Platform Screen Door System by using Mitsubishi new series DIPIPM™ Ver.4

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Abstract:
This paper presents platform screen door system by using Mitsubishi new series DIPIPM™ of PS219A3. Features of Mitsubishi new series DIPIPM™, circuit topology of platform screen door system and applied control approach are introduced. Lastly, a picture of platform screen door system based on PS219A3 and operation curve are given.

1. Features of new series Super Mini DIPIPM™ Ver.4

The new series super mini DIPIPM™ Ver.4 developed by Mitsubishi Electric for applications such as air conditioner, washing machine, refrigerator and industrial motor control, which makes it easy for AC100-200V class low power motor inverter control.

The internal circuit of new series super mini DIPIPM™ Ver.4 is mainly composed of IGBTs, FWDS in three-phase topology and control ICs (HVIC and LVIC). Three Boothstrap Diodes (BSD) are added near the control IC. Fig.1 shows internal block diagram of new series super mini DIPIPM™ Ver.4.

Super Mini DIPIPM Ver.4 can realize higher thermal dissipation by incorporating thermal structure with high thermal conductive isolating sheet. Therefore, the chip shrink becomes...
possible and the temperature rise is lower than previous DIPIPM Ver.3. In addition, this PS219A* series integrates bootstrap diodes for P-side driving supply, which can contribute to reduce the components on the PCB and PCB area. Fig.2 shows the package photograph, and Fig.3 shows the internal cross-section structure.

Compared with the current type super mini DIPIPM™ Ver.4 (PS2196*series), the new DIPIPM™ PS219A* series adopt the latest full gate CSTBT™ IGBT chip to achieve low power loss, embedded Bootstrap Diodes to reduce the system cost and reduce the circuit current reduction of HVIC. Moreover, the new series DIPIPM™ have shorten dead time restriction. The new series super mini DIPIPM™ has short circuit protection, control supply under voltage protection and over temperature protection, same as the current type.

2. System construction and control approach

The circuit diagram of platform screen door system is shown in Fig.4. It’s a general 3-phase inverter topology, and the input voltage is 220VDC. Thanks to the internal HVIC, in this system, there is no need to use optocoupler for signal isolation. Besides the DIPIPM™ driver circuit, we also designed the measuring circuit for DCBUS voltage, output current and the temperature of the heat sink, to provide the under voltage, over current and overload protection. In order to achieve the high efficiency and power density, PMSM (Permanent Magnet Synchronous Motor) is applied in the system, in which the widely-used vector current closed loop motor control strategy is adopted.
The basic idea of vector control through the establishment of field-oriented coordinates, the stator current vector is decoupled into two components, which are perpendicular to each other. One is torque current and the other is magnetizing current. We can adjust each of the two components to control the motor torque. Fig.5 shows the block diagram of vector control of PMSM. The error of actual speed (n) and the speed reference (n_{ref}) input to the speed regulator, which will output the torque current reference (i_{Sqref}). We can get the exciting current component (i_{Sd}) and the torque current component (i_{Sq}) by transforming the stator current (i_a, i_b, i_c) into rotating coordinate system through Clarke and Park transformation. Based on the error between the reference of rotating coordinate system (i_{Sqref}, i_{Sdref}) and actual current (i_{Sq}, i_{Sd}), the current regulator output the control voltage (V_{S\alpha ref}, V_{S\beta ref}), which are also in the rotating coordinate system. The control voltage (V_{S\alpha ref}, V_{S\beta ref}) can back to three-phase stator voltage component coordinate system through Park inverse transform and Clarke inverse transform. Ultimately we can control of the inverter bridge through SVPWM.

In this system, current feedback is used to reflect the status of the load, make the torque signal $i_q^*$ follow the load changes, and control the PMSM as a DC motor. Speed feedback is used to reflect actual speed of the motor drive system and the error between the reference values, and as soon as possible to correct the error and improve the system dynamic performance.
3. Reliability and Lifetime

As the key component of the platform screen door system, the lifetime of DIPIPMTM is the most concern for the end user.

We have simulated 2 working conditions in the free power loss simulation software which is provided by Mitsubishi electric.

3.1. For normal operation

The working condition is shown as below:

\[
\begin{align*}
Vcc &= 350V, \quad Ic(\text{rated}) = 1.5\text{Arms}, \quad Ic(\text{maximum when speed up}) = 5\text{Arms}, \\
fc &= 12\text{kHz}, \quad PF = 0.99, \quad tf(\text{max}) = 90°C
\end{align*}
\]

According to the simulation result (Fig.6), the \(Tj(\text{IGBT})_\text{Ave} = 111.66°C\) and \(Tj(\text{Diode})_\text{Ave} = 94.54°C\) is within Mitsubishi recommend Tj range (-20°C ~ 125°C).

According to the power cycles curve (Fig.8), the cycle number \(@\Delta Tj(\text{IGBT})_\text{Ave} = 19.84°C\) is over 10M cycles.

If this platform screen door system works for: 20years * 365days * 24hours * 60mins * 4times (2times open & 2times close), that means 4.2M cycles is needed.

So the lifetime of PS219A3 will over 20years, and the system has enough margins.

![Fig.6 Simulation result for normal working](image)

3.2. For motor lock operation

If the motor lock happens, the MCU will limit the \(Ic(\text{peak}) \leq 3A\) for maximum 10s. So the working condition for motor lock is:

\[
\begin{align*}
Vcc &= 350V, \quad Ic(\text{peak}) = 3A, \quad fc = 12\text{kHz}, \quad Duty = 0.3, \quad tf(\text{max}) = 90°C
\end{align*}
\]

According to the simulation result (Fig.7), the \(Tj(\text{IGBT})_\text{Max} = 109.97°C\) and \(Tj(\text{Diode})_\text{Max} = 104.81°C\) are also within Mitsubishi recommend Tj range (-20°C ~ 125°C). The system is safe.
4. Prototype and Test Results

The outline of the control board is shown in the Fig.9. PS219A3 is just under the heat sink.
Fig. 10 Operation curve (right door closing)

The operation curve shown in Fig. 10 is the speed-time curve when the right door is closing. According to the curve, the maximum speed is 290 mm/s and the speed for last 100 mm is 30 mm/s. Considered the door weight (around 55 kg), the kinetic energy of the door is no more than 10 J in maximum speed and 1 J in last 100 mm, which can meet related standard.

5. Conclusions

PS219A3 is convenient to be used in platform screen door system with high reliability. The latest full gate CSTBT™ IGBT chip makes low power loss. Shorten dead time restriction can limit the EMC noise. The protect functions make the system more reliable. And this system will be applied in Hangzhou metro line No.1.

6. Literature

1) Liang Xiaoguang, BSD embedded new series super mini DIPIPM™ Ver.4
2) Mitsubishi Electric, new series super mini DIPIPM™ Ver.4 application note