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Minimum component count low frequency sinusoidal oscillator based on Single OTRA

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Abstract : This paper proposes single Operational Transresistance Amplifier (OTRA) based low frequency (LF) oscillator with minimum component count. It uses five passive elements namely three resistors and two capacitors. The effect of non-ideal behavior of OTRA on performance of oscillator is investigated. Sensitivity of oscillation frequency towards component variations is also analyzed. Workability of the proposed oscillator is verified through PSPICE simulations using 0.18µm AGILENT CMOS process parameters. Effect of resister ratio variation towards oscillation frequency is also examined. This design can also be used for Medium frequency (MF) ranges. The total harmonic distortion (THD) is found to be 2.24% at 50 Hz frequency . The operation of the proposed circuit is also verified experimentally wherein OTRA is realized using AD844 ICs.

Keywords : OTRA, Oscillator, LFO, THD.

1. INTRODUCTION

Signal generation circuits namely sinusoidal oscillators find extensive use in applications [1, 2] pertaining to communication, instrumentation, control and other electronic systems. Sinusoidal oscillators are most commonly designed with single/ multiple active building block (ABB) and frequency shifting networks placed in feedback loop. Researchers have used variety of active blocks for this purpose and the topologies given in [3-15] along with references cited therein are representative of it. The active block OTRA [16-19] has received considerable interest for developing signal generating circuits [12-13, 20-22] in recent past due to its terminal properties which results in simpler topologies.

Low frequency oscillator (LFO) is used in biological and biomedical field, geophysical, control and instrumentation systems and also in audio oscillators [23-26]. A limited number of LFOs are available in open literature that employs opamp [23], CFOA [24, 25] and CDBA [26] as ABB. Following are the features of these LFOs:

- Two ABBs are used in [25, 26] while single ABB is employed in [23, 24].
- Number of resistors in [23], [25] and [24, 26] are 7, 6 and 4 respectively.
- Two capacitors are used in [23, 25, 26] whereas in [24] three capacitors have been employed.
- Total component count is ten in [23, 25] and eight in [24, 26].

It is useful to minimize number of ABBs and passive elements from power consumption optimization and area efficient design viewpoint. This paper presents single OTRA based LFO, three resistors and two capacitors. Overall count of component is six in the proposed topology in contrast to minimum of eight as available in [24, 26]. Thus the proposed topology uses minimum component count. Additionally the viability of available single OTRA

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based oscillators [20-22, 27-29] providing LF oscillations are also examined. It is observed that all these topologies have oscillation frequency of type (1/25πRC) and hence require high values of passive components to obtain LF oscillations. However, proposed topology has a factor (1–*n*) in the numerator which allows LF oscillations with moderate component values, where n represents resistor ratio.

The paper has been arranged in the following manner: section II gives description of OTRA and proposed circuit. The behavior of proposed circuit is investigated in presence of OTRA non-ideal analysis in section III. Sensitivity analysis is also included in this section. Section IV includes the functional verification of proposed circuit through SPICE simulation and experimentation using IC AD844. Finally conclusion is given in section V

2. PROPOSED LFO CIRCUIT

The OTRA is represented by circuit symbol of Figure.1. It is a three terminal device and is characterized by (1). Symbol Rm in (1) represents transresistance and its value is quite high. Therefore negative feedback is imperative for most of the OTRA based circuit applications.

$$\begin{bmatrix} V_p \\ V_n \\ V_0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ R_m & -R_m & 0 \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ I_0 \end{bmatrix} \tag{1}$$

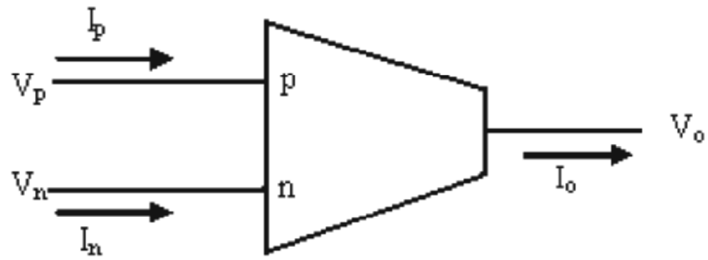

Fig. 1. OTRA Symbol.

The circuit of proposed OTRA based LFO is shown in Figure. 2. It uses single OTRA, and five passive components namely two capacitors and three resistors. Routine analysis of the circuit gives the characteristic equation of (2)

$$s^2 C_1 C_2 + s\left(\frac{C_2}{R} - \frac{C_1}{R_1}\right) - \frac{1}{R_1 R} + \frac{1}{R^2} = 0 \tag{2}$$

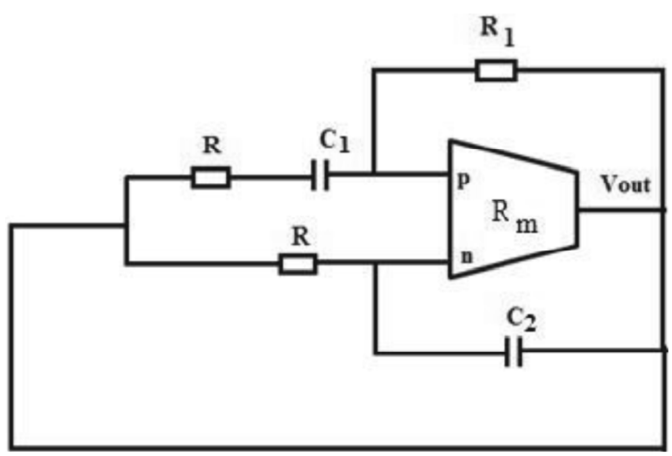

Fig. 2. Proposed OTRA based LFO.

The condition of oscillation (CO) and frequency of oscillation (FO) (*f*) are obtained as

$$CO : C_2 R_1 = C_1 R ;$$

$$\text{FO:}\quad f = \frac{1}{2\pi R\sqrt{C_1C_2}}[1-n]^{\frac{1}{2}}$$

where
$$n = \frac{R}{R_1} \tag{3}$$

By choosing appropriate value of n, the proposed oscillator can provide frequencies ranging from LF to MF. The sensitivity of f with respect to circuit components is computed as

$$\left|S_{C_1}^{f}\right| = 1$$

$$\left|S_{n}^{f}\right| = \frac{1}{(1-n)} \tag{4}$$

It is found from (4) that the sensitivity depends on n.

3. NON-IDEAL ANALYSIS

The output of the oscillator, in practice [18], may deviate due to non-ideality of OTRA. Ideally the trans resistance gain R_m is assumed to approach infinity. However, practically R_m is a frequency dependent finite value. With single pole model, the trans-resistance gain, R_m can be expressed as

$$R_m(s) = \frac{R_0}{1+\frac{s}{\omega_0}} \tag{5}$$

where R_0 is *dc* transresistance gain. For high frequency applications the transresistance gain $R_m(s)$ reduces to

$$R_m(s) = \frac{1}{sC_P} \tag{6}$$

where
$$C_P = \frac{1}{R_0\omega_0}$$

Considering (5), characteristic equation of (2) modifies to (7).

$$s^2C_1(C_2+C_p)R^2 + s[(C_2+C_p)R - C_1\frac{R^2}{R_1}] - \frac{R}{R_1} + 1 = 0 \tag{7}$$

The modified CO and FO are computed as

$$\text{CO}: R_1\,(C_2+C_p) = C_1R$$

$$\text{FO}\ :\ f = \frac{1}{2\pi(C_2+C_p)\sqrt{RR_1}}[1-n]^{\frac{1}{2}} \tag{8}$$

There is slight deviation in FO due to presence of non-idealities. However, (8) reduces to (3) if $C_2 >> C_P$. The sensitivity of f, given in (4), changes to

$$\left|S_{n}^{f}\right| = \frac{n}{2(1-n)}$$

$$\left|S_{Cp}^{f}\right| = \frac{C_p}{(C_2+C_p)} \tag{9}$$

4. SIMULATION AND EXPERIMENTAL RESULTS

The operation of proposed LFO is verified through SPICE simulations using the CMOS based schematic of OTRA [9] (Figure 3). SPICE simulations are performed using 0.18µm CMOS process parameters provided by MOSIS (AGILENT). Supply voltages taken are ±1.5V.

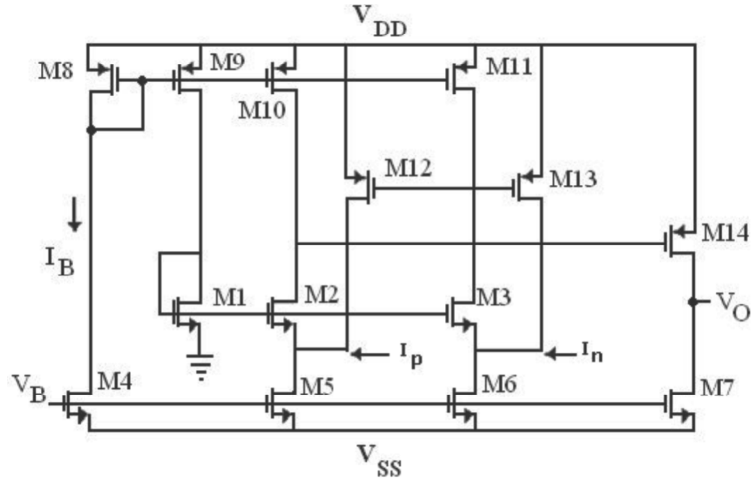

Fig. 3. Schematic of OTRA [18].

Simulations are carried out for $f = 47$Hz by selecting $R_1 = 10.1K\Omega$; $R = 10K\Omega$, $C_1 = 110nF$, $C2 = 100nF$. The corresponding timing waveform and its frequency spectrum are depicted in Figures.4 and 5. The percentage total harmonic distortion (THD) is observed to be 2.24%. Figure 6 shows variation of frequency with resistor ratio n and graph is drawn by fixing R_1 and C_1 at 1MΩ and 100nF respectively. At $n = 0.8$ the frequency is 1 Hz.

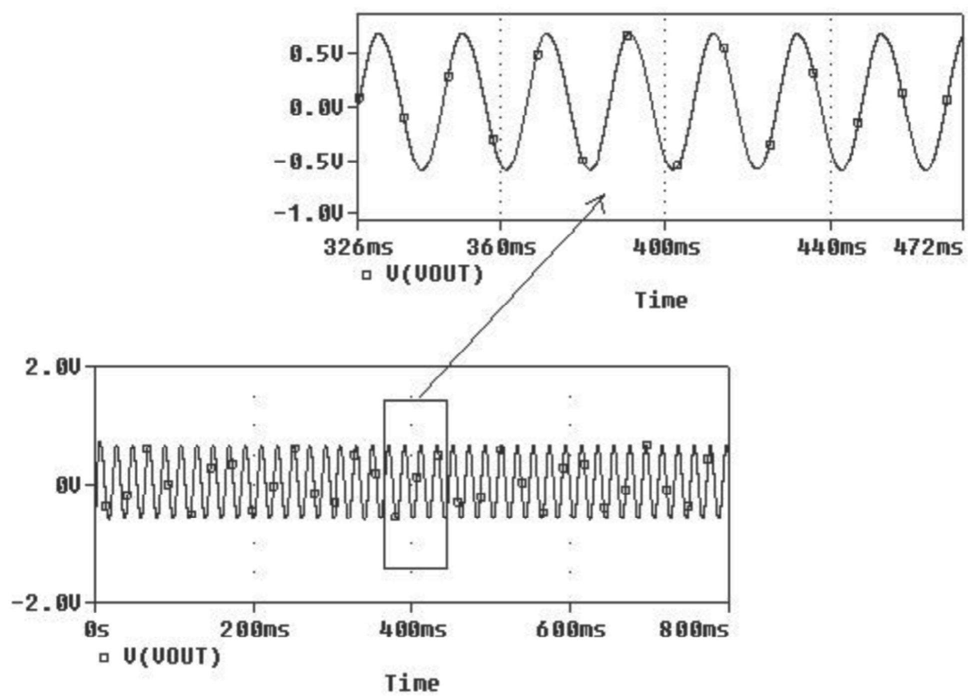

Fig. 4. Timing waveform of proposed LFO (*f* = 50Hz).

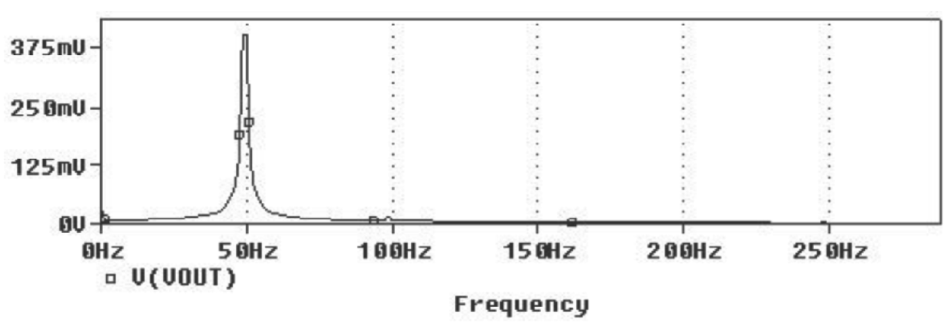

Fig. 5. Frequency spectrum of proposed LFO (*f* = 50Hz).

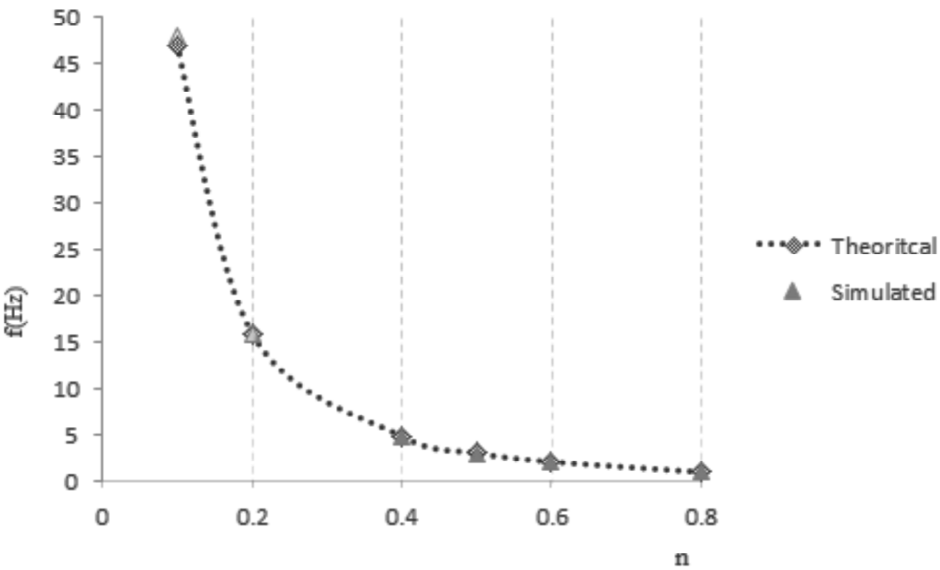

Fig. 6. Variation of frequency *w.r.t n*.

The proposed topology can also provide oscillations at higher frequencies. To illustrate this point, the oscillator was designed for an FO of 1.59MHz by selecting component values as R = 1KΩ, R1 = 2KΩ, C1 = 100pF, C2 = 50 pF. The simulated timing waveform and its frequency spectrum are plotted in Figures.7 and 8 respectively. The %THD is 0.47 at FO of 1.59MHz.

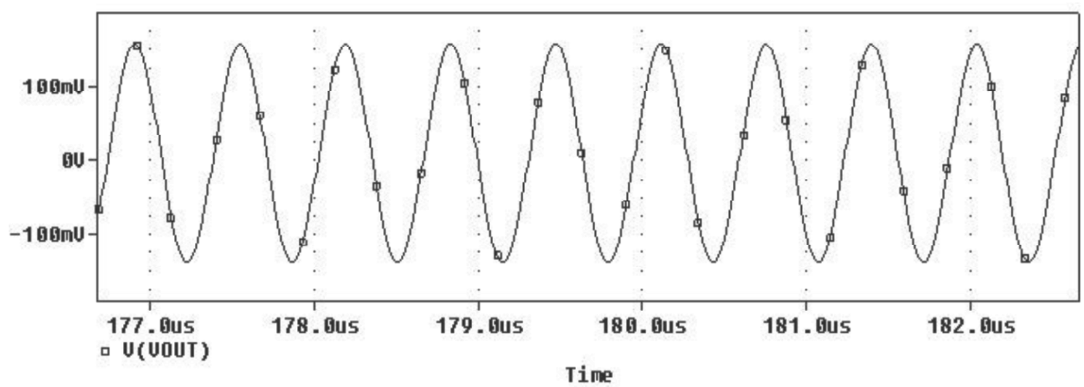

Fig. 7. Timing waveform of proposed oscillator (*f* = 1.59MHz).

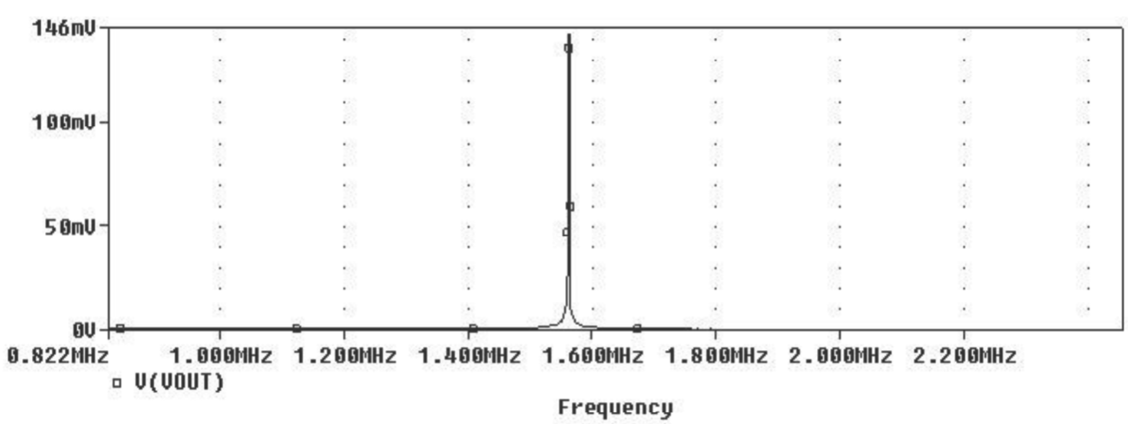

Fig. 8. Frequency spectrum of proposed LFO (*f* = 1.59MHz).

The proposed LFO is verified experimentally on breadboard by using IC AD844 using schematic [21] of Figure. 9. Figure.10 shows the measured output oscillations.

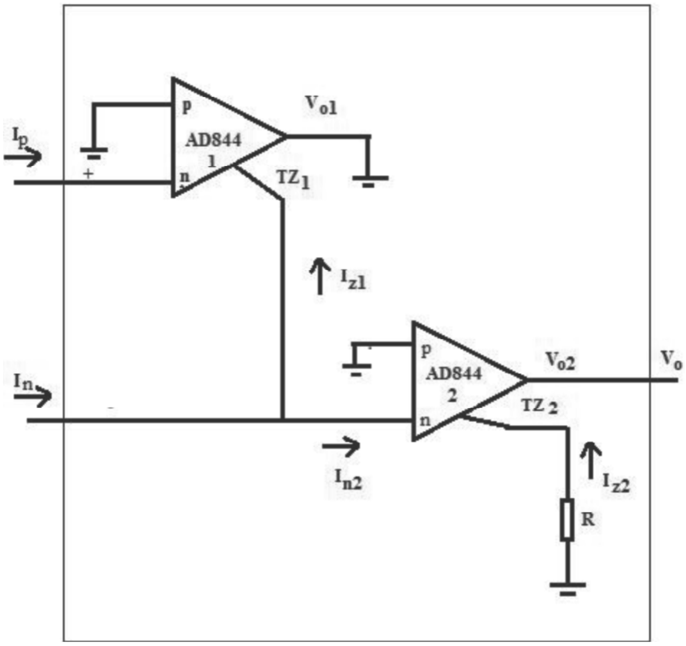

Fig. 9. OTRA implementation using IC AD 844[21].

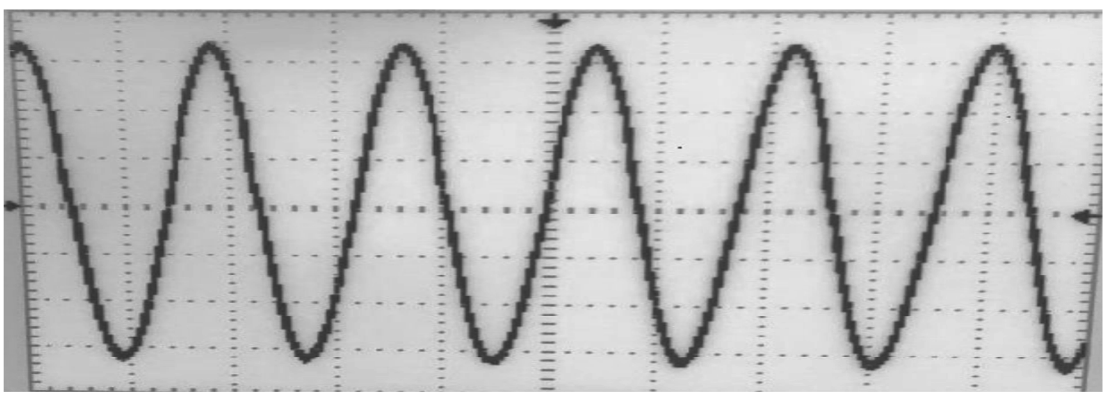

Fig. 10. Measured output.

5. CONCLUSION

A new minimum component count LFO based on single OTRA is presented in this paper. It uses five passive elements namely three resistors and two capacitors. The performance of oscillator in presence of non-idealities and component variations is analyzed. PSPICE simulations using 0.18µm AGILENT CMOS process parameters are included to show workability of the proposed structure. Effect of resister ratio variation towards oscillation frequency is also examined. This design can also be used for MF range. It is observed that the simulation results are in close agreement with theoretical propositions.

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