Study of some Circuits in Radio Communication Designed to Generate Chaotic Signals

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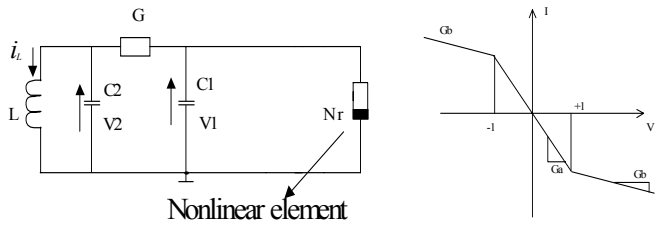
Abstract - **In this paper some versions of generators, designed to produce chaotic signals, are presented. The suggested devices have been developed and experiments on the working prototypes have been carried out. The obtained results have been discussed. It has been shown, that the proposed circuits are appropriate for developing of chaotic generators.**

Keywords – **Chaotic circuits, Chua's circuit**

I. INTRODUCTION

Generating of chaotic signals is discussed in many papers. The study of circuits, designed to produce chaotic signals, can be used for different purposes. Investigations, concerning the nonlinear dynamics and the mechanism of chaotic oscillations, can be based on such circuits. Devices, belonging to the global class of chaotic generators, can be used in communication for obtaining of signals with different properties. A lot of the devices, designed for this purpose, are based on the well known Chua's circuit. Some of them are discussed in the presented work.

It is well known, that the circuit, designed to generate chaotic signals, so called canonical Chua's circuit, includes nonlinear element with negative conductance. On Fig.1a is presented Chua's circuit, which consists of three linear reactances (inductor L and two capacitors C1 and C2), a linear resistor G and a nonlinear element (most usually nonlinear resistor). It's piecewise linear volt-current characteristic is presented on Fig.1b [1-5].



(a) (b)

Fig.1.

The equations, describing the processes in Chua's circuit, are [2]:

$$\frac{dv_1}{dt} = \frac{1}{C_1}.\left[G.(v_2 - v_1) - \left(G_b.v_1 + \frac{1}{2}(G_a - G_b).(|v_1 + 1| - |v_1 - 1|)\right)\right] \quad (1)$$

$$\frac{dv_2}{dt} = \frac{1}{C_2}.[G.(v_1 - v_2) + i_L]$$

$$\frac{di_L}{dt} = -\frac{v_2}{L}$$

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The nonlinear element is an irreversible ingredient part of the Chua's circuit and has a negative slope in it's volt-current characteristic.

II. CLASSIFICATION

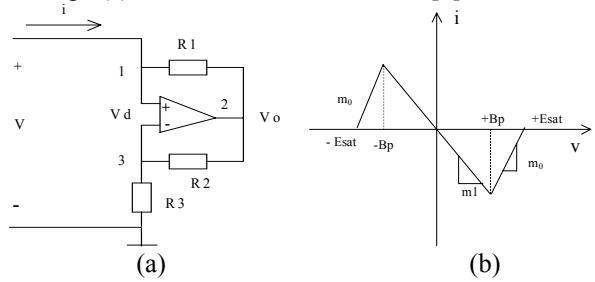
The aim of the versions, presented in [7-10], is to show the application of controlled nonlinearity in chaotic signal generators. The volt-current characteristics of the proposed nonlinearities [7-10] should be similar to the well known volt-current characteristic of the nonlinearity in the Chua's circuit.

There are different variants of modelling the nonlinear element using operational amplifiers (OA). Usually in the known circuits one or several OA with properly chosen values of the components in their feedbacks are applied.

In what follows some versions of chaotic signal generators are considered.

1. There are different methods for modelling of nonlinear element with volt-current characteristic, presented on Fig.1b. One of them, realized with OA, is presented in [7], where a suggestion for new circuit with modified driven nonlinearity has been proposed. In the model of the nonlinear element, proposed in [7], some versions and relations have been used [1], but at the same time, the model, suggested in [7], has substantial differences.

On Fig.2(a) a circuit with OA is shown [1].



(a) (b)

Fig.2.

The corresponding volt - current characteristic is displayed on Fig 2(b) [1]. For the central part of the characteristic the following basic relations are valid [1]:

$$i = \frac{1}{R_1}.(V - V_o)$$

$$i \approx \left(-\frac{R_2}{R_1.R_3}\right).V \quad (2)$$

$$m_1 \approx -\frac{R_2}{R_3.R_1}$$

where m_1 is the slope in the central part of the volt-current characteristic. In the circuit, presented in [1], an element with negative part in the volt-current characteristic has been used.

In [7] the nonlinear element has been modelled by means of OA with additional modified nonlinearity in the feedback, as shown on Fig.3.

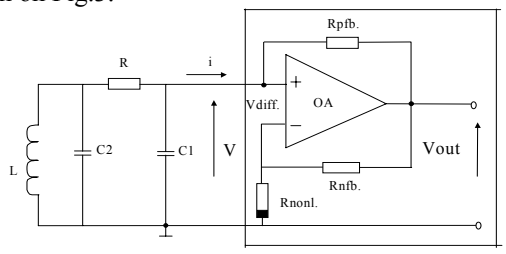


Fig.3.

The model of the nonlinear element is similar to the model of Fig.2a, but at the same time, it has substantial differences: in the negative feedback it has additional nonlinearity Rnonl.

2. Another chaotic generator is presented in [8], where a new circuit with external driven nonlinearity is proposed. A working prototype of this version has been developed. In the device, discussed in [8], as driven nonlinearity the dynamic resistance collector - emitter of a bipolar transistor has been used. The realization of the variant, proposed in [8], is based on the circuit, presented on Fig.3, but unlike the device, presented in [7], the nonlinearity (Rnonl) in [8] is developed in a different way.

By the investigations in [7], [8] another experimental setup has been realized. Some measurements have been carried out. An appropriate computing procedure has been developed. Using the obtained data, the necessary calculations have been made. As it has been shown, that the proposed nonlinearities are appropriate for design of chaotic signal generators.

3. The circuit, presented in [9], can be attached to the same class of circuits, designed to obtain chaotic signals, based on the canonical realization of Chua's circuit. In [9] a new model of the nonlinearity is shown. The related equations, describing the volt-current characteristic of the proposed model of nonlinearity, are also presented. It has been proven, that the proposed model of nonlinearity is appropriate for circuits, designed to obtain chaotic signals. One possible approach to modelling of the nonlinearity is presented on Fig.4 [9].

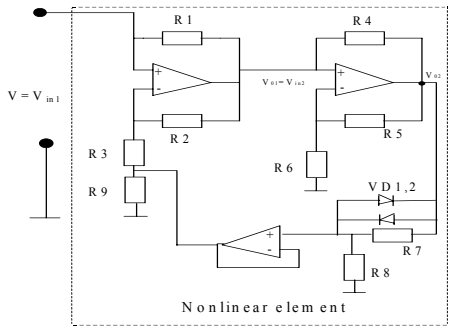


Fig.4.

The model of the nonlinear element has been realized with cascaded OAs. The nonlinearity includes feedback, which has a buffer, realized with third OA. One of the outputs of the discussed variant is connected to the input "X" of the oscilloscope, the another is connected respectively to the input "Y". Mathematical analysis of the proposed variant has been made. It has been shown, that the discussed model of nonlinearity is appropriate for developing of chaotic generators. The related analytical expressions are presented in [9].

4. The next representative of the discussed class of circuits, designed to obtain chaotic signals, based on the canonical realization of Chua's circuit, is presented in [10], where a chaotic signal generator with non - conventional nonlinearity is discussed. A description of methods to model resistors with negative conductance, using OA, is considered.

In [6] is presented a circuit (Fig.6), with volt - current characteristic, shown on Fig.5.

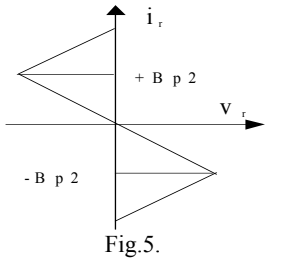


Fig.5.

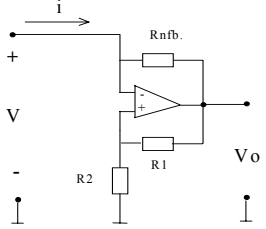


Fig.6.

In [5] a method for modelling element with volt - current characteristic, as shown on Fig.7, is described. The circuit design is shown on Fig.8 [5].

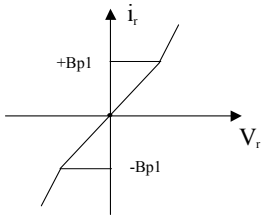


Fig.7.

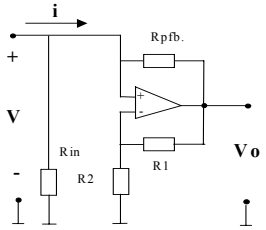


Fig.8.

It has been turned out, that element with such characteristic is very appropriate as part of the model of the general nonlinearity in the Chua's circuit.

On this basis a novel circuit, including two elements connected in series, has been developed in [10]. The proposed configuration is displayed on Fig.9 [10].

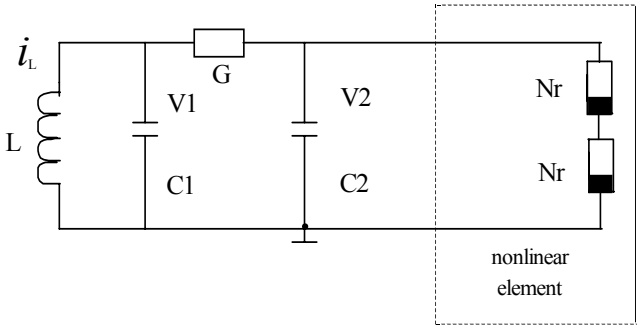


Fig.9.

The nonlinearity in [10] is composed, using elements with strange volt - current characteristics. The obtained configuration performs successfully the role of nonlinear element in Chua's circuit. The first element of the circuit, which models the nonlinear element, is based on the presented on Fig.6 variant. By the modeling of the second element a different variant has been used. An element with characteristic, as the characteristic, presented on Fig.7, has

been chosen. On Fig.10 the way of the composition of the resultant characteristic is given [10].

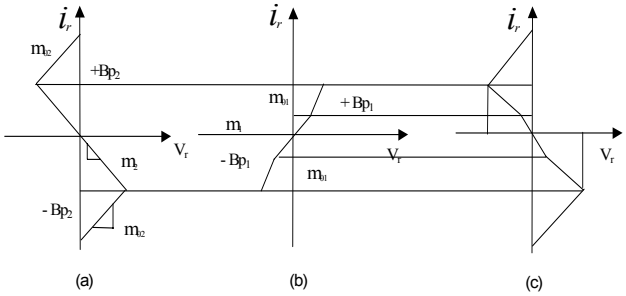


Fig.10.

Each one of the two components, composing the general configuration, has different slopes in the three areas from the corresponding volt - current characteristics. It allows by constructing the model of the general nonlinearity, a characteristic from the type, shown on Fig.10(c), to be obtained. The model of the nonlinearity is shown on Fig.11[10].

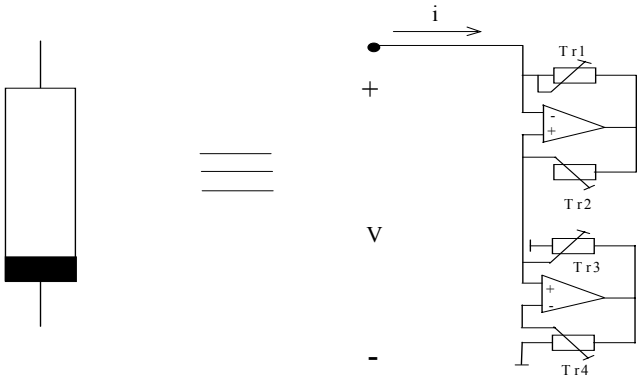


Fig.11.

The feedback parameters can be controlled by the proper choice of the parameters of the passive elements. This leads to the change in the state condition of the whole circuit, which reflects respectively on the output signal.

III. EXPERIMENTAL RESULTS

1. On Fig.12 a specified realization of the circuit from Fig.3 has been shown [7].

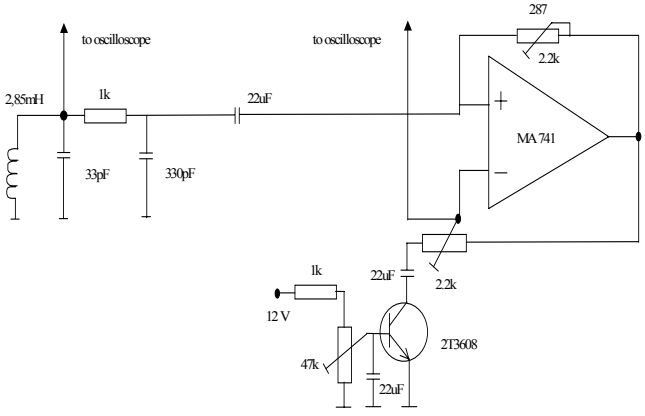


Fig.12.

The output signals, observed in the phase plane, are presented on Fig.13.

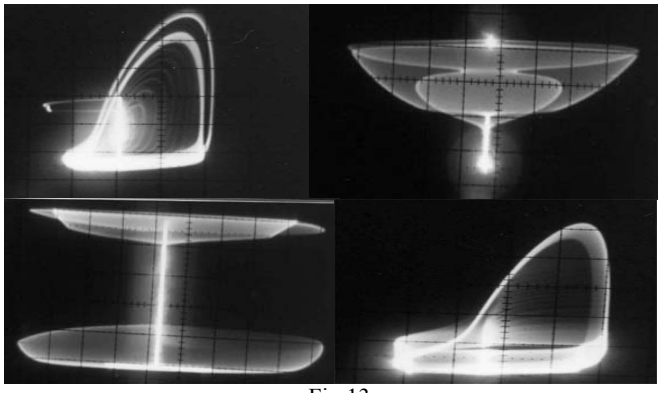


Fig.13.

The results, obtained by the physical experiments, confirm the possibility of obtaining chaotic signals by means of the discussed circuit.

The main advantage of the circuit, proposed in [7], is that it includes driven nonlinearity, based on bipolar transistor, with a base, AC - connected to the ground. Different parameter values of the driven nonlinearity can be obtained changing the base voltage. This is directly related to the form of the output signal of the whole device.

2. Experiments, concerning the investigation of the nonlinear element in the proposed new circuit with driven nonlinearity, have been made in [8]. In the proposed version the nonlinear element is designed, as shown on Fig.14.

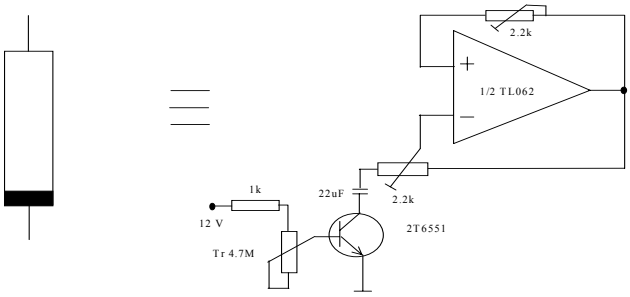


Fig.14.

Experimental results from the working circuit are obtained. The trajectories of the output signal, as well as the volt - current characteristic of the total nonlinearity in Chua's circuit, observed on oscilloscope in the phase plane, are shown on Fig.15.

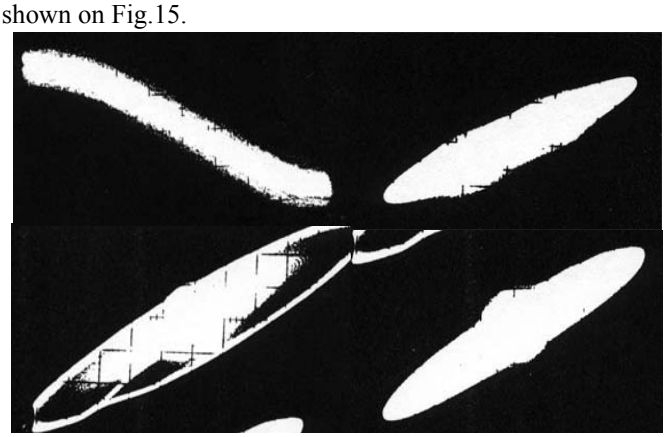


Fig.15.

The observed trajectories prove the following statements:

* The shape of the volt - current characteristic of the general nonlinearity in the working prototype is in accordance to the expected theoretical form [8].
* By appropriate choice of the values of the elements chaotic signals can be obtained.
* The main advantage of the variant, proposed in [8], is the driven nonlinearity. Through change of voltage values on the base of the transistor the circuit parameters can be controlled. This leads to an adequate change in the functioning of the proposed device.

3. Experiments and investigations on the working prototype of the new circuit, developed in [9], have been carried out. The experimental results are discussed. Photos of the output signals, observed on oscilloscope in the phase plane, have been made. They are presented on Fig.16.

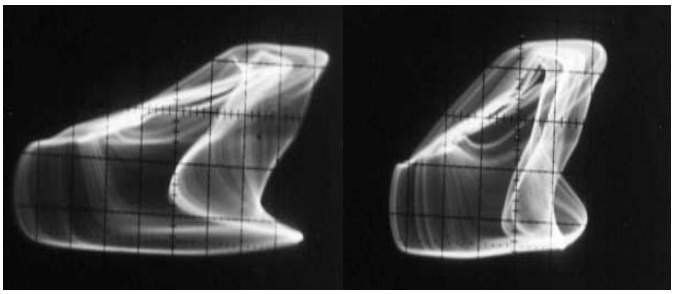


Fig.16.

By proper choice of the parameters of the elements, included in the specified realization [9], chaotic signals can be obtained. The experimental results, observed in the phase plane, are an illustrative example, that through the variant, proposed there, chaotic signals can be obtained. By change of the values of the parameters in the analyzed circuit an essential change in the form of the output signal has been observed.

4. Experiments and investigations on the working prototype of the suggested in [10] device have been carried out. The obtained experimental results have been discussed and analyzed. Photos of the observed in the phase plane trajectories are presented on Fig.17 [10].

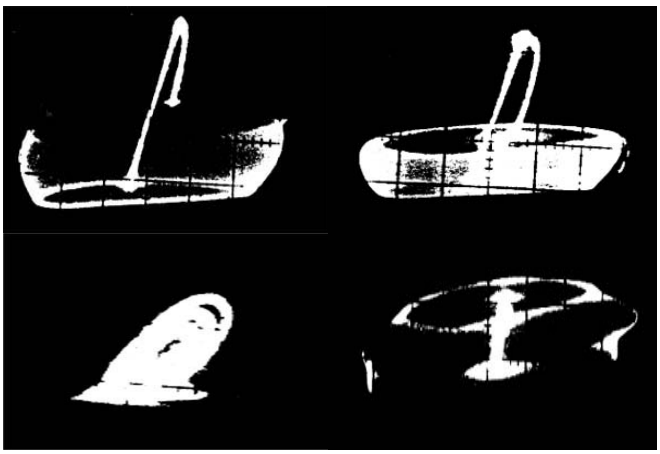


Fig.17.

The experimental results, observed in the phase plane, are an illustrative example, that the variant, proposed in [10], is appropriate for generating of chaotic signals.

By change of the values of the parameters in the circuit, analyzed in [10], an essential change in the form of the output signal has been observed.

IV. CONCLUSIONS

* New circuits, designed for obtaining of chaotic signals, have been proposed [7-10].
* In some of the discussed variants ([7], [8]) besides, another experimental setup has been realized and measurements, concerning the driven nonlinearity, have been carried out. An appropriate computing procedure has been developed. Using the obtained data, the necessary calculations have been made.
* The suggested variants have been practical developed and on the working prototypes experiments have been carried out.
* By appropriate choice of the values of the components of the proposed devices chaotic signals have been obtained.
* Photos of the observed in the phase plane trajectories have been taken.
* The obtained experimental results have been discussed .
* It has been shown, that the proposed circuits are appropriate for developing of chaotic generators.

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