Design of A 10MHz Bandpass Filter Using Grounding and Floating CDTA Active Inductors

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Abstract This paper presents a bandpass filter using a current differencing transconductance amplifier (CDTA) for application to low-voltage and low-power analog signal processing systems. The presented filter employs grounding and floating active inductors, which are composed of two or three CDTAs, and is capable of realizing all the standard functions of the filter without requiring any component matching criteria or extra active components. The HSPICE simulation result of the designed active bandpass filter showed that it had a 10MHz center frequency with -2.5dB attenuated bandwidth from 9.5 MHz to 10.5 MHz, and -50dB from 8 MHz to 17 MHz.

1. Introduction

Recently studies regarding current differential transconductance amplifier (CDTA) are widely in progress and its usefulness is especially recognized in analog circuit design fields as shown in [1-3] and [4]. The input of CDTA is current, and the difference between two input currents creates the initial voltage. This voltage is determined by the impedance of the initial output terminal, and also, this voltage drives the transconductance amplifier connected at the back terminal, creating current in CDTA output. Due to this structure, CDTA is capable of having high linearity and wide frequency bandwidth and is possible to minimize its size as a circuit when used in constructing analog circuits[5].

Key Words : Active filter, Bandpass filter, CDTA, Floating inductor, Grounding inductor
In this paper, a synthesis method is present to realize active floating inductors using CDTA. The presented method has some improvement in aspects of number of small sized circuits, simplicity of the realization method and the area the circuit as well as reduction in the power. Chapter 2 introduces basic characteristics and existing methods for the realization of floating and grounding inductors using CDTA. Chapter 3 presents the band pass filter with 10MHz center frequency is constructed using the designed CDTA inductor for checking its usability and verified through simulation.

2. The synthesis of floating and ground inductors with CDTAs

CDTA is an active filter with five terminals shown in Fig. 1. In Fig. 1, \( I_p \) and \( I_n \) are differential current input signals and these current signals are converted into voltage signal by the impedance determined at terminal \( z \). The signals converted into voltage are converted again into output currents \( I^+ \) and \( I^- \). According to this structure, CDTA can be seen as a current amplifier. The current and the voltage from equivalent circuit can be written as equation (1).

\[
V_p = V_n = 0 \\
I_z = I_p - I_n \\
I^+_z = g_m V_z \\
I^-_z = -g_m V_z 
\]  

(1)

Also, when the current gain from equation (1) is \( \alpha_p \) it can be written as equation (2)

\[
I_z = \alpha_p I_p - \alpha_n I_n 
\]

(2)

\( \alpha_p \) and \( \alpha_n \) from equation(2) are current gains, and each can be written as equation (3)

\[
\alpha_p = 1 - \beta_p \\
\alpha_n = 1 - \beta_n 
\]

(3)

Here, \( \beta_p \) and \( \beta_n \) are current error values, and the values are smaller than 1. When input differential current \( I_z\) is converted into voltage signals at terminal \( z \), the external impedance value is connected to terminal \( z \), and the \( g_m \) value of the voltage from terminal \( z \) determines positive output current \( (I^+_z = g_m V_z) \) and negative output current \( (I^-_z = -g_m V_z) \). At that time, the \( g_m \) value of the transconductance can be adjusted by external bias current and this also can adjust output current. There is an important circuit design method for designing a circuit in order to construct a circuit resistant to noises produced during constructing integrated circuits and this is by composing all devices in a passive circuit with grounded devices as shown in [6-8] and [9-12]. From this point of view, CDTA is grounded by terminal \( z \) and this makes it strong to noises produced during construction. Because all input differential currents flow into terminal \( z \), differential currents can be converted into voltage by using one or more grounded passive devices.
Fig. 2(a) is a passive floating Inductor and 2(b) shows a CDTA floating inductor. The structural characteristics shown above allow the size of the circuit to become small when using CDTA to compose circuits.

\[
I_L = \frac{V_1 - V_2}{sL}
\]  
(4)

This floating inductor shows an equivalently composed circuit using CDTAs, as in Fig. 2(b). The voltage \( V_{Z2} \) that is put in the capacitor \( C_L \) in Fig. 2(b) can be obtained from equation (5).

\[
V_{Z2} = \alpha_2 \frac{g_{m1}V_1 - g_{m3}V_2}{sC_L}
\]  
(5)

In equation (5), \( \alpha_2 \) is the current gain from the internal current source in CDTA-2, and \( g_{m1} \) and \( g_{m3} \) are the transconductance of CDTA-1 and CDTA-3. Current \( I_{L_{in}} \) and \( I_{L_{out}} \) can be obtained from equation (6).

\[
I_{L_{in}} = \alpha_1 g_{m1} V_{Z2}, I_{L_{out}} = \alpha_3 g_{m2} V_{Z2}
\]  
(6)

Set the values of \( \alpha_1 \) and \( \alpha_3 \) as \( \alpha \) and \( g_{m1} \) and \( g_{m3} \) as \( g_m \), and from the relations of equation (1), equation (5) and equation (6), equation (7) which shows the inductance \( L \) value can be obtained.

\[
L = \frac{C_L}{\alpha_2 g_m g_{m2}}
\]  
(7)

From the equation (7), it can be seen that inductance \( L \) can be determined by CDTA’s current gain, the transconductance and capacitor’s \( C_L \) value. Next, Fig. 3(a) is the grounding inductor with one side of terminal grounded, and the equation for the current flowing through the inductor can be written as equation (8). Also, the circuit composing the grounding inductor with two CDTAs used is shown in Fig. 3(b).

\[
I_L = \frac{V_1}{sL}
\]  
(8)

The voltage \( V_{Z2} \) put into the capacitor’s \( C_L \) in Fig. 3(b) can be obtained from equation (9).
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\[ V_{z2} = \alpha_2 \frac{g_{m1} V_i}{SC_L} \]  \hspace{1cm} (9)

In equation (9), \( \alpha_2 \) is the current gain from the internal current source in CDTA-2, and \( g_{m1} \) is the transconductance of CDTA-1. The current \( I_L \) can be obtained from equation (10).

From the relations of equation (8), equation (9) and equation (10), the \( L \) value of the grounding inductance can be written as equation (11).

\[ I_L = \alpha_1 g_{m2} V_{z2} \]  \hspace{1cm} (10)

\[ L = \frac{C}{\alpha \alpha_1 g_{m2} \alpha_2} \]  \hspace{1cm} (11)

This shows that similar to the floating inductor, the grounding inductor’s \( L \) value can be determined by CDTA’s current gain, transconductance and the capacitor’s \( C_L \) value.

3. Design of a band pass filter using CDTA.

Because an inductor can be composed of CDTA, which itself is an active circuit, passive filters can be easily replaced with active filters. Fig. 4 shows a passive band pass filter with center frequency value designed to be 10 MHz and the device value is as in Table 1. Fig. 5 shows the active bandpass filter with the floating inductors \( L_1 \) and \( L_3 \) each composed of three CDTA’s, and the grounding inductor \( L_2 \) composed of two CDTAs from Fig. 5.

![Table 1] Device values for active filter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_1 )</td>
<td>1.17pF</td>
<td>( g_{m1} )</td>
<td>1ms</td>
</tr>
<tr>
<td>( C_2 )</td>
<td>0.202nF</td>
<td>( g_{m2} )</td>
<td>1ms</td>
</tr>
<tr>
<td>( C_L1 )</td>
<td>0.215nF</td>
<td>( g_{m3} )</td>
<td>1ms</td>
</tr>
<tr>
<td>( C_L2 )</td>
<td>1.25pF</td>
<td>( R )</td>
<td>1kΩ</td>
</tr>
</tbody>
</table>

![Fig. 4] Passive band pass filter

![Fig. 5] Active band pass filter using CDTA

The HSPICE simulation result of the designed active band pass filter is shown as in Fig. 6. The device values of the active filter obtained from the converted device values (Table 1) of the passive filter have 10MHz of center frequency with 9.5MHz to 10MHz of -2.5dB attenuated bandwidth, 8MHz to 17MHz of -50dB attenuated bandwidth, and has the cutoff characteristics.

![Fig. 6] Simulation results of the active band pass filter using CDTA
4. Conclusion

A CDTA based tunable band pass active filter is proposed. The proposed filter employs grounding and floating active inductors which are composed of two or three CDTAs, and is capable of realizing all the standard functions of the filter without requiring any component matching criterions and any extra active components. The HSPICE simulation result of the designed active band pass filter showed that it had 10MHz of center frequency with 9.5 MHz to 10.5 MHz of -2.5dB attenuated bandwidth, 8 MHz to 17 MHz of -50dB attenuated bandwidth, and had the cutoff characteristics. The designed band pass filter will be applied to design the low-voltage and low-power analog signal processing systems.

References


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