PROSPECT OF MICROWAVE NEGASENSORS APPLICATION FOR ECOLOGICAL MONITORING

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ABSTRACT

The principles of operation of new microwave sensors on circuits with negative resistance based - negasensors has been presented. Several negasensors' circuits with capacitive and inductive resistance have been described. Patents protect all presented circuits of negasensors. It was shown that negative active resistance could be used for sensitivity increasing as well as negative inductance and capacitance. Negasensors have high sensitivity, noise immunity and could be manufactured as a single chip without wireless signal transfer. It is necessary to notice that negasensor's sensitivity increases along with the frequency. Prospects of negasensors application at distributed multipoint-measuring systems for ecological monitoring and remote measurements are described. Negasensors could be also applied for microwave optic transformation of signals in telecommunicational networks.

INTRODUCTION

The negasensors - are the devices, which integrates in itself the sensor (measuring element) and circuit with negative resistance. Circuit with negative resistance – negatron (1,2,3) is using for the transformation, amplification, and elements matching. The integration of these functions in the negasensors is realized not by the series connection of elements, but by the construction of an integral functional device.

Negasensors may be divided into several classes depending on physical principles of negatron operation:
- Negatrons with negative resistance and S-mode static voltage-ampere characteristics (dinistor, trinistor);
- Negatrons with negative conductivity and N-mode ampere-voltage static characteristics (tunnel, Gun diodes);
- Dynamic negatrons with the differential resistance on alternate current only (avalanche diodes, inverted common collector transistor circuits) (1,4).
- Negatrons on the base of gyrator effect (5).

The use of those or other types of circuits with a negative resistance allows receiving a number of advantages on a comparison with the traditional circuits.

PRINCIPLES OF OPERATION

In contrast to traditional transformation scheme negasensors don't amplify electric signal but transform it to the equivalent inductance or capacitance. Resonant circuit frequency F and signal amplitude A that is transmitted to output are changed as a result. Thus negasensor with luminous flux Φ as input transformable quantity have transfer function that may be written as

$$\Delta\Phi \Rightarrow \nabla i \Rightarrow X_{L,C} \Rightarrow \Delta L, \Delta C \Rightarrow \Delta\varphi, \Delta F, \Delta A. \tag{1}$$

where ∇i –changing of transistor current; ΔL, ΔC – changing of equivalent inductance or capacitance of negatron;

Alternating current i leading of alternating voltage could be presented as equivalent capacitance (fig.1,a) and alternating current lagging behind alternating voltage could be presented as equivalent inductance (fig.1,b). Negative active resistance is used for the Q-factor increasing of negasensor resonance circuit. Negative

active resistance appear if alternating current lag or precede the voltage in the range of $(\pi/2 \div 3\pi/2)+2\pi n$, where $n=0,1,2\ldots$

Equivalent resistance may be inductive or capacitive $X_{L,C}$ depending on character of transistor feedback. As it follows from the Fig.1a, if alternating current precedes alternating voltage in the range of $(\pi \div 2\pi)+2\pi n$, where $n=0,1,2\ldots$ then equivalent resistance between transistor emitter and collector could be presented as negative capacitance.
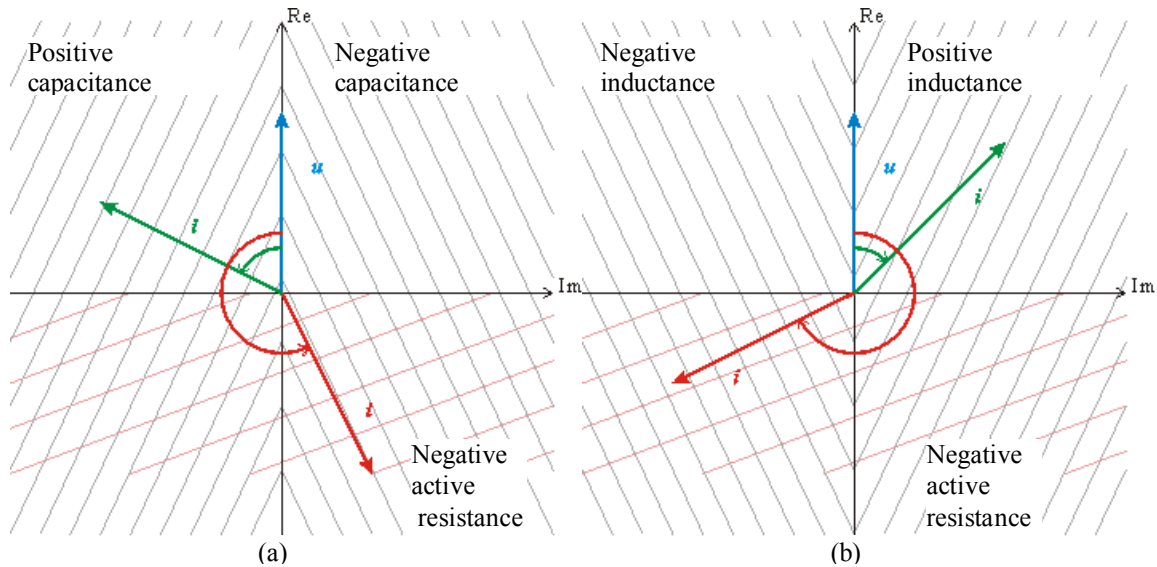

Fig.1 Vector representation of alternating currents and voltages in negasensor.

If alternating current lags behind voltage in the range of $(\pi \div 2\pi)+2\pi n$, where $n=0,1,2\ldots$, then equivalent resistance between transistor emitter and collector could be presented as negative inductance (Fig.1b). Negative capacitance has simple physical sense. Capacitance is the proportionality coefficient between the charge Q and applied voltage U changing:

$$C_d=\partial Q/\partial U. \tag{2}$$

If the increase in voltage lead to charge decrease then there is a negative capacitance. Semiconductor devices (6) or transistor circuits with feedback (2) might be used for obtaining of negative inductance or capacitance. The functioning principle of dynamic negatron is based on using of transistor reactive characteristics i.e. phase dependencies between alternating current and voltage in transistor. Dynamic negatrons work at frequencies close to cutoff that allows using it frequency characteristics in the best way. Furthermore, using of transistor reactive resistance in negatron circuits don't require additional matching, hence, undesirable noises could be reduced. Negasensor that consists of sensor and negatron connected as series elements has the following transfer function

$$Y(t) = F_2\{F_1[X(t)]\}, \tag{3}$$

where $X(t)$ – input transformable quantity; $Y(t)$ – output transformable quantity; F_1 - transfer function of the sensor;

$$F_1 = \nabla i / \nabla \Phi, \tag{4}$$

where F_2 - transfer function of the circuit with negative resistance, negatron;

$$F_2 = \nabla \varphi, \nabla F, \nabla A / \nabla i. \tag{5}$$

If the sensitive element (sensor) and the circuit with negative resistance are integrated the output measurable quantity can be defined as

$$Y(t)=F_3[X(t)], \tag{6}$$

where $F_3[X(t)]$ - transfer function of the circuit with negative resistance which is also optical sensitive element (sensor),

$$F_3 = \nabla\varphi, \nabla F, \nabla A/\nabla\, \Phi. \tag{7}$$

NEGASENSORS SIMULATION

In ecological monitoring systems negasensors carry out transformation physical quantity (pressure, density, temperature, humidity etc) into the variation of output frequency or phase.

Output frequency depends on the magnitude of negative resistance R and equivalent inductance L_{eq} or capacitance C_{eq} created by transistor circuit

$$\Delta f = F_1(R_{\_}, \Delta L_{eq}) \text{ or } \Delta f = F_1(R_{\_}, \Delta C_{eq}). \tag{8}$$

Reactive component of negasensor's complex impedance is a result of intrinsic processes in transistor(s). Magnitude of equivalent inductance or capacitance vary depending on current or voltage of sensitive element

$$R_{\_}, \Delta L_{eq}, \Delta C_{eq} = F_2(\Delta i_s, \Delta u_s). \tag{9}$$

Current or voltage of sensitive element originates from measured actuating quantity

$$\Delta i_s, \Delta u_s = F_3(\Delta X). \tag{10}$$

Thus, variation of measured physical quantity X results in changing of equivalent inductance or capacitance and, hence, has influence on negasensor output signal. Mathematical model based on the application of Volterra series (2) has been used for negasensors simulation that allow also to carry out analysis of nonlinear distortions in transistor negasensors. It was determined that negasensor circuits could work in oscillating, amplifying, detector modes and in mode with one or few steady states. Stability and limiting behavior of negasensor were described in our work (7). It is necessary to notice that negasensor's sensitivity increases along with the frequency. The same changing of luminous flux could result in wider frequency variations if the resonant frequency of circuit is higher. Integration of the sensor, matching, active and passive elements allows: to increase sensitivity of the sensor, to reduce the dimensions, to expand the range of input signals, to improve the negasensor's bandwidth, to improve the matching of elements. Advantages of negasensors are better displayed in microwave range, where the functions of matching and amplification practically not separated.

NEGASENSORS SAMPLES

Semiconductor devices with negative resistance as well as transistor circuits can be used for obtaining of negative resistance in negasensors. Sensor may be external and connected to the negatron, or circuit with negative resistance may be designed for use as a sensitive and transforming element at the same time (Fig.2,a). Sensitive element in negasensors can be included in the feedback of transistor circuit, resonant circuit or simultaneously in feedback of transistor circuit and resonant circuit (Fig.2,b).
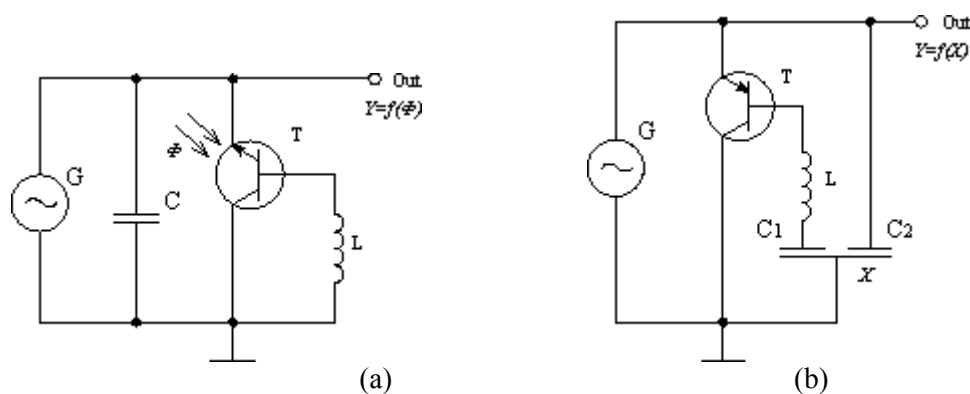
(a)   (b)

Fig.2 Negasensor circuits: (a) photosensitive, (b) with sensor in feedback and resonant circuit simultaneously.

The different types of negasensors circuits based on FET and bipolar transistors in the course of research were developed. Several patents have already received for protect of research results (8,9,10).

PROSPECTS OF APPLICATION

Advantages of negasensors are better displayed in microwave range were the functions of matching and amplification are practically not separated. Negasensors could be applied for measurement of temperature, humidity, turbidity control etc. Possibility of use of inductance, capacitance or both simultaneously and their high sensitivity give an opportunity to use the negasensors for ecological monitoring. Negasensors could be used as autonomous control devices in distributed measuring systems. For example, when large quantity of sensors covering large area must be applied. The use of frequency as output parameter of negasensor improves their noise immunity. Negasensors application for optic microwave transformation of signals in optical telecommunication nets appears due to their high sensitivity and noise immunity.

CONCLUSION

The principles of negasensors based on the FET and bipolar transistors with the use of optical inductive and capacitive sensitive elements where described.

Transfer function of negasensor was determined for different types of output signals. It was defined that negasensor's sensitivity increases along with the frequency.

Samples of negasensors for ecological monitoring based on the FET and bipolar transistors presented.

It was investigated that using of phototransistors connected to negasensors circuits allows to increase their operating frequency in comparison with the traditional connection as well as working frequency.

Prospects of negasensors application for ecological monitoring and optical telecommunicational systems were considered.

REFERENCES

1. Molchanov P.A. A Nonlinear Dynamic Transistor Negatrons Theory. 7th Int. Workshop on Nonlinear Dynamcs of Electronic Systems, Ronne, Denmark, July 15-17, 1999. P.99-102.
2. Molchanov P.A. Principles of Transistor Negatrons Nonlinear Theory. Monograph. "Universum-Vinnytsia", Vinnytsa, 1998. 207 p.
3. T. Itoh, C. Chang, Microwave active filters based on coupled negative resistance method. IEEE Trans. Microwave Theory Techn. Vol. 38, Dec. 1990. pp.1879 - 1884.
4. Adams D.K., Ho R.Y. Application of interted common-collector transistor circuits to microwave filtering, friguency multiplexing, and impedance matcing. G-MTT Internatl.Microwave Symp. Dallas, Tex., May 1969. - 345 p.
5. Giannini F., Limiti E., Orengo G., Sanzi P. A monolitic active notch tunable filter based on the gyrator principle, Microwave Simposium Digest, 1997, IEEE MTT-S International, Vol.2, pp.809-812.

6. Maxim Ershov, H.C. Liu, L. Li, M. Buchanan, Z. R., Wasilewski, Andrew K. Jonscher. Negative Capacitance Effect in Seniconductor Devices. IEEE Trans. On Electron Devices. Vol. 45, NO 10, Oct. 1998. Pp 2196-2203.
7. Pavlo Molchanov, Helen Linnik, Pavlo Mulyar. The nonlinear distortions estimation for dynamic transistor negatrons. Proc. 5th International Conference on Development And Application Systems. – Suceava (Romania) – May 18-20, 2000. P.52-55.
8. Invention Patent of Ukraine G 01 R 27/26. Gyrator transducer. P.A. Molchanov, A.V. Burekhin, P.S. Mulyar, T.K. Kornijchuk. Registrated October 23, 2000 #2000105955.
9. Invention Patent of Ukraine N97020633, 6 H01 R 27/26, Oscillating Transducer. /P.A. Molchanov, O.V. Vojtcehovska, O.A.Zima, Published 09.January, 1998.
10. Invention Patent of Ukraine N20719 A,G 01 R 27/26. Active Telemetric Transducer. P.A. Molchanov, O.V. Vojtcehovska, O.A.Zima, Published 07.October, 1997.