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Novel Active-C Voltage-Mode Quadrature Oscillator Realization Employing CCCIIs

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Abstract: A current controlled sinusoidal voltage-mode quadrature oscillator circuit is presented here which has employed three second-generation current-controlled-conveyors (CCCIIs) and two grounded capacitors (GCs). The condition of oscillation (CO) and frequency of oscillation (FO) of the proposed circuit are uncoupled and can be electronically controllable through an external dc bias current of CCCII. Sensitivities of active and passive elements are very low and the voltage outputs which are in 90° phase difference have high output impedances. Moreover, if apply the input at terminal Y of CCCII-03 it behaves as biquad filter which produce the band-pass (BP) and low-pass (LP) responses instantaneously and it have high input impedance which is very useful in cascading. The PSPICE simulation results verify the workability of the oscillator and filter circuit.

Keywords: Electronically tunable, sinusoidal quadrature oscillator (SQO), second-generation current-controlled-conveyor (CCCII).

1. Introduction

Oscillators are mostly used to generate a different form of analog signals such as sinusoidal, triangular, square, etc. on various technical grounds, whereas, sinusoidal oscillator plays a very important role in analog integrated circuits. Thus the sinusoidal oscillator circuits have been proposed by researchers under different names according to their characteristics like output mode: voltage-mode or current-mode or both (or hybrid) oscillator; output phase: quadrature oscillator (QC), multiphase oscillator; tunable oscillators: single-resistance controlled-oscillators (SRCO), single-capacitor controlled-oscillators (SCCO); electronic tunable oscillator: voltage control oscillators (VCO), current-control oscillators (CCO); dependence of FO on CO: coupled, uncoupled and fully uncoupled. For the last few decades, sinusoidal quadrature oscillators (SQO) acquired further attention of researchers as these are very beneficial in communication and instrumentation systems as the circuit provides two sinusoids with 90^0 phase difference. The realization of SQOs was more focused on less number of passive components moreover with resistor-less and/or grounded capacitors which are more suitable for IC implementation.

In literature [1-21] sinusoidal quadrature oscillators are proposed using either voltage-mode or current-mode active-building-blocks (ABBs), such as second-generation current-conveyor (CCII) [6-9, 14, 17, 18, 20], current-feedback-operational-amplifier (CFOA) [10, 11, 16], current-controlled-voltage-conveyor (CCVC) [12], differential-voltage-current-conveyor (DVCC) [13], current-controlled current-differencing-buffered-amplifier (CCCCDBA) [19], second-generation current-controlled-conveyor (CCCII) [15], differential-difference-current-conveyor (DDCC) [21]. The use of

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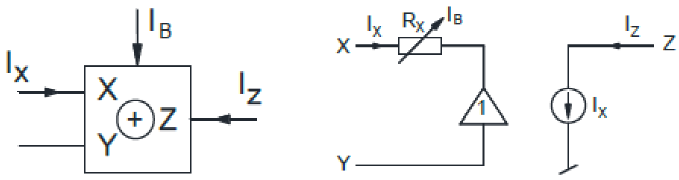
the current-mode (CM) approach over voltage-mode (VM) in analog signal processing/ generation has been already proven through different literature as the CM approach is better in terms of extensive signal bandwidth, low power consumption, greater linearity, higher slew rates, etc. The second-generation current-controlled-conveyor (CCCII) which was proposed by Fabre, Saaid, and Boucheron in 1995 [1] is a versatile CM building block that permits current conveyor applications to be prolonged to the area of electronic tunability. Electronic tunability of the CCCII is credited to the dependence of the parasitic resistance at port X on the bias current of the current conveyor. As mentioned above CM approach is beneficial over the VM approach, some researchers tried with CM ABBs quadrature oscillator [12, 15] but with a higher power supply which provides poor efficiency of oscillators due to heat dissipation. To design a sinusoidal quadrature oscillator our approach is to provide a less complicated IC design so that the size will be smaller which can be possible by eliminating resistors, with CM ABBs as it is beneficial over VM, electronically tunable, independent control of CO and FO and good efficiency by providing lower power supply.

In this work, the aim was to generate a sinusoidal quadrature oscillator with only grounded capacitors. Here, the circuit employs three CCCIIs and two GCs, and CO and FO can be controlled by the dc bias current of CCCIIs. Given circuit can also work as a biquad filter if break the feedback loop at point ‘P’ as shown in Fig. 2, and applied input signal at the Y terminal of CCCII-03, then the proposed circuit can give a response as BP and LP, simultaneously. PSPICE simulation response is given here to prove the theory.

2. Proposed circuit description

The second-generation current-controlled-conveyor (CCCII) is a three-port (X, Y, and Z) tunable circuit building block. The symbolic representation and corresponding circuit of the CCCII are shown in Fig. 1(a) and (b).



(a) (b)

$$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & R_x & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix}$$

(c)

Fig. 1 - CCCII (a) Symbolic notation (b) corresponding circuit and (c) port characteristic matrix of CCCII

The matrix equation is shown in Fig. 1(c) represents the port relationships of the CCCII (i.e. in ideal CCCII, the current through the y-terminal is equal to zero which means the input impedance at the y-terminal is high, the voltage at the x-terminal is equal to the y-terminal voltage, and the current through the z-terminal is same as the x-terminal current and the plus sign shows that the current direction of the x-terminal and the z-terminal is same either inside the block or outside the block such conveyor known as positive CCCII (CCCII+), whereas negative sign indicates that the direction of the current is opposite and such type of conveyors known as negative CCCII (CCCII-)). The x-terminal has intrinsic (or parasitic) resistance (i.e. R_x) which is controlled by the dc bias current I_B ($R_X = V_T / 2I_B$), where $V_T \cong 26mV$ at room temperature.

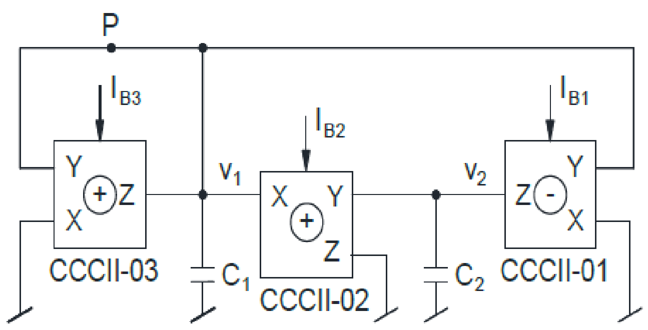


Fig. 2 - Proposed electronically tunable sinusoidal quadrature oscillator circuit

The proposed electronically-tunable sinusoidal quadrature oscillator circuit is shown in Fig. 2. Repetitive analysis of the circuit by using the port characteristic matrix of CCCII shown in Fig. 1(c), characteristics equation can be written as:

$$s^2C_1C_2R_{x1}R_{x2}R_{x3} + sC_2(R_{x1}R_{x3} - R_{x1}R_{x2}) + R_{x3} = 0 \qquad (1)$$

The condition of oscillation (CO) and frequency of oscillation (FO) of the circuit shown in Fig. 2 can be obtained from the Eq. (1) written as:

$$CO: R_{x2} = R_{x3} \qquad (2)$$

$$FO: \omega_O = \sqrt{\frac{1}{C_1C_2R_{x1}R_{x2}}} \qquad (3)$$

Thus, from Eq. (2) and Eq. (3), it is evident that the CO can be satisfied by adjusting bias current I_{B2} while keeping the value of R_{X3} fixed through $I_{B3,}$ and the FO can be independently varied by bias current I_{B1}. From the Fig. 2, the relationship between output voltage v_2 and v_1 can be given as:

$$\frac{v_2}{v_1} = -\frac{1}{sC_2R_{x1}} \qquad (4)$$

It is clear from Eq. (4) that the voltage outputs v_1 and v_2 have a phase difference of 90° from each other. Thus, the proposed oscillator can be used as a quadrature oscillator.

Using the definition of the frequency stability factor (S_F) as:

$$S_F = \frac{d\phi}{du}\Big| u = 1 \qquad (5)$$

Where u=ω/ω$_o$ and $\phi(u)$ represents the phase function of the open-loop transfer function, $C_1 = C_2 = C$, $R_{x2} = R_{x3} = R$, and $R_{x1} = R/n$, Thus, the frequency stability factor of the oscillator circuit is found to be S_F=2√n which shows excellent frequency stability.

3. Non-ideality and Sensitivity analysis

In reality, the x-terminal voltage is not equal to the y-terminal voltage ($V_x \neq V_y$) and the z-terminal current is not equal to the x-terminal current ($I_z \neq I_x$) it has voltage and current tracking error. Now, considering the current and voltage tracking errors into explanation, the current-voltage terminal characteristic of the non-ideal CCCII given as

$$V_x = \beta V_y + I_xR_x\ ,\ \ I_z = \alpha I_x \qquad (6)$$

Where α and β are the non-ideal current and voltage gains, which can be deviated from one. Now considering current and voltage tracking errors taken into an explanation for the non-ideality analysis are carried out for circuit shown in Fig. 2 and Eq. 2 and 3 can be re-written as

$$CO: \alpha_3\beta_3R_{x2} = R_{x3} \qquad (7)$$

$$FO: \omega_O = \sqrt{\frac{\alpha_1\beta_1}{C_1C_2R_{x1}R_{x2}}} \qquad (8)$$

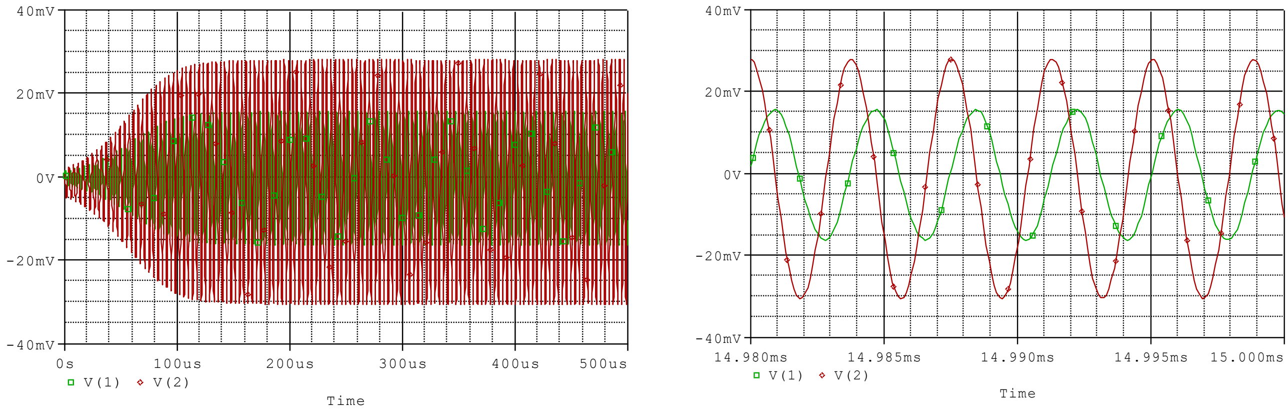
The sensitivities of active and passive elements w.r.t radial frequency (ω_0) of the proposed circuit are obtained as follows and it shows that all of them have low value.

$$S_{R_{x2}}^{\omega_o} = S_{R_{x1}}^{\omega_o} = S_{C_1}^{\omega_o} = S_{C_2}^{\omega_o} = -S_{\alpha_1}^{\omega_o} = -S_{\beta_1}^{\omega_o} = -1/2 \qquad (9)$$

4. Simulation Results

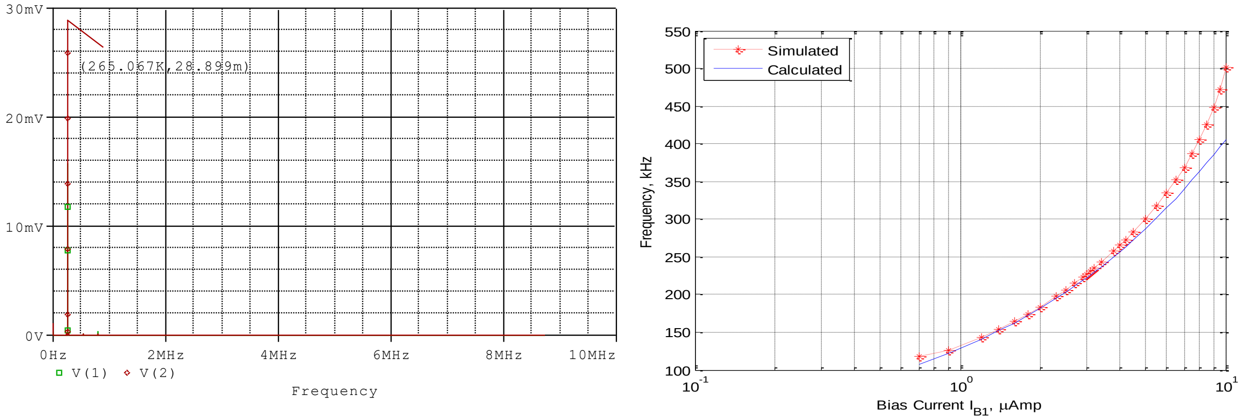
The electronically tunable sinusoidal quadrature oscillator circuit illustrated in Fig. 2 was simulated in PSPICE. The structure of CCCII is obtained from Ref. [1]. The PR100N (PNP) and NR100N (NPN) bipolar transistors were used in the CCCII structure for which the model parameters are obtained from Ref. [3].

In Fig. 2, CCCIIs were biased with ±2.5V dc power supplies and the values of capacitors C_1 and C_2 were chosen as 100nF. The PSPICE results of Fig. 3(a) and Fig. 3(b) show the transient and steady-state output voltage responses of the quadrature oscillator circuit respectively. Fig. 4(a) shows the frequency spectrum and at the frequency 265.067kHz, the THD is 0.64% only which is reflected to the good spectrum purity of the generated signal. The variation of frequency of oscillation w.r.t. change in dc bias current I_{B3} is shown in Fig. 4(b) and Fig. 4(c) shows the Lissajous pattern of the waveform.

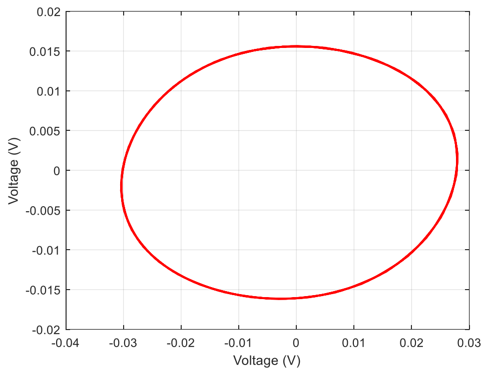


(a) **(b)**

Fig. 3 - (a) Transient waveform and (b) steady-state response of oscillator circuit in Fig. 2



(a) **(b)**



(c)

Fig. 4 - (a) Spectrum of the output waveform, (b) variation of FO w.r.t. I_{B3}, (c) lissajous pattern of waveform

It is worthwhile to mention that in Fig. 2, if the feedback path is split at the point 'P', and the Y-terminal of the CCCII-03 is considered as the input terminal and the outputs are taken from V_1 and V_2 terminals, the two transfer functions are obtained after doing this modification in the proposed circuit are given as:

$$\frac{V_1}{V_{in}} = \frac{s/C_1R_{x3}}{s^2 + s(\frac{1}{C_1R_{x3}}) + \frac{1}{C_1C_2R_{x1}R_{x3}}} \quad (10)$$

$$\frac{V_2}{V_{in}} = \frac{1/C_1C_2R_{x1}R_{x3}}{s^2 + s(\frac{1}{C_1R_{x3}}) + \frac{1}{C_1C_2R_{x1}R_{x3}}} \quad (11)$$

Eq. (10) and (11) show that the proposed circuit can be configured to realize low-pass and band-pass filters respectively. Fig. 5 shows the PSPICE simulation results after the modification of the circuit in Fig. 2 which is the frequency response of the low-pass and band-pass filter.

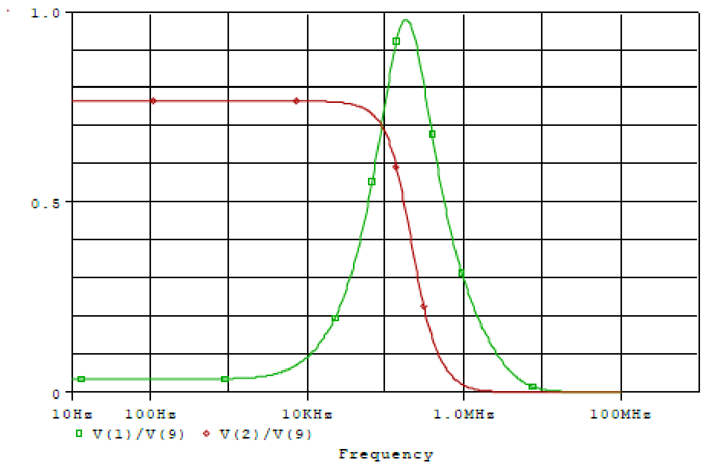


Fig. 5 - Frequency response of the low-pass and band-pass filter realized from the circuit in Fig. 2 after modification

5. Comparison with previous works

A comparison of the proposed circuit is done by different published circuits which employ three active building blocks (ABB) and is shown in Table 2. As shown in Table 2 numbers of resistors are connected as floating [6, 9, 10, 13, 16, 17, 20, 21] and/or grounded [6-9, 11, 13, 14, 16-18, 20, 21] connection which is complicated for IC designing as it takes larger space to implement. Except [12, 15, 19] which are electronically tunable others are not tunable and [10, 11, 13-16, 21] CO and FO are not independently controlled.

After comparison with the literature given in [6-21], the proposed circuit is more beneficial in terms of IC implementation as: (i) it does not connect any kind of resistors, (ii) has grounded capacitors, (iii) electronically tunable via DC bias current of CCCII, (iv) low voltage required as it employed CM building blocks.

Table 2- Comparison with previous work

Ref. No.	ABB Name	Fig. No.	Number of resistors		Number of capacitors		Supply voltage	Indep-endent control	Tun-ability	Quadrature Oscillator
			G	F	G	F				
6	CCII±	7	2	1	2	-	±4V	Y	N	Y
7	CCII+	1(a)	3	-	3	-	±2.5V	Y	N	Y
8	CCII±	2	1	-	2	-	±2.5V	Y	N	N
9	CCII+	5	1	1	2	-	±1.5V	Y	N	Y
10	CFOA	4	-	4	2	-	±6V	N	N	Y
11	CFOA	8(a)	4	-	2	-	±9V	N	N	N
12	CCVC	3	-	-	2	-	±3V	Y	Y	Y
13	DVCC±	10	1	2	2	-	±2V	N	N	Y
14	CCII±	3	3	-	3	-	±12V	N	N	Y
15	CCCII+	2	-	-	2	-	±5V	N	Y	Y
16	CFOA	2	1	3	2	-	±10V	N	N	Y
17	CCII+	3,5	2	1	2	-	±12V	Y	N	N
18	CCII+	2(a)	4	-	2	-	±2.5V	Y	N	Y
19	CCCDBA	3	-	-	2	-	±2V	Y	Y	Y
20	CCII+	6	2	1	2	-	±1V	Y	N	Y
21	DDCC	2	2	2	2	-	±6V	N	N	Y
Proposed	CCCII±	2	-	-	2	-	±2.5V	Y	Y	Y

6. Concluding Remarks

A novel Active-C voltage-mode sinusoidal quadrature oscillator was proposed here which employed three CCCIIs and two grounded capacitors (GCs) with low active and passive sensitivities and the simulated value of %THD is quite low. A comparison between the proposed circuit and the different published circuits which employs three active building blocks (ABBs) from the literature [6-21] is shown in Table 2. The proposed circuit can be used in a wide range of applications in analog integrated circuits where electronic tunability is needed, as well as in QAM and QPSK transmitter and receiver circuits, etc. This circuit has excellent frequency stability and workability; the response of the proposed circuit was validated by PSPICE simulations.

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References

[1] Fabre, A., Saaid, O., Wiest, F., & Boucheron, C. (1995). Current controlled bandpass filter based on translinear conveyors. Electronics Letters, 31, 1727-1728.
[2] Sedra, A., & Smith, K. C. (1970). A second generation current conveyor and its applications. IEEE Trans. Circuit Theory, 17, 132-134.
[3] Frey, D. R. (1993). Log-domain filtering: An approach to current-mode filtering. IEE Proceedings G Circuits, Devices and Systems, 140, 406-416.
[4] Senani, R., Bhaskar, D. R., & Singh, A. K. (2015). Current conveyors: variants, applications and hardware implementations (Springer International Publishing, Switzerland).
[5] Senani, R., Bhaskar, D. R., Singh, V. K., & Sharma R. K. (2016). Sinusoidal oscillators and waveform generators using modern electronic circuit building blocks (Springer International Publishing, Switzerland).
[6] Sotner, R., Hrubos, Z., Sevcik, B., Slezak, J., Petrzela, J., & Dostal, T. (2011). An Example of Easy Synthesis of Active Filter and Oscillator using Signal Flow graph Modification and Controllable Current Conveyors. Journal of Electrical Engineering, 62, 5, 258–266.
[7] Minhaj, N. (2009). CCII-based single-element controlled quadrature oscillators employing grounded passive Components. International Journal of Recent Trends in Engineering, 1, 3, 294-296.

[8] Turkoz, S., & Minaei, S. (2000). A New Current-Controlled Sinusoidal Oscillator Using the Current Controlled Conveyor. Frequenz, 54, 5-6.
[9] Ben Salem, S., Ben Saied, A., & Sellami Masmoudi, D. (2016). High-performance Current-Controlled Quadrature Oscillator Using an optimized CCII. Journal of Microelectronics, Electronic Components and Materials, 46, 2, 91-99.
[10] Fu Wang, S., Pin Chen, H., Ku, Y., & Yu Chen, P. (2019). A CFOA-Based Voltage-Mode Multifunction Biquadratic Filter and a Quadrature Oscillator Using the CFOA-Based Biquadratic Filter. Appl. Sci., 9, 2304, 1-19.
[11] Soliman, A. (2000). Current Feedback Operational Amplifier Based Oscillators. Analog Integrated Circuits and Signal Processing, 23, 45-55.
[12] Piyatat, T., Tangsrirat, W., & Surakampontorn, W. (2005). Electronically Tunable Quadrature Oscillator Using Current-controlled Voltage Conveyors. IEEE proceedings, 133-136.
[13] Maheshwari, S. (2010). High Input Impedance Voltage-Mode Universal Filter and Quadrature Oscillator. Journal of Circuits, Systems, and Computers, 19, 7, 1597-1607.
[14] Wei Horng, J. (2005). Current conveyors based allpass filters and quadrature oscillators employing grounded capacitors and resistors. Computers and Electrical Engineering, 31, 81–92.
[15] Siripruchyanun, M., Koseeyaporn, P., Koseeyaporn, J., & Wardkein, P. (2004). Fully Current Controllable AM/FM Modulator and Quadrature Sinusoidal Oscillator based on CCCIIs. ISCAS, 549-552.
[16] Maheshwari, S. (2020). Generalised approach for active-RC quadrature oscillator circuit with grounded Capacitors. IET Circuits Devices Syst., 14, 6, 758-761.
[17] Mart´ınez, P., Sabadell, J., Aldea, C., & Celma, S. (1999). Variable Frequency Sinusoidal Oscillators based on CCII+. IEEE Transactions on circuits and Systems—I: Fundamental theory and Applications, 46, 11, 1386-1390.
[18] Minhaj, N. (2007). Current conveyor-based voltage-mode two-phase and four-phase quadrature oscillators. International Journal of Electronics, 94, 7, 663–669.
[19] Jaikla, W., & Siripruchyanun, M. (2006). A Versatile Quadrature Oscillator and Universal Biquad Filter Using CCCDBAs. ECTI International Conference, 501-504.
[20] Yucela, F., & Yuce, E. (2020). Supplementary CCII based second-order universal filter and quadrature Oscillators. Int. J. Electron. Commun. (AEÜ), 118, 153138.
[21] Unuk, T., Abacr, A., & Yüce, E. (2020). Quadrature Oscillator Realization Based on DDCC+. 28th Signal Processing and Communications Applications Conference (SIU), 1-4.