UDC 621.382.049.77:[621.382.23.026+621.382.33.026] :621.318.57

INTELLIGENT POWER MODULES USING IGBTs FOR INVERTERS

Masami Ichijô
Tôru Hôsen
Manabu Watanabe

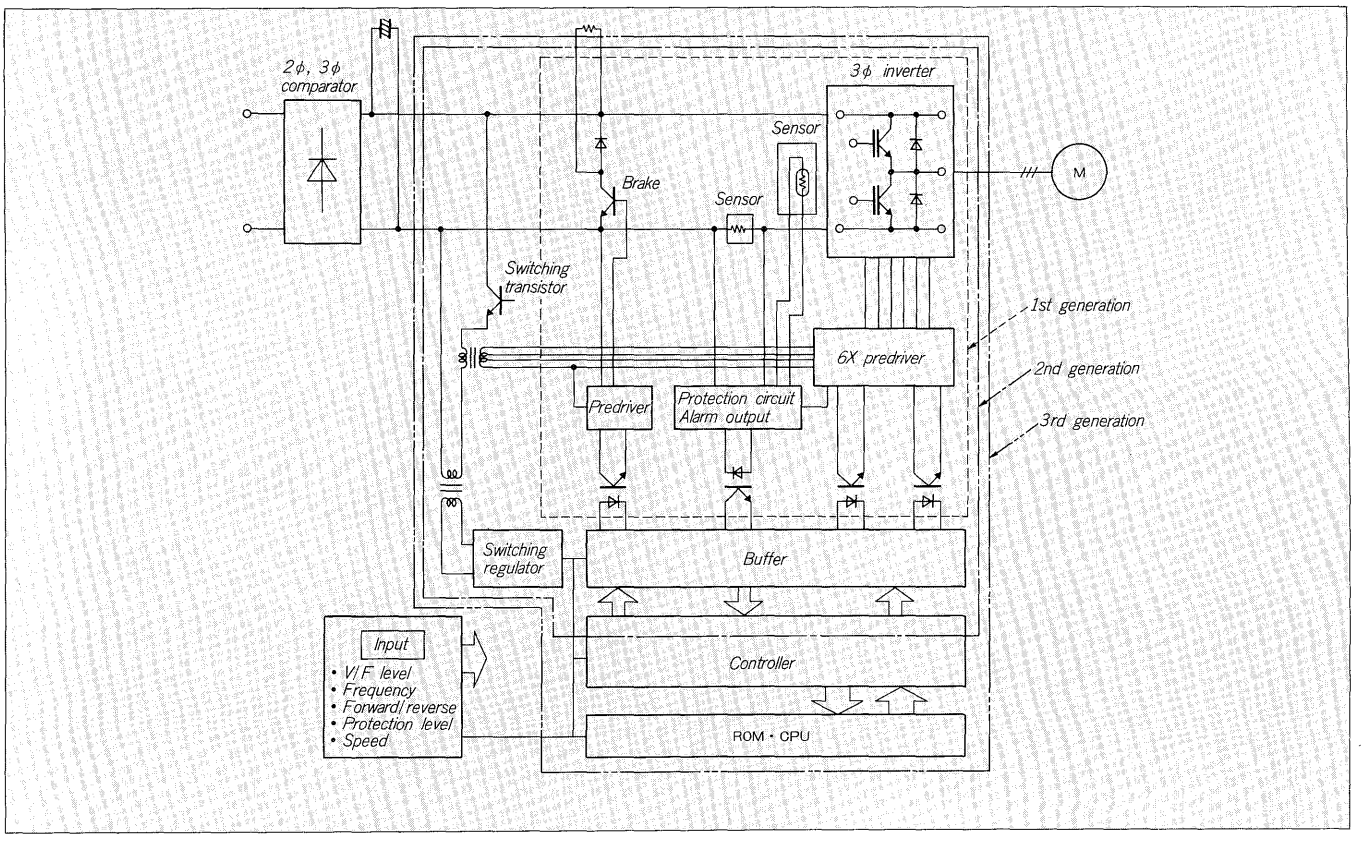
1. FOREWORD

Against the background of an age which strongly calls for energy saving, labor saving, and advanced informationalization, general-purpose inverters, NC machine tools, industrial robots, computer power supplies, and other electronics-applied equipment which support this age have grown rapidly.

Diversification of value is advancing even in home living and as the pursuit of comfort has become a more important problem, power electronics equipments, represented by the inverter air conditioner and inverter microwave oven, have become more familiar.

The growth of power electronics was supported by development of higher voltage, higher capacity and ultra-high h_{FE} bipolar transistor, and other new devices such as power MOSFET and IGBT. However, in the entry of power electronics into the age of keen competition focused on more exact and advanced control and smaller size and lower price, not only the simple function of turning power on and off, but also the advance to devices with more advanced built-in functions is strongly demanded. Fuji Electric has promoted research and development focused on advanced power device functions to meet this demand and has already commercialized and sent to the market eight kinds of intelligent power modules for inverters.

Fig. 1 Inverter equipment configuration



These modules use bipolar transistors with the world's most advanced functions developed by concentration Fuji Electric's know-how.

We have just developed intelligent power modules using IGBT with faster switching speed for inverter. These modules are introduced.

2. INTELLIGENT POWER MODULE CONCEPT

The circuit configuration of inverter equipment is shown in *Fig. 1.*

Fuji Electric has the following concept regarding the intelligent power modules developed this time.

2.1 Advance of functions

The functions built into the intelligent power modules are arranged serially as shown below.

(1) 1st generation

The 1st generation had the following two built-in functions:

(a) Driver circuit which is the interface circuit that connects the power device and control circuit.

(b) Overcurrent protection circuit and overheating protection circuit.

The 1st generation of intelligent power modules were very easy to connect to the control circuit and the main circuit was very easy to manufacture.

(2) 2nd generation

The 2nd generation has the following three built-in functions:

(a) Built-in functions of 1st generation

(b) Top and bottom arms signal distribution circuit (top and bottom arms short-circuit prevention circuit)

(c) Power supply for built-in circuits

The 2nd generation intelligent power modules could be handled as block boxes that self-connected one main circuit and released from the difficult of understanding power device application technology and the difficulty of circuit deisgn.

(3) 3rd generation

The 3rd generation has the following four built-in functions:

(a) Built-in function of 2nd generation

(b) PWM control circuit

(c) Overload protection circuit (protects the module itself against overloads)

(d) Overvoltage protection circuit (protects the module itself against abnormal DC voltage)

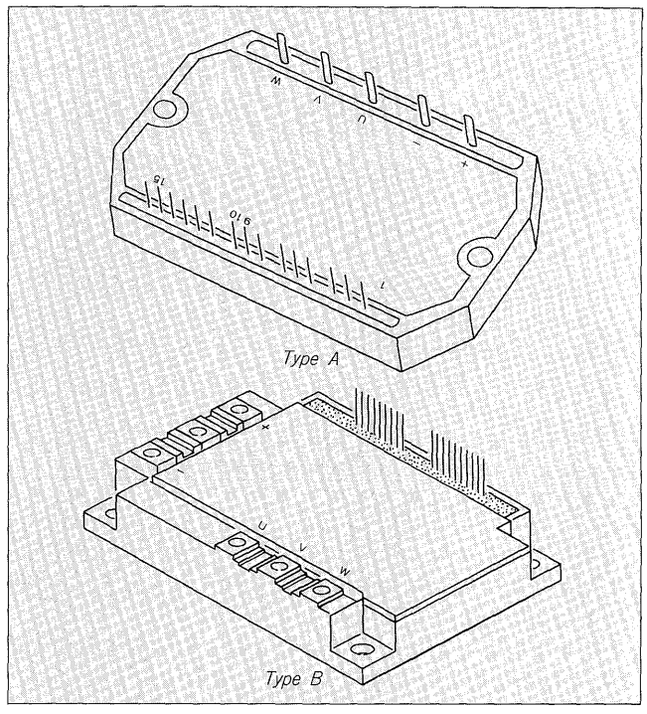
The 3rd generation intelligent power modules have the basic functions of inverter equipment.

2.2 Advance of package and onboard chip

Fuji electric considers the advance of the package and onboard chip used with the intelligent power modules as follows.

2.2.1 Current situation

Fig. 2 Intelligent module packages



Two typical packages currently available from Fuji Electric are shown in *Fig.2.*

(1) Type A

The Type A is a package suitable for low capacity devices of 30A or less. It mounts the power chip and control circuit electronics together on a single insulated substrate. Its feature is it is thin.

(2) Type B

The Type B is a package suitable for high capacity devices of 30A or more. The power chip insulated substrate and control circuit PC board are separate. Its feature is small mounting space.

2.2.2 Future direction

Currently, the same power chip as that used with ordinary power modules is mounted on the two packages described above and the control circuit is formed by using a dedicated IC or general-purpose IC and discrete electronic components. In the future, we expect to advance to smaller and more advanced functions devices with the drive circuit and protection circuits integrated on the power chip.

We also expect the package itself to be advanced to packages with a smaller thermal resistance or smaller size and lower weight and efforts to be directed toward the realization of subminiature and high performance intelligent power modules with advanced functions.

3. FEATURES OF IGBT OUTPUT TYPE INTELLIGENT POWER MODULES

The new IGBT output type intelligent power modules were realized by combining the concept of the 1st generation previously described with a Type B package. Its

features are summarized below.

(1) Lower loss achieved by using the newly developed 2nd generation IGBT.
(2) High speed switching made possible (20kHz correspondence) by using a high-speed photocoupler.
(3) Positive overcurrent protection made possible by using dedicated IC.
(4) Small size and high allowable loss realized by using the Type B package construction and substrate.
(5) Easy connection to the outside by using screw terminals (for power circuit) and connector terminals (for control signal).
(6) Use in high regeneration energy application made possible by built-in dynamic brake circuit.

4. IGBT OUTPUT TYPE INTELLIGENT POWER MODULES SERIES

The rated characteristics of the IGBT output type intelligent power modules are shown in *Table 1*. The modules are shown in *Fig. 3*.

There are three models of IGBT output type intelligent power models for AC 200V input inverter use. A 2nd generation IGBT is used at the inverter section for 20kHz correspondence as shown in the equivalent circuit of Fig. 4. However, a high h_{FE} bipolar transistor is used at dynamic brake circuit which is used only as a switch.

5. BUILT-IN FUNCTIONS

The built-in functions of the new IGBT output type intelligent power modules are shown in *Table 2*.

The built-in functions featured by the devleoped modules are described below.

5.1 Short-circuit protection circuit

The IGBT withstand short-circuit overcurrent for only a short time. Therefore, a circuit system which can detect overcurrents at high speed and protect the device is used with the intelligent power modules.

The principle circuit is shown in *Fig. 5*. A function which monitors the IGBT collector voltage and judges that an overcurrent is flowing when an ON command is input and $V_{CE(sat)}$ is abnormally high is provided.

Figure 6 shows the operating waveforms when the output of the intelligent power module is shorted.

Overcurrent tripping is completed with a sudden current change within 8μs after the output is shorted.

5.2 Overcurrent protection circuit

Besides the short-circuit protection circuit, an over-

Fig. 3 Intelligent power modules

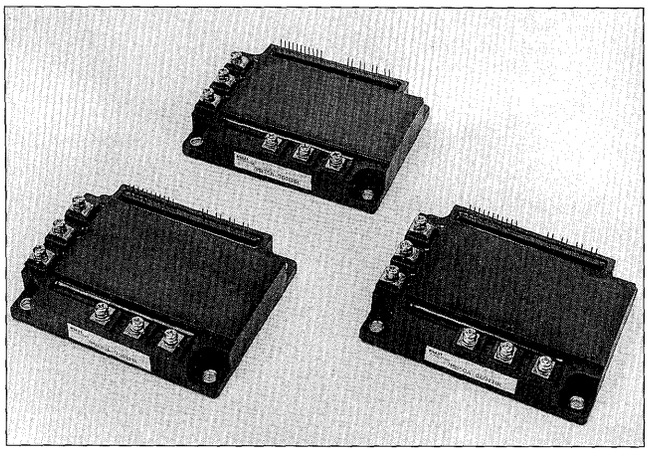


Fig. 4 Intelligent power module equivalent circuit

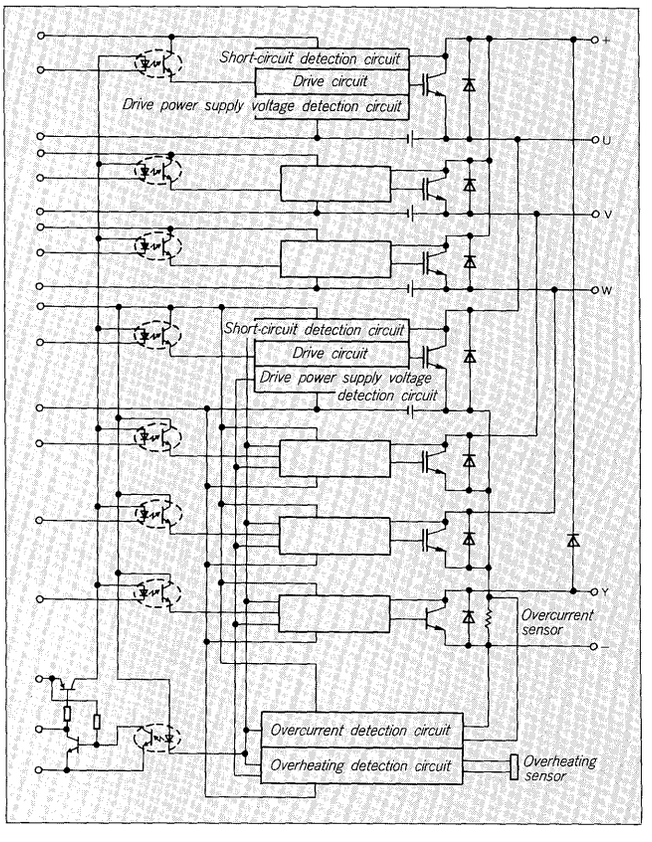


Table 1 Rated characteristics of intelligent power module

Type	Inverter section						Brake section			Predriver		Overheating protection	Overcurrent protection		Short-circuit protection		Alarm output
	V_{cc} (V)	I_c (A)	P_c (W)	t_{on} (μs)	t_{stg} (μs)	t_f (μs)	V_{cc} (V)	I_c (A)	P_c (W)	V_{pd} (V)	I_{pd} (mA)	T_{SD} (°C)	I_{SD} (A)	t_{oc} (μs)	V_{CE} (V)	t_{oc} (μs)	t_{lat} (ms)
7MB30A-060EHR	450	30	150	6	6	0.5	450	20	100	20	50	90	45	50	5	20	10~30
7MB50A-050EHR	450	50	200	6	6	0.5	450	20	100	20	50	90	75	50	5	20	10~30
7MB75A-050EHR	450	75	240	6	6	0.5	450	20	100	20	50	90	113	50	5	20	10~30

V_{pd}: drive voltage, I_{pd}: drive current, T_{SD}: protection start temperature, I_{SD}: protection start current, t_{oc}: tripping time, V_{CE}: protection start voltage, t_{lat}: output pulse width

Table 2 Intelligent power module built-in functions

Element	Built-in function	Number built-in
Power semi-conductor element	IGBT for inverter	6
	High-speed regeneration diode	6
	Brake transistor	1
	Brake regeneration diode	1
Sensor	Overcurrent sensor	1
	Overheating sensor	3
Driver	Forward gate voltage control circuit	7
	Reverse gate voltage control circuit	7
Light isolation	Opto coupler	8
Power supply	Gate reverse bias power supply	4
Detection circuit	Short-circuit detection circuit	6
	Overcurrent detection circuit	1
	Overheating detection circuit	1
	Drive power supply voltage detection circuit	4
Protection and self-test	Latch circuit	1
	Timer	1

Fig. 5 Short-circuit detection principle circuit

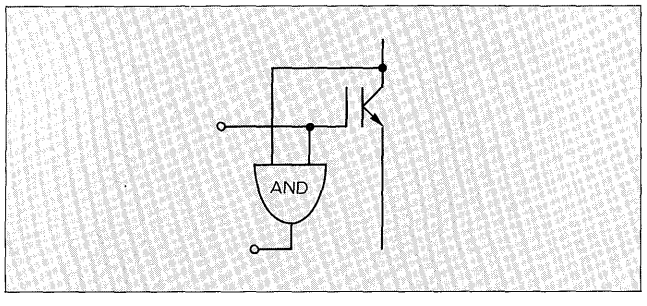
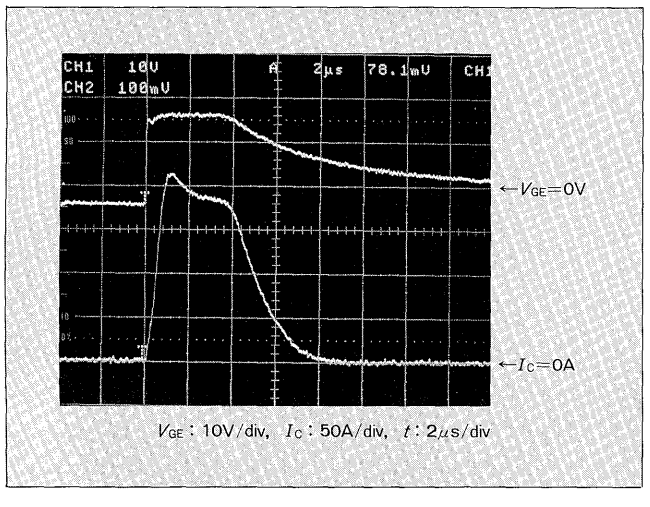


Fig. 6 7MB50A-060EHR output short-circuit protection waveforms



current is also built in.

Since the short-circuit protection circuit described previously is set at each control signal on, off cycle, with only this circuit, overcurrent, etc. in the state in which an overload is applied continuously for a comparatively long time overloads the power chip.

The overcurrent protection circuit operates and locks all the IGBTs in the off state when the power chip current reaches 1.5 times the rated value.

Table 3 Comparison of performances of existing IGBT and 2nd generation IGBT

Item			Existing IGBT	2nd generation IGBT	Units
V_{CES}		Minimum value	600	600	V
$V_{CE(sat)}$		Standard value	3.5	2.8	
		Maximum value	5.0	3.5	
Switching time	t_{on}	Standard value	0.7	0.6	μs
		Maximum value	1.2	0.8	
	t_{off}	Standard value	0.8	0.6	
		Maximum value	1.5	1.0	
	t_f	Standard value	0.4	0.2	
		Maximum value	1.0	0.35	

This off state lock is released after 10ms.

5.3 Power circuit

The newly developed 2nd generation IGBT chip is mounted on the intelligent power module as previously mentioned. The performances of the existing IGBT and 2nd generation IGBT are compared in *Table 3*. The 2nd generation IGBT also has an excellent $V_{CE(sat)}$ and switching time and is more suitable for high frequency switching.

To pull out the performances of the 2nd generation IGBT, the drive circuit uses a high-speed optocoupler at the signal isolation section.

5.4 Other circuits and functions

5.4.1 Overheating protection circuit

Three temperatures sensors are built-in with the phase of each inverter section so that the temperature of each power chip can be detected at good precision.

5.4.2 Alarm function

A function which outputs an alarm signal when the short-circuit protection circuit, overcurrent protection circuit, or overheating protection circuit operates is provided.

This alarm signals are isolated by a optocoupler and isolation processing at the control PC board is unnecessary.

6. CONCLUSION

The Fuji Electric approach to intelligent power module development and the newly developed IGBT output type intelligent power module were described.

We think that the IGBT output type intelligent power module will meet high-speed switching expectations and promote the development of higher performance, smaller, and lighter inverter equipment.

We will promote higher performance and more functional power chips and package improvements and the advance of built-in functions in the future.