Design of Multilphase Sinusoidal Oscillator Based on FTFN*

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Abstract. A new multiphase sinusoidal oscillator is presented. The circuit realization uses the four-terminal floating nullor（FTFN）to generate arbitrary n current sinusoidal signals equally spaced in phase. The proposed circuit consists of n CCCIIs, n grounded capacitors and 2n grounded resistors. The oscillation condition and oscillation frequency are independently controlled. The former depends on the grounded resistance R_1 and the latter depends on the grounded capacitor C. The circuit also enjoys having simple structure and very low component count and it is highly suitable for monolithic implementation.

Keywords: Four-Terminal Floating Nullor, Multiphase Sinusoidal Oscillator, PSPICE Simulation.

1 Introduction

Current-mode circuits have become very attractive due to some important advantages in comparison with their counterpart voltage-mode circuits. These advantages are: a wider bandwidth and dynamic range, a greater linearity, and a lower power consumption. In numerous active device, four-terminal floating nullor(FTFNs) is very conspicuous. This model is more flexible and versatile than an operational amplifier(OA) and a current conveyor(CCII), it can easily replace arbitrary nulltor and norator device without requiring any conditions. The performance of high frequency is good, the impedance of output is very high, and it can directly realizes high order transfer function by cascade not need of match.

At present, many filters have been developed which use FTFNs. However, few papers concern sinusoidal oscillators using FTFNs. In this papers, a new multiphase sinusoidal oscillator is presented useing the four-terminal floating nullor（FTFN）to generate arbitrary n current sinusoidal signals equally spaced in phase. The oscillation condition and oscillation frequency are independently controlled [1-3].

2 Circuit Description of FTFN

An FTFN is equivalent to an ideal nullor or is called an operational floating amplifier. The nullor model is shown in Fig.1 and its port relations can be characterized as equation (1).

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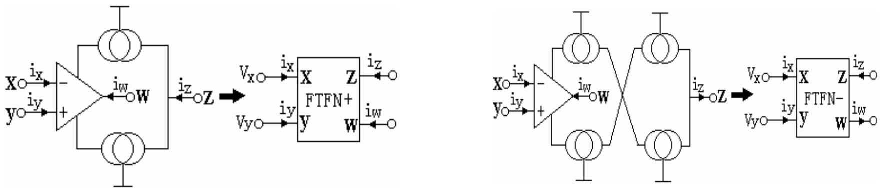
$$v_x = v_y\,, \quad i_x = i_y = 0\,, \quad i_w = i_z\,. \tag{1}$$

The plus and minus sign in equation(1) denotes positive and negative types of the positive and negative type four-terminal floating nullor (FTFN++ and FTFN-) respectively. Although the output impedance of the Z and W terminal of the FTFN are arbitrary, we adopt an FTFN where the output impedance of the Z terminal is very high, and that of the W terminal is very low, as shown in Fig. 1b.



(a) (b)

Fig. 1. (a) FTFN+; (b) FTFN-

3 Circuit Principle of Multiphase Sinusoidal Oscillation

The design of a multiphase sinusoidal oscillator has received a great deal of attention in the fields of power electronics, communications and signal processing. Numerous techniques for designing a multiphase sinusoidal oscillator have been developed. Early versions of the multiphase sinusoidal oscillator circuits provide good performance but they share common disadvantages of being complicated and constructed with large number of both active and passive elements. A simple multiphase sinusoidal oscillator is presented in the previous papers [4-14]. This paper proposes a new and generalized scheme to realize a multiphase oscillator with a arbitrary n number of the phase signal of the oscillator, where $n \geq 3$ and n can be odd. The signal flow graph of multiphase sinusoidal oscillator's principle is shown in Fig.2.

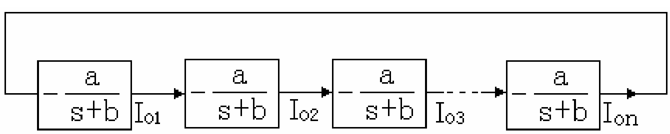


Fig. 2. Signal flow graph of multiphase sinusoidal oscillator's principle

In Fig.2, the basic building block is a first-order negative lowpass section. Every section has the same transfer function and can been described as

$$A_I(s) = -\frac{a}{s+b}\,. \tag{2}$$

In addition, a is the gain and b is the pole angular frequency.

Now connecting n identical block results in structure of Fig.2. From Fig.2, the open loop gain can be expressed as

$$T(s) = [A_I(s)]^n = (-\frac{a}{s+b})^n \quad . \tag{3}$$

For oscillation to sustain, the Barkhausen criteria must be satisfied:

$$T(j\omega) = 1 \quad . \tag{4}$$

That is:

$$(-\frac{a}{b+j\omega})^n = e^{j2\pi m}(m = 1,2,3,4,\cdots) , \tag{5}$$

Therefore the proper equation can be characterized by

$$a + (b + j\omega)(\cos\frac{2\pi m}{n} + j\sin\frac{2\pi m}{n}) = 0 . \tag{6}$$

From (6) the system will oscillate continuously at a frequency, provided that the following oscillation condition(OC) and oscillation frequency(OF) are satisfied

OF: $$\omega_0 = -btg\frac{2\pi m}{n} , \tag{7}$$

OC: $$a = -b / \cos\frac{2\pi m}{n} . \tag{8}$$

The circuit can be oscillated only when n is odd number.

For example, when

$$n = 3 , \tag{9}$$

the oscillation condition (OC) and oscillation frequency(OF) can be written as

OF: $$\omega_0 = \sqrt{3}b \approx 1.732b \ , \tag{10}$$

OC: $$a = 2b \ . \tag{11}$$

The oscillation condition (OC) and oscillation frequency(OF) are illustrated in table I when $n = 3,5,7,9$. The arbitrary n-phase sinusoidal oscillator is shown in Fig.3. It consist of CCCII- and phase-shifting circuits.

Table 1. The oscillation condition (OC) and oscillation frequency(OF)

n-phase oscillator	OC	OF(ω_0)
3	a=2b	1.732b
5	a=1.236b	0.727b
7	a=1.11b	0.48b
9	a=1.064b	0.36b

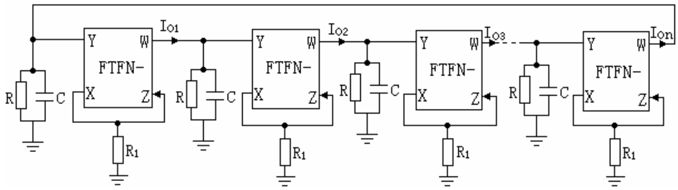


Fig. 3. Generalized building block of the arbitrary n-phase sinusoidal oscillators

From Fig.3, it is not hard to find the current transfer function in every section

$$A_I(s) = -\frac{1/R_1C}{s+1/RC} \, , \tag{12}$$

where $a = 1/R_1C$, $b = 1/RC$. (13)

From table.1, the oscillation condition (OC) and oscillation frequency(OF) when $n = 5$

OF: $\omega_0 = 0.727/RC$, (14)

OC: $1/R_1 = 1.236/R$. (15)

On amplitude frequency, the same transfer function of every section can be given as

$$A_I(j\omega_0) = -\frac{R/R_1}{0.727j+1} \, . \tag{16}$$

Hence, it can be concluded that the oscillation condition and oscillation frequency are independently controlled. The condition of oscillation can be adjusted by tuning R_1 without disturbing the frequency of oscillation. At the same time, the frequency of oscillation can be adjusted by tuning *C* without disturbing the condition of oscillation.

4 Simulations Results

The validity of the oscillation for $n = 3$ and $n = 5$ is verified using PSPICE. The negative FTFN(FTFN-) consists of two AD844 op amp and modified Wilson current mirror. The supply voltage is taken as $V_{cc} = \pm 5$ V. The passive components are given in table 2. The results shown in Fig.4 validate the feasibility of the proposed circuit.

Table 2. The parameter of the third and fifth phase sinusoidal oscillators

n-phase	*R*(kΩ)	R_1(kΩ)	*C*(uF)	OC	OF(kHz)
3	10	5	0.01	$1/R_1C$=2/*RC*	2.76
5	10	8.1	0.01	$1/R_1C$=1.237/*RC*	2.76

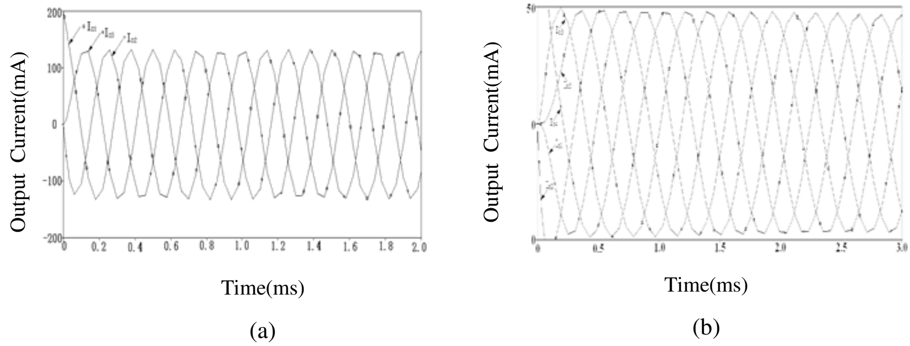


Fig. 4. (a) Output currents of three phase oscillator; (b) Output currents of five phase oscillator

5 Conclusions

A novel and generalized scheme to realize multiphase sinusoidal oscillators has been presented. The proposed method is able to produce multiphase output currents equally spaced in phase for odd-numbers of phases. The circuit realization employs n FTFNs, n grounded capacitors and 2n grounded resistors. The circuits offer several advantages. It has simple structure and very small number of grounded passive components. Besides, the control of oscillation condition is only depended on the grounded resistance R_1 and does not interfere with the oscillation frequency, which depends on the grounded capacitor C. Whereas, The proposed circuits are therefore highly suitable for IC implementation.

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