

ENHANCING RELIABILITY OF ELECTRONIC EQUIPMENT AT THE INITIAL DESIGN STAGES

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Ensuring and enhancing the reliability of electronic equipment during the design stage is critically important, as this is the stage where the fundamental technical decisions are made that determine the product's failure-free operation, durability, maintainability, and other key characteristics [1]. Ignoring reliability aspects at the early stages can lead to significant financial losses due to the necessity of introducing design changes, retesting, altering technological lines, as well as reputational losses due to the need for product recalls.

The starting point for the systematic assurance and enhancement of electronic equipment reliability, in accordance with DSTU 2861-94 and 2863-94 [2, 3], is the creation of a **reliability assurance program (RAP)**. The recommended content and sequence of the main RAP measures include 124 steps, of which over 50 are assigned to the design stages. The methods for improving the reliability of electronic equipment during the design process are classified into several main areas: **circuit-design methods** – minimize the influence of destabilizing factors at the level of electrical signals and operating electrical modes; **structural methods** (constructional) – are associated with the physical realization of the device, material selection, component layout, provision of mechanical protection, and optimal thermal regimes; **software methods** (for equipment with program control) – include the development of reliable software, detection, and correction of errors at the program level.

Optimal **selection of the component base** is closely linked to both circuit-design and structural methods, as is the method of **derating** (applying eased operating modes). Optimal structural materials are selected for effective heat dissipation, reducing the degradation of soldered joints during thermal cycles, and increasing the equipment's resistance to mechanical loads and aggressive environmental conditions. **Redundancy** is applied in critically important equipment. **Thermal management methods** are aimed at diverting excess heat from components to the environment. Radiators, heat pipes, thermal interface materials, thermal polygons (in printed circuit boards), and copper jumpers under high-heat components are used. Active (forced) cooling and specialized thermal management systems are employed for high-power devices.

In the provisions of DSTU 2861-94, attention is focused on the need to transition towards deeper, analytical, and systemic approaches at the design stage. These include the creation and improvement of methods that allow for the formalization of design and search investigations, as well as increasing the accuracy of reliability calculation [2]. One such approach is the increase in the number of design solutions subject to analysis at the design stage.

For various design solutions, the difference in the mean time to failure (MTTF) between the most and least thermo-resilient electronic components can vary significantly [4]. Accordingly, their rational placement on the printed circuit board (PCB) is one of the most fundamental and at the same time complex tasks in design. Traditional approaches are based on engineering experience, where designers use a number of rules and principles for component placement.

The use of computer technologies and model-oriented design allows for the implementation of two key principles. Firstly, it provides the possibility of conducting a more detailed and diverse analysis of the reliability of each design solution. Secondly, and even more importantly, it opens the way to increasing the number of design solutions subject to reliability analysis.

Instead of relying on the designer's experience and intuition when creating one or two design options, the possibility arises for automated generation and comparison of thousands of variants, which significantly increases the probability of finding a optimal or near-optimal solution. Figure 1 shows the results of calculations of the probability of failure-free operation for 500 automatically generated topology options. Successful implementation of this process requires the automation of reliability information flows, at least at the

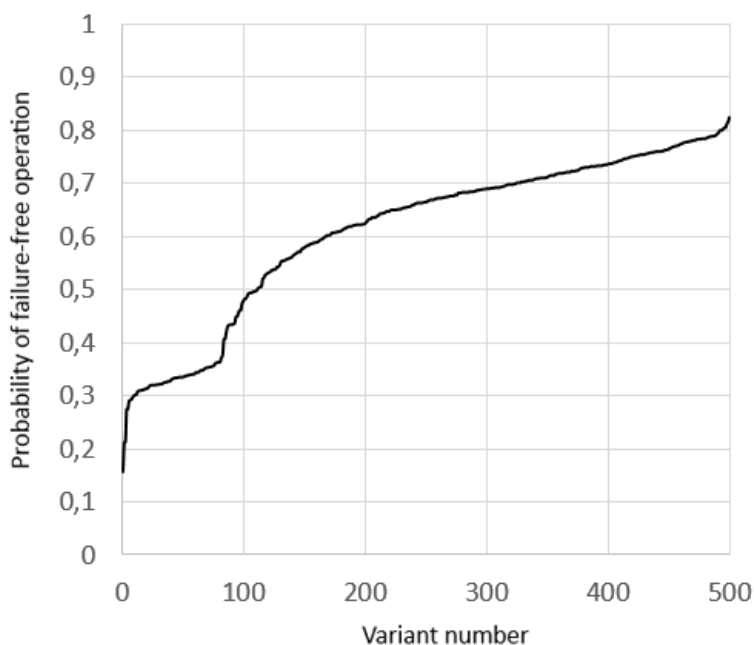


Fig. 1. Probability of failure-free operation for 500 automatically generated topologies

level of integrating models of different physical processes into a single software complex. To solve this problem, it is necessary to overcome the key challenge, which lies in the fundamental compromise between the accuracy and speed of existing mathematical models.

In the presented example (Fig. 1), the difference in reliability indicators between the worst and best topology proved to be significant –

the probability of failure-free operation of the best variant (0.824) exceeds the indicator of the worst (0.157) by more than 5 times (525%). Although the specific reliability indicators depend on the equipment class, its thermal power, and the specified operating time, the mere fact of such a substantial difference confirms the expediency and necessity of applying automated optimization, as well as the unacceptability of subjective layout selection.

The developed tool for enhancing the reliability of electronic equipment at the initial design stages ensures the effective implementation of DSTU requirements regarding the increase in the number of analyzed design solutions and allows the design process to be transformed into a systematic, objective, and evidence-based search for the optimal construction.

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Abstract

Methods for enhancing the reliability of electronic equipment at the design stage are considered, in accordance with the requirements of DSTU standards. It is established that the use of computer technologies allows for the automated generation and analysis of thousands of layout options to find an optimal structural solution. Calculation results are presented confirming that the automated search for optimal component placement significantly increases the probability of failure-free operation.

Keywords: reliability, electronic, equipment, devices, optimization, thermal, topology, variants.

Анотація

Розглянуто методи підвищення надійності електронної апаратури на етапі проектування, відповідно до вимог ДСТУ. Встановлено, що використання комп'ютерних технологій дозволяє автоматизувати генерацію та аналіз тисяч варіантів компоновання для знаходження оптимального конструкційного рішення. Наведено результати розрахунків, які підтверджують, що автоматизований пошук оптимального компоновання дозволяє значно підвищити ймовірність безвідмовної роботи.

Ключові слова: надійність, електронна, апаратура, пристрої, оптимізація, тепловий, топологія, варіанти.