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DEVELOPMENT AND TESTING OF A SYSTEM FOR THERMOBARIC CHAMBER TEMPERATURE CONTROL DURING ELECTRONIC ITEMS RELIABILITY TESTS

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Abstract: This paper concerns development and testing of a *PID* (Proportional Integral Derivative) regulation system intended to perform temperature control of a thermobaric chamber for electronic items reliability tests. The system provides an option for quasi real-time temperature control and data transfer to a personal computer. A proper graphical user interface for the *PID* law coefficients preset and data visualization is designed. The capabilities of the system to manage the temperature change and to maintain a constant temperature for a time in accordance with the *PID* law are examined.
Keywords: reliability, reliability tests, temperature control, *PID* regulation

РАЗРАБОТВАНЕ И ТЕСТВАНЕ НА СИСТЕМА ЗА УПРАВЛЕНИЕ НА ТЕМПЕРАТУРАТА НА ТЕРМОБАРОКАМЕРА ПО ВРЕМЕ НА НАДЕЖДНОСТНИ ИЗПИТВАНИЯ НА ЕЛЕКТРОННА АПАРАТУРА

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Резюме:Настоящата статия засяга разработване и тестване на система за *ПИД* управление, предназначена да осъществява температурен контрол на термобарокамера за надеждностни изпитвания на електронна апаратура. Системата предлага опцияза управление на температурата в квази-реално време и изпращане на данните към персонален компютър. Разработен е подходящ графичен интерфейс за задаване на коефициентите в *ПИД* закона и визуализация на данните. Изпитани са възможностите на системата за управление на температурната промяна и поддържане на константна температура за определено време в съответствие с *ПИД* закона.
Ключови думи:надеждност, надеждностни изпитвания, управление на температурата, *ПИД* управление

INTRODUCTION

A basic requirement for achieving a high quality of electronic items is ensuring the required values of their reliability parameters [1, 2]. The reliability tests are used for verification ofthe items characteristics accordance with the parameters required over a long period of time under certain environmental conditions. Reliability tests are labor intensive, prolonged and expensive but when these are considered as an element of the design stage they are very useful and often indispensable tool in achievinga high reliability level [3-8].
The reliability tests, with the exception of operational reliability tests, are performed in reliability laboratories. The main equipment of such laboratories includes chambers and stands by which

the effects of destabilizing factors of the external environment are simulated. The tests can be carried out by modeling of the temperature profile, thermal stresses [9] - increased or decreased temperature [10], simulating increased or decreased atmospheric pressure, high humidity, vibrations, acceleration, the presence of acoustic or electromagnetic fields, radiation (or combination of these factors) and others. The temperature tests are performed in a special chamber where electronic items are put under stress. The temperature in the chamber must be adjusted automatically for to achieve a desired temperature profile with a certain precision and with a certain process speed.

In some cases, the dynamic properties of the systems for automatic control of the processes in the chamber appeared to be unacceptable. For example, transition processes with relatively long duration, large maximal dynamic deviations and significant number of oscillations might be observed during reliability tests. This is the reason why such control systems need to be improved. The correction consists in involving of additional devices in the system structure called corrective (compensating) devices. The physical implementation of these must be designed and developed within control system structures that allow relatively easy to change the regulator parameters in a wide range.

The types and methods of corrective devices incorporation vary depending on system disadvantages which must be removed. The algorithm for *PID* (Proportional Integral Derivative) regulation is the most widely used algorithm for automatic control. It is applied for to eliminate a wide range of system shortcomings.

The *PID* controller provides with the best quality the transition processes in management of processes distinguished with a large time delay and presence of fast changing disturbances. The *PID* controller output variable is formed by the effect which is proportional to the input variable, its integral with respect to time and its derivative, i.e. a composite regulator. There are three setup parameters of these regulators. This fact allows extending the opportunities of the process regulation [11]. Such a controller can also act as various more simple controllers by removal of one or more *PID* law components. To remove any *PID* law component (proportional, integral or derivative) the coefficient of this component must be equated to zero.

MATHEMATICAL DESCRIPTION

The *PID* control consists in constant monitoring of the output (process) value and calculation of the current error and its correction so that the regulator output to remain almost unchanged. The important point in the subsequent tuning is finding a proper proportional, integral and differential coefficient of the regulator. The proper tuned regulator actsintensive enough to eliminate the error but not allowing output variable to get into extreme states.

The *PID* controller calculates the temperature correction by computing three control terms [11, 12]. These are the proportional term that depends on the currenterror, the integral term that represents the accumulation of the error and the derivative term which is a prediction of future error [12].

In the classical *PID*algorithm the control action $\mu(t)$ is determined [11] by the equationbelow

$$\mu(t) = k_p \varepsilon(t) + k_i \int \varepsilon(t) dt + k_d \frac{d\varepsilon(t)}{dt} \qquad (1)$$

where

$$\varepsilon(t) = y(t) - x(t) \tag{2}$$

denotes an error in the system (*x*(*t*) is the assignment, *y*(*t*) is the process variable), $k_p$denotes a proportional coefficient,

$$k_i = \frac{k_p}{T_i} \tag{3}$$

denotes an integral coefficient where T_i is an integral constant and

$$k_d = k_p T_d \tag{4}$$

denotes a differential coefficient where T_d is a differential constant.
Hence, the *PID* law can be written [11] as

$$\mu(t) = k_p \left[\varepsilon(t) + \frac{1}{T_i} \int \varepsilon(t) dt + T_d \frac{d\varepsilon(t)}{dt} \right]. \tag{5}$$

In case when the thermobaric chamber is supplied by AC power supply a triac is often used as a power switch for regulation of the voltage applied to the chamber heaters. The voltage $U_{d\alpha}$ applied to the load at phase control by usage of atriac is determined by the following formula

$$U_{da} = \frac{U_d (1 + \cos \alpha)}{2} \tag{6}$$

where$U_d$denotes the supply voltage *RMS* value and α is the phase angle. Hence, α can be expressed by the ratio of $U_{d\alpha}$to U_d, as follows

$$\alpha = ar\cos\left(\frac{2U_{d\alpha}}{U_d} - 1 \right). \tag{7}$$

EXPERIMENTAL RESULTS

The system developed consists of a personal computer, a microcontroller performing *PID* control of the output variable (temperature in this case) and data transfer to the computer through a serial interface, a temperature and humidity sensor, a zero crossing detector circuit, a thermobaric chamber for electronic items reliability tests and a triac which performs power control of the chamber. The block diagram of the system is shown in *Figure 1*.

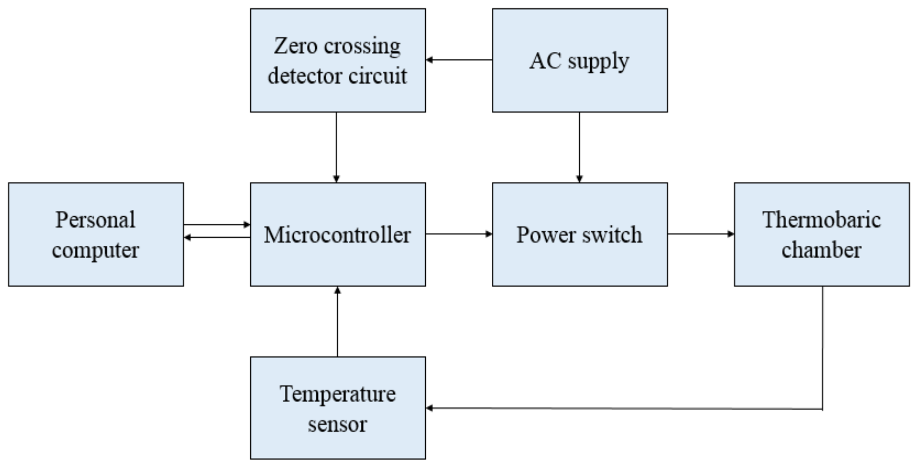

Fig. 1.Block diagram of the developed system for a thermobaric chamber temperature control

In addition to phase control (*Figure 2 a*) the system provides an option for zero voltage switching control (*Figure 2 b*) which consists in applying a proper number of half periods to the load for a certain time. In this type of control the triac is always switching at zero voltage applied to it. Thus the electromagnetic interference caused by rising edges of the voltage is significantly reduced.

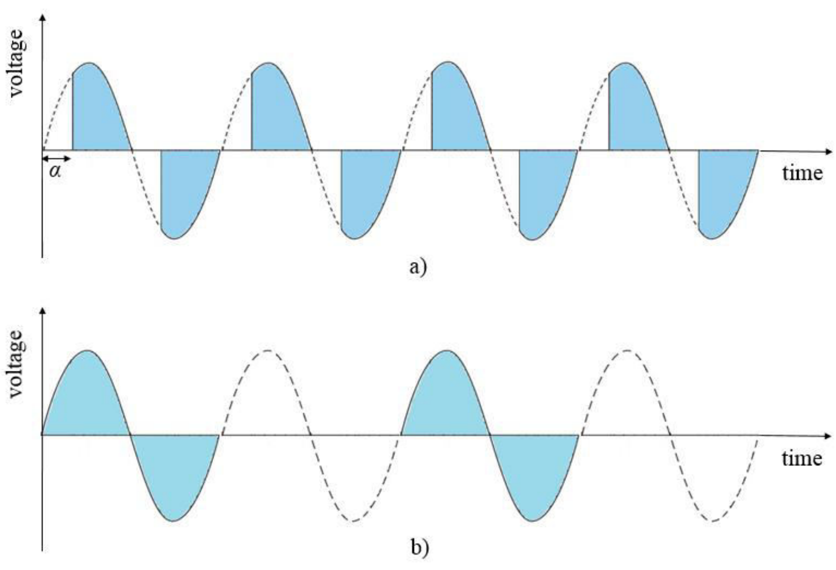

Fig. 2.Comparison between phase control and zero voltage switching control

The thermobaric chamber is equipped with an air compressor and valves for changing the internal pressure. The maximal power of the chamber heating elements intended for temperature effect reliability tests is *700 W*. The internal chamber volume is $70\ 000\ cm^3$. The system developed is capable to perform temperature control of chambers with power up to *3000 W* and maximal temperature inside the chamber up to $80\ ^\circ C$. If the electronic switch and the sensor are replaced by other elements with proper characteristics the system would be able to control the temperature of objects with higher power and higher maximal temperature.

A proper graphical user interface (see *Figure 3*) for data visualization in quasi real-time and correction of the *PID* law coefficients and the temperature preset is designed. The interface provides an option for the data to be exported to an output file in form of a table. The number of samples for a certain time can be adjusted according to the type and speed of the process controlled.

In order to check of the system workability an experiment with another load (a small heater) instead of the thermobaric chamber is performed. Finding the exact coefficients in the *PID* law valid for a particular chamber requires additional measurements and calculations. Furthermore, there is a difference between the coefficients corresponding to an empty chamber and those corresponding to a chamber in which a test object with certain thermal characteristics is placed.

The object (heater) temperature T and the phase angle α as a function of time t at *PID* control are shown in *Figure 3*.

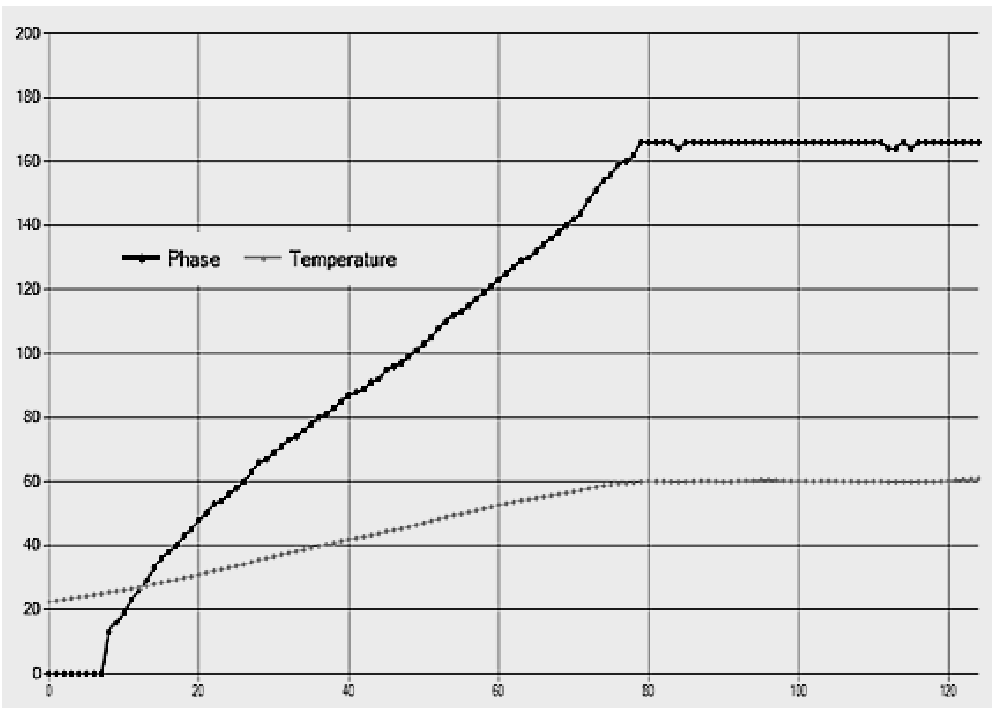

Fig.3. Functions $T = f(t)$ and $\alpha = f(t)$ visualized by the developed graphical user interface

The developed and tested system for a thermobaric chamber temperature control is shown in *Figure 4*.

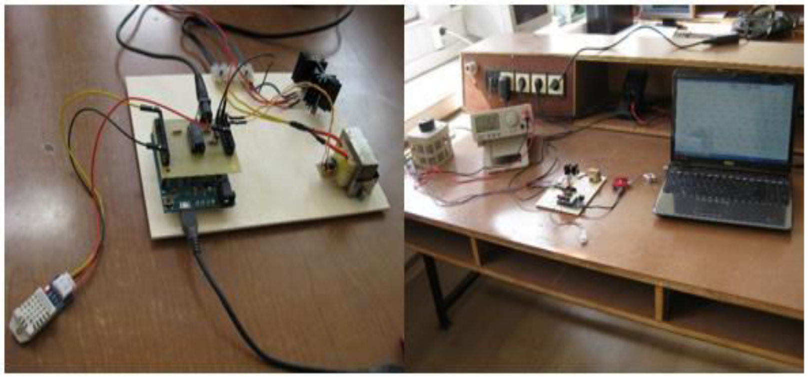

Fig. 4.The tested system for a thermobaric chamber temperature control

The data for the recorded object temperature and the phase angle both experimentally obtained by the developed system are presented in *Table 1*. Because of the large number of samples (120 samples) occurred for the observed period of time the results are presented as reports at every 5 seconds.

Time, t [s]	Temperature, T [°C]	Phase angle, α [degrees]
0	22.4	0
5	24.2	0
10	26.0	19
15	28.4	36
20	30.9	48
25	33.6	58
30	36.6	69
35	39.3	78
40	41.9	87
45	44.4	95
50	47.0	103
55	49.8	113
60	52.7	123
65	54.8	132
70	56.8	142
75	59.1	156
80	60.2	166
85	60.0	166
90	60.0	166
95	60.5	166
100	60.2	166
105	60.2	166
110	60.1	166
115	59.9	164
120	60.3	166

Table 1.Data for the object temperature and the phase angle

CONCLUSIONS

By the experimental results the capability of the system developed to perform the *PID* algorithm for temperature control is demonstrated. The developed graphical user interface allows to easy change the controller parameters in a wide range and to visualize the data obtained during reliability tests. As a future work it is possible to study and propose an appropriate approach for finding the exact *PID* law coefficients related to the specific thermobaric chamber and the electronic items putted under stress.

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