Programmable Multiphase Sinusoidal Oscillator

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ABSTRACT
A reconfigurable current mode programmable multiphase sinusoidal oscillator is realized using digitally controlled low voltage CMOS current conveyors. The realized current mode programmable multiphase sinusoidal oscillator can provide independent digital control to its oscillating frequency through n-bit control words with high resolution capability, as well as reconfigurability. The realized multiphase oscillator is suitable as programmable analog module for current mode field programmable analog array. The programmable multiphase sinusoidal oscillator is designed and verified using PSPICE and the results thus obtained justify the theory.

Keywords
Current conveyors, current mode filters, oscillators.

1. INTRODUCTION
Recently, the introduction of digital control to the current conveyor (CCII) has boosted its functional capability and versatility in addition to its higher signal bandwidth and greater linearity. This digital control has eased the on chip control of continuous time systems with high resolution capability and reconfigurability [1-14].

This paper basically deals with the realization of current mode programmable multiphase sinusoidal oscillator using digitally controlled low voltage CMOS CCII [2-7]. The realized programmable multiphase sinusoidal oscillator (PMSO) can provide independent and direct digital control to its oscillating frequency through n-bit control words. The current mode PMSO can also provide multiphase voltage outputs just by loading the current outputs with appropriate equal valued resistors. The PMSO can be used as a programmable module of a field programmable analog array (FPAA) [15-17]. To verify the theory, the realized PMSO is designed and verified using PSPICE and the results thus obtained justify the theory.

2. THE CMOS DPCCII
The digitally programmable CCII (DPCCII) symbol is shown in “Figure 1(a)” and its CMOS implementation with 4-bit control word is shown in “Figure 1(b)” [2-8]. The current summing network (CSN) is included at port-X. The transfer matrix of the DPCCII can be expressed as

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ \alpha & 0 & 0 \\ 0 & \pm\beta N^m & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \quad (1)$$

Thus the port voltages and currents for DPCCII can be expressed as

$$\begin{aligned} I_Y &= 0, \\ V_X &= \alpha V_Y, \\ I_Z &= \pm\beta N^m I_X \end{aligned} \quad (2)$$

In equation (2) α is the voltage transfer gain from terminal-Y to terminal-X and β is the current transfer gain from X to Z. Both the voltage gain (α*)* and the current gain (β) are ideally unity. N is an n-bit digital control word, the plus sign (+) is for I_{Z+} and minus sign (-) is for I_Z-. The power integer m = 1 for current summing network (CSN) at port-Z and m = -1 for current summing network (CSN) at port-X of the DPCCII [1], [4-8]. The additional number of Z+ or Z- outputs may be added as per requirement just by connecting in parallel a set of PMOS and NMOS for each output as shown in “Figure 1(b)”.

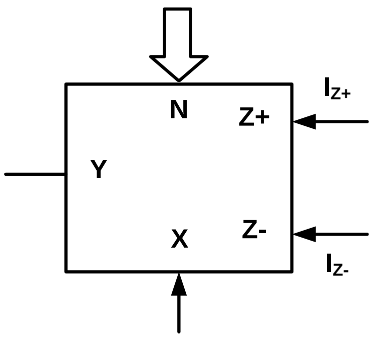

Fig 1(a): Symbol for n-bit DPCCII

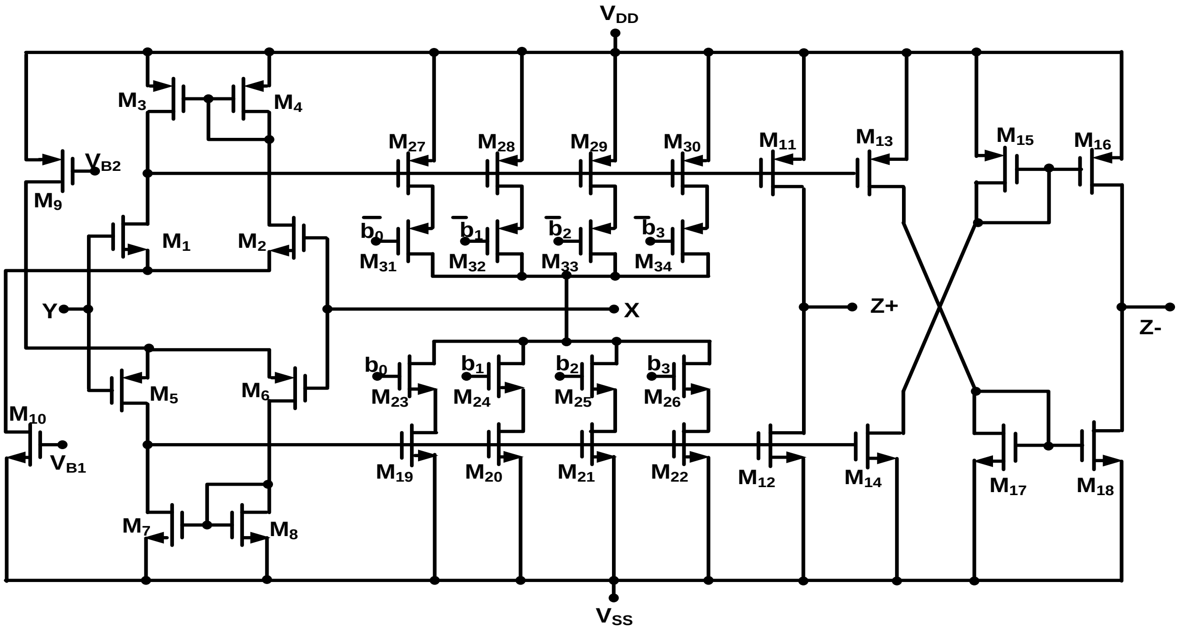

Fig 1(b): The CMOS implementation of a 4-bit DPCCII with CSN at port X

3. THE PMSO CIRCUIT

The current mode PMSO circuit using low voltage digitally controlled CMOS DPCCII with m = 1, is shown in "Figure 2". The circuit uses three DPCCII and two CCII, each one with two outputs along with grounded R and C elements. The CCIIs are also implemented in low voltage CMOS form without CSN at port-X [8].

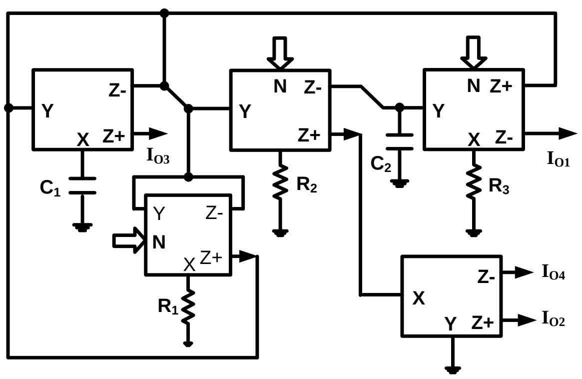

Fig 2: The PMSO circuit

The routine analysis yields its characteristics equation as follows.

$$s^2 + s\frac{N}{C_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) + \frac{N^2}{R_2 R_3 C_1 C_2} = 0 \qquad (3)$$

Equation (3) yields the condition of oscillation as

$$R_1 = R_2 \qquad 4(a)$$

and the frequency of oscillation as

$$f_0 = \frac{N}{2\pi\sqrt{C_1 C_2 R_2 R_3}} \qquad 4(b)$$

With $R_1 = R_2 = R_3 = R$, and $C_1 = C_2 = C$, the frequency of oscillation reduces to

$$f_0 = \frac{N}{2\pi RC} \qquad (5)$$

From equation (5) it is evident that the, frequency of oscillation f_0 can directly and independently be controlled through digital control word N.

The output current phasers can also be expressed as

$$\begin{aligned} I_{o2} &= jI_{o1} \\ I_{o3} &= -I_{o1} \\ I_{o4} &= -jI_{o1} \end{aligned} \qquad (6)$$

and are shown in "Figure 3". Thus the PMSO gives four quadrature outputs with equal magnitudes.

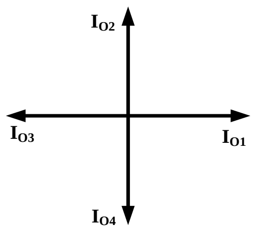

Fig 3: The output current phasers of the PMSO

Taking the non-idealities of current conveyors into account as given in equation (2), for the PMSO of "Figure 2", with identical α and β for all the current conveyors, the ideal relationship of the oscillating frequency given in equation(5), yields the non-ideal f_0, as follows.

$$f_0 = \frac{N}{2\pi RC}\sqrt{\alpha\beta} \tag{7}$$

It is evident from equation (7) that the non-idealities slightly affect the of the oscillating frequency f_0.

4. DESIGN AND VERIFICATION

The realized digitally controlled current mode PMSO of "Figure 2" was designed and verified by performing PSPICE simulation with supply voltage ± 0.75 V using CMOS TSMC 0.25 µm technology parameters. The aspect ratios used are given in the Table 1. The PMSO was verified using the DPCCII with the CSN at port-Z (i.e. m = 1).

Table 1: The aspect ratios of the MOSFETs of the DPCCII

MOSFETs	W µm	L µm
M_1, M_2, M_5, M_6	5	0.25
M_3, M_4, M_7, M_8	0.5	0.5
M_9, M_{10}	0.5	0.25
M_{11}, M_{12}, M_{13}, M_{14}, M_{15}, M_{16}, M_{17}, M_{18}, M_{19}, M_{23}, M_{27}, M_{31}	25	0.25
M_{20}, M_{24}, M_{28}, M_{32}	50	0.25
M_{21}, M_{25}, M_{29}, M_{33}	100	0.25
M_{22}, M_{26}, M_{30}, M_{34}	200	0.25

The PMSO was initially designed for an oscillating frequency of f_0 = 33 kHz with N = 1, R = 4.6 kΩ and C = 1 nF. The observed wave shapes of the four current outputs are shown in "Figure 4(a)". To obtain the four voltage quadrature outputs, as given in "Figure 4(a)", the respective four current outputs were loaded with equal valued resistors each with 10kΩ. Then the pole frequency was controlled through digital control word N. The observed frequency variation of the PMSO for different control words are given in "Figure 4(b)". The observed frequency spectrums at N = 4 for current and voltage outputs are given in "Figure 4(c). Thus observed results of "Figure 4", show the close conformity with the design.

5. CONCLUSION

The current mode multiphase sinusoidal oscillator is realized using digitally controlled low voltage CMOS current conveyors. The realized current mode multiphase sinusoidal oscillator also provides four phase quadrature voltage outputs just by loading the four current outputs with appropriate equal valued resistors. The oscillating frequency of the oscillator is digitally programmable through n-bit control words with high resolution capability and reconfigurability. The programmable

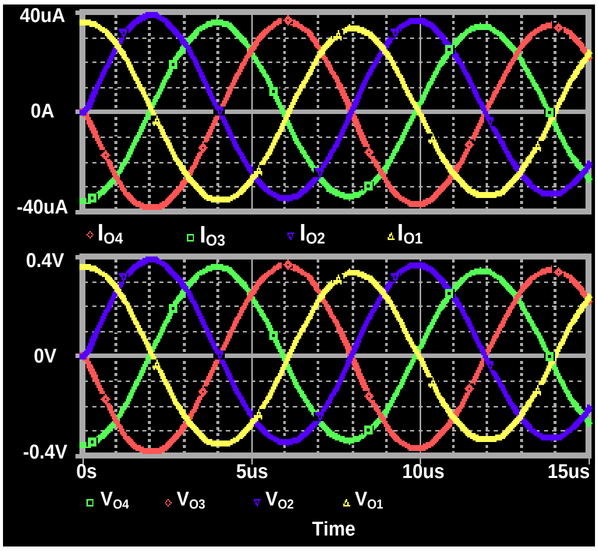

Fig 4(a): The four phase quadrature current and voltage outputs of the PMSO at N = 4

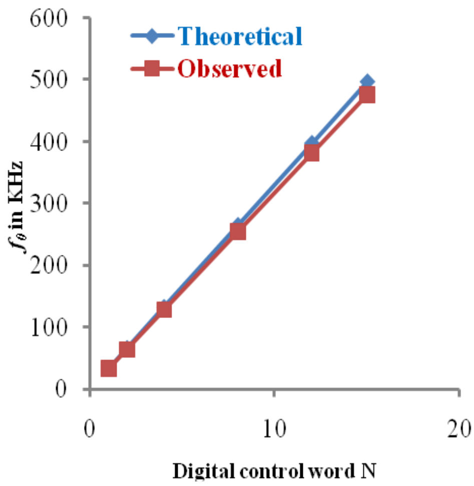

Fig 4(b): Variation of frequency of oscillation with digital control word N of the PMSO

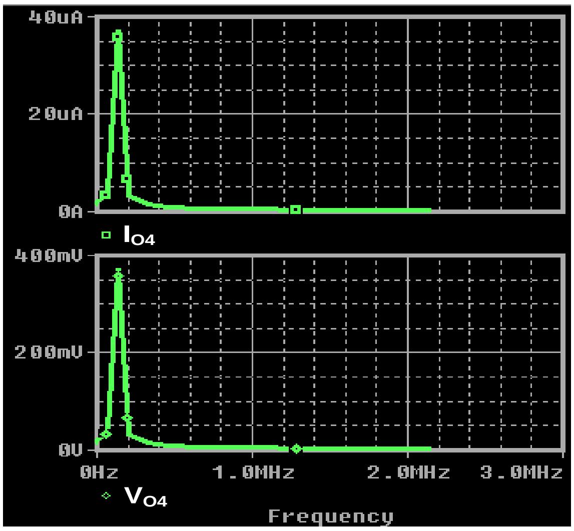

Fig 4(c): Frequency spectrum of the PMSO at digital control word N = 4

multiphase sinusoidal oscillator is suitable as a programmable analog module for the current mode field programmable analog array. The realized multiphase sinusoidal oscillator was designed with minimal passive components spread and verified using PSPICE. All the results thus obtained justify the theory.

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