A NEW HIGH STABILITY SINE OSCILLATOR WITH SIMULATED INDUCTANCE

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Abstract A new sine LC oscillator is developed, with simulated inductance using two operational amplifiers. Thus, the oscillator becomes a RC one. The resulting parallel resonant LC circuit may provide a high quality factor, which assures very good frequency stability and very small harmonic distortions.

1. OSCILLATOR PRINCIPLE

It is known a double-simulation sine oscillator based on a resonant parallel circuit $L_{eq} \| C_{eq}$, whose components are simulated by the help of OA's [2]. This oscillator has been named "the electronic quartz" because of their very high frequency stability. Using a similar principle, we propose a new $L_{eq}C$ oscillator whose only inductance is simulated by the help of an OA [3].

The circuit in Fig.1, without the D_1 and D_2 diodes, fed by v_i voltage from a generator with medium-value output resistance (less than 1 MΩ) is a band-pass Antoniou-type filter [1].

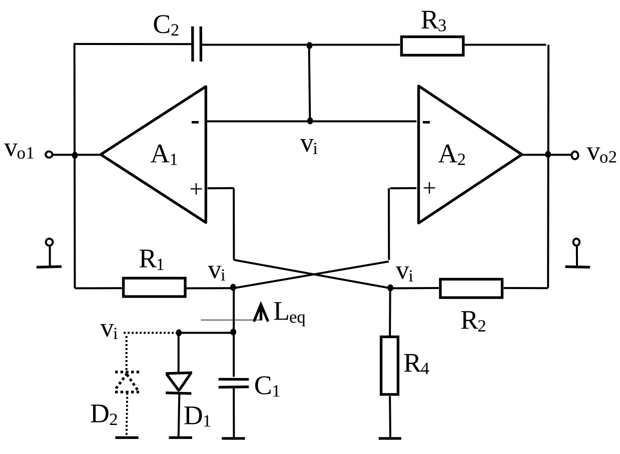

Figure 1. Oscillator scheme

The attached to C_1-capacitor circuit, including the A_1 and A_2 operational amplifiers and the C_2, R_1, R_2, R_3, R_4 passive components represents a simulated small-loss inductance [1]:

$$L_{eq} = C_2 \frac{R_1 R_3 R_4}{R_2} \qquad (1)$$

Thus, the C_1 capacitor and the L_{eq} inductance achieve a resonant parallel circuit with a high quality factor which is deteriorated by the generator output resistance.

When the generator is eliminated and low resistances are used, the circuit in Fig.1 become a sine oscillator. To obtain small output-voltage amplitude it is necessary to use a limiting device such as a simple diode, two counter-parallel diodes, a serial combination of a Zener diode and a simple diode or two back to back Zener diodes. The limiting device does not actually deteriorate the quality factor of the oscillating parallel C_1-L_{eq} circuit because of the very slight diode opening, whose dynamic equivalent resistance is moreover amplified by the quality factor [2].

This new-type oscillator [3] is of the same category as the presented in the work [2] one, which may be obtained by a similar procedure from another Antoniou-type band-pass filter [1]. We have established both the circuits pass from the filter function to oscillator function when the quality factor exceeds a certain minimum value. When eliminates the generator and its output resistance, the oscillating parallel C_1-L_{eq} circuit may attain a very high quality factor.

In order to derive the circuit oscillation condition one use the open-loop technique. From the obtained characteristic equation the oscillation frequency may be written:

$$f = \frac{1}{2\pi}\sqrt{\frac{R_2}{C_1 C_2 R_1 R_3 R_4}} \quad \text{and for } C_1=C_2=C,\ R_1=R_3=R: \quad f_o = \frac{1}{2\pi RC}\sqrt{\frac{R_2}{R_4}} \qquad (2)$$

One may observe the frequency-adjusting possibility by the help of a potentiometer replacing both the resistors R_2 and R_4 (Figure 3). For yet $R_2=R_4$ the frequency has the simplest expression: $f_o = 1/2\pi RC$.

The circuit simulation established this oscillates also with both diode amplitude limiter and small-loss capacitors.

2. VOLTAGE PHASE DIAGRAMS

The output and input-voltage phase diagrams are provided in Fig.2 for different situations. If the diodes are missing, from the R_1-C_1 divider in Fig.1 one may find the phase difference between voltages v_i and v_{o1}. This may be modified through simultaneous adjustment of R_1 and R_2 resistors whose ratio must be kept invariable so that the frequency does not change. Unfortunately, as may

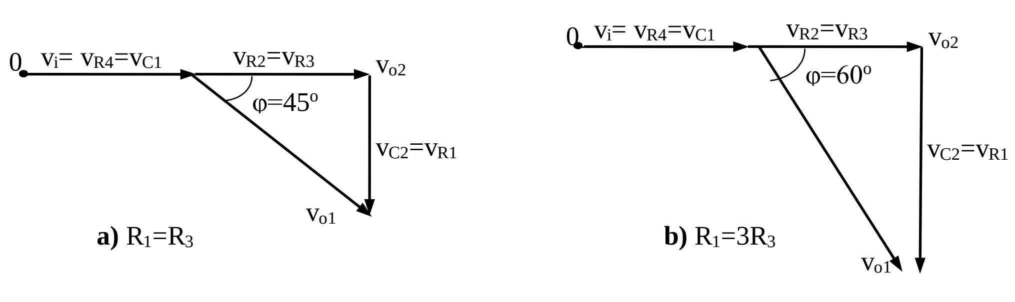

Figure 2. Voltage phase diagrams with $C_1=C_2$ and $R_2=R_4$.

see below, in this case the output-voltage amplitudes modify. It is yet possibly, if limiting diode exists, to use v_i as oscillator constant output voltage (by the help of an AO repeater, Figure 3) instead of v_{o2}. Thus, the oscillator may be used as two voltage generator with adjustable phase displacement.

For the case of equalities: $R_1=R_3$ and $R_2=R_4$ the diagram in Fig.2a is valid, $\varphi=45^o$ and the output- voltage amplitudes are: $v_{o1m}=\sqrt{2}v_{im}$ and $v_{o2m}=2v_{im}$. For $R_1=3R_3$ and $R_2=R_4$ the diagram in Fig.2b is valid, $\varphi=60^o$ and the output-voltage amplitudes are: $v_{o1m}=v_{o2m}=2v_{im}$. This last situation may be exploited to generate, with the help of another two OA's, a three-phase sine voltage [4].

3. QUALITY FACTOR AND AMPLITUDE LIMITING

The calculus of the resonant circuit $Leq \| C_1$ quality factor, including the regulating diode, OA input resistance and capacitor losses effects, for $C_1=C_2$ and $R_1=R_2=R_3=R_4=R$, gives the formula:

$$Q \cong \frac{r_{deq}}{R(2R+r_{deq})}\left(R_i \| 0.5R_{pC}\right) \tag{3}$$

where: r_{deq} is the diode equivalent dynamic resistance [2], R_{pC} is the parallel loss resistance of each capacitor, R_i is the OA input resistance. Usually r_{deq}>>R and the above formula may be simplified.

Using low-value resistors R, low-loss capacitors and high-input resistance OA's, a quality factor of 1000…2000 may be achieved at low frequency.

The symmetrical amplitude limitation using two devices assures better spectral purity. The

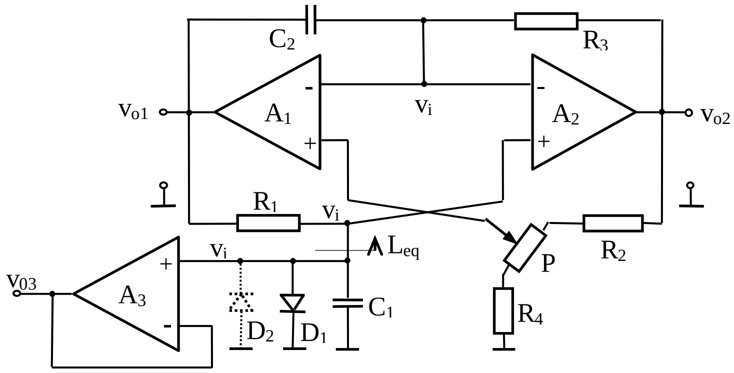

Figure 3 Adjusted-frequency oscillator.

most successful limiting solution is the use of one or two thermo-stabilized transistor collector junctions from µA726 (Fairchild) integrated circuit. In this case the temperature influence on the output voltage amplitude and frequency is minimized [2].

Figure 3 shows an oscillator with frequency adjusting by the help of the P potentiometer. This changes the R_2/R_4 ratio and, unfortunately, also changes the output voltage amplitudes apart from v_{im}, if limiting diodes exist. To use v_i as oscillator approximately-constant output voltage relative to the frequency the scheme needs an AO repeater.

The extended work will also treat the simulation and experiment results for this oscillator.

4. CONCLUSIONS

A new sine LC oscillator is developed, with simulated inductance, using two operational amplifiers. Thus, the oscillator becomes a RC one. The resulting parallel resonant L_{eq}-C circuit may provide a high quality factor (>1000), which assures very good frequency stability and very small harmonic distortions (THD of 0.02%).

Using R-C thermal reciprocally-compensated pairs and collector-junctions from μA726 IC (with thermo-stabilized regime) as limiting diodes one may achieve the relative frequency instability of $2.10^{-6}/^{o}C$ and the relative voltage-amplitude instability of $2.10^{-4}/^{o}C$.

The phase-diagram of output voltages shows a phase displacement of 45^{o} or 60^{o}. This last situation may be exploited to generate, with the help of another two OA's, a three-phase sine voltage. The oscillator may be used as two voltage generator with adjustable phase displacement.

The simulations confirmed the oscillator theory and quality performances. This new circuit enriches the high-stability simulated-inductance oscillator family.

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