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The Efficiency of the Flexible Endotechnologies

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Internal and external technologies

Technologies related to electronic devices (ED) are often called electronics technologies (ET). This group consists of ET, which are used in devices and in the processes associated with their applications, also device manufacture ET and control ET. In short way the first two types can be called as *endotechnologies* (ENT) and *exotechnologies* (EKT). Both these technologies are interrelated. The features of one determine the structures, processes, efficiency indexes and other parameters of the other. In most cases the flexible ET can be created only by assuring the flexibility of ENT and EKT. Specific objectives, structurization principles, complexes of used measures, operation algorithms are characteristic to each of them, therefore they can be also characterized by specific factors influencing operation efficiency, efficiency indexes and their levels. Still, when designing, optimizing and exploiting the flexible ET (ENT and EKT) and when increasing their efficiency, the general principles (in some cases even methods) of synthesis and analysis can be applied. When synthesizing the structures of the flexible ENT and EKT, the frame creation and control methods can be used. When analyzing the operation efficiency, general algorithm quality evaluation methods can be used. Common fundamentals of analysis of informational processes of ENT and EKT are widely applicable. Let's consider the peculiarities and the efficiency of ENT.

ENT features

Main feature of ENT is that all of them are implemented almost exclusively by using the processes of electronics [1] – electronic processes in vacuum, gases, liquid and solid bodies and in plasma, also in junctions of materials. Mostly these are concentrated, high-performance and relatively more determined technologies compare to EKT. Their operation efficiency is highly influenced by the features of ED. Considerably less influence (compare to EKT) to them is made by human operator. Several laws of evolution are dominant in them: constant change; complex expansion; organizational stability; structural (logical) cognition; increase of artificial intelligence and others.

Considering the tasks assigned to them, the ENT are divided into: informational; designed to perform operation tasks of various objects; and control technologies. Main features, common to all ENT (excluding features of functional purpose) are: adaptivity; flexibility; expedience; optimality; reliability (efficiency); persistence [2] and others. Most of these features are determined by several factors, including ENT components: unification level; modularity; intercompatibility (of structures, functions, interfaces, flows of information); integrality; level of automation; degree of intellectualization and others. This is attributable to all main levels of ENT: macro and micro structures; information networks; operation algorithms; programs; decision making models, etc.

ENT efficiency evaluation

Considering the laws of ENT evolution, the performance of technology component, performing some certain task and for which earlier indicated features and groups of factors which determine them, are characteristic, is determined by all the combinations presented in Fig. 1.

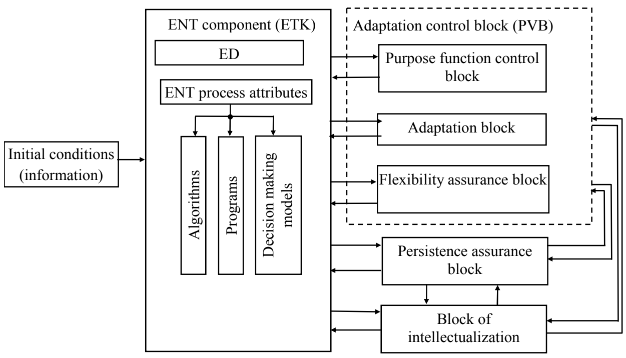

Fig. 1. The composition of ENT components and its control measures

If we considered, that the technical part of ED will be operational, when all its technical components will be operational, then the probability of such occurrence at any time t can be expressed as

$$P_E(t) = f_p\left(\{\lambda_i(t)\},\{K_{ai}(t)\},\{F_{ij}(t)\},t\right); \quad (1)$$

here $\lambda_i(t)$ and $K_{ai}(t)$ – the failure intensity of the *i*-th component and the coefficient of the average load; $F_{ij}(t)$ – the value of parameter of *j*-th external impact onto the *i*-th component.

When ED is repairable, then the probability, that it will operate for a time period t_0 beginning from any time *t*, will be

$$P_E(t, t+t_0) = \sum_{k=0}^{\infty} p\left\{ \sum_{j=0}^{k}\left(T^{(j)} + \xi^{(j)}\right) < t < t+t_0 \le \right.$$
$$\left. \le \sum_{j=0}^{k}\left(T^{(j)} + \xi^{(j)} + T^{(k+1)}\right) \right\}; \quad (2)$$

here $p\{\cdot\cdot\}$ – the probability of the event, indicated in the brackets; $T^{(j)}$ – output of the ED from the (*j*-1)-th till the *j*-th failure; $\xi^{(j)}$ – the duration of ED repair after the *j*-failure.

The probabilities of readiness of other technical measures (for control of purpose functions, adaptation, flexibility and persistence assurance, and also intended for intellectualization) during time period from *t* to $(t+t_0)$ can be calculated analogously (listed respectively): $P_f^{(')}(t,t+t_0)$; $P_{AD}^{(')}(t,t+t_0)$; $P_L^{(')}(t,t+t_0)$; $P_A^{(')}(t,t+t_0)$ and $P_I^{(')}(t,t+t_0)$. General values of the readiness indexes of all these control measures will be determined not only by technical measures, but also by processes inside them. Therefore, e.g. the general readiness of control measures of purpose functions

$$P_f(t, t+t_0) = P_f^{(')}(t, t+t_0) \cdot P_{fp}^{(')}(t, t+t_0) \; ; \quad (3)$$

here $P_{fp}(t, t+t_0)$ – the probability of no-failure of processes inside the control measures of technical purpose functions during time period from *t* to $(t+t_0)$.

ED will be ready to perform the tasks assigned to it (considering its control) with the probability

$$P_{EF}(t, t+t_0) = P_E(t, t+t_0) \cdot P_f(t, t+t_0) \; . \quad (4)$$

Analogously, when assessing the influence of all PVB components, we have that

$$P_{EP}(t, t+t_0) = P_E(t, t+t_0) \cdot P_f(t, t+t_0) \times$$
$$\times P_{AD}(t, t+t_0) \cdot P_L(t, t+t_0) \; . \quad (5)$$

All PVB measures are the systems, the efficiency of which can be evaluated by applying general efficiency evaluation methods of electronic systems (ES) [3, 4]. The persistence and intelligence is often characteristic to ETK and PVB. Thus the measures of these blocks are often influenced by the systems of persistence assurance and intellectualization. These systems alter the values of all components of the formula (5).

Let's analyze the influence of persistence assurance on the efficiency of ED.

Assume, that ETK ED task accomplishment (at the first attempt) duration is t_1 (Fig. 2).

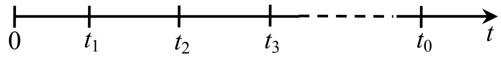

Fig. 2. The durations of repetitive task accomplishments

If the first attempt to accomplish the task is unsuccessful, the attempts are made repetitively so that $t_2 > t_1$, but $t_2 = t_3 = \ldots = t_i =$ $= \ldots = t_n$, then

$$n = \left| \frac{t_0 - t_1}{t_i} + 1 \right| ; \quad (6)$$

here $|\cdot|$ – the whole part of the calculated value.

So the ETK due to the fault of ED can get into the B_1, B_2, ..., B_i, ..., B_{n-1} or B_n state (Fig. 3).

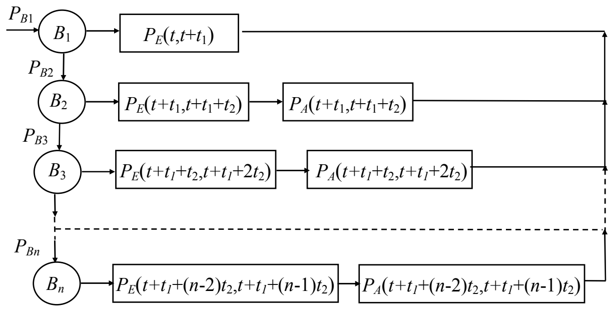

Fig. 3. ETK states and the readiness probabilities of the blocks which determine these states

The probability that ETK will get into the initial state B_1 is $P_{B1} = 1{,}0$; for the B_2 state –

$$P_{B2} = 1 - P_E(t, t+t_1) ; \quad (7)$$

for B_3 –

$$P_{B3} = P_{B2} \cdot [1 - P_E(t+t_1, t+t_1+t_2) \times$$
$$\times P_A(t+t_1, t+t_1+t_2)], \quad (8)$$

and for B_n

$$P_{Bn} = P_{B(n-1)}[1 - P_E(t+t_1+(n-3)t_2, t+t_1+(n-2)t_2) \times$$
$$\times P_A(t+t_1+(n-3)t_2, t+t_1+(n-2)t_2)]. \quad (9)$$

The probability, that ETK ED (with the features of persistence) will accomplish its tasks over the time period from *t* to $(t+t_0)$ is

$$P_{E\xi}(t, t+t_0) = \sum_{i=1}^{n} P_{Bi} \cdot P_E\left(t+t_1+(i-2)t_2, t+t_1+(i-1)t_2\right) \times$$
$$\times P_A\left(t+t_1+(i-2)t_2, t+t_1+(i-1)t_2\right), \quad (10)$$

however, when $i = 1$

$$P_A\left(t+t_1(i-2)t_2, t+t_2+(i-1)t_2\right) = 1{,}0. \quad (11)$$

The persistence assurance block influence on the efficiency of the PVB component technical measures can be assessed analogously As the block of intellectualization, it constantly changes the values of probabilities over the time *t*: $P_E(t+t_1+(i\text{-}2)t_2, t+t_1+(i\text{-}1)t_2)$ and $P_A(t+t_1+(i\text{-}2)t_2, t+t_1+$

+(i-1)t_2), and the values of $P_{El}(t,t+t_0)$ at the same time. This is the topic for the additional discussion. Due to the influence of the persistence and the intellectualization, all the components indicated in the formula (5) change their values: $P_E(t,t+t_0)$ becomes $P_{El}(t,t+t_0)$, etc.

Other part of factors determining the ETK efficiency consists of the attributes of its processes. Most common attributes of this part [5] are various operation algorithms and program complexes intended to implement them. The former and the latter are often created in the modular way. Possibilities of transition from each module into another are characterized by probabilities. Therefore the same models can be used in order to evaluate the efficiency. The Markov model is also suitable for this [3]. Task accomplishment probability can be taken as the main index for the efficiency evaluation of each algorithm or program complex module.

Some certain series of executive components (modules) corresponds to each task of ETK. Therefore ETK efficiency depends on the efficiency of the module series and each module (including decision making models implemented in them), necessary to accomplish the task, at that time. If at least one module will not accomplish its task, the possibility to continue the further task implementation will be lost. Such condition could be changed only by the persistence assurance block, which provides the possibilities to repeat the task performance or to change the structure of the algorithm (complex of programs) and in this manner will attempt to carry out the task by other way (ignoring the failed part). Naturally, in this case it is necessary, that such a change would have no influence on the performance results of the earlier modules, and only the changes to the frame of the failed module would be made.

The directional graph is created by using the scheme of the modeled algorithm, in which each i-th component of the algorithm is represented by the graph node $G_i = (\overline{1,n})$, and the arc between G_i and G_j represents the possible control transfer from G_i to G_j. The possibility of this transfer is described by the probability P_{ij}. The efficiencies of graph nodes are characterized by task fulfillment probability values $\{E_i\}$.

We will consider a case, when such graph has only one initial point G_1 and ending point G_n (when evaluating the efficiency or polygraph, this problem should be solved for each pair of initial and ending points, considering the node and arc loads) and two additional nodes: G_0 − task accomplishment, $\overline{G_0}$ − failure (when performing the task of any i-th module). When failure (disturbance) arises, the transfer to the node $\overline{G_0}$ over the branch $G_i\overline{G_0}$ will be made. The probability of such transfer is $(1-E_i)$. If the i-th module fully accomplished its tasks, the G_j task is taken over. The probability of such transfer is E_iP_{ij}. Transfer to the node G_0 is made with probability $P_{n0} = E_n$ (Fig. 4).

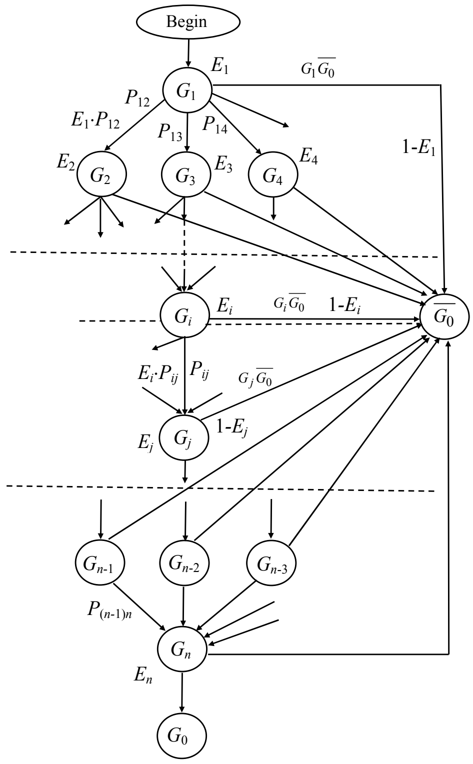

Fig. 4. Algorithm (program complex) operation graph

It is possible to form the matrix of the transfer probabilities (**P**), the elements of which (P_{ij}) correspond to the transit of the Markov process from the i-th state into he j-th state. This matrix will have such form:

$$\mathbf{P} = \begin{array}{c} \\ G_1 \\ G_2 \\ G_3 \\ \vdots \\ G_i \\ \vdots \\ G_{n-1} \\ G_n \\ G_0 \\ \overline{G_0} \end{array} \begin{array}{ccccccccc} G_1 & G_2 & G_3 & \dots & G_j & \cdots & G_n & G_0 & \overline{G_0} \\ 0 & E_1P_{12} & E_1P_{13} & \cdots & E_1P_{1j} & \cdots & E_1P_{1n} & 0 & 1-E_1 \\ 0 & 0 & 0 & \cdots & E_2P_{2j} & \cdots & E_2P_{2n} & 0 & 1-E_2 \\ 0 & 0 & 0 & \cdots & E_3P_{3j} & \cdots & E_3P_{3n} & 0 & 1-E_3 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \cdots & E_iP_{ij} & \cdots & E_iP_{in} & 0 & 1-E_i \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \cdots & 0 & \cdots & E_{n-1}P_{(n-1)n} & 0 & 1-E_{n-1} \\ 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & E_n & 1-E_n \\ 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & 1 & 0 \\ 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 & 1 \end{array} . \quad (12)$$

The efficiency of overall algorithm (complex of programs) is the probability, that all the tasks will be accomplished over the assigned time (e.g., t_0) and the state G_0 will be reached correctly. In order to calculate this probability let's analyze the matrix **Q**, which is obtained when G_0 and $\overline{G_0}$ columns and rows (describing the final states) are discarded from the matrix **P**.

$$\mathbf{Q} = \begin{array}{c} \\ G_1 \\ G_2 \\ G_3 \\ \vdots \\ G_i \\ \vdots \\ G_{n-1} \\ G_0 \end{array} \begin{array}{ccccccc} G_1 & G_2 & G_3 & \dots & G_j & \cdots & G_n \\ 0 & E_1P_{12} & E_1P_{13} & \cdots & E_1P_{1j} & \cdots & E_1P_{1n} \\ 0 & 0 & 0 & \cdots & E_2P_{2j} & \cdots & E_2P_{2n} \\ 0 & 0 & 0 & \cdots & E_3P_{3j} & \cdots & E_3P_{3n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \cdots & E_iP_{ij} & \cdots & E_iP_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \cdots & 0 & \cdots & E_{n-1}P_{(n-1)n} \\ 0 & 0 & 0 & \cdots & 0 & \cdots & 0 \end{array} . \quad (13)$$

For each whole value of $k > 0$ we find $\mathbf{P}^k$, as the *k*-th order of **P**. It is obvious, that $\mathbf{P}^k(i, j)$ is the probability, that Markov process will make the transit from the *i*-th state into the *j*-th state after *k* "steps". Then the matrix

$$\mathbf{T} = 1 + \mathbf{P} + \mathbf{P}^2 + \ldots = \sum_{k=0}^{\infty} \mathbf{P}^k \qquad (14)$$

defines the transit from one state to another, when undefined number of "steps" is used. Assume, that **S** is a square matrix of the *n*-th order, so that

$$\mathbf{S} = 1 + \mathbf{Q} + \mathbf{Q}^2 + \ldots = \sum_{k=0}^{\infty} \mathbf{Q}^k \,. \qquad (15)$$

If we assume, that [1]

$$\mathbf{W} = 1 - \mathbf{Q} \,, \qquad (16)$$

then we have that

$$\mathbf{S} = \mathbf{W}^{-1} = (1 - \mathbf{Q})^{-1} \,. \qquad (17)$$

Then the efficiency of algorithm (complex of programs), when persistence assurance block does not operate,

$$E_p = \mathbf{S}(1, n) \cdot E_n \,. \qquad (18)$$

In order to assess persistence assurance block influence on the value of E_p, it is necessary to know each module performance durations (at the first and second attempts), allowable overall ETK work duration and also the persistence degree of each module (graph node) [2].

Advantages of the method and directions for the improvement

The offered ENT efficiency evaluation method is convenient since it is generalized and is applicable when assessing any of endotechnologies. It can be used to calculate the efficiency of informational, control and other endotechnologies. Other advantage of the method – it provides the opportunities to consider the persistence of separate ETK parts, intellectualization processes and other peculiarities when evaluating ENT efficiency. When continuing this research direction the intellectualization block influence on the ETK efficiency and dynamics should be analyzed more extensively. Separate research task consists in the evaluation of efficiency of the entire graph, when its separate nodes have different level of persistence, and the maximal allowable time (e.g., t_0) for the accomplishment of the tasks of the entire ETK is limited. One more research direction can be distinguished, when considering a structure analogous to the graph shown in Fig. 4, but with several inputs, from which it is possible to get to different outputs $\{G_{0v}\}$.

References

1. **Balaišis P., Besakirskas A., Eidukas D.** Elektroninių sistemų techninis efektyvumas. – Kaunas: Technologija, 2006. – 259 p.
2. **Balaišis P., Eidukas D., Navikas D., Vilutis G.** Persistence of electronic devices // Modern Problems of Radio Engineering, Telecommunications and Computer Science. – Lviv Slavsko, Ukraine, 2002. – P. 13 – 15.
3. **Balaišis P., Eidukas D., Valinevičius A., Žilys M.** Informacinių elektroninių sistemų efektyvumas. – Kaunas: Technologija, 2004. – 358 p.
4. **Žickis A.** Gamybos kontrolės valdymo sistemų efektyvumo tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2003. – Nr.2 (44). – P.69 – 72.
5. **Martin L. Shooman.** Reliability of computer systems and networks. – New York: John Wiley & Sons, Chichester, 2002. – 552 p.

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The peculiarities of endotechnologies, related to electronic devices, were analyzed. The composition of the component of endotechnologies and of its control measures was presented. The example of implementation of endotechnologies (complex of programs) was offered, which allows to analyze and evaluate the efficiencies of the separate components and their interfaces. Endotechnology efficiency calculation method was created using Markov processes, which can be applied when investigating the readiness of many electronics technologies and their components considering the influence of persistence on the task accomplishment probability. Ill. 4, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

П. Балайшис, А. Жицкис. Эффективность гибких эндотехнологий // Электроника и электротехника. – Каунас: Технология, 2007. – № 1(73). – С. 13–16.

Исследованы особенности с электронными устройствами связанных эндотехнологий. Приведен состав средств компонента эндотехнологий и управления. Составлен пример графа алгоритма (программного комплекса) эндотехнологий, позволяющего исследовать и оценивать эффективности отдельных компонентов и связей между ними. На основании марковских процессов составлен метод расчета эффективности эндотехнологий. Предложенный метод приемлем для исследования дееспособности многих эндотехнологий и их компонентов с учетом влияния упорности на вероятность выполнения задания. Ил. 4 , библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

P. Balaišis, A. Žickis. Lanksčiųjų endotechnologijų efektyvumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 1(73). – P. 13–16.

Išanalizuoti su elektroniniais įtaisais susijusių endotechnologijų ypatumai. Pateikta endotechnologijų komponento ir jo valdymo priemonių sudėtis. Sudarytas endotechnologijų atlikimo (programų komplekso) pavyzdys, leidžiantis tirti ir vertinti atskirų komponentų ir jų sąsajų efektyvumus. Naudojant Markovo procesus, sudarytas endotechnologijų efektyvumo skaičiavimo metodas, kuriuo galima pasinaudoti tiriant daugelio elektronikos technologijų bei jų komponentų veiksnumą, nustatant atkaklumo įtaką užduoties įvykdymo tikimybei. Il. 4, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).