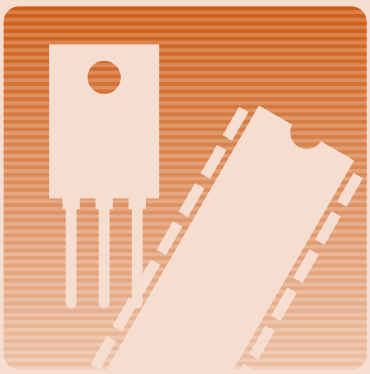
Electronic Devices



Power Semiconductors
Photoconductors
Disk Media

Outlook

Power Semiconductors

In an effort to prevent global warming, seek harmony with the environment and realize a safe, secure and sustainable society, power electronics technologies that support "energy creation," or proliferation of renewable energy, and "energy conservation," or efficient energy use, are raising great expectations from society. In this situation, Fuji Electric is developing power semiconductor products that feature high energy conversion efficiency, reduced noise and friendliness to the global environment. Power semiconductors are used for products in the environment/energy field, industrial machinery, automobiles and home appliances and contribute to society.

In the environment/energy field, we have expanded the lineup of insulated gate bipolar transistor (IGBT) modules for 3-level power conversion circuits to be used in power conditioning sub-systems (PCS) for photovoltaic power generation. The IGBT modules have a neutral-point bidirectional switch equipped with an advanced T-type neutral-point-clamped (AT-NPC) circuit that applies Fuji Electric's proprietary reverse-blocking (RB)-IGBT capable of withstanding a voltage of 900 V to a middle bi-directional switch in order to pursue even higher power conversion efficiency for meeting the recent need for input voltage increase.

For the industrial machinery field, we have expanded the lineup of intelligent power module (IPM) products that apply the latest "V Series" IGBT technology intended for machine tools with NC units, servomechanisms or spindles. In addition, we have commercialized "MiniSKiiP" for motor drive applications with a capacity of up to 22 kW. This can make contributions to further miniaturization of equipment. We have also developed the "High Speed W Series" of 1,200-V high-speed discrete IGBTs, which contribute to miniaturization of welding machines and uninterruptible power systems (UPS). This series allows higher-speed switching than before and contributes to miniaturization of welding machine and UPS.

In the field of automobiles, we have expanded the lineup of large-current intelligent power switches (IPS) used for controlling high-output motors and other applications. As compared with conventional products, the new IPS can reduce the on-resistance by 37.5% with the same package and realize maximum energy capability equivalent to that of the conventional products. A lineup of relative pressure sensors has been added to the 6th-generation pressure sensors. They are capable of measuring a relative pressure in the 100 kPa range with an accuracy of ±1 kPa. They are used for monitoring the internal pressure of brake boosters during idling stops to contribute to fuel efficiency improvement and exhaust gas reduction. Furthermore, in the field of in-vehicle IGBT used for motor driving of hybrid and electric vehicles, Fuji Electric is establishing a lineup of products that use its proprietary direct water cooling structure and reverse-conducting RC-IGBT chip.

In the field of power supplies for home appliances, we have expanded the lineup of 6th-generation PWM control IC for notebook PCs, printers and relatively small TVs. We have made it possible to perform miniaturization of parts such as transformers by supporting high-frequency operation at a switching frequency of up to 100 kHz in addition to the conventional 65 kHz and offer a lineup compatible with a variety of specifications of power supplies.

In the future, we intend to continue developing power semiconductor products that are friendly to the global environment so as to realize a safe, secure and sustainable society.

Photoconductors

The photoconductor market is undergoing polarization between price-oriented customers and quality-oriented customers, along with the growth of Chinese manufacturers. Fuji Electric is working to enhance the performance of photoconductors to accommodate higher-speed operation and longer service life of equipment.

In FY2014, we developed and mass-produced positively charged organic photoconductors with the improved print quality. We achieved this by applying a new layer design technology, and high-durability or-

ganic photoconductors with the durability doubled by applying materials with excellent storage stability and wear resistance. We will further help to conserve energy, reduce cost and improve the efficiency of the office environment through the provision of photoconductors that meet customer needs.

Disk Media

With the proliferation of big data analytics and cloud computing, perpendicular magnetic recording media for hard disk drives (HDDs) is required to provide with larger capacity and lower cost.

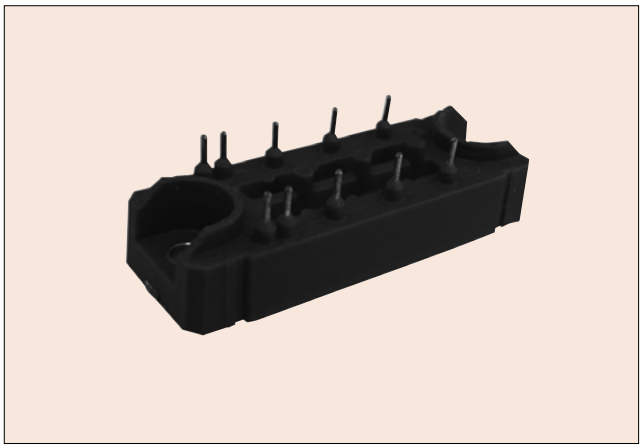
In FY2014, Fuji Electric developed and mass-produced characteristics-improved models of 3.5-inch aluminum substrate media with a capacity of 1 TB per disk and new models of 2.5-inch aluminum substrate media with a capacity of 500 GB per disk. The aim is to contribute to cost reduction and improvement of the manufacturing yield of customers. In order to contribute to the advancement of IT society, we are committed to making continued development of large-capacity media suited for shingled magnetic recording (SMR), a new technology.

Power Semiconductors

1 Industrial RC-IGBT Module Technology Using a New Package

For industrial IGBT modules, the market for which has been rapidly expanding in recent years, we have developed a reverse-conducting IGBT (RC-IGBT) integrating an IGBT and diode. We have combined it with a new package that achieves excellent heat dissipation and high reliability at the same time, and thereby realized significant miniaturization and improvement in the power density of an IGBT module. The RC-IGBT has accomplished a low power dissipation equivalent to that of the conventional IGBTs and diodes and achieved a 27% reduction in the chip area at the 1,200 V and 100 A rating. In addition, combining the RC-IGBT and the new package has made it possible to achieve low inverter losses equivalent to, and a significant IGBT chip temperature decrease from, the conventional 2-in-1 modules, with the footprint reduced to 42%. A comparison based on the same IGBT chip temperature shows that it can operate with a 58% larger output current. This helps to reduce the size and cost of power converters.

Fig. 1 RC-IGBT module in new package



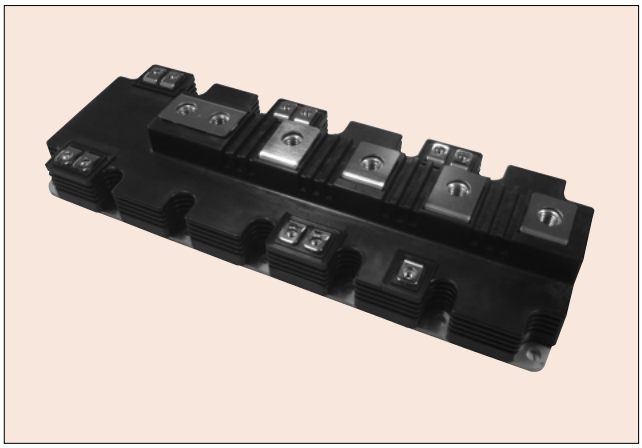
2 High-Power 3-Level IGBT Module

Fuji Electric is committed to developing high-power 3-level insulated gate bipolar transistor (IGBT) modules applied to the renewable energy field including wind and photovoltaic power generation, and has been highly rated by the market.

The high-power 3-level IGBT module integrates a 3-level power conversion circuit in one package and the ratings available are 1,200 V/450 A, 600 A and 900 A. It realizes improved power conversion efficiency and miniaturization of equipment and also makes it easier to increase the capacity of equipment by making parallel connections. Furthermore, in preparation for future photovoltaic power generation systems with higher voltage levels, we will commercialize an I-type module (1,200 V/600 A) capable of accommodating 1,500 V DC. The main features are as follows:

(1) T-type: RB-IGBT applied to realize efficiency improvement
(2) I-type: terminal compatibility with T-type for easy replacement

Fig. 2 High-power 3-level module common to T-type and I-type

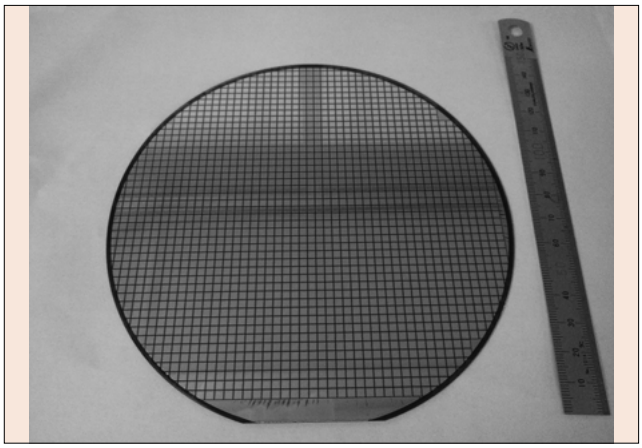


3 6-Inch SiC-MOSFET

Fuji Electric is working on the development of a silicon carbide metal-oxide-semiconductor field-effect transistor (SiC-MOSFET) that uses a 6-inch SiC substrate. As compared with conventional Si devices, SiC-MOSFETs are characterized by having more electron and hole traps in the gate oxide film formed on an SiC substrate. These traps may cause poor long-term stability of the gate threshold voltage under gate bias conditions. We have figured out suitable conditions for manufacturing a gate oxide film to successfully develop an SiC-MOSFET with excellent threshold stability.

We are continuing to move forward with the development of an All-SiC module equipped with a 1,200-V rated SiC-MOSFET and SiC-Schottky barrier diode (SiC-SBD). In addition, we plan to develop high blocking voltage SiC-MOSFETs with ratings of 1,700 V and up to 3,300 V.

Fig. 3 6-inch SiC wafer



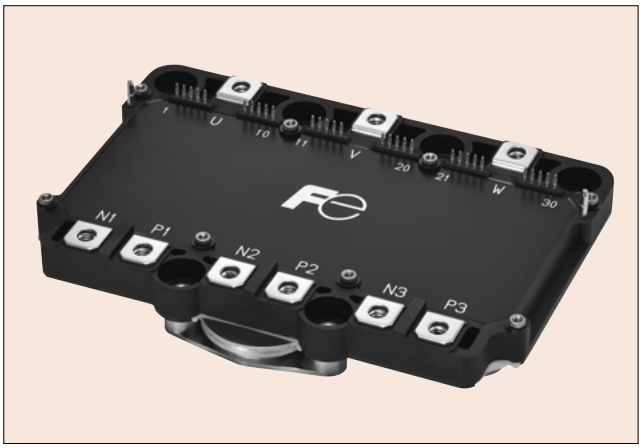
Power Semiconductors

4 High-Power In-Vehicle Standard Module for Electric and Hybrid Electric Vehicles

As electric vehicles have been undergoing power increase recently, power modules are also required to offer larger capacity. We have developed a high-power in-vehicle standard module for electric and hybrid electric vehicles.

This product is a power module with a built-in inverter circuit for driving a motor. It features a high power class of 750 V/800 A, which is among the largest of general-purpose modules. As the device, a reverse-conducting IGBT (RC-IGBT) that applies the 7th-generation chip technology is used. This device integrates an IGBT and free wheeling diode (FWD) on the same chip and contributes to miniaturization of the module. The cooling unit uses an aluminum water jacket and realizes an improvement of approximate 40% in cooling performance from Fuji Electric's conventional aluminum heat sink.

Fig. 4 High-power in-vehicle standard module



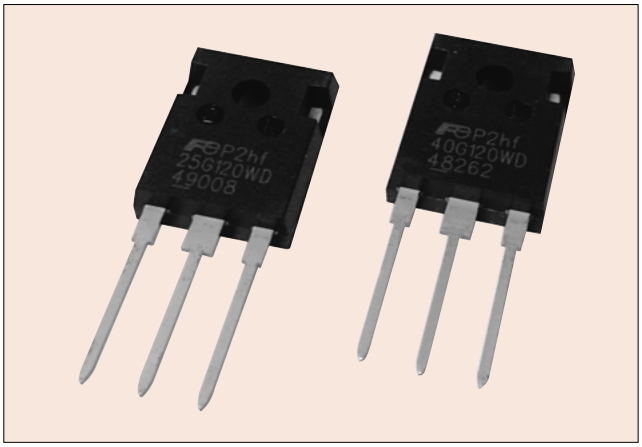
5 1,200-V High-Speed Discrete IGBT "High-Speed W Series"

Recently, there has been a strong demand relating to welding machines and uninterruptible power systems (UPS) for frequency and efficiency increase in order to achieve miniaturization of the devices. For these devices, we have developed the "High-Speed W Series," a series of 1,200 V high-speed discrete IGBTs.

The conventional "High-Speed V Series" has been optimized for high-frequency applications to significantly reduce the switching loss. The main features are as follows:

(1) High-frequency drive (20 to 100 kHz)
(2) Turn-off loss reduced by approximately 40% (from previous products)
(3) Rated voltage/current: 1,200 V/25 A, 40 A
(4) T_{jmax} = 175°C guaranteed
(5) Package: TO-247 (all lead-free)

Fig. 5 "High-Speed W Series"



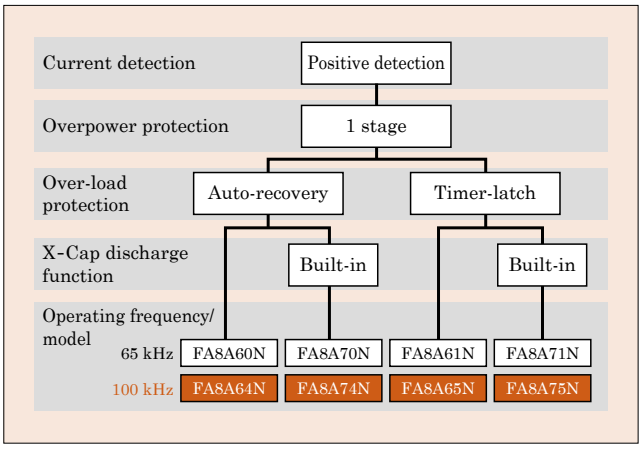
6 Expansion of the 6th-Generation PWM Control IC Lineup

Recently, an increasing number of electronic devices such as home appliances and servers have become always-on systems and the demand for reducing the standby power is ever increasing. Fuji Electric has already commercialized the 6th-generation PWM control IC "FA8A60 Series," which have many state setting functions and various protective functions. However, in addition, there is a growing need for miniaturization.

In order to meet this need, we have developed the "FA8A64 Series" with the operating frequency changed from 65 kHz to 100 kHz for miniaturization of the transformer, which is a major factor of the power supply volume, as an addition to the product lineup.

It is compatible with the FA8A60 Series in terms of the terminals, functions and characteristics. This means the design assets of the conventional power supplies can be used and the new power supply design elements can be simplified.

Fig. 6 6th-generation PWM control IC series table



Power Semiconductors

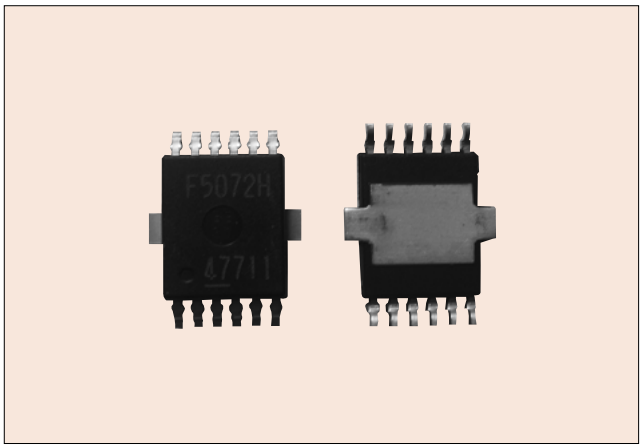
7 High-Current IPS for Vehicles

In the field of automotive electrical components, there is growing demand for miniaturization, reliability improvement and functional enhancement of systems. In order to meet these requirements, we have developed a high-current intelligent power switch (IPS) used for controlling high-output motors and other applications.

This IPS uses a power metal-oxide-semiconductor field-effect transistor (MOSFET) with a trench structure and a control IC built into a chip-on-chip structure to realize a low on-resistance (5 mΩ max.) within a small package. In order to achieve high reliability, protective functions including overcurrent and overheat detection and low voltage detection have been provided. In addition, a package featuring excellent heat dissipation is used and a good energy sharing balance in parallel connections is realized to deal with any temperature rise due to a current increase arising from the lower on-resistance.

Reference: FUJI ELECTRIC REVIEW 2014, vol.60, no.4, p.243

Fig. 7 Hig-current IPS for vehicles



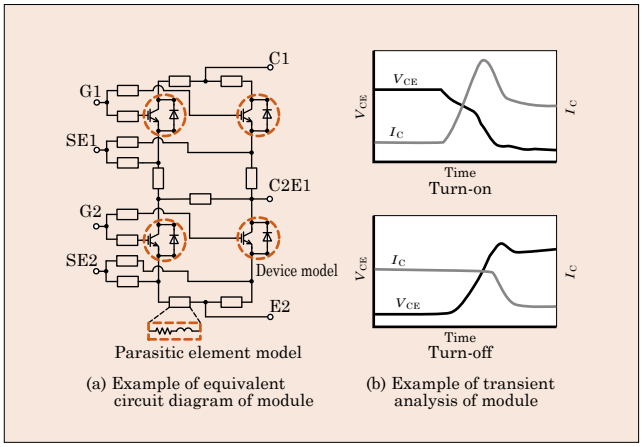
8 Power Semiconductor Simulation Technologies

As there is growing demand for reduced power dissipation and larger capacity of power semiconductors, simulation technologies are gaining importance.

Fuji Electric is working on the development of simulation technologies not only for device and package design but for analyzing the behavior of entire modules, which are increasingly complicated by SiC and other devices. We verify a switching operation of the module utilizing the transient analysis with an equivalent circuit of the module, which is combination of device model and parasitic element model inherent in the package structure as shown in Fig. 8. We are also engaged in the development of electromagnetic field analysis technologies for noise reduction.

These simulation technologies contribute to functionality and higher quality of Fuji Electric's power semiconductors.

Fig. 8 Example of simulation of module switching characteristics

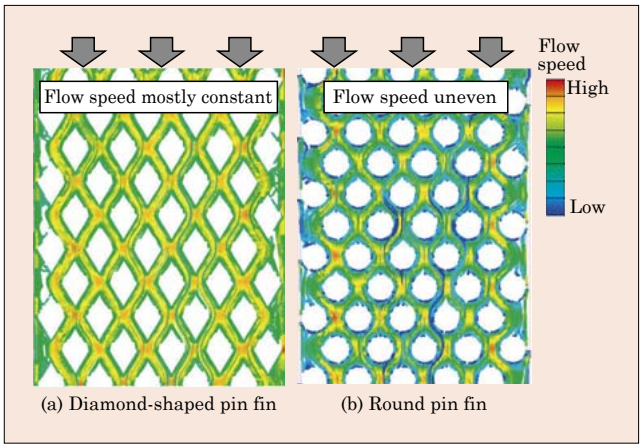


9 Fluid Simulation Technology for Next-Generation Power Semiconductors

For power semiconductor modules, which are used in power converters and motor controllers, studies are recently being conducted for water cooling in order to improve the efficiency of cooling systems.

A thermal-fluid dynamics simulation is used to analyze the cooling performance of a cooler. We have developed a fluid simulation technology that allows integrated analysis of the flow speed and pressure loss of the coolant that flows in a cooler. The figure shows the result of analysis of the coolant flow of a cooler. This simulation technology has made it possible to optimize the coolant flow speed and pressure loss in a short term. We have also attempted to improve the efficiency of customer-specific cooling systems by designing an entire system in view of the pump performance. As a result, coolers can now be built that are capable of cooling approximately three times as much loss (heat) as that of air-cooling systems.

Fig. 9 Result of analysis of coolant flow speed of a cooler



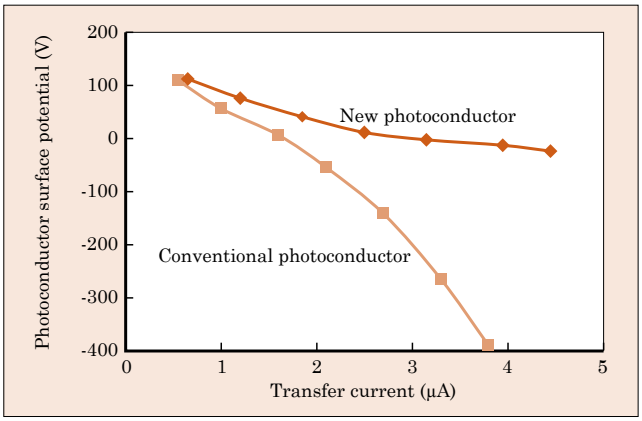
Photoconductors

1 High-Quality Positively Charged Organic Photoconductors

Electrophotographic printers and photocopiers are becoming increasingly high-speed and offering higher image quality. The photoconductors provided in these devices are key components that determine the image quality, and they need to have high stability against stress from various peripheral processes. In the transfer process by positive charging, a negative polarity bias is applied to transfer the toner attached to the surface of the photoconductor to the paper to form an image. It is known that, if the applied bias is too high, the history by the presence of toner on the surface of the photoconductor may vary, causing degradation of image quality.

Fuji Electric has established a new layer design technology for controlling electron injection in the transfer process. By applying this technology, we have developed a photoconductor that suppresses negative charging of the surface of the photoconductor after transfer to provide a stable image quality.

Fig. 10 Transfer characteristic of positively charged organic photoconductors

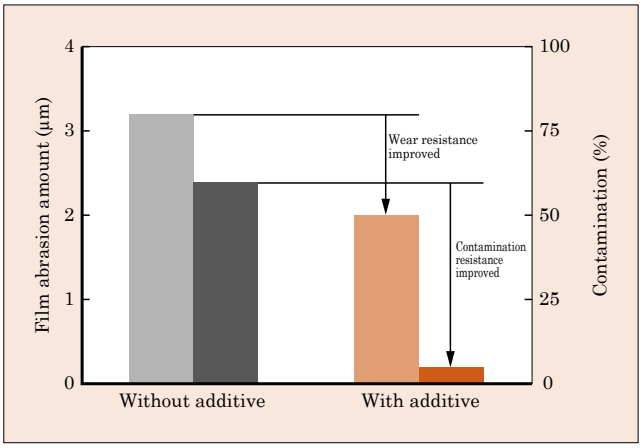


2 High-Durability Organic Photoconductors

Recently, image forming devices such as photocopiers, printers and facsimiles have been undergoing evolution in terms of miniaturization, speed-up and service life extension. Regarding peripheral members that come in contact with photoconductors such as charging and transfer rollers, a variety of products are offered. And the surface of photoconductors is required to have durability against eluting components from various peripheral members.

Fuji Electric has designed an additive molecule in a size appropriate for voids formed in the photosensitive layer on the surface to have the voids filled with the additive, and thereby made it possible to form a more robust film. In addition, we have improved the contamination resistance and wear resistance by preventing components eluting out of the peripheral members from infiltrating into the surface of the photoconductor. And we have realized a high-durability organic photoconductor with electrical characteristics stable against repetitive use and changing use environment conditions.

Fig. 11 Improvement of durability with additive



Disk Media

1 Perpendicular Magnetic Recording Medium for Shingled Magnetic Recording (SMR)

To further increase the recording capacity of HDDs, adoption of shingled magnetic recording (SMR), a new magnetic recording system, is about to start. With SMR, data tracks, which have conventionally been arranged at regular intervals, are overlapped like shingles for recording. This makes it possible to narrow the effective track width and in turn improve the recording density.

Fuji Electric is working to develop technology for an SMR-enabled perpendicular magnetic recording medium. By ingenuities such as multi-layering of the magnetic layer, we have successfully suppressed mutual magnetic interference between data tracks while maintaining ease of recording. Furthermore, we have optimized the carbon protective film and lubricant to achieve a lower head flying height without affecting the durability, and improved the recording and reproduction performance. We plan to apply this technology to the medium (recording density: 1,500 Gbits/in^2, 1 TB per 2.5-inch medium) for HDDs to be commercialized in FY2016.

Fig. 12 Schematic depiction of data track recording method in shingled magnetic recording