ENGINEER

international scientific journal

ISSUE 2, 2025 Vol. 3

E-ISSN
3030-3893

ISSN
3060-5172

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A bridge between science and innovation

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

ENGINEER

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E-ISSN: 3030-3893

ISSN: 3060-5172

VOLUME 3, ISSUE 2

JUNE, 2025

engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL
VOLUME 3, ISSUE 2 JUNE, 2025

Founder of the international scientific journal “Engineer” – Tashkent State Transport University, 100167, Republic of Uzbekistan, Tashkent, Temiryo‘lchilar str., 1, office: 465, e-mail: publication@tstu.uz.

The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Tashkent State Transport University had the opportunity to publish the international scientific journal “Engineer” based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **E-ISSN: 3030-3893, ISSN: 3060-5172.** Articles in the journal are published in English language.

Study of the theoretical failure model of the NPM-69-M microelectronic block

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Abstract: The article addresses the question of studying the paired axis control model of a microelectronic block, obtaining the numerical value of the operational failure intensity (EIO) of a microelectronic block, studying the theoretical model of failures, obtaining the eio numerical values of a microelectronic block. One of the most dynamically developing industries in the modern world is mirkroprotssesor and microelectronic systems. Important when processing information resources and exchanging information between the device and users, these systems play an important role. The hardware supply structure of these systems is enriched by a new integrated circuit and equipment day by day, in exchange for the rapid development of semiconductor technology. These tools and systems are the main technical component of the activities of most small and medium-sized industrial enterprises, as well as large industrial sectors that use modern work organization solutions. The introduction of similar systems into practice in the railway industry, which is calculated from such large industries, does not remain without contributing to the development of the industry. In particular, the issue of replacing electromagnetic relays with microelectronic devices, which were commissioned in the 60s of the last century in most of the railway lines currently in use in our country in railway automation and telemechanics systems, is considered in this article. To address these issues, NPM-69-m studied and analyzed the failure rate of the block under investigation, as well as the rate of qisim failure, which is twice as high as similar indicators of other components of the NPM-69-m microelectron block.

Keywords: NPM-69-M microelectronic block, electrical/radio products (ERP), basic failure rate (BFR), mathematical model of the OFR

1. Introduction

Ensuring safe control of the train movement process is mainly entrusted to the automation and telemechanics devices of railway transportation. Until recently, the safety requirements for these systems have been met by the use of safe elements, in this case by the use of railway relays of the first reliability class installed in devices and assemblies directly related to the movement of trains. In the objects of railway automation and telemechanics not directly related to the movement of trains, and which are not subject to safety requirements are used electromagnetic relays of lower reliability class, such as code type KDR. Further use of electromagnetic relays in control systems is a very problematic solution because these devices have high material intensity, power consumption, as well as continuously increasing cost indicators.[1]

Train delays caused by malfunctions of signalling equipment are tangibly reflected in the form of economic losses. The main part of the equipment ensuring the safety of train traffic consists of devices and instruments whose service life has exceeded 50 years, this explains the short-term damages caused by the state of morally and technically obsolete equipment, it is especially reflected in the quality of the contact group of used relays. In this connection, the solution of innovative tasks on creation and implementation of microelectronic technologies and modules made on their basis in the existing automation systems of railroads, is an actual scientific task. The use of achievements of modern microelectronic technologies allows to provide more effective and safe control of the transportation process [2]. Reliable operation of such systems is possible in the presence of sufficient, reliable and timely information about the state of railway automation and telemechanics devices [3]. In this situation, great importance is given to the problems associated with the introduction of computer technologies, microcontrollers in devices and systems of railway automation and telemechanics, in order to replace by them traditional relay devices and systems. [8.9].

One of the methods of increasing the reliability and reliability of technical means related to optimal train control is the introduction of devices that do not contain mechanical switching, which are directly involved in the setting of train routes. Realization of the innovative project, directed on that in existing system of block route relay centralization, block of control of train and shunting routes (NPM-69), realized on relay, to replace on microelectronic with application of microcontroller and contactless switching devices, which are opto-relay, (NPM-69-M) functional possibilities of which, on control of routes, are completely identical to relay block NPM-69. Having previously developed and investigated the reliability model of the microelectronic device [10,11.12].

2. Research methodology

To achieve the set goal it is necessary to determine the reliability indicators of means of realization and algorithm of electric circuits operation when setting train and shunting routes, with the help of microprocessor unit of the set group.

The relevance of the study of the failure model of the microelectronic unit NPM-69-M, is determined by the need to replace the existing unit, made with the use of electromagnetic relays, and assess its operational failure rate (OFR).

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The purpose of the work is to study the fault model of the microelectronic block NPM-69-M, in order to obtain numerical values of OFR.

Objects of the study are theoretical models of OFR of means of realization of the microelectronic block, namely microcontroller, optorele, resistors, connecting elements and printed circuit board.

Scientific novelty, consists in determining the numerical value of OFR of the proposed microelectronic block NPM-69_M, assuming that it consists of separate groups of complex products, the total flow of failures, which is made up of independent flows of failures of component parts of ERP, the mathematical model for calculating the failure rate is [6].

$$\lambda_э = \sum_{j=1}^{m} \lambda_{бj} \times \prod_{i=1}^{n_j} K_{ij}$$

where $\lambda_{бj}$ – initial (baseline) failure rate of the j-th failure stream;

m – number of independent failure streams of the components of the microelectronic block;

K_{ij} – coefficient that takes into account the influence of the i-th factor in the j-th failure flow;

n_{ij}– number of factors considered in the j-th failure flow.

The proposed models for calculating the operational failure rate apply to the perpod of constant failure rate in time.

The value of the operational failure rate of a separate group of electro-radio products (ERP) is determined by a mathematical expression, which has the following form [7]

$$\lambda_э = \lambda_б \times \prod_{i=1}^{n} K_i$$

or

$$\lambda_э = \lambda_{б.с.г.} \times \prod_{i=1}^{n} K_i$$

In doing so $\lambda_б(\lambda_{б.с.г.})$ – basic failure rate (BFR) of ERP, revealed on the basis of the results of tests of radio products for reliable operation and durable time resource, the value of which is given in reference books;

K_i – the value of coefficients determining the change in EER depending on a variety of factors;

n – multiple factors.

The following groups of elements, namely microcircuits (PVG-612 optocouplers, microcontroller), resistors, connecting wires, through-holes, board) were used in the implementation of the microelectronic unit NPM-69-M. To determine the OFR of integrated circuits, the mathematical model is used

$$\lambda_{э.м.сх} = \lambda_{б.м.сх.} \times K_{с.т.} \times K_V \times K_{корп} \times K_p \times K_э \times K_{пр}$$

where $\lambda_{б.м.сх.}$ – basic intensity of microcircuit failure, with the following coefficients used:

$K_{с.т.}$ – justifies the complexity of integrated circuits (IC) and the temperature of its operation value of the coefficient reflects the complexity of the IC and ambient temperature, is taken depending on the configuration and temperature, the parameter under consideration is proportional to the complexity of the device, the analysis of Table 7, [3] showed that the more elements, the greater the value of this coefficient takes, assume that the microcontroller used STM type has the most complex device with a number of elements above 250 000.

Then $K_{ст} = 10.06$ for a temperature of 25ºC, since the device is operated indoors, it is therefore assumed that$K_{с.т.} = 1$ [3];

K_V – value of applied supply voltage for CMOS microcircuits, for devices with power supply up to +5V, it is taken equal to 1 [3];

$K_{корп}$– housing type of the used IC is assumed to be equal to1 [3];

K_p – mode index is necessary to determine the available EI according to the conditions of product application in the microelectronic unit, it is determined in the known tables of reference books, mode index, for a set of products is revealed by known analytical expressions $K_p = 1$. [8];

$K_э$ – operation coefficient reflects the level of rigidity of the object operation conditions, when the microelectronic unit is placed in the station room, the value of $K_э$=1 [4];

$K_{пр}$ – acceptance coefficient of the product, i.e. the rigidity of requirements for quality control and operation is taken into account, the unit under study can be attributed to products with acceptance ‘5’, so the value of $K_{пр} = 1$ [4].

In the considered device optocoupler microcircuits and microcontroller were used. Numerical values of operational failure rates of these devices are given in [5], therefore it is necessary to determine the number of these elements, for the device under consideration. In the microprocessor unit NPM-69-M one microcontroller is used, therefore $\lambda_{э.мк.} = 0{,}023 \bullet 10^{-6}\ 1/о$. The operating IO of the optocoupler [5] is assumed to be equal to

$\lambda_{эопт} = 0{,}0029 \bullet 10^{-6}, 1/о$, taking into account the number of optocouplers used,$m = 65$ we get $\lambda_{эопт} = 0{,}1885 \bullet 10^{-6}, 1/о$.

$\lambda_{э.} = \sum_{j=1}^{m} \lambda_{бj.} \bullet \prod_{i=1}^{n_i} K_i$, 1/о.,

The total EI of a microelectronic unit should be calculated according to the formula, where, in order to simplify its designation, we take as an index the variable k

$$\lambda_k = K_a \bullet \sum_{j=1}^{m} \sum_{i=1}^{n} \lambda_{эij},$$

where K_a– the degree of quality of hardware production;

$\lambda_{эij}$ – IE of the i-th type of products of the j-th group;

n– list of objects of the j-th group;

m – number of product groups.

Hardware manufacturing quality index K_a, takes into account the requirements for the preparation and adjustment of the technical process of production and the degree of its realisation, in the equipment and reflects the average probability difference in the IE produced according to the requirements, in the case of a microelectronic block, is taken to be equal to 1.

Hence, for the block НПМ-69-М

BIO can be represented as the sum of the base scores of the constituent elements.

$$\lambda_{б.k.} = \lambda_{б.мк.} + \lambda_{б.опт.} + \lambda_{б.рез.} + \lambda_{б.плама.} + \lambda_{б.соед.} \quad (1)$$

Here with $\lambda_{б.нпм}$ – BIO block NPM-69-M;

$\lambda_{б.мк.}$ – BIO microcontroller;

$\lambda_{б.рез.}$ – BIO resistors;

$\lambda_{б.опт.}$ – BIO optocouplers;

$\lambda_{б.плам.}$ –BIO board;

$\lambda_{б.соед.}$ – BIO compounds.

https://doi.org/10.56143/3030-3893-2025-2-48-51 A bridge between science and innovation

To calculate the OFR of the microelectronic unit NPM-69-M, we use a mathematical model, where in order to simplify its designation, we take as indices the variable$k$.

$$\lambda_{эk} = \lambda_{б.k} \bullet \prod_{i=1}^{n} K_i$$

In doing so.$\lambda_{б.k}$BIO of the microelectronic block NPM-69-M

$K_i -$ coefficients determining the change in EER depending on real factors;

$n -$ number of countable elements used in the block.

To calculate the OFR of the microcontroller block NPM-69-M, the mathematical model is used,

$$\lambda_{э.мк} = \lambda_{б.мк} \bullet \prod_{i=1}^{n} K_i \,, 1/ч$$

To calculate the OFR resistances, we will use the following model[3]

$$\lambda_{э.рез} = m \bullet (\lambda_{б.рез} \bullet \prod_{i=1}^{n} K_i)\,,\ \ 1/ч$$

where $\lambda_{б.рез.}$- БИО сопротивлений равна $0{,}048 \cdot 10^{-6}$, 1/о;

K_i- coefficients reflecting the peculiarities of resistor operation;

m - the number of resistors used in the microelectronic unit, in this case is equal to 79 pieces.

The following coefficients are used to calculate the IO resistors:

K_R - value of ohmic resistance, for permanent non-wire resistors in the range

R< 1 kOm, is taken equal to 1;

K_M- value of rated power for resistors with power less than 0.5 W is equal to 0.7;

K_S- ratio of the actual voltage to the maximum possible voltage according to the specifications, for the case of $U/U_{макс} \leq 0{,}8$, equal to 1;

$K_{сл}$- the number of elements (complexity) for resistor microcircuits, at n > 20, is assumed to be 1.3;

$K_{стаб}$- manufacturing accuracy (tolerance) of the resistor, in our case is equal to 1;

$K_{корп}$- type of resistor microcircuit housing, in this case equal to 1.

Substituting the numerical values we obtain$\lambda_{э.рез.} = 0{,}048 \times 10^{-6} \times 1 \times 0{,}7 \times 1 \times 1 \times 1 = 0{,}034 \times 10^{-6}, 1/о$

The OFR of the resistors used in the microelectronic unit NPM-69-M is equal to$\lambda_{э,рез.k} = 79 \times 0{,}034 \times 10^{-6} = 2{,}686 \times 10^{-6},\ 1/о$

To calculate the EIR of the connections during operation is calculated by the model:

$$\lambda_{э.соед} = K_э \bullet \sum_{i=1}^{n} N_i\, \lambda_{б.соед},$$

where $\lambda_{б.соед.}$ - basic value of IO of manual solderpng without twisting of microelectronic block NPM-69-M according to Table 1 [3] equal to $0{,}13 \cdot 10^{-8}$, 1/о;

N_i- number of connections of one type, for this block is assumed to be equal to 150;

n - number, types of connections in the device is equal to 1;

$K_э$ - stiffness index of operating conditions according to Table 2 [3] equal to 1.

Substituting the calculated values, we obtain the OFR of the compounds$\lambda_{э.соед} = 0{,}195 \bullet 10^{-6},\ 1/о$

To calculate the EI of the board, let's determine the EI of multilayer boards with metallised holes during operation, which is calculated by the formula below:

$$\lambda_{э.платы} = \lambda_{б.платы} \bullet K_{э.платы} \bullet [N_{i.платы} \bullet K_{с.платы} + N_{2.платы} \bullet (K_{с.платы} + 13)],$$

In doing so. $\lambda_{б.платы}$- BIO depending on the connection technology. According to Table 2 for printed wiring is assumed to be equal to $0{,}0017 \times 10^{-8}$, 1/о;

$K_{э.платы}$- the coefficient of rigidity of fee application conditions is assumed to be equal to 1;

$N_{i.платы}$- number of through holes soldered by the wave, in this case it is assumed to be 0;

$N_{2.платы}$- number of through holes soldered by hand solderpng, based on visual inspection of the board, we take 120;

$K_{с.платы}$- coefficient depending on the number of layers in the board, with the number of layers equal to 2, $K_{с.платы}$=1 Substituting the obtained values, we obtain the OFR of the board with metallised through holes at operation

$$\lambda_{э.платы} = 238 \bullet 10^{-6},\quad 1/о$$

To obtain the OFR of the whole microelectronic unit NPM-69-M, it is necessary to sum up the OFR of all components, then we obtain

$$\lambda_{э.k.} = 241{,}1 \bullet 10^{-6}, 1/о$$

The main contribution determining the value of the OFR of the investigated NPM-69-M block is the OFR of the board under consideration, which is two orders of magnitude higher than similar indicators of other components of the NPM-69-M microelectronic block.

3. Conclusion

As a result of development and research of the mathematical model of reliability of the microelectronic control unit for shunting and train routes NPM-69-M, the indicators of operational failure rate of the constituent elements of the unit are obtained and the operational failure rate of the whole unit is calculated. As a basis for calculations the basic failure rate is taken in accordance with the data given in 'Reference book. Reliability of Electrical and Radio Produc.

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