Chapter 2

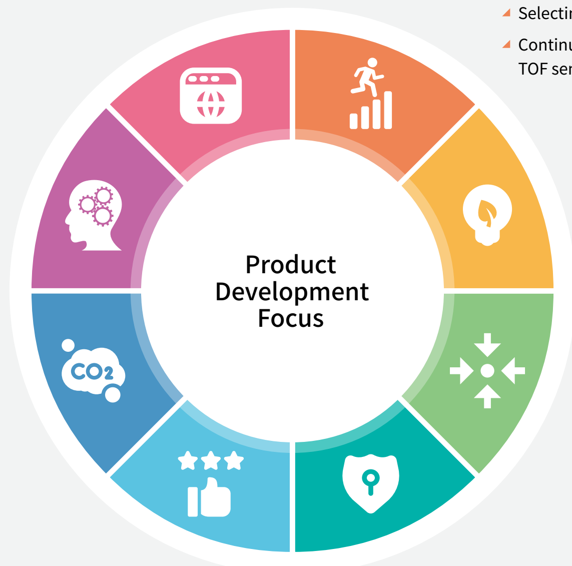
Green Products

2024 Performance Highlights

- Promoted a new **endpoint AI** platform to accelerate the development of fully functional microcontroller AI products
- The NuMicro® M2L31 of low-power, high-performance microcontrollers incorporates up to 11 additional power-saving modes in chip design, reducing full-speed operation power consumption by **40%** (from 110 µA/MHz to 66 µA/MHz) compared to the previous generation NuMicro® M253 series.
- Completed the carbon footprint verification of wafer products at the wafer fab in accordance with **ISO 14067:2018** and underwent third-party verification
- The cumulative number of patents granted to Nuvoton exceeded **5,100** worldwide.

THE GLOBAL GOALS For Sustainable Development
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Nuvoton sees "Innovation in Research and Development" as the driving force for the sustainable transformation of semiconductor IC design products, and is committed to developing the latest technologies in the industry, while continuously reducing the environmental impact throughout the process of design, production, packaging, and logistics. Safer green products based on new technologies and high computational efficiency are introduced to meet energy-saving and carbon reduction goals. In addition to environmental benefits, Nuvoton also pursues social contributions through product innovation, including medical equipment, IoT devices, and smart city solutions that bring added convenience to society. Nuvoton rigorously controls product quality through quality management systems and conducts systematic hazardous substance management.



01 Enhancing Product Performance

- Improving power consumption
- Achieving faster computational efficiency
- Higher performance computing core units
- Selecting low power and low leakage processes
- Continuously reducing the power consumption of products, such as 3D TOF sensor modules and MOS on-resistance

02 Reducing Production Energy Consumption

- By reducing wafer chip area and shortening production time, more products are produced with the same process, reducing energy consumption per wafer.

03 Achieving Smaller Size

- Continuously developing technologies to reduce wafer chip area compared to previous generation products, including NuMicro® M2003 microcontroller chip, low-power and high-performance microcontroller NuMicro® M2L31 chip, high-power and high-quality voice chip, and auxiliary management control chip NPCM400 which supports multi-node cloud server architecture
- The low-power microcontroller NuMicro® M2L31series with built-in ReRAM memory won the "EE Awards Asia 2024 - Product Award (Taiwan) - Best MCU/Driver IC of the Year." The chip area of the digital power control MCU for server power supplies, the measurement and monitoring IC for electric vehicle battery management systems, and the power brushless motor control IC for office equipment has been reduced by more than 5% compared to the previous generation model.

04 Ensuring Information Security and Confidentiality

- Strengthening information security technologies, continuously providing advanced security function designs in products, and developing server security solutions: System firmware protection module Nu-SysPFR

05 Improving Quality

- Continuously improving product quality in three major aspects: quality control, reliability assurance, and failure analysis

06 Controlling Pollution

- Reducing consumables generated during the manufacturing process, lowering carbon footprint emissions
- Establishing a system for managing hazardous substances in products to reduce or eliminate hazardous substances included in products in a "process-oriented" manner

07 Layout of Patents and Intellectual Property Protection

- Adopting international standards in the internal proposal stage of patent applications to enhance patent quality and application success rates
- Improving the protection of intellectual property rights through internal education and training, signing confidentiality agreements and so forth

08 Expanding the Market for Product Applications

- Utilizing existing motor microcontroller products and integrating software applications for keyboards in laptops and M-PESTI management solutions in servers

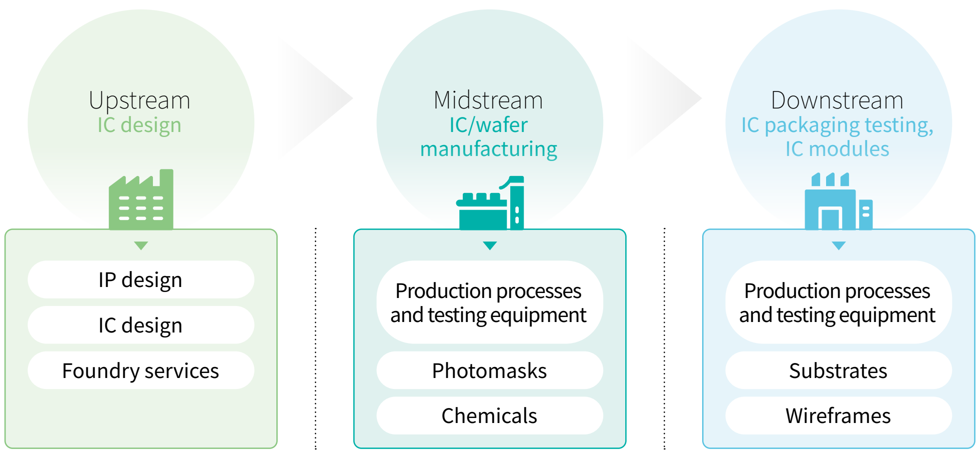
2.1 Innovation in Research and Development

The development of green semiconductor technology can have a positive impact on the future for humankind and our environment. Nuvoton envisions itself as the "Hidden Champion in Providing Sustainable Semiconductors to Enrich Human Life," regards "Innovation in Research and Development" as the driving force for the sustainable transformation of semiconductor IC design products, and aspires for its products to continue expanding their footprint in overseas applications. At the same time, in response to new trends in the international market, Nuvoton is expanding resources to pursue product optimization in major areas of development, such as microcontrollers, cloud computing, and automotive industrial control networks. Products are designed and applied at terminals to achieve energy-saving and carbon reduction goals, and customers are continuously provided with high-quality products and new solutions, thus maintaining Nuvoton's leading position in the IC design house market.

2.1.1 Strategy for Innovation in Research and Development

Semiconductor Industry Chain Positioning

Nuvoton is an IC design company positioned upstream in the semiconductor industry chain, facing the front-line impact of changes in market demand. Our technical research and development require flexibility, advancement, and integration. From the perspective of the supply chain, Nuvoton's products serve as the control and computing core of end products. Nuvoton provides downstream customers with microcontrollers, microprocessors, audio applications, cloud security, battery monitoring, image sensing, IoT, and other related application ICs and semiconductor components. Relevant products have secured a leading position in industrial, automotive, communication, consumer electronics and computer markets with deep expertise cultivated over many years. Additionally, Nuvoton is one of a few domestic IC design companies with wafer fabrication capabilities, owning a 6-inch wafer fab in Taiwan. It manufactures its own IC products, provides specialized wafer foundry services, and establishes long-term and stable cooperation models with upstream players (raw material and equipment suppliers).



Research and Innovation Management Strategy

Nuvoton has four main missions in technical innovation:

Becoming a Trusted Partner for Customers

Deeply understanding and cultivating relationships with customers, Nuvoton is committed to becoming a trusted partner by accurately designing and manufacturing solutions that meet customer needs.

Talent Cultivation

Empowering employees and fostering an environment of open learning, Nuvoton equips its staff with comprehensive skills and encourages agile responses to market changes and challenges.

Team Collaboration

Collaborating across borders and between teams both internally and externally, Nuvoton maintains its leading position and continuous development in multiple core technologies. Internally, teams collaborate across borders, learning from each other, leveraging experiences, exploring new opportunities, and creating new product directions together.

Digital Technology

Nuvoton keeps a close eye on market technology developments. Continuously integrating various digital technologies and tools, Nuvoton enhances operational efficiency and product design and manufacturing quality.

Based on the four innovation missions, Nuvoton has formulated management policies for its product development-related business groups to ensure consistency in product planning and design across different periods. It is committed to launching new technologies, high computational efficiency, and safer green products to meet energy-saving and carbon reduction goals.

Nuvoton Taiwan Business Group

Microcontroller Business Group

Research and development efforts are centered on MCU/MPU and audio products. MCU/MPU products prioritize user product safety and information security as the fundamental requirements. They incorporate energy-saving improvements and endpoint AI trends, exploring and defining key IPs or architectures in line with customer, market, and environmental trends for technical and product development.

Audio products are application-oriented, introducing technologies to save battery consumption, reduce power consumption, achieve lighter and thinner packaging, minimize peripheral component and board material consumption, and gradually invest in high-end AI intelligent interaction research to develop comprehensive management strategies.

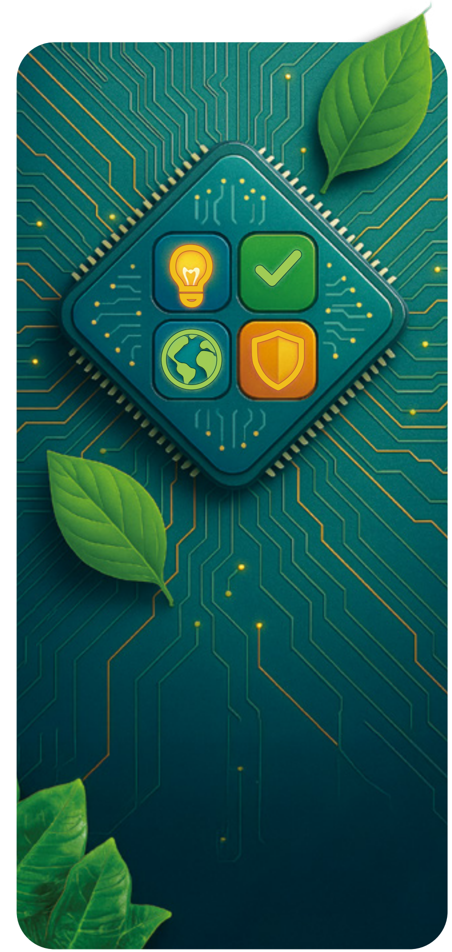
Manufacturing Business Group

In the global trend towards energy-saving and high-efficiency, the Manufacturing business group continues to cultivate high-voltage process platforms for various application areas, providing customers with green semiconductors. In the high-voltage integrated circuit (HVIC) process, industrial-grade reliability verification was completed in 2024, enabling customer products to have a longer lifespan and high-quality characteristics, jointly achieving the goals of a circular economy through green design. Additionally, in terms of production, resources will be invested in promoting smart manufacturing operations, executing innovative projects, monitoring carbon emissions automatically, improving operational efficiency, and reducing environmental consumption to achieve sustainable production goals.

Cloud Security Business Group

The application areas include data centers, cloud servers, edge computing, and end-device-related computing device ecosystems, covering applications, such as security architecture, interface processing, and energy management. In response to the trends of remote work and education, the business group is dedicated to developing low-power, high-computing performance products. Additionally, for rapidly evolving cloud data centers, a highly secure remote control module is being constructed to meet the security environment requirements for personal and corporate cloud data processing. The business group focuses on three main directions for developing green products:

1. Energy-saving and carbon reduction in manufacturing processes: reducing wafer chip area, shortening production time, and producing more products per unit wafer energy consumption in the same process
2. Energy-saving and carbon reduction in product functionality: products feature faster computational efficiency, integration of more interfaces, higher-performance computing core units, and system integration from multiple chips into one chip, overall improving customer system efficiency and reducing unit time energy consumption
3. Our products will be extended to various new applications, such as supporting new architectures for cloud servers, and USB Dock, ARM host SOC, ensuring system firmware information security, and remote management of devices in plants or open areas.



Nuvoton Japan Business Group

Components Business Group

Focus on the research and development of MOSFET (CSP) and RF-GaN products:

1. MOSFET: Compact size and low on-resistance. In mobile applications, it enables extended battery life and quick charging, while achieving high power and precision in automotive and sensing applications.
2. RF-GaN: With more than 30 years of high-frequency circuit knowledge, GaN process technology and integrated module design skills, we provide high efficiency and miniaturized modules for 5G base stations.

Image Sensing Business Group

Focus on the development of image sensors, ISPs, and DSPs:

1. Image sensor: High resolution, high frame rate, compact size, and low power consumption. It can accurately detect and identify obstacles, and exhibits strong adaptability to environmental changes.
2. ISP: AI-driven noise reduction and detection provide high dynamic range and high resolution.
3. DSP： Quick boot and high resolution offer a comfortable display environment inside the vehicle. High-performance simulation and digital audio processing (including noise suppression) deliver a comfortable acoustic space.

Battery and Analog Solutions Business Group

Focus on the R&D of battery monitoring ICs and fan motor driver IC products:

1. Battery monitoring IC: BM-IC utilizing proprietary Silicon on Insulator (SOI) technology enhances system reliability and compliance with ASIL-D standards. Leveraging Nuvoton Japan's expertise in the automotive sector, we make contributions to industrial applications, such as energy storage systems and electric bicycles.
2. Fan motor driver IC: With over 30 years of experience in the industrial equipment market and over 600 million units shipped, Nuvoton Japan's unique Real-time Automatic Phase Control (APC) technology provides long-lasting motor drivers for a wide range of applications.

IoT with Security Business Group

Focus on the development of microcontrollers and secure/edge AI products:

1. Microcontrollers: Possess excellent system knowledge with over 40 years of business experience in consumer, automotive, and industrial markets.
2. Secure/Edge AI: Ensure highly reliable communication with the latest security technology based on Common Criteria 6+, and offer ultra-low-power edge AI solutions suitable for wearable devices and personal healthcare applications.

Laser and GaN Technology Business Group

Focus on laser diode products and GaN foundry services:

1. Laser diode: A leading supplier of laser diodes for optical disks with a cumulative shipment of over 3 billion units. High-power, reliable GaN/GaAs laser diodes for direct imaging and industrial processing
2. GaN foundry services: Provide epitaxial and full-process manufacturing for GaN power devices

In 2024, Nuvoton continued to expand its R&D scale, with R&D expenses exceeding NT$12.7 billion[1] in Taiwan and Japan for the year. With more than 2,589[2] R&D personnel from Taiwan and Japan participating in improving product design, technology development, testing, and production efficiency, Nuvoton demonstrates its determination and commitment to product and technological innovation.

1 In 2024, Nuvoton Taiwan and Nuvoton Japan invested NT$8,775,360 and NT$4,024,900 in R&D respectively.

2 In 2024, Nuvoton Taiwan and Nuvoton Japan invested 1,378 and 1,211 people in R&D respectively.

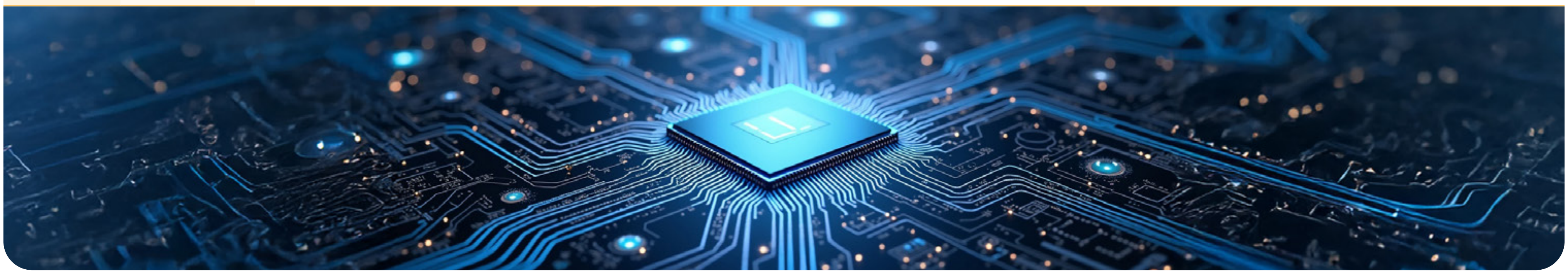
2.1.2 Achievements of Innovation in Research and Development by the Business Groups

Nuvoton’s product-related business groups continue to develop key technologies and have released notable products in recent years, spanning multiple application areas, showcasing Nuvoton’s abundant capabilities in IC design. Since its acquisition in 2020, Nuvoton Japan has further supplemented research and development capabilities in the automotive electronics field, enhancing Nuvoton’s overall competitiveness in the international semiconductor and automotive markets.

Company	Business Group	Key Technology Projects	Highlighted Product	Areas of Application
Nuvoton Taiwan	Microcontroller Business Group	Efficient Cortex-A35 dual-core Built-in Stack DRAM to save costs and space Provide a variety of connection interfaces and robust, up-to-date security options Support industrial-grade operating temperature range (Tj) from -40° C to 125° C	Industrial human machine interface NuMicro® MA35D0 series microprocessor	Industrial edge devices, industrial IoT, factory automation, industrial control, smart infrastructure, smart buildings, smart homes, smart gateways, new energy systems
		High versatility product specifications balancing performance and system cost, combining high speed (144 MHz) with low power consumption (in the deep power-saving mode, the power consumption is only 0.35 mA) Provide high-speed data acquisition and processing, real-time control, and high-precision complex computing capabilities	NuMicro® M433 series microcontrollers	Industrial control, BMS, MiniLED control
		Compact package size integrating rich analog peripherals High analog functionality and precision digital control	NuMicro® M433 series microcontrollers	Industrial intellectualization/ automation, smart factory sensors, etc.
		An ideal choice for upgrading from 8/16-bit cores to 32-bit cores Equipped with fast computing capabilities and built-in hardware divider Support 5V operating voltage and high anti-interference capability	NuMicro® M2003 series microcontrollers	Smart buildings, smart homes/ appliances, industrial control, battery management systems
		Equipped with 64-512 Kbytes ReRAM (Resistive Random-Access Memory), accelerating write operations while offering lower energy consumption and enhanced durability Up to 11 power-saving modes, with outstanding low-power capabilities significantly extending battery life and reducing the need for frequent battery replacements (For more information, please refer to the Highlights Section II)	NuMicro® M2L31 series microcontrollers 	Battery management, industrial automation, consumer interface devices

Company	Business Group	Key Technology Projects	Highlighted Product	Areas of Application
Nuvoton Taiwan	Microcontroller Business Group	▲ Paired with an online model training tool, developers without extensive programming knowledge or a deep understanding of complex algorithms can train an image recognition model in as little as three minutes, significantly simplifying the development process of endpoint AI. (For more information, please refer to the introduction in Highlights Section I)	NuEzAI-M55M1 development boards 	Smart home devices, smart cities, industrial automation, interactive toys, wearable devices, etc.
		▲ Industrial-grade high-power high-fidelity auxiliary solution with internal oscillator supporting 48 kHz frequency ▲ Simulated Class D PWM driver, capable of providing a maximum output power of 3 watts to drive 4-ohm speakers or buzzers	ISD3810 ChipCorder chip	Home appliances, medical, industrial control, charging stations, automotive and motorcycle instrumentation
		▲ Multifunctional high-compression voice control solutions, enhancing capacitive touch performance and meeting the requirements of various MCP low-pin-count packages	N589S080 voice control chip	Smart toy application market
		▲ Highly integrated and high-precision audio measurement controller to meet the needs of voice-assisted/medical portable electronics and high-precision measuring instruments	NSC128L42 audio controller	Electronic blood pressure monitor, precision electronic scale
	Manufacturing Business Group	▲ 600V component technology has passed industrial-grade reliability verification	High-voltage integrated circuit (HVIC) process platform	Motor driver, power tools, electric bicycles, white household appliances, etc.
		▲ 120V BCD technology	BCD (Bipolar CMOS DMOS) process platform	DC/DC transformers, driver chips, and automotive electronics, etc.
	Cloud Computing Business Group	▲ Support various new features of the Intel Birch Stream server platform, such as Platform Monitoring Technology and Flashless Boot	NPCM8xx	Cloud server
		▲ Support management functions in conjunction with BMC under a multi-node cloud server architecture	NPCM400	Cloud server
		▲ USB Dock controller firmware platform	NCT9650	USB Dock
		▲ Information security assurance for system firmware	eSIO product line: NCT6801, NCT6694	Various computers and embedded systems
		▲ Keyboard Controller	NCT9640Y	Laptop
		▲ M-PESTI peripheral management interface	TF5103Y	Server

Company	Business Group	Key Technology Projects	Highlighted Product	Areas of Application
Nuvoton Japan	**Components Business Group**	Miniature low on-resistance technology 12-Inch aafer fabrication technology	Cross-membrane metal-oxide semiconductor MOSFET/Dual N-channel 12V products: Lithium battery protection for wearable devices	Mobile devices
	Visual Sensing Business Group	Sensor pixel design and distance calculation/ISP development technology Four imaging signals and background light elimination function Four memory units for pixels Built-in distance calculation circuit in sensors	KW33000A1T, KW33000A1K, KW33000AR: 3D TOF sensors with built-in distance calculation circuit	Smart door locks for passenger detection and face recognition, XR headsets, luggage size measurement, truck loading volume rate measurement, autonomous mobile robots, etc.
	Battery and Analog Business Group	Battery measurement IC design technology Achieve voltage measurement accuracy of +/-2.9mV (the highest level in the industry) The main circuits such as the AD converter and multiplexer are equipped with self-diagnostic functions	KA49701A, KA49702A: 17-cell battery monitoring ICs suitable for industrial 48V applications	Servers/automotive, energy storage systems (ESS), servers, electric scooters, electric bicycles, robots, drones, etc.
		Motor driver IC design technology Proprietary high-resolution real-time feedback control for motor driver current and phase	KA44370A: Industrial-grade 48V direct-drive motor driver IC	Servers, base stations, FA equipment, and other industrial devices
	IoT with Security Business Group	Microcomputer development technology	Motor control MCU	Home appliance industry
	Laser and GaN Technology Business Group	Laser component development technology	KLC420: Indigo laser component	Electronics and semiconductor package board manufacturing

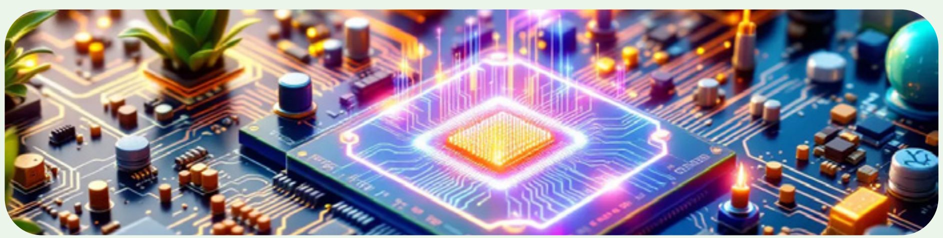


Highlights Section I Micro Machine Learning MCU Products Assist AI Applications

As various industries increasingly recognize the potential of Artificial Intelligence (AI), endpoint AI, which involves deploying AI models directly on device endpoints, has emerged as a significant trend and is widely applied in smart home devices, smart cities, industrial automation, interactive toys, and wearable devices. These application scenarios require real-time data processing and analysis capabilities while maintaining low power consumption and high efficiency to ensure the stable operation of devices over extended periods. Therefore, a new generation of Microcontroller Units (MCUs), Neural Processing Units (NPUs), and Microprocessor Units (MPUs) solutions emerge. Nuvoton's microcontroller-based endpoint AI platform extends the AI ecosystem to the microcontroller domain. This platform is based on the microcontroller and microprocessor with Nuvoton's new architecture, including NuMicro® MA35D1, NuMicro® M467 and NuMicro® M55M1 series with Arm® Ethos ™ -U55 NPU. It can be applied to applications, such as TinyML, industrial IoT, smart home, security access control, smart city, industrial automation, smart agriculture, interactive toys, fitness equipment, wearable devices and so forth, adding AI value to embedded system products.

As a leading microcontroller platform supplier, Nuvoton not only offers advanced hardware chips but also provides developers with comprehensive software development tools, significantly enhancing development efficiency.

Nuvoton will continue to invest in endpoint AI platform microcontrollers, integrating AI features to add value to products. Despite the growing market interest in endpoint AI, developers face numerous design challenges and pain points in implementing endpoint AI functionalities. Traditional workflows typically require extensive programming knowledge, a deep understanding of machine learning frameworks, and the ability to optimize models. These challenges may slow down innovation and make it difficult for developers to rapidly prototype and deploy AI solutions. In light of this, Nuvoton will continue to invest in providing developers with comprehensive software development tools and machine learning sample programs that cover processes, such as data collection, volume label, model training, and verification, making the machine learning development process easier. Nuvoton Taiwan collaborates with top electrical engineering departments at universities in Taiwan on artificial intelligence development projects, supplys development boards for academic teaching and offers technical advice on products used in the curriculum, contributing to the cultivation of national endpoint AI technical talents. Nuvoton Japan also engages in joint research and technical cooperation with top universities in Japan, including the University of Tokyo, on innovative AI semiconductors and system development.



The NuEdgeWise IDE offers a powerful yet simple machine learning development environment.

NuEdgeWise is an easy-to-use graphical Python machine learning development tool. It provides a rich set of machine learning example programs that cover processes, such as data collection, volume label, model training, and verification, making the machine learning development process easier.

NuEzAI-M55M1 development boards

The online model training tool allows developers without extensive programming knowledge or a deep understanding of complex algorithms to train an image recognition model in as little as three minutes by simply using devices such as cameras to capture data in real-time. After training, the online model training tool can output the model in the int8 format of tflite, which can be directly deployed on the NuEzAI-M55M1 development board. It is suitable as an evaluation tool kit for early-stage development, allowing developers to get started quickly and shortening the product time-to-market.

Highlights Section II Products in the Industrial Control IoT Field Pursue High Energy Efficiency and Low Energy Consumption Design

With the rise of AI and high-performance computing (HPC), large-scale data processing places higher demands on transmission speed and efficiency. However, traditional electrical signal transmission faces two major challenges: insufficient transmission speed and heat dissipation. Silicon photonics technology utilizes optical signals for data transmission, significantly enhancing transmission speed and reducing energy consumption. This not only solves the problems of transmission delay and energy waste, but also provides a more reliable data transmission foundation for AI servers and high-performance computing. The NuMicro® series MCU of Nuvoton provides core support for optical communication modules:

M029G/ M030G/M031G Microcontrollers	Suitable for low-power and compact applications, they efficiently support the operational requirements of silicon photonics modules, ensuring stable data transmission with low latency.
M471/M485 Microcontrollers	Featuring high-speed computing capabilities and low-energy design, they are specifically designed for high-bandwidth transmission applications in silicon photonics, meeting the demands of rapid data exchange in AI and IoT devices.

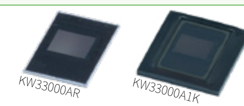
The MA35D1 High-Performance Edge Industrial IoT Series, MA35D0 Industrial Edge Device Series, and MA35H0 Industrial Human-Machine Interface (HMI) Series can meet the high computational power required for industrial IoT edge applications. They enable edge-side data processing and real-time responses, while also providing advanced security mechanisms to prevent malware attacks, confidential data theft, and tampering. Additionally, stacked DRAM within the package can significantly reduce PCB layers, device size, BOM costs, and electromagnetic interference (EMI), helping to achieve the target application's cost, performance, size, and energy efficiency requirements. They are highly suitable for applications requiring control and networking, such as smart infrastructure, manufacturing automation, and new energy systems.

In an era where performance is critical, Nuvoton's new M2L31 microcontroller series are designed to meet the growing demand for high-performance embedded computing. As Nuvoton's representative product designed for high performance and low power consumption, M2L31 series rely on Arm® Corte® -M23 core, advanced ReRAM technology and excellent low power consumption characteristics, suitable for a variety of high-performance automation and energy-saving application scenarios:

Industrial automation equipment	The M2L31 can be used in the sensing and control devices of smart factories, such as robot controllers, sensors, and motor drivers. Thanks to its high efficiency and low-power design, these devices can operate longer and more stably, effectively reducing energy consumption.
Battery management and new energy systems	A supply voltage range as low as 1.6V makes them particularly suitable for battery-powered devices with limited energy, such as monitoring devices for solar power generation systems and intelligent energy storage systems.
Consumer interface devices and IoT devices	The three low-power modes of M2L31 (normal power-down, standby power-down, and deep power-down) are suitable for IoT terminal devices, such as smart home appliances, smart building sensors, and edge computing devices, achieving higher energy efficiency and longer device lifespan.

Highlights Section III Nuvoton Japan Strengthens Competitive Advantage in the Automotive Market

Electric vehicles represent the long-term trend of green energy technology, and Nuvoton Japan has shown remarkable performance in automotive-related components, such as MCU, BMIC, and HMI-IC. For example, in BMIC products, Nuvoton Japan began mass production of its third-generation Battery Management chip (BMIC) in 2023 to meet the growing demand of the electric vehicle market in China. In the future, Nuvoton Japan will release the fourth-generation electric vehicle BMIC, capable of high-precision measurement of the voltage, temperature, of battery cells and current of batteries.

Highlighted Product	Application
TMOS	40V/60V Compact MOSFET for automotive switches
Human machine interface chip (HMI-IC)	With ISP/DSP as the key technology, Nuvoton Japan's HMI-IC has been adopted by a major Chinese automotive manufacturer as a component of the Head Up Display (HUD). A Japanese automotive manufacturer launched a model equipped with digital rearview mirrors using Nuvoton Japan's HMI-IC.
Battery management chip (BMIC)	The third-generation electric vehicle BMIC is in mass production. The fourth-generation electric vehicle BMIC will be released, capable of high-precision measurement of the voltage, temperature of battery cells, and current of batteries. A 17-cell battery monitoring IC suitable for industrial 48V applications, with voltage measurement accuracy of +/-2.9mV (KA49701A, KA49702A) 
Motor driver	Industrial-grade 48V direct-drive motor dedicated chip (KA44370A) 
Image sensor	3D TOF sensor with built-in depth calculation circuit (KW33000A1T, KW33000A1K, KW33000AR) 
Microcontroller Unit (MCU)	Newly developed Arm® Cortex®-M4F core motor control MCU has commenced mass production.
Laser	Indigo semiconductor laser with an optical output power of 1.7W and a wavelength of 420nm (KLC420)

2.2 Green Manufacturing

Developing Green Products

Nuvoton's main products are IC chips, which are widely and diversely used in terminal markets and devices. Therefore, Nuvoton is committed to considering the environment during the chip design phase. Through technological innovation, Nuvoton continues to develop chips with lower power consumption and smaller sizes. Nuvoton's principles and actions for producing green products are evident in the four aspects of design, process, packaging, and logistics:

Design

Nuvoton focuses on minimizing product chip size to reduce raw material usage and waste. Additionally, efforts are made to improve product efficiency and reduce power consumption to minimize environmental impact. The Microcontroller Application business group's NuMicro® M2L31 series of low-power, high-performance microcontrollers incorporate up to eleven additional power-saving modes in chip design, reducing full-speed operation power consumption by 40% (from 110 µA/MHz to 66 µA/MHz) compared to the previous generation NuMicro® M253 series. Furthermore, intelligent hardware circuits are added, allowing for normal communication and data collection through automation mode without needing CPU wake-up in certain usage scenarios. In this automation mode, it can save over 90% of power compared to the previous generation chip.

Process

Nuvoton Taiwan

The use of advanced processes is prioritized in new flagship products to achieve higher computing performance, lower energy consumption, smaller chip sizes and packaging, and smaller system PCB space, and to establish a healthier and more durable production supply chain. The representative products of Cloud Computing business group include EdgeBMC edge computing management control chip and the Embedded Controller for commercial notebooks, both of which have optimized chip processes and performance.

Nuvoton Japan

Continues to invest in the research and development of related products, such as MCU and sensors, which have lower power consumption and smaller chip area and improved energy efficiency compared with the previous generation

Packaging

Nuvoton adopts the circular economy concept for packaging materials, allowing them to be reused multiple times throughout their lifecycle to reduce environmental impact.

Logistics

Nuvoton focuses on consolidating shipments, increasing carrying capacity, optimizing delivery routes, and supporting green logistics networks.

In addition to outsourced production, Nuvoton also has in-house process platforms. Green products manufactured outside the wafer fab via wafer foundry service gradually account for a significant proportion. Key results in the development of three key components focusing on "high efficiency, high integration, and low power consumption" were achieved in the power management chip process. Products produced by Nuvoton Taiwan are based on 6-inch wafers. In 2024, Nuvoton Taiwan completed a carbon footprint verification of 6-inch wafers according to ISO 14067:2018 and underwent third-party verification to grasp the key stages of the product's life cycle with carbon reduction potential.

Nuvoton Japan plans to obtain ISO 14067 certification for products with high customer demand by 2025. To understand resource consumption during the product lifecycle, Nuvoton develops products with green design to reduce resource consumption during production. The Company has identified product emissions during the raw material and production stages, promoted the elimination of prohibited substances in products from the development stage, and developed low-energy products to reduce emissions during the usage stage.

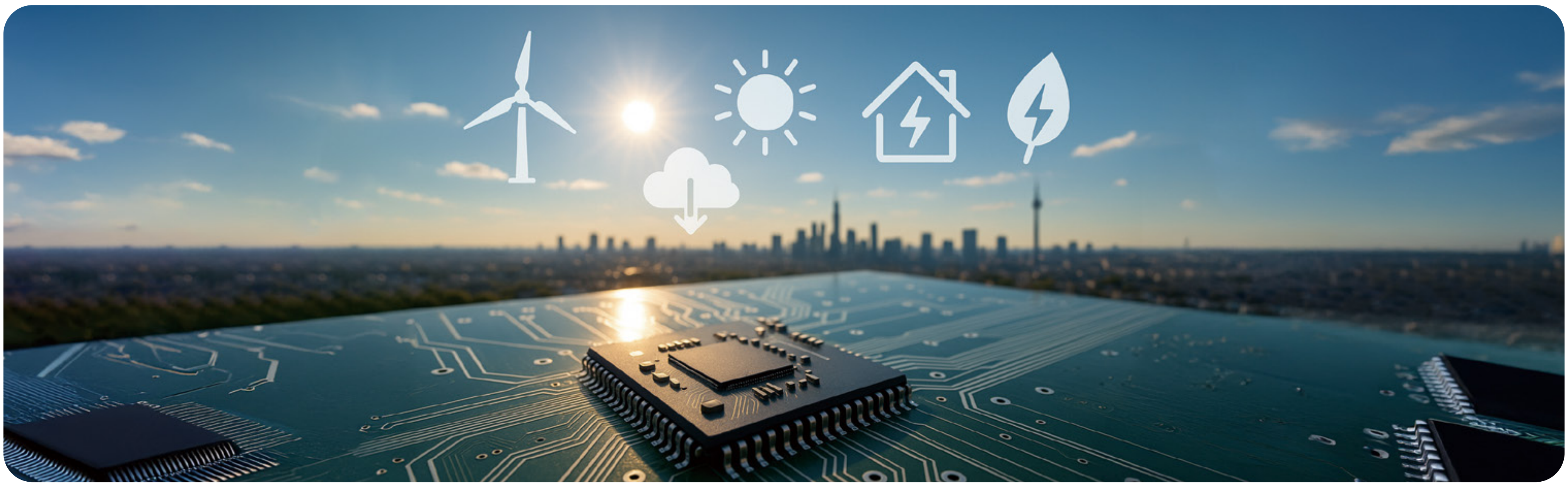
These innovative products of Nuvoton not only benefit the environment but also have a positive impact on society. The low-power characteristic of the new generation of microcontrollers means more compact, lightweight products, which are helpful in various applications, such as medical devices, IoT devices, and smart city solutions. The introduction of these products not only improves efficiency and performance but also brings more convenience and accessibility to society.

Nuvoton's products were widely used in various sustainability-related fields, such as automotive (for example, autonomous driving systems/power management systems, charging piles/batteries), consumer electronics (home appliances/smart homes), industrial control (environmental monitoring sensors/energy management and distribution), and security management, contributing to higher energy efficiency in related products/services on the market.

Nuvoton's Green Products

Benefit Type	Product Name	Benefit Description
Reduced power consumption	N589S080 smart toy chip	Power consumption is reduced by 25% compared to previous models.
	NuMicro® M2L31 chips for low-power, high-performance microcontroller	Multiple power-saving modes are available to reduce operational and standby power consumption. Compared to the previous-generation NuMicro® M253 series, full-speed operation power consumption is reduced by 40% (from 110 μA/MHz to 66 μA/MHz).
	HMI, Motor Driver IC, MCU, BMIC, Image Sensor	Power consumption is reduced by more than 15% compared to previous models.
Saved chip size	NuMicro® M2L31 chips for low-power, high-performance microcontroller	The chip size is reduced by 30% compared to previous-generation NuMicro® M253.
	ISD3810 ChipCorder	The chip size is reduced by 49% compared to the previous generations.
	NSC128L42 audio vontroller	A singe chip is adopted to replace the functionality of the previous-generation chip and customer products.
	N589S080 smart toy chip	The chip size is reduced by 10% (core component size is reduced by 38%) compared to the previous generations.
	EdgeBMC (Edge computing management control chip)	This is a new product for 2023, featuring a more efficient chip packaging. The chip packaging area is reduced by 67% compared to the previous generations. This reduction decreases the demand for silicon raw material during chip manufacturing, and also saves circuit board material consumption and space in end-system applications.
	A digital power control microcontroller used for server power supplies	The chip area is reduced by more than 5% compared to the previous generations.
	Measurement and monitoring IC for electric vehicle battery management systems	
	Power brushless motor control IC for office automation equipment	
Lower on-resistance	TMOS	The on-resistance is reduced by 15%, lowering energy consumption and thereby improving product efficiency compared to previous models.
Increased operational efficiency	Motor driver IC brushless DC Motor	Brushless DC motors are highly efficient, contributing to energy savings. Due to the high degree of design freedom, brushless DC motors are used in various markets and come with multiple voltage, speed, and load options.
	8bit KM101 MCU	It is the microcontroller series developed by Nuvoton Japan and equipped with an 8-bit original CPU. With low power consumption, high code efficiency, and high performance, it achieves capabilities comparable to 16-bit microcontrollers from other companies.
	Arm® Cortex®-M7 MCU	KM1M7 series is a 32-bit flash memory microcontroller equipped with Arm® Cortex®-M7. It features high processing capability and low power consumption, with high-performance PWM, high-speed, high-precision AD converter, and feedback control auxiliary functions suitable for motor control/digital power control applications, making it an ideal choice for power electronic control.
	LD	Luminous efficiency is increased by over 10% compared to previous models.
	NCT9640Y	Existing products are introduced into different market sectors to explore their inherent value and save IC development costs.
	TF5103Y	

The world is currently pursuing sustainability, with smart buildings and IoT technologies being crucial for enhancing energy management efficiency. To minimize the waste and excessive consumption of energy and electricity, it is key for these smart devices to reduce power usage as much as possible. In response to ever-changing market demands, the Microcontroller business group's long-term goal is to design the next generation of ultra-low-power microcontrollers, striving to enable MCUs to operate longer in power-saving sleep modes and further reduce average energy consumption requirements to a maximum degree. Moreover, with the increasing demand for edge computing, MCUs need to feature high-speed interfaces, high bandwidth for external memory, and low power consumption. Designing microcontrollers specifically for edge AI tasks is becoming increasingly important to cater to a wider range of application scenarios, such as image processing, voice recognition, and gesture control. In the future, microcontrollers will evolve towards multi-core architectures with high memory bandwidth support or the ability to accommodate large-capacity external memory, achieving low latency and highly scalable designs to meet future demands. In our planning for the future, Nuvoton will continue to develop products that can reduce energy consumption and minimize size to save resources. We will also strive to improve processes, reducing environmental impact while meeting market demands and operational strategies. Nuvoton will integrate our expertise in servers and personal computers, actively cultivating the three layers of cloud, edge, and endpoint. We will develop high-efficiency, low-power computer chip products that meet the latest security standards, offer zero-compromise security, and incorporate artificial intelligence based on enterprise and market needs. At the same time, we will continue to improve our TMOS, HMI, motor drivers, microcontrollers, and LD products. In the short term, Nuvoton will launch new products with market-leading pointer security features, high performance and low power consumption, as well as the ability to be applied across multiple domains.



Digital Transformation and Smart Manufacturing

Nuvoton is fully promoting digital transformation, integrating digital technology into all areas of the enterprise to create organizational competitive advantages. Both Nuvoton Taiwan and Nuvoton Japan have established digital transformation committees, with members from production, sales, human resources, R&D, finance, and other units. We strive to introduce digital tools to assist in optimizing internal management and improving corporate productivity. In 2024, Nuvoton Taiwan conducted 12 digital transformation sharing sessions, with monthly case studies presented. Each monthly meeting features two units sharing their digital transformation cases or plans. The short-term goal is to raise awareness of the importance of digital transformation across the Company. Through monthly case sharing, Nuvoton employees replicate successful experiences, digitizing and automating more work scenarios and workflows, thereby optimizing work methods and improving work efficiency. During the digitalization and automation process, employees are empowered, enhanced in digital literacy and fostered greater enthusiasm and passion for both work and personal growth. Members of the 12 sub-committees participated in the transformation sharing sessions every month in 2024, with a total of 29 case studies shared and over 1,000 employees and supervisors in attendance. Nuvoton Japan also held 12 digital transformation sharing sessions in 2024, training 200 employees in the basics of digital tools. This initiative aims to help employees utilize digital tools to improve work efficiency, with an estimated annual productivity increase of 8,000 hours. In addition to organizational upgrades through the use of digital tools, Nuvoton also places a heavy importance on smart manufacturing at the factory level. We began promoting smart manufacturing in 2010, referring to concepts such as Industry 4.0 and Industry 3.5 during this period to plan a smart manufacturing blueprint for our 6-inch wafer foundry. The factory launched its smart manufacturing infrastructure in 2010, and from 2012 to 2019, it started the digitization of production information. In 2020, a smart manufacturing management team was established, incorporating relevant projects into KPIs for regular progress reviews to ensure the implementation of relevant strategies. Currently, the smart manufacturing initiative has progressed to the software upgrade stage, where we continue to introduce software development and AI technologies to reduce repetitive operations and labor-intensive tasks. The team is continuously driving various innovative projects with the hope of creating an energy-efficient, environmentally friendly, and highly productive smart manufacturing factory, fulfilling the Company's vision of being a "Hidden Champion in Providing Sustainable Semiconductors to Enrich Human Life."

2024 Smart Manufacturing and Industrial AI Project Achievements

Project Name	Project Description	Project Effectiveness
Automatic machine function update management system	Developed a system to automate the "changeover operation of the gatekeeping mechanism during machine function conversion" which was previously performed manually	Reduce personnel burden and allow engineers to focus on high-value analysis and optimization work, thereby **enhancing job satisfaction**
Cryo-Pump health monitoring and early warning system	Established a system to monitor the Cryo-Pump temperature in real-time to ensure it meets control standards and accurately predict its service life	Lifetime prediction ensures that equipment is maintained or replaced at the optimal time, avoiding premature or delayed replacement, **reducing material waste, and minimizing the environmental burden of part replacement**.
Optimized defect image recognition technology	Utilized AI for the analysis and optimization of machine image capture settings, enhancing the system's accuracy in identifying defect images through image quality optimization	After AI optimizes image quality, defect detection accuracy is improved, thereby reducing the entry of defective products into the market, **enhancing customer satisfaction**, and strengthening brand reputation.
Ice machine AI management system	Established an AI system to execute real-time optimization strategies for the operation of ice machines and auxiliary equipment	**Energy savings of 200K kWh/year**

2.3 Quality and Responsibility

2.3.1 Prodcut Quality Management

Nuvoton continuously provides excellent products and services to solidify its position as an indispensable top-tier partner for customers. The Company adheres to the IATF 16949 international standard to guide the establishment and improvement of the quality management system, ensuring that all processes and their interactions enhance overall quality performance. By implementing stringent quality control measures, ensuring product reliability, and conducting thorough failure analyses, Nuvoton consistently enhances its products to meet and even surpass customer expectations.

Quality Management System Process

Quality Control

Implements a series of quality control mechanisms covering all stages of the production process. By monitoring the manufacturing process, it enables rapid and effective detection of problems, root cause analysis, correction, and prevention.

Reliability Assurance

Each manufacturing stage undergoes continuous review, analysis, and evaluation, with corrective actions taken to improve future quality and reliability, meeting international standards, such as JEDEC (Joint Electron Device Engineering Council) and AEC (Automotive Electronics Council) requirements for product quality and reliability.

Failure Analysis

Nuvoton uses advanced failure analysis equipment to determine the cause of product failures, provide corrective actions, and conduct risk assessments using the FMEA (Failure Mode and Effect Analysis) method to identify potential issues.

In the chip packaging sector, Nuvoton diligently oversees every phase of the manufacturing process, gathers feedback from multiple sources, and promptly and precisely detects issues for analysis and evaluation. Corrective actions are being taken to ensure the development of a high-quality and dependable product line. In terms of packaging technology and supplier management, Nuvoton closely collaborates with packaging companies to ensure that the provided packaging solutions maximize component performance while meeting specific customer requirements. Additionally, Nuvoton rigorously screens outsourcing companies to ensure the quality of products they delivered.

To ensure that employees possess the necessary knowledge, skills, competencies, and attitudes to perform their duties, Nuvoton continuously provides internal and external quality management education and training each year. This includes induction training for new employees, on-the-job education, and professional staff training, all aimed at comprehensively enhancing employees' quality awareness and their application of quality control methods. The training sessions cover topics, such as Quality Control Circles activities, the Seven Quality Control Tools, statistical analysis methods, FMEA and so forth. The following is the implementation of quality management education and training courses in 2024:

Course Name	Course Hours	Cumulative Attendees
QC080000 hazardous substance process management system	1	1,927
Basic FMEA concepts	2	1,359
Basic statistics	6	423
SPC	3	302
QIT	3	573
QC 7 tools	3	287
General education on ISO 9001 / ISO 14001 / ISO 45001 / ISO 50001 (Nuvoton Japan)	1	1,681

Nuvoton develops and enacts robust management systems grounded in international standards like ISO 9001, IATF 16949 and IECQ QC080000. These systems focus on product quality and green products. By doing so, Nuvoton improves operational efficiency and effectiveness, elevates the quality of products and services, and upholds sustainable responsibilities. Nuvoton Japan has established an ISO 9001 quality management system and obtained ISO 9001:2015 quality certification. Additionally, it has also acquired ISO 21434.

2.3.2 Management of Hazardous Substances in Products

Nuvoton implements a rigorous five-step process to manage hazardous substances in all its products. This stringent self-imposed regulatory framework has been recognized by customers. Since 2009, Nuvoton has been a SONY-certified Green Partner and has regularly passed SONY's Green Partner audits. Based on the management system framework of ISO 9001 and IATF 16949, Nuvoton Taiwan obtained the IECQ QC 080000 certification for hazardous substance process management from the International Electrotechnical Commission (IEC) in 2008. This "process-oriented" approach minimizes or eliminates hazardous substances in products, enabling systematic hazardous substance management that meets RoHS, REACH, WEEE, and other customer-specific requirements, effectively operating a robust hazardous substance management system. No incident related to hazardous substance noncompliance occurred in Nuvoton Taiwan in 2024. In response to significant regulatory updates in 2024, it is confirmed that all Nuvoton Taiwan products meet the requirements of the REACH Regulation SVHC, which includes the addition of 7 new controlled substances, bringing the total to 242 items. Additionally, it also follows the EU POPs (Regulation (EU) 2019/1021) requirements after the inclusion of 3 new controlled substances in 2024, and the SONY SS-00259 ver.22 requirements. Nuvoton Taiwan discloses the packaging plant for the source of product components/ingredients, and Nuvoton Japan has marked compliance with RoHS and lead-free requirements.

2024 Nuvoton Achieved Targets

- ✓ Non-compliance issues in hazardous substance management: **0 case**
- ✓ **100%** completion of basic hazardous substance training
- ✓ **100%** of new R&D products and materials comply with hazardous substance management requirements
- ✓ **100%** completion of annual wafer & IC hazardous substance content testing, in compliance with RoHS and halogen-free requirements

Step 1

Declare a Hazardous Substance-Free Policy

Nuvoton is committed to designing, procuring, manufacturing, and selling hazardous substance-free products to comply with international regulations, meet customer demands, and fulfill its environmental responsibility.

Step 2

Establish a Hazardous Substance Control List

Based on international environmental regulations and major customer requirements, Nuvoton maintains a controlled substance list that includes prohibited, restricted, and declarable substances. This list is reviewed and updated annually based on current conditions.

Step 3

New Material Evaluation System

Nuvoton has established a new material evaluation process to ensure that newly developed products and materials comply with Nuvoton's hazardous substance management procedures and environmental, health, and safety requirements.

Step 4

Green Procurement and Supplier Management

Raw material suppliers and subcontractors are required to sign a "Non-Use of Hazardous Substances Certificate" and provide third-party testing reports annually to ensure their products meet international standards.

Step 5

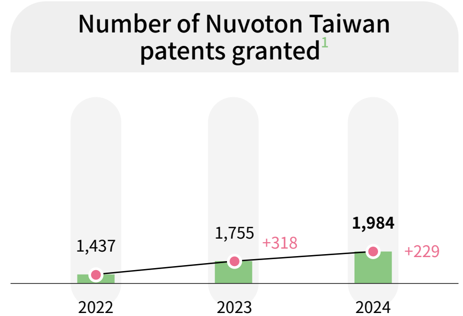
Hazardous Substance Testing

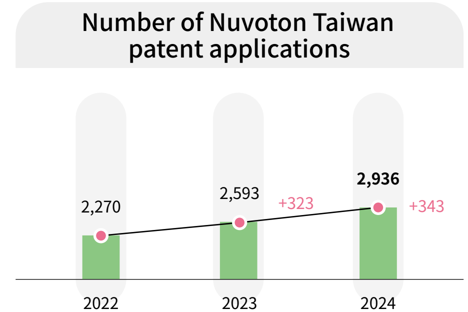
Nuvoton conducts annual testing of harmful substance content in wafers and ICs. The testing items in Taiwan include RoHS and halogens. Third-party accredited organizations measure and monitor banned substances that have environmental impacts and are harmful in raw materials and products to comply with RoHS and halogen-free requirements.

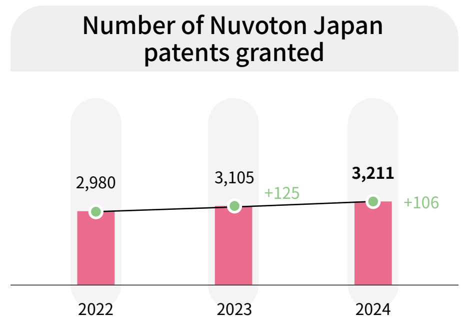
2.4 Intellectual Property Rights

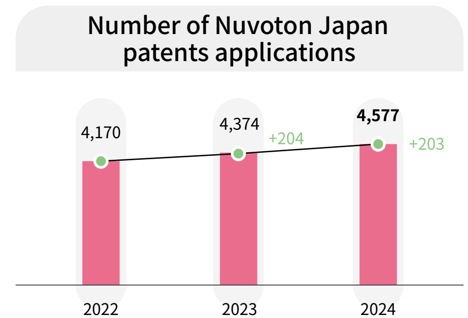
Nuvoton recognizes research and development (R&D) and innovation as essential competitive strengths for sustainable business operations and survival. Intellectual property (IP) protection is a crucial factor in safeguarding brand value. To reinforce its industry leadership and protect its hard-earned advanced technological achievements, the Company has formulated an IP strategy that aligns with its business objectives and R&D resources. This strategy establishes an operational model for protecting the Company's R&D and technological innovations, thereby enhancing its competitive edge and solidifying the foundation for its development. The Company's patent management strategy primarily encompasses patent portfolio deployment strategies, mechanisms for identifying and cultivating key patents, and expanding patent application portfolios. Through the implementation of application and review mechanisms, incentive systems, education and promotion, and talent training at the execution level, the Company protects its R&D outcomes and technological leadership, continuously accumulating IP strength. Nuvoton has established an IP department and a patent review committee to strengthen its IP management strategy work, including patent evaluation and review, awards and incentives for innovative results, creativity-stimulating activities, and strategic utilization of IP.

To improve the number of patent applications and approvals, the Company adopts international standards in the internal proposal stage of patent applications, following patent laws, examination guidelines, and commercial potential of various countries to review each proposal. This approach aims to improve the quality of patents and the probability of successful approval, ensuring that the Company's R&D innovations can receive adequate legal protection. In addition, the Company sets patent application targets at the beginning of each year and designs a variety of innovation incentive mechanisms to continuously encourage employees to submit invention applications. It also establishes a systematic IP management system, utilizes digital transformation tools to establish a patent knowledge platform to share patent information, and holds multiple creative brainstorming activities to assist colleagues in generating patent proposals more efficiently. In 2024, Nuvoton Taiwan filed 343 patent applications, with 229 patents granted, ranking 17th among domestic legal entities for patent applications in Taiwan. Nuvoton Japan filed 203 patent applications, and the total number of patents filed globally exceeded 4,500. The number of patents granted globally reached 106, with a cumulative total of over 3,200 granted patents worldwide.









1 The data information here has been recompiled and the adjustment instructions compared with the previous year's report are detailed in Appendix 3.

In addition to continuously pursuing diverse patent layouts, Nuvoton also pays close attention to the protection and management of trade secrets for comprehensive IP protection. The Company's new employee training programs include a theme to remind new employees to safeguard the Company's trade secrets. In 2024, the new employee training course, "Legal Issues that Knowledge Workers Should Pay Attention" was conducted, with a total of 194 trainees. In addition, Nuvoton signs confidentiality agreements with long-term cooperating suppliers or customers at the initial stage of contact to protect Nuvoton's confidential information and trade secrets. In 2024, Nuvoton did not encounter any disputes involving breach of confidentiality agreements or infringement of trade secrets.