High output impedance current-mode universal filter employing dual-output current-controlled conveyors and grounded capacitors

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Outline

- Introduction
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- Simulation Results
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Introduction

- In this presentation, a new current controlled current mode universal filter is introduced. It is a multi input and multi output (MIMO) configuration with two inputs and three outputs.
- It uses only three DOCCCIIs and two grounded capacitors.
- The filter is electronically tunable.
- By selecting the input signals properly, the circuit can realize 7 biquadratic filtering functions. These are HP, LP+, LP-, AP, BS, BP+, BP-.
- Filter performance parameters ω_o, ω_o/Q can be tuned over a wide range through adjusting bias current of DOCCCII.
- Both active and passive sensitivities are low.

Circuit Description[1]

- DOCCCII is a four terminal active building block as shown in Figure 1. It gives negative and positive outputs. I_o is the bias current of the current conveyor and it is tunable.

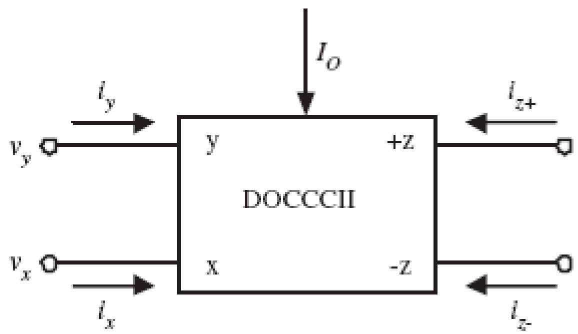

Fig. 1. Circuit symbol of the DOCCCII.

$$i_y = 0, \quad v_x = v_y + i_x R_x, \quad i_{z+} = +i_x, i_{z-} = -i_x \qquad R_x = \frac{V_T}{2I_O}$$

Circuit Description[2]

Bipolar implementation of DOCCCII is given in Figure 2.

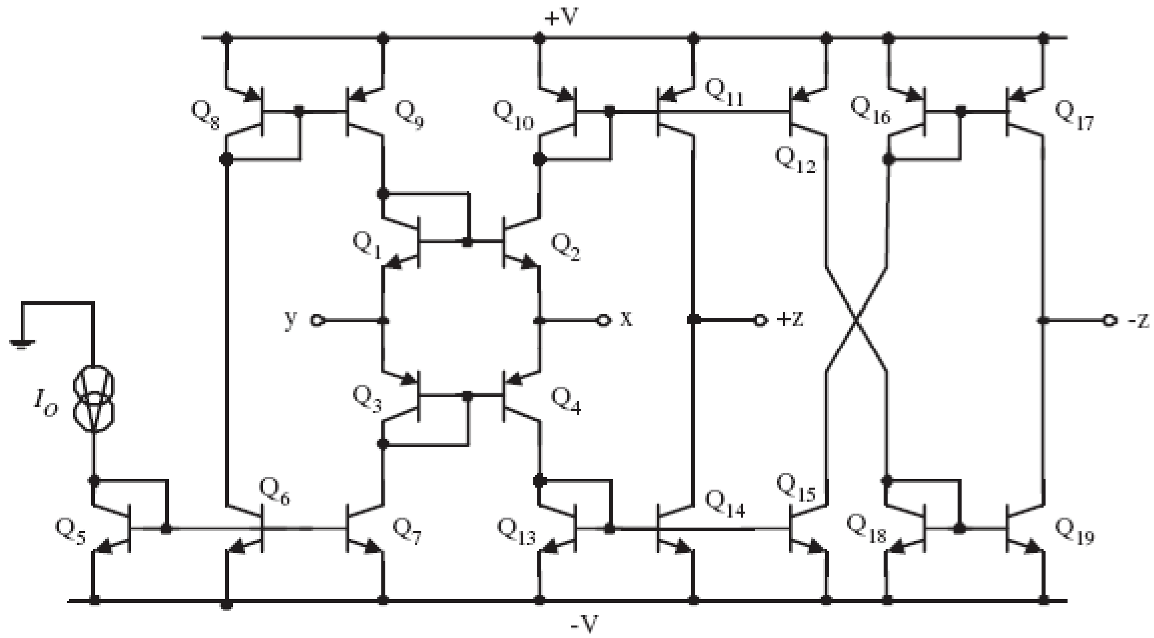

Fig. 2. Schematic bipolar implementation of the DOCCCII.

Proposed Filter[1]

Proposed filter is given in Figure 3. It uses three DOCCCIIs and two grounded capacitors. I_1 and I_2 are the input signals, I_{oA} , I_{oB} , I_{oc} are the output signals.

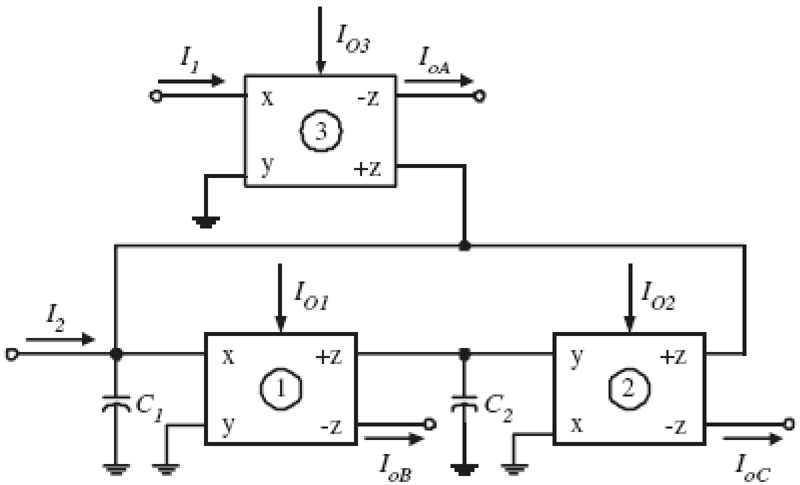

Fig. 3. Proposed current-mode universal filter.

$$I_{oA} = \frac{(s^2 R_{x1} R_{x2} C_1 C_2 + s R_{x2} C_2 + 1) I_1}{D(s)},$$

$$I_{oB} = -\frac{(s R_{x2} C_2)(I_1 - I_2)}{D(s)}$$

and

$$I_{oC} = -\frac{(I_1 - I_2)}{D(s)},$$

$$D(s) = s^2 R_{x1} R_{x2} C_1 C_2 + s R_{x2} C_2 + 1$$

Proposed Filter[2]

By choosing proper values of the input signals, 7 biquadratic filter functions can be realized.

(1) The inverting-type LP response can be realized with $I_2 = 0$, $I_1 = I_{in}$ and $I_{oC} = I_{out}$.
(2) The noninverting-type LP response can be realized with $I_1 = 0$, $I_2 = I_{in}$ and $I_{oC} = I_{out}$.
(3) The inverting-type BP response can be realized with $I_2 = 0$, $I_1 = I_{in}$ and $I_{oB} = I_{out}$.
(4) The noninverting-type BP response can be realized with $I_1 = 0$, $I_2 = I_{in}$ and $I_{oB} = I_{out}$.
(5) The HP response can be realized with $I_2 = 0$, $I_1 = I_{in}$ and $I_{oA} + I_{oB} + I_{oC} = I_{out}$.
(6) The BS response can be realized with $I_2 = 0$, $I_1 = I_{in}$ and $I_{oA} + I_{oB} = I_{out}$.
(7) The AP response can be realized with $I_1 = I_{in}$, $I_2 = -I_{in}$ and $I_{oA} + I_{oB} = I_{out}$.

$$I_{oA} = \frac{(s^2 R_{x1} R_{x2} C_1 C_2 + s R_{x2} C_2 + 1) I_1}{D(s)},$$

$$I_{oB} = -\frac{(s R_{x2} C_2)(I_1 - I_2)}{D(s)}$$

and

$$I_{oC} = -\frac{(I_1 - I_2)}{D(s)},$$

$$D(s) = s^2 R_{x1} R_{x2} C_1 C_2 + s R_{x2} C_2 + 1$$

$$\omega_o = \frac{1}{\sqrt{R_{x1} R_{x2} C_1 C_2}}$$

$$\frac{\omega_o}{Q} = \frac{1}{R_{x1} C_1},$$

Proposed Filter[3]

- Incremental passive sensitivities of the parameters ω_o and ω_o/Q are calculated as:

$$S_{R_{x1}}^{\omega_o} = S_{R_{x2}}^{\omega_o} = S_{C_1}^{\omega_o} = S_{C_2}^{\omega_o} = -\frac{1}{2}, \quad S_{R_{x3}}^{\omega_o} = 0$$

and

$$S_{R_{x1}}^{\omega_o/Q} = S_{C_1}^{\omega_o/Q} = -1, \quad S_{R_{x2}}^{\omega_o/Q} = S_{R_{x3}}^{\omega_o/Q} = S_{C_2}^{\omega_o/Q} = 0$$

Non Ideal Effects

If DOCCCII non idealities are taken into account, DOCCCII equations are written as:

$$i_y = 0, \quad v_x = \alpha v_y + i_x R_x, \quad i_{z+} = +\beta_p i_x, \quad i_{z-} = -\beta_n i_x$$

$$\alpha = 1 - \varepsilon_v \text{ and } \varepsilon_v(|\varepsilon_v| \ll 1)$$

ϵ_v is voltage tracking error from y to x

$$\beta_p = 1 - \varepsilon_{ip}$$
$$\beta_n = 1 - \varepsilon_{in}$$

ϵ_{ip} and ϵ_{in} are current tracking error from x to z+ and x to z– respectively.

Proposed Filter[4]

- By taking non idealities into account, filter equations are calculated again.

$$I_{oA} = \frac{\beta_{n3}(s^2 R_{x1} R_{x2} C_1 C_2 + s R_{x2} C_2 + \alpha_2 \beta_{p1} \beta_{p2}) I_1}{D_n(s)}$$

$$I_{oB} = -\frac{(s R_{x2} C_2 \beta_{n1})(\beta_{p3} I_1 - I_2)}{D_n(s)}$$

$$I_{oC} = -\beta_{n2}\left[\frac{(\alpha_2 \beta_{p1} \beta_{p3} I_1) - I_2}{D_n(s)}\right]$$

$$D_n(s) = s^2 R_{x1} R_{x2} C_1 C_2 + s R_{x2} C_2 + \alpha_2 \beta_{p1} \beta_{p2}$$

$$\omega_o = \sqrt{\frac{\alpha_2 \beta_{p1} \beta_{p2}}{R_{x1} R_{x2} C_1 C_2}}$$

and

$$\frac{\omega_{on}}{Q_n} = \frac{1}{R_{x1} C_1}$$

Proposed Filter[5]

- Incremental active sensitivities of ω_o and ω_o/Q are given below:

$$S^{\omega_{on}}_{\alpha_2,\beta_{p1},\beta_{p2}} = \frac{1}{2},$$

$$S^{\omega_{on}}_{\alpha_1,\alpha_3,\beta_{n1},\beta_{n2},\beta_{p3},\beta_{n3}} = 0,$$

$$S^{\omega_{on}/Q_n}_{\alpha_1,\alpha_2,\alpha_3} = 0$$

and

$$S^{\omega_{on}/Q_n}_{\beta_{p1},\beta_{n1},\beta_{p2},\beta_{n2},\beta_{p3},\beta_{n3}} = 0$$

Incremental active sensitivities are within 0.5 in magnitude. Thus, the proposed circuit exhibits a low sensitivity performance.

Simulation Results[1]

- The DOCCCII transistor model of PR100N (PNP) and NP100N (NPN) of the bipolar arrays ALA400 fromAT&T are used.

  DC supply voltage is ±3V.

  For C1=C2= 10 nF and I_o =100μA. Filter was designed to obtain Q=1 and f_o=127kHz for LP, BP, HP, BS filters.

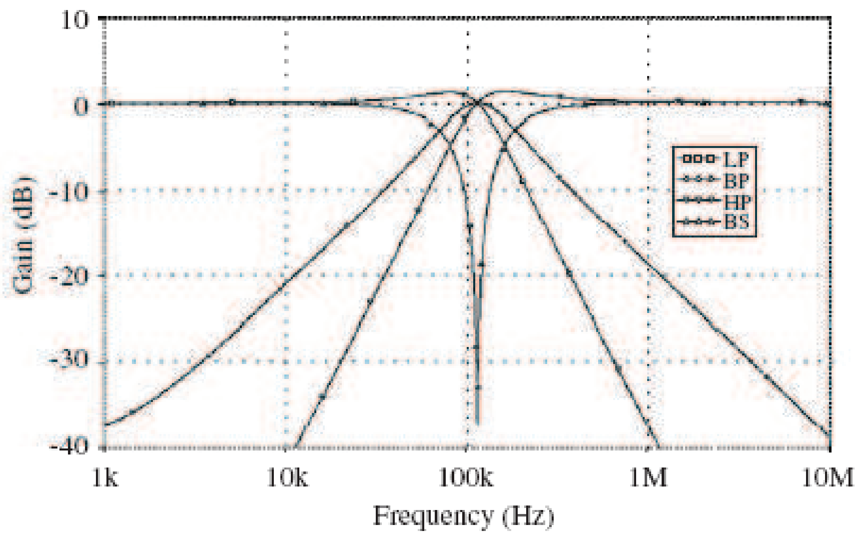

Fig. 4. Simulated frequency responses of the proposed current-mode filter of Fig. 3.

Simulation Results[2]

- Fig. 5 shows the simulated frequency response and the theoretical behavior of the gain and phase characteristics of the AP filter at f_o =127kHz.

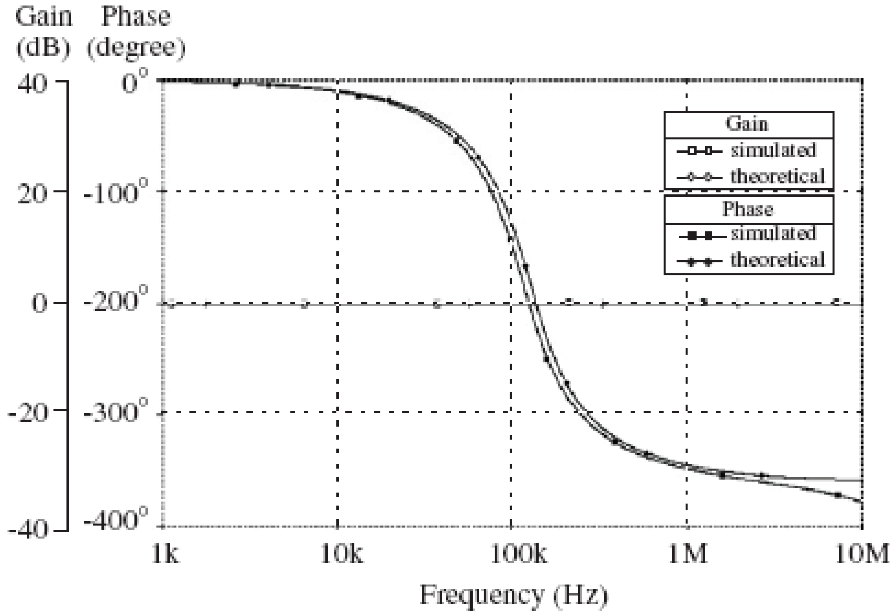

Fig. 5. Gain and phase characteristics of the AP filter at $f_o \cong 127\,\text{kHz}$.

Conclusion

- A new current-controlled current mode universal biquadratic filter using only three DOCCCIIs and two grounded capacitors was proposed.
- The proposed filter can realize the inverting-type LP, noninverting-type LP, inverting-type BP, noninverting-type BP, HP, BS and AP filter responses.
- The filter also requires no component matching conditions and has low passive and active sensitivities.
- ω_o and the parameter ω_o/Q_o are electronically controlled.

References

- [1] Worapong Tangsrirat, Wanlop Surakampontorn, High output impedance current-mode universal filter employing dual-output current-controlled conveyors and grounded capacitors, Int. J. Electron. Commun. (AEÜ) 61 (2007) 127 – 131.
- [2] Fabre A, Saaid O,Wiest F, Boucheron C. Current controllable bandpass filter based on translinear conveyors. Electron Lett 1995;31:1727-8.