ON THE REALIZATION OF CFA-BASED OSCILLATORS USING STATE EQUATIONS AND BLOCK DIAGRAMS

Ece Olcay Güneş *Ali Toker*

Istanbul Technical University
Electrical and Electronics Faculty, Department of Electronics and Communications Eng.
80626 Maslak, Istanbul, Turkey

ABSTRACT

A synthesis method using state variable technique and block diagrams for Current Feedback Amplifier (CFA) based oscillators has been presented. In this method, if the state equations can be represented by a suitable block diagram, then the corresponding circuit realisation can be easily found. The most critical step of the method is the selection of the characteristic equation. Some conditions that can be used in this step have been given. By using state variable method, suitable sub-circuits and block diagrams single CFA based single resistance controlled oscillators (SRCO) can be obtained.

1. INTRODUCTION

The realisation of oscillators using current feedback amplifiers (CFA) as active elements has received much attention in the literature [1-7]. Most presented circuits have been derived from a given configuration [5-7]. In these works, first an oscillator circuit configuration, which consists of one or more CFA and passive elements, has been given. Then, the circuit is analysed, the condition of oscillation and frequency of oscillation are obtained by choosing the type of the passive elements. A systematical oscillator synthesis method using CFAs has been given by Senani and Gupta [8]. In this method, first a characteristic equation is chose. The state equations are written by using characteristic equation, and condition of oscillation and frequency of oscillation are obtained. Then, the oscillator circuit is realised. The most critical step of this method is to realise the oscillator circuit by using state equations. And also, Gupta and Senani have reduced the active element number two with this method [9].

In this work, for to facilitate the last step of the state variable technique, the block diagrams are used. If the state equations represented by a suitable block diagram, then the corresponding circuit realisation using only one CFA can be easily found.

2. CURRENT FEEDBACK AMPLIFIER

The Current Feedback Amplifier (CFA) whose circuit symbol is given in Fig.1 can be defined by the following constitutive relations [10];

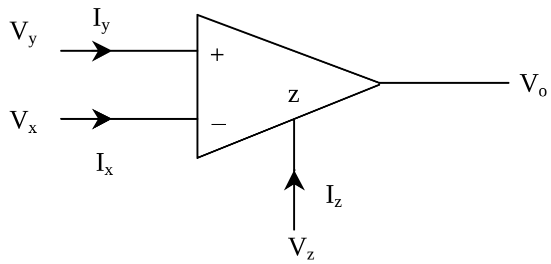


Fig. 1 Current Feedback Amplifier

$$\begin{bmatrix} I_y \\ V_x \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} . \begin{bmatrix} V_y \\ I_x \\ V_z \end{bmatrix} \qquad V_0=V_z \qquad (1)$$

The x and y terminal of CFA are denoted (-) sign and (+) sign respectively. A CFA is equivalent to a plus type current conveyor with a voltage buffer and is very suitable building block for realisation of active RC oscillators. Furthermore, CFA has a larger bandwidth, which is relatively independent of the closed-loop gain and higher slew-rate than the operational amplifier [11].

3. SYNTHESIS METHOD

The steps of the method are as follows;

i) Specify the characteristic equation

A second order oscillator can, in general, be characterised by the following state equation [8]:

$$\frac{d}{dt}\begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} . \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} \qquad (2)$$

From the above, the characteristic equation

$$p(s) = |sI - A| = s^2 - (a_{11} + a_{22})s + (a_{11}a_{22} - a_{12}a_{21}) \qquad (3)$$

gives the condition of the oscillation (CO) and frequency of oscillation (FO) as

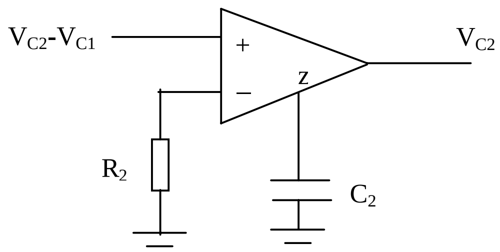
$$a_{11} + a_{22} = 0 \tag{4a}$$

$$\omega_0 = \sqrt{a_{11}a_{22} - a_{12}a_{21}} \tag{4b}$$

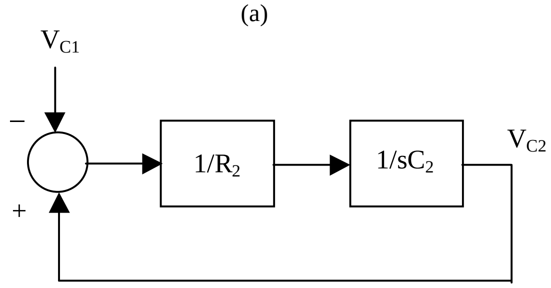
The most critical step of this method is to choose a proper characteristic equation. In the characteristic equation the coefficient of s must be the difference of two terms. If independent oscillation frequency and independent oscillation condition are wanted, then at least one parameter in Eqn.(4a) will not be seen in Eqn.(4b), and at least one parameter in Eqn.(4b) will not be seen in Eqn.(4a). If these two conditions are satisfied, in this case the control of oscillation condition between oscillation frequency can be made independently. If the only the second condition is satisfied, then the oscillation frequency can be controlled without disturbing the oscillation condition [12]. And also, the state equations consist of difference of the state variables.

ii) Obtain the a_{ij} parameters by using CO and FO (Eqn.(4a) and (4b))
iii) Write the state equation using the a_{ij} parameters (Eqn.(2))
iv) Take the Laplace transform of the state equations
v) Draw the block diagram of these equations
vi) Obtain the CFA-based oscillator using sub-diagrams and sub-circuits

The sub-circuits, the functions that realised with the sub-circuits and sub-diagrams which can be drawn using the functions shown below;



(a)

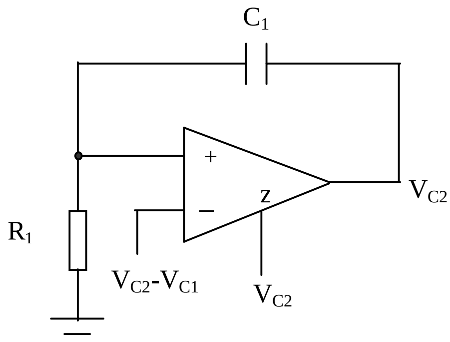


(b)

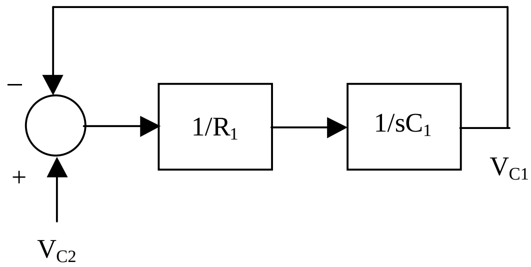
Fig. 2 Sub-circuit 1 and sub-diagram 1

The realised function

$$V_{C_2} = \frac{1}{sC_2}\left(\frac{V_{C_2} - V_{C_1}}{R_2}\right) \tag{5}$$



(a)

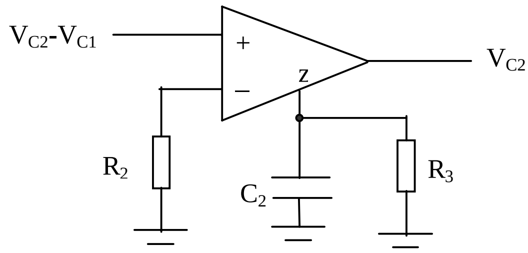


(b)

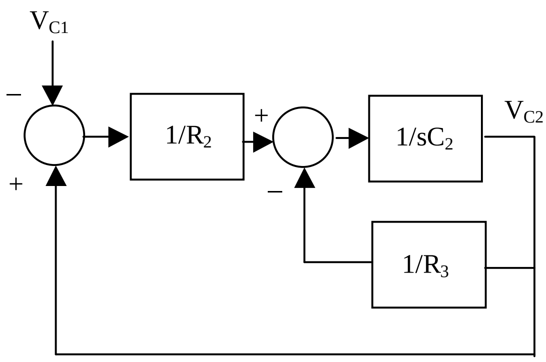
Fig. 3 Sub-circuit 2 and sub-diagram 2

The realised function;

$$V_{C_1} = \frac{1}{sC_1}\left(\frac{V_{C_2} - V_{C_1}}{R_1}\right) \tag{6}$$



(a)

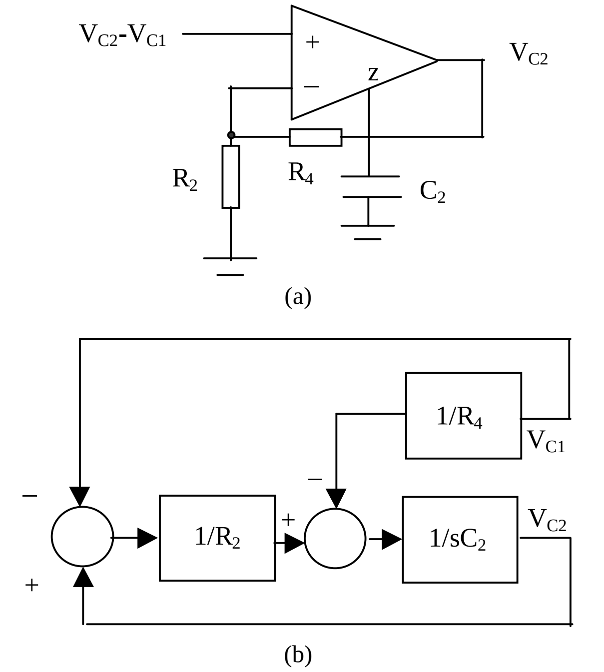


(b)

Fig. 4 sub-circuit 3 and sub-diagram 3

The realised function;

$$V_{C_2} = \frac{1}{sC_2}\left[\frac{1}{R_2}\left(V_{C_2} - V_{C_1}\right) - \frac{1}{R_3}V_{C_2}\right] \tag{7}$$



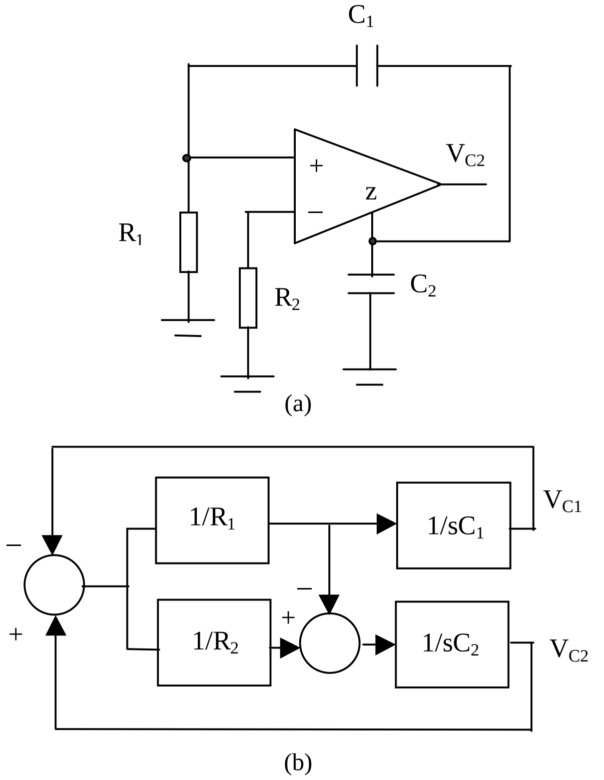
(a)

(b)

Fig. 5 Sub-circuit 4 and sub-diagram 4

The realised function;

$$V_{C_2} = \frac{1}{sC_2}\left[\frac{1}{R_2}\left(V_{C_2} - V_{C_1}\right) - \frac{1}{R_4}V_{C_1}\right] \tag{8}$$



(a)

(b)

Fig. 6 Sub-circuit 5 and sub-diagram 5

The realised functions

$$V_{C_1} = \frac{1}{sC_1}\left[\frac{\left(V_{C_2} - V_{C_1}\right)}{R_1}\right]$$

$$V_{C_2} = \frac{1}{sC_2}\left[\frac{1}{R_2}\left(V_{C_2} - V_{C_1}\right) - \frac{1}{R_1}\left(V_{C_2} - V_{C_1}\right)\right] \tag{9}$$

If the state equations are represented by a suitable block diagram which is composed of the sub-diagrams shown in Fig.2(b), Fig.3(b), Fig.4(b), Fig5(b) and Fig.6(b) then the corresponding circuit realisation can be easily found using Fig.2(a), Fig.3(a), Fig.4(a), Fig.5(a) and Fig.6(a).

4. AN EXAMPLE FOR THE PROPOSED METHOD

An example of the proposed method,

i) The characteristic equation is specified as follows,

$$p(s) = s^2 - s\left[\frac{1}{C_1R_1} + \frac{1}{C_2}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)\right] + \frac{1}{C_1C_2R_1R_3} \tag{10}$$

ii) The a_{ij} parameters can be obtained by the aid of CO and FO (Eqn.(4a) and (4b))

$$a_{11} = -\frac{1}{C_1R_1} \qquad a_{12} = \frac{1}{C_1R_1}$$

$$a_{21} = \frac{1}{C_2}\left(\frac{1}{R_1} - \frac{1}{R_2} - \frac{1}{R_3}\right) \qquad a_{22} = -\frac{1}{C_2}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \tag{11}$$

iii) The state equations using these parameters can be written as

$$C_1\frac{dV_{C_1}}{dt} = -\frac{V_{C_1}}{R_1} + \frac{V_{C_2}}{R_1}$$

$$C_2\frac{dV_{C_2}}{dt} = V_{C_1}\left(\frac{1}{R_1} - \frac{1}{R_2} - \frac{1}{R_3}\right) + V_{C_2}\left(\frac{1}{R_2} - \frac{1}{R_1}\right) \tag{12}$$

iv) The Laplace transforms of these equations are as follows,

$$V_{C_1} = \frac{1}{sC_1}\left(\frac{V_{C_2} - V_{C_1}}{R_1}\right)$$

$$V_{C_2} = \frac{1}{sC_2}\left(\frac{V_{C_2} - V_{C_1}}{R_2} - \frac{V_{C_2} - V_{C_1}}{R_1} - \frac{V_{C_1}}{R_3}\right) \tag{13}$$

v) Using these equations we can draw a block diagram shown in Fig.7. This block diagram is combination of sub-diagrams shown in Fig.5(b) and Fig.6 (b).

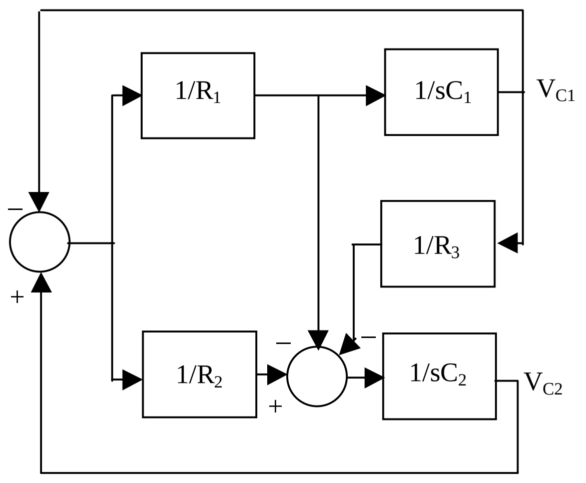


Fig. 7 Block diagram representing Eqn.(13)

vi) Then the CFA-based circuit in Fig.8 can be easily obtained with the aid of sub-circuits shown in Fig.5(a) and Fig.6(a).

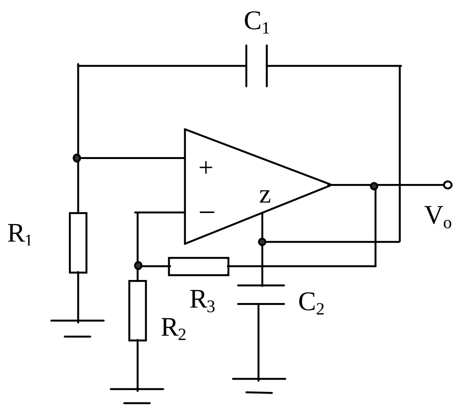


Fig.8 CFA-based oscillator circuit

This circuit is as same as the circuit in ref [6] and it is found by systematical way. Different types of CFA-based oscillator circuits can be easily obtained by using this method.

5. CONCLUSION

A systematically CFA-based oscillator realisation method by using state variable technique and block diagrams has been presented. The most critical step of the method is the first one, which is the selection of the characteristic equation. Some conditions that can be used in this step have been given. By using state variable technique, suitable sub-circuits and sub-diagrams single CFA-based oscillators can be obtained.

In this work, CFAs have been used as an active element. But, the steps, except the last step, of this method are independent from the active element. And also, other type active elements can be used in oscillator realisation with this method, if proper sub-circuits and sub-diagrams are found.

REFERENCES

[1] Celma S., Martinez P.A. and Carlosena A., “Current feedback amplifiers based sinusoidal oscillators”, IEEE Trans. on Circiuts and Systems Vol. 41, pp. 906-908, 1994

[2] Martinez, P.A., Sabadell J. and Aldea C., “Grounded resistor controlled oscillator using CFOAs”, Electronics Letters, Vol. 33, pp. 346-347, 1997

[3] Liu, S.I. and Tsay, J.H., “Single resistance controlled sinusoidal oscillator using current feedback amplifiers”, Int. J. Electronics, Vol. 80, pp. 661-664, 1996

[4] Martinez, P.A., Celma, S. and Sabadell J., “Designing sinusoidal oscillators with current feedback amplifiers” Int. J. Electronics, Vol. 80, pp.637-646, 1996

[5] Abuelma’atti, M.T. and Al Shahrani S. M., “New CFOA-based sinusoidal oscillators”, Int. J. Electronics, Vol. 82, pp. 27-32, 1997

[6] Liu, S.I., Shih, C.S. and Wu, D.S., “Sinusoidal oscillators with single element control using a current feedback amplifier”, Int. J. Electronics, Vol. 77, pp. 1007-1013, 1994

[7] Abuelma’atti, M.T. and Al Shahrani S.M. “Novel low count single element controlled sinusoidal oscillator using CFOA pole” Int. J. Electronics, Vol.80, pp.747-752, 1996

[8] Senani, R. and Gupta, S.S., “Synthesis of single resistance controlled oscillators using CFOAs: simple state-variable approach”, IEE Proc. Circiuts Devices Sys. Vol. 144, pp. 104-107, 1997

[9] Gupta, S.S. and Senani, R., “State variable synthesis of single resistance controlled grounded capacitor oscillators using only two CFOAs”, IEE Proc. Devices Sys. Vol. 145, pp. 135-138, 1998

[10] Svoboda, J.A., McGory L. and Webb, S., “Applications of commercially available current conveyor”, Int. J. Electronics, Vol. 70, pp. 159-164, 1991

[11] Mahattanakul, J., and Toumazou, C., “A theoretical study of stability of high frequency current feedback op-amp integrators”, IEEE Trans. on Circuits and Systems, Vol. 43, pp. 2-12, 1996

[12] Yüksel, E. ,“Genelleştirilmiş durum denklemleriyle CFOA temelli osilatör sentezi”, Yüksek Lisans Tezi, Istanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, 1999