– Chapter 3 –

Description of functions

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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.

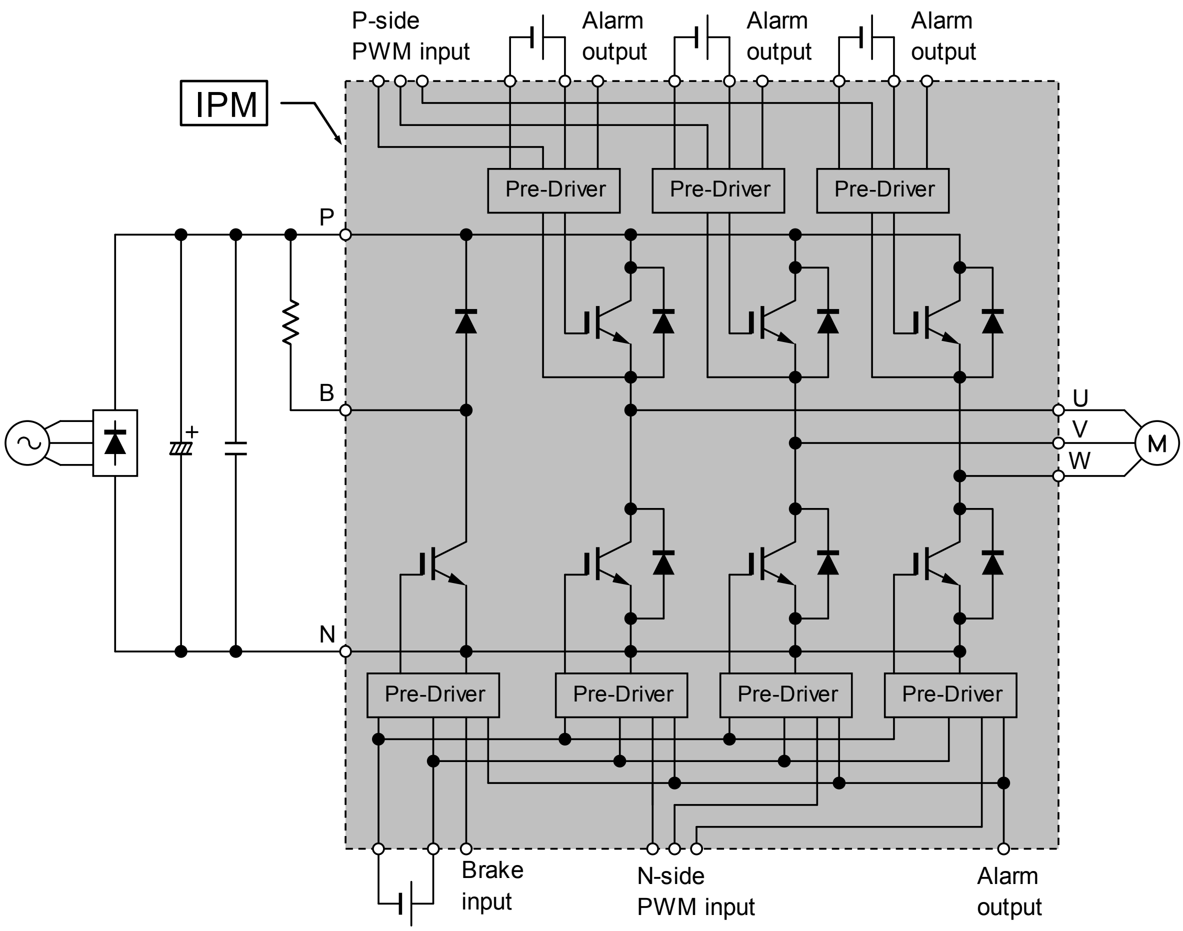


Figure 3-1 Typical application of 3-phase inverter (Example: 7MBP200VDA060-50 with built-in brake)

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.

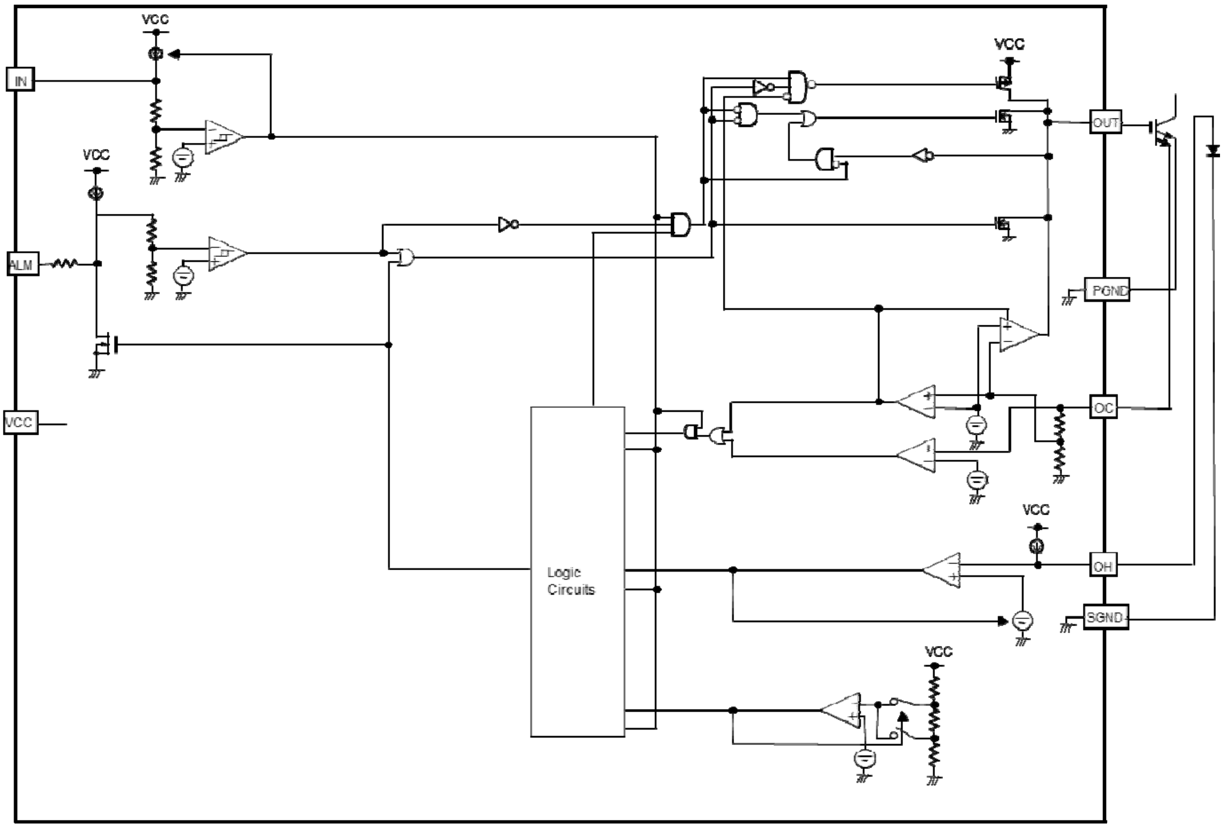


Figure 3-2 Pre-Driver block diagram (Example: 7MBP200VDA060-50)

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.

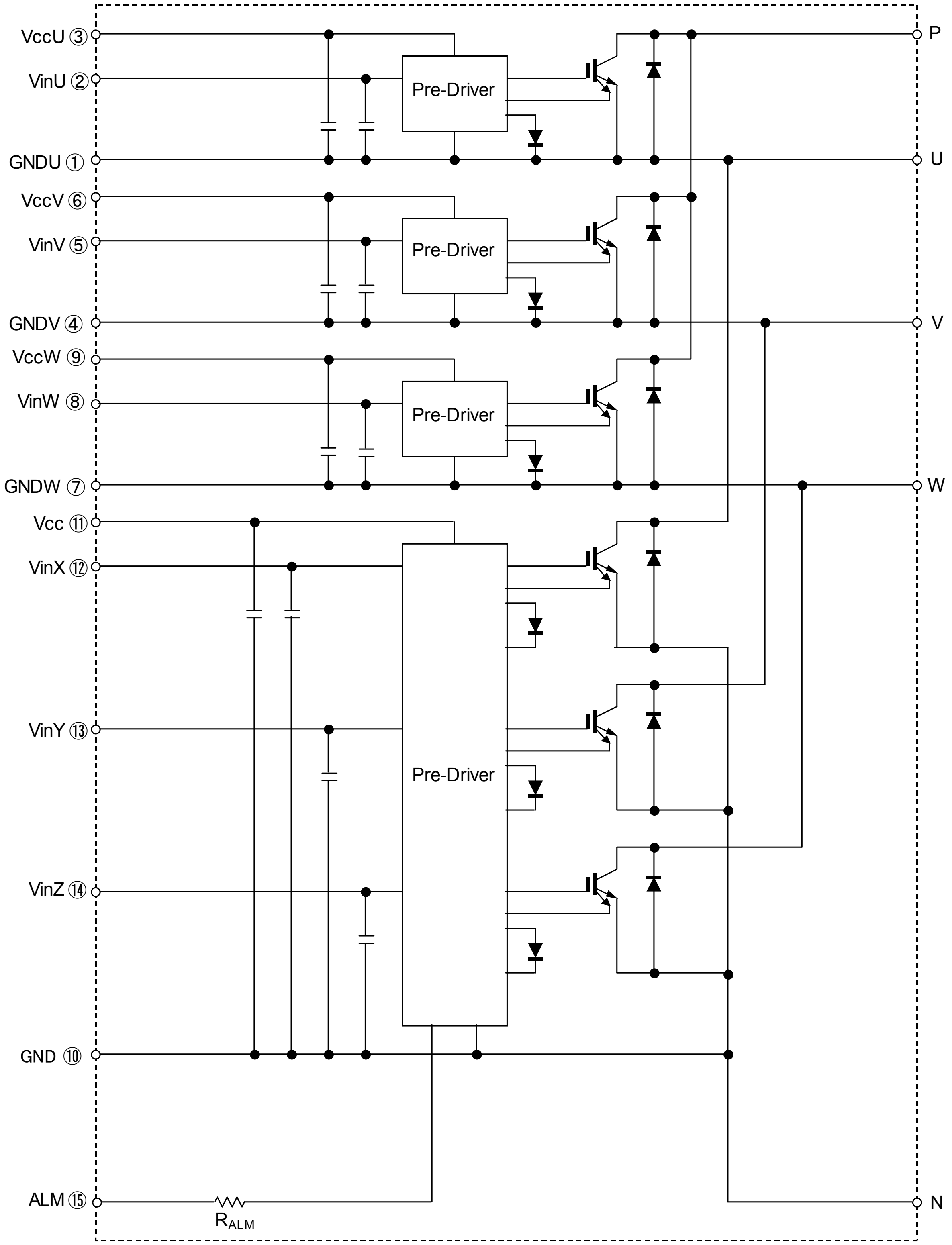


Figure 3-3 IPM block diagram (P629)

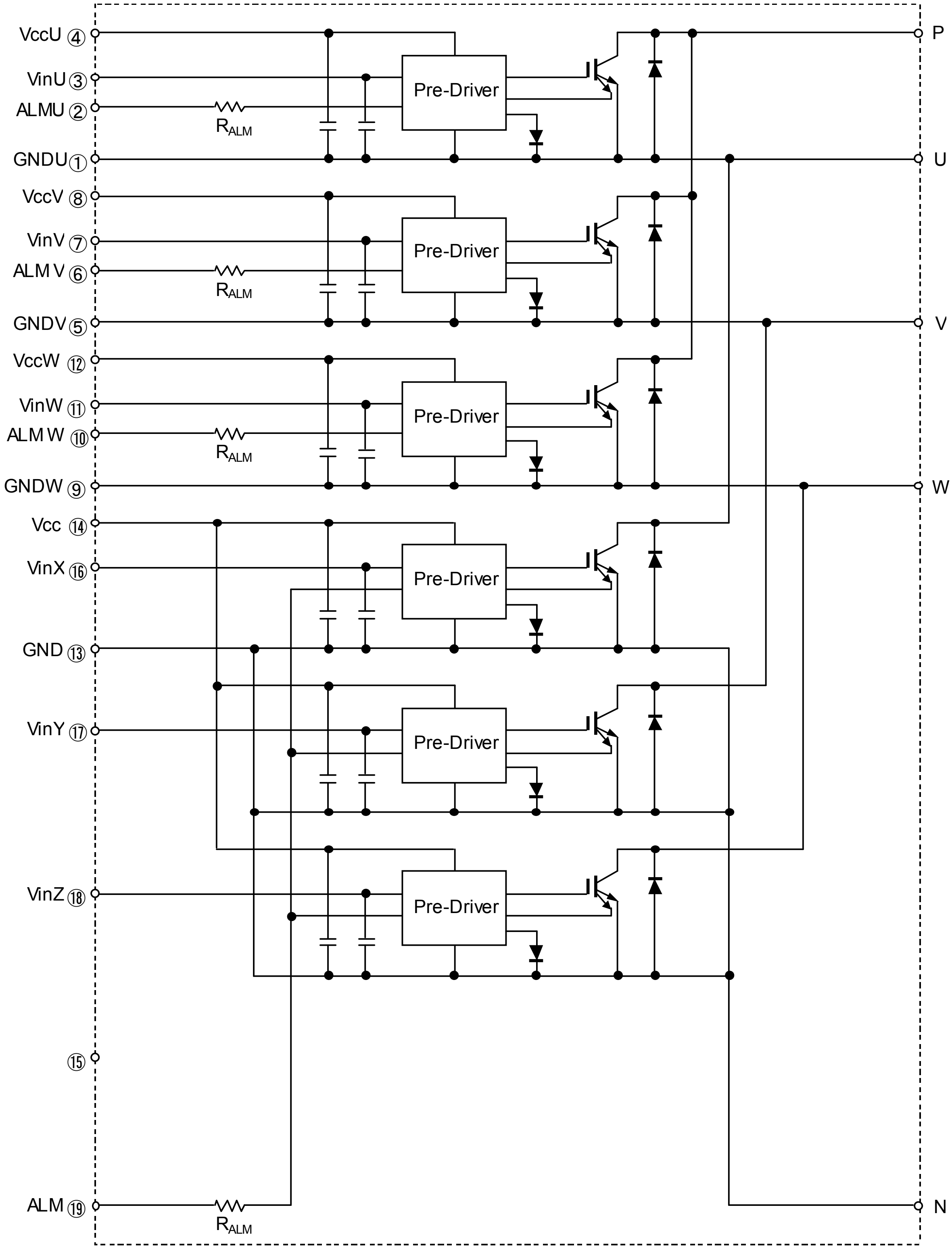


Figure 3-4 IPM block diagram (P626)

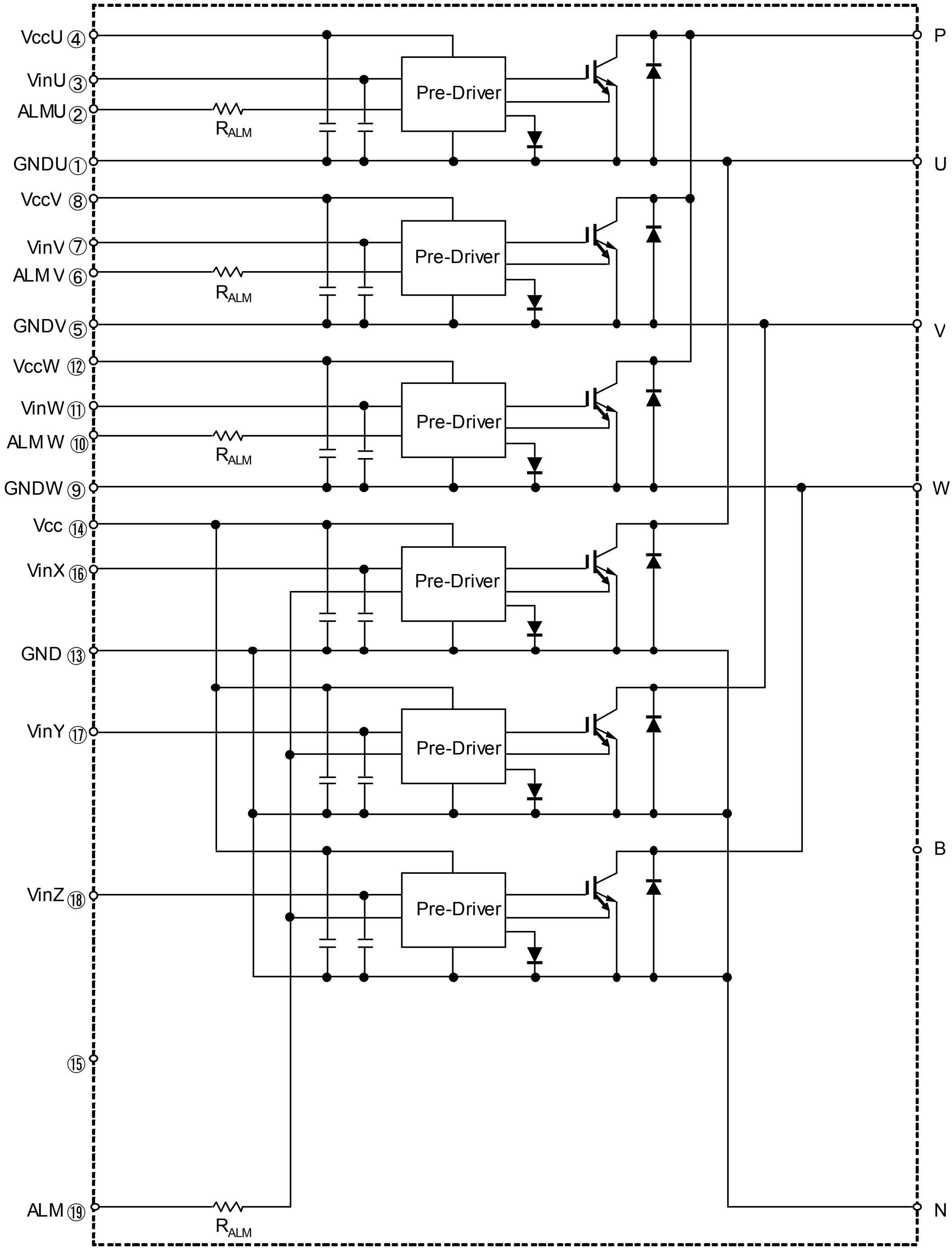


Figure 3-5 IPM block diagram (P630 without break)

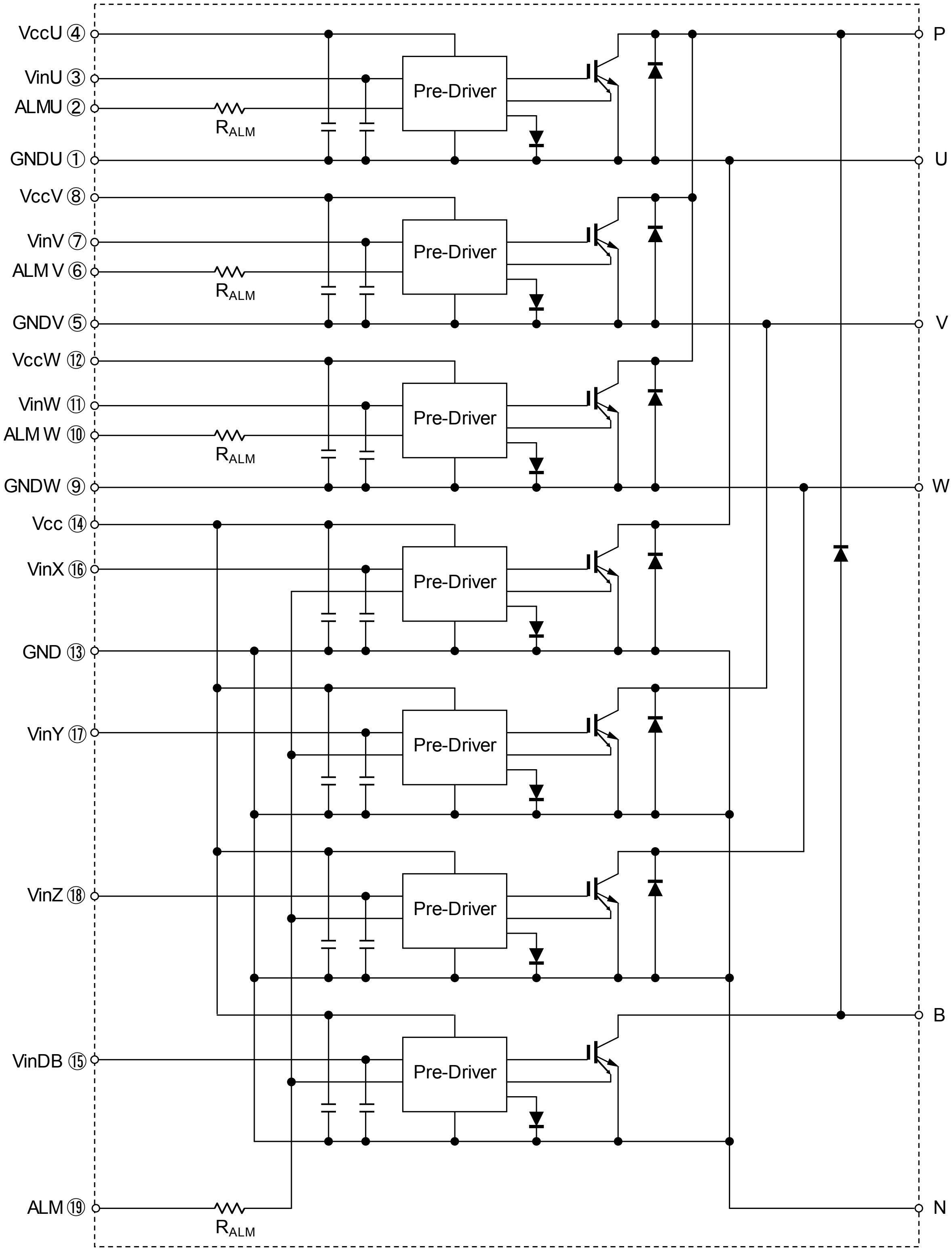


Figure 3-6 IPM block diagram (P630 with built-in brake)

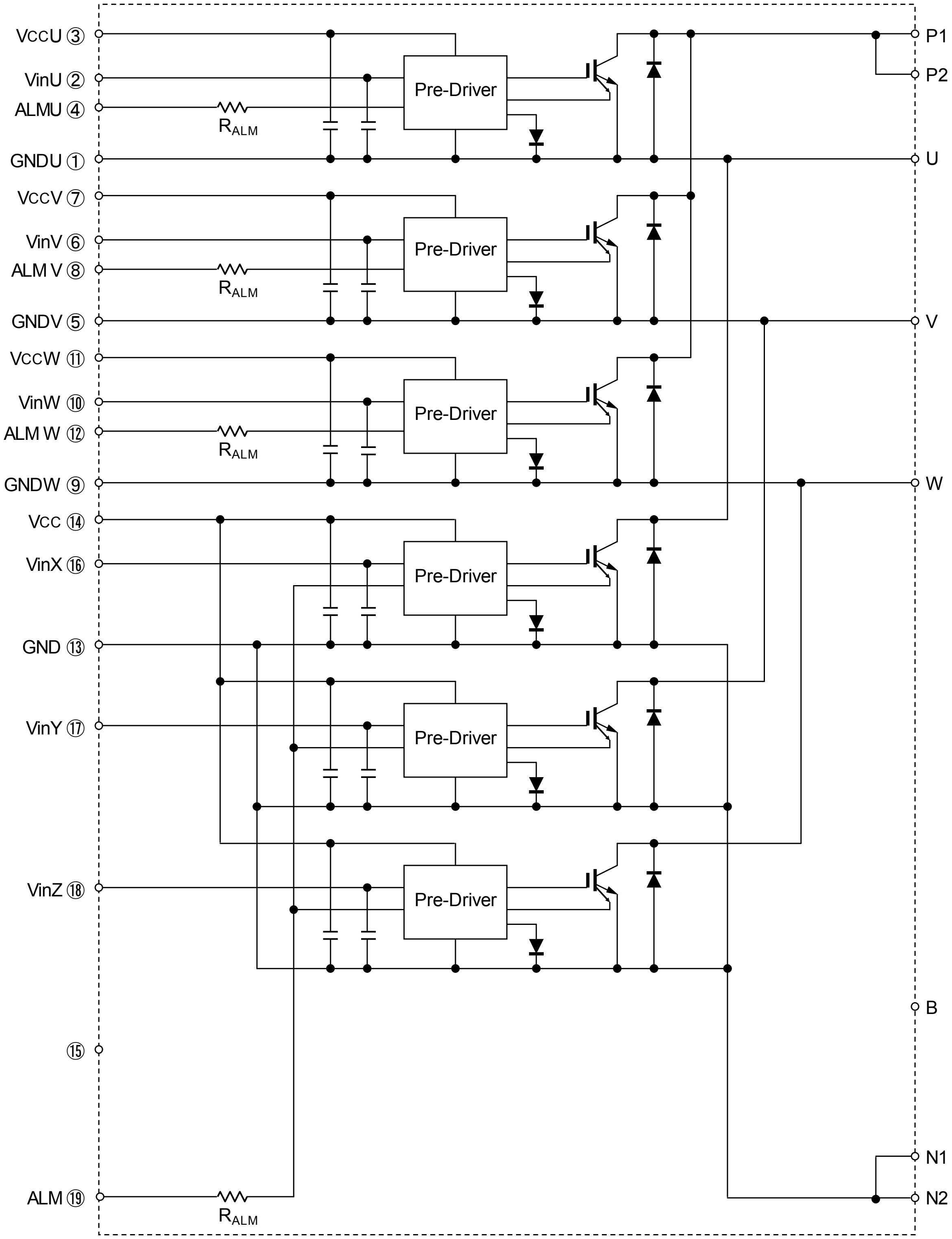


Figure 3-7 IPM block diagram (P631 without brake)

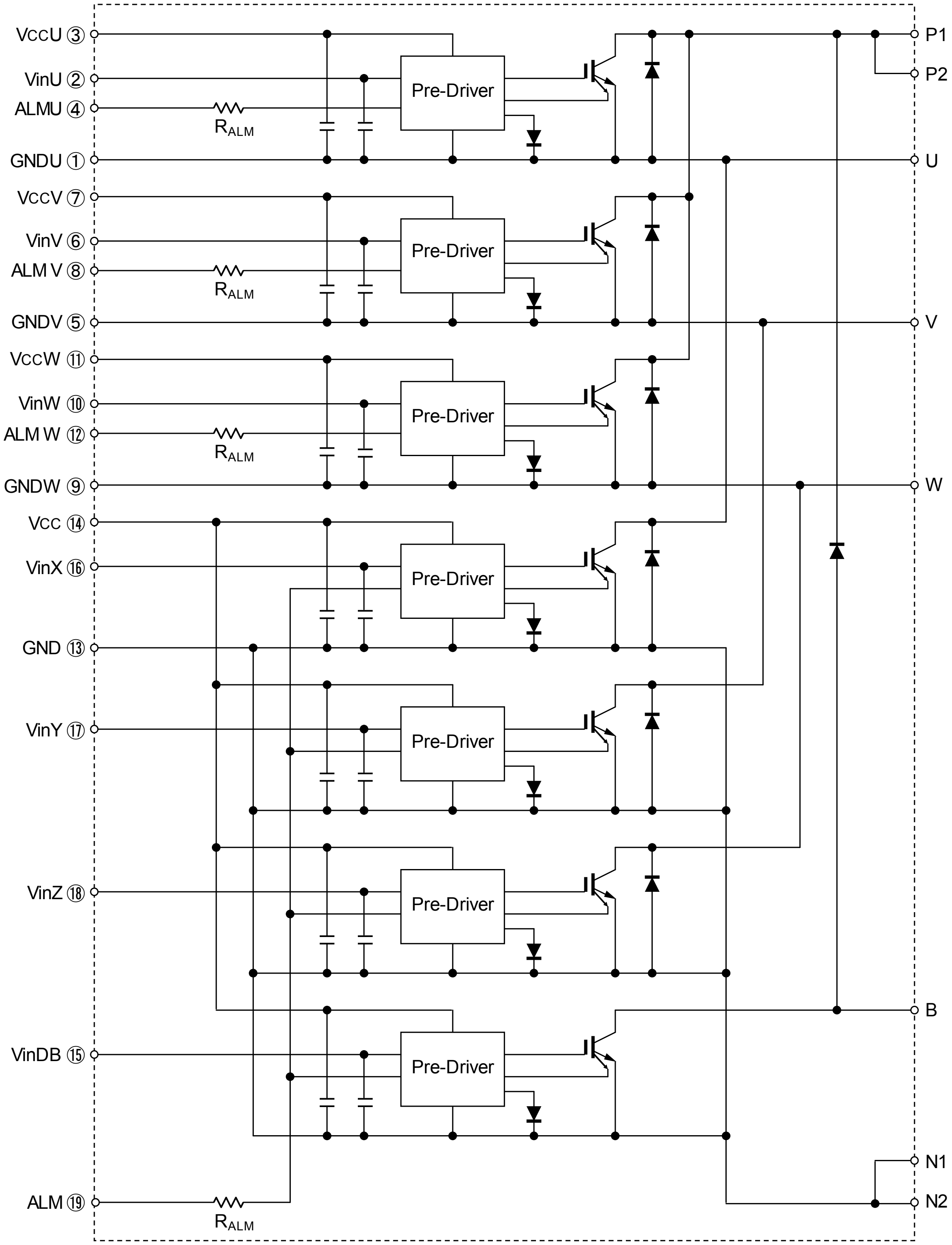


Figure 3-8 IPM block diagram (P631 with built-in brake)

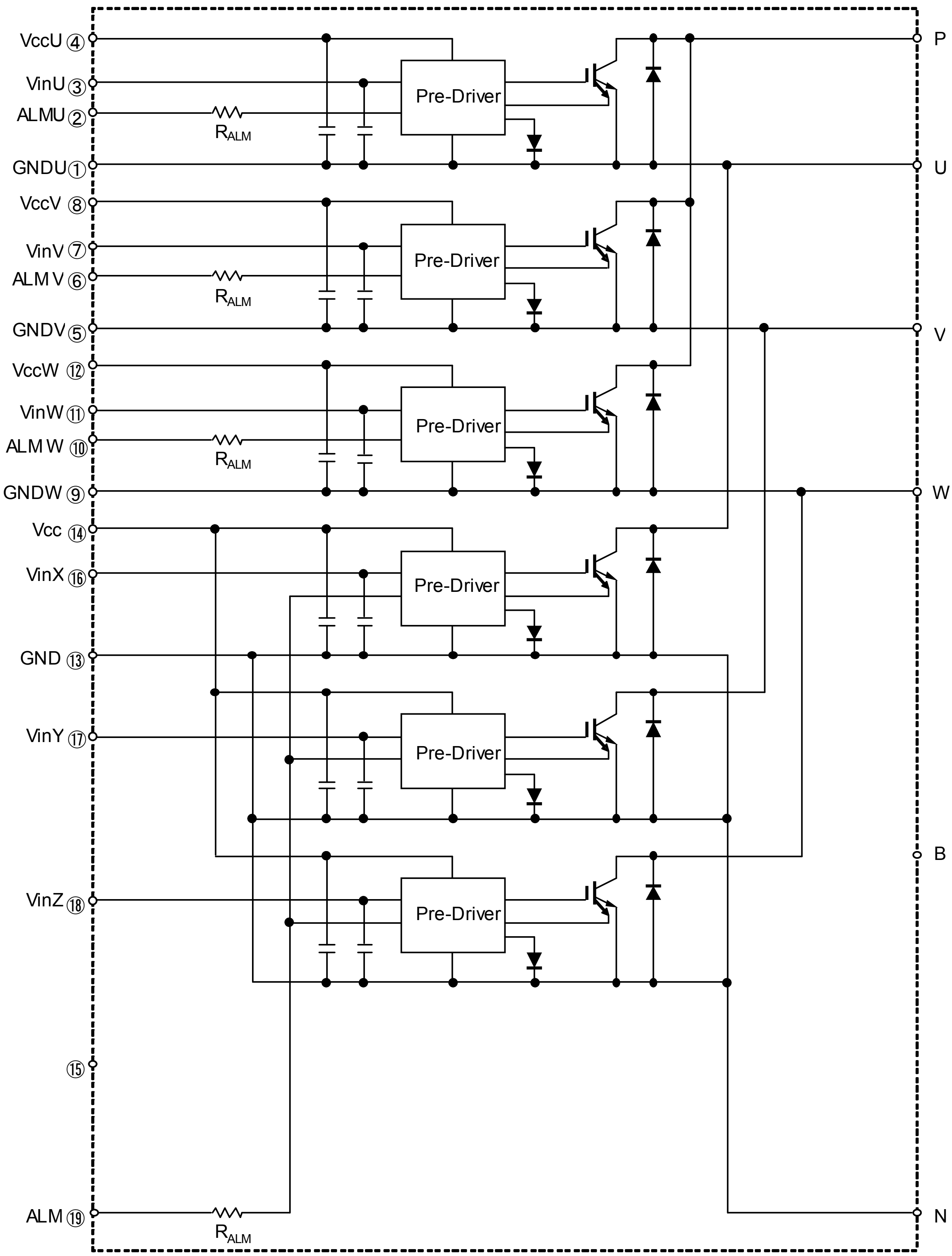


Figure 3-9 IPM block diagram (P636 without built-in brake)

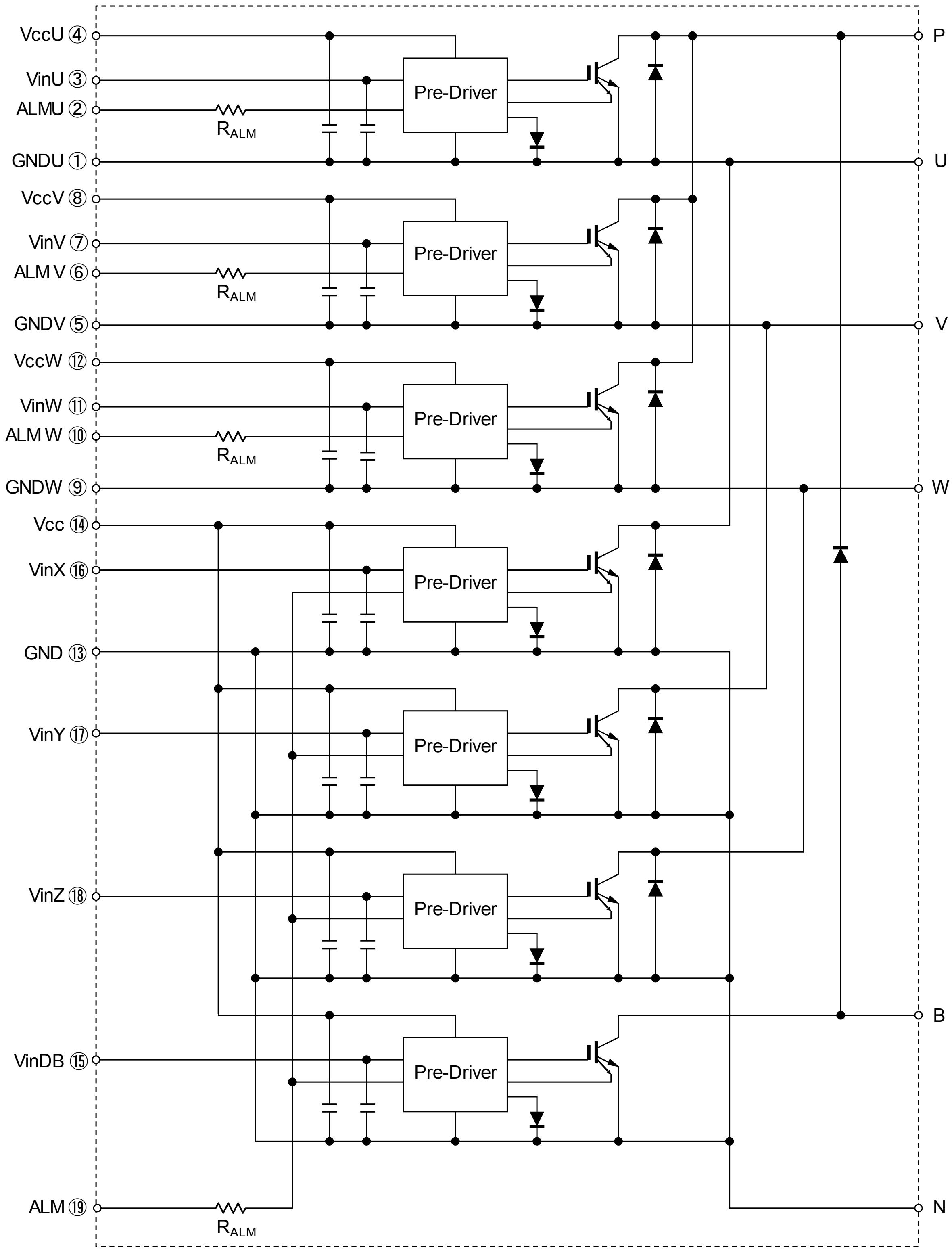
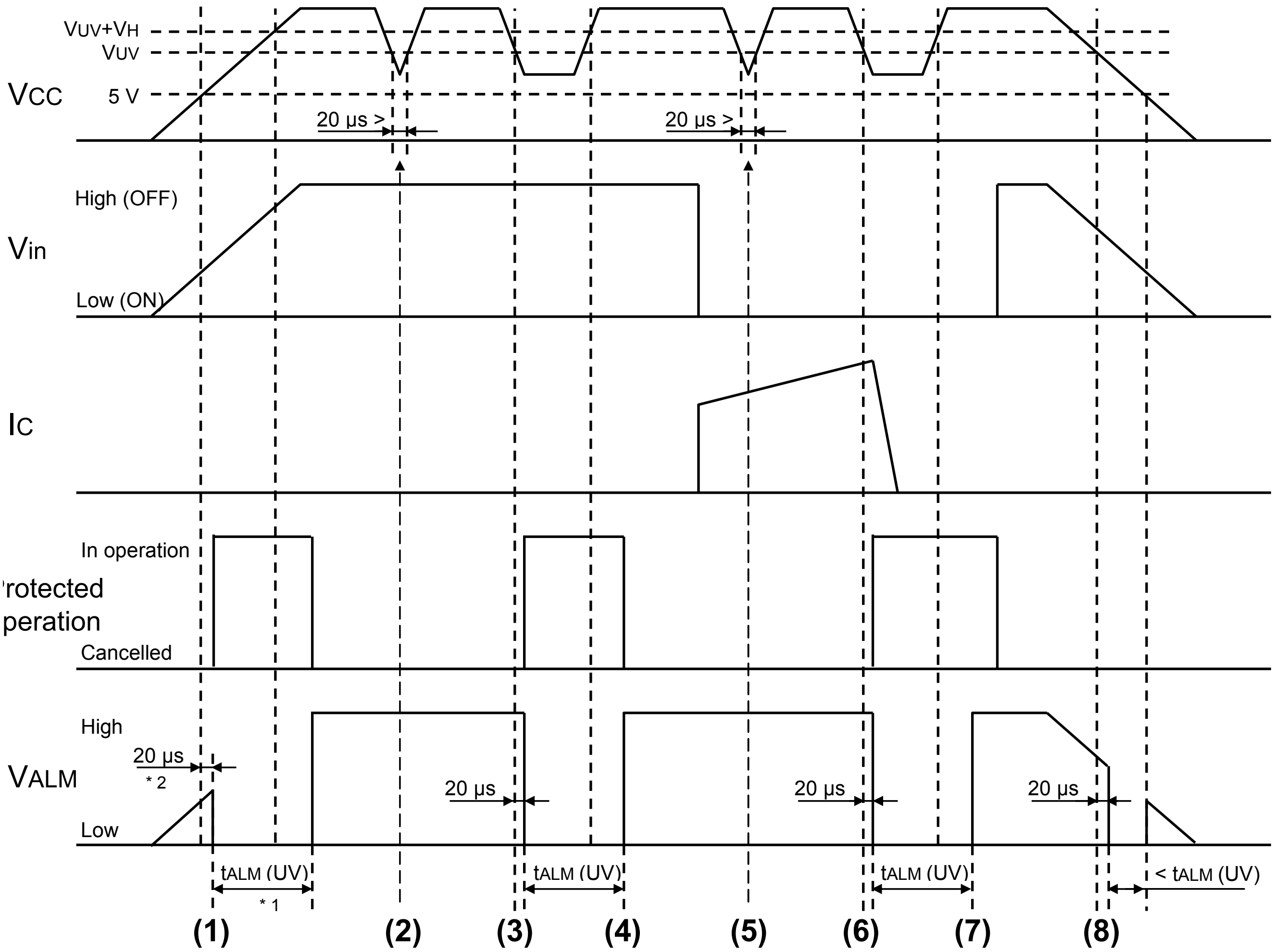


Figure 3-10 IPM block diagram (P636 with built-in brake)

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 VCC ramp-up, alarm output begins when the VCC exceeds 5 V and less than VUV. (See 5.3 for details.)

(2) Protective function is not activated if the length of time during which VCC is lower than VUV is shorter than 20 µs. (While Vin is off)

(3) While Vin is off, an alarm is generated 20 µs after the VCC drop below VUV, and the IGBT is kept in the off status.

(4) UV protected operation continues during the tALM (UV) period even if the VCC returns to over (VUV + VH) and Vin is off. Normal operation is restarted from protected operation after the elapse of the tALM (UV) period.

(5) Protection operation is not activated if the length of time during which VCC is lower than VUV is shorter

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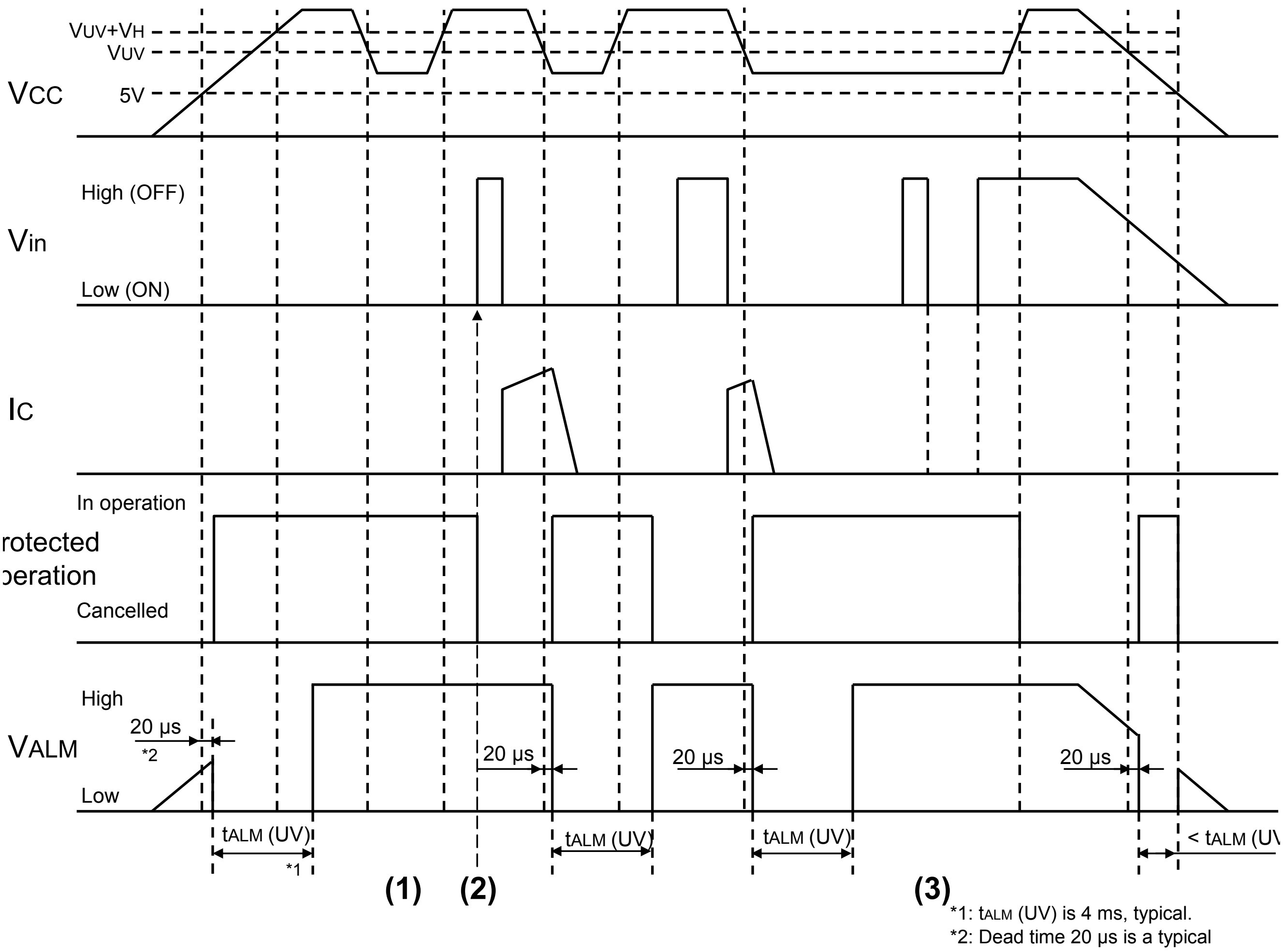
than 20 μs. (While V_{in} is on)

(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) 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.

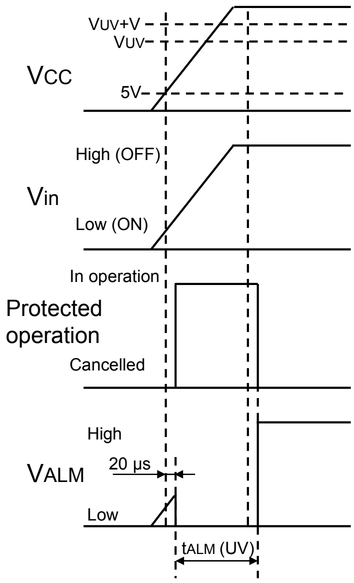
(3) The protective function continues because the V_{CC} is lower than V_{UV}. Then V_{in} signal is ignored and then the IGBT is not turned on. In addition, even if the duration of the protective operation is much longer than the $t_{ALM (UV)}$, the alarm output is generated only once.

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

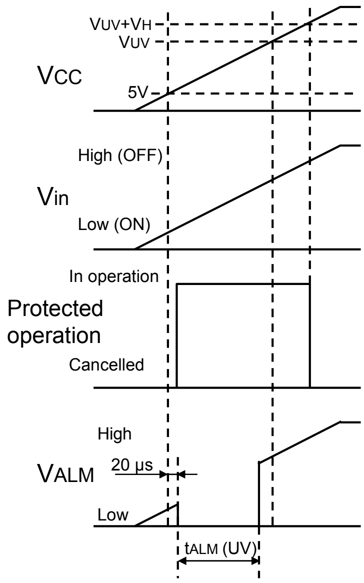
V-IPM has control power supply under voltage protection (UV) function. Because of this function, an alarm output is generated during the startup and shutdown of the power supply. Its details are described below:

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.



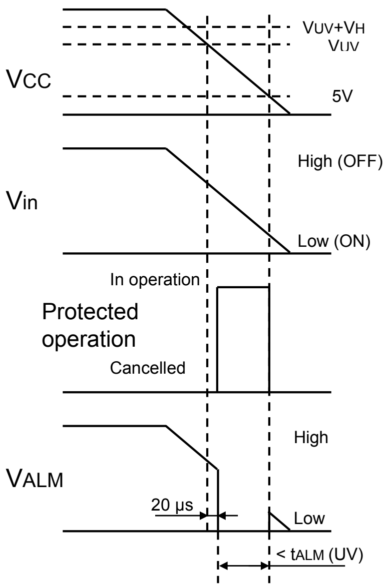
Case 1



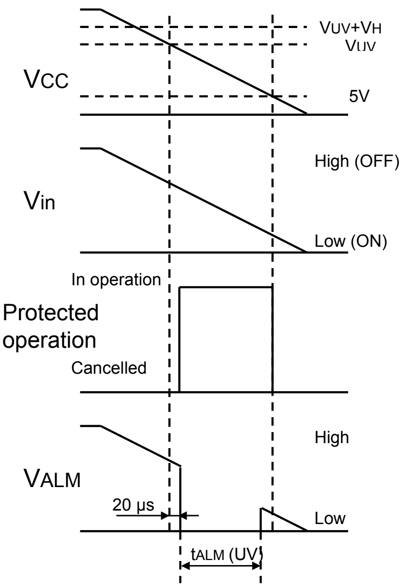
Case 2

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.

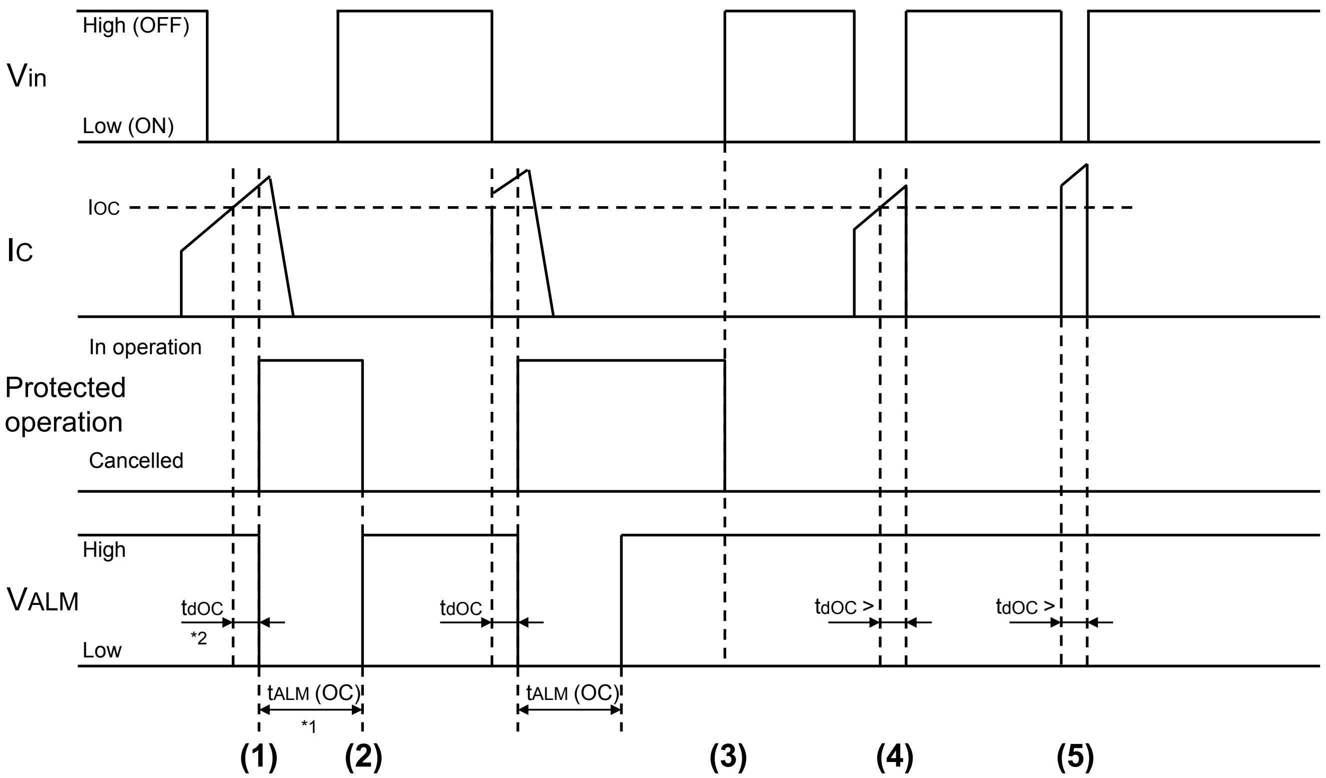


Case 3



Case 4

5.4 Overcurrent protection (OC)



(1) When the I_C exceeds the overcurrent trip level I_{OC}, an alarm signal is generated after the elapse of the t_{dOC}, and the IGBT is softly turned off.

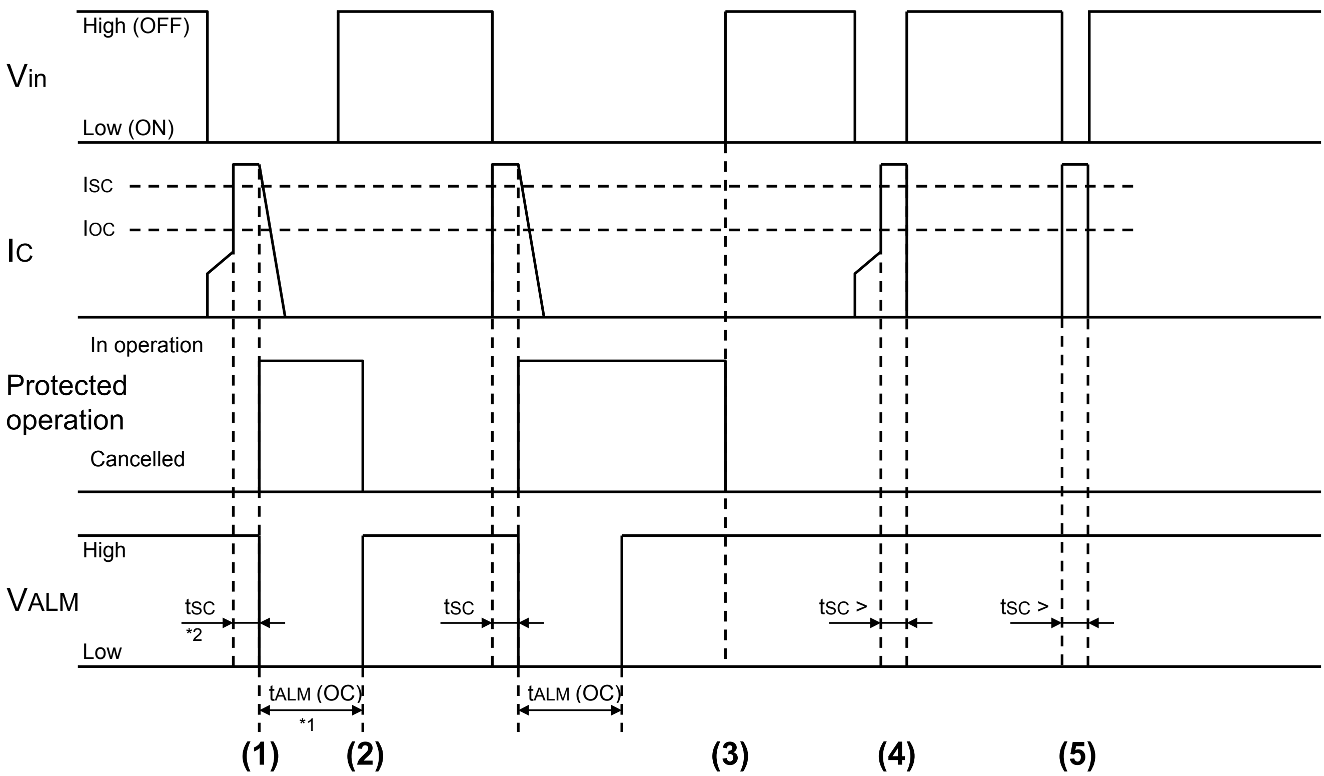
(2) The protected operation continues during the $t_{ALM\ (OC)}$ period even if the V_{in} becomes off-state, and resumes to normal operation after the elapse of the $t_{ALM\ (OC)}$ and V_{in} is in the off-state.

(3) OC protected operation continues if the V_{in} is on-state after the elapse of the $t_{ALM\ (OC)}$, and resumes to normal operation when the V_{in} becomes off-state. In addition, even if duration of the protection operation is much longer than the $t_{ALM\ (OC)}$, alarm signal output is generated only once.

(4) When the V_{in} is off-state before the elapse of the t_{dOC} since the I_C exceeds the I_{OC}, protection operation is not activated and the IGBT is softly turned off by the V_{in} off-state input.

(5) If I_C is higher than I_{OC} when V_{in} becomes on-state and if Vin becomes on-state before the elapse of t_{dOC}, 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).

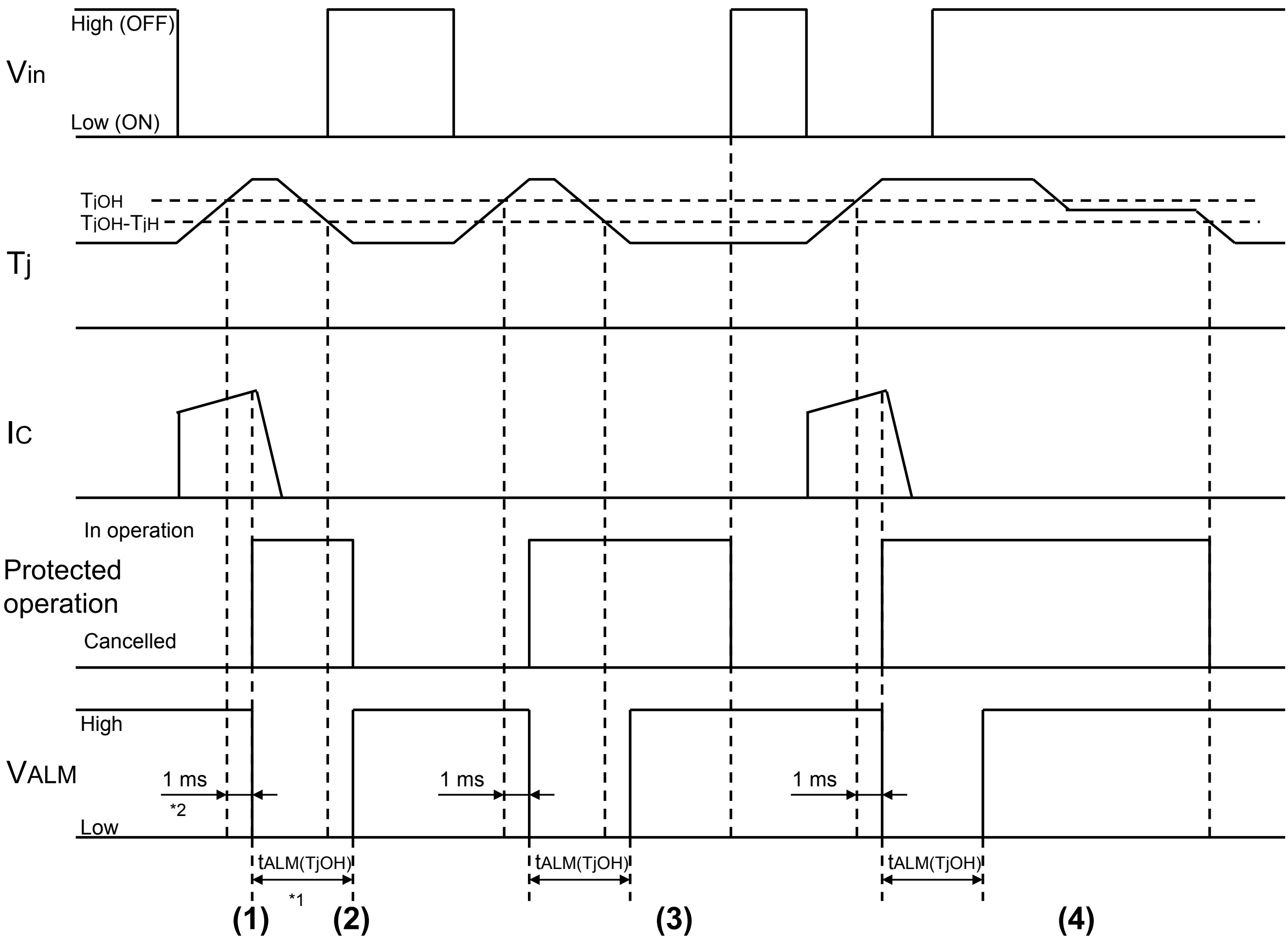
(3) When a load short-circuit occurs immediately after the IC is flowing and if the IC exceeds ISC the peak current is suppressed momentarily. After the elapse of tSC an alarm is generated and the IGBT is softly turned off.

(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: tALM (TjOH) is 8 ms, typical.
*2: Dead time 1 ms is a typical value.

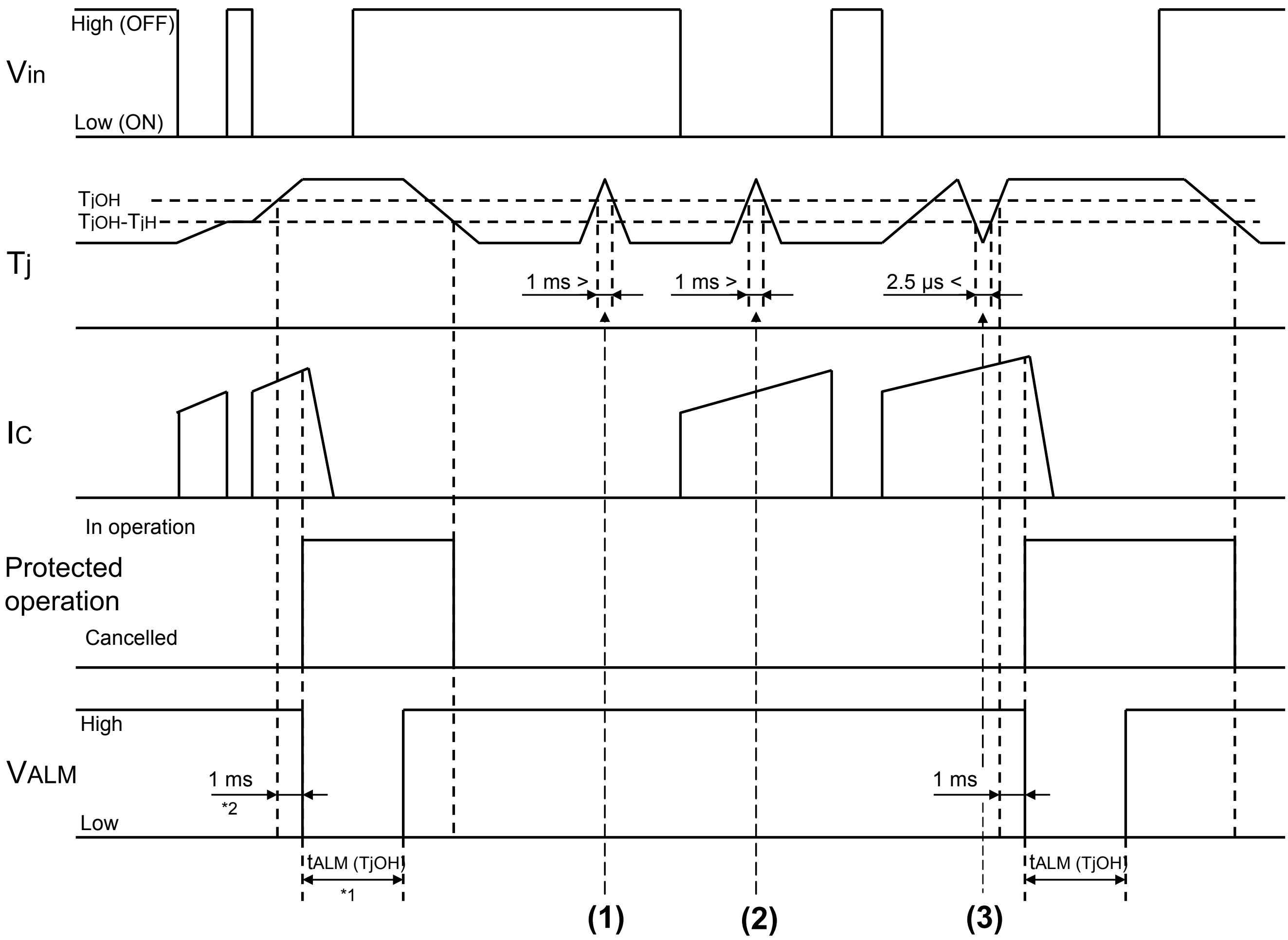
(1) If chip junction temperature T_j is higher than T_{jOH} for a period exceeding 1 ms, an alarm is generated and the IGBT is softly turned off.

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

(4) Protection operation continues after the elapse of the $t_{ALM\ (TjOH)}$ 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 $t_{ALM\ (TjOH)}$, alarm output is generated only once.

5.7 Chip temperature heating protection (TjOH): Case 2

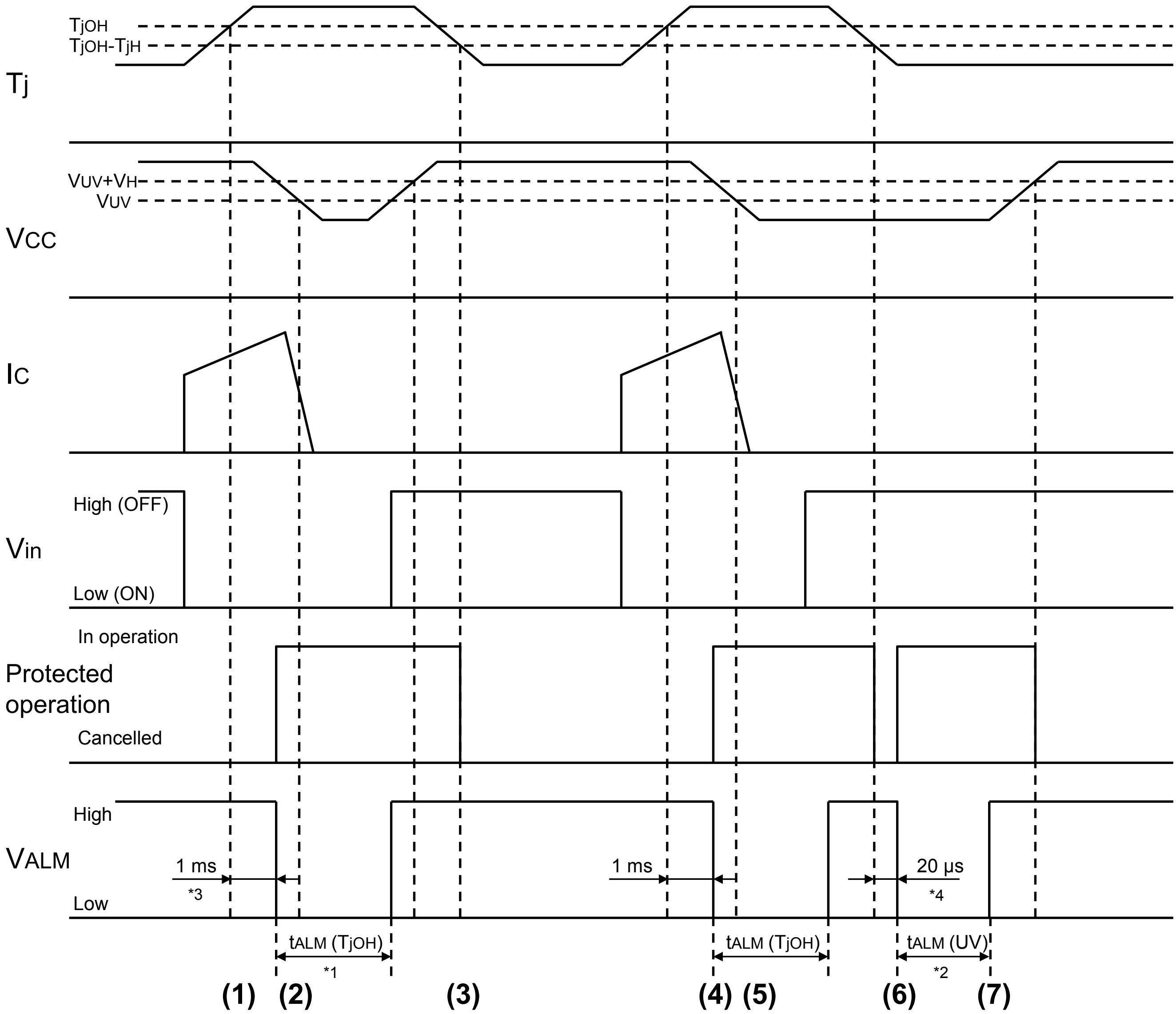


*1: t_{ALM} (T_{jOH}) is 8 ms, typical.
*2: Dead time 1 ms is a typical value.

(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: tALM (TjOH) is 8 ms, typical.
*2: tALM (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.

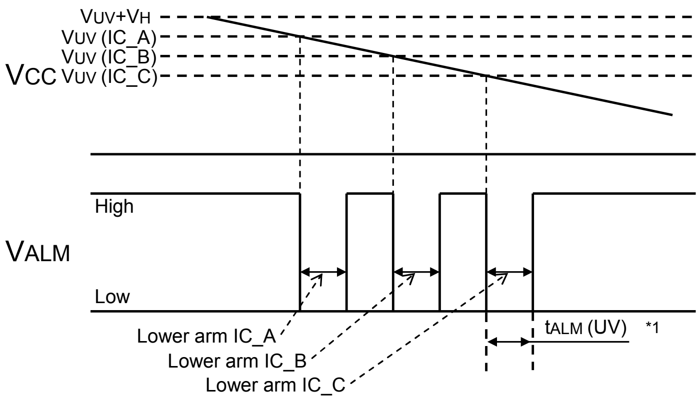
(5) Similar to the case (2), alarm output by VUV is stopped while protection operation of the $t_{ALM\ (TjOH)}$ is continued.

(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.