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SYNTHESIS OF MINIMAL SCHEMES OF SYSTEMS CONTROL OF HYDRAULIC AND PNEUMATIC DRIVES

The existing schemes of command apparatus are presented. Their analysis is carried out and the shortcomings are indicated. The scheme of a fundamentally new command apparatus is given, which can significantly reduce the number of its elements. The synthesis of the pneumatic control system of the foundry machine was carried out on the basis of the design approach proposed by M. Cherkashenko, which as a result led to a reduction in the devices by 3.5 times. A graph of operations of the pneumatic control system of the molding machine is constructed. A matrix of correspondences is obtained, which determines the correspondence between the signals that cause transitions and the complete input sets acting in the transitions. Analysis of the matrix of correspondences made it possible to identify and eliminate contradictory transitions. On the basis of the elongations, a system of equations describing the scheme of the control system is synthesized. Further, minimization is performed due to factorization and decomposition of equations, and obtaining equations in their final form. A diagram is presented pneumatic control system of the molding machine, consisting of a command apparatus containing three cells, five cylinders, two vibrators, six limit switches, a time relay and other devices. The circuit simultaneously uses the functional and logical capabilities of limit switches, the possibility of implementing the functions of three variables by distributors. Thus, the use of the proposed command apparatus, in contrast to the existing schemes of command apparatus, can significantly reduce the number of distributors in the synthesis of the command apparatus itself and significantly reduce the number of elements when using the chosen approach to the design of circuits of pneumohydraulic control systems.

Keywords: mathematical model, graph of operations, minimal scheme, equations, matrix of correspondences, command apparatus.

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СИНТЕЗ МІНІМАЛЬНИХ СХЕМ СИСТЕМ УПРАВЛІННЯ ГІДРО- І ПЕВМОПРИВОДІВ

Представлені існуючі схеми командоапарату. Проводиться їх аналіз і вказуються недоліки. Наведено схему принципово нового командоапарату, який дозволяє значно скоротити кількість його елементів. Синтез пневматичної системи управління ливарним верстатом здійснювався на основі конструктивного підходу, запропонованого М. Черкашенко, що в результаті призвело до скорочення пристроїв в 3,5 рази. Побудовано граф операцій пневматичної системи управління формувальної машини. Синтезована матриця відповідностей, яка визначає відповідність між сигналами, що викликають переходи, і повними вхідними множинами, що діють в переходах. Аналіз матриці відповідностей дозволив виявити і усунути суперечливі переходи. На основі подовжень синтезується система рівнянь, що описують схему системи управління. Далі виконується мінімізація за рахунок факторизації і розкладання рівнянь, і отримання рівнянь в їх кінцевому вигляді. Представлена схема пневматичної системи управління формувальної машини, що складається з командоапарату, що містить три осередки, п'ять циліндрів, два вібратори, шість кінцевих вимикачів, реле часу та інші пристрої. Схема одночасно використовує функціональні та логічні можливості кінцевих вимикачів, можливість реалізації розподільниками функцій трьох змінних. Таким чином, застосування запропонованого командоапарату, на відміну від існуючих схем командоапаратів, дозволяє значно скоротити кількість розподільників при синтезі самого командоапарату і значно зменшити кількість елементів при використанні обраного підходу до проектування схем пневмогідролічних систем управління.

Ключові слова: математична модель, граф операцій, мінімальна схема, рівняння, матриця відповідностей, командоапарат.

Existing command apparatuses. In Fig. 1, *a*, *b* shows the schemes of command devices designed for the implementation of the memory unit in pneumatic high-pressure control systems. In these devices, when a signal is applied S to one of the inputs on one of the outputs signal $y = 1$, and on the rest – signals $y = 0$. In addition, when the next distributor of the chain is turned on, the previous one is turned off (the first one is considered the next after the last distributor).

Command apparatus (Fig. 1, *b*). The input signals in it are fed not to the control chambers of the distributors, but to their input channels. In addition, each subsequent distributor turns off the previous one and turns on the next one and thereby prepares it to receive the input signal. The circuits (Fig. 1, *a*, *b*) are passive, require the installation of additional elements to return the distributors to their original position, but in some cases allows you to save elements.

The command apparatus (a.s. no. 1242926) (Fig. 2) increases the speed of its shutdown, but has a significant number of distributors scheme.

The command apparatus works in this way. Signals in the initial position $x_1 - x_n$ in input channels and signals $y_1 - y_n$ in the output channels are zero. During the start

signal p_n through the \vee the distributor 1 of the first cell is switched, the supply pressure enters the output channel ($y_1 = 1$). During the signal $x_2 = 1$ the distributor 2 of the second cell is switched, the output signal of which will cause the switch of the distributor 1 of the second cell, the output signal $y_2 = 1$. This signal through the \vee turns off the allocator 1 of the first cell, as a result $y_1 = 0$.

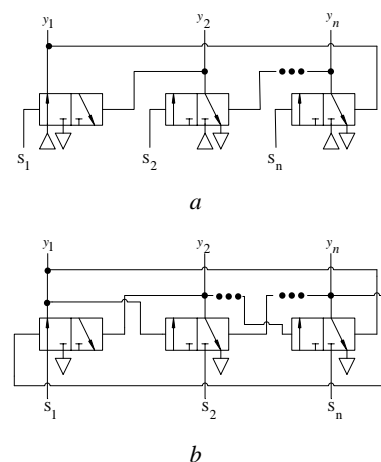


Fig. 1. Scheme of command apparatus built on switchgears

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Sequential input $x_i = 1$ will cause sequential generation of output signals $y_i = 1$. During the shutdown signal p_0 , regardless of the presence of an input signal $x_i = 1$, all distributors 2 are switched by connecting the control chambers of the distributors 1 to the atmosphere. At the same time, the signal p_0 through the elements \vee passes into the control chambers of the distributors 1, which causes the removal of output signals ($y_i = 0$). If the valves are removed from this diagram \vee , connected to the emergency reset signal, we get a well-known scheme of the command apparatus with the control of the previous stroke.

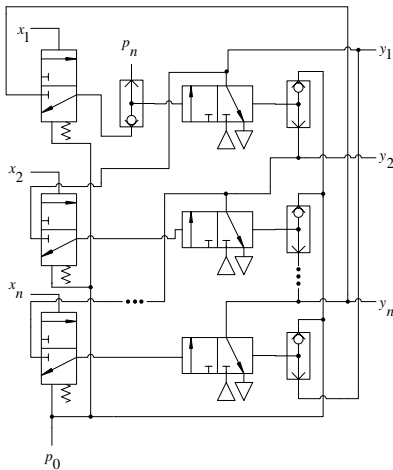


Fig. 2. Scheme of the command apparatus built on distributors and valves

In the scheme of the command apparatus (a.s. no. 1303656), shown in Fig. 3, used to memorize signals logic gates, which can reduce the number of elements, but has a large number of distributors.

The command apparatus works in this way. In the initial position, the signals at the inputs (x_1, x_2, \dots, x_n) and outputs (y_1, y_2, \dots, y_n) are equal to 0. When a signal is given ($p_n = 1$) to the input of the element \vee the allocator 1 of the first cell is switched. In this case, the supply pressure is supplied to the output of the first cell ($y_1 = 1$).

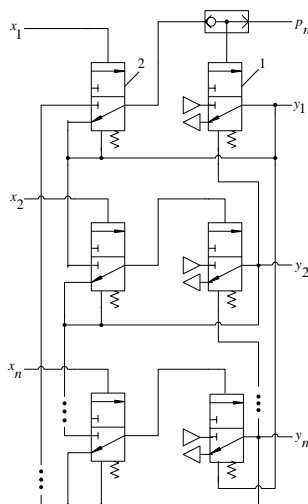


Fig. 3. Scheme of the command apparatus using distributors with one-way control

At the other outputs of the command apparatus, the signals are 0 ($y_2, y_3, \dots, y_n = 0$). The signal, which is equal to 1, also enters the control chambers of the distributor 2 of the first cell and the distributor 1 of the last cell, fixing their initial state, at the input of the distributor 2 of the next second cell and at the input of the distributor 2 of the first cell. Through the distributor 2, the signal, which is equal to 1, passes through the element \vee to the control chamber of the distributor 1. This ensures that the output signal is stored $y_1 = 1$ after the signal is removed p_n . When the input of the second signal cell is applied $x_2 = 1$ the distributor 2 of the second cell is switched and the signal enters the control chamber of the distributor 1 of the same cell, switching the distributor 1. The supply pressure through the distributor 1 of the second cell enters the output of the second cell of the command apparatus ($y_2 = 1$) and into the control chambers of the distributor 2 of the second cell and the distributor 1 of the first cell by switching them. After switching the distributor 2 of the second cell in the starting position, the signal, which is equal to 1, passes through this distributor to the control chamber distributor 2 this the same cells. In this case, the signal, which is equal to 1, is stored at the output ($y_2 = 1$). At the same time, the distributor 1 of the first cell returns to its original position under the action of the backwater spring and the signal $y_2 = 1$, which enters the inverse control chamber of the distributor 1 of the first cell. At the same time, the output signal y_1 , as with other outputs, signals y_3, y_4, \dots, y_n , are equal to 1. Further signaling x_n causes a signal to appear y_n , which is equal to 1, at the output of the last cell. At the last outputs, the signals are equal to 0, the work of the command apparatus here is similar to the work of the cells under consideration. The cycle of operation of the command apparatus resumes when a signal is applied $x_1 = 1$ into the control chamber of the distributor 2 of the first cell. In the event of a removal of the supply pressure, including in an emergency, the command apparatus is set to the initial state due to the use of distributors with backwater springs.

The reprogrammable complex command apparatus (a.s. no. 1241217) is shown in Fig. 4.

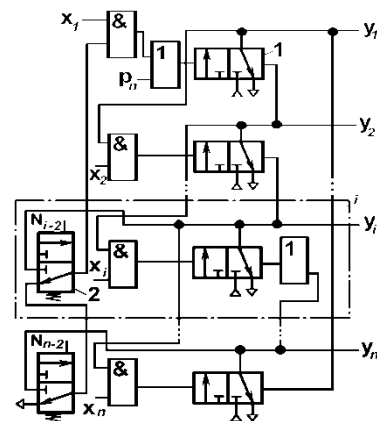


Fig. 4. Scheme of the reprogrammable command apparatus

The command apparatus works in this way. During the start signal p_n through the \vee the allocator 1 of the first cell is switched. A signal is generated in the output

Table 1 – Interaction of input signals and actuators

Output signals		Inputs signals					
Designation	Name	Automatic Mode				Adjustment	
		Starting position	Final position	Intermediate		Included	Closed
				Naming	Designation		
Z1	Moving the flask	X7	X8	–	–	–	–
Z2	Pre-pressing	X5	τ (Z2)	–	–	–	–
Z3	Broach	–	–	–	–	–	–
Z4	Moving the gate	X9	X10	–	–	–	–
Z5	Moving the crosshead	–	X11	–	–	–	–
Z6	Shaking the flask	–	–	–	–	–	–
Z7	Shaking the hopper	–	–	–	–	–	–
Z8	Blowing molds	–	–	–	–	X4	–

descends (-Z1 = 1), pre-pressing is coming to an end (-Z2 = 1), the broach cylinder is extended (Z3 = 1) and the flask vibrator is switched on (Z6 = 1). At the signal X5X7 = 1, the traverse returns to its original position (-Z5 = 1) and the shaking the flask vibrator turns off (-Z6 = 1). After that, the operator manually turns on (X4 = 1) mold blowing (Z8 = 1) and disables the broach (-Z3 = 1). The cycle ends. Device: X1 – start button; X4 – mold blowing button.

The operation graph [5, 6] is shown in Fig. 6.

For the synthesis of the scheme, it is advisable to use the approach proposed by M. Cherkashenko.

The mapping matrix is presented below.

Here, the bold units on the main dial (shifted by one line) of the matrix of correspondences correspond to transitions; the underlined contradictory unit is eliminated; the remaining units are not contradictory. Elongations are shown in bold, and identical input sets are marked with asterisks. The matrix of correspondences defines the

correspondence between the signals that cause the transitions and the complete input sets that act in the transitions. Analysis of the matrix of correspondences made it possible to identify and eliminate contradictory transitions. On the basis of the elongations carried out, a system of equations describing the scheme of the control system is synthesized. Further, minimization is performed due to factorization and decomposition of equations, and obtaining equations in final form.

$$\begin{aligned}
 S_1 &= w = \bar{z}_7 = x_9y_3; S_2 = \bar{z}_2 = z_3 = z_6 = \tau; \\
 S_3 &= \bar{z}_3 = z_8 = x_4; R_1 = y_2; R_2 = y_3; R_3 = y_1; \\
 z_1 &= x_1 + x_{11}; \bar{z}_1 = w + \tau; z_2 = x_{11}; \\
 z_4 &= z_7 = x_5x_8; \bar{z}_4 = x_{10}; \\
 z_5 &= x_7y_1; \bar{z}_5 = \bar{z}_6 = x_5x_7y_2; \\
 z_8 &= x_4 - \text{blowing molds.}
 \end{aligned}$$

The diagram of the pneumatic control system of the molding machine is shown in Fig. 7.

It should be noted that the methods of designing circuits are presented in [7–12].

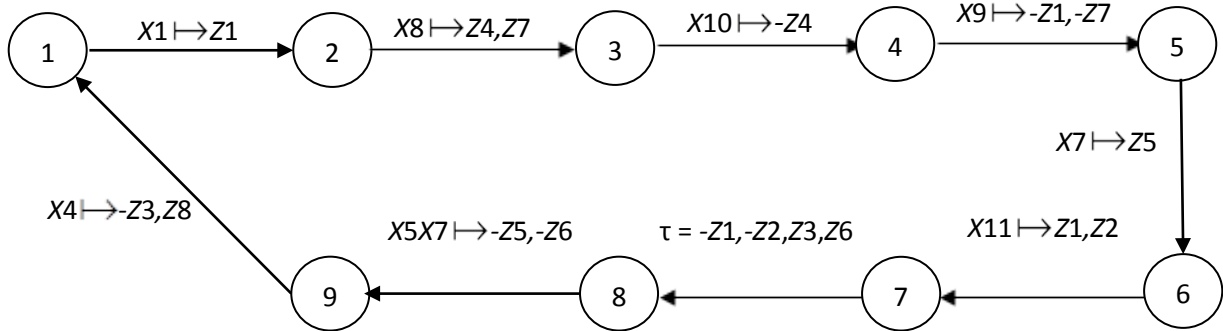


Fig. 6. Graph of operations: -Z – signal to return the cylinder rod to its original position

	x_1	x_8x_5	x_{10}	x_9y_3	x_7y_1	x_{11}	τ	$x_5x_7y_2$	x_4
$\emptyset, x_5x_7x_9 \rightarrow \emptyset *$	0	0	0	1	0	0	0	0	0
$x_1, x_5x_7x_9 \rightarrow z_1$	1	0	0	1	0	0	0	0	0
$x_8, x_5x_9 \rightarrow z_4z_7$	0	1	0	1	0	0	0	0	0
$x_{10}, x_5x_8 \rightarrow \bar{z}_4$	0	1	1	0	0	0	0	0	0
$x_9, x_5x_8 \rightarrow \bar{z}_1\bar{z}_7S_1$	0	1	0	1	0	0	0	0	0
$x_7, x_5x_9 \rightarrow z_5 *$	0	0	0	0	1	0	0	0	0
$x_{11}, x_5x_7x_9 \rightarrow z_1z_2$	0	0	0	0	1	1	0	0	0
$\tau, x_8x_9 \rightarrow \bar{z}_1\bar{z}_2z_3z_6S_2$	0	<u>1</u>	0	0	0	0	1	0	0
$x_5x_7, x_9 \rightarrow \bar{z}_5\bar{z}_6 *$	0	0	0	0	0	0	0	1	0
$x_4, x_5x_7x_9 \rightarrow \bar{z}_3z_8S_3$	0	0	0	1	0	0	0	0	1

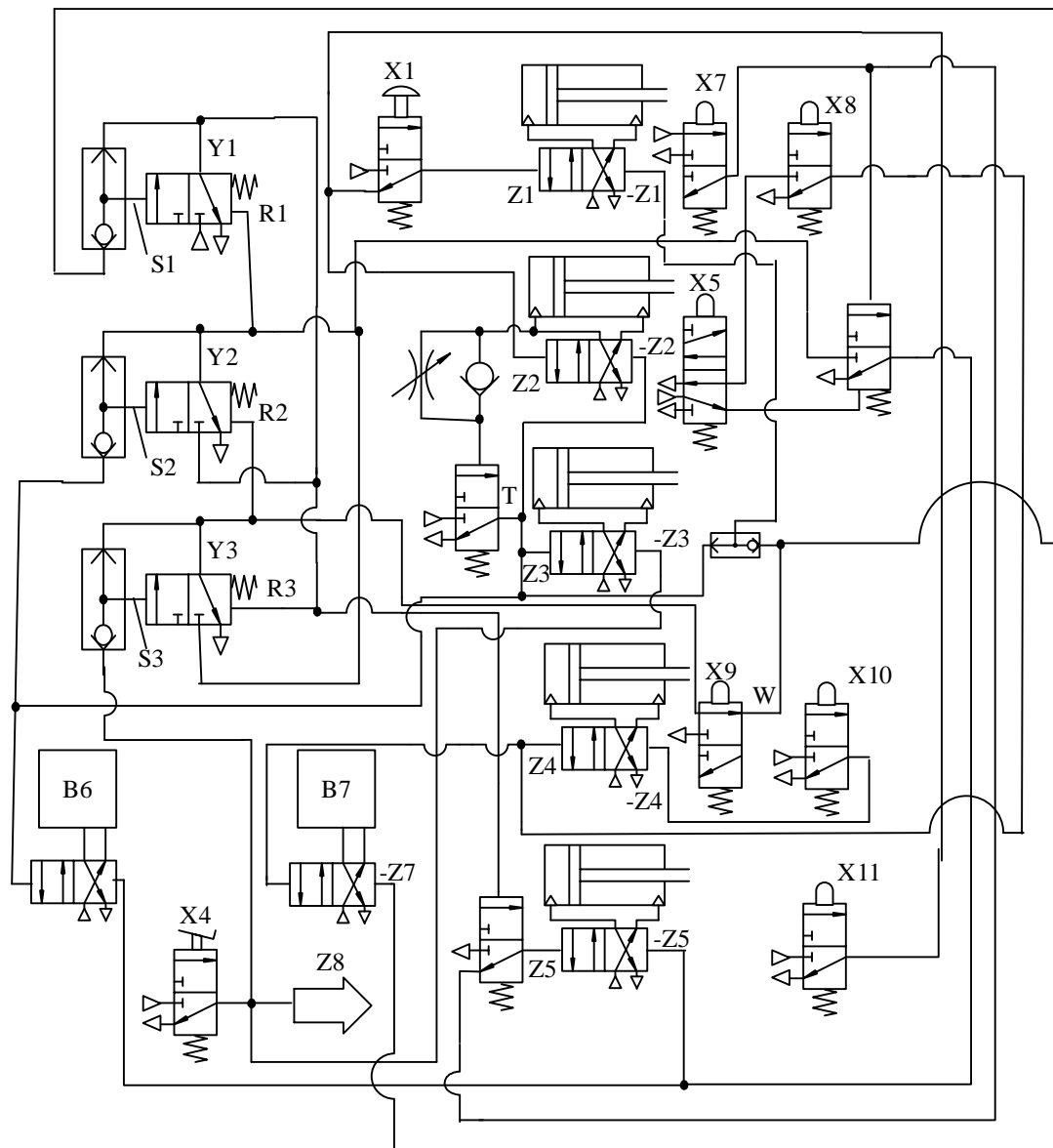


Fig. 7. Scheme of the pneumatic control system of the molding machine: T-signal from the output of the time relay

Findings. Thus, the use of the proposed command apparatus, the difference from the existing schemes of command apparatuses, makes it possible to reduce by a third the number of distributors in the synthesis of the command apparatus itself and significantly reduce the number of elements when using the chosen approach to the design of circuits of pneumohydraulic control systems. Note that the minimized scheme contains 9 devices for its implementation, instead of 32 using the standard method, i.e. 3.5 times less.

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