Summary

Candidate: *Ph.D. Botond Sándor KIREI*
Title: *Advancing Microelectronics through HDL-Based Digital Circuit and System Design and Implementation*
Field: Engineering Science – Electronics, Telecommunications and Nanotechnologies
Institution: Technical University of Cluj-Napoca (UTCN)

Overview and Motivation

The habilitation thesis presents the scientific, academic, and professional achievements of **Ph.D. Botond Sándor KIREI** following the completion of his doctoral studies in 2009. The work reflects more than fifteen years of research, teaching, industrial collaboration, and project leadership in digital hardware design, signal processing, energy systems, and space technologies. The central objective of the thesis is to demonstrate the candidate's contribution to strengthening the Romanian and European microelectronics ecosystem through the development of advanced digital systems implemented using Hardware Description Languages (HDLs), FPGA platforms, and modern electronic design methodologies.
The thesis is motivated by the historical decline of the Romanian semiconductor industry after 1990 and by the current shortage of specialists in digital integrated circuit design. Against this background, the candidate advocates for stronger cooperation between academia and industry, enhanced education in digital design, and the development of innovative hardware solutions. The work aligns closely with the objectives of the European Chips Act, particularly regarding semiconductor innovation, workforce development, and technological competitiveness.

Scientific Contributions

The scientific achievements are organized around four major research directions.

1. HDL-Based Digital Design Methodologies

The first research direction focuses on digital circuit and system design using VHDL, Verilog, and SystemVerilog. The candidate investigates methods for improving the design, verification, power estimation, and implementation of digital systems on FPGA and ASIC platforms.
A major contribution is the development of **PAELib**, a power- and area-aware VHDL library that enables designers to estimate power consumption and silicon area during simulation without requiring expensive Electronic Design Automation (EDA) tools. This approach supports early design optimization and facilitates cost-effective hardware development.
Another important achievement is the modeling, design, and implementation of **all-digital phase-locked loops (ADPLLs)**. The research provides theoretical and practical frameworks for analyzing oscillator resolution, quantization effects, jitter performance, and frequency synthesis. The work also resulted in patented solutions for improving digitally controlled oscillators and frequency synthesizers used in modern communication systems.

2. Adaptive Filters and Signal Processing Applications

The second research direction addresses adaptive signal processing algorithms and their hardware implementation. The candidate developed methods for:

- Blind source separation of audio signals;
- Acoustic echo cancellation;
- Adaptive linear and nonlinear filtering;
- I/Q imbalance compensation in communication receivers;
- FPGA implementation of signal processing architectures.

The research combines advanced algorithms with practical hardware realizations, enabling efficient deployment in wireless communication and audio processing applications. Significant attention is devoted to Software Defined Radio (SDR) systems, broadband receivers, and spectrum monitoring solutions. A notable outcome is the development of a wideband RF front-end capable of monitoring frequencies from 10 MHz to 8 GHz using FPGA-based architectures.

3. Energy Management Systems

The third research direction extends the candidate's expertise into renewable energy and power electronics. The work focuses on photovoltaic energy systems, energy conversion circuits, and energy optimization strategies.

Contributions include:

- Modeling and simulation of photovoltaic cells and solar plants;
- Design and analysis of switched-mode power supplies;
- Development of energy management methodologies;
- Optimization of power conversion and energy utilization.

These results support the efficient integration of renewable energy sources and demonstrate the applicability of digital modeling and control techniques in sustainable energy systems.

4. Space and Aerospace Technologies

The fourth research direction demonstrates the application of digital hardware expertise to space exploration technologies. The candidate participated in several national and European space projects involving:

- Inter-satellite communication systems;
- FPGA-based satellite communication modules;
- SpaceWire communication interfaces;
- Radiation-tolerant wireless communication systems;
- Hybrid inter-satellite links.

Key projects include **IntraSAT-Tech**, **HiSAT**, **H-ISL**, and **RT-UWB**, where the candidate contributed to the design of communication architectures and digital hardware modules intended for satellite networks and spacecraft communication systems. These projects highlight the transfer of advanced digital design methodologies into highly demanding aerospace applications.

Academic and Professional Achievements

The thesis documents a successful academic career at the Technical University of Cluj-Napoca, where the candidate progressed from Teaching Assistant to Associate Professor. He has been actively involved in curriculum development and teaching in areas such as:

- Digital Systems Design and Verification;
- FPGA-Based System Design;
- Advanced Signal Processing;
- Energy Management;
- Software Defined Radio Systems.

The candidate has authored or co-authored **76 scientific and educational works**, including books, book chapters, journal papers, conference publications, teaching materials, and patents. More than fifty publications are indexed in major international databases, demonstrating sustained scientific productivity and international visibility.

Beyond academia, he accumulated valuable industrial experience as an ASIC and FPGA verification engineer at companies including PitagorASIC, Movidius (Intel), Broadcom, Marvell Technologies, and Control Data Systems. This industrial background significantly strengthened the practical relevance of his research activities.

The thesis further demonstrates the candidate's capacity to lead research projects, manage multidisciplinary teams, supervise students, and establish productive collaborations with universities, research institutes, and industrial partners in Romania and abroad.

General Conclusion

The habilitation thesis presents a coherent and mature academic profile characterized by strong scientific productivity, multidisciplinary expertise, extensive teaching experience, successful project leadership, and meaningful industrial engagement. Through contributions to HDL-based digital design, adaptive signal processing, renewable energy systems, and space technologies, Ph.D. Botond Sándor KIREI has established himself as an active researcher and educator capable of leading doctoral research and contributing significantly to the development of microelectronics and digital systems engineering. The thesis convincingly demonstrates his qualifications for habilitation and for supervising future doctoral candidates in the field of Electronics and Telecommunications.