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Research Article

Design and Implementation of a Multiphase Sinusoidal Oscillator Using Ic Lt1228

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ABSTRACT

This research paper focuses on the development and implementation of a multiphase sinusoidal oscillator (MSO) based on the LT1228 integrated circuit. The proposed circuit is designed to produce sinusoidal signals with precise phase shifts, making it well-suited for used in communication systems, signal processing, and instrumentation. The oscillator operates on a transconductance-based principle, utilizing the operational transconductance amplifier (OTA) characteristics of the LT1228. Theoretical analysis, design equations, and simulation results validate the MSO's capability to achieve the desired frequency and phase stability. Additionally, the design approach is informed by prior research on voltage-mode and current-mode MSOs, emphasizing electronic tunability and stability. A major benefit of this circuit is its incorporation of negative feedback, which enhances stability and performance, all while utilizing just one resistor and one capacitor, leading to a simplified design.

Keywords: LT1228, Multiphase sinusoidal oscillator (MSO), Voltage Mode (VM), Current feedback amplifier (CFA).

INTRODUCTION

Multiphase sinusoidal oscillators (MSOs) are essential components in a wide range of electronic systems, such as signal processing, telecommunications, and control applications [1-12]. The multiphase sinusoidal oscillator (MSO) has attracted considerable attention in diverse fields, notably in telecommunications for its application in phase-shift keying (PSK) modulation [3] and in areas such as measurement systems and power electronics [6]. Recently there has been an increasing trend toward utilizing active building blocks in analog signal processing to streamline circuit design. These active elements enable the construction of functional circuits with fewer passive components, thereby minimizing design complexity. These oscillators produce sinusoidal signals with defined phase differences, making them essential for applications such as phase modulators, quadrature mixers, and vector signal generators. The LT1228 integrated circuit, which combines an operational transconductance amplifier (OTA) and a current feedback amplifier (CFA), is well-suited for designing MSOs that demand high stability and accuracy. Its electronically tunable transconductance gain allows for accurate frequency control by adjusting the bias current [1, 4].

To develop an understanding of the IC LT1228 as a filter, insights were adopted from Reference [1], which provided a comprehensive overview of the LT1228 and its performance under various conditions. For a deeper understanding of oscillators, References [4, 7] were consulted, focusing on different operating conditions and the implementation of oscillators using active building blocks with minimal passive components. The design and analysis of the MSO, along with the study of integrators and active building blocks, were supported by References [2, 12-33]. These references offered valuable information on the behavior of MSOs under varying phase-shift conditions, frequency control techniques, and considerations related to input and output impedance.

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OVERVIEW OF IC LT1228

Manufactured by Linear Technology, The LT1228 is a widely available IC housed in an 8-pin plastic dual in-line package (PDIP). It includes eight terminals: two for inputs, three for outputs, one terminal for adjusting the DC bias current—facilitating electronic tuning of the transconductance—and two terminals for accommodating a broad power supply range, spanning from ±2 V to ±15 V. Figure 1 illustrates the LT1228's electrical symbol. This active device integrates an Operational Transconductance Amplifier (OTA) with a Current Feedback Amplifier (CFA).The OTA acts as a voltage-controlled current source, where the output current varies in proportion to the external bias current [1, 4, 24]. This property, along with its electronically adjustable transconductance, makes it particularly suitable for applications such as filters, oscillators, and modulators. The CFA offers high-speed operation with improved bandwidth and slew rate, ideal for applications requiring fast signal processing with minimal distortion. Figure 2 depicts the equivalent circuit of the LT1228.

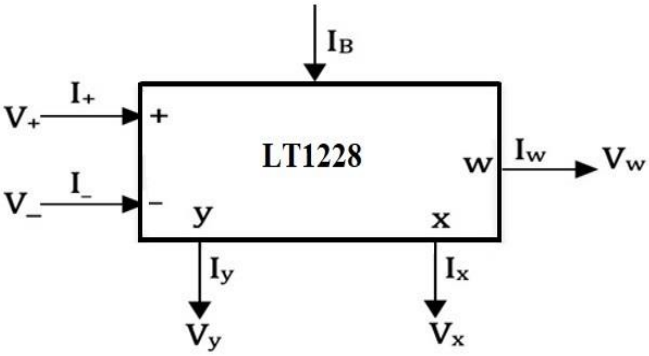

Fig.1. Symbol of IC LT1228

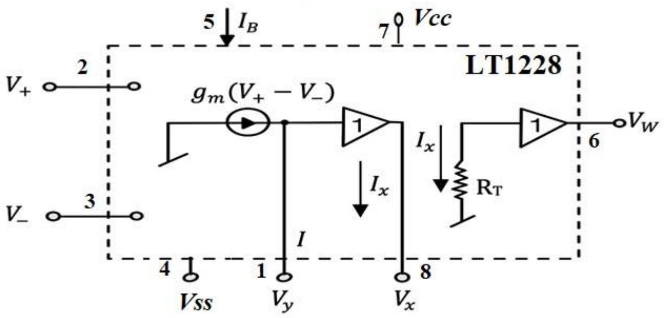

Fig.2. Equivalent circuit of IC LT1228

The associated port relationship matrix equation, provided in Equation (1), serves as the foundation for subsequent analysis [1, 4].

$$\begin{pmatrix} I_{V+} \\ I_{V-} \\ I_y \\ V_x \\ V_w \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ g_m & -g_m & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & R_T & 0 \end{pmatrix} \begin{pmatrix} V_+ \\ V_- \\ V_y \\ V_x \\ I_w \end{pmatrix} \tag{1}$$

The matrix equation given in equation (1) defines the ideal terminal characteristics of the LT1228, describing the relationship between voltage and current. It provides a mathematical model that captures the device's functional behavior and interactions at its terminals. It defines the internal connections between ports and their response to various circuit configurations.

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As shown in Fig. 1 and Fig. 2, the transconductance (g_m) can be easily adjusted using Bias current (I_B). How does g_m, changes with the change in the I_B, and the thermal voltage (V_T) can be seen in equation (2).

$$g_m = \frac{I_B}{3.87V_T} \tag{2}$$

where V_T is the thermal voltage.

g_m at room temperature is around g_m= 10.I_B.

CIRCUIT DESIGN OF MULTIPHASE SINUSOIDAL OSCILLATOR

A typical multiphase sinusoidal oscillator (MSO) is structured by connecting n identical stages in a cascaded manner, where n is an odd integer with a minimum value of 3. Each stage operates as a lossy integrator—essentially a first-order low-pass filter—that contributes to the cumulative phase shift, as depicted in Figure 3. In this setup, 'a' denotes the time constant and 'k' represents the gain. The signal from the nth stage is fed into the next lossy integrator, enabling progressive phase shifts across stages without requiring an external amplifier. The output of the nth stage is fed back to the input of the first stage, forming a closed loop that ensures sustained oscillations. This architecture inherently allows only an odd number of phase outputs, limiting n to values like 3, 5, 7, etc.

From the block diagram shown in Figure 3, the frequency of oscillation (FO) and the condition for oscillation (CO) can be derived as follows:

Frequency of oscillation:

$$w_{osc} = \frac{1}{a} \tan\left(\frac{\pi}{n}\right) \tag{3}$$

Condition of oscillation:

$$k \geq \sec\left(\frac{\pi}{n}\right) \tag{4}$$

Equations (3) and (4) reveal that the frequency of oscillation and the condition for oscillation can be independently controlled.

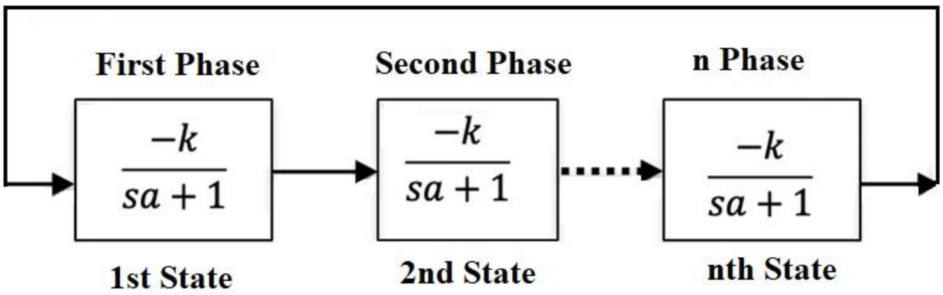

Fig. 3. Lossy integrator-based MSO

In a three-phase sinusoidal oscillator, the output waveforms are expected to be equally spaced in phase across a complete cycle of 360°. For an n-phase system, the ideal phase difference between consecutive output signals is given by:

$$\Delta\emptyset = \frac{(\Delta t)}{T} \times 360° \tag{5}$$

Where Δt the time difference between 2 waves, T is time period. In the present design, with n = 3, the theoretical phase difference between each output is 120°. This ensures proper multiphase operation, which is particularly important in applications such as motor drives, communication systems, and signal generation.

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IMPLEMENTATION OF N-CASCADED LT1228 BASED MSO

The proposed multiphase sinusoidal oscillator (MSO) is realized using cascaded lossy integrator stages, as previously described. Figure 4 illustrates a potential configuration where each lossy integrator is implemented with the LT1228 integrated circuit.

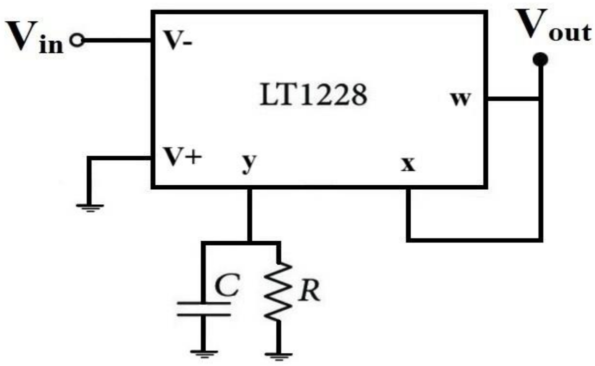

Fig. 4. LT1228-based lossy integrator

Figure 5 presents the complete MSO design using the LT1228, incorporating negative voltage feedback. The input terminal exhibits a high input impedance, ensuring minimal loading. Each integrator stage consists of a single LT1228 IC, along with a grounded capacitor and grounded resistor. The voltage transfer function for an individual integrator stage is expressed as follows:

$$\frac{V_{out}}{V_{in}} = \frac{-g_m R}{SCR + 1} \tag{6}$$

Based on equations (3) and (4),

FO (f_{osc}) is governed by:

$$\omega_{osc} = \frac{1}{CR} \tan\left(\frac{\pi}{n}\right) \tag{7}$$

where, C = Capacitance, R = Resistance,

n = Number of phases.

The Condition of Oscillation is governed by:

$$g_m R \geq \sec\left(\frac{\pi}{n}\right) \tag{8}$$

Based on Equations (7) and (8), the condition of oscillation can be independently and electronically adjusted using the bias current (I_B), whereas the frequency of oscillation is determined by the values of the resistor and capacitor components. By substituting n = 3 into the derived expressions, the necessary condition for the onset of oscillation can be determined

Similarly, a single block in Fig. 4 can be cascaded in an n-cascaded manner with negative voltage feedback, as we can see in Figure 5, and at each stage, we can collect an output at a different phase.

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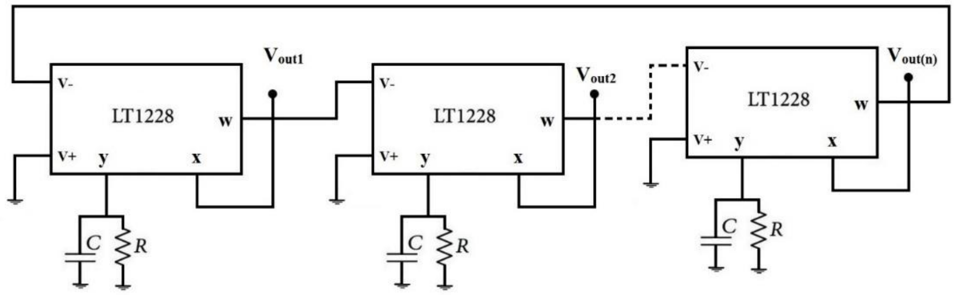

Fig. 5. LT1228 based MSO with negative voltage feedback

SIMULATION RESULT

PSPICE simulations has been conducted for Fig. 5 using n is equal to 3. Table 1 represents the simulated and theoretical values for different values of capacitors. The oscillator circuit is tested with C = 1 nF, R = 1 kΩ, and I_B= 271.5 µA that found simulated frequency of oscillation is 280.25 kHz and theoretical value is 275.66 kHz. The simulated frequency of oscillation closely matched the theoretical calculations, with a very less error margin. The time difference between first two consecutive wave is 1.19 us and phase difference is 122.7° from equation (5), similarly the time difference between 2nd and 3rd wave is 1.15 and phase difference 118.2° from equation (5), which is nearly equal to the theoratical i.e. 120°. The oscillator maintained phase across multiple outputs. Figure 6 represents the initial state of oscillator. Figure 7 shows the steady state of multiphase oscillator respectively.

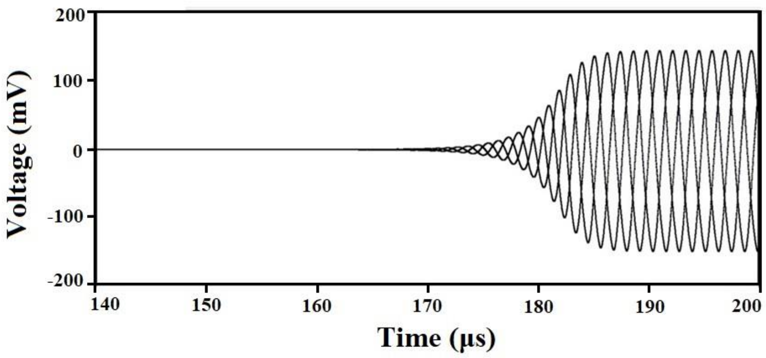

Fig. 6. Initial state of oscillator

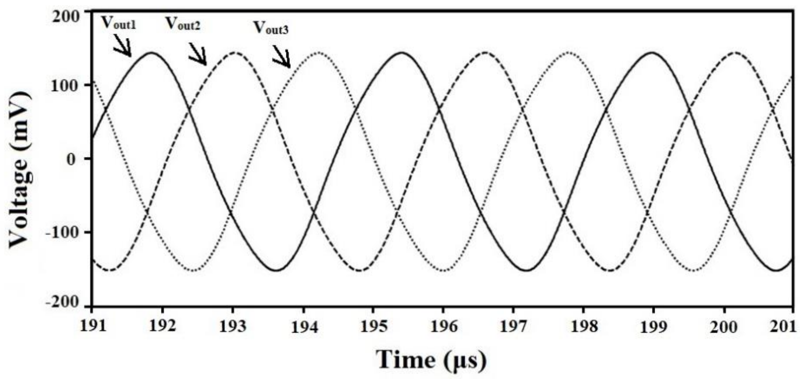

Fig. 7. Steady state of oscillator

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Table 1: The simulated and theoretical values of oscillator for different values of capacitors

S. No.	R (kΩ)	C (nF)	T(μs)	Frequency (Simulated) (kHz)	Frequency (Theoretical) (kHz)
1	1	0.5	1.81	552.03	551.13
2	1	1	3.56	280.25	275.66
3	1	2	7.08	141.1	137.8
4	1	4	14.11	70.86	68.91
5	1	7	24.64	40.62	39.3
6	1	9	31.68	31.56	30.6
7	1	10	35.17	28.42	27.56

NON-IDEALITIES ANALYSIS

Figure 9 represents the non-ideal analysis incorporating parasitic elements leads to modified system behavior. By accounting for these non-idealities, equations (8) and (9) are obtained, these represent the practical expressions that define both the oscillation frequency, and the criteria required to initiate oscillation.

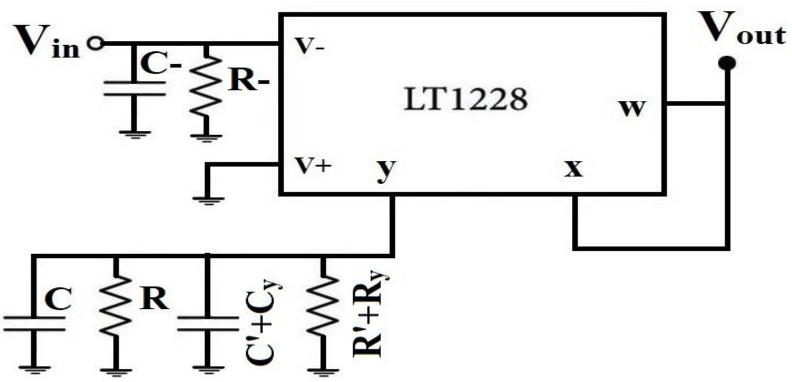

Fig. 9. The LT1228-based lossy integrator with parasitic

The oscillation frequency, considering the effect of parasitic elements, is given by:

$$\omega = \frac{1}{(R||R_y||R'||\frac{1}{g_m})(C_y + C + C')} \tan\left(\frac{\pi}{n}\right) \tag{9}$$

The condition for oscillation with parasitic parameter

$$g_m\left(R\ ||R_y||R'||\frac{1}{g_m}\right).(R_-) \geq \sec\left(\frac{\pi}{n}\right) \tag{10}$$

Compared to the ideal case, minor adjustments in the capacitor and resistor values can effectively compensate for the non-ideal behavior of the oscillator

COMPARATIVE ANALYSIS

Table 2. represents a comparative analysis of various previously reported multiphase sinusoidal oscillators [2, 12-16, 18-22, 25-30], focusing on key aspects such as the design technique used, type and number of active building blocks per phase, requirement of additional amplifiers, grounding of passive components, and the total number of resistors and capacitors employed per phase. It also highlights whether the circuits support electronic tunability of condition

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of oscillation (CO), along with their mode of output. The final column outlines the underlying technology. This comprehensive evaluation emphasizes the benifit of this proposed LT1228-based MSO in terms of simplicity, tunability, and performance efficiency.

Table 2: Comparative Overview of Existing Multiphase Sinusoidal Oscillator

Reference	Technique Type	Active Block (ABB)	Active Devices per Phase	Extra Amplifier Used	Grounded Capacitor	R + C Elements
[2]	Lossy Integrator	VDDDA	1	No	Yes	1 + 1
[12]	All-pass	CDTA	1	No	No	2 + 1
[13]	Lossy Integrator	CCII	1	No	No	3 + 1
[14]	Lossy Integrator	OTRA	1	Yes	No	2 + 1
[15]	Lossy Integrator	CFA	1	No	*	2 + 0
[16]	All-pass	CDTA	2	Yes	No	0 + 1
[18]	Lossy Integrator	CDBA	1	No	No	2 + 1
[19]	Lossy Integrator	OPA	1	Yes	Yes	3 + 1
[20]	All-pass	OPA	1	Yes	Yes	3 + 1
[21]	Lossy Integrator	CCII	1	No	No	2 + 1
[22]	Lossy Integrator	CCCII	1	No	Yes	0 + 2
[25]	Lossy Integrator	CCII	1	No	No	2 + 1
[26]	All-pass	CDU	1	Yes	Yes	1 + 1
[27]	Lossy Integrator	CA	1	No	Yes	0 + 1
[28]	All-pass	DO-VDBA	1	No	Yes	0 + 1
[29]	All-pass	CCCDTA	1	No	No	1 + 1
[30]	Lossy Integrator	CFOA	1	No	*	2 + 0
Proposed	Lossy Integrator	LT1228	1	No	Yes	1+1

CONCLUSION

The Proposed multiphase sinusoidal oscillator using the IC LT1228 successfully generates stable and phase-accurate sinusoidal waveforms. The theoretical analysis and simulation results align closely, demonstrating the oscillator's potential for applications in communication and signal processing domains. The ability to electronically tune the oscillation frequency and maintain independent control of oscillation conditions is a significant advantage.

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