Development and research of a model of a microprocessor device of a set-up control unit for paired points

Asadulla Azizov

Abstract. The use of electromagnetic relays in railway control systems is very problematic. The solution to this problem is based on process modelling and the use of microelectronic devices. The functional scheme for different modes of operation of twin switches control unit has been developed and investigated. Algorithms and functional scheme of microelectronic unit are given.

1 Introduction

The need to apply the latest scientific and technical developments, progressive labour methods, and thorough reform of the transport process management is motivated by the high intensity of train traffic and constantly increasing freight turnover, while unconditionally ensuring the safety of train traffic.

Modern automation and monitoring of the technical condition of railway automation devices help to meet these challenges. The current pace of development of microelectronics allows their free application for the development of automation tools, linking them by means of hardware and software complexes [1-14].

This is justified by the response speed, reliability and multifunctional capabilities of microelectronic computing systems. The level of reliability of automation and telemechanics devices has a direct impact on train delays, which in turn results in economic losses. The use of microprocessor devices with higher reliability indicators in the control systems of the transport process is an urgent task. In the field of railway automatics and telemechanics, the priority in solving innovative technical problems is to refuse to use electromagnetic relays, in devices that are not responsible for the safety of trains [7, 8]. In the block route relay interlocking system there are blocks of set group, not directly responsible for train operation safety, made on relays of the second class of reliability of the KDR type. These include the unit responsible for controlling the twin switches, which consists of the plus control relays (PC) and the minus control relay (MC). A schematic diagram of the winding connection of the relays is shown in Fig.1 [1]. The main task of this article is to solve the problem of synthesis of microelectronic control unit for twin switches without using electromagnetic relays, contacts of which will be replaced by contactless switching devices of the type PVG-612, and the relay windings are replaced by an opto-pair element РС-817.
2 Method

The purpose of this article is to solve innovative problems on application of non-contact devices, in the existing relay system of block route interlocking, which will provide increase of transportation safety due to increase of reliability, technical condition of devices, and control. To achieve this goal, methods of refusal from hardware implementation of logic functions and transition to software solution of these dependencies, as well as refusal from mechanical contacts and transition to microelectronic non-contact switching devices were used [1, 5, 6, 8, 9, 10, 13].

3 Results and discussion

To this end, the task of synthesising a microelectronic control unit for twin switches is solved (NSS) block interlocking routing systems, replacing the used electromagnetic relays of the second reliability class of the KDR type. A single STM-32 type microcontroller is to be used to implement the logical operations performed by the block by means of software NSS. The schematic diagram of the twin-arm relay control unit is shown in Figure 1. The unit contains the first plus control relay PC1, second plus control starting relay PC2, minus control starting relay MC and an angle relay CR. Let us consider building a microelectronic control unit for twin switches by first developing and investigating its model, focusing on the triggering and de-energizing conditions of the starting switches and corner relays [6-13]. Assuming that all logical operations will be performed at the software level of the microcontroller, we assign to each relay a corresponding variable, consonant with the name of the electromagnetic relay. The graph position of the first plus control relay is designated as $MC_1$, for the excited state of this relay we have the following value of variables $MC_1 = 1, MC_1 = 0$, the de-energised state of this relay is reflected by the values of the variables $MC_1 = 0, MC_1 = 1$. The graph position of the second plus control relay is marked as $MC_2$, for the case where this relay is energised we have the following value of variables $MC_2 = 1, MC_2 = 0$, the de-energised state of this relay is reflected by the values of the variables $MC_2 = 0, MC_2 = 1$. Setting the route according to the minus position of the twin switches involves triggering a relay MC, in which case the state variables will have the following values $PC = 1, PC = 0$, otherwise we have $PC = 0, PC = 1$. A t the start of the route setting procedure and assuming that it can be set by the minus position of the twin switches, a relay is provided in the relay unit CR, which is energised precisely at the moment the first button is pressed by the station attendant on duty. In the Petri net graph, the operation of this relay is simulated by the position $CR$. For the excited state case of this relay, there is a ratio of variables $CR = 1, CR = 0$, for its de-energised state we have $CR = 0, CR = 1$. Chip availability in positions $MC_1, MC_2, MC, CR$ corresponds to the excited state of these relays. Presence of a chip in inverse positions, i.e., $MC_1, MC_2, PC, CR$ corresponds to the de-energised state of these relays. The column also contains variables reflecting the state of the unit's terminals, in the following relationship, for example the variable reflects the presence of potential on terminal 1-3, the variable $(1 - 3)$ reflects the absence of voltage on that terminal. These statements are also true for other variables reflecting the presence or absence of voltage at the same terminals.
$I(MC_1) = \{t_1\}$

$I(MC_1) = \{t_2\}$

$I(t_1) = \{(1 - 13 \land 1 - 3 \land \neg CR), MC_1\}$

$I(t_2) = \{(CR \lor 1 - 3 \lor 1 - 13), MC_1\}$

$I(MC_2) = \{t_1\}$

$I(MC_2) = \{t_2\}$

$O(MC_1) = \{t_1\}$

$O(MC_1) = \{t_2\}$

$O(CR \land 1 - 3 \land 1 - 13) = \{t_1\}$

$O(CR \lor 1 - 3 \lor 1 - 13) = \{t_2\}$

$O \neg t = MC$

$O \neg t = MC$

$I(t_1) = \{(2 - 13 \land 2 - 3 \land \neg PC), MC_2\}$

$I(t_2) = \{(PC \lor 2 - 3 \lor 2 - 13), MC_2\}$

$O(MC_2) = \{t_2\}$

$O(MC_2) = \{t_1\}$

$O \neg PC \land \neg t = MC$

$O \neg PC \land \neg t = MC$

$O \neg PC \land \neg t = MC$

$O \neg t = MC$

$O \neg t = MC$
Fig. 1. Schematic diagram of a relay unit NSS

\[ I_{PC} = t_1 \]
\[ I_{PC} = t_2 \]
\[ O_{PC} = t_3 \]
\[ O_{PC} = t_4 \]

\[ O_{PC} = \overline{t_1} \]
\[ O_{PC} = \overline{t_2} \]

\[ I_{t_1} = \overline{t_3} \wedge \overline{t_4} \wedge MC \wedge CR \]
\[ I_{t_2} = \overline{t_3} \wedge \overline{t_4} \wedge MC \wedge CR \]
\[ I_{t_3} = t_1 \wedge MC \wedge CR \]
\[ I_{t_4} = t_2 \wedge PC \]

\[ O_{t_1} = PC \]
\[ O_{t_2} = PC \]
In the initial state, when there is no action on the task, the state graphs responsible for the state of the relay are $PC_1$, $PC_2$, $MC$, and $CR$ is shown in Figure 2-5.

Consider the operation of the microelectronic control unit when setting a route that runs through the twin switches at the plus position of the first switch. In this case, according to the block interlocking algorithm, the plus switch of the first switch must be activated and the chip on the graph (Fig. 2) must be moved to the position of $MC_1$. From the initial state of the relay graph $PC_1$ it can be seen that the chip is in position $MC_1$, i.e. the relay is de-energised, to move the terminal to a position reflecting the energised state of that relay, the conditions for starting the transition must be met, in accordance with $I(MC_1) = \{t_1\}$ and $I(t_1) = \{(1 - 13 \land 1 - 3 \land CR), MC_1\}$.

To fulfil this condition, a logical function must be performed $(1 - 13 \land 1 - 3 \land CR)$, which corresponds to the voltage on the terminals, and the de-energised state of the relay at the same time $CR$, and check the de-energised state of the relay $PC_1$ according to safety requirements and place the token in the same position, the status of the graph is shown in Figure 7. Starting a transition will move the chip to the position $MC_1$, which corresponds to the excited state of the relay $PC_1$. De-energising the relay $PC_1$ occurs when the conditions for starting the transition are met according to its input function $I(t_2) = \{(CR \lor 1 - 3 \lor 1 - 13), MC_1\}$ and realised by performing a logical operation "OR", either $1 - 3$ or the relay winding must be de-energised $CR$, as well as relays $PC_1$ d.c. under current. As a result of the terminal transfer, the relay status graph $PC_1$ will reset to its original state.
\[ I(MC2) = \{t_1\}, \quad I(t_1) = (2 - 3 \land 2 - 13 \land MC2 \land CR), PC \] 

\[ I(t_2) = \{(PC \lor 2 - 3 \lor 2 - 13), MC2\}, PC \]

\[ O(t_2) = MC2 \land \neg PC \quad I(MC2) = \{t_2\} \]

The conditions can be realised by performing a logical operation “OR”, i.e. \( \neg MC \lor PC \) or \( \neg MC \lor \neg PC \), which should be reflected in the status of the graph.

\[ I(\neg MC) = \{t_1\}, \quad I(t_1) = (2 - 3 \land 1 - 3 \land MC2 \land CR), \neg PC \]

\[ I(t_2) = \{(PC \lor 2 - 3 \lor 1 - 3), PC\}, PC \]

\[ O(t_2) = MC1 \land \neg PC \quad I(MC1) = \{t_2\} \]

The “OR” operation results in the conditions being met, which, when started, will move the chip from the position input functions \( MC \land PC \), and \( PC \land \neg MC \) to the position output functions \( t_2 \).
Transition $t_1$ or $I(t_1) = \{(1 - 5) \land \overline{MC1}, CR\}$ according to the system of equations (4), i.e. $I(t_1) = \{(1 - 5) \land \overline{MC1}, CR\}$ and input functions $I(t_2) = \{MC1, CR\}$.

Transition $t_4$ or $I(t_4) = \{(PC \land MC1 \land MG), \overline{CR}\}$ according to the system of equations (4), i.e. $I(t_4) = \{(PC \land MC1 \land MG), \overline{CR}\}$ and input functions $I(t_2) = \{MC1, CR\}$.

The state of the graph in this situation is shown in Figure 11. Independent start of transitions $t_2$ and $t_3$ will reset the graph to its original state.

4 Conclusion
Fig. 2. Relay status graph PC1 at baseline

Fig. 3. Relay status graph PC2 at baseline

Fig. 4. Relay status graph MC at baseline

Fig. 5. Relay status graph CR at baseline

Fig. 6. Relay status graph PC1 if the conditions for moving the chip to the position MC2 are met

Fig. 7. Relay status graph PC2 if the conditions for moving the chip to the position MC2 are met
Fig. 8. Relay status graph MC if the conditions for moving the chip to the position PC are met

Fig. 9. Relay status graph CR if the first condition for moving the chip to the position CR is met

Fig. 10. Relay status graph CR if the second condition for moving the chip to the position CR is met
Fig. 11. Relay operation algorithm PC1

Fig. 12. Relay operation algorithm PC2
Fig. 13. Relay triggering algorithm MC

Fig. 14. Relay triggering algorithm CR

References

1. V.V. Sapozhnikov, A.B. Nikitin, Microprocessor-based electrical interlocking system MPC-MPK. Science and transport (Spb., Publishing house OOO "T-PRESSA", 2009)


3. A.B. Nikitin, Automation, communication, computer science 4, 4-7 (2010)


