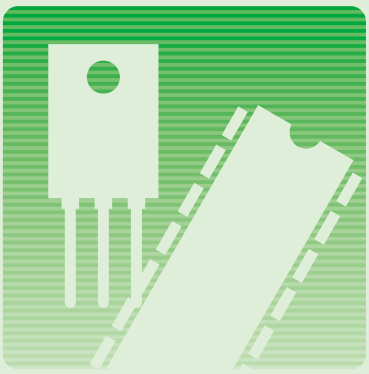
Semiconductors



Industrial
Automotive

Global efforts to realize a decarbonized society are progressing rapidly in order to solve the climate change problem, which is one of the aims of the Sustainable Development Goals (SDGs). Increasing the efficiency of power electronics equipment for the electrification of automobiles and the stable and efficient use of energy is an effective approach toward decarbonization, and Fuji Electric's power semiconductors are key devices that contribute to the realization of these efforts. Specifically, we have developed products that meet the needs for higher efficiency, size reduction, and higher reliability, mainly with the insulated gate bipolar transistor (IGBT), a typical device of power semiconductors, together with many technical innovations.

Industrial

Fuji Electric is expanding its product line-up of industrial modules that use the latest 7th-generation IGBT technology, which guarantees low-loss, high-temperature operation. The standard product line-up of 7th-generation IGBT modules is complete, and a line-up of intelligent power modules (IPMs) with drive and protection functions is in progress. In the line-up of 7th-generation IGBT-IPMs are medium capacity products with withstand voltages of 650 V and 1,200 V for application in FA, machine tools, and air conditioners, as well as a line-up of large capacity products of 650 V/200 to 450 A and 1,200 V/100 to 300 A. For room air conditioners and motor drives, we have developed 3rd-generation small capacity IPMs of 650 V /15 to 30 A. We have also been working to expand the scope of application of SiC devices and develop a line-up of products equipped with 2nd-generation SiC trench gate MOSFETs. For this line-up, we developed a new 3.3-kV/750-A All-SiC module for railway applications.

With the new module, we can contribute to higher efficiency, reduced size and weight, and increased reliability of power conversion equipment.

For IC products, we have developed the "FA8C00 Series" of 7th-generation PWM power supply control ICs in order to meet the market demand for higher efficiency of power supplies, reduction of standby power, and improved safety in response to various power supply conditions due to globalization. By selecting external components to connect to the terminals of the IC, it is possible to optimize efficiency under light load and reduce standby power according to the power source in use, and the safety of the IC has also been improved by the high voltage input terminals.

Automotive

For the automotive field, we have developed and commercialized compact, high-power-density power modules for inverters used to control driving motors of electrified vehicles (xEVs). As part of these efforts, we have developed a 6-in-1 directly water-cooled automotive power module for 100-kW class motors. By improving the performance of reverse conducting-IGBTs (RC-IGBTs) and using a newly designed aluminum cooler, we now lead the industry in compactness and high power density. In response to the high integration of power conversion devices such as DC/DC converters for xEVs, we have commercialized the 2nd-generation SJ-MOSFETs with a high-efficiency, compact, low-noise super junction structure. In order to accommodate the increase in battery voltage and the size reduction of equipment, we have added products that use T-packs (D2-packs), which are small surface-mount packages with a rated voltage of 650 V.

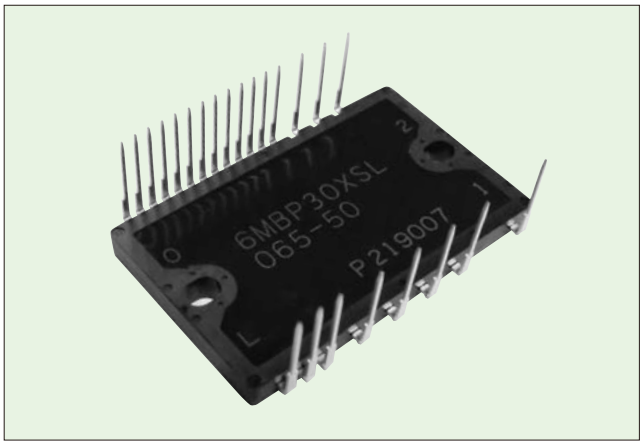
Industrial

1 Line-Up of the "P633C Series" 3rd-Generation Small IPMs

In response to the growing need for global energy efficiency improvements to realize a decarbonized society, the use of inverters in industrial motor drive equipment has accelerated, and the application of IPMs with built-in IGBTs and drive circuits has been expanding, particularly in low-capacity equipment. Fuji Electric has developed a line-up of products that can be used with large current loads in industrial inverters and servo amplifiers, based on the "P633C Series" of 3rd-generation small IPMs previously commercialized for use in room air conditioners overseas. The main features are as follows:

(1) The low-power-dissipation design for operation under high current loads has reduced the IGBT on-voltage $V_{CE(sat)}$ by approximately 13% compared with previous products, contributing to higher equipment efficiency.
(2) Two types of the overheat protection functions: One type is temperature sensor output only. Another type is temperature sensor output with self-shutdown function.

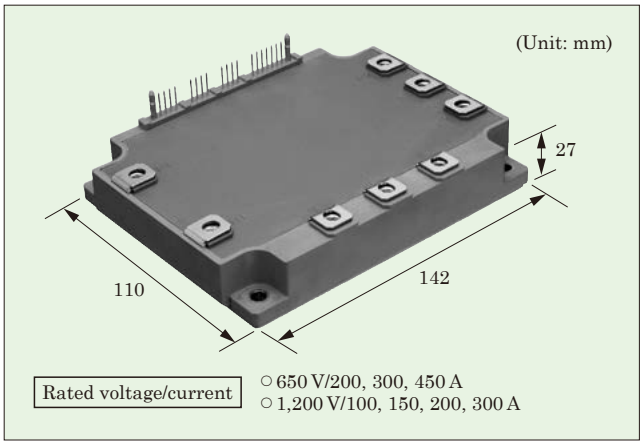
Fig.1 "P633C Series"



2 Line-Up of the "P631" 7th-Generation High-Power IGBT-IPM

In order to save power and space for power conversion devices, the intelligent power modules (IPMs) must have even lower power dissipation and higher output current. In response to this, Fuji Electric offers the 7th-generation IGBT-IPM, which achieves a 10% reduction of the power dissipation compared to the 6th-generation IGBT-IPM by applying the 7th-generation technology. The maximum output current has also been increased by expanding the allowable chip temperature during continuous operation from 125°C to 150°C. Fuji Electric now provides a line-up of the "P631" 7th-generation high-power IGBT-IPM. Using the same package as the previous P631 6th-generation high-power IGBT-IPM, The P631 7th-generation high-power IGBT-IPM has expanded the maximum rating from 600 V/400 A and 1,200 V/200 A to 650 V/450 A and 1,200 V/300 A. This allows the device to handle more power with the same external dimensions as the previous IPM, contributing to power and space savings for customer equipment.

Fig.2 "P631"



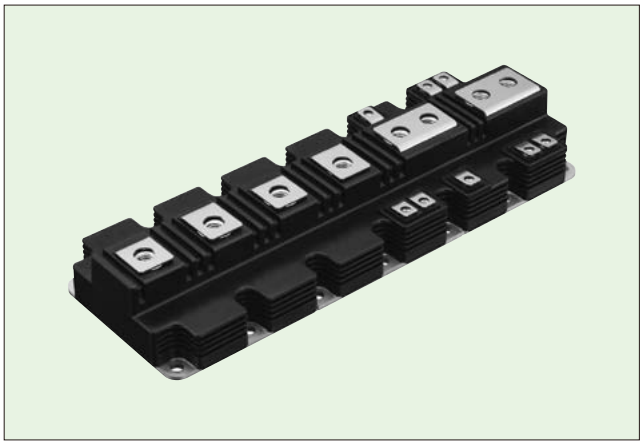
3 Line-Up of the "X Series" 7th-Generation High-Power IGBT Modules

Fuji Electric has commercialized the "X Series" of 7th-generation 1,200-V, 1,800-A, 2-in-1 IGBT modules to meet the market demand for less power dissipation and high reliability in IGBT modules. To support further increases in capacity of power conversion equipment for solar and wind power generation, we developed the "PrimePACK™*3+," which features additional output terminals, and added it to our line-up. The main features are as follows:

(1) Less power dissipation by applying 7th-generation X Series chip technology
(2) High reliability in high-temperature operation (up to 175°C) through the application of 7th-generation package technology

* PrimePACK™: A trademark or registered trademark of Infineon Technologies AG

Fig.3 "PrimePACK™3+" high-power IGBT module



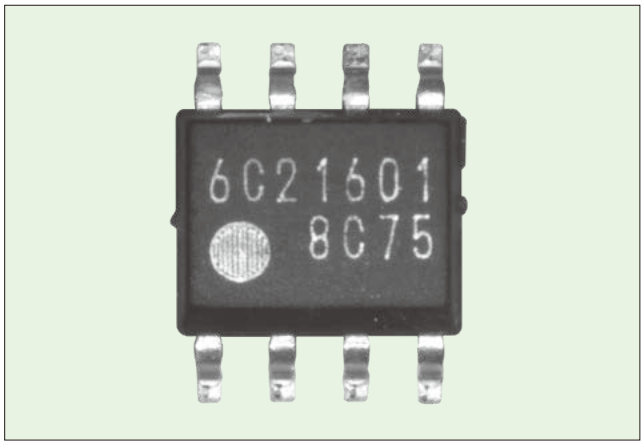
Industrial

4 "FA8C00 Series" 7th-Generation PWM Power Supply Control ICs

In recent years, efforts to reduce greenhouse gas emissions as a countermeasure against global warming have attracted attention, and there has been a demand for more efficient electronic equipment. There is also a need to respond to power supply conditions in various countries and regions. In response to this demand, Fuji Electric has developed the "FA8C00 Series" 7th-generation PWM power supply control ICs.

(1) High-voltage input terminals with higher withstand voltages (from 650 V to 710 V) enable use in markets outside Japan where the power supply is unstable.
(2) It is equipped with an X-cap discharge function to prevent electric shock while reducing the number of required parts.
(3) The minimum pulse width of the MOSFET gate signal is selected from three types based on the constants of the external components to achieve high efficiency under light load.
(4) External regulators can be removed with the built-in output voltage clamp function.

Fig.4 "FA8C00 Series"

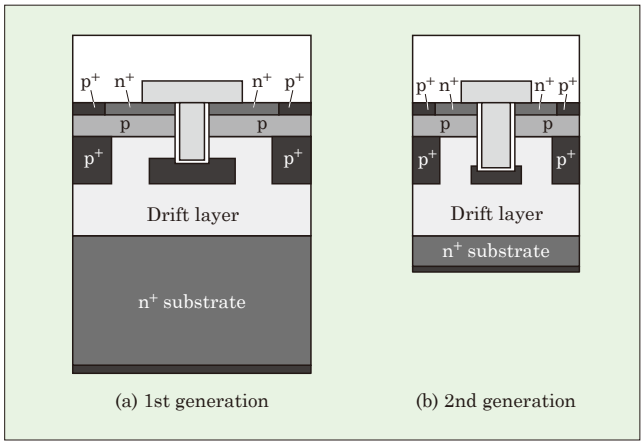


5 3.3-kV 2nd-Generation SiC Trench Gate MOSFETs

Fuji Electric has developed a 2nd-generation SiC trench gate MOSFETs rated at 3.3 kV with lower on-state resistance than conventional MOSFETs for railcars. The main features are as follows:

(1) The cell pitch has been reduced to approximately two-thirds, and the thickness of the SiC substrate to approximately one-fourth of 1st-generation MOSFETs. As a result, the on-state resistance per unit area has been reduced by approximately 7%.
(2) Fuji Electric's unique technology suppresses the increase of on-state resistance caused by defects when the current flows through the body diode of SiC-MOSFETs.
(3) The recommended gate drive voltage could be +15 V by the optimization of device structure for ease of replace of Si-IGBTs.

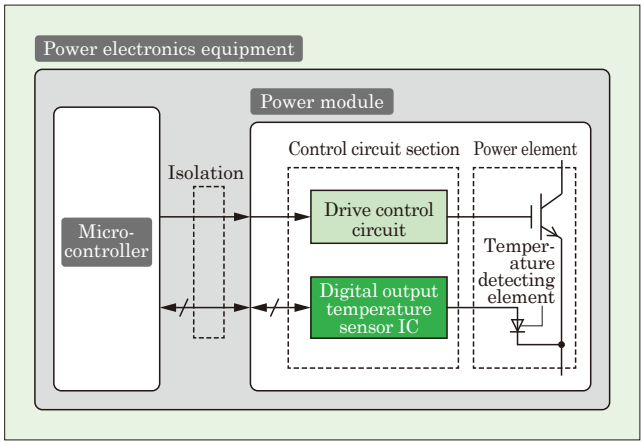
Fig.5 Cross section of SiC trench gate MOSFETs



6 Digital Output Temperature Sensor IC Technology

To support predictive maintenance of power electronics equipment, there is a demand for technology to enable high-precision temperature measurement of power elements mounted on a power module. In addition, as IoT utilization is progressing in the industrial fields where power electronics devices are used, it is desirable to have the ability to output measured values as digital data. To address the demand, Fuji Electric has developed a technology for high-precision digital output temperature sensor ICs incorporated in power modules. The output range of the newly developed IC is from −50°C to +200°C, the resolution is 0.25°C, and the precision is ±3°C. By detecting the temperature of the power element, converting the data into digital values using an AD converter built into the IC, and outputting them, the data can be processed in a digital device such as a microcontroller. This IC has a broad scope of industrial application, and it contributes to the high-precision predictive maintenance of power electronics.

Fig.6 Digital output temperature sensor IC application example



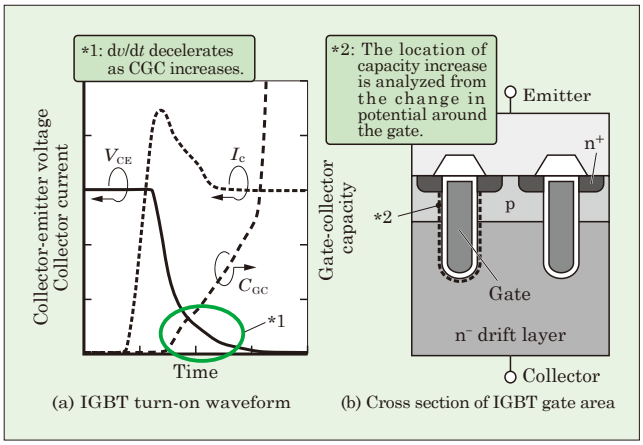
Industrial

7 Capacitance Analysis Technology to Reduce IGBT Turn-On Loss

To improve the efficiency of IGBTs, it is important that turn-on loss is reduced. The rate of change (dv/dt) of collector-emitter voltage during turn-on is not constant and slows down partway, causing loss increases.

Through TCAD simulation, Fuji Electric has discovered that dv/dt is slow due to the increase in capacitance between the gate and the collector (C_{GC}) during turn-on. We also have established a method to analyze where the capacitance increases from changes in potential around the gate. In the future, we will use this analysis method to reduce turn-on loss and further improve the characteristics of IGBTs.

Fig.7 IGBT Capacitance analysis example



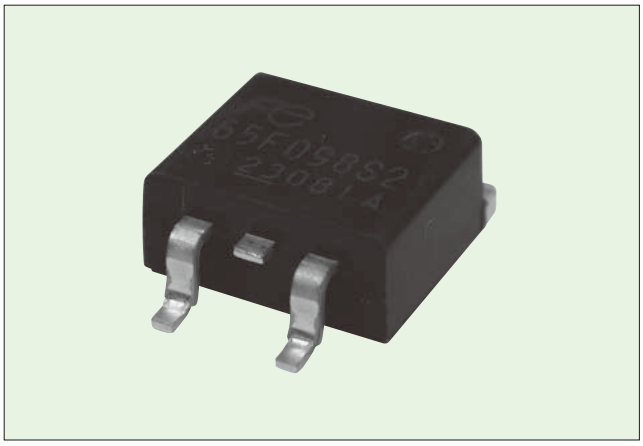
Automotive

1 Line-Up of the "Super J MOS S2FDA Series" 2nd-Generation Automotive SJ-MOSFET

Fuji Electric offers a line-up of the "Super J MOS S2FDA Series" 2nd-generation automotive SJ-MOSFET with rated voltages of 400 V to 600 V for use as a power MOSFET suitable for power conversion devices such as an automotive DC/DC converter and on-board charger. To meet the demand for higher battery voltage and smaller DC/DC converters, we added products with a rated voltage of 650 V in the small surface-mount T-pack (D2-pack) to the line-up. The T-pack (D2-pack) line-up will contribute to higher power density (reduced size) of power conversion equipment. The main features are as follows:

(1) Low on-state resistance (98 mΩ) achieves less power dissipation
(2) AEC-Q101 compliance ensures the reliability of automotive products

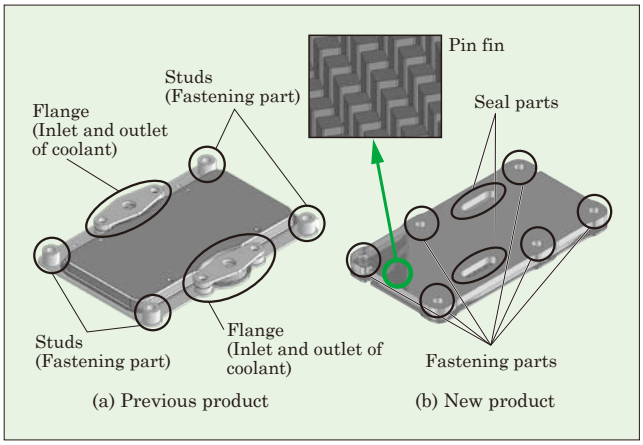
Fig.8 "Super J MOS S2FDA Series"



2 Ultra-Compact RC-IGBT Module Coolers for xEVs

For electrified vehicles (xEVs), the development of integrated electric and mechanical systems with integrated drive systems is accelerating, and there is a demand for power modules with high power density (small, thin, and high output) suitable for these systems. Fuji Electric has developed a new aluminum cooler using pin fins to achieve higher power density in power modules. The cooling performance was improved by optimizing the shape of the pin fins and the flow of the coolant using particle image velocimetry (PIV) in addition to thermal fluid analysis. In addition, the cooler has been miniaturized by integrating the seal part and the fastening part with the plate. In addition to this compact and high-heat dissipation cooler, the 4th-generation power module, which applies RC-IGBT elements and leadframe wiring technology, achieves approximately twice the power density of the 3rd-generation power module.

Fig.9 Aluminum cooler



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