1,700-V Line-Ups of 7th-Generation "X Series" IGBT Modules

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In recent years, it has become necessary to reduce CO_2 emissions in terms of measures against global warming. Energy conversion efficiency is being improved, and utilization of renewable energy such as wind power generation and photovoltaic power generation is being expanded. Accordingly, the output current per piece of power conversion equipment tends to increase, and there is growing demand for large-capacity insulated gate bipolar transistor (IGBT) modules, which serve as key devices in such equipment. At the same time, the above equipment, which constitutes part of social infrastructure, also needs to be highly reliable.

To meet demands for a higher output current, lower power consumption and higher reliability of power conversion equipment, Fuji Electric has developed 1,700-V products of the 7th-generation "X-Series" IGBT modules.

1. Features

Table 1 shows the line-up of 1,700-V X-Series IGBT modules. Compared with the conventional "V Series," the features are as follows.

(1) Increase in output current
(2) Increase in junction temperature at continuous operation T_{vjop}

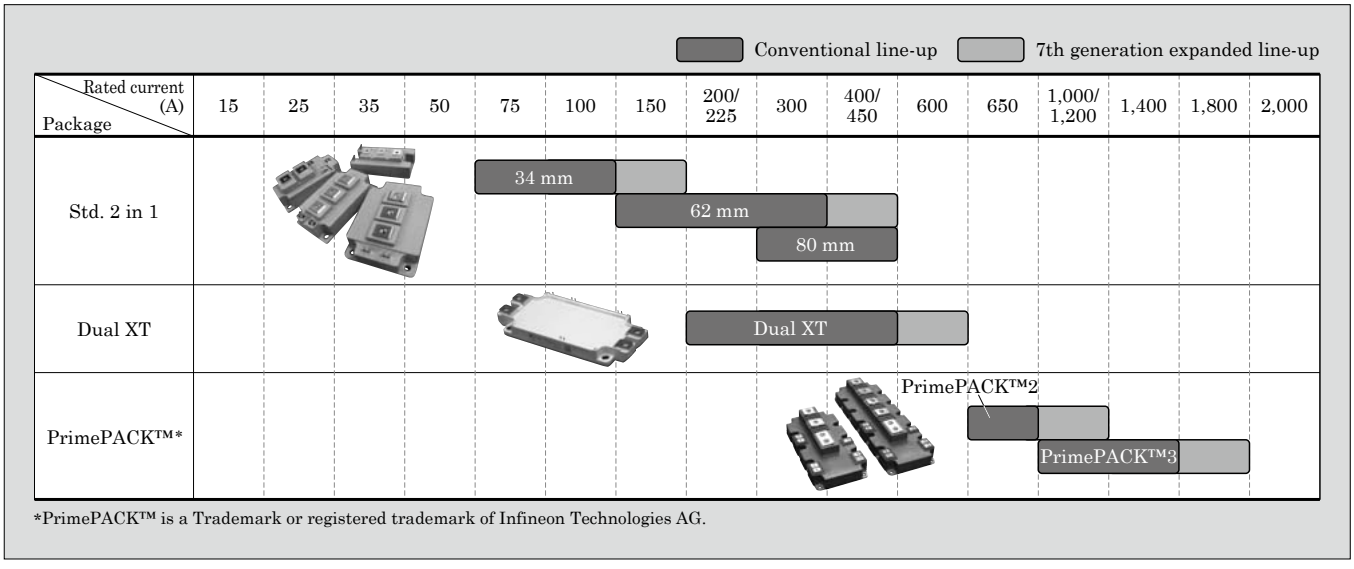
2. Electrical Features

In the 1,700-V X Series IGBT modules, the power dissipation has been greatly reduced compared with the conventional products (V Series) by applying X Series chip technology. The following refers to the result of comparing the modules with a rated current of 450 A and a rated voltage of 1,700 V using Dual XT (M254) packages.

Figure 1 shows the trade-off characteristic between the saturation voltage of the IGBT and the turn-off energy, and Fig. 2 shows the trade-off characteristic between the forward voltage of the free wheeling diode (FWD) and the reverse recovery energy. In X Series IGBTs, the latest miniaturization technique and the wafer thinning technology are applied. Therefore, compared with the V Series IGBTs, the saturation voltage has been reduced by approximately 0.4 V and the turn-off energy, by approximately 12%, resulting in a great improvement. In the X series FWDs, the forward voltage is reduced by approximately 0.2 V by applying the latest wafer thinning technology. In addition, by optimizing the life time control, a smooth reverse recovery waveform is formed and the reverse recovery energy is reduced by approximately 17%.

Figure 3 shows the results of calculating power consumption. Compared with the V Series, the power con-

Table 1 Line-up of 1,700-V X-Series IGBT modules



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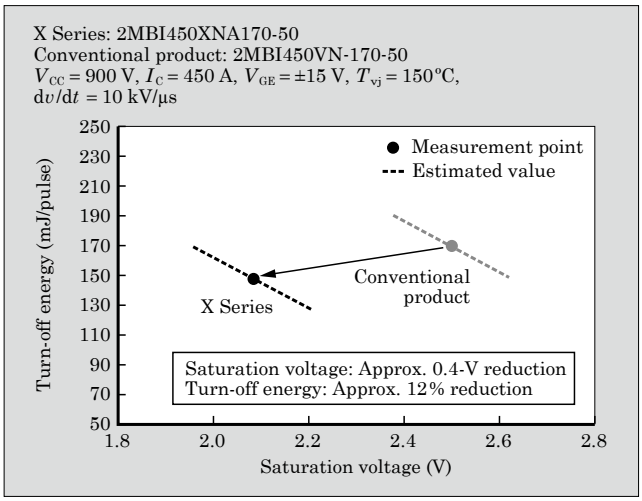

Fig.1 Trade-off characteristics (IGBT)

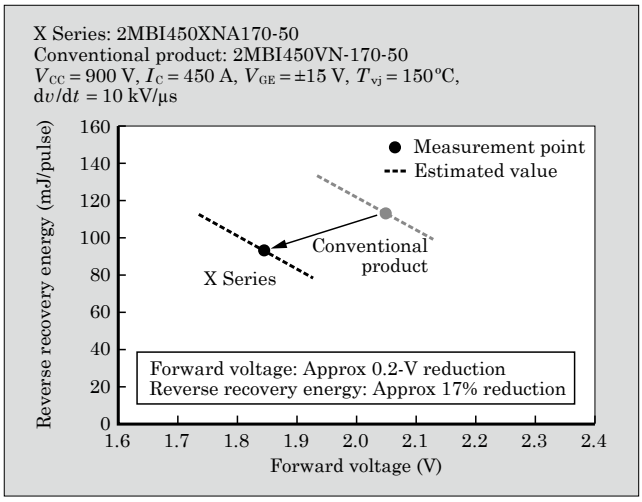

Fig.2 Trade-off characteristics (FWD)

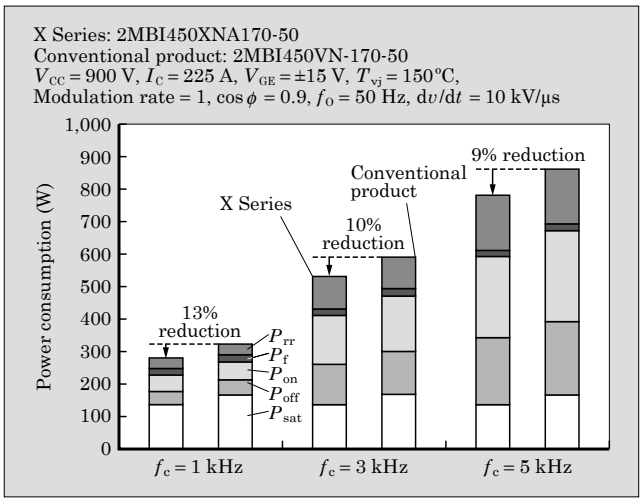

Fig.3 Power consumption

sumption of the X Series has been reduced by approximately 13% under the condition of a carrier frequency of 1 kHz.

3. Packaging Technology

To further improve the output current, the junction temperature of the X Series at continuous operation (T_{vjop}) is increased from 150 °C (conventional product) to 175 °C. To increase T_{vjop}, it is necessary to improve the ΔT_{vj} power cycle capability, which is lifetime with respect to the temperature change, and the heat resistance property of insulation silicone gel, which affects the long-term reliability at high temperature. A newly developed solder material and new wire bonding technology on semiconductor chips are applied to the X Series. Thus, compared with the conventional product, the T_{vj} power cycle capability has been improved by approximately twice under the condition of T_{vjmax} = 175 °C and ΔT_{vj} = 50 °C. In addition, by adopting new silicone gel with a high heat resistance property, gel hardening under the environment of 175 °C is controlled and a long-term insulation performance is ensured.

Moreover, a high heat-radiating insulating substrate using AlN with high thermal conductivity is applied to efficiently dissipate the joule heat of semiconductor chips. Figure 4 shows the transient thermal resistance characteristics. Compared with the conventional product using an Al_2O_3 insulating substrate, the thermal resistance between the junction and the case has been reduced by about 45% with the same chip size.

Figure 5 shows the results of calculating the output current of an inverter and the junction temperature of an IGBT, in the X Series module having the maximum rated current of 600 A and V Series module having the maximum rated current of 450 A of the Dual XT packages. Compared with the conventional product, the output current of the 1,700-V X Series products has been improved by approximately 30% by applying the latest X Series chip technology and package technology described above. The product can meet demands such as miniaturization of conversion equipment, lower power consumption and higher reliability.

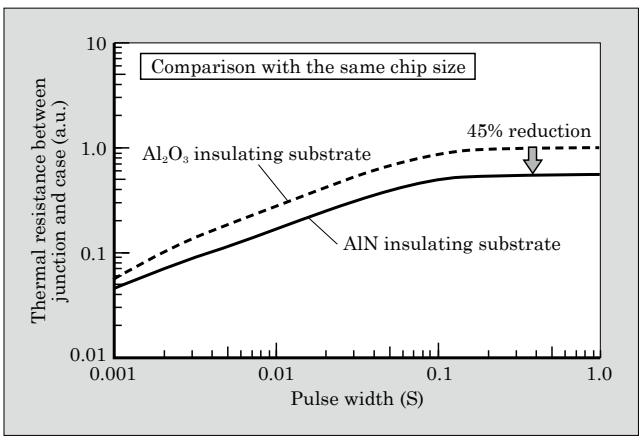

Fig.4 Transient thermal resistance characteristics

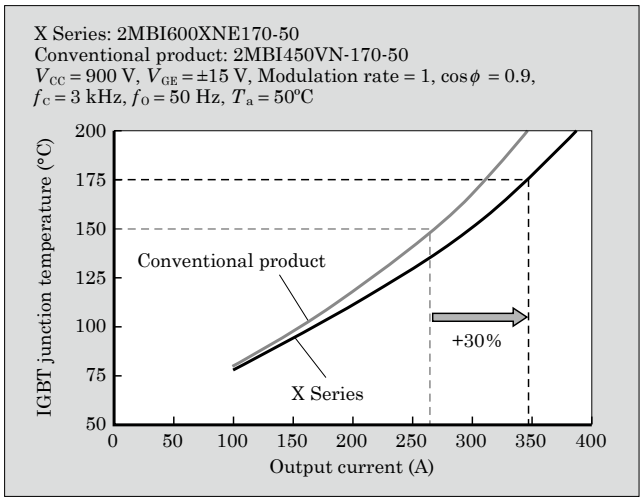

Fig.5 Output current of inverter and junction temperature of IGBT

Launch time

Starting in June 2019

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