# DIGITALLY TUNED SINUSOIDAL OSCILLATOR USING MULTIPLE-OUTPUT CURRENT OPERATIONAL AMPLIFIER FOR APPLICATIONS IN HIGH STABLE ACOUSTICAL GENERATORS

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*The conception of multiple output current operational amplifier and its applications in current amplifiers circuits having amplification digitally tuned, has been presented. The general structure of the realisation of a sinusoidal generator with one MOCOA and digitally tuned parameter such as a condition and frequency of oscillation, has been described. One versions of a sinusoidal oscillator with RC elements, have been shown. Simulations the form of generated oscillations as amplifier output current, have been carried out and the effect of tuning of its amplification on the form of those characteristics, has been investigated. The system may be applied in high stable acoustical generators.*

*Keywords: current operational amplifier, sinusoidal oscillator, digitally tuned circuits, multiple output amplifier*

## 1. INTRODUCTION

With the development of computing techniques as well as computing possibilities for digital systems, the requirements, as for analogue electronic systems, have changed. One of them is as large as possible degree of integration with decrease of the number of necessary additional external elements, at the same time. Those requirements can be met by transferring many functions performed by the circuit to its interior, increasing its versatility and simultaneously increasing the number of terminals used for communication with the environment. In addition, these circuits should, in easy way, cooperate with digital systems in order to enable tuning or programming their parameters by means of analogue keys. The example of such circuit can be a multiple output current operational amplifier (MOCOA). It is a modified conventional current operational amplifier whose number of outputs is increased. Its symbol is shown in Fig. 1 and it is described by the following dependence:

$$I_{0Pk} = -I_{0Nk} = K_0 I_W \tag{1}$$

for $K_0 \rightarrow \infty$. It is assumed that the number $n$ of reversible P and non-reversible N outputs is the same, so it is a 2n-outputs current operational amplifier.

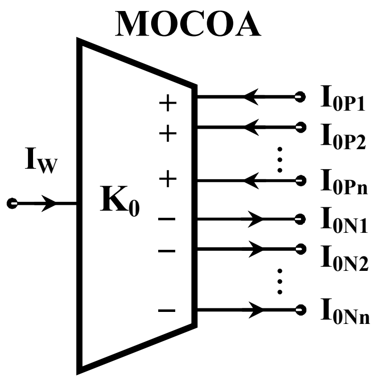


Fig. 1 Symbol of multiple-output current operational amplifier

Its simplified realisations in form of integrated systems made in CMOS techniques can be a development of circuit conception applied for the number output blocks (Fig. 2).

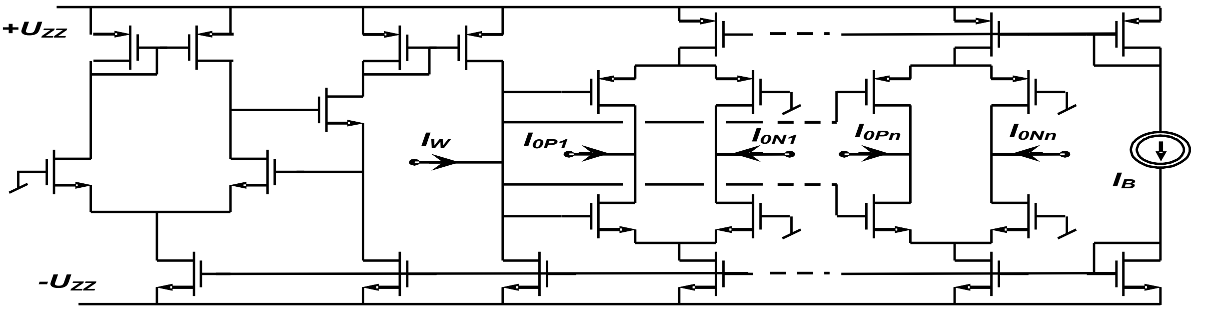


Fig. 2. Simple practical realisation of MOCOA in CMOS techniques

The MOCOA can be also realised using other types of electronic amplifiers e.g. classic OA-s, current conveyors or amplifiers with a current feedback amplifier (Fig. 3).

The MOCOA enables, in an easy way, realisation of current amplifiers of low integer or fractional values of amplification without using additional external elements. This can be realised by applying output signals to the selected number of outputs and the feedback to the determined number of other outputs. Non-used outputs are connected to the reference terminal having zero potential. The switching of output terminals can be performed by means of analogue key sets controlled by a digital signal $D_m(d_1,d_2...d_m) = \beta$ (Fig. 4), where symbol $\beta$ denotes the number of keys connecting the amplifier outputs to the input terminal.

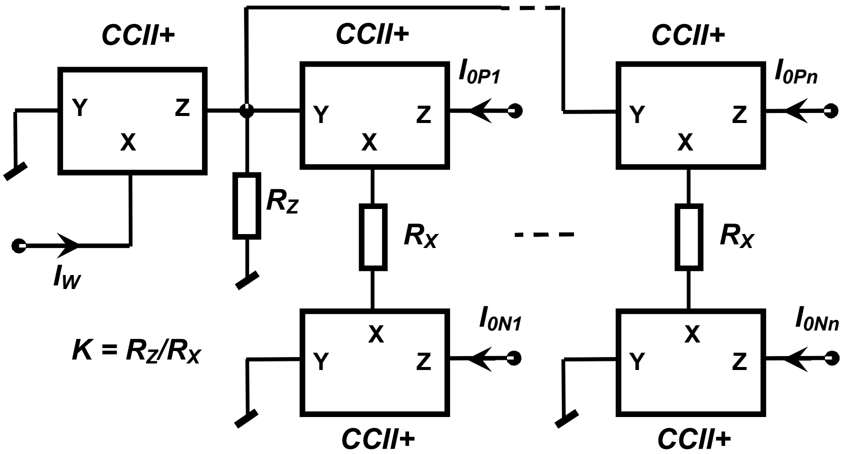


Fig. 3 Realisation MOCOA on the current conveyor basis

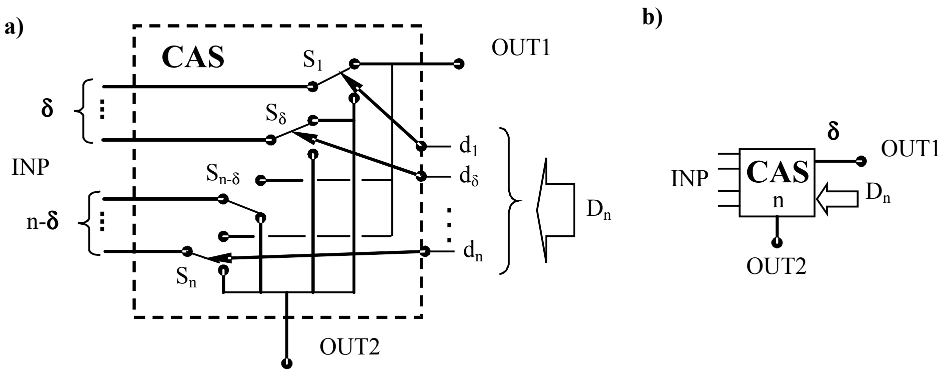


Fig. 4 Analogue key set controlled by digital signals

## 2. GENERAL CONCEPTION OF THE OSCILLATOR WITH ONE MIOA

Basing on a current amplifier with digitally controlled amplifications, which is constructed on the one MOCOA, can realise an oscillation circuit shown in Fig. 5.

Assuming that the blocks $T_1$ and $T_2$ of the circuit is described by the second order transmittances:

$$T_1(s) = \frac{I_{T1}}{I_{01}} = \frac{a_0}{s^2 + b_1 s + b_0} \tag{2}$$

$$T_2(s) = \frac{I_{T2}}{I_{02}} = \frac{a_1 s}{s^2 + b_1 s + b_0} \tag{3}$$

the whole circuit is described by the characteristic equation:

$$\alpha T_1(s) + \beta T_2(s) = \gamma \tag{4}$$

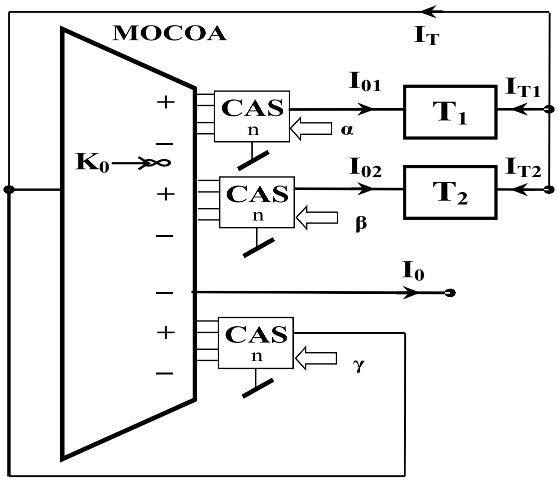


Fig. 5 General conception of the oscillator with one MOCOA

which, taking into account the relationships (1) and (2), can be presented as follows:

$$\gamma s^2 + (\gamma b_1 - \beta a_1)s + (\gamma b_0 - \alpha a_0) = 0 \tag{5}$$

Basing on the above equation, the condition of oscillation (CO) takes the following form:

$$b_1 = \frac{\beta}{\gamma} a_1 \tag{6}$$

and the frequency of oscillation (FO) has the following value:

$$f_0 = \frac{1}{2\pi}\sqrt{b_0 - \frac{\alpha}{\gamma} a_0} \tag{7}$$

So, the CO and FO can be digitally tuned by means of the coefficients β and α. The tuning step can be set by the γ coefficient. If the suggested oscillator is to be a circuit with one MIOA, its block $T_1$ and $T_2$ should be a passive circuit of RLC or RC type.

## 3. OSCILLATOR WITH PASSIVE CIRCUIT RC

Second order current transmittances in a passive circuit can be also obtained in more complicated resistances/capacitance circuit RC. It is composed of input low-pass filter $R_1C_1$ and two output filters: low-pass and high-pass filters composed of $R_2C_2$ elements. Current $I_{01}$ is input signal for $T_1(s)$ transmittance and current $I_{02}$ for $T_2(s)$ transmittance. That is why after a connection to it digitally controlled MIOA in the way presented in Fig. 6, an oscillator described by the following dependences:

$$T_1(s) = \frac{I_T}{I_{01}} = \frac{\alpha}{(sR_1C_1 + 1)(sR_2C_2 + 1)} \tag{8}$$

from $I_{02} = 0$, and:

$$T_1(s) = \frac{I_T}{I_{01}} = \frac{\beta s R_2 C_2}{(sR_1C_1 + 1)(sR_2C_2 + 1)} \tag{9}$$

from $I_{01} = 0$ is obtained. A characteristic equation has the following form:

$$s^2 + s\frac{\gamma(R_1C_1 + R_2C_2) - \beta R_2C_2}{\gamma R_1C_1R_2C_2} + \frac{\gamma - \alpha}{\gamma R_1C_1R_2C_2} = 0 \tag{10}$$

Hence, a condition of oscillation (CO) and frequency of oscillation (FO) is the following:

$$\frac{R_1C_1}{R_2C_2} + (1 - \frac{\beta}{\gamma}) = 0 \tag{11}$$

$$\omega_0 = \sqrt{\frac{1 - \frac{\alpha}{\gamma}}{R_1C_1R_2C_2}} \tag{12}$$

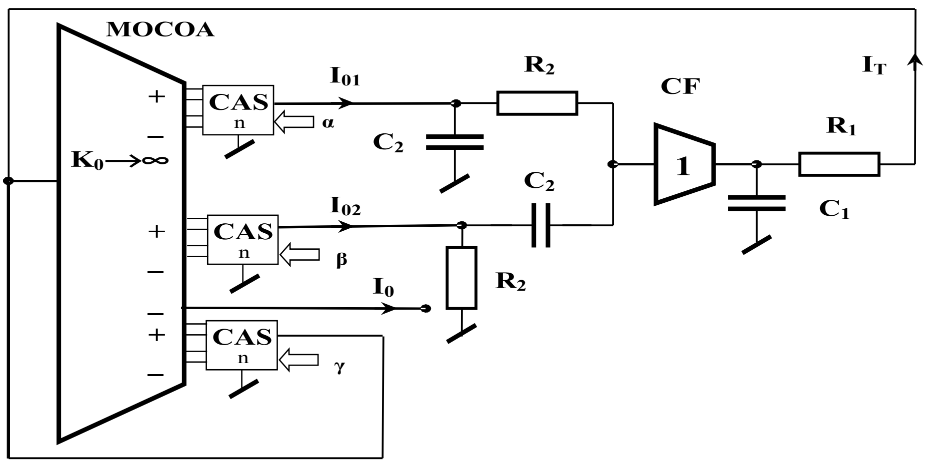


Fig. 6. Oscillator with one MOCOA with RC passive circuit and additional current follower

In order to verify a conception of oscillators with MOCOA simulations for the circuit in Fig. 6 for $R_1$=$R_2$=1kΩ, $C_1$=$C_2$=3.2nF as well which are presented above. The models of an ideal amplifier of MOCOA type, have been applied there. The impact of parameter β value change in the waveform of amplifier output signal, has been investigated which has been presented in Fig. 7.

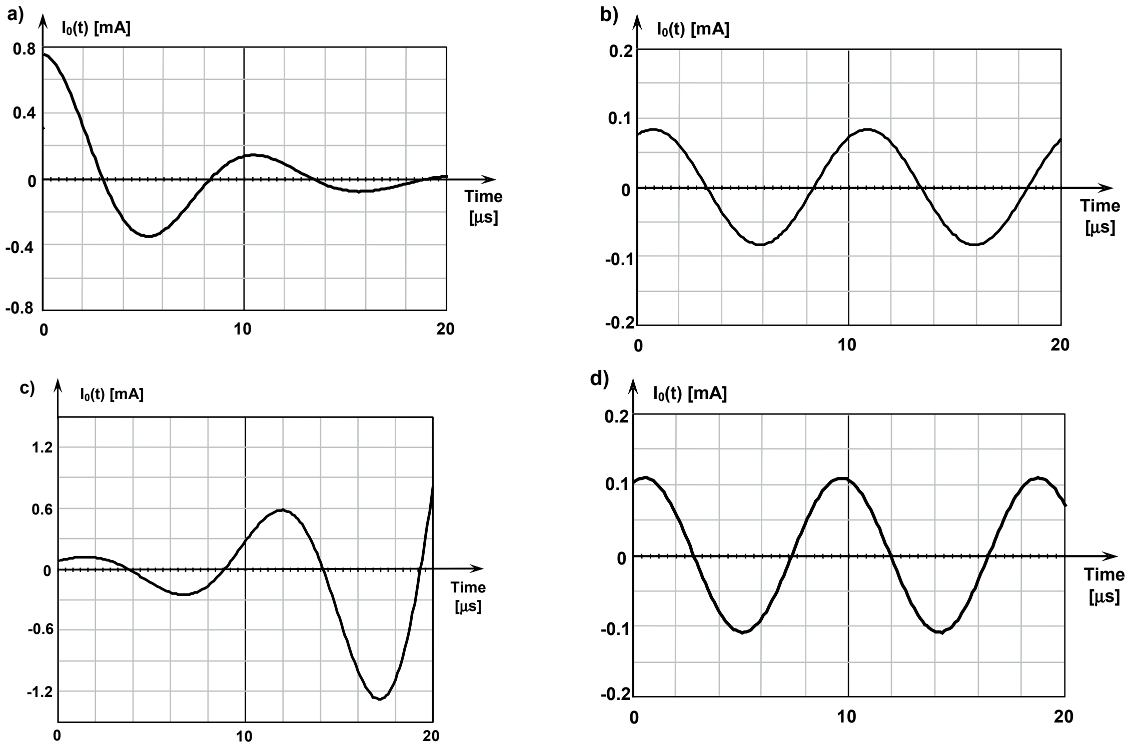


Fig. 7. Waveform of MOCOA output signal for: $\alpha$ = -3 and $\beta$ = 1 (a), $\beta$ = 2 (b), $\beta$ = 3 (c), $\alpha$ = -4 and $\beta$ = 2 (d)

## 5.CONCLUSION

Multiple output current operational amplifier due to its developed internal structure in relation to classic current amplifier is the very versatile circuit. It enables the realisation of circuits which are more complicated and having new properties but using less number of additional external elements. Oscillators having digitally tuned parameters are adequate examples there. The preliminary analysis shown that it can be applied in high stable acoustical generators.

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