Abstract—This article proposes a voltage-mode multifunction filter using differential voltage current controllable current conveyor transconductance amplifier (DV-CCCCTA). The features of the circuit are that: the quality factor and pole frequency can be tuned independently via the values of capacitors; the circuit description is very simple, consisting of merely 1 DV-CCCCTA, and 2 capacitors. Without any component matching conditions, the proposed circuit is very appropriate to further develop into an integrated circuit. Additionally, each function response can be selected by suitably selecting input signals with digital method. The PSpice simulation results are depicted. The given results agree well with the theoretical anticipation.

Keywords—DV-CCCCTA, Voltage-mode, Multifunction filter

I. INTRODUCTION

In analog signal processing applications it may be desirable to employ active filters. They can be found in many applications: e.g., communication, measurement and instrumentation and control systems [1-2]. One of most popular analog filters is a multi-function filter since it can provide several functions, depending on desired selections. The literature surveys show that the voltage-mode multifunction filter circuits [3-13] have been reported. Unfortunately, these reported circuits suffer from one or more of following weaknesses:

- Excessive use of the active and/or passive elements [3, 5-6, 7, 9, 11, 13].
- Requirement for changing circuit topologies to achieve several functions [4, 9, 12].
- The pole frequency and quality factor can not be tuned independently [8-9].

In 2010, A reported active element, namely differential voltage current controllable current conveyor transconductance amplifier (DV-CCCCTA) [14], seems to be a versatile component in the realisation of a class of analog signal processing circuits. The fact is that the device can operate in both current and voltage-modes, provides flexibility and enables a variety of circuit designs. In addition, output current of DV-CCCCTA can be electronically adjusted.

The aim of this paper is to propose a voltage-mode multifunction filter, emphasizing on use of the DV-CCCCTA. The features of proposed circuit are that: the proposed multifunction filter can provide completely standard functions (low-pass, high-pass, band-pass, band-reject and all-pass) without changing circuit topology; the circuit description is very simple, it uses 2 capacitors as passive elements, which is suitable for fabricating in monolithic chip or off-the-shelf implementation; quality factor and pole frequency can be independently adjusted. The performances of proposed circuit are illustrated by PSpice simulations, they show good agreement as mentioned.

II. CIRCUIT CONFIGURATION

A. Basic Concept of DV-CCCCTA

This section describes the principle of DV-CCCCTA, it was proposed by A. Jantakaun and M. Siripruchyanun in 2010. Figs 1(a) and (b) illustrate the schematic symbol and equivalent circuit of DV-CCCCTA, respectively. In ideal case, the relationship of voltage and current of DV-CCCCTA can be shown by (1)

Since the DV-CCCCTA is design by BJT technology, \( R_s \) and \( g_m \) can be expressed as

where

\[ R_s = \frac{V_t}{2T_m} \]

and

\[ g_m = \frac{I_{ss}}{2V_t} \]

\( R_s \) and \( g_m \) are the parasitic resistance and transconductances of the DV-CCCCTA at x and o terminals, respectively. They can be adjusted via bias currents. \( V_t \) is the thermal voltage, its values is about 26mV at 27°C.
From (5) and (6), the voltage output \( V_{out} \) can be ultimately obtained

\[
V_{out} = \frac{R_x C_1 C_2 s V_{in1} + V_{in2} (C_3 s + g_m) + R_x g_m C_2 s V_{in3}}{R_x C_1 C_2 s^2 + C_3 s + 2g_m} \quad (7)
\]

From (7), the amplitudes of input voltages \( V_{in1}, V_{in2} \) and \( V_{in3} \) are selected as Table 1 by digital method to obtain a standard function of the 2nd order network. From (7), the pole frequency \( \omega_0 \) and quality factor \( Q_0 \) of each filter response can be expressed as

\[
\omega_0 = \sqrt{\frac{2g_m}{R_x C_1 C_2}} \quad \frac{1}{V_r \sqrt{C_1 C_2}} \quad (8)
\]

And

\[
Q_0 = \frac{2R_x C_1 g_m}{C_2} \quad \frac{1}{\sqrt{2C_1 I_{b1}}} \quad (9)
\]

In addition, bandwidth \( BW \) of the system can be expressed by

\[
BW = \frac{1}{R_x C_1} \quad \frac{2I_{b1}}{V_r C_1} \quad (10)
\]

For simple consideration, if we set \( C_1 = C_2 = C \), then (8) and (9) are subsequently modified to

\[
\omega_0 = \frac{1}{CV_r} \quad \sqrt{\frac{2I_{b1}}{g_m}} \quad (11)
\]

and

\[
Q_0 = \frac{I_{b1}}{\sqrt{2I_{b1}}} \quad (12)
\]

From (11) and (12), it can be clearly seen that the \( \omega_0 \) and \( Q_0 \) can be independently controlled by \( C \).

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>( V_{in1}, V_{in2} ) AND ( V_{in3} ) VALUES FOR EACH FILTER FUNCTION RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Responses</td>
<td>( V_{in1} )</td>
</tr>
<tr>
<td>BP ((R_x=1/g_m))</td>
<td>0</td>
</tr>
<tr>
<td>HP</td>
<td>1</td>
</tr>
<tr>
<td>LP ((R_x=1/g_m))</td>
<td>0</td>
</tr>
<tr>
<td>BR ((R_x=1/g_m))</td>
<td>1</td>
</tr>
<tr>
<td>AP ((R_x=1/g_m))</td>
<td>1</td>
</tr>
</tbody>
</table>

From (5) and (6), the voltage output \( V_{out} \) can be ultimately obtained

\[
V_{out} = \frac{R_x C_1 C_2 s V_{out1} + V_{out2} (C_3 s + g_m) + R_x g_m C_2 s V_{out3}}{R_x C_1 C_2 s^2 + C_3 s + 2g_m} \quad (7)
\]
III. SIMULATION RESULTS

The performances of the proposed voltage-mode filter have been tested by PSpice simulation. This work employed a DV-CCCCTA realized by a BJT technology. The PNP and NPN transistors employed in the proposed circuit as shown in Fig. 3 were simulated by respectively using the parameters of the PR200N and NR200N bipolar transistors of ALA400 transistor array from AT&T [15] with ±2V supply voltages, $I_s = 100 \mu A$. Fig. 3 depicts the schematic description of DV-CCCCTA used in the simulations. Table I shows the parameters of BJT where it is used in the proposed circuit.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>PARAMETER OF BIPOLAR JUNCTION TRANSISTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPN</td>
<td>MODEL NR200N NPN(RB=262.5 IRB=0 RBM=12.5 RC=25 RE=0.5</td>
</tr>
<tr>
<td></td>
<td>IS=2.42E-18 EG=1.206 XTI=2 XTB=1.538 BF=137.5</td>
</tr>
<tr>
<td></td>
<td>BF=137.5 IKF=13.94E-3 NF=1 VAF=159.4 ISE=72E-16 NE=1.713</td>
</tr>
<tr>
<td></td>
<td>BR=0.2528 IKR=9.396E-3 NR=1 VAR=10.73 ISC=0 NC=2</td>
</tr>
<tr>
<td></td>
<td>TF=0.425E-9 TR=0.425E-8 CJE=0.428E-12 VJE=0.5</td>
</tr>
<tr>
<td></td>
<td>MJE=0.26 CJC=1.97E-13 VJC=0.65 ISC=0.3 XCJC=0.065</td>
</tr>
<tr>
<td></td>
<td>+CSI=1.17E-12 VJS=0.64 MJ=0.4 FC=0.5</td>
</tr>
<tr>
<td>PNP</td>
<td>MODEL PR200N PNP(RB=163.5 IRB=0 RBM=12.27 RC=25 RE=1.5</td>
</tr>
<tr>
<td></td>
<td>IS=1.47E-18 EG=1.206 XTI=1.7 XTB=1.86E-6 BF=110</td>
</tr>
<tr>
<td></td>
<td>BF=110 IKF=4.718E-3 NF=1 VAF=51.8 ISE=50.2E-16 NE=1.82</td>
</tr>
<tr>
<td></td>
<td>BR=4.745 IKR=12.96E-3 NR=1 VAR=9.96 ISC=0 NC=2</td>
</tr>
<tr>
<td></td>
<td>TF=0.610E-9 TR=0.610E-8 CJE=0.36E-12 VJE=0.5</td>
</tr>
<tr>
<td></td>
<td>MJE=0.28 CJC=0.328E-12 VJC=0.8 MJ=0.4 XCJC=0.074</td>
</tr>
<tr>
<td></td>
<td>+CSI=1.39E-12 VJS=0.55 MJ=0.35 FC=0.5</td>
</tr>
</tbody>
</table>

The results shown in Fig. 4 are the gain and phase responses of the proposed biquad filter obtained from Fig. 2 with different functions as shown Table 1, where $I_{R1}$ and $I_{R2}$ are equal 20$\mu A$ and 80$\mu A$. There are clearly seen that the proposed biquad filter can provide low-pass, high-pass, band-pass, band-reject and all-pass functions dependent on selection as shown in Table I, without modifying major circuit topology.

Fig. 3 Internal construction of DV-CCCCTA

![Diagram of DV-CCCCTA](image)

Fig. 4 Normalized magnitude and phase responses of the biquad filter
(a) BP (b) HP (c) LP (d) BR (e) AP
Fig. 5 displays the gain of Band-pass responses at different values of $C$. From this result, it can be found that if $C_1 = C_2$, the $Q$ and $\alpha_0$ can be independently adjusted by $C$.

IV. CONCLUSION

The voltage-mode multifunction biquadratic filter base on DV-CCCCCTA has been presented. The features of the proposed circuit are that: it performs low-pass, high-pass, band-pass, band-reject and all-pass functions with only single output depending on a digital selection method of input terminals as given in Table 1: the quality factor and the pole frequency can be independently controlled via values of capacitors. In addition, from simulation results, the proposed circuit can work at low supply voltages ($\pm 2V$), low power consumption. The circuit description consists of only 1 DV-CCCCCTA and 2 floating capacitors. By the way, from Table 1, the proposed voltage-mode biquad filter can be easily improved to achieve digital programmability, by adding digitally selective circuit [16]. With mentioned features, it is very suitable to realize the proposed circuits in monolithic chip for use in battery-powered, portable electronic equipments such as wireless communication system devices.

REFERENCES


Chatchaphon Ketviriyakiat received the B. Eng. degree in Electrical Engineering from Kasern Bundit University, Thailand in 1997, the M. Ed. degree from Narasuan University in 1999. Presently, he works with Department of Electrical Computer and Industrial, Faculty of Industrial Technology, Uttaradit Rajabhat University, Uttaradit, Thailand since 2004. His research interests include electronic circuit, power electronics and its application.

Weerapan Kongmun received the B. Eng. degree in Instrument Engineering and the M. Eng. degree in Electrical Engineering from King Mongkut’s Institute of Technology Ladkrabang (KMITL) in 1999 and 2002. Presently, he works with Department of Electrical Computer and Industrial, Faculty of Industrial Technology, Uttaradit Rajabhat University, Uttaradit, Thailand since 2004. His research interests include electronic circuit, microcontroller, power electronics and its application.

Chaiyan Chanapromma received his B. Tech. Ed. degree in electrical Engineering from the King Mongkut's Institute of Technology North Bangkok (KMITNB) and the M.Eng. from the Mahanakorn University of Technology (MUT) Thailand, in 2006, and 2008, respectively. Presently, he has been with Department of Electrical Computer and Industrial, Faculty of Industrial Technology, Uttaradit Rajabhat University, Uttaradit, Thailand since 2009. His research interests include electronic communications, analog signal processing and analog integrated circuit. His biography has published in Marquis Who’s Who 2011-2012 in the topic of science and engineering.
Phamorn Silapan received the B. Eng. degree in electrical engineering from Mahanakorn University of Technology, Thailand in 2002, the Master of Tech. Ed. in Electrical Technology and Ph.D. in Electrical Education from King Mongkut's University of Technology North Bangkok (KMUTNB) in 2005 and 2011, respectively. Now, He has been with Department of Electrical Computer and Industrial, Faculty of Industrial Technology, Uttaradit Rajabhat University, Uttaradit, Thailand since 2006. His research interests include electronic communications, analog signal processing and analog integrated circuit. His biography has published in Marquis Who’s Who 2011-2012 in the topic of science and engineering.