DIGITAL SYNTHESIZER WITH TEMPERATURE AND VIBRATION COMPENSATION OF FREQUENCY INSTABILITY

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Abstract – **Digital synthesizer of frequency with circuit of temperature and vibration compensation, which can be used as highly stable source of supporting oscillations, is studied.**

Keywords – **Quartz resonator, multimode oscillator, temperature compensation, vibration compensation.**

I. INTRODUCTION

As a result of rapid development of the systems of radio communication, radio broadcasting and TV broadcasting, radiolocation and radio navigation harder demands are put forward before generators of stable time intervals, which at overwhelming majority define the basic technical characteristics of these systems. Today the basic type of secondary standards of frequency is the Quartz Oscillators (QO), which are widely used in mobile equipment of radio and video communication, devices of digital data transmitting, in the computing and micro-processor technique, in telecommunication and navigational equipment, measuring equipment, etc. That is why the important radio-engineering task are the research and creation of devices of generating on basis of Multi-Frequency Piezoresonant Oscillation Systems (POS) with temperature and vibration compensation of frequency instability.

II. BASIC PART

The research proposes the device of generating the signals (Fig.1), which contains Multi-Frequency Quartz Resonator (QR) 1, First Quartz Oscillator 3 for the formation of oscillations of the reference mode f_{REF}, the active part of which is connected to the first pair of electrodes of multi-frequency Quartz Resonator 2-2', the Second Quartz Oscillator 5 for forming the oscillations of temperature- sensitive mode $f_{T,}$ the active part of which is connected to the second pair of electrodes of multi- frequency QR 4-4', the Third Quartz Oscillator 7 for forming the oscillation of vibration-sensitive mode f_G, the active part of which is connected to the third pair of electrodes of multi-frequency QR 6-6', the first Mixer 8 for defining the difference frequency of reference and temperature-sensitive mode of oscillations ΔF_T, second Mixer 9 for defining the difference frequency of reference and vibration-sensitive modes of oscillations $\Delta F_{G,}$ the Scheme of forming the signal of compensation 10 on basis of the signals of difference frequencies, Digital Synthesizer of Direct Synthesis (DDS) 12 for forming the oscillations of reference frequency and the Scheme of Transference the Oscillation Spectrum 11 on basis of the system of Phase-Locked Loop (PLL), which consists of Phase Detector 13, the Filter of Low Frequency 14, Frequency Divider 15 and Voltage-Controlled Oscillator 16.

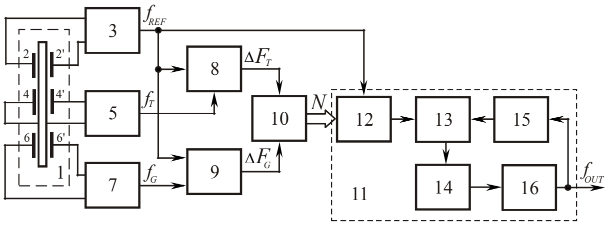

Fig. 1. Digital synthesizer

QR 1 has three pairs of electrodes, moreover they all are placed on one piezoplate, that minimizes the gradients and dynamic errors, induced by the factors of influence, mainly temperature and vibration. Multi-frequency excitation of POS is necessary for combining the function of stabilizing the frequency with measuring function, which allows the simultaneous identification of influence factors (temperature, vibration) and allows to define POS as multi-dimensional object, in the model of which the controlled perturbations appear:

$$y_i(p) = y_{s_i}(p) + \Delta y_{c_i}(p) + \Delta y_{nc_i}(p) = W_{ii}(p)x_{s_i}(p) + \qquad (1)$$
$$+ \sum_{j=1, j\neq i}^{m} W_{ij}(p)x_{s_j}(p) + \sum_{k=1}^{n} A_{i_c}(p)x_{c_k}(p) + \Delta y_{nc_i}(p)$$

where $X_s(p) = \{x_{s_i}\}_{j=1}^{m}$ – is the vector of control which is set; $X_c(p) = \{x_{c_k}\}_{k=1}^{n}$ – is the vector of controlled perturbations; $W(p)$, $A(p)$ – are the transmission functions of direction channels and the channels of perturbations accordingly; $\Delta y_{nc_i}(p)$ is the additional movement by means of non-controlled perturbations [2].

Dependence of QR frequencies from temperature T and vibration acceleration G are presented as:

$$f_{REF} = f_{REF}^0 + a_{1T}T + a_{1G}G\,; \qquad (2)$$

$$f_T = f_T^0 + a_{2T}T + a_{2G}G\,; \qquad (3)$$

$$f_G = f_G^0 + a_{3T}T + a_{3G}G\,, \qquad (4)$$

where f_{REF}^0, f_T^0, f_G^0 are nominal meanings of

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frequencies; a_{1T}, a_{2T}, a_{3T} - are coefficients of temperature sensitivity; a_{1G}, a_{2G}, a_{3G} - are the coefficients of vibration-sensitivity.

On the exit of Mixer 8 and 9 the oscillations of difference frequencies are distinguished:

$$F_T = f_T - f_{REF} = \left(f_T^0 - f_{REF}^0\right) + a_1^* T + a_2^* G = F_T^0 + \Delta F_T ;(5)$$

$$F_G = f_G - f_{REF} = \left(f_G^0 - f_{REF}^0\right) + a_3^* T + a_4^* G = F_G^0 + \Delta F_G , (6)$$

where $a_1^* = (a_{2T} - a_{1T})$, $a_2^* = (a_{2G} - a_{1G})$, $a_3^* = (a_{3T} - a_{1T})$, $a_4^* = (a_{3G} - a_{1G})$ – are difference coefficients.

Solving together (5) and (6) we get a possibility of synchronous identification of temperature T and vibration acceleration G:

$$T = \frac{a_4^* \Delta F_T - a_2^* \Delta F_G}{a_1^* a_4^* - a_2^* a_3^*}; \quad G = \frac{a_1^* \Delta F_G - a_3^* \Delta F_T}{a_1^* a_4^* - a_2^* a_3^*}. \quad (7)$$

The figure 2, 3 shows total time dependence of frequency shifts $\Delta f_\Sigma / f_0$ of POS on conditions of a change of temperature mode of Quartz Resonator (spasmodic change of capacity of excitation on the level of P_{ex}=100 μW, P_{ex}=500 μW) and vibration acceleration (on the level 5g). The main contribution to the dynamic of variations of oscillation frequency is made by the Quartz Resonator self-heating up, hereat the thermo- dynamic component of instability of QR can exceed the meaning (0,5…1)·10^{-5}. At the same time the vibration instability on this stage of oscillations is one or two degrees less (Fig.2, Window 1). After establishing the temperature balance of Quartz Resonator for $t >$ (80…100) the dynamics of frequency shifts is defined mainly by vibration-dynamic component (Fig.2, Window 2).

The similar character of dependences can be observed also for the third harmonic component of QR oscillations (Fig.3, Window 1, Window 2), which is determined by the localization of mechanic oscillations of resonator in one capacity and proves high correlation dependence between the oscillations of the first and third mechanic frequency of QR. Temperature and vibration components of instability of QR frequency in the form of difference dependences is shown in Fig.4.

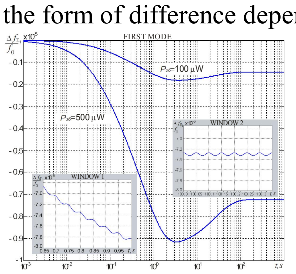

Fig. 2.

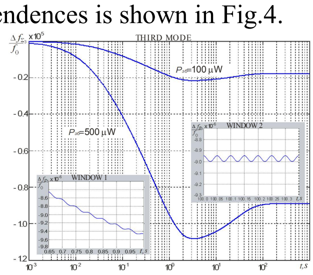

Fig. 3

It can be seen that for the difference component δf_{dif} because of high correlation of shifts of oscillation frequencies f_1, f_3 the sharp shortening of the process of establishing the frequency of difference oscillation f_{dif} (approximately by a degree) with synchronic decrease of vibration-dynamic instability to a value (0,3…0,5).10^{-8} can be observed (Fig. 4, Window 2).

On the basis of frequencies of difference oscillations ΔF_T (5), ΔF_G (6) the scheme of formation the signal of compensation 10 provides the currant identification of temperature and vibration influences onto Quartz Resonator in accordance with (7) and the formation of correcting code $N(T,G)$ for Digital Synthesizer of Direct Synthesis 12 in accordance with (2).

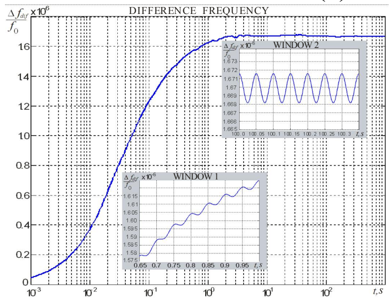

Fig. 4.

The temperature-compensated oscillation, of reference frequency f'_{OUT} is conveyed onto the input of the system of PLL (the first port of Phase Detector 13) from the output of Synthesizer of Direct Synthesis 12, and onto the second input of Phase Detector 13 the oscillation f'_{OUT} with the Voltage-Controlled Oscillator of controlled by the stress 16 is conveyed through the Frequency Divider 15. The signal of the error, which is proportional to the difference of signal phases on the inputs, is formed, which is after the correction by means of Filter of Low Frequencies 14 is used to control the frequency of the Voltage-Controlled Oscillator 16. Thus, frequency of output signal of sequencer will equal $f_{OUT} = n \cdot f'_{OUT}$ where n – is a coefficient of division of a divider to frequency 15.

III. Conclusion

Proposed digital synthesizer provides higher stability of frequency of the source of output oscillations (from five to ten times, depending on the type of QR) by means of compensation the temperature and vibration-dynamic components of instability of QR in multi-frequency mode of excitation with current identification of temperature and vibration destabilizing influences.

III. References

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