R-IPM3 and Econo IPM Series of Intelligent Power Modules

Manabu Watanabe
Yoshiyuki Kusunoki
Naotaka Matsuda

1. Introduction

Fuji Electric has developed and mass-produced several series of IGBT-IPMs (insulated gate bipolar transistor-intelligent power modules), beginning with the J-series in 1993, followed by the N-series in 1995 and then the R-series in 1997. The J-series realized low loss, the N-series achieves soft switching and the R-series realized high reliability, high cost performance and improved protection accuracy by adopting a protection function to guard against overheating of the chip.

Against the backdrop of recent demands for higher frequency, smaller size, higher efficiency and lower noise requested of power electronics products, Fuji Electric has developed two new intelligent power modules, the R-IPM3, which is based on the R-IPM and provides improved loss characteristics, and the small and thin Econo IPM, which combines concepts of the R-IPM and Econo modules. This paper will introduce both of these modules.

For the IGBT, we developed a NPT (non punch through) microchip (T-series) having a thickness of 100 µm, which was realized by the establishment of a thin wafer process. For the FWD (free wheeling diode), we newly developed a new structure-FWD dies. This new FWD dies has an improved soft-recovery function. Table 1 lists the special features of each IPM series. We developed three series: the RTB type that has improved cost performance, the Econo IPM that is realized in a small-size and thin package, and the RTA type that has a low loss level. In Fig. 1, external views of the R-IPM3, Econo IPM and small capacity R-IPM3 are shown.

Table 1 Special features of IPM

Item \ Series name	R-IPM3		Econo IPM	Low capacity R-IPM3
	RTA	RTB		
External dimensions	○ Interchangeable with R-IPM series (Standard package) ○ Screw terminal		○ Small size, thin-type ○ Pin terminal	○ Package with copper base ○ Small size
Special feature	○ Low power dissipation (18 % less than R-IPM)	○ Low power dissipation (10 % less than R-IPM) ○ Cost performance	○ Low power dissipation (10 % less than R-IPM) ○ Cost performance	○ Heat dissipation was improved with base. (Compared to baseless module)

2. R-IPM3 and Econo IPM Series

Table 2 lists the product series, characteristics and internal functions of the R-IPM3 and Econo IPM. IGBT dies adopted a NTP planer structure and attempted to reduce the switching loss. FWD dies optimized the anode structure and further improved the soft-recovery function.

The R-IPM3 series has external dimensions and functions that are interchangeable with the prior R-IPM series, and consequently, it is the most suitable replacement.

The Econo IPM series minimized its external dimensions and decreased its footprint by about 30 % compared to the conventional R-IPM. Further, by adding the upper arm alarm output, more reliable protection against a grounding fault can be realized.

For both of these series, we prepared a 6-in-1 module set and a 7-in-1 module set (including a built-in IGBT for braking) with 50 to 150 A of rated current for the 600 V class modules. Further, for 20 A low

Fig.1 External view of IPM

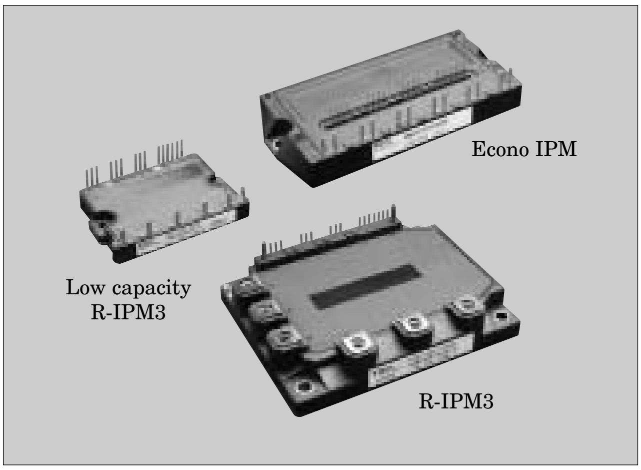


Table 2 Series, special characteristics and internal functions of IPM

(a) Econo IPM

Number of elements	Model	V_{DC} (V)	V_{CES} (V)	Inverter part		Brake part		Internal function								Package type
								Upper and lower arms common			Upper arm		Lower arm			
				I_C (A)	P_C (W)	I_C (A)	P_C (W)	Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP 50TEA060	450	600	50	144	–	–	○	○	○	○	○	○	○	×	P622
	6MBP 75TEA060			75	198	–	–	○	○	○	○	○	○	○	×	
	6MBP 100TEA060			100	347	–	–	○	○	○	○	○	○	○	×	
	6MBP 150TEA060			150	431	–	–	○	○	○	○	○	○	○	×	
7 in 1	7MBP 50TEA060	450	600	50	144	30	144	○	○	○	○	○	○	○	×	P622
	7MBP 75TEA060			75	198	50	198	○	○	○	○	○	○	○	×	
	7MBP 100TEA060			100	347	50	198	○	○	○	○	○	○	○	×	
	7MBP 150TEA060			150	431	50	198	○	○	○	○	○	○	○	×	

(b) R-IPM3

Number of elements	Model	V_{DC} (V)	V_{CES} (V)	Inverter part		Brake part		Internal function								Package type
								Upper and lower arms common			Upper arm		Lower arm			
				I_C (A)	P_C (W)	I_C (A)	P_C (W)	Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP 20RTA060*	450	600	20	103	–	–	○	○	○	×	×	○	○	×	P619
	6MBP 50RTA060			50	198	–	–	○	○	○	○	×	○	○	○	P610
	6MBP 80RTA060			80	347	–	–	○	○	○	○	×	○	○	○	
	6MBP 100RTA060			100	431	–	–	○	○	○	○	×	○	○	○	P611
	6MBP 160RTA060			160	500	–	–	○	○	○	○	×	○	○	○	
	6MBP 50RTB060			50	144	–	–	○	○	○	○	×	○	○	○	P610
	6MBP 75RTB060			75	198	–	–	○	○	○	○	×	○	○	○	
	6MBP 100RTB060			100	347	–	–	○	○	○	○	×	○	○	○	P611
	6MBP 150RTB060			150	431	–	–	○	○	○	○	×	○	○	○	
7 in 1	7MBP 50RTA060	450	600	50	198	30	144	○	○	○	○	×	○	○	○	P610
	7MBP 80RTA060			80	347	50	198	○	○	○	○	×	○	○	○	
	7MBP 100RTA060			100	431	50	198	○	○	○	○	×	○	○	○	P611
	7MBP 160RTA060			160	500	50	198	○	○	○	○	×	○	○	○	
	7MBP 50RTB060			50	144	30	144	○	○	○	○	×	○	○	○	P610
	7MBP 75RTB060			75	198	50	198	○	○	○	○	×	○	○	○	
	7MBP 100RTB060			100	347	50	198	○	○	○	○	×	○	○	○	P611
	7MBP 150RTB060			150	431	50	198	○	○	○	○	×	○	○	○	

Dr : IGBT Driving circuit, UV : Under voltage lockout for control circuit, TjOH : Protection for device heating, OC : Overcurrent protection, ALM : Alarm output, TcOH : Protection for case temperature

* 6MBP20RTA060 : Adopt detection method by shunt resistance at N line.

capacity elements, we improved the ease of use by using a copper base type package. Consequently, the user can select an appropriate product from a diverse product line-up. Figure 2 shows the external view of each IPM.

3. Special Features of the Power Devices

Cross-sectional views of the PT (punch through)-IGBT applied to the prior R-IPM and the NPT-IGBT applied to the R-IPM3 and Econo IPM are shown in Fig. 3.

The three special features of the NPT-IGBT are as follows:

(1) The saturation voltage between collector and emitter ($V_{CE\,(sat)}$) has a positive temperature coefficient, and consequently current does not concentrate in a unit cell in the chip.

(2) The temperature dependency of turn-off loss (E_{off}) is small.

(3) There is no lifetime control, and consequently the fluctuation of ($V_{CE\,(sat)}$) is small.

The trade-off relation between $V_{CE\,(sat)}$ and turn-off loss is shown in Fig. 4. From Fig. 4, it can be seen that the prior IGBT chip's N-series and S-series have a high temperature dependence. On the other hand, the newly developed NPT planer chip mounted T-series has low temperature dependence, and therefore can reduce the turn-off loss at high temperatures.

Figure 5 compares the fluctuation of $V_{CE\,(sat)}$,

Fig.2 External dimensions of IPM

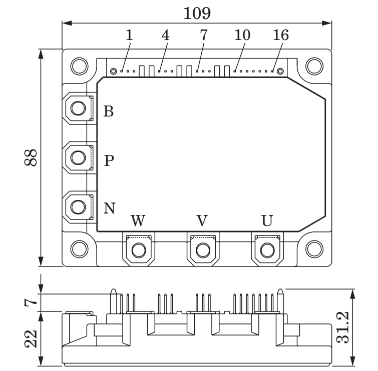
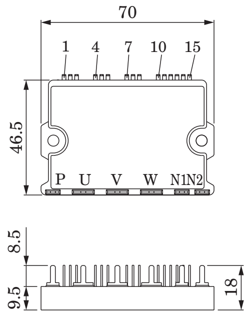
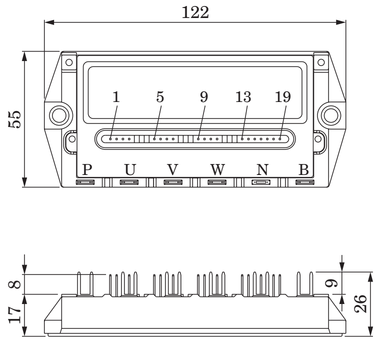
Series name	R-IPM3		Econo IPM
Package type	P610, P611	P619	P622
Outline drawings			
Dimensions	L109×W88×H22 (mm)	L70×W46.5×H9.5 (mm)	L122×W55×H17 (mm)
Mass	450g	85g	270g

Fig.3 Comparison of IGBT chip cross-sections

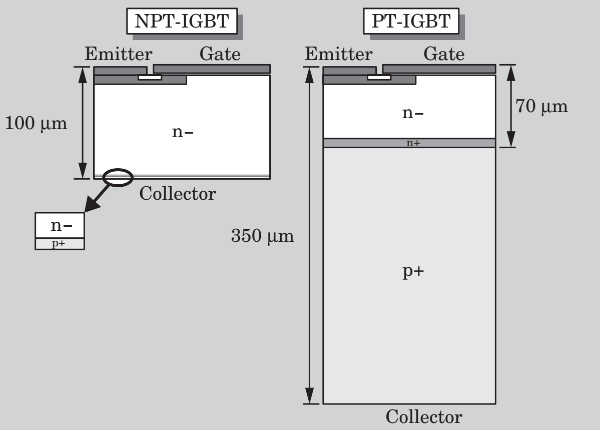


Fig.5 Distribution chart of $V_{CE\ (sat)}$

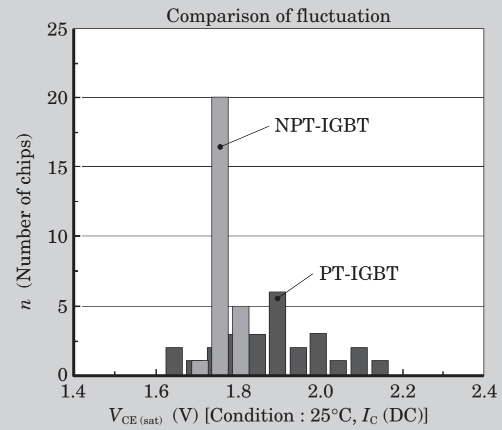


Fig.4 Trade-off curve of IGBT chips

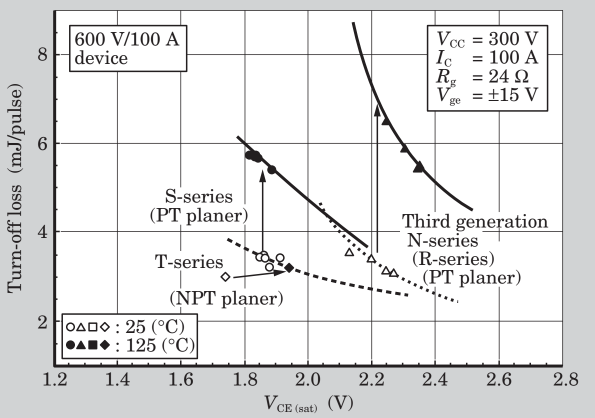
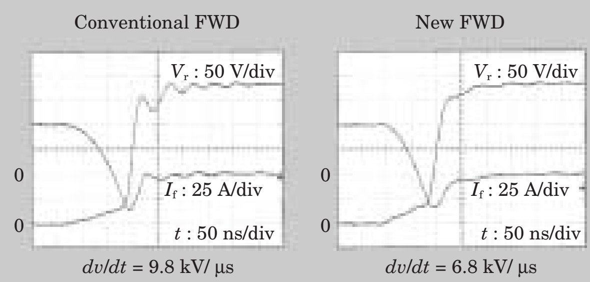


Fig.6 Comparison of recovery switching waveform of FWD between conventional FWD and new FWD



between the PT-planer chip and the NPT-planer chip. $V_{CE\ (sat)}$ of the NPT-planer chip is distributed in a limited range and exhibits stable, steady-state loss characteristics.

Next, we shall describe the FWD that has been utilized in the R-IPM3 and Econo IPM. Fuji Electric applied the new structure to the FWD in order to decrease emission noise. Figure 6 shows comparison of recovery switching waveform of FWD between conventional FWD and new FWD. New structure FWD achieves, that suppress the injection of holes from the anode and decrease the reverse recovery peak current to achieve soft recovery.

4. Package Construction

In order to achieve smaller and thinner dimensions, the Econo IPM is manufactured with a different construction than the prior IPM. In the prior package, a terminal bar was used for the interconnects. But with that method, the height of package cannot be decreased because of the limitations of the bar interconnects. For this reason, the Econo IPM changed from a terminal bar construction to a method of using

Fig.7 Internal construction of Econo IPM

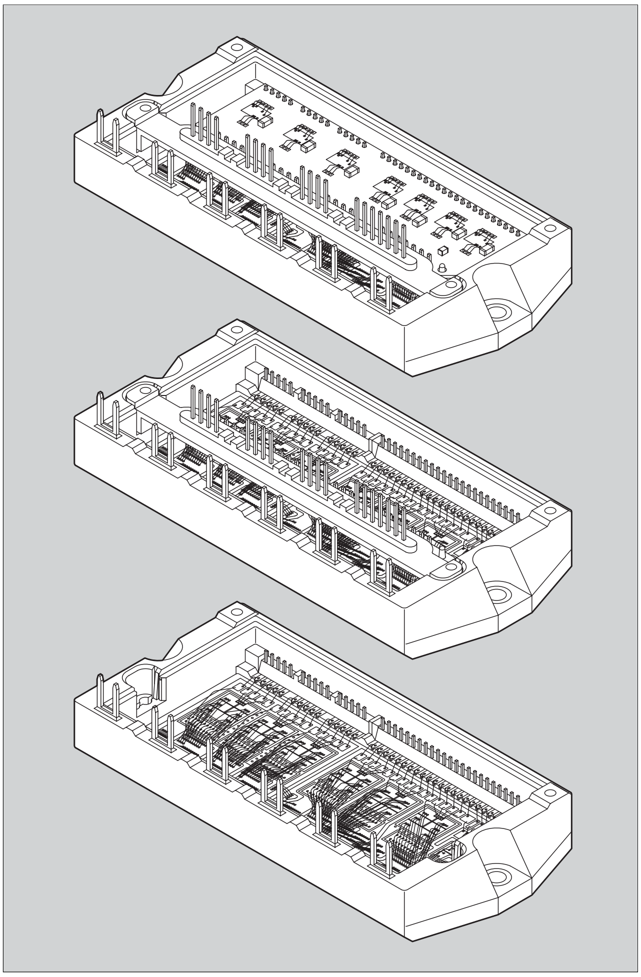


Fig.8 Example of Econo IPM installation

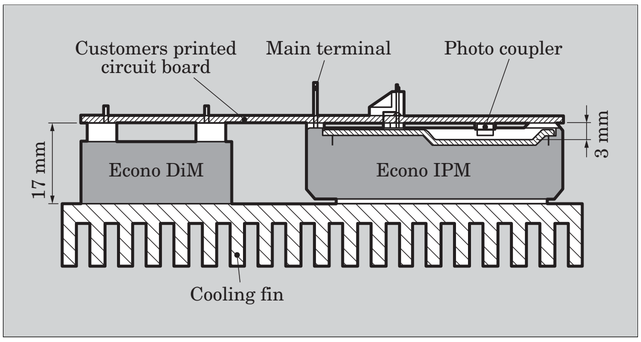


Fig.9 Comparison of total loss

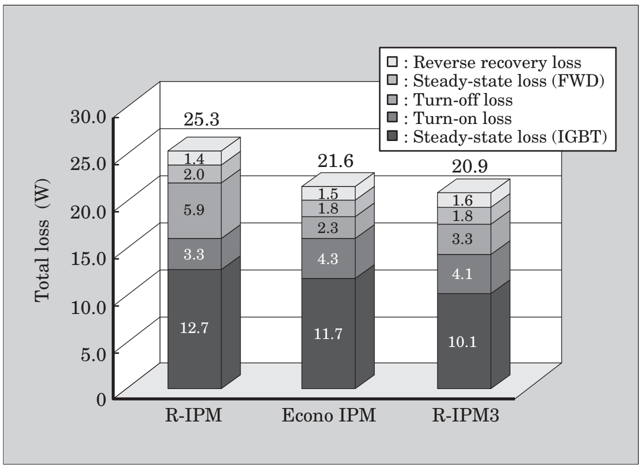


Fig.10 Turn-off waveform

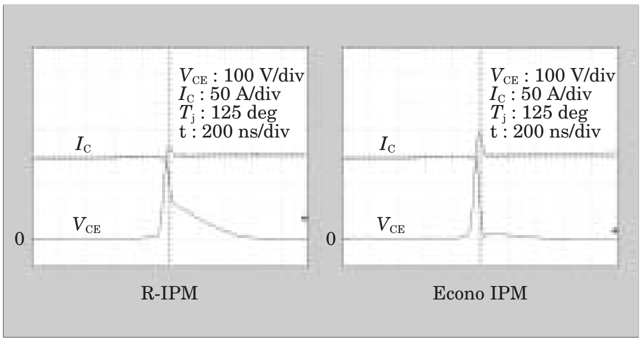


Fig.11 Comparison of the spectrum of emission noise

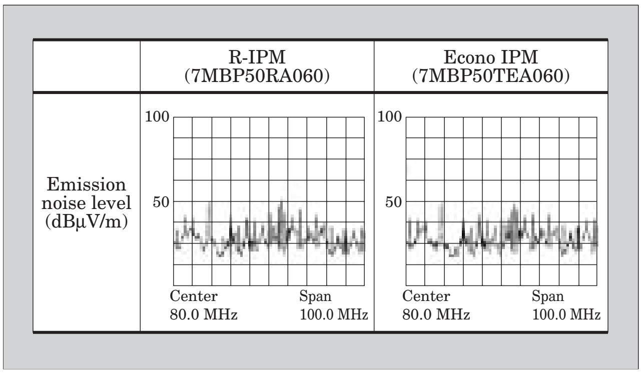
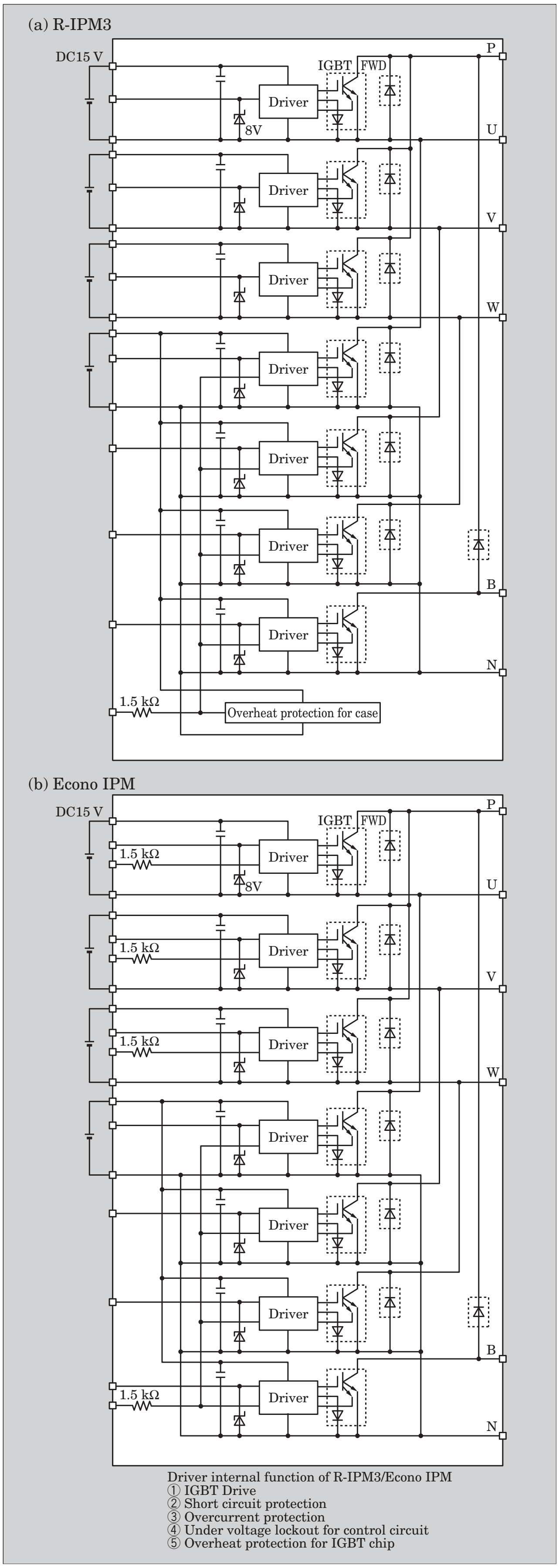


Fig.12 Block diagram of IPM circuit



aluminum wires for all internal interconnects. Further, to limit the package width, we introduced a construction wherein the control card printed circuit board is positioned on the second level. By adopting these changes, we succeeded in manufacturing a very compact package (see Fig. 7).

Figure 8 shows an example of an Econo IPM installed in a side-fin type servo-amp. The Econo-DiM (Econo Diode Module) in this drawing was developed with the same concept (the Econo-module concept) as the Econo IPM, and therefore has the same height of 17 mm as the Econo IPM. Since the Econo IPM and Econo-DiM have the same height, they can be connected on the same printed circuit board. By utilizing these two modules, simplification of the design of printed circuit boards can be expected. Further, in order to utilize the thin package more effectively, the Econo IPM reduces the height of a part of its lid. By ensuring a 3 mm space between the printed circuit board and the Econo IPM lid, the mounting of electronics components such as a photo-coupler on the back of the printed circuit board is possible. Consequently, it is expected that dead space in customers' equipment can be decreased, further contributing to reducing the footprint customer's equipment.

5. Reduction of Loss

As product development concepts, the reduction of loss and the level of emission noise, which have a mutual tradeoff relationship, are the most important items.

These items were one of the important themes of the newly developed Econo IPM and R-IPM3 modules. During development, we were able to decrease IGBT loss by adopting the newly developed NPT-IGBT, and moreover, by installing a new diode that has a soft-recovery function and by optimizing the driving conditions, we succeeded in realizing the same or lower noise level than the prior R-IPM.

Figure 9 compares total loss between the newly developed Econo IPM, R-IPM3 and the prior R-IPM. As a result of installing the new IGBT chip and FWD chip, loss decreases of 15 % in the Econo IPM and 18 % in the R-IPM3, compared to the prior R-IPM, were realized. In particular, the decrease in turn-off loss greatly contributed to the decrease in total loss. Figure 10 shows turn-off waveforms of the prior IPM and Econo IPM. Figure 11 shows the emission noise spectrum of the R-IPM and Econo IPM. The emission noise spectrum was measured by the 3 m method for accelerating and decelerating operation utilizing a servo-amp with a 4 kHz carrier frequency. Consequently, it was learned that the noise level is kept at the same level as the prior type over the frequency range from 30 to 130 MHz.

6. Block Diagram of IPM

Figure 12 shows block diagrams of modules with built-in dynamic brake functions. Figure 12(a) is the R-IPM3, and 12(b) is the Econo IPM. In case of Econo IPM, the alarm signal of the upper arm circuit is output externally.

7. Conclusion

IGBT-IPMs which incorporate the latest power device technology from Fuji Electric have been presented. We are convinced that these IPMs will enable the development of highly efficient and small size power electronics application products and will satisfy the market expectations.

We at Fuji Electric will continue to develop and produce new products in order to meet the requirements of markets in the future.

References

(1) Kusunoki, Y. et al. A new compact intelligent power module with high reliability for servo drive application. PCIM Europe 2002.

(2) Matsuda, N. et al. New 600V Compact Intelligent Power Module "Econo IPM". CIPS2002, p.101-106.