

Electronically tunable simple oscillator based on single-output and multiple-output transconductor

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Abstract: The electronically tunable oscillator with a single-output and a multiple-output transconductor and with three passive grounded elements is presented and verified in this paper. The active elements are modeled on the transistor level for the possibility to implement the whole oscillator on chip. The characteristic equation and condition for oscillation are discussed together with the major influence of the parasitic properties of the active devices. Using the proposed concept an experimental verification employing two commercially available transconductance amplifiers is given via associated time-domain and frequency-domain results.

Keywords: electronic tuning, oscillators, multiple-output transconductor

Classification: Electron devices, circuits, and systems

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1 Introduction

Nowadays it has become very popular to design new circuit structures in the current-mode [1]. It is mainly because of its better frequency-response,

that these circuits are ready for high-frequency applications, for example. Current-mode systems also satisfy the trend to implement complex systems on a single chip using the BiCMOS or CMOS technology. Lately, a range of the interesting active building blocks were suggested in [2] fulfilling all the requirements for current-mode circuits. These blocks could be used, for example, in analog filters and other sections of high-speed data communication systems, regulation and measurement techniques, electro-acoustics, automobile industry, and sensors. For example, the current differencing transconductance amplifier (CDTA) can be utilized as a core element for filters [3] or oscillators [4]. Similarly, the differential input buffered and transconductance amplifier (DBTA) [5] is a useful active element for analog signal processing. The multiple-output transconductors (M-OTA) [2] or single-input multiple-output transconductance amplifiers are still good choices for analog-circuit design [6]. Some types of OTA have the advantage of simplicity and commercial availability in comparison with, for example, CDTA. In the field of oscillators interesting simple [7, 8] as well as more complicated [9, 10, 11, 12] circuits employing OTA-s and other active elements [13, 14, 15, 16, 17, 18] were published. In this paper a very simple tunable oscillator (in comparison with [8, 9, 10, 11, 12]) with two active and three passive elements is presented. In comparison with [10], all the passive elements are grounded and therefore easy on-chip implementation is obvious. The proposed circuit provides current or voltage output signals, direct electronic tuning, and independent control of the condition of oscillation. The circuit for amplitude stabilization (limiter) is not necessary. The proposed circuit was tested with commercially available active elements. To the best of authors' knowledge, no similar oscillator based on one single output and one multiple output transconductor with minimum passive components in the current mode has been reported in the literature yet.

2 Oscillator based on single-output and multi-output OTA

An active device known as transconductor has been known for decades [2]. The most common configuration of OTA is a differential voltage input and a single current output resulting in a voltage-controlled current-source, $I_{OUT} = g_m V_{INP}$. Theoretically, the input and output resistances are infinity. Practically, these values reach megaohms, depending on the particular technology. Sometimes these values strongly depend on the transconductance trimmed by external current I_{SET} . The basic transistor-level structure of OTA from [6] was modified as shown in Fig. 1 (a), while the electronic adjustment of g_m is preserved. The W/L ratios of all transistors were re-designed in order to obtain utmost bandwidth. In the case of the proposed oscillator, one single-input single-output transconductor and one single-input three-output transconductor are sufficient.

We proposed an oscillator that is given in Fig. 1 (b). Its structure is very simple and utilizes three passive elements and two single-input OTAs. Two

integrators are connected in loop, which leads to the characteristic equation

$$s^2 + \frac{C_2 - C_1 R g_{m2}}{C_1 C_2 R} s + \frac{g_{m2}(R g_{m1} - 1)}{C_1 C_2 R} = 0. \quad (1)$$

The condition for oscillation and oscillation frequency can be easily derived as

$$\frac{C_2}{C_1} = R g_{m2}, \quad \omega_0 = \sqrt{\frac{g_{m2}(R g_{m1} - 1)}{C_1 C_2 R}}. \quad (2), (3)$$

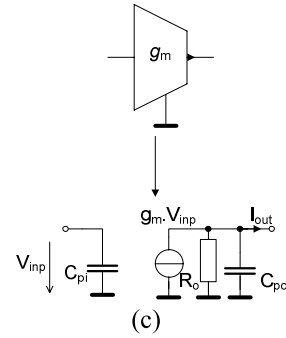
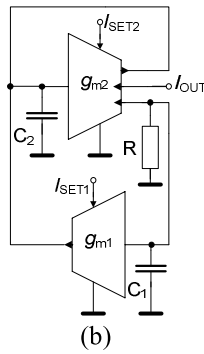
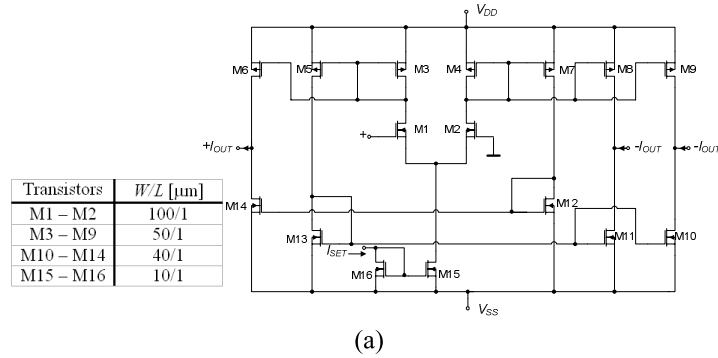


Fig. 1. (a) Internal structure of multiple-output OTA used for simulations, (b) proposed current-mode oscillator employing single-output and three-output OTA, (c) non-ideal OTA model with significant parasitic elements.

According to (2) it is evident that if $R g_{m1} > 1$, the oscillation frequency can be changed independently, without corrupting the condition for oscillation. The sensitivities of the oscillation frequency to circuit elements are

$$S_{C_1}^{\omega_0} = S_{C_2}^{\omega_0} = -S_{g_{m2}}^{\omega_0} = 0.5, \quad S_{g_{m1}}^{\omega_0} = 0.5 \cdot \frac{R g_{m1}}{R g_{m1} - 1}, \quad (4), (5)$$

$$S_R^{\omega_0} = 0.5 \cdot \frac{C_1 C_2 R^2 \left(\frac{g_{m1} g_{m2}}{C_1 C_2 R} - \frac{g_{m2}(R g_{m1} - 1)}{C_1 C_2 R^2} \right)}{g_{m2}(R g_{m1} - 1)}. \quad (6)$$

3 Major influences of parasitic elements

To ensure proper functioning of the proposed oscillator, the major parasitic properties of the active devices used should be considered (Fig. 1 (c)), namely

input capacitances C_{pi} , output capacitance C_{po} , and output resistances R_o . In the case of multiple-output OTA the output capacitances for each particular current output are assumed to be equivalent. The terms involving these new circuit components will be much more complicated, as can be seen from the following

$$\frac{C_2^* R_{o1} (R_{o2} + R)}{C_1^*} = R(g_{m2} R_{o1} R_{o2} - R_{o1} - R_{o2}), \quad (7)$$

$$\omega_0 = \sqrt{\frac{g_{m2} R_{o1} R_{o2} [R_{o2} (R g_{m1} - 1) + R] + R_{o2}^2 + R_{o1} R_{o2} + R R_{o2} + R R_{o1}}{C_1^* C_2^* R R_{o1} R_{o2}^2}}, \quad (8)$$

where $C_1^* = C_1 + C_{pi1} + C_{po2}$ and $C_2^* = C_2 + C_{pi2} + C_{po1} + C_{po2}$. These parasitic capacitances mostly influence the frequency of oscillation, which is lower than expected, as will be obvious from the next chapter. Due to the high values, the effects of input resistances can be neglected.

4 Experimental results

4.1 PSpice Simulation Results

The features of the proposed oscillator have been verified by using a transistor-level model of OTAs. The AMIS C5 0.5 μm mixed-mode technology was

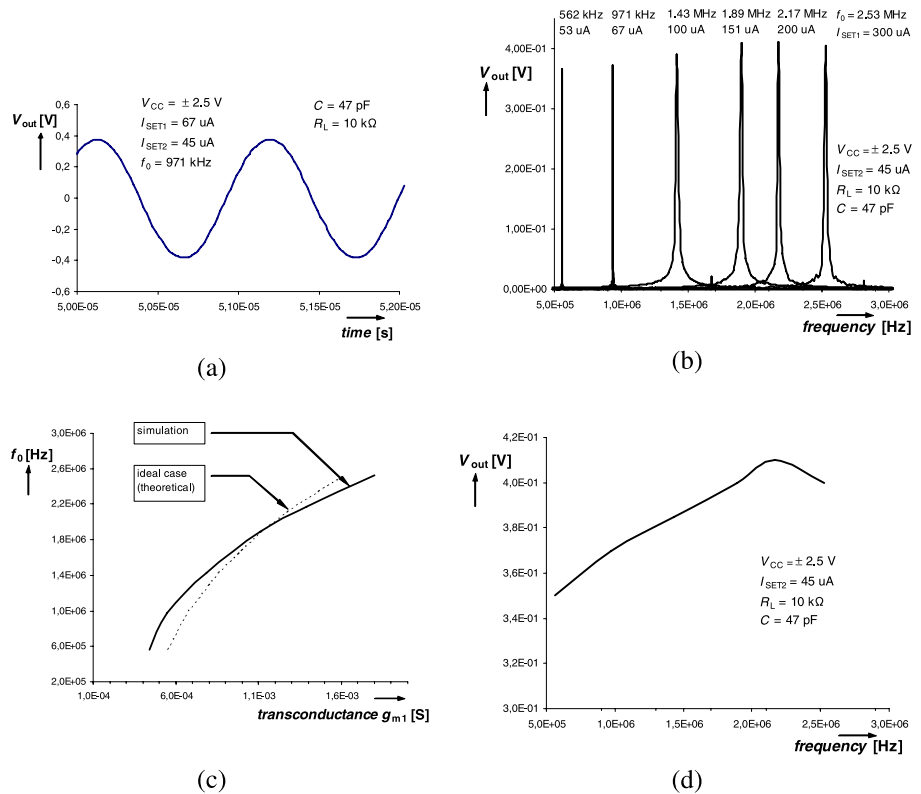


Fig. 2. Simulation results (a) output waveform of proposed oscillator, (b) adjustment of oscillation frequency, (c) dependence of f_0 on g_{m1} , (d) output amplitude versus oscillation frequency.

used, which is available free of charge on [19]. The oscillator is fundamentally designed to work on 1 MHz, capacitors are $C_1 = C_2 = C = 47$ pF and $g_{m2} = 0.5$ mS ($I_{SET2} = 45$ μ A). The supply voltage is $V_{CC} = \pm 2.5$ V. The other circuit components must be computed using (2) and (3), namely $R = 2$ k Ω and $g_{m1} = 0.56$ mS ($I_{SET1} = 67$ μ A). The generated signal in the time domain is given in Fig. 2 (a). For the purpose of measurement the current can be converted to voltage by connecting a 10 k Ω resistor. Fig. 2 (b)-(d) illustrates the tunability and output amplitude of the proposed harmonic oscillator. For $g_{m1} \in (53, 300)$ μ A the appropriate oscillation frequency changes in the range $f_0 \in (0.56; 2.53)$ MHz. Power consumption (obtained from simulation) is about 8 mW, which is really a low value.

4.2 Measurement results

Two commercially available OTAs manufactured under the designation MAX 435 [20] were used for experimental verification. The measurement results are summarized in Fig. 3, where the measured signal is demonstrated in the time (Fig. 3 (a)) and the frequency domains (Fig. 3 (b)). For capacitances $C = 29$ pF we even obtained $f_0 = 7$ MHz, as shown in Fig. 3 (c). The total harmonic distortion (THD) achieved is 0.8%, the suppression of higher harmonics is about 42 dB).

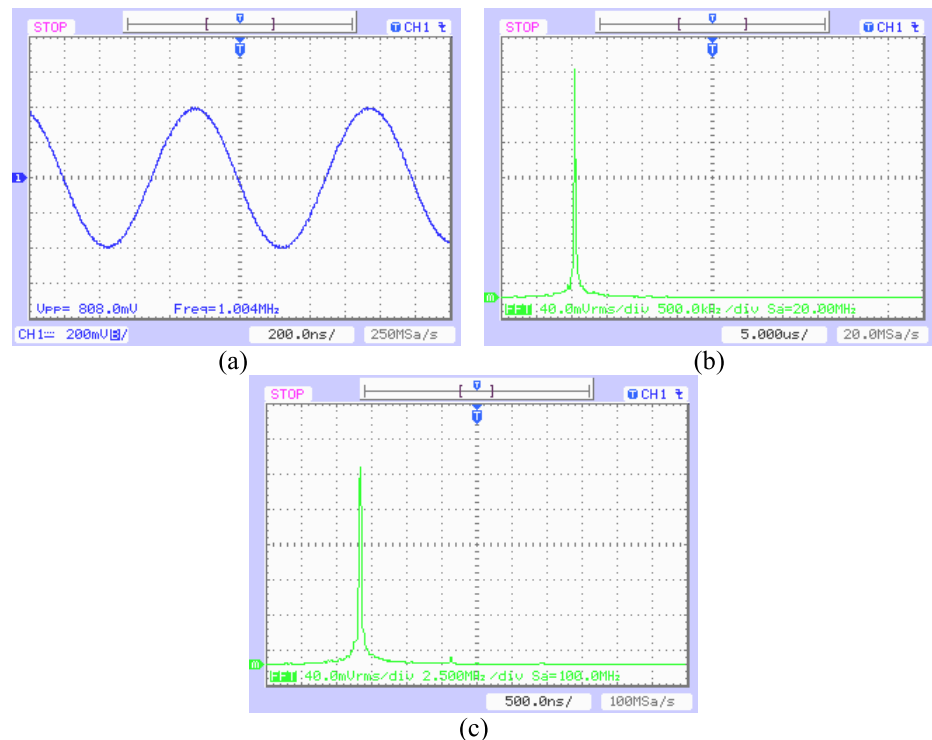


Fig. 3. Measurement results (a) waveform of proposed oscillator, (b) freq. domain for $f_0 = 1$ MHz, (c) freq. domain for $f_0 = 7$ MHz.

5 Conclusion

A quite simple current-mode harmonic oscillator has been proposed in this paper. The on-chip integrable oscillator's version is suggested because R could be easily replaced also by OTA for full on chip implementation. The experimental verification is two-fold, i.e. by simulation with transistor-level models and by measurement with MAX 435. Due to the internal OTA non-linearity, the circuit for amplitude stabilization is not necessary. The circuit was experimentally tested on frequencies of several MHz. The simulation and measurement results confirmed the theoretical assumptions. By careful adjustment of circuit elements (especially g_m) a very low THD (under 1%) can be achieved.

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