"PFC + Inverter" IPM (Intelligent Power Module) in 21mm x 36mm for Low Power Drives

A PFC+Inverter IPM (Intelligent Power Module) optimized for low power Drives is introduced. A three phase inverter and a single boost PFC stage are integrated in one single miniaturized DIL (Dual-In-Line) transfer molded type package with a SOI (Silicon On Insulator) gate driver.

With this IPM, the size and cost of system can be dramatically reduced.

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Overview
The internal circuit of the new IPM is composed of inverter stage and PFC stage. The three phase inverter stage has six 600V rated TRENCHSTOP™ IGBTs and six Emitter Controlled Diodes together with one SOI gate driver IC which provides integrated bootstrap circuit, and thermistor for temperature monitoring. The PFC stage consists of a 650V rated TRENCHSTOP™ IGBT and a Rapid Switching Emitter Controlled Diode which has fast and soft switching characteristics (figure 1).

Cost reduction
Minimizing total cost is the most important consideration for system engineers when developing new motor drives. Not only material cost like IPM itself, heatsink and PCB but also development time to market is main factors of the total cost.

Miniaturized transfer molded package (package size and structure)
Package outlines of the IPM with high level integration are shown in figure 2. The IPM builds in a compact size of Infineon Technologies CIPOSTM (Control Integrated Power System) Mini package of 21mm x 36mm x 3.1mm. The new IPM is UL approved (UL 1557 File E314539) and RoHS compliant.

DCB (Direct Copper Bond) which is a substrate with good thermal conductivity is adopted as a substrate for high thermal performance. Figure 3 shows the cross section view of the new IPM. All of the major heat sources like IGBTs and Diodes are mounted on DCB, in order to fully utilize the heat transfer capability of this package. Therefore the new IPM can be an excellent solution for up to 3kW motor drives even though the package size is extremely compact [1].
**Heatsink and PCB size**

All of the power semiconductor components (i.e. a bridge rectifier, a discrete IGBT for PFC, a discrete boost diode, and an IPM for motor drive) are normally mounted on one heatsink for their heat dissipation. Figure 4 shows how much the size of PCB and heatsink can be reduced and the assembly process can be simplified by integrating discrete power semiconductor and drivers into one package [2].

**Discrete PFC and inverter IPM solution**

**The new IPM solution**

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**Development speed up (reference board, Figure 5 and 6)**

Circuit design, artwork and PCB assembly take much time in system development process. To reduce the time spent in the process, and quickly determine whether the new IPM can run a motor, a reference board has been developed. The minimum set of peripherals to operate a motor are mounted on the board and the others like PWM signals, +5/+15V dc power source, PFC inductor, DC-link electrolytic capacitor can be utilized from outside of the board via wire connection to the reference board.

**650V rated PFC stage**

Infineon Technologies has developed two kinds of products according to their PFC IGBT characteristics. They are High Speed 3 (HS3) for 20kHz switching frequency and TRENCHSTOP™ 5 (TS5) for 40kHz switching frequency, as listed in Table 1. The Rapid Emitter controlled Diode of Infineon is optimized to operate with TRENCHSTOP™ IGBT as a boost diode in PFC topology. It combines low VF for lower conduction losses and low Ir for to reduce Eon of the IGBT [3]. All of the power devices have 650V of voltage rating and it provides higher reliability and ruggedness against unstable AC grid [4].

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**Features of inverter stage**

Inverter stage has many functions for safe operating of Inverter. These functions can be achieved by a rugged SOI gate driver and a thermistor.

- Allowable negative VS potential up to -11V for signal transmission at VBS=15V
- Integrated bootstrap functionality
- Under-voltage lockout at all channels
- Cross-conduction prevention

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<table>
<thead>
<tr>
<th>Part number</th>
<th>PFC Stage</th>
<th>Inverter Stage</th>
<th>Maximum motor power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voltage</td>
<td>Current</td>
<td>Target Fsw</td>
</tr>
<tr>
<td></td>
<td>rating</td>
<td>rating</td>
<td>Fsw</td>
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<tr>
<td>IFCM15P60GD</td>
<td>650V</td>
<td>30A</td>
<td>40kHz</td>
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<td>20kHz</td>
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<td>IFCM10S60GD</td>
<td>650V</td>
<td>30A</td>
<td>20kHz</td>
</tr>
</tbody>
</table>

**Table 1: Product line up, ratings and target switching frequency**
• All of 6 switches turn off during protection
• Over current shutdown
• Temperature monitor

**Over current protection**
The new IPM monitors the voltage of ITRIP pin and when the voltage exceeds the $V_{IT,TH+}$ (positive going threshold voltage), a fault signal is activated and all the 6 IGBTs are turned off. The maximum over current trip level is generally set to below 2 times of the nominal rated collector current [5].

**Over temperature protection**
For over temperature protection, a thermistor is integrated in this IPM. The resistance is typically 85kΩ at 25°C and 5.4kΩ at 100°C (Figure 8).

**Thermal evaluation**
Figure 11 is the test circuit and measured waveforms which show the test system’s operating status for evaluating thermal performance at input power of 2kW. The operating conditions are PFC controller=ICE2PCS05G, input power $P_{in}=2$kW, AC input voltage $V_{IN}=220V/60Hz$, DC-link voltage $V_{DC}=400V$, switching frequency of inverter=5kHz, switching frequency of PFC=20kHz, R-L load ($R = 13.75Ω$, $L = 2.96mH$, Power factor=0.99), $MI=0.69$, Gate resistor $R_g=5.1Ω$, ambient temperature $Ta=25°C$. The device under test is IFCM15S60GD. Input power factor is about 0.995 and THD is about 9.78%.

**Figure 7:** Time chart of over current protection

**Figure 8:** Thermistor resistance vs. temperature

As shown in Figure 9, VFO pin is connected directly to ADC and fault detection terminals of micro controller because the thermistor is connected in parallel with fault out terminal which has open drain configuration. For example, when pull-up resistor $R_1$ is 3.6kΩ VFO voltage at about 100°C is $2.95V_{typ}$ at $V_{CRT}=5V$ and $1.95V$ at $V_{CRT}=3.3V$ as shown in Figure 10.

**Figure 9:** Circuit for over temperature protection

**Figure 10:** $V_{VFO}$ voltage vs. temperature

**Figure 11a:** Test circuit and waveform of the new IPM, Test circuit

**Figure 11b:** Test circuit and waveform of the new IPM, waveform
The case temperature under PFC IGBT’s position is about 67.5°C as the highest point and it is higher than that of inverter part. IFCM15S-60GD is enough to deal with over 2kW power.

Summary
New Intelligent Power Module is the best solution with inverter and PFC topologies for variable speed motor drive such as room air conditioner. Infineon Technologies owns all necessary technologies and is committed to support its customers to realize compact and more efficient solutions with minimized system size, total cost and time to market.

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