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ELECONS

Department Of Electronics & Communication Engineering

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Department Of Electronics & Communication Engineering



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CREATING TECHNOLOGY
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APRIL 2026

Department of Electronics & Communication Engineering
JYOTHI ENGINEERING COLLEGE, CHERUTHURUTHY
THRISSUR 679 531

VISION OF THE INSTITUTE

Creating eminent and ethical leaders through quality professional education with emphasis on holistic excellence.

MISSION OF THE INSTITUTE

- To emerge as an institution par excellence of global standards by imparting quality engineering and other professional programmes with state-of-the-art facilities.
- To equip the students with appropriate skills for a meaningful career in the global scenario.
- To inculcate ethical values among students and ignite their passion for holistic excellence through social initiatives.
- To participate in the development of society through technology incubation, entrepreneurship and industry interaction.

VISION OF THE DEPARTMENT

Create eminent and ethical leaders in the field of Electronics and Communication through quality professional education to excel in academia and industry.

MISSION OF THE DEPARTMENT

- To impart comprehensive knowledge and practical skills in the field of Electronics and Communication Engineering
- To provide an environment that nurtures a culture of innovation and entrepreneurship, to develop solutions to real-world challenges and explore opportunities for technology commercialization
- To foster socially responsible engineers and ethical leaders who drive positive change through innovative technology and a commitment to the betterment of society

PROGRAMME EDUCATIONAL OBJECTIVES (PEOS)

PEO I : Graduates shall have fundamental and advanced knowledge in electronics and communication engineering along with knowledge in mathematics, science and computing and get employed in national or international organizations or government agencies.

PEO II : Graduates shall have ability in analyzing, designing and creating innovative solutions which lead to a lifelong learning process or higher qualification, making them experts in their profession thus helping to solve electronics & communication engineering and social problems.

PEO III: Graduates shall have good organizing capabilities, presentation skills, communicating ability, leadership, team work and ethical practices.

PROGRAMME SPECIFIC OUTCOMES (PSO's)

- PSO 1:** Apply theoretical knowledge and practical skills in the field of Electronics and Communication Engineering to analyze, design, and implement electronic systems, communication networks, and signal processing solutions effectively.
- PSO 2:** To cultivate a culture of innovation and entrepreneurship among students, enabling them to identify and address real-world challenges in electronics and communication.
- PSO 3:** To instill a sense of social responsibility and ethical awareness in students by preparing them to use their technical expertise for the betterment of society and the environment.

PROGRAMME OUTCOMES (POS)

Engineering Graduates will be able to:

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

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
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.
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.
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.

LETTER FROM OUR HOD



Dear Readers,

I'm delighted to present to you the latest edition of our department's technical magazine. Packed with insightful articles, research updates, and innovative projects, this publication showcases the exceptional talent and dedication of our students.

I invite you to explore the diverse topics covered within these pages, from AI and machine learning to signal processing and communication systems. Your engagement and feedback are invaluable as we continue to push the boundaries of knowledge in our field.

Thank you for your support and enthusiasm for our department's endeavors.

Best regards,

Dr. JOSE P THERATTIL

PROFESSOR

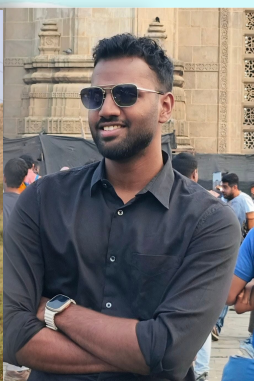
Table Of Contents

- 01** TERAHERTZ VISION: THE NEXT FRONTIER IN IMAGING SCIENCE
- 02** EDGE AI: THE FUTURE OF ARTIFICIAL INTELLIGENCE IN EMBEDDED SYSTEMS
- 03** SMART FACTORIES: THE CORE OF INDUSTRY 4.0
- 04** BREAKING THE ILLUSION OF DIGITAL REALITY: DEEPPAKE DETECTION IN THE MODERN WORLD
- 05** COMMUNICATION SYSTEMS IN INDIA'S UPCOMING SPACE MISSIONS
- 06** 6G TECHNOLOGY: THE FUTURE BEYOND CONNECTIVITY
- 07** INDIAN SILICON DREAMS: A BRIEF LOOK INTO INDIA'S SEMICONDUCTOR AWAKENING
- 08** ELECTRONICS WARFARE: THE INVISIBLE BATTLEFIELD
- 09** BEYOND MOORE: THE FUTURE OF VLSI – CHIP REVOLUTION 2.0
- 10** BEYOND ELECTRONICS: THE ERA OF SILICON PHOTONIC CIRCUITS

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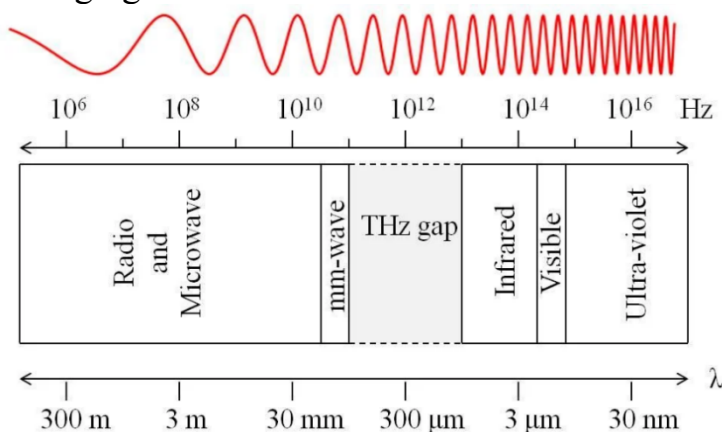
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TERAHERTZ VISION: THE NEXT FRONTIER IN IMAGING SCIENCE

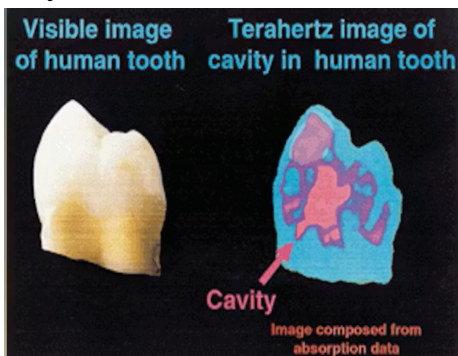


JOYAL JAIMY

Imagine being able to look beneath surfaces, detect hidden defects, or identify materials without cutting, opening, or damaging anything. Terahertz (THz) radiation makes this possible. Positioned between microwaves and infrared in the electromagnetic spectrum, typically from 0.1 to 10 terahertz, this once-overlooked region is now becoming one of the most exciting frontiers in modern science and engineering. For years it was called the terahertz gap because generating and detecting signals in this range was extremely difficult. Today, thanks to rapid progress in semiconductors, photonics, nanotechnology, and advanced computation, that gap is steadily closing, and practical terahertz systems are emerging.



What makes terahertz waves special is how they interact with matter. Unlike X-rays, they are non-ionizing, meaning they do not carry enough energy to damage living tissue. This makes them far safer for biological imaging. At the same time, they can pass through many non-conductive materials such as plastics, fabrics, paper, ceramics, and certain composites. Because of this unique combination of safety and penetration, terahertz technology can reveal concealed or internal features without harming the object or person being examined. Even more interesting is that many molecules absorb terahertz waves in distinct patterns, allowing the technology not only to show structure but also to identify chemical composition—something most conventional imaging systems cannot do.



In a typical terahertz imaging setup, waves are directed toward a target and the reflected or transmitted signals are captured by sensitive detectors. These signals change depending on

the material's thickness, composition, refractive index, and internal structure. Advanced algorithms then process this information to reconstruct images that reveal hidden details. Modern systems often use time-domain or frequency-domain techniques to measure tiny differences in signal timing and spectral characteristics. This allows them to distinguish between materials, detect flaws, and analyze internal properties with impressive precision. Because of these capabilities, terahertz technology is attracting attention across many fields. In medicine, researchers are studying its potential for early detection of skin conditions, dental decay, and subtle tissue changes, especially since terahertz waves are highly sensitive to water content differences in biological tissue. In security screening, terahertz scanners can detect concealed objects beneath clothing or packaging without exposing people to harmful radiation. Industrial

applications are equally promising, particularly in non-destructive testing, where the technology can inspect multilayer coatings,

Semiconductor wafers, and composite structures for hidden cracks or defects. In scientific research, terahertz spectroscopy is helping scientists investigate molecular vibrations, crystal structures, and material properties in ways that were previously difficult or impossible.

Recent technological advances are accelerating this progress. Improvements in compact radiation sources, sensitive detectors, and integrated photonic systems have increased imaging speed, resolution, and reliability. At the same time, artificial intelligence is being used to interpret terahertz signals automatically, enabling faster analysis and more accurate detection. Researchers are also developing portable and fiber-coupled devices, opening the door for real-world applications outside specialized laboratories. These innovations signal a clear shift from purely experimental instruments to practical tools.

Challenges still remain. Terahertz systems can be expensive, imaging depth can be limited in materials that contain a lot of water, and precise alignment is often required for accurate measurements. However, ongoing research in materials science, device engineering, and computational methods is steadily addressing these limitations. As components become smaller, more efficient, and more affordable, terahertz technology is expected to move closer to widespread use.

Looking ahead, terahertz imaging is poised to complement—and in certain specialized cases outperform—traditional imaging methods. What was once considered an inaccessible portion of the electromagnetic spectrum is now emerging as a powerful technological platform. With its unique ability to combine safety, sensitivity, and analytical insight, terahertz vision is set to play a transformative role in the future of medical diagnostics, industrial inspection, security screening, and scientific discovery.

EDGE AI : THE FUTURE OF ARTIFICIAL INTELLIGENCE IN EMBEDDED SYSTEMS



SREELAKSHMI K G

Artificial Intelligence (AI) has revolutionized many industries, enabling applications that seemed unlikely just a few years ago. At the same time, the exponential growth of data and the need for real-time responses have led to the emergence of a new paradigm: edge AI. This type of technology is essential for the implementation of distributed systems, where data processing must occur as close to the point of origin as possible to minimize delays and improve security and privacy. The revolutionary approach of edge AI promises to transform the way embedded systems manage processing and workloads, moving AI from the cloud to the edge of the network.



Edge AI simplifies data processing

Traditionally, Artificial Intelligence (AI) relied on cloud computing because complex models required high computational power unavailable in embedded devices. In this approach, data from sensors is sent to the cloud for processing, and the results are returned to the device. However, this introduces latency, which is critical in applications like healthcare monitoring and autonomous vehicles. It also raises privacy and security concerns since sensitive data is transmitted and stored externally. Edge AI overcomes these limitations by enabling data processing directly on embedded devices, reducing latency, improving security, and minimizing dependence on cloud infrastructure. Instead of sending raw data to the cloud, devices analyze data locally and transmit only relevant information. Advances in efficient algorithms and specialized hardware, such as Neural Processing Units (NPUs) integrated into microcontrollers, now allow AI models to run on resource-constrained devices.

Italian-French technology company STMicroelectronics (ST) develops embedded devices for edge AI, offering solutions that integrate AI capabilities directly into devices. ST develops advanced microcontrollers such as the STM32 series, which include integrated

AI accelerators and are designed to run machine learning algorithms directly on the device, enabling fast processing and reducing latency. ST offers complete development platforms that include software tools to train and deploy AI models on embedded devices, such as the STM32Cube.AI library that allows developers to convert trained neural networks into code that can run directly on STM32 microcontrollers. The ST Edge AI Suite is a set of tools for integrating AI capabilities into embedded systems. It supports STM32 microcontrollers and microprocessors, Stellar automotive microcontrollers, and MEMS smart sensors, and includes resources for data management, optimization, and deployment of AI models.

Concluding considerations

While it is one of the most advanced frontiers of digital transformation today, edge AI also presents some significant challenges. Running AI models on resource-constrained embedded devices requires optimization in both software and hardware. Models must be compressed to reduce memory and power usage while maintaining accuracy, and hardware must support real-time processing with high energy efficiency, especially in battery-powered systems.

Another challenge is the diversity of embedded hardware, which requires developers to customize AI models for different devices and applications. Security is also a concern, as edge devices are more vulnerable to attacks than centralized systems, making strong encryption and authentication essential. In the future, improvements in embedded processors and communication technologies like 5G will enable more powerful and efficient edge AI systems. Edge AI is becoming a key technology in embedded systems, enabling faster, secure, and cost-effective real-time intelligent applications, and bringing AI closer to everyday devices.

SMART FACTORIES : THE CORE OF INDUSTRIES 4.0



ANTONY JOHNSON

The global manufacturing sector is undergoing a silent yet powerful transformation. Traditional factories, once dependent on manual supervision and isolated machines, are evolving into intelligent, interconnected ecosystems known as Smart Factories. At the core of Industry 4.0, smart factories integrate automation, data exchange, and advanced digital technologies to create highly efficient, adaptive, and self-optimizing production environments. Unlike conventional automation systems that operate based on fixed sequences, smart factories function as dynamic systems capable of analyzing data, predicting outcomes, and responding to real-time conditions. This transformation is driven by the convergence of Industrial Internet of Things (IIoT), Artificial Intelligence (AI), cyber-physical systems, cloud computing, robotics, and advanced control systems.

A smart factory is built upon interconnected layers of technology that enable machines, sensors, and control systems to communicate seamlessly.

Industrial IoT (IIoT)

Sensors embedded in machinery continuously monitor parameters such as temperature, vibration, pressure, and speed. This real-time data provides complete visibility of production processes and enables early detection of abnormalities.

Cyber-Physical Systems (CPS)

Cyber-physical systems integrate physical machines with digital intelligence. Machines are not only controlled digitally but are also capable of making autonomous decisions based on data inputs. For instance, a production line can adjust its operational speed if a downstream bottleneck is detected.

Advanced PLC and SCADA Systems

Modern programmable logic controllers are integrated with Supervisory Control and Data Acquisition (SCADA) systems and cloud platforms. They ensure synchronized control, real-time monitoring, and optimized coordination across complex industrial processes.

Edge Computing and Cloud Integration

Edge devices handle low-latency decision-making near the machine level, while cloud systems perform large-scale data analytics and long-term optimization. This hybrid architecture ensures both speed and intelligence.

Collaborative Robotics (Cobots)

Cobots are designed to safely work alongside humans. Unlike traditional industrial robots confined within cages, cobots enhance flexibility, precision, and safety in assembly operations.

One of the leading global examples of smart factory implementation is **Bosch**. The company has transformed several of its manufacturing plants into fully connected production environments under its Industry 4.0 initiatives. At Bosch's Homburg plant in Germany, thousands of sensors collect real-time data from hydraulic component production lines. These sensors monitor machine health, energy consumption, and process parameters. Using predictive analytics, the system can detect anomalies before they result in machine failure, significantly reducing downtime. Bosch also utilizes digital twins virtual replicas of physical production systems to simulate manufacturing processes before implementation. This enables engineers to test modifications digitally, reducing risk and improving efficiency. Furthermore, Bosch integrates supply chain data with production planning systems. When customer demand changes, the system automatically adjusts production schedules, minimizing waste and optimizing resource allocation. The result is not merely automation but intelligent manufacturing where machines, systems, and humans collaborate through continuous data exchange.

Smart factories are already delivering measurable improvements across industries:

Predictive Maintenance

Machine data is analyzed to forecast failures, allowing maintenance to be scheduled proactively rather than reactively.

Automated Quality Inspection

Machine vision systems inspect products in real time, identifying micro-level defects and improving overall product reliability.

Energy Management

Smart monitoring systems optimize energy consumption, reducing operational costs and supporting sustainability goals.

Flexible Manufacturing

Production lines can rapidly adapt to different product variants without major reconfiguration, enabling mass customization.

Integrated Supply Chains

Real-time communication between inventory systems and production units enables just-in-time manufacturing.

Despite its advantages, implementing smart factory technology presents challenges:

- High initial infrastructure costs
- Integration difficulties with legacy systems
- Cybersecurity vulnerabilities
- Shortage of engineers skilled in automation, networking, and data analytics

Industries must strategically plan their digital transformation journey to overcome these barriers.

The evolution of smart factories is far from complete. Emerging technologies such as AI-driven optimization, 5G-enabled machine communication, autonomous mobile robots, and advanced digital twins will push automation to the next level. Future factories may become largely self-organizing systems capable of autonomous scheduling, self-diagnosis,

and self-correction. AI algorithms will continuously optimize production parameters based on real-time global demand data. Human operators will shift from manual supervision to high-level decision-making and system oversight. In the coming decades, we may witness “lights-out factories” facilities that operate with minimal human intervention, running continuously with intelligent automation. However, the goal is not to replace humans but to enhance human capability through collaboration with intelligent machines.

Industry 4.0 is not merely about smarter machines it is about building resilient, adaptive, and sustainable industrial ecosystems that can respond to global challenges with speed and precision. Smart factories represent the operational backbone of Industry 4.0. By integrating real-time data, intelligent control systems, robotics, and predictive analytics, they redefine manufacturing from a static process into a dynamic, data-driven ecosystem. As demonstrated by companies like Bosch, the transition toward intelligent manufacturing is already underway. While challenges remain, the long-term benefits in productivity, efficiency, sustainability, and competitiveness are undeniable. The future of manufacturing belongs to systems that can think, adapt, and evolve and smart factories are leading that transformation.

BREAKING THE ILLUSION IN DIGITAL REALITY : DEEPFAKE DETECTION IN MODERN WORLD



BHANUPRIYA

The modern highly connected digital world makes pictures and videos evidence, personality, and the truth. Videotapes captured in the courtroom, CCTV videos, political speeches and social media all influence the general opinion and choices made by the people. However, a more advanced threat to digital authenticity is brought about by deepfake technology. Such artificial, hyper-realistic videos and images have the ability to have individuals say or do something they never actually did and undermine the credibility of digital communication.

Deepfakes are artificial media that are produced using high-quality deep-learning models, in particular Generative Adversarial Networks (GANs) and autoencoders. One network produces counterfeit content in these systems, and a second network develops to identify it. The fakes continue to get more realistic as the training advances such that it is almost impossible to detect them manually. The tools previously needing the skills of professional editors are now able to produce persuading deepfakes using consumer-grade computers, which increases the risk of misuse. Even though deepfakes have some



positive applications in filmmaking, VR and digital avatars, unhealthy applications pose great danger. False political speeches can influence the vote, fake corporate announcements can confuse the market, and impersonation video can result in identity theft or social-engineering. This has made detection of deepfakes an important research field of image processing and communications.

Deepfake detection begins by identifying inconsistencies added in the process of synthesis. Generative models are very advanced but not very perfect. Minuscule anomalies are introduced into the image or video, which can not be seen but can be discerned using signal-processing techniques.

One of such methods is spatial feature analysis. There are common artifacts of deepfake images: artificial skin texture, blurred edges of facial features, uneven lighting, or distortions of facial symmetry. To identify these anomalies, high-resolution extraction algorithms scan pixel distributions, sharpening of edges, and color gradient to detect

anomalies. Systems can identify when there is authentic content and when the content is manipulated by examining micro-level inconsistencies.

Frequency-domain methods provide more insight than spatial analysis. Compared to synthetics, natural frequency patterns the patterns created by real lighting and sensors can be compared by Fourier or Discrete Cosine Transform by converting images. The frequency-based techniques are some of the most effective instruments in digital forensics because synthetic images frequently distort high-frequency components.

Video deep fakes introduce time. One frame might be believable, but discrepancies appear between frames. The facial features of human beings are biomechanical constraints, including regular blinking, coordinated lips movement, and head motion that is smooth. Optical flow, motion vectors and frame to frame coherence are analysed with temporal detectors. Minor variations in the blink rate or the lipsync are also indicative of manipulation.

Naive studies examine the analysis of biological signals. Faces exhibit minute blood variations that result in photoplethysmographic (PPG) responses. Generative models have difficulty in replicating these micro-signals. Detectors will have an added level of reliability by extracting and analysing subtle physiological patterns of regions of the face, combining biomedical signal processing with image analytics.

The accuracy is enhanced by multimodal verification. There are numerous deepfakes that do not match audio and visual streams. Speech spectral analysis (in conjunction with lip-motions) unveils voice-facial discrepancies. A combination of audio processing and visual feature extraction makes the cross-verification frameworks more robust and can identify more advanced manipulations.

Although this has changed, deepfake detection remains a challenge. The generative models are developed and less visible artifacts are minimized and the models can imitate natural behavior more accurately. Adversarial attacks is an act of targeting detection systems. The real time deployment is also computationally intensive, particularly on embedded surveillance and edge devices. To overcome these obstacles, it needs to have optimised algorithms, hardware acceleration with FPGA and GPU, and feature extraction. The future of hybrid architectures is dependent on spatial, frequency, temporal, and biological cues. Smart cameras, networks, and platforms could have lightweight, real-time modules embedded into them as the standard safeguards. Cryptographic signatures, blockchain authentication, and digital watermarking are also coming to ensure that the integrity of the media is not compromised even before its creation.

Deepfake detection is at the intersection of digital signal processing, image-video analytics, communication security, embedded design, and hardware optimisation for electronic and communication engineers. Deepfake is a technology that is risky and innovative. As much as synthetic media makes it possible to be creative, its misuse affects the credibility of digital communication. The need to maintain authenticity in an era of manipulation requires sophisticated engineering solutions that are based on sophisticated signal processing and secure communications. Engineers are protecting truth, securing identities and preserving trust in the connected world by developing detection technologies.

COMMUNICATION SYSTEMS IN INDIA'S UPCOMING SPACE MISSIONS



C SANJANA MANOJ

As India steps into a defining decade of space exploration, communication electronics are emerging as the invisible yet indispensable backbone of every mission. Whether it is astronauts orbiting Earth, a rover navigating the lunar south pole, a probe studying the dense atmosphere of Venus, or a future Indian space station circling the planet, the success of each venture depends on one fundamental capability: staying connected. In modern space systems, communication electronics do far more than transmit signals. They ensure safety, enable autonomy, protect data integrity, and bridge vast interplanetary distances with precision and reliability.

The upcoming **Gaganyaan** mission places communication at the center of human survival in space. Unlike robotic spacecraft, a crewed capsule demands uninterrupted voice, telemetry, and command links between astronauts and ground control. Every heartbeat reading, cabin pressure parameter, and trajectory update must reach Earth in real time. This requires highly redundant S-band communication systems, robust transceivers, and fault-tolerant onboard avionics capable of switching seamlessly between primary and backup links. During re-entry, when plasma blackout can temporarily disrupt signals, intelligent buffering electronics ensure that no critical data is lost. The communication architecture for Gaganyaan is therefore designed not merely for performance, but for trust—because human life depends on it.



With **Chandrayaan-4**, the complexity of communication multiplies. A lunar sample return mission requires coordination between multiple spacecraft elements: an orbiter, a lander, and an ascent module carrying samples back into lunar orbit before their journey home. Each stage demands precise telemetry, tracking, and ranging. High-gain antennas operating in higher frequency bands such as Ka-band enable large volumes of scientific data and imagery to be transmitted efficiently across the nearly 400,000-kilometer distance between the Moon and Earth. Deep-space communication electronics must maintain signal clarity despite cosmic radiation and signal attenuation.

Precision frequency synthesizers and stable oscillators become critical for Doppler measurements that determine spacecraft velocity and trajectory during Earth return. In

such missions, communication electronics are not passive systems—they actively guide navigation accuracy and mission safety.

The challenges intensify further with the **Lunar Polar Exploration Mission (LUPEX)**, which aims to explore the Moon's polar regions. Permanently shadowed craters and uneven terrain can obstruct direct communication with Earth, making relay systems essential. The rover must transmit data to an orbiter, which then forwards it to ground stations. In such extreme cold conditions, communication electronics must operate reliably at cryogenic temperatures while consuming minimal power. Advanced phased-array antennas and adaptive link management systems are being explored to maintain signal alignment and optimize bandwidth. Because bandwidth is precious, onboard processing electronics compress and prioritize scientific data before transmission. In polar exploration, communication is not just about distance—it is about overcoming isolation.

Looking beyond the Moon, the **Venus Orbiter Mission** presents a different set of communication challenges. Venus lies much farther from Earth, and communication signals must endure greater propagation delays and solar interference. The intense thermal and radiation environment demands highly reliable RF electronics and radiation-hardened components. Maintaining a strong signal-to-noise ratio becomes essential when transmitting scientific measurements from orbit around a planet shrouded in dense clouds. Highly stable oscillators ensure accurate frequency references, while sophisticated error correction techniques safeguard data integrity over millions of kilometers. In interplanetary missions like this, communication systems must operate autonomously for extended periods, detecting faults and adjusting parameters without immediate ground intervention.

Perhaps the most transformative communication infrastructure will be required for the planned Bharatiya Antariksha Station, envisioned as a permanent Indian presence in low Earth orbit. Unlike mission-based spacecraft, a space station demands continuous, high-bandwidth connectivity for crew operations, scientific experiments, docking maneuvers, and potential commercial activities. Future communication systems may incorporate optical or laser communication terminals, dramatically increasing data rates compared to traditional radio frequency systems. Inter-satellite links could allow the station to communicate through relay satellites, ensuring near-constant coverage. Encrypted and secure networks will protect sensitive data, while intelligent onboard network management systems dynamically allocate bandwidth depending on mission priorities. In such a scenario, the space station becomes part of an orbital communication ecosystem rather than an isolated platform.

Across all these missions, a few technological trends unify India's communication strategy. Software-defined radios allow reconfigurable frequency bands and modulation schemes, enabling adaptability across mission phases. Miniaturized RF integrated circuits reduce payload mass while increasing efficiency. Advanced error correction coding techniques ensure data survives noise and interference. Artificial intelligence is gradually entering onboard communication systems, enabling predictive fault detection and adaptive link optimization. At the same time, there is a growing emphasis on indigenous development of RF components and communication subsystems, strengthening technological self-reliance.

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As India prepares to send astronauts into orbit, retrieve lunar samples, explore polar ice, study Venus, and build its own space station, communication electronics will remain the silent enabler of every milestone. They will carry the voices of astronauts, the measurements of distant worlds, and the commands that steer spacecraft safely home. In many ways, communication systems are the nervous system of space exploration—connecting spacecraft to Earth, science to society, and ambition to achievement.

6G TECHNOLOGY : THE FUTURE BEYOND CONNECTIVITY



DARSANA C K

The world is moving rapidly toward an era where everything is connected, from smartphones and smart homes to autonomous vehicles and intelligent cities. While 5G technology is still being deployed globally, researchers and engineers are already working on the next generation of wireless communication: 6G technology. Expected to emerge around 2030, 6G promises to revolutionize communication. 6G refers to the sixth generation of wireless communication systems that will succeed in 5G networks. It is designed to provide data transmission speeds up to 100 times faster than 5G, with latency reduced to microseconds.



6G aims to create a fully connected ecosystem where devices, machines, and humans interact seamlessly. It will use terahertz (THz) frequency bands, advanced artificial intelligence (AI), and next-generation network architectures to deliver faster and smarter communication.

One of the most significant features of 6G technology is its ultra-high data rate, which could reach up to 1 terabit per second. This will enable high-quality holographic communication, immersive virtual reality (VR), and real-time data processing. Another important feature is ultra-low latency, which ensures near-instant communication between devices, making technologies like autonomous vehicles and remote surgery more reliable and safer.

6G will also introduce AI-driven communication systems. Artificial intelligence will be integrated into the network itself to optimize performance, manage traffic, and improve security.

Additionally, 6G aims to provide **global connectivity**, including remote and rural areas, through the integration of satellites, drones, and high-altitude platforms.

The impact of 6G technology will be felt across multiple industries. In healthcare, 6G will enable advanced telemedicine, remote surgeries using robotic systems, and real-time health monitoring through wearable devices. Doctors will be able to perform complex

procedures from different parts of the world with minimal delay.

Students will be able to attend virtual classrooms, interact with 3D models, and experience practical simulations from anywhere in the world.

Smart cities will benefit greatly from 6G technology. Intelligent transportation systems, smart traffic management, and connected infrastructure will improve urban living and reduce congestion. Autonomous vehicles will communicate with each other and with city infrastructure in real time, enhancing safety and efficiency.

Industries and manufacturing sectors will also adopt 6G-enabled automation and robotics. Smart factories will use real-time data to optimize production processes, reduce errors, and improve productivity. The concept of the **Internet of Everything (IoE)** will become a reality, where billions of devices communicate seamlessly.

Several advanced technologies will support the development of 6G networks. **Terahertz communication** will provide extremely high data rates but requires advanced antenna and signal processing techniques. Artificial intelligence and machine learning will be integrated into network management to ensure efficient operation and resource allocation.

6G will also use edge computing, where data processing occurs closer to the user instead of centralized servers. This reduces latency and improves the speed of applications such as autonomous vehicles and real-time analytics.

Despite its promising potential, 6G technology faces several challenges. Developing infrastructure for terahertz communication requires advanced hardware and high investment. The high-frequency signals used in 6G have limited range and may require more base stations and new transmission techniques.

Security and privacy are also major concerns. As more devices become connected, protecting sensitive data from cyber threats becomes increasingly important. Engineers and researchers must design secure communication protocols to prevent unauthorized access.

Another challenge is energy consumption. High-speed networks require significant power, for sustainable implementation.

6G technology is expected to transform the way humans interact with technology. It will not only improve communication speed but also enable intelligent systems that can understand and respond to human needs. Concepts like holographic communication, smart healthcare, digital twins, and fully autonomous systems will become a reality.

6G technology represents the next major step in the evolution of wireless communication. With its ultra-fast speeds, intelligent networks, and advanced applications, it has the potential to redefine connectivity and transform industries. Although there are challenges in implementation, continuous research and technological advancements will pave the way for a smarter and more connected world. The journey toward 6G has already begun, and it promises to create a new era of communication that goes beyond connectivity.

INDIAN SILICON DREAMS: A BRIEF LOOK INTO INDIA'S SEMICONDUCTOR AWAKENING

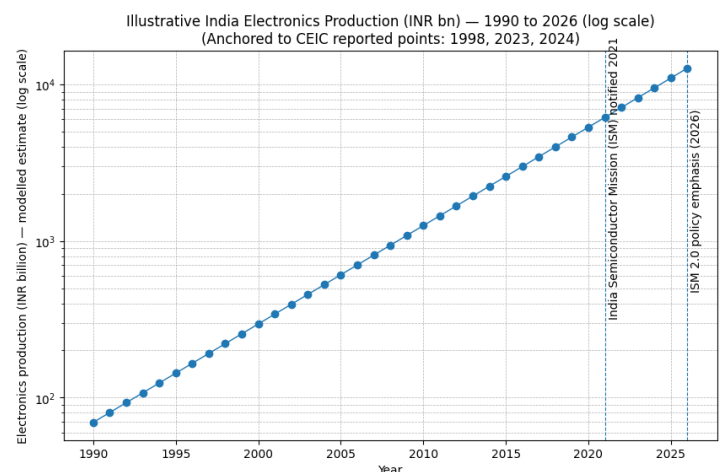


AIVIN SIMON

A Brief History

An exceptional duality has long marked India's relationship with the semiconductor industry. Even as the country emerged as a significant centre for chip design, embedded systems, and research, it remained largely absent from the manufacturing landscape that defines the global semiconductor economy. From the late twentieth century onward, multinational corporations established research and development centres across India, drawing upon a growing pool of engineering talent. These centres played a crucial role in advancing design architectures, verification processes, and firmware development. Yet, despite this intellectual presence, the physical production of chips continued to take place elsewhere, primarily in East Asia and other established manufacturing hubs.

Several factors contributed to this divergence. Semiconductor fabrication demands sustained capital investment, technological precision, and policy continuity over extended time horizons. India's industrial policy environment, while supportive of electronics and information technology more broadly, did not consistently generate the conditions required for large-scale fabrication facilities. Consequently, India's semiconductor ecosystem evolved with a pronounced emphasis on design capabilities, reinforcing its reputation as a knowledge-driven participant in the global value chain. Over time, however, the strategic implications of this imbalance became increasingly evident, particularly as semiconductors assumed central importance in telecommunications, consumer electronics, automotive systems, and national security infrastructure.

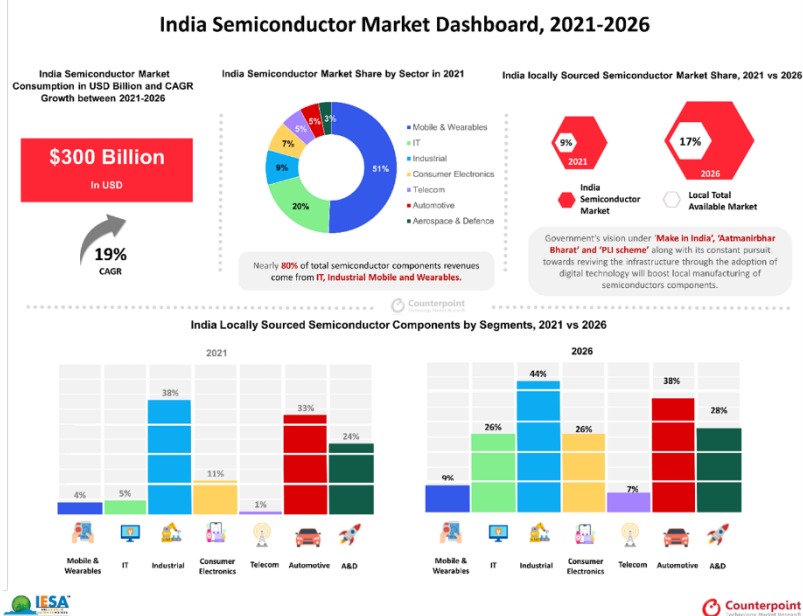


India's Strategic Reorientation

The past decade has witnessed a notable shift in India's approach to semiconductors. Global disruptions, including supply chain vulnerabilities exposed during the pandemic period and intensifying geopolitical tensions, underscore the risks associated with concentrated manufacturing networks. For India, a rapidly expanding consumer of electronic goods and semiconductor-intensive technologies, reliance on imports acquired

heightened economic and strategic significance. These developments prompted a reassessment of the country's industrial priorities and its positioning within critical technology sectors.

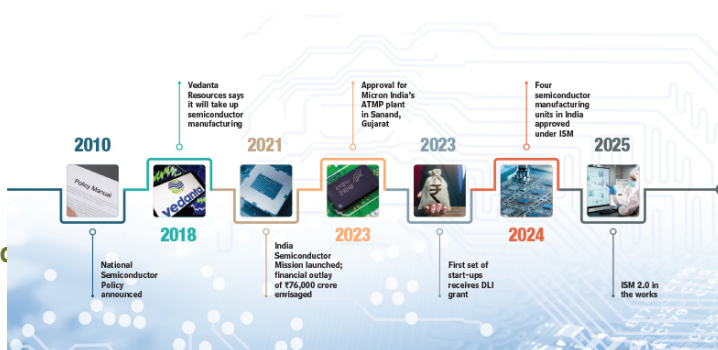
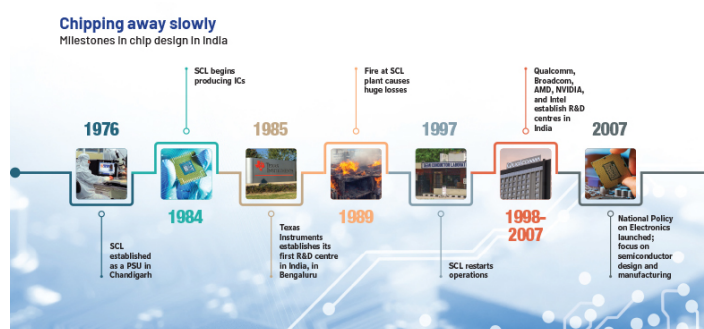
The policy response has been anchored in a more coordinated and assertive framework, reflecting an understanding that semiconductor development cannot be treated as a narrow industrial initiative. The establishment of targeted incentive mechanisms and institutional structures signalled an effort to align fiscal support, regulatory facilitation, and long-term strategic planning. Importantly, this reorientation recognised the systemic nature of the semiconductor industry, rather than focusing exclusively on wafer fabrication, policy emphasis extended to packaging, testing, compound semiconductor technologies, and design-linked incentives. This broader perspective sought to integrate India's existing strengths with emerging manufacturing capabilities, while acknowledging the inherent complexities of technological catch-up.



Ecosystem Formation and Industrial Participation

India's semiconductor strategy increasingly reflects an ecosystem-oriented approach. The global semiconductor industry relies on intricate networks that encompass materials, equipment, research institutions, specialized skills, and downstream manufacturing. Consequently, recent policy frameworks have been designed to foster not only capital investment in facilities but also the development of supporting infrastructure and knowledge linkages. Collaborative efforts between industry and academia, partnerships with global technology providers, and active engagement at the state level have become essential components of this evolving landscape.

The involvement of established domestic industrial groups represents a particularly significant advancement. Semiconductor manufacturing necessitates patient capital and a willingness to endure extended gestation periods—traits that have historically been less associated



with private investment patterns in India. However, the readiness of major firms to commit to large-scale investments indicates a convergence of policy confidence, market opportunity, and strategic foresight. While the long-term success of these investments will hinge on technological execution and operational stability, their presence plays a crucial role in gradually solidifying a domestic semiconductor base. This process remains inherently incremental, influenced by global dependencies, technological hurdles, and the cumulative nature of manufacturing expertise.

Future of the Semiconductor in India

India's semiconductor ambitions must be viewed within the framework of long-term structural transformation. Building a robust semiconductor ecosystem requires continuous alignment of industrial capabilities, technological development, and institutional support, rather than relying solely on isolated policy initiatives or singular projects. Currently, India is in an early but significant phase of this journey. The country's strengths in design, growing domestic demand, and evolving policy frameworks lay a solid foundation on which deeper manufacturing capabilities can gradually be built.

Success in this area is not likely to be defined simply by leading cutting-edge fabrication technologies. Instead, a more realistic measure of progress may be the establishment of competitive capabilities in areas such as packaging, specialty semiconductors, mature-node fabrication, and integrated design-to-manufacturing processes. These achievements would not only strengthen economic resilience but also shift India's position within global technology supply chains.

However, the challenges are substantial, including high capital requirements, technological complexity, supply chain vulnerabilities, and the need for specialized skills. Despite these obstacles, the strategic reasons for India's focus on semiconductors are compelling. In an age where silicon is crucial for both economic activity and national security, developing semiconductor capabilities is less about seeking dominance and more about ensuring relevance and stability.

Collage: Major Indian Semiconductor & Electronics Policies (post-2005)

Modified Special Incentive Package Scheme (M-SIPS) (2012) Capital subsidy for electronics manufacturing (25% SEZ / 25% non-SEZ); promoted ESDM investments. www.meit.gov.in/	National Policy on Electronics (NPE) (2012) Framework to develop Electronics System Design and Manufacturing (ESDM) in India. www.indiaelectronics.gov.in/ncet/ncettechnology/electronics/electronics-research-communications-and-information-technology
National Policy on Electronics (NPE) (2019) Updated vision to position India as a global ESDM hub and encourage fab and display facility development. nm.gov.in/	SPECS: Scheme for Promotion of Manufacturing of Electronic Components & Semiconductors (SPECS) (2020) Fiscal support (25% of CapEx) to boost component and semiconductor manufacturing. www.meit.gov.in/static/uploads/2024/02/scheme_for_promotion_of_manufacturing_of_electronic_components_and_semiconductors.pdf
Production Linked Incentive (PLI) for Electronics & IT Hardware (2020-21) Performance linked incentives to attract large-scale electronics manufacturing and localization. www.pli.team.in/	Electronics Manufacturing Clusters (EMC 2.0) (2020 (modified)) Support for world-class infrastructure and common facilities to deepen ESDM value chain. www.pmeitdta.gov.in/newsroom_updates/ncet/ncet approves modified electronics manufacturing clusters emc-2-0 scheme/
India Semiconductor Mission (ISM) / Semicon India (2021) Nodal mission to develop semiconductor & display ecosystem with large fiscal incentives ₹16,000 Cr. ism.gov.in/	ISM Schemes: Semiconductor Fabs / Display Fabs / Compound Semiconductors (2021-present) Scheme level fiscal support (up to 50% CapEx) for fabs, AMOLEDs, compound fabs and displays. ism.gov.in/semiconductor-fab
Design Linked Incentive (DLI) / futureDESIGN (2023-present) Incentives for semiconductor design firms to develop IP cores and strengthen domestic design ecosystem. chips-dti.gov.in/	ISM 2.0 / Modified Programme for 2026-27 (2026) Focus on equipment, materials, scaling, ATPM/packaging, and design targets; fresh budgetary support. pib.gov.in/

ELECTRONICS WARFARE: THE INVISIBLE BATTLEFIELD



ANITTA PALAMUTTAM THOMAS

In modern warfare, victory is no longer determined solely by the number of soldiers, tanks, or missiles deployed on the battlefield. Today, wars are increasingly fought in an invisible domain the electromagnetic spectrum. From radar systems and communication networks to satellite links and missile guidance systems, every modern military platform depends heavily on electronics. Electronic Warfare (EW) refers to the strategic use of electromagnetic energy to detect, disrupt, deceive, or destroy an adversary's electronic systems while protecting one's own. In this silent battlefield, controlling signals and frequencies can be as decisive as controlling land, sea, or air. Electronic Warfare operates across the electromagnetic spectrum, which includes radio waves, microwaves, infrared, and other frequency bands used for communication and sensing. Modern military systems rely on these frequencies for radar detection, navigation, targeting, and secure communication. If these signals are jammed, intercepted, or manipulated, even the most advanced weapon systems can become ineffective. For example, a fighter aircraft equipped with precision-guided missiles depends on radar and satellite navigation for accurate targeting. If an enemy disrupts these signals, mission success can be severely compromised. Thus, spectrum superiority has become a crucial component of national defence strategies.

Electronic Warfare is broadly divided into three main categories: Electronic Support (ES), Electronic Attack (EA), and Electronic Protection (EP). Electronic Support involves detecting, intercepting, and analysing enemy electromagnetic emissions. Through advanced sensors and signal intelligence systems, military forces can identify the location and type of enemy radar or communication transmitters, providing valuable battlefield awareness. Electronic Attack focuses on disrupting or degrading enemy systems. Techniques such as radar jamming, deception signals, and high-power microwave interference are used to confuse or disable adversary equipment. Electronic Protection ensures that friendly systems remain secure and resilient. Methods like frequency hopping, encryption, shielding, and adaptive filtering safeguard communication networks from interference and interception. Modern military platforms integrate sophisticated EW capabilities. Fighter jets carry radar warning receivers that alert pilots when they are being tracked. Naval vessels deploy electronic countermeasure systems to divert incoming missile threats. Ground-based mobile units use powerful jammers to suppress enemy communications during tactical operations. The development of Active Electronically Scanned Array (AESA) radar systems has further enhanced resilience against jamming by enabling rapid frequency switching and electronic beam steering.



Electronic Warfare in India

India has recognized the strategic importance of electronic warfare and has made significant investments in indigenous EW capabilities. Organizations such as the Defence Research and Development Organisation (DRDO) and Bharat Electronics Limited (BEL) play a central role in developing advanced electronic warfare systems for the Indian Armed Forces. One of India's notable achievements is the development of the Samyukta Electronic Warfare System, designed for the Indian Army. It is capable of intercepting, locating, and jamming enemy communication and radar signals across a wide frequency range. For the Indian Air Force, DRDO has developed airborne self-protection jammer systems integrated into fighter aircraft, enhancing survivability during combat missions. These systems can detect radar threats and automatically deploy countermeasures. The Indian Navy has also deployed indigenous electronic warfare suites on its warships. Modern naval platforms are equipped with electronic support measures and electronic countermeasure systems to detect hostile radars and missile guidance systems. With the increasing focus on network-centric warfare, India is strengthening secure communication systems and spectrum monitoring technologies.

Under the "Aatmanirbhar Bharat" initiative, India is pushing toward self-reliance in defence electronics manufacturing. Indigenous development of radar systems, electronic intelligence receivers, and jamming equipment reduces dependency on foreign suppliers and enhances strategic autonomy. As future warfare becomes more technology-intensive, India's emphasis on electronic warfare ensures preparedness against both conventional and asymmetric threats.

Future Outlook

The future of Electronic Warfare lies in miniaturisation, improved power efficiency, and enhanced spectrum dominance. Compact EW systems are being developed for drones and mobile platforms, increasing operational flexibility. Advances in semiconductor technology are enabling faster processors capable of complex signal analysis in real time. As military systems become more interconnected and digital, electronic warfare will continue evolving as a decisive force multiplier.

Electronic Warfare represents a fundamental transformation in modern conflict. It is a battle fought without visible explosions, yet its impact can determine the outcome of entire operations. By mastering the electromagnetic spectrum, nations secure a powerful strategic

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advantage. For India, continued innovation and indigenous development in Electronic Warfare are essential for maintaining defence readiness in an increasingly technology-driven world. In the invisible battlefield of signals and frequencies, electronics has become one of the most powerful weapons of the twenty-first century.

BEYOND MOORE: THE FUTURE OF VLSI – CHIP REVOLUTION 2.0



ARUN SHANKAR T K

VLSI has transformed modern electronics by enabling billions of transistors to be integrated onto a single chip. For years, progress was driven by transistor scaling under Moore's Law. However, as physical limits approach, the focus is shifting beyond simple size reduction.

Today, innovation in VLSI includes advanced transistor architectures, chiplet-based design, 3D integration, and AI-driven optimization. The industry is evolving from pure scaling to smarter, system-level engineering to meet the growing demands of AI, high-speed communication, and energy-efficient computing.

Entering the Angstrom Era: The Rise of Ribbon-Based Transistors

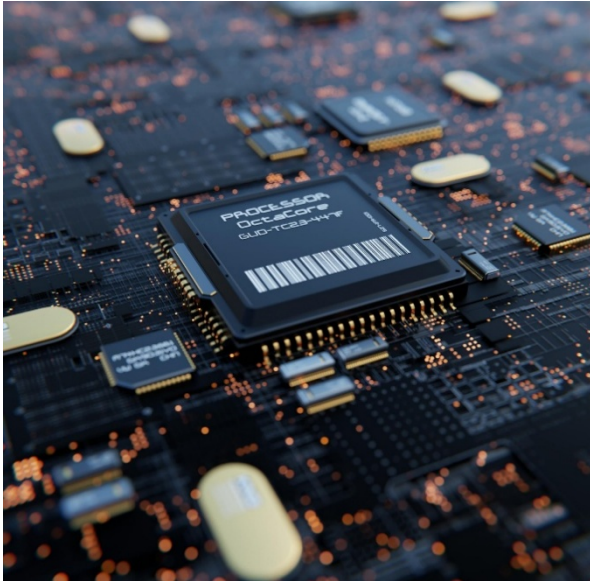
For decades, the semiconductor industry progressed by simply making transistors smaller. But as we move below 3nm technology nodes, scaling is no longer just about shrinking dimensions — it is about redesigning the transistor itself. After FinFETs and GAAFETs, the industry is now adopting nanosheet and ribbon-based transistor structures that offer even better control over current flow.

In these advanced devices, the gate surrounds the channel more effectively, reducing leakage and improving efficiency. What makes them even more promising is their flexibility — engineers can adjust the width of the nanosheets to balance performance and power consumption depending on the application. This marks the beginning of what many call the “Angstrom Era,” where innovation is driven not only by size reduction but by smarter structural design. It shows that even when physical limits seem close, engineering creativity continues to push boundaries.

Backside Power Delivery: Redesigning the Chip

As chips became more complex, one major problem started to appear — congestion. Traditionally, both power lines and signal interconnections were placed on the same side of the chip. With billions of transistors packed into tiny spaces, this created routing challenges, increased resistance losses, and reduced overall efficiency.

The solution? Move the power lines to the backside of the wafer. This new approach, known as backside power delivery, separates power distribution from signal routing. By doing so, it improves current flow, reduces power loss, and frees up valuable space for signal optimization. It may sound simple, but it represents a fundamental architectural shift in chip design. Instead of only focusing on smaller transistors, engineers are now rethinking how the entire chip is structured. This is a clear sign that the future of VLSI lies in holistic innovation.



High-NA EUV: Printing the Future

No matter how advanced a transistor design is, it must still be manufactured with extreme precision. This is where next-generation lithography comes into play. Extreme Ultraviolet (EUV) lithography already enabled sub-7nm technologies, but now High Numerical Aperture (High-NA) EUV systems are taking it even further.

These advanced systems allow chipmakers to print finer patterns with greater accuracy, reducing errors and improving yield. As we approach 2nm and beyond, such precision becomes absolutely critical. High-NA EUV ensures that manufacturers can continue scaling without compromising reliability. It reminds us that semiconductor progress is not just about circuit design — it is equally about breakthroughs in manufacturing technology.

Advanced Packaging and 3D Integration: Stacking for Speed

In today's high-performance systems, moving data quickly between memory and processors is just as important as computation speed. This has led to major advancements in packaging technologies. Instead of placing components side by side, engineers are now stacking them vertically using 3D integration techniques. By reducing the physical distance between logic and memory, data can travel faster while consuming less power. Technologies such as 2.5D integration and hybrid bonding allow incredibly dense interconnections between stacked layers. Packaging, which was once considered a final step in manufacturing, has now become a powerful tool for improving performance. In many modern designs, real innovation is happening not only inside the transistor but also above it.

The future of VLSI lies in integration and specialization. Breakthroughs will increasingly come from chiplet architectures, 3D packaging, new materials, and AI-assisted design methodologies. As applications become more data-intensive and performance-hungry, customized silicon solutions will dominate the market. Sustainability and energy efficiency will also become key priorities in semiconductor development. With strong global investments and expanding applications, the semiconductor industry is set for continued growth. For aspiring engineers, this transformation presents a remarkable opportunity. The next era of VLSI will not be defined by smaller transistors alone, but by smarter design thinking. The road ahead is challenging — but it is filled with possibilities.

BEYOND ELECTRONICS: THE ERA OF SILICON PHOTONIC CIRCUITS



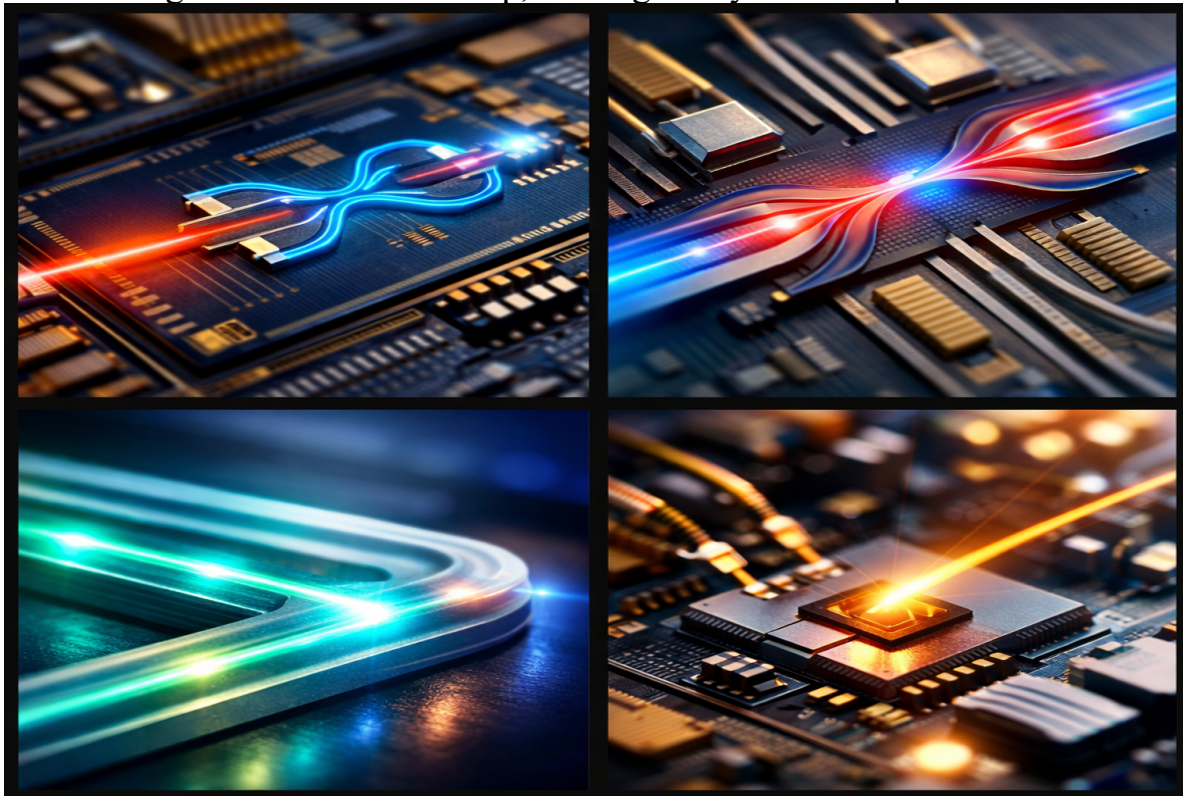
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In today's digital era, the demand for faster data transmission and higher bandwidth is increasing rapidly. Technologies such as artificial intelligence, cloud computing, and data centers require extremely high-speed communication systems. Traditional electronic communication, which uses electrical signals, is reaching its performance limits due to power consumption and bandwidth constraints. To overcome these challenges, a new technology called silicon photonics is emerging as a key solution for next-generation data transfer.

Silicon photonics is a technology that uses light instead of electrical signals to transmit data through silicon-based optical devices. By integrating optical components onto silicon chips, it enables ultra-fast and energy-efficient communication systems. Since silicon is already widely used in semiconductor manufacturing, photonic and electronic components can be integrated on the same chip, making the system compact and cost-effective.

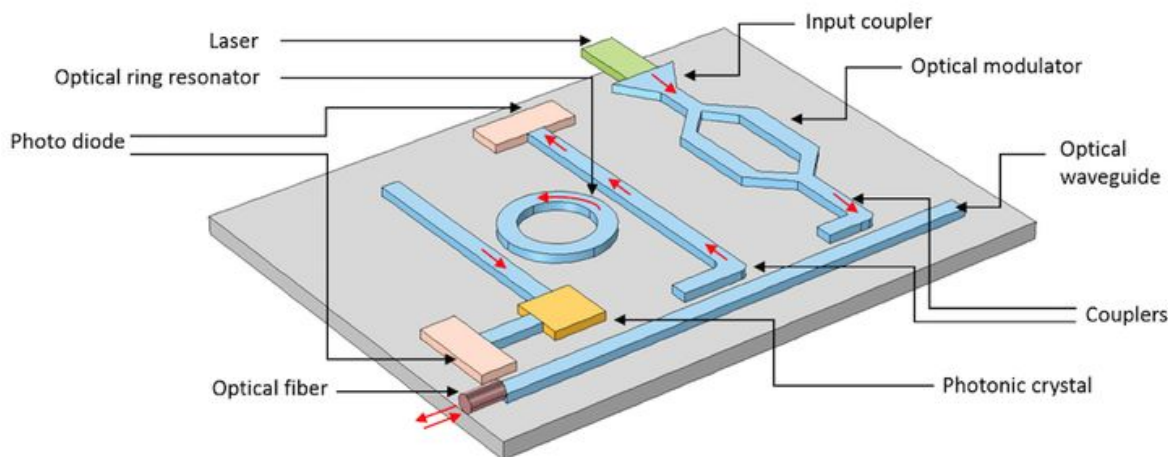


The basic working of silicon photonics involves generating, modulating, transmitting, and detecting light signals. A laser source generates light, which is modulated with data using optical modulators. The light then travels through optical waveguides and reaches the receiver, where photodetectors convert it back into electrical signals. This method allows faster data transfer with very low signal loss and power consumption.

Silicon photonics is widely used in modern data centers, where large volumes of data must

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be transferred between servers at high speed. Optical interconnects based on silicon photonics provide high bandwidth and low latency communication, improving system performance and energy efficiency. In telecommunications, silicon photonics supports high-speed optical networks required for 5G and future 6G communication systems. It enables faster internet connectivity and efficient data transmission. The technology also plays an important role in artificial intelligence and high-performance computing, where rapid data exchange between processors and memory is essential. Silicon photonics provides high-speed and low-power communication, making computing systems more efficient. It is also used in sensing and biomedical applications due to its high sensitivity and compact design.



One of the major advantages of silicon photonics is its ability to achieve extremely high data transfer speeds while consuming less power. It allows integration of optical and electronic components on a single chip, reducing size and cost. The technology supports high bandwidth and low latency communication, which are essential for modern communication systems.

However, silicon photonics faces some challenges. Integrating efficient light sources onto silicon chips is difficult due to material limitations. Manufacturing complexity and initial costs are also high. Researchers are continuously working to improve integration techniques and device performance.

The future of silicon photonics is highly promising. As data usage continues to grow, this technology will play a crucial role in next-generation communication, artificial intelligence hardware, and advanced computing systems. With continuous research and innovation, silicon photonics is expected to transform high-speed data transfer and become a key technology in future communication networks.

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