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It is represented that book articles will be interesting for experts in the field of information technologies as well as for practical users.

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CALCULATING OF RELIABILITY PARAMETERS OF MICROELECTRONIC COMPONENTS AND DEVICES BY MEANS OF VIRTUAL LABORATORY

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Abstract: *Today together with actual designing and tests it is often used virtual methods of designing, which support prior calculations of parameters of the developed devices. Such parameters include reliability. For this purpose the virtual laboratory for computer-aided design, which is developed during joint project by V.M. Glushkov Institute of Cybernetics of NAS of Ukraine and Institute of Mathematics and Informatics of BAS, contains program unit for calculating reliability parameters of separate microelectronic components and whole devices. The program unit work is based on two computing method: the first one uses exponential distribution of failure probability and the second one – DN-distribution of failure probability. Presence of theoretical materials, computing methods description and other background materials lets to use this program unit not only for designing and scientific researches, but also in education process.*

Keywords: *Virtual Laboratory; Computer-Aided Design; Reliability Calculation; Distributed System.*

ACM Classification Keywords: *J.6 Computer-Aided Engineering – Computer-Aided Design (CAD); K.4.3 Organizational Impacts – Computer-Supported Collaborative Work.*

Introduction

Modern microelectronic component base lets to develop portable devices for wide and everyday using on the base of effects and phenomena, which exist in medicine, biology, biochemistry etc. Actual design of new devices and systems, which is often used, needs a lot of time, material and human resources. These expenses may be reduced with help of virtual methods of designing, which are realized by means of virtual laboratories of computer-aided design (VLCAD) [Palagin, 2009].

VLCAD is worth to be used on the stage of the requirements specification or EFT-stage, because it gives the possibility enough fast to estimate the project realization, certain characteristics and, as a result, expected benefit of its practical realization. Using of VLCAD doesn`t need expensive actual tests and complicated equipments.

Calculating of parameters

Devices, what are developed, are, generally, data acquisition and processing channels. During designing and modeling such systems (channels) it is very important to make prior parameters calculating and evaluating. These parameters include reliability, precision, performance, cost etc.

Having only model of future device it is possible enough quickly to make prior calculating of device parameters. Also we have possibility to calculate several alternative variants of project and choose the optimal one according to user' criteria (or predetermined criteria). For prior calculating we developed and filled databases, which contain information about a large amount of microelectronic components and units. Databases contain next main parameters: 1) microelectronic component name; 2) manufacturer of microelectronic component; 3) group, to which microelectronic component belongs; 4) parameters, which are intrinsic to some group of microelectronic components, e.g. nominal currents, voltages and powers, interface types; 5) manufacturing technique;

6) reliability parameters; 7) work temperature range; 8) price; 9) body type and conditions of installing; 10) unique properties of microelectronic component.

For prior calculating of each parameter it is developed program model. Under program model we mean separate program, group of programs or program complex, which let by means of calculating sequence and graphical display of result to reproduce processes of object functioning under influence of, as a rule, random (or predetermined) factors. The model purpose is to obtain quantitative or qualitative results. Quantitative result is intended to predict some future values or explain some past values, which characterized whole systems. Qualitative results, on the base of analysis, let to detect some earlier unknown system characteristics.

Generalized graphical display of stages sequence of prior calculating is shown on the fig. 1 (portable device "Floratest" [Romanov, 2007] is as example).

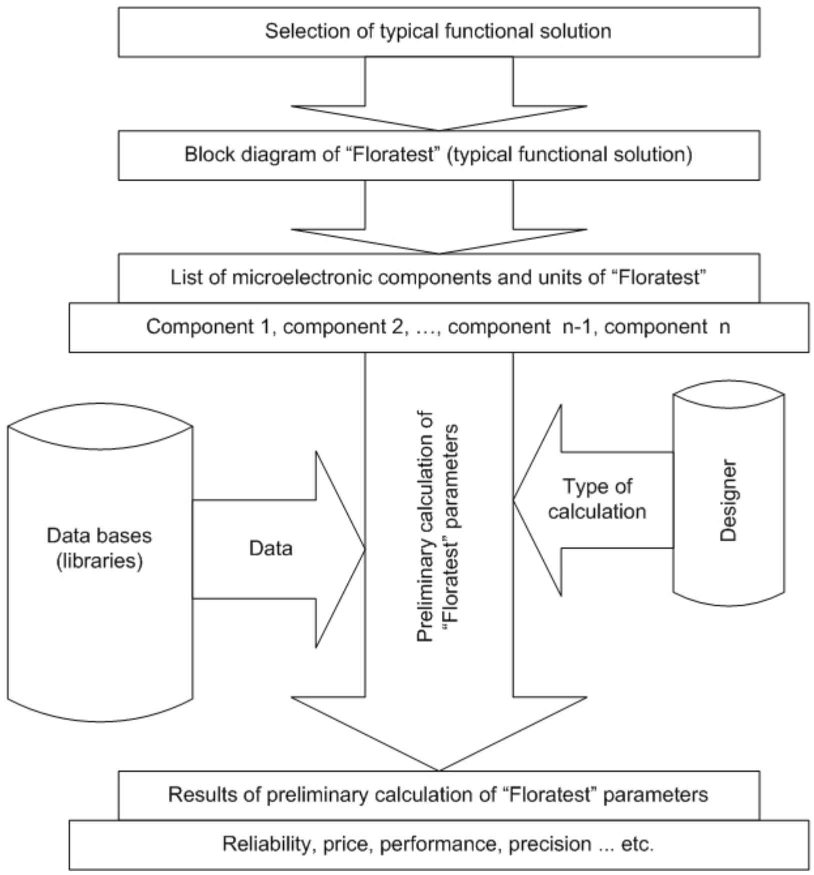

Fig. 1. Sequence of stages of prior parameter calculating of developed devices

Calculating of reliability

Most devices are generally data acquisition and processing channels. Such channels are, per se, systems without recovery, elements of which are connected serially. But meaning "series connection" doesn't always agree with physical series connection [Belyaev, 1985]. In this case we mean, that failure of any system element causes failure of whole device or channel.

Because of complexity of physical processes, which cause failures, impossibility to take account of all start conditions and random influences, in present days it is accepted to consider a failure as random event in meaning, that if we even know structure type of system and application conditions it is impossible to detect time and place of failure.

As a rule, prior evaluation of reliability parameters of separate microelectronic components is made by manufacturers on the base of results of highly accelerated stress tests [MIL-STD-883]. Reliability parameters are shown in general form and grouped by types of manufacturing technique or large classes of functional-similar components (amplifiers, converters, processors, controllers, memory etc.). Reliability level of modern microelectronic components is estimated by next characteristics:

1) failure rate λ, which measured in units FIT (failure in 10^9 hours of work);

2) mean time to failure T_0.

Mean time to failure is estimated as function of failure rate in consideration of distribution law of failure probability. Today there are many computing methods of reliability, which are based on different distribution laws of failure probability [Azarskov, 2004]. We analyzed methods, which are oriented on computer and instrumentation tools, and adapted them for realization as program models.

For prior calculating of reliability parameters of components, devices and systems it is created program unit for calculating of reliability parameters. This program unit has next features:

1) calculating reliability parameters of separate microelectronic component or whole device;

2) using different computing methods, which are based different distribution laws of failure probability;

3) selecting for calculating reliability parameters of device both component experimental data, which are got by manufacturers with help of accelerated tests, and component data, which calculated by program unit;

4) comparing of reliability parameters calculating results, which were obtained by means of different computing methods;

5) optimizing reliability index on the base of microelectronic components from VLCAD databases;

6) containing fundamentals about reliability theory, including computing sequence of reliability parameters by means of every computing method.

The work of program unit for calculating reliability parameters of microelectronic components and whole devices is based on using two computing methods, which are adapted by us for realization as program models:

1) by using exponential law of distribution of failure probability (probabilistic model of failure distribution), which is used by many manufacturers of microelectronic components;

2) by using DN-distribution of failure probability (probabilistic-physical model of failure distribution), which was proposed by Ukrainian scientists V. Strelnikov and O. Feduhin [Azarskov, 2004, Streljnikov, 2004].

Selected models of distribution have very important difference. Probabilistic model allows only two state of system elements – operable and faulty. Probabilistic-physical model considers continuous set of system element and system states with continuous time. First model uses exponential law of distribution of failure probability, the second one – DN-distribution.

As was written above the exponential law of distribution of failure probability is used by many manufacturers of microelectronic components, such as: Analog Devices Inc. [ADI, 2004], Motorola [Motorola, 1996] etc. This law of distribution is recommended by Department of Defense of USA [MIL-STD-883]. Exponential law is one-parametric function.

According to this method failure rate λ is got from experimental data of manufacturer or calculated by formula

$$\lambda = \frac{\chi^2}{2 \cdot N \cdot H \cdot At}, \qquad (1)$$

where χ^2 – function, values of which depend on component failure quantity and confidence bounds of interval and are received from [Romanov, 2003, Motorola, 1996]; N – quantity of components under accelerated tests; H –

duration of accelerated tests, hours; *At* – coefficient of failure rate acceleration, which is calculated by the formula [Streljnikov, 2002] (Arrhenius law)

$$At = e^{-\frac{Ea}{k}\left(\frac{1}{T_v}-\frac{1}{T_r}\right)}, \tag{2}$$

where *Ea* – activation energy (= 0,7 eV); *k* – Boltzmann constant (=8,617·10^-5^); T_v – temperature of accelerated tests, K; T_r – work temperature of microelectronic component, K.

Mean time to failure T_0, in accordance with exponential law, is calculated by formula

$$T_0 = \frac{1}{\lambda}. \tag{3}$$

For calculating mean time to failure T_{cp}^e (exponential law) of whole device it is used the next formula

$$T_{cp}^e = \left(\sum_{j=1}^{n} m_j \lambda_j\right)^{-1}, \tag{4}$$

where m_j – quantity of units of *j* type (*j* = 1, 2,…, *n*); λ_j – failure rate of units of *j* type.

For calculating reliability parameters by means of second adapted method it is used DN-distribution of failure probability, which is two-parametric function as opposed to exponential law. In [Azarskov, 2004, Streljnikov, 2004] it is shown, that by using DN-distribution it is possible to get result, which are more close to real data.

For calculating reliability parameters of microelectronic components by means of DN-distribution it was updated and adapted algorithm, which is shown in [Azarskov, 2004]. It will be shown on the example the features of every method. For this it is necessary to calculate mean time of test of every sample by formula

$$t_н = \frac{EDH}{N}, \tag{5}$$

where *EDH* – parameter "equivalent device hours", which can be found in the manufacturer documentation, manufacturer web-site or calculated by formula

$$EDH = N \cdot H \cdot At. \tag{6}$$

Mean time to failure T_0 is calculated by substitution of values λ and $t_н$ in formula (λ can be calculated by (1) or found in the manufacturer documentation)

$$\lambda = \frac{f(t_н)}{R(t_н)}, \tag{7}$$

$$\text{where } f(t_н) = \frac{\sqrt{T_0}}{t_н\sqrt{2\pi t_н}}\exp\left[-\frac{(t_н - T_0)^2}{2T_0 t_н}\right]; \tag{8}$$

$$R(t_н) = \Phi\left(\frac{T_0 - t_н}{\sqrt{T_0 t_н}}\right) - \exp(2)\cdot\Phi\left(-\frac{t_н - T_0}{\sqrt{T_0 t_н}}\right). \tag{9}$$

Since during experimental evaluation of failure rate of microelectronic components the rate of microelectronic components with failures is 1…5 % [Streljnikov, 2004], so it is possible to consider $\lambda \approx f(t_н)$. So, the formula (7) can be written as

$$\lambda \cong \frac{\sqrt{T_0}}{t_н\sqrt{2\pi t_н}}\exp\left[-\frac{(t_н - T_0)^2}{2T_0 t_н}\right]. \tag{10}$$

For calculating mean time to failure T_{cp}^D (DN-distribution) of whole device it is used next formula

$$T_{cp}^{D} = \left(\sum_{j=1}^{n} m_j T_j^{-2} \right)^{-\frac{1}{2}} . \qquad (11)$$

Computing algorithms of reliability parameters by means of these two methods are shown on fig. 2. Program unit, which is developed by authors, is a part of VLCAD and operates on the base of these computing algorithms.

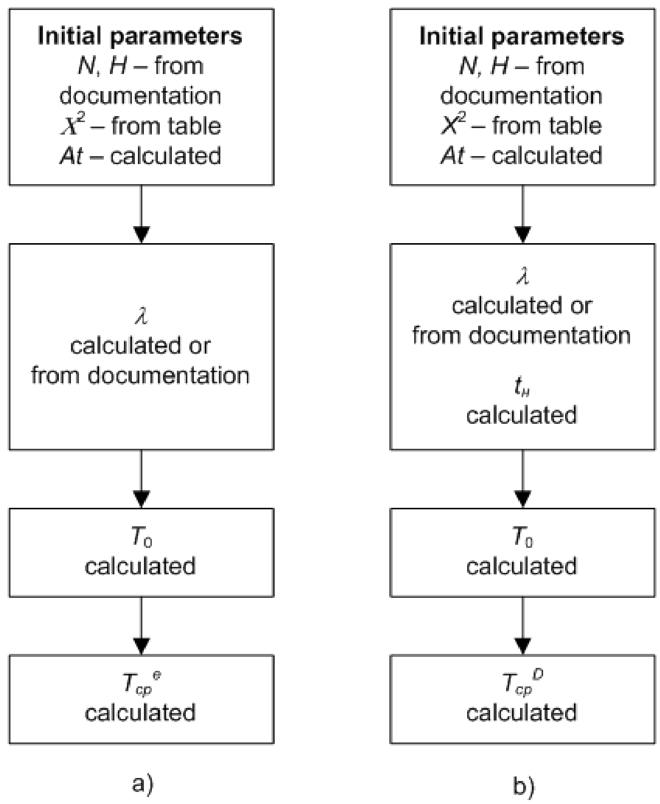

Fig. 2. Computing algorithms of reliability parameters with using of exponential law of distribution of failure probability (a) and DN-distribution of failure probability (b)

Using developed program unit it were obtained dependences of system operating reliability versus time. For simplifying it is considered, that system consists of same microelectronic components, that are manufactured by means of same manufacturing technique (e.g. "Bipolar < 2.5 μm^2"). Should note, that program unit allows to calculate reliability parameters of systems, which consist of different quantities of microelectronic components, manufactured by means of different manufacturing technique. Dependences were obtained for 4 systems, which consist of 1 thousand, 10 thousand, 20 thousand and 100 thousand microelectronic components respectively. Confidence bounds equal 60 %. Dependences, obtained by means of method on the base of exponential law of distribution of failure probability, are shown on fig. 3 and fig. 4. Dependences, obtained by means of method on the base of DN-distribution of failure probability, are shown on fig. 5.

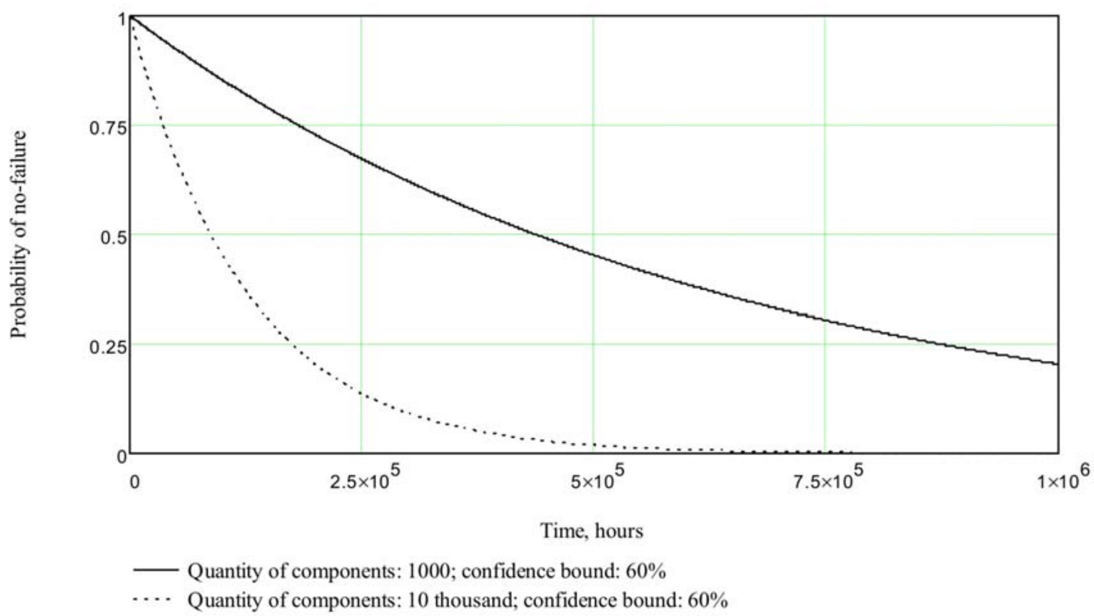

Fig. 3. Dependence of probability of system operating reliability (1 000 and 10 000 components) versus time, exponential law of distribution of failure probability

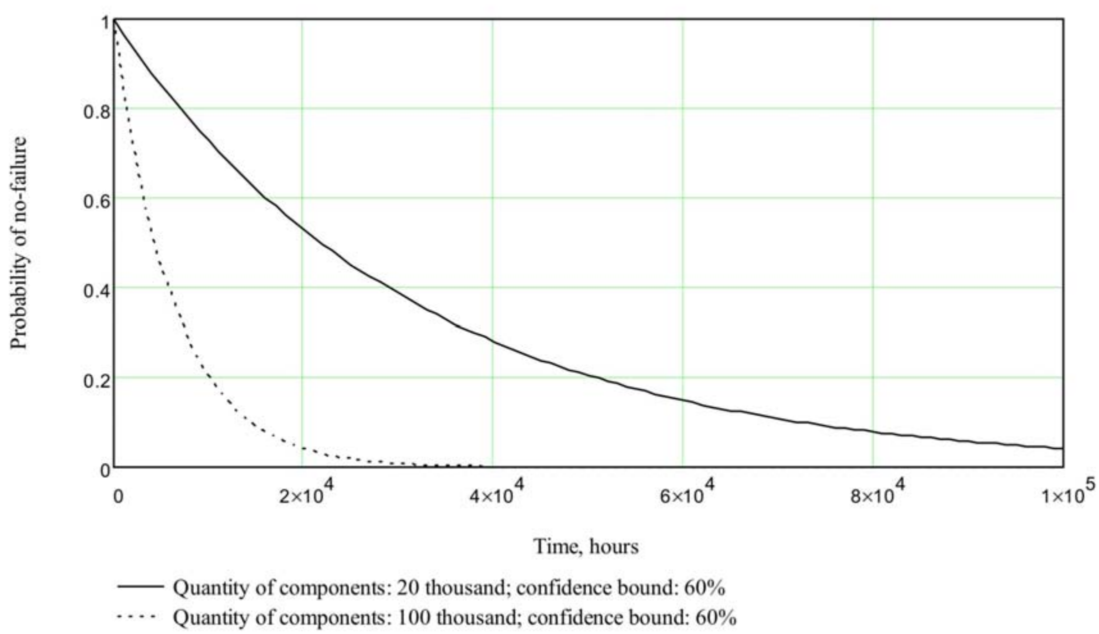

Fig. 4. Dependence of probability of system operating reliability (20 000 and 100 000 components) versus time, exponential law of distribution of failure probability

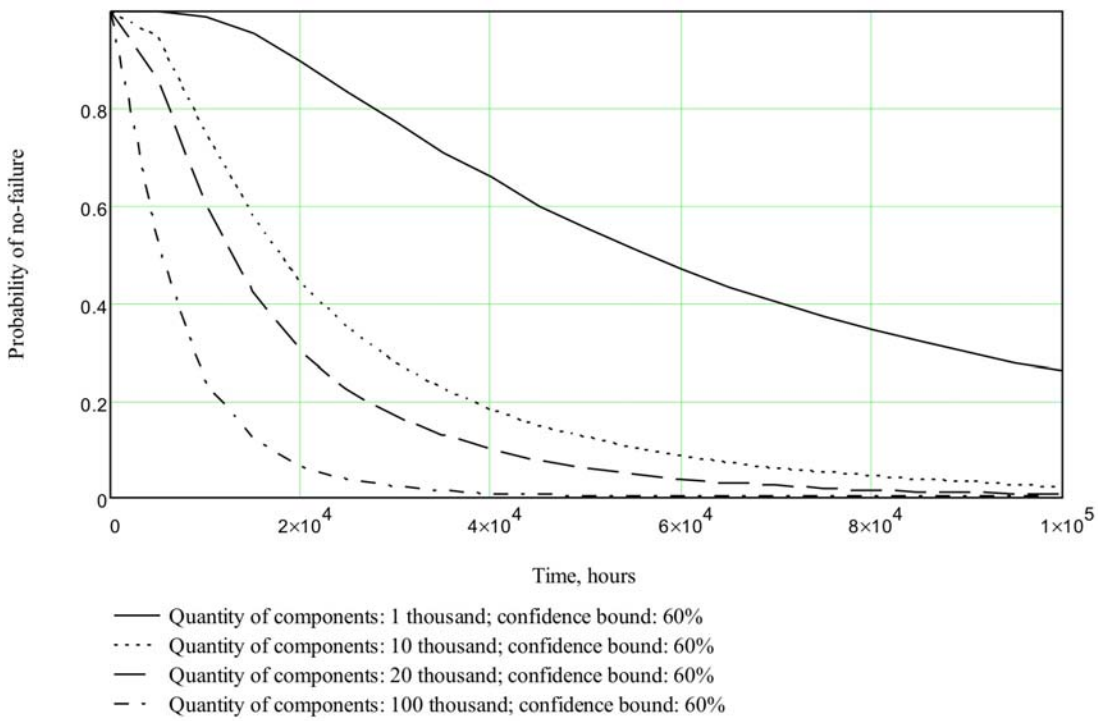

Fig. 5. Dependence of probability of system operating reliability (1 000, 10 000, 20 000 and 100 000 components) versus time, DN-distribution of failure probability

Combine some calculated values to the table for more detail analysis of obtained dependences (table 1). For more visualization the table data are used for plotting graphic (fig. 6). Should note, that, as in previous cases, system consists of same microelectronic components, that are manufactured by means of same manufacturing technique "Bipolar < 2.5 μm^2".

Table 1. Duration of no-failure operation of systems, which consist of different quantities of components

Quantities of micro-electronic components	T_0	Exponential law of distribution		DN-distribution	
		CB* = 60 %	CB = 90 %	CB = 60 %	CB = 90 %
1 000	hours	629723	320256	82298	76647
	years	71,886	36,559	9,395	8,749
20 000	hours	31486	16372	18402	17139
	years	3,594	1,869	2,101	1,956
50 000	hours	12594	6549	11639	10840
	years	1,438	0,748	1,329	1,237
100 000	hours	6297	3274	8230	7665
	years	0,719	0,373	0,939	0,875
200 000	hours	3149	1637	5819	5420
	years	0,359	0,187	0,664	0,619

* CB = Confidence bounds

It was analyzed systems, which consist of from 1 thousand to 200 thousand microelectronic components. Such range of components wasn't selected by accident. On this range according to our analysis it is happened some changes in ratio of reliability parameters, which were calculated by two methods.

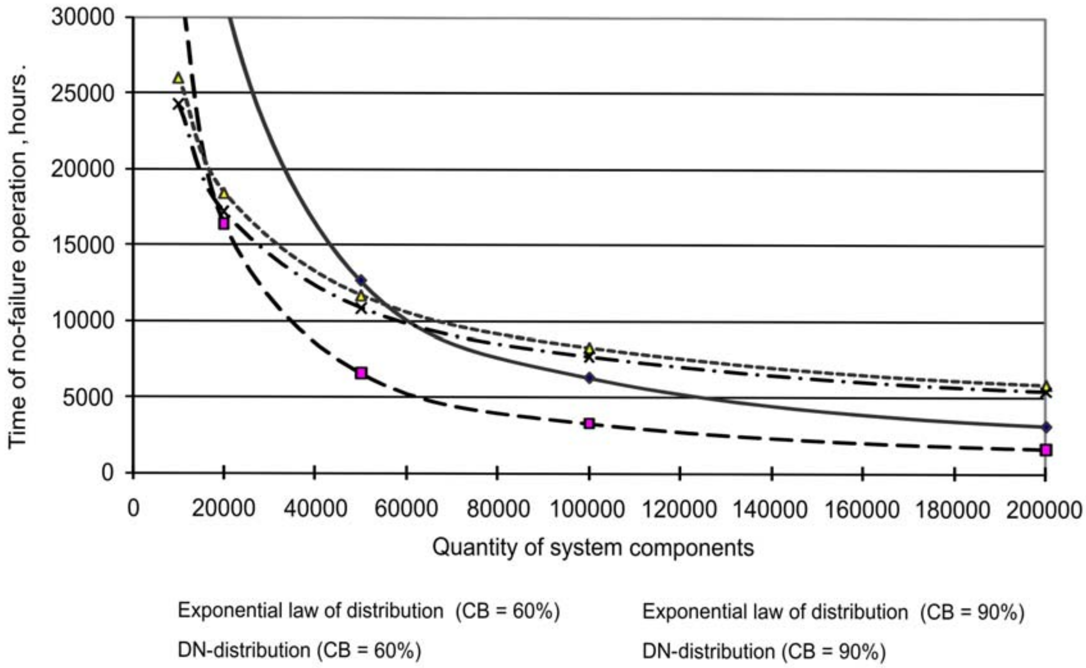

Fig. 6. Dependence of duration of no-failure operation of systems, which consist of different quantities of components, versus quantities of system components

Having analyzed graphics (fig. 3–6) and table 1, it is possible to make next conclusions. For every confidence bound (in our case there are 60 % and 90 %) there is such system components quantity, below of which the method on basis of exponential law of distribution overstates the reliability parameters, and above of which – puts too low them. For confidence bound 60 % this quantity equals approximately 60 thousand components, and for confidence bound 90 % – respectively 20 thousand. The difference of results, that are obtained by means of these two computing methods, can be explained by method error [[Streljnikov, 2004]. The method error becomes apparent, because exponential law of distribution is one-parametric function, while DN-distribution is two-parametric function or, in other words, diffusive distribution.

Our conclusion conforms very well with test and computing results, which were fulfilled by Ukrainian scientists in the field of reliability theory [Streljnikov, 2005]. Should note, that results in article were obtained for the first time thanks to using developed virtual (program) models of computer tools.

Program models were used for calculating reliability parameters (e.g. time of no-failure operation) of portable device for express-diagnostic of plant state "Floratest", which is developed and created in the V.M. Glushkov Institute of Cybernetics of NAS of Ukraine.

Conclusion

Presence of program unit for reliability parameters calculating as a part of VLCAD allows to fulfill prior calculating of reliability parameters of designed device and, on the basis of obtained results, make conclusion about correspondence of calculated parameters to beforehand specified ones. Positive features of program unit is availability of two methods of reliability parameters calculating of separate microelectronic components and whole devices, which are based on different models of distribution of failure probability (one- and two-parametric functions).

Program unit can be used not only for calculating of reliability parameters, but in education process for gaining theoretical information from reliability theory.

Program unit now is used in practical tasks for calculating reliability parameters of portable devices.

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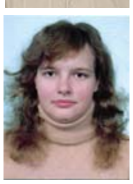

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