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SYNTHESIS OF SCHEMES OF PNEUMOAUTOMATICS ON THE VALVES

The universal method of designing of schemes of hydropneumoautomatics on the valves, using modular realization is offered. In a basis of a method it is put factorization systems and decomposition of the equations, the analysis of modules with use of the simplified table of conditions, due to consideration of conditions only for inputs of controlling of valves. M. V. Cherkashenko's formulas of decomposition of functions on two variables are effectively used, iso present decisions of modules on which outputs given formulas are presented are realized that as a result leads to the minimal schemes. Examples of use of a method are resulted.

Keywords: hydropneumoautomatics, valves, decomposition, algorithm, matrix, scheme.

Introduction. There are two principles of construction of schemes of hydropneumoautomatics – separate and undivided decomposition of the equations. The principle of separate decomposition is based on allocation of the fragments containing usually three or two variables for realization by known schemes in the set basis. Then the composition of the received fragments will be made. For realization of system of the equations the principle of factorization is known also, i.e. allocation of the general parts for reduction of number of devices at their realization. The method of undivided decomposition of M. Cherkashenko is base on decomposition of the equations on two variables with the received original residual functions [1]. The Shannon's formula of decomposition of function on $(k-1)$ variable has the next form [2]:

$$y = \bar{x}_1 ... \bar{x}_{k-2}\bar{x}_{k-1}\varphi_1(0,...,0,0,x_k) + \\ + \bar{x}_1 ... \bar{x}_{k-2}x_{k-1}\varphi_2(0,...,0,1,x_k) + ... + \\ + x_1 ... x_{k-2}\bar{x}_{k-1}\varphi_{2^{k-1}}(1,...,1,0,x_k) + \\ + x_1 ... x_{k-2}x_{k-1}\varphi_{2^{k-1}}(1,...,1,1,x_k),$$

where $(x_1 - x_k)$ – variables;

$(\varphi_1 - \varphi_{2^{k-1}})$ – residual functions.

On figure 1 there is the scheme, constructed on valves, of extremely universal module with the original *l*-linear distributive equipment [3, 4], which realizes function:

$$y = \bar{x}_1 ... (\bar{x}_{k-1}(\bar{x}_k\varphi_1 + x_k\varphi_2) + x_{k-1}(\bar{x}_k\varphi_3 + x_k\varphi_4)...) + \\ + ... + x_1 ... (\bar{x}_{k-1}(x_k\,\varphi_{2^{k-1}-3} + x_k\varphi_{2^{k-1}-2}) + \\ + x_{k-1}(\bar{x}_k\varphi_{2^{k-1}-1} + x_k\varphi_{2^{k-1}})...),$$

where $\varphi_1,...,\varphi_{2^{k-1}}$ – functions of one variable $\{0, 1, X, \bar{X}\}$.

The given equation is easy for receiving by the method of substitution of functions on outputs of each valve that coincides with the Shannon's formula. The universal device (fig. 1) includes original valves for which if $k \geq 2$ that there is a dependence, number of valves $n = k - 1$. Linearity of the valve i (where $i = 1, \ldots, n$) calculate by the formula $l = 2^{i+1} - 1$.

The basic part. The offered universal method consists of the factorization of systems and undivided decomposition of the equations. It is consists of following partitions: analysis of serially produced elements and modules of systems of hydropneumoautomatics of using the simplified tables of conditions; factorization of systems of the equations; design of base schemes of decomposition of the equations on two variables; direct decomposition of the equations by definition of variables of decomposition and calculation of residual functions; realization of residual functions by their further decomposition or with use of the received of decisions.

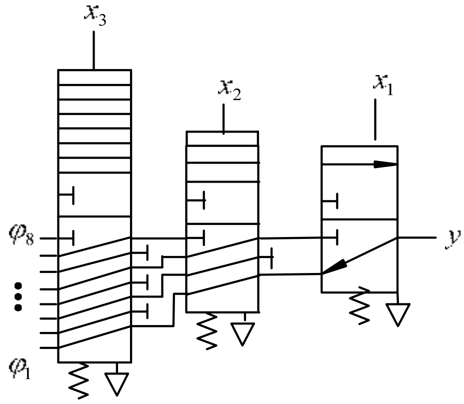


Fig. 1 – Scheme of extremely universal device

The analysis of elements and modules of schemes of hydropneumoautomatics. Let's show synthesis of the simplified table of conditions due to consideration of various conditions only for inputs of controlling of valves. Dimension of the table in this case will make for one input of controlling of valve 2*m*, for two inputs of controlling of valves 4*m*, where *m* – number of outputs. It allows to receive the convenient means of the analysis. Let's note, that dimension of the usual table of conditions – $2^n(n+m)$.

Let's make the table of conditions for controlling inputs of controlling of valves, and in columns for outputs we shall write adjusting inputs if the signal on a considered output is equal 1, and 0 – otherwise. In tab. is shown the hydraulic or pneumatic valve. Channels of valve are noted by the digits of international identification mark. The table is constructed for two for inputs of controlling of valves.

So, we find for two for controlling inputs of valves:

$$y = a(\bar{x}_i\bar{x}_j + \bar{x}_i x_j + x_i x_j) + b x_i \bar{x}_j = a(\bar{x}_i + x_j) + b x_i \bar{x}_j .$$

The formula of decomposition of function on two variables has the next form:

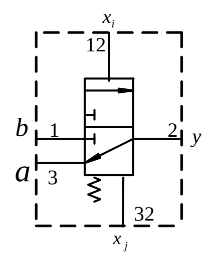
$$y = \bar{x}_i\bar{x}_j g + \bar{x}_i x_j c + x_i \bar{x}_j b + x_i x_j q \qquad (1)$$

where $g = f_0(0, 0)$; $c = f_1(0, 1)$; $b = f_2(1, 0)$; $q = f_3(1, 1)$ – residual functions from decomposition, which are smaller than initial on two the order of magnitude.

For the module (tab. 1), the equation:

$$a(\bar{x}_i + x_j) + b x_i \bar{x}_j \,. \qquad (2)$$

The table 1 – The accepted designations of channels

For two for inputs of controlling of valves x_i/x_j	Output y	
$\bar{x}_i\bar{x}_j$	a	
$\bar{x}_i x_j$	a	
$x_i\bar{x}_j$	b	
$x_i x_j$	b	

If to accept

$$a = \bar{x}_j g + x_i q + \bar{x}_i x_j c = \bar{x}_j f_0(0{,}0) + x_i f_3(1{,}1) + \bar{x}_i x_j f_1(0{,}1)\,;$$

$$b = f_2(1{,}0)\,,$$

and to substitute in the equation (2) expressions for a and b it is received:

$$y = (\bar{x}_i + x_j)(\bar{x}_j g + x_i q + \bar{x}_i x_j c) + x_i \bar{x}_j b\,.$$

And further, removing the brackets, we have the equation (1).

It is necessary to note, that modules on fig. 2, *and* [5], fig. 2, [6], realize the equation

$$y = (\bar{x}_i\bar{x}_j + x_i x_j)d + \bar{x}_i x_j c + x_i \bar{x}_j b\,. \qquad (3)$$

If to accept

$$d = \bar{x}_i g + x_i q = \bar{x}_i f_0(0{,}0) + x_i f_3(1{,}1)\,;$$

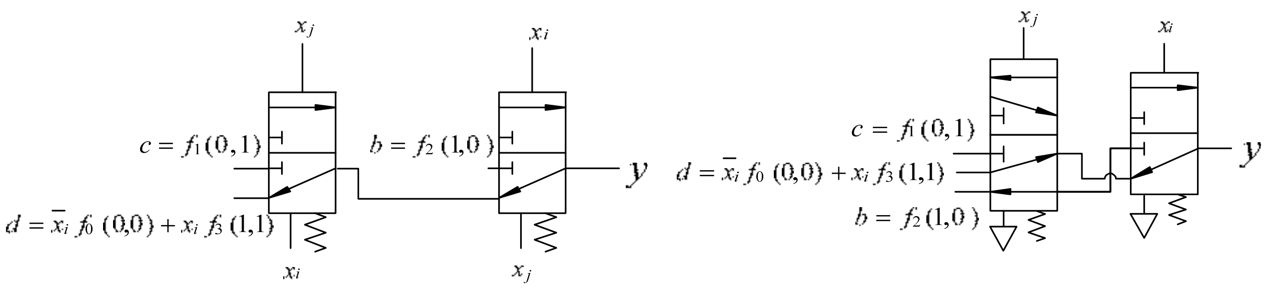
$$c = f_1(0{,}1)\,;\ b = f_2(1{,}0)\,,$$

and to substitute in the equation (3) expressions for d, c and b it is received:

$$y_2 = (\bar{x}_i\bar{x}_j + x_i x_j)(\bar{x}_i g + x_i q) + \bar{x}_i x_j c + x_i \bar{x}_j b\,,$$

and further, removing the brackets, we have the equation (1).

The method is put in a basis *of algorithm of realization of the scheme* [1].



a *b*

Fig. 2 – *a* and *b* – modules for realization of decomposition of function on two variables

Factorization *of systems of the equations* (SE). Generally, synthesis of minimal composition SE this introduction of intermediate variables W of the general parts, which most repeat.

$$\text{SE}\ \begin{cases} t_1 = \tau_1(x_1,\ldots,x_t;\, y_1,\ldots,y_k); \\ \qquad\quad \text{K} \\ t_{m+k} = \tau_{m+k}(x_1,\ldots,x_t;\, y_1,\ldots,y_k) \end{cases}$$

turn into

$$\text{SEm}\ \begin{cases} w_1 = \varphi_1(w_1,..,w_p;x_1,..,x_t;y_1,..,y_k); \\ \qquad \ldots \\ w_p = \varphi_p(w_1,..,w_{p-1};x_1,..,x_t;y_1,..,y_k); \\ t_1 = \tau_1(w_2,..,w_p;x_1,..,x_t;y_1,..,y_k); \\ \qquad \ldots \\ t_{m+k} = \tau_{m+k}(w_1,..,w_p;x_1,..,x_t;y_1,..,y_k), \end{cases}$$

where p – quantity of the general parts; t – quantity of inputs; k – quantity of outputs memory cells; m –quantity of effectors; $t_1, \ldots, t_m$ – functions Z of switching effectors; $t_{m+1}, \ldots, t_{m+k}$ – functions S of switching memory cells.

Let's note two properties SEm:

1. Parenthesis forms SEm cannot have depth of more unit as depth two and more gives the general part which consists of two elements and more at disclosing brackets and enters into the general of conjunction.

2. At brackets of the equation or its part it is impossible to take out more than one variable as presence of two and more variables at disclosing brackets gives the general conjunction.

SE which can be presented by a matrix C_M. The quantity of strings and columns of a matrix is equaled to quantity of variables and their inversions in all equations. Matrix C_M – square and symmetric concerning the main diagonal. In a basis factorization selection of the general parts in all equations is necessary.

Procedure we shall consider on an example of system of the equation:

$$y_1 = \bar{x}_1 x_3 x_5 + x_1 x_2 x_5;$$

$$y_2 = \bar{x}_1 x_3 x_8 + \bar{x}_1 x_3 \bar{x}_6 + x_1 x_2 x_8 + x_1 x_2 \bar{x}_6 + x_6 x_7 \bar{x}_8; \quad (4)$$

$$y_3 = \bar{x}_1 x_3 + x_1 x_2 + x_4\,.$$

If conjunction f_j of SLE contains variables x_α and x_β, then on crossing of a row α and a column β an element $c_{\alpha\beta} = m$.

The matrix C_M can be constructed also directly on elementary functions "AND" of system of the equations.

Matrix C_M is symmetric relative to the main diagonal, it is presented further. Algorithm for finding the set of the most repeated parts W of the system [7] is presented. W will enter into the minimal system of the equations. So $w_1 = x_1x_2$ four times repeat, $w_2 = \bar{x}_1 x_3$ four times also repeat. Further using algorithm [7], we find $w_3 = w_1 + w_2$ three times repeat.

$$C_M = \begin{array}{c} \\ x_1 \\ \bar{x}_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ \bar{x}_6 \\ x_7 \\ x_8 \\ \bar{x}_8 \end{array} \begin{array}{c} \begin{array}{ccccccccccc} x_1 & \bar{x}_1 & x_2 & x_3 & x_4 & x_5 & x_6 & \bar{x}_6 & x_7 & x_8 & \bar{x}_8 \end{array} \\ \left\Vert \begin{array}{ccccccccccc} 0 & 0 & 4 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ & 0 & 0 & 4 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ & & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ & & & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ & & & & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & & & & 0 & 0 & 0 & 0 & 0 \\ & & & & & & & 0 & 0 & 0 & 0 \\ & & & & & & & & 0 & 0 & 0 \\ & & & & & & & & & 0 & 0 \\ & & & & & & & & & & 0 \end{array} \right\Vert \end{array}$$

Algorithm of a finding of set ψ [2]. First we choose a line in which the element with the greatest value the located.

1. Suppose $\alpha = 1$ (where $\alpha = 1, 2, \ldots, n$); n – quantity of variables, we pass to item 2.

2. In a line α of a matrix R_{G_m} there is an element $c_{\alpha\beta} = \mu$ (where $\beta = 1, 2, \ldots, n$), that pass to item 3, differently – to item 4.

3. For lines α and β each element we find function $P_{\alpha\beta} = \min(\alpha\beta)$, we pass to item 5.

4. We replace α on $(\alpha + 1)$ and we pass to item 1.

5. If in line $P_{\alpha\beta}$ there is an element $c_{\alpha\gamma} = \mu$ (where $\gamma = 1, 2, \ldots, n$), that pass to item 7, differently – to item 6.

6. It is received $\psi_v = \alpha\beta\ldots$, we pass to item 9.

7. For lines $P_{\alpha\beta}$ and γ we find function $P_{\alpha\beta\gamma} = \min(P_{\alpha\beta\gamma})$, we pass to item 8.

8. We replace indexes $\alpha\beta$ on a, and γ on β and we pass to item 5.

9. If in line α there is an element $c_{\gamma\delta} = \mu$ (where $\delta = 1, 2, \ldots, n$; $x_\delta \notin \psi_\mu$), that is replaced β on δ and we pass to item 3, differently – to item 10.

10. If $\alpha = n$, that is select $\{\psi_\mu\}$ and we pass to item 11, differently – to item 4.

11. If $\mu = 1$, that is select $\{\psi\}$ and we pass to item 12, differently we replace in R_{G_m} elements which are equaled μ, on $(\mu - 1)$ and we pass to item 1.

If to write the system of equations (4), substituting in it set of general parts, and taking out the brackets of the common elements, then it has the next form:

$$y_1 = x_5 w_3;$$
$$y_2 = w_3(x_8 + \bar{x}_6) + x_6 x_7 \bar{x}_8;$$
$$y_3 = w_3 + x_4 .$$

It is obvious, that for realization the equations it is required $y_1 = x_5 w_3$ the valve "AND", for the equation $y_3 = w_3 + x_4$ – the valve "OR".

The decomposition of the equation $y_2 = w_3(x_8 + \bar{x}_6) + x_6 x_7 \bar{x}_8$ must be made. As variables most often repeat $\tilde{z}_6$ and $\tilde{z}_8$ (direct and inverse value of a variable is shown by a wavy line), variables of decomposition is expedient for choosing [1] $x_i = z_6$ and $x_j = z_8$.

Let's define residual functions from decomposition $f_0(0,0) = w_3$; $f_1(0,1) = w_3$; $f_2(1,0) = x_7$; $f_3(1,1) = w_3$. The scheme of realization of function is presented on fig. 3.

Thus, the offered method is effective, and its use – expedient.

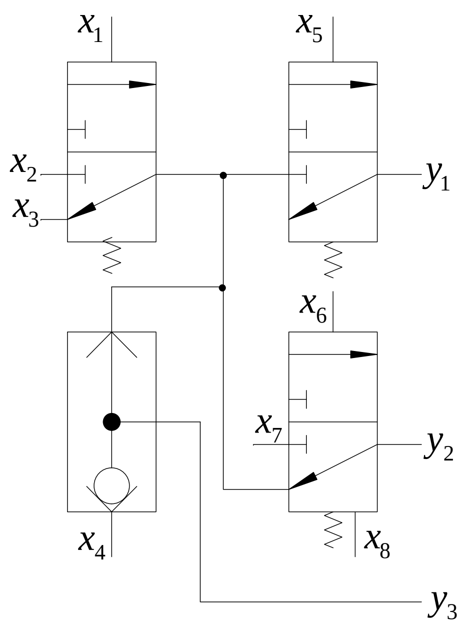


Fig. 3 – The scheme of realization of function

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