International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 10, 2018 (Special Issue)

Extra-X Current Controlled Current Conveyor based resistorless current mode quadrature sinusoidal oscillator

A. Kumari[1], A. Ranjan[2*]

[1]*Dept. of ECE, National Institute of Technology Manipur, Imphal, India, abhilasha.119003@gmail.com*
[2]*Dept. of ECE, National Institute of Technology Manipur, Imphal, India, ashish.ism@rediffmail.com*
**Corresponding author*

Abstract
This paper brings a novel design for the realization of sinusoidal quadrature oscillator without any external resistor. The proposed circuit uses a recently developed advance building block (AAB) termed as Extra-X Current Controlled Current Conveyor (EX-CCCII) along with traditional capacitors that hold the features of the sinusoidal oscillator. Oscillator topology is free from the external resistor because of the intrinsic resistance present in EX-CCCII and grounded capacitors in it gives a flexibility for the monolithic integrated circuit (IC) design. The theoretical observation of the proposed design is well simulated with PSPICE. Also, the legitimacy of the proposed oscillator is proved by utilizing 0.25 micron CMOS technology.

***Keywords*: EX-CCCII, Quadrature Oscillator, Monte Carlo Analysis.**

1. Introduction

The wide protrusion of current-mode active elements has accomplished new dimensions in the field of analog signal processing. The high-performance activity of these current mode active circuit, especially in terms of their low power consumption, better dynamic range, low supply voltage, high slew rate, wide bandwidth, and much more are acknowledged in comparison to the well-known voltage mode operational amplifier (Op-Amp) [1]. After successful development of current conveyor by Sedra and Smith [2] have prompted a technology-specific approach for the design of analog active circuits. Then after, successive development in that field over last three decade have made growing advancement in analog blocks such as CCCII, OTRA, CDBA, CCCCTA, DVCCTA,and many more [3]. Among the above advance active blocks CCCII is an extension of CCII and provides an extra intrinsic resistance at port X as R_X [4]. This simple intrinsic resistance minimizes the passive component in a circuit. Some paper that specifies the speciality of CCCII in various analog processing circuits are enriched in literature as active filter [5], oscillator [6]and many more. More recently, EX-CCCII [7] may be considered as an extension of CCCII that gives an extra X port in comparison to simple CCCII port X1 and port X2. This development contributes extra facility in terms of extra intrinsic resistance in a circuit that exhibits electronically tunable property similar to CCCII.

In current scenario, oscillators are widely used in function generator for electronic communication systems, phase locked loops, in instrumentation [8] etc. In the early phase, a number of popular oscillator circuits based on the active operational amplifier (OP-Amp) with RC combinations have been developed but the operational activity is limited to low frequency operation and electronically tunability. From literature evaluation, it is analyzed that lots of oscillators have been developed using analog building blocks (ABB) such as DO-CCII [9], CDBA [10], CDTA [11] etc. which does not exhibit the electronically tunability property.

The objective of this paper is to realize a resistor free sinusoidal quadrature oscillator using a newly advance active block named EX-CCCII. Oscillator circuit uses two number of EX-CCCII and external grounded capacitors each. The proposed oscillator is free from external resistors and has electronically adjustability for cut-off frequency and condition of oscillation via the bias current present in EX-CCCII. Some important analysis such as non-ideality behavior, Monte Carlo simulation, and percentage Total Harmonic distortion (%THD) are well reported using PSPICE simulation.

2. Circuit description and its analysis

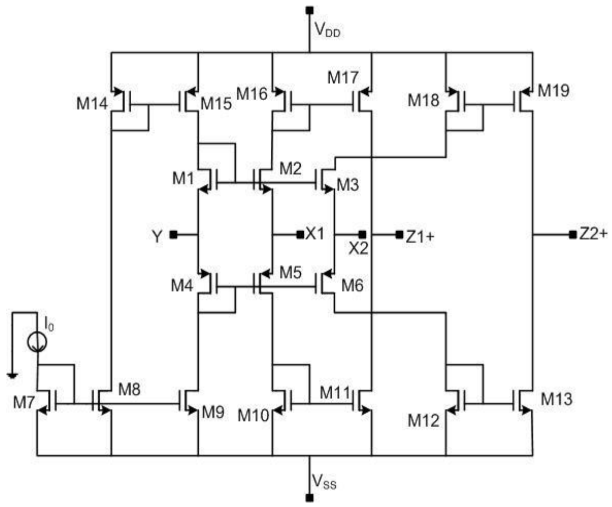
The CMOS implementation of a six terminal EX-CCCII [7] and its circuit symbol are illustrated in Figure 1 that follows the port equations in matrix form as:

$$\begin{bmatrix} I_Y \\ V_{X1} \\ V_{X2} \\ I_{Z1} \\ I_{Z2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & R_{X1} & 0 & 0 & 0 \\ 1 & 0 & R_{X2} & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_{X1} \\ I_{X2} \\ V_{Z1} \\ V_{Z2} \end{bmatrix} \tag{1}$$

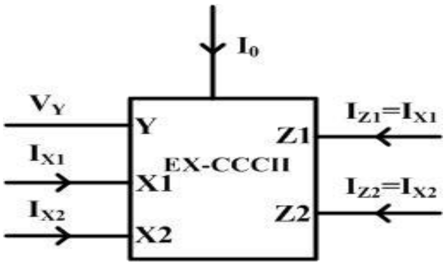
Where R_{X1} and R_{X2} be the intrinsic resistance developed at port X_1 and X_2 respectively and electronically tuned by the biasing current (I_o) of the EX-CCCII. The circuit design follows two intrinsic resistances in EX-CCCII that closely resembles each other similar to CCCII. The mathematical expression of R_{X1} and R_{X2} may be expressed as:

$$RX1 = RX2 = RX = \frac{1}{\sqrt{8\mu I_0 C_{OX} \frac{W}{L}}} \tag{2}$$

Here, the intrinsic resistance (R_X) depends on bias current.



(a)



(b)

Figure 1: Representation of EX-CCCII (a) CMOS implementation (b) Circuit symbol

The proposed quadrature oscillator circuit employing EX-CCCIIs and capacitors as shown in Fig. 2 and suitable for monolithic integration due to the grounded capacitors and absence of external resistors. It also exhibits quadrature current output at port Z3+ in EX-CCCII (1) and port Z2+ in EX-CCCII (2) respectively.

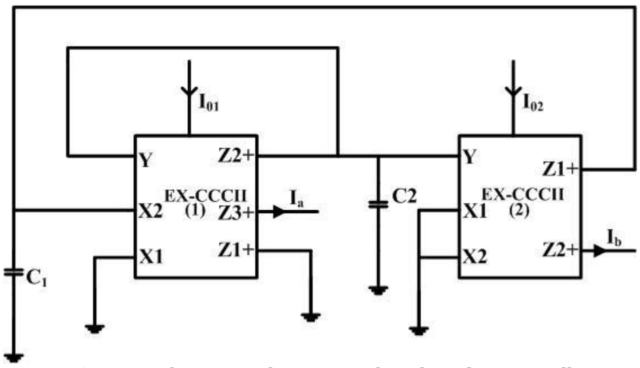


Figure 2: The proposed EX-CCCII based quadrature oscillator

The proposed quadrature sinusoidal oscillator circuit as shown in Fig. 2 yields the following characteristic equation as:

$$s^2C_1C_2R_{X12}R_{X21} + sR_{X12}(C_2 - C_1) + 1 = 0 \qquad (3)$$

The extra X- terminal intrinsic resistance of EX-CCCII can be viewed in the following manner:
$R_{X11} = R_{X21} = R_{X1}$ is the intrinsic resistance (for either of the two X terminals) for EX-CCCII (1) and can be tunable by bias current I_{01}.
$R_{X12} = R_{X22} = R_{X2}$ is the intrinsic resistance (for either of the two X terminals) for EX-CCCII (2) and can be tunable by bias current I_{02}.
Then, Equation (3) can be modified as

$$s^2 + s\frac{(C_2 - C_1)}{C_1C_2R_{X21}} + \frac{1}{C_1C_2R_{X12}R_{X21}} = 0 \qquad (4)$$

The modified characteristics equation for the quadrature oscillator given in equation (4) gives the following necessary conditions for oscillation:

$$FO: f_0 = \frac{1}{2\prod\sqrt{C_1C_2R_{X12}R_{X21}}} \qquad (5)$$

$$CO: C_1 > C_2 \text{ if } R_{X12}=R_{X21} \qquad (6)$$

The above expression for FO and CO enjoys the tunable property due to two separate bias currents of EX-CCCII. In addition, the two quadrature current outputs are procured as I_a and I_b and these current outputs are associated as $I_a = I_b\,(j\Omega_0C_2R_{x22})$. Finally, the variation of frequency of oscillation with respect to the frequency parameter (R_{X1}, R_{X2}, C_1, and C_2) is judged through sensitivity analysis and the obtained results are low as given in equation (7):

$$\left|S^{f0}_{C_1,C_2,R_{X12},R_{X21}}\right| = \frac{1}{2} \qquad (7)$$

3. Non-ideal analysis

The actual behavior of EX-CCCII may deviate from the ideal port relationship given in equation (1) and transformed in terms of non-ideal parameters such as current transfer gain (α) and voltage transfer gain (β) [7]. The non-ideal port characteristics of EX-CCCII can be expressed as:

$$V_{X1} = \beta_i V_Y + I_{X1}R_{X1}$$
$$V_{X2} = \beta_i V_Y + I_{X2}R_{X2}$$
$$I_Y = 0,\ I_{Z1} = \alpha_1 I_{X1}, I_{Z2} = \alpha_2 I_{X2} \qquad (8)$$

Where, (β_1, β_2) represent the voltage transfer gains for Y terminal with respect to X1 and X2 terminals respectively and (α_1, α_2) represent the current transfer gain as a ratio of current gain as I_{X1}/I_{Z1} and I_{X2}/I_{Z2} respectively. Also, the numerical value for α and β can be written in terms of (1-ε_i) and (1-ε_v) respectively where ε_i and ε_v be the current tracking error and voltage tracking error with values $|\varepsilon_i| << 1$and $|\varepsilon_v| << 1$ respectively. By considering the non-ideal port characteristics of EX-CCCII, the obtained characteristics equations for the proposed oscillator becomes

$$s^2C_1C_2R_{X12}R_{X21} + sR_{X12}(C_2 - \beta_2C_1) + \beta_1 = 0 \qquad (9)$$

Thus, the new oscillation parameter can be modified as per the nonideal parameter as :

$$CO: \beta_2C_1 > C_2 \qquad (10)$$

$$FO: \frac{1}{2\prod}\sqrt{\frac{\beta_1}{C_1C_2R_{X12}R_{X21}}} \qquad (11)$$

Where $R_{X12}=R_{X21}$

Equations (10) and (11) clearly show the significance of voltage transfer gain (β_1) as a non-ideal parameter that affects the oscillation behaviour. Finally, the sensitivity for frequency of oscillation incorporating the non-ideal parameter (β) gives

$$S^{f0}_{\beta} = \frac{1}{2},\ \left|S^{f0}_{C_1,C_2,R_{X12},R_{X21}}\right| = \frac{1}{2} \qquad (12)$$

It means that the active sensitivities with respect to voltage transfer gain are well within acceptable limit that is less than unity.

4. Simulation results

The current mode electronically tunable quadrature oscillator employing EX-CCCII is simulated using PSPICE with 0.25 micron TSMC technology. The symmetrical DC control supply voltages for EX-CCCII uses ±1.25V and the corresponding aspect ratio of MOS transistors used in it is given in Table 1.

Table 1: Aspect ratio for MOS transistors

Transistors	W (μm)	L (μm)
M1-M3	10	0.5
M4-M6	16	0.5
other NMOS	6	0.5
other PMOS	10	0.5

The proposed circuit is designed with the following component specification: C_1 = 220 pF, C_2 = 190 pF, $R_{X1} = R_{X2} = R_X$ = 0.819 kΩ and I_{01} = 85μA, I_{02}= 70μA. The simulation results for the frequency of oscillation of the proposed quadrature oscillator attains a nearby value of the theoretical frequency of oscillation as 1MHz. Moreover, the Lissajous pattern is shown in Fig. 3 that confirms output current waveforms with a phase difference of 90°. Figure 4 shows the time-domain perspective of the acquired quadrature current waveforms and the corresponding frequency domain representation of current outputs are shown in Fig. 5. %THD variation with bias current is shown in Fig. 6 to judge the quality of output. Figure 7 shows the Monte Carlo simulation of proposed oscillator circuit by taking results of 15 runs with 5% tolerance The scattering of samples over the different amplitude of output currents (I_a and I_b) are clearly examined using histogram. Apart from this, the total power dissipation of the proposed EX-CCCII based quadrature oscillator in simulations is approximately found as 6.03 mW.

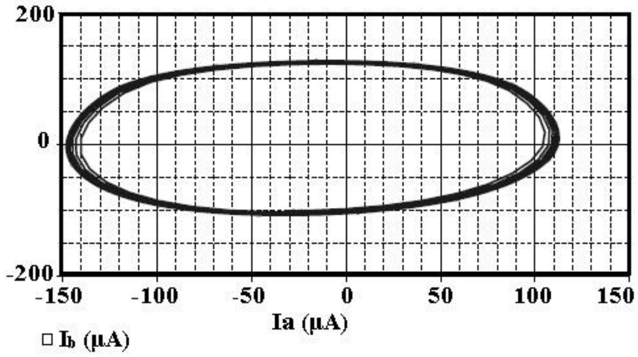


Figure 3: Lissajous curve for proposed oscillator

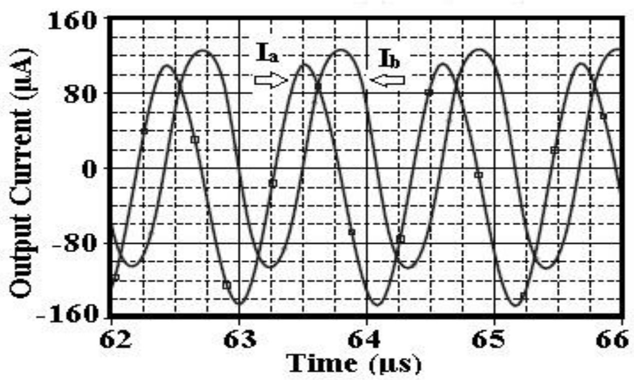
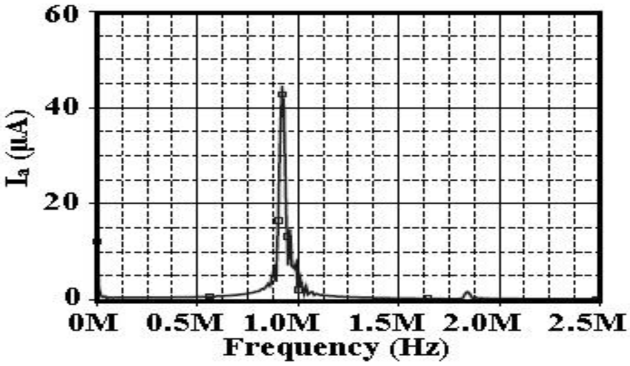
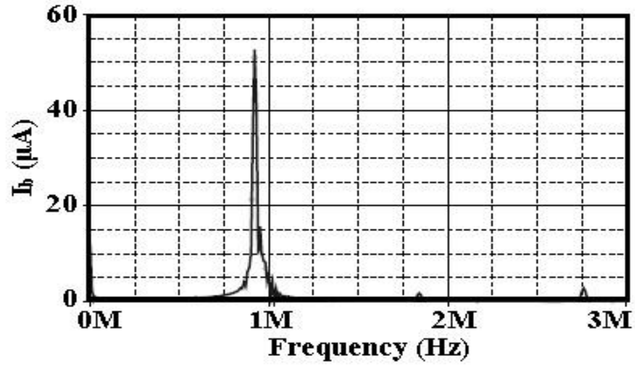


Figure 4: Quadrature current output waveform



(a)



(b)

Figure 5: Frequency spectrum of oscillator output (a) I_a (b) I_b

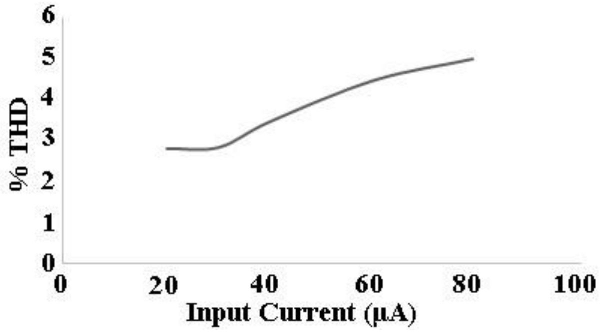
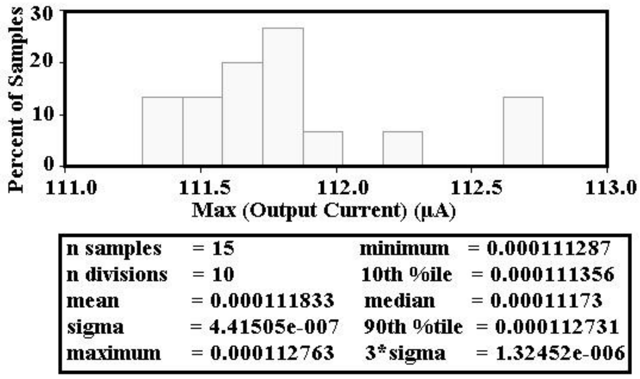
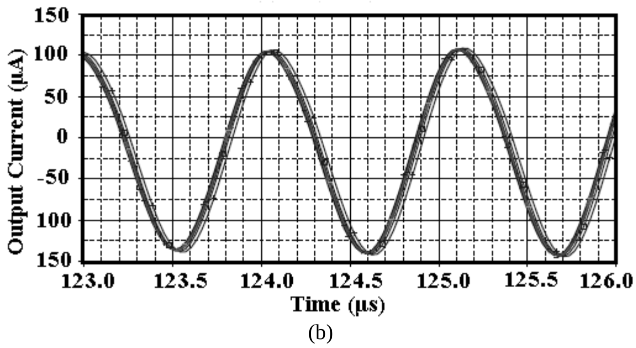


Figure 6: % THD variation with bias current



(a)



(b)

Figure 7: Monte Carlo simulation output (a) histogram (b) waveform

Finally, a comparative study of existing oscillator with the proposed one is illustrated in table II in terms of various parameters such as number of passive and active components, mode of operation, frequency of operation and %THD.

Table 2: Comparison table of proposed oscillator with existing one

[Ref] Fig. No.	Active elements	Number of active and passive components				Operating mode / Tunability	Independent control of OC and OF	Operating frequency	THD (%)
		A	R	C	GC				
[13] Fig. 2 (b)	CDBA	2	5	3	2	VM / No	Yes	1 MHz	2.1
[11] Fig. 4	CDTA	2	4	2	0	CM / No	No	779kHz	7
[9] Fig. 3 Fig. 6	DO-CCII DO-DVCC	2 2	2 2	2 2	All All	VM / Yes VM / Yes	No No	1284kHz 1234kHz	6.06, 1.98 4.96, 2
[12] Fig. 8	DVCC	3	2	2	All	VM / No	No	569.4kHz	<5
[10] Fig. 2	CDBA	2	3	3	2	VM / No	Yes	15.37kHz	1.58
[14] Fig. 4	CDBA	2	4	2	2	VM / No	Yes	15.52kHz	2.95
[15] Fig. 2	CDBA	2	4	2	2	VM / No	Yes	15.10kHz	0.94
[Proposed] Fig. 2	EX-CCCII	2	0	2	All	CM / Yes	Yes	1MHz	2.26, 3.27

* A = Active element, R= Resistor, C= Capacitor, GC= Grounded Capacitor, VM= Voltage Mode, CM= Current Mode OC= Oscillation Condition, OF= Oscillation Frequency, THD= Total Harmonic Distortion

5. Conclusion

Electronically tunable current-mode quadrature sinusoidal oscillator using EX-CCCIIs and grounded capacitors without external passive resistor is introduced in this paper. The oscillator produces two sinusoidal signals with phase 90° phase difference. The designed oscillator circuit produces the following features:

i) Sinusoidal quadrature current outputs.

ii) Only grounded capacitors for oscillator realization.

iii) Uses low supply voltage and less power dissipation.

iv) Oscillation parameters are electronically adjustable.

v) Acquires low values of sensitivities.

The viability of circuit is verified through PSPICE simulations that satisfies the theoretical observations

References

[1] C. Toumazou, F. J. Lidgey, and D. G. Haigh, "*Analogue IC Design: The Current-Mode Approach*," Peter Peregrinus Ltd, London, 1990.

[2] A. Sedra and K. Smith, "A Second-Generation Current Conveyor and its applications," *IEEE Transcations Circuit Theory*, vol. 17, no. 1, (1970), pp. 132–134.

[3] D. Biolek, R.Senani, V. Biolkova, Z. Kolka, "Active Elements for analog signal processing:classification, review and new proposals, "*Radioengineering,* vol. 17, no.4, December 2017.

[4] N. Tripathi, N. Saxena, and S. Soni, "Design of an Amplifier through Second Generation Current Conveyor," *Int. J. of Eng. Trends Technology*, vol. 4, no. May 2013, (2014), pp. 1325–1330.

[5] A. Ranjan and S. K. Paul, "Voltage mode universal biquad using CCCII," *Active and Passive Electron. Components*, vol. 2011, 2011.

[6] M. Kumngern and S. Junnapiya, "A sinusoidal oscillator using translinear current conveyors," *IEEE Asia-Pacific Conference Circuits Syst. Proceedings, APCCAS*, no. 2, (2010), pp. 740–743.

[7] S. Maheshwari and D. Agrawal, "Cascadable and Tunable Analog Building Blocks Using EX-CCCII," *J. Circuits, Syst. and Comput.*, vol. 26, no. 6, (2017), p. 1750093.

[8] B. Wilson, "Recent developments in current conveyors and current-mode circuits," *IEE Proc. Circuits, Devices and Systems*, vol. 137, no. 2, (1990), pp. 63–77.

[9] E. Yuce, "DO-CCII/DO-DVCC Based Electronically Fine Tunable Quadrature Oscillators," *J. Circuits, Syst. Comput.*, vol. 26, no. 2, (2017), p. 1750025.

[10] B. W. Tangsrirat and S. Pisitchalermpong, "CDBA-based Quadrature Sinusoidal Oscillator," Frequenz (61), *Journal of RF-Engineering and Telecommunications vol. 61,* (2007), pp. 3–4.

[11] D. Biolek and A. K, U, "Current mode quadrature oscillator using current differencing transconductance amplifiers," *IEE Proceedings- Circuits, Devices and Sys.,* vol. 152, no. 3, (2005), pp. 189–209.

[12] S. Minaei and E. Yuce, "Novel voltage-mode all-pass filter based on using DVCCs," *Circuits, Sys and Sig Processing*, vol. 29, no. 3, (2010), pp. 391–402.

[13] S. D. M. K. R. Nandi P. Venkateswaran, "CDBA-Based Electronically Tunable Filters and Sinusoid Quadrature Oscillator," *Journal of Telecommunication.*, vol. 4, no. 1, (2010), pp. 35–41.

[14] W. Tangsrirat, T. Pukkalanun, and W. Surakampontorn, "CDBA-based universal biquad filter and quadrature oscillator," *Active and Passive Electron. Components*, vol. 2008, 2008.

[15] W. Tangsrirat, D. Prasertsom, T. Piyatat, and W. Surakampontorn, "Single-resistance-controlled quadrature oscillator using current differencing buffered amplifiers," *Int. J. Electron.*, vol. 95, no. 11, (2008), pp. 1119–1126.