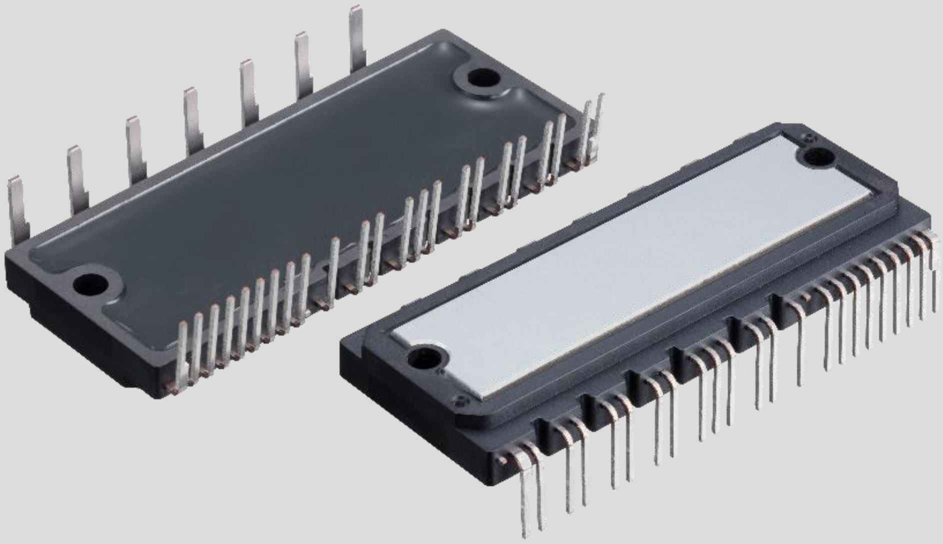

Fuji Small IPM (Intelligent Power Module)
P642 Series
6MBP**XT*065-50
Chapter 4 Details of Inverter Block

Application Manual

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Fuji Electric Co., Ltd.

Chapter 4 Details of Inverter Block

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

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. 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	Bus voltage (+) input terminal. This terminal is connected to the collector of the high-side IGBTs internally. Connect a snubber capacitor close to this terminal to suppress the surge voltage generated by wiring inductance and the PCB pattern. (Generally, film capacitor is used)
U, V, W	Inverter output terminal. Connect to motor load.
N(U), N(V), N(W)	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.

2. Recommended wiring for shunt resistor and snubber capacitor

External shunt resistors are connected to detect overcurrent (OC) condition and phase current. Long wiring pattern between the shunt resistors and the IPM might generate excessive surge voltage that might damage the control IC and the OC detection components. The wiring between the shunt resistors and the IPM should be as short as possible.

As shown in Fig. 4-1, snubber capacitor should be connected at the right location to suppress surge voltage effectively. Generally, a snubber capacitor of 0.1 to 0.22uF is recommended. If the snubber capacitor is connected at point "A", the surge voltage cannot be suppressed effectively because the wiring inductance is not negligible.

If the snubber capacitor is connected at point "B", the charging and discharging current flowing through the snubber capacitor also flows through the shunt resistor. This will impact the current sensing signal, thus the OC protection level will be lower than the designed value. Although the surge voltage suppression effect when the snubber capacitor is connected at point "B" is better than at point "A" or point "C", in consideration of the current detection accuracy, point "C“ is recommended.

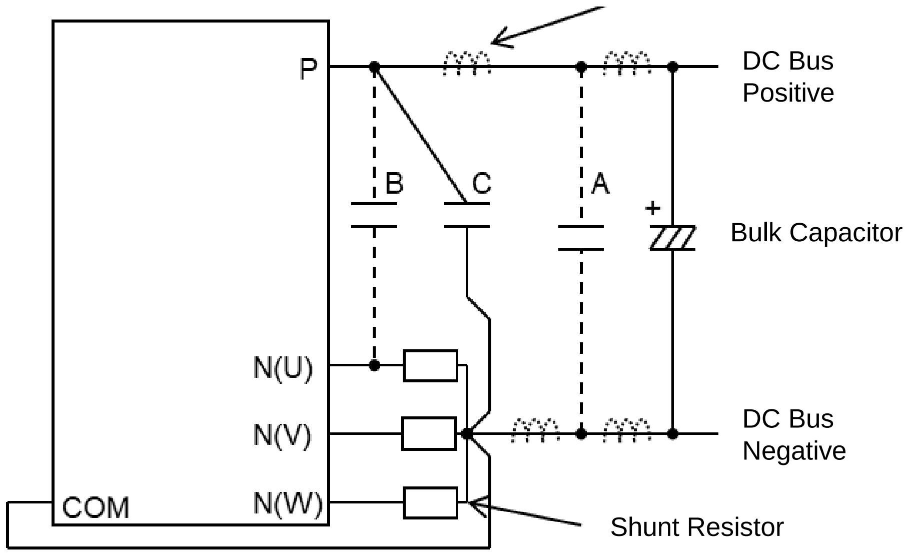
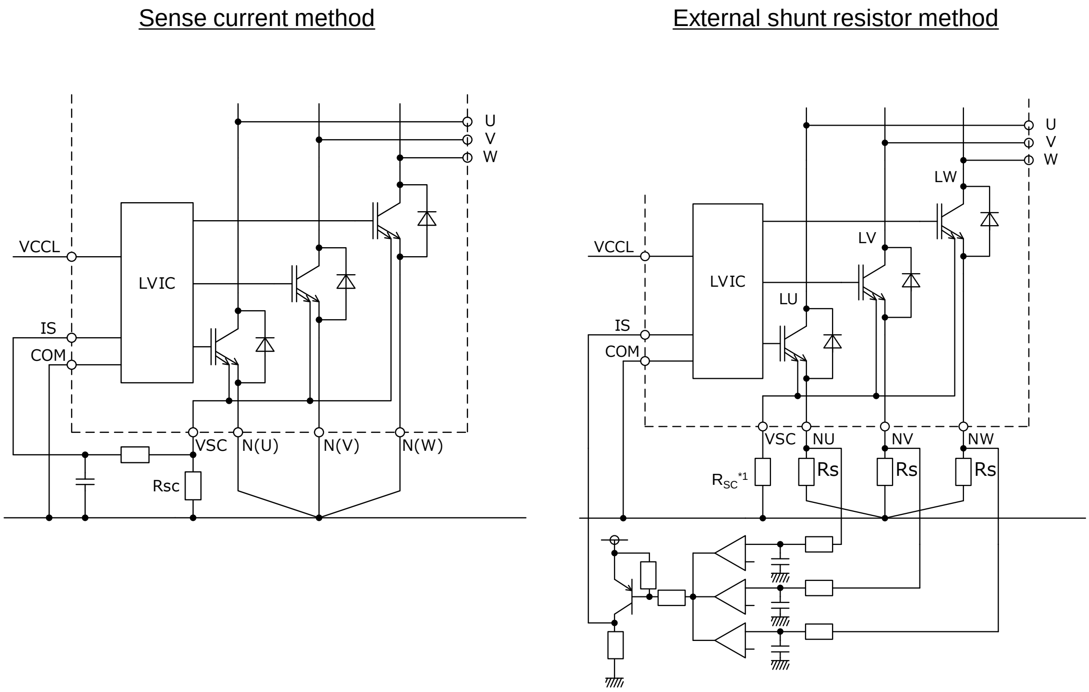


Fig. 4-1 Recommended wiring of shunt resistor and snubber capacitor

2. About Short Circuit Protection

There are two methods for short circuit (SC) protection in this IPM. 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.



* 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.

Fig. 4-2 SC detection circuits

1. 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.

To activate 6MBP50XTA065-50 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.

2. 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.

Table 4-3 SC protection current value with shunt resistors (6MBP50XT*065-50, R_{sc}=40.2Ω)

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

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.

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.

<u>1. Selecting shunt resistor</u>

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 of IPM, 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 IPM 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.

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2. 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.

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

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.