Discussion on Reliability Design Technology of Electronic Communication Equipment

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Abstract. With the development of the social economy, the reliability of electronic communication products has played a great role in quality improvement. In this paper, the applications of design technology, electromagnetic compatibility design technology, thermal design technology, environment resistance design technology, and software reliability design technology that ensure reliability indexes in electronic communication equipment are summarized.

Keywords: Reliability Design, Reliability Indexes, Electromagnetic Compatibility, Thermal Design, Software Reliability

1. Introduction

In the fierce competition nowadays, users are paying increasing attention to the quality of products. It is unlikely that electronic equipment manufacturers can secure the market share by reducing costs only. There are many factors affecting product quality, where the reliability of the product plays a significant role in quality improvement [1]. Currently, many companies have changed from the traditional quality concept “Guarantee product quality by inspection” to the contemporary quality concept [2]. This is because the content of the latter is a great expansion of the former, and reliability is one of the essential contents [3-4]. The implementation of comprehensive and whole-process management is emphasized, and the concept that “product reliability is designed, produced, and managed” is proposed. Reliability technology is integrated into the product design to ensure product reliability from the source to achieve the dual purpose of improving reliability and reducing development costs, thereby enhancing the market competitiveness of products [5-6].

The reliability design technology of electronic equipment includes many contents. In this paper, the following aspects are considered: design technology, electromagnetic compatibility (EMC) design technology, thermal design technology, environment-resistant design technology, and software
reliability design technology that ensure reliability indexes.

2. Design technology of reliability index of electronic communication equipment

For users, the biggest concern is the availability of the equipment. For electronic communication equipment, reliability and maintenance indexes are often used to specify their performance quantitatively. There are many factors that can affect the reliability index of equipment. In general, reliability design techniques such as component control, derating design, simplified design, redundant design, and robust design are used to ensure and improve the reliability index of the equipment.

2.1. Component control

Electronic communication equipment is mainly composed of electronic components. The reliability of components directly affects the reliability of the equipment. Hence, to ensure the reliability of electronic communication equipment, reduce the variety and specifications of components, correctly select and rationally use components, and reduce comprehensive guarantee costs and life cycle costs, we must control the components.

To ensure the reliability of component use, we should implement effective quality and reliability management in the entire process of selection, procurement, supervision, acceptance, screening, storage, custody, and use of components at all stages of equipment development, production, and use.

2.2. Derating design technology

The derating design is to make the working stress of the component or electronic equipment lower than the rated value of the component or electronic equipment to reduce the basic failure rate and improve the reliability of use. The reliability of electronic communication equipment is relatively sensitive to electrical and temperature stress. Hence, the derating design is crucial, which is an essential reliability design technology.

2.3. Simplified design technology

The basic reliability model of the system shows that the greater the number of units that consist of the equipment, the lower the reliability of the equipment. Hence, on the premise of ensuring the performance requirements, the design of the equipment should be simplified as much as possible, that is, simplified design technology is adopted. While improving reliability, the simplified design can also reduce equipment maintenance workload and production costs.

2.4. Margin design technology

Redundancy (redundant) design is a relatively common design method for equipment to obtain high reliability.

“Redundancy” means that the equipment has more than one set of units that can perform a given function. The equipment loses its function only when the specified sets of units fail, thereby improving the task reliability of the equipment. However, the margin design increases the complexity, weight, cost, and volume of the device, and reduces the basic reliability of the equipment. According to engineering experience, only when the application of better components and simplified design, derating design, and other technologies fails to meet the reliability requirements of the equipment, or when the cost of improving components is higher than that of equipment using margin technology
should the redundancy design technology be adopted.

2.5. Robust design technology
Robust design is developed based on Taguchi’s method, a system optimization design method that seeks low cost and high stability. Its guiding ideology is to optimize the design carefully using quality function deployment (QFD), three-dimensional design and other methods based on user needs to solve the problems in the design stage and achieve high stability at a minimal cost, namely, a robust product.

2.6. Transient suppression technology
Transient disturbances in the use of electronic products will result in damage. Hence, transient suppression technology has gained increasing attention from designers. Transient disturbances in electronic communication equipment include electrostatic discharge, electrical rapid pulse trains, and lightning surges.

In addition to the above design techniques for transient disturbance suppression, it is mainly about the selection of transient suppression protection devices. Commonly used protection devices include the following: gas discharge tubes, solid discharge tubes, varistor and silicon transient voltage absorption diode (TVS) (Table 1).

| Device name         | Nominal voltage | Current sinking capacity | Responding speed | Electrostatic capacitance | Application                                                                 |
|---------------------|-----------------|--------------------------|------------------|---------------------------|------------------------------------------------------------------------------|
| Gas discharge tube  | 100–800V        | Big                      | Lower            | small                     | Relatively suitable for primary protection of networks and devices            |
| Solid discharge tube| Dozens~300V     | Big                      | Higher           | Smaller                   | Suitable for protection of networks, communication equipment, components, etc.|
| Varistor            | Dozens~1kV      | Depending on the shape   | high             | Larger                    | Transient overvoltage protection for networks, equipment, components, and high-power thyristor devices |
| TVS                 | Dozens~400V     | general                  | high             | Smaller                   | Suitable for the protection of equipment, devices, printed boards, communication lines, and electrostatic discharge |

2.7. Thermal design technology
The thermal design of the electronic equipment should be performed simultaneously with the circuit design, structural design, and maintainability design to meet the reliability and maintainability requirements of the equipment.

The thermal design generally includes the following steps:
1) Determine the heat dissipation area of the equipment (or components), the extreme ambient temperature range of the radiator or surrounding air;
2) Determine the cooling method;
3) Conduct stress analysis on a small number of crucial heating components, determine their maximum allowable temperature and power consumption, and analyze their failure rate;
4) Calculate the heat flux density according to the assembly form of the device and equipment;
5) Determine the maximum surface temperature through the internal thermal resistance of the
device (check the device manual);
   6) Determine the total thermal resistance from the device surface to the heat sink or air;
   7) Analyze and assign thermal resistance based on factors such as heat flow density, make an
        evaluation and determine the heat transfer method and cooling technology;
   8) Select a plan.

3. Software reliability design
With the widespread application of software technology in communication equipment, the proportion
of software in communication systems continues to increase.

In general, the following design guidelines should be followed in the design to improve the
reliability and maintainability of the software:
   a) The system requirements of the software should be listed in detail and completely, and a
      software task statement and interface description should be presented. The task book must be
      comprehensive, complete, and detailed: what is the correct output under the correct input; how to react
      correctly under the incorrect input; not only what should be done but also what should not be done is
      described.
   b) In the software development process, the transparency of the software must be ensured and the
      necessary documents generated in a timely manner.
   c) Structured analysis, design methods, and program design should be adopted, using the single
      entry/exit control structure.
   b) Standardization
      It is stipulated that various standards should be implemented, including the programming language
      used, internal conventions, and style. In the same system, the number of programming languages
      should be reduced as much as possible; according to the type of software, when implementing the
      same type of software, only one version of the language is used for programming.
   c) Simplification of the structure
      The source code statements executable by each program unit should not exceed 200 lines, and the
      average should not exceed 60 lines. The number of direct subordinate modules to which a module
      belongs is called the “fan-out” number; the number of all upper-level modules corresponding to the
      same subordinate module is referred to as the “fan-in” number. In principle, the fan-out and fan-out of
      the module should be less than 7, and the maximum is 9. It is required that higher-level modules have
      higher fan-out, and lower-level modules have higher fan-out.
   f) Improvement of the module independence
      The independence of modules is reflected in the degree of cohesion and the degree of coupling
      between modules.

4. Design Evaluation
Given a design sample set \((x_1, y_1), \ldots (x_i, y_i), \ldots (x_N, y_N)\), the input vector is \(x_i \in x \subset \mathbb{R}^n\), and
\(y_i = \{-1, 1\}\) is the classification label of the input vector \(x_i\). Through the introduction of the
insensitive loss function \(\varepsilon\), the regression problem can be transformed into a minimum problem, and
the constraint conditions are shown in Eq. (1):
The problem shown in Eq. (2).

$$\begin{align*}
\max & -\frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \left( \alpha_i + \alpha_j^* \right) \Phi \left( x_i, x_j \right) \left( \alpha_i + \alpha_j^* \right) \\
& - \varepsilon \cdot \sum_{i=1}^{N} \left( \alpha_i + \alpha_j^* \right) + \sum_{i=1}^{N} \left( \alpha_i + \alpha_j^* \right) \cdot y_i \\
\text{s.t.} & \sum_{i=1}^{N} \left( \alpha_i - \alpha_j^* \right) = 0 \\
& \alpha_i, \alpha_j^* \in [0, C]
\end{align*}$$

Hence, the regression decision function is shown in Eq. (3).

$$f(x) = \sum_{i=1}^{N} \left( \alpha_i - \alpha_j^* \right) K \left( x, x_i \right) + b$$

Where $\alpha_i$ and $\alpha_j^* \ (i = 1\ldots N)$ are non-negative Lagrange multipliers, and $K \left( x, x_i \right)$ is a kernel function. Different kernel functions have different emphasis and are suitable for different situations.

Different basis functions have a different emphasis on input processing. Hence, the results are different, and sometimes significantly different.

$$\psi \left( x \right) = \cos \left( k \cdot \frac{x}{\gamma} \right) \cdot \exp \left( -\frac{x^2}{\lambda^2} \right)$$

In Eq. (4), $\gamma$ represents a parameter of the Gaussian function, and $k$ represents a parameter that controls the shape of WBF. Through the introduction of the variable $k$, the kernel function shape of the algorithm will not be fixed to a shape.

$$K \left( x, x' \right) = \prod_{i=1}^{D} \left[ \cos \left( k \cdot \frac{x_i - x_i'}{a \cdot \gamma} \right) \cdot \exp \left( -\frac{\|x_i - x_i'\|^2}{a^2 \cdot \gamma^2} \right) \right] + b$$

The parameter $k$ can improve the generalization capacity, and the regression analysis of sample points with different characteristics can be used to obtain better results. Hence, Eq. (5) is introduced into (3) to obtain the decision function, as shown in Eq. (6):

$$f(x) = \sum_{i=1}^{N} \left( \alpha_i - \alpha_j^* \right) \cdot \prod_{j=1}^{D} \left[ \cos \left( k \cdot \frac{x_{i,j} - x_{j,j}}{a \cdot \gamma} \right) \cdot \exp \left( -\frac{\|x_{i,j} - x_{j,j}\|^2}{a^2 \cdot \gamma^2} \right) \right] + b$$
5. Conclusions

With the development of the social economy, the reliability of electronic communication products has played a great role in quality improvement. In this paper, mainly applications of design technology, electromagnetic compatibility design technology, thermal design technology, environment resistance design technology, and software reliability design technology that ensure reliability indexes in electronic communication equipment are summarized to lay a theoretical foundation for the production of communication products.

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