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An Interactive Program System for Training Students in Operation with Digital and Analog Regulators

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CSYLAB is an interactive system, combining in itself the capacities for controlled plant identification, selection and setup of analog and digital regulators and direct digital control as well. The basic approaches in classic automatic control theory are illustrated and a possibility is given to control real technological objects. In this connection CSYLAB is a convenient tool for teaching students from some specialized schools in the subjects production automation and during the initial stage of training at high schools in automatic control theory and technological processes automation.

The software system consists of three basic subsystems:

1. Identification of the plant controlled with subsystems: Transient characteristics determination and approximation of the plant controlled.

2. Selection and setup of the regulator with subsystems: selection of the control law, setup of the digital regulator, optimal setup of an analog regulator with respect to a preset damping degree, optimal setup of an analog regulator with fixed reserves in module and phase, optimal setup of an analog regulator with respect to a given typical transient process.

3. Direct digital control with subsystems for automatic and manual control.

CSYLAB is built on modular principle. The activation of each one of the system functions is done through a selection in a corresponding menu. The system allows the execution of DOS commands also. User-friendly interface is supported in it. The whole information entered by the operator is analyzed, providing directing and warning messages.

Graphic representation of the results from the system operation is widely used. Pressing a functional key, the graphics obtained on the screen can be printed. CSYLAB has also good possibilities to represent auxiliary information, selecting "Help" from the main menu or through F1, when the cursor is positioned on an option in any menu, with the purpose to get information about the option selected.

The software system consists of the following programs:

I. CSYLAB.EXE program serves to take down transient characteristics, to realize direct digital control of technological plants with one input and to start the programs below described.

The following functionally separated modules are included in the program:

– main menu – it gives the opportunity to select a desired function of CSYLAB system, unites all the software modules of the system;

– identification – realizes the definition of the process transient characteristics and the data processing; activates AOA2.EXE program approximating the object on the basis of the transient characteristic;

– selection of the control law and setup of a digital and analog regulator - activates ITZ.EXE, NDR.EXE, TSR.EXE, NMF.EXE, ON.EXE programs chosen by the user from the corresponding menu;

– control – carries out direct digital control of an object with one input and one output;

– help – gives help information for the system functions and the way of operation with it;

– setting the type of the videomonitor - alters the active palette depending on the type of the monitor for better readability of the image on the screen.

A. “MAIN MENU” MODULE calls the separate programs, which realize the system functions.

B. “IDENTIFICATION” MODULE – activated after “Identification” is selected from the main menu. Two operation modes are possible – “Transient characteristic” taking down and “Object approximation”. In the option “Connection with the object” the input and output channels for connection with the object are set, the coefficient for sensor indications transformation into technical units is selected and also the voltage, which corresponds to entirely closed or entirely open position of the actuating mechanism.

In order to take down the transient characteristic, “Taking down” is selected. The introduction of the operating point, the amplitude of the step function and the quantization tact have to be entered before the procedure starts. The values taken down are stored in an array and shown as graphics on the screen. They can be stored in a file by operator’s wish as well.

In order to approximate the object on the basis of the data taken, they have to be additionally processed. For this purpose “Data preparation” is chosen. This submode has its own menu, in which different functions are activated, aiding the obtaining of the approximation final data.

The data taken are stored in a text file in MS-DOS standard with the following elements: number of values from the transient characteristics, quantization tact, amplitude of the input step action of the actuating mechanism complete motion in percent; the values of the transient characteristics in technical units, from which the value of the object output at the operating point is extracted and they are stored in the sequence of their appointment, each element being written on a new line. This file is an input to the program for approximation AOA2.EXE and has to be named DANNI.DAT.

C. “SELECTION OF THE LAW FOR ANALOG AND DIGITAL REGULATORS SETUP” MODULE activates the functions realized as separate executive files, as subprocesses.

D. “CONTROL” MODULE – activated after the choice of “Control” in the main menu. The module has its own menu. The first two positions - “CSY-10” and “Connection with the object” call the same programs that are called in “Taking down” mode and operate in a similar way. The same variables are manipulated and the values determined in one mode, are valid for the other.

There exist two modes of control – manual and automatic, chosen by the operator from the corresponding alternatives in the menu.

After the selection of "Automatic", a menu appears with the following options:

1 – "Regulator type and parameters",

2 – "Alteration of regulator parameters",

3 – "Control constraints",

4 – "Technological and failure limits",

5 – "Visualization",

6 – "Graphics setup",

7 – "Assignment",

8 – "Control starting".

Before the control is started, the entering of the regulator type and parameters is required, besides this the assignment and the technological and failure limits for the value controlled must be set. Default values are accepted for the rest of the parameters and their alteration is done according to the operator's wish.

Within each quantization tact the following actions are performed:

1. Measuring of the object output,

2. Computing the gradient of the object output,

3. Control of the measured value of the technological and failure limits.

In case it is beyond the failure limits or if its gradient in two successive tacts exceeds the feasible one, a sound message is produced to interrupt the control. In case the value is outside the technological limits a sound appears, accompanied by a message and step 4 is executed.

4. The control action is computed taking into account the control values, that are set.

5. The control action computed is produced through the DAC selected.

6. The values chosen for visualization appear on the screen.

7. It is checked whether there is any pressed key by the operator. If so, the control is interrupted.

The transient process obtained can be printed.

Six types of regulators are realized in CSYLAB: positioning, proportional, integral, proportional-differential, proportional-integral, proportional-integral-differential.

Depending on the setup parameters entered by the operator, positioning regulators with static characteristics of the following type can be realized in Figs. 1 and 2.

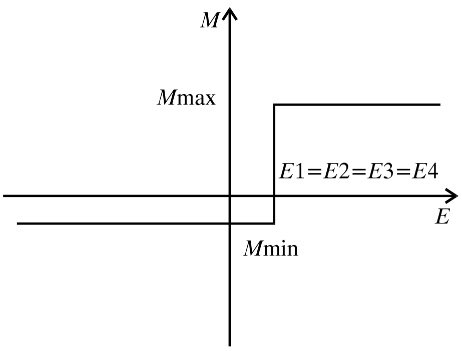

Fig. 1

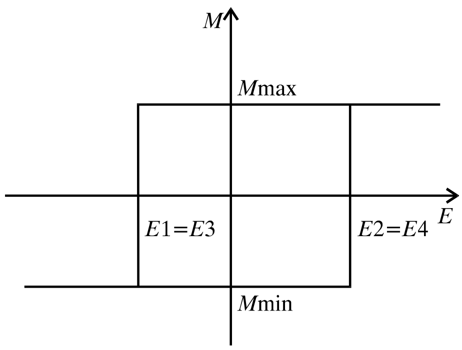

Fig. 2

The regulator computes the control action *M* on the basis of the error *E* at the current moment and the old value of the control action *M*. The error *E* is computed according to the formula:

(1) $$E = X_{\text{assigned}} - Y_{\text{current}} .$$

Fig. 1 shows the static characteristics of a two-positional regulator without insensibility zone and without hysteresis (non-ambiguity). The control action *M* can get two values *M*min and *M*max, entered by the user. *M*min and *M*max together with *E*1= *E*2= *E*3= *E*4, are the parameters for setup of the regulator, realizing such a static characteristic.

Fig. 2 represents the scheme of a two-positional regulator with an ambiguity (hysteresis) zone *X*, that is equal to

(2) $$X = E2 - E1 .$$

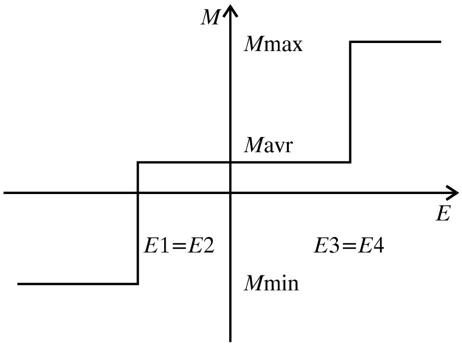

Fig. 3

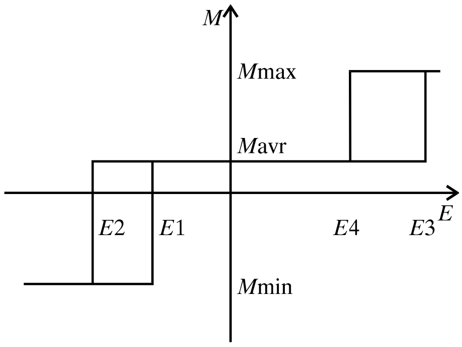

Fig. 4

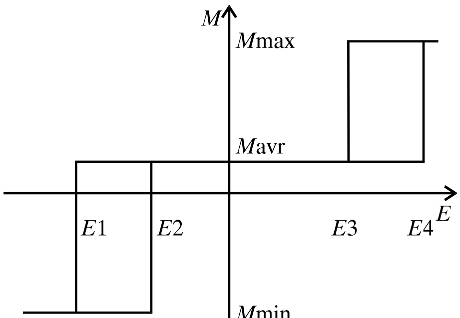

Fig. 5

The setup parameters here are *M*min, *M*max , *E*1= *E*3 and *E*2= *E*4.

Fig. 3–5 show the characteristics of a three-positional regulator with an insensibility zone (Fig. 3), without hysteresis (Fig. 3), with straight (Fig. 4) or inverse hysteresis (Fig. 5). In the three-positional regulator the control action *M* can accept values of *M*min, *M*avr, *M*max, which are regulator setup parameters together with *E*1, *E*2, *E*3 and *E*4.

In all the remaining regulators the control action *M*[*k*] is computed by the recurrent relation:

(3) $$M[k] = M[k-1] + q_0 E[k] + q_1 E[k-1] + + q_2 E[k-2],$$

where $M[k]$ and $M[k-1]$ are the values of the control action in the current and previous quantization tact, $E[i]$ is the error in the corresponding quantization tact, and the coefficients Q_i are computed as follows:

(4) $$q_0 = K_p,\ q_1 = -K_p,\ q_2 = 0 \text{ for P regulator,}$$

(5) $$q_0 = 0,\ q_1 = T_0/T_i,\ q_2 = 0 \text{ for I regulator,}$$

(6) $$q_0 = K_p(1+T_d/T_0),\ q_1 = -K_p(1+2T_d/T_0),\ q_2 = K_p T_d/T_0 \text{ for PD regulator,}$$

(7) $q_0 = K_r$, $q_1 = -K_r + K_r T_0 / T_i$, $q_2 = 0$ for PI regulator,

(8) $q_0 = K_r (1+T_d/T_0)$, $q_1 = -K_p (1+2T_d/T_0 - T_0/T_i)$, $q_2 = K_p T_d / T_0$ for PID regulator,

where T_0 is the quantization tact, K_r – the regulator coefficient, T_d – the isodrome time, T_d – time constant of the differentiation.

The error in the system at the current K-th tact of quantization is computed after the formula

(9) $$E[k] = X_{\text{assigned}} - Y_{\text{current}}[k].$$

The control action $M[k]$ computed according to (3) is compared with the limits, set by the user in "Control Constraints" and in case it exceeds them, the control action $M[k]$ is assigned the value of the corresponding limit violated – Mmin or Mmax.

The formulae (3–9) are derived from the generalized PID law:

$$M[t] = K_r X[t] + K_r / T_i + X[t]\,dt + K_r T_d\,dx/dt,$$

and the integration is done by the rectangles method, the differentiation is replaced by the first inverse difference.

This is described in more details in [1].

E. "HELP" MODULE – activated after the selection of the "help" option in the main menu or pressing F1 key, when the cursor is positioned on an alternative in any of the system menus. The information about the respective function of CSYLAB, appointed by the cursor, is directly shown.

F. "MONITOR" MODULE changes alternatively the numbers of the active palette and produces once again the image on the screen in the corresponding colours. The monitor type is marked in the menu.

G. "DOS" MODULE started after "DOS" option is selected in the main menu. A second command processor is set up and the control is transferred to it. The return to CSYLAB is done by EXIT command of DOS.

II. AOA2.EXE program serves to determine the parameters of a selected model of the automation object with or without self-regulation with respect to the data of its transient characteristic.

The program comprises the following modules:

– a main program – it realizes the interaction with the operator and external data files and computes the object model parameters,

– a subprogram computing the efficiency criterion of the approximation for current parameters of the object model,

– a subprogram computing the gradient of the efficiency vector,

– a subprogram smoothing an evenly tabulated function,

– a subprogram drawing transient characteristics,

– a subprogram for digital integration,

– a subprogram checking the real number entered.

III. ITZ.EXE program serves to define the type of the control law for objects, represented by models of first order with a delay, and from the requirements for achieving a prescribed type of the transient process in the control system.

The program consists of the following module – a main program, interacting with the operator, external data files, determination of the control law type.

The methodic of Kopelovich, described in [1] is used.

IV. NDR.EXE program serves to define the parameters of the modified digital P, PI or PID laws of objects control with self-regulation and a lag, represented by first-order models from the requirements for minimal time of regulation and integral-quadratic error in the closed loop system.

The program comprises the following modules – main program, interaction with the operator, external data files, computation of the regulator parameters.

The algorithm is described in details in [2].

V. ON.EXE program serves to determine the optimal parameters of an analog regulator from the requirements for achieving a given degree of damping in the system controlled.

The program consists of the following modules:

– a main program – interacts with the operator and external data files and computes the regulator parameters.

– a subprogram defining a point from the extended amplitude-phase frequency characteristic (EAPFC) of the inverse object $1/W_0$ $(-mw+jw) = OU + jOU$.

– a subprogram defining a point from the amplitude-phase frequency characteristic (APFC), (P=1) or EAPFC, (P=2) of the object.

– a subprogram defining a point from EAPFC of the polynom $C(p)$,
$C(-mw + jw) = CR + jCI$.

– a subprogram determining a point from APFC of a polynom $C(p)$,
$C(-mw + jw) = CR + jCI$

– a subprogram for approximate determination of a root of a transcendental equation within the range 0–20.

– a subprogram defining the root of a transcendental equation with accuracy of 0.0001 up to 100 iterations.

– a subprogram for digital integration,

– a subprogram defining the subintegral function AF of additional criteria 2 and 3.

VI. NMF.EXE program is used to determine the parameters of an analog regulator from the requirement to achieve a prescribed reserve in module and phase in the closed loop system.

The program includes the following modules:

– a main program – interacting with the operator and external data files and computing the regulator parameters.

– a subprogram defining a point in the amplitude-phase frequency characteristic (APFC) of a polynom $C(p)$.

– a subprogram computing a point in APFC of the object – $U+jV$.

– a subprogram for approximate determination of a transcendental equation with accuracy from 0.0001 up to 100 iterations.

– a subprogram computing the additional criterion.

– a subprogram for digital integration.

– a subprogram defining the subintegral function AF of the additional criteria 2 and 3.

– a subprogram computing and drawing the hodograph of APFC of the open system that is setup.

VII. TSR.EXE program serving to define the parameters of an analog regulator with P, I, PI or PID law for an object with or without self-regulation and a delay, represented by first-order models from the requirements for obtaining a given typical transient process.

The program contains the following modules:

– a main program interacting with the operator and external data files and computing the regulator parameters.

The engineering approach of Kopelovich is used. It is described in details in [1].

Object identification

Transient characteristic taking down

Command PATH C:\CSY;C:\DAT is executed.

Command CD C:\DAT is executed.

GCYR command is executed.

CSYLAB is started.

"IDENTIFICATION" is selected from the main menu. "TRANSIENT CHARACTERISTIC" is selected among the vertically located options.

This mode has its own menu.

Selection of the control law type and setup of a digital and analog regulator.

"Regulator" option is selected in the main menu. A vertical menu appears, where all the functions are selected for the type of the control law and the setup is defined of a digital and analog regulator.

Direct digital control

"Control" is selected in the main menu. The main menu of the mode appears.

The alternatives "CSY-1000" and "CONNECTION WITH THE OBJECT" are analogous to those in "TRANSIENT CHARACTERISTIC" mode. Since the necessary parameters are set there, in this case nothing is to be entered.

The software for unit CSY-1000 is described in details in [3].

The software system is used for training students at the Technical University, Sofia.

References

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Интерактивная программная система обучения студентов в работе с цифровыми и аналоговыми регуляторами

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(Резюме)

В работе рассматривается программная система КСИЛАБ, предназначена для обучения студентов высших школ в области автоматизации технологичных объектов.

Указаны основные функции системы – идентификация объекта управления, получая переходную характеристику объекта, обрабатывание полученных данных и апроксимация объекта, выбор закона регулирования и настройки цифровых и аналоговых регуляторов, прямое цифровое управление объекта с одным входом и одным выходом. Описаны дополнительные возможносты системы, как например графическое передставление результатов работы системы и получение помощной информации. Представлены отдельные програмные модули системы и их функции, технические параметры.