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# Single-Capacitor-Controlled Oscillators using a Single CFOA

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**Abstract:** Single-Resistance-Controlled-Oscillators have been widely investigated in literature because of their several applications, however, it has been largely ignored in the earlier literature that single capacitance controlled type Single Element Controlled Oscillators are also no less important and may be useful in several situations such as varactor-tuned high frequency oscillators and as transducer oscillators in conjunction with capacitive transducers. As a consequence, Single capacitor controlled oscillators have not received much attention in literature. In this paper, eight single Current Feedback Operational Amplifier (CFOA) based oscillators are reported each of which provide independent control of frequency of oscillation through a single variable capacitance. The workability of the proposed configurations has been verified by hardware implementation results based on commercially available AD844 type CFOAs and some sample experimental results have been given.

**Keywords:** Oscillators, Current-feedback-operational-amplifiers, current mode circuits, varactor-tuned oscillators, single element-controlled oscillators.

## 1. Introduction

Interest in Current feedback op-amps (CFOA) as alternatives to the traditional voltage operational amplifiers (VOA) grew when it was observed [1] that use of a CFOA rather than a VOA in the classical Wien bridge oscillator results in significant advantages like better accuracy, higher frequency range, greater linearity, larger signal generating capacity, higher slew rate and decoupling of the effects of CFOA-parasitics on the tuning of condition of oscillation and frequency of oscillation.

There have been a large number of studies as the evolution of single resistance control oscillators capable of providing independent single resistance control of condition of oscillation as well as frequency of oscillation using one or more CFOAs, for instance, see [1]-[9] and the references citied there in. Single-Resistance-Controlled-Oscillators have been the main focus of attention in the most of the earlier technical literature due to their possible use as variable frequency test oscillators and also as transducer oscillators in conjunction with resistive transducers. However, it has been largely ignored in the literature that single capacitance controlled type Single Element Controlled Oscillators are no less important and may also be useful in several situations such as varactor-tuned high frequency oscillators and as transducer oscillators in conjunction with capacitive transducers. As a consequence, Single capacitor controlled oscillators (SCCO) have not received much attention in literature. The main objective of this paper is to present a class of such SCCOs realizable with a single CFOA to fill this void.

## 2. Derivation of SCCOs using a single CFOA

A CFOA is a four terminal building block characterized by the following terminal equations.

$$i_y = 0,\ v_x = v_y,\ i_z = i_x,\ v_w = v_z$$

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The symbolic notation of the CFOA and its equivalent circuits are shown in Fig 1.

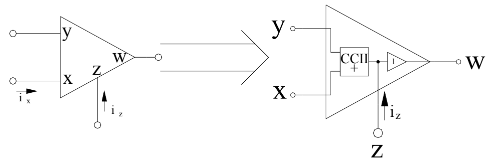



Fig. 1 Symbolic notation and equivalent circuit of the CFOA characterized by equation (1)

For the intended purpose of deriving SCCOs providing independent control of condition of oscillation, while employing no more than three capacitors along with a small number of resistors, we have formulated a generalized five node network (as in [8]) which is shown here in Fig. 1. By straight forward analysis, the characteristic equation of the circuit is found to be:

$$y_0(y_1 + y_3 + y_6) + y_3(y_2 + y_6 + 2y_7) - y_4(y_1 + y_6) = 0 \quad (1)$$

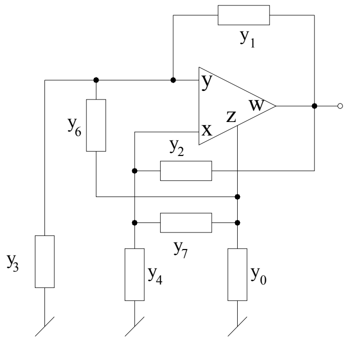
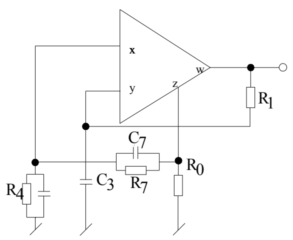


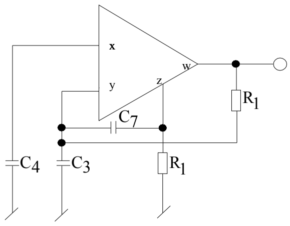
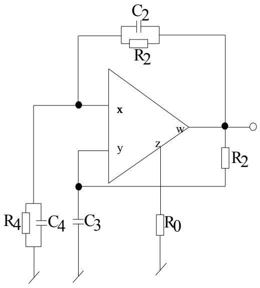
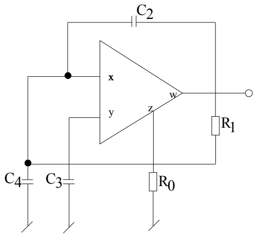
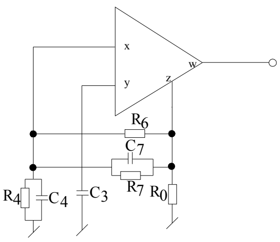
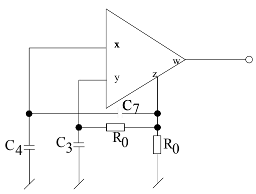
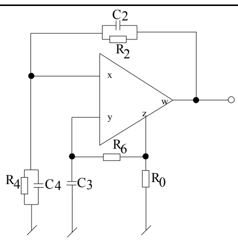

Fig. 2 Five node generalized structure for oscillator realization

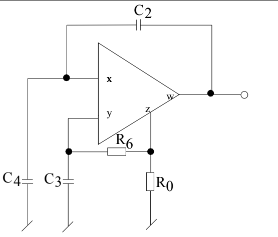
From the above structure and the generalized characteristic equation (1) all possible circuits of SCCOs employing not more than three capacitors were searched and it has been found that a total number of only eight structures are possible which belong to the intended type, excluding a number of circuits which could only realize fixed frequency oscillators and circuits which although provide the control of condition of oscillation but not that of the frequency of oscillation. The resulting circuits are summarized in Table 1. Table 1 also shows the condition of oscillation (CO) and frequency of oscillation (FO) along with the details of simplified versions as applicable in some cases and other qualifying remarks about the various circuits.

In [9] a family of 8 Single CFOA based Single Resistance Controlled Oscillators (SRCO's) has been presented. In principle, from these 8 SRCO's, an equal number of SCCOs may be obtained by applying RC: CR transformation. However, it must be mentioned that only the circuit number 8 is common with the above-mentioned set of 8 SCCO's; the remaining 7 circuits are entirely new and have not been known earlier.

Table 1 Single-Capacitor-Controlled Oscillators derived from the generalized structure of Fig. 2

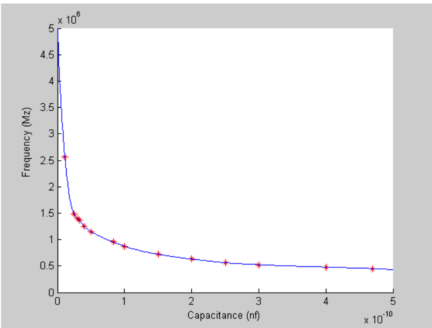
| Circuit no. | | Condition of Oscillation | Frequency of Oscillation | Controllability | Remarks |
|---|---|---|---|---|---|
| 1 |  | $\frac{C_4}{C_3} = \frac{R_1}{R_0} + \frac{2R_1}{R_7}$ | $f_0 = \frac{1}{2\sqrt{2}\pi}\sqrt{\frac{\frac{R_4}{R_0} - 1}{R_1 R_4 C_3 C_7}}$ | CO by $C_4$ FO by $C_7$ | (i) In both modes, FO is Controllable by $R_4$ also. (ii) difference term permits realization of very low frequency (VLF) oscillations also. |
| | | with $R_0 \to \infty$ $\frac{C_4}{C_3} = \frac{2R_1}{R_7}$ | $f_0 = \frac{1}{2\sqrt{2}\pi}\sqrt{\frac{1}{R_1 R_4 C_3 C_7}}$ | | |

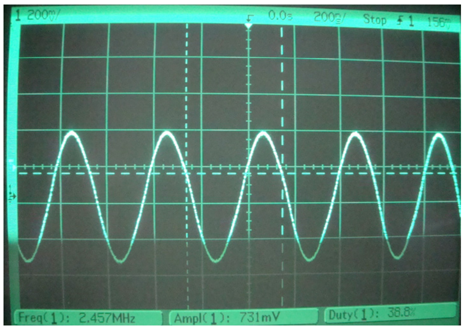
| | | | | | |
|---|---|---|---|---|---|
| 2 |  | $\frac{C_4}{C_3}=\frac{R_1}{R_0}$ | $f_0=\frac{1}{2\pi}\sqrt{\frac{1}{2R_0R_1C_3C_7}}$ | CO by $C_4$ FO by $C_7$ | Circuit uses minimum possible number of passive components |
| 3 |  | $\frac{C_4}{C_3}=\frac{R_1}{R_0}+\frac{R_1}{R_2}$ | $f_0=\frac{1}{2\pi}\sqrt{\frac{\frac{R_4}{R_0}-1}{R_1R_4C_2C_3}}$ | CO by $C_4$ FO by $C_2$ | (i) FO is controllable by $R_4$ also<br><br>(ii) difference term permits realization of VLF also |
| 4 |  | $\frac{C_4}{C_3}=\frac{R_1}{R_0}$ | $f_0=\frac{1}{2\pi}\sqrt{\frac{1}{R_0R_1C_2C_3}}$ | CO by $C_4$ FO by $C_2$ | Minimum component structure |
| 5 |  | $\frac{C_4}{C_3}=1+\frac{R_6}{R_0}+\frac{2R_6}{R_7}$ | $f_0=\frac{1}{2\sqrt{2}\pi}\sqrt{\frac{\frac{R_4}{R_0}-1}{R_4R_6C_3C_7}}$ | CO by $C_4$ FO by $C_7$ | (i) FO is controllable by $R_4$ also<br><br>(ii)VLF generation possible. |
| 6 |  | $\frac{C_4}{C_3}=1+\frac{R_6}{R_0}$ | $f_0=\frac{1}{2\pi}\sqrt{\frac{1}{2R_0R_6C_3C_7}}$ | CO by $C_4$ FO by $C_7$ | Another minimum component design |
| 7 |  | $\frac{C_4}{C_3}=\frac{R_6}{R_0}+\frac{R_6}{R_2}$ | $f_0=\frac{1}{2\pi}\sqrt{\frac{\frac{R_4}{R_0}-1}{R_4R_6C_2C_3}}$ | CO by $C_4$ FO by $C_2$ | (i) FO is controllable by $R_4$ also<br><br>(ii)VLF generation possible. |

| | | | | | |
|---|---|---|---|---|---|
| 8 |  | $\frac{C_4}{C_3}=1+\frac{R_6}{R_0}$ | $f_0=\frac{1}{2\pi}\sqrt{\frac{1}{R_0R_6C_2C_3}}$ | CO by $C_4$ FO by $C_2$ | Minimum component design |

## 3. Experimental Results

The workability of all the circuits of Table 1 has been checked by breadboard versions realized using AD844 type of CFOAs biased with ±12V DC power supplies and all the circuits have been found to work as predicted by theory. However, to conserve space, we give in the following, experimental results for the oscillator 2 of Table 1. The circuit was tested with $R_1$=1k, $C_4$=100pF, $C_3$=100pF, using a variable capacitance $C_7$ varied from 10pF to 1nF. Fig.3 (a) shows the variation of FO with $C_7$, which is seen to be in good agreement with the theory where as a typical waveform generated from this circuit is shown in Fig.3 (b). The experimental results have, thus, confirmed the practical variability of the new derived SCCOs.




(a) (b)

Fig. 3 (a) Experimental results of oscillator 2 variation of oscillation frequency with variable capacitance (b) a typical waveform generated by the circuit (2.45 MHz, 731mV p-p)

## 4. Concluding Remarks

Eight new SECOs each using a single CFOA but capable of realizing SCCO have been presented in this paper. An inspection of the SCCOs of Table 1 reveals the following:

i. The oscillator numbers 1, 3, 5 and 7 contain a difference term in the expression for frequency of oscillation due to which these circuits can also be readily used as very low frequency oscillators without having to use large RC component values.

ii. In circuits 1, 3, 5, 7, FO is also controllable by a variable resistance hence, apart from acting as SCCOs, they can also be used as SRCOs.

iii. Circuits 2, 4, 6, 8 are minimum-component designs of SCCOs.

The practical workability of the proposed SCCOs has been verified using commercially available AD844 type CFOAs. In view of the continued research on the development of CMOS CFOAs [30-32], the determination of the feasibility of realizing very high frequency varactor-tuned oscillators using the new SCCOs presented here requires further investigations.

## 5. Acknowledgement

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