THE DEPARTMENT OF
ELECTRONICS AND COMMUNICATION ENGINEERING

SPARK

AN ARC OF STUDENT PASSION

VOLUME 4, ISSUE 1
DECEMBER 2025

AHALIA SCHOOL OF ENGINEERING & TECHNOLOGY

NAAC
NATIONAL ASSESSMENT AND ACCREDITATION COUNCIL

ISO 9001:2015 Certified Institution I Approved by AICTE & Affiliated to A.P.J Abdul Kalam Technological UniversityAhalia Campus,Palakkad I Ph: 04923 226666

VISION

Grow as a center of learning and research, transforming students to professionals with knowledge, skill, competence, commitment, confidence through decisive learning and contribute to the sustainable development of the society.

MISSION

- To instill technical expertise in order to address current and emerging challenges in the quest for creating sustainable and high-quality livelihoods.

- To foster a culture of research, innovation, and entrepreneurship through determined learning.

- To promote an environment that supports the welfare of society through ethical and professional conduct.

About ECE Department

The Department of Electronics and Communication Engineering (ECE) is a dynamic and innovative hub committed to excellence in teaching, research, and industry collaboration. Established with the vision to produce competent professionals, the department focuses on developing strong foundational knowledge and advanced technical skills in electronics, communication systems, embedded systems, VLSI design, IoT, and signal processing.

Our faculty comprises highly qualified educators and researchers who bring a wealth of academic and industry experience. The department offers undergraduate programs that blend rigorous theoretical instruction with hands- on practical training. State-of-the-art laboratories, modern research facilities, and industry-standard software tools support experiential learning and innovation.

We actively promote research, internships, and student participation in technical events and competitions. With regular guest lectures, industrial visits, and collaboration with leading companies, the department ensures students are industry-ready and equipped to face emerging global challenges in technology.

Graduates from the ECE department are well-placed in top-tier companies, pursue higher studies at renowned institutions, and contribute significantly in areas such as telecommunications, robotics, AI, space technology, and consumer electronics.

Vision, Mission of Department (ECE)

VISION:

To provide quality education in Electronics and Communication Engineering through determined learning, promoting innovation and research, upholding professional ethics and contribute to sustainable societal progress.

MISSION:

The mission statements of the department are:

MD-1 To provide a holistic technical education that empowers students with a robust foundation of theoretical expertise and practical skills in Electronics and Communication Engineering.

MD-2 To foster lifelong learning, research and inspire entrepreneurship, empowering students to excel in their field of expertise.

MD-3 To nurture professional ethics, team work and leadership skills in students for their overall development and contribution to the society

Program Educational Objectives (PEOs)

PEO1: Apply the knowledge of electronics and communication engineering to design, develop and maintain systems that meet industry and societal requirements

PEO2: Pursue lifelong learning, advanced studies and research, staying updated with emerging technologies and adapting to evolving professional landscapes.

PEO3: Work effectively as individuals and in multidisciplinary teams, demonstrating problem solving, leadership and communication skills.

Program SpecificOutcomes (PSOs)

PSO1:
Develop electronics-based solutions for real-life challenges integrating entrepreneurship and sustainability.

PSO 2:
Upholdethics and values in designing sustainable technologies while embracing lifelong learning for professional growth.

Program Outcomes (POs)

PO 1.Engineering Knowledge:
Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3.Design/Development of Solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct Investigations of Complex Problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The Engineer and Society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and Sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8.Ethics:
Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and Team Work:
Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11. Project Management and Finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. Life-long Learning:
Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

LIST OF FACULTY MEMBERS

Dr .Krishna Kumar Kishore
Vice Principal

Dr V Balamurgan
HOD ECE

Dr Leesha Paul
Professor

Dr Aneesh K
Associate Professor

Dr. Divya Mohan
Assistant
Professor

Ms. Vijitha Khan
Assistant Professor

Ms. Swetha C
Assistant Professor

Ms. Asha Aravind
Assistant Professor

Ms. Gayathri P S
Assistant
Professor

Mr. Vinod Kumar P
Assistant
Professor

Mr. Sanish V S
Assistant
Professor

Ms. Priyanka K

Ms Sindhu V R

Mr. Sathyan P

Sreejesh R

Department Association Office Bearers

Department Association Office bearers

Chairman
Dr. Balamurugan V
HoD ECE

Faculty in Charge
Mrs. Gayathri P S
Assistant professor ECE

Student office bearers

Al- Ameen K H
S4 ECE
Member

Arya B
S6 ECE
Member

ATHISH R
S8 ECE
President

Nandana N
S8 ECE
Member

SreeVishnu
S6 ECE
Member

Keerthy S
S4 ECE
Member

Mr. Sanish V S

Staff Editorial

It is with great pride and enthusiasm that we present this edition of Spark, the annual magazine of the Department of Electronics and Communication Engineering. Spark is not just a collection of articles—it is a reflection of the creativity, technical curiosity, and collective spirit of our department.

The world of Electronics and Communication is advancing at an unprecedented pace, touching every facet of human life—from the smartphones in our hands to satellites orbiting the Earth. As engineers of tomorrow, it becomes essential for us to not only keep pace with these changes but also to become innovators who shape the future. Through Spark, we aim to ignite thought, showcase talent, and celebrate the academic and creative pursuits of our students and faculty.

This magazine is a platform where knowledge meets imagination. It brings together insightful articles, technical explorations, interviews, and creative contributions that mirror the vibrant energy of our department. It is also a tribute to the dedication of our students, whose passion for learning and innovation keeps the flame of progress alive.

We extend our heartfelt gratitude to the Principal, Vice Principal, and Head of the Department for their constant encouragement and support. A special thanks goes to our faculty members for guiding us, and to our student community whose hard work and enthusiasm breathe life into this publication. We hope that this edition of Spark inspires readers to think beyond boundaries, to question, to innovate, and to shine with brilliance—just as a spark lights the way for a greater flame.

– The Editorial Team

Ajil Madhav C K

Student Editorial

With immense joy and excitement, we bring to you this edition of Spark, the magazine of the Department of Electronics and Communication Engineering. For us students, Spark is more than a magazine—it is a canvas where ideas take shape, creativity finds voice, and innovation gets celebrated.

In today's world, technology is evolving faster than ever before. As students of ECE, we witness how electronics and communication form the backbone of modern life—powering everything from everyday gadgets to space exploration. Through Spark, we aspire to highlight not only these advancements but also the energy, imagination, and curiosity that define our student community.

This magazine is a reflection of our journey as learners and dreamers. It captures diverse contributions—technical articles, creative writings, artwork, and reflections— that together showcase the talent and passion of our department. Working on Spark has also taught us the value of teamwork, patience, and persistence, qualities that are as important in life as they are in engineering.

We take this opportunity to thank our Principal, Vice Principal, and Head of the Department for their encouragement and support. A heartfelt note of gratitude goes to our faculty, whose guidance continually inspires us to aim higher. Above all, we thank our fellow students for pouring their thoughts, ideas, and creativity into this magazine, making it truly special.

We hope Spark ignites curiosity, inspires innovation, and reminds us all that even the smallest spark has the power to light up great possibilities.

– The Student Editorial Board

Contents

Message From Principal

It gives me immense pleasure to pen a message for "Spark", the annual magazine of the Department of Electronics and Communication Engineering. The name itself—Spark —reflects the essence of innovation, curiosity, and the vibrant spirit of the ECE community within our institution.

The field of Electronics and Communication continues to evolve at an unprecedented pace, playing a pivotal role in shaping the future of technology. From embedded systems and VLSI design to communication networks and signal processing, ECE forms the backbone of countless modern advancements. I am proud to see our department nurturing this spirit of exploration and excellence through academic rigor, hands-on learning, and meaningful research.

"Spark" is more than just a collection of articles; it is a platform that showcases the creativity, technical prowess, and achievements of our students and faculty. It reflects the dynamic environment of the department—one where ideas are kindled, challenges are embraced, and knowledge is transformed into innovation.

I extend my heartfelt congratulations to the editorial team, faculty, and students who have contributed to this edition. Your efforts in curating and presenting the vibrant activities, projects, and accomplishments of the department are truly commendable. I encourage all students to continue striving for excellence, staying curious, and pushing the boundaries of what is possible.

May Spark continue to ignite young minds and inspire future innovations.

Warm Regards,
Dr PR Suresh
Principal

Message From Vice Principal

It is a pleasure to extend my warmest greetings to the Department of Electronics and Communication Engineering on the publication of their departmental magazine, "Spark". This magazine reflects the energy, creativity, and technical brilliance that the ECE department consistently brings to our institution.

The world of electronics and communication is at the heart of modern innovation—from smart systems and wireless networks to artificial intelligence and embedded technologies. In such a rapidly evolving domain, it is inspiring to see our students and faculty staying ahead through continuous learning, practical exploration, and a passion for problem-solving.

"Spark" serves as a platform for students to express their ideas, showcase their projects, and share insights into the latest technological trends. It captures the intellectual spirit and collaborative culture that define the ECE department. Initiatives like these are vital for nurturing innovation and encouraging students to think beyond the classroom.

I congratulate the editorial team, contributors, and faculty members who made this edition possible. Your dedication is evident in every page, and your efforts add immense value to the academic fabric of our institution.

Wishing the ECE department continued success in all its future endeavors. May "Spark" continue to ignite innovation and inspire excellence.

Warm Regars,
Dr. Krishna Kumar Kishor
Vice Principal - ASET

Message From HOD

It gives me great joy to present the latest edition of "Spark", the annual magazine of the Department of Electronics and Communication Engineering. This publication is a reflection of our department’s vibrant academic culture, technical achievements, and creative spirit.

In an era where technology evolves rapidly, the role of ECE professionals has become more critical than ever. From next-generation communication systems and embedded technologies to IoT and artificial intelligence, the scope of ECE is vast and ever-expanding. At our department, we are committed to equipping students with not only strong technical foundations but also the mindset to innovate, explore, and lead.

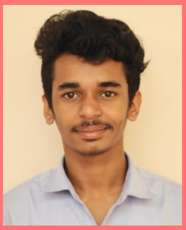
"Spark" showcases the hard work, dedication, and talent of our students and faculty. It captures the essence of what we strive to achieve—academic excellence, research-driven learning, and holistic development. I believe that platforms like this are essential to nurture creativity and to give students an opportunity to express their ideas beyond textbooks and classrooms.

I would like to congratulate the editorial team, contributors, and faculty mentors for their efforts in bringing this magazine to life. Your work is a testament to the spirit of collaboration and excellence that defines our department.

Let "Spark" continue to inspire, inform, and ignite new ideas in the minds of its readers.

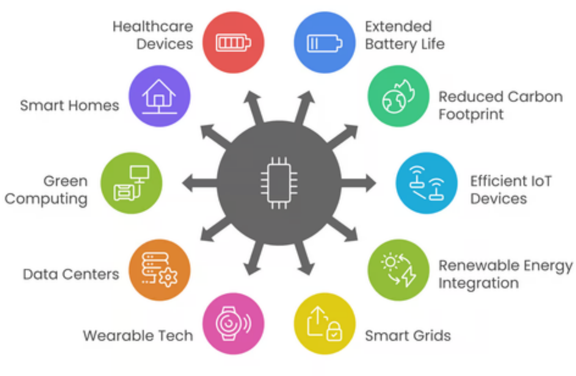
Warm regards,
Dr. V Balamurugan
Professor & HOD - ECE

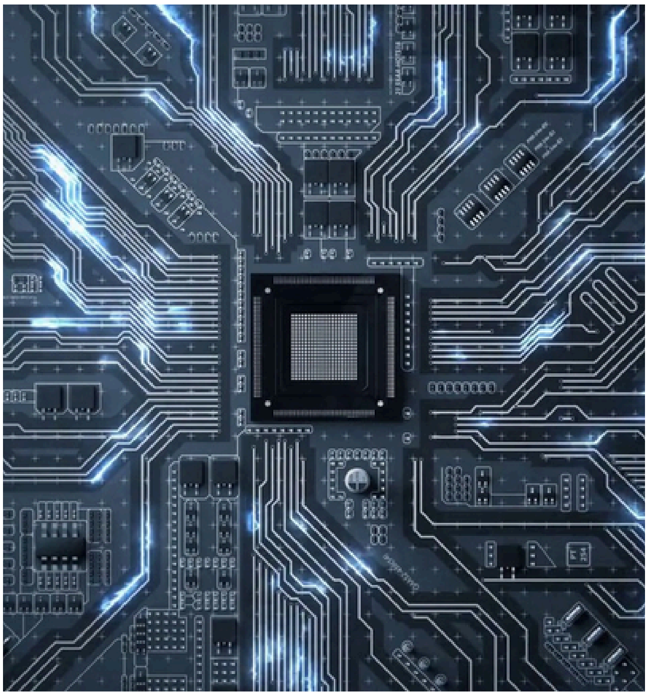
Energy-Efficient VLSI Designs: Shaping the Future of Electronics



Ajay N J
S6 ECE

In today's world, where technology is advancing at an unprecedented rate, the demand for energy-efficient devices is more crucial than ever. "Very Large Scale Integration (VLSI)" plays a vital role in this transition by integrating millions (and sometimes billions) of transistors into a single chip, enabling the development of modern electronics. As the complexity of devices increases, so does their power consumption. However, there is an increasing focus on "energy-efficient VLSI designs" to ensure that devices are not only powerful but also consume less energy. These energy-efficient designs are essential for a wide range of applications, from mobile devices to large-scale data centers.





Energy-efficient VLSI design focuses on reducing power consumption while maintaining performance, which is critical for modern electronic systems. One key technique is power gating, where unused circuit blocks are temporarily switched off to reduce static power dissipation, often implemented using multi-threshold CMOS technologies. Clock gating complements this by disabling clock signals to inactive components, thereby lowering dynamic power consumption caused by unnecessary switching.

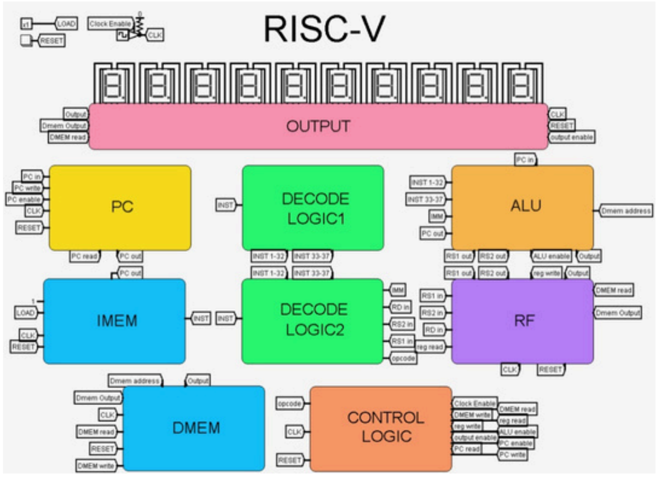
Another widely used approach is Dynamic Voltage and Frequency Scaling (DVFS), which adjusts a chip's operating voltage and frequency according to workload demands. This technique is especially effective in mobile and portable devices, as it conserves energy during low activity while allowing high performance when needed. Energy-efficient circuit design, including low-power architectures and multi-threshold voltage CMOS, further minimizes switching activity and optimizes energy usage. Additionally, sub-threshold operation enables circuits to function below nominal voltage levels, significantly reducing power consumption, making it suitable for IoT devices, wearables, and sensor networks. These techniques have a major impact across applications such as mobile devices, data centers, and IoT systems, helping extend battery life, reduce operational costs, and support sustainable technology goals. Despite challenges like leakage power and scaling limitations, future advancements in materials, transistor architectures, and AI-aware hardware design promise even greater energy efficiency.

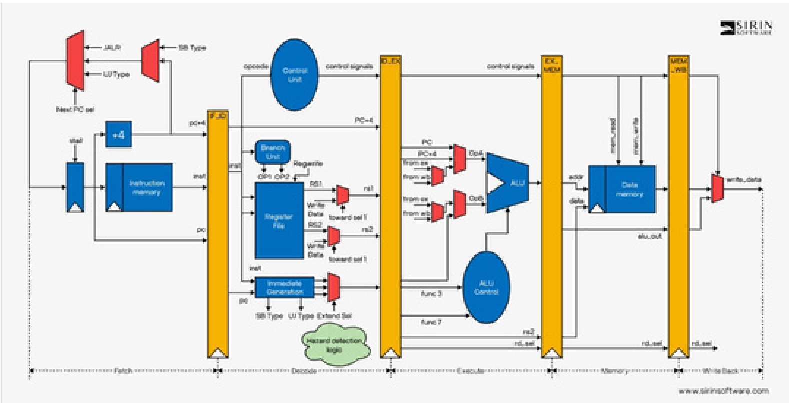
RISC-V Open-Source Processor Design

Abhinandh P N
S6 ECE

RISC-V is an open-source Instruction Set Architecture (ISA) based on the principles of Reduced Instruction Set Computer (RISC). It was developed to provide a free, flexible, and extensible alternative to proprietary processor architectures. Unlike traditional ISAs that require expensive licenses, RISC-V can be used, modified, and manufactured by anyone, making it highly attractive for education, research, startups, and semiconductor industries.

The RISC-V architecture follows a simple and clean design philosophy. It uses a load–store architecture, where all arithmetic and logical operations are performed on registers, and memory is accessed only through load and store instructions.





A basic RISC-V processor consists of a Program Counter, Instruction Fetch Unit, Register File (32 general-purpose registers), ALU, Control Unit, and Load/Store Unit. This simplicity helps in achieving high performance with low power consumption.

One of the most important features of RISC-V is its modular instruction set. It has a small base integer instruction set (RV32I or RV64I) and several optional extensions such as M (multiply/divide), F and D (floating point), C (compressed instructions), and V (vector extension). Designers can select only the required extensions, which reduces chip area, power, and cost. This makes RISC-V suitable for applications ranging from tiny IoT devices to high-performance computing systems.

From a VLSI design perspective, RISC-V processors are implemented using standard design flows. The process starts with ISA selection and micro-architecture design, followed by RTL coding using Verilog or VHDL, functional simulation, synthesis, physical design, and verification. Because the ISA is open, students and engineers can study and modify real processor designs, which is difficult with proprietary architectures.

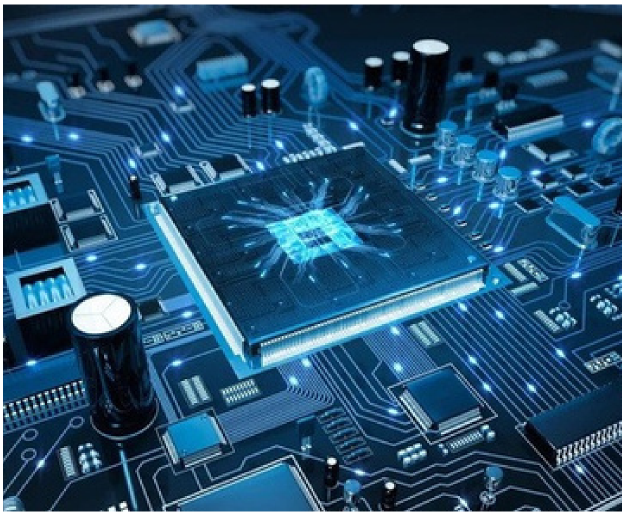
RISC-V offers several advantages such as zero royalty cost, high customizability, low power operation, and strong academic support. However, its software ecosystem is still developing compared to ARM or x86. Despite this, rapid industry adoption and open-source community support are closing this gap quickly.

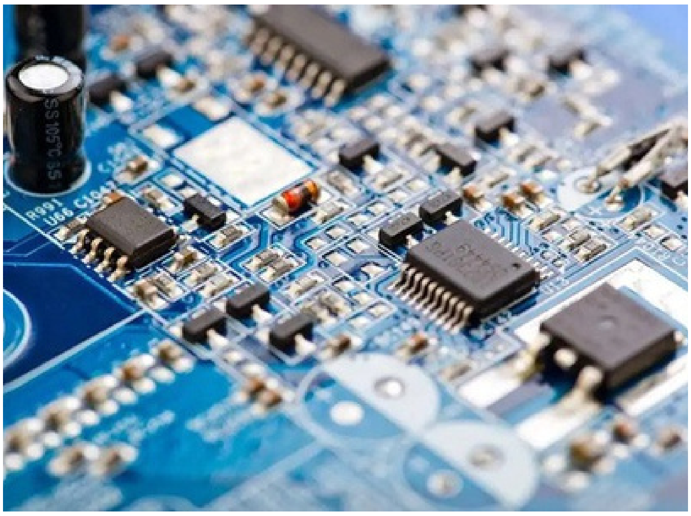
Today, RISC-V is used in embedded systems, IoT devices, AI accelerators, automotive electronics, and research processors. Its openness and flexibility make it a key technology for the future of VLSI and semiconductor innovation.

Internet of Things (IoT) and Massive Machine Connectivity

AJIL J
S8 ECE

The Internet of Things (IoT) represents a paradigm shift in Electronics and Communication Engineering, where physical objects such as sensors, actuators, machines, and devices are interconnected through the internet to collect, exchange, and process data intelligently. A key evolution of IoT is Massive Machine Connectivity (MMC), which focuses on enabling communication among millions of low-power devices simultaneously, forming the backbone of smart and autonomous systems. In traditional communication systems, networks were primarily designed for human-to-human communication. However, with the growth of IoT, the focus has shifted to machine-to-machine





(M2M) communication, where devices autonomously transmit data with minimal human intervention. Massive Machine Connectivity supports this transformation by allowing large-scale device deployments while maintaining reliability, scalability, and energy efficiency.

IoT systems typically consist of sensing units, embedded processors, communication modules, cloud platforms, and user interfaces. Sensors measure physical parameters such as temperature, humidity, gas concentration, pressure, or motion. Embedded controllers process this data and transmit it using communication technologies like NB-IoT, LTE-M, LoRaWAN, 5G, and upcoming 6G networks. These technologies are specifically designed to handle massive device density with low latency and low power consumption.

One of the major challenges in massive machine connectivity is energy efficiency. Most IoT devices operate on batteries or energy-harvesting sources and are expected to function for years without maintenance. To address this, modern protocols use sleep modes, lightweight signaling, and optimized data transmission techniques. Another critical challenge is network congestion, as thousands of devices may attempt to communicate simultaneously. Advanced scheduling algorithms and AI-based traffic management are used to ensure smooth data flow. Security is also a vital concern in IoT and MMC systems. Since devices are often deployed in open or remote environments, they are vulnerable to cyberattacks. Techniques such as end-to-end encryption, secure authentication, and blockchain-based security models are increasingly adopted to protect data integrity and privacy.

Applications of IoT with massive machine connectivity are widespread. These include smart cities, where sensors manage traffic, lighting, and waste; industrial IoT (IIoT) for predictive maintenance and automation; healthcare monitoring systems; environmental and air quality monitoring; and smart agriculture for efficient resource utilization.

Solar-Powered DC Oxygen Concentrator with Integrated Real-Time Monitoring

ABHISHEK K V
S8 ECE

Medical oxygen delivery systems play a vital role in the management of chronic respiratory diseases, post-infectious pulmonary impairment, and long-duration oxygen therapy for elderly and dependent patients. While oxygen concentrators are widely deployed in home-care and clinical settings, conventional designs remain constrained by high power consumption, reliance on unstable electrical grids, limited energy efficiency, and a lack of embedded intelligence for performance and patient monitoring. These constraints significantly limit their effectiveness in rural, remote, and resource-constrained environments.

A solar-powered DC oxygen concentrator with integrated real-time monitoring addresses these limitations through a system-level redesign that combines renewable energy utilization, DC-based electromechanical architecture, intelligent control, and continuous physiological data acquisition.

Traditional oxygen concentrators predominantly use AC compressors, which necessitate internal AC–DC conversion for control electronics, resulting in conversion losses, thermal stress, and reduced operational efficiency. A DC-based architecture eliminates redundant power conversion stages by directly utilizing a BLDC oil-less air compressor driven through electronic speed control.

This configuration offers improved electrical efficiency, reduced acoustic noise, minimized heat dissipation, and extended component lifespan.

The system is designed to operate primarily on solar energy, harvested through photovoltaic panels and stored in battery banks managed by power regulation and protection circuitry. Intelligent power management ensures stable operation across varying solar conditions. To further enhance energy resilience, future expansion includes the integration of fuel cell technology as an auxiliary power source, enabling uninterrupted operation during prolonged low-irradiance periods or concurrent grid.

Oxygen enrichment is achieved using the Pressure Swing Adsorption (PSA) process, a well-established separation technique for medical-grade oxygen production. Ambient air is compressed and directed through molecular sieve beds, typically zeolite-based, which selectively adsorb nitrogen under pressurized conditions while allowing oxygen to pass through. System efficiency and output purity are governed by precise control of PSA parameters such as compressor pressure, valve switching frequency, adsorption–desorption timing, and flow regulation. Dynamic tuning of the PSA cycle enables consistent oxygen purity levels while minimizing energy consumption.

AI Enhanced Optical Wireless Communication System

Pooja P Menon
S8 ECE

The evolution of AI-enhanced Optical Wireless Communication (OWC) has moved beyond simple data transmission into the realm of self-governing, "AI-native" networks. At the physical layer, the integration of Deep Learning (DL) architectures, specifically those utilizing Transformer-based models and Temporal Convolutional Networks, has solved the long-standing issue of atmospheric scintillation. These models process high-dimensional sensor data to predict the refractive index fluctuations of the air in real-time. By anticipating how a laser beam will distort before it even leaves the transmitter, the AI can apply adaptive optics and digital pre-distortion to ensure the signal remains coherent upon arrival,

effectively turning a chaotic medium like the atmosphere into a predictable channel for multi-terabit data transfer.

The management of these systems is now driven by Deep Reinforcement Learning (DRL), which governs the complex task of beam steering and handover in highly mobile environments. In a 2026 deployment scenario, such as a Heterogeneous Network (HetNet), DRL agents continuously evaluate the Quality of Service (QoS) across multiple spectrums, including visible light (Li-Fi) and infrared. If a physical obstruction—such as a person walking or a drone flying—interrupts an optical path, the AI agent performs a "proactive handover." It redirects the data stream to an adjacent optical node or switches to a backup Radio Frequency (RF) link with sub-millisecond precision, ensuring that the user experiences zero-latency connectivity even as the physical environment changes.

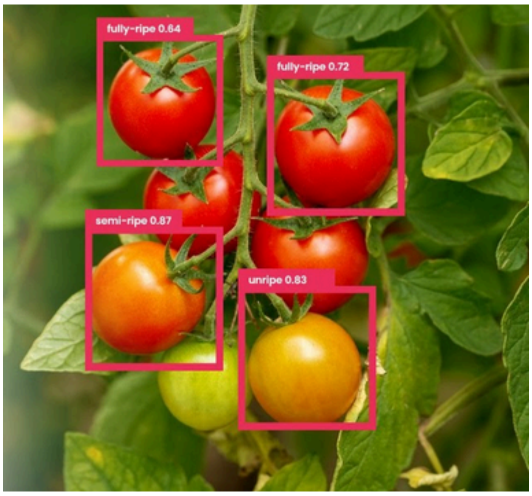
Furthermore, hardware miniaturization through AI-driven Photonic Integrated Circuits (PICs) has enabled the deployment of these systems in power-constrained environments like Low Earth Orbit (LEO) satellites and underwater autonomous vehicles. These chips incorporate dedicated Neural Processing Units (NPUs) that execute complex inference tasks directly on the transceiver, eliminating the need for data to be sent to a central cloud for processing. This "edge intelligence" is vital for Optical Intersatellite Links (OISLs), where AI algorithms must compensate for the mechanical jitter and high-velocity relative motion of satellites to maintain a laser lock across thousands of kilometers, a feat that requires a level of precision impossible to achieve with manual or legacy control systems.

Finally, the convergence of AI and OWC is the primary catalyst for Integrated Sensing and Communication (ISAC) within the 6G framework. Because light waves are highly directional and sensitive to the environment, AI-enhanced OWC systems can dual-purpose their communication beams to act as high-resolution LiDAR-like sensors. This allows the network to "see" its surroundings, mapping indoor spaces for industrial robotics or monitoring air quality by analyzing light absorption patterns. This dual capability transforms the communication infrastructure into a ubiquitous sensing grid, where the AI manages a delicate balance between maximizing data throughput and gathering environmental intelligence, marking the transition from a passive utility to an active, cognitive ecosystem.

Automated Tomato Quality Classification Using Deep Learning

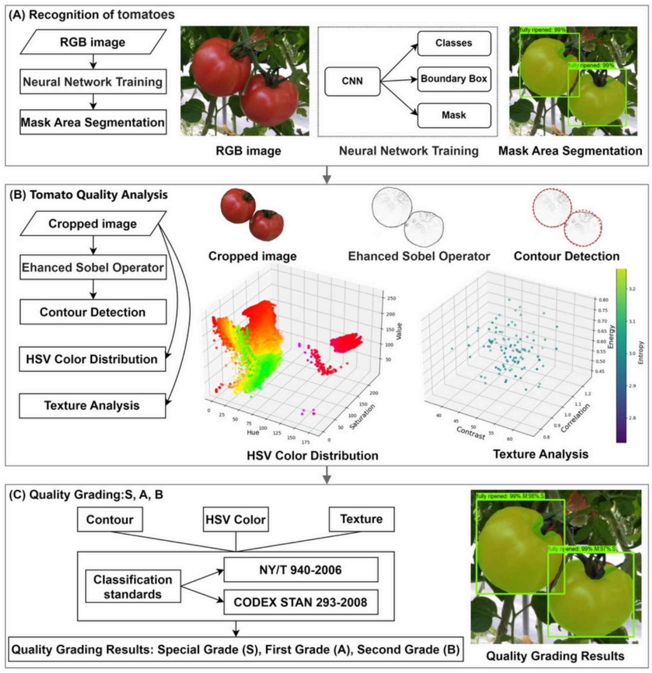
Sreelakshmi V
S8 ECE

The increasing demand for efficient agricultural quality control has highlighted the limitations of manual tomato inspection, which is time-consuming, inconsistent, and prone to human error. To overcome these challenges, this project presents an automated tomato quality classification system using deep learning techniques. The system classifies tomatoes into four categories—Unripe, Ripe, Old, and Damaged—helping improve grading accuracy, reduce food waste, and enhance supply chain efficiency. The dataset used for training and evaluation is sourced from Kaggle and contains labeled tomato images representing various quality conditions.



To ensure robust model performance, the images undergo preprocessing steps such as resizing, normalization, and data augmentation including rotation, flipping, and scaling. The first model implemented is a Convolutional Neural Network (CNN), which automatically extracts spatial features from images through convolutional and pooling layers. The CNN model achieves an accuracy of 95%, demonstrating strong classification capability across most classes, with minor misclassification observed in the "Old" tomato category.

To further enhance accuracy, a ResNet model is employed, which uses residual connections to overcome the vanishing gradient problem and enables deeper network training



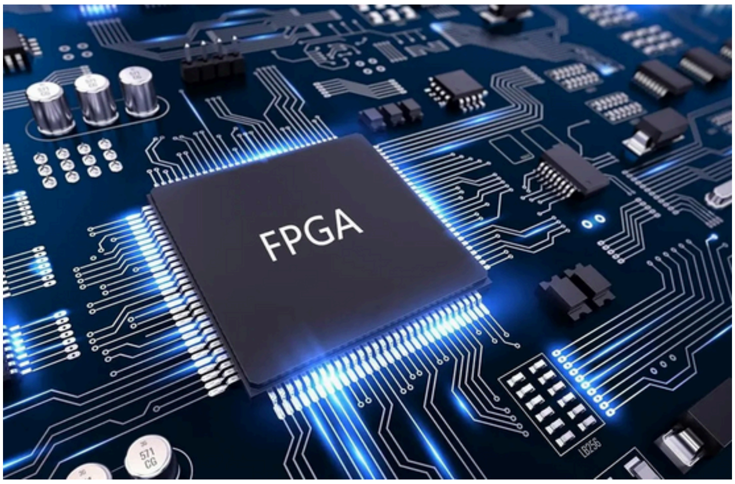
The ResNet model outperforms the CNN by achieving an accuracy of 98%, with high precision and recall across all classes, indicating reliable and consistent predictions. In addition, a hybrid approach combining Swin Transformer and Random Forest is explored, where the Swin Transformer extracts both local and global image features and the Random Forest classifier improves robustness and generalization.

The system undergoes extensive testing, including unit testing, integration testing, functional testing, white box testing, and black box testing, with all test cases passing successfully. Feasibility analysis confirms that the system is economically viable, technically feasible, and socially acceptable due to its use of open-source technologies and user-friendly design. Overall, the proposed system provides a fast, accurate, and scalable solution for automated tomato quality assessment and can be extended to other agricultural products for improved quality control.

FPGA -Based Approach to LASER Beam Control and Profiling for Quantum Applications

Arya P R
S8 ECE

In 2026, Field-Programmable Gate Arrays (FPGAs) have transitioned from being simple interface components to the deterministic "brain" of quantum optical control stacks. The primary challenge in quantum systems—such as neutral atom traps or superconducting qubits—is the requirement for sub-microsecond feedback to counteract environmental decoherence. Modern FPGA-based architectures, particularly System-on-Chip (SoC) platforms like the Xilinx Alveo or Zynq UltraScale+, provide the massive parallelism needed to process multi-megapixel camera streams and photodiode signals simultaneously.



By implementing image processing pipelines directly in the FPGA fabric, researchers can extract Gaussian beam parameters from 5 MP cameras at rates exceeding 50 fps with a total processing latency of less than 500 ns, a feat impossible for traditional CPU or GPU-based systems which often suffer from millisecond-scale jitter.

The implementation of Hardware-Accelerated Machine Learning within these FPGAs represents a significant technological leap. Rather than using fixed-function mathematical models, 2026 systems utilize lookup-table-based Multilayer Perceptrons (MLPs) and systolic array decoders to perform real-time beam profiling. These AI-driven blocks can identify and stabilize "exotic" beam modes, such as Laguerre-Gaussian (LG) or Hermite-Gaussian (TEM01) modes, which are increasingly used in optical lattices to create complex trapping potentials. Because the inference happens at the "edge" of the sensor, the system can provide active phase-feedback on optical lattices and stabilize independent optical tweezers in an array within 5 µm accuracy, ensuring that individual atoms remain trapped despite thermal drift or mechanical vibrations.

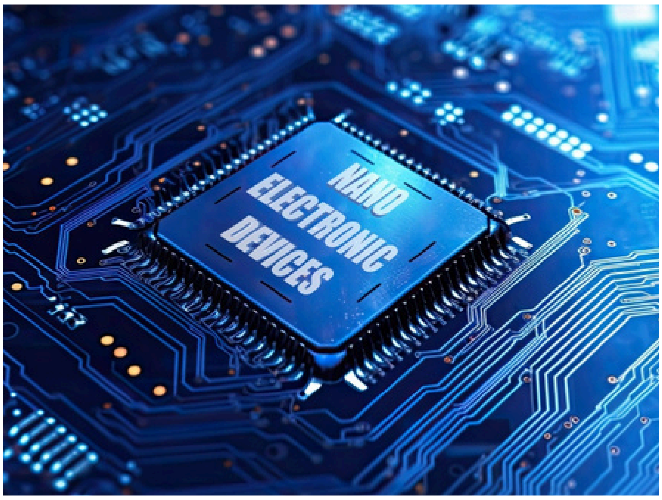
Beyond spatial control, FPGAs are now the standard for Frequency and Phase Stabilization through digital Pound-Drever-Hall (PDH) locking and frequency-comb stabilization. By integrating 16-bit, 100 MS/s ADCs and 20-bit high-speed DACs, a single FPGA can manage multiple Proportional-Integral-Derivative (PID) control loops in parallel. This allows for the simultaneous locking of laser repetition frequencies and the stabilization of semiconductor laser drive currents with a temperature accuracy of $\pm0.01\text{°C}$. The use of Partial Reconfiguration technology further allows these controllers to switch their internal logic—for example, changing from a frequency locker to a Pulse-Shape Analyzer—on-the-fly without interrupting the broader quantum experiment, providing a level of flexibility essential for scaling from tens to hundreds of qubits.

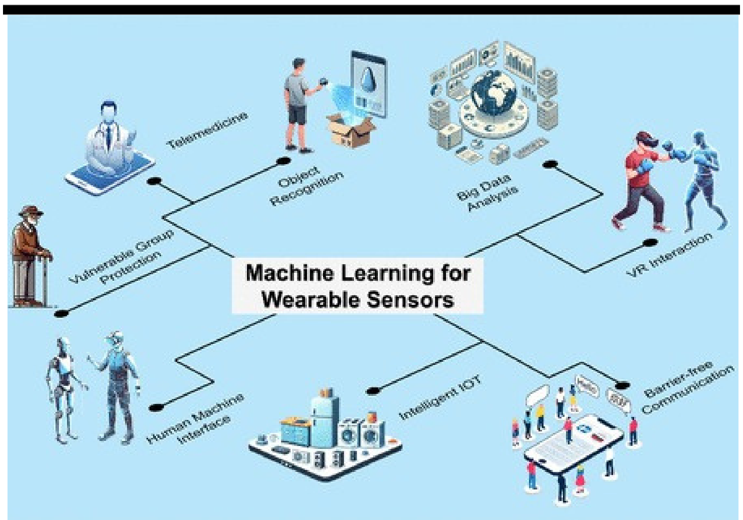
The final layer of this technology is its integration into Integrated Quantum Orchestration platforms. In these systems, the FPGA serves as the master synchronizer, coordinating laser pulses with cryogenic microwave electronics and RF signals for Acousto-Optical Deflectors (AODs). This ensures that "rearrangement sequences"—the moving of atoms to fill defects in a quantum array —occur within the narrow 10–40 ms window before the configuration's lifetime expires. By pushing the "classical-quantum interface" into the FPGA fabric, 2026 systems achieve the deterministic timing and high-speed error correction necessary for Fault-Tolerant Quantum Computing (FTQC), effectively bridging the gap between laboratory-scale physics and industrial-grade quantum processors.

Closed-Loop Implantable Neurostimulation Systems: A Life-Saving ECE Innovation

M MOHAMMED NIYAS
S6 ECE

Sudden Cardiac Death (SCD) is a leading cause of unexpected mortality, often occurring without warning and leaving little time for emergency medical intervention. Conventional implantable cardiac devices such as pacemakers and defibrillators are largely reactive, responding only after a critical cardiac event has begun. Recent advancements in Electronics and Communication Engineering (ECE) have enabled a more effective preventive solution: closed-loop implantable neurostimulation systems.





Closed-loop implantable neurostimulation systems continuously monitor physiological signals such as electrocardiograms (ECG) and heart rate variability using miniaturized biomedical sensors. The collected signals are processed in real time through low-power signal processing circuits and embedded intelligent algorithms to detect early signs of abnormal cardiac activity.

When a potential risk is identified, the system automatically delivers precise, low-energy electrical stimulation to specific neural pathways involved in cardiac rhythm control. This targeted neurostimulation helps stabilize the heart's electrical activity and prevent the onset of sudden cardiac arrest, often without the need for high-energy shocks.

The development of these systems relies heavily on ECE principles, including biosignal acquisition, low-power electronics, embedded intelligence, and secure wireless communication for remote patient monitoring. Designed to operate autonomously within the human body for extended periods, these devices act as continuous, internal life-saving safeguards.

In conclusion, closed-loop implantable neurostimulation systems represent a significant advancement in preventive cardiac care. By shifting from reactive treatment to predictive intervention, this technology highlights the critical role of Electronics and Communication Engineering in developing intelligent solutions that directly save human lives.

By combining adaptive control algorithms, personalized machine learning models, biocompatible encapsulation, energy harvesting techniques, and secure real time telemetry, closed loop implantable neurostimulation systems achieve enhanced safety, long term autonomy, patient specific optimization, fault tolerance, reduced surgical interventions, improved clinical outcomes, and scalable deployment across diverse healthcare environments worldwide, with regulatory compliance, interoperability, and ethical data governance standards ensured globally.

Cybersecurity for Communication Networks

AJIL MADHAV C K
S8 ECE

Cybersecurity for communication networks is a critical area in Electronics and Communication Engineering, driven by the rapid growth of digital communication, wireless systems, and internet-based services. Communication networks form the backbone of modern society, enabling mobile communication, internet access, cloud computing, smart grids, and critical infrastructure. As these networks expand, they become attractive targets for cyberattacks, making robust security mechanisms essential.
Communication networks include wired networks, wireless systems, mobile networks (4G/5G/6G), optical networks, and Internet of Things (IoT) platforms.

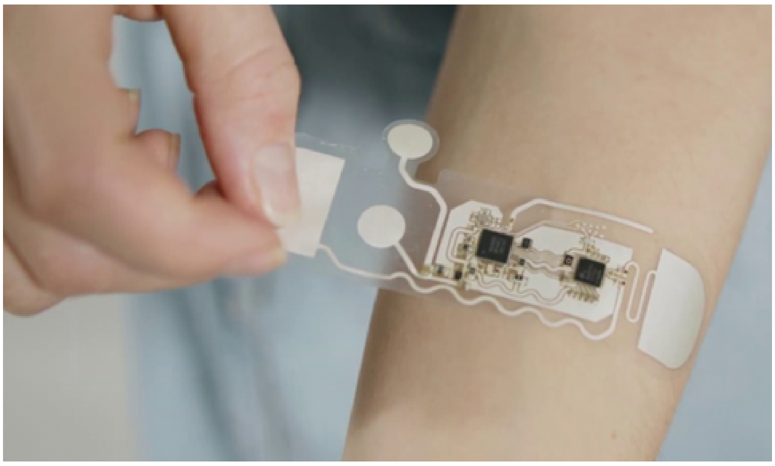
Cybersecurity in these networks focuses on protecting data, devices, and services from unauthorized access, attacks, and disruptions. The primary security goals are confidentiality, integrity, authentication, and availability. Ensuring these goals is challenging due to high data volumes, real-time requirements, and the heterogeneous nature of modern networks.
Common threats to communication networks include eavesdropping, denial-of-service (DoS) attacks, man-in-the-middle attacks, malware, spoofing, and jamming in wireless systems. In mobile and wireless networks, attackers may exploit vulnerabilities in signaling protocols, base stations, or user devices. IoT networks are especially vulnerable due to limited processing power and weak security configurations in many devices.

To counter these threats, various cybersecurity techniques are employed. Encryption protects data confidentiality during transmission, while authentication protocols ensure that only legitimate users and devices can access the network. Firewalls, intrusion detection systems (IDS), and intrusion prevention systems (IPS) monitor network traffic to identify suspicious activities. In wireless communication, techniques such as secure key management, frequency hopping, and physical-layer security are used to improve resilience against attacks.
With the evolution of 5G and upcoming 6G networks, cybersecurity is becoming more intelligent and adaptive. Artificial Intelligence (AI) and Machine Learning (ML) are increasingly used to detect anomalies, predict attacks, and automate network defense. Additionally, emerging technologies such as blockchain and quantum-safe cryptography are being explored to enhance trust and long-term security.
In conclusion, cybersecurity for communication networks is a vital and evolving field that ensures reliable and secure information exchange. As networks become more complex and interconnected, continuous research and innovation in security techniques are essential to protect users, services, and critical infrastructure.

Electronics in Health Care

Keerthi.S
S4 ECE

Electronics play a vital role in modern health care, transforming the way medical services are delivered, managed, and improved. The integration of electronic systems into health care has led to more accurate diagnoses, effective treatments, better patient monitoring, and improved overall efficiency of medical facilities. From basic diagnostic tools to advanced life-support systems, electronics have become the backbone of contemporary medical practice. These technologies assist health professionals in making informed decisions, reduce human error, and enhance patient safety, thereby improving the overall quality of health care.



One of the most important applications of electronics in health care is in medical diagnostic equipment. Devices such as electrocardiograms (ECG), electroencephalograms (EEG), X-ray machines, ultrasound scanners, CT scans, and MRI machines rely on electronic circuits to-collect, process, and display data from the human body. These instruments enable early detection of diseases, accurate monitoring of organ functions, and non-invasive examination of internal structures. Electronics allow high-speed data processing and clear imaging, which-are essential for effective diagnosis and treatment planning.

Electronics are also extensively used in patient monitoring systems, particularly in hospitals, intensive care units, and emergency wards. Electronic monitors continuously track vital signs such as heart rate, blood pressure, respiratory rate, oxygen saturation, and body temperature. Any abnormal changes are immediately detected and reported to medical staff, enabling rapid response and preventing complications. In addition, wearable electronic devices and home-monitoring systems allow patients to manage chronic conditions and maintain their health outside hospital environments, promoting preventive health care.

Therapeutic and life-support systems represent another crucial area where electronics are applied in health care. Equipment such as ventilators, defibrillators, pacemakers, infusion pumps, dialysis machines, and radiation therapy devices operate using sophisticated electronic components. These systems support or replace vital body functions and are essential in critical and emergency care. The precision offered by electronic controls ensures accurate delivery of treatment, reduces risks, and improves patient survival rates.

Electronics have further advanced surgical practices through the use of computer-assisted and robotic technologies. Electronic surgical instruments and robotic systems enable minimally invasive procedures with greater accuracy and stability. Surgeons can perform complex operations with enhanced visualization and control, resulting in reduced pain, minimal scarring, and faster recovery for patients. Imaging systems and electronic navigation tools also assist surgeons during operations, improving surgical outcomes and safety.

In addition to clinical applications, electronics have significantly improved health care administration and data management. Electronic health records (EHRs) allow secure storage and easy retrieval of patient information, reducing paperwork and improving communication among health care providers. Telemedicine, supported by electronic communication technologies, enables remote consultation, diagnosis, and follow-up care. This has expanded access to medical services, especially for individuals in rural or underserved areas.

Despite the numerous benefits, the use of electronics in health care presents certain challenges. High costs, technical complexity, equipment maintenance, and data security concerns can limit widespread adoption. There is also a need for proper training of health care professionals to ensure effective and safe use of electronic systems. Addressing these challenges through policy support, technological innovation, and education is essential for maximizing the benefits of electronic health care systems.

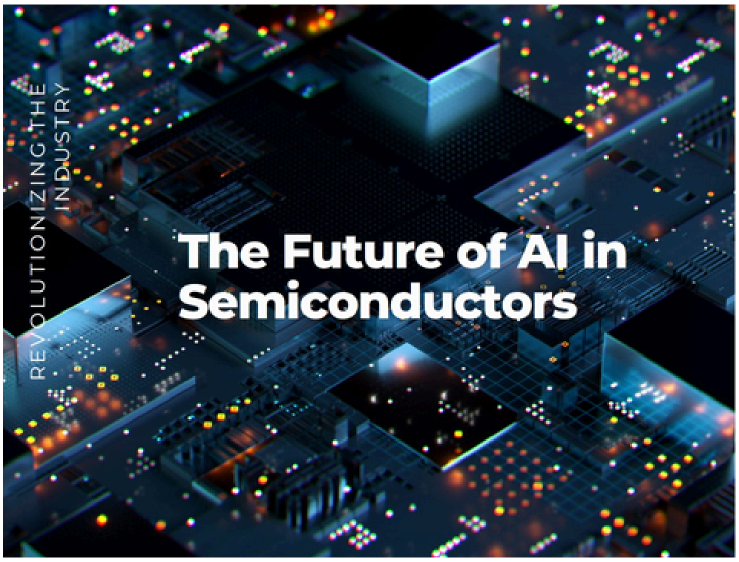
In conclusion, electronics have become an indispensable part of modern health care, improving diagnosis, treatment, patient monitoring, surgery, and health care management.

They enhance efficiency, accuracy, and patient safety while enabling advanced medical technologies and services. As electronic technology continues to evolve, its role in health care will expand further, contributing to better health outcomes and improved quality of life for people around the world.

Role of Semiconductors in Artificial Intelligence

RINTO JOSE
S4 ECE

Semiconductors play a fundamental and indispensable role in the field of Artificial Intelligence (AI), as they provide the physical hardware foundation that enables intelligent machines to function, learn, and make decisions. Semiconductors are materials, most commonly silicon, whose electrical conductivity lies between that of conductors and insulators, allowing precise control of electrical signals. This unique property makes them ideal for manufacturing electronic components such as transistors, integrated circuits, and microchips, which form the heart of all modern computing devices. In AI systems, semiconductor-based processors such as Central Processing Units (CPUs),



(CPUs), Graphics Processing Units (GPUs), and specialized AI accelerators like Neural Processing Units (NPUs) and Tensor Processing Units (TPUs) are used to perform highly complex computations. Artificial Intelligence relies heavily on large datasets and mathematical models, especially in areas such as machine learning and deep learning, where millions or even billions of calculations must be performed to train algorithms. Semiconductors enable these calculations to be executed at extremely high speeds and with great accuracy, making it possible for AI applications to perform tasks such as image and speech recognition, language translation, facial identification, medical image analysis, and autonomous navigation. As AI models have become more advanced and data-intensive, the demand for powerful and efficient semiconductors has increased significantly. Modern AI applications require chips that can handle parallel processing, where multiple operations are carried out simultaneously, and this capability is made possible through advanced semiconductor architectures. Another important contribution of semiconductors to AI is energy efficiency. AI systems, especially those operating in data centers and cloud environments, consume vast amounts of electricity.

Advanced semiconductor technologies help reduce power consumption while maintaining high performance by using smaller transistors, improved materials, and optimized chip designs. This balance between performance and energy efficiency is crucial for making AI systems practical, affordable, and environmentally sustainable. Furthermore, semiconductors enable edge AI, where artificial intelligence runs directly on devices such as smartphones, smart cameras, wearable devices, and autonomous machines without constant reliance on

cloud servers. This allows faster response times, improved privacy, and reduced network load. Continuous innovation in semiconductor manufacturing, including developments in nanotechnology, three-dimensional chip stacking, and system-on-chip integration, has greatly accelerated the progress of AI. Each new generation of semiconductor technology allows more transistors to be packed into smaller spaces, increasing processing power and enabling

more sophisticated AI models. In addition, the close relationship between AI and semiconductors is mutually beneficial, as AI itself is now being used to design better semiconductor chips and improve manufacturing processes. In conclusion, semiconductors are the backbone of Artificial Intelligence, providing the speed, efficiency, reliability, and scalability required for intelligent systems to operate effectively.

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