ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 7, July 2013

Dual Mode Quadrature Oscillator Employing Single Current Controlled Current Conveyor Transconductance Amplifier

Saikat Maiti [1], Radha Raman Pal [2]

Research Scholar, Department of Physics and Technophysics, Vidyasagar University, Midnapore 721102, West Bengal, India[1]

Professor, Department of Physics and Technophysics, Vidyasagar University, Midnapore 721102, West Bengal, India[2]

Abstract: This paper presents new realizations of dual mode i.e. both voltage mode and current mode quadrature sinusoidal oscillators using a recently proposed current mode active building block (ABB), namely the current controlled current conveyor transconductance amplifier (CCCCTA). The proposed circuit employs single CCCCTA and four passive grounded elements. The proposed circuits offer two explicit quadrature voltage outputs and two quadrature current outputs. The tuning laws for the condition of oscillation (CO) and the frequency of oscillation (FO) are independently adjustable by the separate bias currents. Non–ideal analyses of the proposed circuits are provided. PSpice simulation results have been included that validate the workability of the proposed circuits.

Keywords: Current controlled current conveyor transconductance amplifier (CCCCTA), Voltage mode (VM), Current mode (CM), Quadrature oscillator, Condition of oscillation (CO), Frequency of oscillation (FO).

I. INTRODUCTION

In recent years designing electronic circuits that can operate from low supply voltages has been gaining an increasing interests due to the fact that the battery operated portable devices require low power dissipation to increase battery life and minimum number of cells to reduce the volume and weight. For this reason the current mode technique is more suitable rather than the voltage mode technique. Also the current mode structures are more favorable because of their advantages such as, larger dynamic range, greater linearity, higher signal bandwidth and simple circuitry [1–2].

Quadrature oscillators (QO) that simultaneously provide two sinusoids, which are 90º phase shifted have become a very important blocks for various communication systems such as in telecommunications for quadrature mixers, in direct conversion receivers , in single sideband generators or for measurement purpose in vector generators or selective voltmeters [3–5].

Now several realizations of voltage mode and current mode quadrature oscillators based on various ABBs have received considerable attention. These include oscillators based on different ABBs like second generation current conveyor (CCII) [6–8], fully differential second generation current conveyor (FDCCII) [9–10], differential difference current conveyor (DDCC) [11], differential input buffered and transconductance amplifier (DBTA) [12], current feedback amplifiers (CFA) [13], current differencing buffered amplifier (CDBA) [14–15] and most recently by current differencing transconductance amplifier (CDTA) [16–18]. Recently a new kind of current mode active building block namely, the current controlled current conveyor transconductance amplifier (CCCCTA) has been introduced. Various researchers have designed new kind of oscillators and filters using this ABB.

The published CCCCTA based oscillators are compared here. Siripruchyanun introduced an oscillator based on a single CCCCTA and two grounded capacitors both in bipolar [2] and in CMOS [19] technology. In both the cases no quadrature output is obtained and the total harmonic distortion (THD) is 2.92% in the first case and 1.07% in the later. Jaikla introduced an oscillator based on a commercially available CCCCTA, one resistor and two grounded capacitors [20]. But no quadrature output is obtained and in this case the THD is about 5.75%. The oscillator proposed by Pissutthipong [21] gives current mode quadrature outputs and in this case the THD is about 2.445%. But a careful observation indicates that most of the circuits can not provide explicit quadrature voltage outputs and quadrature current outputs. These oscillator circuits contain one [2, 9, 10, 12, 16, 19, 20], two [11, 13, 14, 15, 17, 21], or three [6, 8, 18] ABBs and the oscillators in [6, 8, 9, 11, 12, 15] use at least five passive elements. But realizations with one ABB are more acceptable. Also the circuits in [16] employ floating capacitors which is not favorable for monolithic implementation.

In this paper both the voltage mode and current mode quadrature oscillators have been proposed using single CCCCTA and grounded passive components. The CO and FO are independently adjustable by different bias currents. The grounded passive components make the circuit suitable for monolithic implementation. PSpice simulation results have been included that validate the working of the proposed circuit.

II. CURRENT CONTROLLED CURRENT CONVEYOR TRANSCONDUCTANCE AMPLIFIER

The current controlled current conveyor transconductance amplifier (CCCCTA) is an active block which consists of two principal building blocks, a multiple output current controlled current conveyor at the front end and operational transconductance amplifiers at the rear end. The circuit symbol of the CCCCTA is shown in Fig. 1. A possible bipolar implementation of the CCCCTA is shown in Fig. 2.

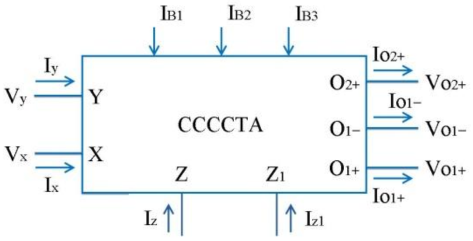


Fig. 1 The schematic symbol of the CCCCTA

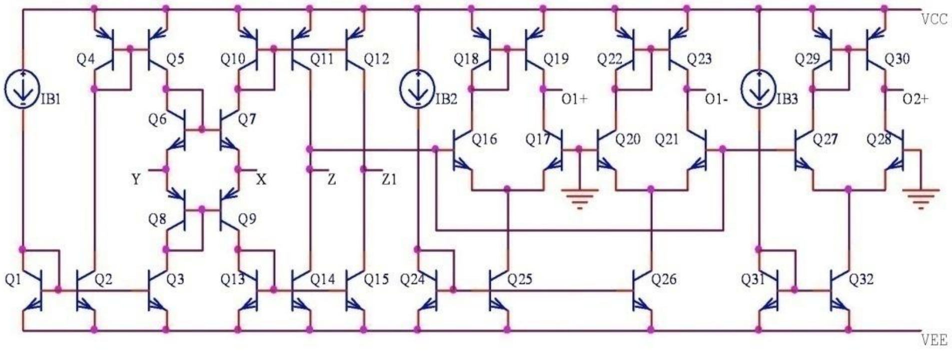


Fig. 2 A possible bipolar implementation of the CCCCTA

The circuit consists of a translinear loop (Q_6–Q_9) which is dc biased by the current mirrors (Q_1–Q_3 and Q_4–Q_5). The CCCCTA used here is defined by the following equations:

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_{z1} \\ I_{o1+} \\ I_{o1-} \\ I_{o2+} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ R_x & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & +g_{m1} \\ 0 & 0 & -g_{m1} \\ 0 & 0 & +g_{m2} \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_z \end{bmatrix} \tag{1}$$

where R_x represents the parasitic resistance at the X terminal, g_{m1} and g_{m2} represent the transconductance gains. For bipolar implementation of the CCCCTA as shown in Fig. 2, the parasitic resistance R_x and the transconductance gains g_{m1} and g_{m2} are given as

$$R_x = \frac{V_T}{2I_{B1}}, \quad g_{m1} = \frac{I_{B2}}{2V_T}, \quad g_{m2} = \frac{I_{B3}}{2V_T} \tag{2}$$

where V_T is the thermal voltage whose value is 26mV at 27°C. For large value of I_{B1} the effect of R_x could be neglected.

III. PROPOSED QUADRATURE OSCILLATOR CIRCUIT

The proposed dual–mode quadrature oscillator circuit using single CCCCTA and grounded passive elements is shown in Fig. 3. Using (1) and doing routine circuit analysis, the characteristic equation can be written as

$$s^2 C_1 C_2 R_1 R_2 + sC_1 R_1 (1 - g_{m2} R_2) + g_{m1} R_2 = 0 \tag{3}$$

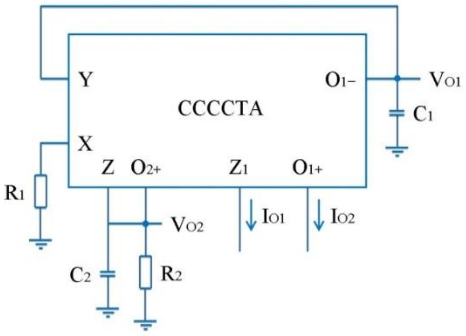


Fig. 3 The proposed quadrature oscillator circuit using the CCCCTA

It is seen from (3) that the condition of oscillation (CO) and frequency of oscillation (FO) are given as

$$CO: R_2 \geq \frac{1}{g_{m2}} \tag{4}$$

$$FO: f_{osc} = \frac{1}{2\pi}\sqrt{\frac{g_{m1}}{C_1 C_2 R_1}} \tag{5}$$

It is clear from (4) and (5) that the condition of oscillation and frequency of oscillation are independently adjustable by the transconductance gains g_{m2} and g_{m1}, respectively and therefore by the bias currents I_{B3} and I_{B2}, respectively. Also from (5) it is clear that R_1 can be used for electronic tuning of the oscillation frequency. The two marked quadrature voltages in Fig. 3 are related as

$$V_{o2} = -jk_1 V_{o1} \text{ where } k_1 = \frac{\omega_o C_1}{g_{m1}} \tag{6}$$

For k_1=1 the two quadrature voltages have equal magnitude. Similarly, the two marked quadrature currents in Fig. 3 are related as

$$I_{o2} = -jk_2 I_{o1} \text{ where } k_2 = \omega_o C_1 R_1 \tag{7}$$

For k_2=1 the two explicit quadrature current outputs have equal magnitude. It is clear from (6) and (7) that factors k_1 and k_2 are operating frequency dependent terms that is they depend on g_{m1} and hence temperature dependent. Thus the changing of frequency of oscillation by g_{m1} simultaneously changes the ratio of the magnitudes of quadrature voltages and quadrature currents. The circuit provides current outputs from high impedance port for explicit utilization but external voltage buffers would be required for the quadrature voltage outputs.

IV. NON-IDEALITIES AND SENSITIVITY ANALYSIS

In the non–ideal case, the CCCCTA can be characterized by the following equations [22]

$$\begin{bmatrix} I_y \\ V_x \\ I_z \\ I_{z1} \\ I_{o1+} \\ I_{o1-} \\ I_{o2+} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ R_x & \alpha & 0 \\ \beta & 0 & 0 \\ \beta_1 & 0 & 0 \\ 0 & 0 & +\gamma_1 g_{m1} \\ 0 & 0 & -\gamma_2 g_{m1} \\ 0 & 0 & +\gamma_3 g_{m2} \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_z \end{bmatrix} \tag{8}$$

where α represents the voltage transfer gain from Y terminal to X terminal, β and β_1 represent the current transfer gains from X terminal to Z and Z_1 terminals and γ_1, γ_2 and γ_3 represent the current transfer gains from Z terminal to O_{1+}, O_{1-} and O_{2+} terminals, respectively.

The non–zero parasitic resistance R_x appears in series with the external resistor R_1. Therefore this parasitic resistance R_x increases the external resistor R_1 as

$$R_1^{'} = R_1 + R_x \tag{9}$$

The parasitic resistances R_z, R_{o1}, R_{o2} and parasitic capacitances C_z, C_{o1}, C_{o2} appear between the high output impedance current terminals Z, O_{1-}, O_{2+} and ground. Since the values of R_z and R_{o2} are in the order of MΩ, hence an external resistor R_2 should be connected at this terminal so that $R_z \| R_{o2} \| R_2 = R_2$. The parasitic capacitances (C_z+C_{o2}) and C_{o1} are absorbed into the external capacitors C_2 and C_1, respectively, as they appear in shunt with them. Therefore the original capacitances C_1 and C_2 are increased to C_1' and C_2' as

$$C_1^{'} = C_1 + C_{o1} \tag{10}$$

$$C_2' = C_2 + C_z + C_{o2} \tag{11}$$

Taking into account the aforementioned non–idealities the modified expression of CO and FO are

$$CO: R_2 \geq \frac{1}{\gamma_3 g_{m2}} \tag{12}$$

$$FO: f_{osc} = \frac{1}{2\pi}\sqrt{\frac{\alpha\beta\gamma_2 g_{m1}}{(C_1 + C_{o1})(C_2 + C_z + C_{o2})(R_1 + R_x)}} \tag{13}$$

The sensitivity of any active network is given as:

$$S_e^F = \frac{e}{F}\frac{\partial F}{\partial e} \tag{14}$$

where *F* represents a network function and *e* represents the element of variation of the filter. The oscillation frequency is the parameter of interest. Using this definition the active and passive sensitivities are given as:

$$S_{\alpha}^{f_o} = S_{\beta}^{f_o} = S_{\gamma_2}^{f_o} = S_{g_{m1}}^{f_o} = \frac{1}{2}, \tag{15}$$

$$S_{C_1}^{f_o} = -\frac{C_1}{2(C_1 + C_{o1})}, \tag{16}$$

$$S_{C_{o1}}^{f_o} = -\frac{C_{o1}}{2(C_1 + C_{o1})}, \tag{17}$$

$$S_{C_2}^{f_o} = -\frac{C_2}{2(C_2 + C_z + C_{o2})}, \tag{18}$$

$$S_{C_z}^{f_o} = -\frac{C_z}{2(C_2 + C_z + C_{o2})}, \tag{19}$$

$$S_{C_{o2}}^{f_o} = -\frac{C_{o2}}{2(C_2 + C_z + C_{o2})}, \tag{20}$$

$$S_{R_1}^{f_o} = -\frac{R_1}{2(R_1 + R_x)}, \tag{21}$$

$$S_{R_x}^{f_o} = -\frac{R_x}{2(R_1 + R_x)} \tag{22}$$

Therefore it is evident that the circuit exhibits low active and passive sensitivities.

V. RESULTS AND DISCUSSIONS

The proposed oscillator circuit as shown in Fig. 3 has been simulated in PSpice by using the bipolar implementation of the CCCCTA. The circuit is biased with ±1.5 V supply voltages. The passive components were chosen as $C_1=C_2=220$ pF, $R_1=1$ kΩ, $R_2=1$ kΩ, $R_x=130$ Ω ($I_{B1}=100$ µA), $g_{m1}=1$ mS ($I_{B2}=50$ µA) and $g_{m2}=1$ mS ($I_{B3}=50$ µA). With these values, the condition of oscillation is satisfied. The start up of oscillations and the steady state waveforms for both the quadrature voltages and currents are shown in Fig. 4 and Fig. 5, respectively. The steady state is reached approximately within 30 µs. The frequency spectrums (FFT) for both the voltage mode and current mode are shown in Fig. 6. The total harmonic distortions (THD) for both the voltage mode and current mode structures are nearly 3.61% and 3.42%, respectively at the oscillation frequency of 380 kHz. The electronic tuning of the oscillation frequency with the bias current I_{B2} for different capacitor values is shown in Fig. 7. For practical measurement the CCCCTA can also be constructed using commercially available circuits AD844 and LM13600. It is expected that the experimental results would agree well with the simulated and theoretical results.

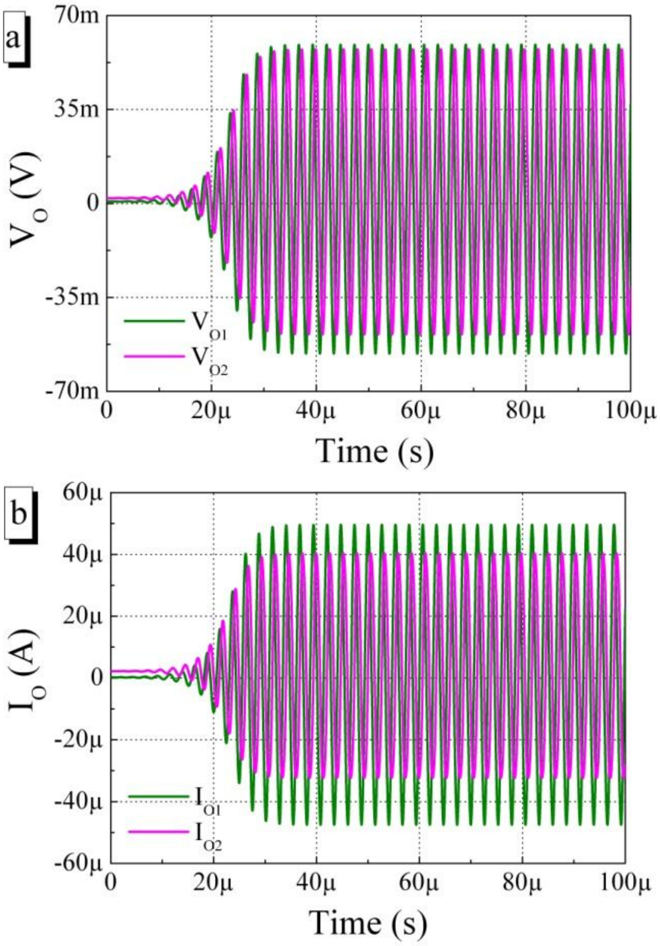
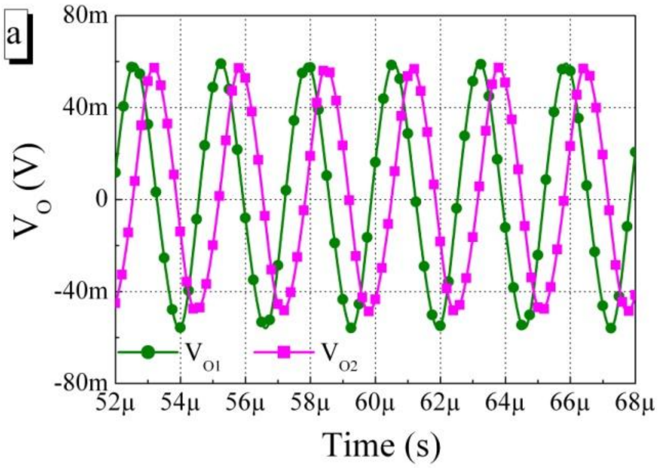


Fig. 4 The growing oscillations of quadrature outputs for (a) Voltage mode (b) Current mode



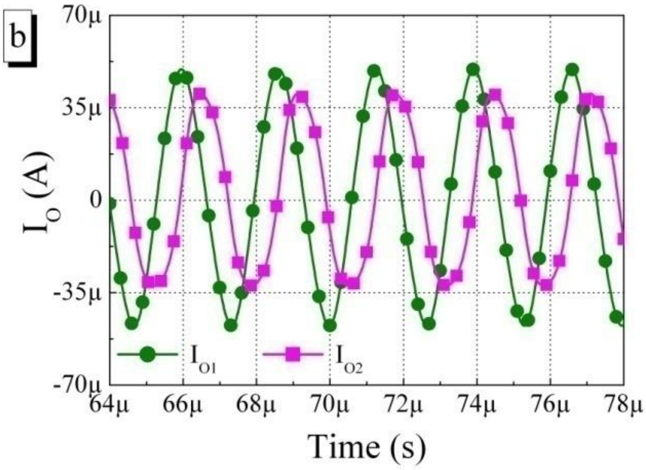


Fig. 5 The steady state time domain waveforms of the quadrature outputs for (a) Voltage mode (b) Current mode

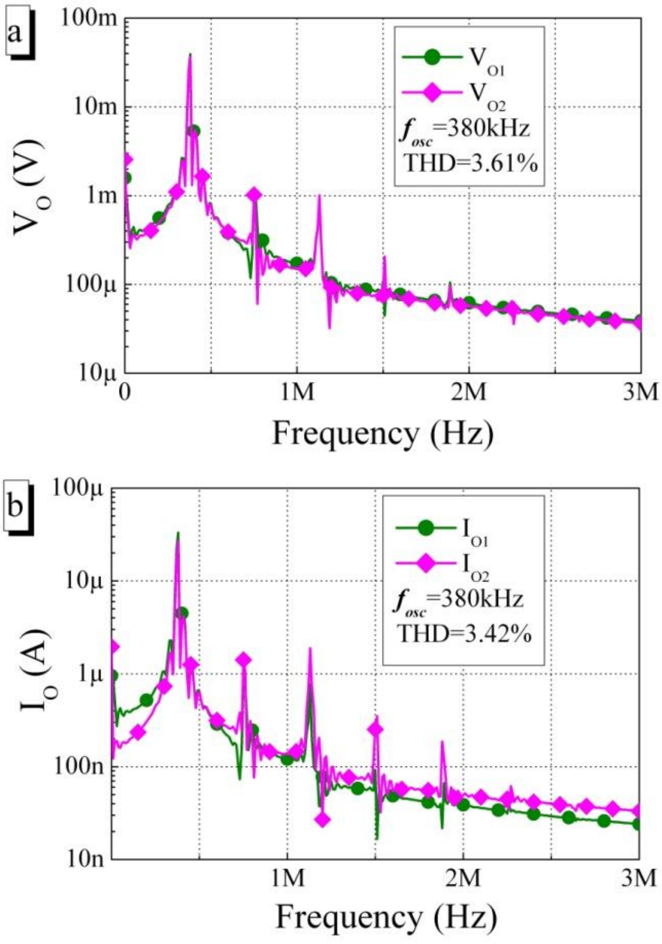


Fig. 6 The FFT spectrum of outputs for (a) Voltage mode (b) Current mode

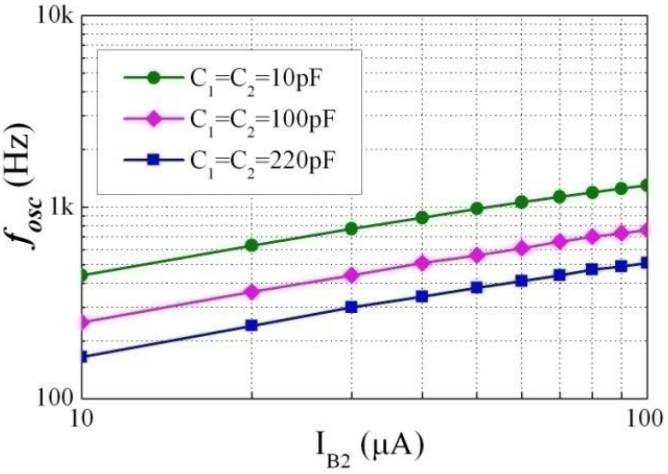


Fig. 7 The dependence of the oscillation frequency on bias current I_{B2}

VI. CONCLUSION

In this paper, a dual mode quadrature sinusoidal oscillator using a single CCCCTA has been proposed, which simultaneously provides two explicit quadrature voltage outputs and current outputs. The oscillator circuit proposed in this paper is attractive because it provides independent adjusting of the oscillation frequency and the oscillation condition. It also uses all grounded passive components, which is advantageous from the viewpoint of integrated circuit manufacturing. Also the circuit provides low total harmonic distortion and low sensitivities. The simulation results are in good agreement with the theoretical anticipation. Since the circuit consists of single CCCCTA and grounded passive components it is thus suitable for monolithic implementation to employ in portable electronic equipments.

ACKNOWLEDGMENT

This work was supported in part by a grant from SAP–University Grants Commission, India. Also the authors gratefully acknowledge FIST, Department of Science and Technology, India.

REFERENCES

[1] Bhaskar, D. R., Sharma, V. K., Monis, M., and Rizvi, S. M. I., "New current–mode universal biquad filter", *Microecectronics Journal*, Vol. 30, pp. 837–839, 1999.

[2] Siripruchyanun, M., and Jaikla, W., "Current controlled current conveyor transconductance amplifier (CCCCTA): a building block for analog signal processing", *Electrical Engineering*, Vol. 90, pp. 443–453, 2008.

[3] Khan, I. A., and Khawaja, S., "An integrable g_m–C quadrature oscillator", *International Journal of Electronics*, Vol. 87, No. 11, pp. 1353–1357, 2000.

[4] Tangsrirat, W., Prasertsom, D., Piyatat, T., and Surakompontorn, W., "Single–resistance–controlled quadrature oscillators using current differencing buffered amplifiers", *International Journal of Electronics*, Vol. 95, No. 11, pp. 1119–1126, 2008.

[5] Jaikla, W., Siripruchyanun, M., and Lahiri, A., "Resistorless dual–mode quadrature sinusoidal oscillator using a single active building block", *Microelectronics Journal*, Vol. 42, pp. 135–140, 2011.

[6] Minhaj, N., "Current conveyor–based voltage mode two–phase and four–phase quadrature oscillators", *International Journal of Electronics*, Vol. 94, No. 7, pp. 663–669, 2007.

[7] Horng, J. W., "Current conveyors based all pass filters and quadrature oscillators employing grounded capacitors and resistors", *Computers and Electrical Engineering*, Vol. 31, pp. 81–92, 2005.

[8] Minhaj, N., "Dual–Output Second–Generation Current conveyor–based Voltage–Mode Sinusoidal Oscillator modified for Chaos Generators", *International Journal of Recent Trends in Engineering*, Vol. 2, No. 5, pp. 315–318, 2009.

[9] Horng, J. W., Hou, C. L., Chang, C. M., Chou, H. P., Lin, C. T., and Wen, Y. H., "Quadrature Oscillators with Grounded Capacitors and Resistors Using FDCCIIs", *ETRI Journal*, Vol 28, No. 4, pp. 486–494, 2006.

[10] Horng, J. W., Hou, C. L., Chang, C. M., Cheng, S. T. and Su, H. Y., "Current Or/And Voltage–Mode Quadrature Oscillators Using FDCCIIs", *WSEAS TRANSACTIONS on CIRCUITS AND SYSTEMS*, Vol. 7, Issue 3, pp. 129–138, 2008.

[11] Kumngern, M., and Dejhan, K., "DDCC–Based Quadrature Oscillator with Grounded Capacitors and Resistors", *Active and Passive Electronic Components*, Vol. 2009, Doi: 10.1155/2009/987304, 2009.

[12] Herencsar, N., Koton, J., Vrba, K., and Lahiri, A., "New voltage–mode quadrature oscillator employing single DBTA and only grounded passive elements", *IEICE Electronics Express*, Vol. 6, No. 24, pp. 1708–1714, 2009.

[13] Kumbun, J., Silapan, P., Siripruchyanun, M., and Prommee, P., "A Current–mode Quadrature Oscillator Based on CC–CFAs", in *Proc. The sixth International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI–CON 2009*, Thailand, 6–9 May, 2009, pp. 542–545.

[14] Pisitchalermpong, S., Prasertsom, D., Piyatat, T., Tangsrirat, W., and Surakampontorn, W., "Current Tunable Quadrature Oscillator Using Only CCCDBAs and Grounded Components", in *Proc. The fourth International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI–CON 2007*, Thailand, 9–12 May, 2007, pp. 32–35.

[15] Tangsrirat, W., Pukkalanun, T., and Surakampontorn, W., "CDBA–Based Universal Biquad Filter and Quadrature Oscillator", *Active and Passive Electronic Components*, Vol. 2008, Doi: 10.1155/2008/247171, 2008.

[16] Pradsad, D., Bhaskar, D. R., and Singh, A. K., "Realisation of Single–Resistance–Controlled Sinusoidal Oscillator: A new application of the CDTA", *WSEAS Transactions on Electronics*, Vol. 5, Issue 6, pp. 257–259, 2008.

[17] Lahiri, A., "Novel voltage/current–mode quadrature oscillator using current differencing transconductance amplifier", *Analog Integrated Circuits and Signal Processing*, Vol. 61, pp. 199–203, 2009.

[18] Horng, J. W., "Current–Mode Third–Order Quadrature Oscillator Using CDTAs", *Active and Passive Electronic Components*, Vol. 2009, Doi: 10.1155/2009/789171, 2009.

[19] Siripruchyanun, M., Silapan, P., and Jaikla, W., "Realization of CMOS Current Controlled Current Conveyor Transconductance Amplifier (CCCCTA) and Its Applications", *Journal of Active and Passive Electronic Devices*, Vol. 4, pp. 35–53, 2009.

[20] Jaikla, W., Silapan, P., Chanapromma, C., and Siripruchyanun, M., "Practical Implementatin of CCTA Based on Commercial CCII and OTA", in *Proc. The International Symposium on Intelligent Signal Processing and Communication Systems*, Bangkok, Thailand, 8–11 Feb., 2009.

[21] Pisutthipong, N., Silapan, P., and Siripruchyanun, M., "CC–CCTA–Based Current–mode Quadrature Oscillator", in *Proc. The Seventh PSU Engineering Conference*, Prince of Songkla University, Hatyai, Songkla, Thailand, 21–22 May, 2009, pp. 302–305.

[22] Jaikla, W., Lahiri, A., Kwawsibsame, A., and Siripruchyanun, M., "High–input Impedance Voltage–mode Universal Filter Using CCCCTAs", in *Proc. The seventh International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI–CON 2010*, Chiang Mai, Thailand, 19–21 May, 2010, pp. 754–758.