Design, modeling and research of the new non-autonomous chaotic generator

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Introduction. General scientific fields where can be used non-autonomous circuits that realize chaotic behavior and generate chaotic oscillations are presented. Main characteristic about non-autonomous chaotic circuits is described. For modelling, analysis and demonstrate results was selected MultiSim software environment.

Modelling of Non-Linear Element. The simplest chaotic non-autonomous second-order circuit which belongs to the single-loop RL-diode series circuit, system of equations has described RLC circuit and theoretical nonlinear characteristic and circuit for realization of nonlinear characteristic, nominal components, parameters are presented. This non-linear element has designed to have a piecewise-linear characteristic and built only in one opamp. For realization of nonlinearity use only one bipolar power source for the opamp is enough. Results of computer modelling and simulation using MultiSim, i.e. the volt-ampere characteristic (VAC) at certain values of the components of the scheme's nominal values, is presented.

Modelling and Analysis of the New Non-Autonomous Chaotic Circuit. System's behaviour is investigated through numerical simulations, by using well-known tools of nonlinear theory, such as chaotic attractor and time distributions of the chaotic coordinates. This designed non-autonomous circuit, which generate a chaotic attractor, can be used in modern transmission and reception systems of information.

Conclusions. For the first time was designed a new non-autonomous circuit that generate chaotic oscillations. The circuit, system of equations that describe circuit and nominal of components are presented. This circuit that generate chaotic oscillations can be used as one of the main part of modern telecommunication systems for masking and decrypt of information carrier.

Key words: chaos; non-autonomous generator; MultiSim

Introduction

Chaos is a very interesting complex nonlinear phenomenon which has been intensively studied in the different areas of science, mathematics and engineering communities. Chaos has been found to be very useful and has great potential in many technological disciplines such as in information and computer sciences, power systems protection, flow dynamics, liquid mixing, biomedical systems analysis [1–15]. Chaotic signals can be generated with simple electronic circuits. Chaotic signal depends very sensitively on initial conditions, have unpredictable features and wide band spectrum. Chaotic systems are deterministic, highly sensitive to system parameters. A circuit is said to be non-autonomous if it is driven by at least one AC signal. A first-order non-autonomous circuit cannot be chaotic because its state equation can be transformed into an equivalent second-order autonomous system. However, a non-autonomous second-order circuit can become chaotic.

1 Modelling of Non-Linear Element

The simplest chaotic non-autonomous second-order circuit is the single-loop RL-diode series circuit shown in Fig. 1.

Following system of equations has described RLC circuit:

$$\begin{cases} C\frac{dV_C}{dt} = i_L - g(V_C) \\ L\frac{di_L}{dt} = -R \cdot i_L - V_C + F \cdot sin\Omega t, \end{cases} \quad (1)$$

where $g(V_C)$ − nonlinear function.

A great interest is the simulation that using different software environments allows to demonstration different information properties of chaotic oscillations [16–18]. Nonlinear elements − these are elements in which the relation between voltage and current is a nonlinear function. An example is a diode, in which the current is an exponential function of the voltage. Circuits with nonlinear elements are harder to analyse

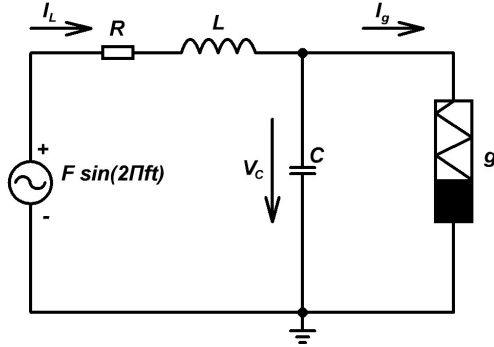and design, often requiring circuit simulation computer programs such as SPICE.

Fig. 1. Electrical circuit: R, L, C − linear elements; g − nonlinear element; $F \sin(\Omega t)$ − sinusoidal generator

A single-port network having the characteristic of a linear negative resistance, terminated at both ends with linear positive resistance (Fig. 2) was chosen as the nonlinear element.
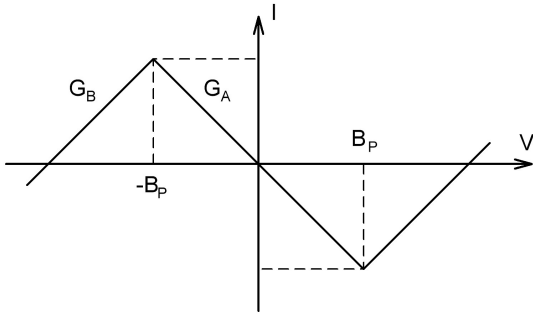

Fig. 2. Nonlinear characteristic

It possesses the advantage that it may be realized, approximately, using an op-amp and three resistors, with two back-to-back diodes to set the break points (Fig. 2) or more precisely, by the switching-in of the series combination of an appropriate resistor and voltage-source at the break-point voltages. With careful design this version can exhibit close to ideal behavior.

The network's DC, V/I characteristic, is that of a voltage-controlled, short-circuit stable, negative resistance. It has been shown by Chua and Lin that, in dynamic operation, where, when what used to be called "jumps" occur, that, both in modeling this characteristic, and in reality, to provide a path for the continuity of current, a transit capacitor, however small, must exist across the terminals of the device. This suggested the placing of a capacitor in this position. The remainder of the circuit is the series combination of a periodic voltage source, a linear inductor and a resistor. The resistor comprises an actual resistor and the DC resistance of the inductor. The total resistance value was chosen to be greater than 1/Ga so that the circuit was not capable of starting or maintaining sustained oscillation when the driving voltage was reduced to

zero. The circuit values shown and used in simulation are the measured values of nominal components.

The circuit realization of the above is displayed in Fig. 3, with component: one operational amplifier DA1-TL082, R2 = R3 = 1,2 kΩ, R4 = 2,4 kΩ, two diodes 1N4148. Voltage - ± 12 V. Probe X correspond current I, probe Y correspond voltage U, respectively.
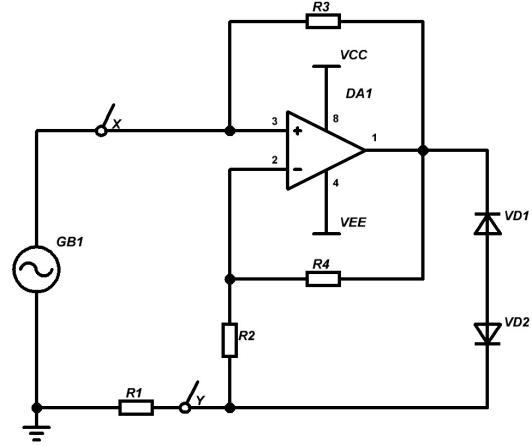

Fig. 3. Circuit for realization of nonlinear characteristic

Nonlinear characteristic was modeled by the following parameters: GB1 = 9 V, f = 1 kHz, R1 = 1000 Ω.
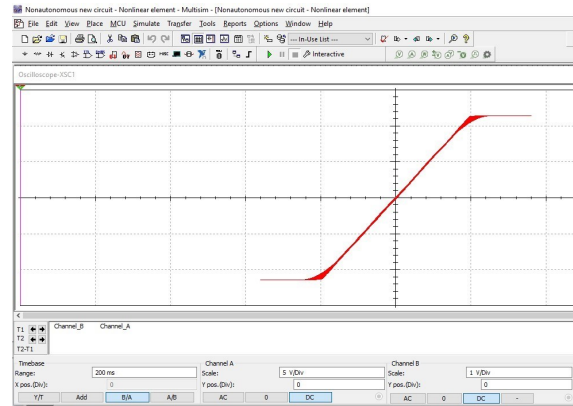

Fig. 4. Nonlinear characteristic

Fig. 4 show result of modeling of nonlinear element using MultiSim. The simulation parameters: U1 = 5 V/div, U2 = 1 V/div.

2 Modelling and Analysis of the New Non-Autonomous Chaotic Circuit

Fig. 5 shows proposed of the new chaotic non-autonomous scheme of the simplest chaotic generator.

Circuit was realized on the one operational amplifier DA1 − TL082, powered by a 12V, two diodes 1N4148, resistors R1 = 500 Ω, R2 = R3 = 1.2 kΩ, R4 = 2.4 kΩ, capacitor C1 = 10 nF, inductor L1 = 7 mH. Sinusoidal source GB1 = 1.5 V, f = 2 kHz.
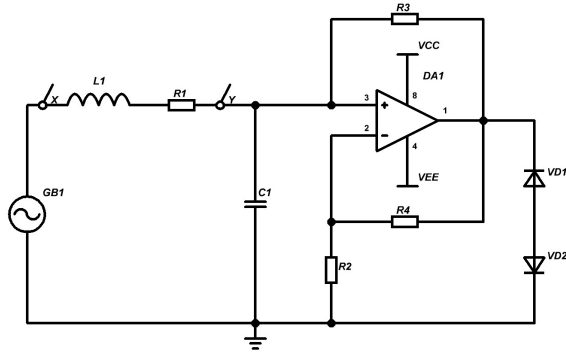
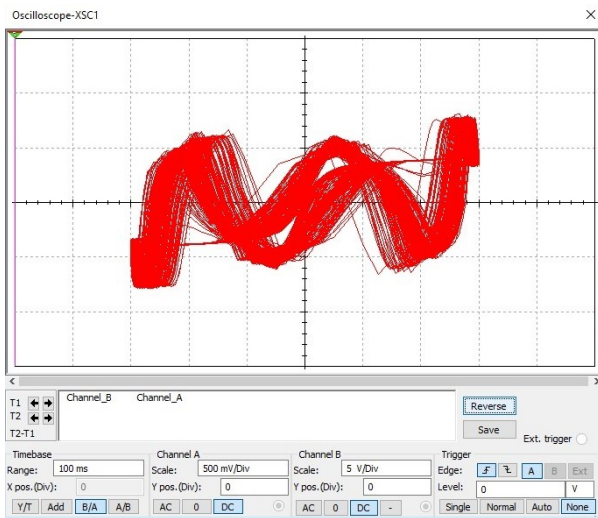Fig. 5. Circuit of a new non-autonomous chaotic generator

Fig. 6. Chaotic attractor

Fig. 6 shows the result of circuit simulation. Generated chaotic signal in the plane XY presented on the virtual oscilloscope. Coordinate X in the circuit correspond "plus" of the sinusoidal generator V1, coordinate Y − the non-inverting input of operational amplifier DA1.

In Fig. 7 and Fig. 8 shows time dependences of the coordinates X and Y respectively.
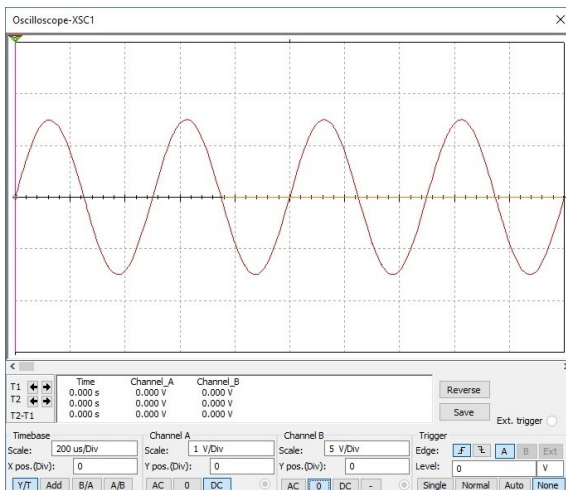

Fig. 7. Time dependence of the coordinate X

Fig. 8. Time dependence of the coordinate Y

Conclusions

Many circuits realize chaotic generators. For the first time was presented a new chaotic non-autonomous circuit. Using MultiSim software environment conducted scheme technical analysis circuit of a nonlinear element that consist one operational amplifier with two diodes and generator that implements a chaotic behavior. Submitted by a chaotic attractor and time distributions of two chaotic coordinates.

This circuit that generate chaotic oscillations can be used as one of the main part of modern telecommunication systems for masking and decrypt of information carrier.

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Розроблення, моделювання та дослідження нового неавтономного хаотичного генератора

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У даній роботі представлена нова версія схеми неавтономного хаотичного генератора з нелінійністю "діод-операційний підсилювач". Це свого роду одна із найпростіших схем, яка проявляє хаотичну поведінку. Дана схема неавтономного хаотичного генератора містить чотири резистора, один конденсатор, одну котушку індуктивності, два діоди з одним операційним підсилювачем і зовнішню періодичну силу. Найпростіший нелінійний елемент, спроектований таким чином, щоби отримати кусково-лінійну характеристику, тобто комбінацію одного операційного підсилювача з двома діодами, що ввімкнені назустріч один одному. Для реалізації нелінійності, для двох діодів не потрібно окремого джерела живлення, а тільки достатньо лише одного двополярного живлення для операційного підсилювача. Приведено схему для під'єднання та дослідження нелінійного елементу, а також результати комп'ютерного моделювання, тобто вольт-амперну характеристику (ВАХ) при певних значеннях номіналів компонентів схеми. За допомогою одного із найсучасніших програмних середовищ проведено схемотехнічний аналіз та представлено результати комп'ютерного моделювання нового неавтономного генератора, що генерує хаотичні коливання. В даному випадку було застосовано програмне середовище MultiSim компанії National Instruments. Досліджена поведінка системи за допомогою чисельного моделювання, використовуючи відомі інструменти нелінійної теорії, такі як фазовий портрет (хаотичний атрактор) і часові розподіли хаотичних координат. Тобто представлено сигнал до нелінійного елемента (синусоїдальний), і відповідно згенерований після нелінійного елементу – хаотичні коливання. Запропонована неавтономна схема генератора, що генерує хаотичні коливання, може бути використана як основна частина сучасних систем передавання і приймання інформації для маскування і дешифрування носія інформації.

Ключові слова: хаос; неавтономний генератор; Multi-Sim

Разработка, моделирование и исследование нового неавтономного хаотического генератора

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В работе представлена разработанная новая неавтономная хаотичная схема, которая реализует хаотическое поведение. Эта схема имеет простой нелинейный элемент, спроектированный так, чтобы получить кусочно-линейную характеристику. Данная разработанная схема может использоваться в современных системах передачи и приема информации. Генерируемый ею аттрактор может применяться для маскировки информационного носителя и его восстановления. С помощью программной среды MultiSim проведен схемотехнический анализ и представлены результаты моделирования нелинейного элемента и разработанной новой неавтономной хаотической схемы. Исследовано поведение системы с помощью численного моделирования, используя известные инструменты нелинейной теории, такие как хаотичный аттрактор и временные распределения хаотических координат.

Ключевые слова: хаос; неавтономный генератор; MultiSim