Current mode quadrature oscillator using two CDTAs and two grounded capacitors

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Abstract: A current mode quadrature oscillator consisting of only two Current Differencing Transconductance Amplifiers (CDTAs) and two grounded capacitors is introduced. The oscillation frequency can be made adjustable by internal transconductances of active elements without affecting the oscillation condition.

Keywords: - Quadrature oscillator, CDTA, current mode

1 Introduction

Quadrature oscillators (QOs) employing various types of active elements are reported in the literature. Current conveyors and other active components, enabling high-speed current-mode or mixed-mode operation, have been increasingly used. A QO in [1] consists of two operational transresistance amplifiers (OTRAs), but six virtually grounded passive R and C components are required. Horng [2] reported a QO with two current differencing buffered amplifiers (CDBAs), two grounded capacitors, and four virtually grounded resistors. More economical QO in [3] uses three current-controlled current conveyors CCCII and only one grounded and one virtually grounded capacitor. However, it generates relatively low-amplitude and unequal sinusoidal output signals. Salama and Soliman [4] proposed a pair of lossy and lossless integrators in the feedback loop, implemented by two CDBAs and six virtually grounded CMOS transistors, with a possibility of digital control of oscillation frequency. OTA-C tunable QO in [5] contains four operational transconductance amplifiers (OTAs), two grounded capacitors, and special circuits for current-mode amplitude control. QO in [6, 7] consists of two allpass sections, each employing one current differencing transconductance amplifier (CDTA) and virtually grounded pair of R and C components. Frequency of generated waveforms is insensitive to transconductances g_m of CDTAs and is given by passive R and C components.

Most of reported oscillators provide non-interacting controls for the frequency of oscillation (FO) and condition of oscillation (CO). There are several methods of amplitude control from simple nonlinear limiters [8] to sophisticated control loops which can represent more complicated circuitry on the chip than the primary oscillator [5].

2 New QO configuration

The proposed economical oscillator is shown in Fig. 1 (a). It consists of one inverting and one noninverting lossless current integrator in a feedback loop. The CDTA elements [9] in Fig. 1 (b) are exploited for integration by a simple way: difference of currents, flowing into low-impedance p and n terminals, flows out of the z-terminal into a capacitor, causing 90° phase-shifted voltage at the z terminal. Internal transconductance g_m, controllable by an outside current source I_g, converts this voltage into a couple of bidirectional output currents I_{out}. Ideally, such configuration represents a 2nd order system with infinity quality factor, enabling harmonic oscillation.

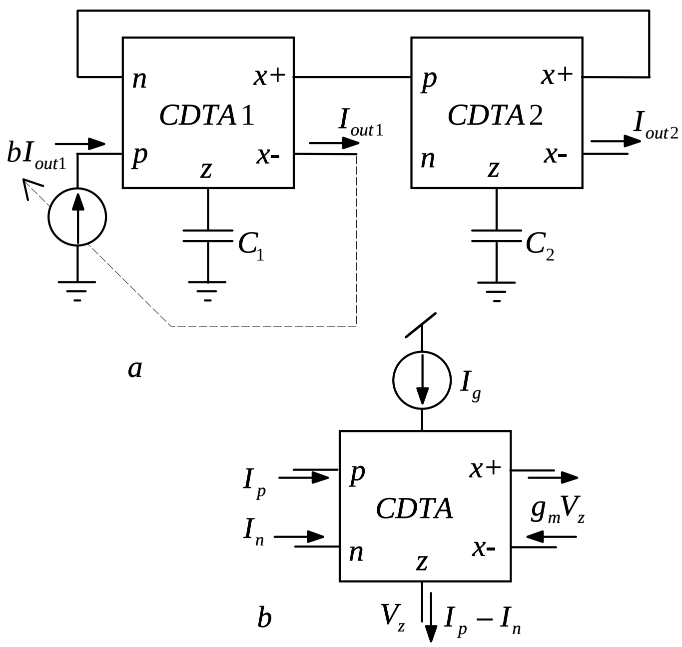

Fig. 1: Proposed QO circuit employing CDTA elements, a) circuit diagram indicating a possibility of gain control, b) CDTA symbol.

An auxiliary circuitry, represented in Fig. 1 (a) by a controlled current source ßI_{out1}, stabilizes the amplitude of generating waveform and dynamically fulfills the CO by local feedback from the output to positive input of CDTA1. More economical alternative is to connect simple nonlinear resistor [8] in parallel to C_1.

The condition of oscillation and the frequency of oscillation are:

CO: $$b = 0\,, \qquad (1)$$

FO: $$f_{osc} = \frac{1}{2p}\sqrt{\frac{g_{m1}g_{m2}}{C_1 C_2}}\,, \qquad (2)$$

where g_{m1} and g_{m2} are transconductances of CDTAs No. 1 and 2.

The current gain ß is controlled according to the formula

$$b = I_{amplitude}(t)/I_{adjust} - 1 \qquad (3)$$

where $I_{amplitude}$ is instantaneous amplitude of generated waveforms, sensed by rectifying, Four-Phase MAX [5] or other method, and I_{adjust} is adjustable value of the required amplitude. In the initial state, the value of ß = -1 provides flat soft-start of the oscillation. In steady-state operation, amplitude is dynamically perturbed around the nominal value I_{adjust}, causing changes of ß around zero which subsequently stabilize the amplitude.

3 CMOS implementation and PSPICE simulation results

The presented QO has been simulated using the CMOS-based CDTA circuit given in Fig. 2 of [6]. The parameters of the 0.5µ MIETEC real transistor model are implemented for all MOSFETs in the circuit. Transistor aspect ratios are indicated in Table 1 of [6]. The DC supply voltages were ±2.5V. CDTA transconductances were set by current Ig=600µA to g_m =0.625mS. For C_1=C_2=10pF, the theoretical oscillation frequency (2) is 9.947 MHz.

The proposed auxiliary circuitry for stabilizing the amplitude in Fig. 2 consists of two CDTAs. The element "B" utilizes internal OTA for simulating the gmB conductance at the z-terminal. The CDTA "A" is connected as current amplifier which current gain is given by a ratio of g_{mA}/g_{mB}. The current source connected at the x+ output of CDTA "A" simulates subtraction of this current from the output current of the current amplifier. This source can be implemented by a current mirror or by simple applying the x-terminal of multiple-output CDTA [10]. The current gain ß is then given by the relation

$$b = g_{mA}/g_{mB} - 1\,. \qquad (4)$$

For well-matched control laws $g_m(I_g)$ of both the CDTAs, ß = 0 when $I_{amplitude} = I_{adjust}$. For the simulation, Iadjust has been set to 60µA. Amplitude sensing was simulated by a block which performed squared root of the sum of powers of quadrature output currents, followed by a simple RC filter. PSpice simulation led to the following results:

The steady-state oscillations were reached within 0.7µs after turning the supply sources on. The amplitudes of output currents I_{out1} and I_{out2} are approx. 60µA. The FO is 9.954 MHz which is in a good agreement with Eq. (2). The THD of generated waveforms is about 2.5%. It can be further decreased by improving the loop gain stabilization circuitry.

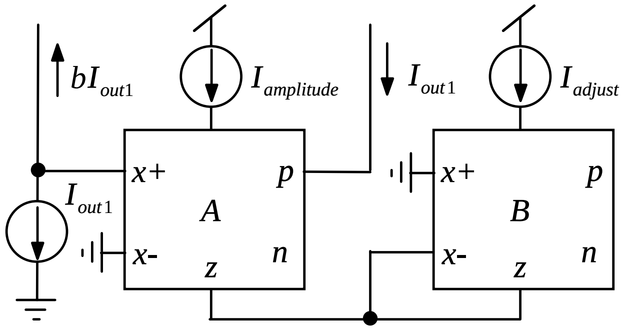

Fig. 2: Proposed circuit for automatic gain control.

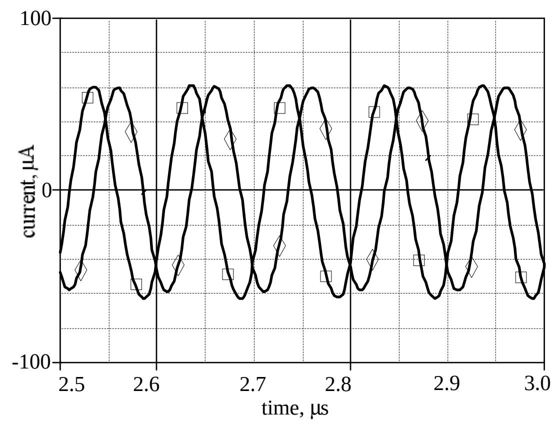

Fig. 3: PSpice simulation results: steady-state oscillation, □ Iout1, ◇ Iout2.

4 Conclusions

Proposed quadrature oscillator circuit has the following features: (i) use of two CDTAs for providing direct current-to-current integration; (ii) use of only two grounded capacitors; (iii) dynamical fulfilling the CO by simple auxiliary circuitry; (iv) electronic gm-control of FO which does not affect the CO. All these features have not been achieved simultaneously in any of the previously QOs published in [1 – 8] including those cited therein. As follows from (i) and (ii), the new QO also represents economical circuit solution because its core consists only of two active elements and two grounded capacitors. One can choose a circuitry for stabilizing the amplitude from simple nonlinear limiter to complicated systems of loop gain control. The proposed stabilizing circuit, consisting of two CDTAs, is a compromise between the circuit complexity and attainable THD.

Acknowledgments

This work has been supported by the Grant Agency of the Czech Republic under grants No. 102/04/0442 and 102/05/0277, and by the research programmes of Brno University of Technology and University of Defence Brno.

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