A Current-mode Square/Triangular Wave Generator with Independently Linear Controllability of Frequency and Amplitudes

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Abstract: A current-mode square/triangular wave is presented. Due to operation in current-mode, the proposed circuit provides a wide frequency response, a low supply voltage, low power consumption and electronic controllability. Thus, it is very suitable for use in portable and battery-powered equipments. The feature of the proposed circuit is that it can provide simultaneously both a square wave and a triangular wave whose frequency and amplitudes can be independently controlled by input bias currents. The performances of the proposed circuit are explored through HSPICE using BSIM3V3 model from MOSIS.

1. Introduction

Voltage/Current Controlled Oscillators (VCOs/CCOs) play important roles in many fields such as instrumentation, electronic and communication systems. The VCO based on OTA has been proposed [1]. Its advantage is that the oscillation frequency is independent of the temperature. However, it has much a complicated scheme and a small range of the oscillation frequencies due to comprising of operational amplifiers, which have narrow bandwidth relative to an OTA [2]. Especially the amplitude adjustments of square/triangular wave can not be achieved. Recently, current controlled oscillator over a wide range has been introduced [3], this circuit performs square/triangular waves with electronic controllability only frequency, not include its amplitudes. Hence, these schemes still do not provide sufficient stability to implement them as a precise component in the design of instrumentation and communication systems, particularly under varying environment conditions. Besides, most of literatures consume high supply voltage and power consumption.

In the last decade, there has been much effort to reduce the supply voltage of an analog CMOS system. This is due to the command for portable and battery-powered equipment. Since a low-voltage operating circuit becomes necessary, the current–mode technique is ideally suited for this purpose [4]. Unfortunately, most of previous square/triangular wave generators work in voltage-mode, which is not suitable for working in a current-mode signal processing system.

The purpose of this article is to present a realization of a novel square/triangular wave generator functioning in current-mode. All circuits can be realized using a CMOS technology. The simulation results through HSPICE using BSIM3V3 model of MOSIS are achieved to confirm that the realized circuit can provide a wide dynamic range, a low supply voltage, a wide bandwidth including low-power consumption. In addition, the output frequency and amplitudes can be independently-linearly tuned through input bias currents. Consequently, the proposed circuit is very appropriate for further fabricating into Integrated Circuit (IC) form to employ in the current-mode signal processing system.

2. Circuit Principle and Description

2.1 The Proposed Principle

The proposed square/triangular wave generator is composed of 3 main parts, illustrated in Fig. 1. Current-mode Schmitt trigger is employed to change a triangular wave to a square wave, which is feed-back as input signal to current-mode integrator. A current squarer is employed to make the integrator able to linearly control of frequency. As briefly explained, the current-mode square wave can be achieved at the output of the Schmitt trigger while the current-mode triangular wave can be obtained at the output of the integrator.

![Fig. 1: Proposed principle](image)

2.2 Circuit Description and Operation

Fig. 3 shows circuit details of the current squarer [5]. The current-mode Schmitt trigger, shown in Fig. 1 [6], whose transfer characteristic can be found in Fig. 4. If the aspect ratios of the MOS transistors are set to appropriate values, it can be found that both output current and threshold current can be adjusted by a control current: $I_{\text{Control}}$. The circuit description of the current-mode integrator is shown in Fig. 5. From straightforward analysis, the output current of the integrator: $I_{\text{Tri}}(t)$ can be obtained by

$$I_{\text{Tri}}(t) = \frac{K g_m}{C} \int_0^t I_{\text{Square}}(t) \, dt$$

(1)

where $K$ is an arbitrary value dependent on current source $KI$ and aspect ratio of M16.

Period ($T$) of output signals can be easily achieved from Eqn. (1) by

$$I_{\text{Control}} = \frac{K g_m}{C} \int_0^{T/2} I_{\text{Control}} \, dt.$$  

(2)

Fig. 2 shows circuit details of the current squarer [5]. The current-mode Schmitt trigger, shown in Fig. 1 [6], whose transfer characteristic can be found in Fig. 4. If the aspect ratios of the MOS transistors are set to appropriate values, it can be found that both output current and threshold current can be adjusted by a control current: $I_{\text{Control}}$. The circuit description of the current-mode integrator is shown in Fig. 5. From straightforward analysis, the output current of the integrator: $I_{\text{Tri}}(t)$ can be obtained by

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addition, the frequency deviations due to variations of supply voltages are also investigated. The maximum frequency deviation is only 0.78% when supply voltages vary from ±1V to ±2.5V, where frequency is set to 1MHz at ±1V supply voltage. The frequency deviations due to temperature variations from 0 to 100°C, where frequency is set to 1MHz at the room temperature (27°C) show that the absolute maximum deviation is merely 1.8%. These deviations derive from the circuit performances such as DC offset currents, switching delays, stability of current with temperature and temperature coefficient of switching delays. The maximum consumed power is about 8.4μW.

4. Conclusion
A new square/triangular wave generator has been introduced. The realized circuit shows good performances, in which the oscillation frequency and output amplitudes can be independently controlled by input bias currents. The linear control of oscillation frequency can be achieved by employing a current square. The simulation results obtained from HSPICE confirm the theoretical anticipations, while the maximum frequency is up to 100MHz range. It is also found that the circuit can work at low-supply voltage (±1V) and low-power consumption (8.4μW). Consequently, the proposed circuit is very suitable for further implementing in integrated circuit to employ in a current-mode signal processing system.

References