6. Electronic Devices and Storage

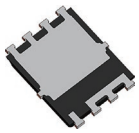
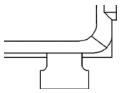
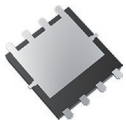
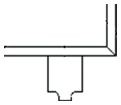
6.1 Surface-Mount MOSFET Package Contributing to Enhanced Current-Carrying Capability and Reduced On-Resistance

Automobile electrification is expanding worldwide in response to increasingly stringent environmental regulations. To enhance the performance and increase the output of electrical units, automotive power metal-oxide-semiconductor field-effect transistors (MOSFETs) are required to support motors with high current and high power. On the other hand, with the advancement of autonomous driving technology, the required level of redundancy in electronic control units (ECUs) is increasing, leading to a higher number of components and more limited installation space. Consequently, power MOSFETs are required to provide higher current-carrying capability and reduced power losses while maintaining or even reducing device size.

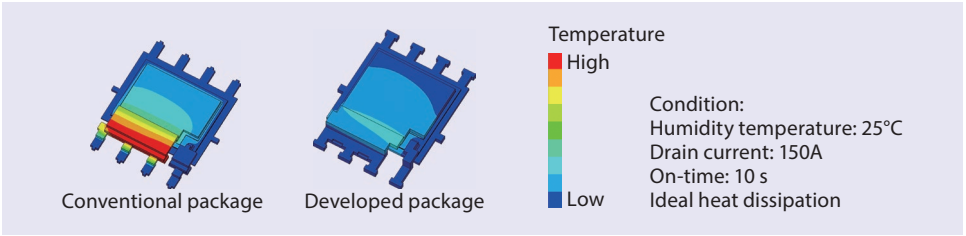
To address these requirements, Toshiba Electronic Devices & Storage Corporation has developed a compact surface-mount power MOSFET package with a wettable flank (WF) structure. This package features a postless structure that integrates the source connector and the leadframe to eliminate the solder joint posts between them, as well as a source-coupled structure in which the three source terminals are electrically connected on the backside of the package. This configuration reduces package resistance by approximately 54% compared with the conventional SOP Advance(WF) package, thereby enabling maximum utilization of the chip's current-carrying capacity. In addition, to reduce the on-resistance and improve the current-carrying capability, the maximum die attachable area has been increased by approximately 23%.

As a result, while the conventional MOSFET in the SOP Advance(WF) package exhibits a maximum on-resistance of 0.79 mΩ, the MOSFET in the new package achieves a maximum on-resistance of 0.59 mΩ, representing a reduction of approximately 25% and enabling lower power losses. Furthermore, in terms of maximum rated current, the conventional MOSFET in the SOP Advance(WF) package is rated at 150 A, whereas the MOSFET in the new package is rated at 180 A, a 20% increase, thereby improving current-carrying capability. In addition, since the new package adopts a WF structure similar to that of the SOP Advance(WF) package, it is compatible with automated optical inspection systems.

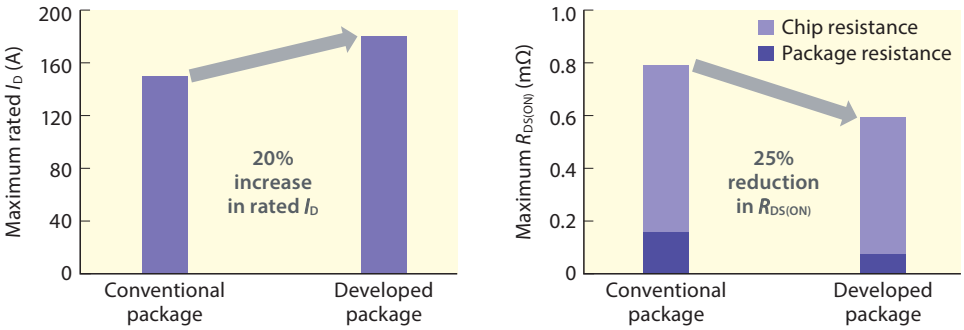
Going forward, we will continue to provide products aligned with evolving ECU trends and contribute to the advancement of the automotive industry.

Package	Internal construction (schematic diagram)	Package configuration	Terminal structure
Developed package	 Post-less structure	 Source connection	 Wettable flank (in shape of hammer)
Conventional SOP Advance(WF) package (XPHR7904PS)	 Post (solder joint)	 Source separation	 Wettable flank (convex shape)

Comparison of developed package and conventional SOP Advance(WF) package structures



Comparison of simulation results for heat generation from internal frames of developed package and conventional package



$R_{DS(ON)}$: drain-source on-resistance

Comparison of maximum rated current and on-resistance of developed package and conventional package

6.2 Semiconductor Models for In-Vehicle System Verification

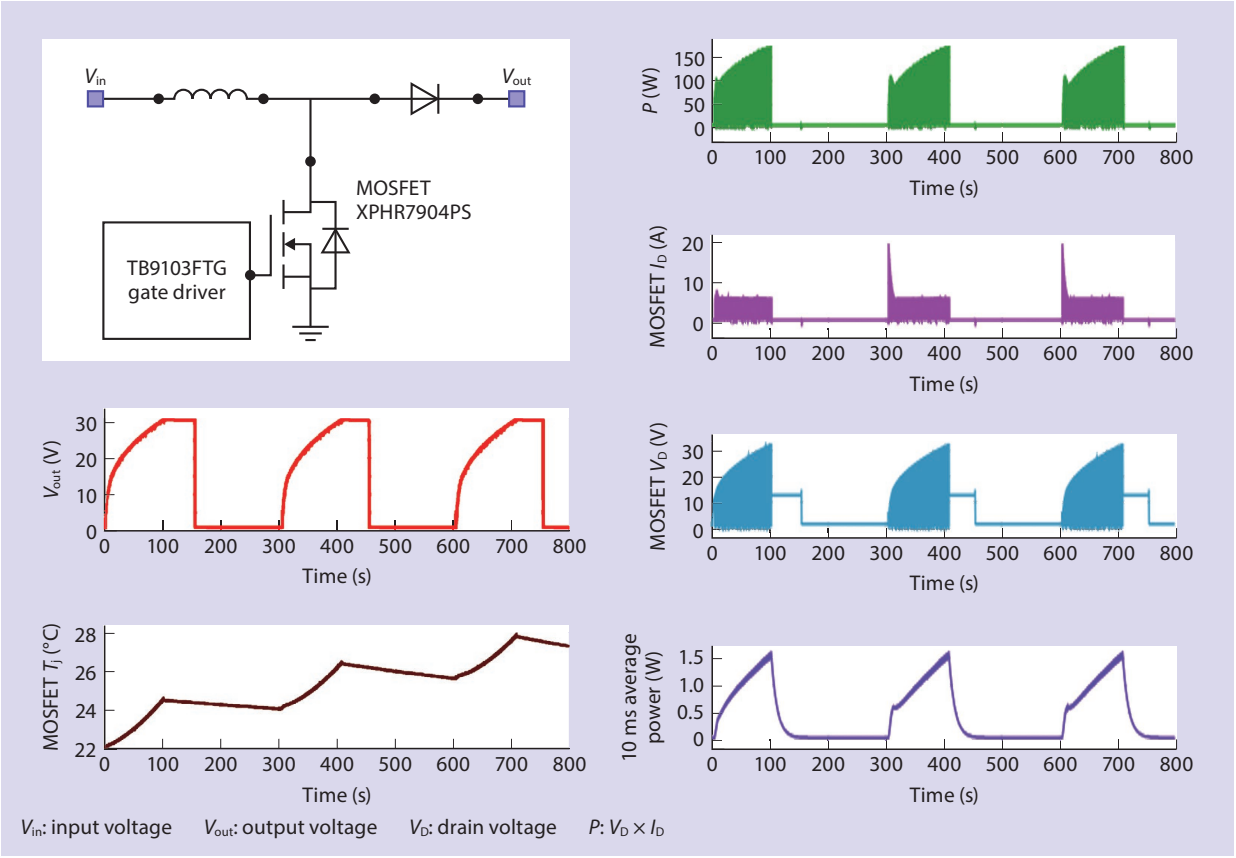
With advances in digital twin technology, model-based development (MBD) using computer-aided design (CAD) has been widely adopted in fields such as automotive engineering, robotics, and factory production lines. In particular, in the automotive field, the increasing complexity of in-vehicle functions has driven a growing demand for simulation-based functional verification. At the same time, the engineering effort required for thermal analysis and for evaluating electromagnetic interference (EMI) and electromagnetic susceptibility (EMS) has increased, making it essential to improve simulation accuracy in the early stages of product development.

Against this background, Toshiba Electronic Devices & Storage Corporation has been focusing on the development and provision of high-accuracy models for automotive semiconductor products, as well as on enhancing functional verification using MBD. As part of this initiative, we developed a VHDL-AMS (Very High Speed Integrated Circuit Hardware Description Language–Analog and Mixed Signal) model for the TB9103FTG, a newly developed H-bridge gate driver integrated circuit (IC). Using this model, we participated in verification activities organized by the Society of Automotive Engineers of Japan and performed transient thermal analysis of a DC-DC converter composed of the 40 V XPHR7904PS and 60 V XPH3R206NC automotive MOSFETs.

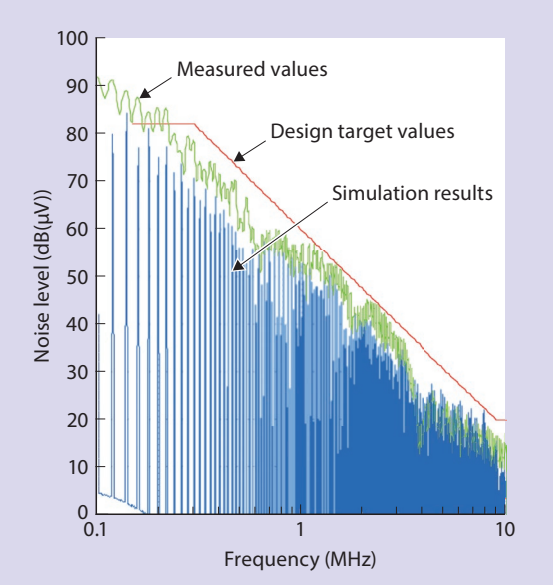
Furthermore, we performed electromechanical (mechatronic) co-simulation of the entire actuator board, including the DC-DC converter. This approach enabled verification of functional operation that closely reproduces actual hardware behavior, as well as prediction of the MOSFET junction temperature (T_j), within a short analysis time. Looking ahead, we will continue to enhance model accuracy and expand the application of these models to other products. In addition, with the aim of applying them to hardware-in-the-loop verification activities within the Society of Automotive Engineers of Japan, we will further promote the development of more practical and user-friendly models.

In the area of EMI and EMS, we are also advancing the development of high-accuracy models for the TB9032FTG automotive communication IC. By comparing simulation results with measured noise levels obtained using methods compliant with International Electrotechnical Commission (IEC) standards, we confirmed a high degree of correlation for both the EMI and EMS models. These high-accuracy models enable simulations that include surrounding passive components and printed circuit boards, thereby reducing the risk of rework in later stages of automotive system development.

Through the continued development and provision of semiconductor models that meet market needs, we will contribute to improving the efficiency of automotive development.

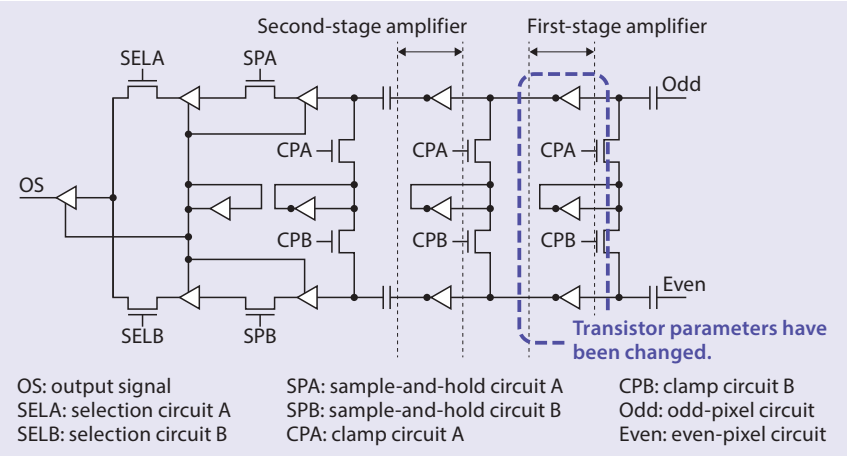


DC-DC converter operating waveforms and transient thermal behavior of MOSFETs



EMI simulation results (green: actual measurements, blue: simulation results)

6.3 TCD2728DG Linear Image Sensor for High-Speed and High-Resolution Scanning Applications



Schematic diagram of output amplifier gain circuit with reduced gain

TCD2728DG CCD linear image sensor package

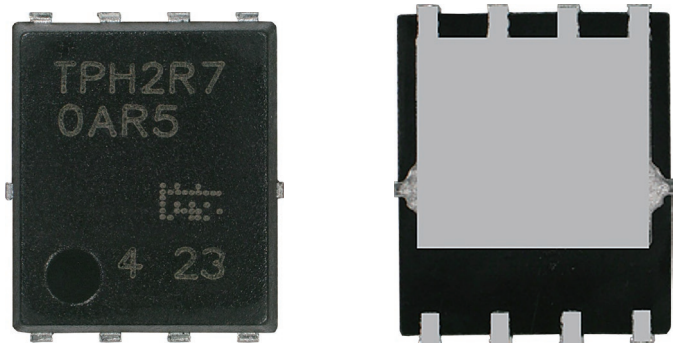
In office environments, multifunction printers (MFPs) are increasingly required to copy and scan large volumes of diverse paper documents at high speed and high resolution. In particular, for A3 MFPs, improvement of image quality is a critical issue. For high-speed data readout, lens-reduction-type charge coupled device (CCD) linear image sensors, which optically reduce images using lenses, are widely used. However, to improve image quality, it is necessary to reduce the impact of random noise in the signal.

To address this issue, Toshiba Electronic Devices & Storage Corporation has released the TCD2728DG, which features a modified output amplifier gain in the CCD linear image sensor compared with its predecessor, the TCD2726DG, thereby reducing the signal amplification factor and consequently reducing random noise. The TCD2728DG achieves approximately 40% lower measured random noise than the TCD2726DG, resulting in a wider dynamic range and improved overall image quality. In addition, it supports a data rate of 100 MHz (50 MHz × 2 channels), which is among the fastest for CCD linear image sensors. This enables high-speed processing of large volumes of image data, making it suitable for line-scan cameras used in various inspection systems that require real-time pass/fail judgment.

Furthermore, the TCD2728DG incorporates a timing generator, significantly reducing the number of CCD drive terminals and thereby mitigating EMI—which tends to increase during high-speed operation. The device also eliminates the need for customers to generate and shape multiple types of CCD drive signals, including the adjustments of rise and fall times, pulse widths, and inter-signal phase relationships, as well as measures to suppress undershoot and overshoot, thereby contributing to improved development efficiency.

Going forward, to meet the growing demand for high-speed and high-quality imaging and sensing technologies, we will further expand our product lineup to support not only scanning applications such as MFPs but also a wide range of sensing applications, including various inspection systems.

6.4 U-MOS11-H 100 V Power MOSFET



TPH2R70AR5 100 V power MOSFET fabricated with U-MOS11-H process

Process technology	U-MOSX-H 100 V	U-MOS11-H 100 V	
Typical product	TPH3R10AQM (conventional product)	TPH2R70AR5 (new product)	Reduction in percentage
R_{on} (mΩ) (V_G=10 V, I_D=50 A)	2.5	2.3	8%
C_{rss} (pF) (V_D=50 V)	45	23	49%
Q_{gd} (nC) (V_D=50 V)	22	9.1	59%
Q_g (nC) (V_G=10 V)	83	52	37%
Q_{rr} (nC) (-dI/dt=100 A/μs, I_S=50 A)	89	55	38%
$R_{on} \times Q_{gd}$ (mΩ·nC)	55	20.9	62%
$R_{on} \times Q_g$ (mΩ·nC)	207.5	119.6	42%
$R_{on} \times Q_{rr}$ (mΩ·nC)	223	127	43%

V_g: gate voltage I_s: source current Q_{gd}: electric charge between gate and drain

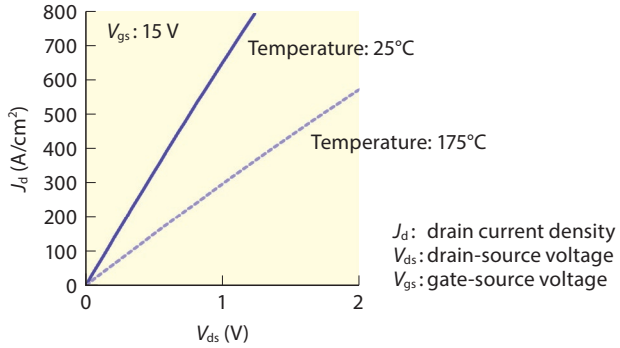
Comparison of conventional U-MOSX-H series and new U-MOS11-H series product characteristics

The advancement of artificial intelligence (AI) and telecommunication technologies has increased the need for further reductions in power consumption in data centers and telecom base stations. To address this need, Toshiba Electronic Devices & Storage Corporation has released the TPH2R70AR5, a 100 V n-channel power MOSFET fabricated using the latest U-MOS11-H process.

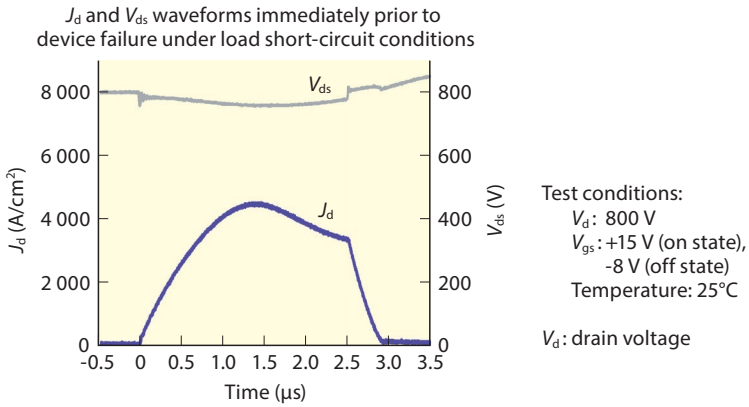
Compared with the previous U-MOSX-H process, the new device features a finer trench pitch and reduced gate electrode dimensions, as well as reduced variations in gate electrode fabrication. In addition, lifetime control technology is optionally applied. As a result, we have achieved an 8% reduction in on-resistance (R_{on}), which affects conduction loss; a 49% reduction in reverse transfer capacitance (C_{rss}), which affects switching loss; a 37% reduction in gate charge (Q_g), which affects gate drive loss; and a 38% reduction in reverse recovery charge (Q_{rr}), which affects reverse recovery loss. These improvements contribute to the enhancement of power conversion efficiency of power management systems.

This technology will also be applied to 80 V MOSFETs (U-MOS11-H 80 V).

6.5 1 200 V-Class SiC Trench-Gate MOSFETs Combining Low Loss and High Reliability



SiC trench-gate MOSFET prototype output characteristics



Short-circuit current density waveform immediately prior to device failure

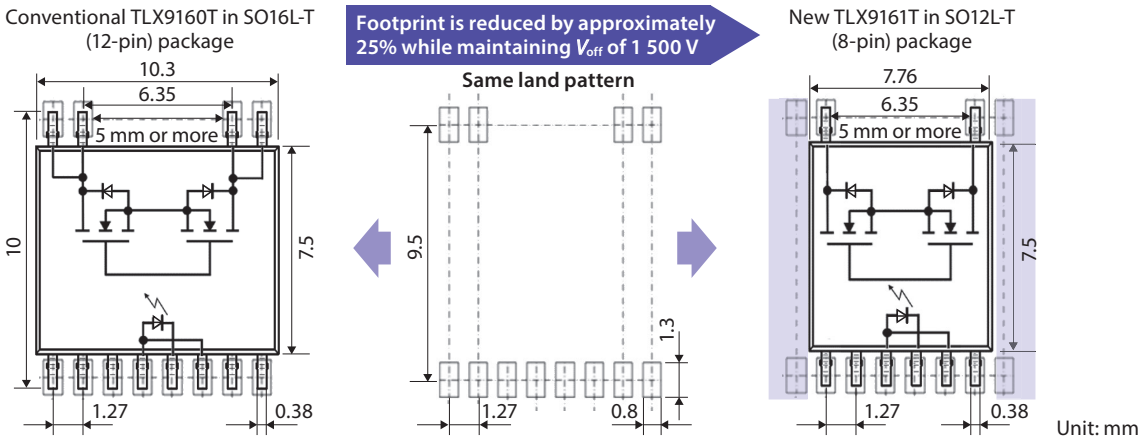
Low-loss silicon carbide (SiC) power semiconductor devices are attracting increasing attention as a key technology for achieving a carbon-neutral society.

To reduce the specific on-resistance ($R_{on}A$)—one of the key performance metrics of power MOSFETs—through cell-pitch scaling, Toshiba Electronic Devices & Storage Corporation has fabricated a prototype 1 200 V-class SiC trench MOSFET. The prototype device exhibits a breakdown voltage of 1 500 V or higher while achieving an $R_{on}A$ of 1.50 mΩ·cm² at 25°C, representing an approximately 30% reduction compared with conventional SiC planar MOSFETs. A short-circuit withstand time of 2.5 µs was confirmed, demonstrating that the device achieves both low $R_{on}A$ and extended short-circuit capability. Furthermore, optimization of the fabrication improved the gate oxide lifetime and suppressed threshold voltage variations caused by gate switching instability (GSI).

Based on this technology, we aim to commercialize SiC trench MOSFETs that combine low loss with high reliability.

This work is based on results obtained from a project, JPNP21029, subsidized by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

6.6 High-Voltage Solid-State Relay in Compact Package Contributing to Miniaturization of Vehicle Battery Management Systems



Comparison of conventional and new package external dimensions

Item	TLX9160T	New TLX9161T
Package size (width × depth)	SO16L-T (10.3 × 7.5)	New SO12L-T package (7.76 × 7.5)
Storage temperature	-55 to 150°C	
Operating temperature	-40 to 125°C	
V_{off} (T_a=25°C)	1 500 V, bidirectional	
Operating temperature (T_a=25°C)	1 000 V	
CTI	> 600 (Material Group I)	
Pin-to-pin creepage distance* (secondary side)	≥ 5 mm, satisfying 1 000 V requirement	

T_a: ambient temperature

* Creepage distance specified in Table F.4 of IEC 60664-1 standard 60664-1) for operating voltage of 1 000 V, comparative tracking index (CTI) of > 600, and pollution degree of 2.

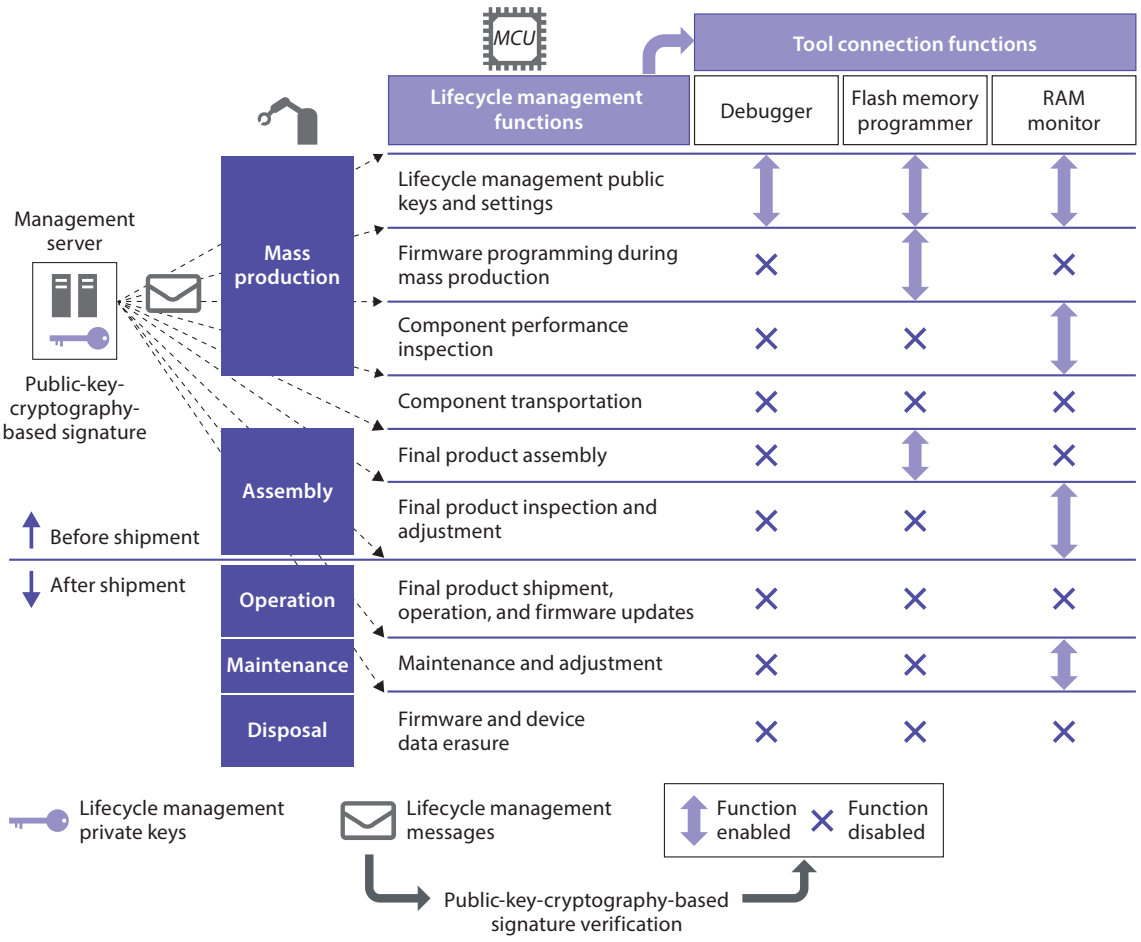
Comparison of rated specifications of newly developed and conventional photorelays

Battery management systems (BMS), which contribute to extending the driving range of electric vehicles, require solid-state relays that combine high withstand voltage with a compact form factor. To address these requirements, Toshiba Electronic Devices & Storage Corporation has developed the TLX9161T based on the existing TLX9160T, with an output withstand voltage (V_{off}) of 1 500 V. The TLX9161T features a compact SO12L-T package, achieving approximately a 25% reduction in mounting area.

The MOSFET chip incorporated into the TLX9161T leverages insulated-gate bipolar transistor (IGBT) design technology. By shortening the termination structure and optimizing the curvature of the chip corners, the chip area has been reduced by approximately 56% while maintaining a V_{off} of 1 500 V. Furthermore, the SO12L-T package is compatible with the land patterns of the conventional SO16L-T package, enabling direct replacement without requiring modifications to the printed circuit board (PCB) design.

Photorelays with a V_{off} of 1 500 V in the SO12L-T package contribute to the miniaturization and cost reduction of automotive BMS. The TLX9161T is also compliant with AEC-Q101, an automotive reliability qualification standard.

6.7 MCU Lifecycle Management Technology



FW: firmware

Overview of MCU lifecycle management

Recent cybersecurity regulations, such as the European Union (EU) Cyber Resilience Act, require comprehensive security measures covering the entire lifecycle of electronic equipment. In addition to protection against cyberattacks during operation, products incorporating microcontroller units (MCUs) increasingly require security measures throughout the mass-production and maintenance phases.

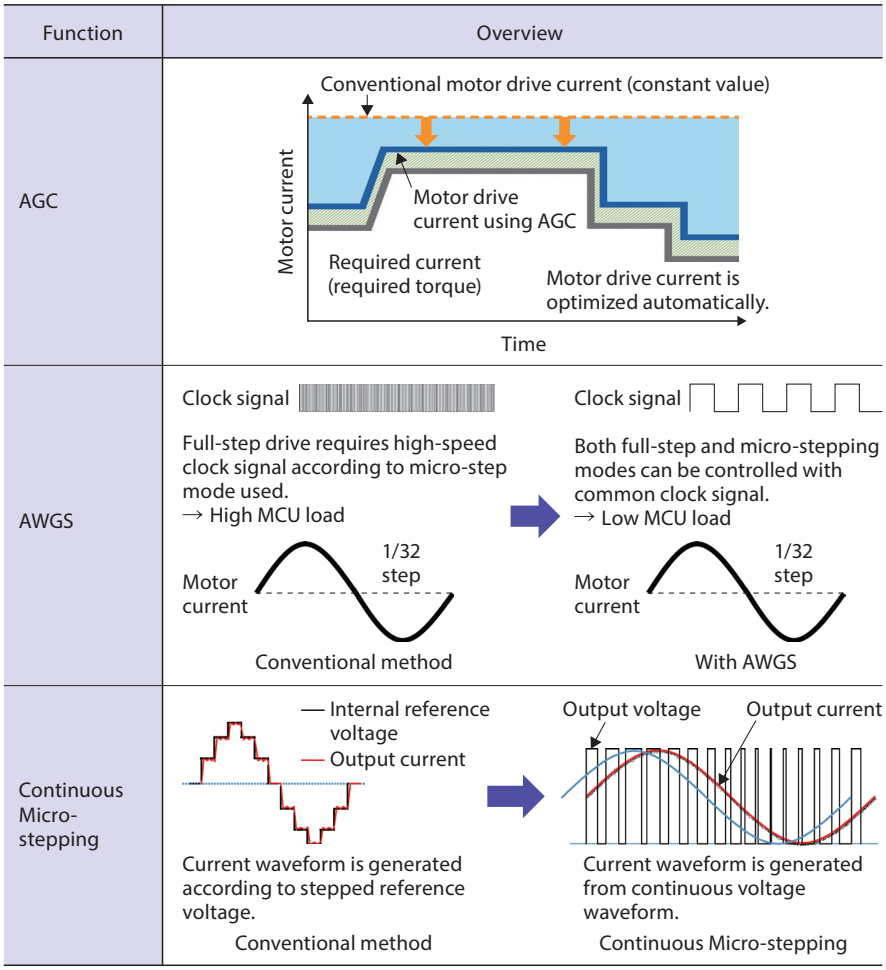
In particular, functions that enable such products to connect with debuggers, flash memory programmers, and other tools—which can be sources of cyber threats—require strict management. These functions must be enabled or disabled in accordance with each stage of the product lifecycle, including mass production, assembly, operation, maintenance, and disposal. Furthermore, in light of increasingly diverse supply chains, it is necessary to address complex equipment lifecycles that encompass transportation and inspection processes.

To address these requirements, Toshiba Electronic Devices & Storage Corporation has developed an MCU lifecycle management technology that enables customers to flexibly customize connection control for MCUs at each stage of the product lifecycle. A key feature of this

technology is the use of public-key–based signature verification to control the enabling and disabling of functions. This approach enhances security throughout the product lifecycle while reducing the operational burden on customers.

We will continue to advance the development of MCUs incorporating this lifecycle management technology, with the aim of further enhancing the security and usability of a wide range of applications.

6.8 40 V, 2 A Constant-Current Stepping Motor Driver IC Incorporating Advanced Micro-stepping Technology



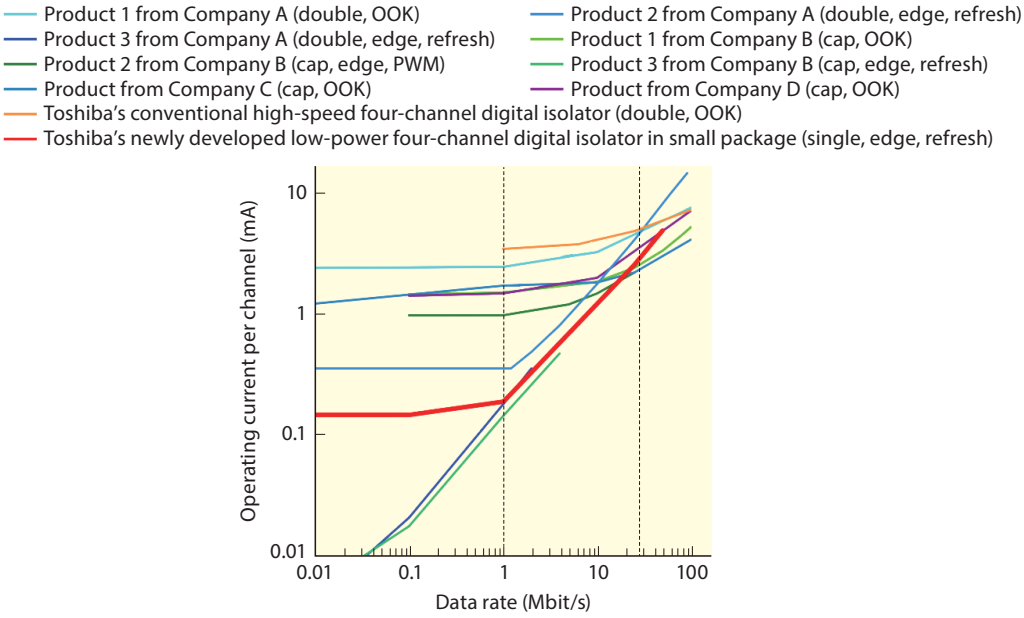
Three features of new stepping motor driver IC

Demand for stepping motors for general office automation and industrial applications continues to grow. Driver ICs for these stepping motors are required to provide high efficiency, as well as low vibration and low acoustic noise.

To meet these requirements, Toshiba Electronic Devices & Storage Corporation has developed and commercialized the TB67S579FTG, which incorporates three new advanced micro-stepping functions: Active Gain Control (AGC), Automatic Wave Generation System (AWGS), and Continuous Micro-stepping.

AGC automatically controls motor current according to load conditions, enabling highly efficient and energy-saving operation. AWGS enables micro-stepping without changing the clock frequency, thereby reducing the load on MCUs and related components. Furthermore, Continuous Micro-stepping provides closer approximation of sinusoidal drive waveforms than conventional micro-stepping methods, thereby reducing motor vibration and acoustic noise. Mass production of the TB67S579FTG began in September 2025.

6.9 Digital Isolator Contributing to Reduced System Power Consumption



cap: capacitive coupling structure
OOK: on-off keying
edge: edge encoding
PWM: pulse-width modulation

single: isolation transformer with single-insulation structure
double: isolation transformer with double-insulation structure
refresh: refresh pulse generator

* As of June 2025 (according to Toshiba Electronic Devices & Storage Corporation research)

Comparison of data rate-versus-supply current curves of Toshiba Electronic Devices & Storage Corporation's conventional and new digital isolators and competitor products

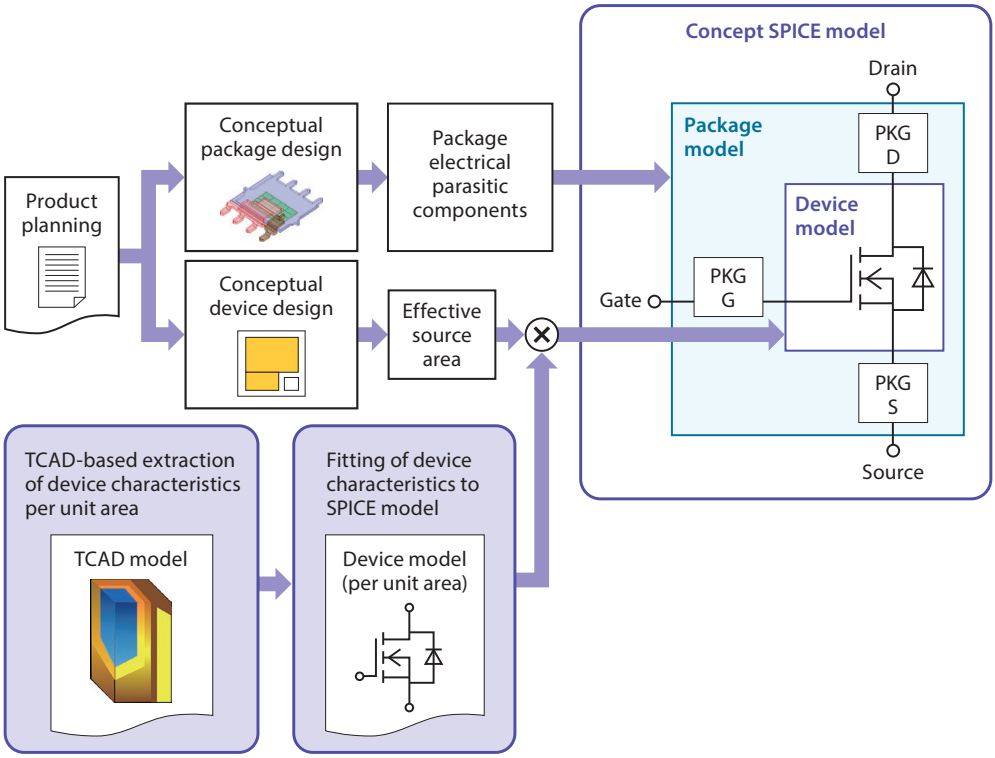
The global movement toward carbon neutrality is accelerating efforts across industries to improve efficiency and achieve decarbonization through energy conservation, the adoption of renewable energy, and digitalization.

Digital isolators play a critical role in equipment requiring electrical isolation between different voltage domains, ensuring stable operation of communication and control functions. Reducing their power consumption can contribute to the realization of carbon neutrality across a wide range of applications, including industrial and automotive systems.

In this context, Toshiba Electronic Devices & Storage Corporation has developed a digital isolator in a small package that achieves reduced power consumption through the adoption of a novel circuit technology for the isolated signal transmission section. In the operating data rate range from 1 Mbit/s to a maximum of 25 Mbit/s, the device achieves supply current consumption comparable to or lower than that of conventional and commercially available products.

Going forward, we will continue to expand the product lineup of digital isolators and pursue further performance improvements to contribute to the realization of an energy-efficient society.

6.10 Semiconductor SPICE Model Generation Technology Enabling Prototype-Free Development



TCAD: technology computer-aided design

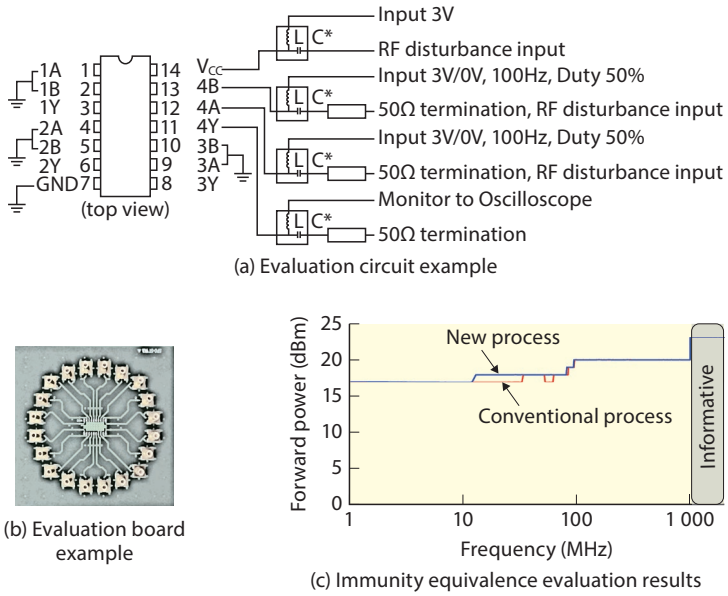
Verification of design change impacts on electrical characteristics by integrating SPICE device and package models

In the field of power electronics, semiconductor product development is becoming increasingly complex due to rapid technological advances and the diversification of market needs. Consequently, MBD-based front-loading design approaches are attracting growing attention.

To enable the prediction of electrical characteristics at the conceptual design stage, Toshiba Electronic Devices & Storage Corporation has developed (1) a high-accuracy device characterization technique based on physics-based models that account for various physical effects, including stress-dependent carrier mobility and electric-field-dependent tunneling effects, and (2) a proprietary fitting technique for generating semiconductor SPICE (Simulation Program with Integrated Circuit Emphasis) models. Because this model is intended for conceptual design studies, we refer to it as a "concept SPICE model."

The accuracy of this model has been confirmed through comparisons with measurement-based models derived from existing products. It enables verification of circuit operation prior to prototyping, thereby ensuring better alignment with customer requirements and improving development efficiency. Going forward, we will incorporate temperature characteristics and reliability considerations into the model to realize prototype-free development.

6.11 Establishment of Equivalence Evaluation Method for Semiconductor EMC Performance



GND: Ground L: Inductor C: Capacitor RF: Radio Frequency

* Bias-Tee is used for LC circuit.

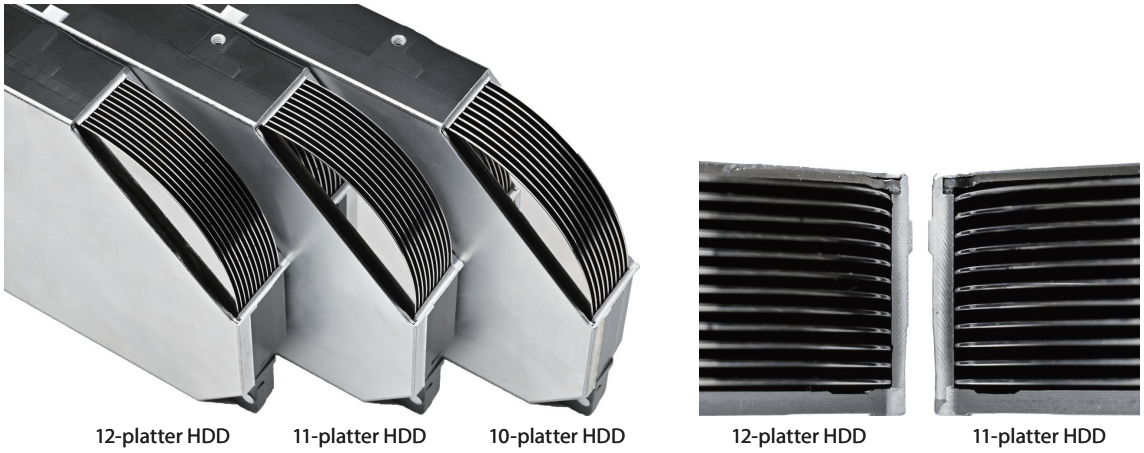
Practical application of equivalency evaluation methods to semiconductor EMC testing

For automotive semiconductor devices, manufacturing process changes subject to process change notifications (PCNs) often require vehicle recertification, thereby increasing the burden of the approval process. This issue is particularly significant for product lines encompassing a wide variety of devices, creating a need for industry-wide standardization in the selection of evaluation samples and the assurance of reproducibility.

To address this need, the Japan Electronics and Information Technology Industries Association (JEITA) established JEITA Standard ED-5008A, "Equivalence Evaluation Method for Semiconductor EMC Performance," which defines a standardized evaluation methodology. Furthermore, for automotive semiconductor products, the Japanese Automotive Standards Organization (JASO) developed JASO Standard D019, "Equivalence Test Method for EMC Performance of Automotive Semiconductors," in collaboration with the Society of Automotive Engineers of Japan (JSAE).

In the development of these standards, Toshiba Electronic Devices & Storage Corporation conducted standard-compliant evaluations on a wide variety of products at in-house EMC testing facilities to verify the validity of sample selection criteria and evaluation metrics, thereby contributing to improvements in the effectiveness and reproducibility of the standards. In addition, through active participation in JEITA and JSAE committees, we contributed to consensus building across the industry and the dissemination of the standards, thereby helping to reduce the burden associated with PCNs.

6.12 Validation of Industry's First 12-Platter Stacking Technology for HDDs for Data Centers



12-platter HDD prototype

With the continued expansion of cloud services, the growing popularity of streaming video services, and the rapid advances in generative AI and data science, the volume of data handled in data centers is increasing at an unprecedented rate.

Recognizing the need to significantly increase the storage capacity of hard disk drives (HDDs), Toshiba Electronic Devices & Storage Corporation has successfully validated the industry's first 12-platter stacking technology for high-capacity HDDs(*1). This technology leverages advanced design and analysis capabilities cultivated through the development of compact and slim products. Key advances include the introduction of newly developed dedicated stacking components and the replacement of conventional aluminum substrates with more durable glass substrates, thereby reducing platter stack height while enabling higher storage density.

These innovations improved mechanical stability and in-plane precision, while achieving higher recording density and enhanced reliability. By combining this achievement with microwave-assisted magnetic recording (MAMR) technology, we aim to introduce 3.5-inch HDDs with 40 TB(*2)-class capacities for data center applications to the market in 2027.

The ultimate goal is to deliver higher-capacity HDD solutions that can keep pace with the ever-growing storage demands of data centers, while also reducing the total cost of ownership (TCO) for customers.

(*1) As of October 14, 2025 (according to Toshiba Electronic Devices & Storage Corporation research)

(*2) Definition of capacity: Toshiba Electronic Devices & Storage Corporation defines a terabyte (TB) as 10^{12} (1 000 000 000 000) bytes.

6.13 MA11 3.5-Inch Nearline HDD Series Achieving Maximum Storage Capacity of 28 TB Using SMR Technology

MA11 series 3.5-inch nearline HDD for data centers

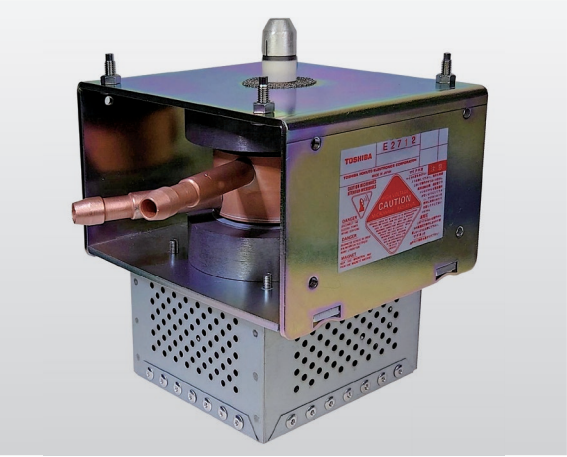
The growing use of generative AI continues to drive a rapid increase in demand for data center storage. As a result, low-cost HDDs with high storage capacity are expected to continue playing a vital role.

In this context, Toshiba Electronic Devices & Storage Corporation has commercialized the MA11 series of 3.5-inch nearline HDDs for data center applications, employing shingled magnetic recording (SMR) technology. The series adopts a variable-capacity scheme, in which the capacity of each drive varies depending on the achievable areal density, thereby enabling a maximum storage capacity of 28 terabytes (TB)(*).

In SMR, data tracks are written in a partially overlapping manner to reduce the track pitch, thereby increasing storage capacity. However, external vibration sources can cause the read/write head to deviate from its intended position, resulting in increased positioning errors that may affect data recorded on adjacent tracks. The MA11 series addresses this issue by interrupting recording to protect adjacent tracks when the potential impact on those tracks exceeds the error correction capability.

(*) Definition of capacity: Toshiba Electronic Devices & Storage Corporation defines a terabyte as 10^{12} (1 000 000 000 000) bytes.

6.14 E2712 12 kW High-Power Industrial Magnetron



E2712 12 kW high-power industrial magnetron

In recent years, the synthetic diamond market has expanded rapidly, particularly for jewelry applications, driving increased demand for higher-output magnetron tubes used in diamond manufacturing equipment. In response to this market trend, Toshiba Hokuto Electronics Corporation has developed the E2712, a new magnetron capable of delivering a stable 12 kW output, based on the preceding 6 kW model, E3327.

During development, key issues related to electrical, cooling, magnetic, and lifetime performance were identified, and comprehensive performance improvements were implemented. Electrical performance was improved by revising the specifications of major components to increase the magnetron output and redesigning the structure of the filter box. Cooling performance was improved by optimizing water-flow control without altering the basic structure, thereby enhancing heat dissipation efficiency. Magnetic performance was enhanced by securing the required magnetic flux density using only ferrite magnets, without relying on expensive rare-earth magnets, thereby achieving both cost reduction and stable operation in high-temperature environments owing to the excellent heat and corrosion resistance of ferrite magnets. Lifetime performance was improved with particular attention to frequency drift during long-term operation. The materials used for resonant circuit components were also reviewed, and the strap ring material was changed from conventional oxygen-free copper to a hardened copper alloy. This material exhibits superior heat resistance and mechanical strength, minimizing deformation and degradation during prolonged high-power operation and ensuring stable oscillation characteristics. Accelerated lifetime test conditions were established to reduce development time, and reliability evaluations confirmed stable operation over the target lifetime of 10 000 hours.

The E2712 maintains compatibility with existing equipment while achieving weight reduction and improved ease of handling. In addition, its proprietary mounting interface and frequency adjustment function enhance both ease of installation and overall competitiveness.

Future efforts will focus on establishing mass production and accelerating market deployment with the aim of further business growth and enhanced customer value.