ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2010. No. 1(97)
ELEKTRONIKA IR ELEKTROTECHNIKA

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ELEKTRONIKA

Ensuring Efficiency of Electronic Devices

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Introduction

The article is aimed at analyzing electronic devices. In the intervals between periodic controls, inspection of serviceability of devices with the help of the built–in test equipment is carried out. At device design, production and exploitation stages, actions directed at ensuring their reliability and efficient operation are projected [1].

The article deals with the method of ensuring efficiency of devices. Requirements related to device efficiency index are analyzed. Efficiency index is considered to depend on simple reliability indexes: mean time between failures and mean time of restoration. Methods of ensuring projected requirements related to the given simple reliability index are offered.

Electronic device efficiency index requirements

It shall be considered that during an interval between periodic device control, N serviceability inspections with periodicity T is projected. The effect of device operation is possible in case the device is serviceable and used according to its function. In this case, device operation efficiency can be calculated in this way [2]:

$$W = \sum_{j \in E} W_j P_j , \tag{1}$$

where E – set of possible device states; P_j – stationary probability of managing the device in j state; W_j – efficiency of operating a device in j state. W_j shall be defined as follows

$$W_j = \begin{cases} W_1,\ j \in E_1, \\ 0,\ j \in E \setminus E_1, \end{cases} \tag{2}$$

where E_1 – the variety of states in which device is serviceable and used according to its function. Given (2), the formula is as follows:

$$W = \sum_{j \in E_1} W_1 P_j = W_1 \sum_{j \in E_1} P_j . \tag{3}$$

Parameter W depends [2] on simple reliability indexes: mean time between failures T_0 and mean time of restoration T_t. Values W are influenced by the conditions of built – in test equipment, sizes N and T, durations of control and serviceability inspections. Size T_t depends on design features of the device, characteristics of system of repairs and provision of spare components. At device efficiency requirement design stage, W_{DS} can be set as follows:

$$W_{DS} \geq W_* , \tag{4}$$

where W_* – preset value of index W. Out of possible variants of realization of the device, system of its service and repair, the one that provides the smallest index of total expenses shall be chosen.

Let's consider that parameter W_* is known and, in view of (4), requirements to index T_0 and T_t are established. We shall stop on the development of methods of fulfilling requirements to indexes T_0 and T_t.

Fulfilling requirements of mean time between failures of electronic devices

During device operation, industrial failures are possible. Therefore, while designing, it is necessary to provide value of time between failures T_{0DS}:

$$T_{0DS} > T_{0*} , \tag{5}$$

where T_{0*} – preset value of time between failures T_0.

In case of the Poisson flow of failures of the electronic device it is possible to calculate:

$$\Lambda_{DS} \leq (1 - \gamma_P) T_{0*}^{-1} , \tag{6}$$

where Λ_{DS} – failure rate of the device which should be identified at design stage; γ_P – factor including presence of industrial failures during operation.

When choosing a variant of realization of the device performing (5) and (6) functions, it is necessary to establish reliability requirements of its components (blocks, units and so forth). These actions are performed by using the block diagram of the device.

The method of analogues can be applied for the specified purposes. But in this case, conditions on conformity of the designed device and an analogue being operated should be met. In case given conditions are not met or at the absence of an analogue, the following is recommended. Categories of components which should be applied for the device are defined. Categories of components of failure rate are established. Failure rate of separate components λ_{Si} and failure rate of the device Λ_{S*} are defined. Value of failure rate of i component that should be defined during design stage, shall be defined by the expression

$$\lambda_{SiDS} = \lambda_{Si}\Lambda_{S*}^{-1}\Lambda_{DS} . \quad (7)$$

Value λ_{SiDS} is found by design decisions, selection of components, work modes and use of reserve.

It is also necessary to consider an opportunity of exception of some failures by using certain circuit and software. This occurs in cases when the output of separate parameters for the established limits without infringement of process of device operation according to its functions is compensated. The failure rate which in this case should be divided between components equals to:

$$\Lambda_{DS1} = \Lambda_{DS}(1+\beta\pi_*) , \quad (8)$$

where β – the factor describing a part of failures, subjected to exception from a flow; π_* – probability of exception of failures from a flow.

Let's consider that elimination of consequences of given failures is carried out following the results of the inspection by the built–in test equipment in the intervals of time T. During T, a flow of considered failure shall be considered the Poisson flow. Then, considering [3], the following shall be stated:

$$\pi_* = P(A_2/A_1) = \sum_i P(H_i/A_1)P(A_2/H_iA_1), \quad (9)$$

where A_1 – the event in which duration of work of the device without considering a kind of failure is less than T; A_2 – the event in which elimination of failure consequences has taken place; H_i – hypotheses, one of which can be accompanied by event A_1. Probability π_* at m_0 independent parameters of a controllable part of the device shall be calculated as follows:

$$\pi_* = \sum_{i=1}^{m_0}\frac{\Lambda_{ki}}{\Lambda_{S*}}(1-P_{ni})\pi_{*1i} , \quad (10)$$

where Λ_{ki} – failure rate of a part of the device forming i parameter of a controllable part of the device; P_{ni} – probability of undiscovered failure during control of i parameter; π_{*1i} – probability of elimination of consequences of the failure related to finding i parameter of the device outside established limits.

We shall consider a case of dependent parameters of a controllable part of the device. Probability π_* shall be calculated as follows:

$$\pi_* = \sum_{h=1}^{m_0}\frac{\Lambda_{kh}}{\Lambda_{S*}}(1-P_{nh})\pi_{*1h} + \sum_{\vartheta=1}^{M_1}\frac{\Lambda_{k1\vartheta}}{\Lambda_{S*}}\prod_{j\in A_\vartheta}(1-P_{nj})\pi_{*1\vartheta} \quad (11)$$

where Λ_{ki} – failure rate of a part of the device forming one h parameter ($h=\overline{1,m_0}$) of a controllable part of the device; $\Lambda_{ki\vartheta}$ – failure rate of a part of the device forming some of the parameters of their ϑ entirety ($\vartheta=\overline{1,M_1}$) of a controllable part of the device; A_ϑ – set of numbers of ϑ entirety of parameters of a controllable part of the device. Moreover, the equation should be calculated:

$$\Lambda_k = \sum_{h=1}^{m_0}\Lambda_{kh} + \sum_{\vartheta=1}^{M_1}\Lambda_{k1\vartheta} , \quad (12)$$

where Λ_k – failure rate of a controllable part of the device.

During the analysis of multifunctional devices, it is necessary to consider an opportunity of switching–off some components for a certain period of time. Considered components do not take part in forming the function used at present to time. The device shall be considered as operating in k_F modes. Operating time in l mode equals to d_l, with $\sum_{l=1}^{k_F} d_l = 1$. During operation in l mode, the failure rate amounts to Λ_l ($l=\overline{1,k_F}$). Possible states of the device are as follows: X_l – state of serviceability and the device is operated in l mode (subset D_1), X_0 – restoration state. The description of functioning of the device shall be executed by means of the semi – Markov stochastic process. Then, the mean time between failures of the device can define in the following way:

$$T_0 = \sum_{l=1}^{k_F}\pi_l a_l\left(\sum_{l=1}^{k_F}\pi_l p_{l0}\right)^{-1} , \quad (13)$$

where p_{l0} – probability of transition of Markov circuits from state X_l to X_0; a_l – average unconditional time of process in state X_l; π_l – stationary probability of Markov circuits in a state X_l. Then, in case of any l ($l=\overline{1,k_F}$), the following is correct:

$$\pi_l a_l = d_l\sum_{l=1}^{k_F}\pi_l a_l . \quad (14)$$

In case, for example, π_1 and a_1 are known values:

$$\sum_{l=1}^{k_F} \pi_l a_l = \frac{\pi_1 a_1}{d_1}, \quad (15)$$

$$\pi_l a_l = \pi_1 a_1 \frac{d_l}{d_1}, \; (l = \overline{1, k_F}). \quad (16)$$

Let's move to the case, in which durations of operation in X_l state prior to transition to other states of a subset D_1, are distributed under exponential law by using parameters, the total value of which is equal to Z_l. Then, it is possible state that:

$$p_{l0} = \frac{\Lambda_l}{\Lambda_1 + Z_l}. \quad (17)$$

Considering condition (16) and the fact that $a_l = (\Lambda_l + Z_l)^{-1}$ p_{l0} shall be counted in the following way:

$$p_{l0} = d_l \Lambda_l \frac{\pi_1 a_1}{\pi_l d_1}. \quad (18)$$

Then, after transformations for failure rate of the multifunctional device, the following is received:

$$\Lambda = \sum_{l=1}^{k_F} d_l \Lambda_l. \quad (19)$$

Ensuring electronic device restoration mean time requirements

General mean of restoration of the device, considering condition [4], shall define by the following expression:

$$T_t = T_{tr} + T_{lk} + T_{pr} + T_{op}, \quad (20)$$

where T_{tr} – mean time of delivery of the device from operation site to the repair organization and back; T_{lk} – mean time of staying queue of restoration; T_{pr} – mean time of waiting in queue of a serviceable component; T_{op} – mean operating time of restoration.

Value T_{tr} depends on the system of device maintenance service: a repair organization can be situated on the operation site or far from it. Value T_{lk} depends on characteristics of devices. It also depends on features of queueing system that features performance of the repair organization.

Time T_{pr} depends on presence or absence of stocks of components and on their characteristics. Operating time of restoration T_{op} consists of two parts. The first part is the time of identification of failure. The second part is the time of elimination of consequences of failure.

Let's make a condition that during the design stage, the following fact must take place:

$$T_{tDS} \le T_{t*}, \quad (21)$$

where T_{t*} – preset value of index T_t. The value T_{tDS} can be defined by (20), component T_{tr} according to the developed recommendations, component T_{lk} according to [4, 5]. Value T_{op} is considered to be known. Then, requirements to T_{pr} shall be formulated in this way:

$$T_{pr} \le T_{t*} - T_{t1}, \quad (22)$$

$$T_{t1} = T_{tr} + T_{lk} + T_{op}, \quad (23)$$

Further, we shall stop on ensuring requirements for component T_{pr}. Therefore for the certain way of restoration find size T_{pr} [4]. At performance (22) necessity for stocks the component is absent. Otherwise, it is necessary to perform works on designing supply system of components [6¸ 8]. Definition of quantitative structure of stocks is based on application of direct and return task of optimization [6, 7]. The direct task of optimization simultaneously provides maintenance (22) and conditions $F_* \to \min$ (F_* – cost of stocks of components). When choosing rational structure of supply system of components, a set of characteristics, including cost indexes [8], is to be considered.

It should be noted during the device design stage, calculations of stocks of components are done based upon value λ. The given value is an estimation of mean value λ_{av} of failure rate of components of considered type. Then, at confidential probability α, the bottom limit of failure rate shall be λ_B, the top limit – λ_T.

Further, the question of specifying values of failures rates of components shall be considered by using results of operation in structure of the device. Let's consider that operation of devices can be launched at various times, unserviceable components are replaced. Supervisions cease when the total operating time of all supervised components has reached t_Σ. Mean value of failure rate according to the results of exploitation shall be defined by the formula:

$$\lambda_S = m t_\Sigma^{-1}, \quad (24)$$

where m – quantity of failures of components for t_Σ. Equation (24) is correct under exponential law of distribution of operating time of components. The bottom and top limits of average value of failure rate of components at confidential probability α, considering [3], are equal to:

$$\lambda_{SB} = \frac{\lambda_S}{2m} \chi^2_{1-\alpha}(2m), \quad (25)$$

$$\lambda_{ST} = \frac{\lambda_S}{2m} \chi^2_{\alpha}(2(m+1)), \quad (26)$$

where $\chi^2_{1-\alpha}(2m)$ – $100(1-\alpha)$ percentage point χ^2 of distribution with $2m$ degrees of freedom; $\chi^2_{\alpha}(2(m+1))$ – 100α percentage point χ^2 of distribution with $2(m+1)$ degrees of freedom.

To implement considered specification, an experiment must be planned. This includes defining its volume t_Σ which sets the limit of the relative mistake of definition λ_{av}^{-1} not exceeding value δ. Experiment is carried on until m_* of failures of components of considered type is received. Considering given δ and confidential probability α, taking into account [3], size m_*, shall be defined by the following equation:

$$\frac{2m_*}{\chi^2_{1-\alpha}(2m_*)} = 1+\delta . \qquad (27)$$

Value t_Σ at which with confidential probability β there will be m_* failures a component, with the account [3], is equal:

$$t_\Sigma = \frac{\chi^2_\beta(2m_*)}{2\lambda_{ev}}, \qquad (28)$$

where λ_{ev} – expected average value of failure rate of components, for which value $\lambda_{ev} = \lambda$ can be used. The decision on conformity of the considered two kinds of failures rate of components is accepted on the basis of comparison of λ_S, λ_{SB}, λ_{ST}, with values λ, λ_B, λ_T.

Conclusions

1. The method of ensuring requirements of efficiency of devices that are controlled by using built–in test equipment is considered. Efficiency index requirements are analyzed.
2. The structure efficiency index is reviewed. It is shown that efficiency index depends on mean time between failures and mean time of restoration.
3. The method of ensuring requirements of time between failures provides distribution of requirements on serviceability between components of the device. Industrial failure, influence of an opportunity of exception of some failures from the general flow is taken into account. The method is applicable for multifunctional devices.
4. The method of ensuring requirements to mean time of restoration considers estimating separate components of the given index. The expediency of development of complete sets of stocks of components is considered. The question of necessity of specifying stocks of components according to the results of exploitation of devices is analyzed.

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Received 2009 09 24

V. Stupak. Ensuring Efficiency of Electronic Devices // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 1(97). – P. 15–18.

Electronic devices which that are inspected by using built–in test equipment are considered. The method of ensuring requirements of efficiency index of devices is analyzed. It is shown that the index of efficiency depends on simple index of reliability: mean time between failures and mean time of restoration. The method of ensuring requirements of time between failures provides distribution of serviceability requirements between parts of the device. The opportunities of exception of some failures from the general flow, multifunctional nature of device are taken into account. The method of ensuring requirements of mean time of restoration provides an estimation of separate components of the given index. The expediency of development of complete sets of stocks of components is considered. The question of necessity of specifying stocks of components according to the results of exploitation of devices is analyzed. Bibl. 8 (in English; summaries in English, Russian and Lithuanian).

В. Ступак. Обеспечение эффективности электронных устройств // Электроника и электротехника. – Каунас: Технология, 2010. – №. 1(97). – С. 15–18.

Рассматриваются электронные устройства, контролируемые с помощью встроенных средств контроля. Анализируется метод обеспечения требований к показателю эффективности устройств. Показано, что показатель эффективности зависит от единичных показателей надёжности: наработки на отказ и среднего времени восстановления работоспособного состояния. Метод обеспечения требований к наработке на отказ предусматривает распределение требований по безотказности между частями устройства. Учитываются возможность исключения ряда отказов из общего потока и многофункциональность устройств. Метод обеспечению требований к среднему времени восстановления работоспособного состояния предусматривает оценку отдельных составляющих данного показателя. Анализируется вопрос целесообразности разработки комплектов запасов компонент. Рассматривается необходимость уточнения запасов компонент по результатам эксплуатации устройств. Библ. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

V. Stupak. Elektroninių įtaisų efektyvumo užtikrinimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 1(97). – P. 15–18.

Nagrinėjami elektroniniai įtaisai, kurių darbingumo kontrolė atliekama vidiniais kontrolės įrenginiais. Analizuojamas efektyvumo rodikliui keliamus reikalavimų užtikrinimo metodas. Parodyta, kad efektyvumo rodiklio vertėms įtakos turi šie du patikimumo rodikliai: vidutinė darbo trukmė tarp gretimų gedimų ir vidutinė taisymo trukmė. Reikalavimų pirmajam rodikliui užtikrinimo metodas numato negendamumo normų paskirstymą sudėtinėms įtaiso dalims. Įvertinama galimybė pašalinti iš bendro srauto daugelį gedimų, nagrinėjami daugiafunkciai įtaisai. Reikalavimų antrajam rodikliui užtikrinimo metodas numato sudėtinių šio rodiklio dalių vertinimą. Analizuojamas komponentų komplektų projektavimo tikslingumo klausimas. Nagrinėjama būtinybė komponentų atsargas patikslinti pagal įtaiso eksploatacijos rezultatus. Bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).