Constructing a Specialized Computer Integrated Circuit Reliability Experiment Platform

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Abstract. Against the backdrop of the strategy to build a manufacturing powerhouse and the rapid development of integrated circuits (ICs), the emergence of new technologies, materials, and processes has rendered traditional IC reliability techniques inadequate for the evolving needs of IC development. Addressing the construction of an innovative IC reliability experiment platform has become a critical issue for scientific researchers at our city's universities. This paper takes the Shenyang branch of the National Special Computer Research Center as a case study to explore how to optimize the construction of an IC reliability innovation platform. The discussion is structured around three dimensions: expanding the platform's application scope, enhancing talent capabilities, and improving technological innovation levels. The findings are instrumental in elevating the standard of innovation platforms within the city.

Keywords: Integrated circuit reliability, Technological innovation, Talent cultivation.

1. Introduction

On March 17, 2021, the Liaoning Province Manufacturing Industry Digital Transformation Work Exchange and Tiexi Intelligent Manufacturing Partnership Dialogue were held in the Shenyang Economic and Technological Development Zone. Shenyang's intelligent manufacturing has also entered a critical stage in response to new international challenges and scenarios [1]. How to achieve the directive issued at the Shenyang Science and Technology Innovation and Intelligent Manufacturing Special Session on April 1, 2021, to "arrange the innovation chain around the industrial chain and to strengthen new drivers for high-quality development," represents a significant issue that requires in-depth contemplation and methodological exploration by local universities.Specialized computers are a vital component of China's high-end manufacturing sector, serving critical roles in communication and control across various domains, including military, energy, and aerospace. The construction of an innovative experimental platform for specialized computers is pivotal for the entire lifecycle-from research and development to production, service, and management-of specialized computers [2]. It undertakes the critical tasks of tackling common technical challenges and nurturing talent in specialized computer technology.

However, traditional integrated circuit reliability platforms face a disconnect between technology and talent and the requirements of new engineering projects under the current paradigm. Reliability analysis experiments primarily simulate actual operating conditions in the laboratory, recording data such as sample data, conditions, number of failures, and failure times. These experiments use a limited amount of data to fit distributions and subsequently predict lifespans [3-5]. With the extended lifespan of chips in the new paradigm, the experimental cycle becomes longer. The use of accelerated life testing also implies uncertainties in the mechanisms of new materials and processes. Traditional reliability prediction methods, which rely on reliability prediction manuals, are insufficient for estimating elements in the design phase of new chips. Current feasibility screening methods can only apply non-destructive stresses such as mechanical, environmental, and electrical stresses to test all products. The drawbacks are evident, particularly in the context of the new paradigm where chip replacement cycles are short, batch sizes are small, costs are high, and failure patterns do not conform to the bathtub curve [6-8].

Therefore, this paper, using the Shenyang branch of the National Special Computer Research Center co-established by our university and the Yanxiang Group as an example, investigates the construction of an integrated circuit reliability innovation experiment platform. It aims to achieve multi-faceted innovation and development in the platform across industry, academia, research, and application. The discussion is centered on three aspects of platform construction: leveraging university-enterprise cooperation to expand the platform's application scope, enhancing the capabilities of platform talent, and continuously improving the platform's level of technological innovation [9-11].

2. Expanding Platform Application Scope Through University-Enterprise Cooperation

Shenyang Jianzhu University, in collaboration with the Yanxiang Group, has established the Shenyang branch of the National Special Computer Research Center. This initiative has catalyzed the creation of an interdisciplinary talent cultivation innovation platform, leading with information technology, civil engineering, and mechanical engineering specialties, and guided by engineering projects. It achieves a one-stop verification and testing function for the reliability of integrated circuits under electromagnetic, mechanical, temperature, and environmental conditions.

2.1. Electromagnetic Performance Design and Verification Platform

Electromagnetic compatibility (EMC) is a comprehensive assessment of the level of electromagnetic interference and the ability of electronic products to resist such interference, serving as one of the most critical indicators of product quality. EMC testing is conducted to determine whether the electromagnetic radiation limits of specialized computers exceed standards and whether their immunity to electromagnetic disturbances meets standard requirements. This laboratory primarily focuses on testing and researching protective technologies in complex electromagnetic environments to enhance the electromagnetic protection capabilities of products [12-16].

2.2. Mechanical Environmental Reliability Platform

The Mechanical Environmental Reliability Laboratory is dedicated to evaluating the mechanical endurance of products against a spectrum of physical stresses, including vibration, impact, and mechanical forces. By simulating the rigors of transportation and operational conditions, this platform ensures that specialized computers can meet the diverse demands of various application systems. It provides a comprehensive suite of testing environments, equipment, methodologies, processes, and standards that are pivotal for industry compliance and product reliability.

2.3. Temperature (Environmental Laboratory) Platform

The environmental laboratory is designed to test whether specialized computers can operate reliably under simulated harsh climatic conditions, including high temperatures, low temperatures, rapid temperature changes, and high humidity. It is capable of conducting a range of tests such as low temperature, high temperature, constant humidity, alternating humidity, temperature cycling, low temperature storage, and high temperature storage. The high and low temperature, humidity chambers are used to test the quality and performance requirements of products under extreme wide temperature and humidity conditions.

2.4. Sand and Dust Platform

The sand and dust test is applicable for assessing the sealing performance of product casings, primarily for tests specified in the IP5X and IP6X levels of the casing protection standard. It can perform sand and dust experiments to examine the performance of electronic and electrical products, as well as seals, in sandy environments during use, storage, and transportation [17-21].

2.5. Water Spray Platform

The water spray test is suitable for products that may be subjected to water or underwater use at different environmental temperatures during transportation, storage, or operation. These water conditions may originate from heavy rain, wind-driven rain, sprinkler systems, wheel splash, water jets, violent wave impacts, or underwater use. The platform can perform IPX1, IPX2, IPX3, IPX4, IPX5, IPX6, IPX7, and IPX8 protection level tests to assess product performance indicators and quality management.

2.6. Aging Platform

Aging tests apply high temperatures to products to impose environmental stress, accelerating the exposure of potential defects into failures. The purpose is to identify and eliminate inherent defects, thereby continuously improving product processes and quality. High-temperature aging experiments can be conducted.

2.7. Light Exposure Platform

The xenon light exposure test uses a xenon arc lamp as a light source to simulate and intensify the aging process, quickly obtaining results similar to natural atmospheric aging. It is used to evaluate the weather resistance of materials. Xenon light exposure testing can be performed. Weather resistance testing is an important means in the research and production process to screen formulations and optimize product composition, and it is also an essential part of product quality inspection.

3. Enhancing Platform Talent Capabilities

Under the new circumstances, an innovative platform that adapts to the new trends in chip development requires not only a more comprehensive technical platform capable of conducting reliability tests from multiple perspectives. Most importantly, it necessitates a faculty with interdisciplinary knowledge to analyze the underlying logic and mechanisms of failures rather than relying on simple testing. It is also crucial to cultivate students who can truly solve practical project problems and to have a continuous influx of scientific research personnel dedicated to the platform's development.

3.1. Advanced Studies in Interdisciplinary Professional Knowledge

Teachers from the School of Information are encouraged to pursue further studies in civil engineering and mechanical engineering to fill in the gaps in their foundational knowledge. The reliability of integrated circuits mainly involves three departments: information, civil engineering, and mechanical engineering. For undergraduates, courses related to mechanics include material mechanics, elasticity, plasticity, structural mechanics, solid mechanics, fracture mechanics, and composite material mechanics; mechanical modeling courses include Pro/E technology. Information-related courses include electrical and electronic technology experiments, etc.

3.2. Building an Interdisciplinary Practical Teaching System

An interdisciplinary practical teaching system is constructed to foster a mindset among teachers that allows them to consider problems comprehensively within a multidisciplinary context. The teaching content and methods are designed to integrate multiple disciplines around engineering projects, enhancing teaching resources. Innovation capabilities are integrated into the practical teaching process, leading to improvements in engineering technology and forming a teaching team that combines the strengths of different generations.

3.3. Engineering Problem-Oriented Guidance

Emphasis is placed on the relevance of teaching content to engineering practice projects. A learning model guided by project problems is established to enhance the practical engineering experience of theoretical teachers, cultivate their ability to integrate across professions, and encourage engineering innovation.

3.4. Process-oriented Faculty Assessment

A process-oriented faculty assessment system is established, utilizing both online and offline methods to evaluate and provide feedback on teachers' teaching levels and content. This approach promotes continuous improvement and construction, encourages teachers to learn online to make up for insufficient training time, and allows teachers to arrange their study of interdisciplinary knowledge according to their own schedules. The team's strength is leveraged to guide young teachers in learning new knowledge, encourage veteran teachers to continuously embrace new ideas, and focus on utilizing the core strength of the teaching staff to enhance communication and collaboration.

4. Continuously Improving Platform Technological Innovation Level

The reliability of integrated circuits is widely applied in fields such as machinery, automotive, military research institutes, electronics, and rail transit. Especially in the field of bridge and building seismic disaster prevention, it plays a role in health monitoring, which can reduce after-sales and maintenance costs from a proactive maintenance perspective. Only by continuously targeting market demands and enhancing the platform's technological level can the platform maximize its social value. Based on market demands and technological implementation, the platform focuses on technological innovation in six key areas: system fault recovery, electromagnetic environment protection, high-speed signal circuit design, buffering and vibration resistance, environmental protection, and thermal design.

4.1. System Fault Recovery Technology

Computer system failures are inevitable due to operator errors or other unpredictable situations. In the past, most system failures required human intervention for repair or restoration, resulting in a low level of product availability. Research on system fault mode analysis technology and the establishment of a system fault self-recovery mechanism ensure that products can self-recover and repair when a failure occurs. This technological breakthrough has increased the availability of products to over 99.999%.

4.2. Complex Electromagnetic Environment Protection Technology

Research on electromagnetic compatibility technology, electrostatic protection testing technology, and electromagnetic shielding technology can meet the requirements of 5 items for the army, 9 items for the navy, 7 items for the air force system, and European standards EN50155 and EN50121.

4.3. High-Speed Signal Circuit Design Technology

As bus technology continues to evolve, high-speed serial buses are gradually replacing parallel buses. Research has been conducted on high-speed PCB stack design, electromagnetic interference common mode and differential mode signal routing design, and high-speed signal integrity design for computer motherboards at high signal transmission rates. This has led to the realization of an 18-layer high-density PCB board design and high-quality interconnection of 8GHz signals, enhancing the product's signal integrity and electromagnetic compatibility.

4.4. Buffering and Vibration Resistance Technology

Buffering and vibration resistance technology is key to ensuring the stable operation of computers in harsh mechanical environments. Research is conducted on the buffering and vibration resistance of critical components such as hard drives and display screens, as well as the buffering and vibration resistance technology for entire machine products under strong external impacts.

4.5. Environmental Protection Technology

Environmental protection technology mainly refers to protection against natural environmental conditions, including waterproofing, dustproofing, humidity resistance, corrosion resistance, and mold prevention. Breakthroughs in this technology enable specialized computers to operate in extremely harsh environments such as at sea or in the desert, with a protection level reaching IP68. During the transportation and use of electronic products, they are also subject to thermal coupling (temperature drop coupling).

4.6. Thermal Design Technology

Thermal design technology has been developed to adapt to harsh environments such as wide temperature ranges and rapid temperature changes. It mainly includes heating and cooling technologies. Thermal design technology ensures that computers can operate normally and stably under conditions of sudden temperature changes and wide temperature ranges, freeing computer applications from the constraints of temperature fluctuations.

The author has explored the construction of the platform from three aspects: the application scope of the platform, the enhancement of talent capabilities, and the level of technological innovation. Starting from the interdisciplinary integration of information, civil engineering, and mechanical engineering, the aim is to undertake scientific research tasks and cultivate high-quality intelligent manufacturing talent with innovative awareness and practical engineering capabilities. By breaking down the barriers between disciplines and professions and exploring experimental teaching reforms in interdisciplinary fields, the platform aims to cultivate compound talents with backgrounds in information technology, civil engineering, and mechanical engineering. Through the innovative platform, a student-centered approach is established, implementing a project-oriented, multi-disciplinary collaborative model for student training. A teaching team with a multi-disciplinary background is formed through the platform, and the research and teaching levels of faculty are improved, oriented by industrial demands. By relying on university-enterprise cooperation to expand the platform's application scope, enhancing platform talent capabilities, and continuously improving the platform's technological innovation level, an innovative platform is created to meet the development requirements of the new situation, thereby enhancing the development level of the city's equipment manufacturing industry.

5. Conclusion and Future Work

The rapid evolution of integrated circuit (IC) technology within the context of a manufacturing powerhouse strategy has necessitated the development of innovative reliability experiment platforms to address the emerging needs of IC advancement. This paper presents a case study of the Shenyang branch of the National Special Computer Research Center to illustrate the optimization of an IC reliability innovation platform. The study is anchored on three pivotal dimensions: expanding the platform's application scope, enhancing talent capabilities, and improving technological innovation levels, which are crucial for elevating the city's innovation platform standards.

The platform's application scope is broadened through university-enterprise cooperation, which facilitates the creation of an interdisciplinary talent cultivation platform. This platform leads with information technology, civil engineering, and mechanical engineering specialties and is guided by engineering projects to provide a comprehensive verification and testing function for IC reliability under various conditions.

To enhance talent capabilities, the platform encourages advanced studies in interdisciplinary professional knowledge, builds an interdisciplinary practical teaching system, and emphasizes engineering problem-oriented guidance. A process-oriented faculty assessment system is also established to ensure continuous improvement and adaptation to new trends in chip development.

Technological innovation is a core focus, with the platform concentrating on six key areas: system fault recovery, complex electromagnetic environment protection, high-speed signal circuit design, buffering and vibration resistance, environmental protection, and thermal design. These innovations are driven by market demands and are aimed at maximizing the platform's social value.

The paper concludes that the construction of the platform, which integrates information, civil engineering, and mechanical engineering, is essential for undertaking scientific research tasks and cultivating high-quality intelligent manufacturing talent. The platform's innovative approach, centered on students and oriented by industrial demands, is designed to break down disciplinary and professional barriers, fostering a new generation of compound talents. By leveraging university-enterprise cooperation and focusing on talent and technological advancement, the platform is well-positioned to meet the challenges of new engineering projects and contribute to the advancement of the city's equipment manufacturing industry.

6. Conflict of Interest

All authors disclosed no relevant relationships.

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