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# Framework development for software functionality in Uzbekistan's block route centralization system

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**Abstract.** The article notes the relevance of the use of the latest scientific and technical developments, in transportation management justified by the need to increase the intensity of train traffic and ever-increasing freight turnover while maintaining the safety of train traffic. The solution of actual innovative tasks on the application of electronic devices in railway automation and telemechanics devices will allow to increase the level of transportation safety. Digital information processing and frame modeling techniques were used to achieve this goal. The method of microelectronic implementation of blocks of the set group of the route relay centralization system functional purpose is considered. To formalize the description of blocks of the set group, the method of role frames has been developed, which allows to obtaining of unified information and mathematical support for microprocessor blocks of the set group that control the switching of points, the operation of shunting, and trainset signals. The software purpose of the coupled point control unit is to constantly survey the slot descriptions to determine a positive or negative response. Change of state〖g〗_"PU1," g_"MU1" indicates the beginning of the procedure for setting a route passing through this point. Changes in the state of the variable g_"NKN," g_"KN" control units of shunting and trainset signals determine the directions of the software when setting routes. The use of role frame models allowed to optimize the software structure of microcontrollers used to replace the relay contact hardware of the route relay centralization system.

## 1 Introduction

The need to apply the latest scientific and technological developments, progressive work methods, and thorough reform of the management of the transportation process is dictated by the need for high intensity of train traffic and constantly increasing cargo turnover, while unconditionally ensuring train traffic safety [1]. The set tasks can be accomplished by modern means of railway automation and telemechanics. The current pace of development of microelectronics makes it possible to freely use them for the development of automation equipment, intelligent control, and modeling systems to link them using hardware and software systems [1-6].

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Fast performance, reliability, and multifunctionality are distinctive features of systems built with the use of microelectronic computing facilities. The level of reliability and optimal functioning of automation and telemechanics devices is directly reflected in the number of train delays, which in turn entails economic losses. The use of microprocessor devices with optimal hardware design and information and mathematical software that have higher reliability indicators in transportation process control systems is an urgent task. In the field of railway automation and telemechanics, the priority in solving innovative technical problems is the refusal to use electromagnetic relays of the code-dispatch type (CDR), in devices that are not responsible for the safety of train traffic. In block systems of relay centralization, there are blocks of the set group not directly responsible for the safety of train traffic, made on railway relays, type CDR. These include single point control units (NSP), coupled points control units (NCP), single shunt signal control units (NS1), shunt signal control units in the gate (NSIIT, NSIIAT), and control units of trainset and shunt signals (NTS). The main objective of this article is to develop a method for building a frame model for functioning the software of the set group of the block route centralization system, to solve the issue of organizing information and mathematical support for microcontrollers, optimizing and unifying its software.

## 2 Method

The purpose of this article is to develop a method of building a frame model of the functioning of the software of the set group of the block route centralization system, to solve innovative problems in the application of contactless devices in the devices of railway automation and telemechanics, optimization of their information and mathematical support. Digital information processing and frame-based modeling techniques have been used to achieve this goal [2, 7-12].

## 3 Results and discussion

Consider the state of the role frame $f_{\mathrm{NSP}}$of the NSP block, which contains the slots$\nu_i$, where the question words about the relay state are their names, the answers to which are the values of the description slots [4]. As $i$ - the relay status definitions included in the NSP unit are used, for example, the slot name$\nu_{\mathrm{1PU}}$is defined as "relay 1PU energized?". The values of the slots$\nu_i$ are described by the variables$g_i$, which have the meaning of the answer to the question and take two values, i.e. "Yes" when$g_i = 1$ the corresponding relay is in the energized state and vice versa "No" when $g_i = 0$ the corresponding relay is in the de-energized state.

Thus, the role frame $f_{\mathrm{NSP}}$is described by the slots$\nu_{\mathrm{1PU}}$,$\nu_{\mathrm{1MU}}$ and their state by variables, i.e. answers to the posed questions contained in$g_{\mathrm{1PU}}$and$g_{\mathrm{1MU}}$. Analyzing the value of the variables $g_{\mathrm{1PU}}$and $g_{\mathrm{1MU}}$, namely$g_{\mathrm{1PU}} = 0, g_{\mathrm{1MU}} = 0$ determines the initial state of the NSP block, under the condition that $g_{\mathrm{1PU}} = 1, g_{\mathrm{1MU}} = 0$or $g_{\mathrm{1PU}} = 0, g_{1MU} = 1$the use of the block in the process of setting the route. To fulfill the conditions for train safety, the value of the slots$\nu_{\mathrm{1PU}}$, $\nu_{\mathrm{1MU}}$described by the variables$g_{\mathrm{1PU}} = 1, g_{1MU} = 1$is mutually exclusive. Thus, when modeling the operation of all set units in the computer in the database, the state of controlling and monitoring relays is determined from the role frame, by analyzing the slots$\nu_i$. When the operation is performed to specify a route that passes through the plus position of the point, the role frame$f_{\mathrm{NSP}}\left[\langle \nu_{\mathrm{1PU}}, g_{1_{\mathrm{PU1}}}\rangle, \langle \nu_{\mathrm{1MU}}, g_{1_{\mathrm{MU}}}\rangle\right]$ and its slots will be described by the following expression$\langle \nu_{\mathrm{1PU}}, g_{\mathrm{1PU1}} = 1\rangle, \langle \nu_{\mathrm{1MU}}, g_{\mathrm{1MU}} = 0\rangle$. When setting the route to the minus position of the points, the role frame and its slots will be described by the following expression.$\langle \nu_{\mathrm{1PU}}, g_{\mathrm{1PU1}} = 0\rangle, \langle \nu_{\mathrm{1MU}}, g_{\mathrm{1MU}} = 1\rangle$

Consider the state of $f_{\mathrm{NCP}}$ a role frame describing the state of the NSS coupled point control unit having pairs such as:

$$\langle \nu_{\mathrm{PU1}}, g_{\mathrm{PU1}} \rangle, \langle \nu_{\mathrm{PU2}}, g_{\mathrm{PU2}} \rangle, \langle \nu_{MU}, g_{MU} \rangle \text{and} \langle \nu_{UK}, g_{UK} \rangle,$$

under the frame $f_{\mathrm{NCP}}$ we will understand the structure of the following type

$$f_{\mathrm{NCP}}[\langle \nu_{\mathrm{PU1}}, g_{\mathrm{PU1}} \rangle, \langle \nu_{\mathrm{PU2}}, g_{\mathrm{PU2}} \rangle, \langle \nu_{\mathrm{MU}}, g_{\mathrm{MU}} \rangle, \langle \nu_{\mathrm{UK}}, g_{\mathrm{UK}} \rangle]$$

In this case, the slot $\nu_{\mathrm{PU1}}$ is assigned the name "PU1 relay energized?" response to which is determined by its value, i.e., at $g_{\mathrm{PU1}} = 1$ "Yes" the relay is energized, at "No" $g_{\mathrm{PU1}} = 0$ corresponds to the de-energized state of the PU1 relay. A similar reasoning is true for other slots. At the same time, it is necessary to note the dangerous state of the role frame when at least one of the following conditions is met

$$f_{\mathrm{NCP,dangerous}}[\langle \nu_{\mathrm{PU1}}, g_{\mathrm{PU1}} = 1 \rangle, \langle \nu_{\mathrm{PU}}, g_{MU} = 1 \rangle];$$

$$f_{\mathrm{NCP,dangerous}}[\langle \nu_{\mathrm{PU2}}, g_{\mathrm{PU2}} = 1 \rangle, \langle \nu_{\mathrm{MU}}, g_{MU} = 1 \rangle];$$

$$f_{\mathrm{NCP,dangerous}}[\langle \nu_{\mathrm{PU1}}, g_{\mathrm{PU1}} = 1 \rangle, \langle \nu_{\mathrm{UK}}, g_{\mathrm{UK}} = 1 \rangle].$$

The functional purpose of the software of the control unit of coupled points is to constantly poll the slots, namely the fulfillment of the conditions of their description if the conditions are met

$$f_{NCP}[\langle \nu_{\mathrm{PU1}}, g_{\mathrm{PU1}} = 0 \rangle, \langle \nu_{\mathrm{PU2}}, g_{\mathrm{PU2}} = 0 \rangle, \langle \nu_{MU}, g_{MU} = 0 \rangle, \langle \nu_{UK}, g_{UK} = 0 \rangle]$$

a decision is made about the initial state of the block, i.e., no operation to set the route through these points and it is necessary to go to the beginning of polling, i.e. operation of cyclic polling. The presence of a unit in the description of any slot

$$f_{\mathrm{NCP}}[\langle \nu_{\mathrm{PU1}}, g_{\mathrm{PU1}} = 1 \rangle \vee \langle \nu_{\mathrm{PU2}}, g_{\mathrm{PU2}} = 1 \rangle \vee \langle \nu_{MU}, g_{MU} = 1 \rangle]$$

means that the unit is involved in setting the route and the software switches the necessary electrical circuits.

Consider the state of the role frame $f_{\mathrm{NS1}}$, describing the functioning of the single shunt signal control unit (NS1) having such pairs as:

$$\langle \nu_{\mathrm{NKN}}, g_{\mathrm{NKN}} \rangle, \langle \nu_{\mathrm{KN}}, g_{\mathrm{KN}} \rangle, \langle \nu_{\mathrm{MP}}, g_{MP} \rangle, \langle \nu_{\mathrm{VKM}}, g_{\mathrm{VKM}} \rangle, \langle \nu_{VP}, g_{\mathrm{VPV}} \rangle$$

and $\langle \nu_{\mathrm{AKN}}, g_{\mathrm{AKN}} \rangle$ as the frame $f_{\mathrm{NS1}}$ we will understand the structure of the following form:

$$f_{\mathrm{NS1}}[\langle \nu_{NKN}, g_{NKN} \rangle, \langle \nu_{KN}, g_{\mathrm{KN}} \rangle, \langle \nu_{\mathrm{MP}}, g_{\mathrm{MP}} \rangle, \langle \nu_{\mathrm{BKM}}, g_{\mathrm{BKM}} \rangle, \langle \nu_{\mathrm{VP}}, g_{\mathrm{VP}} \rangle, \langle \nu_{\mathrm{AKN}}, g_{\mathrm{AKN}} \rangle]$$

The illogical frame state should be detected when the following conditions are met

$$f_{\mathrm{NS1,\ illogical}}[\langle \nu_{\mathrm{NKN}}, g_{\mathrm{NKN}} = 1 \rangle, \langle \nu_{KN}, g_{KN} = 1 \rangle, \langle \nu_{\mathrm{AKN}}, g_{\mathrm{AKN}} = 0 \rangle];$$

$$f_{\mathrm{NS1,\ illogical}}[\langle \nu_{\mathrm{MP}}, g_{MP} = 1 \rangle, \langle \nu_{VKM}, g_{VKM} = 1 \rangle]$$

When setting a shunting route, as the beginning, the role frame will take the form:

$$f_{\mathrm{NS1}}\begin{bmatrix}\langle \nu_{\mathrm{NKN}}\ g_{\mathrm{NKN}}=1\rangle, \langle \nu_{KN}, g_{\mathrm{KN}}=0\rangle, \langle \nu_{\mathrm{MP}}, g_{MP}=1\rangle, \langle \nu_{VKM}, g_{VKM}{=}0\rangle, \\ \langle \nu_{VP}, g_{VP}=0\rangle, \langle \nu_{\mathrm{AKN}}, g_{\mathrm{AKN}}=0\rangle \end{bmatrix}$$

Software block NS1 having determined the change of state of the description of slots $\nu_{NKN}$ and $\nu_{\mathrm{MP}}$ provides switching of elements of electric circuits, control relays of points (PU-MU), automatic button relays (AKN), and compliance circuits (CC).

Given a shunting route as the end, the role frame will take the form:

$$f_{\mathrm{NS1}}\begin{bmatrix}\langle \nu_{\mathrm{NKN}}\ g_{\mathrm{NKN}}=0\rangle, \langle \nu_{\mathrm{KN}}, g_{KN}=1\rangle, \langle \nu_{\mathrm{MP}}, g_{\mathrm{MP}}=0\rangle, \langle \nu_{\mathrm{VKM}}, g_{VKM}{=}1\rangle, \\ \langle \nu_{\mathrm{VP}}, g_{VP}=0\rangle, \langle \nu_{AKN}, g_{\mathrm{AKN}}=0\rangle \end{bmatrix}$$

Software block NS1 having determined the change in the state of the slot description $\nu_{KN}, g_{\mathrm{KN}}$and$\nu_{\mathrm{VKM}}, g_{\mathrm{VKM}}$ provides switching of elements in electrical circuits of the PU-MU, AKN, and CC.

When setting train routes in any direction and shunting in the opposite direction, the role frame will look like:

$$f_{\mathrm{NS1}}\begin{bmatrix}\langle \nu_{\mathrm{NKN}}\ g_{NKN}=1\rangle, \langle \nu_{KN}, g_{KN}=1\rangle, \langle \nu_{MP}, g_{MP}=0\rangle, \langle \nu_{VKM}, g_{VKM}{=}0\rangle, \\ \langle \nu_{VP}, g_{VP}=1\rangle, \langle \nu_{AKN}, g_{AKN}=1\rangle \end{bmatrix}$$

The software of the NS1 block determines the change of state in the description of slots$\langle \nu_{\mathrm{NKN}}, g_{NKN}\rangle$,$\langle \nu_{\mathrm{KN}}, g_{KN}\rangle$,$\langle \nu_{\mathrm{VP}}, g_{VP}\rangle$and$\langle \nu_{AKN}, g_{AKN}\rangle$and ensures the switching of the PU-MU, AKN, and CC electrical circuit elements. According to the frame model, the algorithm of software behavior when specifying the start of the route is shown in Figure 1 and is reduced to analyzing the description of slots answering the question "button relays are energized" (the 3rd block of the algorithm), in case of affirmative answer in the route under consideration, the NKN relay will be excited and the variable$g_{\mathrm{AKN}}$takes a single value.

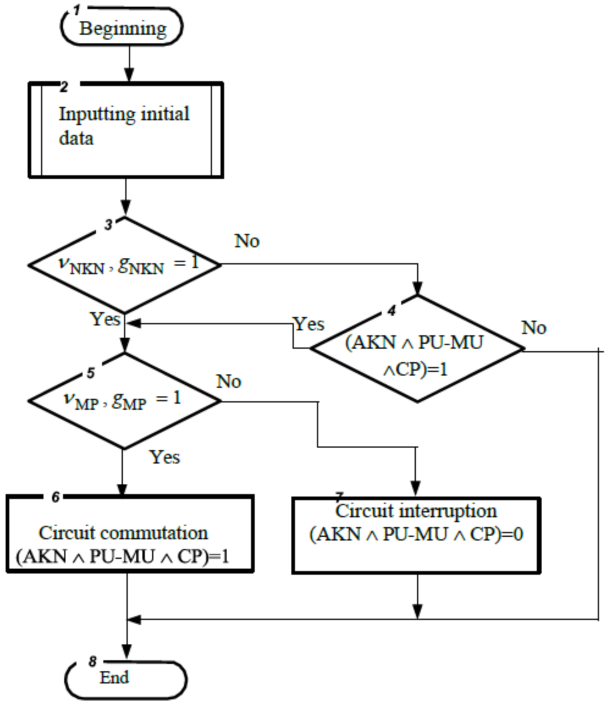


**Fig. 1.** Algorithm of software functioning when setting the beginning of shunting route of NS1 block.

Fulfillment of this condition requires the subroutine of slot description analysis$\langle \nu_{MP}, g_{MP} \rangle$, and if the condition $g_{MP} = 1$ (5th block of the algorithm) is fulfilled, the procedure of realization of switching of electrical circuits PU-MU, AKN, and CC (6th block of the algorithm) with the help of hardware is started. The algorithm for the functioning of the software of the NS1 unit, which is the end of the shunting route being formed, is shown in Figure 2. It follows that the analysis of the slot and its description $\langle \nu_{\text{KN}}, g_{KN} \rangle$determines that the block is used at the end of the route and it is necessary to check the slot condition$\langle \nu_{VK}, g_{VK} \rangle$ (block 5 of the algorithm) and, if the condition is met, that $g_{VK} = 1$it is necessary to start the procedure for ensuring the switching of the PU-MU, AKN, and CC circuits (the 6th block of the algorithm).

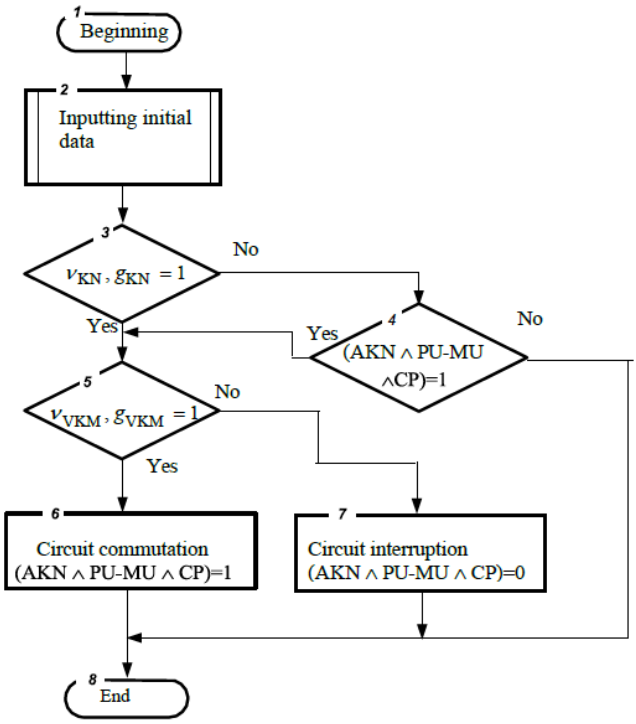


**Fig. 2.** Algorithm of software functioning when setting the end of the shunting route of NS1 block.

The frame models of control units of coupled shunting traffic lights, namely NMIIP and NMIIAP are described by the following expressions:

$$f_{\text{NMIIP}}[\langle v_K\ g_K = 0, v_{\text{KN}}\ g_{KN} = 0, v_{MP}\ g_{\text{MP}} = 0, v_{VKM}\ g_{VKM}{=}0, v_{VP}\ g_{VP} = 0\rangle];$$

$$f_{\text{НМIIАП}}[\langle v_K\ g_K = 0, v_{KH}\ g_{KH} = 0, v_{MP}\ g_{MP} = 0, v_{VKM}\ g_{VKM}{=}0, v_{VP}\ g_{VP} = 0, v_{AKN}\ g_{AKN} = 0\rangle]$$

Analysis of the functionality of control units of coupled shunt signals showed their identity with the NS1 unit.

The role frame model of the control unit of train and shunt signals (NTS), in the absence of the procedure of route assignment, is characterized by the de-energized state of all relays. In this case, the frame model of the NTS block is described by the following expression:

$$f_{NTS}\begin{bmatrix}\langle v_{NKN}, g_{NKN} = 0\rangle, \langle\ v_{KN}, g_{KN} = 0\rangle, \langle v_{OP}, g_{OP} = 0\rangle, \langle v_{PP}, g_{PP} = 0\rangle, \\ \langle v_{VKM}, g_{VKM}{=}0\rangle, \langle v_{VK}, g_{VK} = 0\rangle\end{bmatrix}$$

When specifying a train route from the NTS block in the role frame model, the description of slots will change to affirmative, namely$\langle v_{NKN}, g_{NKN} = 1\rangle$,$\langle v_{OP}, g_{OP}\rangle = 1$ and$\langle v_{PP}, g_{PP} = 1\rangle$, the algorithm of the software is shown in Figure 3-4.

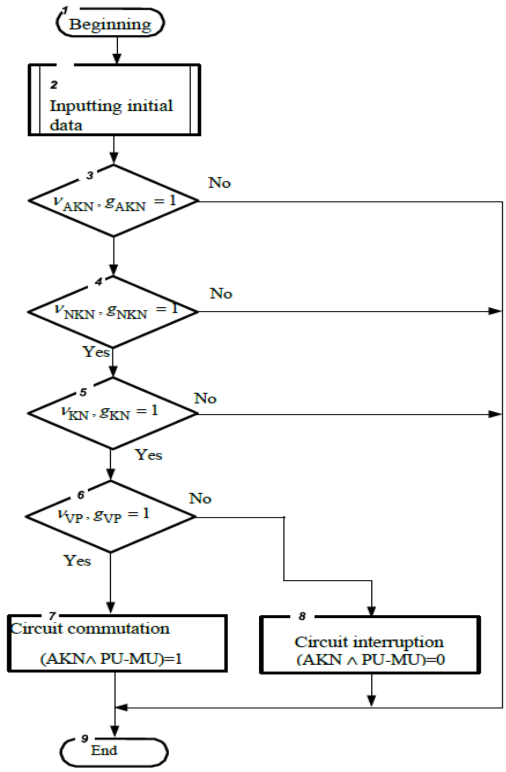


**Fig. 3.** Algorithm of NS1 block software functioning when setting train and shunting routes of the opposite direction.

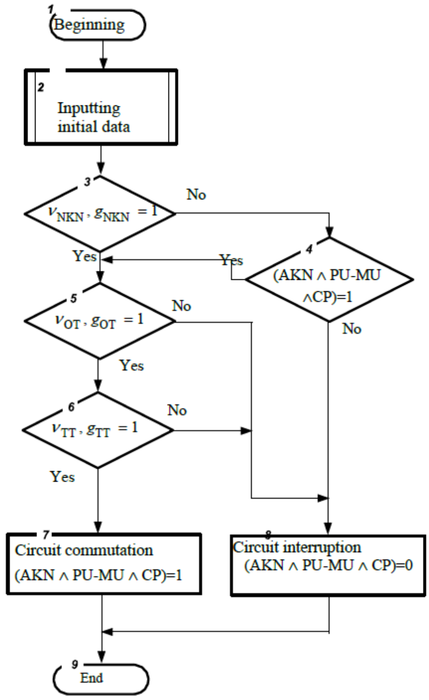


**Fig. 4.** Algorithm of software functioning when setting the beginning of the train route of the NTS block.

When setting the train route with a block at the end the slot descriptions $\cdot$ $v_{NKN}, g_{NKN}\rangle = 1$and$\langle v_{VK}, g_{VK} = 1\rangle$will change. The software operation algorithm is shown in the Figure 5. The program analyzes the fulfillment of conditions formulated in the description of slots.

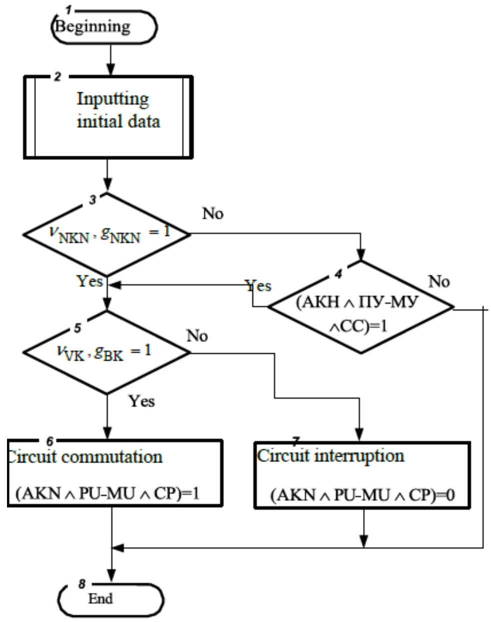


**Fig. 5.** Algorithm of software functioning when setting the end of the train route of the NPM block.

For the case when a shunting route is set and the block is at the beginning of it, then the description of slots will change to $\langle v_{KN}, g_{KN} = 1\rangle$and$\langle v_{OP}, g_{OP} = 1\rangle$. The algorithm of software operation for this case is shown in Figure 6 assumes when installing a shunting route with a block at the end, then the description of the slots will change to $\langle v_{\mathrm{KN}}, g_{KN} = 1\rangle$and$\langle v_{\mathrm{VKM}}, g_{\mathrm{VKM}}\rangle = 1$.

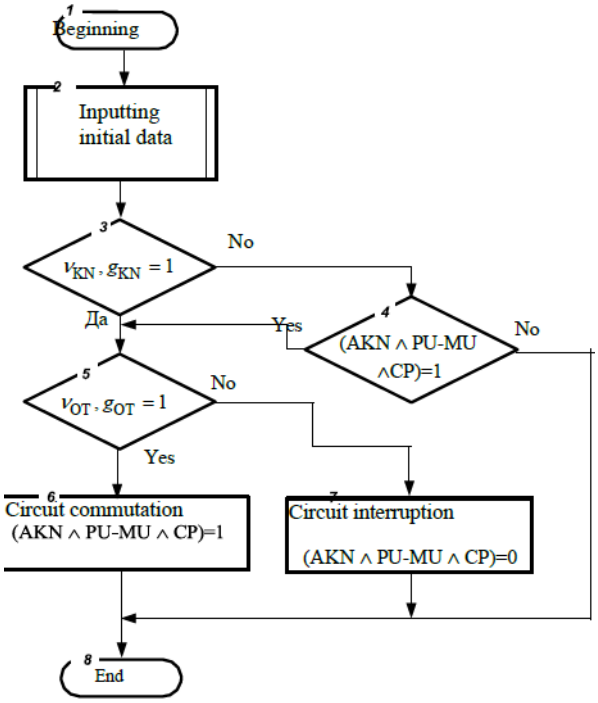


**Fig. 6.** Algorithm of software functioning when setting the start, and shunting route of the NTS unit.

In any case, when the NTS block is used and the slots state is changed, the AKN, PU-MU, and CC circuits are switched.

## 4 Conclusions

So far, the main attention has been paid to the development and optimization of the hardware of computing systems [13-20], but the optimal construction of software also plays an important role in the successful functioning of the latter. This paper presents an attempt to develop a method for constructing role frames aimed at optimizing and standardizing the process of software development for microelectronic modules in the modular group of the block route centralization system. The use of role frame models allowed to optimize the structure of the software of microcontrollers used in the replacement of relay contact hardware.

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