ANALYSIS OF THE STORABILITY CHARACTERISTICS OF ELECTRONIC COMPONENTS

Zhadnov V.V., Panasik D.S.
National Research University “Higher School of Economics”
+7 (495) 916-88-80, vzhadnovt@hse.ru

Abstract – The paper deals with the mathematical model of the failure rate and storage time for electronic components. It is shown that the use of standardized models allows us to calculate only the Reliability function. For calculation of the indicators of the "storage time", a method based on the methodology of estimation of indicators of durability.

Keywords – electronic components; storability; mathematical model; failure rate; storage time.

INTRODUCTION

For the apparatus to operate most of the time is in standby mode (storage) in the de-energized state with periodic health monitoring, standardized indicators of storability. In the design phase to confirm the required level of these indicators apply calculation methods. These methods are based on exponential model of distribution storage time, a parameter of which is the failure rate. To calculate the failure rate of electronic components apply a mathematical models of the failure rate for storage mode. However, these models do not allow us to calculate metrics such as gamma-percent storage time, mean storage time, warranty period etc. Therefore, the calculation of these values causes some difficulties due to the lack of methods of calculation of indicators of "storage time".

PROBLEM STATEMENT

The method of calculating persistence are given in standard [1]. Under this standard the probability of not failure of the equipment during storage is determined by the formula:

$$P\left(t_{\text{хр}}\right)=\exp\left(-\Lambda_{\text{хр}}\cdot t_{\text{хр}}\right). \tag{1}$$

The value of the failure rate of the equipment in the storage mode is determined by the formula:

$$\Lambda_{\text{хр}}=\sum_{i=1}^{I}\lambda_{\text{хр}_i}\cdot \tag{2}$$

The value of the failure rate of electronic components is determined by the formula given in handbook [2]:

$$\lambda_{\text{хр}}=\lambda_{\text{х.с.г}}\cdot \text{К}_{t.\text{х}}\cdot \text{К}_{\text{усл}}\cdot \text{К}_{\text{пр}}. \tag{3}$$

The numerical values of the coefficients of model (3) are determined by the tables of handbook [2]. In addition, in handbook [2] for some electronic components provides models for the calculation of the coefficient К$_{t.\text{х}}$. For example, the value К$_{t.\text{х}}$ for resistors is determined by the formula:

$$\text{К}_{t.\text{х}}=A\cdot e^{B\cdot\left(\frac{t+273}{N_t}\right)^G}\cdot e^{B_1\cdot\left(\frac{t+273}{273}\right)^J}. \tag{4}$$

In the standard [1] gives also the formula for calculating P($t_{\text{хр}}$) for the case when during the period of operation ($t_{\text{э}}$) equipment stored under different conditions.

For example, if:

$$t_{\text{э}}=\sum_{s=1}^{S}t_{\text{хр}_s}, \tag{5}$$

then:

$$P\left(t_{\text{э}}\right)=\prod_{s=1}^{S}P\left(t_{\text{хр}_s}\right)\cdot \tag{6}$$

Note that from (6) it follows that for equipment:

$$\Lambda_{\text{э}}=\frac{\sum_{s=1}^{S}\left(\Lambda_{\text{хр}_s}\cdot t_{\text{хр}_s}\right)}{t_{\text{э}}}. \tag{7}$$

Then, for electronic components:

$$\lambda_{\text{э}}=\frac{\sum_{s=1}^{S}\left(\lambda_{\text{хр}_s}\cdot t_{\text{хр}_s}\right)}{t_{\text{э}}}\cdot \tag{8}$$

Taking into account that:

$$\frac{t_{\text{хр}_s}}{t_{\text{э}}}=\text{К}_{\text{и.э}_s}, \tag{9}$$

the expression (8) takes the form:

$$\lambda_{\text{э}} = \sum_{s=1}^{S}\left(\lambda_{\text{хр}_s} \cdot \text{К}_{\text{и.э}_s}\right) \cdot \tag{10}$$

As follows from the above ratios, the method of standard [1] allows to estimate the failure rate of electronic components for the storage mode but is not intended for calculations of their characteristics of storability of the "storage time".

SOLUTION OF THE PROBLEM

To assess the service life of the electronic components in the handbook [2] in the table "Characteristics of reliability of individual types of electronic components" lists the values to their minimum (gamma-percentile) storage time. However, methods of estimation of indicators of the "storage time" for electronic equipment in this handbook is not given.

In the monograph [3] it is shown that the indicators of "storage time" refers to the durability of the electronic equipment and electronic components storage mode. On this basis, to calculate their values, you can use the calculation methods given in the standard [4]. According to these methods, the minimum lifetime of equipment is defined as:

$$\text{Т}_{\text{с.с.м}} = \frac{\text{Т}^{*}_{\text{н.м}}}{\text{К}_{\text{и.э}_{\text{РЭА}}} \cdot 8760} \cdot \tag{11}$$

The minimum operating time of equipment ($\text{Т}^{*}_{\text{н.м}}$) in formula (11) is defined as:

$$\text{Т}^{*}_{\text{н.м}} = \min_{n=1,N}\left(\text{Т}^{**}_{\text{н.м}_1}, \text{Т}^{**}_{\text{н.м}_2}, \ldots, \text{Т}^{**}_{\text{н.м}_N}\right) \tag{12}$$

The value of the minimum operation time of the electronic component ($\text{Т}^{**}_{\text{н.м}_n}$) in the formula (12) is defined as:

$$\text{Т}^{**}_{\text{н.м}} = \frac{\text{Т}_{\text{н.м}}}{\text{К}_{\text{н}} \cdot \text{К}_{\text{и.э}_{\text{ЭРИ}}}} \cdot \tag{13}$$

When using this technique to calculate the minimum storage time equipment ($\text{Т}_{\text{с.х.м}}$) in formulas (11)-(13) take that: $\text{К}_{\text{н}} = \text{К}_{t.\text{х}} \cdot \text{К}_{\text{усл}}$; $\text{Т}_{\text{н.м}} = \text{Т}_{\text{хр}} \cdot 8760$; $\text{Ки}\text{э}_{\text{эри}} = \text{Ки}\text{э}_{\text{рэа}} = 1$; $\text{Т}^{**}_{\text{н.м}} = \text{Т}^{**}_{\text{хр.м}}$; $\text{Т}^{*}_{\text{н.м}} = \text{Т}^{*}_{\text{хр.м}}$; $\text{Т}_{\text{с.с.м}} = \text{Т}_{\text{с.х.м}}$.

In the case where the period of operation ($t_{\text{э}}$) equipment stored under different conditions, in (12) instead of the values $\text{Т}^{**}\text{хр.м}_n$ values are used $\text{Т}^{***}\text{хр.м}_n$, calculated according to the formula:

$$\text{Т}^{***}_{\text{хр.м}} = \sum_{s=1}^{S}\left(\text{К}_{\text{И.Э}_s} \cdot \text{Т}^{**}_{\text{хр.м}_s}\right). \tag{14}$$

The method of standard [4] can also be applied for calculations of gamma-percentile and medium storage time equipment. Calculation gamma-percentile ($\text{Т}_{\text{хр.}}$) and the medium storage time ($\text{Т}_{\text{хр.с}}$) the electronic components held by the formulae:

$$\text{Т}_{\text{хр.}\gamma} = \frac{1\text{-}0{,}15 \cdot \chi_{\gamma}}{1\text{-}0{,}15 \cdot 3{,}09} \cdot \text{Т}_{\text{хр}} \cdot 8760 \qquad (15);$$

$$\text{Т}_{\text{хр.с}} = \frac{1}{1\text{-}0{,}15 \cdot 3{,}09} \cdot \text{Т}_{\text{хр}} \cdot 8760. \tag{16}$$

These values are used in equation (13) for the calculations of $\text{Т}^{**}_{\text{хр.}\gamma}$ and $\text{Т}^{**}_{\text{хр.с}}$ electronic components.

If the criterion of the limiting state of the equipment ($\text{К}_{\text{п.с}}$) is formulated as the achievement of the gamma-percent storage time of a certain percentage of the electronic components, then the formula (12) is not used, and for calculating $\text{Т}^{*}_{\text{хр.}\gamma}$ the following procedure applies:

- an array $\text{Т}^{**}\text{хр.}\gamma_1, \text{Т}^{**}\text{хр.}\gamma_2, \ldots, \text{Т}^{**}\text{хр.}\gamma_N$ (or an array $\text{Т}^{***}\text{хр.}\gamma_1, \text{Т}^{***}\text{хр.}\gamma_2, \ldots, \text{Т}^{***}\text{хр.}\gamma_N$) is ordered in ascending order;
- calculates the number of the electronic components:

$$n = \frac{\text{К}_{\text{П.С}}}{100} \cdot N + 1; \tag{17}$$

- determines the value $\text{Т}^{*}\text{хр.}\gamma$:

$$\text{Т}^{*}_{\text{хр.}\gamma} = \text{Т}^{**}_{\text{хр.}\gamma_n} \;\; (\text{или } \text{Т}^{*}_{\text{хр.}\gamma} = \text{Т}^{***}_{\text{хр.}\gamma_n}\;). \tag{18}$$

Similar procedure applies for the calculation of the $\text{Т}^{*}_{\text{хр.с}}$.

Consider the calculation of the indicators of persistence on the example of resistors С2-33Н (see Fig.1).

In the Data Sheet [5] on resistors given 95% storage life equal to 25 years.

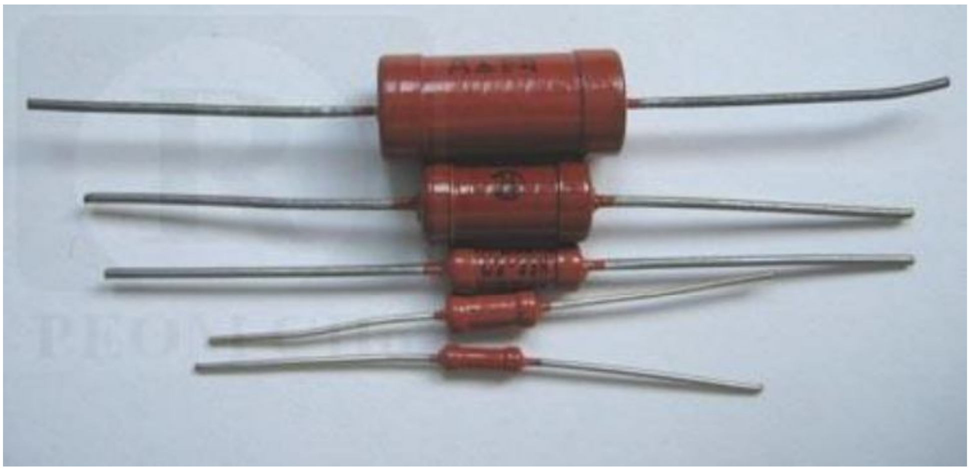

Fig. 1. Resistors C2-33H

The conditions and modes of storage of equipment:
- storage under cover within $0{,}2\cdot t_{\text{э}}$ at a temperature of $\leq 40\ {}^{0}\text{C}$;
- storage in a heated room within $0{,}8\cdot t_{\text{э}}$ at a temperature of $\leq 40\ {}^{0}\text{C}$.

For these conditions we calculate the minimum storage life.

As in the Data Sheet [5], the 95 % storage life, find the minimum storage life, allowing (15) relative to the $\text{Т}_{\text{хр}}$:

$$\text{Т}_{\text{хр}}=\frac{1\text{-}0{,}15\cdot 3{,}09}{1\text{-}0{,}15\cdot 1{,}645}\cdot 25=17{,}8 \text{ years.}$$

In handbook [2] determine the values of coefficients of $\text{К}_{\text{усл}}$ and $\text{К}_{t.\text{х}}$ the specified storage conditions:
- $\text{К}_{\text{усл}} = 1{,}4$ и $\text{К}_{t.\text{х}} = 1$ (storage under cover at a temperature of $\leq 40\ {}^{0}\text{C}$);
- $\text{К}_{\text{усл}} = 1$ и $\text{К}_{t.\text{х}} = 1$ (storage in a heated room at a temperature of $\leq 40\ {}^{0}\text{C}$).

We find the value $\text{Т}^{**}_{\text{хр.м}}$ in the formula (13):

$$\text{Т}^{**}_{\text{хр.м}_1}=\frac{17{,}8}{1\cdot 1{,}4}=12{,}7 \text{ years;}$$

$$\text{Т}^{**}_{\text{хр.м}_1}=\frac{17{,}8}{1\cdot 1}=17{,}8 \text{ years.}$$

On the basis of specified storage mode $\text{К}_{\text{и.э}_1} = 0{,}2$ $\text{К}_{\text{и.э}_2} = 0{,}8$. With these values of the coefficients we find the value $\text{Т}^{***}_{\text{хр.м}}$ in the formula (14):

$$\text{Т}^{***}_{\text{хр.м}}=0{,}2\cdot 12{,}7+0{,}8\cdot 17{,}8=16{,}8 \text{ years.}$$

Thus, the minimum storage life of resistors C2-33H within specified modes and conditions of storage was 16.8 years.

CONCLUSION

The above methodology allows for early design stages to calculate indicators of the persistence of an instrument. The adequacy of the methodology is confirmed by the fact that it is based on the current methodology of estimating reliability indices. However, it should be borne in mind that this methodology has several limitations, so the calculated values of persistence must be confirmed by the results of tests and (or) storage of controlled equipment.

REFERENCES

1. OST V 4G 0.012.241-84. Apparatura radioehlektronnaya. Metody rascheta pokazatelej nadezhnosti v rezhimah hraneniya i ozhidaniya i opredeleniya prodolzhitel'nosti ispytanij, imitiruyushchih dlitel'noe hranenie, (rus).
2. Nadyozhnost' EhRI: Spravochnik. - M.: MO RF, 2006. - 641 s., (rus).
3. Zhadnov V.V. Raschyot nadyozhnosti ehlektronnyh modulej: nauchnoe izdanie. - M.: SOLON-Press, 2016. - 232 s. (Seriya «Biblioteka studenta»), (rus).
4. OST 4.012.013-84. Apparatura radioehlektronnaya. Opredelenie pokazatelej dolgovechnosti, (rus).
5. OZhO.467.093 TU. Rezistory postoyannye neprovolochnye C2-33H. Tekhnicheskie usloviya, (rus).