Radioelectronics and Communications Systems
Vol. 47, No. 4, pp. 50–55, 2004

Izvestiya VUZ. Radioelektronika
Vol. 47, No. 4, pp. 66–73, 2004
UDC 621.373.072.9

APPROXIMATION OF TRUNCATED EQUATIONS OF NON-AUTONOMOUS SELF-OSCILLATOR WITH PHASE FEEDBACK

V. V. Rapin

"Gaztest" scientific-and-production company, Kharkov, Ukraine

A new locked self-oscillator with phase feedback is suggested. The truncated differential equations describing the oscillator operation are solved by an analytical method specially developed.

The difficulties related to analysis of nonlinear oscillations in dynamic systems and scarcity of new decisions do not permit realizing in full measure the potentialities of locked self-oscillators. A series of analytical methods have been developed for investigating self-oscillation systems: several versions of the method of averaging [1, 2], a method of frequency separation [3], a quasilinear method [4], and others. Most of these methods reduce the problem formulation to nonlinear truncated differential equations, whose solution is realized by numerical methods taking much time and not permitting efficient analysis of the self-oscillators [5, 6].

The purpose of this paper is to develop a simple and accurate analytical method for solving the truncated equations of a locked single-loop LC self-oscillator, and to investigate the effect of the proposed phase feedback (PFB).

Synchronized self-oscillators may perform various functions and have different truncated equations. Consider one of the most intricate equation systems describing a harmonic frequency doubler. The approach used in this situation is also applicable to other cases.

For definiteness sake, consider a locked self-oscillator with transformer feedback (Fig. 1). Creation of PFB consists in introducing the phase of the self-oscillator's signal into the synchronizing (clock) signal. To do this, the clock signal $e' = E' \cos(\omega_c t + \varphi_c)$ (ω_c = const) is raised to the third power, and then we eliminate the first mode and the constant term. The remaining third mode is multiplied by the locked self-oscillator signal $u = A\cos(2\omega_c t + \varphi)$. The first mode of the product $e = E\cos(\omega_c t + \psi)$ is the required signal of synchronization, where $\psi = 3\varphi_c - \varphi$. The equation of the locked self-oscillator can be written in the form

$$\frac{d^2 u}{dt^2} + \omega_0 kR\delta \frac{d}{dt}\left(\frac{u}{kR} - i\right) + \omega_0^2 u = 0$$

where $u = A\cos(2\omega_c t + \varphi)$ and i are the voltage and the current at the input of the amplifying element of the self-oscillator, ω_0 is the loop resonant frequency, $k = M/L$ is the positive feedback ratio, L and M are the loop inductance and mutual inductance, R and Q are the loop resonant resistance and quality factor, and $\delta = 1/Q$.

Let E = const, $E < A$, and $i = a_0 + a_1 u_y + a_2 u_y^2 + a_3 u_y^3 + a_4 u_y^4$ is a polynomial approximating the nonlinear characteristics of the inertialess amplifying element $u_y = u + e + u_0$, u_0 = const. Then, in the case of high Q-factor of the loop, we come to the truncated equations

$$\frac{dy}{d\tau} + \frac{\varepsilon}{2}\left[y^3 - \left(1 - 2E^2 / A_0^2\right) y\right] = \frac{\varepsilon}{2}(B_1 + 3B_2 y^2)\cos\theta,$$

REFERENCES

1. N. N. Bogolyubov and Yu. A. Mitropol'skii, Asymptotic Methods in the Theory of Nonlinear Oscillations [in Russian], Gos. Izd. Fiz.-Mat. Lit., Moscow, 1963.
2. Yu. A. Mitropol'skii, Methods of Averaging in Nonlinear Mechanics [in Russian], Naukova Dumka, Kiev, 1971.
3. L. A. Vainshtein and D. Ye. Vakman, Separation of Frequencies in the Theory of Oscillations and Waves [in Russian], Nauka, Moscow, 1983.
4. V. S. Andreyev, Theory of Nonlinear Electric Oscillations [in Russian], Svyaz', Moscow, 1972.
5. V. Rapin, IEEE Transactions on Circuits and Systems, CAS-49, No. 2, 2002.
6. K. S. Polulyakh, Resonant Methods of Measurement [in Russian], Energiya, Moscow, 1980.

14 February 2002