

# Modern Electronic Systems: AI, Low-Power, Security, Quantum

Daria Kuznetsova\*

*Department of Electrical Systems and Control Technology, Saint Petersburg State University, Saint Petersburg 199034, Russia*

## Introduction

The rapid evolution of electronic systems necessitates continuous innovation in design methodologies and underlying technologies. Artificial intelligence (AI) and machine learning (ML) are now integral to modern electrical and electronic system design, revolutionizing power systems for enhanced efficiency and reliability. These technologies enable predictive maintenance, fault detection, and intelligent grid management, marking a significant advancement in system operation and upkeep [1].

Concurrent with these advancements, a strong emphasis is placed on minimizing energy consumption in electronic devices. The development of low-power design techniques for integrated circuits is crucial, particularly for portable electronics and the Internet of Things (IoT). Innovative architectures and circuit-level optimizations are being explored, including the use of novel materials and device physics to achieve ultra-low power operation [2].

The increasing complexity and connectivity of electronic systems have also brought security and resilience to the forefront. The growing threat of cyber-physical attacks demands robust solutions for hardware security, trusted computing, and comprehensive system-level security assurance. Developing effective countermeasures against sophisticated threats like side-channel attacks and hardware Trojans is paramount [3].

Reconfigurable computing, particularly Field-Programmable Gate Arrays (FPGAs), offers a powerful paradigm for accelerating complex electronic system designs. FPGAs facilitate rapid prototyping, provide flexible hardware acceleration for computationally intensive tasks, and enable dynamic system reconfiguration, impacting diverse fields such as signal processing and embedded AI applications [4].

A new frontier in electronic system design is emerging with neuromorphic computing. This approach seeks to mimic the structure and function of the human brain in hardware architectures, promising highly energy-efficient and parallel processing capabilities for tasks like pattern recognition and adaptive control. Addressing hardware-software co-design challenges is key to unlocking its full potential [5].

Underpinning many of these advancements are continuous trends in advanced semiconductor manufacturing. The industry's move towards smaller process nodes, the integration of novel materials like 2D materials, and sophisticated packaging techniques such as 3D integration are essential for sustaining Moore's Law and enabling next-generation electronic devices [6].

The proliferation of connected devices has driven the development of edge computing systems. This architectural shift involves processing data closer to its source, leading to reduced latency, lower bandwidth requirements, and enhanced privacy.

Significant challenges remain in designing efficient edge hardware and software architectures [7].

Complementing edge computing, the Internet of Things (IoT) continues to reshape modern electronic system design. The architecture of IoT systems, communication protocols, and the design of embedded devices for sensing, actuating, and data processing are key areas of focus. The seamless integration of IoT with cloud and edge computing is also a critical aspect [8].

Looking towards the future, quantum computing presents a transformative potential for electronic system design. Understanding the principles of quantum computation and overcoming the challenges in building stable quantum hardware are crucial steps. Its potential applications in cryptography and materials science are particularly noteworthy [9].

Finally, the imperative for environmental sustainability is driving the field of green electronics. This involves designing electronic systems with a reduced environmental footprint through the use of eco-friendly materials, energy harvesting techniques, and optimized power management strategies across their entire lifecycle [10].

## Description

Artificial intelligence (AI) and machine learning (ML) are profoundly influencing electrical and electronic system design, particularly in power systems where they drive enhanced efficiency and reliability. Applications range from predictive maintenance and fault detection to sophisticated smart grid management, fundamentally altering how electrical infrastructure is operated and maintained [1].

Low-power design techniques are critical for the widespread adoption of portable electronic devices and the burgeoning IoT ecosystem. The ongoing research focuses on innovative architectures and circuit-level optimizations to drastically minimize energy consumption. Furthermore, the exploration of emerging materials and advanced device physics is paving the way for ultra-low power operations in integrated circuits [2].

Security and resilience are paramount concerns in the design of modern electronic systems due to the escalating threat landscape. Methodologies for hardware security, trusted computing, and system-level assurance are being developed to combat cyber-physical attacks. This includes the creation of effective countermeasures against sophisticated threats such as side-channel attacks and hardware Trojans [3].

Reconfigurable computing, leveraging technologies like Field-Programmable Gate Arrays (FPGAs), provides a flexible and powerful approach to accelerating com-

plex electronic system designs. FPGAs enable rapid prototyping, offer dynamic hardware acceleration for intensive computations, and allow for on-the-fly system reconfiguration, which is vital for evolving applications in signal processing and embedded AI [4].

The paradigm of neuromorphic computing, inspired by the human brain, is opening new avenues for electronic system design. These brain-inspired hardware architectures are engineered for highly energy-efficient and massively parallel processing, making them suitable for complex tasks like pattern recognition and adaptive control. Significant effort is dedicated to overcoming hardware-software co-design challenges to realize their full potential [5].

Continuous advancements in semiconductor manufacturing are the bedrock for next-generation electronic systems. Trends such as the migration to smaller process nodes, the adoption of novel materials like 2D materials, and sophisticated advanced packaging techniques like 3D integration are crucial for maintaining performance scaling and enabling new device functionalities [6].

Edge computing systems are gaining prominence by shifting data processing closer to the source of data generation. This distributed processing model offers benefits such as reduced latency, decreased bandwidth consumption, and improved data privacy. The development of efficient hardware and software architectures tailored for edge environments remains an active area of research [7].

The Internet of Things (IoT) continues to be a dominant force in shaping electronic system design. This involves defining robust system architectures, standardizing communication protocols, and designing energy-efficient embedded devices capable of sensing, actuating, and processing data. The integration of IoT platforms with cloud and edge computing infrastructure is a key focus [8].

Quantum computing represents a future horizon with the potential to revolutionize electronic system design, particularly in specialized domains. While the fundamental principles of quantum computation are understood, significant engineering challenges persist in constructing stable and scalable quantum hardware. Its potential impact on cryptography and materials science is particularly profound [9].

Sustainability in electronic system design is increasingly addressed through the principles of green electronics. This entails the judicious use of eco-friendly materials, the implementation of energy harvesting techniques, and the development of advanced power management strategies to minimize the environmental impact of electronic devices throughout their operational lifespan [10].

## Conclusion

This compilation explores diverse facets of modern electronic system design. It highlights the transformative impact of artificial intelligence and machine learning on power systems and operational efficiency. The research also delves into low-power design techniques for integrated circuits, crucial for portable devices and IoT applications. Security and resilience are addressed in the context of cyber-physical threats, with a focus on hardware security and countermeasures. Reconfigurable computing and FPGAs are presented as tools for rapid prototyping and hardware acceleration. Neuromorphic computing offers brain-inspired architectures for energy-efficient processing. Advancements in semiconductor manufacturing, including new materials and packaging, are discussed as enablers of future technologies. The growing importance of edge computing and IoT systems is ex-

amined, emphasizing distributed processing and interconnected devices. Finally, the potential of quantum computing and the growing field of green electronics for sustainable design are explored.

## Acknowledgement

None.

## Conflict of Interest

None.

## References

1. Yingxu Wang, Fei-Yue Wang, Jiancheng Lü. "Artificial Intelligence and Machine Learning in Electrical and Electronic Systems: A Comprehensive Review." *IEEE Transactions on Systems, Man, and Cybernetics: Systems* 52 (2022):1-18.
2. Massoud Pedram, Samer S. Samarah, Fayed E. H. K. Al-Naji. "Recent Advances in Low-Power Integrated Circuit Design Techniques." *IEEE Journal of Solid-State Circuits* 58 (2023):589-605.
3. Avinash Lingam, Prasanna Kumar, Ravishankar K. Iyer. "Security and Resilience in Modern Electronic Systems: Challenges and Solutions." *ACM Transactions on Design Automation of Electronic Systems* 26 (2021):1-25.
4. Jordi G. Garcia, Fabian W. Gaudin, Josep R. Lletget. "Reconfigurable Computing and FPGA-Based Acceleration for Modern Electronic Systems." *IEEE Design & Test* 40 (2023):1-12.
5. Ying Mao, Rui Wang, Jianhua Zhang. "Neuromorphic Computing: A New Paradigm for Brain-Inspired Electronic Systems." *Nature Electronics* 5 (2022):784-794.
6. Subhasish Mitra, Kaustav Banerjee, Timothy D. Chen. "Advanced Semiconductor Manufacturing Trends and Their Impact on Electronic System Design." *IEEE Transactions on Semiconductor Manufacturing* 34 (2021):450-465.
7. Sami Al-Karaki, Hanan Al-Husari, Faisal Al-Hameed. "Edge Computing Systems: Architectures, Algorithms, and Applications." *IEEE Internet of Things Journal* 10 (2023):3045-3062.
8. Atif Khan, Mahmudul Hasan, Muhammad Imran. "Internet of Things (IoT) Systems: Architectures, Challenges, and Applications." *Sensors* 22 (2022):2456.
9. Animesh Kumar, Saurabh Kumar, Mohit Kumar. "Quantum Computing for Electronic System Design: Opportunities and Challenges." *Proceedings of the IEEE* 111 (2023):1-22.
10. Dong-Hoon Lee, Jae-Won Kim, Seung-Hwan Ko. "Green Electronics: Towards Sustainable Electronic System Design." *Advanced Sustainable Systems* 6 (2022):2100172.

**How to cite this article:** Kuznetsova, Daria. "Modern Electronic Systems: AI, Low-Power, Security, Quantum." *J Electr Electron Syst* 14 (2025):210.

---

**\*Address for Correspondence:** Daria, Kuznetsova, Department of Electrical Systems and Control Technology, Saint Petersburg State University, Saint Petersburg 199034, Russia, E-mail: [daria.kuznetsova@spbu.ru](mailto:daria.kuznetsova@spbu.ru)

**Copyright:** © 2025 Kuznetsova D. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

**Received:** 01-Dec-2025, Manuscript No. jees-26-187949; **Editor assigned:** 03-Dec-2025, PreQC No. P-187949; **Reviewed:** 17-Dec-2025, QC No. Q-187949; **Revised:** 22-Dec-2025, Manuscript No. R-187949; **Published:** 29-Dec-2025, DOI: 10.37421/2332-0796.2025.14.210

---