SYNTHESIS OF RELAY-CONTACT CIRCUITS

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Abstract

Full Text

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In the present article, certain classes of relay-contact circuits are defined and a method for their synthesis is set forth. Each of the relay-contact circuits constructed here consists of two parts: the first is an auxiliary circuit controlling the operation of additional relays and, roughly speaking, preparing the circuit for operation in the next cycle; the second is a contact circuit carrying out the required change during one cycle. The auxiliary circuit, along with the contacts of the given and auxiliary relays, also contains the auxiliary relays themselves. The contact circuit contains only the contacts of the given and auxiliary relays.

1. Contact circuits with memory. Let time t take the discrete values $1, 2, \dots$ (i.e. $\Delta t = 1$). Denote by F_t the value of the conductivity matrix F of the contact (p, q)-terminal network* at the moment of time t.

Definition 1. A contact (p, q)-terminal network containing contacts belonging to the relays $x_1, x_2, \dots, x_n$ will be called a **contact** (p, q)**-terminal network with memory of order** k if the value of the matrix F_{t+k} depends only on the values $x_1, x_2, \dots, x_n$ and on the k preceding values of F, i.e.

$$F_{t+k} = f_t(x_1, x_2, \dots, x_n; F_t, \dots, F_{t+k-1}).$$

Below we consider the case when the memory is stationary in time, i.e. $f_t \equiv f$ does not depend on the time t. Expression (1) will then be rewritten in the following form:

$$F^{(k)} = f(\mathbf{x}, F^{(0)}, F^{(1)}, \dots, F^{(k-1)}),$$

where $\mathbf{x}$ denotes the n-dimensional vector $(x_1, x_2, \dots, x_n)$. In the special case, the variables $x_1, x_2, \dots, x_n$ may be absent.

A typical example of a contact circuit with memory of the first order is an electric bell, whose conductivity is given by the function

$$F^{(1)} = x\overline{F}^{(0)}.$$

We indicate a realization of circuit (2).

Number, in the binary number system, all possible values of systems of k matrices $\{F^{(0)}, F^{(1)}, \dots, F^{(k-1)}\}$. Suppose that, for a given value of $\mathbf{x}$,

$$s = \sum_{\nu=1}^{m} y_\nu \, 2^{\nu-1}$$

corresponds to the system $\{F^{(0)}, F^{(1)}, \dots, F^{(k-1)}\}$, and the number

$$s' = \sum_{\nu=1}^{m} y'_\nu \, 2^{\nu-1}$$

corresponds to the system $\{F^{(1)}, F^{(2)}, \dots, F^{(k)}\}$.

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* In paper (?) the notation used here is explained.

Obviously, condition (2) can be specified as follows:

A. $F = \varphi_1(\mathbf{x}, \mathbf{y})$.

B. $\mathbf{y}' = \varphi_2(\mathbf{x}, \mathbf{y})$.

Here $\mathbf{y}$ and $\mathbf{y}'$ denote, respectively, the vectors $(y_m, y_{m-1}, \dots, y_1)$ and $(y'_m, y'_{m-1}, \dots, y'_1)$. Condition A is realized by the contact (p, q)-terminal network $\varphi_1(\mathbf{x}, \mathbf{y})$. Condition B, which specifies the change of $\mathbf{y}$, is realized by the contact $(1, m)$-terminal network $\varphi_2(\mathbf{x}, \mathbf{y})$, to whose ν-th output the relay Y_ν is connected. Note that all relays Y_ν in contact circuits with memory must operate after a definite interval of time Δt. The time Δt determines the duration of one cycle.

The contact part implementing condition A and the relay part implementing condition B should, generally speaking, be constructed not separately but together, in the form of a $(p, q + m)$-terminal network, which may lead to a reduction in the number of contacts.

Example 1. A cycle during which the conductance of a two-terminal network is equal to unity will be called a **working** cycle; otherwise it will be called an **idle** cycle. It is required to construct such a two-terminal network F depending on the variable x that, when $x = 1$, two working cycles alternate with one idle cycle, and when $x = 0$, one working cycle alternates with one idle cycle; i.e., for $x = 1$ the alternation is $(1, 1, 0)$, while for $x = 0$ the alternation is $(1, 0)$. Obviously, F is a two-terminal network with memory of order 2. Since the different pairs of values of F will be $(0, 1)$, $(1, 0)$, $(1, 1)$, we number them as follows: for $x = 1$, respectively $0, 2, 1$; for $x = 0$, respectively $1, 0$ (the state $(1, 1)$ for $x = 0$ is not realized).

We give the table of values of F and the table of alternation of the number s:

Fig. 1

Figure 1: Fig. 1

s	0	1	2
F	1	0	1

$$x = 1, \quad 0 \to 1 \to 2 \to 0$$

$$x = 0, \quad \begin{matrix} 0 \\ 2 \end{matrix} \searrow 1 \to 0$$

For $x = 0$ one must also take into account $s = 2$, since it may occur in the transition from $x = 1$ to $x = 0$. We introduce auxiliary relays y_1 and y_0. They correspond to the digits of the number

$$s = y_1 \cdot 2 + y_0 \cdot 1.$$

From consideration of the table we conclude that $F = \overline{y_0}$. The relay part is found very simply from condition B. Combining the relay and contact circuits, we obtain a realization of the required circuit F with the reacting element A (Fig. 1).

Fig. 1

A special case of contact circuits with memory is furnished by the automaton systems considered by V. I. Shestakov ([1]). In the cited paper, automaton systems are realized in the class of P-circuits.

II. Circuits with blocking. Let, at t equal to $t_0, t_1, \ldots, t_s, \ldots$, the variable vector $\mathbf{x}$ assume the values $\mathbf{x}(0), \mathbf{x}(1), \ldots, \mathbf{x}(s)$. A system of subsets is given

$$M_1, M_2, \ldots, M_r$$

of the set M of values of the vector $\mathbf{x}$.

Introduce r binary variables $y_\nu(k)$ $(\nu = 1, 2, \ldots, r)$, determined by the following conditions:

1a) $y_\nu(s) = 1$, if there exists k such that $k < s$ and $\mathbf{x}(k) \in M_\nu$;

2a) $y_\nu(s) = 0$, if for all $k < s$ all $\mathbf{x}(k) \notin M_\nu$;

3a) $y_\nu(0) = 0$.

Below we denote the variables $y_\nu(s)$ by the vector $\mathbf{y}(s)$.

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

Definition 2. A circuit that realizes the matrix-function

of (p, q)-order

$$F(s) = f\{x(s), y(s)\},$$

where $y(s)$ is determined by conditions 1a)–3a) over the system of subsets (a), we shall call a **circuit with interlocking**. A circuit with interlocking consists of two parts. The first, contact part is a contact (p, q)-terminal network $f(x, y)$. The second, relay part Φ, is a contact $(1, r)$-terminal network, to whose ν-th output the relay Y_ν is connected. The operating conditions of the circuit Φ are such that the operation of the relay Y_ν (the ν-th output) occurs only under the condition that $x \in M_\nu$. In order that the circuit "remember" this fact (i.e., that conditions 1a)–3a) be fulfilled), all relays Y_ν are interlocked. Unlike contact circuits with storage, the time t in circuits with interlocking changes not at equal intervals Δt, but is determined only by the change of x.

Fig. 2

Example 2. Realize a circuit whose action is specified by the following conditions: when a call is received, relay B operates and lamp L must light up; after pressing button x, the lamp must go out and must not light up after the button is released; the circuit must return to its quiescent state after relay B releases.

It is obvious that contact b closes and opens the circuit. The set M of values of x consists of two elements: 0 and 1. Let M_1 denote the subset of M consisting of the single 1.

Introduce a binary variable $y(s)$ such that:

1a) $y(s) = 1$, if there exists a k such that $k < s$ and $x(k) \in M_1$, i.e. $x(k) = 1$;

2a) $y(s) = 0$, if for all $k < s$ all $x(k) = 0$;

3a) $y(0) = 0$,

It is obvious that the contact part $F = \bar{y}$, and the relay part $\Phi = x$. At the output we place relay Y with interlocking. After combining, we obtain the circuit of Fig. 2.

Fig. 3

III. **Combinatorial circuits.** We shall call an input element of the pushbutton type such an input element that returns to its initial position after the cessation of the action.

Definition 3. A multi-terminal network with pushbutton-type input elements $A_1, A_2, \dots, A_m$, whose conductivity depends only on the order in which the input elements operate and does not depend on the moments at which the elements operate, will be called a **combinatorial multi-terminal network**.

Below we shall consider combinatorial multi-terminal networks in which only one input element operates in one cycle. We represent the order of operation of the input elements by a "word." For example: $A_1^\circ A_2^\circ A_1^\circ A_2^\circ A_3$. The number of letters in the "word" will be called the **length of the "word."**

A combinatorial circuit F consists of two parts: a combinatorial part K, constant for all combinatorial circuits with a given number of input elements, and a contact part Φ, characteristic of the given circuit. Let the operating conditions of the circuit be specified by words whose maximum length is n. For the input element A_ν ($\nu = 1, 2, \dots, m$), introduce auxiliary variables $x_{1\nu}, x_{2\nu}, \dots, x_{n\nu}$ (the vector x_ν). By the **combinatorial part** K of the circuit F we shall call such a circuit that closes contact $x_{i\nu}$ if, at the i-th cycle, the input element A_ν has operated.

In Fig. 3 an implementation is given of one cycle of the combinatorial part K with two

receiving elements. The entire combinational part is obtained by connecting such typical circuits in series (Q and R are auxiliary relays, a_1 and a_2 are contacts of the receiving elements A_1 and A_2).

The operating conditions of the circuit F are now formulated for the contacts $x_1, x_2, \dots, x_m$

$$F = f(x_1, x_2, \dots, x_m).$$

The contact part Φ realizes condition (3). By combining the contact part Φ and the combinational part K, we obtain a realization of the combinational circuit according to its operating conditions.

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CITED LITERATURE

[1] V. I. Shestakov, *Avtomatika i telemekhanika*, **15**, No. 2, No. 4 (1954). [2] A. Sh. Blokh, *DAN*, **111**, No. 5 (1956).