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Digitally Programmable Voltage Mode Quadrature Oscillator Using Current Conveyors

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Abstract:- A simple technique is presented to realize a digitally programmable voltage mode quadrature oscillator using second generation current conveyors. Firstly, the current conveyors based tunable quadrature oscillator is realised. A digital block is introduced in the realized tunable quadrature oscillator so that the oscillator can be controlled digitally. The realized Digitally Programmable Quadrature oscillators enjoys attractive features such as use of low components count, independent digital control to frequency of oscillation and low sensitivity figures. The realized digitally programmable quadrature oscillator circuits are designed and verified with attractive results.

Keywords:- Current conveyors, Voltage-mode circuits, quadrature oscillators.

I. INTRODUCTION

The current conveyors, introduced in 1968, is an extremely powerful analogue building block, combining voltage and current–mode capability. It possess higher signal bandwidth, greater linearity and large dynamic range. It has proved to be functionally flexible and versatile, rapidly gaining acceptance as a practical device with a wide range of high performance circuit and system application [1]-[2]. And the use of grounded resistors and capacitors is beneficial from the point of view of IC fabrication.

The sinusoidal quadrature oscillator find wide applications in instrumentation and communication systems. As a result several circuits using various active devices have been reported in technical literature [3]-[14]. In this paper a sinusoidal quadrature oscillator has been proposed using current conveyor as a basic building block. For the realization of digitally programmable quadrature oscillator (DPQO). Firstly a tunable quadrature oscillator using two current conveyors, three grounded resistors, one grounded capacitor and one floating resistor and capacitor, is realized. Secondly, digital block is introduced in the realized tunable quadrature oscillator so that it can be controlled digitally. So the realized oscillator provides wide adjustment range through digital control word, high resolution capability and complete reconfigure ability. The working ability of the oscillator has been confirmed by SPICE Simulation.

II. QUADRATURE OSCILLATOR

The quadrature oscillator is given in Figure 1. It uses two CCIIs, four resistors and two capacitors where R_0, R_1, R_3 and C_0 are in grounded form. For digital control the grounded resistors and capacitors can be replaced by the digitally programmable impendence multiplier, according to the requirement.

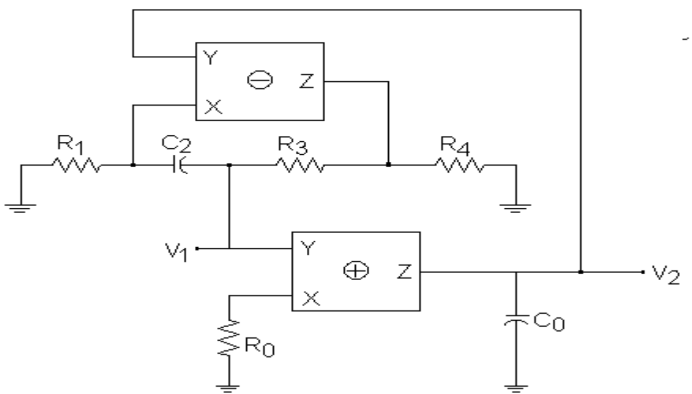


Fig.1: Tunable quadrature oscillator.

The routine analysis of the circuit gives the characteristic equation

$$s^2 + s\left(\frac{1}{R_2C_1} - \frac{1}{R_0C_0}\right) + \left(\frac{R_3/R_1}{R_0C_0R_2C_1}\right) = 0 \qquad (1)$$

Which results in the condition of oscillation as

$$C_0\,R_0 = R_2\,C_1 \qquad (2)$$

and frequency of Oscillation as

$$\omega_0 = \left(\frac{R_3/R_1}{R_0C_0R_2C_1}\right)^{\frac{1}{2}} \qquad (3)$$

For the digital control of the realised tunable quadrature oscillator, the grounded resistor or capacitor can be replaced by digitally programmable impedence multiplier, as per the requirement. For digital control, the digital module of reference [3] is used.

III. DIGITAL CONTROL MODULE

he realization of the digital control module(DCM) used in the DPGIM is shown in Figure 1(a), which uses R-2R ladder and analog switching array [6].

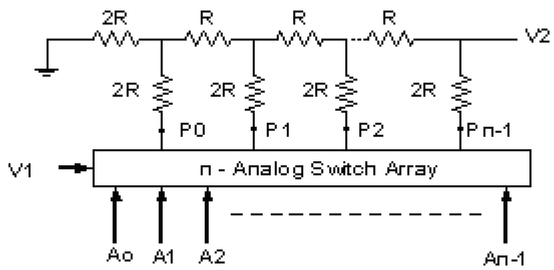


Fig. 2(a): Digital Control Module- DCM.

Its routine analysis yields the output voltage V_2 as

$$V_2 = \frac{V_1}{2^n}\left(A_0 + 2A_1 + 4A_2 + - - - + 2^{n-1}A_{n-1}\right) \qquad (4)$$

Where, A_0, A_1, …, A_{n-1} are the bit values of the n-bit digital control word (N). Equation (1) can also be expressed as

$$V_2 = K_1V_1 \qquad (5)$$

where , $K_1 = N/2^n$.

The equivalent of the Figure 2(a) is given in Figure 2(b) and now onwards shall be expressed as the K_1-Block. If two stages of the K_1- Block with same control word are cascaded through a voltage buffer as shown in Figure 2(c),

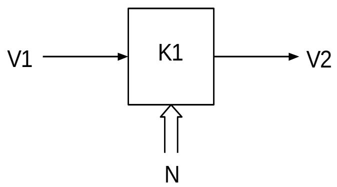


Fig. 2(b): The K_1 – Block.

the transfer gain can be expressed as

$$\frac{V_2}{V_1} = K_2 \qquad (6)$$

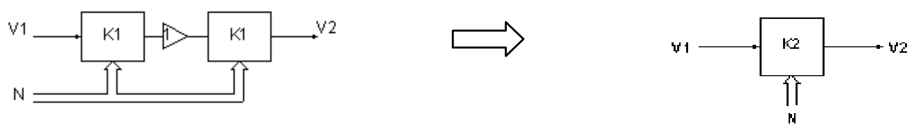
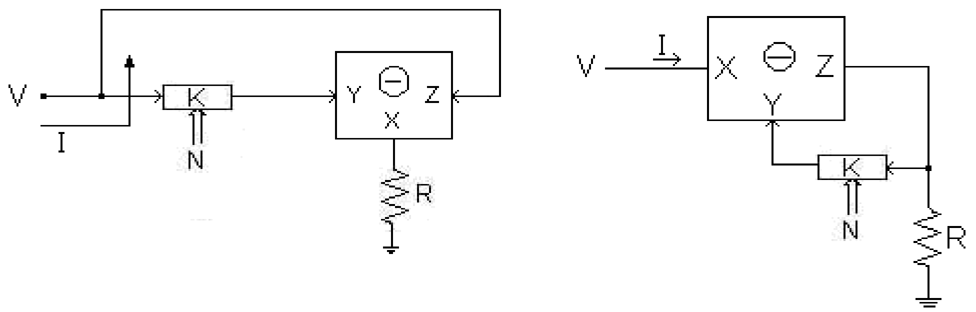


Fig. 2(c): The K_2 – Block

Where, $K_2 = K_1 K_1 = (N/2^n)^2$. Henceforth, this double stage block shall be referred as the K_2 – Block. Its equivalent is also shown in Figure 2(c). It is obvious from equation (5) and (6) that the transfer gain of the K_1 and K_2 modules can be controlled through digital control word (N)

IV. DIGITALLY PROGRAMMABLE RESISTANCE MULTIPLIERS (DPRM)

The basic scheme for realizing digitally programmable impedance multiplier (DPIM) reference [14]-[15] is shown in Figure 3. It uses one $CCII^-$, one digital control module of Figure 1, and the grounded impedance(Z) under control.



(a) (b)

Fig. 3: Digitally programmable impedence multipliers

The routine analysis for DPIM of Figure 3(a) and Figure 3(b) yields the input impedance function respectively as

$$Z_{in} = \frac{V}{I} = \frac{R}{K} \tag{7a}$$

$$Z_{in} = \frac{V}{I} = KR \tag{7b}$$

where, $K = \frac{N}{2^n}$. It is to be noted that K-block input is to be buffered and K-block can be K_1 or K_2 block as per requirement.

V. DIGITALLY PROGRAMMABLE QUADRATURE OSCILLATOR

For the realization of digitally programmable quadrature oscillator, the DPRM of section 2 can be substituted in place of grounded resistors.

Case I : Digitally Programmable Quadrature Oscillator 1 (DPQO1)

For realizing DPQO1, the two resistances R_3 and R_1 will be replaced by DPIM reference [14] [15]. With the digital control module, the quadrature oscillator using CCII is shown in Fig 4. Where $R_1=R_4/K_1$ and $R_3=R_5K_1$

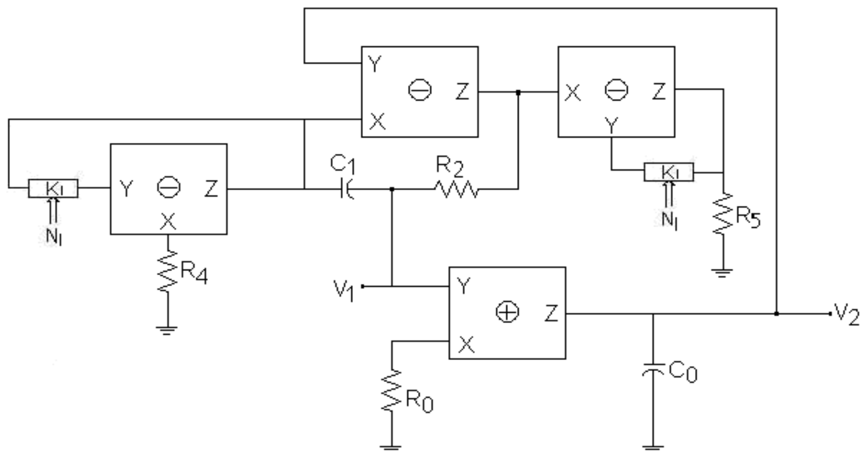


Fig. 4: DPQO with digital control word N_1

This results in characteristic equation as

$$s^2 + s\left(\frac{1}{R_2C_1} - \frac{1}{R_0C_0}\right) + \left(\frac{\dfrac{R_5K_1}{R_4/K_1}}{R_0C_0R_2C_1}\right) = 0 \tag{8}$$

condition of oscillation: $C_0\, R_0 = R_2\, C_1$

Frequency of oscillation is

$$\omega_0 = \left(\frac{\mathrm{R}_5\ \mathrm{K}_1^2/R_4}{R_0C_0R_2C_1}\right)^{\frac{1}{2}} \tag{9}$$

$R_0 = R_2 = R_4 = R_5 = R$ and $C_0 = C_1 = C$

$$\omega_0 = \frac{N}{2^n RC} \tag{10}$$

It is to be noted that the frequency of oscillation ω_0 can be tuned over a wide range by controlling the digital control N_1

Case II: Digitally Programmable Quadrature Oscillator 2 (DPQO2)

For realizing DPQO2 the grounded resistor R_1 is replaced by DPIM reference [14] having K_1 – block where as R_3 is replaced by DPIM having K_2 – block, shown in Figure 5. Where $R_1 = R_4K_1$ and $R_3 = R_5K_2$

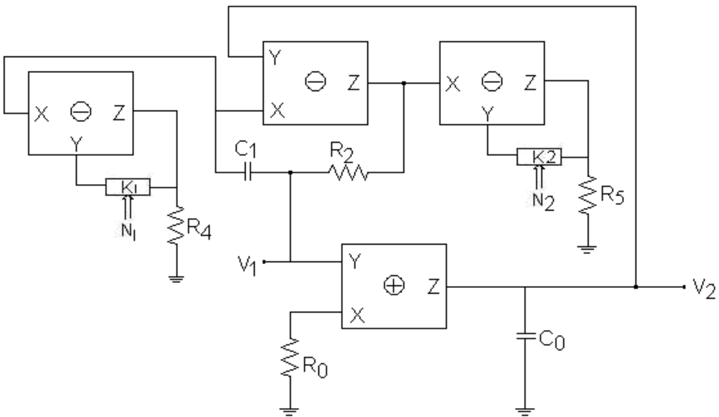


Fig. 5: DPQO with digital control word N_1 and N_2.

This results in characteristic equation as

$$s^2 + s\left(\frac{1}{R_2C_1} - \frac{1}{R_0C_0}\right) + \left(\frac{\dfrac{R_5K_2}{R_4K_1}}{R_0C_0R_2C_1}\right) = 0 \tag{11}$$

Condition of oscillation: $C_0\, R_0 = R_2\, C_1$

$$\omega_0 = \left(\frac{\mathrm{R}_5\ \mathrm{K}_2/R_4K_1}{R_0C_0R_2C_1}\right)^{\frac{1}{2}} \tag{12}$$

If $R_0 = R_2 = R_4 = R_5 = R$ and $C_0 = C_1 = C$

$$\omega_0 = \frac{1}{RC}\left(\frac{N_2}{N_1}\right)^{\frac{1}{2}} \tag{13}$$

From equation (13), it is clear that the frequency of oscillation can be controlled directly through the digital control word N_2 and inversely through digital control word N_1.

Hence in both the cases, the realized digitally programmable quadrature oscillators, frequency of oscillation can be controlled digitally by varying digital control word N.

VI. SENSITIVITY STUDY

The incremental sensitivities for parameters used in digitally programmable quadrature oscillator given in equation (1) have been analysed and given as

$$\left|S^{\omega_0}_{R_0,R_1,R_2,C_0,C_1}\right| = \frac{1}{2} \tag{14a}$$

For equation (7) i.e. DPQO1 the sensitivity study is

$$\left|S^{\omega_0}_{R,C,K_1}\right| = 1 \tag{14b}$$

And the sensitivity study for equation (8) i.e. DPQO2 is

$$\left|S^{\omega_0}_{R,C}\right| = 1 \qquad \left|S^{\omega_0}_{K_1,K_2}\right| = 1 \tag{14c}$$

The sensitivity of frequency of oscillation to passive and active components is quite low.

VII. SIMULATION RESULTS

Tunable quadrature oscillator of Figure 1 was designed for a cut off frequency f_0 = 3kHz with C = 0.01 μF and R = 5.3 kΩ. The simulated response of this tunable quadrature oscillator is shown in Figure 6. The DPQO1 of Figure 4 having K_1 block was designed for cut off frequency f_0 = 2.8125 KHz with N=15, C = 0.01 μF and R = 5.3 kΩ. Its simulated response is shown in Figure 7(a). The frequency variation with digital control word N is shown in Figure 7(b). The second case i.e. DPQO2 of Figure 5 having two K-block was designed for the cut off frequency $f_0 = 3(N_2/N_1)^{1/2}$ KHz with C = 0.01 μF and R = 5.3 KΩ. The simulated response is shown in Figure 8(a). The variation of frequency with digital control words N_1 and N_2 are shown in Figure 8(b). Also the frequency variation with R_4 and R_1 is also shown in Figure 8(c) and 8(d) respectively.

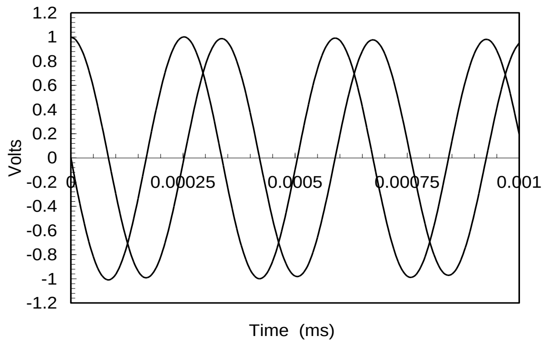


Fig. 6: Response for tunable quadrature oscillator.

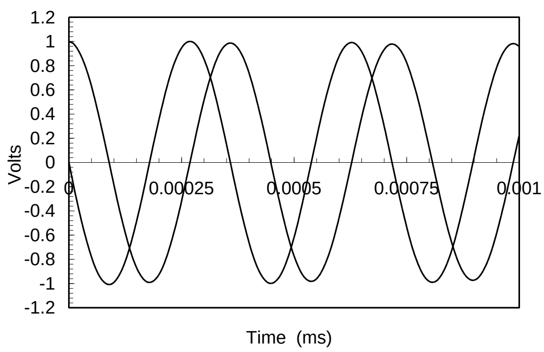


Fig. 7(a): Response for DPQO1 control

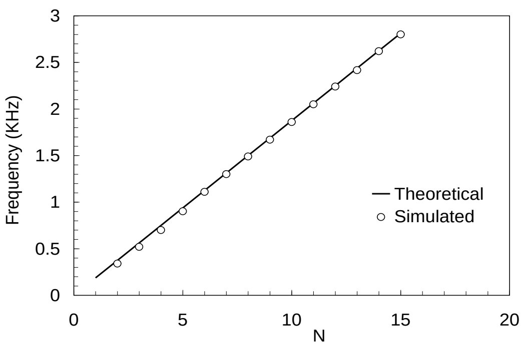


Fig. 7(b): Frequency variation of DPQO1 with digital Word N_1

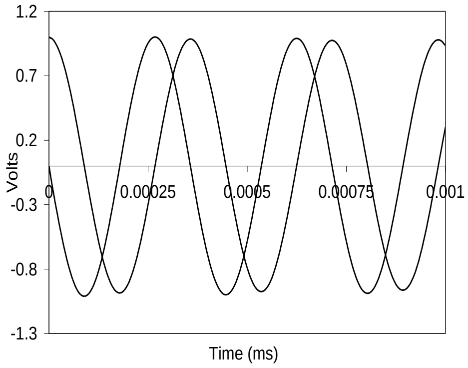


Fig. 8(a): Response for DPQO2.

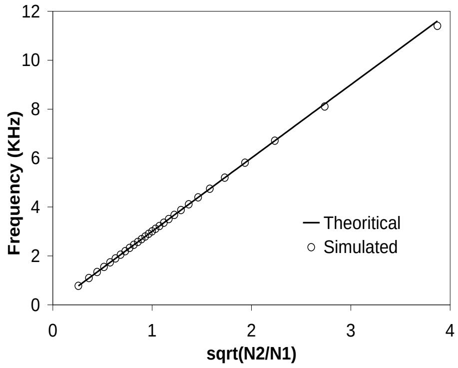


Fig. 8(b): Frequency variation of DPQO2 with digital Control word N_1 and N_2

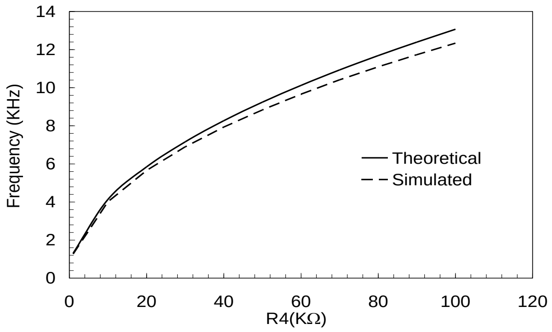


Fig. 8(c): Frequency variation of DPQO2 with R_4

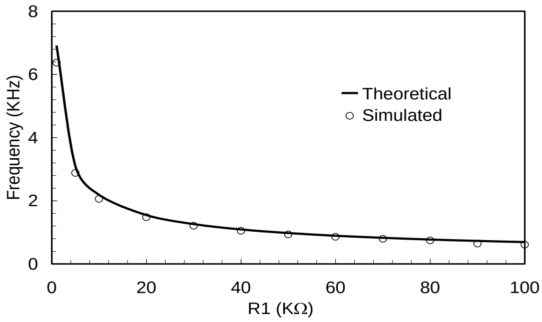


Fig. 8(d): Frequency variation of DPQO2 with R_1

VIII. CONCLUSION

A simple technique has been used to transform the tunable quadrature oscillator into a digitally programmable quadrature oscillator. The realized DPQOs exhibits quadrature outputs with equal magnitudes. The oscillator enjoys the attractive features of digital tuning of frequency of oscillation ω_0 through digital control words, low incremental sensitivities, large dynamic range, suitability for IC implementation and high resolution capability. The used digitally programmable circuit parameters are reconfigurable. The resolution of the digital control can be improved by using larger number of bits in the digital control module. All the realized circuits were designed and simulated using PSPICE . The results thus obtained verify the theory.

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