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SOME PECULIAR PROPERTIES OF OSCILLATORS WITH AUTOMATIC BIAS

Differential RC-cell (grid leak) is inserted to the circuit of the feedback of oscillators for automatic bias so additional phase rotation appears that causes some shift of the generated frequency in comparison with the resonance frequency of the oscillatory circuit.

If the feedback is strong enough, the automatically bias results also to the appearance of interrupted generation, where the periodicity of the pulses becomes irregular. This is caused by internal noises causing the moment and the magnitude of the appearance of the next pulse.

Key words: phase rotation, frequency shift, interrupted generation, irregular periodicity.

Introduction. The automatic bias (so called grid leak) is often applied in order to stabilize the operation of the auto-generators (oscillators). The grid leak is an RC-cell inserted into the circuit of the transistor base [3, 4].

The oscillations that are detected (rectified) by the diode being formed in the base circuit on the p-n junction existing between the base and the emitter of the transistor. In the base circuit a current I_D arises creating a voltage drop RI_D on the resistor R which counteracts with the voltage E_B, decrease the direct voltage on the base, lowers down the working point on the common emitter–base characteristic and locks the transistor. This effect becomes so stronger so stronger are the generated oscillations.

Thus owing to the automatically bias the self-excitation of the oscillator begins in a soft regime, but the following operation occurs in a more economical steady hard regime. But the existence of a differential RC-cell in the feedback chain must in any way affect on the process of the self-excitation and on the generated frequency.

As is well known, the generated frequency is determined by self-excitation phase condition $\psi_K + \psi_\beta = 2\pi$ where ψ_K is the phase rotation in the amplifier, and ψ_β – in the feedback loop.

In the oscillator, similar to shown in Fig.1, ψ_β is determined by the corresponding switching of the inductances L and L_{FB} so as to form $\psi_\beta = \pi$. And with the oscillator where the transistor is switched in the scheme with a common emitter, the condition $\psi_K = \pi$ is satisfied if the load in the collector circuit is purely active that is exactly at the resonant frequency of the oscillating circuit.

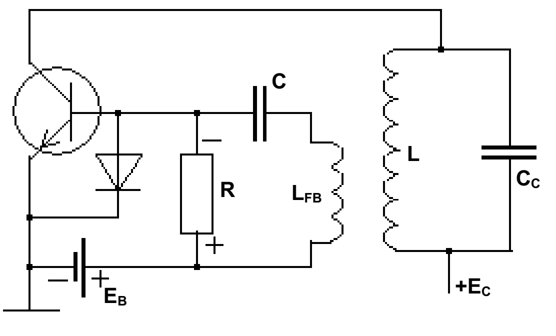

Fig. 1. Schematic diagram of the oscillator

The gridleak inserted into the input circuit of the transistor is a differential RC-cell that creates in the feedback loop a shifting of phase $\varphi(\omega) = \mathrm{arctg}(1/\omega\tau)$, where the $\tau = RC$ is the grid leak time constant, and ω - the generated frequency which is no longer exactly equal to the resonant frequency ω_0 of the oscillating circuit, and will be different from its as $\Delta\omega = \omega - \omega_0$

The phase shift delivered by the grid leak must be compensated by a phase shift in the oscillator circuit $\psi(\omega) = -\mathrm{arctg}(2Q\frac{\Delta\omega}{\omega_0})$, due to its detuning on the $\Delta\omega$. Therefore for the performance of the phase condition it may be [1, 7]

$$\mathrm{arctg}(\frac{1}{\omega_0\tau}) = \mathrm{arctg}(2Q\frac{\Delta\omega}{\omega_0}),$$

or
$$\frac{1}{\omega_0\tau} = 2Q\frac{\Delta\omega}{\omega_0},$$

hence
$$\Delta\omega = \frac{1}{2Q\tau}.$$

Further it must be verified, if it will be performed the amplitude condition of the self-excitation, because by the detuning of the oscillator circuit on $\Delta\omega$ the module of the its equivalent resistance decreases

$$|Z_{equ}(\Delta\omega)| = \frac{R_{equ}}{\sqrt{1+(2Q\frac{\Delta\omega}{\omega_0})^2}} = \frac{R_{equ}}{\sqrt{1+(\frac{1}{\omega_0\tau})^2}}$$

For instance, when $\omega_0 = 10^6 s^{-1}$, $Q = 30$, $C = 0.5nF$, $R = 1k\Omega$, the shift of the frequency is

$$\Delta\omega = \frac{1}{2Q\tau} = \frac{1}{2.30.5.10^{-10}.10^3} = 3{,}33.10^4 s^{-1}.$$

As for the amplitude condition,

$$|Z_{equ}(\Delta\omega)| = \frac{R_{equ}}{\sqrt{1+(\frac{1}{\omega_0 RC})^2}} = \frac{R_{equ}}{\sqrt{1+(\frac{1}{10^6.10^3.5.10^{-10}})^2}}\frac{R_{equ}}{\sqrt{5}},$$

and the supply for the self-excitation amplitude condition must be greater than in the absence grid leak of 2.23 times.

This in account of availability of the automatically bias in the autogenerator a negative feedback is formed and stabilizing the level of the generated oscillation.

Consequently, the surplus of the amplitude conditions of self-excitation must be greater than in the absence of the gridleak.

But due to the inertia of the oscillatory circuit, so as of the RC-cell, in the feedback circuit arises a additional phase shift, which can under certain conditions convert the negative feedback to the positive. Then in the scheme are beginning some oscillations of the level of the generated signal with a period commensurate to the inertia of the feedback circuit (selfmodulation). Herewith the capacitor C can be loaded so strong, that the transistor becomes completely closed. But even thereafter because to the large quality and inertia of the oscillatory circuit his oscillations continue to be supported and are further loading the capacitor of the grid leak. The transistor remains closed while the capacitor is discharged through the R-resistor during the time of the order of the RC-product. The generated oscillations becomes the sequence of periodical pulses. This phenomenon of interrupted generation is well known and described in the literature [2, 4].

But when modeling in Multisim software or when dealing with real oscillator layout similar to shown in Fig.1, we found that the time between pulses is not stable and may be subject to change disordered within about ten percent (Fig.2).

The spectrum of such oscillations (Fig.3) is indicating the chaotic nature of this process. From this figure we can determine the oscillation frequency of the pulses which is approximately in the vicinity of 370 kHz. This frequency corresponds just to the upper limit of the spectrum

On the Fig.2, one also can see well that the interval between pulses is that greater, than greater was the previous pulse.

To understand the reason for this is we could observing the course of the voltage on the transistor base (Fig.4). It is clearly seen that the transistor is opened and the next pulse is beginning at the same voltage about 0.7V. In the process of pulse generating the voltage on the base is reduced through the rectifying of the base-emitter diode, that charges the capacitance C in the greater extent, the larger was the previous pulse. And the longer is the process of discharge of the capacity to a level, at which the transistor is opened and can create the next pulse.

As for the size of most pulses, it is determined, perhaps, by the level of noise or interference, from which starts the self-excitation of the next pulse generated. The randomness of the noise and interferences causes the random nature of these processes, just as is the case in the absence of regular input signals in some superregenerators [2,5,6].

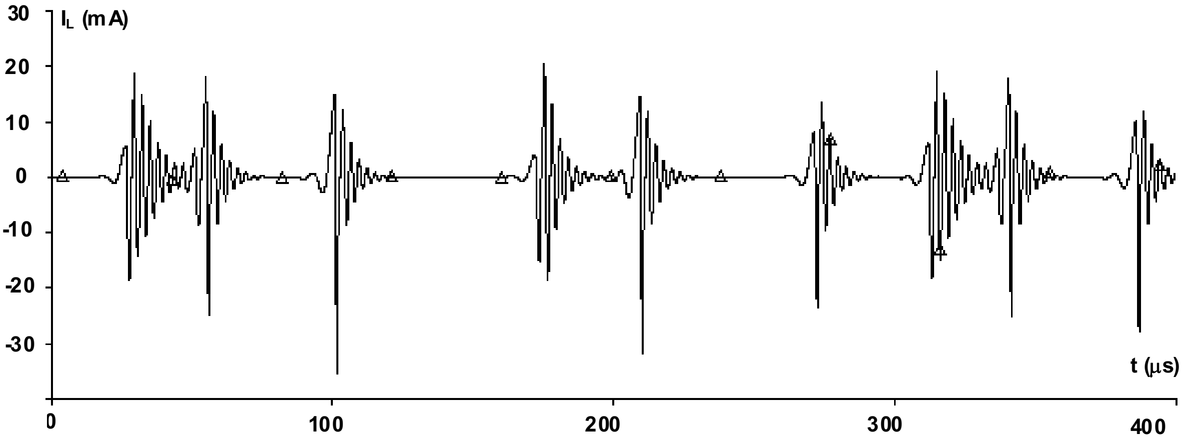

Fig. 2. Waveform of the current through inductor L

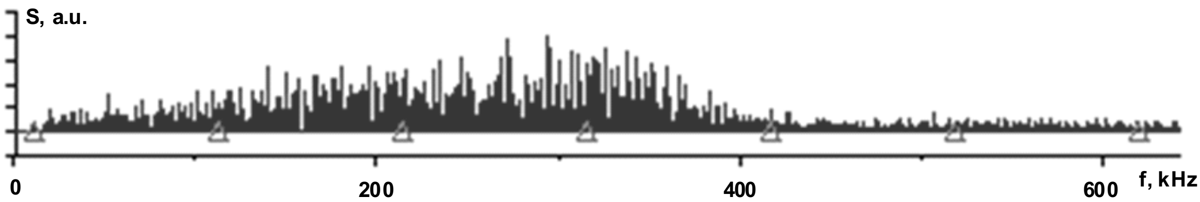

Fig. 3.Spectrum of the current through inductor L

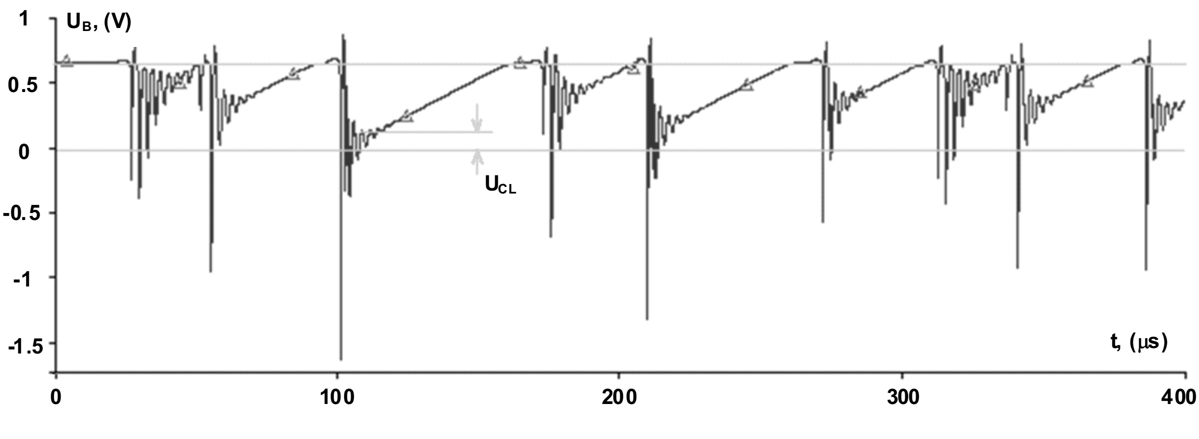

Fig. 4. Waveform of the transistor base voltage

Certain confirmation of these considerations was an experiment when we forcibly injected from an external source a slight signal in the circuit of the base with a frequency near to the frequency of oscillation of the circuit. When the amplitude of this external signal was large enough to exceed the potential of the noise and interference, the value of all the pulses and the intervals between them were identical.

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As for the magnitude of most pulses, it is determined, perhaps, by the level of noise or interference, from which starts the self-excitation of the next pulse generated. The randomness of the noise and interferences causes the random nature of these processes, just as is the case in the absence of regular input signals in some superregenerators [5, 6].

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ДЕЯКІ ВЛАСТИВОСТІ АВТОГЕНЕРАТОРІВ З АВТОМАТИЧНИМ ЗМІЩЕННЯМ

У автогенераторах RC-комірка автоматичного зміщення створює зсув фази коливань, що призводить до зсуву генерованої частоти.

У випадку переривчастої генерації (при досить великій сталій часу RC-комірки) при відповідних параметрах RC-комірки та величині зворотнього зв'язку періодичність імпульсів стає нерегулярною. Це спричиняється внутрішніми шумами які обумовлюють момент і величину виникнення чергового імпульсу генерації.

Ключові слова: обертання фази, зсув частоти, переривчаста генерація, нерегулярна періодичність.

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НЕКОТОРЫЕ СВОЙСТВА АВТОГЕНЕРАТОРОВ С АВТОМАТИЧЕСКИМ СМЕЩЕНИЕМ

В автогенераторах RC-ячейка автоматического смещения создает сдвиг фазы колебаний, что приводит к смещению генерируемой частоты. В случае прерывистой генерации (при достаточно большой постоянной времени RC-ячейки) при соответствующих параметрах RC-ячейки и величине обратной связи периодичность импульсов становится нерегулярной. Это происходит засчет внутренних шумов, обуславливающих момент и величину возникновения очередного импульса генерации.

Ключевые слова: вращение фазы, сдвиг частоты, прерывистая генерация, нерегулярная периодичность

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DYNAMICS OF ELECTRON BUNCH IN THE EXTERNAL MAGNETIC FIELD: COMPUTER SIMULATION

Influence of the longitudinal magnetic field on the electron bunch expansion in vacuum was studied. Analytic estimation of the spatial dependence of the bunch radius is compared with the simulation results via PIC method. Results obtained from simulation correlate satisfactory with theoretical estimations for the large magnetic field and low bunch density. Dynamics of the relativistic bunches was also studied.

Keywords: electron bunch expansion, longitudinal magnetic field, simulation via PIC method.

Introduction Problem of dynamics of electron beams and bunches is important for a wide range of branches [2], including inertial thermonuclear fusion and creation of the high frequency vacuum tubes [3], various types of spectrometry, electronic and ionic mycroscopy. In most cases top forming, focusing the bunch, and preventing of it's swelling due to the space charge are the priority tasks [2]. One of the most common ways to prevent swelling is the longitudinal magnetic field imposing to the system. Other methods use the external electric field and the spatial charge of residual plasma (for electron beams). Analytic solution of problem of the dynamics of electron bunch is rough [1]. Therefore the aim of this work is to carry out the computer simulation of the dynamics of electron bunch in a vacuum system with the longitudinal magnetic field.

Analytic estimation The simplest model of the homogeneous cylindrical electron beam of infinite length is treated. From the Gauss theorem one can obtain the electric field on its boundary:

$$E_r = -2\pi Rne = -\frac{2Ne}{R}, \tag{1}$$

where R is the current cylinder radius, n and $N = \pi R^2 n$ are spatial and linear electron densities, respectively. Note that linear density N remains constant during the beam electrons' transversal oscillations. The motion equations for the electrons at the cylinder boundary have a form:

$$m\frac{dv_r}{dt} = -eE_r - \frac{e}{c}v_\varphi B; \quad m\frac{dv_\varphi}{dt} = \frac{e}{c}v_r B; \quad m\frac{dv_z}{dt} = 0, \tag{2}$$

where $\vec{B} = \vec{e}_z B$ is the external magnetic field.

From the last equation (2) it is clear that $v_z = const \equiv v_0$.

One can obtain the following equations for the transversal velocity components from (1)–(2):

$$\frac{d^2v_r}{dt^2} + \Omega^2 v_r = 0; \quad \frac{d^2v_\varphi}{dt^2} + \omega_c^2 v_\varphi = -\frac{\omega_c e}{m}E_r\left(R(t)\right), \tag{3}$$

Where $\omega_c = \frac{eB}{mc}$, $\omega_p^2 = \frac{4\pi ne^2}{m}$, $\Omega^2 = \omega_c^2 + \frac{\omega_p^2}{2}$

(note that $v_r = dR/dt$). Initial conditions have a form:

$$R(t=0) = R_0; \quad v_r(t=0) = v_\varphi(t=0) = 0. \tag{4}$$