Chapter 4

Power Terminals

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1. Connection of bus input terminal and low side emitters

In this chapter, the guideline and precautions in circuit design on the power terminals, such as how to determine the resistance of shunt resistor are explained.

(1) Description of the power terminals

Table 4-1 shows the detail about the power terminals.

Table 4-1 Detail description of power terminals

Terminal Name	Description
P	Positive bus voltage input 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 pin. (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 low-side IGBT emitter of the each phase. In order to monitor the current on each phase, shunt resistors are inserted between these terminals and the negative bus voltage input (power ground).

(2) Recommended wiring of shunt resistor and snubber capacitor

External current sensing resistors are applied to detect OC (over current) condition or phase currents. A long wiring patterns between the shunt resistor and the IPM will cause excessive surge that might damage internal IC, and current detection components. To reduce the pattern inductance, the wiring between the shunt resistors and the IPM 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. Generally a 0.1 ~ 0.22 μF snubber is recommended. If the snubber capacitor is connected at the wrong location "A" as shown in the Fig.4-1, the snubber capacitor cannot suppress the surge voltage effectively because inductance of wiring is not negligible.

If the capacitor is connected at the location "B", the charging and discharging currents generated by wiring and the snubber capacitor will appear at the shunt resistor. This will impact the current sensing signal and the OC protection level will be lower than the calculated design value. Although the suppression effect when the snubber capacitor is connected at location "B" is greater than location "A" or "C", location "C" is a reasonable position considering the impact to the current sensing accuracy. Therefore, location "C" is recommended.

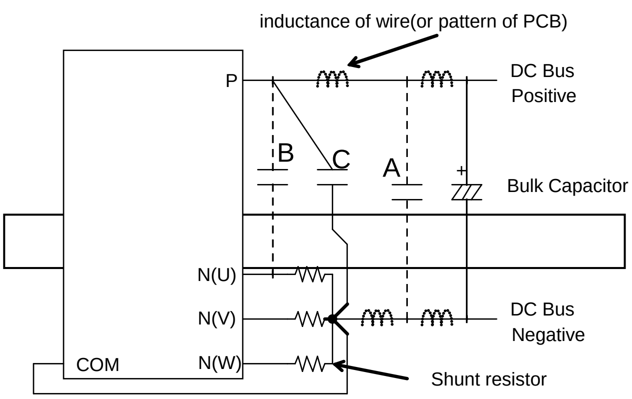

Fig.4-1 Recommended wiring of shunt resistor and snubber capacitor

2. Setting of Shunt Resistor of Over Current Protection

(1) Selecting current sensing shunt resistor

The value of current sensing resistor is calculated by the following equation:

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

Where $V_{IS(ref)}$ is the Over current protection (OC) reference voltage level of the IPM and I_{OC} is the current of OC detection level. $V_{IS(ref)}$ is 0.455V(min.), 0.48V(typ.) and 0.505V(max.).
And R_{Sh} is the Resistance of the shunt resistor.

The maximum value of OC level should be set lower than the repetitive peak collector current in the spec sheet of this IPM considering the tolerance of shunt resistor.

For example, if OC level is set at 45A, the recommended value of the shunt resistor is calculated as:

$$R_{\mathrm{Sh(min)}} = \frac{V_{\mathrm{IS(ref)(max)}}}{I_{\mathrm{OC}}} = \frac{0.505}{45} = 11.2\,[\mathrm{m\Omega}] \tag{4.2}$$

Where $R_{Sh(min)}$ is the minimum resistance of the shunt resistor.

Based on above expressions, the minimum shunt resistance of shunt resistor is calculated.

It should be noted that a proper resistance should be chosen considering OC level required in practical application.

(2) Filter delay time setting of over current protection

An external RC filter is necessary in the over current sensing circuit to prevent unnecessary over current protection caused by noise. The RC time constant is determined by the applying time of noise and the short circuit withstand capability of IGBTs. It is recommended to be set approximately 1.5μs.

When the voltage across the shunt resistor exceeds the OC level, the filter delay time (t_{delay}) that delays the rises of input voltage of IS terminal to the OC level is caused by the RC filter delay time constant and is given by:

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

Where τ is the RC time constant, I_P is the peak current flowing through the shunt resistor.
In addition, there is a shut down propagation delay $t_{d(IS)}$ of OC.
Therefore, the total time t_{total} from OC triggered to shut down of the IGBT is given by:

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

The short circuit withstands capability of IGBT must be considered for the total delay time t_{total}.

Please confirm the proper delay time in actual equipment.