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Research of Electronic Information Systems

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Introduction

The main objective of this paper is to present the subjects of quality, efficiency and reliability of electronic devices (ED), electronic systems (ES) and electronic information systems (EIS), which are analyzed by paper coauthors in their works [1].

Structure of EIS quality will be presented in the paper. Conceptions of quality, value and efficiency, which describe the EIS, will be given. Efficiency is the best illustration of EIS features; therefore, detailed structure of the general efficiency theory will be presented. Review of parameters that affect efficiency will be made. Efficiency often is identified with probability of task's accomplishment, and as the main element used in EIS structure is digital electronic device (DED), subject of DED reliability will be widely presented in the paper. As illustration, trends of research of efficiency (reliability) dynamics and persistence [2] will be shown.

Structure of EIS quality theory

When seeking EIS quality, it is necessary to understand the concept of the quality; how to measure (evaluate); analyze; synthesize; support; change-manage. Therefore theory of the quality consists of the following sections (Fig. 1): "object class allocation (1)", "quality conception (2)", "qualimetry (3)", "quality analysis (4)", "quality synthesis (5)" and "quality dynamics (6)". When evaluating EIS features, this theory has to emphasize: "class of EIS (7)", "analysis of their values (8)", "economic qualimetry (9)", "systemic analysis (10)", "systemic synthesis (11)" and "systemic dynamics (12)".

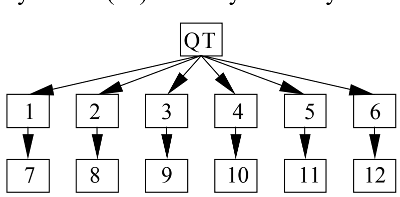

Fig. 1. Structure of theory of EIS quality

The "Triangle of Quality", that consist of the main EIS features (from users perspective) is shown in Fig. 2 [1].

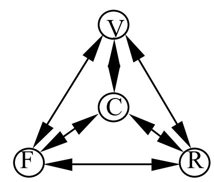

Fig. 2. Partial graph of functional, reliability and cost features (V – value, C – cost, F – functionality, R – reliability)

That was the reason why so many EIS analysis and synthesis methods (Fig. 3) were created [3].

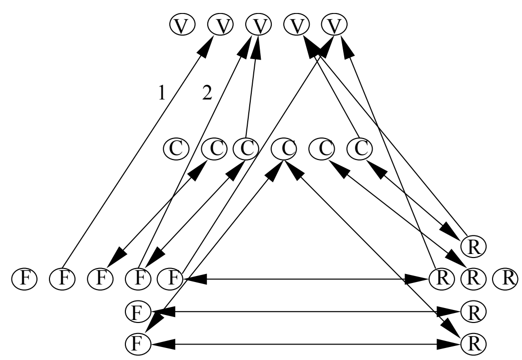

Fig. 3. Systemic analysis (SA) structure of feature groups (1 – primary; 2 – secondary SA)

Directions of the primary systemic analysis – researches of: function and cost, function and value, function and reliability. Directions of the secondary systemic analysis – researches of: reliability, cost and value; reliability of functions and cost. For particular EIS value, it is possible to create another set of features. Variation of interdependent objects, their features, processes and indicator values is called systemic dynamics. This research direction analyses relationship between objects and its dynamics, and is trying to find rational path in time axis.

Quality – Value – Efficiency

EIS quality is described as the level of befit, considering the purpose. "Total quality control" (TOC) methodology is formed, when connecting EIS quantity, quality and cost to one managed object. Practically, it is a rudiment of total quality methodology. The widest and most perspective is methodology of *total EIS quality*. Referring the methodology, another quality theories, quality management systems, quality standardization and other methodologies should be made. But at this moment the methodology is only under development. Currently, it is not possible to evaluate and to optimize the total quality level. Therefore, quantity of quality indicators has to be lowered, by dividing them to groups. Another (narrower) description of EIS quality is its value. *EIS value* – the benefit, that is created by this system. Therefore, from designers, manufacturers and users perspective, it will be different. So, it is very difficult to calculate the value, too. Therefore, we need to look after another description – efficiency [4].

EIS efficiency – the grade that shows systems befit to its purpose. The description, practically, can be used to all EIS. Considering, to what set of features the description is used, it can be divided to: general efficiency; technical efficiency; economical efficiency; functional efficiency; technical-economical efficiency and etc. General EIS efficiency – the grade of all its features, that shows systems befit to its purpose. Technical EIS efficiency – the grade of its technical features, that shows systems befit to its purpose. Economical EIS efficiency – the grade of its economical features, that shows systems befit to its purpose. The same way, another efficiencies can be described. It is evident, that efficiency is used to evaluate quality of complex EIS. Therefore, when evaluating efficiency, foundations of system theory, complex system research theory and foundations of general system theory should be used.

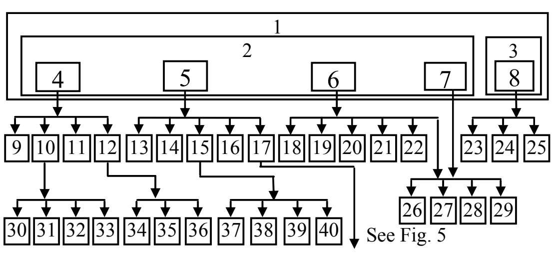

Fig. 4. General structure of CEIS efficiency theory

General structure of efficiency theory of complex EIS (CEIS) is shown in Fig. 4 (1 – General theory of CEIS efficiency; 2 – Theory of CEIS technical efficiency; 3 – Theory of CEIS economical efficiency; 4 – Theory of functionality; 5 – Theory of stability; 6 – Theory of manageability; 7 – Theory of self- organize; 8 – Theory of economy; 9 – Adequacy to functional influences; 10 – Functional organization; 11 – Level of surroundings control; 12 – Functional dynamics; 13 – Resistance; 14 – Stability; 15 – Unstoppability; 16 – Reliability; 17 – Persistence; 18 – Coverage of management; 19 – Deepness (degree) of management; 20 – Flexibility of management; 21 – Operatibility of management; 22 – Efficiency of management; 23 – Economic efficiency; 24 – Economic dynamics; 25 – Economic qualimetry; 26 – Situation identification; 27 – Adaptivity; 28 – Self-education; 29 – Opportunity to select choices; 30 – Function actuality; 31 – Functional density; 32 – Degree of functional relationship; 33 – Functional flexibility; 34 – Dynamic stability; 35 – Invariantivity; 36 – Adaptivity; 37 – Incorruptibility; 38 – Longevity; 39 – Repairability; 40 – Persistency.).

Technical CEIS efficiency, as a part of general CEIS efficiency, depends on consistency, while consistency depends on persistence, which research directions are shown in Fig. 5.

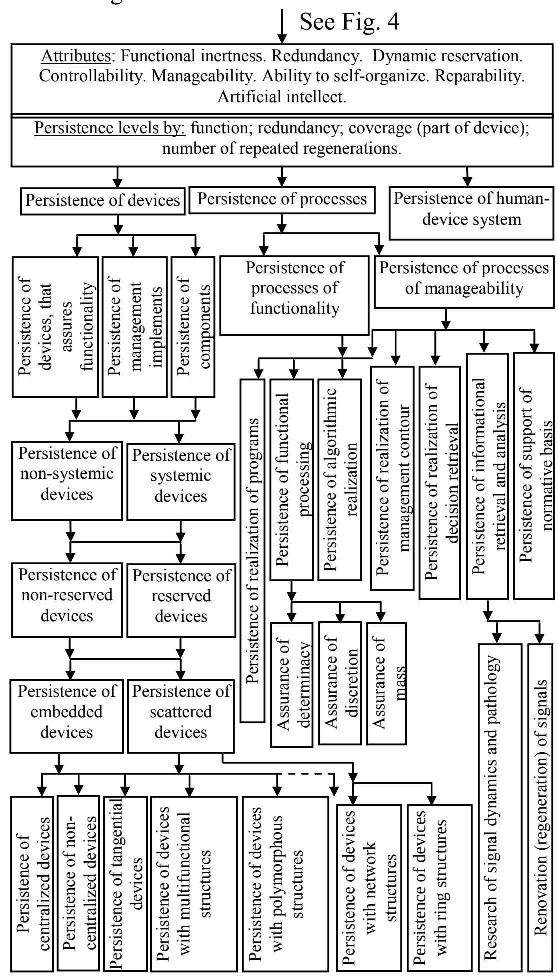

Fig. 5. Structure of persistence

The level of digital electronic device's reliability

The main trend of electronic device's (ED) development is the development of digital electronic device (DED). While development of ED elements nomenclature is rapid, reliable components are used in integrated circuits (IC). Semiconductor chip defectivity level often reaches one defective from 200000. Degradation process of chips quality within all exploitation period, practically, is invisible. IC components are chosen so, that their aging don't decide to any parameters change, and the failure rate of such IC is 10^{-8} – 10^{-9} 1/h. Therefore, even if DED is made from a hundred of such IC, value of their failure rate doesn't create bigger problems. Even smaller DED (for example personal computer (PC)) incorruptibility depends on usage and operating conditions. Specialists assert, that at switch-on moment – devastating electrical impact runs through PC elements. Defective PC components are especially sensitive. Therefore, most manufacturers train PC more than 10 hours by switching them on and off.

The mentioned above decides a distinctive trend of DED reliability research.

Conception of dynamic reliability

Lasting researches confirm that most ED calculations of incorruptibility don't tally with test results, and both of them – with exploitation results.

It is defined, that 80 – 90% of ED failures are related with component failures (50% determined by exploitation conditions, 40% - by duration of production). However, 85% of ED components load coefficient is 0,4 and about 50% electrical load coefficient $0 < K_a \le 0{,}3$. And only 3,87% components have $K_a \le 0{,}7$. During exploitation only 6% of components (n_v Fig. 6) fails.

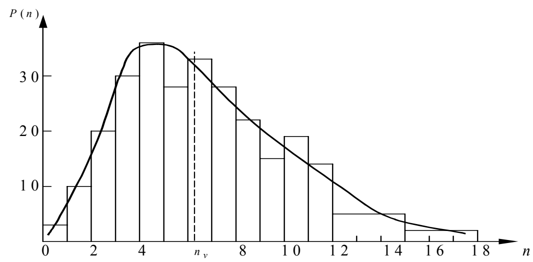

Fig. 6. Distribution density of components failure number (n)

If we can calculate *i*-th component and whole ED failure rates - λ_{Si} and $\lambda_{S\Sigma}$, we can determine this index values λ_{fi}, $\lambda_{f\Sigma}$, then from exploitation data we can find ratio

$$S = \frac{\dfrac{\lambda_{fi}}{\lambda_{f\Sigma}}}{\dfrac{\lambda_{Si}}{\lambda_{S\Sigma}}} = \frac{\lambda_{fi}\lambda_{S\Sigma}}{\lambda_{Si}\lambda_{f\Sigma}}. \tag{1}$$

If calculation and exploitation results are adequate, the ratio *S* must be equal to one. But it's not so (Fig. 7).

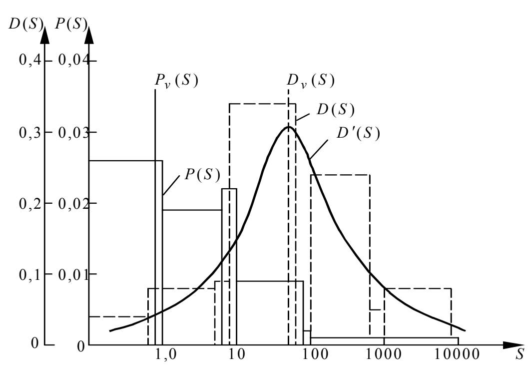

Fig. 7. Dispersion of index *S*

For ED, which fails during exploitation, average index *S* value (S_v) is 50. In Fig. 7 *D*(*S*) is a part of components, which value is in interval shown in figure; $D'(S)$ - approximation curve; *P*(*S*) – *S* value of distribution density function. It shows that ED failures are conditioned by other factors.

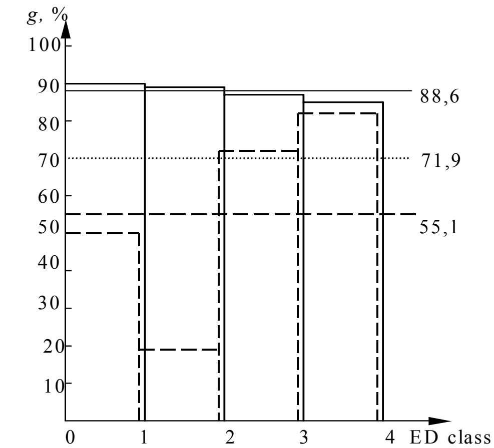

Fig. 8. Distribution of ED failures (caused by switching-on moment) in manufacture (__) and exploitation (_ _ _) periods

If ED exploitation is controlled (by special program), then 90% failures are caused by switching-on moment (Fig. 8).

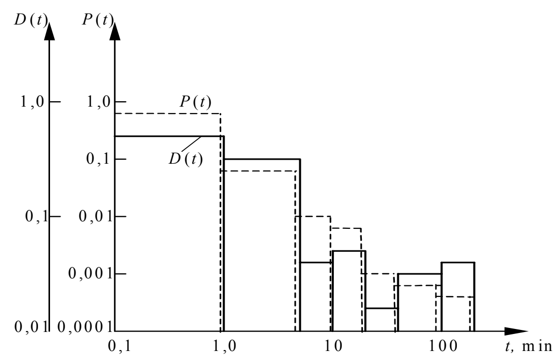

Fig. 9. Distribution of time intervals from ED switching-on till failure

During manufacture period, 55,1% of all failures occurs at switching-on moment. Currently, 71,9% of all ED failures occurs during manufacture and exploitation. Fig. 9 shows shares (*D*(*t*)) of ED failures distributed to time intervals and time till failure (after switching-on) distribution density *P*(*t*).

Distribution of failures, which occurs at switching-on moment, during first 24 months of ED exploitation, is shown in Fig. 10. (*D*(*n*) – share of failures at switching-on moment during time interval; *P*(*n*) – distribution density of failure number as time function).

Fig. 10 shows, that transient processes, which occur at switching-on moment, have decisive influence on defective ED components. Further researches show, that various inner and outer short-term actions decide most DED failures. Conception of dynamic reliability [5], based on ED exploitation analysis results, [2] was formulated.

This trend of reliability includes research and assurance of DED resistance to dynamic action, analysis and control of reliability dynamics and DED "vitality" assurance.

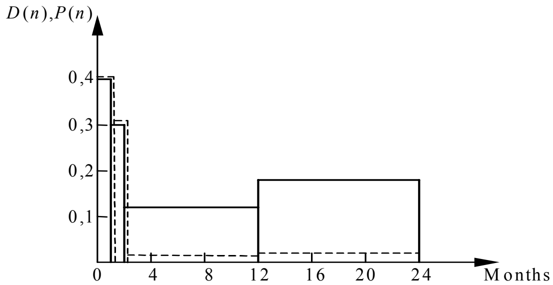

Fig. 10. Distribution of failures at the beginning of exploitation

Research of task's execution possibilities (when DED are used), can be separated into two dynamic action influence areas: DED ability to function and information distortion in DED.

There was shown, that when electrical load on DED component increases, even if its period of time decreases, less energy is needed to provoke component's failure. So, though transient process duration is short (Fig. 11), those actions are dangerous for DED components. It's interesting, that short-term and big amplitude electrical actions on DED components determine quite different than permanent loads or degradation processes. There were made lots of DED component incorruptibility calculations, estimating dynamic action. Difference between these calculations and calculations according average level of electrical load may be even 100%. It determines necessity to create new unfailure calculation methods.

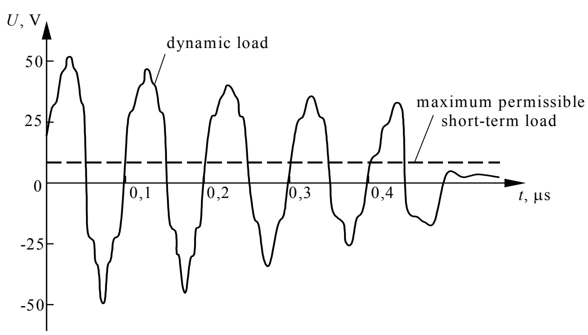

Fig. 11. Dynamic load of TV transistor base-emitter circuit during switch-on moment

As it was mentioned earlier, another group of dynamic reliability tasks – analysis of reliability dynamics and reliability control. The first group of tasks is orientated to simple DED and DED components, the second group – to complex systems. Seeking for assurance of rational DED reliability dynamics, we need to investigate DED states, create structure of controlled DED, foresee structure of reliability states control complex, and realize what are the components of that structure. The third group of dynamic reliability assurance tasks is assurance of DED "vitality". Classic reliability theory investigates how to avoid DED failures, how to repair it, how to exploit it for a long time. When complex DED has excess of: time, information, structures, algorithms, programs, then it becomes possible to carry out some tasks, even if failure (in traditional meaning) occurs. This trend of research is not very new, but, when dynamic reliability conception has been formed, it obtains a row of new aspects.

Conception of persistence

Electronic device's (ED) *persistence* is an ability to change itself when failure of some part occurs (to change its structure, functions, algorithms and other) and to finish the task. Reliability research includes: research of four features (*unfailure*, *durability*, *reparability* and *maintenance*), research all ED conditions from beginning of exploitation to total failure in expected and unexpected surroundings, and persistence analyses of task execution possibilities after different ED parts failed. ED undisturbance doesn't belong to mentioned features. Persistence is an attribute of complex, responsible, with high artificial intelligence electronic systems (ES).

Main trends of persistence's research

ES persistence mostly is determined by these ES features: functional inertness; results undevaluation; excessity; controllability; reorganisability; artificial intelligence; reparability and other. Functional inertness is an ability of ES to stop task's execution for some time and to resume it later. Undevaluation of results is an ability of ES to keep partial task's execution results, which were obtained till failure, for some time. Excessity is an ability of ES to make task's execution more possible, when needed. Other two features determine abilities to control and manipulate ES states and to reorganize the system (in case of failure). Reparability, in this case, determines abilities to repair faulty ES components till the task is executed (without them) and if needed use them later (after repairing). Estimation of these features and a search of improvement ways are supplementary trends of ES persistence research.

Description of ES features that determine the persistence

ES functional inertness is determined by: integrated principle of task execution, additivity of separate execution stages and excessity of time.

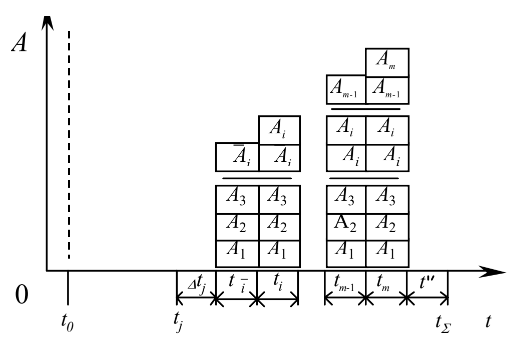

Fig. 12. Illustration of functional inertness

In this case (Fig. 12) the final result

$$A = A_1 \cup A_2 \cup A_3 ... \cup A_i \cup A_{i+1} ... \cup A_m = \cup \underset{\rightarrow}{A}; \quad (2)$$

where A_i – result of i-th stage of task's execution; $\underset{\rightarrow}{A}$ – the set of task execution results.

From this point of view, probability of task execution at permissible time:

$$P_U(t_\Sigma) = p\left\{\left(\sum_{i=1}^{m} t_i + \sum_{i=1}^{\overline{m}} t_{\bar{i}} + \sum_{j=1}^{n} \Delta t_j\right) \le t_\Sigma\right\} \times$$

$$\times \prod_{i=1}^{m}\left[1-(1-P_i)^{V_i}\right]; \quad (3)$$

where t_Σ – maximal permissible function execution term; $t_{\bar{i}}$ – the term of i-th stage of task's execution, that caused false result; $\overline{m}$ – stage's number of task execution, that caused false result; (in common case $t_{\bar{i}} = Mt_i$; $1<M<\infty$; M – number of i-th stage repeat); Δt_j – the term of j-th pause in task's execution; n – number of pauses; P_i – probability of i-th stage's execution from the first time; V_i – number of i-th stage's executions. In this case

$$\sum_{i=1}^{m}(V_i - 1) = \overline{m}. \quad (4)$$

Then, when $P_i \to 1$,

$$P_U(t_\Sigma) = p\left\{\left(\sum_{i=1}^{m} t_i + \sum_{j=1}^{n} \Delta t_j\right) \le t_\Sigma\right\}. \quad (5)$$

In all cases

$$A_1(t_j) \cup A_2(t_j) \cup ... \cup A_L(t_j) = \\ = A_1(t_j + \Delta t_j) \cup A_2(t_j + \Delta t_j) \cup ... \cup A_L(t_j + \Delta t_j); \quad (6)$$

where L – number of stages executed till moment t_j. It means that

$$A_1(t_1) = A_1(t_1 + t_2) = ... = A_1\left(\sum_{S=1}^{L} t_S\right) = \\ = A_1(t_j) = A_1(t_j + \Delta t_j). \quad (7)$$

Functional inertness degree is referred by:

- share of stages (m_i), after which the task's execution may be stopped

$$d_e = \frac{m_i}{m}; \quad (8)$$

- share of permissible pauses terms (Δt_l)

$$d_t = \int_0^{\Delta t_l} p(\Delta t) d\Delta t; \quad (9)$$

where $p(\Delta t)$ – density of factual (possible) pauses terms distribution;

- number of permissible average term interruptions

$$n_p = \frac{t_\Sigma - \sum_{i=1}^{m} t_i}{M[\Delta t]}. \quad (10)$$

Results undevaluation is determined by integrated principle of task's execution, aditivity of execution results and task's modality (divisibility to independent and functionally finished modules); result persistence (ability to fix and keep results obtained till failure (foul-up)); controllability (ability to estimate results quality); repeatability of task's parts (ability when false result is obtained, to go back to task's or task's module beginning and repeat the execution).

ES excessity degree

$$\eta = \sum_{i=1}^{Z} d_{zi} \eta_i; \quad (11)$$

where η_i – excess degree of i-th group; d_{zi} – i-th group's excess importance coefficient; z – number of excess groups. For example, i-th excessity degree of j-th ES component

$$\eta_{ji} = 1 - (1 - P_j)^{k_{ji}}; \quad (12)$$

where P_j – probability of j-th component's unfailure during task's execution period; (k_j–1) – number of components that compose the excess. Then i-th excessity degree of whole ES

$$\eta_i = \prod_{j=1}^{S}\left[1-(1-P_j)^{k_j}\right]; \quad (13)$$

where S – number of ES components.

$$\sum_{i=1}^{Z} d_{zi} = 1. \quad (14)$$

Each d_{zi} is calculated considering to ES failures share in failures stream.

Proper task execution controllability and reorganisability are assured by proper ES artificial intelligence. These features are determined by possibilities to control the states of all ES components, foresee preconceived failure's (foul-up) features, control the states, identify failures, reconfigurate the system (system parts) structures and so on. Using event independency precondition, groups of features can be defined by one of these indexes

$$P_v = P_K \cdot P_K^* \cdot P_I \cdot P_I^* \cdot P_V \cdot P_V^* \quad (15)$$

or

$$P_r = P_K \cdot P_K^* \cdot P_G \cdot P_G^* \cdot P_R \cdot P_R^*; \quad (16)$$

where P_K and P_K^* – probabilities, that it will be possible to control approach of failure (foul-up) moment and during the control correct control results will be obtained; P_I and P_I^* – probabilities, that failure features will be preconceived and noticed; P_V and P_V^* – probabilities, that it will be possible by manipulation to avoid ES failure and the succeed of that; P_G and P_G^* – probabilities, that it will be possible to detect system (component) failure and that the failure will be detected.; P_R and P_R^* – possibilities, that system excessities and artificial intelligence will be able to reconfigure the system by eliminating improper component and that it will be successfully done. Probabilities P_K, P_V, P_R refer the degrees of ES controllability, manipulatability and reorganisability, P_v and P_r – degree of artificial intelligence assuring the persistence.

Conclusion

Analysis of EIS efficiency was started from determination of its structures, qualities, values and efficiencies conceptions, with evaluation of systemotechnic peculiarities and other; united methodology of the system analysis and synthesis is shown.

Structure of EIS quality is presented in the paper. Detailed structure of the general efficiency theory is shown. Review of parameters that affect the efficiency is made. Subject of digital electronic devices (DED) reliability is widely presented in the paper. Trends of research of efficiency (reliability) dynamics and persistence are shown.

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Pagrindinis šio straipsnio tikslas – pristatyti jo bendraautorių darbuose tyrinėjamus elektroninių įrenginių (EĮ), elektroninių sistemų (ES) ir elektroninių informacinių sistemų (EIS) kokybės, efektyvumo ir patikimumo klausimus.

Straipsnyje pateikiama EIS kokybės teorijos struktūra, taip pat kokybės, vertės ir efektyvumo sampratos. Parodyta detali bendrojo efektyvumo teorijos struktūra. Atlikta efektyvumui įtaką darančių parametrų apžvalga. Kadangi pagrindinis EIS struktūros elementas yra elektroninis įrenginys (EĮ), o efektyvumas dažnai tapatinamas su užduoties įvykdymo tikimybe, tai straipsnyje plačiai nagrinėjamas EĮ patikimumas. Iliustracijai pateikiamos efektyvumo (patikimumo) ir atkaklumo tyrimų kryptys. Il. 12, bibl. 5 (anglų kalba; santraukos lietuvių, anglų ir rusų k.).

P. Balaišis, D. Eidukas, A. Besakirskas, P. Tervydis, L. Gočelkienė. Research of Electronic Information Systems // Electronics and Electrical Engineering. – Kaunas: Technologija, 2005. – No. 1(57). – P. 5–10.

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Structure of theory of EIS quality will be presented in the paper. Conceptions of quality, value and efficiency, which describe the EIS, will be given. Efficiency is the best illustration of EIS features; therefore, detailed structure of the general efficiency theory will be presented. Review of parameters that affect efficiency will be made. Efficiency often is identified with probability of tasks accomplishment, and as the main element used in EIS structure is electronic device (ED), subject of ED reliability will be widely presented in the paper. For illustration, trends of research of efficiency (reliability) dynamics and persistence will be shown. Ill. 12, bibl.5 (in English; summaries in Lithuanian, English and Russian).

П. Балайшис, Д. Эйдукас, А. Бесакирскас, П. Тервидис, Л. Гочелкене. Исследование электронных информационных систем // Электроника и электротехника. – Каунас: Технология, 2005. – № 1(57). – С. 5–10.

Главная цель нашей статьи состоит в том, чтобы представить предметы качества, эффективности и надежности электронных устройств (ЭУ), электронных систем (ЭС) и электронных информационных систем (ЭИС), которые анализированы соавторами этой статьи в их работах.

В статье представлена структура теории качества ЭИС. Даются концепции качества, ценности и эффективности, которые описывают ЭИС. Эффективность – лучшая иллюстрация особенностей ЭИС, поэтому детальная структура общей теории эффективности будет представлена. Сделан обзор параметров, которые затрагивают эффективность. Эффективность часто идентифицируется с вероятностью выполнения задач, и поскольку главный элемент, используемый в структуре ЭИС – электронное устройство (ЭУ), предмет надежности ЭУ будет широко представлен в статье. Для иллюстрации показаны тенденции исследования динамики эффективности (надежности) и настойчивости. Ил. 12, библ. 5 (на английском языке; рефераты на литовском, английском и русском яз.).