Design of new Universal Filters with Second Generation Current Conveyor

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Abstract

In this paper, new type of single input and three output universal filters is proposed. Second order current conveyor (CCII) is chosen as an active element. These circuits are designed using the similar type of active element and grounded passive components. The responses of High pass filter, Low pass filter and Band pass filter are measured simultaneously. The notch and all pass filters can also be realized by adding the appropriate components. All simulation work is carried out with MULTISIM 11.0. The comparative analysis is carried out with the existing techniques and is tabulated.

Keywords: Current mode, Universal Filter, Dual output, Second Generation Current Conveyor, Bandwidth, Sensitivity

INTRODUCTION

In analog circuit design either voltage mode or current mode of operation can be used [1]. When compared to voltage mode, current mode is preferable with respect higher band width, large dynamic range, greater linearity and power consumption [5, 9]. Today filters play vital role in Mobile Communication, Signal Processing, Automatic control and instrumentation. So, the design of current mode universal filter is an important problem of research.
As per literature survey, Current Mode (CM) filter topologies can be classified into three types. Namely, (i) Multi Input and Multi Output (MIMO) type (ii) Multi Input and Single Output (MISO) type (iii) Single Input and Three Output (SITO) type. In this paper, SITO type is considered to realize Universal filter.

The paper is organized as follows. Basics of Second Generation Current Conveyors are presented in Section 2. Proposed Universal Filter topologies in discussed in Section 3. Finally results and conclusions are drawn section 4.

SECOND GENERATION CURRENT CONVEYOR

The block diagram of CCII is shown in Figure.1. It has two outputs $Z+$, output currents in opposite directions. The matrix representation for the second generation current conveyor is [2-4],

$$
\begin{bmatrix}
I_y \\
V_x \\
I_z
\end{bmatrix} =
\begin{bmatrix}
0 & 0 & 0 \\
1 & 0 & 0 \\
0 & \pm 1 & 0
\end{bmatrix}
\begin{bmatrix}
V_x \\
I_x \\
V_z
\end{bmatrix}
$$

(1)

The block diagram of CCII is implemented using CMOS technology is shown in Fig.2. The aspect ratio of MOS transistors used in implementation of CCII are shown in Table 1.
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Figure 2: Internal Circuit diagram of CCII using CMOS [3].

Table 1: $\frac{W}{L}$ Ratio of various Transistors used in CCII

<table>
<thead>
<tr>
<th>Transistor</th>
<th>$\frac{W}{L}$ ratios (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1, M2, M3</td>
<td>14/0.7</td>
</tr>
<tr>
<td>M4, M5</td>
<td>16.8/0.7</td>
</tr>
<tr>
<td>M6, M7, M9, M10</td>
<td>5.6/0.7</td>
</tr>
<tr>
<td>M8</td>
<td>56/0.7</td>
</tr>
</tbody>
</table>

PROPOSED CIRCUITS

One of the proposed Current mode Universal filters realized with three second generation current conveyors (CCII) and 4 passive elements (two resistors and two capacitors) is as shown in Fig.3. High pass, Band pass and Low pass filter responses are observed at CCII-1, CCII-2, and CCII-3 respectively. From the CCII, it is known that $I_{zp} = I_x$, $V_x = V_y$. Let the input variables as $V_{in}$ and $I_{in}$. Applying KCL at input node,

$$I_{in} = I_{ip} + I_{hp} \quad (2)$$

Applying KVL at the input,
\[ V_{in} = I_{tp}R_1 = I_{bp}(R_2 + \frac{1}{SC_2}) = I_{hp} \frac{1}{SC_1} \quad (3) \]

Therefore \( I_{in} = \frac{V_{in}}{R_1} + \frac{V_{in}}{1/SC_1} \)

**Figure 3:** Proposed Current Mode Universal Filter

\[ I_{in} = V_{in}(\frac{1}{R_1} + SC_1) \]

We have,

\[ I_{in} = I_{bp}(R_2 + \frac{1}{SC_1}) \left( \frac{1}{R_1} + SC_1 \right) \]

\[ I_{in} = I_{bp} \left( \frac{R_2}{R_1} + \frac{1}{SC_2R_1} + SC_1R_2 + \frac{C_1}{C_2} \right) \]

\[ \frac{l_{bp}}{l_{in}} = \frac{SC_2R_1}{s^2C_1C_2R_1R_2 + s(C_1R_1 + C_2R_2) + 1} \quad (4) \]

The relation between lowpass and Bandpass currents is,

\[ I_{tp}R_1 = I_{bp}(R_2 + \frac{1}{SC_2}) \]

By substituting \( I_{bp} \) value,

\[ I_{tp}R_1 = I_{in} \left[ \frac{SC_2R_1}{s^2C_1C_2R_1R_2 + s(C_1R_1 + C_2R_2) + 1} \right] (R_2 + \frac{1}{SC_2}) \]
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\[
\frac{l_{lp}}{l_{in}} = \frac{sC_2R_1[R_2 + \frac{1}{sC_2R_1}]}{s^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1}
\]

\[
\frac{l_{lp}}{l_{in}} = \frac{1 + sC_2R_2}{s^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1}
\]

Similarly using the relation between Bandpass and HighPass filters,

\[
l_{bp}(R_2 + \frac{1}{sC_2}) = l_{hp} \frac{1}{sC_1}
\]

By substituting \(l_{bp}\) value in above equation,

\[
l_{hp} \frac{1}{sC_1} = l_{in} \left[ \frac{sC_2R_1}{s^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1} \right] (R_2 + \frac{1}{sC_2})
\]

\[
l_{hp} \frac{1}{sC_1} = \frac{sC_2R_1(sC_1R_2 + \frac{C_1}{C_2})}{s^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1}
\]

\[
l_{hp} \frac{1}{sC_1} = \frac{s^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1}{s^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1}
\]

The values of \(\omega_n\) and \(Q\) are shown to be

Natural frequency \(\omega_n = \frac{1}{\sqrt{R_1R_2C_1C_2}}\)

Quality factor \(Q = \frac{R_1C_1 + R_2C_2}{\sqrt{R_1R_2C_1C_2}}\)

Sensitivity analysis:

\[
S_{R_1}^{\omega_n} = S_{R_2}^{\omega_n} = S_{C_1}^{\omega_n} = S_{C_2}^{\omega_n} = -\frac{1}{2}
\]

\[
S_{R_1}^{Q} = S_{C_1}^{Q} = -S_{R_2}^{Q} = -S_{C_2}^{Q} = \frac{R_1C_1 - R_2C_2}{R_1C_1 + R_2C_2}
\]

The Fig.4. Shows another proposed Current mode Universal filters. This employs with two CCII and 5 passive elements (three resistors and two capacitors). Band pass and High pass filter responses are observed simultaneously at output terminals of CCII-1, CCII-2. Finally, Low pass filter response observed at \(R_3\) .From the CCII, it is known that \(I_{z+} = I_x, V_x = V_y\).Let the applied input voltage is \(V_{in}\) and Current is \(l_{in}\).Applying KCL at input node,
**Figure 4:** Proposed Current Mode Universal Filter Responses with high impedance outputs

\[ I_{hp} = \frac{V_{in}-V_{x2}}{1/SC_2} \]

\[ I_{hp} = (V_{in} - V_{x2})SC_2 \]

\[ I_{hp} = [I_{lp}(R_2 + R_3) - I_{lp}R_3]SC_2 \]

Where \( V_{x2} = V_{y2} = R_3I_{lp} \) and \( V_{in} = I_{lp}(R_2 + R_3) \)

Therefore \( I_{hp} = I_{lp}R_2SC_2 \) \hspace{1cm} (9)

\[ I_{lp} = \frac{V_{in}}{R_2+R_3} \text{ and } I_{bp} = \frac{V_{in}}{R_1+\frac{1}{SC_1}} \]

\[ V_{in} = I_{lp}(R_2 + R_3) \]

\[ -I_{bp} = \frac{I_{lp}(R_2+R_3)}{R_1+\frac{1}{SC_1}} \]

Therefore \( I_{bp} = -I_{lp} \frac{SC_1(R_2+R_3)}{SC_1R_1+1} \) \hspace{1cm} (10)

\[ \frac{I_{hp}}{I_{bp}} = \frac{-R_2C_2(1+SC_1R_1)}{C_1(R_2+R_3)} \] \hspace{1cm} (11)

From circuit

\[ I_{in} = I_{lp} + I_{hp} \]

\[ I_{in} = \frac{I_{hp}}{SR_2C_2} + I_{hp} \text{ (From Eq (9))} \]
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\[ \frac{I_{hp}}{I_{in}} = \frac{SR_2C_2}{1 + SR_2C_2} \]  

(12)

Since input current can be expressed as a sum of Low pass and HighPass currents,

\[ I_{in} = I_{lp} + I_{hp} \]

\[ I_{in} = I_{lp} + I_{lp}SR_2C_2 \]

\[ \frac{I_{lp}}{I_{in}} = \frac{1}{1 + SR_2C_2} \]  

(13)

The simplified expression for the Band pass Filter response will be,

\[ \frac{I_{bp}}{I_{in}} = -\frac{SC_1(R_2+R_3)}{S^2C_1C_2R_1R_2+S(C_1R_1+C_2R_2)+1} \]  

(14)

The Third proposed Current mode Universal filters is shown in Fig.5. It has two CCII and 5 passive elements (three resistors and two capacitors). Band pass and Low pass filter responses are observed at output terminals of CCII-1, CCII-2 respectively. Finally, High pass filter response is observed at \( C_2 \). Applying KCL at input node,

\[ I_{in} = I_{lp} + I_{hp} \]

\[ I_{lp} = \frac{V_{in}-V_{xz}}{R_2} \]

\[ I_{lp} = \frac{I_{hp} \left( \frac{1}{SC_2} + R_3 \right) - I_{hp}R_3}{R_2} \]

![Diagram](image)

**Figure 5:** Proposed Current Mode Universal Filter Responses with high impedance outputs
Where $V_{in} = I_{hp} \left( \frac{1}{Sc_2} + R_3 \right)$

Therefore $I_{lp} = I_{hp} \frac{1}{Sc_2 R_2}$ \hspace{1cm} (15)

$I_{hp} = \frac{V_{in} - V_{y2}}{1/Sc_2}$

$I_{hp} = \frac{-I_{bp}(R_1 + \frac{1}{Sc_1}) - I_{hp} R_3}{1/Sc_2}$

$I_{hp} \left( \frac{1}{Sc_2} + R_3 \right) = -I_{bp} \left( R_1 + \frac{1}{Sc_1} \right)$

$I_{hp} \frac{I_{lp}}{I_{in}} = \frac{(1 + Sc_1 R_1) C_2}{(1 + Sc_2 R_3) C_1}$

We know,

$I_{in} = I_{lp} + I_{hp}$

$I_{in} = I_{lp} \left( 1 + Sc_2 R_2 \right)$

Therefore,

$I_{lp} \frac{I_{bp}}{I_{in}} = \frac{1}{1 + Sc_2 R_2}$ \hspace{1cm} (16)

$I_{in} = I_{lp} + I_{hp}$

$I_{in} = I_{hp} \frac{1}{Sc_2 R_2} + I_{hp}$

$I_{hp} \frac{I_{bp}}{I_{in}} = \frac{Sc_2 R_2}{1 + Sc_2 R_2}$ \hspace{1cm} (17)

The expression for Band pass filter response is,

$I_{bp} \frac{I_{bp}}{I_{in}} = -\frac{(1 + Sc_2 R_2) Sc_2 R_2 C_1}{(1 + Sc_1 R_1)(1 + Sc_2 R_2) C_2}$

$I_{bp} \frac{I_{bp}}{I_{in}} = -\frac{S^2 C_1 C_2 R_2 R_3 + Sc_1 R_2}{S^2 C_1 C_2 R_1 R_2 + S(C_1 R_1 + C_2 R_2) + 1}$ \hspace{1cm} (18)
RESULTS AND CONCLUSION

In this paper, Three Proposed Current Mode Universal Filters are simulated using Multisim software. First Topology have three CCII blocks, remaining two Topologies consists two CCII blocks. The CCII block was realized by the CMOS implementation. For the purpose of simulation 0.7\(\mu\)m, level 1 MOSFETs is used. The supply voltages are \(V_{DD} = -V_{SS} = -1.65V, V_{b1} = -1V, V_{b2} = -0.76V\). The input source current of 2\(\mu\)A with 1 kHz frequency is common for three models. Fig.6 represents frequency responses of Low pass, High Pass and Ban Pass filters corresponding to the Fig.3. The chosen passive components values are \(R_1=100K\Omega, R_2=50K\Omega, C_1=50pF, C_2=100pF\). For, The fig.4 and the fig.5, the chosen values are \(R_1= 2R_2=350K\Omega, R_3=1.5K\Omega, C_1=0.2nF, C_2= 100pF\). The response of simulation results for the Fig.4 and Fig. 5 are showed in Fig.7 and Fig.8 respectively. The Fig.9, Fig.10 and Fig.11 represents the relationship between Input Current and Output Currents of Low pass, High pass and Band pass filters corresponding to Fig.3, Fig.4, Fig.5 respectively. The merits of the proposed filters over the existing filters are tabulated in Table.2.

![Figure 6](image-url): Normalized Magnitude Responses of LP, HP, BP, filters corresponding to Fig.3.

![Figure 7](image-url): Normalize Magnitude Responses of LP, HP, BP, filters corresponding to Fig.4
Figure 8: Normalize Magnitude Responses of LP, HP, BP, filters corresponding to Fig.5

Figure 9: the relationship between Input Current and Output Currents of Low pass, High pass and Band pass filters corresponding to Fig.3

Figure 10: the relationship between Input Current and Output Currents of Low pass, High pass and Band pass filters corresponding to Fig.4
Figure 11: the relationship between Input Current and Output Currents of Low pass, High pass and Band pass filters corresponding to Fig.5

Table 2: Comparison of the proposed and existing circuits

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<th>Ref</th>
<th>Figure No.</th>
<th>No. of CCII</th>
<th>No. of Passive components (R+C)</th>
<th>No. of Floating components</th>
<th>Q</th>
<th>Input impedance</th>
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<td>Two Output (DOCCII)</td>
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<td>[5]</td>
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REFERENCES


