

Research and Practice of a Virtual Simulation Circuit Experiment Platform based on LabVIEW and Multisim

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Abstract: Traditional circuit experiments are constrained by hardware dependency, rigid content, and limitations of time and space. This paper presents the research and development of a virtual simulation circuit experiment platform utilizing the co-simulation technology of LabVIEW and Multisim. The platform expands the component library and creates dynamic experimental scenarios to serve teaching needs. Adopting a Browser/Server (B/S) architecture, it enables remote access, allowing students to conduct experiments flexibly and thereby enhancing their practical innovation capabilities. The implementation of five experimental modules demonstrates the platform's effectiveness, and its pedagogical significance is discussed.

Keywords: Virtual Simulation; Circuit Experiment; LabVIEW; Multisim; Co-simulation.

1. Introduction

Circuit experiments are fundamental to engineering education in electrical and electronic disciplines. However, traditional laboratory setups face challenges such as high costs, logistical constraints, and limited flexibility [1]. The COVID-19 pandemic further highlighted the need for remote and adaptable learning solutions, accelerating the adoption of virtual simulation technologies [2]. The concept of virtual instruments, pioneered by National Instruments (NI) in 1986, introduced the paradigm of "software is the instrument" [3]. Globally, institutions like MIT and the University of Oregon have developed advanced remote laboratory systems [4][5]. In China, universities including Beijing University of Posts and Telecommunications and Sichuan University have also explored integrating LabVIEW with tools like MATLAB or Multisim to create localized virtual simulation platforms [6][7]. Despite progress, challenges remain in achieving seamless integration and creating dynamic, realistic experimental environments. This paper details the development of a virtual simulation platform using LabVIEW-Multisim co-simulation to address these limitations, providing a flexible and effective tool for circuit experiment education.

2. Platform Architecture and co-simulation Methodology

The core innovation of this platform lies in the co-simulation methodology that bridges Multisim's circuit simulation accuracy with LabVIEW's powerful data acquisition and control capabilities.

(1) System design framework

The platform is architected on a B/S model, which separates the front-end user interface from the back-end simulation logic, enhancing accessibility and maintainability [8]. The front-end, developed using modern web technologies like HTML, CSS, and JavaScript (with frameworks such as Vue.js or React), is responsible for user interaction, circuit diagram rendering (utilizing Canvas or SVG), and real-time data visualization. The back-end handles simulation requests by invoking the Multisim simulation engine through dedicated Application Programming Interfaces (APIs). The

integration between Multisim and LabVIEW is achieved using specific interface tools, primarily the HB/SC (Host-Based/Simulation Code) Connector and the LabVIEW-Multisim Co-Simulation Terminal [9]. This setup facilitates real-time bidirectional data exchange, allowing parameters set in LabVIEW to dynamically influence the circuit simulation running in Multisim.

(2) Co-simulation implementation process

The co-simulation process is methodically structured into three key stages, as demonstrated in the project's development [10][11]. The process begins with circuit design in Multisim, where the schematic for a specific experiment is drawn. Critical components requiring dynamic adjustment are configured with HB/SC Connector interfaces, marking them for external control. Subsequently, using the Co-Simulation Terminal tool, the designed Multisim circuit is converted into a LabVIEW sub-Virtual Instrument (sub-VI), known as the Multisim Design VI. This VI encapsulates the entire circuit's simulation model, making it a callable function within the LabVIEW environment. The final stage involves integration and control in LabVIEW. The Multisim Design VI is placed within a LabVIEW program block diagram, typically inside a Control & Simulation Loop. The HB/SC Connector interfaces are linked to corresponding controls and indicators on the LabVIEW front panel. This integration enables users to adjust circuit parameters in real-time and observe simulation results, such as voltage waveforms and current readings, directly on the interactive LabVIEW interface [12]. This co-simulation approach effectively mitigates the idealization bias often present in standalone Multisim simulations by incorporating LabVIEW's capacity for handling real-world control and data variability, leading to more accurate and practically relevant outcomes [13].

3. Platform Development and Key Functional Modules

The research has successfully translated the theoretical framework into a functional platform prototype, incorporating several essential experimental modules.

(1) Developed experimental modules

Following the project plan, five core experiment modules have been designed and implemented, covering fundamental

principles of circuit theory [14]. These modules include the Verification of Superposition Theorem and Homogeneity Theorem in Linear Circuits, the Verification of Thevenin's Theorem and Norton's Theorem, Response Testing of First-Order RC Circuits, Measurement of Phase/Line Voltages and Currents in Three-Phase Circuit (Delta Connection), and Two-Port Network Testing. These modules provide a comprehensive virtual laboratory experience, allowing students to explore and validate key circuit concepts from basic theorems to more complex network analyses. The development process involved detailed circuit design in Multisim, configuration of dynamic parameters through HB/SC connectors, and the creation of interactive LabVIEW interfaces for real-time data visualization and control.

(2) Dynamic scenario simulation and component library expansion

A significant contribution of this platform is the creation of dynamic experimental scenarios that go beyond static circuit analysis. By leveraging LabVIEW's programming capabilities, the platform can simulate the impact of real-world environmental factors on circuit performance [15]. For instance, it can model how temperature fluctuations affect semiconductor characteristics or how voltage disturbances influence power supply stability. Furthermore, the project utilizes LabVIEW's graphical programming environment to expand upon Multisim's built-in component model library. This enrichment allows for the simulation of a wider variety of circuits and components, increasing the platform's versatility and educational scope [16]. The platform's interactive interface, as developed, allows students to autonomously build circuits, set parameters, and observe outcomes, fostering an inquiry-based learning model. The integration of dynamic scenarios ensures that students gain practical insights into circuit behavior under varying conditions, bridging the gap between theoretical knowledge and real-world applications.

4. Pedagogical Significance and Application Value

The virtual simulation platform offers substantial advantages over traditional laboratory methods, aligning with modern educational objectives centered on accessibility, cost-effectiveness, and skill development.

Firstly, it dramatically reduces costs associated with the procurement, maintenance, and physical space of hardware equipment [17]. Updates and improvements are achieved through software modifications, eliminating the need for frequent and expensive hardware replacements. Secondly, it revolutionizes the learning model. The platform's modular and interactive interface encourages students to explore circuit behaviors beyond prescribed steps, promoting deeper understanding and innovative problem-solving [18]. This shift from passive instruction to active exploration is crucial for developing engineering intuition. Finally, it enables a more comprehensive and process-oriented assessment system. The LabVIEW front panel can be configured to record experimental procedures and data in real-time. This allows instructors to evaluate students based on their operational methodology, analytical skills, and debugging strategies, moving beyond a sole focus on the final result [19]. The platform's remote accessibility further supports flexible learning arrangements, making it particularly valuable in situations where physical lab access is limited.

5. Challenges and Technical Solutions

During the development phase, several technical challenges were encountered and systematically addressed, demonstrating the iterative nature of platform refinement [20][21]. A primary challenge involved the initial deployment, where the virtual experiment module circuits could not be correctly called from the LabVIEW Web Module for remote access. The solution involved migrating the platform architecture to a standard B/S model. The LabVIEW Web Publishing Tool was employed to deploy the VI front panels as web services, allowing users to access and operate the experiments directly through a standard web browser without requiring the installation of any client-side software, which greatly enhanced accessibility. Another significant challenge was the lack of a user authentication mechanism in the initially built platform, which prevented students from logging in with personal information. This was resolved by developing a dedicated LabVIEW service VI (Student_Import.vi) to manage user authentication. This VI connects to a backend database (e.g., Microsoft Access), checks for existing usernames or student IDs, inserts new student records upon registration, and returns the operation status, thereby implementing a secure and functional login system. Additional challenges related to real-time data synchronization between Multisim and LabVIEW were addressed through optimized API calls and buffer management, ensuring smooth interaction during complex simulations.

6. Conclusion and Future Work

This paper has detailed the research and practical implementation of a virtual simulation circuit experiment platform based on the co-simulation of LabVIEW and Multisim. The platform effectively addresses the principal limitations of traditional labs by offering a flexible, low-cost, and educationally robust alternative. Its dynamic scenarios and expanded component library significantly enhance students' opportunities for practical innovation. The successful resolution of technical challenges related to web deployment and user authentication underscores the platform's viability. The developed modules cover essential circuit theory concepts, providing a comprehensive learning tool that complements traditional laboratory work. The platform's architecture supports further expansion, allowing for the incorporation of additional experiments and advanced features based on evolving educational needs.

The immediate next phase involves the full deployment of the platform's server and its public release on the web. Future work will focus on continuously optimizing the platform's functionality, stability, and user experience based on feedback from actual teaching applications [22]. Furthermore, the theoretical frameworks established through this research—including architecture fusion theory for software integration, dynamic modeling theory for simulating environmental effects, and modular verification theory for experiment design—provide a solid foundation for future advancements in educational co-simulation technologies [23]. The platform demonstrates significant potential for widespread application in engineering education, paving the way for more immersive, accessible, and effective experimental learning. Planned enhancements include the integration of artificial intelligence for adaptive learning paths, support for collaborative multi-user experiments, and expanded compatibility with mobile

devices to further increase accessibility.

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