International Scientific – Practical Conference «INFORMATION INNOVATIVE TECHNOLOGIES», 2018

MODEL OF ELECTRONIC COMPONENTS FAILURES FOR USE IN SIMULATION

Zhadnov V.V.

National Research University "Higher School of Economics" +7 (495) 916-88-80, vzhadnovt@hse.ru

Abstract – The problems of creating a model of electronic component failures for simulation of electronic equipment failures are considered. The model is designed to calculate the realizations of developments of electronic components in simulation. Unlike standardized models of failures of electronic components, the proposed model allows simultaneously to take into account their characteristics of non-failure, durability and storageability.

Keywords – electronic component, reliability, failure model, simulation.

INTRODUCTION

The dependability model is a mathematical model of the electronic component used to dependability prediction [1]. Analysis of normative documents [2-4] showed that for dependability prediction of electronic components, models that are functions of time distribution are used. In [5], such distribution functions are called the failure model. As follows from [2, 4], the exponential distribution of the operating time to failure is used to estimate the reliability and storability, and the normal distribution of the life is used to estimate the durability [3].

PROBLEM STATEMENT

One of the reasons that determined the set of failure models in [5] is that "... dependability prediction by numerical methods and modeling methods do not meet the requirements of engineering practice". This may have been true in the 1980s, but it is hardly relevant at the present time. In addition, in [6] it is stated that "the universal method of dependability prediction ... is the method of statistical modeling". However, this method is used mainly to calculate indicators of the type of "operating time to failure" (the method of numerical integration). At the same time, the development of methods for simulation of failure processes of electronic equipment necessitates the creation of such models of failures that would allow to obtain adequate values of realizations of developments on the basis of reference data on the dependability characteristics of electronic components.

The dependability characteristics of electronic components are given in the Data Sheet and are systematized in the Hand Book [7]. These include:

- base failure rate in the operating mode;
- gamma-percentile life;
- minimum operating time;
- minimum storage time;
- base failure rate in the storage mode.

In addition, the Hand Book [7] provides mathematical models of failure rates for operating and storage modes and numerical values of their coefficients.

SOLUTION OF THE PROBLEM

Consider the process of building a model of failures using an example of resistors R1-11 [8]. Permanent metal-dielectric general use resistors R1-11 (see fig. 1) intended for use in electrical DC, AC and pulse currents.

International Scientific – Practical Conference «INFORMATION INNOVATIVE TECHNOLOGIES», 2018



Fig. 1. Resistor R1-11 type

For this resistor in the Hand Book [7] the following data are given:

- base failure rate in the operating mode $\lambda_6 = 0.063 \cdot 10^{-6}$ Failures/Hours;
- 95-percentile life $T_{p,\gamma}$ = 60000 Hours our (in all modes according to specifications); minimum operating time $T_{\rm H.M}$ = 30000 Hours (in all modes according to specifications);
 - minimum storage time $T_{xp.m} = 20$ Years;
 - base failure rate in the storage mode $\lambda_{xp,6} = 0,0072 \cdot 10^{-8}$ Failures/Hours;

In addition, the specifications gives the value of the maximum operating temperature at a nominal power of dissipation equal to 70 °C.

Using these data and techniques, given in [2-4], we consider the process of obtaining the realization of the operating time of the resistor for the maximum permissible operation mode.

It follows from [2] and [4] that the operating time in the operating and storage mode is a random variable distributed according to the exponential distribution. It follows from [3] that the resource is a random variable distributed according to the normal distribution.

The value of the failure rate in the operating mode (λ_2) is calculated from the model of the Hand Book [7]:

$$\lambda_{\mathfrak{g}} = \lambda_{\mathfrak{G}} \cdot K_{\mathfrak{p}} \cdot K_{\mathfrak{R}} \cdot K_{\mathfrak{m}} \cdot K_{\mathfrak{craf}} \cdot K_{\mathfrak{g}} \cdot K_{\mathfrak{mp}}$$

For definiteness, take the resistor R1-11-0,25-4,7kOm±5%. Then:

$$\lambda_2 = 0.063 \cdot 10^{-6} \cdot 1.71 \cdot 0.7 \cdot 0.7 \cdot 1.1 \cdot 1 = 0.0527877 \cdot 10^{-6}$$
 Failures/Hours.

It is assumed in the calculation that the quality factor is "5", and environment factor is 1.1.

The value of the mathematical expectation $(m(t_p))$ and the standard deviation $(\sigma(t_p))$ can be found using the formula (1) given in [3]:

$$T_{\text{HM}} = \frac{1 - \mathbf{v} \cdot \boldsymbol{\chi}_{\gamma_1}}{1 - \mathbf{v} \cdot \boldsymbol{\chi}_{\gamma}} \cdot T_{\text{p}\gamma} \qquad . \tag{1}$$

Taking into account that in $[3]_1 = 99.9\%$, substitute the numerical values in the formula (1) and solve it with respect to the coefficient of variation (v), we get:

$$T_{_{\rm H.M}}\!=\!\frac{1\text{--}v\cdot\chi_{\gamma_{\!_{1}}}}{1\text{--}v\cdot\chi_{\gamma_{\!_{2}}}}\!\cdot\!T_{_{\rm p.7}}\Longrightarrow 30000\!=\!\frac{1\text{--}v\cdot3,09}{1\text{--}v\cdot1,645}\cdot60000\Longrightarrow v\!=\!0,22\,.$$

Then:

$$m(t_p) = \frac{1}{1 - v \cdot \chi_{\gamma}} \cdot T_{p,\gamma} = \frac{1}{1 - 0.22 \cdot 1.645} \cdot 60000 = 94029 \text{ Hours};$$

 $\sigma(t_p) = v \cdot m(t_p) = 0.22 \cdot 94029 = 20686 \text{ Hours}.$

International Scientific – Practical Conference «INFORMATION INNOVATIVE TECHNOLOGIES», 2018

When simulating with the help of a random number generator, the implementation of the basic random variable (x) is obtained and for it the implementations of the operating time ($\hat{t}_{\rm H}$) and the life $(\hat{t}_{\rm p})$ are calculated.

Based on the values of (\hat{t}_H) and (\hat{t}_P) , we find the value of the operating time of the resistor ($\hat{t}_{H_{9K}}$), based on the following considerations.

Since by definition $T_{\text{\tiny H.M}}$ is the time during which the failure of the electronic component is not possible and it should be considered as a parameter of the life allocation function shift. In this case, if $\hat{t}_{\text{\tiny II}} \leq T_{_{\text{\tiny H.M}}}$ and $\hat{t}_{\text{\tiny P}} \leq T_{_{\text{\tiny H.M}}}$, then $\hat{t}_{_{^{\text{\tiny II}}}\!_{\text{\tiny OK}}} = T_{_{\text{\tiny H.M}}}$ (in our example, $\hat{t}_{_{^{\text{\tiny H}}\!_{\text{\tiny OK}}}} = 30000$ Hours.).

Otherwise, there are three options:

$$\hat{t}_{p} > \hat{t}_{n}; \tag{2}$$

$$\hat{t}_{p} < \hat{t}_{H}; \qquad (3)$$

$$\hat{t}_{p} = \hat{t}_{H}. \qquad (4)$$

$$\hat{t}_{p} = \hat{t}_{H}. \tag{4}$$

Obviously, in the first two variants, as a criterion for choosing a particular value $\hat{t}_{H_{2K}}$, one should take:

$$\hat{t}_{H_{SK}} = \min(\hat{t}_p, \hat{t}_H). \tag{5}$$

In order to determine how true (2), we calculate the values \hat{t}_{H} for x = 0.999.

$$x = \exp(-\lambda_9 \cdot \hat{t}_H) \Rightarrow \hat{0}, \hat{9}\hat{9}\hat{9} = \exp(-\hat{0}, \hat{0}\hat{5}\hat{2}7\hat{0}77 \cdot \hat{1}\hat{0}^{-6} \cdot \hat{t}_H) \Rightarrow \hat{t}_H = 18953 \text{ Hours.}$$

The obtained result of $\hat{t}_{\text{H}} < T_{\text{H.M}}$ indicates that the function of the exponential distribution decreases faster than the normal one.

Let's find the value x_1 for $\hat{t}_H = T_{H.M.}$:

$$x_1 = \exp(-\lambda_s \cdot \hat{t}_H) = \exp(-0.0527877 \cdot 10^{-6} \cdot 30000) = 0.998417$$
.

From this it follows that in order to ensure that condition (5) is satisfied for $t \geq T_{\text{H.M.}}$ only from $x \ge 0.998417$ it is necessary to calculate $\hat{t}_{\text{H}_{\text{DK}}}$ as $\hat{t}_{\text{H}_{\text{DK}}} = \hat{t}_{\text{H}}$.

Obviously, as the value x decreases, the value \hat{t}_{H} will increase, and faster than the value \hat{t}_p . In confirmation of this we find the values \hat{t}_H and \hat{t}_p for x = 0.997.

$$0,997 = \exp\left(-0,0527877 \cdot 10^{-6} \cdot \hat{t}_{\text{H}}\right) \Rightarrow \hat{t}_{\text{H}} = 56916 \text{ Hours.}$$

$$\hat{t}_{p} = \left(\mathbf{i} - \mathbf{v} \cdot \chi_{\gamma=0,997}\right) \cdot m(t_{p}) = \left(1 - 0,22 \cdot 2,75\right) \cdot 94029 = 37141 \text{ Hours.}$$

As follows from the calculations performed, at the value $x \ge x_2$, condition (3) begins to be fulfilled and then it is necessary to calculate $\hat{t}_{_{\rm H_{\rm DK}}}$ as $\hat{t}_{_{\rm H_{\rm DK}}}=\hat{t}_{_{\rm p}}$.

The value x_2 can be more easily determined from the equation:

$$x_2 = \exp(-\lambda_3 \cdot y),$$

where *y* is a solution of the equation:

$$e^{-\lambda_{3} \cdot y} = \frac{1}{\sqrt{2 \cdot \pi}} \cdot \int_{-\infty}^{y} e^{\frac{\left[t_{p} - m(p)\right]^{2}}{2\sigma(t_{p})^{2}}} dt_{p}.$$
 (6)

To solve equation (6), we can use, for example, the dichotomy method.

International Scientific – Practical Conference «INFORMATION INNOVATIVE TECHNOLOGIES», 2018

Since the function P(t) is defined on the interval $[-\infty, +\infty]$, then as $x \to 0$ $\hat{t} \to +\infty$, and, consequently, and. This contradicts common sense, tk. This contradicts common sense, since the life can not be longer than the storability time.

However, in [4], the methods for calculating the storability time of electronic components are not given, but in [10] it was shown that the calculation of the shelf life is analogous to the calculation of their life. Using the generally accepted assumption that ν in mode of operation and storage (standby) can be regarded as a constant, and the gamma-percentage probability (γ_{xp}) for which we will calculate the maximum value of the storability time in the standby mode ($T_{xp.max}$), by analogy with γ_1 is set to 99.9%. Taking into account that 20 years is 175200 hours, we will receive:

$$T_{xp.max} = \frac{1+v \cdot \chi_{\gamma_{xp}}}{1-v \cdot \chi_{\gamma_{xp}}} \cdot T_{xpM} = \frac{1+0.22 \cdot 3.09}{1-0.22 \cdot 3.09} \cdot 175200 = 919116 \text{ Hours (105 Years)}.$$

Using the formula for recalculating the storability time to the specified conditions of the storage mode (standby) from [9]:

$$T_3 = \frac{T_{xp.max}}{K_{xx} \cdot K_2} \tag{7}$$

for a maximum operating temperature 70 °C C and operating group 1.1, we obtain:

$$T_3 = \frac{919116}{1.3 \cdot 1} = 707012$$
 Hours (80,7 Years).

We find the value x corresponding to this value of the storage time in the storage (standby) mode. For this, we set $\hat{t}_{p_3} = T_3$:

$$\hat{t}_{p_3} = (1 + v \cdot \chi) \cdot m(t_p) \Rightarrow 707012 = (1 + 0.22 \cdot \chi) \cdot 94029 \Rightarrow \chi = 4.476.$$

For $\chi = 4.5$, the probability is 0.999997. Then:

$$x_3 = 1 - 0,999997 = 0,000003$$
.

For comparison, we find the value x for the exponential model:

$$x_3 = \exp(-\lambda_3 \hat{t}_{P_3}) = \exp(-0.0527877 \cdot 10^{-6} \cdot 707012) = 0.963$$
.

As can be seen from the obtained results, the values of the normal distribution function decrease faster than the exponential function. Then at $x_3 \ge 4.476 \hat{t}_{H_{3K}} = 707012$ Hours.

Thus, the failure model of the electronic component is a distribution function whose argument in the interval [1, x_1] is equal to T_{HM} (see fig. 2), in the interval [x_1 , x_2] is calculated from the exponential model, in the interval [x_2 , x_3] is calculated from the normal distribution model, and for $x > x_3$ is equal T_3 , which is calculated by formula (7).

International Scientific – Practical Conference «INFORMATION INNOVATIVE TECHNOLOGIES», 2018

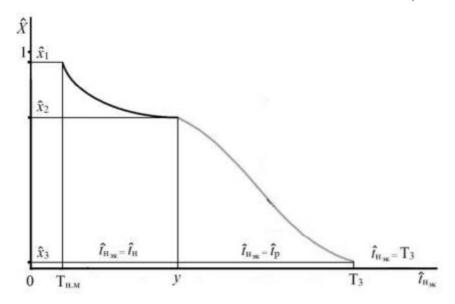


Fig. 2. Failure model of the electronic component

CONCLUSION

Proceeding from the above, it can be concluded that the proposed model of failures of electronic components allows for simulation to obtain the implementation of the operating time of the electronic component, taking into account resource failures and limitations on the amount of its operating time.

Regarding the adequacy of this model, on the one hand, it is confirmed by the use of the rejection models adopted in [2-4], and on the other hand, by using the data given in [7]. Nevertheless, the proposed model, like any other mathematical model, can (and must) be corrected by the results of testing of electronic components and their controlled operation as part of electronic equipment.

REFERENCES

- 1. GOST 27.002-2015. Mezhgosudarstvennyj standart. Nadezhnost v tekhnike. Terminy i opredeleniya.
- 2. OST 4G 0.012.242-84. Otraslevoj standart. Apparatura radioehlektronnaya. Metodika rascheta pokazatelej nadezhnosti.
- 3. OST 4.012.013-84. Otraslevoj standart. Apparatura radioehlektronnaya. Opredelenie pokazatelej dolgovechnosti.
- 4. OST V 4G 012.241-84. Otraslevoj standart. Apparatura radioehlektronnaya. Metody rascheta pokazatelej nadezhnosti v rezhimah hraneniya i ozhidaniya i opredeleniya prodolzhitelnosti ispytanij, imitiruyushchih dlitelnoe hranenie.
- 5. GOST 27.005-97. Mezhgosudarstvennyj standart. Nadezhnost v tekhnike. Modeli otkazov. Osnovnye polozheniya.
- 6. GOST 27.301-95. Nadyozhnost v tekhnike. Raschyot nadyozhnosti. Osnovnye polozheniya.
 - 7. Nadyozhnost EhRI: Spravochnik. M.: MO RF, 2006. 641 s.
- 8. ALYaR.434110.004TU. Rezistory metallodiehlektricheskie R1-11. Tekhnicheskie usloviya.
- 9. Zhadnov V.V. Raschyot nadezhnosti ehlektronnyh modulej: nauchnoe izdanie. M.: «Solon-Press», 2016. 232 s.
- 10. Zhadnov V.V., Panasik D.S. Analysis of the storability characteristics of electronic components. / Information Innovative Technologies: Materials of the International