TWO-TERMINAL DIODE NETWORKS

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Abstract

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TWO-TERMINAL DIODE NETWORKS

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In the modern practice of designing devices and systems for automatic control, telemechanics, and computing technology, diode networks are widely used. A number of methods have been developed for reducing the elements of the structure of diode networks: diodes, additional resistances, contacts, or other actuating organs.

As far as we know, the problem of using diodes for the purpose of reducing contacts in relay structures was first posed by M. A. Gavrilov ([1]). Later he ([2]) developed, for single-contact and multi-contact $(1-k)$-terminal networks, a method for constructing diode networks with one changeover or single contact on each structural element according to a structural formula written in bracketed form (Fig. 1). Among foreign works of that period, ([3]) should be mentioned. Further rationalization of diode networks for the special case of single outputs is given in ([4,5]), and also in ([6,7]), where the results of previous works are partly repeated. However, in all these works the so-called **single-terminal** diode networks were considered, in which both the actuating and the reacting organs are connected to one of the terminals of the power source (Fig. 1).

In the present work, **two-terminal** diode networks ([8]) are considered, which give a further reduction of the elements of the structure in comparison with single-terminal ones. By two-terminal networks we shall understand such diode networks in which the actuating organs are located at both terminals of the power source and control, through the diode network, no fewer than two reacting organs each, while a number of reacting organs located inside the structure are connected in series with no fewer than two actuating organs, necessarily located at different terminals of the power source.

By a **single symbol** we shall understand a make or break contact, as well as their contactless equivalents and the corresponding variables in structural formulas. We shall call a chain between two nodes of the structure **elementary** if it contains only a single symbol. A chain from the positive or negative terminal of the power source to the nearest branching node shall be called **terminal**. A two-terminal diode network in which there are only terminal elementary chains will be regarded as **elementary**. An elementary two-terminal diode network in which all reacting organs of all intermediate and actuating elements are connected in series with at least two terminal chains located at different terminals of the power source will be called **complete**. In what follows we shall consider

Fig. 1. Block diagram of a one-pole diode network proposed by M. A. Gavrilov. $X_1, X_2, \dots, X_m$ are intermediate elements, $Y_1, Y_2, \dots, Y_n$ are actuating elements, $a, b, \dots, r$ are actuating organs of the acting elements

Figure 1: Fig. 1. Block diagram of a one-pole diode network proposed by M. A. Gavrilov. $X_1, X_2, \dots, X_m$ are intermediate elements, $Y_1, Y_2, \dots, Y_n$ are actuating elements, $a, b, \dots, r$ are actuating organs of the acting elements

complete two-terminal diode networks and, for brevity, omit the word "complete."

Two-terminal diode networks, by virtue of their specificity, impose restrictions on the construction of structures. The first restriction is determined by the assertion:

Theorem 1. A complete two-pole diode network, constructed according to a structural formula written in bracketed minimal form, requires, for each intermediate and actuating element, separate responding organs equal in number to the conjunctive terms under the symbol of this element.

The validity of the theorem follows from the following lemmas.

Lemma 1. If the structural formula for an actuating or intermediate element can be reduced to the form

$$\Phi_X = \left(\bigcup_{i=1}^{n} \widetilde{\varphi}_i \right) \left(\bigcup_{l=1}^{p} \tilde{\gamma}_l \right) f_1, \tag{1}$$

where $\widetilde{\varphi}_i \neq \gamma_l,\ i = 1, \dots, n;\ l = 1, \dots, p$, then for this element it is possible to construct a complete two-pole diode network with one responding organ.

Lemma 2. Expanding formula (1) to a disjunctive form by adding at least one variable $\tilde{n}$ not included in formula (1) does not allow the construction of a structure of a complete two-pole diode network with one responding organ.

In formula (1): $\bigcup_{i=1}^{n} \widetilde{\varphi}_i$ is a disjunction placed in correspondence with parallel-connected terminal circuits $\widetilde{\varphi}_k$ at the positive pole of the power supply; $\bigcup_{l=1}^{p} \tilde{\gamma}_l$ is the same for $\tilde{\gamma}_k$ at the negative pole of the power supply; f_1 is any Boolean function. By a **conjunctive** term is meant a term of the structural formula of the form (1).

Fig. 1. Block diagram of a one-pole diode network proposed by M. A. Gavrilov. $X_1, X_2, \dots, X_m$ are intermediate elements, $Y_1, Y_2, \dots, Y_n$ are actuating elements, $a, b, \dots, r$ are actuating organs of the acting elements.

Secondly, a responding organ cannot be connected in series with more than two groups of parallel-connected terminal circuits, necessarily connected to different poles of the power supply, which is clear without proof from Lemma 1.

Fig. 2. Economical binary decoder in the form of a structure of a two-terminal diode network

Figure 2: Fig. 2. Economical binary decoder in the form of a structure of a two-terminal diode network

Along with the indicated limitations, a two-pole diode network has substantial advantages over a one-pole one. The first advantage is determined by Theorem 2.

Theorem 2. A complete two-pole diode network, in comparison with a one-pole network of the very same purpose, gives a saving of from one to $(n-1)$ diodes and resistances for each responding organ, where n is the number of terminal circuits in the corresponding term (1).

Secondly, a two-pole diode network makes it possible to build, on one single symbol of each element, a larger number of structures than a one-pole network, owing to the presence of groups of such symbols at each of the two poles of the power supply.

Thirdly, by reducing the shunting circuits while simultaneously increasing the circuits connected in series with the responding organs, the switching properties of structures with a two-pole diode network are improved.

Fourth, owing to the reduction in the number of diodes, the presence of unit diodes connected in series with a number of parallel-connected ones, and also the applicability of bracketed unipolar diode networks, two-terminal diode networks have fewer parametric restrictions.

Partitions of variables into groups ([2],[3]), as well as bracketed unipolar diode networks, are applicable to two-terminal diode networks, which gives a further minimization of elements. Let us consider the structure in Fig. 2 of a binary decoder with 16 outputs, in which a partition of individual terms into groups and a bracketed unipolar diode network are applied. It uses 32 diodes and 8 resistors, i.e., 40 elements instead of 64 elements (48 diodes and 16 resistors) in the structure of a bracketed unipolar diode network ([3]). The saving of elements is 37%. In general, depending on the character of the structure, the saving of elements, including the actuating devices, in two-terminal diode networks in comparison with bracketed unipolar networks varies within the limits $(25 \div 50)\%$.

Fig. 2. Economical binary decoder in the form of a structure of a two-terminal diode network

The algorithm for constructing a complete two-terminal diode network is as follows:

1. The structural formula is written in bracketed minimal form.
2. By one of the methods proposed by us (the connection polygon method ([8]), the method of taking outside the line in combination with deletion,

the tabular method), two groups of single symbols are found.

3. For the influencing, intermediate, and actuating elements for which a single symbol cannot be taken, switching actuating devices are taken.

4. To the positive pole of the power supply there is connected that group of single symbols which, according to the structural formula, shunts the smaller number of responding devices. The second group of single symbols, the single symbols common to the two groups, and the switching actuating devices are connected to the negative pole of the power supply.

5. The required number of responding devices of each intermediate and actuating element is placed in the middle of the circuits.

6. In constructing a two-terminal diode network according to the structural formula, if possible, one should apply partitioning of the variables of individual terms into groups and bracketed unipolar diode networks.

7. If the multiplier at the symbol of a given element in its structural formula is the single symbol chosen according to item 2, then it is connected in series with the corresponding responding device of the given element.

8. If the multiplier at the symbol of a given element in its structural formula is the inversion of the single symbol chosen according to item 2, then this single symbol is connected to the corresponding responding device of the given element as a shunt. In this case, between the junction of the shunting branch and the corresponding supply pole in ···

to prevent a short circuit, an additional resistance is inserted. If shunting is performed from the side of the positive pole while the same responding element is simultaneously shunted from the side of the negative pole, then a diode is inserted between the connection node of the shunting branch from the side of the positive pole and the corresponding end of the responding element.

9. Switching actuating elements, where possible, should be connected in series with the corresponding responding elements.

10. If a given actuating element participates in a number of circuits controlled by different responding elements, then a diode is inserted in each successive shunting branch leading away from (or arriving at) the branching node (or into the node). All diodes are connected in the direction of flow of the control current in the corresponding branches.

11. It should be checked whether there are any superfluous diodes in the structure.

A reduction in the number of elements, a more rational configuration of the structure, and better parametric relationships lead to an appreciable increase in the reliability and trouble-free operation of relay devices with two-terminal diode networks.

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Note: Figure translations are in progress. See original paper for figures.