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Special Reports

Discrete Semiconductors

Discrete Semiconductors Supporting Innovations in Various Technological Fields
FUJIWARA Takashi

Trends in Discrete Semiconductor Technologies and Future Outlook
MURAKAMI Koichi
Discrete semiconductors, which are considered to be typical commodity products, are used in various fields including consumer electronics, mobile devices, information technology equipment, automobiles, industrial equipment, energy utilities, and so on.
Toshiba has been developing discrete semiconductor products focusing on four categories: power devices, small signal devices, standard logic, and optoelectronic devices. To meet customers' needs, we are continuing our efforts to supply the most advanced products applying state-of-the-art technologies.
Climate change has become a global issue in recent years, and we have also been promoting both the improvement of discrete semiconductor manufacturing processes and the development of new energy-saving products for the reduction of carbon dioxide (CO_2) emissions. We have been providing a range of discrete semiconductor solutions to users through innovative products and services as a global leader in the discrete semiconductor industry.

Low-Voltage Power MOSFETs Achieving High Performance and Low Cost
YOKOTA Makoto / KAWAGUCHI Yusuke
Power metal-oxide-semiconductor field-effect transistors (MOSFETs), which are key devices in the power semiconductor field, are playing an important role in enhancing energy conservation and reducing carbon dioxide (CO_2) emissions because these devices directly affect the energy efficiency and power consumption of equipment. In particular, low-voltage power MOSFETs mounted on mobile equipment are increasingly required to have low power loss for longer battery life; a compact package to achieve smaller, low-profile, and lighter weight equipment; higher power supply required by advanced central processing units (CPUs); and lower cost.
To meet these requirements, Toshiba has developed a new trench technology improving the trade-off between high performance and low cost, and realized more ecologically friendly devices through power conservation.

πMOS-VII and DTMOS-II Series High-Voltage Power MOSFETs for Power Supply Circuits
SAITO Wataru
The characteristics of high-voltage power metal-oxide-semiconductor field-effect transistors (MOSFETs) for power supply circuits in electrical appliances such as home electronics and PCs need to be continuously improved due to the requirements for strengthening of new voltage-class lineups and speeding up of body diodes in addition to reduction of on-resistance.
To meet these requirements, Toshiba has developed two new high-voltage power MOSFETs: the πMOS-VII series with a fine cell-pitch, and the DTMOS-II series with a super junction (SJ) structure in the drift layer. The new voltage class of 650 V has been added to the voltage-class lineup of these series. In addition, we have newly developed a high-speed body diode whose recovery time is reduced to half that of the previous type.

Evolution of IGBTs Suitable for Expanded Range of Applications
NINOMIYA Hideaki / UMEKAWA Shinichi / WAKIYAMA Seiichiro / NISHITANI Kazunobu
Insulated gate bipolar transistors (IGBTs) have been used for many applications, from home appliances to industrial products. The range of applications is now expanding to induction heating (IH) cooking equipment, the environmental field such as photovoltaic and wind-power generation, and so on. Furthermore, higher breakdown voltage, lower switching loss, higher switching speed, and higher robustness are required for IGBTs.
To meet these requirements, Toshiba has developed a non-latch-up IGBT for higher robustness and an injection enhanced gate transistor (IEGT) utilizing the injection enhancement (IE) effect for lower power loss. We are now promoting the development of suitable power devices for each application.

Compact, Highly Efficient Power Supply ICs for DC-DC Converters in Electronic Equipment
INOMATA Keisuke / ENOMOTO Kazuki
Demand has been increasing for high performance, multifunctionality, miniaturization, and low cost in a variety of electronic equipment. With the progress of system-on-chip (SoC) and application-specific integrated circuit (ASIC) technologies using highly miniaturized processes, these devices are supporting larger scale integration and higher performance in electronic equipment. Highly efficient power supply ICs with a low output voltage and a large current are key devices for the system large-scale integrations (LSIs) that serve as the core of such equipment.
Toshiba has been applying the latest process and small packaging technologies to the development of both monolithic type power supply ICs and modules, achieving highly efficient performance and compactness while reducing the cost of the overall system.

1.2 kV Vertical Power SiC MOSFET with Stable High-Temperature Characteristics
KONO Hiroshi / SUZUKI Takuma / SHINOHE Takashi
Silicon carbide (SiC) power devices are regarded as the next generation power devices that are expected to replace conventional Si power devices because of the potentially high performance of SiC materials. The SiC power metal-oxide semiconductor field-effect transistor (MOSFET) can dramatically improve inverter efficiency. However, high channel resistance due to the high interface state density has been an obstacle to achieve low specific on-resistance.
To solve this problem, Toshiba has been focusing on improving the MOS fabrication process and the use of scaled device technology. As a result, we have developed a 1.2 kV-level vertical power SiC MOSFET with a low specific on-resistance of 5.0 $m\Omega cm^2$ and a high blocking voltage of 1,360 V.

High-Performance Magnetic Sensor Technologies Using Si Hall Elements
TAKEDA Toru / KURASHIMA Kyoko / MOCHIZUKI Miho
In recent years, magnetic sensors have come to be used in various applications including opening/closing detection systems in cellular phones and notebook PCs, and image stabilizing systems in digital cameras and digital video cameras. Although compound semiconductor Hall elements are widely used as the magnetic transducer in such systems, it is difficult to reduce the overall size and cost due to the need for additional circuits for signal amplification and so on.
Toshiba has developed compact, low-cost, monolithic magnetic sensors offering high performance, using silicon (Si) Hall elements as the magnetic transducer. These magnetic sensors consist of a Hall element and electrical circuits, which have been newly developed to solve problems in the practical use of Si Hall elements, in one Si chip.

USB Switch ICs for Cellular Phones Supporting USB 2.0 Hi-Speed Mode
KATAFUCHI Fumito / SUWA Yoshito / MIZUTA Masaru
With the increasing diffusion of cellular phones equipped with various functions in recent years, including music recording and reproduction, recording of still images and motion pictures by onboard camera, and reception of one-segment TV broadcasts, such phones must have the ability to process large amounts of data. These data are transmitted from cellular phones to external equipment such as notebook PCs via universal serial bus (USB) signals. However, systems for USB 2.0 full-speed mode and high-speed (Hi-Speed) mode coexist in some cellular phones, and USB signals and other signals are sometimes processed in the same terminal of the connector. In response to the multifunctionality needs of cellular phones, USB switch integrated circuits (ICs) of compact size and low capacitance are required.
Toshiba has developed USB switch ICs for cellular phones supporting the USB 2.0 Hi-Speed mode, featuring low switch on-capacitance through optimized electrostatic discharge (ESD) protection, optimal multilayer aluminum (Al) wiring, and reduction of depletion layer capacitance, as well as achieving the industry's smallest USB switch ICs applying a wafer-level chip scale package (WCSP) structure.

Progressive Application of LED Lamps to Automotive Field
MOTODATE Junya
The fields of application of light-emitting diode (LED) lamps are rapidly expanding due to their excellent characteristics in comparison with existing electric bulbs. In particular, application to the automotive field is spreading due to the advantages of LEDs including low power consumption, long life, and high reliability.
Toshiba has been developing high-brightness LEDs through the following technological advancements: (1) increase of light-emitting efficiency with new materials and structures, (2) optimization of the LED tip structure, (3) development of a new technique for surface treatment, and (4) development of a novel electrically conductive paste with high thermal conductivity. These technologies have been applied to color LEDs for automotive exteriors. We are continuing our efforts to develop LEDs with higher brightness contributing to cost reduction and energy saving.

Photocouplers with High Output Current and Small Package for Direct Driving of IGBTs and Power MOSFETs
KAWANO Fumihiro / UO Toyoaki / FURUYA Miki
Photocouplers, which can connect control signals while maintaining electrical isolation between a control circuit and a power device such as an insulated gate bipolar transistor (IGBT) and a power metal-oxide semiconductor field-effect transistor (MOSFET), are used for inverter circuits in home appliances, industrial equipment, and so on. As the environmental conditions for photocouplers in industrial equipment are becoming very severe, optimum devices for each application are required.
To meet the requirements of industrial equipment, Toshiba has developed two new photocouplers: the TLP358 model, with an output current rating of 6 A in a DIP8 package, and the TLP151 model, whose output current rating is 0.6 A in the smallest SO6 package. These photocouplers can directly drive both an IGBT and a power MOSFET, making it possible to realize smaller inverter circuits in industrial equipment.

Packaging Technologies Supporting Progress of Discrete Semiconductors
OTANI Tadao
Toshiba has been developing discrete semiconductor products in four categories: standard logic devices, small signal devices, power devices, and optoelectronic devices. These devices are highly regarded in the global market, and we are continuing our efforts to supply products corresponding with the market in order to maintain and expand our worldwide top sales in this highly competitive environment.
In response to the needs of the market, we have been focusing on improving assembly and production technologies. For example, we have developed packaging technologies to achieve miniaturization, reduction of thickness, and low resistance for small signal devices, and to achieve a large current and high heat radiation for power devices. We have also developed the manufacturing and assembly equipment operating in our manufacturing bases to produce these products.

Feature Articles

Advanced Demosaicing Method Based on Curvature Fitting to Suppress Color Artifacts
ISOGAWA Kenzo / MISHIMA Nao / ITOH Goh
The demand for small cameras using a single-chip image sensor has been increasing in the field of mobile devices such as cellular phones. However, each pixel of the single-chip image sensor is filtered to detect only one of the three red-green-blue (RGB) color intensities. To interpolate the missing colors, so-called demosaicing method is used. In such cases, color artifacts on images processed by conventional demosaicing methods are a crucial issue.
To avoid this problem, Toshiba has been developing a new demosaicing method based on curvature fitting to suppress such artifacts. We have confirmed the effectiveness of this method through simulations using real images.

2.5-inch Hard Disk Drive with Large Capacity of 640 GB
KUROSAWA Shin / SAKATA Hiromi / ABE Toshiaki
With the accelerating reduction in physical size and increase in capacity of hard disk drives (HDDs), 2.5-inch HDDs are now installed in various types of equipment including notebook PCs, audiovisual equipment, and car navigation systems. Toshiba has remained a leader in this industry by focusing on 2.5-inch or smaller size HDDs.
We have now developed a dual-platter 2.5-inch HDD with a maximum capacity of 640 GB. This level of data storage capacity with an areal density of 817.9 $Mbit/mm^2$ has been achieved by our advanced head and media technologies, higher error correction capability with low-density parity check (LDPC) coding, iterative decoding, and a new mechanism for reduction of air turbulence.
In addition, this model features an advanced latch mechanism that enhances vibration robustness, as well as improved energy consumption efficiency due to the reduction of power consumption during low-power idling.

Completion of Equipment Installation at Iwate Substation of Tohoku Electric Power Co., Inc.
HOSOKAWA Osamu / MAEJIMA Hiroyuki
Tohoku Electric Power Co., Inc. is promoting the development of large-scale power supply in the northern part of Aomori Prefecture. As part of this project, a 500 kV main power line is under construction for both the secure transmission of generated electric power and stable supply of electric power to users, and stepping up of the voltage to 500 kV is in progress at four substations including the Iwate Substation.
Toshiba has delivered the main substation equipment to the Iwate Substation including a 525 kV-1,000 MVA advanced site assembly (ASA) transformer and a 550 kV gas-insulated switchgear (GIS). Space-saving and shortening of the construction period as well as improvement of maintenance through the use of high-quality technologies have been achieved by taking advantage of our accumulated know-how and experience in the construction of large-scale substations.

Distributed Parallel Search Function of TX1$_{TM}$ XML Database Realizing High-Speed Searching of Tens of Terabytes of XML Data
KODA Kazuhisa / TANAKA Satoshi
Toshiba Solutions Corporation released the TX1 extensible markup language (XML) database in 2005, which can retrieve data from large volumes of XML data of several terabytes in size for efficient management of semistructured data. With the rapid proliferation of business databases in recent years, demand has been growing for enhancement of retrieval performance with larger volumes of XML data.
In response to this situation, we have developed a distributed parallel search (DPS) function for the TX1 that makes it possible to search large-volume XML data of tens of terabytes in size at high speed. Experiments on searching speed confirmed that the DPS system achieves efficient and stable operation linked with DNCWARE ClusterPerfect™ EX (CPEX) integrated cluster software.

Frontiers of Research & Development

Realization of High-Speed and Highly Integrated FPGAs Using Spin-MOSFET
Multidimensional Indexing for Embedded Database Realizing High-Speed Searches for Various Data