**Dmitro TRUSHAKOV[1], Serhiy RENDZINYAK[2]**

Kirovograd National Technical University (1), Lviv Polytechnic National University (2)

# Research of the Reliability of Personal Computer “IBM PC” Type

***Abstract**. This paper will present a research of the reliability of personal computer of “IBM PC” type with consideration of sequential and parallel connection of PC parts. The structure of the PC is presented in the form of separate modules. Research of reliability of the PC is carried out with Exponential distribution and Diffusion distribution.*

***Streszczenie.** W artykule zaprezentowano wyniki badań nad niezawodnością komputerów osobistych wraz z ich osprzętem. Autorzy posłużyli się metodami stochastycznymi analizując rozkład wykładniczy współczynnika awaryjności oraz rozkład $D_n$. **(Badania niezawodności komputerów osobistych typu „IBM PC”)***

**Keywords:** personal computer, structure of the personal computer, reliability
**Słowa kluczowe:** komputer osobisty, niezawodność, bezawaryjny czas pracy

### Problem setting

Electronic computers or personal computer (PC) are widely applied in different branches of industry, PC of one type and different configurations being used at different steps of production management. This simplifies creation of elemental base and software. Therefore, special attention must be paid to reliability of PC.

### Analysis of latest research and publications

The given problem was partially enlightened in works [1-4]. In work [1], research of reliability of PC software was described. In work [2-4] research of PC hardware was done, but sequential and parallel connection of PC parts was not taken into account therewith.

### Introduction

Today especially is actual the question about reliability of personal computer, and also specific computing machine, which is charged to solve problems and tasks of various complexity and demanding various level of reliability [5]. Constructing of multi-machine computing complexes with increased reliability based on basic computing complexes can be realized by several methods: by organization of interconnection with implementation of common external memory drives (EMD); by organization of exchange among processors; organization of interconnection with using of multi-input memory [6].

Any microprocessor systems, including PC, have a complex and combined structure. Rehabilitation algorithms of PC up state can be realized hardwarily with support program or exclusively by software method. In the former case, reconstructure is called hardwearily controlled, in the latter case, it is called software controlled. Depending on the type of failure and algorithm of rehabilitation of computation system, its complete rehabilitation is done with return to initial work conditions and replacement of the failed module by a reserve one. For comparative assessment of PC functioning reliability, let us consider a specific case.

A logical simplified structure PC scheme in the form of its basic components with sequential and parallel connection is shown in Fig.2.

Research PC reliability is carried out in two ways:

1) with the help of exponential distribution which uses failure rate λ (so-called „lambda”-method), traditionally used for device reliability calculation with influence of sudden failures;

2) with the help of diffusion distribution, based on DN-distribution function. It is used for device reliability calculation with influence of gradual failures.

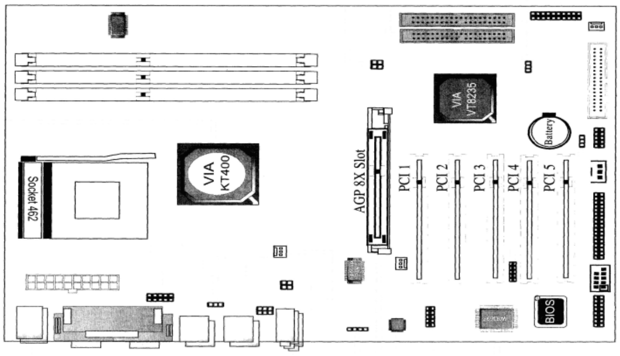



Fig. 1. A typical PC motherboard

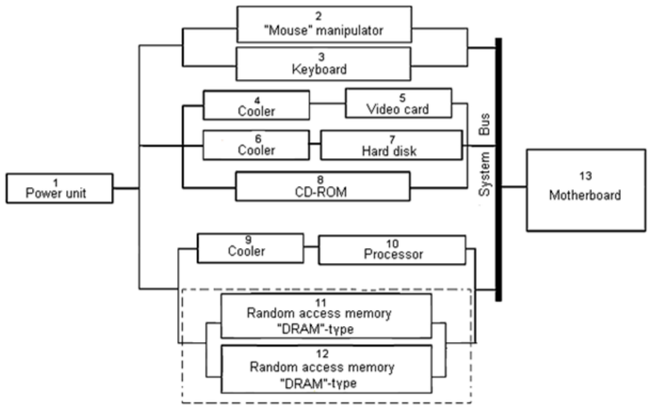



Fig. 2. A logical simplified structure PC scheme

PC modules reliability features are shown in Table 1 [7].

Table 1. PC modules reliability features

| № | Modules | Quantity $m_j$, pcs. | Failure rate $\lambda_j \cdot 10^{-5}$, 1/hour | Average operating time to failure $T_j \cdot 10^5$, hours |
|---|---|---|---|---|
| 1 | Motherboard | 1 | 5.0 | 0.2 |
| 2 | Processor | 1 | 0.1 | 6.6 |
| 3 | Random access memory “DRAM”-type | 2 | 0.5 | 2.0 |
| 4 | Video card | 1 | 2.6 | 0.375 |
| 5 | Hard disk | 1 | 1.0 | 1.0 |
| 6 | CD-ROM | 1 | 5.0 | 0.2 |
| 7 | Keyboard | 1 | 5.0 | 0.2 |
| 8 | “Mouse” manipulator | 1 | 5.0 | 0.2 |
| 9 | Power unit | 1 | 2.6 | 0.375 |
| 10 | Cooler | 3 | 0.76 | 1.3 |

Reliability on system depends of its structure (structural logic scheme) and reliability of elements. That's why for complex systems there are two possible ways to increase reliability: increasing the reliability of elements and changing the structural scheme. Increasing of the reliability of elements on the prima facie seems the simplest way of increasing system reliability, but practical realization of such high reliability of elements can turn out to be impossible. High reliability elements very often have big sizes, weight and high cost. The exception appears to be the use of more modern base of elements. This base is being realised on principally new physical and technological principles. Change of system structure for increase the reliability on the one hand provides modification of functional scheme, changes the principles of functioning separate parts of system. On the other hand, changing of scheme considered as insertion of redundant (additional) elements, which take part in system work after failure of major elements. Thus, reserving is using of additional means and possibilities with the purpose of preservation object (system) up state under the condition of one or few elements failure. As a result of reserving elements and modules of the system and insertion of redundant elements it is possible to ensure higher reliability of the system on the whole, than the reliability of it's separate elements.

**Personal computer reliability calculation according to exponential distribution (lambda method)**

For personal computer reliability calculation according to lambda method the following assumptions are admitted:
– failures of PC components (elements) are primary failures (independent);
– failure of any unit results in complete PC failure;
– basic data for calculation of the PC reliability measures are failure rate $\lambda_j$ of PC components (elements);
– variation coefficient of operation time to failure of PC components is equal to one (ν=1);
– distribution law of operating time to PC failure is described by exponential distribution:

(1) $$F(t) = 1 - e^{-\lambda t}$$

where: $\lambda$ – common failure rate of all PC components, $t$ – PC working time.

(2) $$\lambda = \sum_{j=1}^{n} m_j \lambda_j$$

where: $m_j$ – quantity of the same type PC components in system unit; $\lambda_j$ – failure rate for $j$ type component.

Average operating time to failure $T_{av}$ for PC is determined by equation:

(3) $$T_{av} = 1/\lambda$$

Personal computer reliability calculation using lambda-method with the help of PC modules characteristics shown in table 1 is performed in the following sequence [7]:
– determining average operating time to failure $T_{av}$ for PC by equation:

(4) $$T_{av} = \left(\sum_{j=1}^{n} m_j \lambda_j\right)^{-1} = \left(29.6 \cdot 10^{-5}\right)^{-1} = 3381 \text{ hours}$$

– determining gamma-percentile operating time to failure (γ=0,9) for PC by equation:

(5) $$T_\gamma = -T_{av} \cdot \ln\gamma = 3381 \cdot 0.1054 = 356 \text{ hours}$$

– calculating reliability function (probability of failure-free operation taking into account given operating time t=1500 hours:

(6) $$P(t) = e^{-\lambda \cdot t} = 0.64$$

Probability of failure-free operation of two sequentially connected elements determining by equation:

(7) $$P = P_1 \cdot P_2$$

Probability of failure-free operation of two parallel connected elements determining by equation:

(8) $$P = 1 - (1 - P_1)(1 - P_2)$$

Calculating probability of failure-free operation for a logical simplified PC structure scheme (Fig.2) taking into account sequential and parallel connection of PC modules with considering the following:
– elements 4 and 5, 6 and 7, 9 and 10 create sequential connection. Hence, we replace them with quasi-elements B, C, D accordingly;
– elements 2 and 3, 11 and 12, create parallel connection. Hence, we replace them with quasi-elements A, E accordingly;
– elements B, C, 8 create parallel connection. Hence, we replace them with quasi-element F;
– elements D, E, create parallel connection. Hence, we replace them with quasi-element G;
– elements A, F and G, create parallel connection. Hence, we replace them with quasi-element H;
– elements 1, H and 13 create sequential connection. We receive general equation for calculating probability of failure-free operation for all logical simplified PC structure scheme:

(9) $$P_\gamma = P_1 \cdot P_H \cdot P_{13}$$

– determining the element with the least probability of failure-free operation among $P_1$, $P_H$ and $P_{13}$ (element 13);
– determining wanted probability of failure-free operation of element 13

(10) $$P_{13}^{'} = \frac{P_\gamma}{P_1 \cdot P_H} = \frac{0.9}{0.9189 \cdot 0.9998} = \frac{0.9}{0.9188} = 0.9795$$

– determining the value of failure rate for element 13

(11) $$\lambda_{13}^{'} = -\frac{\ln(P_{13}^{'})}{T} = -\frac{\ln(0.9795)}{0.041} = \frac{0.0207}{0.041} \approx 0.51$$

– receiving the value of probability of failure-free operation for PC with enlarged operating time and reduced failure rate

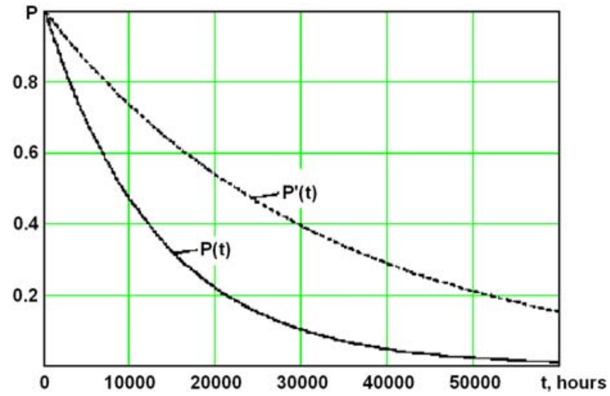
(12) $$P^{'} = P_1 \cdot P_H \cdot P_{13}^{'}$$

Calculation results of PC reliability values with the help of lambda method (exponential distribution) are shown in Table 2.

Table 2. Calculation results of PC reliability values with the help of exponential distribution

| Ele-ment | $\lambda \cdot 10^{-5}$, 1/hour | Operating time, $t \cdot 10^{-5}$, hours | | | | |
|---|---|---|---|---|---|---|
| | | 0,1 | 0,2 | 0,3 | 0,4 | 0,5 |
| 1, 5 | 2.6 | 0.7711 | 0.5945 | 0.4584 | 0.3535 | 0.2725 |
| 2, 3, 8, 13 | 5.0 | 0.6065 | 0.3679 | 0.2231 | 0.1353 | 0.0821 |
| 4, 6, 9 | 0.76 | 0.9268 | 0.8590 | 0.7961 | 0.7379 | 0.6839 |
| 7 | 1.0 | 0.9048 | 0.8187 | 0.7408 | 0.6703 | 0.6065 |
| 10 | 0.1 | 0.9900 | 0.9802 | 0.9704 | 0.9608 | 0.9512 |
| 11, 12 | 0.5 | 0.9512 | 0.9048 | 0.8607 | 0.8187 | 0.7788 |
| A | - | 0.8452 | 0.6004 | 0.3965 | 0.2524 | 0.1574 |
| B | - | 0.7146 | 0.5107 | 0.3649 | 0.2608 | 0.1864 |
| C | - | 0.8386 | 0.7033 | 0.5898 | 0.4946 | 0.4148 |
| D | - | 0.9176 | 0.8420 | 0.7726 | 0.7089 | 0.6505 |
| E | - | 0.9976 | 0.9909 | 0.9806 | 0.9671 | 0.9511 |
| F | - | 0.9819 | 0.9082 | 0.7976 | 0.6770 | 0.5629 |
| G | - | 0.9998 | 0.9986 | 0.9956 | 0.9904 | 0.9829 |
| H | - | 0.9999 | 0.9998 | 0.9995 | 0.9977 | 0.9937 |
| P | - | 0.4677 | 0.2187 | 0.1022 | 0.0477 | 0.0222 |
| 13' | 0.51 | 0.9612 | 0.9048 | 0.8607 | 0.8187 | 0.7788 |
| P' | - | 0.7334 | 0.5379 | 0.3943 | 0.2887 | 0.2109 |

Probability graph of failure-free operation of PC is shown in Fig.3




P(t) - Probability of failure-free operation of PC based on initial data
P'(t) - Probability of failure-free operation of PC as a result of failure rate reduction
Fig. 3. Probability of failure-free operation of PC

**Calculation of PC reliability with assistance of diffusion distribution**

For this method of calculation the following assumptions are admitted:
– failures of elements (modules) are independent;
– failure of any PC component results in complete PC failure;
– basic data for calculation of PC reliability rate is average operating time prior to PC components failure;
– variation coefficient of operation time prior to PC components failure is equal to one (ν=1);
– distribution law of operation time prior to PC components failure is described by equation:

(13) $$F(t)=\Phi\left(\frac{t-\mu}{\sqrt{\mu t}}\right)+e^{2}\Phi\left(-\frac{t+\mu}{\sqrt{\mu t}}\right)$$

where: $\mu$ – parameter of distribution of PC operating time which equals average value for operating time prior to failure ($T_{av}=\mu$), $t$ – PC operating time, $T_j$ – average operating time prior to $j$-type element failure ($j$=1, 2, …, n), $m_j$ – quantity of $j$-type modules.

PC reliability calculation by this method, using characteristics of PS modules shown on Table 1, is carried out in the following sequence [5]:
– determining average operating time prior to PC failure by equation

(14) $$T_{av}=\mu=\left(\sum_{j=1}^{n} m_j T_j^{-2}\right)^{-1/2}=9225 \text{ hours}$$

– determining gamma-percentile operating time prior to PC failure (γ=0,9) by equation

(15) $$\Phi\left(\frac{T_\gamma-\mu}{\sqrt{\mu T_\gamma}}\right)+e^{2}\Phi\left(-\frac{T_\gamma+\mu}{\sqrt{\mu T_\gamma}}\right)=1-\gamma$$

or using DN-distribution function table [5], where the value $x(1-\gamma;\ \nu)$ is determined by the value of probability $F(x)=1-\gamma=0.9$ and by the value of variation coefficient ν=1

(16) $$T_\gamma=\mu\cdot x(1-\gamma;1)=9225\cdot 0.238=2196 \text{ hours}$$

– determining reliability function (probability of failure-free operating time) by equation

(17) $$P(t)=\Phi\left(\frac{T_\gamma-x}{\sqrt{x}}\right)+e^{2}\Phi\left(-\frac{T_\gamma+x}{\sqrt{x}}\right)$$

where $x=t/T_{av}$ ($t$ – given PC operating time).

Using DN-distribution function table [5] we determine probability value by the size $x$ F(x)=0.03.

So, probability of PC failure-free operation determining by equation

(18) $$P(t)=1-F(x)=0{,}97$$

So, research PC reliability is carry out in two ways:
– with the help of exponential distribution which uses failure rate λ (so-called „lambda"-method), traditionally used for device reliability calculation with influence of sudden failures;
– with the help of diffusion distribution, based on DN-distribution function. It is used for device reliability calculation with influence of gradual failures.

The results of calculations PC reliability figures received by exponential distribution and diffusion distribution are shown in Table 3.

Table 3. Results of PC reliability measures calculations.

| Reliability index | Exponential distribution | Diffusion distribution |
|---|---|---|
| Average operating time to failure $T_{av}$, hours | 3381 | 9225 |
| Gamma-percentile operating time to failure $T_\gamma$, hours | 356 | 2196 |
| Reliability function $P(t)$ | 0,64 | 0,97 |

**Conclusions**

In this research we determined PC reliability of IBM PC type taking into account sequential and parallel connection of PC parts through lambda method (exponential distribution) and diffusion distribution.

Calculations prove that determining PC reliability through lambda method (exponential distribution) has "stricter" value for probability of failure-free PC operation.

Practical results obtained during this research can be applied by development of different PC complexity and different reliability status for solving of different problems.

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***Authors***: *PhD, Ass. Prof. Dmitro Trushakov, Kirovograd National Technical University, Prospect Universitetcky 8, 25006, Kirovograd, e-mail: Dmitriy-kntu@yandex.ru; DSc, prof. Serhiy Rendzinyak, Lviv Polytechnic National University, Institute of Electrical Power Engineering and Control Systems, Bandera str 12, 79013 Lviv, e-mail: emd@polynet.lviv.ua*