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Highly reliable power sources for objects of agriculture and automation of the stages of their adjustment

L A Zhuravleva[1], M N Kornienko[2] and V V Fediakov[2]

1 JSK Proektneftegaz, 7 line of Vasilievsky island, Saint Petersburg, 199178, Russia
2 Gmbh Anvilex, Enderstrasse 94, Dresden, Deutschland

E-mail: Energochel2017@gmail.com

Abstract. The technique of experimental research of static, dynamic and thermal characteristics of elements of automation systems based on the use of traditional equipment and special algorithms of information processing is developed. The reliability of information determination is increased by the use of the method of synchronous signal detection in determining the frequency characteristics of the studied elements of automation. An experimental study of the input and output signals of the amplifier module for two modes of operation was carried out, which confirmed the prospects for using an adaptive power supply for the output stages of the amplifier module when working with non-stationary loads. The method of setting up two modes of operation of the elements of the control system for agricultural facilities with non-stationary power sources, including the choice of parameters for the elements of the system, the experimental determination of its parameters and the choice of parameters for corrective relationships, has been proposed.

1. Introduction

Technological agricultural objects are controlled from elements and devices that are powered from non-stationary power sources [1, 2]. Under these conditions, automation elements may fail, which affects the reliability performance of the entire system. As a rule, to solve the problem of increasing reliability, stabilized power sources are used [3]. However, with a significant range of changes in the supply voltage, these solutions do not allow for a given level of reliability [4]. And it requires the application of new solutions for the applied element base and the development of new methods for setting up such systems.

2. Problem statement of the research

In order to improve the reliability indicators of the management system of agricultural objects, the following tasks were solved:

- Development of methods for experimental determination of the characteristics of elements of the control system;
- Determination of the frequency response of the amplifier gain module
- Development of methods for experimental determination of the characteristics of elements of control systems for agricultural facilities;
- Research of the phase-frequency characteristics of the elements of the automation system;

- Development of methods for experimental studies of thermal characteristics of automation elements;
- Development of stages of adjustment and experimental determination of parameters of elements of a control system.

As part of the study of the dynamic characteristics of the amplification module is tested for:

- Input and output resistance.
- Irregularity of the frequency response of the transmission coefficient and measurement of the signal-to-noise ratio.
- The phase shift of the output current relative to the phase of the input voltage.

3. Development of methods for experimental determination of the characteristics of elements of the control system

Measurement of the output resistance of the amplifier is carried out at the rated supply voltage *U*s = 220 V and maximum amplitude of the control voltage *U*contr = 10 V (values of the load resistances are listed in table 1).

Measurement order:

- Set the rated supply voltage;
- Set the maximum control voltage;
- Set the minimum load resistance for the selected mode;
- Measure the output current and voltage of the device (I_1, U_1);
- Set the maximum load resistance for the selected mode;
- Measure the output current and voltage of the device (I_2, U_2);
- To calculate the output resistance of the amplifier according to the formula:

$$R_{out} = -\frac{U_2 - U_1}{I_2 - I_1}$$

Table 1. Load resistance values for measuring the output resistance of the amplifier.

	R_{Lmin}, Ohm	R_{Lmax}, Ohm
Mode 1	0,15	0,67
Mode 2	0,3	1,33

Measurement of the input resistance of the amplifier is performed by an ohmmeter in the off state according to the scheme shown in figure 1.

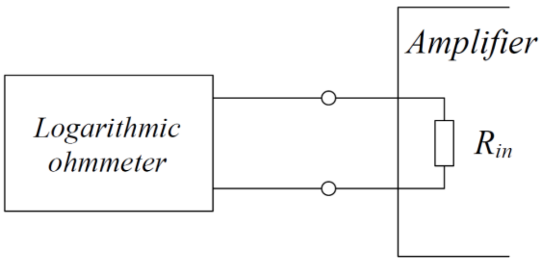

Figure 1. Scheme of the measurement input resistance.

The values of input and output resistances are recorded in [5].

4. Determination of the frequency response of the amplifier gain module

Measurements are made at the nominal supply voltage Us = 220 V and three values of the amplitude of the control voltage Uc=0 V, 10/√2≈7.07 V, 10 V, at the specified load resistances presented in table 2. As a result of each test [6] is compiled. According to the measured values, the frequency transmission coefficient is calculated [7]. Processing of measurement results is carried out according to the above formulas.

Ratio signal-noise

$$RSN = \frac{P_{sign}}{P_{noise}} = \frac{(I_{out}|\, U_{contr} = 10\text{ V})^2}{(I_{out}|\, U_{contr} = 0\text{ V})^2}$$

Transfer ratio

$$TR = \frac{I_{out}}{U_{contr}}$$

Frequency distortion factor

$$FDF = 20lg\left(\frac{TR(1000\text{ Hz})}{TR(f)}\right)$$

Table 2. Resistance of loads to remove the frequency response of the module of the transmission coefficient of the amplifier.

Mode 1	R_L = 0,15 Ohm	R_L = 0,4 Ohm	R_L = 0,67 Ohm
Mode 2	R_L = 0,3 Ohm	R_L = 0,815 Ohm	R_L = 1,33 Ohm

Measurement order:
1. Set the rated supply voltage;
2. Set the amplitude of the control voltage;
3. Set the frequency of the control voltage;
4. Measure the output current and voltage;
5. Repeat step 3-4 to fill the table.

5. Research of the phase-frequency characteristics of the elements of the automation system

The inclusion scheme shown in figure 2 is used for the research.

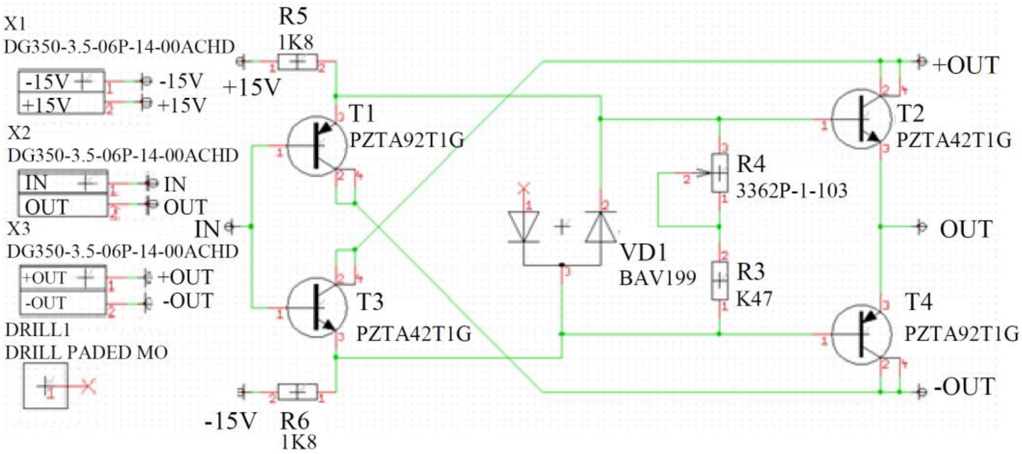

Figure 2. Scheme for setting the initial offset with adjustment.

Using a digital oscilloscope in the phase meter mode, the dependence of the phase shift on the frequency of the signal under study is determined [8, 9]. According to the results of the measurements, [10] is filled in with the specified load resistances presented in table 2.

6. Development of methods for experimental studies of thermal characteristics of automation elements

The method of experimental study of the thermal characteristics of the amplifier module consists in the successive removal of the thermograms of the elements of the amplifier module during operation at various values of the supply voltage, the input signal and the load resistance [11].

Thermograms are taken using a thermal imager with a certain time interval for a period of 180 minutes. Thermal photographs are processed using specialized software to identify elements with a maximum temperature load [12].

The test plan with an experimental sample of the amplifier module is presented in [13, 14]. The results are entered in [15].

7. Development of stages of adjustment and experimental determination of parameters of control system elements

The following devices were used to set up the amplifier module:

- Digital Signal Generator - Agilent Technologies 33250A [16].
- Digital oscilloscope - Fluke 190-202 [17].
- Digital oscilloscope - Rigol DS1102E [18].
- Digital precision multimeter - Rigol DM3051 [19].
- Digital meter RLC - APPA 703 [20].
- Digital multimeter - Fluke 18B [21].
- Industrial thermal imager - Fluke Ti32 [22].

8. Adjusting Mode 1 of amplifier module

The setup scheme of the amplifier module in mode 1 is shown in figure 3, where the input signal e_g is formed by the generator Agilent Technologies 33250A, the input voltage e_g and the output current Iout (through the shount R_{Sh}) digital oscilloscope Fluke 190-202, the output voltage U_{out} is measured by digital oscilloscope Rigol DS1102E, the quiescent current and the current flowing through the resistors R81-R86 and R88-R92 during operation are measured by digital precision multimeter RIGOL DM3051. Since the first arm is a current amplifier [23], an optimal offset voltage of 30 mV (60 mA quiescent current) was established.

Changes were made to the resistors R66, R78 R93 c K10, 10R and 10R on 1K0, K10 and K10 respectively, which facilitated the operation of transistors VT7-VT10, by reducing the current flowing through them.

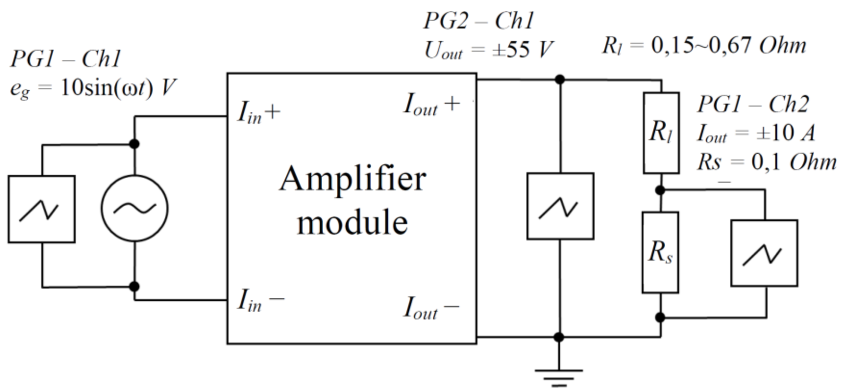

Figure 3. Scheme of adjustment of mode 1 of the amplifier module.

IOP Conf. Series: Earth and Environmental Science **315** (2019) 032044 doi:10.1088/1755-1315/315/3/032044

9. Adjustment of the second control module

The first setup diagram of the amplifier module in operating mode 2 is shown in figure 4, where the input signal e_g is generated by the Agilent Technologies 33250A generator, the input voltage e_g and the output current IOUT (through the shount RSh) are measured with a Fluke 190-202 digital oscilloscope, the output voltage UOUT is measured by a Rigol DS1102E digital oscilloscope, the quiescent current and operating current flowing through the resistors R81-R86, R88-R92, R98-R101 and R110-R115 are measured by digital precision during operation multimeter Rigol DM3051.

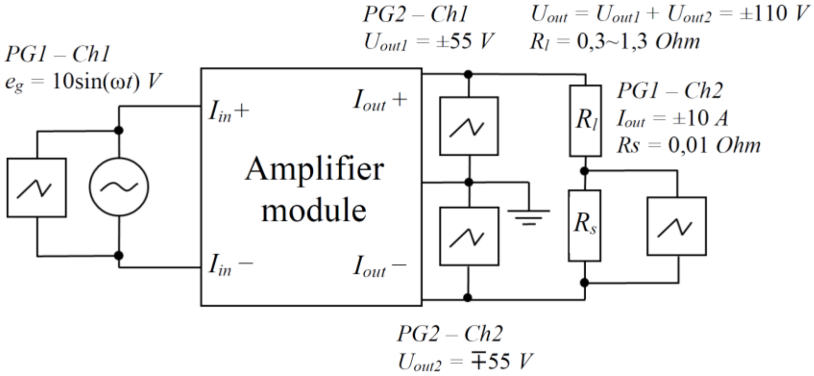

Figure 4. Scheme of adjustment of mode 2 of the amplifier module.

Since the second arm is a voltage amplifier [24], the quiescent current should correspond to the zero value, the measured value was 0.007 mV (0.014 mA).

In the second mode changes to the resistor R107 it was replaced from 10R on the K10, also the resistors R105 and R106 replaced from 20K resistors on 36K with a purpose to set the output current.

During the first adjustment of the second mode of the amplifier module, problems arose due to the appearance of large through currents in the second arm [25]. To eliminate this drawback, the circuitry of the amplifying module was improved [26]. A subtraction circuit at the op-amp with offset was designed to calculate both positive and negative voltage across the load. The model compiled in LTspice [27] is presented in figure 5. The drawing of the scheme [28], the trace of the printed circuit board [29] and the 3D model [30] were performed in the CAD Target3001 [31]. The photo of the finished printed assembly is shown in [32]. Also, a scheme for setting the initial displacement with adjustment for the second arm of the amplifying module for its identical work with the first shoulder was designed. The model compiled in LTspice is presented in [33]. The drawing of the circuit (figure 6), the trace of the printed circuit board [34] and the 3D model [35] were performed in the CAD Target3001. The photo of the finished printed assembly is shown in [36, 37].

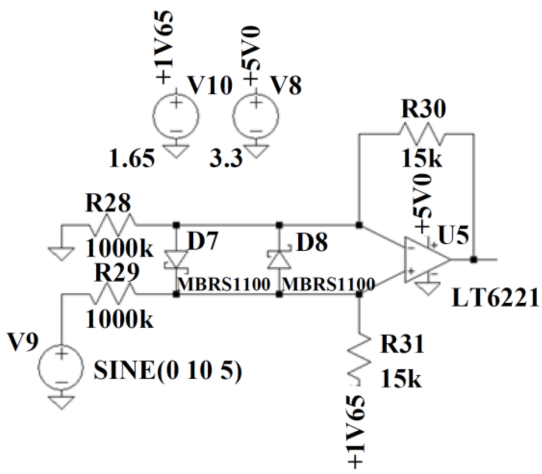

Figure 5. Model of the subtraction scheme on the operational amplifier with offset.

Acritical [38] shows the values of the power supply voltage dependence on the current load resistance in two operating modes. The data of this table confirm the successful operation of the adaptive power supply of the output stages of the amplifier module when working with non-stationary loads [39].

10. Conclusion

The technique of experimental research of static, dynamic and thermal characteristics of elements of automation systems based on the use of traditional equipment and special algorithms of information processing is developed. The reliability of information determination is increased by the use of the method of synchronous signal detection in determining the frequency characteristics of the studied elements of automation.

An experimental study of the input and output signals of the amplifier module for two modes of operation was carried out, which confirmed the prospects for using an adaptive power supply to the output stages of the amplifier module when working with non-stationary loads. A method of setting up two modes of operation of the elements of the control system for agricultural facilities with non-stationary power sources, including the choice of parameters of the elements of the system, the experimental determination of its parameters and the choice of parameters of corrective links, is proposed.

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