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A TUNABLE QUADRATURE OSCILLATOR WITH ONLY TRANSCONDUCTANCE ELEMENTS AND GROUNDED CAPACITORS

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A novel quadrature oscillator is realised with only transconductance elements (TEs) and grounded capacitors. The realised quadrature oscillator uses only two inverting and two non-inverting transconductance elements, along with two grounded capacitors. The quadrature oscillator enjoys the attractive features of low component count, independent frequency tuning and suitability for integration in MOS technology.

Keywords: Active networks, Transconductance element; g_m-C oscillators

1 INTRODUCTION

Recently, the transconductance elements and grounded capacitor (TGC)-based circuits have become very popular in the design of active networks [1–3]. The TGC circuits possesses superior high frequency performance and economised chip area requirement as compared with operational transconductance amplifier (OTA)-based circuits, along with its MOS compatibility for monolithic implementation [4–10].

In this paper a novel quadrature oscillator (QOC) is given which uses only transconductance elements and grounded capacitors. The resulting QOC is in the TGC form. The QOC enjoys independent frequency control through gate voltage (V_G). The QOC was designed and verified using PSPICE-simulation.

2 CIRCUIT REALISATION

The inverting linear transconductance element (ITE) is shown in Figure 1, along with its CMOS implementation, symbol and circuit model [1, 2]. The non-inverting transconductance element (NTE) realisation and symbol is shown in Figure 2. The proposed TGC quadrature

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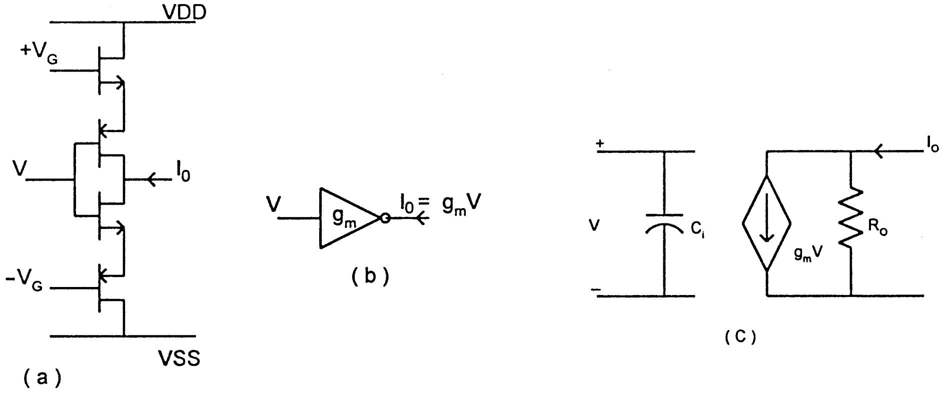


FIGURE 1 Inverting transconductance element (a) CMOS implementation; (b) Symbolic representation; (c) Circuit model.

oscillator using ITE and NTE is shown in Figure 3(a). It is basically realised by cascading an ideal integrator with an adjustable-pole inverting integrator in a closed loop configuration. The gain of the two integrator-loop of Figure 3(a) can be expressed as

$$\frac{V_3}{V_1} = -\frac{g_{m1}/C_1}{s + (g_{m2} - g_{m3})/C_1} \cdot \frac{g_{m4}/C_2}{s} \tag{1}$$

The characteristic equation from (1) is

$$s^2 + s\frac{(g_{m2} - g_{m3})}{C_1} + \frac{g_{m1}g_{m4}}{C_1C_2} = 0 \tag{2}$$

which gives the condition of oscillation as

$$g_{m2} \leq g_{m3} \tag{3}$$

and the frequency of oscillation as

$$\omega_o = \left(\frac{g_{m1}g_{m4}}{C_1C_2}\right)^{1/2} \tag{4}$$

With $g_{m1} = g_{m2} = g_m$ and $C_1 = C_2 = C$, the frequency of oscillation can be expressed as

$$\omega_o = \frac{g_m}{C} \tag{5}$$

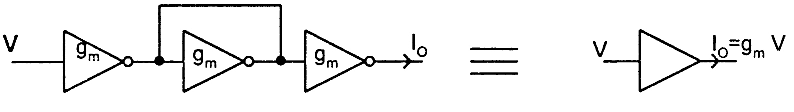
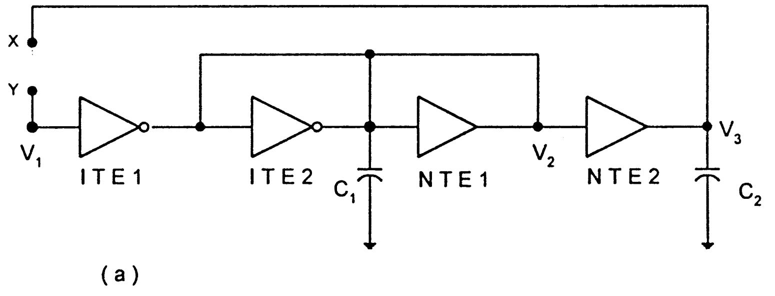


FIGURE 2 Non-inverting transconductance element.



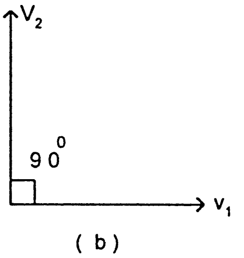
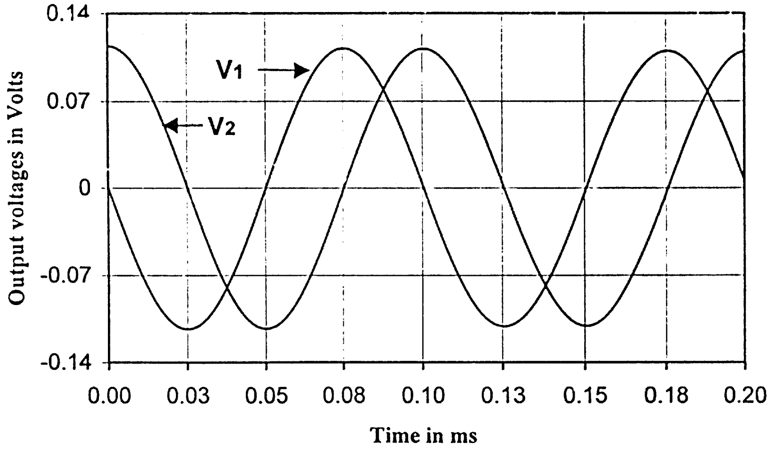


FIGURE 3 (a) TGC-quadrature oscillator; (b) Phasor diagram.

From (3) and (4) it is obvious that the QOC of Figure 3(a) can be set to oscillate through g_{m2} and g_{m3}, while the frequency of oscillations can be controlled through g_{m1} and g_{m4}. Thus it provides non-interactive tuning of the frequency of oscillation. At oscillating frequency

$$V_1\big|_{s=j\omega} = -j\alpha V_2, \quad \text{where } \alpha = \frac{g_m}{\omega C} \tag{6}$$

Equation (6) depicts the quadrature outputs of the oscillator as shown in Figure 3(b).



(a)

FIGURE 4 (a) Simulation-results of TGC quadrature oscillator of Figure 3(a).

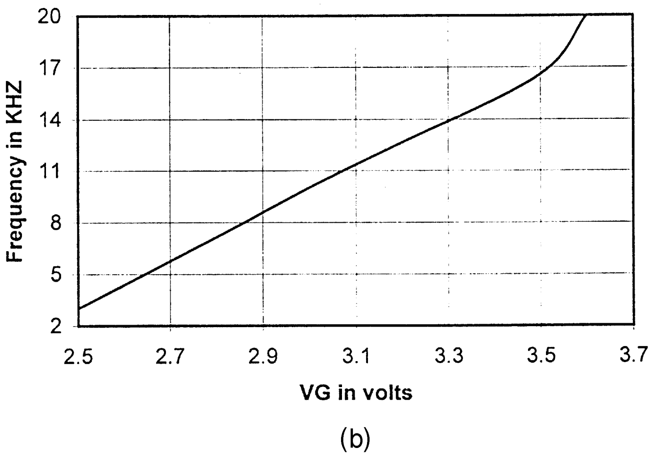


FIGURE 4 (b) Frequency tuning with gate voltage V_4.

3 SIMULATION RESULTS

To verify performance, the QOC of Figure 3(a) was simulated by PSPICE using the CMOS transconductance element of Figure 1(a) with CMOS model parameters given in reference [2]. Initially the QOC of Figure 3(a) (with nodes X and Y shorted) was designed with gate voltage $V_G = \pm 3\,\mathrm{V}$ (for which the transconductance value is 62 μmho), the $C_1 = C_2 = 0.986\,\mathrm{NF}$ for $f_o = 10\,\mathrm{kHz}$. The condition of oscillation was set by controlling the gate voltage of ITE2. The waveshapes obtained are shown in Figure 4(a), which clearly shows the quadrature outputs and thus verify the theory. The frequency of oscillation was controlled by gate voltage V_G of ITE1 and NTE2 of the QOC. The variation of frequency of oscillation with V_G is shown in Figure 4(b), which is linear within 17 kHz.

4 CONCLUSION

A novel quadrature oscillator with only transconductance elements and grounded capacitors is given. The given oscillator uses low component count and provides non-interactive tuning of its frequency of oscillation through gate voltage control. The quadrature oscillator is attractive for monolithic implementation in CMOS technology. The simulation results on the oscillator verify the theory.

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