Realization of variable $Q$ bandpass filter using low-voltage CCII

Susheel Sharma¹, Seema Rana² & K Pal³

¹Department of Physics and Electronics, University of Jammu, Jammu 180 006
²Chetna Enterprises, 15 Purani Tehsil, Roorkee, India
³Department of Earthquake Engineering, Indian Institute of Technology, Roorkee

*E-mail: susheelsharma@gmail.com

Received 12 March 2009; revised 19 December 2009; accepted 2 March 2010

A voltage-mode bandpass filter with variable $Q$, realized using a single FGMOS based second generation current conveyor (CCII) that operates with ±0.75 V supply voltage, has been presented. The $Q$ and pass band gain ($K$) can be adjusted for desired values within some limits by selecting the various passive components used in the circuit. The workability of this circuit has been verified by PSpice simulations using 0.5 µm technology parameters.

Keywords: Low voltage circuits, Current conveyor, Bandpass filter

1 Introduction

The advancements in integrated circuit technology have promoted the development of mobile and portable electronic gadgets that consume low power and operate with low supply voltages. Obviously, the filters being the essential components of any modern communication and instrumentation system need to be operated using low supply voltages in order to dissipate low power. In the past, the design of active filters using CMOS current conveyors has been quite popular due to certain advantages over the conventional operational amplifiers like wider dynamic range, extended operating bandwidth, simple circuitry and low power consumption. CCII operating at low supply voltage can be obtained by employing low voltage design techniques available in the literature. The use of floating gate transistors (FGMOS) offers the advantage of reducing the threshold voltage below its conventional value and thus, can be used to realize low voltage CCII.

A number of band pass filters using CCII are available in literature but that employing single CCII are not found much as compared to those using two or more CCII. In this paper, a simple configuration of second order voltage-mode bandpass filter is presented that has been realized using a low voltage FGMOS based CCII. The simplicity of filter is attributed to the employment of a single CCII and can be designed for variable high $Q$ and variable gain within some limits which avoids the need of an additional amplifier in the systems where this filter may be used. The functionality of the circuit has been verified by using PSpice simulations for 0.5 µm technology at ±0.75 V.

2 Circuit Description

The topology of bandpass filter is shown in Fig. 1. Routine analysis of the circuit yields the following voltage transfer function.

$$V_o(s) = \frac{Z_2(Z_3+Z_4)}{(Z_1Z_3+Z_2Z_3-Z_1Z_2)}$$  \hspace{1cm} (1)

Now, if we substitute

$$Z_1 = R + \frac{1}{sC}, \quad Z_2 = \frac{R}{1+sCR}, \quad Z_3 = \frac{Z_1}{a} \quad \text{and} \quad Z_4 = \frac{Z_1}{b}$$

where $a$ and $b$ are impedance scaling factors, the transfer function in Eq. (1) becomes:

$$V_o(s) = \frac{(1+\frac{a}{b})sCR}{1 + s^2C^2R^2 + sCR(3-a)}$$  \hspace{1cm} (2)

Eq. (2) realizes a bandpass response and gives centre frequency as $f_0=1/(2\pi RC)$, quality factor as $Q=1/(3-a)$ and passband gain as $K=(1+(alb))/(3-a)$. The filter can be designed for higher values of $Q$ with adjustable gain by selecting impedances $Z_3$ and $Z_4$. The minimum value of gain is $K_{min}=1/(3-a)$ for $b>>a$ and maximum gain is $K_{min}=(alb)/(3-a)$ for $a>>b$. By selecting proper values of $a$ and $b$, bandpass
filter with desirable passband gain can be designed in the gain limits. However, for unity passband gain, quality factor becomes low \((Q = 0.5)\).

**3 Filter Design**

The filter may be designed for different relationships between \(a\) and \(b\) given as:

(i) Choosing \(a = b\) results in equal valued components in \(Z_3\) and \(Z_4\) impedance arms and \(K=2/(3-a)\).

(ii) If we choose \(b = 1\), then components in \(Z_1, Z_2\) and \(Z_4\) impedance arms would be equal and \(K=(1+a)/(3-a)\).

(iii) Now, if we choose \(b = 20a\), then \(R\) and \(C\) components in \(Z_4\) impedance arm would be comparatively too small with \(K=1.05/(3-a)\).

**4 Simulation Results**

CCII (+) used for realizing bandpass filter is taken from Ref. (3) in which FGMOS current mirrors \(^{12}\) have been used. It has been simulated using PSpice for 0.5 \(\mu\)m technology with supply voltage of \(\pm 0.75\) V. Simulation results show that it offers an input resistance of 2.53 \(\Omega\) at port \(X\), 10\(^{20}\) \(\Omega\) at port \(Y\) and output resistance of 119.8 M\(\Omega\) at port \(Z\). The power consumed by the circuit is 1.62 mW. Current and voltage transfer ratios are almost unity with an error less than \(\pm 0.2\%\). The bandwidth for both current and voltage transfer has been found to be 100 MHz.
<table>
<thead>
<tr>
<th>(a)</th>
<th>(Q)</th>
<th>(f_0) (kHz)</th>
<th>(K) (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a = 2)</td>
<td>1</td>
<td>398.10</td>
<td>6.02</td>
</tr>
<tr>
<td>(a = 2.4)</td>
<td>1.7</td>
<td>398.11</td>
<td>10.45</td>
</tr>
<tr>
<td>(a = 2.8)</td>
<td>5</td>
<td>397.70</td>
<td>20.0</td>
</tr>
<tr>
<td>(a = 2.9)</td>
<td>10</td>
<td>397.85</td>
<td>26.02</td>
</tr>
</tbody>
</table>

### 5 Conclusions

In this paper, a simple single low-voltage FGMOS CCII based bandpass filter circuit that can realize high \(Q\) and variable gain responses, has been presented. The circuit employs passive components with simple matching conditions which makes it desirable in IC realization. The filter circuit can operate with a supply voltage of \(\pm 0.75\) V. The simulated results show well agreement with the theoretical predictions.

### References