$= [2, 2, 2]^T$. The time instants when the measurement of the outputs are successful are shown by ● in Fig. 1*b*.

By comparison of (i) and (ii), we can verify that the filter proposed in this Letter yields a better result than the continuous-discrete filter that has a seemingly natural remedy to cope with the loss of the measurement data. This clearly shows the effectiveness of the use of our filter. The difference between (i) and (iii) shows the deterioration caused by the loss of the measurement data due to unreliable sampling.

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High input impedance voltage-mode lowpass, bandpass and highpass filter using current-feedback amplifiers

Jiun-Wei Horng and Maw-Huei Lee

Indexing terms: Active filters, Current conveyors

A new configuration for realising high input impedance lowpass, bandpass and highpass filters simultaneously by using three current-feedback amplifiers, three grounded capacitors, three grounded resistors and one floating resistor is presented. The proposed circuit offers the following features: realisation of lowpass, bandpass and highpass signals from the same configuration, no requirements for component matching conditions, orthogonal control of ω_0 and Q, the use of grounded capacitors, low active and passive sensitivities and low output impedance.

Introduction: The applications and advantages in the realisation of active filter transfer functions using current-feedback amplifiers (CFAs) have received considerable attention [1 – 6]. This amplifier can provide not only constant bandwidth, independent of closed-loop gain, but also a high slew-rate capability. Moreover, it has a low-impedance output which makes the circuit cascadable without additional buffers [7]. Thus, it is beneficial to use a current-feedback amplifier as a basic building block to realise various analogue signal-processing circuits. Liu [6] proposed a high input impedance configuration for realising bandpass, lowpass and highpass filters. However, the filter functions (lowpass, highpass and bandpass) cannot be simultaneously realised, which implies the need to change the topology of the circuit. Conversely, two topologies of Liu's circuits [6] use floating capacitors. In this Letter, a new configuration is proposed for realising high input impedance lowpass, bandpass and highpass filters simultaneously, by using three current-feedback amplifiers, three grounded capacitors, three grounded resistors and one floating resistor. Critical component matching conditions are not required in the design. The use of grounded capacitors makes the proposed circuit suitable for integrated-circuit implementation [8, 9]. The output impedance of the proposed circuit is very small, so it is cascadable.

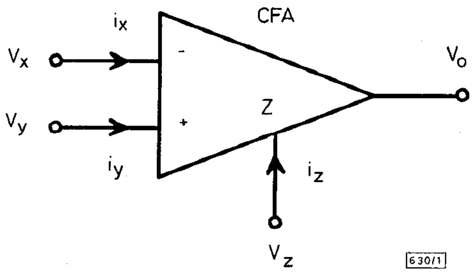

Fig. 1 *Circuit symbol of current-feedback amplifier*

Circuit descriptions: The circuit symbol of a current-feedback amplifier (CFA) is shown in Fig. 1. This circuit is equivalent to a second-generation current conveyor [10] with a voltage buffer [11]. Its characteristics can be modelled as

$$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix} \qquad \text{and } v_o = v_z \qquad (1)$$

The proposed circuit is shown in Fig. 2. In this, three grounded capacitors are used in the design. The use of grounded capacitors is particularly attractive for integrated-circuit implementation [8, 9]. Because the output impedance of terminal V_0 is very small, the three output terminals, V_{01}, V_{02} and V_{03}, can be directly connected to the next stage, respectively. The voltage transfer functions for the network of Fig. 2 can be expressed as

$$\frac{V_{o1}}{V_{in}} = \frac{\frac{1}{C_2C_4R_3R_5}}{s^2 + s\frac{C_1R_6}{C_2C_4R_3R_5} + \frac{R_6}{C_2C_4R_1R_3R_5}} \qquad (2)$$

$$\frac{V_{o2}}{V_{in}} = \frac{s\frac{1}{C_4R_5}}{s^2 + s\frac{C_1R_6}{C_2C_4R_3R_5} + \frac{R_6}{C_2C_4R_1R_3R_5}} \qquad (3)$$

$$\frac{V_{o3}}{V_{in}} = \frac{s^2}{s^2 + s\frac{C_1R_6}{C_2C_4R_3R_5} + \frac{R_6}{C_2C_4R_1R_3R_5}} \qquad (4)$$

Thus, the circuit realises a lowpass signal at V_{01}, a bandpass signal at V_{02} and a highpass signal at V_{03}, simultaneously. Critical component matching conditions are not required in the design.

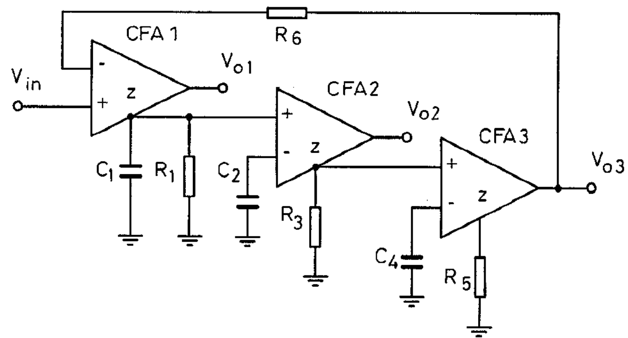

Fig. 2 *New configuration for realising high input impedance lowpass, bandpass and highpass filter using CFAs*

Taking into account the nonideal CFAs, namely $i_z = \alpha i_x$, $v_x = \beta v_y$ and $v_0 = \gamma v_z$, where $\alpha = 1$–ε_1 and ε_1 ($\varepsilon_1 \ll 1$) denotes the current tracking error of a CFA, $\beta = 1$–ε_2 and ε_2 ($\varepsilon_2 \ll 1$) is the input voltage tracking error, and $\gamma = 1$–ε_3 and ε_3 ($\varepsilon_3 \ll 1$) is the output voltage tracking error, the natural frequency ω_0 and quality factor Q are given by

$$\omega_o = \sqrt{\frac{R_6}{C_2C_4R_1R_3R_5\alpha_1\alpha_2\alpha_3\beta_2\beta_3\gamma_3}} \qquad (5)$$

$$Q = \frac{1}{C_1}\sqrt{\frac{C_2C_4R_3R_5\alpha_1\alpha_2\alpha_3\beta_2\beta_3\gamma_3}{R_1R_6}} \qquad (6)$$

Thus, ω_0 and Q can be orthogonally adjustable. The active and passive sensitivities of this filter are

$$S^{\omega_o}_{R_6} = -S^{\omega_o}_{C_2,C_4,R_1,R_3,R_5} = -S^{\omega_o}_{\alpha_1,\alpha_2,\alpha_3,\beta_2,\beta_3,\gamma_3} = \frac{1}{2}$$

$$S^{Q}_{C_2,C_4,R_3,R_5} = -S^{Q}_{R_1,R_6} = S^{Q}_{\alpha_1,\alpha_2,\alpha_3,\beta_2,\beta_3,\gamma_3} = \frac{1}{2}$$

$$S^{Q}_{C_1} = -1$$

All the active and passive sensitivities are low.

PSPICE simulations were carried out to demonstrate the feasibility of the proposed circuit. The current-feedback amplifiers were implemented using AD844s. The following setting was selected to obtain the lowpass, bandpass and highpass filters with unity gain at natural frequency f_0 = 3183Hz and Q = 1: $R_1 = R_3 = R_5 = R_6 = 5\text{k}\Omega$, $C_1 = C_2 = C_4 = 10\text{nF}$. The simulation results are shown in Fig. 3.

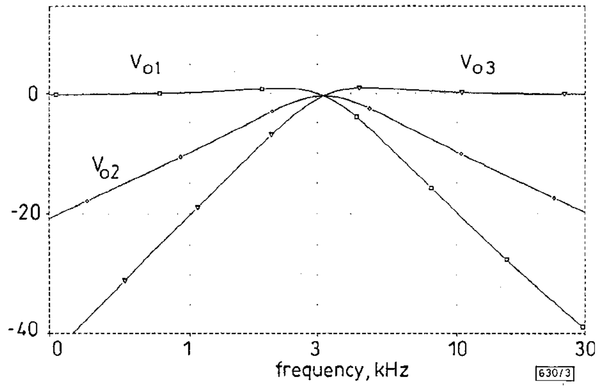

Fig. 3 *Simulation results of Fig. 2 with unity gain at natural frequency* f_0 *= 3183Hz and* Q *= 1:* $R_1 = R_3 = R_5 = R_6 = 5k\Omega$, $C_1 = C_2 = C_4 = 10nF$

□ Vdb (R8:2)
◇ Vdb (R10:1)
▽ Vdb (R6:2)

Conclusion: New high input impedance lowpass, bandpass and highpass filters using three CFAs are presented. This filter provides the following advantages: (i) the lowpass, highpass and bandpass filter functions can be realised simultaneously without changing the circuit topology, (ii) there are no requirements for critical component matching conditions, (iii) there is orthogonal control of the filter's natural frequency and quality factor, (iv) it has low active and passive sensitivities, (v) use of only grounded capacitors makes the circuit suitable for integrated-circuit implementation and (vi) there is very low output impedance which makes the voltage-mode circuit cascadable.

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Universal current-mode filter with reduced number of active and passive components

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Indexing terms: Active filters, Current-mode circuits

A new current-mode (CM) universal active filter with single-input and three-outputs (SITO) employing only four CCIIs and a minimum number of passive components is presented. The proposed filter based on an RLC shunt circuit, has a good sensitivity performance and achieves the desired filter characteristics without any component matching.

Introduction: It is a well-known fact that an RLC shunt circuit is a useful passive prototype for the realisation of universal CM SITO filters [1]. So far, several CCII based filters of this type which are obtained by the classical simulation of ideal inductance (i.e. capacitively-loaded gyrator [2]) have been proposed [1, 3, 4]. However, it has been proved that the use of the simulated lossy inductors rather than ideal inductors generally leads to filters with a simpler structure [1, 5–7].

Considering this fact, in this Letter we present a new CM universal SITO filter which is obtained by the use of a new simulation of lossy inductance (parallel RL circuit), rather than by the simulation of ideal inductance L, in an RLC shunt circuit. As is expected, this approach yields a universal filter with a minimum number of passive components, (i.e. two resistors and two capacitors) and a reduced number of active elements (only four CCIIs). This number of active elements is less than that of the other SITO filters [3, 6, 7] which each require five CCIIs (when the filters provide three high impedance current outputs).

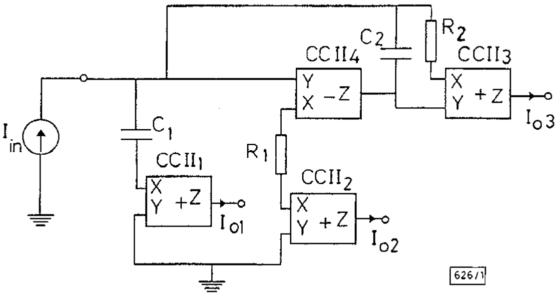

Fig. 1 *Proposed CM universal biquadratic filter*

Proposed circuit: Consider the circuit shown in Fig. 1. Clearly, $CCII_1$ and $CCII_2$ are used to provide high impedance outputs for I_{o1} and I_{o2}. The subcircuit in parallel with C_1, consisting of R_1, R_2, C_2, $CCII_3$ and $CCII_4$ constitutes a grounded parallel RL impedance. This parallel RL simulator realises an RLC shunt circuit along with C_1.

The transfer functions realised by this filter can be given by

$$\frac{I_{o1}}{I_{in}} = \frac{-s^2}{s^2 + \frac{s}{R_1C_1} + \frac{1}{R_1C_1R_2C_2}} \tag{1}$$

$$\frac{I_{o2}}{I_{in}} = \frac{-\frac{s}{R_1C_1}}{s^2 + \frac{s}{R_1C_1} + \frac{1}{R_1C_1R_2C_2}} \tag{2}$$

and

$$\frac{I_{o3}}{I_{in}} = \frac{-\frac{1}{R_1C_1R_2C_2}}{s^2 + \frac{s}{R_1C_1} + \frac{1}{R_1C_1R_2C_2}} \tag{3}$$

Therefore, LP, BP and HP responses can be simultaneously obtained from this filter. Moreover, by interconnecting the z-terminals of the $CCII_1$ and $CCII_3$ from which I_{o1} and I_{o3} are