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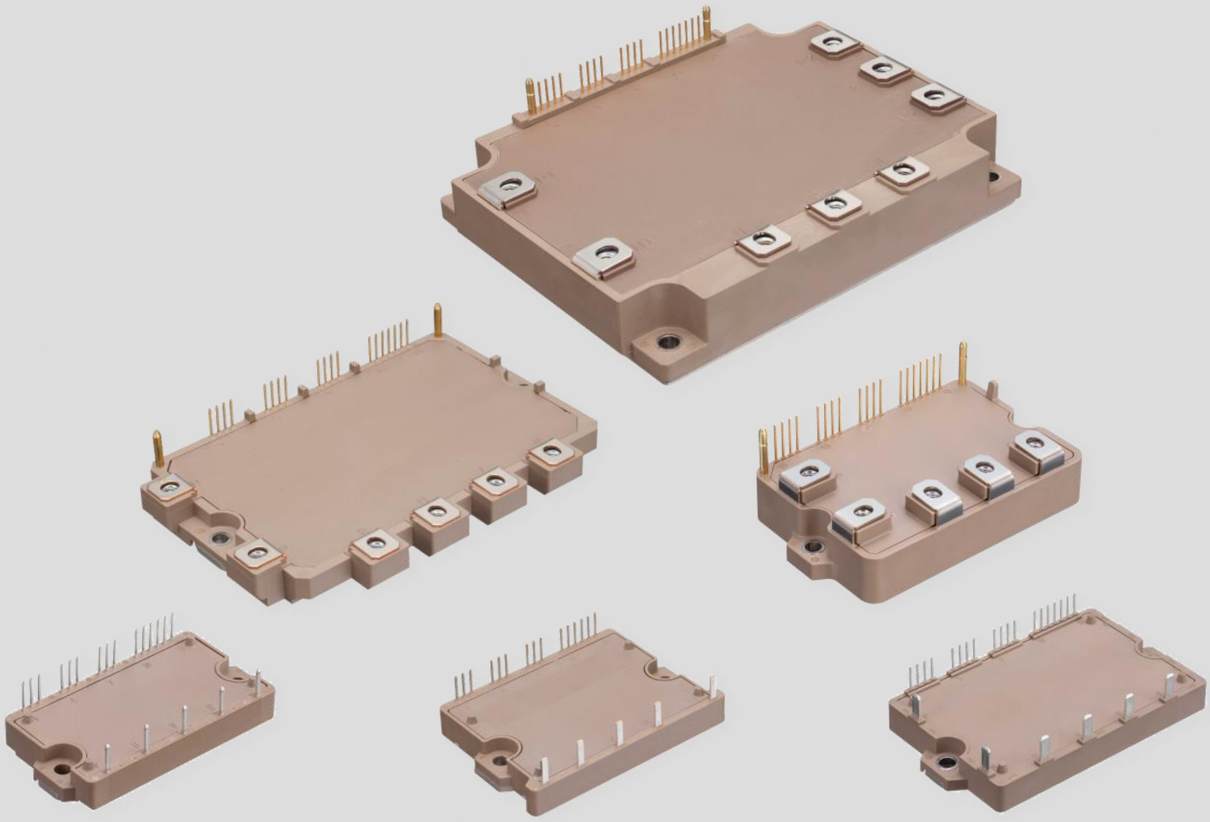

Fuji 7th Generation IGBT-IPM
X Series

Application Manual

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Fuji Electric Co.,Ltd.

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Warning:

This manual contains the product specifications, characteristics, data, materials, and structures as of October 2021.

The contents are subject to change without notice for specification changes or other reasons. When using a product listed in this manual, be sure to obtain the latest specifications.

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⚠ Cautions

(1) During transportation and storage

Keep locating the shipping carton boxes to suitable side up. Otherwise, unexpected stress might affect to the boxes. For example, bend the terminal pins, deform the inner resin case, and so on.

When you throw or drop the product, it gives the product damage.
If the product is wet with water, that it may be broken or malfunctions, please subjected to sufficient measures to rain or condensation.

Temperature and humidity of an environment during transportation are described in the specification sheet. There conditions shall be kept under the specification.

(2)Assembly environment

Since this power module device is very weak against electro static discharge, the ESD countermeasure in the assembly environment shall be suitable within the specification described in specification sheet. Especially, when the conducting pad is removed from control pins, the product is most likely to get electrical damage.

(3)Operating environment

If the product had been used in the environment with acid, organic matter, and corrosive gas (hydrogen sulfide, sulfurous acid gas), the product's performance and appearance can not be ensured easily.

Chapter 6 Precautions for use

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This chapter describes the precautions for use.

1. Main power supply

1.1 Voltage range

- The collector - emitter terminal voltage (=V_{CES}) shall never exceed the absolute maximum rated voltage (650V series = 650V, 1200V series = 1200V).
- In order to keep the maximum surge voltage between all terminals within the rated voltage during switching operation, connect the IPM and other components as close as possible to each other and connect a snubber capacitor between P and N terminals. The term ‘between all terminals’ means the terminal arrangement as shown in Table 6-1.

Table 6-1. Terminal arrangement of each package

Package	Between terminals
P639, P629, P626, P630(6in1) P636(6in1), P638	[P-(U,V,W), (U,V,W)-N]
P630(7in1)、P636(7in1)、P644	[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]

- For P631, connect the main power supply between paired terminals (P1 and N1 or P2 and N2). Do not connect the main power supply between unpaired terminals (P1 and N2 or P2 and N1) as this may cause a malfunction. Connecting snubber circuits to both P1-N1 and P2-N2 is effective in suppressing surge voltage.

1.2 Measures against exogenous noise

- Although measures against exogenous noise are taken in the IPM, there is a possibility where malfunction and breakdown are triggered by exogenous noise depending on the noise kind and intensity. It is necessary to take sufficient measures against noise applied to the IPM.

1.2.1 Measures against noise from outside of the device

- Take measures such as installing a noise filter along the AC line and strengthening earth ground.
- Add a capacitor of <100pF between signal input line and signal GND of every phase if necessary.
- If an excessive noise voltage is applied to the alarm signal output terminal, it may cause incorrect alarm signal output. Connect 0.2kΩ to 1kΩ resistor in series to the alarm signal output terminal if necessary. In this case, choose the most suitable resistance value in consideration of CTR of the optocoupler.
- To prevent noise from entering from the AC line, connect a grounding capacitor of about 4700pF between each of the 3 phases of AC input and ground.
- Apply measures such as provision of an arrester against lightning surge.

1.2.2 Measures against internal noise from the IPM

- Outside of rectifier: Apply the same measures as in Section 1.2.1.
- Inside of rectifier: Add snubber capacitors or similar circuit to the P and N line.

1.2.3 Measures against noise from output terminals

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

2. Control power supply

2.1 Voltage range

- The control power supply voltage including ripple shall not exceed the specification value.

Tabe.6-2 IPM operation by control power supply voltage value

Control power supply voltage (**V_{CC}**) [V]	IPM operation	Control power supply under voltage protection (UV)	IPM input signal voltage	IGBT operation
$0 \leqq V_{CC} \leqq 5.0$	Control IC does not operate correctly and IGBT gate signal is unstable. In addition, IGBT is not turned on because V_{CC} is lower than the gate threshold voltage V_{th}. The UV protection does not work and no alarm signal is output.	—	Hi	—
			Lo	—
$5.0 < V_{CC} \leqq 11.0$	Control IC operate. However, IGBT remains OFF state because UV protection is activated. UV alarm signal is output.	Activated	Hi	OFF
			Lo	OFF
$11.0 < V_{CC} \leqq 12.5$	(1) When UV protection is activated: the IGBT remains OFF state and the alarm signal is output. (2) When UV protection is not activated: The IGBT operation follows the input signal, no alarm signal is output.	(1) Activated	Hi	OFF
			Lo	OFF
		(2) Cancelled or before action	Hi	OFF
			Lo	ON
$12.5 < V_{CC} \leqq 13.5$	UV protection is not activated. The IGBT operation follows the input signal. Power dissipation tends to increase and emission noise tends to decrease.	Cancelled	Hi	OFF
			Lo	ON
$13.5 < V_{CC} \leqq 16.5$	It is recommended voltage range. IGBT driving circuit operates stably. The IGBT operation follows the input signal.	Cancelled	Hi	OFF
			Lo	ON
$16.5 < V_{CC} \leqq 20$	UV protection is not activated. The IGBT operation follows the input signal. Power dissipation tends to decrease and emission noise tends to increase. The short circuit current will increase due to shifts in protection characteristics.	Cancelled	Hi	OFF
			Lo	ON
$V_{CC} < 0$, $20 < V_{CC}$	The use of V_{CC}<0V or >20V may cause malfunction or damage to the device. Never apply such voltage to the device.	—	—	—
			—	—

2.2 Voltage ripple

- The recommended voltage range of V_{CC} is from 13.5 to 16.5V, including voltage ripple.
- The control power supply should be designed with sufficiently low voltage ripple.
  In addition, the noise on the power supply voltage should low as much as possible. If the control power supply voltage exceeds the recommended voltage range, the IPM may cause a malfunction.
- Design the control power supply so that the dv/dt does not exceed 5V/μs.
  Additionally, it is also recommended that fluctuation of the power supply voltage be within ±10%.

2.3 Control power supply startup/shutdown sequence

- Make sure that the control power supply voltage V_{CC} is within the recommended voltage range, before applying the main power supply (between P-N terminals).
- Shut off the main power supply before shutting off the control power supply (V_{CC}).
- If main power supply is applied to the P-N terminals before the V_{CC} reaches the recommended voltage range, or if main power remains, the IPM may cause malfunction or be destroyed due to exogenous noise.

2.4 Alarm signal output during startup/shutdown of control power supply

- UV alarm signal is output during startup of the control power supply.
  The alarm signal is reset after $t_{ALM(UV)}$, but the IPM ignores the input signal unless the protection reset condition is met. The input signal is accepted when all the conditions to reset protection operation functions is met (dissolving of protection factor, elapse of $t_{ALM(UV)}$ and input signal OFF).The driving control circuit should be designed to generate input signals after the alarm signal output period elapsed.
- The alarm signal is output during shutdown of the control power supply.
- Refer to Chapter 3, section 5 for the timing chart.

2.5 Notes on the design of control circuit

- Use four isolated power supply units for the control power supply V_{CC} (3 for upper arm and 1 for lower arm) .
  In addition, it is recommended to connect a capacitor with good frequency response characteristic close to each control power supply terminal in order to suppress transient voltage fluctuation.
- The control circuit should be designed with sufficient current supply capacity in consideration of the consumption current specification (I_{cc}).
- In order to prevent malfunction, pay attention to the distance from other phase wiring and how to parallel, and use a pattern layout that is not easily affected by crosstalk.
- Connect a capacitor between V_{CC} and GND in high-speed optocouplers.
- Use a high-speed optocoupler with tpHL, tpLH ≤ 0.8μs and of high CMR type for the control signal input circuit.
- Use a low-speed optocoupler with CTR ≥ 100% for the alarm signal output circuit.
- Note that if a capacitor is connected between the input terminal and GND, the response time of the optocoupler becomes longer.
- Minimize the wiring length between the optocoupler and the IPM, and the pattern layout should be designed to minimize the floating capacitance between the primary side and the secondary side of the optocoupler.
- The primary side current of the optocoupler I_F should be designed with sufficient margin in consideration of CTR. In order to suppress the influence of noise, design the pull-up resistor on the secondary side of the optocoupler as low as possible to lower the impedance.

3. Protection functions

As described in Chapter 4 “Typical Application Circuits“, it is necessary to determine the I_F of the primary side of the optocoupler so that the total current of the current flowing through the pull-up resistor I_R and the constant current I_{in} can flow on the secondary side of the optocoupler.
If the I_F is insufficient, the secondary side may malfunction. However, since optocouplers have a limited lifetime, it is necessary to consider the lifetime when selecting the primary side current limiting resistor.
In addition, the availability of the upper phase alarm signal output differs depending on the package.
Check the alarm specification of the IPM in Chapter 3.1, "List of functions".

3.1 General protection operation

3.1.1 Range of protection

- The protection function of IPM is designed to handle non-repetitive abnormal operations. Ensure that abnormal operation is not repeated. In the worst case, the IPM may be destroyed. Over current and short-circuit protection are guaranteed under the condition that the control power supply voltage is from 13.5 to 16.5 V and the main power supply voltage is from 200 to 400 V (650 V series) or 400 to 800 V (1200 V series).

3.1.2 Action on occurrence of alarm signal output

- If an alarm signal is output, stop the input signal to the IPM and shutdown the system immediately.
- The protection functions protect the IPM against abnormal operation, but they are not able to eliminate the causes.
- If an abnormal operation is detected in the upper arm, only the IGBT of the detected phase is turned off and an alarm signal is output from the same phase (excluding P629 and P639). At this time, Switching operation of other phases are permitted.
- On the other hand, when an abnormal operation is detected in the lower arm of the inverter part, all the IGBTs in the lower arm of the inverter part are turned off regardless of the phase and an alarm signal is output from the lower phase. At this time, Switching operation of the upper arm and brake part are permitted.
  When an abnormal operation is detected in the brake part, all the IGBTs of the lower arm(including brake part) are turned off and an alarm signal is output from the lower arm. At this time, Switching operation of the upper arm are permitted.

3.2 Precautions for protection operation

3.2.1 Over current (OC)

- If the over current continues for more than t_{dOC}, the IGBT is judged to be in OC state and is slowly turned off. At the same time, an alarm signal is output.
- If the current drops below the over current protection level within the t_{dOC} period, the OC protection is not activated and the IGBT is turned off normally.
- There is no alarm signal output function in the upper arm of P629 and P639, but the OC protection works and the IGBT is turned off slowly.

3.2.2 Short-circuit (SC)

- If the short-circuit current continues for more than t_{dSC}, the IGBT is judged to be in SC state and the is turned off slowly. At the same time, an alarm signal is output.
  If the short-circuit current drops below the protection level within the t_{dSC} period, the SC protection is not activated and the IGBT is turned-off normally.
- There is no alarm signal output in the upper arm of P629 and P639, but SC protection works and the IGBT is turned off slowly.

3.2.3 Ground fault

(1)Ground fault protection and alarm signal output of upper arm IGBT

- When the ground fault current flows through the IGBT of the upper phase more than t_{dOC} or t_{dSC}, the OC (SC) protection is activated, but the alarm signal differs depending on the package.
  P629, P639 : The upper arm are protected by the OC (SC) function, but does not output the alarm signal.
  P626, P630, P631, P636, P638, P644 : The upper arm are protected by the OC (SC) function and the alarm signal is output.

(2)Ground fault protection and alarm signal output of lower arm IGBT

- When the ground fault current flows through the IGBT of the lower arm more than t_{dOC} or t_{dSC}, the OC (SC) protection is activated and the alarm signal is output for all packages.

3.2.4 Start up under short circuit or ground fault status

- The protection is not activated in case of the input signal pulse width that is less than the dead time because the OC/SC protection has a dead time(t_{dOC}, t_{dSC}). Especially, if the IPM starts up under a load short-circuit condition, and the input signal pulse width is shorter than the dead time for a long time (tens of mill seconds), the chip temperature rises rapidly because the protection function does not work. In this case, even if the IGBT chip over heating protection (T_{jOH}) operates against a rise in chip temperature, the protection does not work in time because the T_{jOH} dead time is about 1 ms, and the chip may be damaged by over heating. In addition, when the power is turned on, the FWD chip may be destroyed because the charging current of an electrolytic capacitor flows in the path of AC power → ground → output terminal → FWD chip → electrolytic capacitor.

3.3 IGBT chips over heating protection

- IGBT chip over heating protection (T_{jOH}) is built into all IGBTs including the brake IGBT. T_{jOH} works when the IGBT chip is over heated abnormally. Not building in a case over heating protection, the X-IPM is not protected against the case over heating. Please implement the protection for case over heating if necessary.

3.4 Protection of FWD

- FWDs have no protection functions.

4. Power cycling capability

- The lifetime of semiconductor products is not permanent. Note that thermal fatigue caused by temperature rise/drop restricts the lifetime. If temperature rise and drop occur continuously, the reduction of the temperature change is required.
- The thermal fatigue life due to temperature changes is called the power cycling capability (withstand capacity), and there are the following two patterns.

  ① ΔT_{vj} power cycling capability : Lifetime caused by chip temperature change that occurs in a relatively short cycle (Mainly due to deterioration of the wire junction on the chip surface)
  Please refer to MT6M15364 for the ΔT_{vj} power cycling capability curves.

  ② ΔT_{c} power cycling capability : Lifetime caused by copper base plate temperature (T_c) change that occurs in a relatively long cycle (Mainly due to deterioration of solder joint part between the insulated substrate DCB and copper base)
  Please refer to MT5F39952 for the ΔT_{c} power cycling capability curves.
- Please refer to Chapter 11 "Reliability of power modules" in Fuji IGBT Module Application Manual (REH984).

5. Others

5.1 Precautions for use

① When using the IPM and installing it on the equipment, please refer to the IPM specifications as well.

② Please install a fuse or circuit breaker with sufficient capacity between the input AC power line and the system to prevent secondary destruction in consideration of a destruction of IGBTs/FWDs .

③ Ensure that the switching trajectory at turn-off shall not exceed the RBSOA specification. In addition, the IPM does not define SCSOA because it has a built-in short circuit protection function that detects short circuit current and turns itself off before failure. Ensure that the surge voltage shall not exceed the absolute maximum rating.

④ Before using the product, grasp the environment in which the product will be used and ensure that the reliability of the IPM meets your requirements. If the product is used beyond the specifications, it may cause a malfunction before its design life.

⑤ Even if the product is used within the maximum rating, the product life may vary depending on the temperature and usage environment. Please use it after fully considering the product life and usage environment.

⑥ If the IPM is restarted with a broken power chip, the protection function will not operate properly, which may result in a large-scale destruction. Do not restart the broken IPM.

5.2 Precautions for mounting procedure

① Reduce the contact thermal resistance as much as possible between the IPM and the heat sink by applying thermal grease. (See Chapter 5, Section 3.)

② 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 5.)

③ 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.)

④ Do not apply excessive weight to the IPM.
Do not apply deforming forces to the lid. If pushing force is applied to the lid, the internal circuit may be damaged. If pulling force is applied to the lid, it may come off. Do not bend the control terminals.

⑤ 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.

⑥ Avoid places where corrosive gases are generated or where there is an excessive dust.

⑦ Avoid applying static electricity to main terminals and control terminals of the IPM.

⑧ Please confirm that the V_{CC} is 0V before mounting/dismounting the control circuits to/from the IPM.

⑨ 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)
It may cause malfunction.

⑩ If the IPM is used in a single phase, or if the brake is not used in a built-in brake type, supply the control power to the unused phases as well. Supply the control power and pull up both input terminal (V_{in}) and alarm output terminal (ALM) to V_{CC}. If the control power supply is turned on while the input terminal (V_{in}) is open, the alarm output state will occur.

⑪ If the warning function is not used, it is recommended that the warning pin be left open. If the warning pin is pulled up to V_{CC}, the current consumption by V_{CC}/R_{WNG} increases during warning operation; thus design the control power supply properly. Pulling down the warning pin to GND is not recommended, as a current of about 200uA always flows from the control IC.

⑫ The alarm output is output with different pulse width depending on the protection factor. (See Chapter 3, Section 2.)
The alarm output time on the secondary side of the optocoupler for alarms must be designed in consideration of the delay time of the optocoupler and peripheral circuits..

⑬ The IPM cannot be used in parallel because each IPM has its own driving and protection circuits. If they are operated in parallel, the current may concentrate in a specific IPM and destroy it because of the difference in switching time or the timing of protection..

⑭ The case material meets the standard UL 94V-0, but is not non-flammable.

⑮ The surface temperature of the lid should not exceed the heatproof temperature during soldering. If the solder touches the lid, it may be deformed or the solder may adhere.

⑯ Our IPM is designed for inverter applications. Application to converters requires thorough verification. Please contact us if it is used for converter.

⑰ The brake section is designed on the assumption that resistance load is applied. Please contact us if it is used for inductor load or boost circuit, etc.