This paper introduces the “G1 series” 7th generation IPMs for industrial applications. The G1 series IPMs, which use 7th generation IGBT chips, feature a new package structure as well as a newly designed external shape for improved ease of use. The IPMs also realize a power loss reduction function for the overload region, made possible through the use of a low-noise IGBT drive circuit.

### 1. Introduction

Given the recent trend toward energy efficient equipment for global environmental conservation, there is an increase in demand for power semiconductor devices, which are indispensable for high-power conversion. In particular, IPMs (Intelligent Power Modules) have a built-in drive circuit and protective circuit, so IPMs users are unnecessary to design these circuit. Such characteristics are attractive to those seeking easy-to-use power modules. In addition, as users increasingly prefer modules that allow more efficient design of the housing, there is a need for power module to consider assemblability. Moreover, in the inverter system market in which industrial IPMs are prevalent, there is a high demand for smaller, lighter products and expanded product lineups.

The extensive lineup of the G1 series IPMs is characterized by light weight and high reliability thanks to a structure that uses an insulated metal baseplate, and a low-noise IGBT drive circuit that reduces the power loss. The specifications of the modules were developed in pursuit of user friendliness.

### 2. Outline of the G1 Series IPMs

#### 2.1 Product lineup

The G1 series IPMs mounted with 7th generation power chips constitute a new product lineup. Three different types of packages are available depending on the Voltage/Current rating of the product, as shown in Table 1. The lineup consists of products with rated current from 50 A to 450 A at 650 V rated voltage, and from 25 A to 200 A at 1,200 V rated voltage.

Moreover, given the demand for product downsizing and expanded lineups, there is a clear need for packages with a narrower width or smaller dimensions in order to downsize the housing in which multiple power modules are often mounted. The packages of the G1 series IPMs have a smaller width and dimensions than those of the L1 series IPMs. The mounting area of the B-package is 25% smaller than L1 series IPM with the same rated voltage/current, and that of the C-package is 31% smaller than L1 series IPM. Therefore, G1 series IPMs contribute to miniaturization and weight reduction of the inverter device.

Figure 1 shows the lineup of the G1 series IPMs. As these three package types offer products with common ratings, users can select a package suitable for the intended use.

#### 2.2 Features of A-package

The G1 series A-package modules offer two types of main terminal specifications: the solder pin type and the screw type. The mounting areas are same in both...
terminal types. But these models allow users to select a main terminal type that is suitable for the mounting process or the specifications for the connection of power modules. In addition, consider a case in which multiple modules with different packages are mounted in the same housing, as shown in Fig. 2, in which the G1 series A-package and B-package modules are mounted. As the G1 series A-package modules with the screw main terminals and the B-package modules are of the same height, users can have a uniform main wiring height as shown in Fig.3. Thus, the external shape of the G1 series IPMs is designed to make the modules easy to assemble into devices.

Fig. 2 Layout example of multiple IPMs

Fig. 3 Uniform height of the main wiring that connects an A-package module (with the screw main terminals) with a B-package module

3. Package Structure

For power modules, it is used ceramic insulating substrate from conventional in order to achieve both a high heat radiation and insulation in power module. However, for the G1 series with a goal of extending the service life, ceramic substrate has been replaced by an insulated metal baseplate to form a structure with no soldering; also, the direct potting technology has been applied using epoxy resin as the encapsulation material. Figure 4 shows the cross-sectional view (vertical structure) of an L1 series IPM and a G1 series IPM.

One of the methods for evaluating the service life of a module is thermal cycle testing. When a system is repeatedly started up and stopped, the module temperature is changed. So, thermal stress is generated in the module structural components. This causes a difference in the coefficients of thermal expansion between structural components. As a result, the deterioration (cracks) of the solder layers occur. In conventional IPM structures, solder is used for the bonding between the copper baseplate and ceramic substrate. In such structures, the progress of cracks in the solder layer under the insulation substrate leads to a decrease in thermal cycle resistance. (1)

The G1 series IPMs have optimized coefficients of thermal expansion of the solderless structure under the insulation substrate and encapsulation material, thereby alleviating the thermal stress imposed on the structural components. This improves the thermal cycle life, which has been caused the deterioration of the solder layer under the insulation substrate. And thus the modules have achieved high reliability.

4. Functions of G1 series IPMs

4.1 Low-noise IGBT drive circuit

The G1 series IPMs adopt the low-noise IGBT drive circuit that is used in the L series IPMs for reducing EMI (Electro-Magnetic interface) noise. Figure 5 schematically shows the principle of the low-noise IGBT drive circuit.

Based on conventional control systems, because the dv/dt changes sharply in the low current region, EMI noise is prone to occur. However, when the dv/dt in the
low-current region is reduced in order to suppress the EMI noise, the power loss increases in both the high- and low-current regions. With the adoption of the low-noise IGBT drive circuit in the G1 series, the EMI noise can be suppressed by setting a slow dv/dt in the low-current region, while the power loss can be reduced by setting a high switching speed in the high-current region (rated current). The G1 series IPMs are capable of detecting the current passing through the IGBT in real time at the control IC by elements incorporated in the IGBT chips. When the detected current reaches the threshold value, the drive power is automatically switched. The current detection using the elements in the chips allows for the switchover of the drive systems without the need for an external detection circuit.

While reducing the power loss by this function, it is possible to reduce the EMI noise. The switchover point of the switching speed has been optimally designed for users to maximize the effect of this function.

Figure 6 shows the results of an EMI noise test conducted using two samples mounted with the control substrate of a conventional drive system and the low-noise IGBT drive circuit system as used in the G1 series IPMs. These samples mount the same power chips and same wiring circuit. The values of the EMI noise show almost the same trend across all frequency domains. Figures 7 and 8 show the simulation results for the power loss of these samples during low-current operation (normal operation mode) and high-current operation (locked operation mode) respectively. In the low-current region, the power loss per module is almost equal between the two systems, while in the high-current
region, the power loss of the low-noise IGBT drive circuit system module is smaller than that of the conventional drive system module. As shown in Fig. 5, a major factor in the reduced power loss is the reduction of the turn-on loss in the IGBT chips in the high-current region. By using the function of Low-noise IGBT drive circuit, it realizes an improvement of approximately 10% in the total power loss. Under the condition of the same EMI noise as the conventional drive system, this function reduces the power loss in the region of current that exceeds the switching changing point, and in particular reduces the power loss even when the motor is locked up, an unfavorable condition in terms of energy saving.

4.2 Error identification function
IPMs generally have a protective circuit that turns off the IGBT in the event of an operation abnormality (increase in element temperature, occurrence of high-current, etc.). The G1 series IPMs have an error identification function in addition to the error output function in terms of conventional protective functions (over temperature [OT], under voltage [UV], and short current [SC]). The error output timing (Fo) is set for each protective function, and pulse signals are output at the specified Fo. Users can determine the details of an error when the Fo time is detected.

5. Conclusion
This paper introduced the product features of the new G1 series IPMs. For the new IPM packages, it is possible to make the width narrower and the total dimensions smaller compared to the packages of the L1 series IPMs. As a result, the mounting area on the B-package was reduced by 25%, and that on the C-package was reduced by 31% of the respective size counterparts in the L1 series. G1 series IPMs will help reduce the size and weight of inverter devices. In addition, the G1 series A-package IPMs offer the options of solder pin type and screw type main terminals, allowing users to select a main terminal type in accordance with the required specifications. Moreover, the same main terminal height of the A-package and B-package allows a uniform height for the main wiring, for ease of assembly by users. Furthermore, the low-noise IGBT drive circuit reduces the power loss in the overload region.

As described above, the IPMs in the extensive G1 series lineup were designed with user friendliness in mind, which includes an optimized external shape and main terminal options. The IPMs are provided with enhanced functions based on the conventional IPM products. These G1 series IPMs will satisfy diverse market needs.

References