mode filter also has three current input signals and one current output signal using seven

CCIIIs, eight resistors and two grounded capacitors. However, the active or passive components used in the design of the multi-inputs and single output current-mode universal filters in Refs 2-5 and 7 were not minimum. Moreover, because these circuits<sup>2-7</sup> require two or three current input signals for realizing the notch or allpass filters, therefore, other current followers are needed to duplicate the input current signals for the realization of notch or allpass responses.

Inverting second-generation current conveyor<sup>8</sup> (ICCI) was proposed in 1999 and has been found useful in many applications<sup>9-13</sup>. In the present paper, a new current-mode universal biquadratic filter with five inputs and one output using three ICCIIs, two grounded capacitors and two resistors is presented. The new circuit offers the following advantage features: very low active and passive sensitivities, using of grounded capacitors that is attractive for integrated circuit implementation<sup>14</sup>, the versatility to synthesize any type of active filter transfer functions, without requirements for critical component matching conditions and very high output impedance. Moreover, the proposed circuit does not need another current follower to duplicate the input current signal for the realization of notch or allpass responses with respect to the previous<sup>2-7</sup> multi-inputs current-mode filters.

## 2 Proposed Circuit

The terminal characteristic of the ICCII can be described by the following matrix<sup>8</sup> equation:



(Taiwan Semiconductor Manufacturing Company, Ltd.). The dimensions of the NMOS transistors in the ICCIs are set to be  $W = 4.5 \mu\text{m}$  and  $L = 0.9 \mu\text{m}$ . The dimensions of the PMOS transistors in the ICCIs are set to be  $W = 9 \mu\text{m}$  and  $L = 0.9 \mu\text{m}$ .

Figure 3(a-e) show the simulated frequency responses for the highpass ( $I_{in3}$ ), bandpass ( $I_{in2}$ ), lowpass ( $I_{in1}$ ), notch ( $I_{in4}$ ) and allpass ( $I_{in5}$ ) filters of Fig. 1, respectively, designed with  $Q = 1$  and  $f_o = 1.8947 \text{ MHz}$ :  $C_1 = C_2 = 30 \text{ pF}$  and  $R_1 = R_2 = 2.8 \text{ k}\Omega$ .

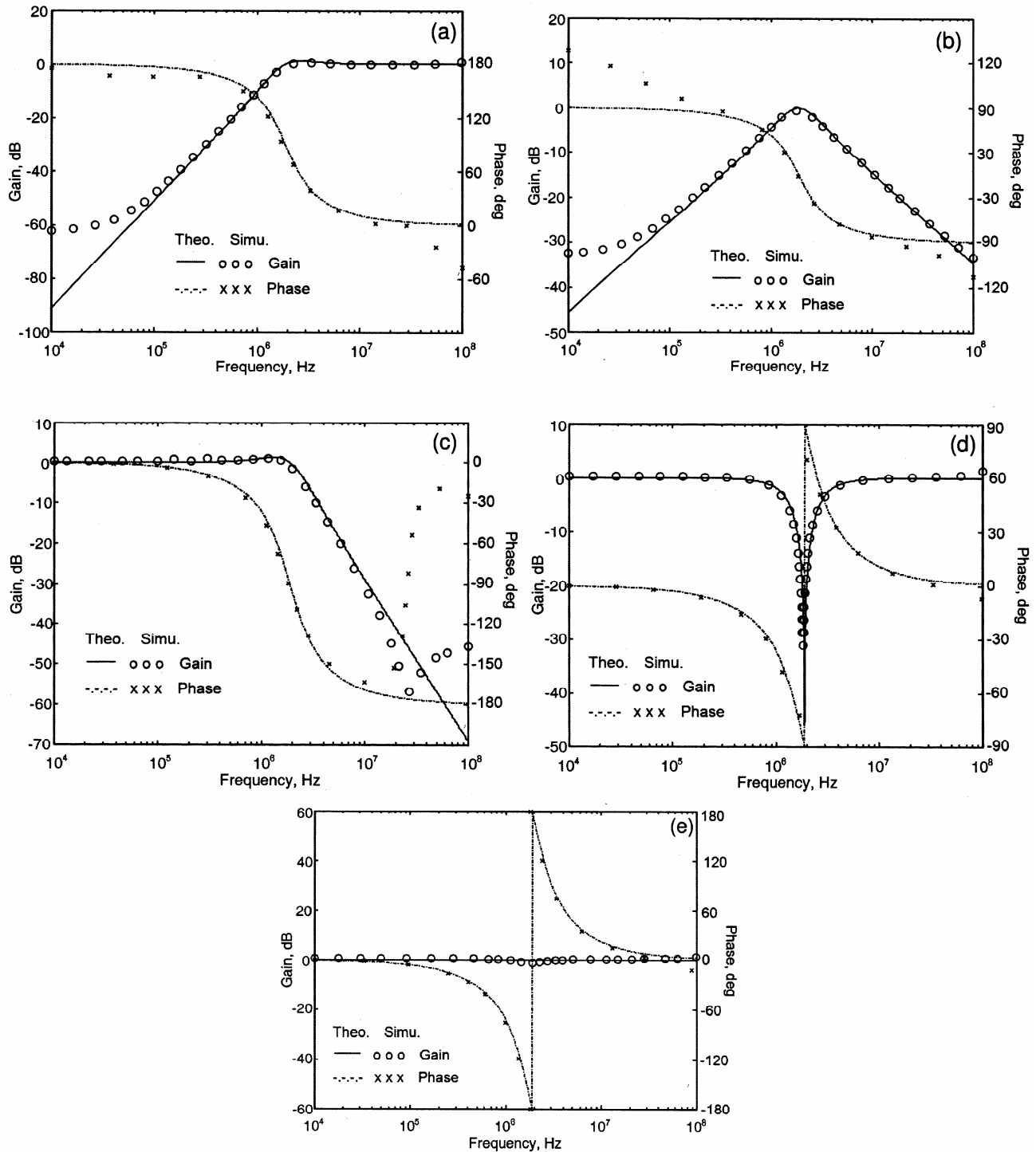


Fig. 3 — Simulated frequency responses of Fig. 1 design with  $C_1 = C_2 = 30 \text{ pF}$  and  $R_1 = R_2 = 2.8 \text{ k}\Omega$ . (a) highpass filter ( $I_{in3}$ ), (b) bandpass filter ( $I_{in2}$ ), (c) lowpass filter ( $I_{in1}$ ), (d) notch filter ( $I_{in4}$ ), (e) allpass filter ( $I_{in5}$ )

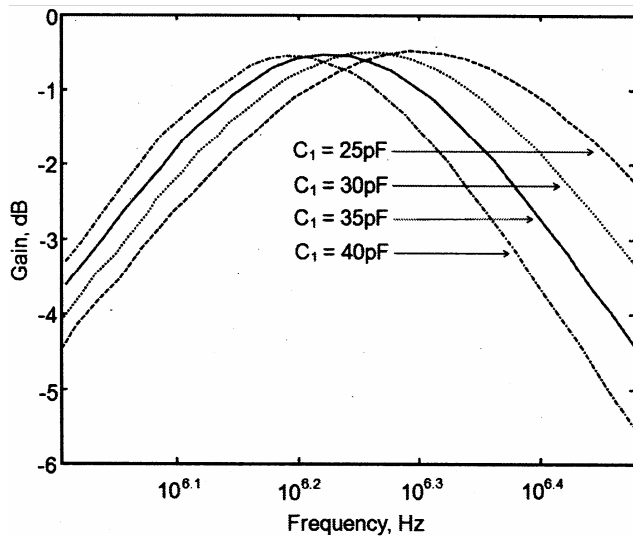


Fig. 4 — Simulated gain frequency responses for the bandpass filter of Fig. 1 as the capacitance  $C_1$  is varied with  $C_2 = 30\text{pF}$  and  $R_1 = R_2 = 2.8\text{k}\Omega$

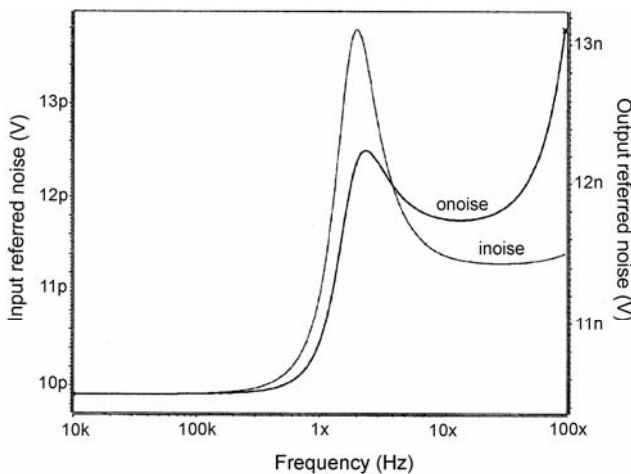


Fig. 5 — Input and output referred noise spectral densities

The supply voltages are  $V_+ = +1.25\text{ V}$ ,  $V_- = -1.25\text{ V}$ ,  $V_{b1} = -0.45\text{ V}$  and  $V_{b2} = +0.3\text{ V}$ . In Fig. 3, the solid line and dash line are the ideal gain and phase frequency responses, respectively, obtained from Eq. (2). The characteristics “o” and “x” are the simulated gain and phase frequency responses, respectively, from HSPICE. Fig. 4 shows the simulated gain frequency responses for the bandpass filter of Fig. 1 as the capacitance  $C_1$  is varied with  $C_2 = 30\text{pF}$  and  $R_1 = R_2 = 2.8\text{ k}\Omega$ . Fig. 5 shows the simulated input and output referred noise spectral densities at the z32- node of the ICCII(3) for the allpass filter in Fig. 1 design with  $2\text{mA}_{p-p}$  input current signal,  $C_1 = C_2 = 30\text{ pF}$ ,  $R_1 = R_2$

$= 2.8\text{ k}\Omega$  and the output terminal (z32-) connected to a  $1\text{ k}\Omega$  resistor. From Fig. 5, the input and output referred noise spectral densities at the output node of Fig. 1 are far below the ideal allpass responses magnitude (1V).

#### 4 Conclusions

Several multi-inputs and single output current-mode universal biquadratic filters were proposed<sup>2-7</sup>. However, because these circuits require two or three current input signals in the realizations of the notch or allpass filters, one more active component is needed in each of these circuits to duplicate the input current signal for the realizations of notch or allpass responses. In the present paper, a new universal active current filter with five inputs and single output using three ICCIIs, two grounded capacitors and two resistors is presented. The proposed circuit offers several advantages, such as very low filter sensitivity to active and passive components, the use of grounded capacitors, the versatility to synthesize any type of active filter transfer functions, without requirements for critical component matching conditions, very high output impedance and needs not one more current follower to duplicate the input current signal in the realizations of notch or allpass filters.

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