Atypical Aspects of Reliability of Measuring Devices (MD)

P. Balaišis, D. Eidukas, A. Besakirskas

Department of Electronics Engineering, KTU
Studentų str. 50, LT-3031 Kaunas, Lithuania

ABSTRACT: *In this paper is presented conception of measurement device dynamic reliability and of persistence. Main electronic system features that determine persistence are singled out. There is shown how to estimate some indexes of these features.*

The Level of Digital Electronic Device Reliability

The main trend of MD development – digital electronic device (DED). Therefore development of MD elements nomenclature is rapid. In integrated circuits (IC) are used reliable components. Often semiconductor chip defectivity level reaches one defective from 200000. Degradation processes of quality chips practically are invisible, within all exploitation period. IC components are chosen so, that their aging don't decide any parameters change. The failure rate of such IC is (10^{-8} – 10^{-9}) h^{-1}. Therefore, even if DED is made from a hundred of such IC, failure rate value doesn't raise large problems.

Even smaller DED (for example personal computer (PC)) no-failure depends on operating conditions of usage. Specialists assert [1], that at power switch on moment trough PC elements runs devastating electrical impact. Especially sensitive are defective PC components. Therefore, most manufacturers train PC more than 10 hours by switching on and off.

The mentioned above decide distinctive DED reliability research trend.

Conception of Dynamic Reliability

Lasting researches confirm, that most MD calculations of no-failure don't tally with test results, and both of them – with exploitation results. Suspicions that calculation and test methodics are not precise, haven't been confirmed.

There is established that 80 – 90% of MD failures are connected with component failures (50 % determine exploitation conditions, 40% - duration of production). However, 85% of MD components load coefficient is 0,4 and about 50% electrical load coefficient $0 < K_a \leq 0{,}3$. And only 3,87% components have $K_a \leq 0{,}7$. During exploitation fail not all, but only 6% of components (n_v Fig.1).

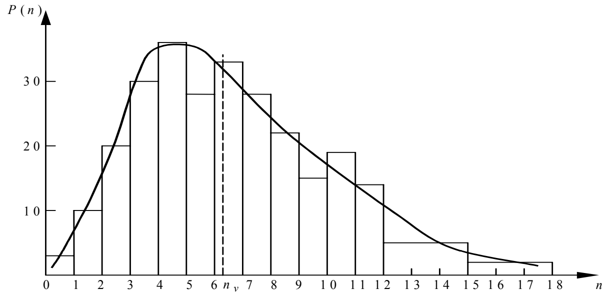

Figure 1. Density of components failure number (n) distribution

If we can calculate failure rate of i component and all MD - $\lambda_{S\Sigma}$ and we can determine this index values λ_{fi} $\lambda_{f\Sigma}$ 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. 2). For MD which fail during exploitation average index S value (S_v) is 50. In Fig.2 $D(S)$ – part of components which value is in interval shown in picture; $D'(S)$ - approximation curve; $P(S)$ – S value distribution function density. It shows that MD failures are conditioned by other factors.

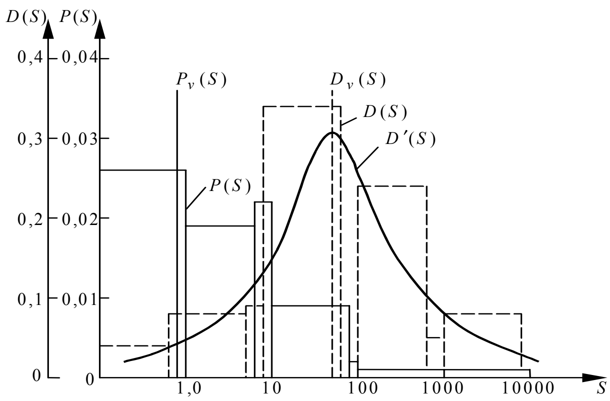

Figure 2. Dispersion of index S

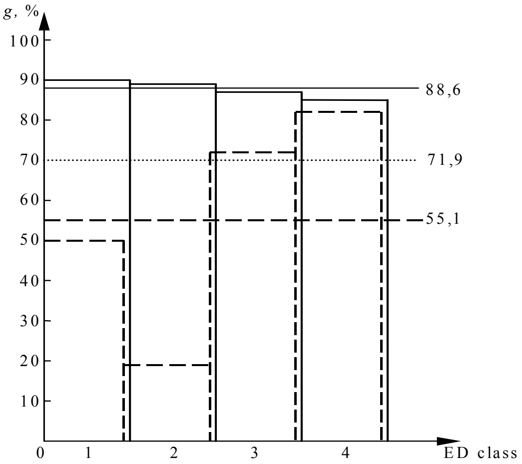

Figure 3. In manufacture (__) and in exploitation (_ _ _) failured at switching moment MD shares

During (according to special program) control MD exploitation is established, that 90% (from all failured) of them fail at switching on moment (Fig. 3).

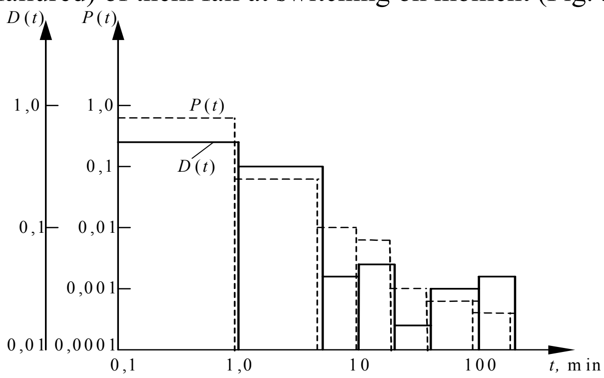

Figure 4. Distribution of intervals from MD switching on till failure

During manufacture 55,1% of all failures occur at switching on moment. At this moment occurs 71,9% of all MD failures during manufacture and exploitation. In figure 4 are shown 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 MD exploitation, is shown in Fig. 5. ($D(n)$ – share of failures at switching on moment during time interval; $P(n)$ – density of failure number distribution in time function).

Figure 5 shows that transient processes which occur at switching moment have decisive influence on defective MD components. Further researches have shown that various inner and outer short-term actions decide most DED failures. Basing on MD exploitation analysis results was formulated conception of dynamic reliability. This trend of reliability includes DED resistance to dynamic action research and assurance, analysis and control of reliability dynamic and DED "vitality" assurance.

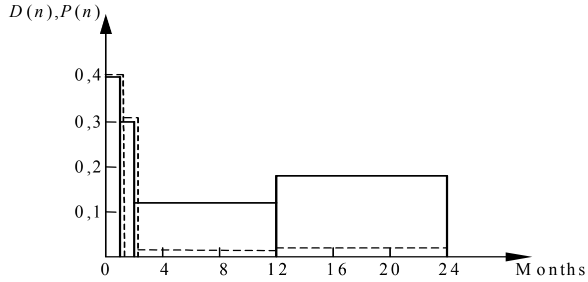

Figure 5. Distribution of failures at exploitation beginning

There were carried out researches investigating DED resistance to dynamic action, established structure of those actions, presented structures of action mathematical models, made mathematical models of some actions, investigated possibilities of models use, formalized components degradation processes, researched local physical process of components, accumulation mechanisms.

For assurance of DED resistance to dynamic action, were investigated possibilities of antidynamic assurance, resistible components selection and dynamic action avoidance.

Researching task execution possibilities (when using DED), there were separated two dynamic action influence areas: DED ability to function and information distortion in DED.

There was shown, that when DED component electrical load increases, even if period of time decreases, less energy is needed to provoke failure. So, though transient process duration is short (Fig. 6), those actions are dangerous for DED components.

It's interesting, that short-term and big amplitude electrical actions on DED components determine quite different, as permanent loads, degradation processes [2].

There were made most of DED component no-failure calculations, estimating dynamic action. Difference between these calculations and calculations according average level of electrical load may be even 100% [3]. It determine necessity create new no-failure calculation methods.

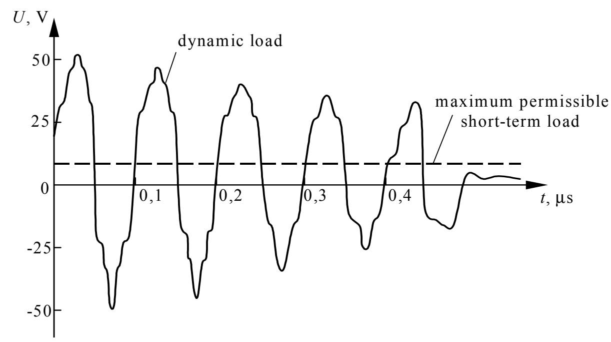

Figure 6. Dynamic load of TV transistor base-emitter circuit during switch on moment

As it was mentioned earlier, another group of dynamic reliability tasks – analysis of reliability dynamic 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, realize components of that structure.

The third group of dynamic reliability assurance tasks – assurance of DED "vitality". Classic reliability theory investigates how to avoid DED failures, how to repair it, how to exploit for a long time. When in complex DED appear excess of time, information, structures, algorithms, programs, it become 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.

The concept of persistence

Persistence is MD ability to change itself (change structure, functions, algorithms and other) when failure of some part occurs and finish the task. Reliability includes four features (no-failure, durability, reparability and maintenance) and research all MD conditions from right functioning to total failure in expected and unexpected surroundings, and persistence analyses task execution possibilities after different MD parts failed. MD undisturbance doesn't belong to mentioned feature. Persistence – attribute of complex, responsible, with high artificial intelligence electronic systems (ES).

Main trends of persistence 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 ES ability for some time stop task executing and to have possibility to resume this task later.

Results undevaluation is ES ability for some time keep partial task execution results that were obtained till failure.

Excessity is ES ability make more then needed possibilities to execute the task.

Other two features determine abilities control and manipulate ES states and reorganize system (in failure case).

Reparability, in this case, determines abilities repair faulty ES components till the task is executed without them and if needed use them later (after repairing).

Estimation of these features and search of improvement ways is supplementary trends of ES persistence research.

Description of persistence determinant ES features

ES functional inertness is determined by: integrated principle of task execution, additivity of separate execution stages and excessity of time. In this case (Fig.7) final result

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

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

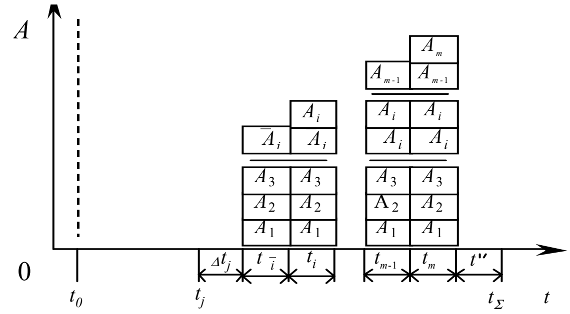

Figure 7. Illustration of functional inertness

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

$$P_U(t_\Sigma) = p\left\{\left(\sum_{i=1}^{m} t_i + \sum_{i=1}^{\bar{m}} t_{\bar{i}} + \sum_{j=1}^{n} \Delta t_j\right) \le t_\Sigma\right\} \times$$
$$\times \prod_{i=1}^{m}\left[1-(1-P_i)^{V_i}\right]; \qquad (3)$$

where t_Σ – maximal permissible function execution term; $t_{\bar{i}}$ – the term of i stage of task execution, that caused false result; $\bar{m}$ – stage of task execution that caused false result number; (in common case $t_{\bar{i}} = Mt_i$; 1<M<∞; M – number of i stage repeat); Δtj– the term of j pause by executing task; n –number of pauses; Pi– probability of i stage execution from the first time; Vi – number of i stage executions. In this case

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

Then, when $P_i \to 1$,

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

In all cases

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

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

$$A_1(t_1) = A_1(t_1 + t_2) = \ldots = A_1\left(\sum_{S=1}^{L} t_S\right) =$$

$$= A_1(t_j) = A_1(t_j + \Delta t_j). \qquad (7)$$

Functional inertness degree is referred by:

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

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

- share of permissible pauses terms (Δt_l)

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

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

-number of permissible average term interruptions

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

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

ES excessity degree

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

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

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

where P_j – probability of j component no-failure during task execution period; (k_j-1) – number of components that compose excess. Then i excessity degree of all ES

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

where S – number of ES components.

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

Each d_{zi} is calculated considering 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 states of all ES components, foresee preconceived failure (foul-up) features, control states, identify failures, reconfigurate system (system parts) structures and so on. Using event independency precondition, groups of features can be defined by one of these indexes

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

or

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

where P_K and P_K^* – probabilities, that will be possibility control approach of failure (foul-up) moment and during control will be obtained correct control results; P_I and P_I^* – probabilities, that will be preconceived failure features and they will be noticed; P_V and P_V^* – probabilities, that will be possibility manipulating avoid ES failure and succeed to do that; P_G and P_G^* – probabilities, that will be possibility detect system (component) failure and that failure will be detected.; P_R and P_R^* – possibilities, that system excessities and artificial intelligence allow to reconfigure system by eliminating improper component and it will be successfully done. Probabilities PK, PV, PR refer degrees of ES controllability, manipulatability and reorganisability, Pv and Pr – degree of artificial intelligence assuring persistence.

Conclusions

Currently DED dynamic reliability conception is at development stage. Therefore maybe further research results will force corrections of some methods, but there is no doubt that most mentioned problems will be researched in future.

Currently the most investigated is the problem of DED resistance to dynamic action assurance.

In future it's expedient to transfer the object of research to macrostructure's level, so seeking to create DED reliability dynamic, reliability control and "vitality" assurance methods.

The conception of complex system persistence is presented, persistence indexes and its estimation methods are proposed.

References

1. **Rathbone A.** Windows 95 for Dummies. Foster City, CA. Chicago, IL. Indianapolis, JN. Sonthlake, TX.: IDG Books Worldwide Inc, 1995.
2. **Balaišis P., Eidukas D., Navikas D.** Dinaminių poveikių įtakos kondensatorių patikimumui tyrimas: Elektronika ir elektrotechnika, Kaunas: Technologija, 1999. - Nr.3(21). - P.71-77.
3. **Balaišis R.J., Eidukas D., Navikas D.** Elektroninių įtaisų negendamumo vertinimas: Elektronika ir elektrotechnika, Kaunas: Technologija, 1997. - Nr.4(13). - P.7-14.