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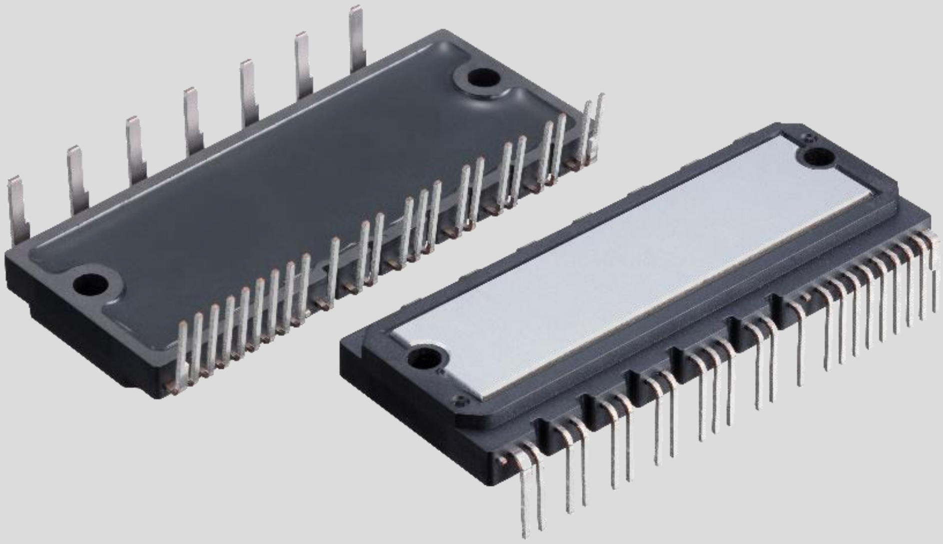

Small IPM (Intelligent Power Module)
P642 Series
6MBP**XT*065-50

Application Manual

April 2024

Fuji Electric Co., Ltd.

MT6M15234 c

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Cautions

This Instruction contains the product specifications, characteristics, data, materials, and structures as of April 2024. The contents are subject to change without notice for specification changes or other reason. When using a product listed in this Instruction be sure to obtain the latest specifications.

The application examples in this note show the typical examples of using Fuji products and this note shall neither assure to enforce the industrial property including some other rights nor grant the license.

Although Fuji Electric Co., Ltd. continually strives to enhance product quality and reliability, a small percentage of semiconductor products may become faulty. When using Fuji Electric semiconductor products in your equipment, be sure to take adequate safety measures such as redundant, flame-retardant and fail-safe design in order to prevent a semiconductor product failure from leading to a physical injury, property damage or other problems.

The products described in this application manual are manufactured with the intention of being used in the following industrial electronic and electrical devices that require normal reliability.

- Compressor motor inverter
- Fan motor inverter for room air conditioner
- Compressor motor inverter for heat pump applications, etc.

If you need to use a semiconductor product in this application note for equipment requiring higher reliability than normal, such as listed below, be sure to contact Fuji Electric Co., Ltd. to obtain prior approval. When using these products, take adequate safety measures such as a backup system to prevent the equipment from malfunctioning when a Fuji Electric’s product incorporated in the equipment becomes faulty.

- Transportation equipment (mounted on vehicles and ships)
- Trunk communications equipment
- Traffic-signal control equipment
- Gas leakage detectors with an auto-shutoff function
- Disaster prevention / security equipment
- Safety devices, etc.

Do not use a product in this application note for equipment requiring extremely high reliability such as:

- Space equipment
- Airborne equipment
- Atomic control equipment
- Submarine relaying equipment
- Medical equipment

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Chapter 4 Details of Inverter Block

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This chapter describes the guidelines and precautions of circuit design for power terminals, such as how to determine the current sense resistor and external shunt resistor.

1. Connection of Bus Voltage Input Terminal and Low-side IGBTs Emitter

<Description of Power Terminals>

Table 4-1 shows the details of the power terminals

Table 4-1 Details of power terminals

Terminal Name	Description
P	Positive bus voltage input terminal. It is internally connected to the collector of the high side IGBTs. In order to suppress the surge voltage caused by the wiring or PCB pattern inductance of the bus voltage, connect a snubber capacitor close to this terminal. (Typically metal film capacitors are used)
U, V, W	Motor output terminal Inverter output terminals for connecting to motor load.
N(U), N(V), N(W)	Negative bus voltage input terminals These terminals are connected to the emitter of the low-side IGBTs of each phase. When using the external shunt resistor method to monitor the current of each phase, connect a shunt resistor between these terminals and power GND.
VSC	Low-side sense current detection terminal. This terminal is connected to the sense terminal of the low-side IGBTs. This terminal detects the sense current shunted from the main current. Connect a sense resistor between VSC terminal and control GND for short-circuit protection.

<Recommended wiring for shunt resistor and snubber capacitor>

- External shunt resistors are connected to detect overcurrent (OC) condition and phase current.
- Long wiring patterns between the shunt resistor and the product will cause excessive surge voltage that might damage the internal control IC and current detection components. To reduce the pattern inductance, the wiring between the shunt resistors and the product should be as short as possible.
- As shown in the Fig.4-1, snubber capacitors should be connected at the right location to suppress surge voltage effectively.
- Connecting the snubber capacitor at location "C" is recommended. If the snubber capacitor is connected at location "A" as shown in the Fig.4-1, the snubber capacitor cannot suppress the surge voltage effectively because the wiring inductance is not negligible. If the capacitor is connected at the location "B", the charging and discharging current of snubber capacitor will flow through the shunt resistor. This will impact the current detection signal and the OC protection level will be lower than the design value. Although the surge voltage suppression effect when the snubber capacitor is connected at location "B" is greater than that at location "A" or "C", location "C" is recommended considering the impact to the current detection accuracy.
- Snubber capacity of 0.1 ~ 0.22 μF is recommended.

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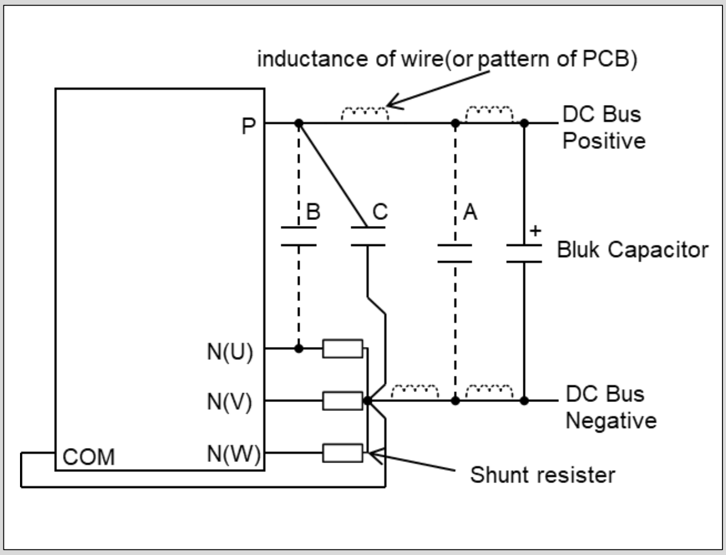

Fig. 4-1 Recommended wiring of shunt resistor and snubber capacitor

2. Short Circuit Protection

There are two methods for short circuit (SC) protection in this product. The first method is by detecting the sense current shunted from the main current flowing through the low-side IGBTs. The second method is to directly sensing the main current with external shunt resistors connected to the N(*) terminals.

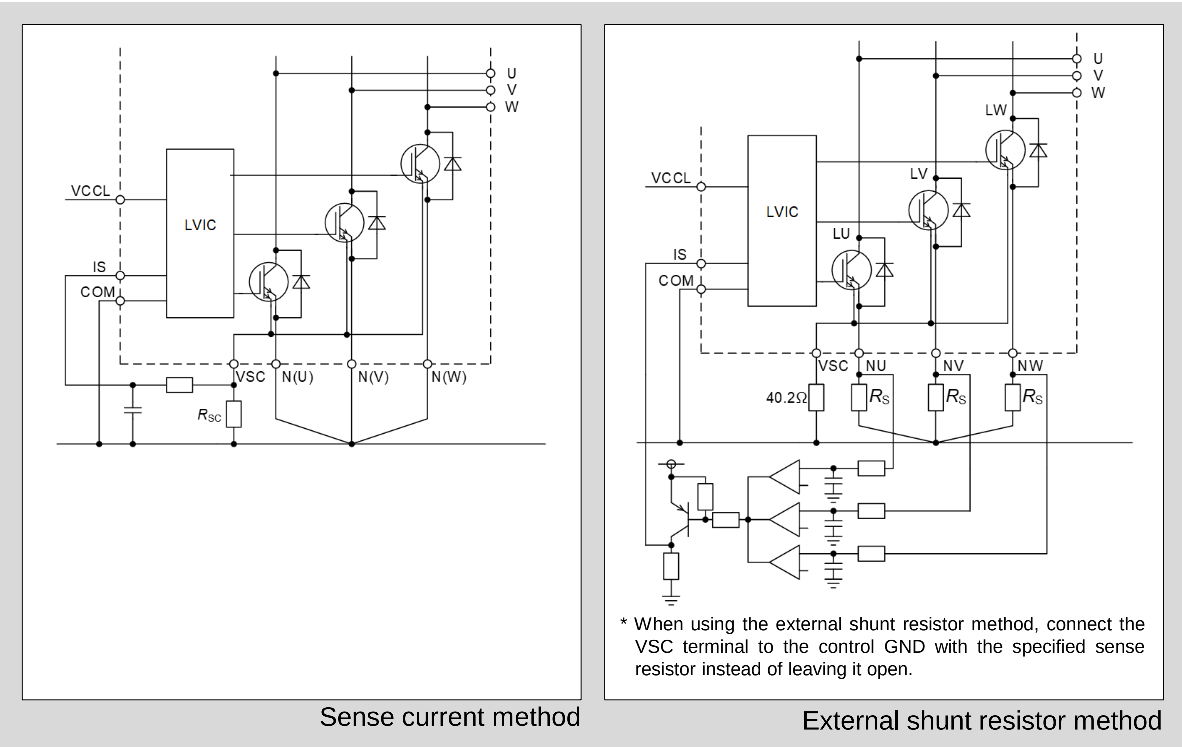

Fig. 4-2 SC detection circuits

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<SC protection by sense current method>

SC protection works by feeding back the voltage generated by the sense resistor R_{sc} to the IS terminal. Table 4-2 shows the specified sense resistor value and short circuit protection current value.

Table. 4-2 SC protection current value (no external shunt resistor connected to N(*) terminals)

Type Name	Sense resistor R_{sc}	SC protection current (Min.)
6MBP50XTA065-50 6MBP50XTC065-50	40.2 Ω	85 A
6MBP75XTA065-50 6MBP75XTC065-50	23.2 Ω	127 A

- It is recommended to connect an RC filter to the input of IS terminal to prevent malfunction of the SC protection circuit caused by noise. The RC time constant is determined by the noise application time and the IGBT's short circuit capability. Time constant of 1.1μs is recommended.
- For example, to activate 6MBP50XT*065-50 SC protection, R_{sc} must be set to 40.2Ω or higher. For R_{sc}, it is recommended to use a resistor with small variation (1% or less) including temperature characteristics, low inductance, and wattage rating of 1/8W or more.

<SC protection by external shunt resistor method>

- The SC protection function by sense current method is intended for short circuit protection when an excessive short circuit current flows, such as arm short circuit or load short circuit.
- For OC protection that requires accuracy, such as demagnetization current protection of motor, external shunt resistor method is recommended.
- When external shunt resistor is connected, the current split ratio between the main and sense current varies, thus the SC protection current value by sense resistor changes too. Table 4-3 shows the minimum SC protection value with shunt resistors connected.
- If the external shunt resistance is too large, the IGBT saturation current will decrease due to the gate voltage of the low-side IGBT is lowered by the shunt resistor voltage drop. It is recommended to set the shunt resistance to 7mΩ or less for 6MBP50XT*065-50, and 4.5mΩ or less for 6MBP75XT*065-50.
- When using external shunt resistors, it is recommended to use low inductance chip resistors to reduce the surge voltage during short circuit. Do not use shunt resistors with large inductance, such as cement resistors.
- When using the external shunt resistor method, connect the VSC terminal to the control GND with the specified sense resistor instead of leaving it open.

Table 4-3 SC protection current value with shunt resistors (6MBP50XTA065-50, R_{sc}=40.2Ω)

External shunt resistance	OC protection current (Min.)
None	85 A
3 mΩ	57 A
5 mΩ	48 A

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3. Setting of External Shunt Resistor for Overcurrent Protection

The following shows an example of selecting external shunt resistor for OC, SC protection, in which OC, SC detection is performed using only external shunt resistor instead of the current sensing method. When using the external shunt resistor method, connect the VSC terminal to the control GND with the specified sense resistor instead of leaving it open.

<Selecting shunt resistor>

The shunt resistance value is calculated by the following equation：

$$R_{Sh} = \frac{V_{IS(ref)}}{I_{OC}} \qquad (4.1)$$

- where $V_{IS(ref)}$ is the OC protection voltage level, and I_{OC} is the OC protection current level.
- $V_{IS(ref)}$ is 0.455V(min.), 0.48V(typ.), and 0.505V(max.).
- R_{sh} is the resistance of shunt resistor. The maximum OC detection level should be set lower than the repetitive peak collector current specified in the specification sheet of the product considering the variations in shunt resistance.
- For example, if the OC detection level is set to 100A, the recommended shunt resistance value can be calculated as:

$$R_{Sh(min)} = \frac{V_{IS(ref)(max)}}{I_{OC}} = \frac{0.505}{100} = 5.05[m\Omega] \qquad (4.2)$$

- where $R_{sh(min)}$ is the minimum shunt resistance.
- Based on the above expressions, the minimum shunt resistance is calculated. It is necessary to select a shunt resistance according to the required OC protection level in practical application.

<Setting the delay time of OC protection>

- An external RC filter is required to prevent malfunction of the OC protection circuit caused by noise. The RC time constant is determined by the noise application time and the IGBT's short circuit capability. Time constant of 1.1μs is recommended.
- When the voltage across the shunt resistor exceeds the OC level, the filter delay time $t_{(delay)}$, which is the time for the IS terminal input voltage to rises to the OC level, is determined by the time constant of the RC filter and is expressed by the following equation.

$$t_{(delay)} = -\tau \cdot \ln\left(1 - \frac{V_{IS(ref)(\max)}}{R_{Sh} \cdot I_P}\right) \qquad (4.3)$$

- where ***t*** is the RC time constant, and I_P is the peak current flowing through the shunt resistor.
- In addition, there is a shutdown propagation delay of OC ($t_{d(IS)}$), thus the total time t_{total} from OC detection until the shutdown of IGBT is given by the following equation.

$$t_{total} = t_{delay} + t_{d(IS)} \qquad (4.4)$$

- The short circuit capability of the IGBT must be considered for the total delay time. Please confirm the appropriate delay time in actual equipment.

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