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A Better Design of Quadrature Oscillator using OTRAs

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Abstract *- A better design of quadrature oscillators using OTRAs is suggested. The simulated results are in close agreement with the theoretical ones.*

Keywords — *Barkhausen Criteria, Oscillator, OTRA, Quadrature Oscillator*

I. INTRODUCTION

Several all-pass filters have been proposed in the past [1]-[37]. Like many other all-pass filters, in [23], the configuration shown in Fig. 1 was chosen as a priory, and the values of the various passive elements are chosen to yield all-pass filters.

A systematic synthesis procedure [24] was given for the same configuration to realize a wider class of voltage transfer functions. The terminal characteristic of the OTRA is given as:

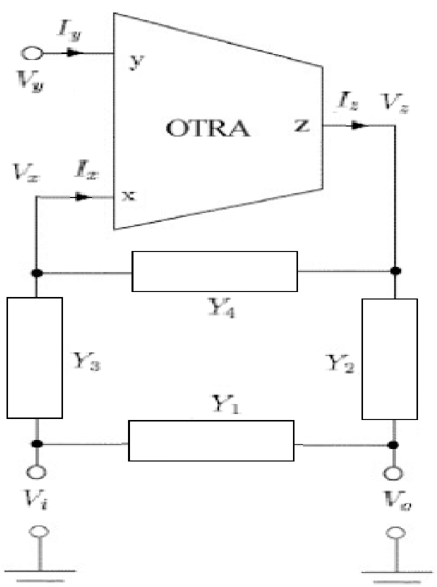


Fig. 1. Configuration used in [23].

$$\begin{bmatrix} V_p \\ V_n \\ V_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -R_m & R_m & 0 \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ I_z \end{bmatrix} \quad (1)$$

For ideal operation, the trans-resistance gain approaches infinity, forcing the input currents to be equal. Thus, the OTRA can be used in a feedback configuration in a way similar to the op-amp.

In [23], the authors used the inverting and non-inverting all-pass filters to realize a quadrature oscillator shown in Fig. 2. We have simulated their designed circuit and obtained the results as shown in Fig. 3. The circuit has several disadvantages, as discussed below.

Analysis of the circuit leads to the following loop gain:

$$A\beta = \frac{R_4}{R_3} = -\left[\frac{s^2 - \left(\frac{1}{\tau_1} + \frac{1}{\tau_1}\right)s + \frac{1}{\tau_1\tau_2}}{s^2 + \left(\frac{1}{\tau_1} + \frac{1}{\tau_1}\right)s + \frac{1}{\tau_1\tau_2}}\right] \quad (2)$$

Here, $\tau_1 = R_1C_1, \tau_2 = R_2C_2$

$$\beta = -\left[\frac{s^2 - \left(\frac{1}{\tau_1} + \frac{1}{\tau_1}\right)s + \frac{1}{\tau_1\tau_2}}{s^2 + \left(\frac{1}{\tau_1} + \frac{1}{\tau_1}\right)s + \frac{1}{\tau_1\tau_2}}\right] \quad (3)$$

Therefore,

$$\beta(jw) = -\left[\frac{\left(\frac{1}{\tau_1\tau_2} - w^2\right) - j\left(\frac{1}{\tau_1} + \frac{1}{\tau_1}\right)w}{\left(\frac{1}{\tau_1\tau_2} - w^2\right) + j\left(\frac{1}{\tau_1} + \frac{1}{\tau_1}\right)w}\right] \quad (4)$$

Thus,

$$\beta|_{w=\frac{1}{\tau_1\tau_2}=w_o} = 1\angle 0 \quad (5)$$

According to Barkhausen Criteria for sinusoidal oscillators:

$$A \cong \frac{1}{\beta|_{w=w_o}} \cong 1\angle 0 \quad (6)$$

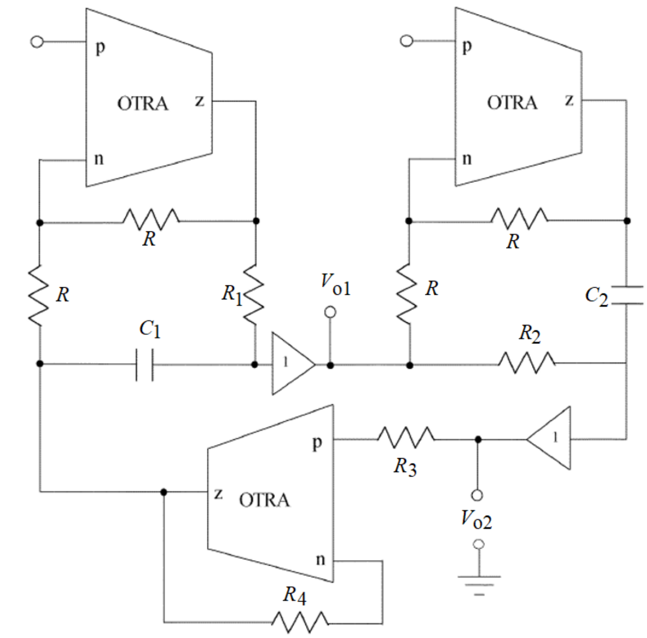
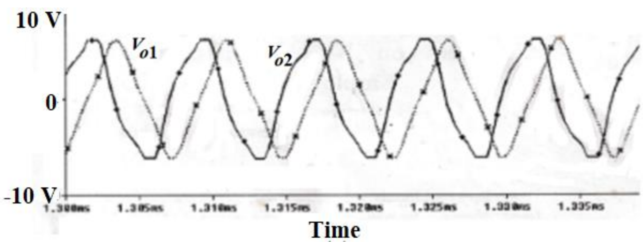
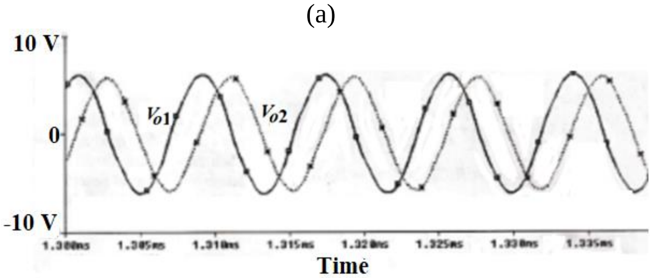


Fig. 2. Quadrature oscillator proposed in [22].



(a)



(b)

Fig. 3. Output waveforms of the oscillator with buffers and A equal to (a) 6 and (b) 1.29.

The authors of [23] have chosen A = 6, a much higher value than given by (6). This results in distortion, as shown in Fig. 3(a).

The unity-gain voltage amplifiers used as buffers have to be realized with a device compatible with the high-frequency range of OTRA. Since a conventional amplifier circuit using OTRA has finite input impedance, it cannot be used as a buffer.

Their designed circuit is shown in Fig. 2, the amplitudes of the two outputs $V_{o1}$and V_{o2} should be equal, but they are observed unequal, as shown in Fig. 8 [23]. Such unequal amplitude quadrature oscillators will have very limited practical utility.

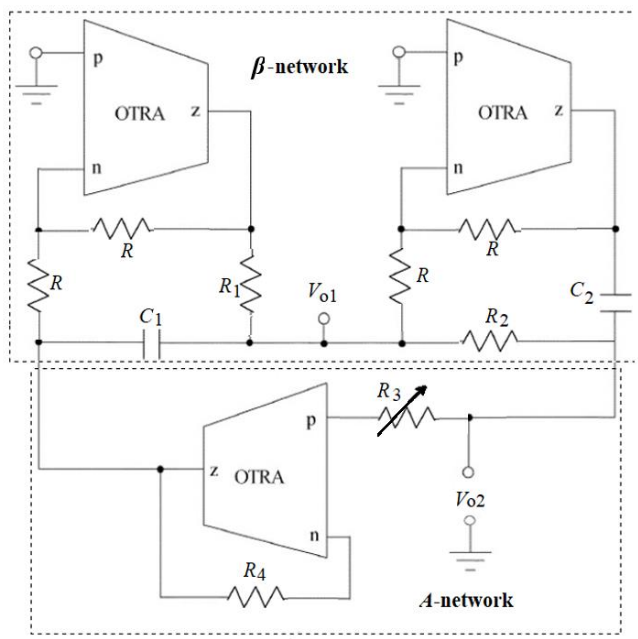
In this short paper, we propose a better design of the quadrature oscillator, which has a less complex circuit and shows improved results.

II. BETTER DESIGN OF QUADRATURE OSCILLATURE

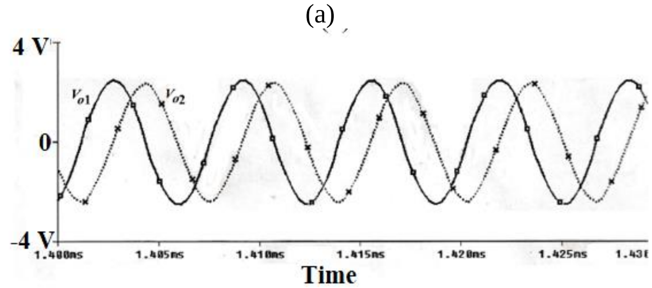
The better-designed circuit is shown in Fig. 4(a). Note that we have done away with the buffers. The values of the resistances are chosen much higher to avoid loading.

III. SIMULATION RESULTS

The oscillator is designed for f_o = 159 kHz. The simulation was carried on ORCAD PSPICE. The OTRA has been realized using two current feedback amplifiers (AD844) [38], and the unity gain voltage amplifiers are realized similar to the gain stage (A-network). The circuit exhibits highly distorted waveforms, as shown in Fig. 3(a).



(a)



(b)

Fig. 4 (a) Quadrature sinusoidal oscillator circuit without buffers (b) Waveforms

However, sinusoidal outputs obtained by adjusting R_3 = 4.65 kΩ (corresponding to gain A = 1.29), are of equal amplitudes and 90o out of phase but with f_o = 125 kHz as shown in Fig. 3(b).

We have simulated the same oscillator circuit without buffers. Choosing R_3 (13.61 kΩ) and R_4 (40 kΩ) of high values to reduce the loading effect. The waveforms V_{o1} and V_{o2} observed are almost sinusoidal and of equal amplitudes, as shown in Fig. 4(b). The simulated f_o = 152 kHz is in close agreement with the designed value of 159 kHz. Moreover, the circuit uses only 3 OTRAs and no buffers.

IV. CONCLUSION

A better design of quadrature oscillators using OTRAs is suggested. This has reduced the circuit complexity and improved performance. The simulated results are in close agreement with the theoretical ones.

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