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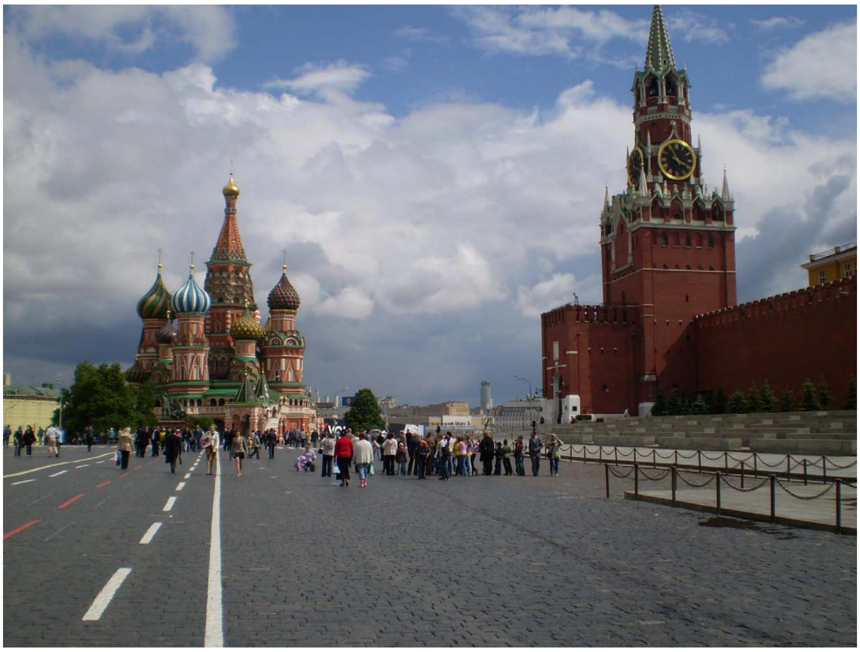

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Estimation of Durability Indices of Integrated Microcircuit Communication Network

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Abstract – The paper offers methodology for estimation of durability indices of the modern integrated circuit communication network, which has reports about the conducted tests on non-failure operations and conservability, but has no data for the durability. The paper describes two approaches, which apply for generation of basic data and which allow to receive reliable result, typical for the certain operating conditions.

Keywords - reliability; durability; gamma-percentile operating life; minimal operating time; integrated circuit, non-failure operation, conservability.

I. INTRODUCTION

Durability – object property to keep working capacity before beginning of limit state, i.e. beginning of the state, when the object should be sent on repair (medium or capital) or seized from the maintenance.

Quantitative estimation of durability indices of electro-radio equipment, particularly gamma-percentile operating life or minimal operating time leads to formation oa base data and carrying out of mathematical calculations. For this procedure has been developed special methodology, which allows by calculation to estimate quantitative values (pictute 1).

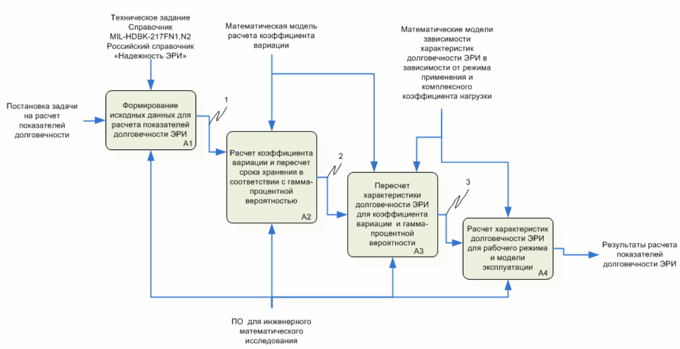


Fig. 1. Methodology of determination by calculation of quantitative values of durability indices of electro-radio equipment

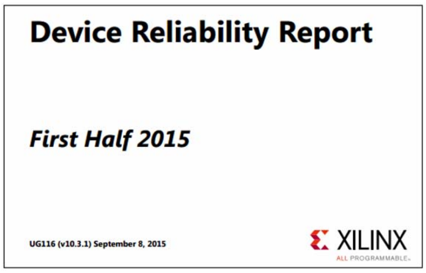
II. BASIK DATA GENERATION

For generation of basic data (block A1, fig. 1) is recommended to use reports about reliability of producer company about non-failure tests. Example of the title page of the report is shown on fig. 2.

For all types of electro-radio equipment it is necessary to determine company and country producer. For this purpose it is recommended to use electronic resource [2] for task solution searching Data Sheet. Thereafter can be applied one of two approaches, which has one feature connected with collection of basic data. Below is stated description of each approach.

A. Application of final table about tests on non-failure operations on official websites of producer company.

For consideration of this approach as an example was selected producer company «Xilinx», which produces programmable logic device (PLD). Figure 2 shows title page with the reliability report in the first half of 2015.


Device Reliability Report

First Half 2015

UG116 (v10.3.1) September 8, 2015

XILINX
ALL PROGRAMMABLE.

Fig. 2. Title page with the reliability report

In the reliability reports are stated data about tests in the form of total table (fig. 3) or free table on the results of tests (fig. 4 and 5), which shows type of electro-radio equipment (Device), time of tests by temperature 125 ^{0}C (Equivalent device hours at Tj = 125 ^{0}C), device quantity, fail quantity and parameters of the tests (temperature of tests Tj = 125 ^{0}C).

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Device	Lot Quantity	Fail Quantity	Device Quantity	Actual Device Hours at $T_J \geq 125°C$	Equivalent Device Hours at $T_J = 125°C$	Failure Rate at 60% CL and $T_J = 55°C$ (FIT)
XC95xxxXL	21	0	1145	1,713,331	2,249,429	5
XCRxxxXL	12	0	535	1,074,715	1,076,451	11
XC2Cxxx/A	12	0	538	1,059,372	1,062,604	11

Fig. 3. Summary of HTOL Test Results

Devices	Lot Quantity	Fail Quantity	Device Quantity	Actual Device Hours at $T_J \geq 125°C$	Equivalent Device Hours at $T_J = 125°C$	Failure Rate at 60% CL and $T_J = 55°C$ (FIT)
XC2C128	2	0	90	181,350	181,690	
XC2C256	5	0	223	426,942	428,364	
XC2C384	4	0	180	360,990	361,868	
XC2C512	1	0	45	90,090	90,682	
XC2Cxxx/A	12	0	538	1,059,372	1,062,604	11 FIT

Fig. 4. HTOL Test Results of 0.18 µm Si Gate CMOS Device

Device	Lot Quantity	Fail Quantity	Device Quantity	Total Device Hours
XC2C64A	2	0	83	83,000
XC2Cxxx/A	2	0	83	83,000

Fig. 5. THB Test Results for Si Gate CMOS Device

By using of the total table (fig. 3) is selected failure rate of the crystal ($\lambda_{кр}$) equal Failure Rate, measured in FIT - failure in 109 component hours or one failure in 109 operating time hours and substituted in the calculation model of failure rate class «Integrated circuit» from the Russian data book «Nadezhnost' ERI» [6]:

$$\lambda_e = (\lambda_{cr} \cdot K_t + \lambda_{corp} \cdot K_e) \cdot K_{pr}, \qquad (1)$$

λ_{cr} – failure rate of the crystal; K_t –temperature coefficient; λ_{corp} – failure rate of the frame; K_e – stiffness coefficient of service conditions; K_{pr} – impact coefficient of production quality.

Failure rate of the frame $\lambda_{корп}$, enters into equation (1) determines by the model from the Russian data book «Nadezhnost' ERI IP» [5]:

$$\lambda_{корп} = 2.8 \cdot 10^{-4} \cdot N^{1.08}, \qquad (2)$$

N – pinouts quantity of microcircuit.

For equation (1) temperature coefficient K_t determines from the Russian data book «Nadezhnost' ERI IP» [5]:

$$K_t = 0.1 \cdot e^{-\frac{E_a}{8.617 \cdot 10^{-5}} \cdot \left(\frac{1}{T_j + 273} - \frac{1}{298}\right)} = 1.21, \qquad (3)$$

E_a – energy of activation from the Russian data book «Nadezhnost' ERI IP» [5]; T_j – crystal temperature.

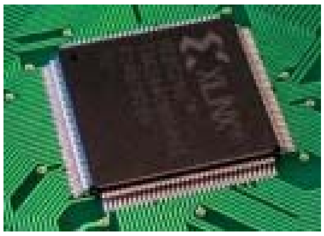

Fig. 6. Integrated microcircuit type «XC2C128-TQ144»

Inputting in the equation (1) values, obtained under the models (2) and (3), receives failure rate of integrated microcircuit type «XC2C128-TQ144» by $E_a = 0.7$; $N = 144$; $T_j = 55\ ^0$C; $K_{pr} = 10$, equal: $\lambda_э = 4.33 \cdot 10^{-7}$ h^{-1}.

B. Application of summary table about tests on official websites of producer company.

If the total table missing in the reliability report (fig. 3) it is necessary to use data from the summary table about the tests results (fig. 4 and 5) from which can be received following information:

- test period (1062604 h.);
- device quantity (538 pc.);
- selection (12 pc.);
- fail quantity (0 шт.);
- crystal temperature by the tests (125 ^{0}C);
- confidence probability (60%).

Using above mentioned parameters and calculation model from [8], reform on the unit of measurement [h], let's make the calculation:

$$\lambda_{кр} = \frac{\chi^2}{2 \cdot N \cdot A}, \qquad (4)$$

χ^2 – value chi-squared distribution by the determined confidence probability with $(2 \cdot f + 2)$ degree freedom – quantity of failure; N – general number of tests hours; A – speedup coefficient, determines by the model (5).

$$A = \exp\left(\frac{E_a}{k} \cdot \left(\frac{1}{T_{j1}} - \frac{1}{T_{j2}}\right)\right), \qquad (5)$$

E_a – energy of activation, determines from the Russian data book «Nadezhnost' ERI IP» [5]; k – Boltzmann constant; T_{j1} – operating temperature, ^{0}K (in our case 328 ^{0}K); T_{j2} – limiting temperature, ^{0}K (in our case 398 ^{0}K).

By model (4) calculated λ_{cr}, using above mentioned data and receive the value $\lambda_{cr} = 11\ 10^{-}$ h^{-1}.

Further using model (1), make calculation of failure rate of integrated microcircuit type «XC2C128-TQ144» and receive $\lambda_e = 4.33\ 10^{-7}$ h^{-1}.

Using GOST PB 20.57.414 [3] determine gamma-percentile probability γ by the known value of selection (in our case equal 12 – fig. 3), hence $\gamma = 0.9$ (fig. 7).

P_0	0,9	0,95	0,96	0,97	0,98	0,99	0,995
n, шт.	15	30	40	50	80	150	320

Fig. 7. Relation of the volume of selection from the probability of failure-free operation.

Sometimes is used specified model from the GOST PB 20.57.414 [3]:

$$\gamma = \frac{100 \cdot n - 100}{n}, \tag{6}$$

n – Volume of selection, pc.

Using model (6) receive $\gamma = 0.917$.

In some technical data (Data sheet) (particularly producer company «Xilins» [8]) is stated shelf life (for example, 20 years. – fig. 8).

Symbol	Description	Min	Max	Units
T_{DR}	Data retention	20	–	Years

Fig. 8. Shelf life of integrated microcircuit type «XC2C128-TQ144»

Consequently all basic data, which is necessary for calculation of durability indices of integrated microcircuit was received.

III. ESTIMATION OF RESOURCE AND MINIMAL OPERATING TIME

For realization of block A2 (fig. 1) we will check correctness of basic data. For this purpose calculate the gamma-percentile resource $T_{p.\gamma}$ by the model from the GOST PB 20.57.414 [3]:

$$\mathrm{T}_{p.\gamma=90\%} = -\frac{\ln 0,9}{\lambda e} = 243 \text{ ths. h.}, \tag{7}$$

λ_e – failure rate of integrated microcircuit type «XC2C128-TQ144» (calculation is above).

Let's calculate shelf life $T_{p.\gamma}(xp)$ by the model 8 in the values of gamma-percentile operating life (fig. 8):

$$\mathrm{T}_{p.\gamma=90\%}(\mathrm{xp}) = \frac{1 - v \cdot \chi_{\gamma=90\%}}{1 - v \cdot \chi_{\gamma=99,9\%}} \cdot 20 \cdot 365 \cdot 24 = 350 \text{ ths. h.}, \tag{8}$$

Value of coefficient of variation electro-radio equipment (v) for model (8) is calculated by the following form:

$$\frac{1 - v \cdot \chi_\gamma}{1 - v \cdot \chi_{\gamma=99,9\%}} = \frac{T_{r.\gamma}}{T_{m.n.}}, \tag{9}$$

γ for χ_γ is selected independently (based on the task) by the model , which is stated on figure 9.

№ п/п	γ, %	χ
1	2	3
1	80,00	0,842
2	81,00	0,878
3	82,00	0,915
4	83,00	0,954
5	84,00	0,994
6	85,00	1,036
7	86,00	1,080
8	87,00	1,126
9	88,00	1,175
10	89,00	1,227
11	90,00	1,282
12	91,00	1,341
13	92,00	1,405
14	93,00	1,476
15	94,00	1,555
16	95,00	1,645
17	96,00	1,751
18	97,00	1,881
19	98,00	2,054
20	99,00	2,326
21	99,90	3,090
22	99,99	3,719

Fig. 9. Quantile of the normal distribution

If the value of gamma-percentile operating life $T_{p.\gamma}$ and minimal operating time $T_{м.н}$ is missing in the Russian data book Nadezhnost' ERI [6] and Nadezhnost' ERI IP [5], according to the GOST [4] its relation is equal 2.

For our case $v = 0.204$ by the model (9). And in further calculations coefficient of variation is invariable.

Make the re-calculation of gamma-percentile operating life of electro-radio equipment to the gamma-percentile operating life (for $\gamma = 98\%$) (Realization of block A3 – fig. 1):

$$\mathrm{T}_{p.\gamma=98\%}(\mathrm{xp}) = \frac{1 - v \cdot \chi_{\gamma=98\%}}{1 - v \cdot \chi_{\gamma=90\%}} \cdot \mathrm{T}_{p.\gamma=90\%}(\mathrm{xp}) = 275 \text{ ths. h.}, \tag{10}$$

$$\mathrm{T}_{p.\gamma=98\%} = \frac{1 - v \cdot \chi_{\gamma=98\%}}{1 - v \cdot \chi_{\gamma=90\%}} \cdot \mathrm{T}_{p.\gamma=90\%} = 191 \text{ ths. h.}, \tag{11}$$

Make calculation of gamma-percentile operating life of electro-radio equipment for operating mode by the model of exploitation (realization block A4 –fig. 1):

$$T_{p.\gamma}(\text{work}) = \frac{1}{\frac{1}{T_{p.\gamma=98\%}(\text{xp})} + \frac{\frac{1}{T_{p.\gamma=98\%}} - \frac{1}{T_{p.\gamma=98\%}(\text{xp})}}{\Pi_{\max_{TU}}} \cdot \Pi_{work}} = 256 \quad (12)$$

Value of complex load factor (Π_{maxTIU}и Π_{work}) determines in the data book Nadezhnost' ERI IP [5].

Also calculate the value of mean life and minimal operating time (by γ = 98%) for operating mode by the model of exploitation:

$$T_{r.sp}(work) = \frac{1}{1 - \nu \cdot \chi_{\gamma=98\%}} \cdot T_{p.\gamma}\text{work} = 440 \text{ ths.h.} \quad (13)$$

$$T_{m.n}(\text{work}) = (1 - \nu \cdot \chi_{\gamma=99,9\%}) \cdot T_{r.sr}(\text{work}) = 127 \text{ ths.h.} \quad (14)$$

IV. CONCLUSIONS

Suggested in the paper engineering methodology for estimation of durability indices of modern integrated microcircuit communication network, having non-failure and conservability indices, allows to determine durability indices taking into account well-known model of exploitation composed of communication network.

The paper shows calculation for the modern integrated microcircuit type «XC2C128-TQ144», unequivocally confirms correctness of the suggested methodology.

The paper describes 2 approaches, which can be used for formation of basic data for calculation of durability indices. Both approaches allows to receive reliable result, which is particular to the concrete service conditions.

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