ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2011. No. 5(111)
ELEKTRONIKA IR ELEKTROTECHNIKA

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ELEKTRONIKA

Accuracy of Electronic Devices Efficiency Evaluation

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Introduction

In the paper, electronic devices are considered. In an interval between periodic inspections of devices, N serviceability controls with periodicity T is stipulated. Serviceability controls of devices are carried out by means of the built-in test equipment. The degree of rationality of the accepted decisions at design and manufacture stages of devices can be estimated by means of an index of efficiency of devices [1–4].

In the article, accuracy of evaluation of efficiency index of devices is analyzed. Accuracy is characterized by an error caused by likelihood properties of parameters, influencing an index of efficiency. The error is defined by means of computing experiment based on a method of statistical modeling.

Factors influencing efficiency index of electronic devices

The major factors influencing efficiency of use of electronic devices can be considered the following [1–4]: technical features of the electronic device; features of maintenance system of the device; failure flow of the device; kind of the index describing efficiency of the device; the mathematical model used to describe exploitation process of the device.

As an efficiency index of the electronic device, size W shall be considered [5]

$$W = f\left(E, E_1, W_j, K\right), \tag{1}$$

where E – set of states of the device; E_1 – subset of states in which device is serviceable and is used as designed; W_j – efficiency of use of the device in j state, $\left(j \in E\right)$; K – utilization factor of the device.

Further, by analogy with [6], we shall admit that there is direct proportional dependence between index W and K. Index W and K shall be considered as calculated according to [6].

Let's consider a case of the Poisson flow of failures. Failures of devices, depending on character of their display, shall be subdivided into two kinds. Failures of the first kind are identified directly according to external attributes. Failures of the second kind are found out at carrying out control of serviceability state and inspections.

Further, we shall enter following designations for the parameters influencing values of index K: æ – index describing share of failures of the second kind; α – probability of detection of failures of the second kind at the control of serviceability state; Λ – failure rate of the device; T_0 – time between failures of the device, $T_0 = 1/\Lambda$; τ_p – mean time of inspection, $\tau_{p*} = \tau_p / T_0$; T_t – restoration mean time of the device, $T_{t*} = T_t / T_0$; τ_k – mean time of control of serviceability state, $\tau_{k*} = \tau_k / T_0$.

Sizes N_r and T_r are rational values N and T, and are defined by expression

$$W \to \max_{N,T}. \tag{2}$$

Accuracy of evaluation of efficiency index of electronic devices

Accuracy shall be expressed by an error of evaluation of efficiency index of electronic devices. Let's consider an error caused by likelihood properties of parameters, influencing on an index of efficiency. Considering a kind of dependence between W and K, it is enough to define an error of evaluation of utilization factor K. The given error shall be characterized by size d_k [7]

$$d_k = 3\sigma_k , \tag{3}$$

where σ_k – sample mean square deviation of index K .

To solve the given task, the computing experiment based on a method of statistical modeling shall be used [8]. During computing experiment, we shall determine sizes $\overline{K}$, σ_k , V_k and ε_0 . Values $\overline{K}$, σ_k , V_k and ε_0 are resulted in Table 1 and calculated for various æ ; α ; τ_{p*} ; T_{t*} ; τ_{k*} ; N_r ; T_r .

Size $\overline{K}$ represents evaluation for a mean of utilization factor in the form of a sample mean. Sizes σ_k and V_k are, respectively, estimations for mean square deviations and factor of variation of a mean of index K . Size ε_0 characterizes confidential interval of 99 percent for a mean of index K .

Table 1. Dependence $\overline{K}$, σ_k , V_k and ε_0 on various æ ; α ; τ_{p*} ; T_{t*} ; τ_{k*} ; N_r ; T_r .

Values æ , α , τ_{p*} , T_{t*} , τ_{k*} , N_r , T_r/T_o				Values $\overline{K}$, σ_k , V_k , ε_0			
æ , α , τ_{p*} , T_{t*}	τ_{k*}	N_r	T_r/T_o	$\overline{K}$	$\sigma_k \cdot 10^2$	V_k ,%	$\varepsilon_0 \cdot 10$,%
æ = 0.1 $\alpha = 0.2$ $\tau_{p*} = 0.001$ $T_{t*} = 0.01$	0.0003	1	0.07	0.9714	0.3172	0.33	0.27
	0.0002	2	0.05	0.9723	0.3153	0.32	0.26
	0.0001	1327	0.02	0.9752	0.3193	0.33	0.27
æ = 0.1 $\alpha = 0.2$ $\tau_{p*} = 0.001$ $T_{t*} = 0.02$	0.0003	1	0.07	0.9623	0.5570	0.58	0.47
	0.0002	2	0.05	0.9630	0.5641	0.59	0.48
	0.0001	1327	0.02	0.9658	0.5660	0.59	0.48
æ = 0.2 $\alpha = 0.2$ $\tau_{p*} = 0.001$ $T_{t*} = 0.01$	0.0003	1	0.05	0.9638	0.3459	0.36	0.29
	0.0002	2	0.04	0.9650	0.3478	0.36	0.29
	0.0001	1868	0.01	0.9699	0.3213	0.33	0.27
æ = 0.2 $\alpha = 0.2$ $\tau_{p*} = 0.001$ $T_{t*} = 0.02$	0.0003	1	0.05	0.9546	0.5649	0.59	0.48
	0.0002	2	0.04	0.9559	0.5635	0.59	0.48
	0.0001	1868	0.01	0.9607	0.5754	0.60	0.49
æ = 0.1 $\alpha = 0.4$ $\tau_{p*} = 0.001$ $T_{t*} = 0.01$	0.0006	0	0.11	0.9707	0.3419	0.35	0.29
	0.0004	1	0.08	0.9715	0.3205	0.33	0.27
	0.0002	653	0.03	0.9758	0.3016	0.31	0.25
æ = 0.1 $\alpha = 0.4$ $\tau_{p*} = 0.001$ $T_{t*} = 0.02$	0.0006	0	0.11	0.9611	0.5732	0.60	0.49
	0.0004	1	0.08	0.9619	0.5611	0.58	0.48
	0.0002	653	0.03	0.9666	0.5645	0.58	0.48
æ = 0.1 $\alpha = 0.2$ $\tau_{p*} = 0.002$ $T_{t*} = 0.01$	0.0006	1	0.10	0.9638	0.3640	0.38	0.31
	0.0004	2	0.08	0.9650	0.3455	0.39	0.29
	0.0002	961	0.02	0.9696	0.3322	0.34	0.28
æ = 0.1 $\alpha = 0.2$ $\tau_{p*} = 0.002$ $T_{t*} = 0.02$	0.0006	1	0.10	0.9549	0.5706	0.60	0.49
	0.0004	2	0.08	0.9556	0.5643	0.59	0.48
	0.0002	961	0.02	0.9605	0.5567	0.58	0.47

In Fig. 1a – 1f, histograms of frequencies p_i of utilization factor K, received during experiment, are presented. On abscissa axis, intervals of grouping of index K are defined.

Parameters, influencing utilization factor, are presented by random variables distributed under the rectangular law in an interval I

$$I = \left(Z(1-\delta), Z(1+\delta)\right), \tag{4}$$

where Z – mean of the considered parameter; δ – dimensionless factor describing possible changes of parameter values within certain limits.

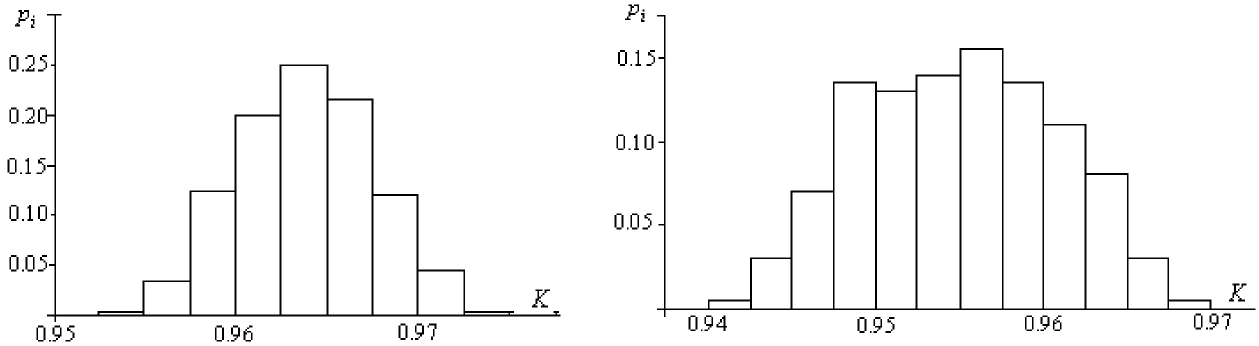
Values æ ; α ; τ_{p*}; T_{t*}; τ_{k*} and T_r are used as corresponding means of parameters Z . Values of factor δ accepted during experiment for considered parameters are $\delta = 0.2$, for τ_{p*} – $\delta = 0.3$, and for T_{t*} – $\delta = 0.5$.

On the basis of data of experiment, sizes $\overline{K}$, σ_k and V_k are defined as follows:

$$\overline{K} = \frac{1}{n}\sum_{i=1}^{n} K_i, \tag{5}$$

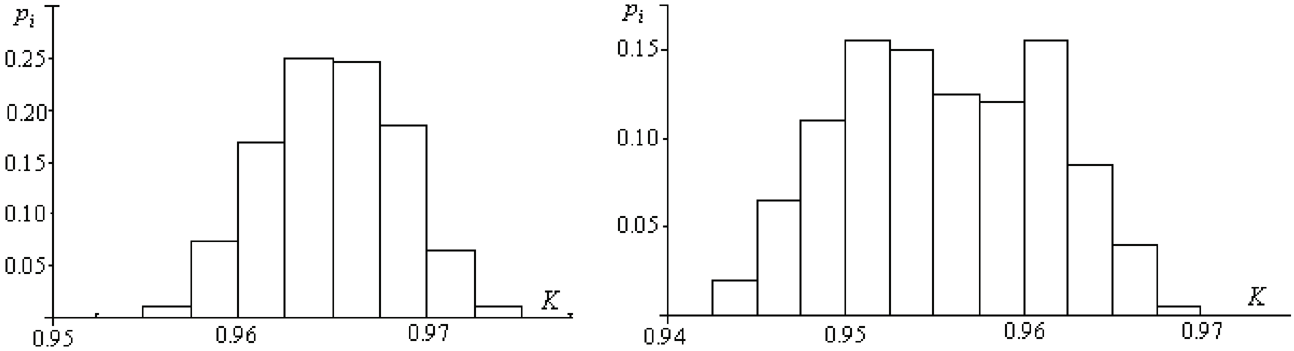
$$\sigma_k = \sqrt{\left(\frac{1}{n}\sum_{i=1}^{n} K_i^2 - \overline{K^2}\right)\frac{n}{n-1}}\,, \tag{6}$$

$$V_k = \sigma_k \big/ \overline{K}\,. \tag{7}$$



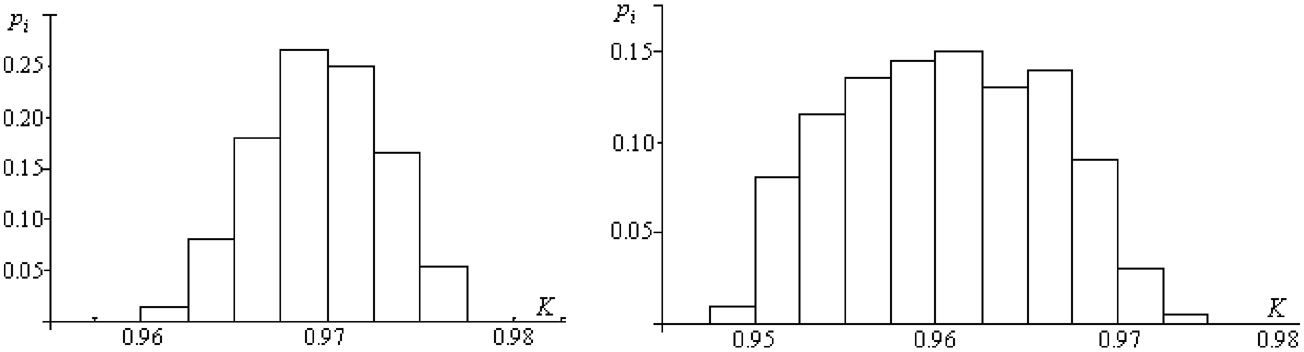
a) $\tau_{k*} = 0.0006;\ T_{t*} = 0.01;\ N_r = 1;\ T_r / T_0 = 0.1$

b) $\tau_{k*} = 0.0006;\ T_{t*} = 0.02;\ N_r = 1;\ T_r / T_0 = 0.1$



c) $\tau_{k*} = 0.0004;\ T_{t*} = 0.01;\ N_r = 2;\ T_r / T_0 = 0.08$

d) $\tau_{k*} = 0.0004;\ T_{t*} = 0.02;\ N_r = 2;\ T_r / T_0 = 0.08$



e) $\tau_{k*} = 0.0002;\ T_{t*} = 0.01;\ N_r = 961;\ T_r / T_0 = 0.02$

f) $\tau_{k*} = 0.0002;\ T_{t*} = 0.02;\ N_r = 961;\ T_r / T_0 = 0.02$

Fig. 1. Histograms of frequencies p_i of utilization factor K for sample $n = 1000$ and various τ_{k*} ; T_{t*} ; N_r and T_r at æ $= 0.1$; $\alpha = 0.2$; $\tau_{p*} = 0.002$.

where K_i $-i$ value of utilization factor by results of statistical modeling, $(i=\overline{1,n})$.

Let's consider that during computing experiment $n=1000$ realizations are received. In relation to this, law of distribution $\overline{K}$ can be considered as close to normal [9]. Then, confidential interval J 99 percent for a mean of utilization factor is the following:

$$J=\left(\overline{K}-\varepsilon_*;\overline{K}+\varepsilon_*\right), \tag{8}$$

$$\varepsilon_*=2.576\cdot\sigma_k\big/\sqrt{n}\,. \tag{9}$$

While ε_0 is equal to

$$\varepsilon_0=\varepsilon_*\cdot 100\%\big/\overline{K}\,. \tag{10}$$

Data of computing experiment show that half of width of confidential intervals 99 percent for an index of efficiency is $\varepsilon_0 \le 0.05\%$ (of size of a sample mean). Values of factor of variation are $V_k \le 0.6\%$, and the error of evaluation of an index of efficiency is $d_k \le 1.8\%$ (of size of a sample mean).

Conclusions

1. In the paper, electronic devices are analyzed. Two kinds of failures of devices are considered depending on character of their display.
2. Devices are exposed to inspection and periodic serviceability controls. Control of serviceability state is carried out by means of the built-in test equipment.
3. The method of definition of accuracy of evaluation of efficiency index of devices is offered. Accuracy is characterized by an error caused by likelihood properties of parameters, influencing an index of efficiency.
4. Error is defined by means of the computing experiment based on a method of statistical modeling. During experiment, 1000 realizations are received. Parameters influencing an index of efficiency are presented by random variables distributed under the rectangular law.
5. Statistical modeling (Table 1 and Fig. 1a - 1f) covers a range of actually possible values of parameters influencing utilization factor and efficiency of the device.
6. Data of computing experiment show that half of width of confidential intervals 99 percent for an index of efficiency is $\varepsilon_0 \le 0.05\%$ (of size of a sample mean). Error of evaluation of a parameter of efficiency is $d_k \le 1.8\%$ (of size of a sample mean).

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Received 2011 04 05

D. Eidukas, V. Stupak. Accuracy of Electronic Devices Efficiency Evaluation // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 5(111). – P. 51–54.

Electronic devices are considered. In an interval between inspections periodic controls of serviceability are stipulated. The method of definition of accuracy of evaluation of efficiency index of devices is offered. Accuracy is characterized by an error caused by likelihood properties of parameters, influencing an index of efficiency. Error is defined by means of the computing experiment based on a method of statistical modeling. During experiment, 1000 realizations are received. Parameters influencing an index of efficiency are presented by random variables distributed under the rectangular law. Data of computing experiment show that half of width of confidential intervals 99 percent for an index of efficiency does not exceed 0.05 % (of size of a sample mean). Values of factor of variation do not exceed 0.60 %, and the error of evaluation of efficiency index does not exceed 1.80 % (of size of a sample mean). Ill. 1, bibl. 9, tabl. 1 (in English; abstracts in English and Lithuanian).

D. Eidukas, V. Stupak. Elektroninių įtaisų efektyvumo vertinimo tikslumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 5(111). – P. 51–54.

Nagrinėjami elektroniniai įtaisai. Laiko intervale tarp patikrinimų periodiškai atliekama darbingumo kontrolė. Nustatomas elektroninių įtaisų efektyvumo vertinimo tikslumas. Tikslumą apibūdina paklaida, atsirandanti dėl parametrų, turinčių įtakos efektyvumo rodiklio vertėms, tikimybinių savybių. Paklaida nustatoma atliekant skaičiavimo eksperimentą, kuris remiasi statistinio modeliavimo metodu. Eksperimento metu gauta 1000 variantų. Parametrai, turintys įtakos efektyvumo vertėms, analizuojami kaip tolygieji atsitiktiniai dydžiai. Eksperimento rezultatai rodo, kad efektyvumo rodiklio matematinės vilties pusė 99 procentinio pasikliautinojo intervalo neviršija 0,05 % empirinio vidurkio vertės. Variacijos koeficientas neviršija 0,60 %, o efektyvumo vertinimo paklaida – 1,80 % empirinio vidurkio vertės. Il. 1, bibl. 9, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).