Chapter 3

Description of Functions

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1 Function Tables

The functions built into the IPM are shown in Tables 3-1 to 3-3.

Table 3-1 IPM Built-in Functions (R-IPM)

600 V system

Element Number	Model	Built-in Functions								Package
		Common for Upper and Lower Arm			Upper Arm		Lower Arm			
		Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP15RH060	√	√	√	–	–	√	√	–	P617
	6MBP20RH060	√	√	√	–	–	√	√	–	P617
	6MBP30RH060	√	√	√	–	–	√	√	–	P617
	6MBP50RA060	√	√	√	√	–	√	√	√	P610
	6MBP75RA060	√	√	√	√	–	√	√	√	P610
	6MBP100RA060	√	√	√	√	–	√	√	√	P611
	6MBP150RA060	√	√	√	√	–	√	√	√	P611
	6MBP200RA060	√	√	√	√	–	√	√	√	P612
	6MBP300RA060	√	√	√	√	–	√	√	√	P612
7 in 1	7MBP50RA060	√	√	√	√	–	√	√	√	P610
	7MBP75RA060	√	√	√	√	–	√	√	√	P610
	7MBP100RA060	√	√	√	√	–	√	√	√	P611
	7MBP150RA060	√	√	√	√	–	√	√	√	P611
	7MBP200RA060	√	√	√	√	–	√	√	√	P612
	7MBP300RA060	√	√	√	√	–	√	√	√	P612

1200 V system

Element Number	Model	Built-in Functions								Package
		Common for Upper and Lower Arm			Upper Arm		Lower Arm			
		Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP15RA120	√	√	√	–	–	√	√	–	P619
	6MBP25RA120	√	√	√	√	–	√	√	√	P610
	6MBP50RA120	√	√	√	√	–	√	√	√	P611
	6MBP75RA120	√	√	√	√	–	√	√	√	P611
	6MBP100RA120	√	√	√	√	–	√	√	√	P612
	6MBP150RA120	√	√	√	√	–	√	√	√	P612
7 in 1	7MBP25RA120	√	√	√	√	–	√	√	√	P610
	7MBP50RA120	√	√	√	√	–	√	√	√	P611
	7MBP75RA120	√	√	√	√	–	√	√	√	P611
	7MBP100RA120	√	√	√	√	–	√	√	√	P612
	7MBP150RA120	√	√	√	√	–	√	√	√	P612
6 in 1	6MBP25RJ120	√	√	√	√	√	√	√	√	P621
	6MBP50RJ120	√	√	√	√	√	√	√	√	P621
	6MBP75RJ120	√	√	√	√	√	√	√	√	P621
7 in 1	7MBP25RJ120	√	√	√	√	√	√	√	√	P621
	7MBP50RJ120	√	√	√	√	√	√	√	√	P621
	7MBP75RJ120	√	√	√	√	√	√	√	√	P621

Dr: IGBT drive circuit, UV: Control power source undervoltage protection, TjOH: Element overheating protection, OC: Overcurrent protection, ALM: Alarm output, TcOH: Case overheating protection

Table 3-2 IPM Built-in Functions (R-IPM3)

600 V system

Element Number	Model	Built-in Functions								Package
		Common for Upper and Lower Arm			Upper Arm		Lower Arm			
		Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP20RTA060	√	√	√	–	–	√	√	–	P619
	6MBP50RTB060	√	√	√	√	–	√	√	√	P610
	6MBP75RTB060	√	√	√	√	–	√	√	√	P610
	6MBP100RTB060	√	√	√	√	–	√	√	√	P611
	6MBP150RTB060	√	√	√	√	–	√	√	√	P611
7 in 1	7MBP50RTB060	√	√	√	√	–	√	√	√	P610
	7MBP75RTB060	√	√	√	√	–	√	√	√	P610
	7MBP100RTB060	√	√	√	√	–	√	√	√	P611
	7MBP150RTB060	√	√	√	√	–	√	√	√	P611
6 in 1	6MBP50RTJ060	√	√	√	√	√	√	√	√	P621
	6MBP75RTJ060	√	√	√	√	√	√	√	√	P621
	6MBP100RTJ060	√	√	√	√	√	√	√	√	P621
	6MBP150RTJ060	√	√	√	√	√	√	√	√	P621
7 in 1	7MBP50RTJ060	√	√	√	√	√	√	√	√	P621
	7MBP75RTJ060	√	√	√	√	√	√	√	√	P621
	7MBP100RTJ060	√	√	√	√	√	√	√	√	P621
	7MBP150RTJ060	√	√	√	√	√	√	√	√	P621

Dr: IGBT drive circuit, UV: Control power source undervoltage protection, TjOH: Element overheating protection, OC: Overcurrent protection,
LM: Alarm output, TcOH: Case overheating protection

Table 3-3 IPM Built-in Functions (Econo IPM)

600 V system

Element Number	Model	Built-in Functions								Package
		Common for Upper and Lower Arm			Upper Arm		Lower Arm			
		Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP50TEA060	√	√	√	√	√	√	√	–	P622
	6MBP75TEA060	√	√	√	√	√	√	√	–	P622
	6MBP100TEA060	√	√	√	√	√	√	√	–	P622
	6MBP150TEA060	√	√	√	√	√	√	√	–	P622
7 in 1	7MBP50TEA060	√	√	√	√	√	√	√	–	P622
	7MBP75TEA060	√	√	√	√	√	√	√	–	P622
	7MBP100TEA060	√	√	√	√	√	√	√	–	P622
	7MBP150TEA060	√	√	√	√	√	√	√	–	P622

1200 V system

Element Number	Model	Built-in Functions								Package
		Common for Upper and Lower Arm			Upper Arm		Lower Arm			
		Dr	UV	TjOH	OC	ALM	OC	ALM	TcOH	
6 in 1	6MBP25TEA120	√	√	√	√	√	√	√	–	P622
	6MBP50TEA120	√	√	√	√	√	√	√	–	P622
	6MBP75TEA120	√	√	√	√	√	√	√	–	P622
7 in 1	7MBP25TEA120	√	√	√	√	√	√	√	–	P622
	7MBP50TEA120	√	√	√	√	√	√	√	–	P622
	7MBP75TEA120	√	√	√	√	√	√	√	–	P622

Dr: IGBT drive circuit, UV: Control power source undervoltage protection, TjOH: Element overheating protection, OC: Overcurrent protection, ALM: Alarm output, TcOH: Case overheating protection

2 Function Descriptions

2.1 IGBT, FWD for 3-phase inverters

As shown in Fig. 3-1, IGBT and FWD for 3-phase inverters are built in, and a 3-phase bridge circuit is formed inside the IPM. The main circuit is completed by connecting the main power source to the P and N terminals and the 3-phase output lines to the U, V, and W terminals. Connect a snubber circuit to suppress the surge voltages.

2.2 IGBT, FWD for brake

As shown in Fig. 3-1, IGBT and FWD for brake are built in, and an IGBT collector is connected internally to the B terminal. By controlling the brake IGBT through connection of brake resistance between the terminals P and B, the regeneration energy can be dissipated while decelerating to suppress the rise of voltage between the P and N terminals.

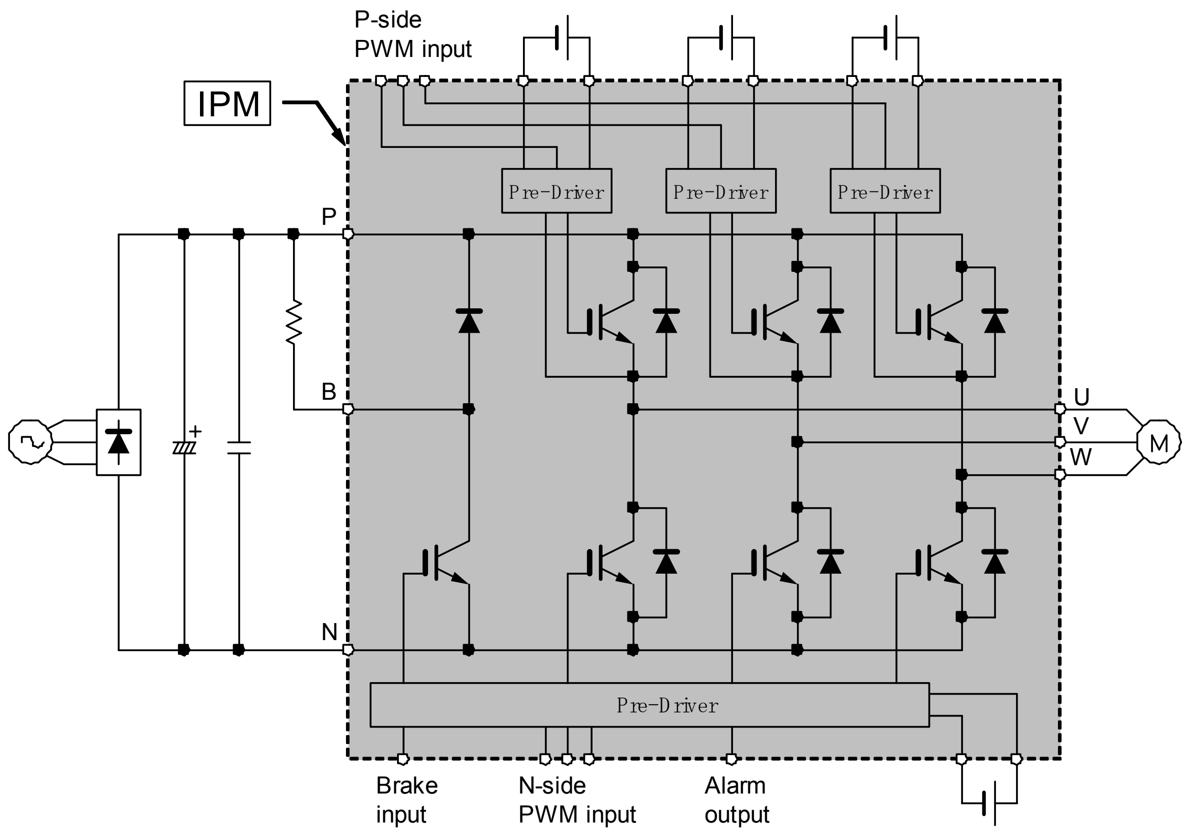

Fig. 3-1 3-Phase Inverter Application Model (in Case of 7MBP150RTB060)

2.3 IGBT drive function

Fig. 3-2 shows the pre-driver block diagram. As the IPM incorporates an IGBT drive function, the IGBT can be driven without designing a gate resistance value by connecting the photocoupler output to the IPM. The features of this drive function are introduced below.

- Independent gate resistance control
  A special turn-on/turn-off Rg not using any exclusive gate resistance Rg is built in. With this, the dv/dt of turn-on and turn-off can be controlled individually, so that the merits of the element are fully demonstrated (Turn on/Normal Shutdown).

- Soft shutdown
  During an overcurrent or other abnormality, the gate voltage is lowered softly and gently to prevent element destruction by surge voltage (Soft Shutdown).

- Errorneous ON prevention
  Since a circuit is set up to ground the gate electrode with low impedance while OFF, erroneous ON caused by the rise of VGE due to noise can be prevented (Off Hold).

- A reverse bias power source is not required.
  As the IPM has a short wiring between the drive circuit and the IGBT, the wiring impedance is small, making driving without reverse bias possible.

- Alarm latch
  Alarms have a latch period of approximately 2 ms, and the IGBT does not operate even when an On-signal enters during the latch period. In addition, as the alarms for each phase, including brake, on the lower arm side are connected mutually, all IGBTs on the lower arm side are stopped for the latch period when a protection operation is performed on the lower arm side.

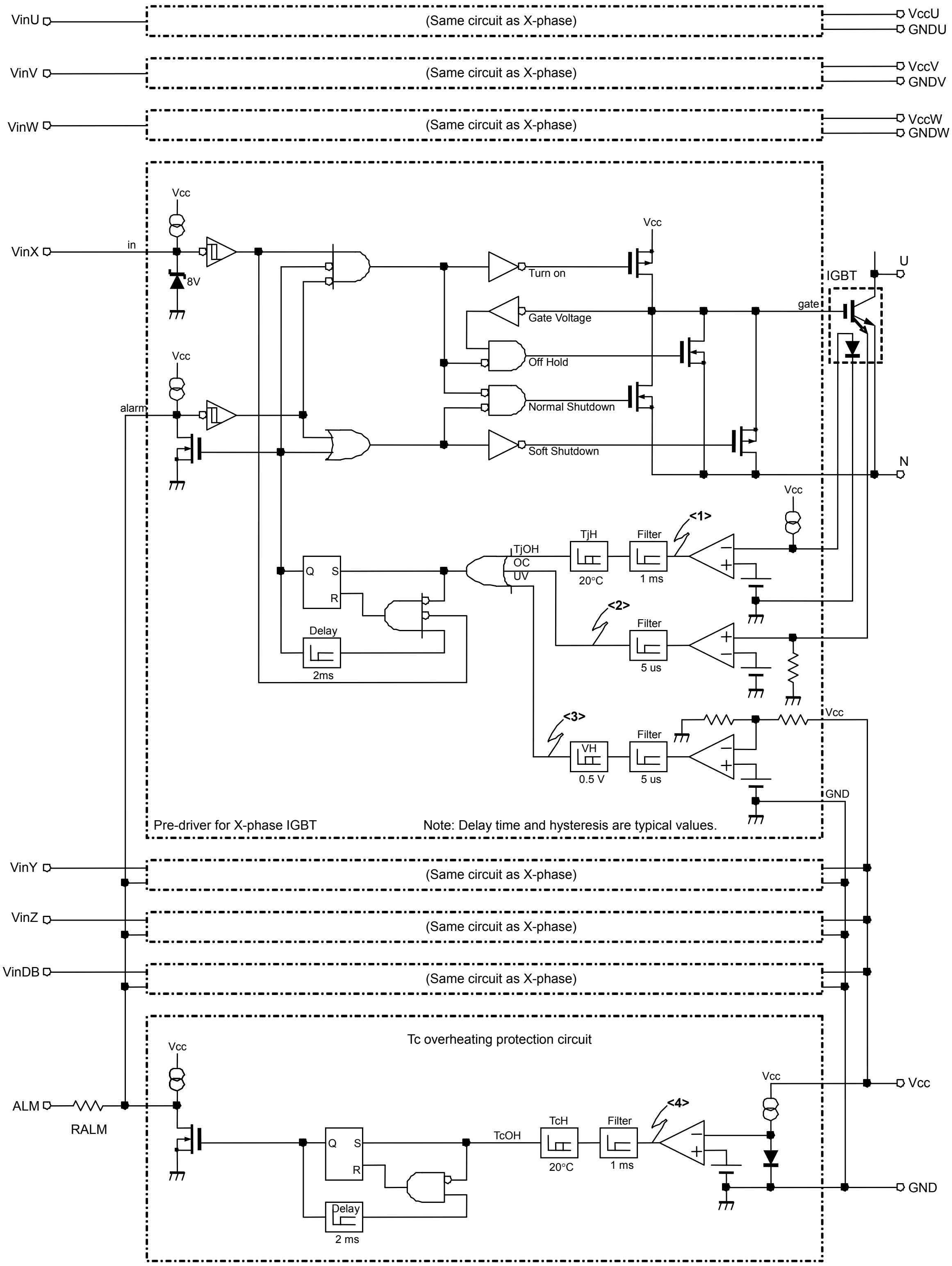

Fig. 3-2 IPM Function Block (Representative Model: 7MBP150RTB060)

2.4 Overcurrent protection function (OC)

Two detection methods are used, the sense IGBT method and the shunt resistance method.

(1) Sense IGBT method

Models: P610/P611/P612/P621/P622

- The main current flowing in the IGBT is detected by taking the sense current flowing in the current sense IGBT inside the IGBT chip into the control circuit. The sense current is extremely small in comparison with the main current, so that the detection loss can be kept minimal in comparison with the shunt resistance method.
- When the overcurrent protection Ioc level is exceeded for a duration of approximately 5 μs (tdoc), the IGBT goes through a soft shutdown. As a detection filter is installed, faulty operations caused by instantaneous overcurrents or noise can be prevented.
- When after approximately 2 ms the level drops below Ioc and the input signal is OFF, the alarm is released.

(2) Shunt resistance method

Models: P617/P619

- Overcurrent protection is performed by detecting the voltage at both ends of the current detection shunt resistance R1, connected to the DC bus bar line N. When the overcurrent detection level Ioc is exceeded for a duration of approximately 5 μs (tdoc), the IGBT goes through a soft shutdown. As a detection filter is installed, faulty operations caused by instantaneous overcurrents or noise can be prevented.
- When after approximately 2 ms the level drops below Ioc and if the input signal is OFF, the alarm is released.

2.5 Short-circuit protection function (SC)

The SC protection function always operates with the OC protection function to suppress the peak current when a load or arm is shorted.

2.6 Undervoltage protection (UV)

- The UV protection function performs soft shutdown of the IGBT when the control source voltage (Vcc) continuously drops below VUV for approximately 5 μs.
- As the hysteresis VH is provided, the alarm is released if Vcc recovers to VUV + VH or more after approximately 2 ms and the input signal is OFF.

2.7 Case temperature overheating protection function (TcOH)

- The TcOH protection function detects the insulating substrate temperature with the temperature detection elements set up on the same ceramic substrate as that on which the power chips (IGBT, FWD) are set up and performs soft shutdown of the IGBT when the detected temperature exceeds the protection level TcOH continuously for approximately 1 ms.
- As the hysteresis TcH is provided, the alarm is released if Tc drops below TcOH-TcH after approximately 2 ms.
- The TcOH detection positions are shown in Fig.3-3 to Fig.3-6.

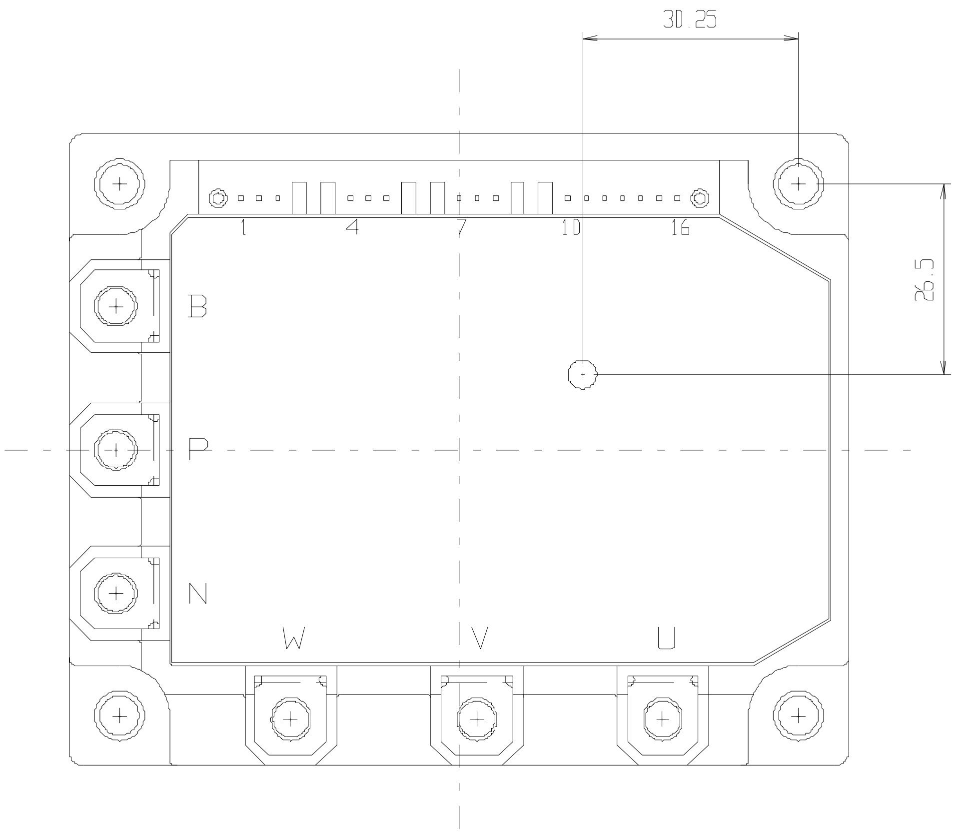

Fig. 3-3 TcOH Detection Position (P610)

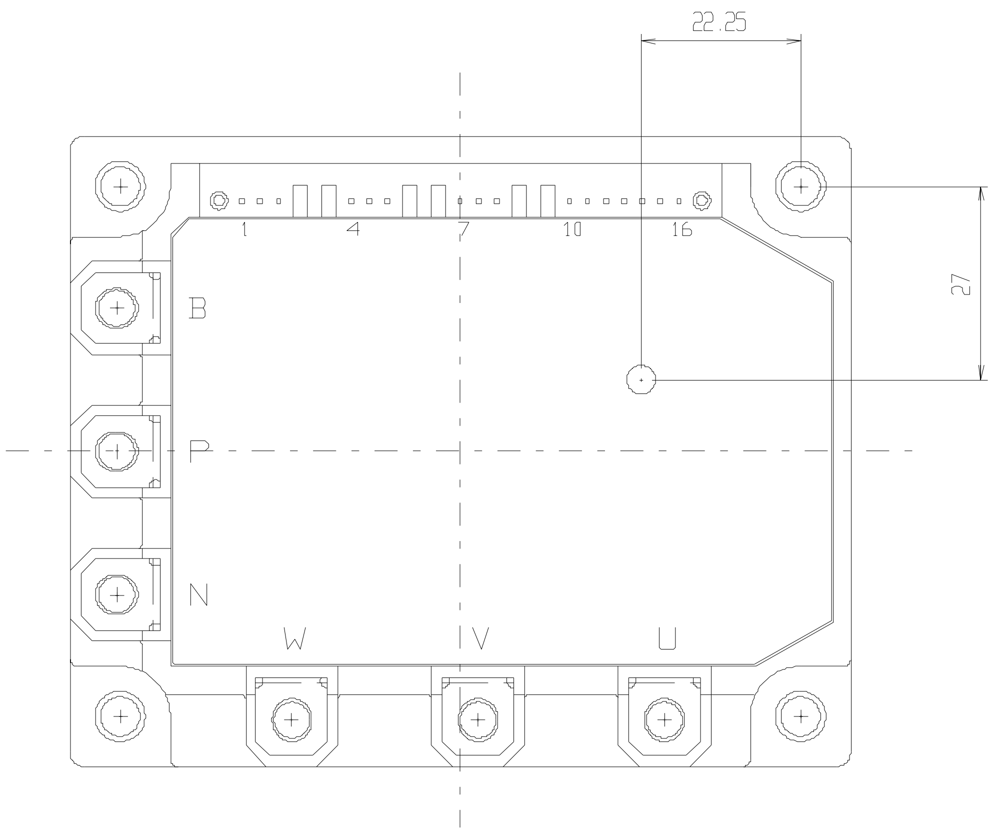

Fig. 3-4 TcOH Detection Position (P611)

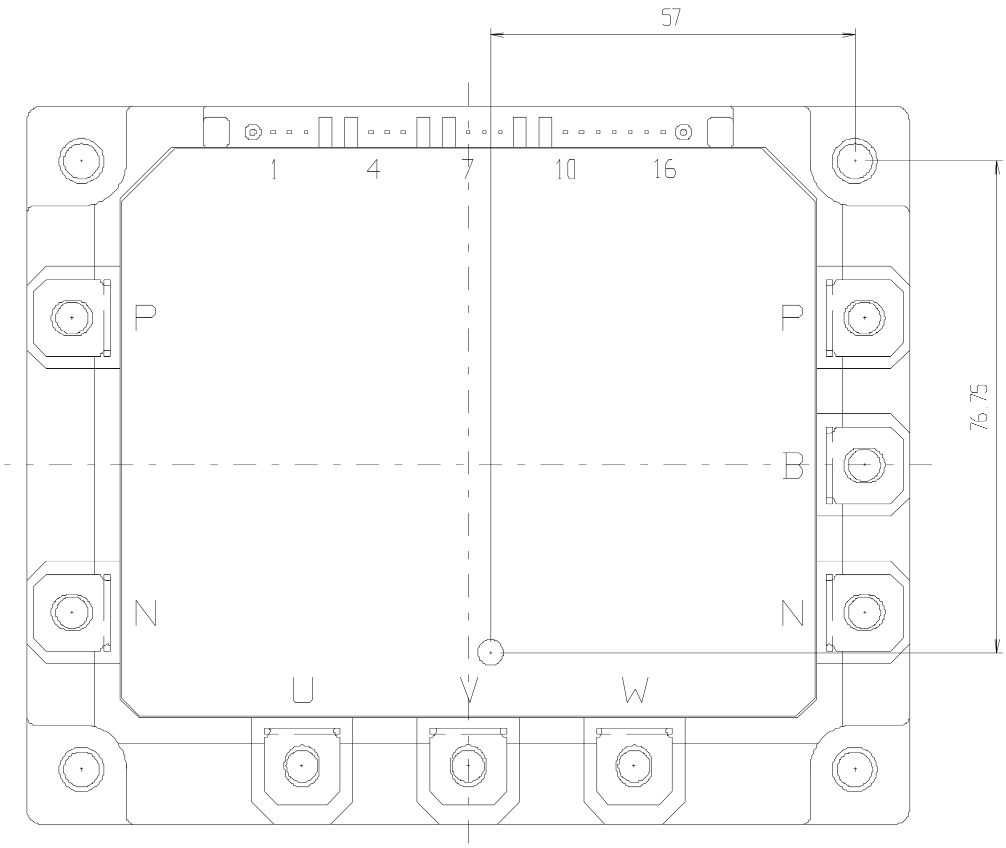

Fig. 3-5 TcOH Detection Position (P612)

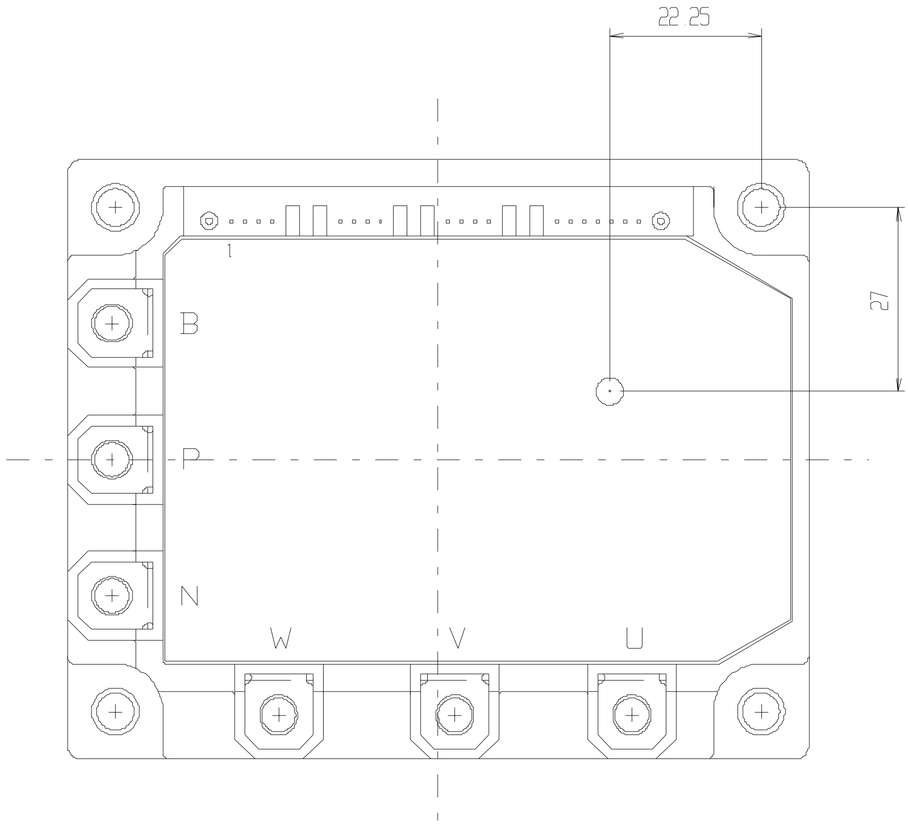

Fig. 3-6 TcOH Detection Position (P621)

2.8 Chip temperature overheating protection function (TjOH)

- The TjOH protection function detects the IGBT chip temperature with the temperature detection elements set up on all IGBT chips and performs soft shutdown of the IGBT when the detected temperature exceeds the protection level (TjOH) continuously for approximately 1 ms or more.
- As the hysteresis TjH is provided, the alarm is released if Tj drops below TjOH-TjH after approximately 2 ms and the input signal is OFF.

2.9 Alarm output function (ALM)

- When a protection function operates, the alarm output terminal becomes conductive against each reference potential GND. With open collector output, a function for direct drive of the photocoupler is provided, and a 1.5 kΩ series resistor is built in.
- When a protection function operates, the alarm signal is output continuously for approximately 2 ms (tALM). The alarm is released when the alarm cause has been removed, tALM has elapsed, and the input signal is OFF. When the cause is TcOH, the alarm is released regardless of the input signal.
- As the alarm terminals of the drive circuit on the lower arm side are connected mutually, all IGBTs on the lower arm side, including the brake, are stopped when any one of the IGBTs outputs an alarm.

3 Truth Tables

The truth tables when a fault occurs are shown in Tables 3-4 to 3-7.

Table 3-4 Truth Table (P617, P619)

	Cause of Fault	IGBT				Alarm Output Low Side
		U-phase	V-phase	W-phase	Low Side	
High side U-phase	UV	OFF	*	*	*	High
	TjOH	OFF	*	*	*	High
High side V-phase	UV	*	OFF	*	*	High
	TjOH	*	OFF	*	*	High
High side W-phase	UV	*	*	OFF	*	High
	TjOH	*	*	OFF	*	High
Low side	OC	*	*	*	OFF	Low
	UV	*	*	*	OFF	Low
	TjOH	*	*	*	OFF	Low

* Depends on input logic

Table 3-5 Truth Table (P610, P611, P612)

	Cause of Fault	IGBT				Alarm Output Low Side
		U-phase	V-phase	W-phase	Low Side	
High side U-phase	OC	OFF	*	*	*	High
	UV	OFF	*	*	*	High
	TjOH	OFF	*	*	*	High
High side V-phase	OC	*	OFF	*	*	High
	UV	*	OFF	*	*	High
	TjOH	*	OFF	*	*	High
High side W-phase	OC	*	*	OFF	*	High
	UV	*	*	OFF	*	High
	TjOH	*	*	OFF	*	High
Low side	OC	*	*	*	OFF	Low
	UV	*	*	*	OFF	Low
	TjOH	*	*	*	OFF	Low
	TcOH	*	*	*	OFF	Low

* Depends on input logic

Table 3-6 Truth Table (P621)

	Cause of Fault	IGBT				Alarm Output			
		U-phase	V-phase	W-phase	Low Side	ALMU	ALMV	ALMW	ALM
High side U-phase	OC	OFF	*	*	*	Low	High	High	High
	UV	OFF	*	*	*	Low	High	High	High
	TjOH	OFF	*	*	*	Low	High	High	High
High side V-phase	OC	*	OFF	*	*	High	Low	High	High
	UV	*	OFF	*	*	High	Low	High	High
	TjOH	*	OFF	*	*	High	Low	High	High
High side W-phase	OC	*	*	OFF	*	High	High	Low	High
	UV	*	*	OFF	*	High	High	Low	High
	TjOH	*	*	OFF	*	High	High	Low	High
Low side	OC	*	*	*	OFF	High	High	High	Low
	UV	*	*	*	OFF	High	High	High	Low
	TjOH	*	*	*	OFF	High	High	High	Low
	TcOH	*	*	*	OFF	High	High	High	Low

* Depends on input logic

Table 3-7 Truth Table (P622)

	Cause of Fault	IGBT				Alarm Output			
		U-phase	V-phase	W-phase	Low Side	ALMU	ALMV	ALMW	ALM
High side U-phase	OC	OFF	*	*	*	Low	High	High	High
	UV	OFF	*	*	*	Low	High	High	High
	TjOH	OFF	*	*	*	Low	High	High	High
High side V-phase	OC	*	OFF	*	*	High	Low	High	High
	UV	*	OFF	*	*	High	Low	High	High
	TjOH	*	OFF	*	*	High	Low	High	High
High side W-phase	OC	*	*	OFF	*	High	High	Low	High
	UV	*	*	OFF	*	High	High	Low	High
	TjOH	*	*	OFF	*	High	High	Low	High
Low side	OC	*	*	*	OFF	High	High	High	Low
	UV	*	*	*	OFF	High	High	High	Low
	TjOH	*	*	*	OFF	High	High	High	Low

* Depends on input logic

4 IPM Block Diagrams

The IPM block diagrams are shown in Fig. 3-7 to Fig. 3-14.

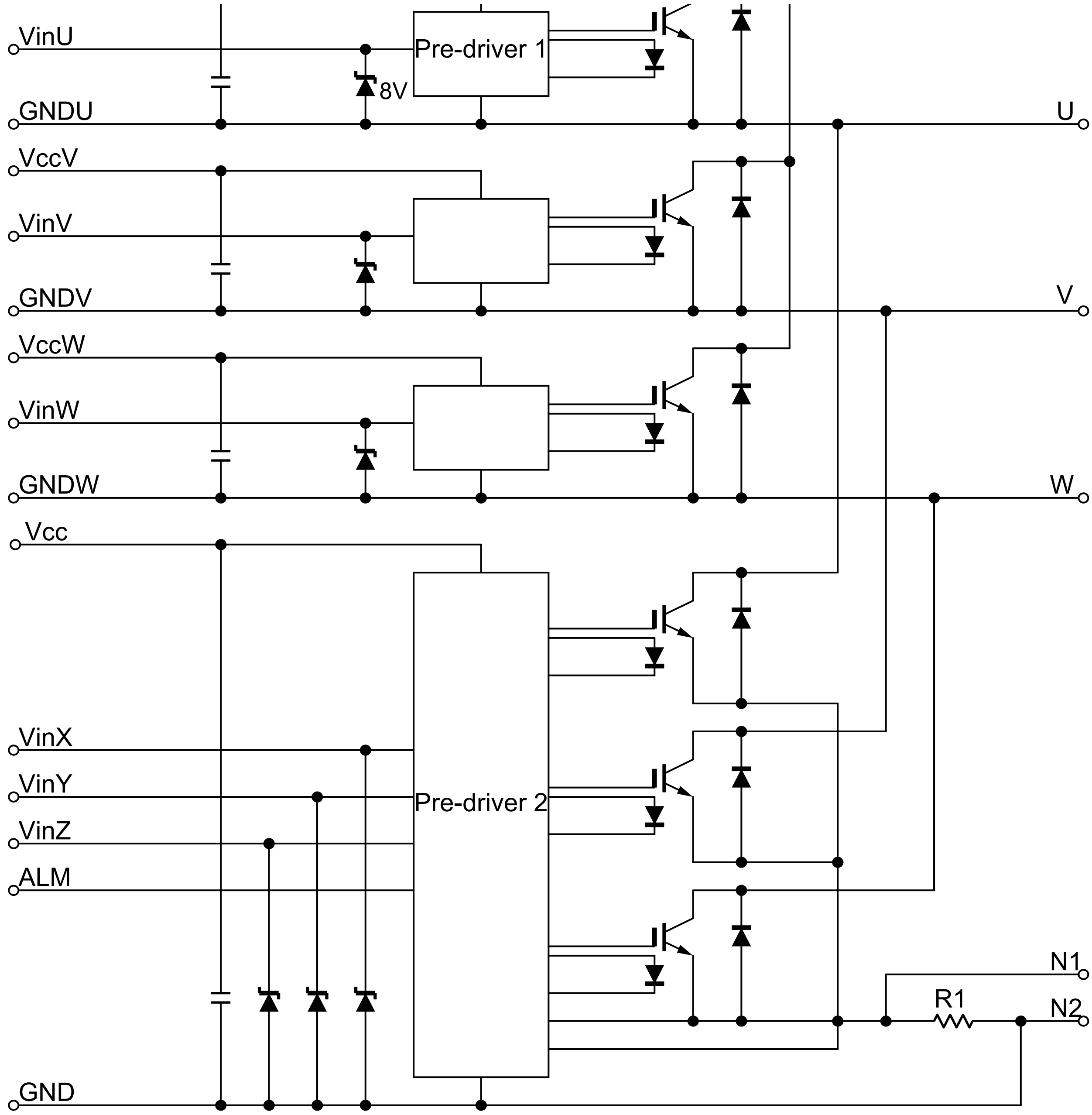

Fig. 3-7 IPM Block Diagram (P617)

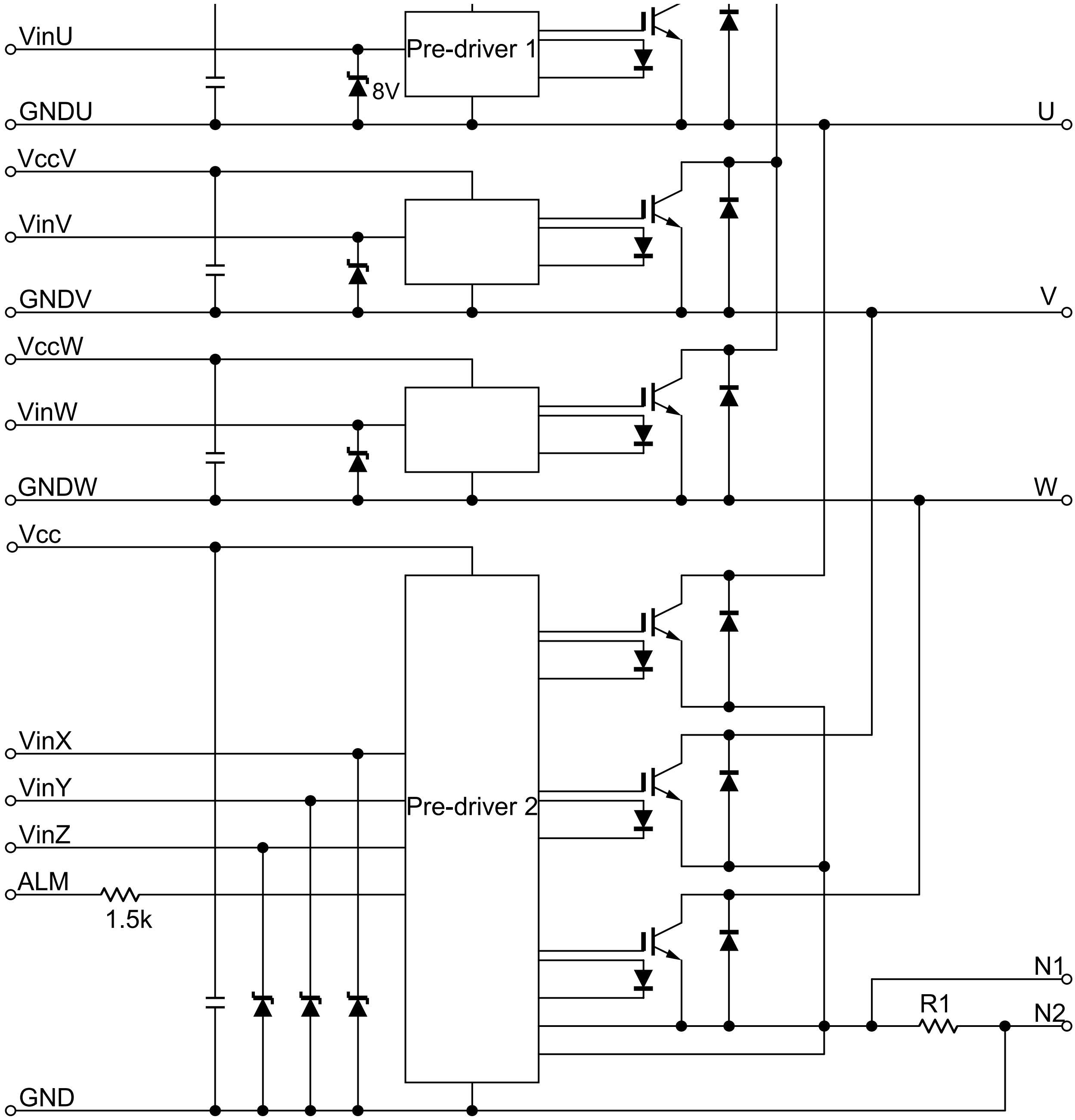

Fig. 3-8 IPM Block Diagram (P619)

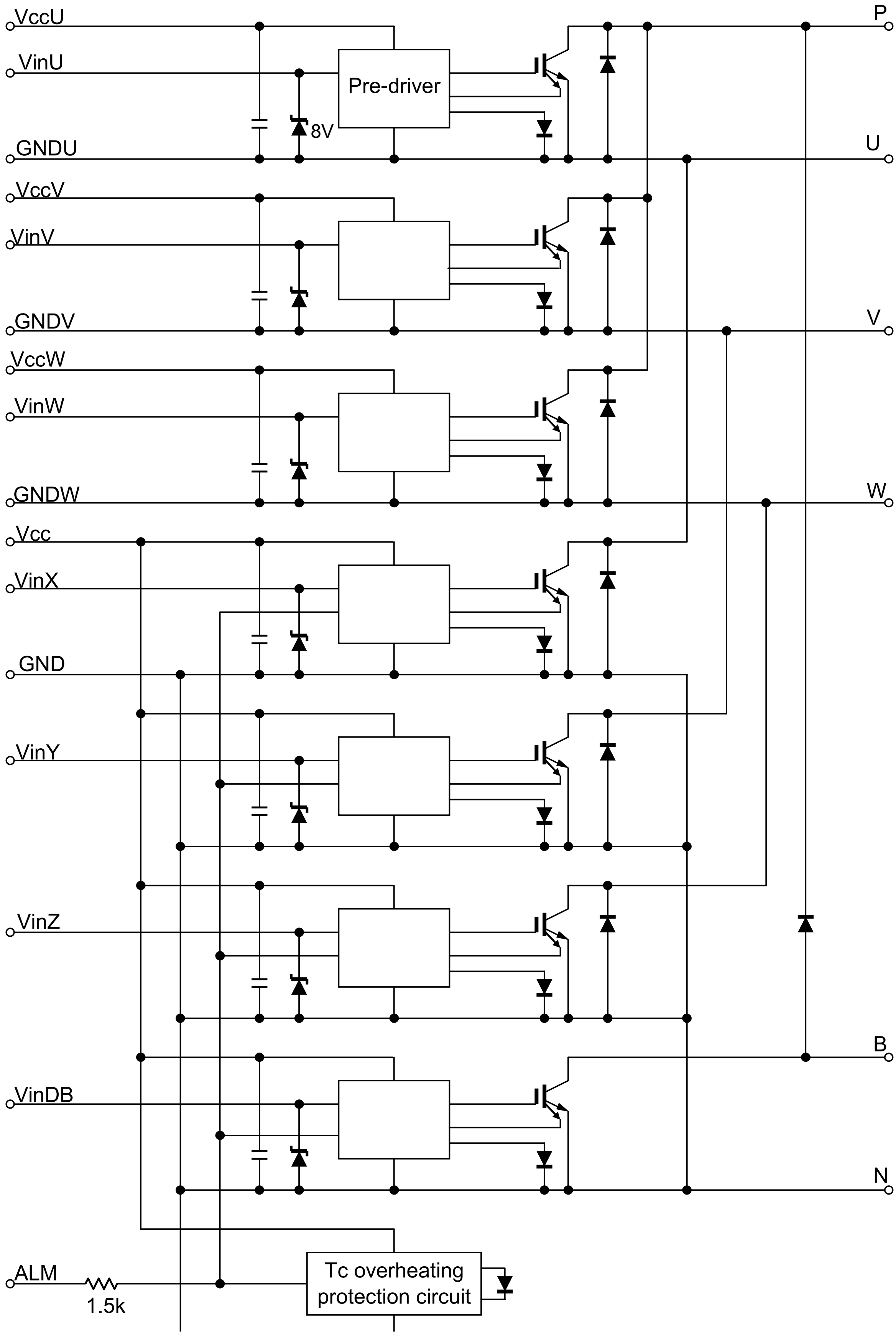

Fig. 3-9 IPM Block Diagram (P610, P611, P612 with Built-in Brake)

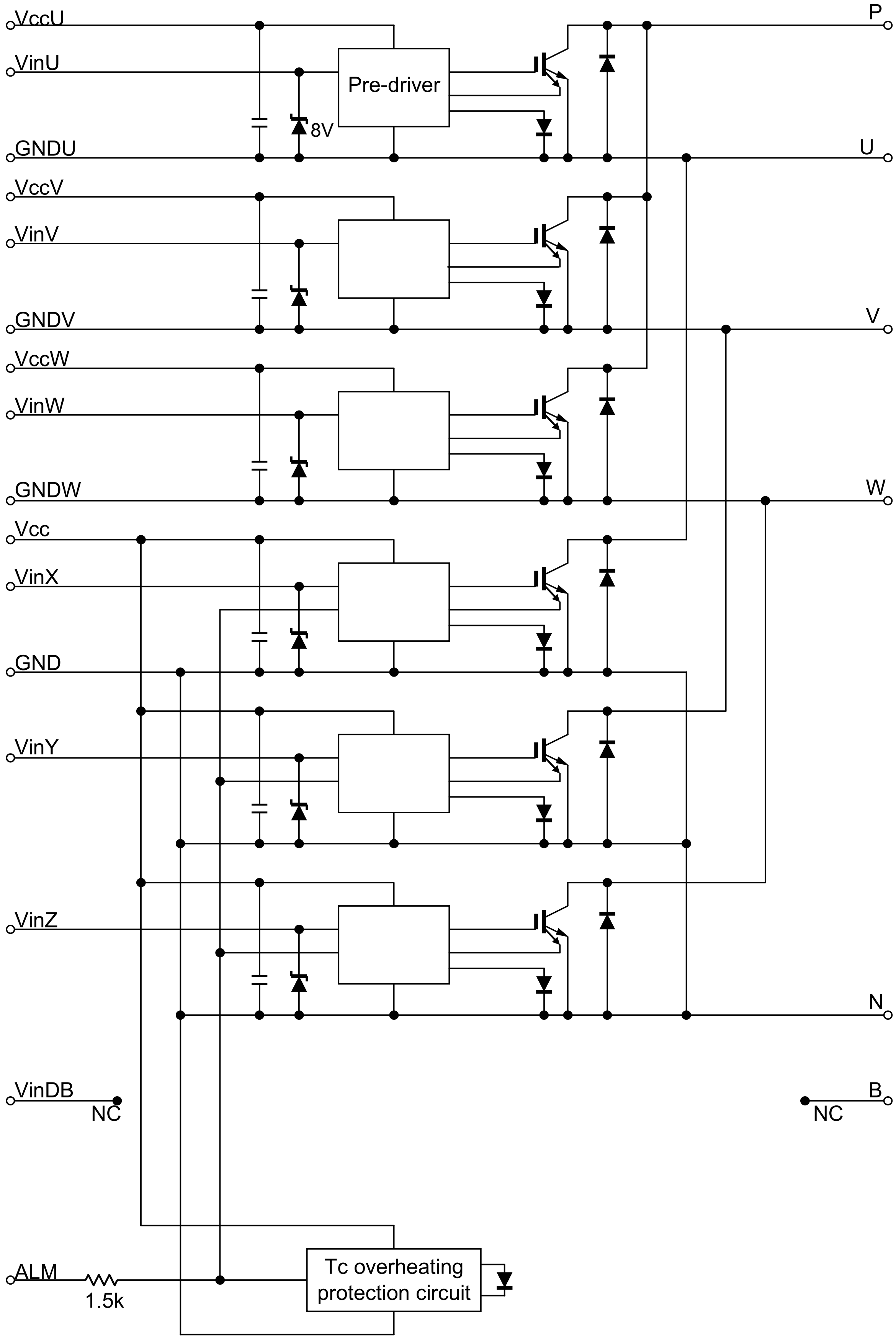

Fig. 3-10 IPM Block Diagram (P610, P611, P612 Without Brake)

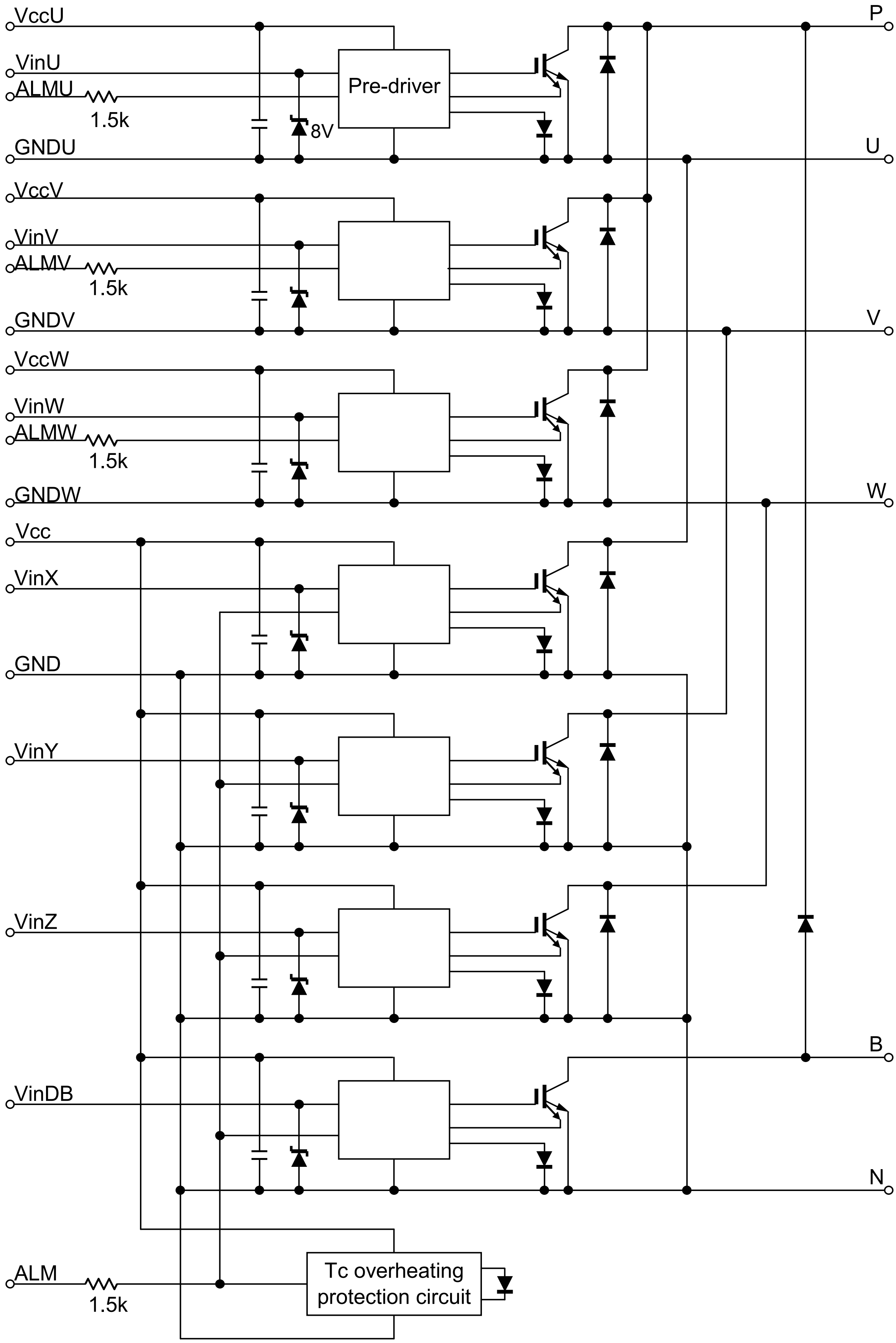

Fig. 3-11 IPM Block Diagram (P621 with Built-in Brake)

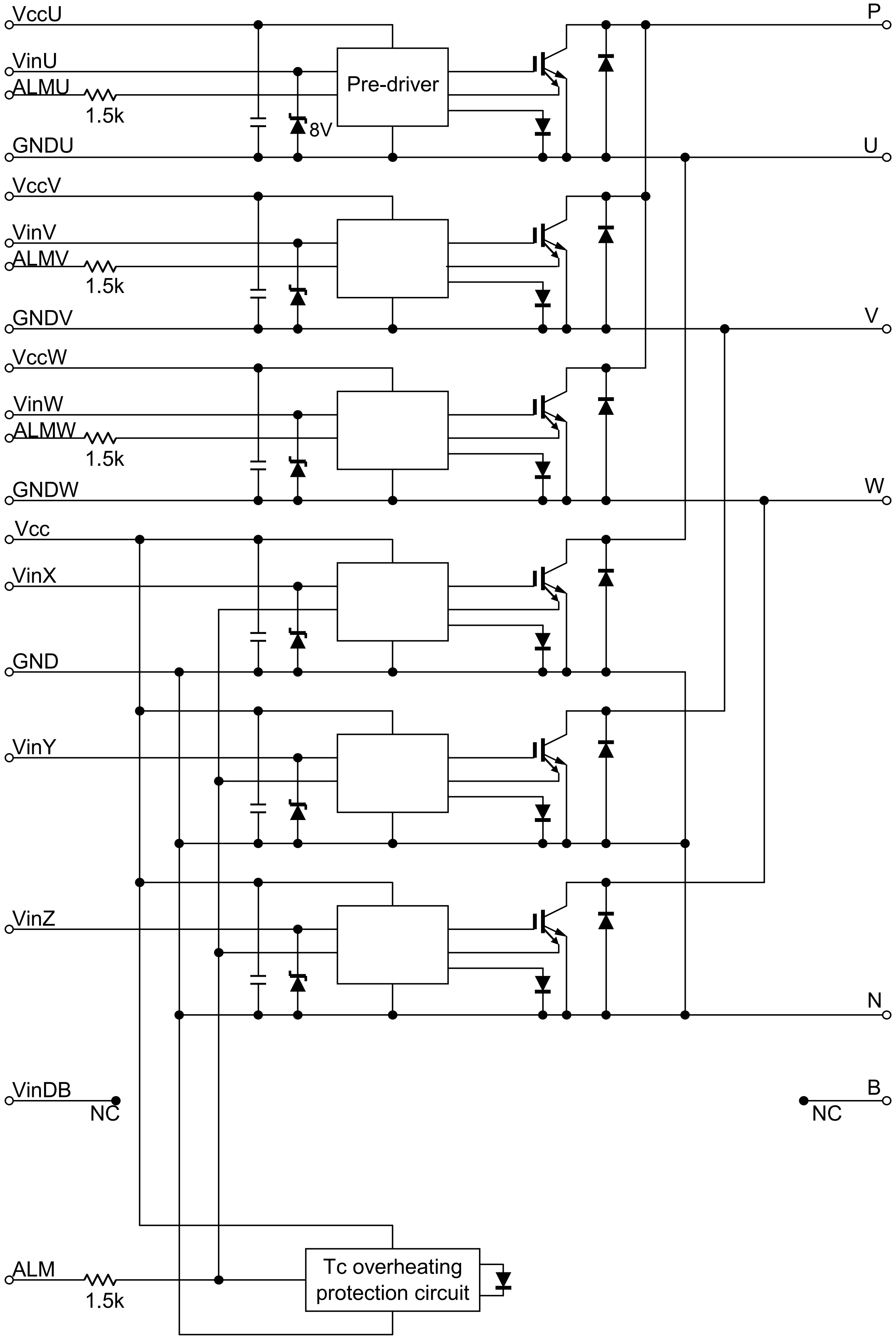

Fig. 3-12 IPM Block Diagram (P621 Without Brake)

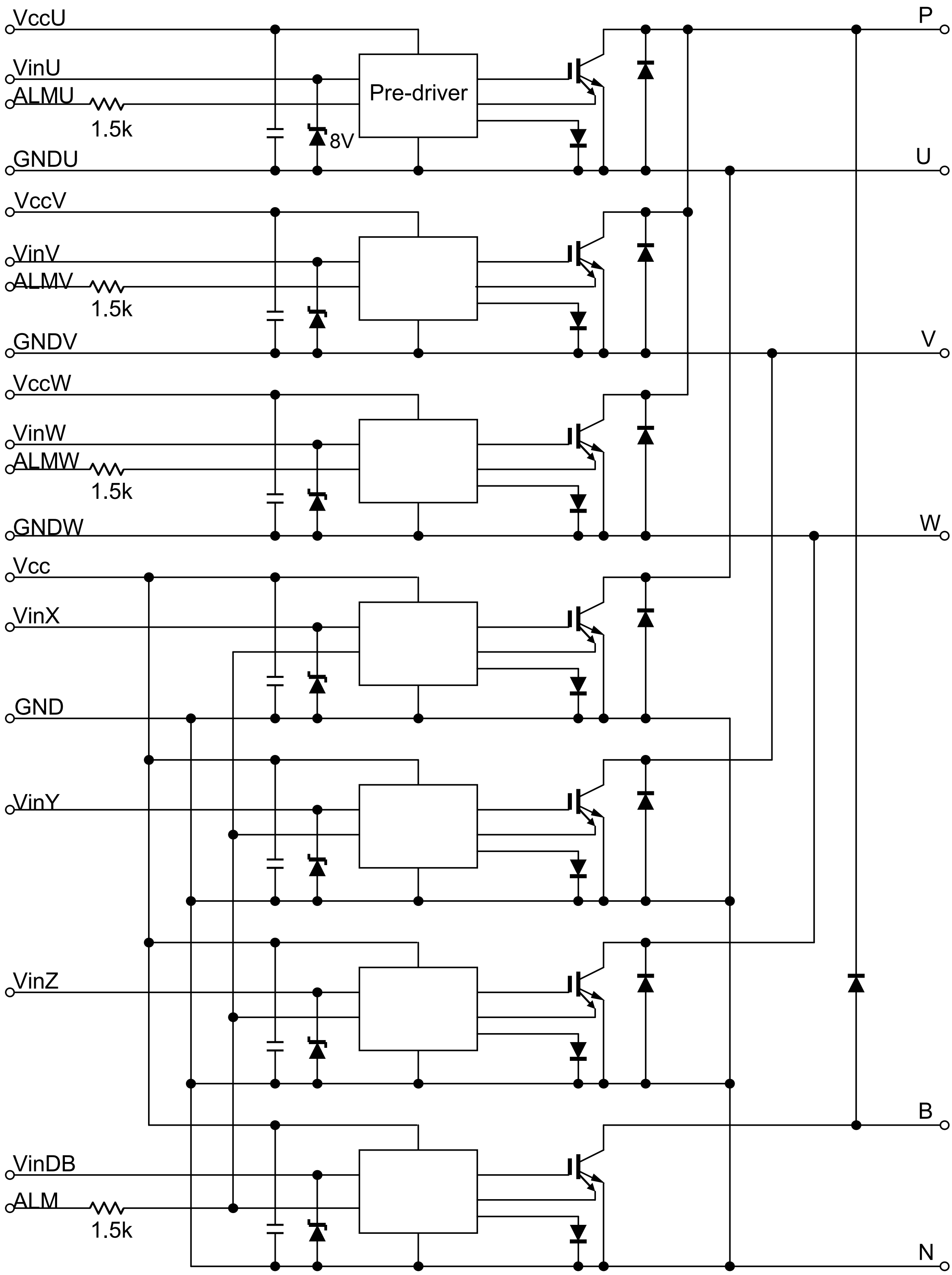

Fig. 3-13 IPM Block Diagram (P622 with Built-in Brake)

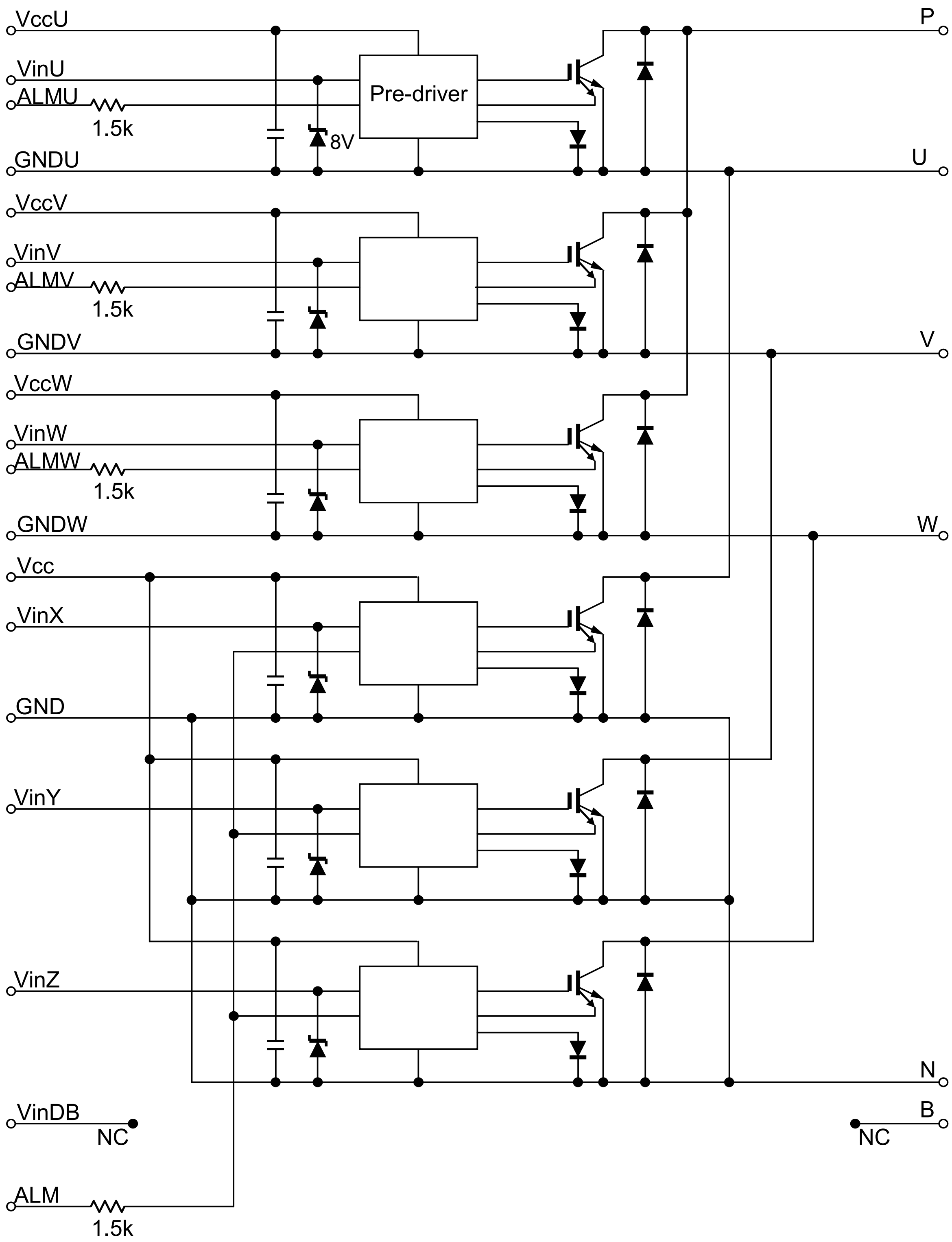

Fig. 3-14 IPM Block Diagram (P622 Without Brake)

5 Timing Charts

The timing charts for the protection functions are shown in Fig. 3-15 to Fig. 3-21.

Undervoltage protection (UV) (1)

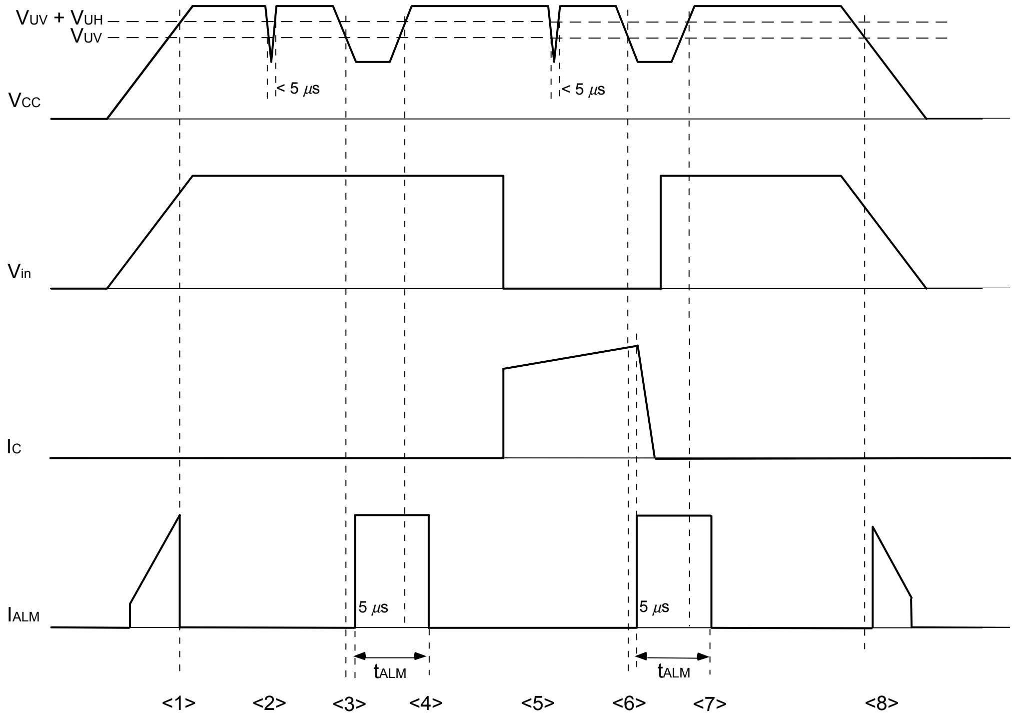

Fig. 3-15 Timing Chart UV (1)

Refer to Fig. 3-2 <3>.

<1> If Vcc is below V_{UV} + V_H while V_{CC} is ON, an alarm is output.

<2> If the period in which V_{CC} falls below V_{UV} is shorter than 5 µs, the protection function does not work (while Vin is OFF).

<3> An alarm is output when a period of about 5 µs elapses after V_{CC} falls below V_{UV} if Vin is OFF, and IGBT remains OFF.

<4> If V_{CC} returns to V_{UV} + V_H after t_{ALM} elapses, UV is reset after t_{ALM} elapses if Vin is OFF and the alarm is also reset simultaneously.

<5> If the period in which V_{CC} falls below V_{UV} is shorter than 5 µs, the protection function does not work (while Vin is ON).

<6> An alarm is output when a period of about 5 µs elapses after V_{CC} falls below V_{UV} if Vin is ON, and a soft IGBT shutdown occurs.

<7> If V_{CC} returns to V_{UV} + V_H after t_{ALM} elapses, UV is reset after t_{ALM} elapses if Vin is OFF and the alarm is also reset simultaneously.

<8> An alarm is output if V_{CC} falls below VUV while V_{CC} c is OFF.

Undervoltage protection (UV) (2)

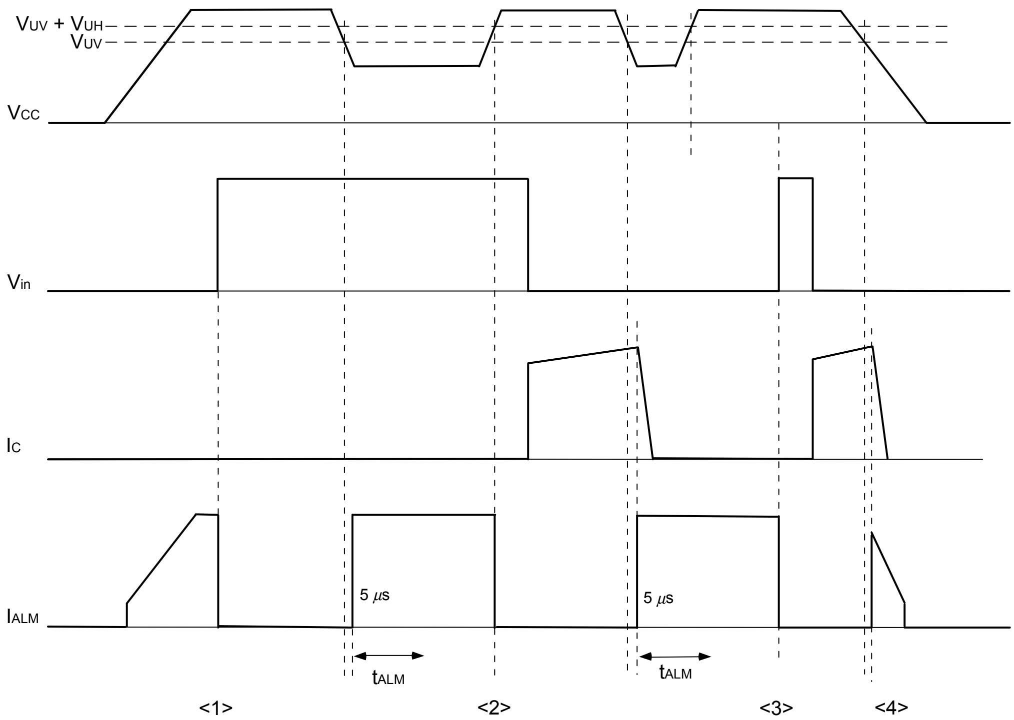

Fig. 3-16 Timing Chart UV (2)

Refer to Fig. 3-2 <3>.

<1> If Vcc is below V_{UV} + V_H while V_{CC} is ON, an alarm is output. (Until Vin changes to OFF)

<2> If Vcc returns to V_{UV} + V_H after t_{ALM} elapses, UV and the alarm are reset simultaneously with the return of V_{UV} + V_H if Vin is OFF.

<3> Even if V_{CC} returns to V_{UV} + V_H after t_{ALM} elapses, UV is not reset after t_{ALM} elapses if Vin is ON. UV and the alarm are reset simultaneously with Vin OFF.

<4> If Vin is ON while V_{CC} is OFF, the alarm is output, and a soft IGBT shutdown is executed while V_{CC} is below V_{UV}.

Overcurrent protection (OC)

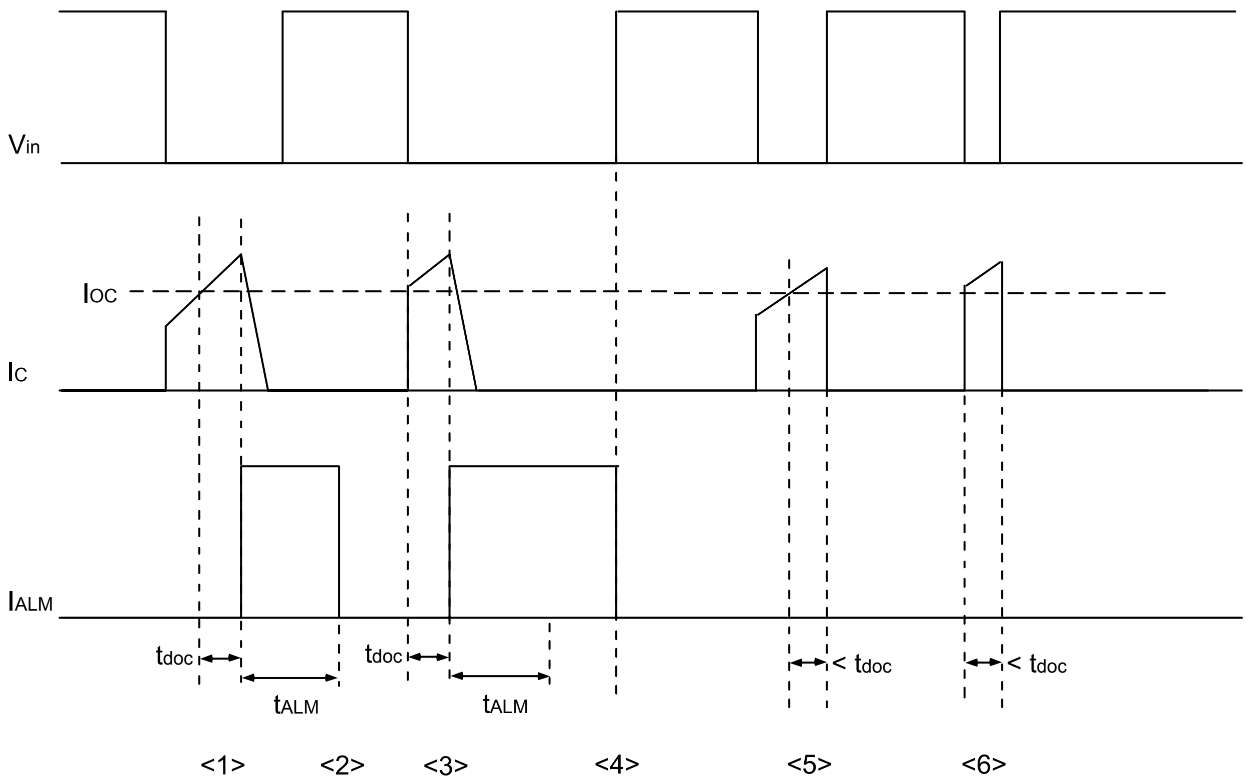

Fig. 3-17 Timing Chart OC

Refer to Fig. 3-2 <3>.

<1> An alarm is output and a soft IGBT shutdown is executed when t_{DOC} elapses after Ic rises above Ioc.

<2> OC and the alarm are reset simultaneously if Vin is OFF when t_{ALM} elapses.

<3> An alarm is output and a soft IGBT shutdown is executed when t_{DOC} elapses after Ic rises above Ioc.

<4> If Vin is ON when t_{ALM} elapses, OC is not reset. OC and the alarm are reset simultaneously when Vin is OFF.

<5> If Vin changes to OFF before t_{DOC} elapses after Ic rises above Ioc, the protection function is not activated and a normal IGBT shutdown is executed.

<6> If Vin changes to OFF before t_{DOC} elapses after Ic rises above Ioc, the protection function is not activated and a normal IGBT shutdown is executed.

Short-circuit protection

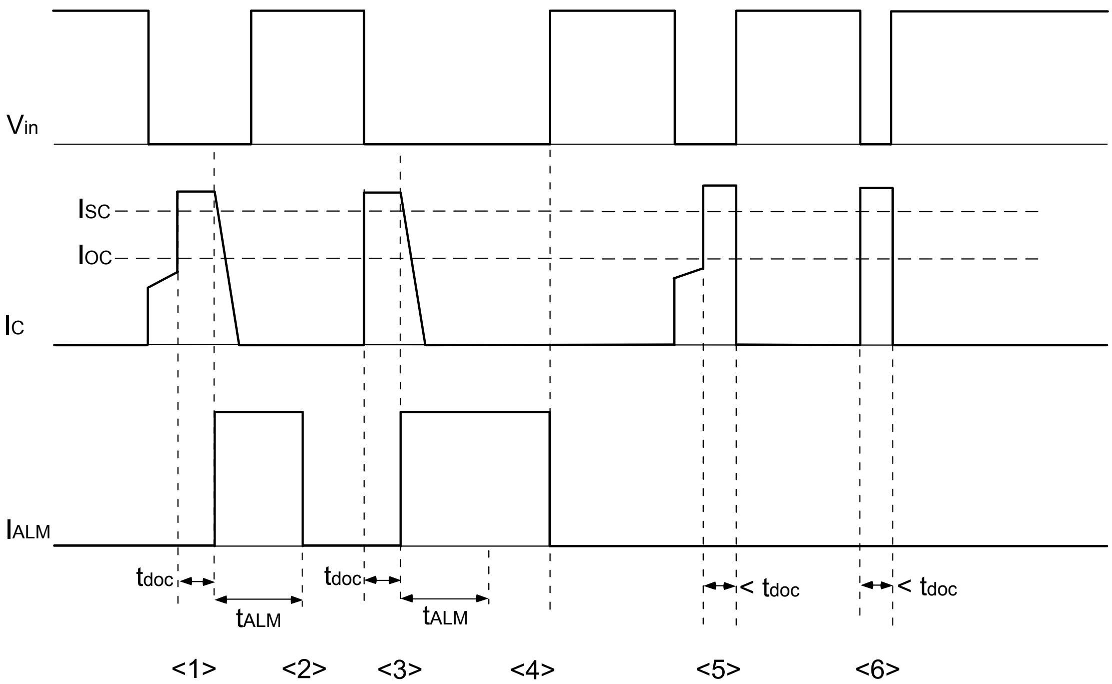

Fig. 3-18 Timing Chart SC

Refer to Fig. 3-2 <2>.

<1> If the load shorts after Ic has started flowing and Ic exceeds Isc, the Ic peak is suppressed instantly. An alarm is output and a soft IGBT shutdown is executed when t_{DOC} elapses.

<2> OC and the alarm are reset simultaneously if Vin is OFF when t_{ALM} elapses.

<3> If the load shorts and Isc is exceeded simultaneously with the start of flow of Ic, the Ic peak is instantly suppressed. An alarm is output and a soft IGBT shutdown is executed after t_{DOC} elapses.

<4> If Vin is ON when t_{ALM} elapses, OC is not reset. OC and the alarm are reset simultaneously when Vin is OFF.

<5> If the load shorts after Ic has started flowing and Ic exceeds Isc, the Ic peak is suppressed instantly. Then, if Vin changes to OFF before t_{DOC} elapses, the protection function is not activated and a normal IGBT shutdown occurs.

<6> If the load shorts simultaneously with the start of flow of Ic and Ic exceeds Isc, the Ic peak is suppressed instantly. Then, if Vin changes to OFF before t_{DOC} elapses, the protection function is not activated and a normal IGBT shutdown is executed.

Case temperature overheating protection (TcOH)

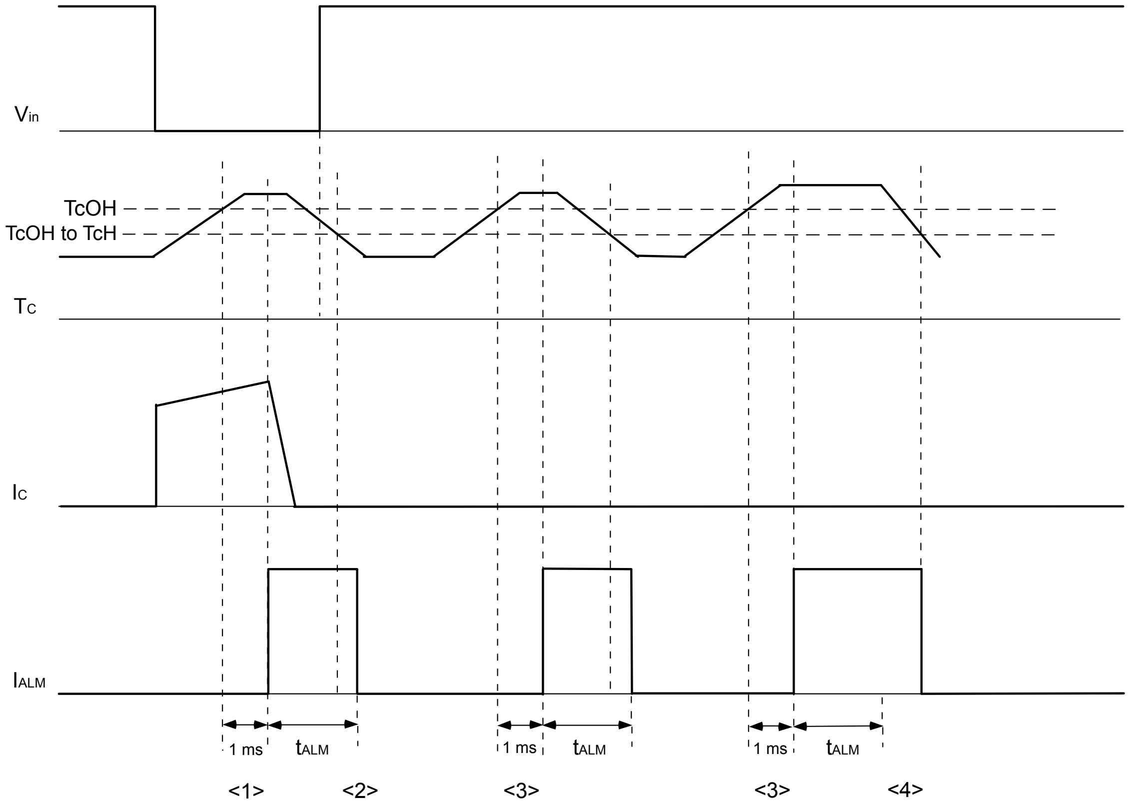

Fig. 3-19 Timing Chart TcOH

Refer to Fig. 3-2 <4>.

<1> An alarm is output if the case temperature Tc continuously exceeds T_{COH} for a period of about 1 ms, and if Vin is ON, a soft shutdown of all IGBTs on the lower arm side is executed.

<2> If Tc falls below T_{COH}-T_{CH} before t_{ALM} elapses, the alarm is reset when t_{ALM} elapses.

<3> If Tc exceeds continuously T_{COH} for a period of about 1 ms, an alarm is output. (While Vin is OFF)

<4> If Tc has not fallen below T_{COH}-T_{CH} when t_{ALM} elapses, the alarm is not reset. When Tc falls below T_{COH}-T_{CH} after t_{ALM} elapses, the alarm is reset.

IGBT chip overheating protection (TjOH) (1)

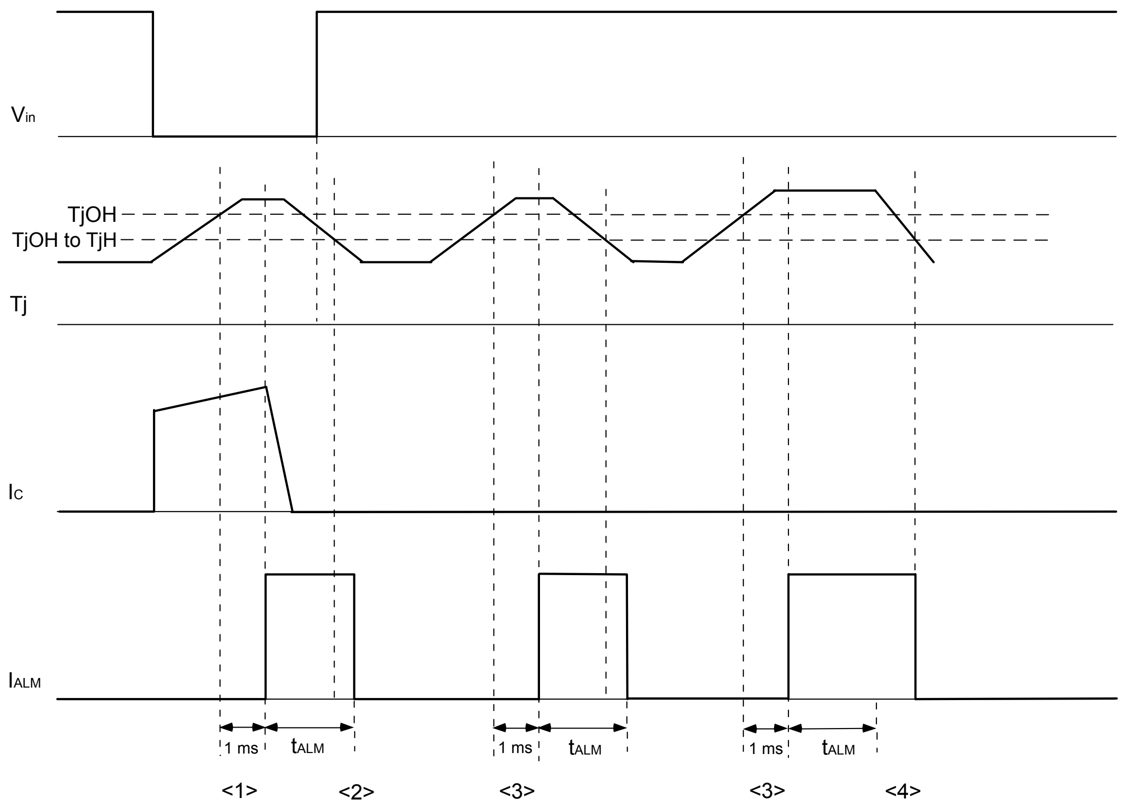

Fig. 3-20 Timing chart TjOH (1)

Refer to Fig. 3-2 <4>.

- <1> An alarm is output and a soft IGBT shutdown is executed if the IGBT chip temperature Tj continuously exceeds T_{jOH} for a period of about 1 ms.
- <2> If Tj falls below Tj_{OH}-Tj_{H} before t_{ALM} elapses, OH and the alarm are simultaneously reset if Vin is OFF when t_{ALM} elapses.
- <3> An alarm is output if Tj continuously exceeds Tj_{OH} for a period of about 1 ms, and if Vin is OFF, the protection function is not activated.
- <4> When Tj falls below Tj_{OH}-Tj_{H} after t_{ALM} elapses, OH and the alarm are reset simultaneously if Vin is OFF.

IGBT chip overheating protection (TjOH) (2)

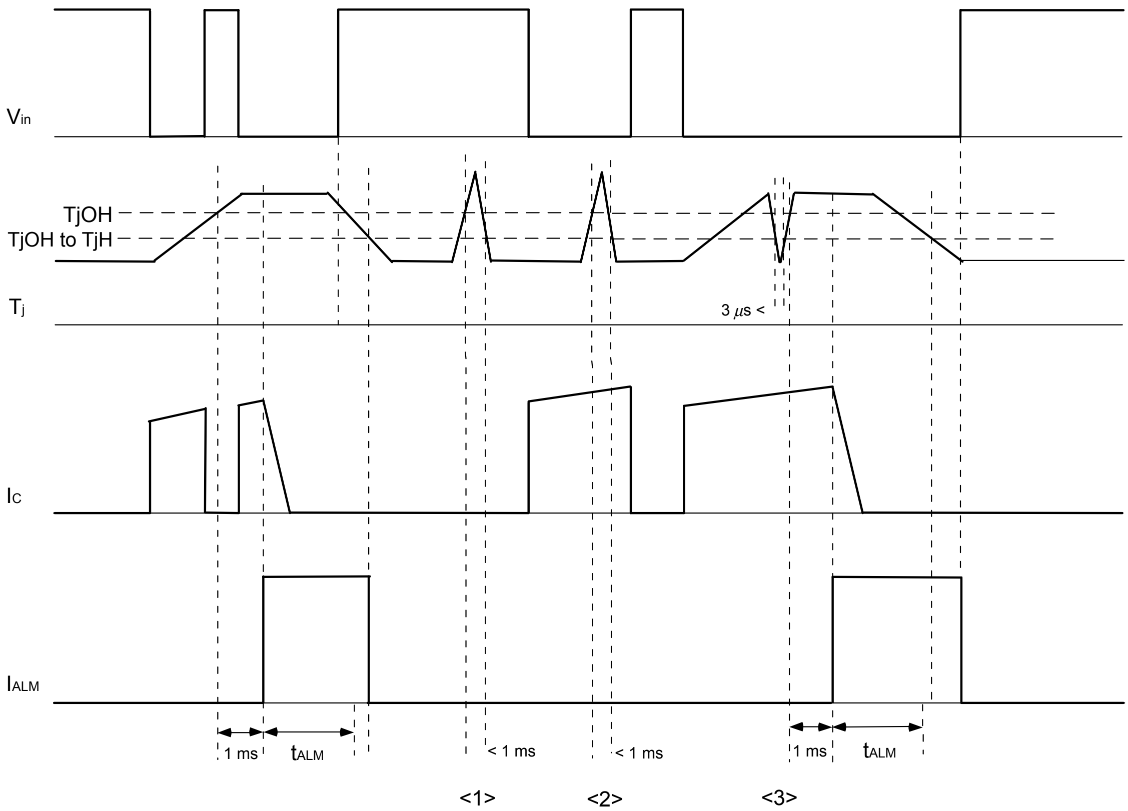

Fig. 3-21 Timing Chart TjOH (2)

Refer to Fig. 3-2.

<1> If Tj exceeds Tj_{OH} and then falls below Tj_{OH} within about 1 ms, OH does not operate regardless of whether Vin is ON or OFF.

<2> If Tj exceeds Tj_{OH} and then falls below Tj_{OH} within about 1 ms, OH does not operate regardless of whether Vin is ON or OFF.

<3> If Tj exceeds Tj_{OH} and then falls below Tj_{OH} for a period of about 3 μs or longer, the 1 ms detection timer is reset.

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