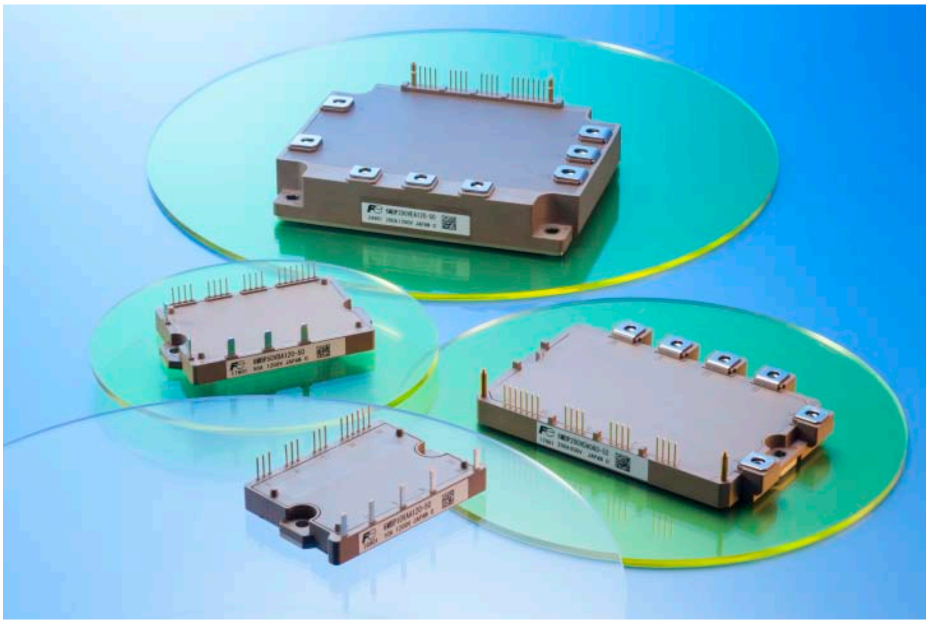
Fuji Electric

Innovating Energy Technology

FUJI IGBT V-IPM
APPLICATION MANUAL



Fuji Electric Co., Ltd.

July 2015
REH985b

URL http: //www.fujielectric.co.jp/products/semiconductor/

CONTENTS

– Chapter 1 –

Features and structure

Table of Contents		Page

1 Features of the V-IPM

An IPM (intelligent power module) is an intelligent IGBT module combining a built-in control IC which includes a drive circuit and a protection circuit. The V-IPM (V-series IPM) has the following features:

1.1 VR-IGBT chip

- Trade-off characteristic between the turn-off switching energy (E_{off}) and the saturation voltage ($V_{ce(sat)}$) is improved by applying the 6th generation IGBT (V-series), so that the total loss is reduced.

1.2 Built-in drive circuit

- Drives the IGBT under the optimized gate control conditions.
- No negative power supply is needed since it has minimum gate impedance between the drive circuit and the IGBT devices.
- Four isolated power supply units are required: one (1) on the lower arm side, three (3) on the upper arm side.

1.3 Built-in protection circuit

- Overcurrent protection (OC), short-circuit protection (SC), controlled power supply under voltage protection (UV), overheat protection (TjOH) and an external alarm output (ALM) are integrated.
- OC and SC are functions to protect the IGBT against breakdown caused by an over current or a load short-circuit. Each IGBT has an on-chip current sensor which can detect the collector current of each IGBT. This feature can protect the IPM module against an over current and a short circuit that may occur in any IGBT.
- UV is the protective function that works against a drive power supply voltage drop. Every control IC has this function.
- TjOH provides a high-speed over temperature protection by using an on-chip temperature sensor.
- ALM sends an alarm signal to the outer peripheral control unit of the IPM when an OC, SC, UV and/or TjOH occur. Additionally the IPM initiates a safe soft stop of the system. *1

  *1 See [Chapter 3 Description of functions] for details of protective functions of each IPM.

1.4 Built-in brake circuit (7in1 IPM)

- A brake circuit can be configured by adding an external resistor that consumes electric power during regeneration.
- The brake circuit has a drive circuit and protection circuit, same as the inverter unit.

1.5 RoHS compliant

- All products of the V-IPM series are compliant with the RoHS directive.

2 Features of the V-IPM by package

2.1 Low power type (P629: 6in1 with lower arm alarm output)

20 A to 50 A for 600V and 10 A to 25 A for 1200V are lined up as the low power type V-IPM.

(P629 package)

- P629 package has a copper base plate with excellent heat dissipation performance.
- Terminal pitch of the control terminals is a standard 2.54 mm (0.1 inch).
- Main terminals are flat type solder pin and the height is the same as the control terminals.
  Therefore, it enables to solder the main terminals and control terminals to the same PCB.

- The IGBT is protected against abnormal overheating by an on-chip temperature sensor. *1
- Over current protection is realized by the on-chip sense IGBT current sensor. *1
- Compatible mounting dimensions with the R-IPM-series P619 package.

  *1 Although the protective function is applied to the upper arm side, but no alarm output function is available for the upper arm.

2.2 Medium-power small-package type (P626: 6in1 with upper and lower arm alarm output)

50A to 75A for 600V and 25A to 50A for 1200V are lined up as the medium-power small-size package type.

(P626 package)

- Terminal pitch of the control input terminals is a 2.54mm (0.1inch) standard pitch.
- Main terminals are flat type solder pin and the height is the same as the control terminals.
  Therefore it enables the main and control terminals to be soldered to the same PCB
- The IGBT is protected against abnormal overheating by an on-chip temperature sensor
- Over current protection is realized by the on-chip sense IGBT current sensor.

2.3 Medium-power thinner package type (P630: 6in1 / 7in1 with upper and lower arm alarm output function)

50A to 200A for 600V and 25A to 100A for 1200V are lined up as the medium-power thinner package type. Additionally, there is a low thermal impedance type for 100A ~ 200A/600V and 50A ~ 100A/1200V.

(P630 package)

- Terminal pitch of the control input terminals is a 2.54mm (0.1inch) standard pitch that can be connected by using a general-purpose connector or by soldering.
  Guide pins assist insertion of a PCB to the IPM.
- Screw size for the main terminals is M4.

- The screw size for mounting to the heat sink is M4, which is the same as the main terminals.
- Solder less connection is also possible for electrical connection (main terminals and control terminals), which facilitates easy disconnection.
- The IGBT is protected against abnormal overheating by an on-chip by the on-chip temperature sensor.
- Over current protection is realized by the on-chip sense IGBT.

2.4 High power type (6in1 / 7in1 with upper and lower arm alarm output function)

200A to 400A for 600V and 100A to 200A for 1200V are lined up as the high power type
(P631 package)

- Main DC bus input terminals (P1, P2, N1, N2), brake terminal (B) and output terminals (U, V, W) are located in proximity to each other and the package structure permits easy main wiring. Terminals P1, P2 and terminals N1, N2 are electrically connected to each other respectively.
- Screw size for the main terminals is M5 which allows large current.
- The screw size for mounting to a heat sink is M5, which is the same size as the main terminals.
- Solder less electrical connection is also possible and it can realize easy disconnection.
- The IGBT is protected against abnormal overheating by an on-chip temperature sensor.
- This package has two different boss heights. The PCB height from the base of the IPM can be set to 17.0 mm or 18.5 mm by changing the boss height (See Figure 1-12).
- Over current protection is realized by the on-chip sense IGBT.
- Mounting dimensions are compatible with the R-IPM-series P612 package products (excluding control terminal positions).

2.5 Medium power small package type (6in1 / 7in1 with upper and lower arm alarm output)

50A to 100A for 600V and 25A to 50A for 1200V are lined up as the medium power type (P636 package)

- Terminal pitch of the control input terminals is a 2.54mm (0.1inch) standard pitch.
- Main terminals are flat type solder pin and the height is the same as the control terminals.
  It enables the main and control terminals to be soldered to the same PCB
- The IGBT is protected against abnormal overheating by an on-chip temperature sensor.
- Over current protection is realized by the on-chip sense IGBT current sensor.

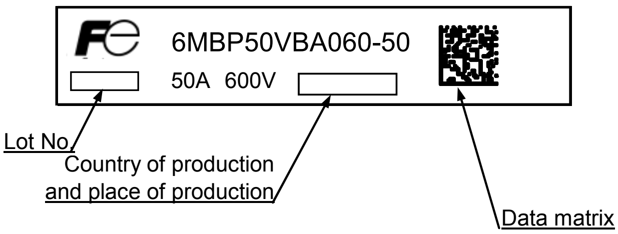
3 Description nomenclature and lot code

- **Type**

6 MBP 50 V B A 060 -50

- -50: Model sequential number (< 50: Non-RoHS, >=50: RoHS)
- 060: Voltage rating
  060: 600 V
  120: 1200 V
- A: Series sequential number
- B: Package
  A: P629
  B: P626
  D: P630
  E: P631
  F: P636
- V: Series name
- 50: Current rating
- MBP: Represents “IGBT-IPM”
- 6: Number of the main IGBT elements
  7: 6 IGBTs with built-in brake
  6: 6 IGBTs without brake

- **Label**



4 Line-up

600V Series

Package / Current rating	P629	P626	P630	P631	P636
20A	6MBP20VAA060-50	-	-	-	-
30A	6MBP30VAA060-50	-	-	-	-
50A	6MBP50VAA060-50	6MBP50VBA060-50	7/6MBP50VDA060-50	-	7/6MBP50VFN060-50
75A	-	6MBP75VBA060-50	7/6MBP75VDA060-50	-	7/6MBP75VFN060-50
100A	-	-	7/6MBP100VDA060-50 7/6MBP100VDN060-50	-	7/6MBP100VFN060-50
150A	-	-	7/6MBP150VDA060-50 7/6MBP150VDN060-50	-	-
200A	-	-	7/6MBP200VDA060-50 7/6MBP200VDN060-50	7/6MBP200VEA060-50	-
300A	-	-	-	7/6MBP300VEA060-50	-
400A	-	-	-	7/6MBP400VEA060-50	-

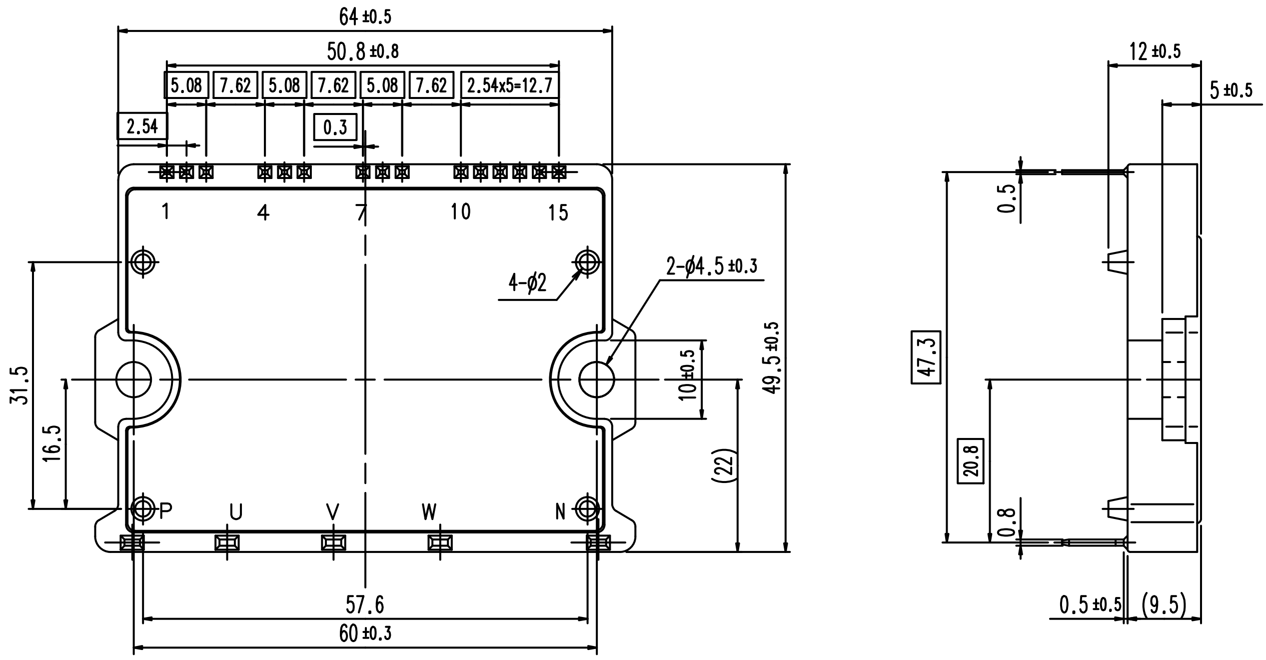
Note) 7/6MBP***VDN060-50 is low thermal resistance version

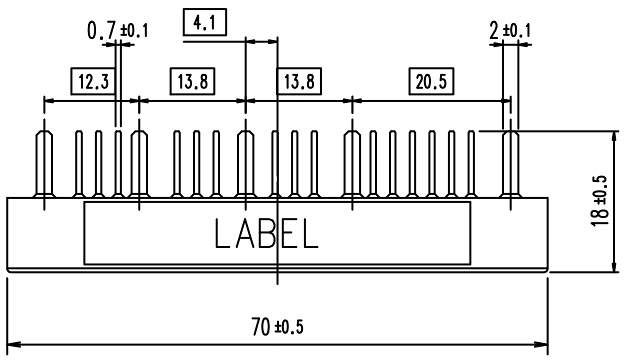
1200V Series

Package / Current rating	P629	P626	P630	P631	P636
10A	6MBP10VAA120-50	-	-	-	-
15A	6MBP15VAA120-50	-	-	-	-
25A	6MBP25VAA120-50	6MBP25VBA120-50	7/6MBP25VDA120-50	-	7/6MBP25VFN120-50
35A	-	6MBP35VBA120-50	7/6MBP35VDA120-50	-	7/6MBP35VFN120-50
50A	-	6MBP50VBA120-50	7/6MBP50VDA120-50 7/6MBP50VDN120-50	-	7/6MBP50VFN120-50
75A	-	-	7/6MBP75VDA120-50 7/6MBP75VDN120-50	-	-
100A	-	-	7/6MBP100VDA120-50 7/6MBP100VDN120-50	7/6MBP100VEA120-50	-
150A	-	-	-	7/6MBP150VEA120-50	-
200A	-	-	-	7/6MBP200VEA120-50	-

Note) 7/6MBP***VDN120-50 is low thermal resistance version

5 Package outlines



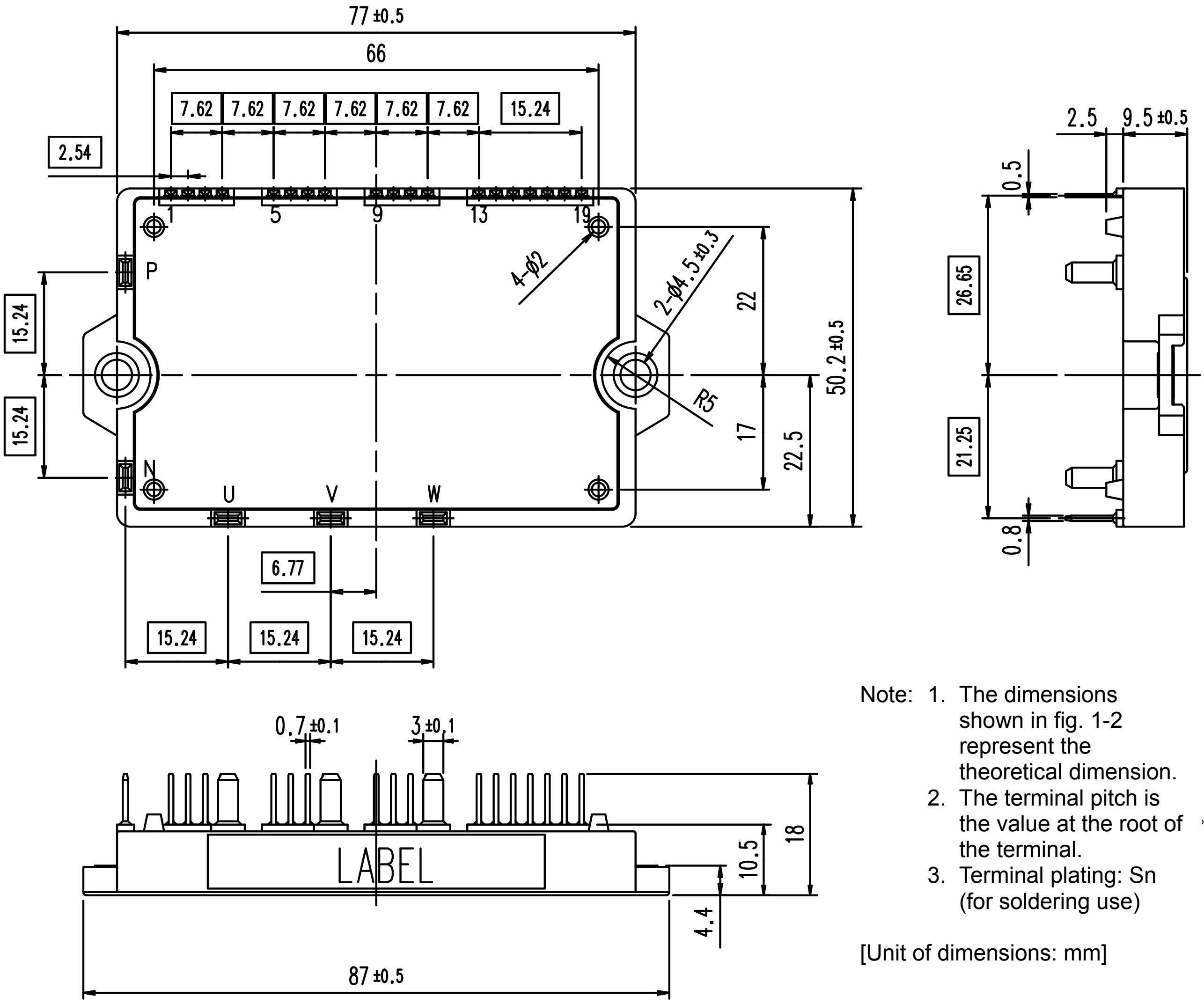


Note:
1. The dimensions shown in fig. 1-1 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Dimensions in brackets are given only for reference.
4. Terminal plating: Sn (for soldering)

[Unit of dimensions: mm]

Figure 1-1 Package outline drawing for P629

Target type: 6MBP20VAA060-50, 6MBP30VAA060-50, 6MBP50VAA060-50,
6MBP10VAA120-50, 6MBP15VAA120-50, 6MBP25VAA120-50

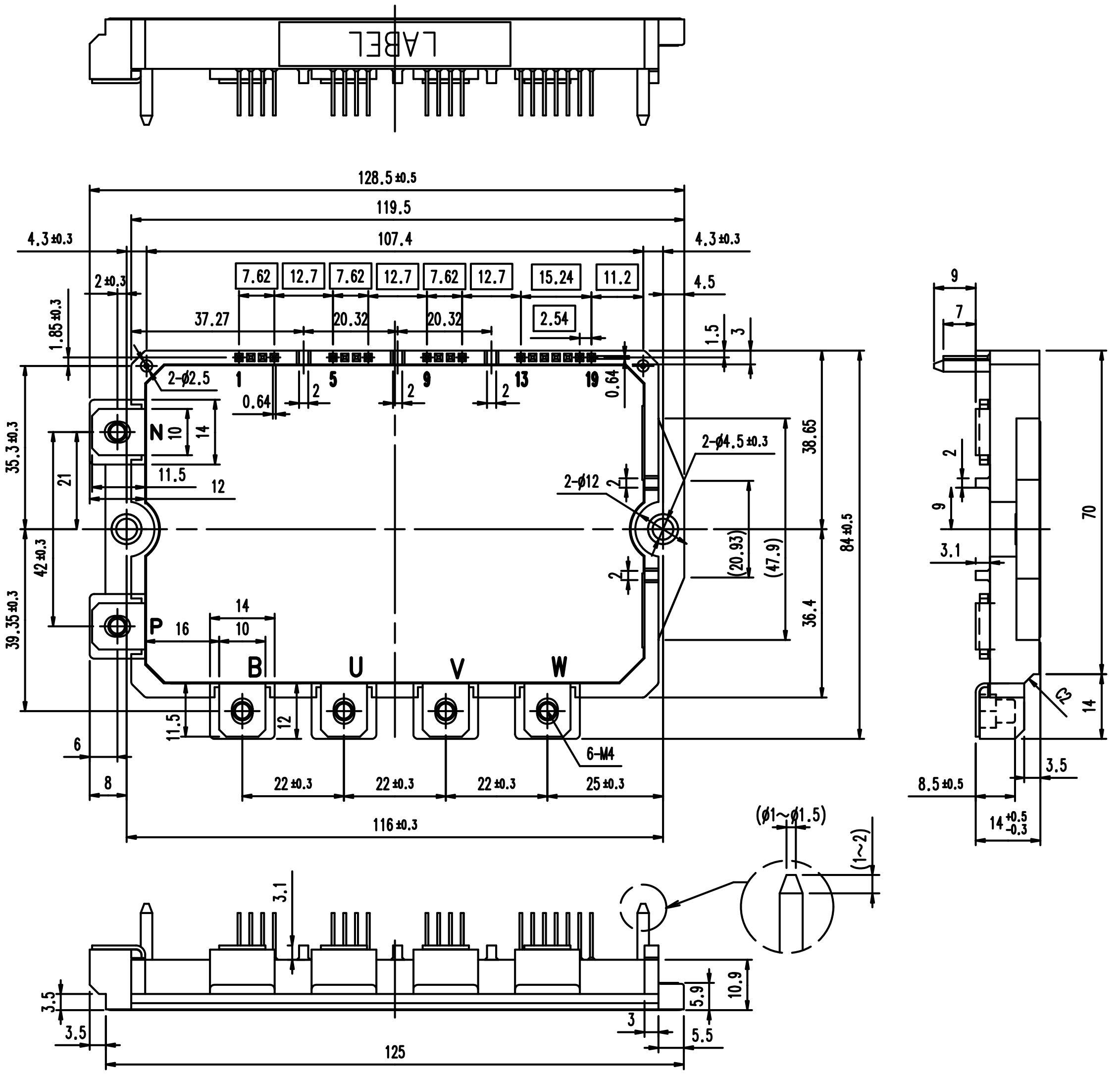


Note: 1. The dimensions shown in fig. 1-2 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Terminal plating: Sn (for soldering use)

[Unit of dimensions: mm]

Figure 1-2 Package outline drawing for P626

Target type: 6MBP50VBA060-50, 6MBP75VBA060-50,
6MBP25VBA120-50, 6MBP35VBA120-50, 6MBP50VBA120-50



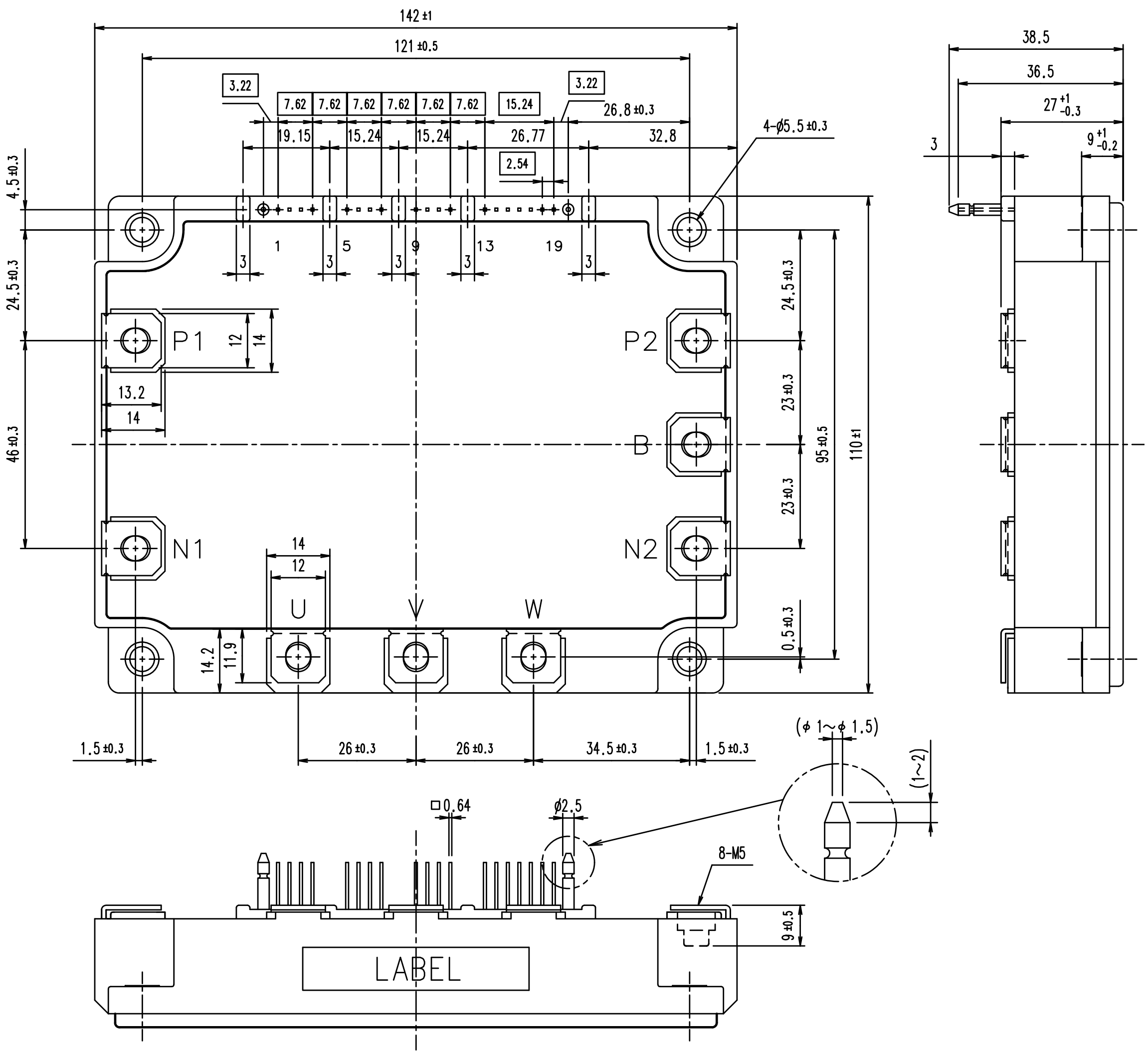
Note:
1. The dimensions shown in fig. 1-3 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Dimensions given in brackets are for reference.
4. Main terminal plating: Ni
   Control terminal plating: Ni plating on the ground, Au plating on the surface.
   (for connector and soldering use)
5. The guide pins located on both sides of a control terminal are made of brass.
   (They are insulated internally and are not connected to any object.)

[Unit of dimensions: mm]

Figure 1-3 Package outline drawing for P630

Target type:

7/6MBP50VDA060-50, 7/6MBP75VDA060-50, 7/6MBP100VDA060-50, 7/6MBP100VDN060-50, 7/6MBP150VDA060-50, 7/6MBP150VDN060-50, 7/6MBP200VDA060-50, 7/6MBP200VDN060-50, 7/6MBP25VDA120-50, 7/6MBP35VDA120-50, 7/6MBP50VDA120-50, 7/6MBP50VDN120-50, 7/6MBP75VDA120-50, 7/6MBP75VDN120-50, 7/6MBP100VDA120-50, 7/6MBP100VDN120-50

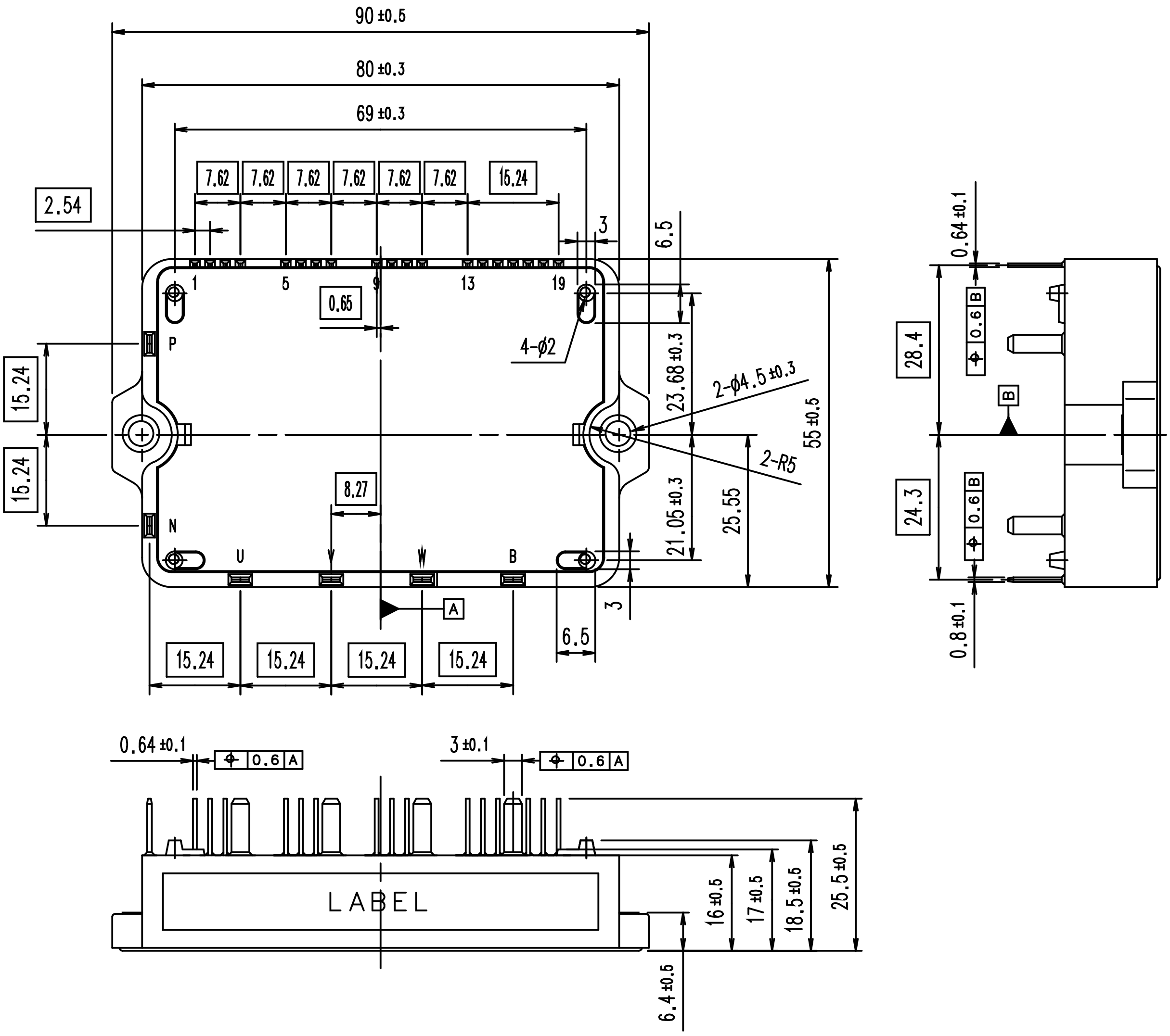


Note: 1. The dimensions shown in fig. 1-4represent the theoretical dimension.
2. The terminal pitch is the dimension measured at the root.
3. Dimensions given in brackets are for reference only.
4. Main terminal plating: Ni
Control terminal plating: Ni plating on the ground, Au plating on the surface.
(for connector rand soldering use)
5. The guide pins located on both sides of a control terminal are made of brass.
(They are insulated internally and are not connected to any object.)

[Unit of dimensions: mm]

Figure 1-4 Package outline drawing for P631

Target type: 7/6MBP200VEA060-50, 7/6MBP300VEA060-50, 7/6MBP400VEA060-50,
7/6MBP100VEA120-50, 7/6MBP150VEA120-50, 7/6MBP200VEA120-50



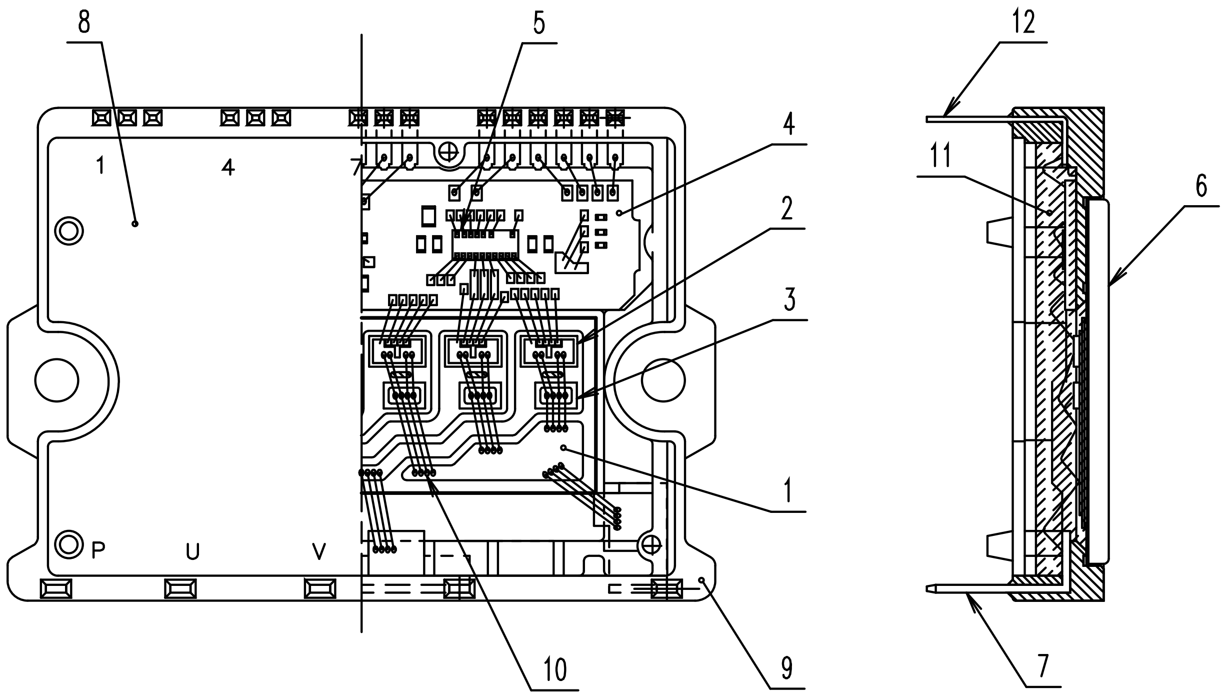
Note:
1. The dimensions shown in fig. 1-5 represent the theoretical dimension.
2. The terminal pitch is the value at the root of the terminal.
3. Terminal plating: Sn (for soldering use)

[Unit of dimensions: mm]

Figure 1-5 Package outline drawing for P636

Target type: 7/6MBP50VFN060-50, 7/6MBP75VFN060-50, 7/6MBP100VFN060-50, 7/6MBP25VFN120-50, 7/6MBP35VFN120-50, 7/6MBP50VFN120-50

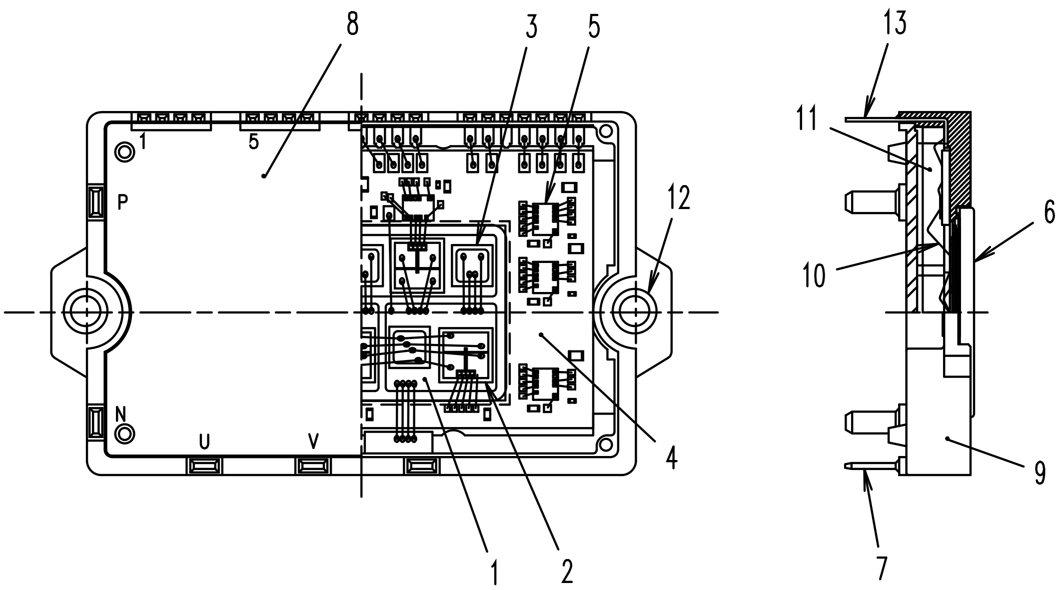
6 Structure



* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

No.	Component	Material (main)	Remarks
1	Isolation substrate	Ceramic	
2	IGBT chip	Silicon	
3	FWD chip	Silicon	
4	Printed Circuit Board (PCB)	Glass reinforced Epoxy resin	Halogen Free
5	IC chip	Silicon	
6	Base Plate	Cu	Ni plating
7	Main Terminal	Cu	Sn plating
8	Lid	PPS resin	UL 94V-0
9	Case	PPS resin	UL 94V-0
10	Wiring	Aluminum	
11	Silicone Gel	Silicone resin	
12	Control Terminal	Brass	Sn plating

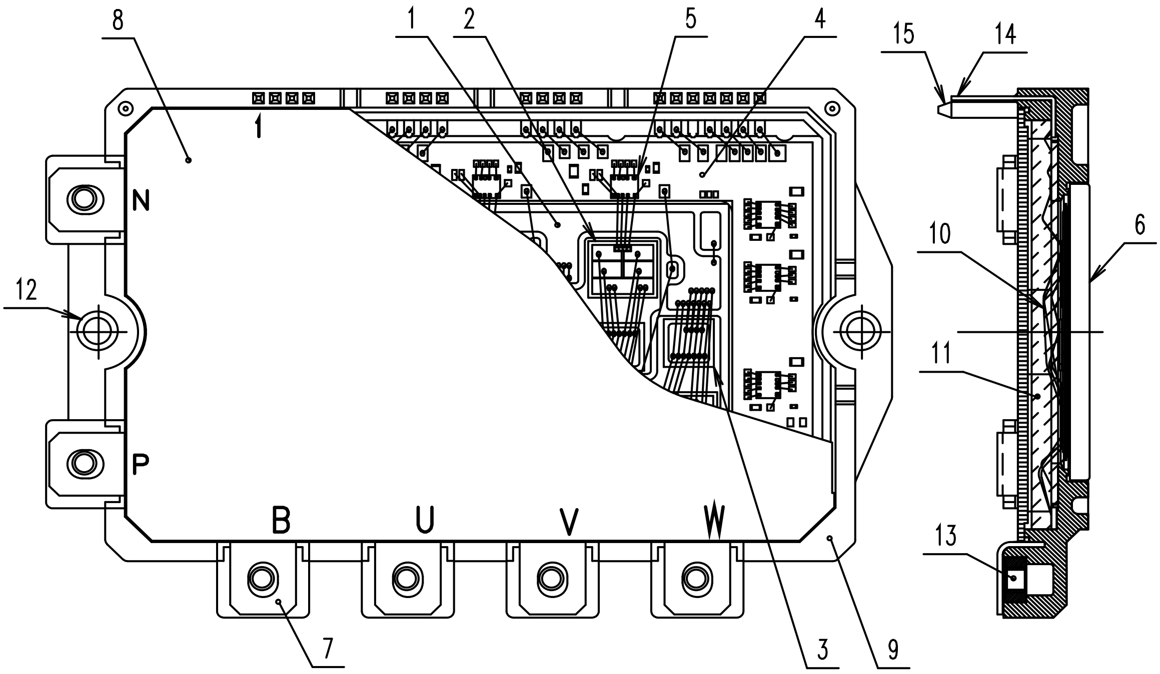
Figure 1-6 Structure and material list (P629)



* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

No.	Component	Material (main)	Remarks
1	Isolation substrate	Ceramic	
2	IGBT chip	Silicon	
3	FWD chip	Silicon	
4	Printed Circuit Board (PCB)	Glass reinforced Epoxy resin	Halogen Free
5	IC chip	Silicon	
6	Base Plate	Cu	Ni plating
7	Main Terminal	Cu	Sn plating
8	Lid	PPS resin	UL 94V-0
9	Case	PPS resin	UL 94V-0
10	Wiring	Aluminum	
11	Silicone Gel	Silicone resin	
12	Ring	SUS	
13	Control Terminal	Brass	Sn plating

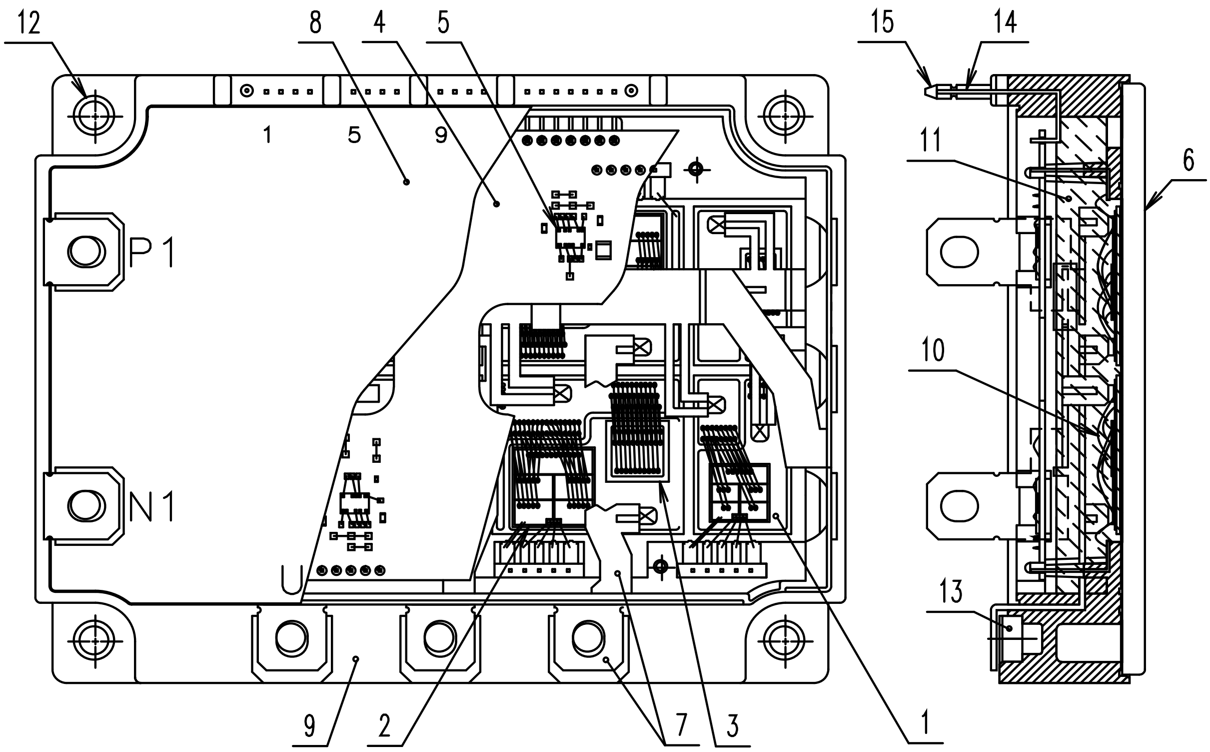
Figure 1-7 Structure and material list (P626)



* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

No.	Component	Material (main)	Remarks
1	Isolation substrate	Ceramic	
2	IGBT chip	Silicon	
3	FWD chip	Silicon	
4	Printed Circuit Board (PCB)	Glass reinforced Epoxy resin	Halogen Free
5	IC chip	Silicon	
6	Base Plate	Cu	Nickel plating
7	Main Terminal	Cu	Surface: Ni plating
8	Lid	PPS resin	UL 94V-0
9	Case	PPS resin	UL 94V-0
10	Wiring	Aluminum	
11	Silicone Gel	Silicone resin	
12	Ring	SUS	
13	Nut	Fe	Trivalent chromate treatment
14	Control terminal	Brass	Au plating on Ni plating
15	Guide pin	Brass	

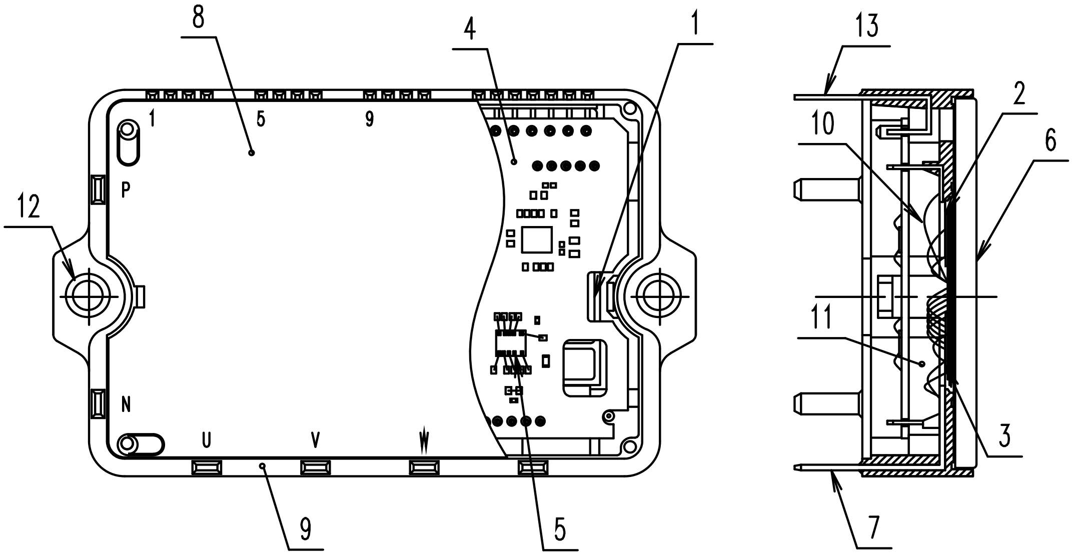
Figure 1-8 Structure and material list (P630)



* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

No.	Component	Material (main)	Remarks
1	Isolation substrate	Ceramic	
2	IGBT chip	Silicon	
3	FWD chip	Silicon	
4	Printed Circuit Board (PCB)	Glass reinforced Epoxy resin	Halogen Free
5	IC chip	Silicon	
6	Base Plate	Cu	Nickel plating
7	Main Terminal	Cu	Surface: Ni plating
8	Lid	PPS resin	UL 94V-0
9	Case	PPS resin	UL 94V-0
10	Wiring	Aluminum	
11	Silicone Gel	Silicone resin	
12	Ring	SUS	
13	Nut	Fe	Trivalent chromate treatment
14	Control terminal	Brass	Au plating on Ni plating
15	Guide pin	Brass	

Figure 1-9 Structure and material list (P631)



* This drawing is prepared for explanation of the material. It does not represent accurate chip size or layout.

No.	Component	Material (main)	Remarks
1	Isolation substrate	Ceramic	
2	IGBT chip	Silicon	
3	FWD chip	Silicon	
4	Printed Circuit Board (PCB)	Glass reinforced Epoxy resin	Halogen Free
5	IC chip	Silicon	
6	Base Plate	Cu	Ni plating
7	Main Terminal	Cu	Sn plating
8	Lid	PPS resin	UL 94V-0
9	Case	PPS resin	UL 94V-0
10	Wiring	Aluminum	
11	Silicone Gel	Silicone resin	
12	Ring	SUS	
13	Control Terminal	Brass	Sn plating

Figure 1-10 Structure and material list (P636)

- **Main terminals of IPM (screw type)**

The structure of the main terminal is shown in Figure 1-9:

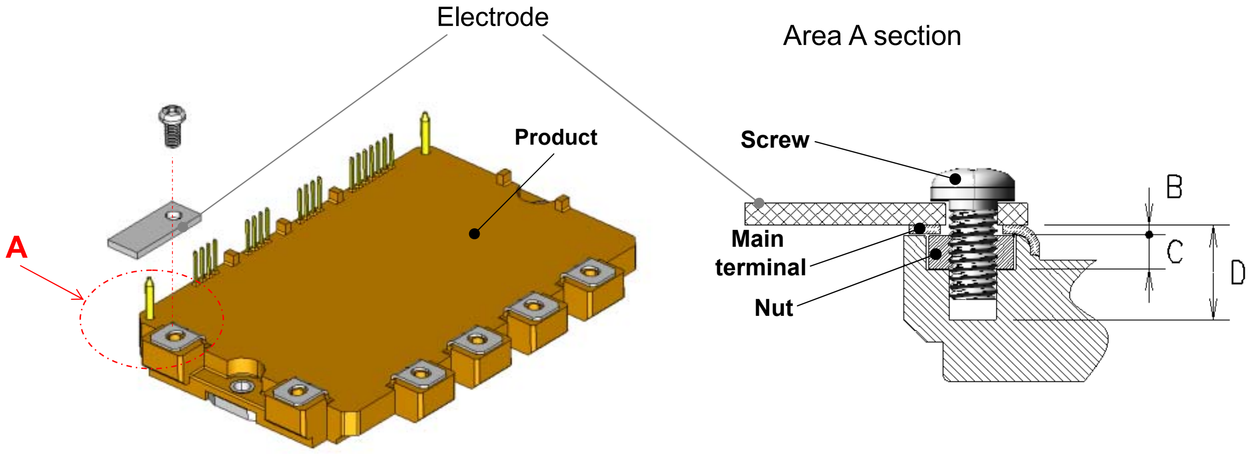


Figure 1-11 Structure of main terminal unit of the IPM (Example: P630)

Table 1-1 Specification for IPM main terminal unit

PKG	Screw standard	Terminal tab thickness (B)	Nut depth (C)	Screw hole depth (D)
P630	M4	0.8	3.5	8.5±0.5
P631	M5	1.0	4.0	9.0±0.5

(Unit: mm)

- **Guide pins of IPM**

The guide pins located on both sides of control terminal portions of P630 and P631 are made of brass. They are insulated in the interior and are not connected to any circuits.

- **Height of boss on lid of P636**

P636 package has two different boss heights (2.5 mm and 1.0 mm) on the lid. The PCB height can be set to 18.5 mm or 17.0 mm by changing the boss height.

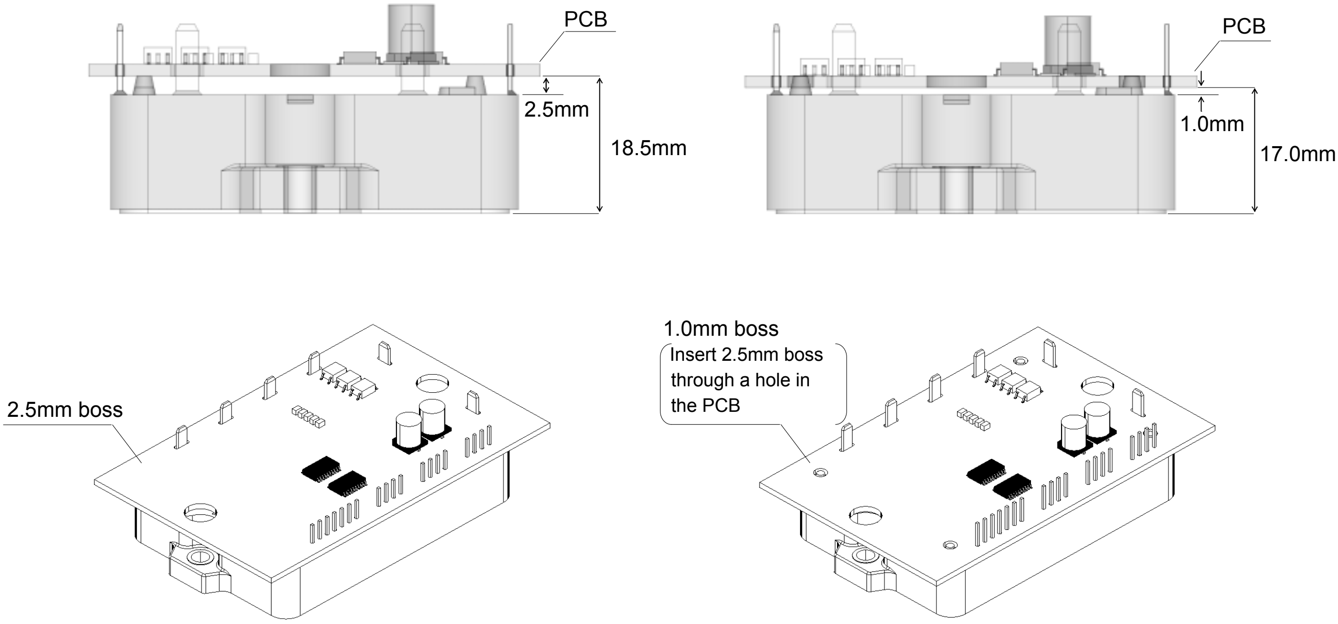


Figure 1-12 Selecting from two different boss heights

– Chapter 2 –

Description of terminal marking and terms

Table of Contents			Page

Fuji Electric
Innovating Energy Technology

1 Descriptions of the I/O terminals

Main terminals

Terminal Name	Description
P (P1, P2) N (N1, N2)	DC-bus terminals after smoothing capacitor P: + side, N: - side
B	Collector terminal of the Brake IGBT. Connect a brake resistor for dissipating regenerated energy
U	3-phase output terminals
V	
W	

* P1, P2, N1 and N2 terminals are P631 package only.

Control terminals

Terminal Name	P629 Pin#	P626, P630, P636 Pin#	P631 Pin#	Description
GND U	1	1	1	Ground reference for the U-arm control power supply
Vcc U	3	4	3	U-arm control power supply positive terminal
Vin U	2	3	2	U-arm control signal input
ALM U	-	2	4	U-arm alarm signal output
GND V	4	5	5	Ground reference for the V-phase control power supply
Vcc V	6	8	7	V-arm control power supply positive terminal
Vin V	5	7	6	V-arm control signal input
ALM V	-	6	8	V-arm alarm signal output
GND W	7	9	9	Ground reference for the W-phase control power supply
Vcc W	9	12	11	W-arm control power supply positive terminal
Vin W	8	11	10	W-arm control signal input
ALM W	-	10	12	W-arm alarm signal output
GND	10	13	13	Ground reference for the lower arm control power supply
Vcc	11	14	14	Control power supply positive terminal for the lower arm
Vin X	12	16	16	X-arm control signal input
Vin Y	13	17	17	Y-arm control signal input
Vin Z	14	18	18	Z-arm control signal input
Vin DB	-	15	15	DB-arm control signal input
ALM	15	19	19	Lower-arm alarm signal output

* Pin (15) of P626 is of no contact.

* Pin (15) of each of P631 (6in1), P630 (6in1) is of no contact.

2 Description of terms

2.1 Absolute maximum rating

Term		Symbol	Description
DC power supply voltage		V_{DC}	Maximum DC bus voltage between the P and N terminal
DC power supply voltage at short circuit		V_{SC}	Maximum DC bus voltage between the P and N terminal during short-circuit protection and over current protection
Collector-Emitter blocking voltage		V_{CES}	Maximum voltage between the collector and emitter terminal of the built-in IGBT, and peak inverse voltage of the FWD.
Collector current		I_C	Maximum DC collector current for each IGBT
		I_{CP}	Maximum peak collector current for each IGBT
		$-I_C$	Maximum DC forward current for each FWD
Diode forward current for DB		I_F	Maximum DC forward current for FWD in brake circuit
Collector loss		P_C	Maximum power dissipation for each IGBT at Tc=25°C, Tj≤150°C
Control power supply voltage		V_{CC}	Maximum voltage between the V_{CC} and GND terminal
Input voltage		Vin	Maximum voltage between the Vin and GND terminal
Alarm voltage		V_{ALM}	Maximum voltage between the ALM and GND terminal
Chip junction temperature		T_j	Maximum IGBT/FWD chip junction temperature during continuous operation
Case temperature during operation		T_{opr}	Allowable case temperature range during operation (measured point of the case temperature Tc is shown in Figure 5-4)
Storage temperature		T_{stg}	Allowable ambient temperature during storage or transportation without being subject to electrical load.
Soldering temperature		T_{sol}	Maximum temperature for soldering the terminals to a PCB
Isolation voltage		V_{iso}	Maximum RMS isolation of sinusoidal voltage between all the terminals and heat sink (all terminals are shorted)
Screw torque	Terminal	-	Maximum screw torque for the main terminal with specified screw
	Mounting	-	Maximum screw torque for mounting the IPM on heat sink with specified screw

2.2 Electrical characteristics

2.2.1 Main circuit

Term	Symbol	Description
Collector-Emitter leakage current	I_{CES}	Leakage current when specified voltage is applied between the collector and emitter and all input signals are "H" (=all IGBTs are turned-off).
Collector-Emitter saturation voltage	$V_{CE(sat)}$	Voltage drop between the collector and emitter when gate input signal is "L" (=IGBT is turned-on)
Diode forward voltage	V_F	Voltage drop across the diode at defined forward current at input signal is "H" (=IGBT is turned of)
Turn-on time	t_{on}	Time interval between the moment when gate input voltage has exceed Vinth(on) and the collector current has increased to 90% of the load current. (see Figure 2-1)
Turn-off time	t_{off}	Time interval between the moment when the gate input voltage has dropped less than Vinth(off) and the corrector current drops to 10% of the load current. If the collector dropping waveform is not a straight line, a tangential line is used as the substitute (see Figure 2-1)
Fall time	t_f	Time interval the collector current decreased from 90% to 10% of the load current
Reverse recovery time	t_{rr}	Time interval between the moment when the collector current exceeds 100% of the load current and the reverse recovery current disappears
Dead time	t_{dead}	Time delay of the turn-on signal from the alternate IGBT turn-off signal.

2.2.2 Control circuit

Term	Symbol	Description
Control power supply consumption current	I_{CCP}	Current flows into V_{CC} terminal of upper arm control power supply
	I_{CCN}	Current flows into V_{CC} terminal of lower arm control power supply
Input threshold voltage	$V_{inth(on)}$	Voltage above which considerable the control IC can detect the input signal as ON
	$V_{inth(off)}$	Voltage below which considerable the control IC can detect the input signal as OFF

2.2.3 Protection circuit

Term	Symbol	Description
Over current protection current	I_{CCP}	Current flows into the V_{CC} terminal of upper arm control power supply
Over current interruption lag time	t_{doc}	Lag time since the over current reaches the trip level until the protection start. See Figure 2-3
Short-circuit protection current	I_{SC}	Threshold current for short-circuit protection
Short-circuit protection lag time	t_{SC}	Lag time since the short circuit current reaches the trip level until the protection start. See Figure 2-4
Chip over heat protection temperature	T_{jOH}	Threshold junction temperature for overheat protection
Chip over heat protection hysteresis	T_{jH}	Lower hysteresis offset temperature to reactivate after the over temperature protection
Control power supply under voltage protection voltage	V_{UV}	Trip voltage to start under-voltage protection
Control power supply under voltage protection hysteresis	V_H	Higher threshold offset voltage to reactivate after the low voltage protection
Alarm output hold time	$t_{ALM(OC)}$	Alarm signal pulse width of the overcurrent protection (OC)
	$t_{ALM(UV)}$	Alarm signal pulse width of under the voltage protection (UV)
	$t_{ALM(TjOH)}$	Alarm signal pulse width of the overheat protection (TjOH)
Alarm output resistance	R_{ALM}	Value of the built-in resistance that is connected in series to alarm terminals. It limits the primary forward current of opto-coupler.

2.3 Thermal characteristics

Term	Symbol	Description
Thermal resistance between chip and case	$R_{th(j-c)Q}$	Thermal resistance between the case and IGBT chip
	$R_{th(j-c)D}$	Thermal resistance between the case and FWD chip
Thermal resistance between case and heat sink	$R_{th(c-f)}$	Thermal resistance between the case and heat sink at the condition
Case temperature	T_C	IPM case temperature (bottom surface of the cupper base plate directly under the chip)

2.4 Noise tolerance

Term	Symbol	Description
Common mode	-	Common mode noise tolerance in our test circuit

2.5 Others

Term	Symbol	Description
Mass	Wt	Mass of the IPM
Switching frequency	f_{SW}	Allowable switching frequency for the control signals to the input terminals.
Reverse recovery current	I_{rr}	Peak value of the reverse recovery current. See Figure 2-1.
Reverse bias safe operating area	RBSOA	The area of the voltage and current which the device can operate without self-damage during turn-off switching. There is a possibility to brake down when voltage or current exceed the area.
Switching loss	E_{on}	Dissipated switching energy of the IGBT during turn-on
	E_{off}	Dissipated switching energy of the IGBT during turn-off
	E_{orr}	Dissipated switching energy of the FWD during reverse recovery
Inverse voltage	V_R	Repetitive reverse peak voltage of the FRD chip in the brake unit
Input current	I_{in}	Maximum current into the Vin terminals

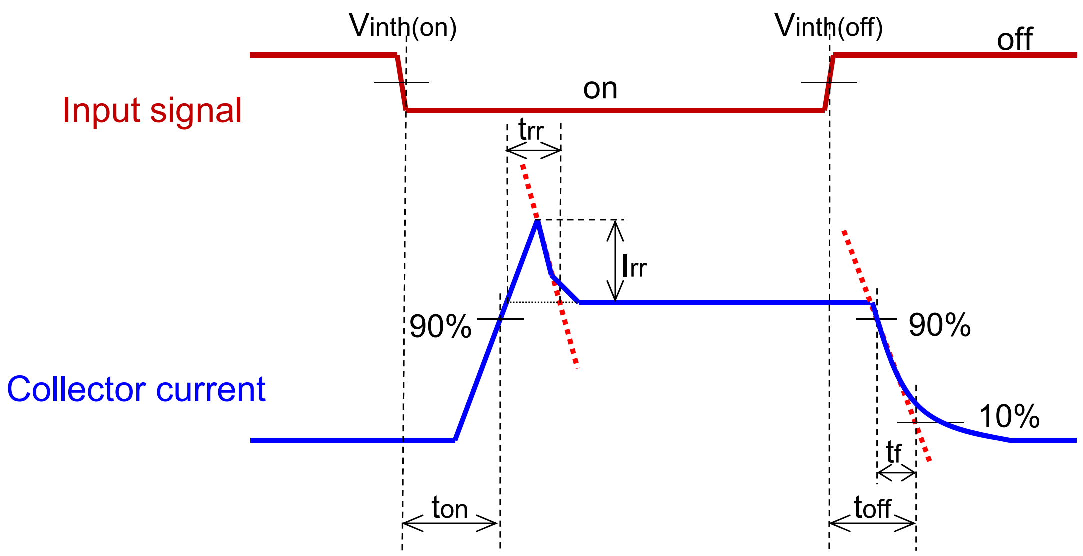


Figure 2-1 Switching times

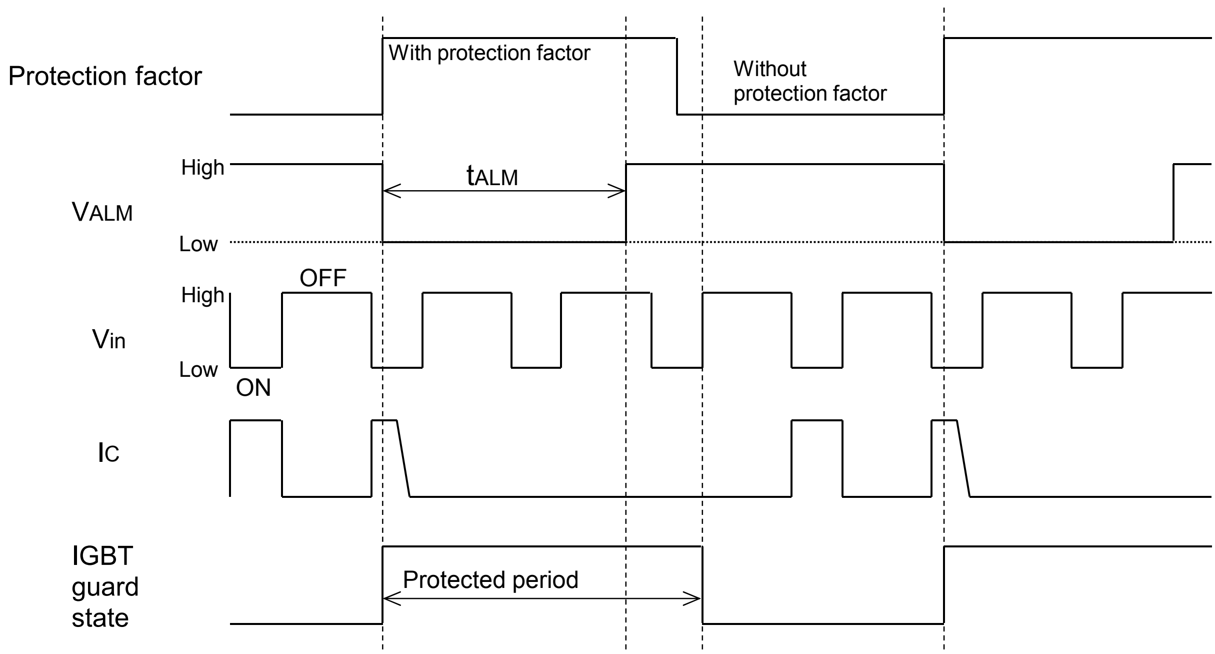


Figure 2-2 Input/output timing diagram

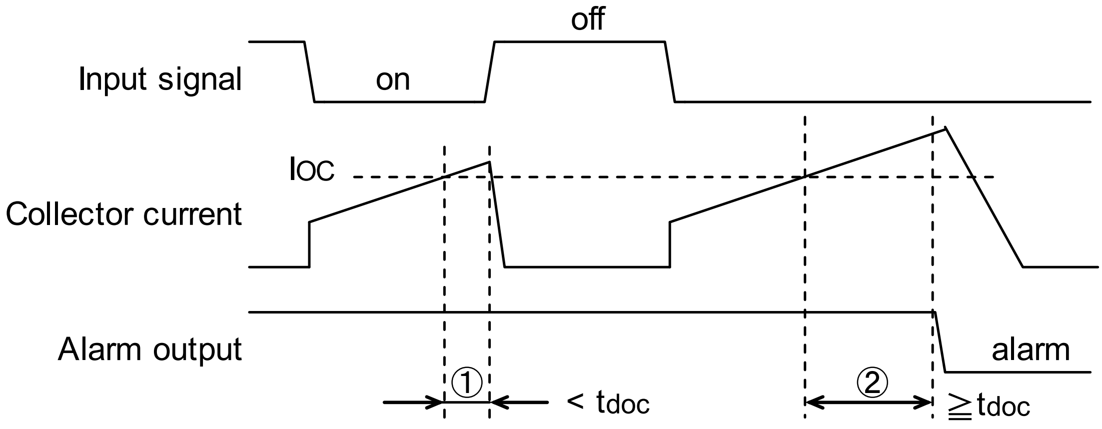


Figure 2-3 Overcurrent interruption lag time (t_{doc})

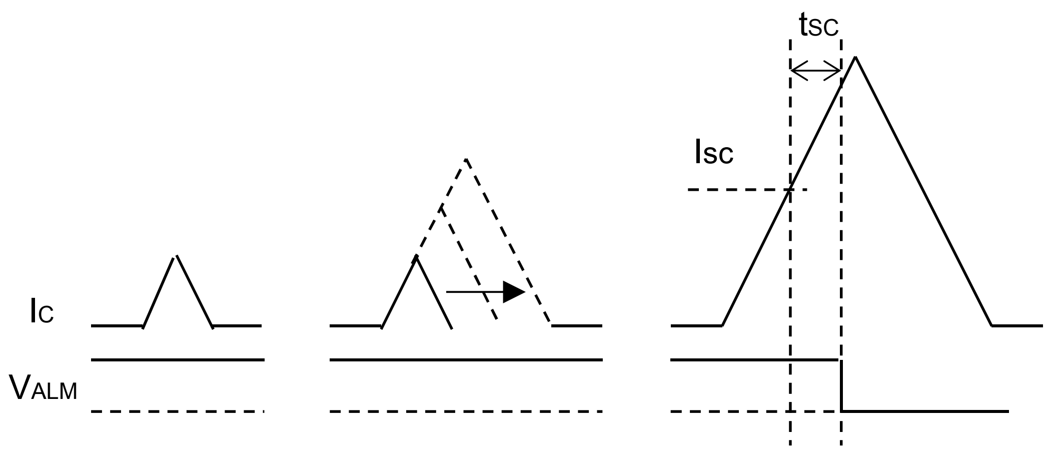


Figure 2-4 Short-circuit protection lag time (t_{sc})

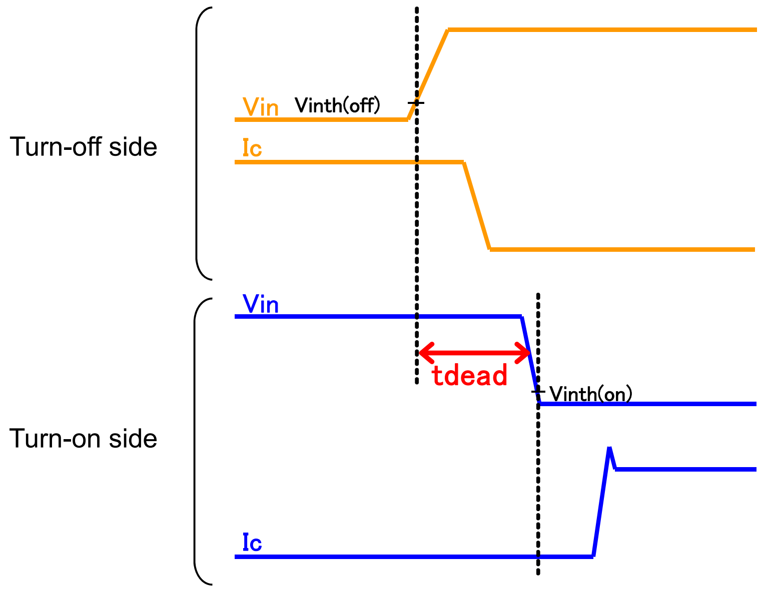


Figure 2-5 Dead time (t_{dead})

– Chapter 3 –

Description of functions

Table of Contents			Page

1 List of functions

The built-in protection functions in the V-IPM are shown in Tables 3-1 and 3-2.

Table 3-1 IPM built-in functions, 600 V-series

Number of Switch	Type Name	Built-in Function						Package
		Upper and Lower arms				Upper arm	Lower arm	
		Drive	UV	TjOH	OC / SC	ALM	ALM	
6 in 1	6MBP20VAA060-50	○	○	○	○	-	○	P629
	6MBP30VAA060-50	○	○	○	○	-	○	
	6MBP50VAA060-50	○	○	○	○	-	○	
	6MBP50VBA060-50	○	○	○	○	○	○	P626
	6MBP75VBA060-50	○	○	○	○	○	○	
	6MBP50VDA060-50	○	○	○	○	○	○	P630
	6MBP75VDA060-50	○	○	○	○	○	○	
	6MBP100VDA060-50	○	○	○	○	○	○	
	6MBP100VDN060-50	○	○	○	○	○	○	
	6MBP150VDA060-50	○	○	○	○	○	○	
	6MBP150VDN060-50	○	○	○	○	○	○	
	6MBP200VDA060-50	○	○	○	○	○	○	
	6MBP200VDN060-50	○	○	○	○	○	○	
	6MBP200VEA060-50	○	○	○	○	○	○	P631
	6MBP300VEA060-50	○	○	○	○	○	○	
	6MBP400VEA060-50	○	○	○	○	○	○	
	6MBP50VFN060-50	○	○	○	○	○	○	P636
	6MBP75VFN060-50	○	○	○	○	○	○	
	6MBP100VFN060-50	○	○	○	○	○	○	
7 in 1	7MBP50VDA060-50	○	○	○	○	○	○	P630
	7MBP75VDA060-50	○	○	○	○	○	○	
	7MBP100VDA060-50	○	○	○	○	○	○	
	7MBP100VDN060-50	○	○	○	○	○	○	
	7MBP150VDA060-50	○	○	○	○	○	○	
	7MBP150VDN060-50	○	○	○	○	○	○	
	7MBP200VDA060-50	○	○	○	○	○	○	
	7MBP200VDN060-50	○	○	○	○	○	○	
	7MBP200VEA060-50	○	○	○	○	○	○	P631
	7MBP300VEA060-50	○	○	○	○	○	○	
	7MBP400VEA060-50	○	○	○	○	○	○	
	7MBP50VFN060-50	○	○	○	○	○	○	P636
	7MBP75VFN060-50	○	○	○	○	○	○	
	7MBP100VFN060-50	○	○	○	○	○	○	

Drive: IGBT drive circuit, UV: Control power supply under voltage protection, TjOH: Chip temperature overheat protection, OC: Overcurrent protection, SC: Short-circuit protection, ALM: Alarm signal output

Table 3-2 IPM built-in functions, 1200 V-series

Number of Switch	Type Name	Built-in Function						Package
		Upper and Lower arms				Upper arm ALM	Lower arm ALM	
		Drive	UV	TjOH	OC / SC			
6 in 1	6MBP10VAA120-50	○	○	○	○	-	○	P629
	6MBP15VAA120-50	○	○	○	○	-	○	
	6MBP25VAA120-50	○	○	○	○	-	○	
	6MBP25VBA120-50	○	○	○	○	○	○	P626
	6MBP35VBA120-50	○	○	○	○	○	○	
	6MBP50VBA120-50	○	○	○	○	○	○	
	6MBP25VDA120-50	○	○	○	○	○	○	P630
	6MBP35VDA120-50	○	○	○	○	○	○	
	6MBP50VDA120-50	○	○	○	○	○	○	
	6MBP50VDN120-50	○	○	○	○	○	○	
	6MBP75VDA120-50	○	○	○	○	○	○	
	6MBP75VDN120-50	○	○	○	○	○	○	
	6MBP100VDA120-50	○	○	○	○	○	○	
	6MBP100VDN120-50	○	○	○	○	○	○	
	6MBP100VEA120-50	○	○	○	○	○	○	P631
	6MBP150VEA120-50	○	○	○	○	○	○	
	6MBP200VEA120-50	○	○	○	○	○	○	
	6MBP25VFN120-50	○	○	○	○	○	○	P636
	6MBP35VFN120-50	○	○	○	○	○	○	
	6MBP50VFN120-50	○	○	○	○	○	○	
7 in 1	7MBP25VDA120-50	○	○	○	○	○	○	P630
	7MBP35VDA120-50	○	○	○	○	○	○	
	7MBP50VDA120-50	○	○	○	○	○	○	
	7MBP50VDN120-50	○	○	○	○	○	○	
	7MBP75VDA120-50	○	○	○	○	○	○	
	7MBP75VDN120-50	○	○	○	○	○	○	
	7MBP100VDA120-50	○	○	○	○	○	○	
	7MBP100VDN120-50	○	○	○	○	○	○	
	7MBP100VEA120-50	○	○	○	○	○	○	P631
	7MBP150VEA120-50	○	○	○	○	○	○	
	7MBP200VEA120-50	○	○	○	○	○	○	
	7MBP25VFN120-50	○	○	○	○	○	○	P636
	7MBP35VFN120-50	○	○	○	○	○	○	
	7MBP50VFN120-50	○	○	○	○	○	○	

Drive: IGBT drive circuit, UV: Control power supply under voltage protection, TjOH: Chip temperature overheat protection, OC: Overcurrent protection, SC: Short-circuit protection, ALM: Alarm signal output

2 Description of functions

2.1 IGBT and FWD for 3-phase inverter

The V-IPM has a 3-phase bridge circuit which consists of six IGBTs and six FWDs as shown in Figure 3-1. The main circuit is completed when the main DC bus power supply line is connected to the P and N terminals and the 3-phase output line is connected to the terminals U, V and W. Connect a snubber circuit to suppress the surge voltage.

2.2 IGBT and FWD for brake

IGBT and FWD for brake circuit are integrated in the V-IPM (7in1 of P630 and P631 series). The collector terminal of the IGBT is connected to the output terminal B as shown in Figure 3-1. The regenerative energy during deceleration is consumed by the resistor which is connected between terminal P and B. Voltage rise between terminals P and N can be suppressed by switching the brake IGBT.

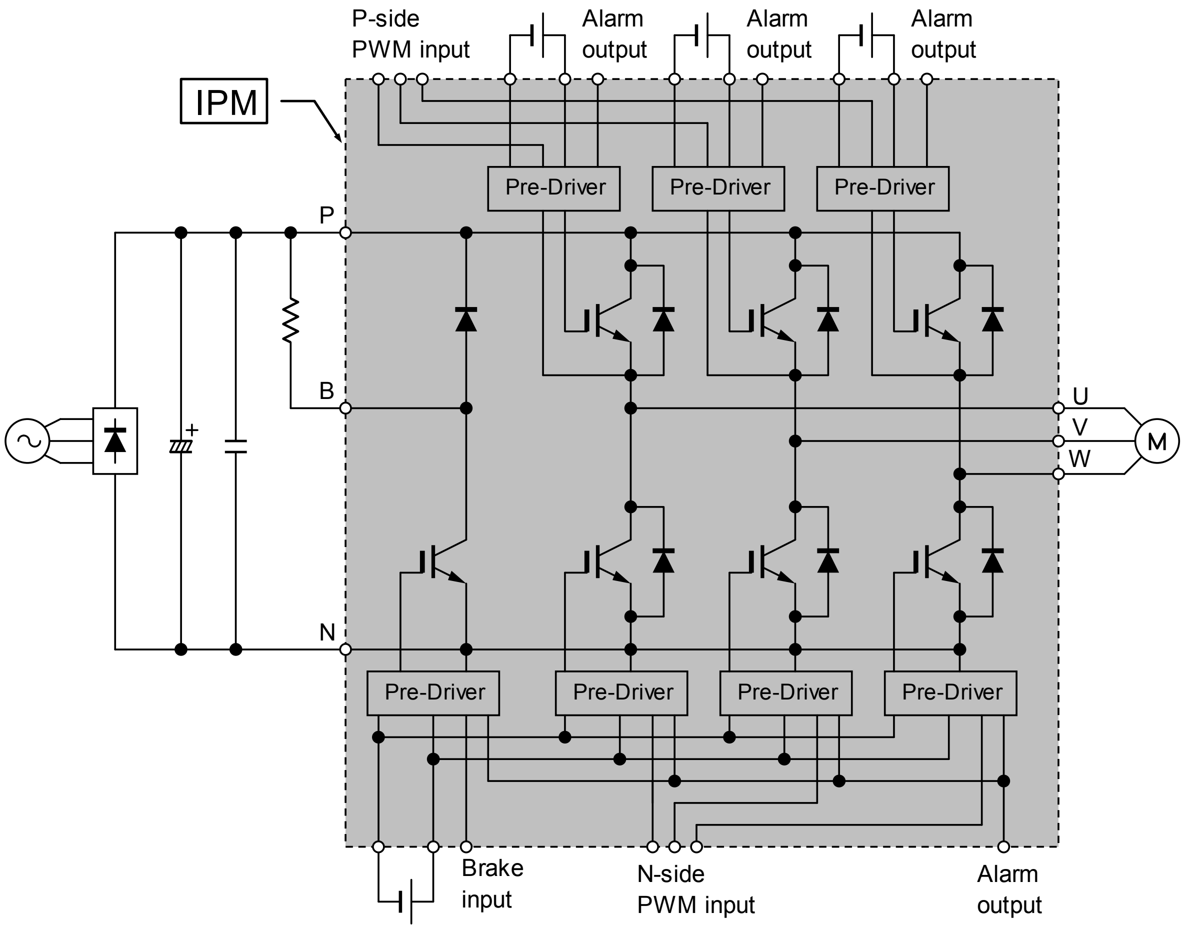


Figure 3-1 Typical application of 3-phase inverter (Example: 7MBP200VDA060-50 with built-in brake)

2.3 IGBT drive function

Figure 3-2 shows a block diagram of the Pre-Driver. The V-IPM has a built-in gate drive circuit for the IGBT and it is possible to drive the IGBT by inputting an opto-isolated control signal to the V-IPM without designing the gate resistance value.

The features of this drive function are introduced below:

□ Independent turn-on and turn-off control

The V-IPM has an independent gate drive circuits for turn-on and turn-off of the IGBT instead of a single gate resistance. The drive circuits control the dv/dt of turn-on and turn-off independently and maximize the performance of the device.

□ Soft shutoff

The gate voltage is gradually reduced at the occasion of the IGBT shutoff when the protection function is activated in various kinds of abnormal modes. The soft shutoff suppresses the surge voltage during the turn-off and prevents the breakdown of the device.

□ Prevention of false turn-on

The gate electrode of the IGBT is connected to the grounded emitter with low impedance. It prevents false turn-on of the IGBT due to the increase of the V_{GE} due to noise or other cause.

□ No reverse bias power supply is necessary

The wiring length between the control IC and the IGBT in the V-IPM are short and the wiring impedance is small, therefore the V-IPM can be driven without reverse bias.

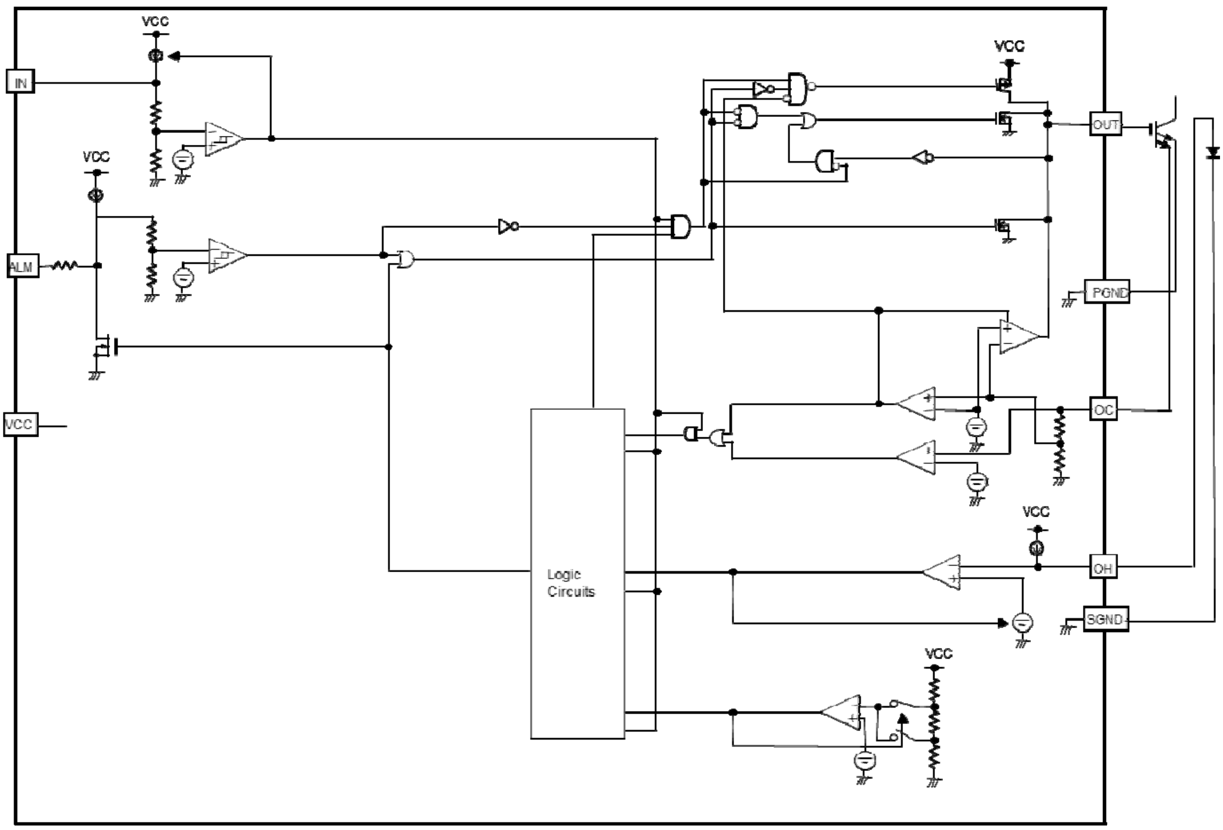


Figure 3-2 Pre-Driver block diagram (Example: 7MBP200VDA060-50)

2.4 Protective functions

The V-IPM has protection circuits which prevent failures of the IPM caused by an abnormal mode. The V-IPM has four kind of protective functions; OC (overcurrent protection), SC (short-circuit protection), UV (control power supply under voltage protection) and TjOH (chip temperature overheat protection).

When a protective function is activated, the MOSFET for alarm output is turned on and the alarm output terminal voltage changes from High to Low. The alarm output terminal becomes conductive to GND. Furthermore, since a 1.3 kΩ resistance is connected in series between the control IC and the alarm output terminal, an opto-coupler that is connected between the ALM terminal and the Vcc terminal can be driven directly.

□ Alarm signal output function

When the protected operation is activated, the IGBT is not turned on even when an ON signal is input. The failure mode is identified and the IGBT goes through soft shutoff. The alarm signal can be output from the phase that detected the failure mode individually.

- After the elapse of t_{ALM} from the alarm signal output the input signal will be OFF then the protection operation is stopped and normal operation is restarts.

- Even in case the alarm factor is dissolved within the alarm signal output period (t_{ALM}), the protected operation continues during the alarm signal output period (t_{ALM}), and accordingly, the IGBT is not turned on.

  Furthermore, the alarm circuits for the lower arm devices including brake circuit are connected mutually. If protection operation occurs on the lower arm side, all the IGBTs of the lower arms are turned off during the protection operation.

* P629 package has protective functions on both of the upper arm and the lower arm devices, but the upper arm devices do not have an alarm signal output function. The lower arm devices have both, the protective functions and alarm signal output function.

□ Alarm factor identification function

As the alarm signal output period (t_{ALM}) varies in correspondence to the failure mode, the failure mode can be identified by measuring the alarm signal pulse width.

Alarm factor	Alarm signal output period (t_{ALM})
Overcurrent protection (OC) Short-circuit protection (SC)	2 ms (typ.)
Control power supply under voltage protection (UV)	4 ms (typ.)
Chip temperature overheat protection (TjOH)	8 ms (typ.)

However, the pulse width of the alarm signal output through an optocoupler varies by the influence of a time delay of the optocoupler and other peripheral circuits. It is necessary to take these influences into account in your design.

2.5 Overcurrent protection function: Over Current (OC)

The IGBT's forward collector current is measured by the current sense IGBT built in the IGBT chip. When the forward collector current exceeds the protection level (I_{OC}) and continues longer than tdoc (typ. 5 μs), it is judged as being in the OC status and the IGBT is turned off to prevent occurrence of breakdown by the overcurrent. At the same time, an alarm signal is provided. The OC status alarm signal period (t_{ALM}) is 2 ms.

- Protection operation is stopped and normal operation is restarted if the current level is lower than the I_{OC} level and the input signal is OFF after 2 ms (t_{ALM}) of the alarm signal output.
- Even in case the current level goes back to below the I_{OC} within the 2 ms (t_{ALM}), the protection operation continues until the end of the period of 2 ms (t_{ALM}) elapses and accordingly the IGBT is not turned on.

2.6 Short-circuit protective function: Short Circuit (SC)

The SC protective function prevents the IPM form being damaged by the peak current during load short-circuit and arm short-circuit. When the IGBT's forward collector current exceeds the protection level (I_{SC}) and continues longer than tdsc, it is judged as being in the SC status and the protective function is activated then the IGBT is softly turned off to prevent occurrence of breakdown by short-circuit. At the same time an alarm signal is output. The SC status alarm signal output period (t_{ALM}) is 2 ms.

- Protection operation is stopped and normal operation is resumed if the current level is lower than the I_{SC} level and the input signal is OFF after 2 ms (t_{ALM}) of the alarm signal output.
- Even in case that the short circuit disappears within 2 ms (t_{ALM}), the protective operation continues until the period of 2 ms (t_{ALM}) elapses and accordingly the IGBT is not turned on.

2.7 Control power supply under voltage protection function (UV)

The UV protective function prevents malfunction of the control IC caused by a voltage drop of the control power supply voltage (V_{CC}) and thermal breakdown of the IGBT caused by increase of the V_{CE} (sat) loss. When V_{CC} is continuously below the voltage protection trip level (V_{UV}) for a period of 20 μs, it is judged as being in the UV status and the IGBTs are softly turned off to prevent malfunction and breakdown caused by the control power supply voltage drop. When it is judged as being in the UV status, the protective function is activated and the alarm signal is generated. The alarm signal output period (t_{ALM}) of the UV protection is 4 ms.

- As hysteresis V_H is provided, protection operation is stopped and normal operation is resumed, if V_{CC} is higher than (V_{UV} + V_H) and the input signal is OFF. A 4 ms (t_{ALM}) alarm signal will be send to the output
- Even in case the supply voltage exceeds (V_{UV} + V_H) within 4 ms (t_{ALM}), the protective operation continues until the period of 4 ms (t_{ALM}) elapses, and accordingly, the IGBT is not turned on.

Furthermore, an alarm signal for judgment of the UV status is provided at the time of startup and shutdown of the control power supply.

2.8 Chip temperature overheat protective function: IGBT chip Over Heat protection (TjOH)

The TjOH protective function includes the direct IGBT chip temperature detected by a built-in on-chip temperature sensor on each IGBT chip. If the IGBT chip temperature is continuously higher than protection trip level (TjOH) for 1.0 ms, it is judged as being in the overheat status, the TjOH protective function is activated then the IGBTs are softly turned off to prevent a failure of the IGBT. At the same time an alarm signal output is generated. The UV status alarm signal output period (t_{ALM}) is 8 ms.

- There is a hysteresis offset Tj_H, the protective operation is stopped and normal operation is resumed, if Tj is below (TjOH – Tj_H) and the input signal is OFF after 8 ms (t_{ALM}) of the alarm signal output.
- Even in case the alarm signal disappears within 8 ms (t_{ALM}), the protected operation continues until the period of 8 ms (t_{ALM}) elapses, and accordingly, the IGBT is not turned on.

A case temperature overheat protective function (T_COH), which is built in the former IPM series, is not built in the V-IPM series. The IGBT chip overheat status is protected by the TjOH protective function.

3 Truth table

The truth tables of the V-IPM series when protective function is activated are shown in Tables 3-3 to 3-5.

Table 3-3 Truth table (P629)

	Alarm factor	IGBT				Alarm signal output
		U-phase	V-phase	W-phase	Lower arm side	ALM-Low side
U-phase	OC	OFF	*	*	*	High
	SC	OFF	*	*	*	High
	UV	OFF	*	*	*	High
	TjOH	OFF	*	*	*	High
V-phase	OC	*	OFF	*	*	High
	SC	*	OFF	*	*	High
	UV	*	OFF	*	*	High
	TjOH	*	OFF	*	*	High
W-phase	OC	*	*	OFF	*	High
	SC	*	*	OFF	*	High
	UV	*	*	OFF	*	High
	TjOH	*	*	OFF	*	High
Lower arm side X, Y and Z-phase	OC	*	*	*	OFF	Low
	SC	*	*	*	OFF	Low
	UV	*	*	*	OFF	Low
	TjOH	*	*	*	OFF	Low

* Dependent on the input signal.

Table 3-4 Truth table (P626)

	Alarm factor	IGBT				Alarm signal output			
		U-phase	V-phase	W-phase	Lower arm side	ALM-U	ALM-V	ALM-W	ALM-Low side
U-phase	OC	OFF	*	*	*	Low	High	High	High
	SC	OFF	*	*	*	Low	High	High	High
	UV	OFF	*	*	*	Low	High	High	High
	TjOH	OFF	*	*	*	Low	High	High	High
V-phase	OC	*	OFF	*	*	High	Low	High	High
	SC	*	OFF	*	*	High	Low	High	High
	UV	*	OFF	*	*	High	Low	High	High
	TjOH	*	OFF	*	*	High	Low	High	High
W-phase	OC	*	*	OFF	*	High	High	Low	High
	SC	*	*	OFF	*	High	High	Low	High
	UV	*	*	OFF	*	High	High	Low	High
	TjOH	*	*	OFF	*	High	High	Low	High
Lower arm side X, Y and Z-phase	OC	*	*	*	OFF	High	High	High	Low
	SC	*	*	*	OFF	High	High	High	Low
	UV	*	*	*	OFF	High	High	High	Low
	TjOH	*	*	*	OFF	High	High	High	Low

* Dependent on the input signal.

Table 3-5 Truth table (P630, P631 and P636)

	Alarm factor	IGBT				Alarm signal output			
		U-phase	V-phase	W-phase	Lower arm side	ALM-U	ALM-V	ALM-W	ALM-Low side
U-phase	OC	OFF	*	*	*	Low	High	High	High
	SC	OFF	*	*	*	Low	High	High	High
	UV	OFF	*	*	*	Low	High	High	High
	TjOH	OFF	*	*	*	Low	High	High	High
V-phase	OC	*	OFF	*	*	High	Low	High	High
	SC	*	OFF	*	*	High	Low	High	High
	UV	*	OFF	*	*	High	Low	High	High
	TjOH	*	OFF	*	*	High	Low	High	High
W-phase	OC	*	*	OFF	*	High	High	Low	High
	SC	*	*	OFF	*	High	High	Low	High
	UV	*	*	OFF	*	High	High	Low	High
	TjOH	*	*	OFF	*	High	High	Low	High
Lower arm side X, Y and Z-phase	OC	*	*	*	OFF	High	High	High	Low
	SC	*	*	*	OFF	High	High	High	Low
	UV	*	*	*	OFF	High	High	High	Low
	TjOH	*	*	*	OFF	High	High	High	Low

* Dependent on the input signal.

4 IPM block diagram

V-IPM block diagrams are shown in Figures 3-3 to 3-8.

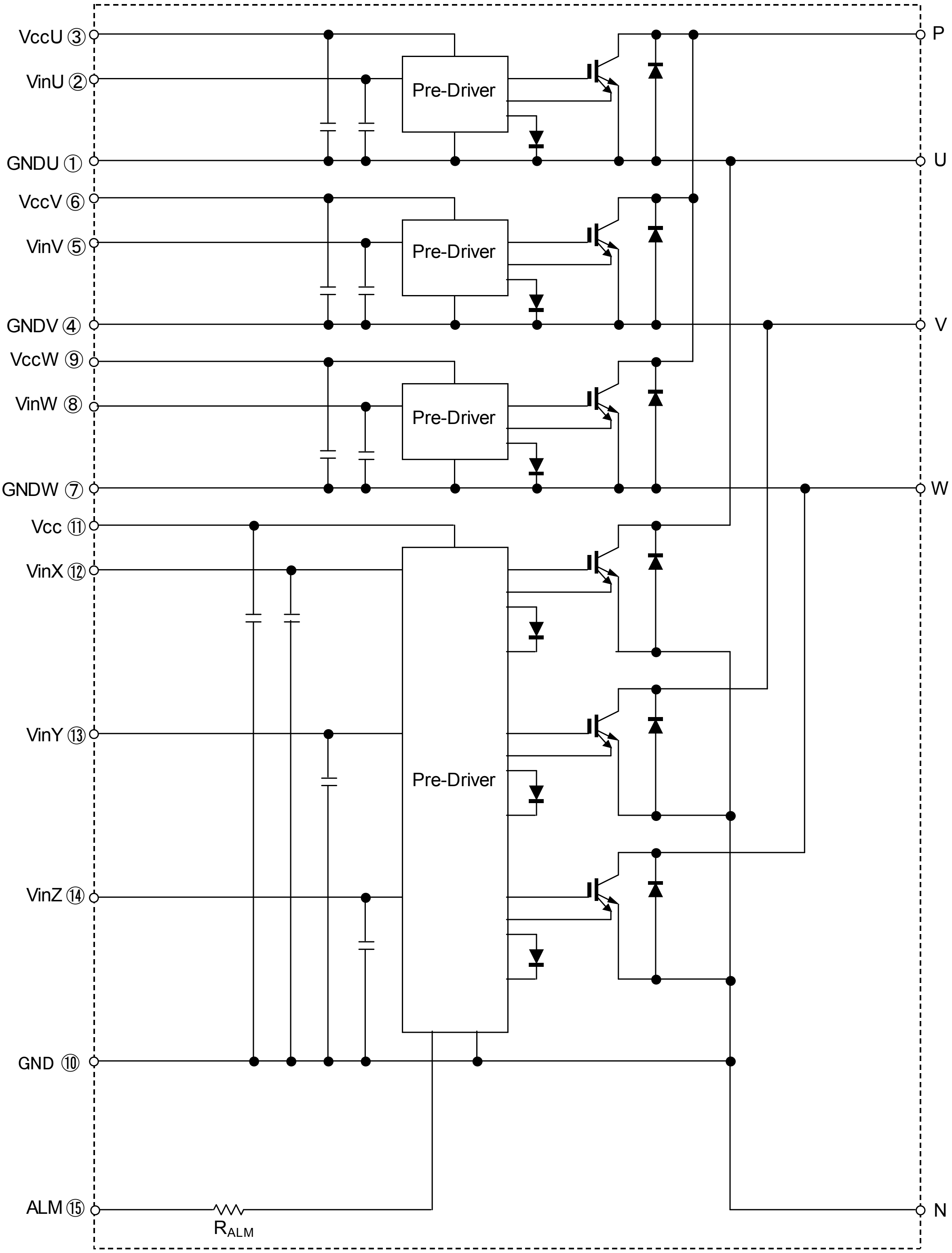


Figure 3-3 IPM block diagram (P629)

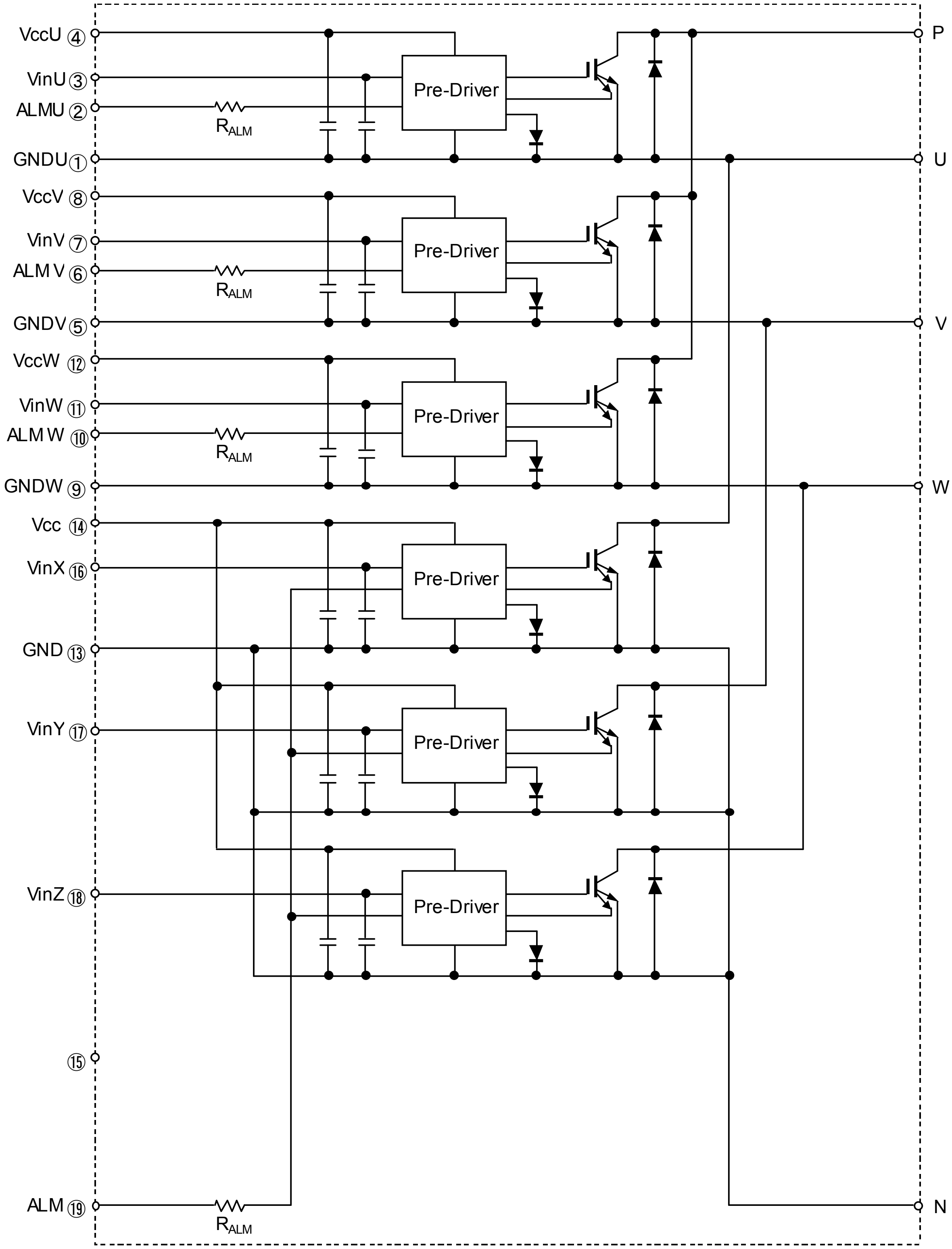


Figure 3-4 IPM block diagram (P626)

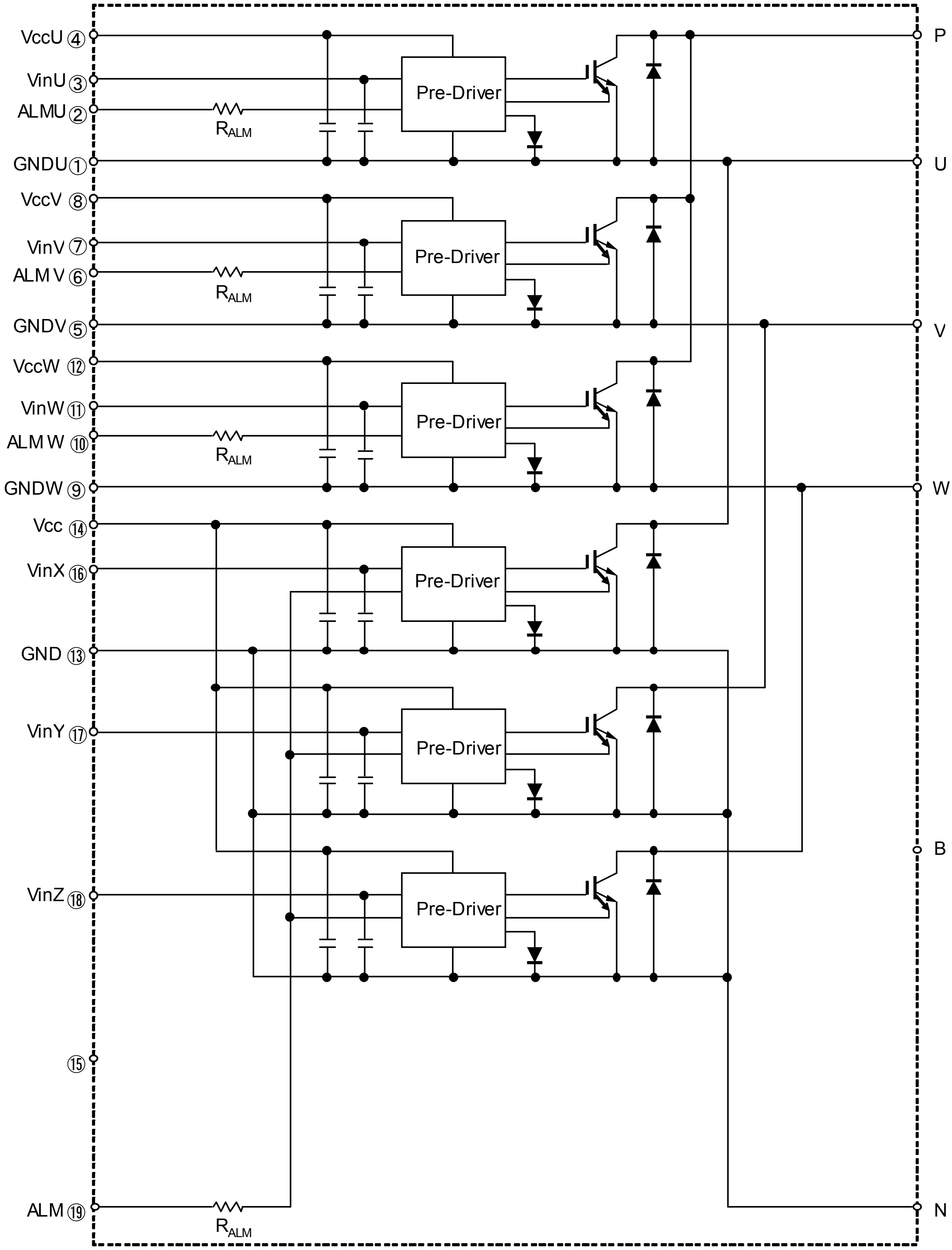


Figure 3-5 IPM block diagram (P630 without break)

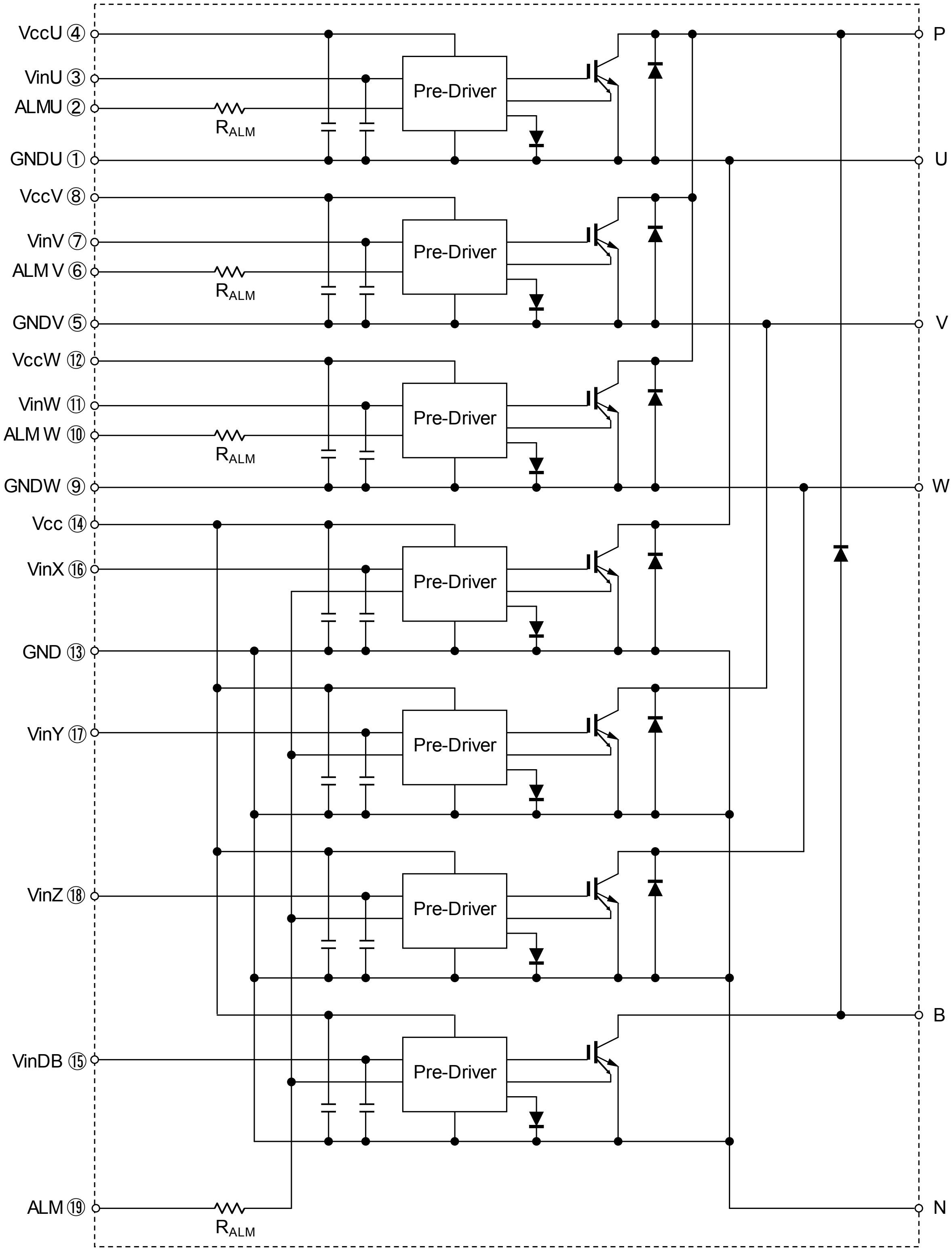


Figure 3-6 IPM block diagram (P630 with built-in brake)

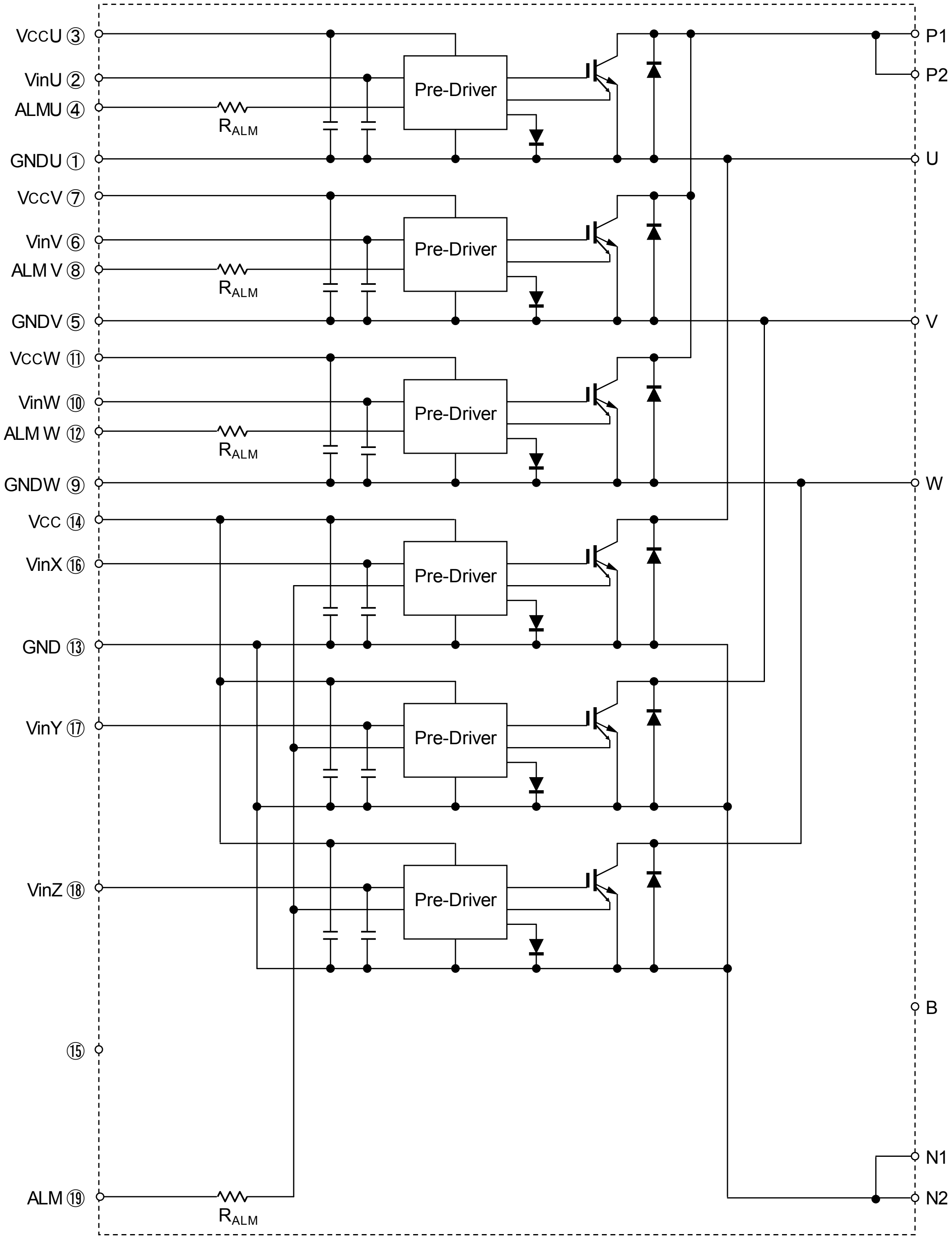


Figure 3-7 IPM block diagram (P631 without brake)

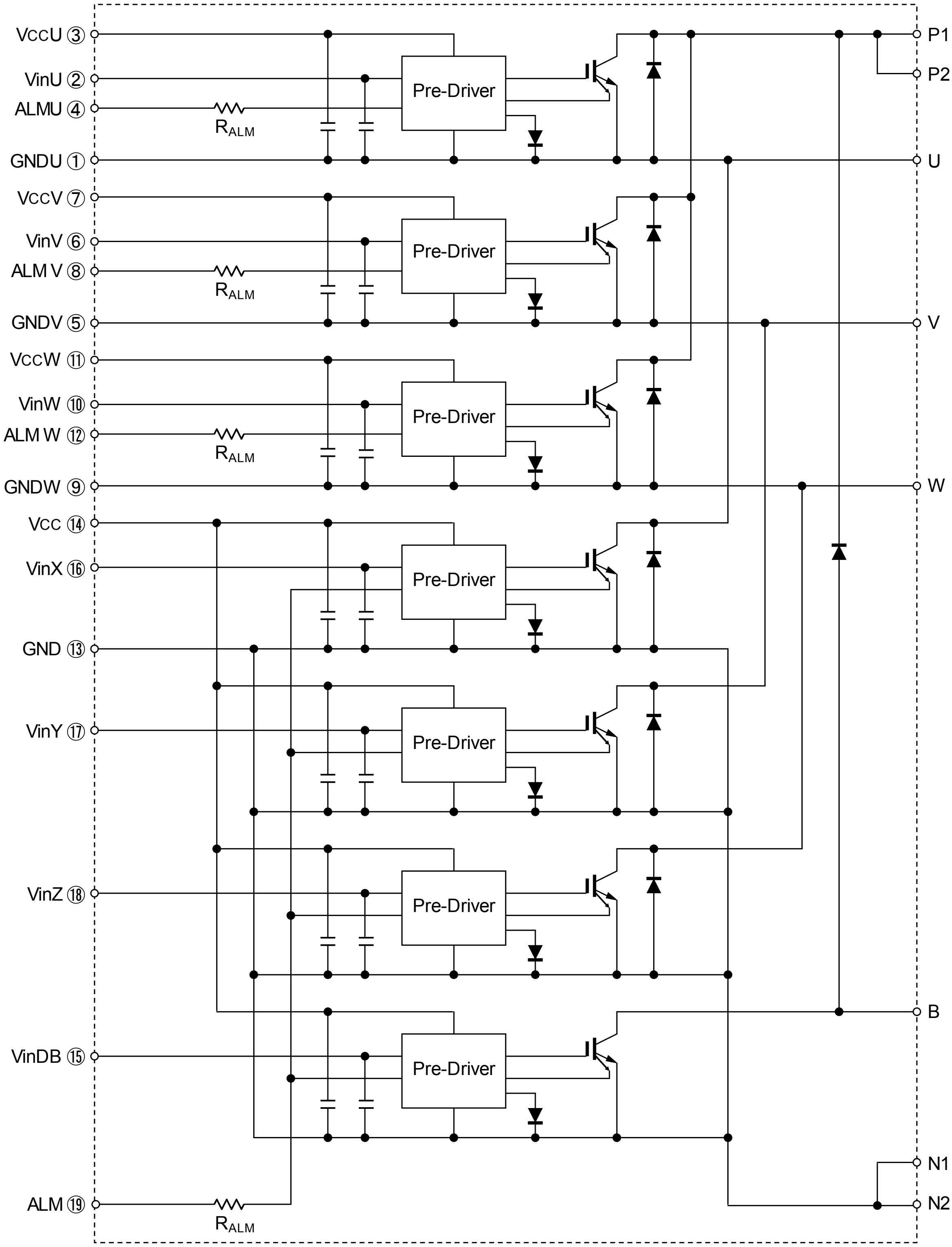


Figure 3-8 IPM block diagram (P631 with built-in brake)

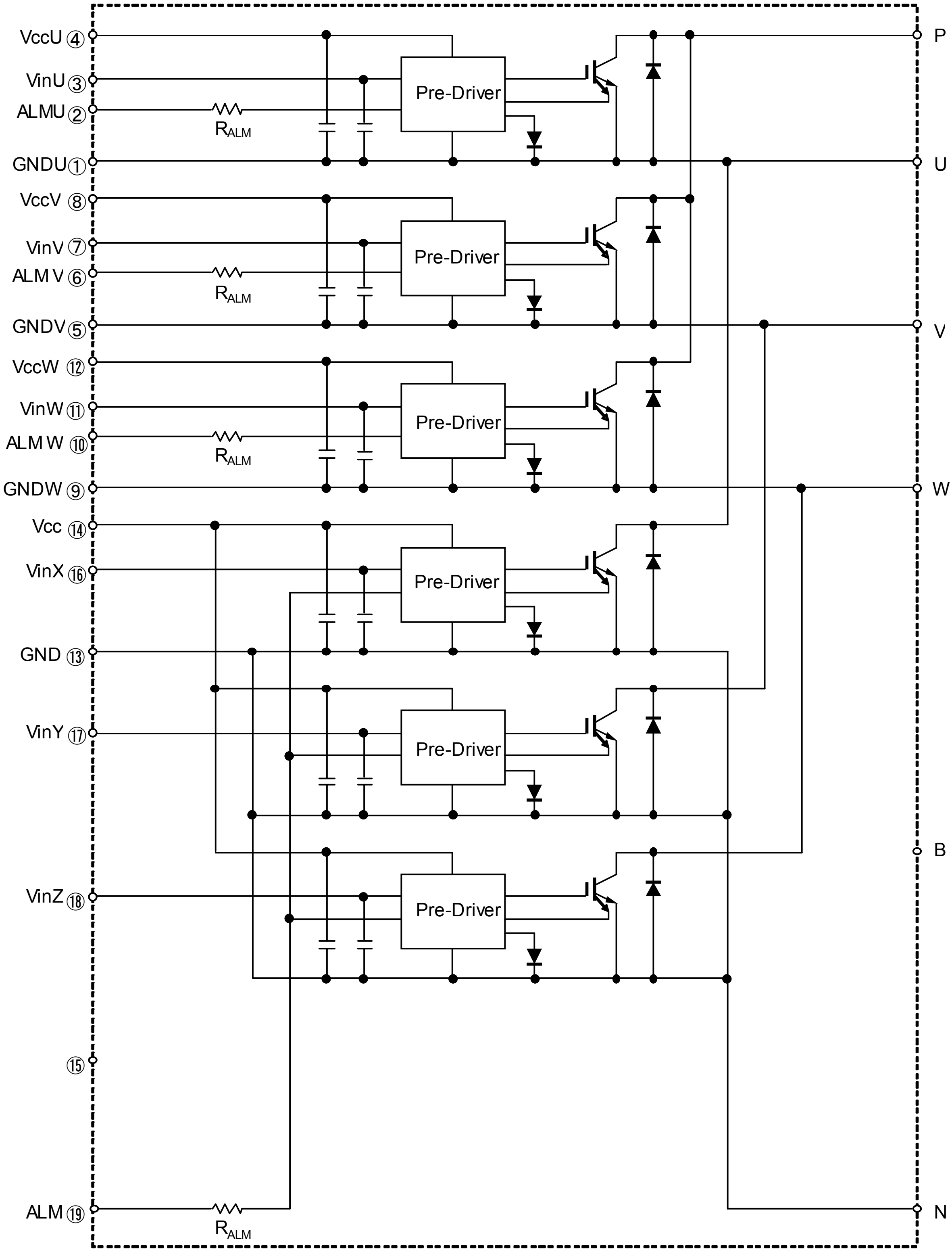


Figure 3-9 IPM block diagram (P636 without built-in brake)

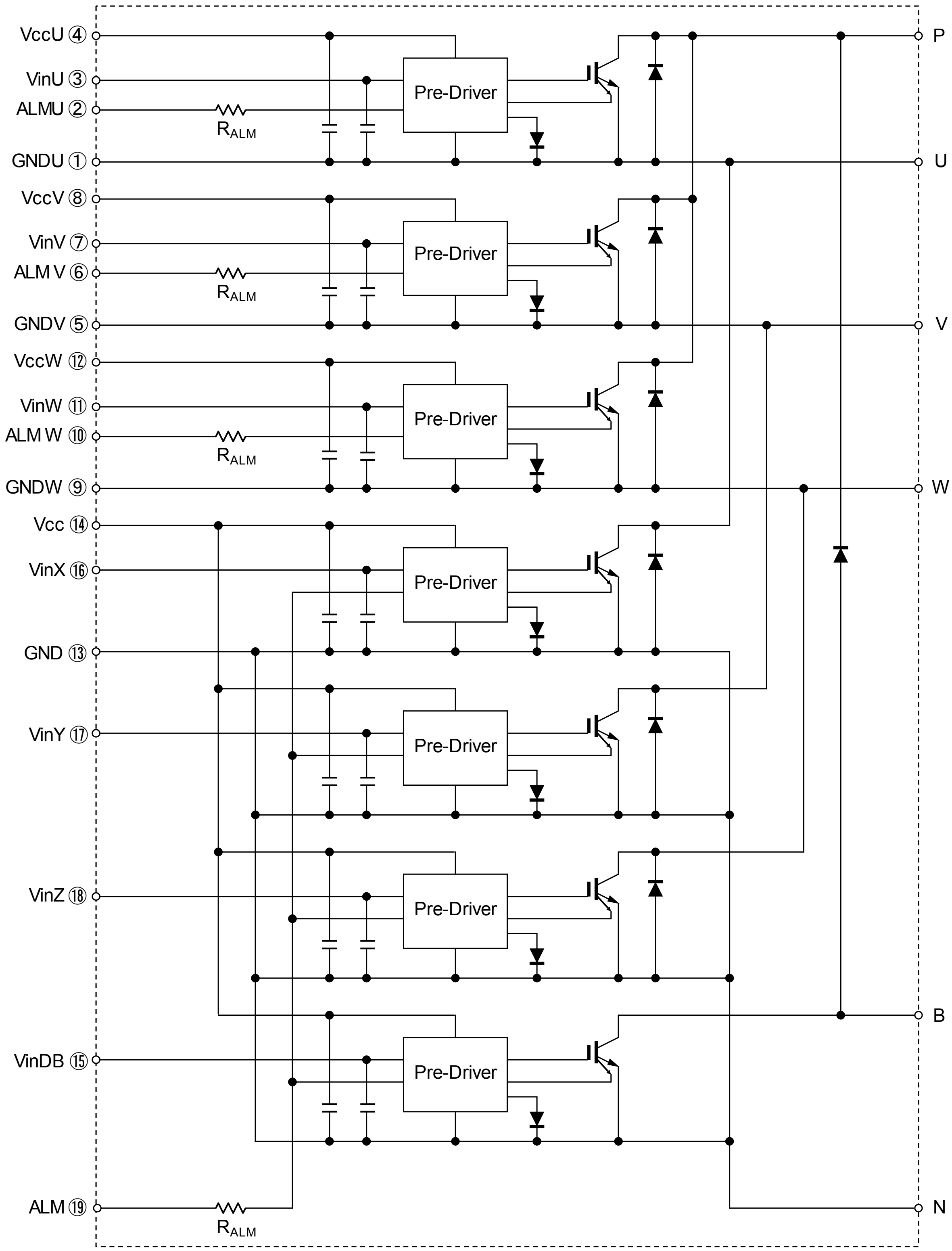
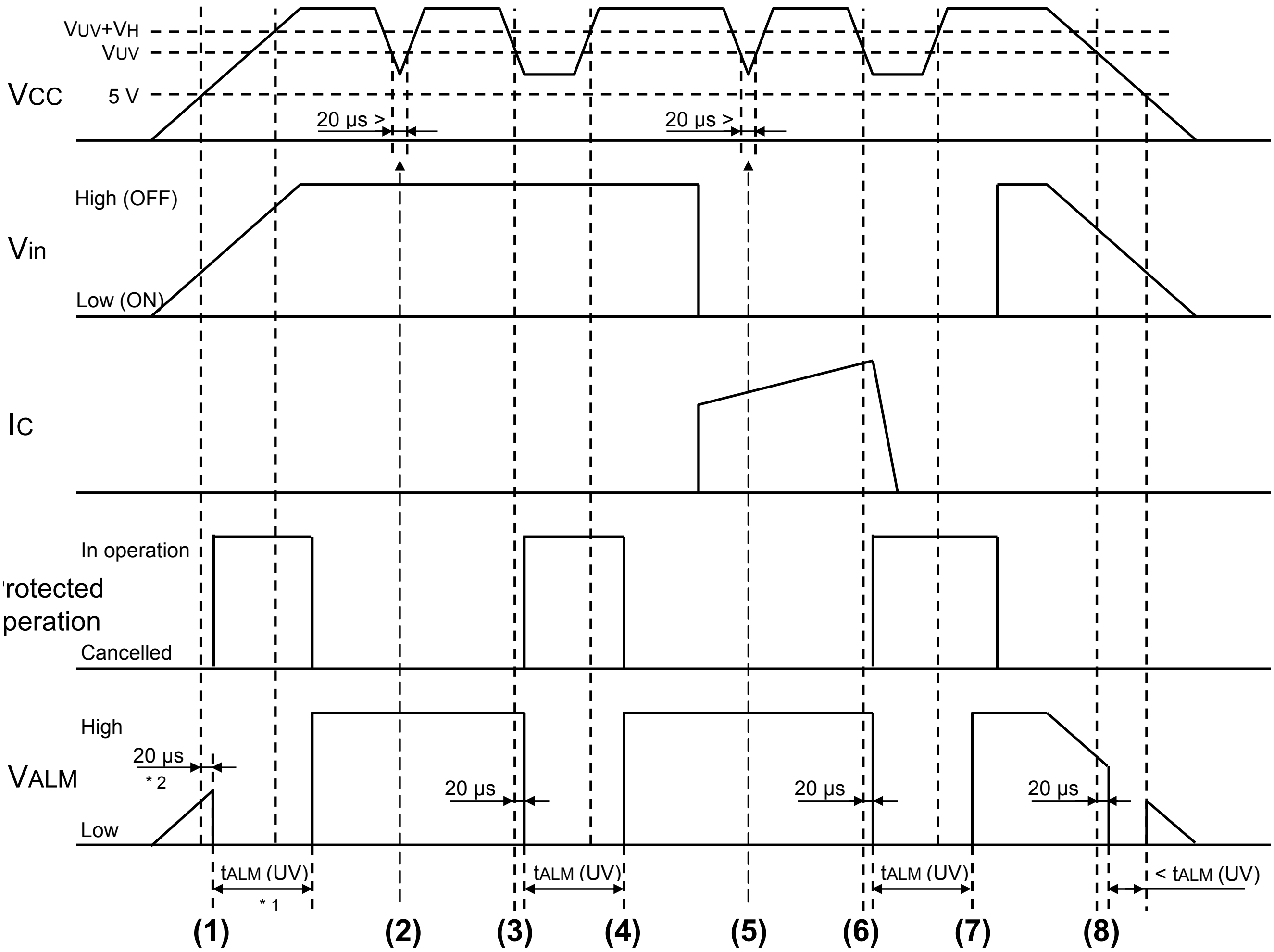


Figure 3-10 IPM block diagram (P636 with built-in brake)

5 Timing chart

5.1 Control power supply under voltage protection (UV): Case 1



*1: tALM (UV) is 4 ms, typical.
*2: Dead time 20 µs is a typical

(1) At the period of the V_{CC} ramp-up, alarm output begins when the V_{CC} exceeds 5 V and less than V_{UV}. (See 5.3 for details.)

(2) Protective function is not activated if the length of time during which V_{CC} is lower than V_{UV} is shorter than 20 µs. (While V_{in} is off)

(3) While V_{in} is off, an alarm is generated 20 µs after the V_{CC} drop below V_{UV}, and the IGBT is kept in the off status.

(4) UV protected operation continues during the $t_{ALM\ (UV)}$ period even if the V_{CC} returns to over (V_{UV} + V_H) and V_{in} is off. Normal operation is restarted from protected operation after the elapse of the $t_{ALM\ (UV)}$ period.

(5) Protection operation is not activated if the length of time during which V_{CC} is lower than V_{UV} is shorter

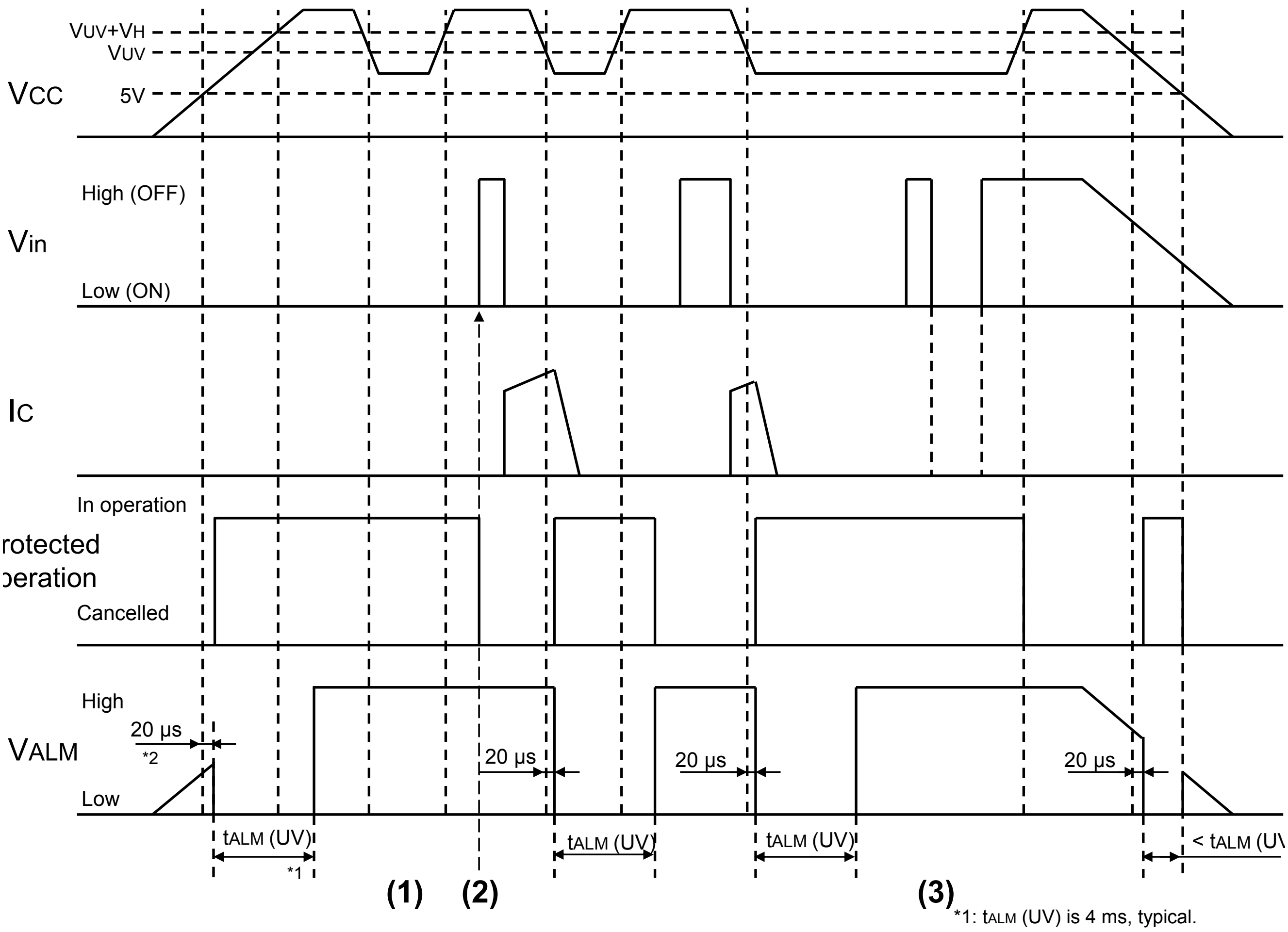
than 20 μs. (While V_{in} is on)

(6) While V_{in} is on, an alarm output signal is generated 20 μs after V_{CC} drops below V_{UV} , and the IGBT is softly turned off.

(7) In case V_{CC} returns to over V_{UV} + V_H before the elapse of $t_{ALM\ (UV)}$ period and V_{in} remains on state, an alarm is output during the $t_{ALM\ (UV)}$ period, but the protective function continues operating until V_{in} is changed to off-state.

(8) An alarm output is generated when V_{CC} is below V_{UV} during shutoff. (See 5.3 for details.)

5.2 Control power supply under voltage protection (UV): Case 2



*1: t_{ALM} (UV) is 4 ms, typical.
*2: Dead time 20 μs is a typical

(1) At the period of the V_{CC} ramp-up, an alarm is generated and V_{in} is kept in the on status. Therefore, UV protected operation is held regardless of the V_{CC} voltage drop.

(2) Reset from protected operation occurs at the timing when the V_{in} is off in the state where V_{CC} is V_{UV}+V_H or higher.

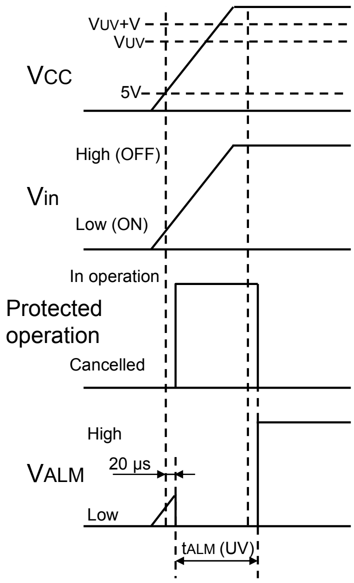
(3) The protective function continues because the V_{CC} is lower than V_{UV}. Then V_{in} signal is ignored and then the IGBT is not turned on. In addition, even if the duration of the protective operation is much longer than the $t_{ALM\ (UV)}$, the alarm output is generated only once.

5.3 Control power supply under voltage protection (UV) during startup and shutdown of power supply

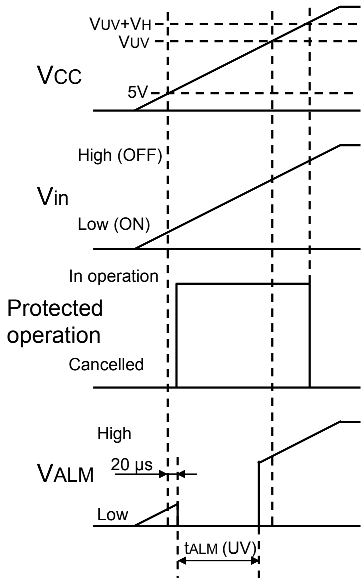
V-IPM has control power supply under voltage protection (UV) function. Because of this function, an alarm output is generated during the startup and shutdown of the power supply. Its details are described below:

5.3.1 During start up

When V_{CC} exceeds 5 V, an alarm output is generated after the elapse of 20 µs in both of Case 1 and Case 2. In Case 1, the V_{CC} voltage reaches (V_{UV} + V_H) and the Vin becomes off-state within the $t_{ALM(UV)}$ and the protective operation is stopped after the elapse of $t_{ALM(UV)}$. In Case 2, protective operation continues even after the elapse of $t_{ALM(UV)}$ because the V_{CC} is still below (V_{UV}+V_H). The protected operation is stopped when V_{CC} exceeds V_{UV} + V_H and V_{in} is off-state.



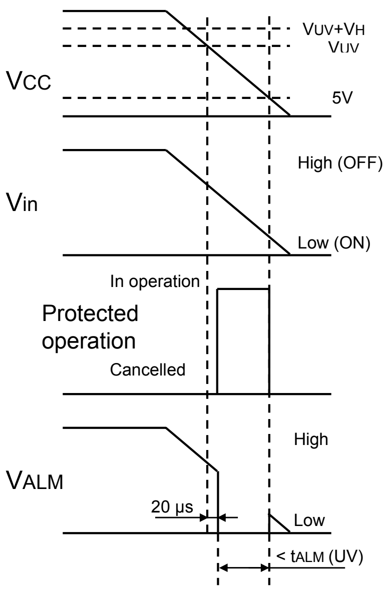
Case 1



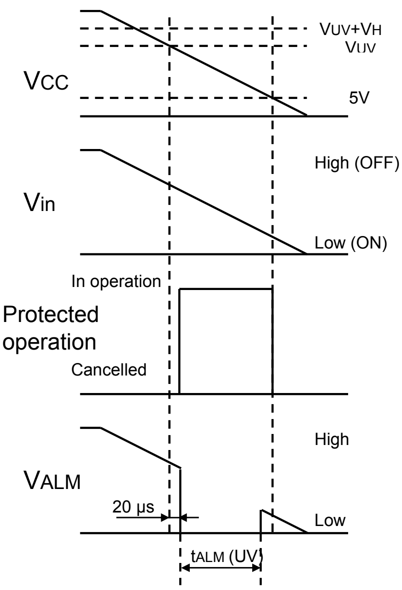
Case 2

5.3.2 During Shutdown

When the V_{CC} becomes less than the V_{UV}, an alarm signal is generated after the elapse of 20 µs in both of Case 3 and Case 4. In Case 3, the alarm is stopped before the $t_{ALM(UV)}$ because the V_{CC} becomes less than 5V before the elapse of the $t_{ALM(UV)}$ and the IPM operation becomes unstable. In Case 4, protected operation continues after the elapse of the $t_{ALM(UV)}$ because the V_{CC} is still higher than 5 V. When the V_{CC} becomes less than 5 V, the protected operation of the control IC is stopped and the V_{ALM} changes to V_{CC} equivalent.

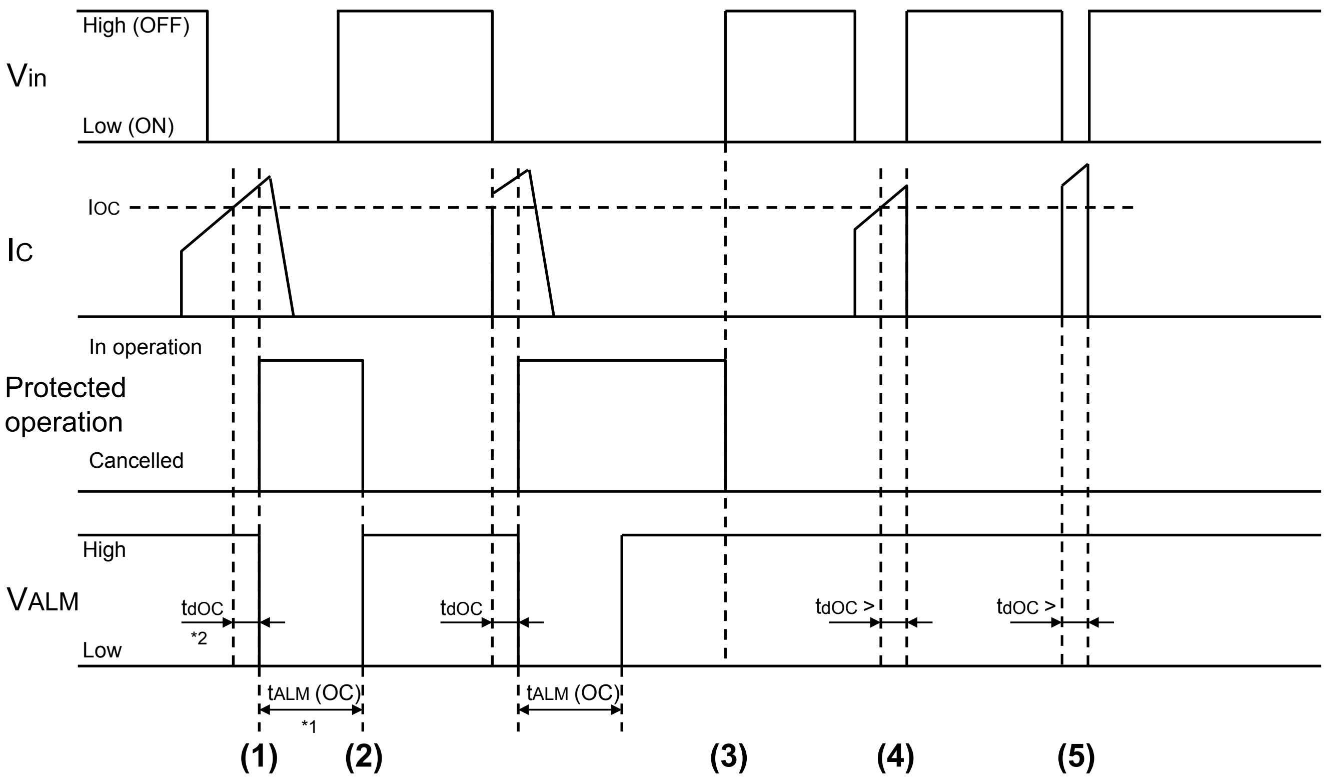


Case 3



Case 4

5.4 Overcurrent protection (OC)



*1: tALM (OC) is 2 ms, typical.
*2: tdOC is 5 μs, typical.

(1) When the IC exceeds the overcurrent trip level IOC, an alarm signal is generated after the elapse of the tdOC, and the IGBT is softly turned off.

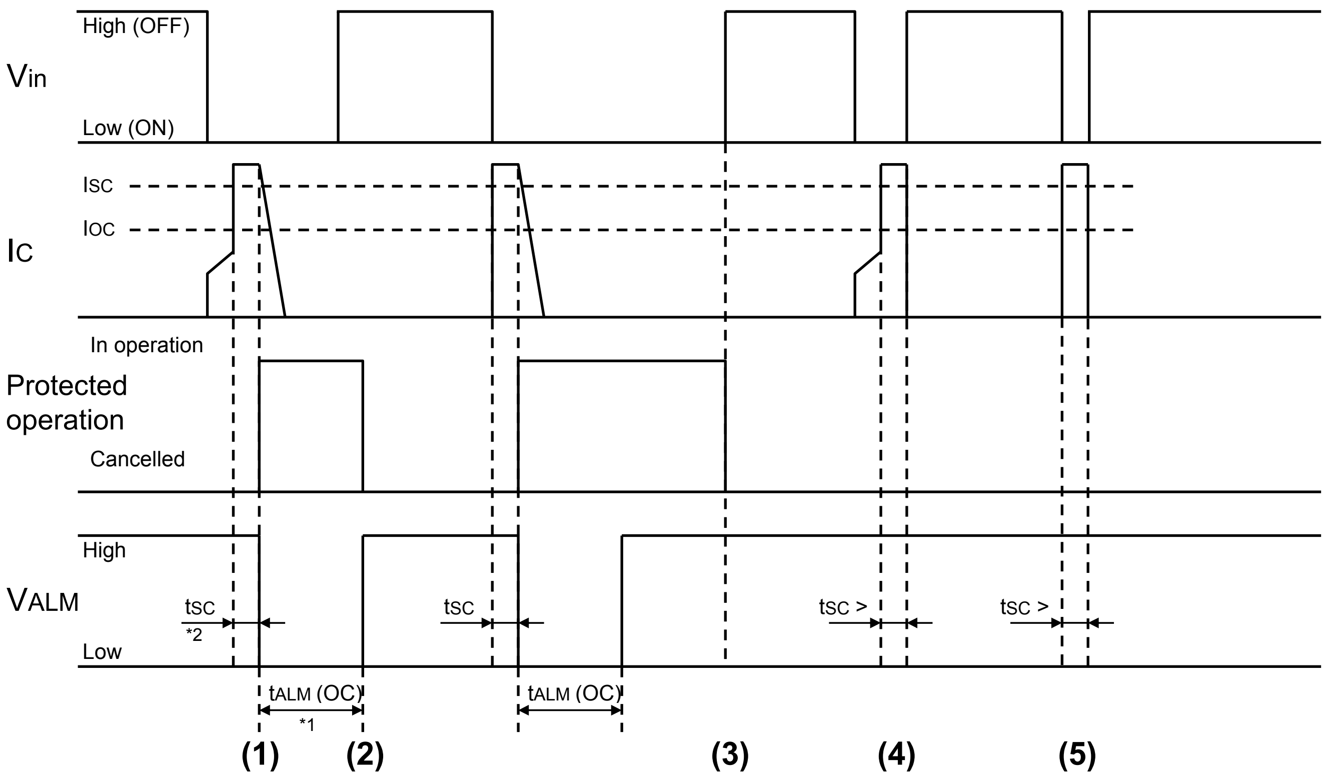
(2) The protected operation continues during the tALM (OC) period even if the Vin becomes off-state, and resumes to normal operation after the elapse of the tALM (OC) and Vin is in the off-state.

(3) OC protected operation continues if the Vin is on-state after the elapse of the tALM (OC), and resumes to normal operation when the Vin becomes off-state. In addition, even if duration of the protection operation is much longer than the tALM (OC), alarm signal output is generated only once.

(4) When the Vin is off-state before the elapse of the tdOC since the IC exceeds the IOC, protection operation is not activated and the IGBT is softly turned off by the Vin off-state input.

(5) If IC is higher than IOC when Vin becomes on-state and if Vin becomes on-state before the elapse of tdOC, protection operation is not activated and the IGBT is softly turned-off normally.

5.5 Short-circuit protection (SC)



*1: tALM (OC) is 2 ms, typical.
*2: tSC is 2 μs, typical.

(1) If a load short-circuit occurs when normal Ic is flowing and if the IC exceeds ISC the peak current of the IC is suppressed momentarily. After the elapse of tSC, an alarm signal is generated and the IGBT is softly turned off.

(2) SC protectioed operation is stopped if the Vin is off-state after the elapse of the tALM (OC).

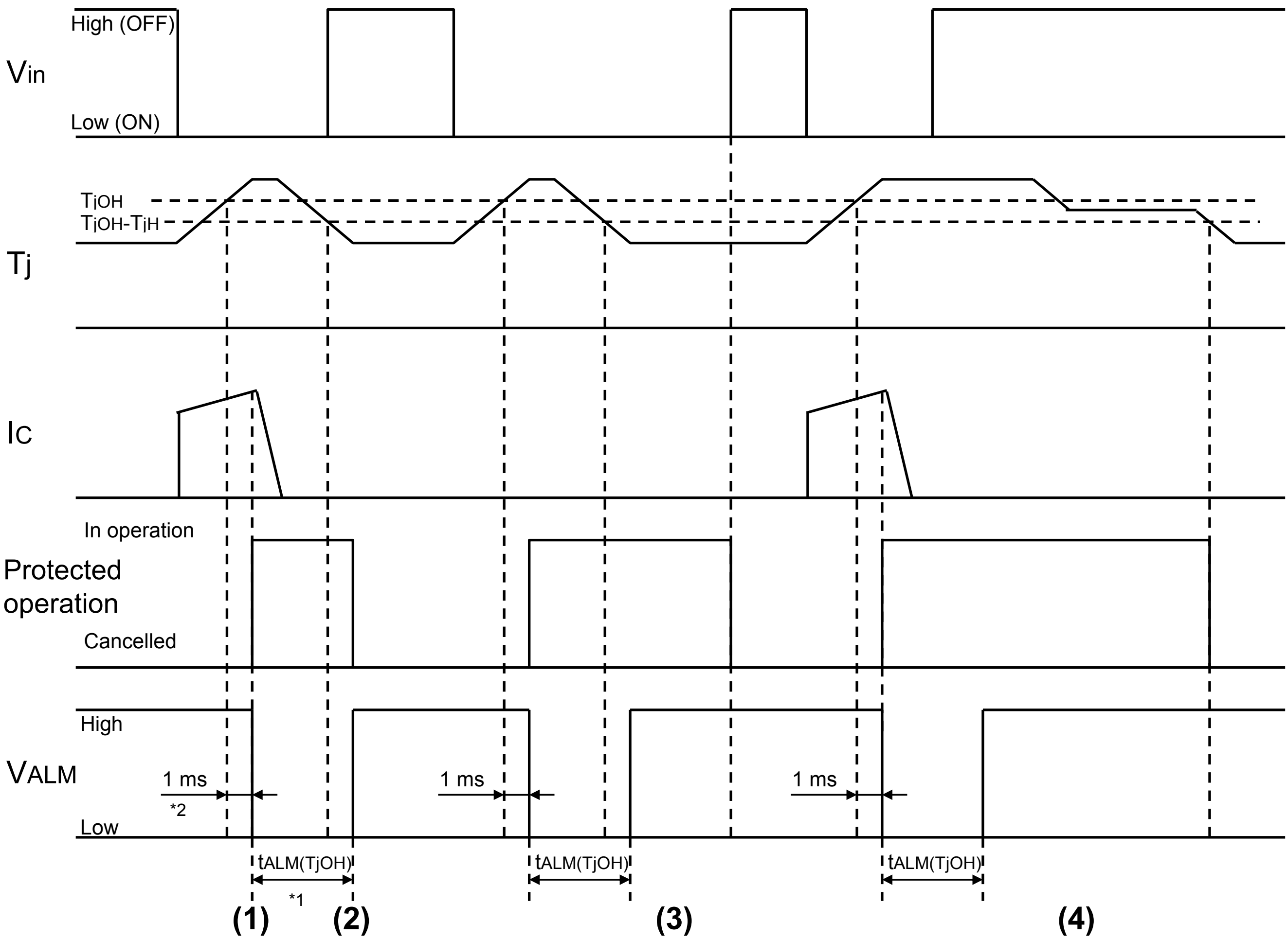
(3) When a load short-circuit occurs immediately after the IC is flowing and if the IC exceeds ISC the peak current is suppressed momentarily. After the elapse of tSC an alarm is generated and the IGBT is softly turned off.

(4) SC protection operation continues if the Vin is on-state even after the elapse of the tALM (OC). SC protection operation is stopped when a Vin signal becomes off-state. In addition, even if duration of the protection operation is much longer than the tALM (OC), alarm output is generated only once.

(5) When a load short-circuit occurs immediately after the IC began to flow and the IC peak is suppressed momentarily as soon as the IC exceeds the ISC. If the Vin becomes off-state before the elapse of the tSC the SC protection operation is not activated and the IGBT is softly turned off normally.

(6) When a load short-circuit occurs immediately after the IC began to flow, and the IC peak is suppressed momentarily when the IC exceeds the ISC. If the Vin becomes off-state before the elapse of the tSC, the SC protection operation is not activated and the IGBT is softly turned off normally.

5.6 Chip temperature heating protection (TjOH): Case 1



*1: t_{ALM} (T_{jOH}) is 8 ms, typical.
*2: Dead time 1 ms is a typical value.

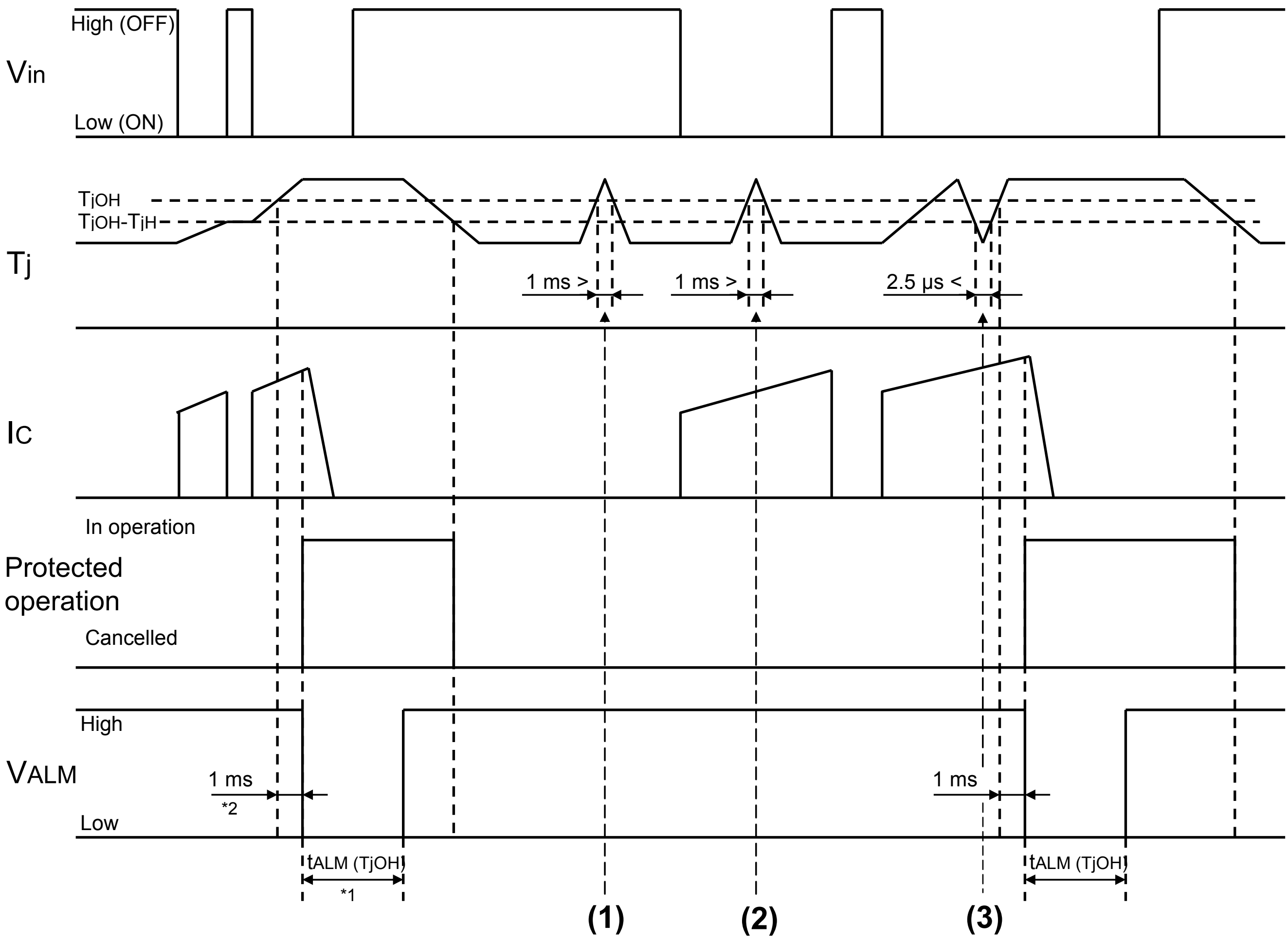
(1) If chip junction temperature T_j is higher than T_{jOH} for a period exceeding 1 ms, an alarm is generated and the IGBT is softly turned off.

(2) Protection operation continues during the t_{ALM} (T_{jOH}) period even if the IGBT chip temperature T_j drops below T_{jOH}-T_{jH} before the elapse of the t_{ALM} (T_{jOH}) period. Normal operation resumes if the V_{in} is off-state after the elapse of t_{ALM} (T_{jOH}) period.

(3) Protection operation continues if V_{in} is on-state, even if the chip temperature T_j drops lower than the T_{jOH}-T_{jH} after the elapse oft_{ALM} (T_{jOH}) period.

(4) Protection operation continues after the elapse of the t_{ALM} (T_{jOH}) period if the chip temperature T_j is higher than T_{jOH}-T_{jH} even when V_{in} is off-state. In addition, even if duration of the protection operation is much longer than the t_{ALM} (T_{jOH}), alarm output is generated only once.

5.7 Chip temperature heating protection (TjOH): Case 2

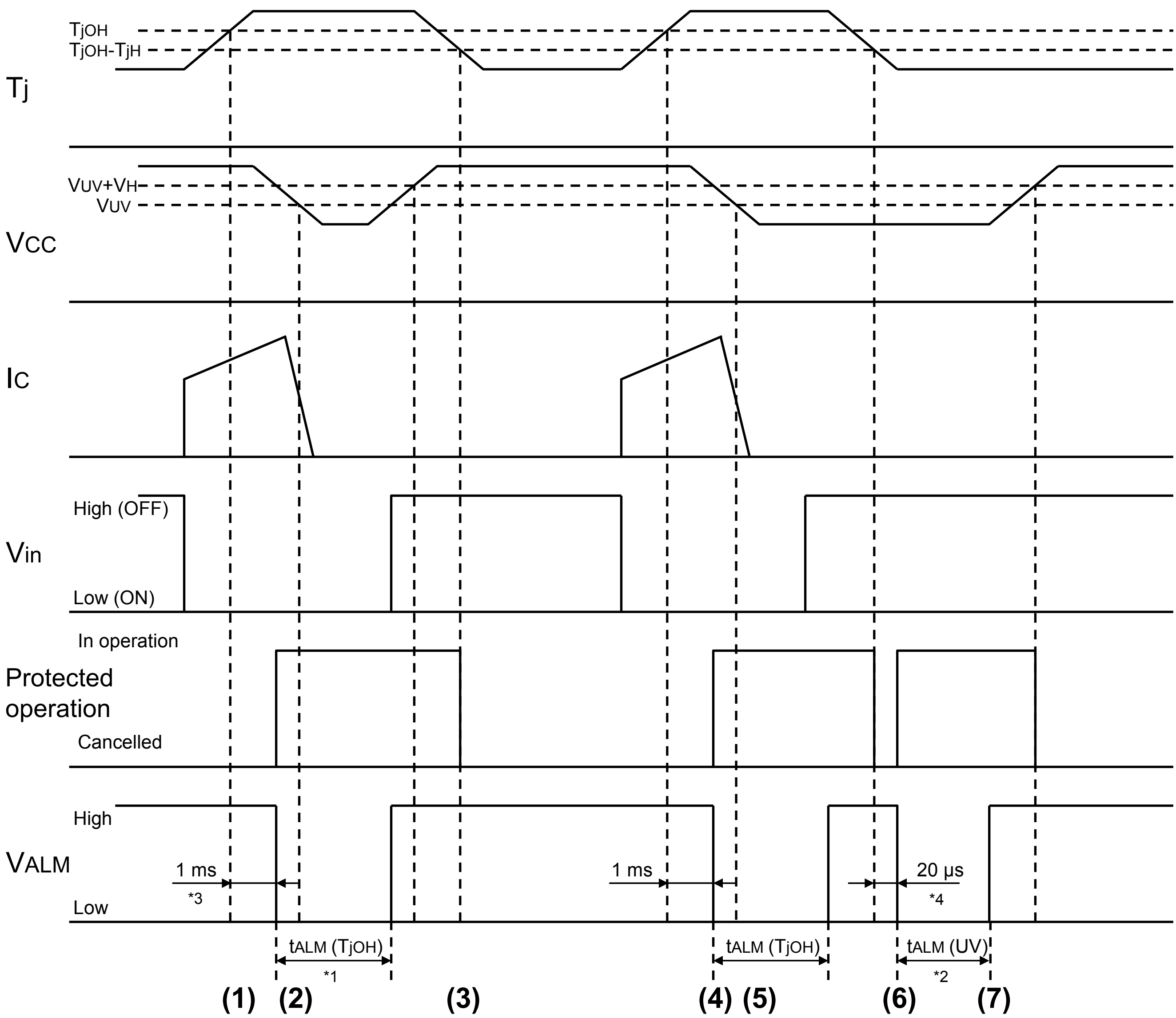


*1: t_{ALM} (T_{jOH}) is 8 ms, typical.
*2: Dead time 1 ms is a typical value.

(1) Protection operation is not activated if the T_j drops lower than the T_{jOH} within 1 ms since T_j exceeds T_{jOH}, regardless of whether the V_{in} is on or off.

(2) The T_{jOH} detection timer of which duration is 1 ms is reset if T_j has been kept lower than the T_{jOH}-T_{jH} for longer than 2.5 μs after the T_j exceeds the T_{jOH}.

5.8 Case where protective functions operated compositely



*1: t_{ALM} (T_{jOH}) is 8 ms, typical.
*2: t_{ALM} (UV) is 4 ms, typical.
*3: Dead time 1 ms is a typical value.
*4: Dead time 20 µs is a typical value.

(1) When an IGBT junction temperature Tj exceeds the TjOH for 1 ms continuously, an alarm is generated and the IGBT is softly turned off.

(2) If the V_{CC} drops lower than the V_{UV} before the elapse of the $t_{ALM\ (TjOH)}$ period, an alarm output of UV protection is cancelled because protected operation of the T_{jOH} is continuing.

(3) Protection operation stops after the elapse of $t_{ALM\ (TjOH)}$ period if V_{in} is off-state and chip temperature Tj drops less than T_{jOH}-T_{jH}.

(4) An alarm signal is generated and the IGBT is softly turned off if the IGBT chip temperature Tj continuously exceeds of T_{jOH} for 1 ms.

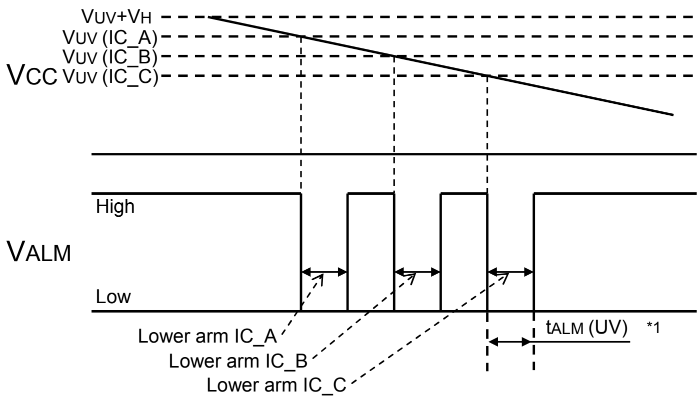
(5) Similar to the case (2), alarm output by VUV is stopped while protection operation of the $t_{ALM\ (TjOH)}$ is continued.

(6) Protected operation stops after the elapse of t_{ALM} (T_{jOH}) period if Vin is off-state and the chip temperature T_j drops lower than the T_{jOH}-T_{jH}. At this time V_{CC} is kept lower than the V_{UV} for 20 μs after the stop of protective functions by T_{jOH}, an alarm is generated by the V_{UV} again and the UV protected operation is activated.

(7) Protected operation stops after the elapse of t_{ALM} (UV) period if V_{in} is off-state and V_{CC} is higher than V_{UV} + V_H.

5.9 Multiple alarm outputs from lower arm by control power supply under voltage protection (UV) (excluding P629)

Each of three (or four for brake built-in type) IGBTs have independent control ICs, but the alarm outputs is a common output for lower arm control ICs. Therefore, there are some cases when several alarm outputs are generated because of distribution of protected operation level of the control ICs. If dv/dt of V_{UV} is less than 0.5 V/ms in the vicinity of V_{CC}, there is a possibility of alarm output such as shown in the figure right. (This is not an abnormal phenomenon.)



*1: t_{ALM} (UV) is 4 ms, typical.

Fuji Electric
Innovating Energy Technology

– Chapter 4 –

Typical application circuits

1 Typical application circuits

Figure 4-1 shows typical application circuits of P629.

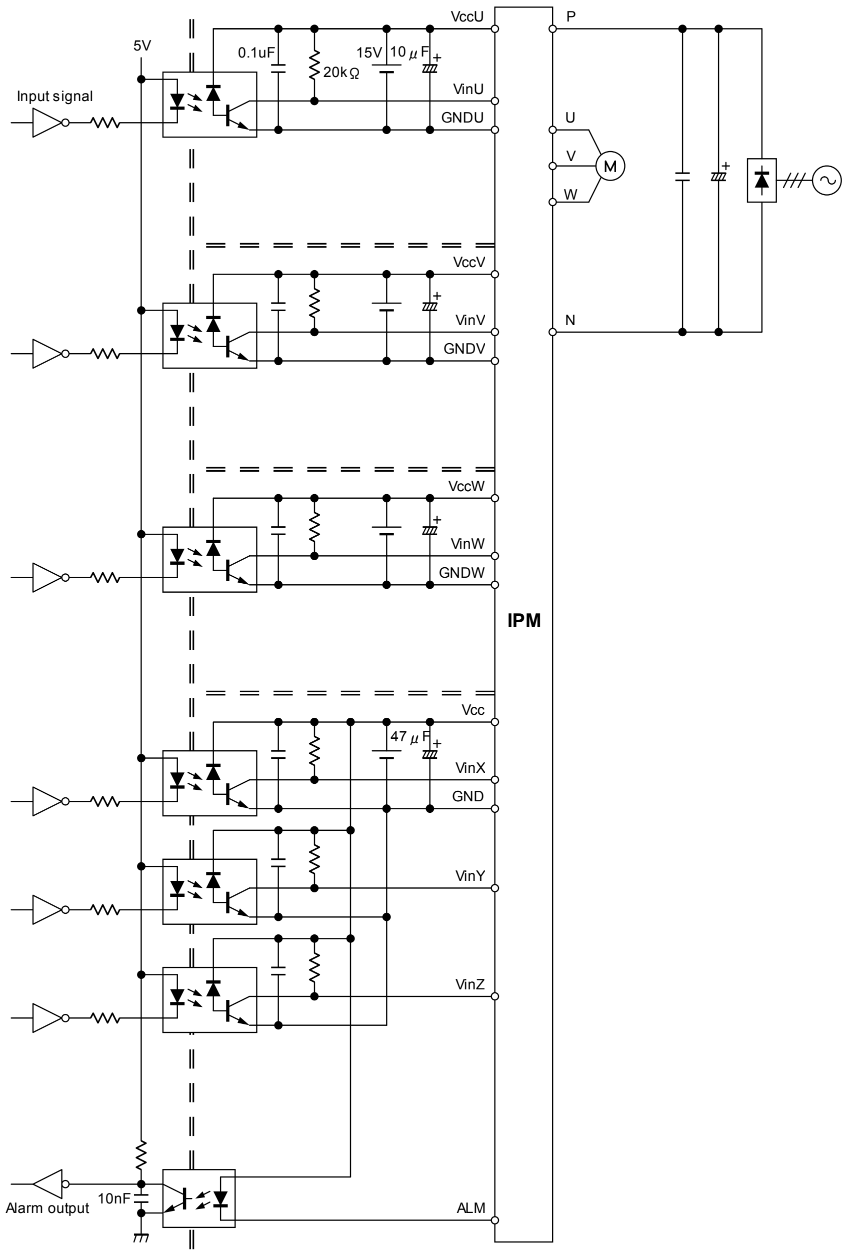
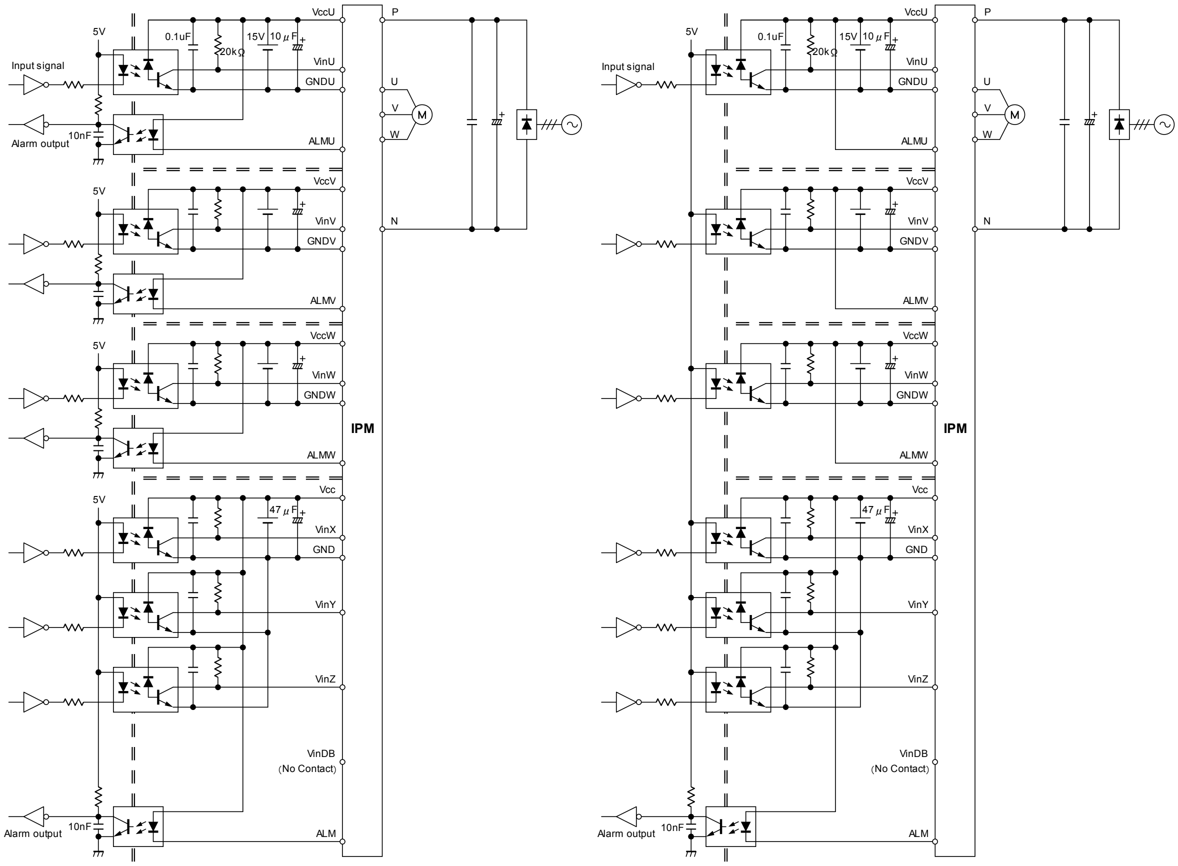


Figure 4-1 Typical application circuits of P629

Figure 4-2 shows typical application circuits of P626.

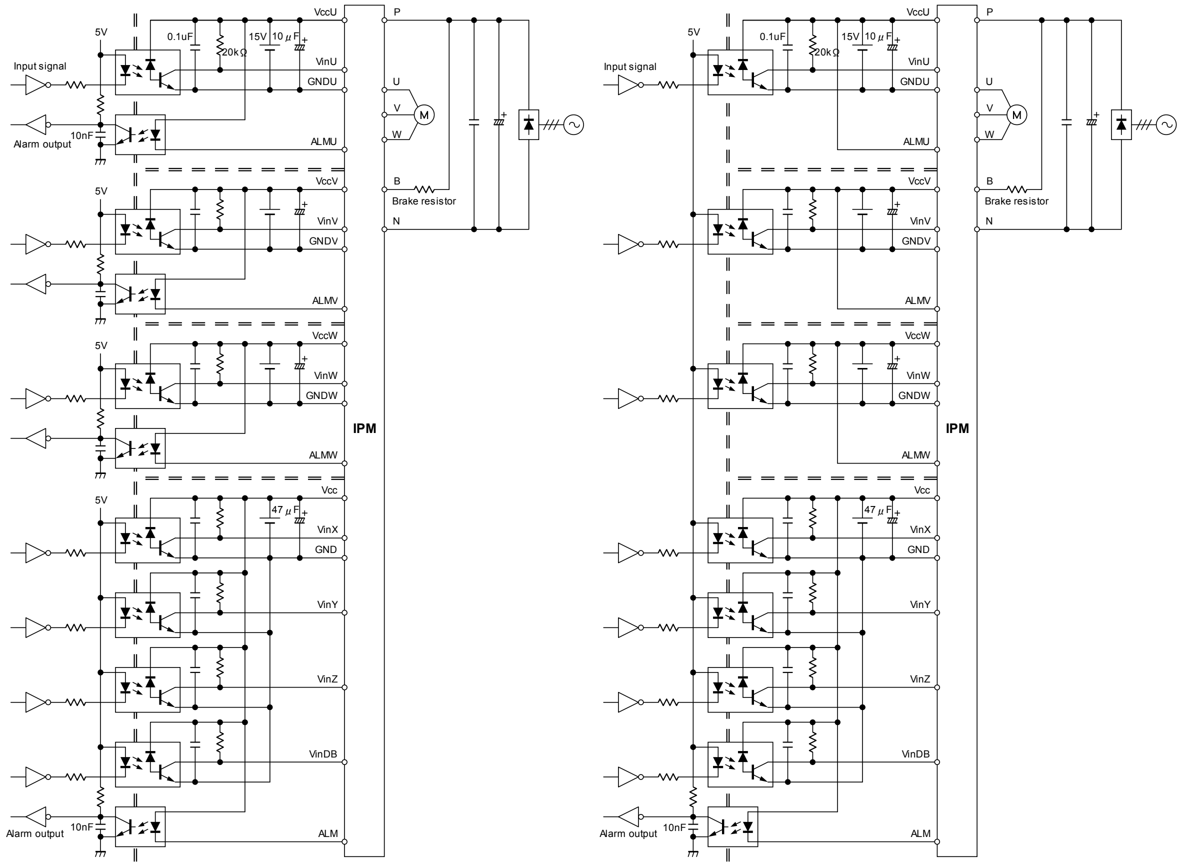


(a) Where upper phase alarm is used

(b) Where upper phase alarm is not used

Figure 4-2 Typical application circuits of P626

Figure 4-3 shows typical application circuits of P630, P631 and P636 with built-in brake type.



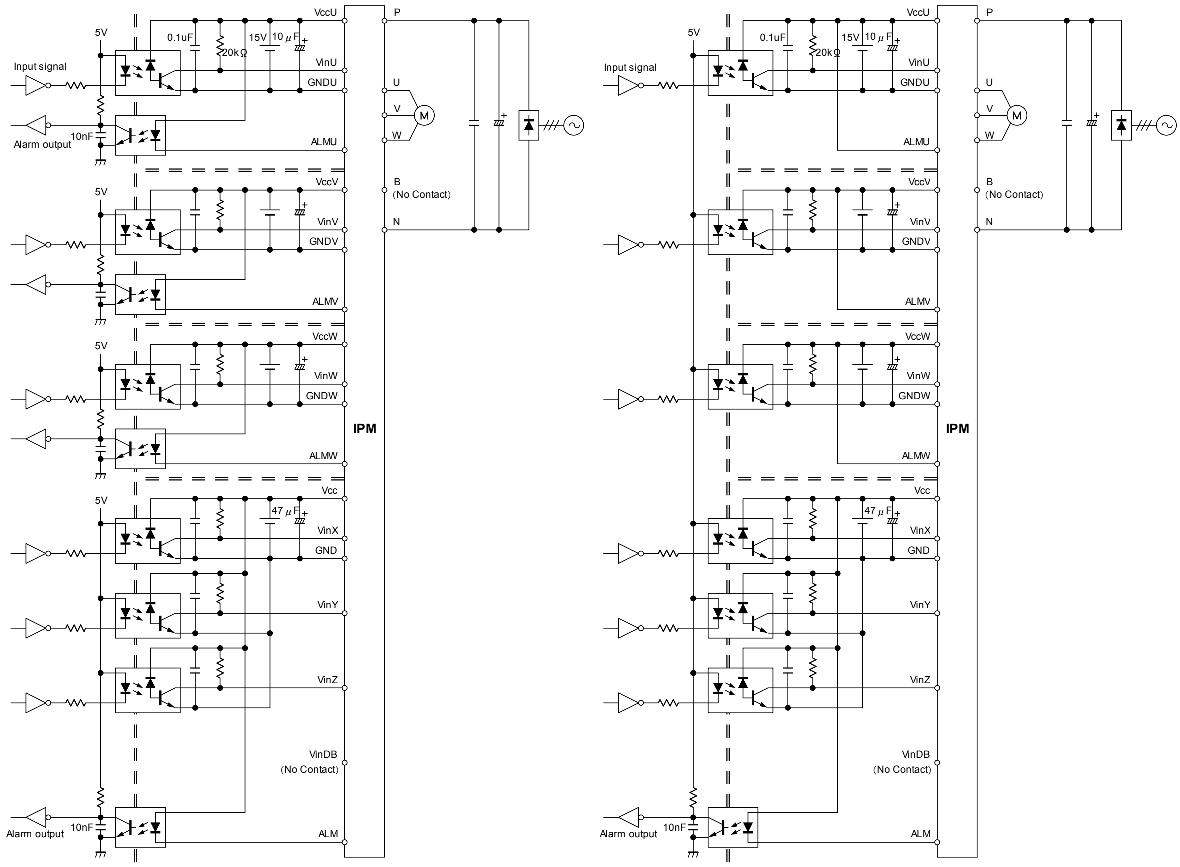
(a) Where upper phase alarm is used

(b) Where upper phase alarm is not used

Figure 4-3 Typical application circuits of P630, P631 and P636 with brake circuit

Fuji Electric
Innovating Energy Technology

Figure 4-4 shows typical application circuits of P630, P631 and P636 of no brake type.



(a) Where upper phase alarm is used

(b) Where upper phase alarm is not used

Figure 4-4 Typical application circuits of P630, P631 and P636 without brake circuit

2 Important remarks

2.1 Control power supply units

Four isolated power supply units; three for the upper arm and one for the lower arm are needed as shown in the application circuit examples. If a readymade power supply unit is used, do not connect the output GND terminals of the power supply unit. If the GND of the output side is connected to the + or – terminals, it may cause a failure of the system because each power supply unit is connected to the ground of input side of the power supply unit. Furthermore, reduce stray capacitance (floating capacitance) between the power supply units and the Earth ground as much as possible.

Furthermore, please use a power supply unit which has enough capability to supply I_{CC} with low output power fluctuation.

2.2 Structural insulation between four power supply units (input portion connector and PCB)

The four power units and the main power supply unit have to be insulated from each other. A sufficient insulation air gap distance is required (2 mm or longer is recommended) because a high dv/dt is applied to the insulation distance during IGBT switching.

2.3 GND connection

Do not connect the control terminal GND U to the main terminals U, control terminal GND V to main terminals V, control terminal GND W to main terminal W, control terminal GND to main terminal N (N1 and N2 in case of P631). If these terminals are connected, it might cause a malfunction.

2.4 External capacitors for control power supply

Capacitors of 10 μF (47 μF) and 0.1 μF, which are connected to each power supply unit shown in typical application circuits are not used for smoothing the output voltage of the control power supply units but are used for reduction of the wiring impedance from the power supply unit to the IPM. Additional capacitors for smoothing the voltage are required.

Furthermore, these external capacitors should be connected to the IPM terminals or optocoupler terminals as short as possible because transient variation occurs by the wiring impedance between the capacitors and control circuits.

Also, an electrolytic capacitor which has a low impedance and god frequency characteristics is recommended. In addition, it is recommended to connect a film capacitor which has good frequency characteristics in parallel.

2.5 Alarm circuit

The alarm terminal has a 1.3 kΩ internal resistor in series, so that an optocoupler can be connected to the terminal directly without an external resistor. The wiring distance between the optocoupler and the IPM should be as short as possible. Also the pattern layout should be designed to minimize the floating capacitance between the primary side and the secondary side of the optocoupler. Because of the potential of the secondary side of the optocoupler it may fluctuate due to high dv/dt. It is recommended that a 10nF capacitor of is connected to the output terminal of the secondary side of the optocoupler as shown in Figure 4-4.

Furthermore, f upper side alarm outputs are not used, please connect the alarm output terminal to VCC as shown in Figure 4-4 (b).

2.6 Pull-up of signal input terminal

Connect the control signal input terminals to Vcc through a 20 kΩ pull-up resistor. Furthermore, unused input terminals also have to be pulled up through a 20 kΩ resistor. If these terminals are not pulled up, an under voltage protection is activated during the starting up so that no ON operation is possible.

2.7 Connection in case there is an unused phase

If there is an unused phase such as the case when a 6in1 IPM (no brake type) is used in single phase or a 7in1 IPM (brake built-in type) is used without using B-phase, please supply a control voltage to these unused phase and connect the input/alarm terminals of the phase to VCC so that it will stabilize the potential of these terminals.

2.8 Handling of unconnected terminals (no contact terminals)

Unconnected terminals (no contact terminals) are not connected to the internal of the IPM. These terminals are insulated from other terminals. There is no need of special treatment such as potential stabilization.

Furthermore, guide pins should also not be connected to the internal of the IPM.

2.9 Snubbers

Connect snubber circuits between P and N terminals directly and as short as possible.

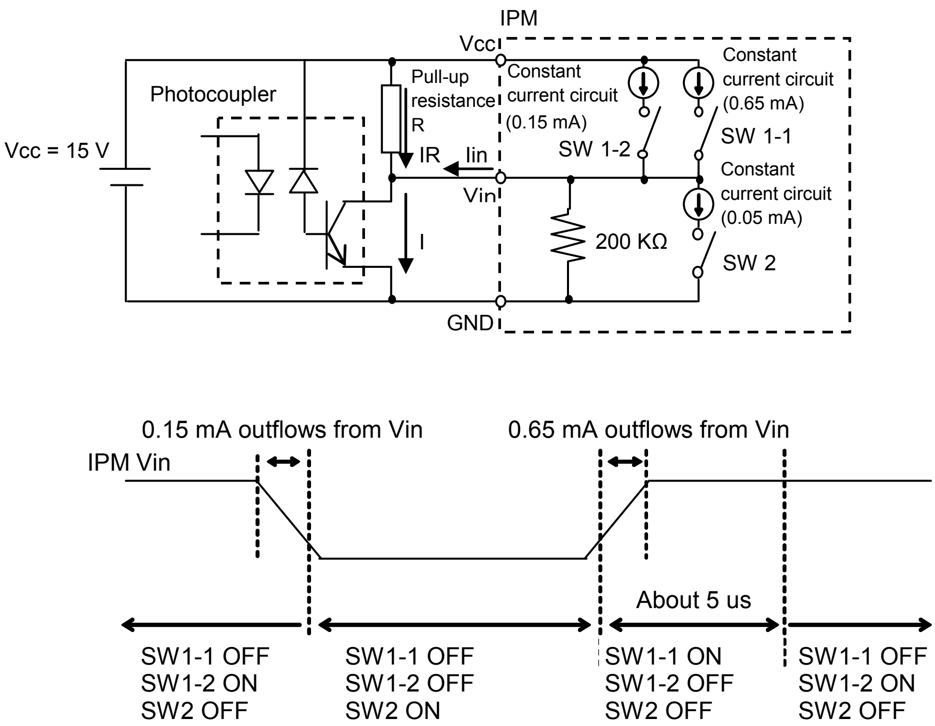
For P631 package which has two P/N terminals, it is effective for surge voltage reduction to connect snubber circuits to the P1-N1 and P2-N2 terminals. Do not connect snubber circuits across the two terminals such as P1-N2 and P2-N1 because it may cause a malfunction.

2.10 Grounding capacitor

Please connect about 4500 pF capacitors between each AC input line and Earth ground to prevent a noise from the AC input line to the system.

2.11 Input circuit of IPM

There is a constant current circuit in the input part of the IPM as shown in Figure 4-5 and constant current of Iin = 0.15 mA or Iin = 0.65 mA flows at that timing shown in Figure 4-5.The current of the secondary side of optocoupler is the sum of the constant current Iin and the current through a pull-up resistor IR. Therefore it is necessary to decide the current of primary side of optocoupler IF so that enough current flows in the secondary side of optocoupler. If the IF is insufficient, there is a possibility that a malfunction arises on the secondary side.



* The operation duration of constant current circuit (0.65 mA) is the length of time until V_{in} reaches V_{CC}, and the maximum length about 5 μs.

Figure 4-5 IPM input circuit and constant current operation timing

3 Optocoupler peripheral circuits

3.1 Control input Optocoupler

3.1.1 Optocoupler rating

Use an optocoupler that satisfies the characteristics indicated below:

- CMH = CML > 15 kV/μs or 10 kV/μs
- tpHL = tpLH < 0.8 μs
- tpLH − tpHL = −0.4 to 0.9 μs
- CTR > 15%

Example: HCPL-4504 made by Avago Technologies

TLP759 (IGM) made by Toshiba

Pay attention to safety standards such as UL and VDE.

The reliability and characteristics of these optocouplers are not guaranteed by Fuji Electric.

3.1.2 Primary side limit resistance

The current limiting resistor on the primary side should be selected to have an ability to flow a sufficient current on the secondary side. Also, an age-related deterioration of CTR of the optocoupler should be considered in the design of the current limiting resistor.

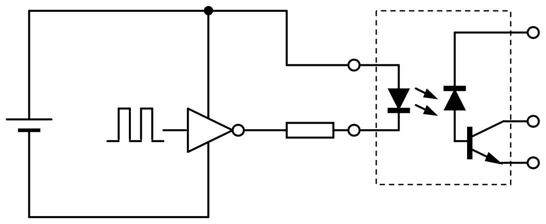
3.1.3 Wiring between optocoupler and IPM

The wiring distance between the optocoupler and the IPM should be short as much as possible to reduce the impedance of the line. The primary line and secondary line of the optocoupler should be kept away from each other to reduce the floating capacitance. High dv/dt is applied between the primary side and the secondary side.

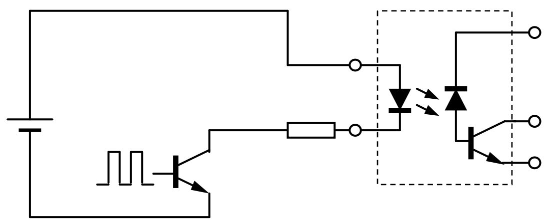
3.1.4 Optocoupler drive circuit

A noise current flows through the floating capacitance between the primary side and the secondary side of the optocoupler due to the high dv/dt that is generated inside or outside of the IPM. The dv/dt tolerance also varies by the optocoupler drive circuit. Good/bad examples of the optocoupler driving circuits are shown in Figures 4-6. As the opotocoupler input is connected in low impedance in these good examples, malfunction caused by noise current hardly occurs. Please contact to the optocoupler manufacturer regarding details of the optocouplers.

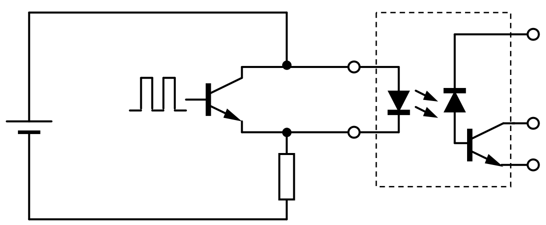
Good example: Totem pole output IC
Current limit resistance on cathode side of photodiode



Bad example: Open collector



Good example: Diodes A and K are shorted
between transistors C and E
(Case that is particularly strong against photocoupler off)



Bad example: Current limit resistance on anode side
of photodiode

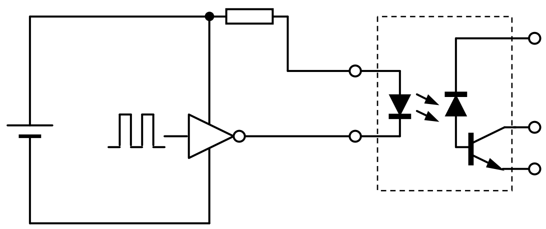


Figure 4-6 Optocoupler input circuits

3.2 Alarm output optocoupler

3.2.1 Optocoupler ratings

A general-purpose optocoupler can be use but an optocoupler of the following characteristics is recommended:

- 100% < CTR < 300%
- Single channel type

Example: TLP781-1-GR rank or TLP785-1-GR rank made by Toshiba

Pay attention to safety standards such as UL and VDE also.

The reliability and characteristics of the optocouplers indicated above are not guaranteed by Fuji Electric.

3.2.2 Input current limiting resistance

A current limiting resistor for input side diode of optocoupler is built in the IPM. The resistance R_{ALM} = 1.3 kΩ, and I_F is about 10 mA when the optocoupler is connected to V_{CC} = 15 V. An external current limiting resistor is not required.

If large current Iout > 10 mA is required for the optocoupler output side, it is necessary to increase the optocoupler's CTR value to achieve the required level.

3.2.3 Wiring between optocoupler and IPM

Note that high dv/dt is applied to the optocoupler for alarm output, please take care as same as to Section 3.1.3.

4 Connector

Connectors that conform to the shape of control terminals of V-IPM are available on the market.

For P630: MA49-19S-2.54DSA and MA49-19S-2.54DSA (01) made by Hirose Electric

For P631: MDF7-25S-2.54DSA made by Hirose Electric

Furthermore, please contact the connector manufacturer for the details of reliability and use of these connectors.

Please note that the reliability and the characteristics of these connectors are not guaranteed by Fuji Electric.

– Chapter 5 –

Cooling Design

1 Guidelines for heat sink selection

- To safely operate the IGBT, it is necessary that the junction temperature Tj should not exceed Tjmax. Carry out thermal design having sufficient margins so that the junction temperature Tj never exceeds the Tjmax also on occurrence of disorder such as overload.
- There is a risk of thermal breakdown, if the IGBT is operated at temperature above the Tjmax. Although the TjOH protected function in the IPM activates when the junction temperature exceeds the Tjmax, however, there is a possibility that the protection cannot work if the temperature rises rapidly. Also pay attention to the FWD so that the Tjmax should not be exceeded, same case for the IGBT.
- The heat sink temperature should be measured just below the center of the chip. Please refer to the IPM specification sheet for the chip layout drawing. In addition, please consider the following documents regarding to the design for your reference.

[IGBT Module Application Manual RH984b]

- How to calculate the occurred loss
- How to select a heat sink
- How to mount IPM to a heat sink
- Troubleshooting

2 Notice for heat sink selection

Although a guideline for heat sink selection is described in the IGBT Module Application Manual (RH984b), please pay attention to the following recommendations as well.

2.1 Flatness of the heat sink surface

It is recommended that flatness of the heat sink surface is less than 50 μm per 100 mm between screw mounting points and the surface roughness is less than 10 μm.

If the heat sink surface is concave or convex, the contact thermal resistance (Rth(c-f)) will be increased.

[Reason]

- Concave: A gap appears between the heat sink surface and the bottom of the IPM, and the heat transfer performance becomes worse (contact thermal resistance Rth(c-f) increases).
- Convex (larger than +50 μm): The copper base of the IPM is deformed and there is a possibility of a generation of cracks on the internal insulated board by the mechanical stress.

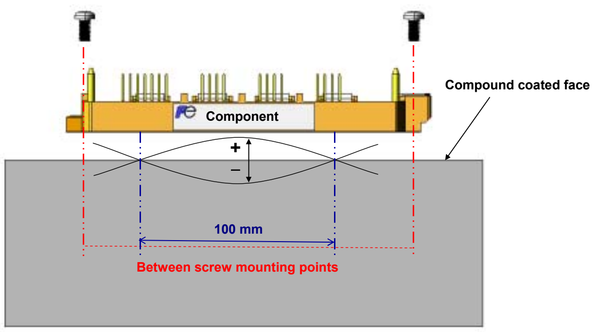


Figure 5-1 Flatness of heat sink surface

3 Mounting instruction of the IPM

3.1 Layout of IPMs on a heat sink

The thermal resistance varies depending on the IPM mounting position. Please note the following matters:

- When an IPM is mounted to a heat sink, it is recommended to place the IPM on the center of the heat sink to maximize the usage of the heat sink.
- When multiple IPMs are mounted to a single heat sink, the IPMs location and layout should be designed with their generated losses. Allocate the largest area to the IPM which generates largest loss.

3.2 Application of thermal grease

To reduce the contact thermal resistance, apply thermal grease between the IPM and heat sink mounting surface.

Use of a stencil mask and use of a roller are available in general as methods for application of thermal grease.

The purpose of the thermal grease is to promote heat transmission to the heat sink, but the grease has a limited thermal capacity. If the thickness of thermal grease is larger than the appropriate thickness, the grease layer prevents the heat transfer from the IPM to the heat sink and the junction temperature will be increased. On the other hand, if the thermal grease thickness is less than the appropriate thickness, such as a void area, a gap or space may be caused between the heat sink and the IPM. This may cause an increasee of the contact thermal resistance. Therefore thermal grease should be applied in appropriate thickness.

If the thermal grease thickness is inadequate, the thermal dissipation of heat becomes worse, and there is a possibility of breakdown in the worst case due to the excess of the junction temperature Tjmax.

Application of thermal grease using a stencil mask is recommended so that uniform thickness can be achieved.

Figure 5-2 shows an example of a thermal grease application using a stencil mask. The basis of this method is applying specified weight of thermal grease to the metallic base of the IPM using a stencil mask. It is possible to achieve a uniform thickness of thermal grease by mounting the IPM with thermal grease to the heat sink and tightening screws with recommended torque for each product. Fuji Electric can provide recommended stencil mask designs upon request of customers.

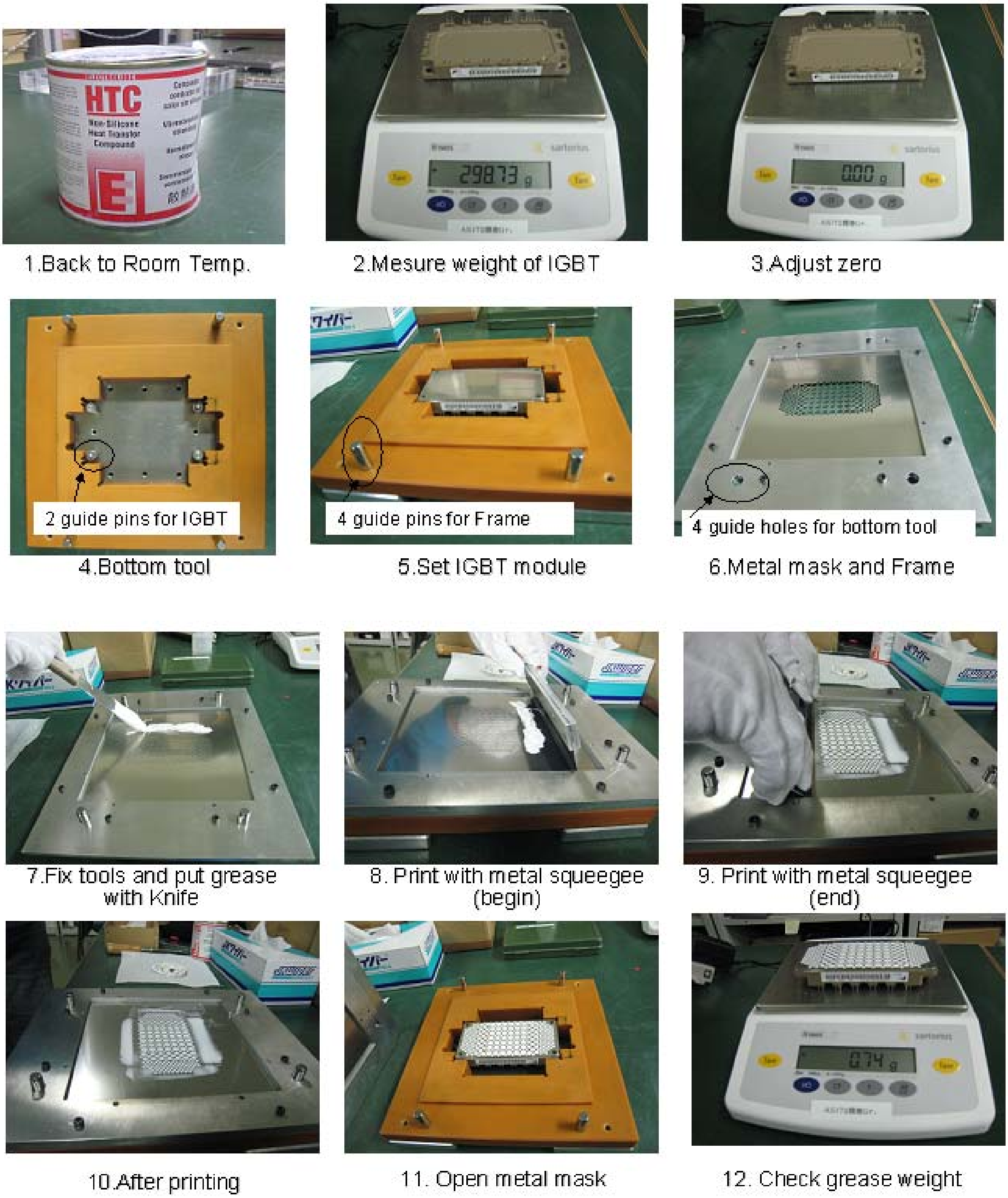


Figure 5-2 Outline of a thermal grease application method

The required thermal grease weight is given by the following equation by assuming uniform thermal grease thickness:

$$\text{Thermal grease weight (g)} \times 10^{-4} = \text{Thermal grease thickness (μm)} \times \text{IPM base area (cm}^2\text{)} \times \text{Thermal grease density (g/cm}^3\text{)}$$

Calculate the thermal grease weight that corresponds to the required thermal grease thickness from this equation, and apply the thermal grease. The recommended thermal grease thickness after spreading of thermal grease is 100 μm. Also please note that the optimum thermal grease thickness varies by the characteristics of the used thermal grease and application method.

Table 5-1 shows the footprint area of IPMs.

Table 5-1 Back Base plate area of IPM

Package	**Back side base area (cm^2)**
P629	21.71
P626	22.77
P630	55.67
P631	141.24
P636	41.17

Table 5-2 Shows recommended thermal greases (typical)

Table 5-2 Typical thermal greases

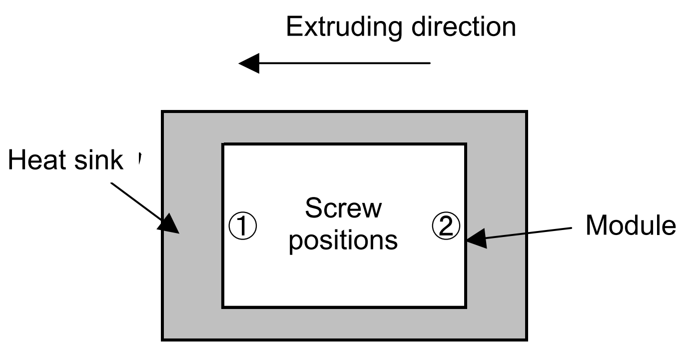
Type	**Manufacturer**
G746	Shin-Etsu Chemical Co., Ltd.
TG221	Nippon Data Material Co., Ltd.
SC102	Dow Corning Toray Co., Ltd.
YG6260	Momentive Performance Materials Inc.
P12	Wacker Chemie
HTC	ELECTROLUBE

The list of thermal greases shown above is based on the information at the time of issuance of this Application Manual. Please contact these manufacturers for details of these thermal greases.

3.4 Screw tightening

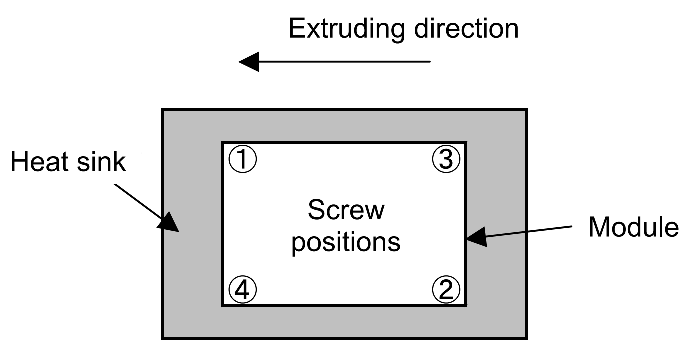
Figure 5-3 shows screw-tightening procedures for mounting an IPM to a heat sink. It is recommended to tighten all screws with specified tightening torque.

The specified tightening torque is described in the specification. If the screw tightening torque is insufficient, there is a possibility of increasing the contact thermal resistance or loosing screws during operation. If the tightening torque is excessive, on the other hand, the case would be damaged.



	Torque	Order
1st time (initial tightening)	1/3 of specified torque	(1) → (2)
2nd time (permanent tightening)	100% of specified torque	(2) → (1)

(1) Case of IPM of 2-point mounting type



	Torque	Order
1st time (initial tightening)	1/3 of specified torque	(1) → (2) → (3) → (4)
2nd time (permanent tightening)	100% of specified torque	(4) → (3) → (2) → (1)

(2) Case of IPM of 4-point mounting type

Figure 5-3 IPM mounting method

3.5 IPM mounting direction

When an IPM is mounted on an extruded heat sink, it is recommended that the IPM is mounted in parallel to the extrusion direction as shown in Figure 5-3. This purpose is to reduce the influence of heat sink deformation.

3.6 Verification of chip temperature

After selecting a heat sink and IPM mounting position is decided, measure the temperature at various points on case (Tc), heat sink (Tf) and junction temperature (Tj).

Figure 5-4 shows an example of measuring method for an accurate measurement of case temperature (Tc). Please measure the case temperature just below the chip center. The chip location is described in the specification.

Please verify that the chip junction temperature does not exceed Tjmax and the thermal design meets required life time of the system.

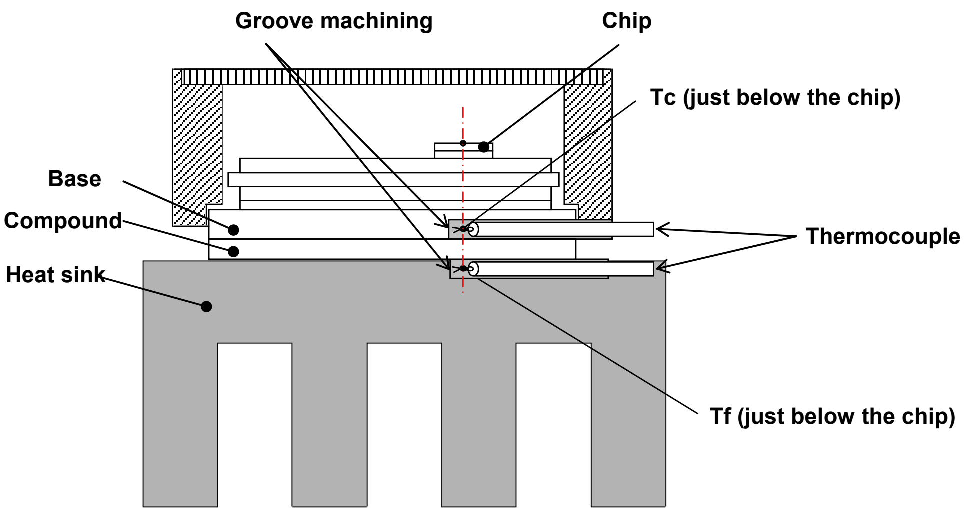


Figure 5-4 Measuring the case temperature

– Chapter 6 –

Precautions for use

Table of Contents | Page

1 Main power supply

1.1 Voltage range

- The collector and emitter terminal voltage (=V_{CES}) should never exceed the absolute maximum rated voltage (600 V-series = 600 V, 1200 V-series = 1200 V).
- In order to keep the maximum surge voltage between all terminals within the rated voltage during the switching, connect the IPM and other components as short as possible to each other and connect a snubber capacitor between P and N terminals.

Between all terminals means as follows:

P629, P626, P630 (6in1), P636 (6in1): [P-(U, V, W), (U, V, W)-N]

P630 (7in1), P636 (7in1): [P-(U, V, W, B), (U, V, W, B)-N]

P631 (6in1): [P1-(U, V, W), P2-(U, V, W), (U, V, W)-N1, (U, V, W)-N2]

P631 (7in1): [P1-(U, V, W, B), P2-(U, V, W, B), (U, V, W, B)-N1, (U, V, W, B)-N2]

- In case of P631, connect the dc bus power supply between the P1 and N1 or between the P2 and N2. Don’t connect cross-multiply connections such as between the P1 and N2 and between the P2 and N1. It might cause a false operation. It is effective to connect snubber capacitors to both terminals between the P1/N1 and between the P2 / N2 terminals to suppress the surge voltage.

1.2 Noise protection

- The V-IPM series has a tolerance against exogenous noise. However, there is a possibility of false operation or breakdown of the V-IPM by exogenous noise depending on the kind and intensity of the noise. It is recommended to implement other protections against the noise applied to the IPM.

1.2.1 Protection against external noise

- Take countermeasures such as installing a noise filter along the AC line and strengthening of insulating grounding.
- Add a capacitor of <100 pF between signal input line and signal GND of every phase, as necessary.
- When the excessive noise voltage increases on the alarm terminal, it may become a false output of the alarm signal. Please connect 0.2 kΩ to 1 kΩ resistor in series to the alarm terminal as needed. Please choose a most suitable resistance level in consideration of CTR of the optocoupler on this occasion.
- Connect a grounding capacitor of about 4700 pF between each line of 3 phases of AC input and ground, for preventing entry of noise through the AC line.
- Insert an arrester against lightning surge.

1.2.2 Protection against the internal noise from the IPM

- Outside of rectifier: Apply the same countermeasures as Section 1.2.1.
- Inside of rectifier: Add snubber capacitors or similar circuit to the P/N line. (Particularly in case multiple inverters are connected to one rectifying converter)

1.2.3 Protection against the noise from output terminals

- Apply countermeasures outside of the module to block contactor switching surge or others from entering the device.

2 Control power supply

2.1 Voltage range

- The control power supply voltage range including ripple should not exceed the spec value.

<table>
<tr><th>Control power supply voltage (Vcc) (V)</th><th>IPM operation</th><th>Control power supply under voltage protection (UV)</th><th>IPM input signal voltage</th><th>IGBT operation</th></tr>
<tr><td rowspan="2">0 < Vcc ≤ 12.5</td><td rowspan="2">Control IC does not work correctly and the gate signal output is unstable. However, the IGBT does not turned on if the Vcc applied to the IGBT directly because VCC is lower than gate threshold voltage Vth. The UV protection does not work and no alarm output.</td><td rowspan="2">-</td><td>Hi</td><td>-</td></tr>
<tr><td>Lo</td><td>-</td></tr>
<tr><td rowspan="2">5.0 < Vcc ≤ 11.0</td><td rowspan="2">Control IC is working normally and IGBT is kept OFF state because UV protection is activated. UV alarm output is generated.</td><td rowspan="2">Activated</td><td>Hi</td><td>OFF</td></tr>
<tr><td>Lo</td><td>OFF</td></tr>
<tr><td rowspan="4">11.0 < Vcc ≤ 12.5</td><td rowspan="4">(1) When UV protection is activated: IGBT is kept OFF state and alarm signal output is generated.
(2) When UV protection is not activated: The IGBT status follows the input signal, no alarm output is generated.</td><td rowspan="2">(1) Activated</td><td>Hi</td><td>OFF</td></tr>
<tr><td>Lo</td><td>OFF</td></tr>
<tr><td rowspan="2">(2) Cancelled or before action</td><td>Hi</td><td>OFF</td></tr>
<tr><td>Lo</td><td>ON</td></tr>
<tr><td rowspan="2">12.5 < Vcc < 13.5</td><td rowspan="2">UV protection is not activated. The IGBT switching follows the input signal, but the losses would be increased and the emission noise relatively small. The protection function does not work sufficiently and the IGBT might be damaged because protection characteristics are shifted.</td><td rowspan="2">Cancelled</td><td>Hi</td><td>OFF</td></tr>
<tr><td>Lo</td><td>ON</td></tr>
<tr><td rowspan="2">13.5 < Vcc ≤ 16.5</td><td rowspan="2">Recommended voltage range. Drive circuit works stably. The IGBT switching follows input signal.</td><td rowspan="2">Cancelled</td><td>Hi</td><td>OFF</td></tr>
<tr><td>Lo</td><td>ON</td></tr>
<tr><td rowspan="2">16.5 < Vcc ≤ 20</td><td rowspan="2">The switching losses are decreased but emission noise tend to be increased. The protection function does not work sufficiently and the IGBT might be damaged because protection characteristics are shifted.</td><td rowspan="2">Cancelled</td><td>Hi</td><td>OFF</td></tr>
<tr><td>Lo</td><td>ON</td></tr>
<tr><td>Vcc < 0, Vcc > 20</td><td>If the Vcc is < 0V or > 20V, the drive circuit and main chip may be damaged. Never apply such voltage to the device.</td><td>-</td><td>-</td><td>-</td></tr>
</table>

2.2 Voltage ripple

- A voltage range of V_{CC} is 13.5 to 16.5 V that includes voltage ripple is recommended.
  The control power supply should be designed to guarantee sufficient low voltage ripple. Also, the noise on the power supply voltage should be as low as possible.
  If the control power supply voltage exceeds the recommended voltage range, there is a possibility of a malfunction or breakdown of the IPM.
- Design the control power supply so that dv/dt will not exceed 5 V/μs.

Additionally, it is recommended that variation of the power supply voltage does not exceed ±10%.

2.3 Power supply startup/shutdown sequence

- Make sure that the main power supply voltage Vcc is within the recommended voltage range, before applying this voltage to the main power supply terminals (P-N terminal).

- Shutdown the voltage supply (Vcc) and disconnect the P-N terminals of the IPM then.
  If V_{CC} is applied to the P-N terminals before the voltage reaches the recommended voltage range there may happen a malfunction due to exogenous noise and the chip might be damaged. Same case occurs if low voltage of V_{CC} remains before disconnecting P-N terminals.

2.4 Alarm output during startup/shutdown of power supply

- An alarm signal (typ = 4 ms) is generated when the power supply voltage is lower than UV protection level during startup of the power supply.
  The alarm signal is stopped after typ = 4 ms but the input signal is ignored unless the root cause of the protection is settled. An input signal is accepted when all the protection operation functions are not activated (dissolving of protection factor, elapse of tALM and input signal OFF). The drive control circuit should be designed to output gate signals after the period of alarm signal output.
- Also note that an alarm signal is generated during VCC shutdown.
- See Chapter 3, section 5 [Timing chart] for considering the timing chart.

2.5 Notes for the design of control circuit

- The control circuit should be well-designed to have enough capability to provide a specified consumption current (Icc).
- Minimize the length of the wiring between the optocoupler and the IPM as well as the pattern layout should be designed to minimize the floating capacitance between the primary side and the secondary side of the optocoupler.
- Add a capacitor between Vcc and GND for high-speed optocouplers.
- Use a high-speed optocoupler of tpHL, tpLH ≤ 0.8 μs and of high CMR type for the control signal input circuit.
- Use a low-speed optocoupler of CTR ≥ 100% for the alarm output circuit.
- The four power supply units for the power supply control Vcc have to be isolated. Also, it is recommended to connect a capacitor which has a good frequency response characteristic on the output terminal of each power supply unit to suppress transient voltage variation.
- Note that if a capacitor is connected between an input terminal and GND, the response time of the optocoupler becomes slow.
- The optocoupler primary side current IF should have enough capability in consideration of CTR of the used optocoupler. To reduce the influence of noise, the pull-up resistance on the optocoupler secondary

side should be small.
As described in Chapter 4 [Typical application circuits], it is necessary to design the IF on the optocoupler primary side so that the constant current through the pull-up resistance IR can flow to the secondary side. . If the IF is insufficient, there is a possibility of a malfunction on the secondary side circuit.
Also, the resistance of current limiting resistor on the primary side of the optocoupler should be designed in consideration of a life time of the optocoupler.

3 Protective functions

- An alarm output function varies depending on the package. Check protective functions of your IPM by referring to Chapter 3.1 [List of functions].

3.1 Protected operation in general

3.1.1 Range of protection

- The protective functions of the IPM deal with non-repeated abnormal phenomena. Avoid a situation of repetitive occurrence of abnormal phenomena.
- Overcurrent and short-circuit protections are guaranteed under the condition of control power supply voltage 13.5 to 16.5 V and main power supply voltage 200 to 400 V (600 V-series) or 400 to 800 V (1200 V-series).

3.1.2 Action on occurrence of alarm output

- When an alarm signal is generated the input signal to the IPM stops and shutdown the system immediately.
- The IPM protective functions protect the IPM against abnormal phenomena but they are not able to eliminate the causes. Please dissolve the abnormal phenomena by finding the root cause and then restart the system.
- When an abnormal phenomenon is detected in the upper arm, the IGBT of the detected phase is only turned off and an alarm output is generated from the same phase (excluding P629). Switching of other phases is permitted at this time. On the other hand, when an abnormal phenomenon is detected in the lower arm all the IGBTs of the lower arm (+ brake unit) is turned off regardless of the phase and an alarm is generated from the lower arm. Switching of all phases of the upper arm is permitted at this time.

3.2 Precautions for protected operation

3.2.1 Overcurrent (OC)

- When overcurrent continues longer than 5 μs (t_{dOC}), it is judged as being in the OC condition and the IGBT is turned off softly. An alarm output signal is generated.

  If current descend below the trip level within the t_{dOC} period the OC protection is not activated and the

IGBT is turned-off normally (hard turn-off).

- P629 does not have an alarm output on the upper side arms but the OC protection does work and the IGBT is turned off softly.

3.2.2 Short-circuit (SC)

- When short-circuit current continues longer than 2 μs (tdsc) it is judged as being in the SC condition and the IGBT is turned off softly. An alarm signal output is generated.
  If short-circuit current descends below the trip level within the tdsc period, the SC protection does not work and soft turn-off is not applied to the IGBT.
- P629 does not have an alarm output on the upper arms but the SC protection does work and soft turn-off is applied to the IGBT.

3.2.3 Ground short circuit

- When ground-fault current flows to the IGBT of the lower arm longer than the dead time tdOC or tdsc

the OC (SC) protection is activated and an alarm signal is generated.

- When the ground-fault current flows to the IGBT of the upper arm longer than tdOC or tdsc the OC (SC) protection is activated but the alarm signal output varies by the package.
  P629: The upper arm is protected by the OC (SC) function without alarm output.
  P626, P630, P631, P636: The upper arm is protected by the OC (SC) function and an alarm signal is generated.

3.2.4 Booting under short-circuit or ground-fault status

- Because the OC or SC protection involves a dead time (tdOC or tdsc), the protected operation is not activated when the input signal pulse width is shorter than the dead time. Especially when the IPM is booted under the load short-circuit condition the input signal pulse width is shorter than the dead time for a long time (tens of mill seconds). The chip temperature rapidly increases because the protection function doesn't work. In this case, even though the chip over heat protection (TjOH) works against the increase of the chip temperature, the response time of TjOH is about 1ms. Therefore, there is a possibility of damaging the chip by over temperature since the protection is not on time.

3.3 Chip overheat protection

- Chip overheat protection (TjOH) is built in every IGBT including brake unit. The TjOH interacts when a chip is abnormally heated up. Since the V-IPM does not have a case overheat protection, TjOH protection does not activate when Tj is lower than the trip level even if Tc reveals an abnormal temperature. Please implement another protection for Tc overheating as required.

3.4 Protection of FWD

- FWDs don't have protective functions (overcurrent, overheat protection).

4 Power Cycling Capability

- The lifetime of semiconductor products is not unlimited. Note that thermal fatigue caused by temperature rise/drop due to self-heating restricts the lifetime. If temperature rise and drop occur continuously the reduction of the temperature variation amplitude is mandatory.

(1) ΔTj power cycle capability: life time determined by junction temperature (Tj) change that arises in a relatively short period and consequently a deterioration of wire connection on the chip surface is possible.
Please refer to MT5Z02525 (P629, P626, P630, P631, P636) for the ΔTj power cycling capability curves.

(2) ΔTc power cycle capability: life time determined by copper base plate temperature (Tc) change that arises in a relatively long period and consequently a deterioration of solder layer between the DCB and copper base can occur which is the main cause of the life time reduction).
Please refer to MT5Z02509 (P629, P626, P630) and MT5Z02569 (P630 low thermal resistance version, P631, P636) for ΔTc power cycling capability curves.

- Please refer to chapter 11 [Reliability of power modules] of Fuji IGBT Module Application Manual (RH984b) in addition.

5 Others

5.1 Precautions for use and mounting procedure

(1) Please refer to the IPM specification in addition to this manual for usage and mounting procedure of the IPM.

(2) Please install a fuse or circuit breaker of an adequate capacity between the input AC power line and the system for stopping the spreading of damage when the IPM is failed.

(3) Designing a turn-off operation of the IGBT chip, please confirm that the turn-off current-voltage operation track does not exceed the RBSOA specification.

(4) Please understand the product usage environment and check if the reliability of the IPM satisfies the demand, before using the product. If the IPM is used beyond the spec, there is a possibility of failure before the designed lifetime of the system.

(5) Please reduce the contact thermal resistance as much as possible between of the IPM and the heat sink by applying thermal compound. (See Chapter 5, Section 3.)

(6) Please use appropriate length of screws. The package may be damaged if the screw length is longer than the screw hole depth. (See Chapter 1, Section 6.)

(7) Tightening torque and heat sink flatness should be within the range of specified values.

Wrong handling may cause an insulation breakdown. (See Chapter 5, Section 2.)

(8) Do not apply excessive weight to the IPM.
Don't apply deforming forces to the lid. If pushing force was applied to the lid, the internal circuit might be damaged. If pull force was applied, the lid might get off. Don't bend the control terminals.
Pay attention not to bend control terminals.

(9) Do not apply reflow soldering to the main terminals or control terminals. In addition, be careful so that heat, flux and cleaners for other products do not affect the IPM.

(10) Avoid a place where corrosive gases are generated and locations of excessive dust.

(11) Avoid any applied static electricity to main terminals and control terminals of the IPM.

(12) Please confirm that the Vcc is 0V before mounting/dismounting of control circuits to/from the IPM.

(13) Do not make the following connections outside of the IPM:
Control terminal GNDU and Main terminal U
Control terminal GNDV and Main terminal V
Control terminal GNDW and Main terminal W
Control terminal GND and Main terminal N (N1, N2 in case of P631)
Malfunction may cause if these terminals are connected.

(14) If there is an unused phase or built-in brake circuit the control power supply voltage should be applied to these unused phases and pull-up both of input terminal voltage (V_{IN}). Connect the alarm output terminal (ALM) to the Vcc line. Otherwise the IPM generates an alarm output if the control power supply voltage is applied to the IPM.

(15) Please pull-up alarm terminal to control power supply Vcc if the alarm is not used.

(16) Regarding the alarm factor identification function, the alarm signal pulse width shown in this manual or specification indicates the output width from the IPM. The time delays of optocouplers and other circuits should be considered when using the alarm output functions.

(17) The IPMs are not allowed to use in parallel. Each individual IPM has its own drive circuits and protection circuits. If multiple IPMs are operated in parallel, there is a possibility of current imbalance and current constriction due to the difference of switching speed and protection timing.

(18) The case and epoxy resin is not a non-flammable material even though the materials meet the standard UL 94V-0. Also, the surface temperature of the lid shouldn't exceed glass-transition temperature during soldering. At a certain temperature the terminals deform, melt or solder material remains on the case material of the package.

– Chapter 7 –

Troubleshooting

Table of Contents			Page

1 Troubleshooting

An IPM has various integrated protective functions (such as overcurrent protection and overheat protection) unlike a standard module. It shuts down safely in the case of an abnormal condition. However, it may breakdown depending on the abnormality of the failure that occurred. When the IPM has failed, it is necessary to take countermeasures upon clarification of the situation and find the root cause of the breakdown.

Failure tree analysis charts are shown in Figure 7-1. Carry out the investigation of the failure mode by using these charts. For the failure criteria, see chapter 4, section 2 [IGBT test procedures] of the IGBT Module Application Manual (RH984b).

Furthermore, when an alarm signal is generated from the IPM investigation of the root cause by reference of the alarm factor analysis chart can be done as shown in Figure 7-2.

2 Failure analysis tree charts

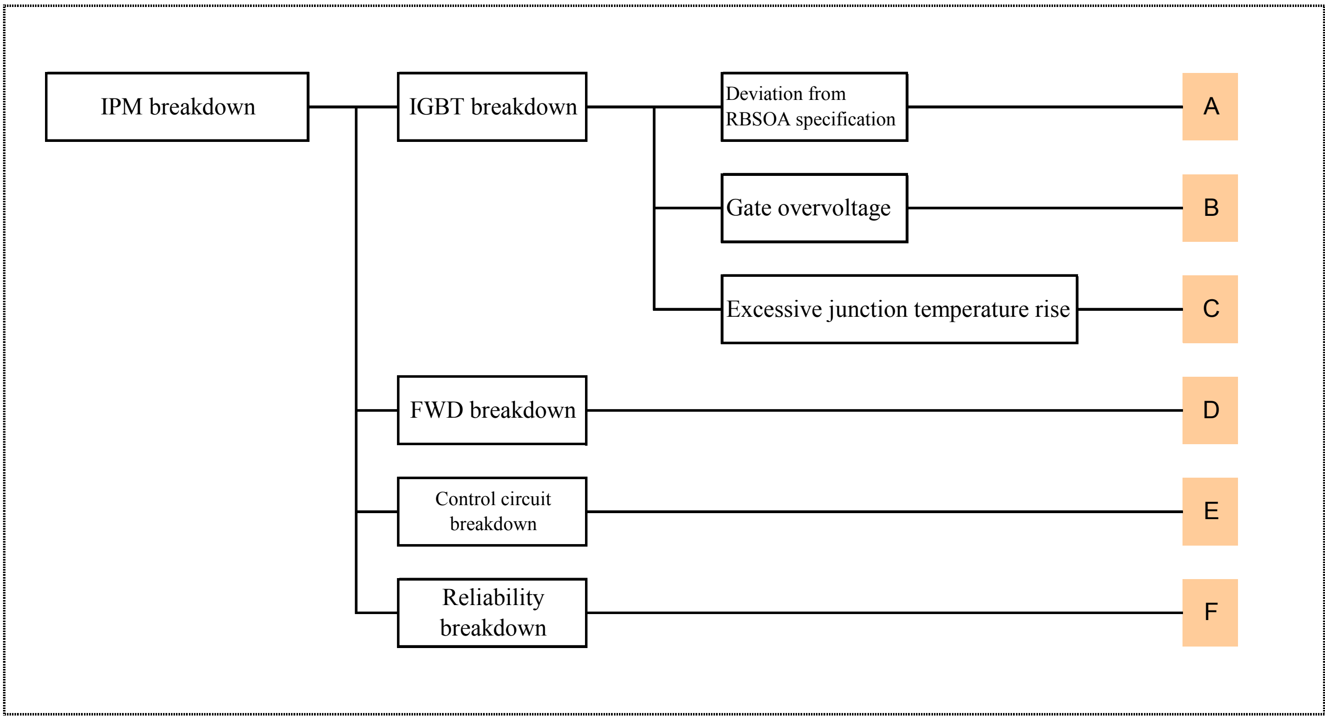


Figure 7-1 (a) IPM failure tree analysis chart

(Codes A to F are linked with those indicated in separate FTA pages.)

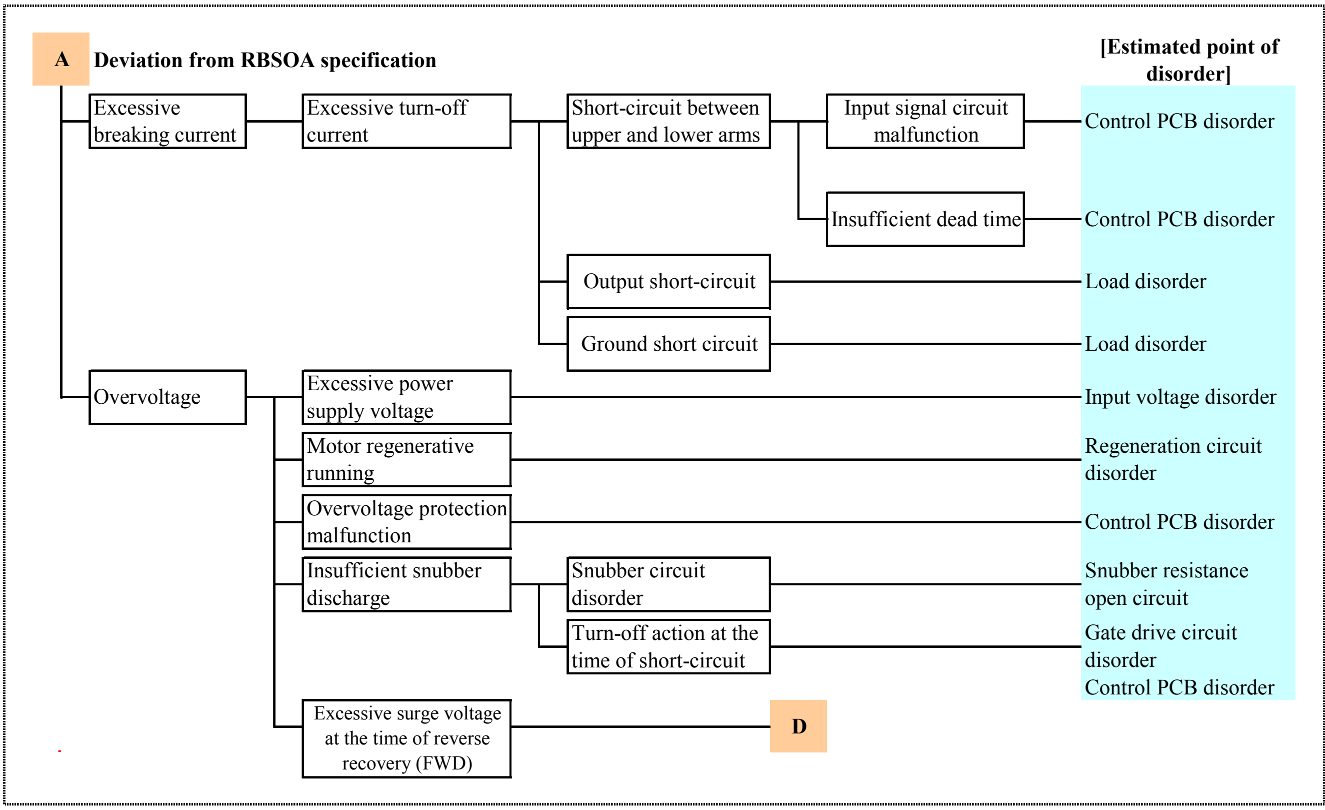


Figure 7-1 (b) Mode A: Deviation from RBSOA specification

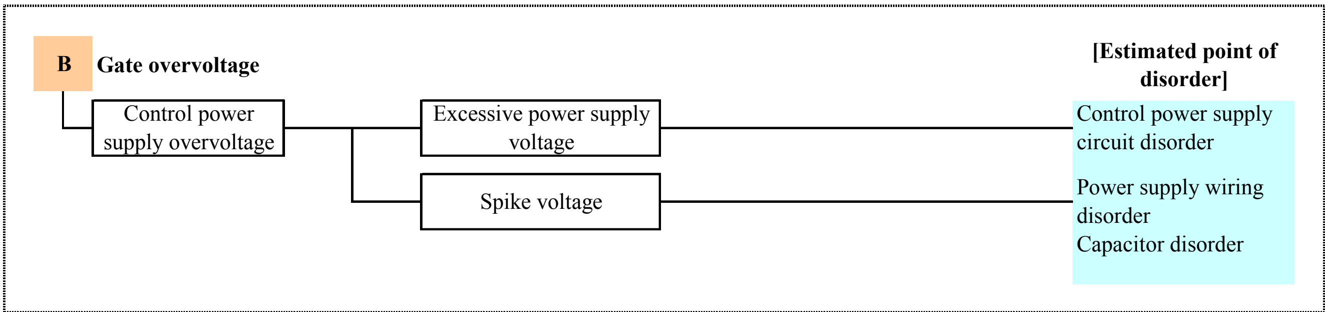


Figure 7-1 (c) Mode B: Gate overvoltage

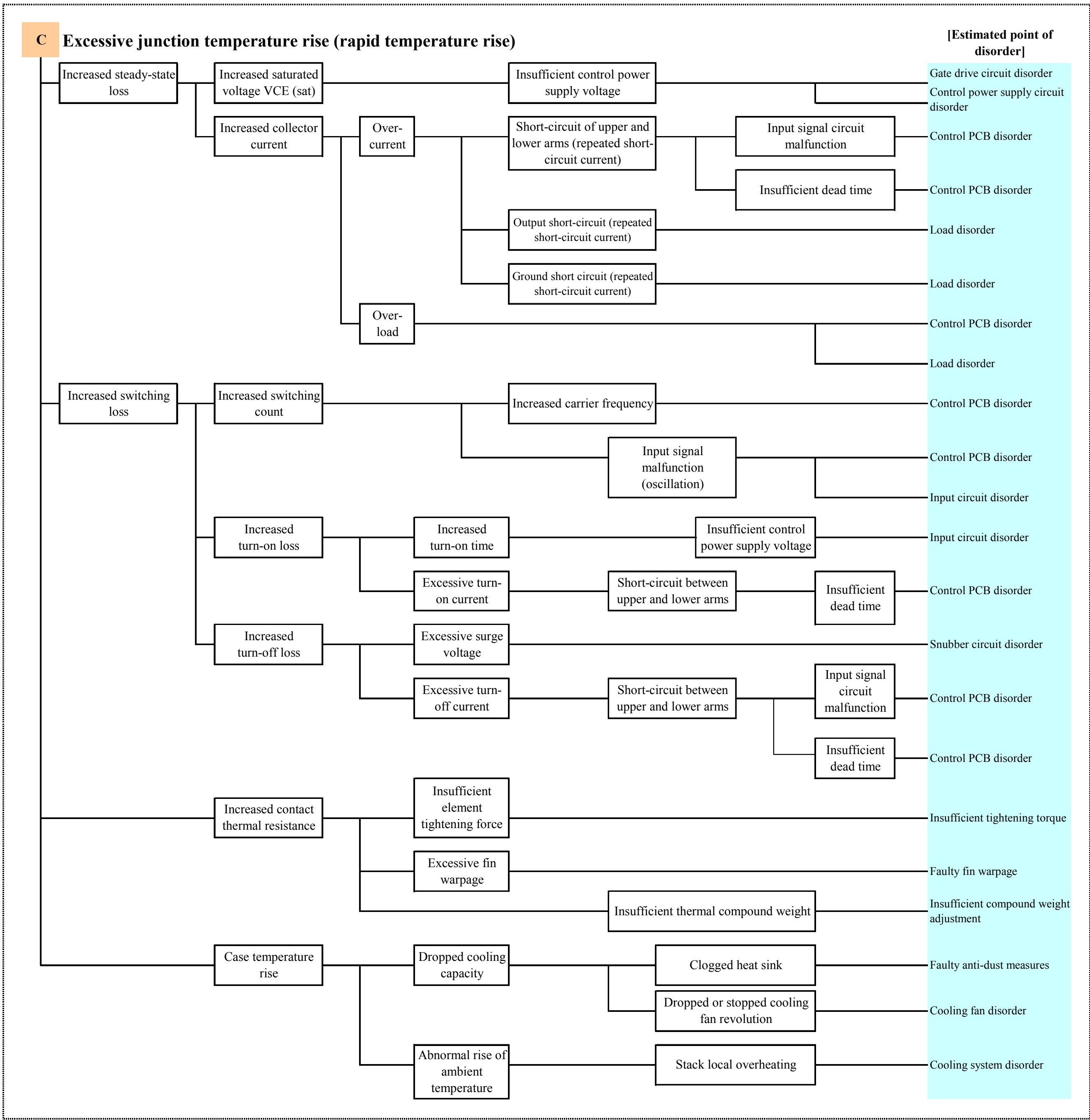


Figure 7-1 (d) Mode C: Excessive junction temperature rise

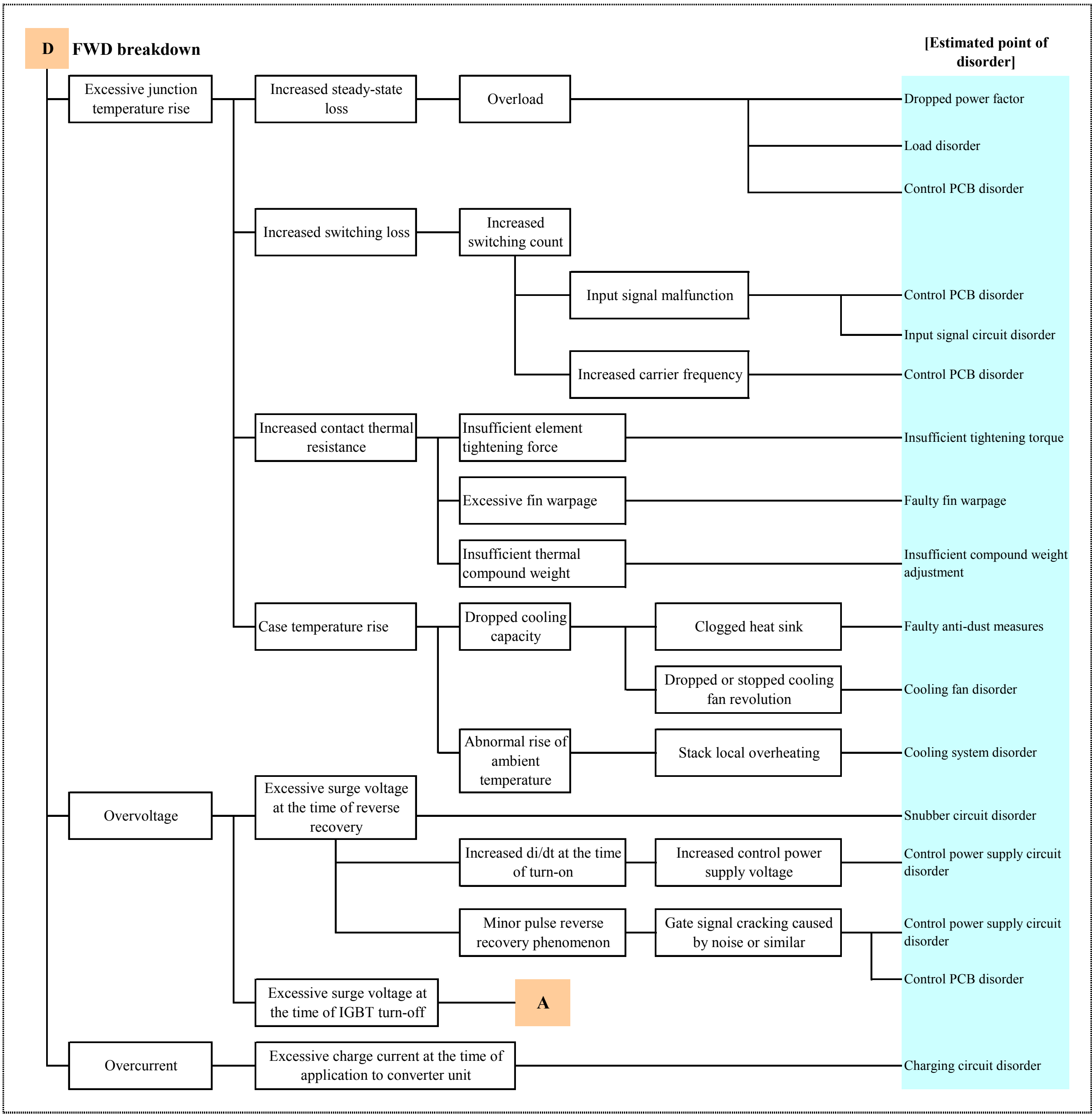


Figure 7-1 (e) Mode D: FWD breakdown

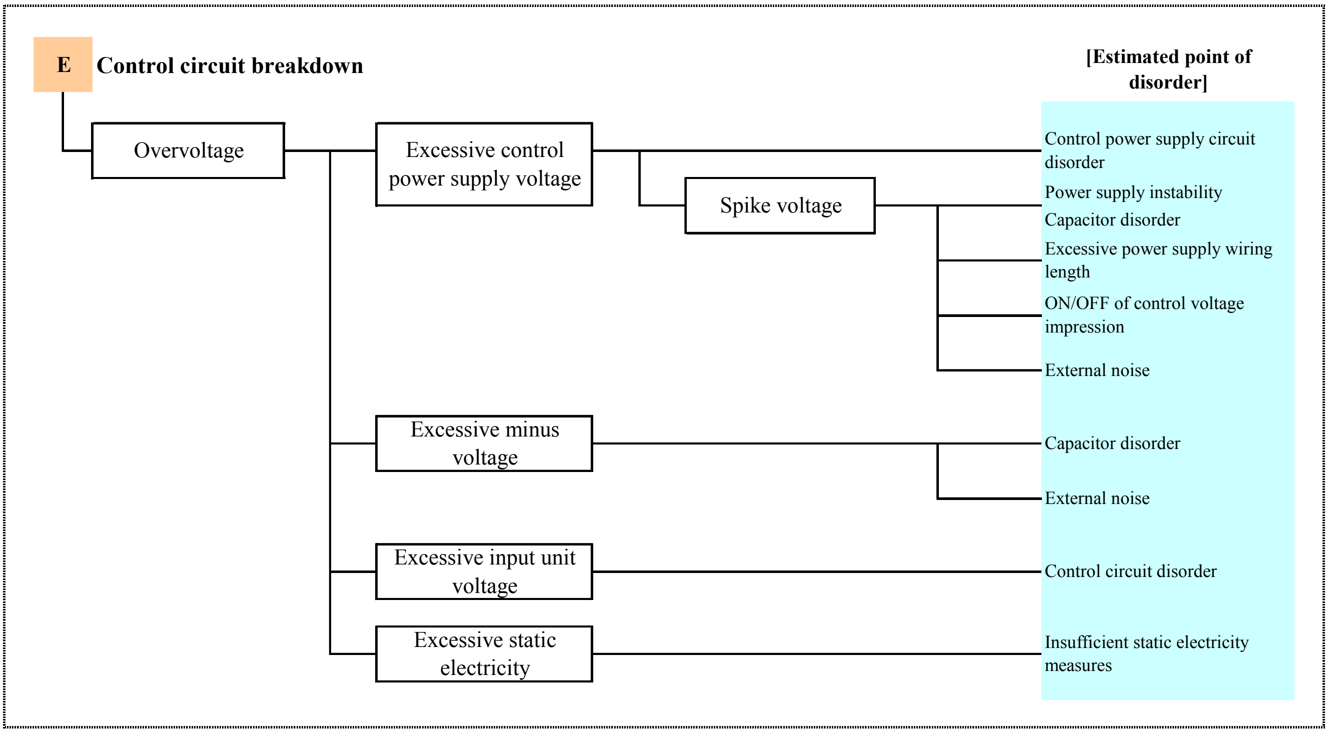


Figure 7-1 (f) Mode E: Control circuit breakdown

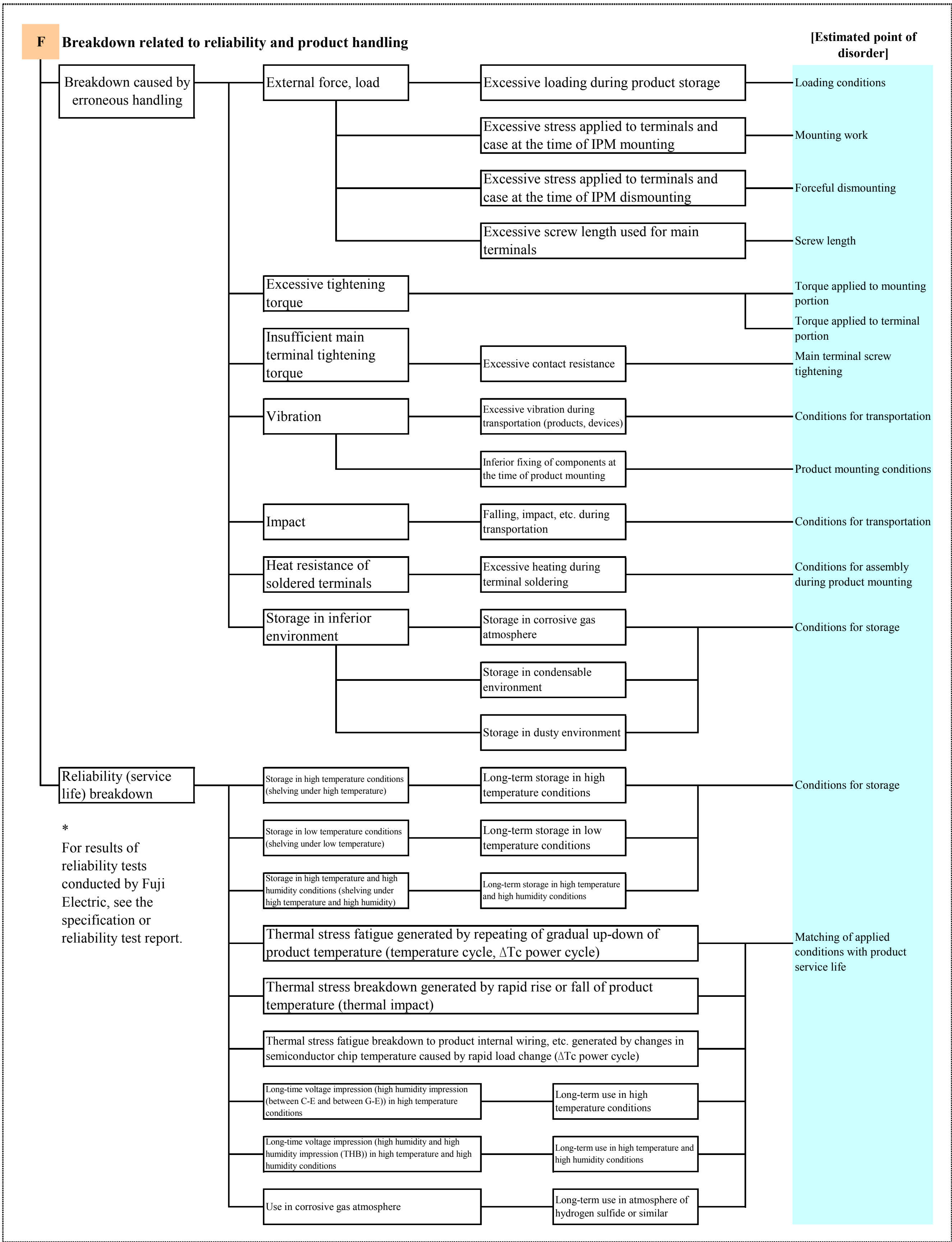


Figure 7-1 (g) Mode F: Breakdown related to reliability and product handling

3 Alarm factor analysis tree chart

When the system equipped with the IPM has stopped and an alarm signal is generated, first carry out investigations to identify where the alarm signal was generated from. Possible locations are athe IPM or the device control circuit.

If the alarm was sent from the IPM, then identify the factor in accordance with the factor tree chart indicated below. V-IPM is easy to identify which protective function is activated by checking the alarm pulse width. Therefore, you can shorten the factor analysis time.

In addition, the alarm output voltage can be easily measured by connecting a 1.3 KΩ resistor in series between the IPM alarm terminal and the cathode terminal of the alarming photodiode.

Phenomenon			Alarm factor and method for identification
Occurrence of an IPM alarm			
	Normal alarm	Overcurrent tALM Typ = 2 ms	The collector current is detected by checking the current that flows to the current sense IGBT that is built in every IGBT chip. The IGBT is OFF for protection, if the overcurrent trip level was continuously exceeded for about 5 μs.
			[Method for identification of alarm factor] • Observe the alarm and output current (U, V, W) using an oscilloscope. • Observe the alarm and DC input current (P, N) using an oscilloscope. • Observe the change in the current 5μs before occurrence of alarm output. • Where a CT or similar is used for current detection, check the trip level and point of detection.
		Low control power supply voltage tALM Typ = 4 ms	The IGBT is OFF for protection, if control power supply voltage Vcc was of undervoltage trip level or less continuously for 20 μs.
			[Method for identification of alarm factor] • Observe the alarm and Vcc using an oscilloscope. • Observe the change in the current 20 μs before occurrence of alarm output.
		Chip overheat tALM Typ = 8 ms	The chip temperature is detected by the temperature detection element (diode) that is built in every IGBT chip. The IGBT is OFF for protection, if the TjOH trip level was exceeded continuously for 1 ms.
			[Method for identification of alarm factor] • Measure control power supply voltage Vcc, DC input voltage Vdc and output current Io. • Measure case temperature Tc just below the chip, calculate ΔTj-c and estimate the value of Tj. • Check the IPM mounting method. (Fin flatness, thermal compound, etc.)
	Erroneous alarm Unstable tALM		If control power supply voltage Vcc exceeds absolute maximum rating, which is 20 V, or if excessive dv/dt or ripple was impressed, there is a possibility where the drive IC is broken and an erroneous alarm is output. Furthermore, also in case noise current flows to the IPM control circuit, there is a possibility where the IC voltage becomes unstable and an erroneous alarm is output.
			[Method for identification of alarm factor] • A short-pulse alarm of an μs is produced. ⇒See chapter 6 section 1.2.1 • Observe the Vcc waveform using an oscilloscope while the motor is running. It is desirable that the point of observation is located nearest to an IPM control terminal. • Confirm that Vcc < 20 V, dv/dt ≤ 5 V/μs, ripple voltage ≤ ±10% (with every one of four power supply unit). • Confirm that no external wiring connection is made between IPM control GND and main terminal GND. If wiring is made, noise current flows through IPM control circuit. • If the drive IC was broken, there is a large possibility where the value Icc rises to an abnormal level. Example: It is abnormal, if Iccp ≥ 10 mA, Iccn ≥ 20 mA, and @Vin = OFF.

WARNING

1. This Catalog contains the product specifications, characteristics, data, materials, and structures as of July 2015.
   The contents are subject to change without notice for specification changes or other reasons. When using a product listed in this Catalog, be sur to obtain the latest specifications.

2. All applications described in this Catalog exemplify the use of Fuji's products for your reference only. No right or license, either express or implied, under any patent, copyright, trade secret or other intellectual property right owned by Fuji Electric Co., Ltd. is (or shall be deemed) granted. Fuji Electric Co., Ltd. makes no representation or warranty, whether express or implied, relating to the infringement or alleged infringement of other's intellectual property rights which may arise from the use of the applications described herein.

3. Although Fuji Electric Co., Ltd. is enhancing product quality and reliability, a small percentage of semiconductor products may become faulty. When using Fuji Electric semiconductor products in your equipment, you are requested to take adequate safety measures to prevent the equipment from causing a physical injury, fire, or other problem if any of the products become faulty. It is recommended to make your design fail-safe, flame retardant, and free of malfunction.

4. The products introduced in this Catalog are intended for use in the following electronic and electrical equipment which has normal reliability requirements.
   • Computers • OA equipment • Communications equipment (terminal devices) • Measurement equipment
   • Machine tools • Audiovisual equipment • Electrical home appliances • Personal equipment • Industrial robots etc.

5. If you need to use a product in this Catalog for equipment requiring higher reliability than normal, such as for the equipment listed below, it is imperative to contact Fuji Electric Co., Ltd. to obtain prior approval. When using these products for such equipment, take adequate measures such as a backup system to prevent the equipment from malfunctioning even if a Fuji's product incorporated in the equipment becomes faulty.
   • Transportation equipment (mounted on cars and ships) • Trunk communications equipment
   • Traffic-signal control equipment • Gas leakage detectors with an auto-shut-off feature
   • Emergency equipment for responding to disasters and anti-burglary devices • Safety devices
   • Medical equipment

6. Do not use products in this Catalog for the equipment requiring strict reliability such as the following and equivalents to strategic equipment (without limitation).
   • Space equipment • Aeronautic equipment • Nuclear control equipment
   • Submarine repeater equipment

8. If you have any question about any portion in this Catalog, ask Fuji Electric Co., Ltd. or its sales agents before using the product.
   Neither Fuji Electric Co., Ltd. nor its agents shall be liable for any injury caused by any use of the products not in accordance with instructions set forth herein.