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Two New Single-Resistor-Controlled Quadrature Sinusoidal Oscillators Using Current-Differencing-Buffered-Amplifiers

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ABSTRACT

Two new single resistor–controlled quadrature oscillator (SRCQO) circuits using only two current differencing buffered amplifiers (CDBAs) as active elements and only three resistors and two capacitors, are presented. First proposed circuit uses all input terminals of the CDBA to exploit full capacity of the CDBAs, offers better sensitivities with respect to active parameters and has wide frequency range of operation. The second proposed circuit provides very good low frequency performance with respect to total harmonic distortion. Separate single resistors can control both oscillation condition and the oscillation frequency of the proposed quadrature oscillator circuits independently. PSPICE simulation results based upon commercially available AD844 ICs, to construct the CDBAs, are included which confirm the practical workability of the new proposed quadrature oscillator circuits.

Keywords: *Sinusoidal Oscillators; Quadrature Oscillators; Analog Circuits; Current Mode Circuits*.

1.0 Introduction

Quadrature oscillators find extensive applications in many Instrumentation and Measurement systems, Signal processing and Communication systems, for example, in the area of telecommunications they are needed in quadrature mixers and single- side band generators [1] and in measurement applications they are required in vector generators and selective voltmeters [2]. Realization of quadrature oscillators has, therefore, received considerable attention in recent literature[3-7].

Traditionally, the IC operational amplifier (op-amp) has been the most prominent component to design sinusoidal oscillators [4-7]. However, to overcome the drawbacks of traditional op-amp circuits, during the past two decades, a variety of new current mode active building blocks have been introduced by a number of researchers, such as various extensions of current conveyor (CC) as in third generation CC, inverting CC, differential voltage CC, multiple output CC, differential difference CC and fully differential CC etc, operational trans-resistance amplifier (OTRA), current differencing trans-conductance amplifier (CDTA), current differencing buffered amplifier (CDBA) and numerous others.

Among the large number of building blocks proposed so far, the recently introduced Current Differencing Buffered Amplifier (CDBA) [8] is particularly attractive as it provides two current input terminals with a virtual ground at the input that is quite helpful in eliminating the effect of various parasitic impedances. On the other hand, it is quite suitable for current mode operation and also provides a voltage mode output at a terminal having very low output impedance, which is very useful for easy cascading. Numerous CDBA applications have been reported by various researchers [8-12].Interest in designing quadrature oscillators using CDBAs grew because of the availability of a voltage mode output at a terminal having very low output impedance, ease of design with least possible number of external components and single element frequency control to avoid tracking problem inherent in dual-element control. CDBA-based sinusoidal oscillator circuits [8, 13] consisting of one CDBA, three resistors and two floating capacitors. The condition of oscillation and frequencies of oscillation of these oscillators are not independently controllable.

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Quadrature oscillator circuits [14-18] consist of more number of passive components than minimum required. Quadrature oscillator circuits [19-20] using CDBA with minimum number of passive components too but these circuits do not exploit the full capacity of the CDBA as negative terminal of one of the CDBAs is left unconnected in these circuits. Moreover, the circuits exhibit high total harmonic distortion at low frequencies.

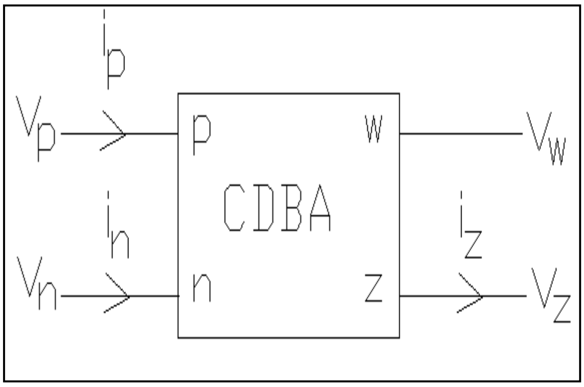
The aim of this paper is to introduce two new single-resistance-controlled quadrature oscillators (SRCQO) circuits providing the advantageous features of providing the employment of a minimum possible number of external passive components and independent control of both the frequency of oscillation as well as the condition of oscillation. First of the two proposed circuit uses all input terminals of the both the CDBAs to exploit the full capacity of the CDBAs, has very low sensitivities with respect to active parameters and has wide frequency range of operation whereas the second proposed circuit provides very low total harmonic distortion at lower frequencies thereby suitable for low frequency operation. The workability of the proposed circuits has been verified through PSPICE simulations based upon the realization of CDBAs using commercially available AD844 type CFOAs.

2.0 The proposed new configurations

The circuit symbol of the CDBA is shown in Figure1.The terminal characteristics of this element are given by

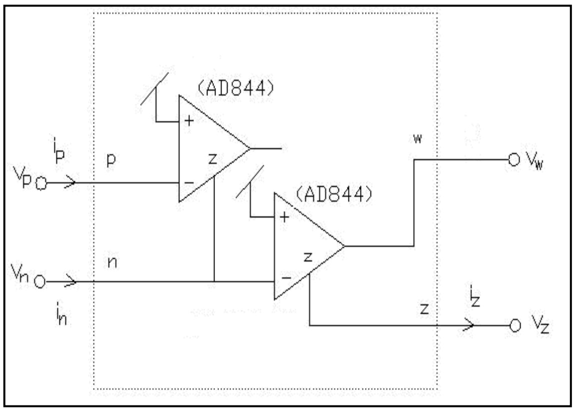
$V_p = V_n = 0, \quad I_z = I_p - I_n, \quad V_w = V_z$ (1)

Fig 1: Symbol for the CDBA



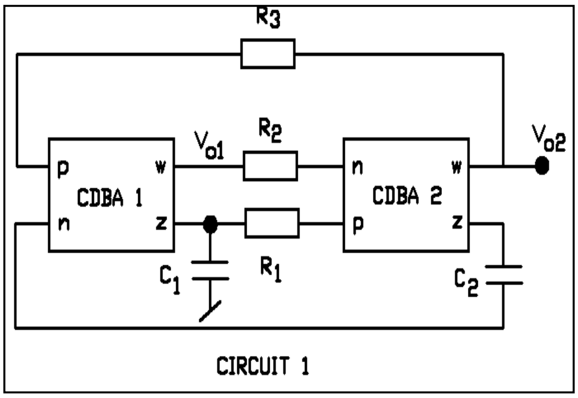
As CDBA is not yet commercially available and it can be implemented using commercially available AD844 type current feedback operational amplifiers (CFOA)[8] although fully integratable versions suitable for implementation in CMOS [21-22] or bipolar technology have also been proposed [23-24]. In the present work, CDBAs have been constructed using commercially available AD844 type CFOAs [8] as shown in figure 2.

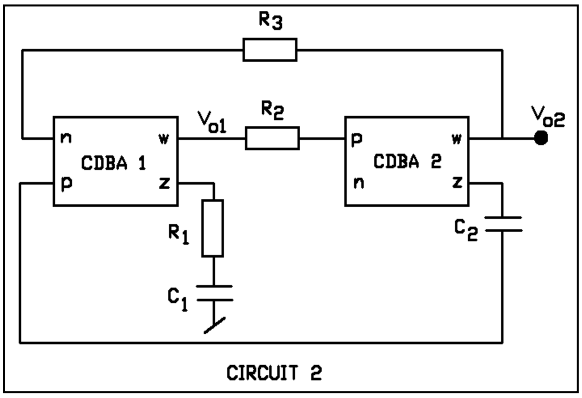
Fig 2: Implementation of CDBA Using Commercially Available AD-844 Type CFOAs [8]



As shown in figure 3, the proposed SRC-QOs, which are composed of two CDBAs, three resistors and two capacitors. From conventional circuit analysis using equation (1), the characteristic equation, condition of oscillation , frequency of oscillation and relation between Vo2 and Vo1 of the proposed CDBA-based SRC-QOs have been derived and are given in Table 1.

Fig 3: Proposed CDBA-Based Single Resistance Controlled Quadrature Oscillator Circuits





It can be seen from Table 1 that the oscillation condition of the proposed SRC-QOs can be controlled by R1 and R2 for circuit 1 and by C1, C2, R1 and R3 for circuit 2, whereas the oscillation frequency can be varied by a single resistor R3 for circuit 1, and by single resistor R2 for circuit 2 without affecting the oscillation condition.

Also, from the relationship between Vo1 and Vo2 as given in Table 1 it is clear that in both the circuits, the phase difference between Vo1 and Vo2 is ф=90o and thus, Vo1 and Vo2 are in quadrature.

Table 1: Characterization of the Proposed SRCQO Circuits

S.No.	Parameter	Circuit 1	Circuit 2
1	Characteristic equation	$s^2C_1C_2R_1R_2R_3 + sC_2R_3(2R_2 - R_1) + (R_1 - R_2) = 0$	$s^2C_1C_2(R_2 - R_1)R_3 + s(C_1R_1 - C_2R_3) + 1 = 0$
2	Condition of oscillation	$2R_2 = R_1$	$C_1R_1 = C_2R_3$
3	Frequency of oscillation	$\frac{1}{2\pi\sqrt{C_1C_2R_1R_3}}$	$\frac{1}{2\pi\sqrt{C_1C_2R_3(R_2 - R_1)}}$
4	Vo2 = f (Vo1)	$\frac{-1}{sC_2R_1}$	$\frac{1}{sC_2R_2}$

3.0 Effects of CDBA Non-Idealities

A practical CDBA can be described by the following terminal relationships that take into account the non-idealities of the device.

$$V_p = V_n = 0, \quad I_z = \beta_p I_p - \beta_n I_n, \quad V_w = \alpha V_z \qquad (2)$$

where βp=1-εp and εp(lεpl<<1) is the current tracking error from p-terminal to z-terminal, βn=1-εn and εn(lεnl<<1) is the current tracking error from n-terminal to z-terminal , and α = 1- εv and εv(lεvl<<1) is the voltage-tracking error from z-terminal to w-terminal of the CDBA.

Re-analysis of the CDBA-based oscillator circuits of Figure.3, using non-ideal equation (2), yields the modified characteristic equation, condition of the oscillation, frequency of the oscillation, relation between Vo2 and Vo1 and sensitivity with respect to passive and active parameters, as given in Table-2.

From Table 2, it is clear that the proposed circuits enjoy very low sensitivities and for circuit 1 it even approaches zero with respect to two active parameters, a clear advantage over the previously reported circuits of [19-20].

Fig 4: Single Resistor Frequency Control of Proposed Circuit 1

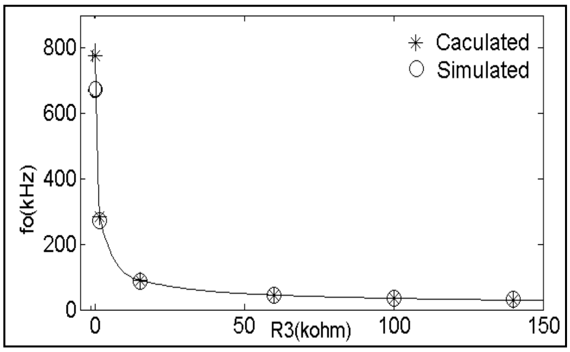


Table 2: Effects of CDBA non-Idealities

S.No.	Parameter	Circuit 1	Circuit 2
1	Characteristic equation	$as^2 + bs + d = 0$ Here $a = C_1C_2R_1R_2R_3$ $b = C_2R_3[R_2(1+\beta_{n1}\beta_{p2}) - \alpha_1\alpha_2\beta_{n1}\beta_{n2}R_1]$ $d = \alpha_2\beta_{p1}(\alpha_1\beta_{n2}R_1 - \beta_{p2}R_2)$	$as^2 + bs + d = 0$ Here $a = C_1C_2(R_2 - \alpha_1\beta_{p1}\beta_{p2}R_1)R_3$ $b = \alpha_1\beta_{p2}(\alpha_2\beta_{n1}C_1R_1 - \beta_{p1}C_2R_3)$ $d = \alpha_1\alpha_2\beta_{n1}\beta_{p2}$
2	Condition of oscillation	$R_2(1+\beta_{n1}\beta_{p2}) = \alpha_1\alpha_2\beta_{n1}\beta_{n2}R_1$	$\alpha_2\beta_{n1}C_1R_1 = \beta_{p1}C_2R_3$
3	Frequency of oscillation	$\frac{1}{2\pi}\sqrt{\frac{\beta_{p1}(1+\beta_{n1}\beta_{p2} - \alpha_2\beta_{p2}\beta_{n1})}{\beta_{n1}C_1C_2R_1R_3}}$	$\frac{1}{2\pi}\sqrt{\frac{\alpha_1\alpha_2\beta_{n1}\beta_{p2}}{C_1C_2R_3(R_2 - \alpha_1\beta_{p1}\beta_{p2}R_1)}}$
4	Vo2=f (Vo1)	$\frac{\alpha_2\beta_{p2}R_2 - \alpha_1\alpha_2\beta_{n2}R_1}{sC_2R_1}$	$\frac{\alpha_1\beta_{p2}}{sC_2R_2}$
5	Sensitivity Coefficients	$S^{\omega_o}_{C_1,C_2,R_1,R_3} = -\frac{1}{2}$, $S^{\omega_o}_{\beta_{p1}} = \frac{1}{2}$, $S^{\omega_o}_{\alpha_2} = -\frac{\alpha_2\beta_{p2}\beta_{n1}}{2(1+\beta_{n1}\beta_{p2} - \alpha_2\beta_{p2}\beta_{n1})}$ $i.e. \leq \frac{-1}{2}$, $S^{\omega_o}_{\beta_{p2}} = \frac{1}{1+\frac{1}{(1-\alpha_2)\beta_{p2}\beta_{n1}}}$ $i.e. \cong 0$, $S^{\omega_o}_{\beta_{n1}} = \frac{-1}{2[1+\beta_{n1}\beta_{p2}(1-\alpha_2)]}$ $i.e. \cong 0$	$0 \leq \lvert S^Y_X \rvert \leq \frac{1}{2}$; $for R_2 >> R_1$ where Y= ω_0 and X=C1, C2, R1, R2, R3, $\alpha_1, \alpha_2, \beta_{n1}, and \beta_{p2}$

4.0 PSPICE Simulation results

To verify the theoretical results, the proposed CDBA-based SRC-QO circuits of figure.3 have been simulated in PSPICE using macro model of commercially available AD844 ICs employed to construct the CDBAs as shown in figure.2 with supply voltages of ± 12V.

For proposed circuit 1, to obtain the quadrature output waveforms, the component values were taken as C1=100pF, C2=100pF, R2=10kΩ, R1=21kΩ (chosen to be larger than 2R2 to ensure that the oscillations will start). The variability of oscillation frequency with resistor R3 is shown in Fig-4 when R3 was varied from 200Ω to 140kΩ. For proposed circuit 2, to obtain the quadrature output waveforms, the component values were taken as C1=1nF, C2=1nF, R1=400Ω, R3= 470Ω (chosen to be larger than R1 to ensure that the building-up of oscillations). The variability of oscillation frequency with resistor R2 (with R2 varied from 3kΩ to 100kΩ) is shown in figure 5.

Fig 5: **Single Resistor Frequency Control of the Proposed Circuit 2**

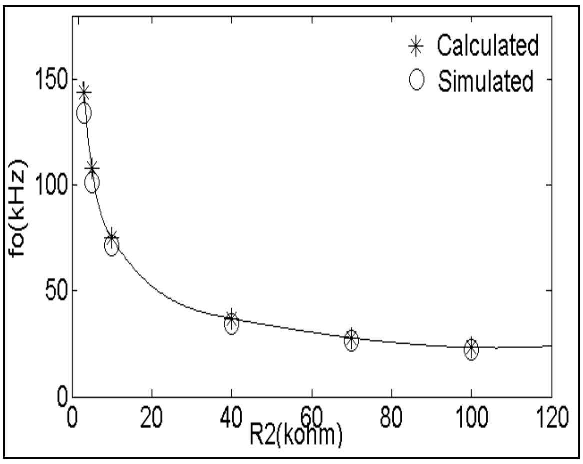
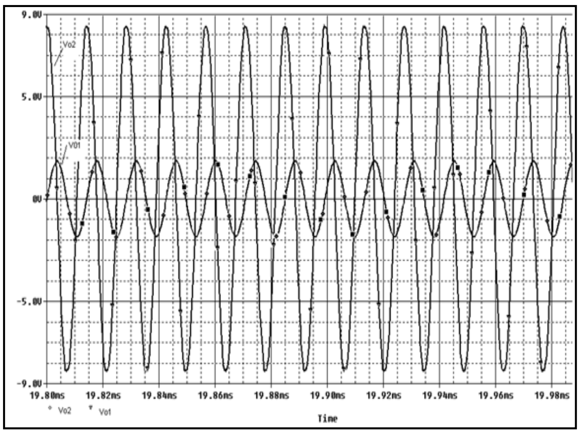
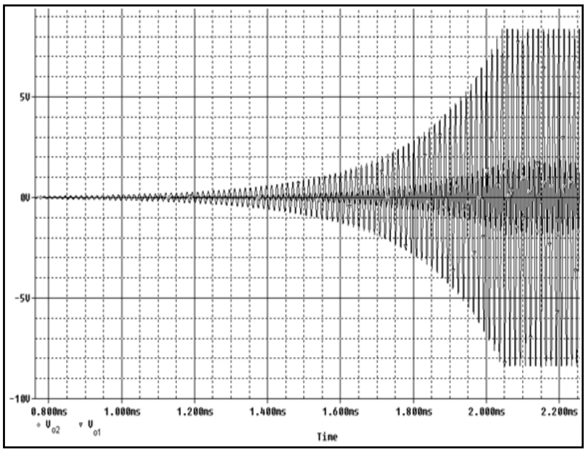


Fig 6: Simulation Results of the Quadrature Outputs Vo1 and Vo2 of Proposed Circuit 1

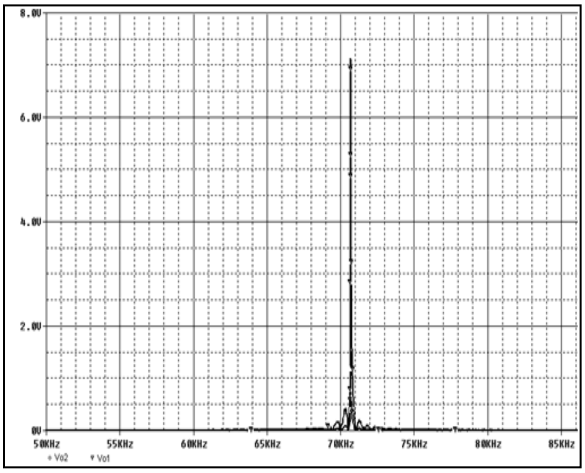
(a) Steady State Output Waveforms



(b) Transient Waveforms



(c) Output Spectrum.



A typical waveform generated by circuit 2 with component values C1=1nF,C2=1nF, R1=400Ω, R3=470Ω and R2=10KΩ is shown in Figure 6(a). The transient response of oscillator showing the build up of the oscillations is shown in figure 6 (b) and figure 6 (c) represents the simulated frequency spectrum of the outputs Vo1 and V02.

The PSPICE simulation results, thus, confirm the practical viability of the proposed circuits.

The results of the total harmonic distortion of the proposed circuits as obtained from simulation are summarized in Table 3.

A comparison of the frequency range for simulation and % THD of the presented circuits as compared with previously reported circuits is shown in Table 4.

Table 3: Total Harmonic Distortion of the Proposed Circuits

S. No.	Proposed circuit 1			Proposed circuit 2		
	Frequency (KHz)	THD (%) of Vo1	THD (%) of Vo2	Frequency (KHz)	THD (%) of Vo1	THD (%) of Vo2
1	30.58	3.90	2.04	22.22	2.59	2.93
2	35.71	3.86	2.34	26.31	1.00	1.37
3	45.25	2.77	1.90	34.48	0.96	1.16
4	87.72	0.98	0.46	71.40	1.67	1.33
5	271.74	0.61	0.61	101.84	2.00	0.52
6	672.94	1.83	1.93	134.05	3.28	0.99

Table 4: Comparison of the Frequency Range for Simulation and % Thd of the Proposed Src-Qo Circuits with Previously Published Src-Qo Circuits Having two Cdbas, two Capacitors and three Resistors

Parameter			Previously known Circuits		Proposed Circuits	
			[19]	[20]	Circuit 1	Circuit 2
Frequency range for simulation (KHz)	fmin		39.90	7.50	30.58	23.20
	fmax		399.00	22.50	672.95	134.05
	Range		359.10	15.00	642.37	110.85
THD (%)	Vo1	at fmin	4.44	2.54	3.90	2.59
		at fmax	3.35	2.62	1.83	3.28
	Vo2	at fmin	2.55	6.63	2.04	2.93
		at fmax	2.26	0.95	1.93	0.99

5.0 Conclusions

Two new SRC quadrature sinusoidal oscillators employing two CDBAs, two capacitors and three resistors have been proposed. These circuits provide two sinusoidal outputs with the phase difference of 90 degree and independent control of CO and FO through two separate resistors. The new circuits have also grounded and virtually grounded capacitors, which is advantageous from integrated circuit implementation point of view. First proposed circuit offers low sensitivities with respect to active parameters and has wide frequency range of operation. Second proposed circuit provides, in addition, very good low frequency performance with respect to % THD. The PSPICE simulation results confirm the practical viability of the proposed circuits.

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