Frequency components with negative resistance for intellectual measurement systems

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ABSTRACT

The aim of the given paper is a critical analysis of the prospects of further development of the frequency components with negative resistance. The possible and most promising areas of the development of new and improvement of existing frequency components in various technical fields, such as measurement of non-electrical and electrical parameters, creation of computer systems and components of radio circuits , are shown.The most promising components, the development of which probably has a substantial interest for further improvement of technical and economic parameters of the engineering equipment, is given in a separate group.

Keywords: negatronics, negative resistance, prospective computer elements, emerging technologies, embedded measurements

INTRODUCTION

The research of various technical devices and systems, related to generation and processing of oscillations at high frequencies based on the devices with negative resistance, has undergone serious development. Every year new negative-resistance based projects are demonstrated to the scientific community, outlined in dozens of articles, reports, patents, and at least in one or two theses.

However, above mentioned process cannot be regarded as an independent. Synthesis of achievements in different electronic branches (including, for example, manufacturing technologies allows a more effective element base (e.g. increasing frequency, reducing parasitic capacity) and more advanced signal processing (microcontroller, DSP, FPGA). This means increasing the degree of integration (which increases noise immunity) and enhancing metrological characteristics (e.g. linearity) of the negatronic systems, which allows its simple inclusion in various information systems. Here is just one example: adding microcontroller processing (measurement and correction) to the frequency signal allowed to avoid a significant nonlinearity error compensation problem, as it opened the way to calculate the conversion and correction function digitally directly by the microcontroller.

This nowadays surge of attention to the invented and studied in 1922 phenomenon, can be explained by “transition from quantity to quality”. This gives new extension of the ”quantity”, and the transition to a new stage of the development. Scientific schools have accumulated a sufficient experience of the negative-resistance based effects and that has caused the invention of interesting fundamental structures, which are used as a base for new projects. So, it’s necessary to have a summary work with the classification of previously studied and promising areas of development of the devices with the negative resistance. This paper is the first part of this work and is focused only on the ≪frequency components≫ – separate sub-group of the negative-resistance based devices. The main purpose of this paper is to assess the state of development of frequency components in different scientific schools and identify possible prospects for future researches.

Defining unsolved aspects of the problem

Is further progress in this area an actual task today? Radio engineering and computer industries give an answer to this question, because they require further improvement of metrological characteristics, as well as reducing the size and price of components. Solving of these key issues will determine the direction of further development of new electronic components. And these are the benefits of using frequency components with negative resistance. They combine:

- high sensitivity and stability of parameters;
- simplicity (i.e.low size and high reliability);
- low cost.

Currently, there are no modern integrating papers, which would describe success in the frequency component development, and simultaneously offer new and original perspective directions of research.

REVIEW OF THE CURRENT STATE OF THE FREQUENCY COMPONENTS WITH NEGATIVE RESISTANCE

Currently a large number of frequency components were developed by scientific schools for use in various industries. They can be applied in the following main engineering areas.

Measurement of environmental parameters

a. Pressure [Belokon (2004)]

b. Humidity [Osadchuk et al. (2003); Sawyckiy (2011)]

c. Temperature [Baraban (2009)]

d. Magnetic field strength [Negodenko and Mardamshina (2000); Negodenko et al. (2000)]

e. Illumination [Ilchenko (2009); Osadchuk et al. (2001)]

A lot of articles, several monographs and dissertations, including the most recent ones (Osadchuk et al., 2003; Sawyckiy, 2011; Baraban, 2009; Osadchuk et al., 2001), are devoted to measuring basic parameters of the environment. Magnetic field sensors are being developed for the needs of specific industries (e.g. aerospace), particularly in Tahanrog scientific school (Negodenko and Mardamshina, 2000; Negodenko et al., 2000).

Measurement of materials, substances and processes parameters

a. Gas concentration

b. Temperature of the materials (contact/non-contact) [Baraban (2009)]

c. Humidity of gases and liquids [Zviagin (2011)]

d. Intensity of radiation [Danilenko (2007)]

e. Etching time [Seletska (2011)]

f. Physical dimensions [Krynochkin (2009)]

g. Weight [Novikov (2007); Negodenko and Mardamshina (2000)]]

h. Value of stress tensor

i. Composition of gases and liquids

It's the largest group of parameters, measurement of which usually occurs in various technical processes.In most cases, the structure of frequency components in this group has **two options**: as a combination of a primary sensor with a separate generator based on the negative resistance (negatron), or as a negatron, the properties of which are directly affected by the measured value. Enlisted parameters are not exhaustive, since the first of these structure options gives a possibility to create a frequency component from practically any conventional sensor.

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Measuring of the electric circuit parameters

a. Voltage

b. Capacity [Krynochkin (2009)]

c. Inductance

d. Resistance

e. Microwave (SHF) parameters

Since the outgoing frequency of the frequency component depends on the supply voltage and the parameters of the constituent elements, there is a possibility to create high-precision electric parameter measurers.

Creating elements of the electronic circuits

a. RF Filters

b. Generators [Koval (2011)]

c. Phase shifters

d. Resistance converters (impedance and immittance)

e. Modulators

f. Protective elements [Negodenko et al. (2004)]

g. Active antennas

h. Multipliers [Semenov (2011)]

i. Transformers [Semenov (2011)]

Frequency components typically have the ability to change impedance under the influence of the control signal (voltage, current), this allows to build effective frequency filters, modulators, converters of resistance etc. on their basis.

Development of advanced components Items a. and d. from the next list are original components, and nowadays we have only their concepts, but not complete engineering designs. Other elements were proposed by different authors previously, but need to have the further developed to become to the "ready-to use" state.

a. Frequency-oriented amplifiers (with internal conversion to the frequency)

b. Energy sources with improved performance (to compensate an internal resistance of the source)

c. Frequency digital logic [Filynyuk (1998)]

d. Elements of the memory (based on on frequency logic)

e. Frequency synthesizers

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THE MOST PROMISING AREAS FOR FURTHER RESEARCHES

Key areas for further development include theoretical and practical study on improving existing frequency components and building fundamentally new ones. In particular, the following points are interesting in **theoretical direction**:

- increase of the adequacy of modelling, by creating new models of the frequency components (probably based on the classical modelling principles), which include, for example, accounting of external factors, dynamic model calculations, spectra measurement and generation modes;
- development of new methods of theoretical calculation of the information parameters (transformation functions, frequency response, phase response, spectral characteristics), as far as calculations made by classical methods (mesh current method, nodal analysis, and so on) do not always give acceptable results, because they focus on the overall calculation of voltages/currents, but not on determining the frequency information parameters;
- automation of the circuit design of the negatron analogues (used in the frequency components), in order to optimize building processes and parameters of their structure for given criteria (Filynyuk, 1998; Kasimov, 1999);
- development of a fundamentally new direction using the negative resistance effect in optics, acoustics, etc.;
- new methods of practical definition of input, output and internal parameters of the frequency components (such as new methods for measuring the frequency or phase change).

In **practical direction** the prospects for development include:

- development of new materials and compounds that provide a negative resistance effect based on their physical properties (”physical negatrons”);
- expanding the scope of use of the frequency components in the measurement of physical parameters and processes and improving their metrology quality (e.g. improving performance, conducting the contactless metering);
- development of new circuit components (frequency-oriented amplifiers, frequency synthesizers, sequential logic, noise immunity logic);
- creation of elements for efficient conversion of information parameters (frequency-to-code, frequency-to-analog, frequency-to-optical converters), which will combine the frequency components with the existing circuits.

CONCLUSIONS

This paper analyzes the main trends of modern development of frequency components with negative resistance (negatrons) that are conducted in various scientific schools. Once again, the main advantages of frequency components, that combine high metrological parameters, simplicity and low price, need to be noted. Obviously, the further development of the frequency components (including negatronic) in general, has broad prospects. In theoretical terms, they relate mainly to the construction of new effective methods of modelling, designing and developing natural negatrons (especially in non-electrical domain - acoustics, optics, etc.). In practical direction – both expanding the scope of use of existing frequency components and the creation of innovative ones, which will significantly raise the quality characteristics of electronic equipment, is totally inevitable.

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