APPLICATION OF CURRENT-MODE MULTIPLIERS IN ADJUSTABLE OSCILLATOR

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Abstract: In the paper an electronically tunable oscillator is presented. Oscillation frequency and the oscillation condition are controllable by DC voltage. Two commercially available current-mode multipliers and two voltage buffers are used. Conception based on two loop integrator structure, characteristic equation, oscillation condition, sensitivities and parasitic influences are discussed. Functionality of presented realization was verified by PSpice simulations and experimental measurements.

Keywords: oscillator, electronic control, adjustability, current conveyor, current-mode multiplier

1. INTRODUCTION

An electronic control in applications of modern active blocks is very important feature. Elementary principle is based on replacement of passive elements (grounded or floating resistor) in so called single resistance controlled oscillators (SRCO-s). Examples in [1] use FET transistor for easy voltage control. Other interesting approach is based on adjustable negative capacitance [2]. Today are very popular controllable applications using bias dependent current input resistances (generally marked $R_x(I_b)$) of current active elements (current followers, conveyors, CFOA-s, etc.). Many of recent works use this approach [3, 4] for electronic adjusting not only in oscillators but also in active current mode filters. Very widespread solution is to use transconductances g_m (I_b) of transconductors (OTA) or OTA section in combined active elements [5] for electronic control. One example is interesting application of oscillator employing current differencing transconductance amplifier (CDTA) [5, 6]. A useful active element called current conveyor transconductance amplifier (CCTA) [7] was used in current mode quadrature oscillators tunable by g_m [8]. Adjustable solutions of oscillators based on transconductors only can be really very easy [9]. Of course, there exists also possibility to combine both methods (R_x and g_m control). Another interesting approach to the oscillator synthesis is using of active all-pass sections for example [10, 11]. Possibility to electronic control of current gain of current conveyors [12] was introduced in recent years. Controllable oscillators based on voltage controlled current gain of current conveyors or amplifiers were verified in applications of simple oscillators in [13, 14]. From recent literature it seems to be not much common approach to the adjusting based on the current gain (or attenuation) control. In this paper controlled current gain is realized by commercially available current-mode multipliers (CM). However, there are some problems with real behavior derivable from non-idealities of real current input properties of used active elements.

2. OSCILLATOR EMPLOYING CM MULTIPLIERS AND VOLTAGE BUFFERS

Circuit realization of voltage adjustable oscillator using two current-mode multipliers (CM-s) and two buffers (VB-s) is shown in Fig. 1a. There were used current mode multiplier EL 4083 [15] and EL 2082 [16] and operational amplifier LT 1364 [17] as voltage buffer. Current multipliers are set up as current amplifiers or attenuators (type of EL 4083 is not able to provide the current gain > 1 [15]). Between output and input currents and current transfer (B) and DC control voltage are relations

$$I_{O+} = -I_{O-} = \frac{I_X I_Y}{2I_Z} = I_X B_1,\ B_1 = \frac{I_Y}{2I_Z} \approx \frac{V_{SET1}}{R_{set1}} \frac{R_{set2}}{2V_{DD}} = \left|R_{set2} = 2R_{set1}\right| = \frac{V_{SET1}}{V_{DD}}. \qquad (1), (2)$$

The second type of CM is EL 2082 where $B_2 \sim V_{SET2}$ in range (0 - 2 V). The circuit in Fig. 1 presents lossless (adjustable) and lossy voltage integrators based on current active elements in loop and adjustable current feedback. The characteristic equation, the oscillation condition and the oscillation frequency (f_0) of the oscillator circuit in Fig. 1a have forms

$$s^2 + \frac{C_1 - C_2 B_2}{R_2 C_1 C_2} s + \frac{B_1}{R_1 R_2 C_1 C_2} = 0,\ B_2 = \frac{C_1}{C_2},\ \omega_0 = \sqrt{\frac{B_1}{R_1 R_2 C_1 C_2}}. \qquad (3), (4), (5)$$

Sensitivities of oscillation frequency on circuit parameters are

$$S_{B_1}^{\omega_0} = -S_{R_1}^{\omega_0} = -S_{R_2}^{\omega_0} = -S_{C_1}^{\omega_0} = -S_{C_2}^{\omega_0} = 0.5. \qquad (6)$$

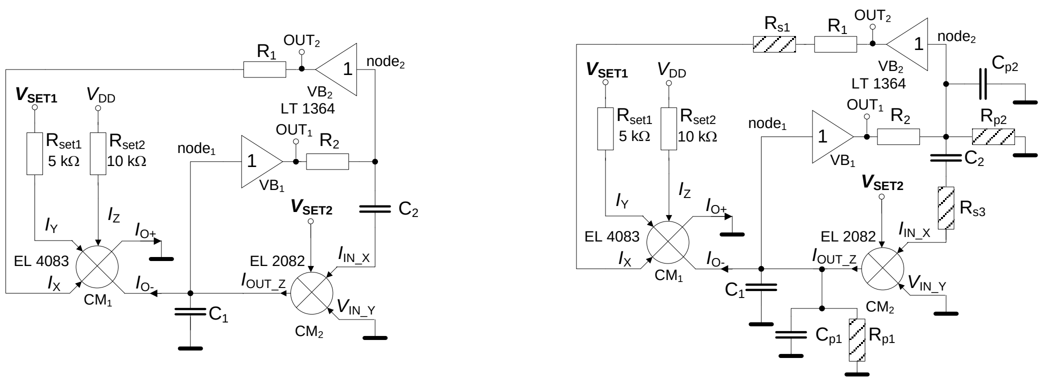


Figure 1: a) oscillator circuit, b) important parasitic influences in structure

3. EXPERIMENTAL RESULTS AND REAL PARASITIC INFLUENCES

The ideal oscillation frequency is f_0 = 1.59 MHz (5) for following design: $R_1 = R_2$ = 1 kΩ, $C_1 = C_2$ = 100 pF, B_1 = 1, B_2 = 1 (4). However, this oscillator solution is influenced by parasitic parameters caused by real behavior of used active elements, see Fig. 1b. We can separate these problems to two areas. First is important in low impedance nodes (inputs of current active elements) and the second is situated to high impedance nodes (outputs of current active elements). Main impacts have current input and output resistances of CM multipliers. Expected value of R_{s1} can be found in range of 40 - 700 Ω for I_Z from 2.5 mA to 0.2 mA. Analyses and measurements show that value is dependent on biasing current I_Z of EL 4083. Value of R_{p1} sums up output resistance of CM_2 (~ 1 MΩ, EL 2082 [16]), output resistance of CM_1 (~ 1 MΩ, EL 4083 [15]) and input resistance of voltage buffer VB_1 (~ 5 MΩ, [17]). Similarly parasitic capacitance C_{p1} is caused by output capacitance of CM_1 (~ 5 pF), CM_2 (~ 5 pF) and input capacitance of VB_1 (~ 3 pF). Resistance R_{p2} and capacitance C_{p2} are formed by input impedance of VB_2 (~ 5 MΩ/ 3 pF). The largest influence is caused by R_{s3}. R_{s3} is input resistance of CM_2 (~ 95 Ω, EL 2082 [16]). It degrades independence of oscillation frequency and oscillation condition (4). The output impedance of buffers is neglectable because is very low (< 1 Ω), therefore influence is minimal. Parasitic elements depicted in Fig. 1 b are considered in following analysis. Characteristic equation has now more complicated form

$$a_3 s^3 + a_2 s^2 + a_1 s + a_0 = 0, \tag{7}$$

where coefficients

$$a_3 = R_1' R_2 R_{p1} R_{p2} R_{s3} C_1' C_2 C_{p2}, \tag{8}$$

$$a_2 = R_1' R_{p1} R_{p2} C_1' \left(R_2 C_{p2} + R_2 C_2 + R_{s3} C_2\right) + R_1' R_2 R_{s3} C_2 \left(R_{p1} C_1' + R_{p2} C_{p2}\right), \tag{9}$$

$$a_1 = R_{p1} R_{p2} C_2 \left(B_1 R_{s3} - B_2 R_3\right) + R_1' R_2 \left(R_{p1} C_1' + R_{s3} C_2 + R_{p2} C_2 + R_{p2} C_{p2}\right) + R_1' R_{p2} \left(R_{p1} C_1' + R_{s3} C_2\right), \tag{10}$$

$$a_0 = R_{p1} R_{p2} B_1 + R_1' \left(R_2 + R_{p2}\right), \tag{11}$$

where $C_1' = C_1 + C_{p1}$ and $R_1' = R_1 + R_{s1}$. The oscillation frequency and the oscillation condition have now form

$$\omega_0^* \approx \sqrt{\frac{R_{p1} R_{p2} C_2 \left(B_1 R_{s3} - B_2 R_3\right) + R_1' R_2 \left(R_{p1} C_1' + R_{s3} C_2 + R_{p2} C_2 + R_{p2} C_{p2}\right) + R_1' R_{p2} \left(R_{p1} C_1' + R_{s3} C_2\right)}{R_1' R_2 R_{p1} R_{p2} R_{s3} C_1' C_2 C_{p2}}}, \tag{12}$$

$$B_2^* \approx \frac{\frac{a_0 a_3}{a_2} - \left[B_1 R_{p1} R_{p2} R_{s3} C_2 + R_1' R_2 \left(R_{p1} C_1' + R_{s3} C_2 + R_{p2} C_2 + R_{p2} C_{p2}\right) + R_1' R_{p2} \left(R_{p1} C_1' + R_{s3} C_2\right)\right]}{R_1' R_{p1} R_{p2} C_2}. \tag{13}$$

Main impact on frequency shift has R_{s1}, C_{p1}, C_{p2} and R_{s3}. PSpice simulation results with professional macromodels provide (including mentioned parasitic features) f_0 = 1.14 MHz.

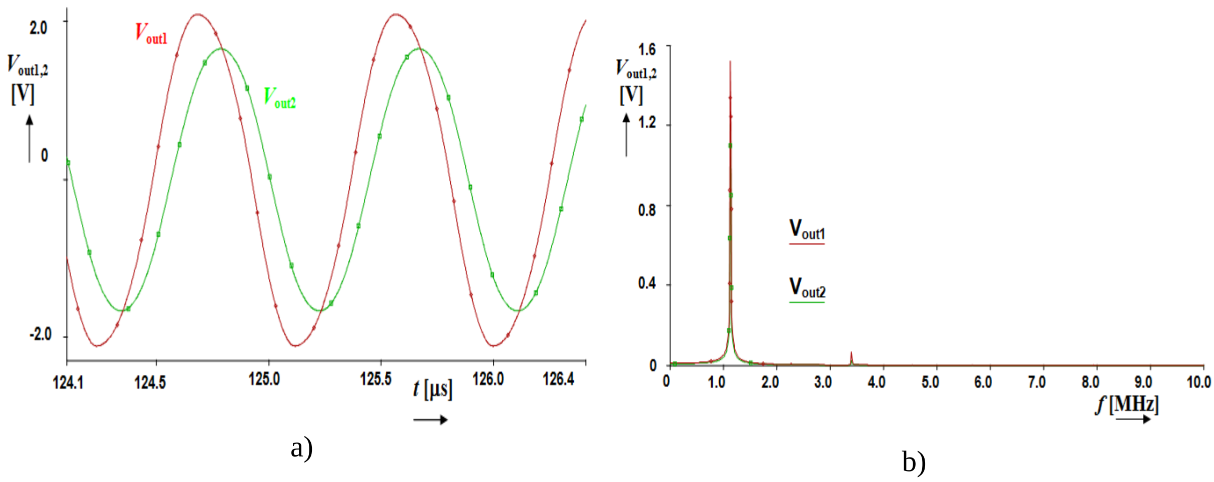
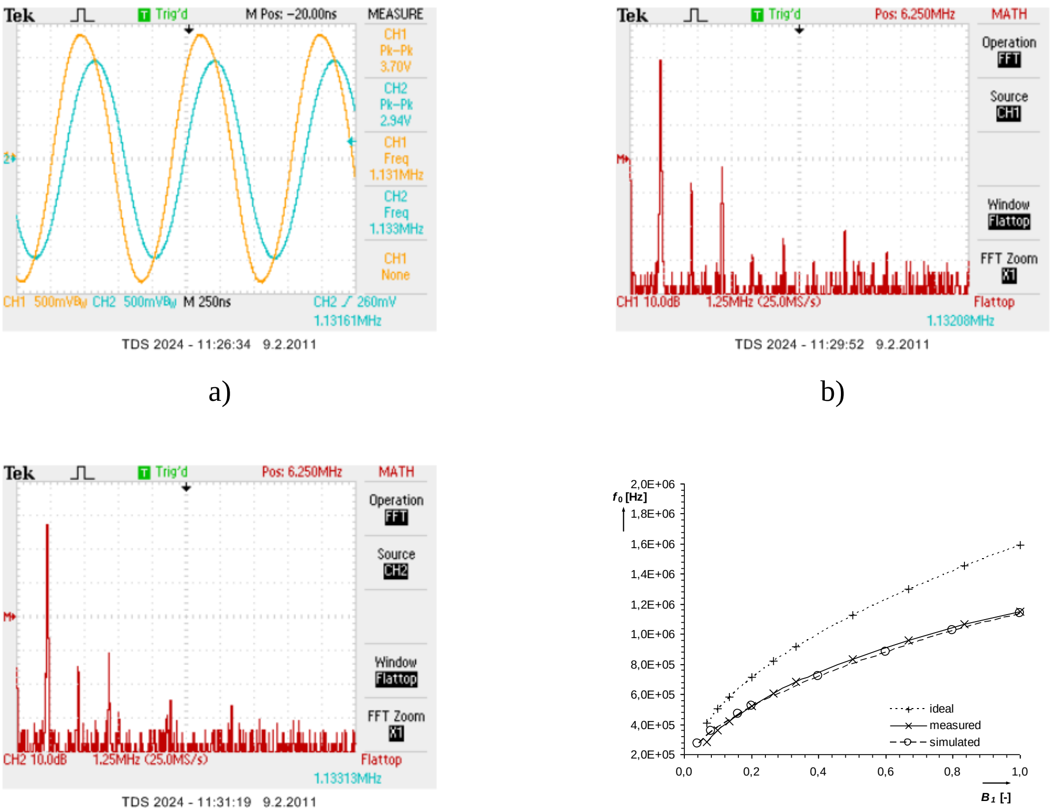


Figure 2: a) simulated transient responses, b) frequency domain

Oscillator was tested without automatic gain control circuit (AGC) therefore the amplitude stabilization was realized by internal nonlinearities of active elements only. It was necessary to set up oscillation condition by (V_{SET2}) in each measurement point for suitable amplitude and low THD. Moreover the conception AGC based on V_{SET2} control used in similar type is in development because for wider tuning is always necessary. Measurements are available for two values of supply voltage. For V_{CC} = ± 5 V was THD above 1.5 %. Decreasing of supply voltage to ± 3 V reduces output amplitudes but improved THD (under 1 %). The THD is even 0.4 - 0.7 % in limited range of f_0 from 700 kHz to 1.14 MHz. Measured f_0 for B_1 = 1 is 1.13 MHz (Fig. 3a). Results in frequency domain (OUT_1 and OUT_2) and dependence of f_0 on B_1 are in Fig. 3b-c.



a) b) c) d)

Figure 3: a) measured output responses, b) c) spectrum of both responses, d) dependence of oscillation frequency on current transfer B_1.

4. CONCLUSION

Quite simple and adjustable oscillator employing current-mode multipliers is presented in this paper. Verifications confirmed functionality but reveal some problems which testified additional parasitic analyses. Most important is the input resistance of CM_2 which disturbed independence of oscillation frequency and condition and together with input resistance of CM_1 and parasitic influences in high impedance nodes cause substantial shift of oscillation frequency.

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