– Chapter 6 –

Precautions for use

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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.

Control power supply voltage (Vcc) (V)	IPM operation	Control power supply under voltage protection (UV)	IPM input signal voltage	IGBT operation
0 < Vcc ≤ 12.5	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.	-	Hi	-
			Lo	-
5.0 < Vcc ≤ 11.0	Control IC is working normally and IGBT is kept OFF state because UV protection is activated. UV alarm output is generated.	Activated	Hi	OFF
			Lo	OFF
11.0 < Vcc ≤ 12.5	(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.	(1) Activated	Hi	OFF
			Lo	OFF
		(2) Cancelled or before action	Hi	OFF
			Lo	ON
12.5 < Vcc < 13.5	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.	Cancelled	Hi	OFF
			Lo	ON
13.5 < Vcc ≤ 16.5	Recommended voltage range. Drive circuit works stably. The IGBT switching follows input signal.	Cancelled	Hi	OFF
			Lo	ON
16.5 < Vcc ≤ 20	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.	Cancelled	Hi	OFF
			Lo	ON
Vcc < 0, Vcc > 20	If the Vcc is <0V or >20V, the drive circuit and main chip may be damaged. Never apply such voltage to the device.	-	-	-

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.