วงจรกำเนิดความถี่แบบ RC ที่ใช้วงจร ขยายค่าความนำ 1 วงจร

อดิศักดิ์ มนต์ประภัสสร [1]
มหาวิทยาลัยเอเซียอาคเนย์

บทคัดย่อ

บทความนี้นำเสนอ วงจรกำเนิดความถี่แบบ RC ที่ใช้วงจรขยายค่าความนำความถี่สูง 1 วงจร ซึ่งสามารถผลิตความถี่ทางเอาท์พุทได้สูงถึง 75 เมกกะเฮิรต์ วงจรนี้ประกอบด้วยส่วนประกอบหลัก 3 ส่วนคือ 1) วงจรขยายค่าความนำแบบ CMOS ซึ่งประกอบด้วยมอสเฟท 4 ตัว และแหล่งจ่ายกระแสคงที่ 1 ตัว 2) วงจรแปลงกระแสเป็นแรงดันซึ่งประกอบด้วยตัวความต้านทาน 1 ตัว 3) โครงข่ายนำหน้า-ล้าหลัง ซึ่งประกอบด้วยตัวต้านทานและตัวเก็บประจุอย่างละ 2 ตัว นอกจากนี้ยังได้นำเทคโนโลยีใหม่ของมอสเฟท 0.8 μm มาใช้ในงานวิจัยนี้ด้วย

ในการทดลอง วงจรที่ออกแบบจะถูกเลียนแบบการทำงานโดยใช้โปรแกรม PSPICE ผลการเลียนแบบพบว่า วงจรที่นำเสนอในบทความนี้มีจุดเด่นคือ ให้ความถี่เอาท์พุทที่มีค่าสูงภายใต้การใช้อุปกรณ์และความต้องการกำลังงานที่ต่ำ โดยสัญญาณเอาท์พุทของวงจรกำเนิดความถี่ที่นำเสนอจะเป็นสัญญาณไซน์ซึ่งสามารถปรับค่าความถี่ได้โดยการปรับค่าของตัวต้านทานหรือตัวเก็บประจุ

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[1] *อาจารย์ ภาควิชาวิศวกรรมอิเล็กทรอนิกส์*

Single OTA RC-Oscillator

Adisak Monpapassorn [1]
South-East Asia University

Abstract

This paper describes an RC-oscillator that applies a high frequency CMOS Operational Transconductance Amplifier (OTA), which is capable of providing an output frequency up to 75 MHz. This circuit consists of three main components: 1) the OTA circuit which is composed of four MOSFETs and a constant current source 2) a current to voltage circuit with a resistor and 3) a lead-lag network which has two resistors and two capacitors. In addition, the new 0.8 μm MOSPET technology has been applied in this research project.

In one experiment, the design circuit was simulated using the PSPICE program. The most important results revealed that the proposed circuit design provides high output frequencies when employed in low-level environments, whether composed of devices or power consumption. The output of the proposed oscillator is displayed as a sine wave, which can adapt the frequency by adjusting the value of the resistance or capacitance.

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[1] *Lecturer, Department of Electronic Engineering*

1. Introduction

In recent years, some research papers in the field of RC oscillators have proposed various uses of amplifiers, such as Voltage Feedback Operational Amplifiers (VFOA) [1], Current Feedback Operational Amplifiers (CFOA) [2, 3], and Current Mirrors [4]. The disadvantages of the VFOA, CFOA and Current Mirror RC oscillators are that they require many components, high voltages, and high power consumption but yield low output frequencies. The circuit described in this paper addresses each of these disadvantages and demonstrates its improved efficiency over previous designs.

The research conducted on the single OTA RC-oscillator demonstrated that there are advantages in using this circuit rather than others: it requires fewer components (i.e. four MOSFETs, a constant current source, three resistors, and two capacitors); low voltages (+5V DC power supply); and low power consumption (single constant current source) yet it provides high output frequencies up to 75 MHz.

2. Principle and Propose Circuit

2.1 Positive feedback

Generally, the oscillator operation is based on the principle of positive feedback. Positive feedback is characterized by the condition wherein a portion of the output voltage of an amplifier is fed back to the input with no net phase shift, resulting in a reinforcement of the output signal. The basic idea is illustrated in Fig. 1. The in-phase feedback voltage is amplified to produce the output voltage, which in turn produces the feedback voltage. That is, a loop is created in which the signal sustains itself and a continuous sine wave output is produced. The resulting phenomenon is oscillation. Two conditions are required for a sustained state of oscillation: the phase shift around the feedback loop must be 0”, and the voltage gain around the closed feedback loop must equal to 1.

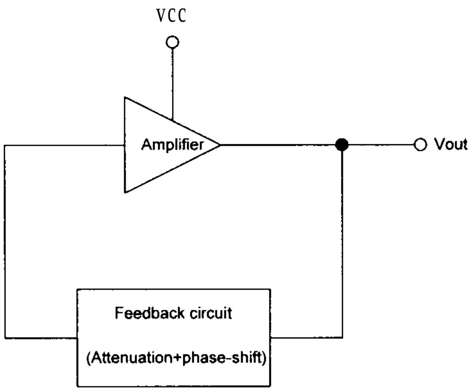

Fig. 1 Basic elements of an oscillator.

2.2 Proposed circuit

The principle of the proposed circuit is illustrated in Fig. 2 and the proposed circuit is displayed in Fig. 3. The current to voltage circuit is composed of R_3. The lead-lag network is composed of resistors R_1, R_2, and capacitors C_1, C_2. The R_1 and C_1 together form the lag portion of the network and the R_2 and C_2 form the lead portion. The operations of the circuit are as follows: at lower frequencies, the lead network dominates due to the high reactance of C_2; as the frequency increases, X_{C2} (X=reactance) decreases, thus allowing the output voltage to increase; at a specified frequency (f_r), the response of the lag network takes over, and the decreasing value of X_{C1} causes the output voltage to decrease. The attenuation rate of the lead-lag network when $R_1 = R_2 = R$ and $C_1 = C_2 = C$ is,

$$\frac{V_{out}}{V_{in}} = \frac{RX_c}{3RX_c + j\left(R^2 - X_c^2\right)} \tag{1}$$

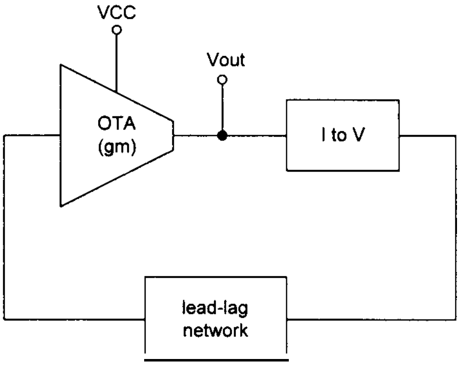

Fig. 2 Basic elements of the proposed oscillator.

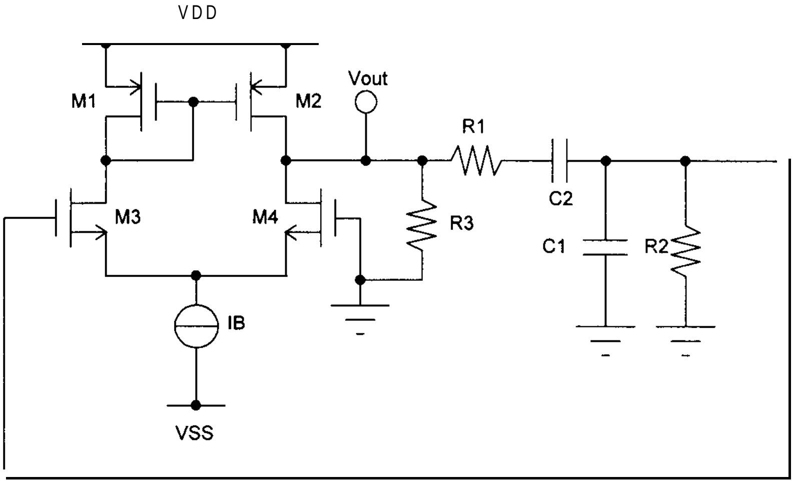

Fig. 3 The proposed oscillator circuit.

For a 0" phase angle there can be no j term. Recall from complex numbers in AC theory that a nonzero angle is associated with a complex number having a j term. Therefore, at f_r the j term is 0. Thus,

$$\frac{V_{out}}{V_{i}} = \frac{1}{3} \qquad (2)$$

From (1), we derive some specified frequency,

$$f_r = \frac{1}{2\pi RC} \qquad (3)$$

The operational transconductance amplifier circuit is composed of Ml -M4 and a constant current source (I_B). The current to voltage circuit is composed of R3. The voltage gain can be achieved from a combination of two circuits, when M3 and M4 have the same characteristics, the voltage gain from Allen and Holberg, 1988 [5] and Ohm's Law is,

$$A_v = \frac{W_2 L_1}{W_1 L_2}\sqrt{\frac{I_B \mu_{o3} C_{ox3} W_3}{L_3}}\left(\frac{R_3 Z_{in(network)}}{R_3 + Z_{in(network)}}\right) \qquad (4)$$

where μ_{o3} is the permitivity.

C_{ox3} is the capacitance per unit area of the gate oxide.

W is the channel width.

L is the channel length.

and

$$Z_{in(network)} = \left(R_1 - jX_{C2}\right) + \left(\frac{R_2\left(-jX_{C1}\right)}{R_2\left(-jX_{C1}\right)}\right)$$

From (2), the voltage gain must be equal to 3 or more, the oscillator circuit will then be oscillated. The voltage gain may be adjusted by the value adjustment of the W/L of M2.

3. Simulated Results

The propose oscillator circuit was simulated by using the PSPICE program. The circuit uses +5 VDC power supply and a 90 μA constant current source. The W/L parameter of Ml, M3 and M4 are 10 μm/0.8 μm ; M2 is 60 μm/0.8 μm, using a standard SPICE model of the 0.8 μm according to MOSFET technology. The value of R_3 is 1 KΩ. The output waveform of the circuit when $R_1 = R_2 = 10$ KΩ and $C_1 = C_2 = 0.1$ PF is shown in Fig. 4. The frequency spectrums included with the percent total harmonic distortion of the circuit, when $R_1 = R_2 = 10$ KR, $C_1 = C_2 = 0.1$ PF are shown in Fig. 5. The relative graphs between the output frequencies and the values of the capacitor when $R_1 = R_2 = 10$ KΩ are shown in Fig. 6. The margin of error between the theory and the simulation output frequencies, as illustrated in Fig. 6, resulted from the number of equivalent resistors and capacitors of the operational transconductance amplifier circuit.

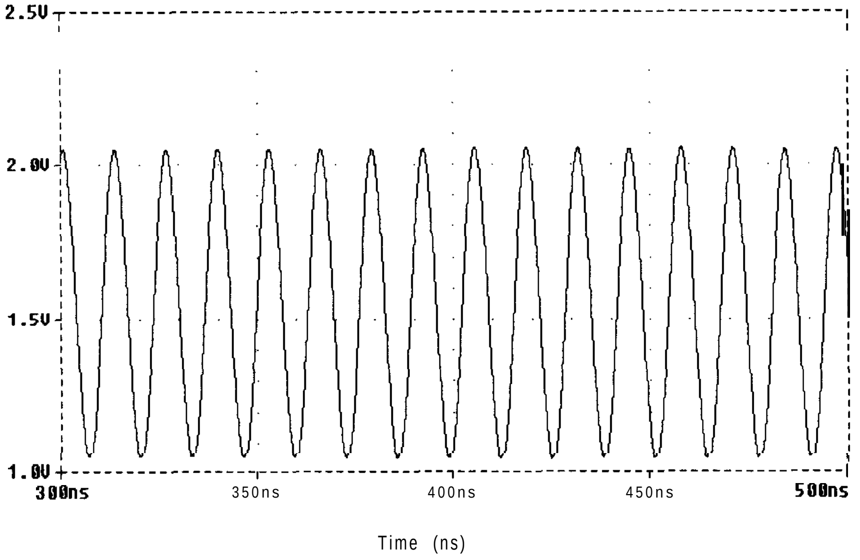

Fig. 4 The output signal of the proposed oscillator circuit.

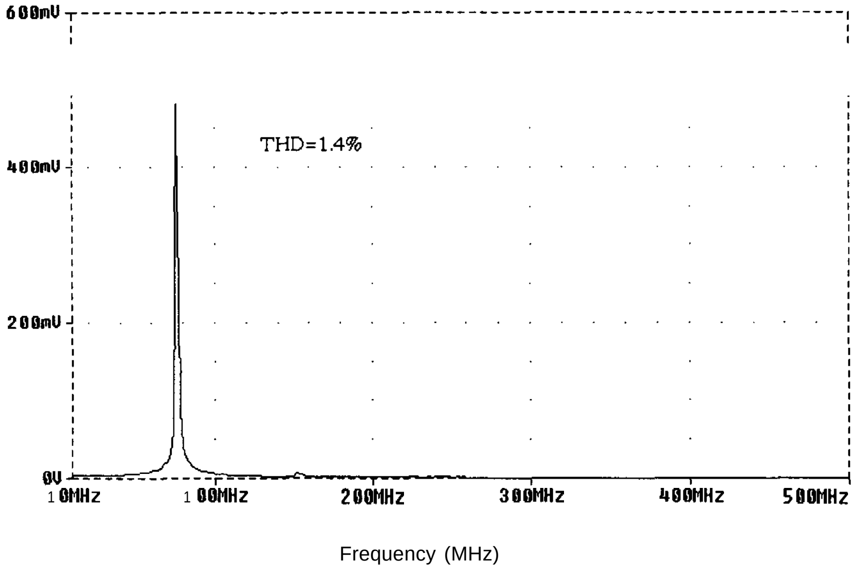

Fig. 5 The frequency spectrum of the circuit, when fixed $R_1 = R_2 = 10$ KΩ, and $C_1 = C_2 = 0.1$ PF.

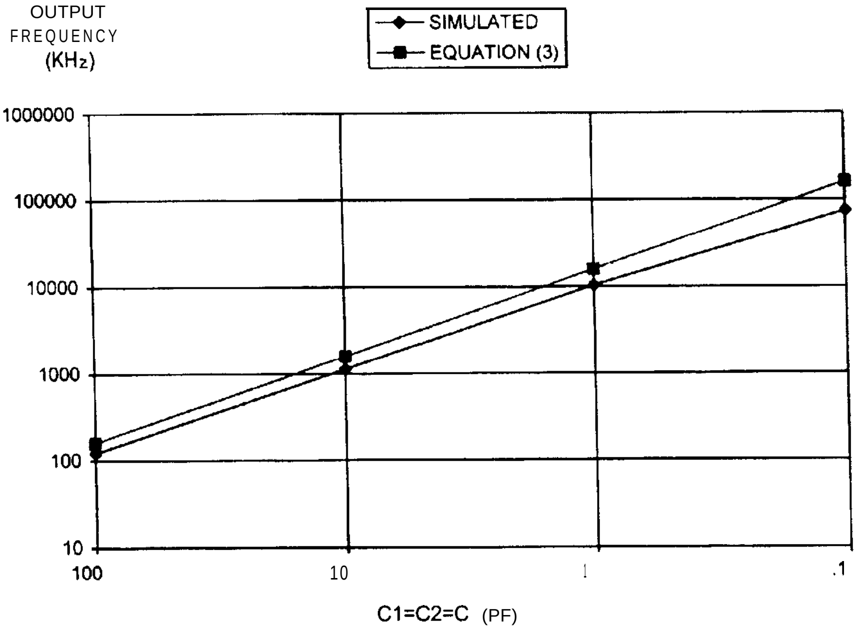

Fig. 6 The relations between the output frequencies and the values of the capacitor for $R_1 = R_2 = 10\ K\Omega$.

4. Conclusion

The advantages of this new 0.8 μm OTA RC-oscillator circuit with CMOS structure are: 1) fewer number of components 2) low power consumption and 3) high output frequencies. The resistor in the current to voltage circuit may be replaced by a CMOS floating-resistor for all MOS structure requirements and two resistors in the lead-lag network may be replaced by CMOS floating-resistors for CMOS voltage controlled oscillator applications. This proposed circuit is suitable for use in electronic and telecommunication applications.

5. Acknowledgements

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