A New Sinusoidal Quadrature Oscillator for Electronics Engineering

Kushaagra Maheshwari
(Corresponding author: Kushaagra Maheshwari)

G.L. Bajaj Institute of Technology & Management
Plot No.2, Knowledge Park III, Greater Noida, Uttar Pradesh 201306, India
(Email: kushaagramaheshwari02@gmail.com)
(Received Aug. 25, 2018; revised and accepted Nov. 3, 2018)

Abstract

This paper presents new sinusoidal oscillator employing operational amplifiers and six passive components with the advantage of easy tuning of oscillator frequency. Separate resistive elements control the frequency and the condition of oscillation. The easy control over the frequency and condition of oscillation through separate resistors makes the circuit practically feasible. The new proposed circuit provides three outputs with progressive quadrature relationship. Simulation results are presented using TINA software. The circuit is further experimentally tested for workablity by using different set of components. The new proposed circuit is verified using low cost general purpose operational amplifier.

Keywords: Circuit Design; Operational Amplifier; Quadrature Oscillators

1 Introduction

Voltage controlled voltage source operational amplifiers, also referred to as voltage operational amplifiers are the most versatile analog building block for voltage mode circuits and systems. The voltage operational amplifiers (simply operational amplifiers) find applications in a wide range of linear and non linear applications. Sinusoidal oscillators form the basic block of a large number of electronic instrumentation and communication systems. The oscillators providing more than one sinusoidal signals are known as quadrature and multi phase oscillators, the former providing a 90^o phase separated signals, while the latter generates multiple outputs for designed phase shifts separation. The quadrature and multiphase sinusoidal oscillators find wide ranging applications as standard test signals, in measurement and instrument systems and in communication systems. For instance, a quadrature oscillator providing 90^o separated signals is an integral part of a large number of communication circuits. Similarly two phase inverted sine waves may be used for phase shift keying, Another example of four quadrature signals application could be in quadrature phase shift keying, Some of these applications and many other such applications have been the motivating factor for a large number of circuits being proposed in open literature [4, 8, 10, 11].

The available oscillator circuits employing operational amplifiers (opamps) are based on the use of two or three opamps. The circuits provide quadrature signals while employing different passive component count [4, 8, 10]. The proposed circuit in this work is based on the use of four opamps while providing three signals. However, the new proposed circuit benefit from an easy tuning of oscillation frequency, which is fully independent from the oscillation condition. The proposed circuit employs six passive components: two capacitors and four resistors. Whereas the two resistors control the oscillation frequency, the other two resistors control the oscillation condition. The subsequent sections deliberates on the proposed circuit description, comparison with existing circuits, simulations results, experimental results and concluding discussion.

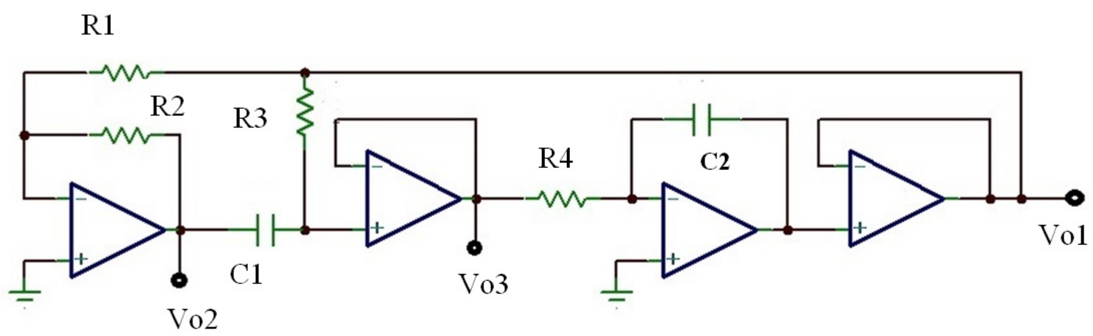

Figure 1: Proposed opamp based quadrature oscillator circuit

2 The Proposed Circuit

The proposed circuit which realizes an oscillator with three 90^o progressive phase shift is shown in Figure 1. The circuit employs four opamps and six passive components. It may be noted that two of the opamps are used as voltage followers, one opamp is configured as an inverter and one opamp is configured as integrator. The circuit is characterized by the following characteristic equation.

$$s^2 + s(\frac{1}{R_3C_1} - \frac{R_2}{R_1R_4C_2}) + \frac{1}{R_3R_4C_1C_2} = 0. \tag{1}$$

Equation (1) yields the following frequency of oscillation (FO) and condition of oscillation (CO) respectively.

$$FO: \qquad \omega_0 = \frac{1}{\sqrt{R_3R_4C_1C_2}} \tag{2}$$

$$CO: \qquad R_4C_2 \leq \frac{R_2R_3C_1}{R_1} \tag{3}$$

As a simple design, involving equal resistors (R_3 and R_4) and equal capacitors simplifies the CO expression as below.

$$CO: R_2 \geq R_1. \tag{4}$$

From the above equations it is evident that the frequency of oscillation can be independently controlled without affecting the condition of oscillation. For example, the CO can be adjusted through R_1 and

R_2 whereas the FO can be independently adjusted through R_3 and R_4. This feature makes the circuit specially attractive, because it allows easy and independent control over the frequency and condition of oscillation. The three outputs of oscillator V_{o1}, V_{o2} and V_{o3} are related as below.

$$v_{o3} = -sR_4C_2v_{o1} \quad (5)$$
$$v_{o2} = -v_{o1}. \quad (6)$$

Equations (5) and (6) imply that v_{o1} leads v_{o3} by 90^o and v_{o2} is phase inverted with respect to v_{o1}. Therefore, the proposed circuit generates three outputs with a progressive 90^o phase shift. Next, the sensitivity of FO to various resistive components is analyzed and found as below.

$$S^{FO}_{R_3,R_4} = -1 \quad (7)$$
$$S^{FO}_{R_1,R_2} = 0. \quad (8)$$

Equations (7) and (8) show that the sensitivity of FO to R_1 and R_2 is zero, the property that makes the circuit easily tune-able through R_3 and R_4. The new proposed circuit is now compared with the existing quadrature oscillators based on operational amplifiers. The Table 1 shows the comparative study, which clearly suggests that the proposed circuit benefit from easy and completely independent control over the oscillator frequency and condition of oscillation, while providing three outputs. It is further seen that the new circuit requires fewer passive components for the available features. The new proposed circuit based on opamps is low cost solution as compared to higher frequency oscillators based on modern active elements [1–3, 5–7, 9].

Table 1: Comparative study

Ref.	Number of opamps	Passive element count	No. of 90^o shifted outputs	FO and CO control complete independence
[10]	2	7	2	No
[4]	3	8	2	No
[8] Fig. 8	2	6	2	No
[8] Fig. 9	4	10	2	No
Work	4	6	3	Yes

3 Simulation and Experimental Studies

The new proposed quadrature oscillator circuit with three outputs is next simulated using UA741 model in the TINA software. The circuit is designed using capacitor values as 0.01 μF. The resistors controlling the FO ($R_3 = R_4$) are varied to obtain different frequency of oscillation, while the resistors controlling CO are chosen as 2.2 kΩ, with R_2 made variable for sustained oscillation in the vicinity of the mentioned value. The results for varying frequency of oscillation are shown in Figure 2, where the FO affecting resistors are varied. It is observed that the FO can be independently tuned without involving CO affecting resistors. Moreover, the simulated results are also in good agreement with the theoretical values calculated using FO expression. Another result in form of three outputs are further shown in Figure 3, where the FO is found as 10 KHz, and the three outputs are evidently spaced 90^o apart in phase.

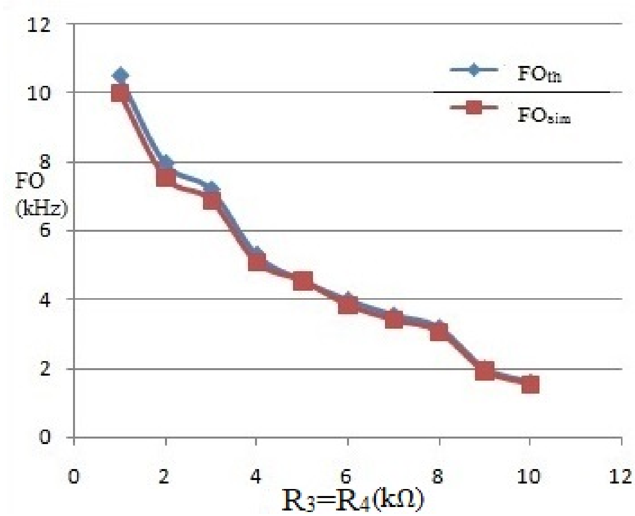

Figure 2: Frequency of oscillation (FO) tuning

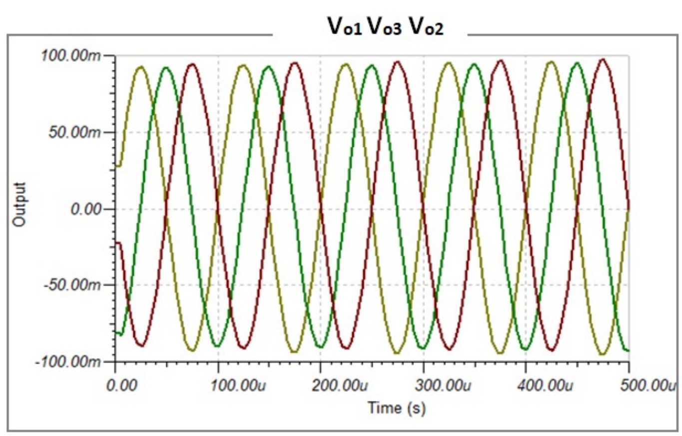

Figure 3: Three simulated outputs (volts) of proposed circuit at 10 kHz

To further verify the practicality of the proposed oscillator, commercially available low cost general purpose opamp IC 741 are used to breadboard the new proposed circuit. The values of capacitor are again chosen as 0.01 μF. The FO controlling resistors ($R_3 = R_4$) are varied, while CO controlling resistors are realized using a 10 kΩ POT. The first set of results for 4.7 kΩ resistive elements is shown in Figure 4. It may be noted that the measured value of resistors was 4.62 kΩ, thus resulting the theoretical value of FO as 3.4 kHz. As seen from Figure 4, the experimental FO is 3.34 kHz which is in good agreement with theoretical value. Furthermore the quadrature relationship of the two shown outputs is also evident. Next set of experimental results for 2.2 kΩ resistors are shown in Figure 5. The measured value of resistors is found as 2.15 kΩ, thus resulting in theoretical FO as 7.4 kHz, whereas the experimental FO from Figure 5 is found as 6.54 KHz.

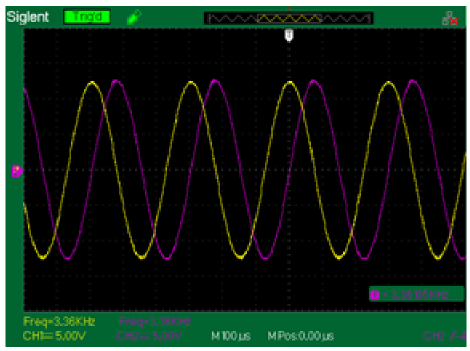

Figure 4: Experimental results for 4.7 kΩ resistors

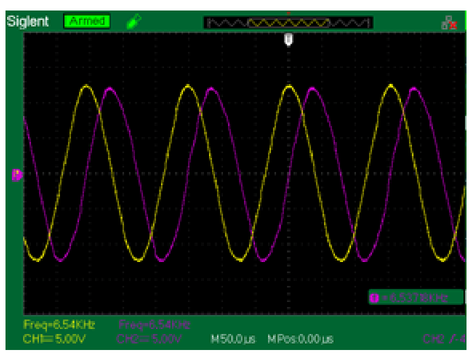

Figure 5: Experimental results for 2.2 kΩ resistors

4 Conclusion

This work presents a new quadrature oscillator circuit using operational amplifiers and six passive elements. The new circuit benefits from easy control over FO through independent resistive elements, which are not involved in CO control. The circuit provides three outputs and is verified both through simulation studies as well as experimental results using low cost commercial opamps. The proposed circuit may further be extended to four phase outputs by augmenting an inverting stage.

Acknowledgement

This work was carried out during summer break June-July 2018, under academic support of Prof. S. Maheshwari, AMU, Aligarh, India.

References

[1] S. Avireni, C. S. Pittala, "Grounded resistance/capacitance controlled sinusoidal oscillator using operational transconducatnce amplifier," *WSEAS Transactions on Circuits and Systems*, vol. 13, pp. 145-152, 2014.

[2] V. Biolekovo, J. Bajer, D. Biolek, "Four-phase oscillator employing two active elements," *Radioengineering*, vol. 20, no. 1, pp. 334-339, 2011.

[3] B. Chaturvedi, J. Mohan, "Single acitive element based mixed mode quadrature oscillator using grounded components," *IU-JEEE*, vol. 15, no. 1, pp. 1897-1906, 2015.

[4] J. W. Horng, "Quadrature oscillators using operational amplifiers," *Active and Passive Electronic Components*, vol. 2011, no. 2, 2011.

[5] A. Kumar, J. Mohan, B. Chaturvedi, S. Maheshwari, "Single active element based orthogonally controllable MOSFET-C quadrature oscillator," in *IMPACT*, India, 2017.

[6] S. Maheshwari, "Analog circuit design using a single EXCCCII," *International Journal of Electronics and Information Engineering*, vol. 9, no. 2, pp. 61-69, 2018.

[7] S. Maheshwari, I. A. Khan, "Novel single resistor controlled oscillator using two CDBAs," *Journal of Acitve and Passive Electronic Devices*, vol. 2, no. 2, pp. 137-142, 2007.

[8] R. Mancani, "Design Of opamp sine wave oscillators," *Analog Application Journal*, pp. 33-37, Aug. 2000.

[9] J. Mohan, B. Chaturvedi, S. Maheshwari, "Low voltage mixed-mode multi phase oscillator using single FDCCII," *Electronics*, vol. 20, no. 1, pp. 36, 2016.

[10] A. S. Sedra, K. C. Smith, *Microelectronic Circuits*, 5th edition, Oxford University Press, 2004.

[11] A. M. Soliman, "Two integrator loop quadrature oscillators: A review," *Journal of Advanced Research*, vol. 4, pp. 1-11, 2013.

Biography

Kushaagra Maheshwari is pursuing B. Tech in Electronics and Communication Engineering from GLBITM, G. Noida, India.