Large Package Transfer Molded DIP-IPM


* Powerex Incorporated, Youngwood, Pennsylvania, USA
** Power Device Works, Mitsubishi Electric Corporation, Fukuoka, Japan

Abstract - This paper presents a new larger version of the Dual In-line Package transfer molded Intelligent Power Module (DIP-IPM) developed by Mitsubishi Electric for home appliance motor control. The new large DIP-IPM utilizes a high thermal conductivity insulating resin sheet and an integrated aluminum heat spreader to provide the reduced thermal impedance and mechanical integrity required for a higher power applications. Using this approach the range DIP-IPM ratings has now been extended to 75A at 600V and 35A at 1200V. Like the lower power DIP-IPMs the new large DIP has High Voltage Integrated Circuit (HVIC) based level shifting gate drive with short circuit protection and under voltage lock-out. However, in order to avoid the need for an excessively large current sensing resistor the new DIP uses IGBT chips with a current mirror emitter that produces a low level current proportional to the main emitter current for short circuit detection. In addition, the new DIP-IPM also provides an analog feedback signal proportional the module’s temperature.

I. INTRODUCTION

The transfer molded DIP-IPM was first introduced by Mitsubishi Electric in 1998 to address the rapidly growing demand for cost effective motor control in consumer appliance applications. These devices soon became widely accepted due to their performance, reliability and cost advantages compared to conventional designs. In the years that followed continuous improvements in package thermal performance, power chip design, and HVIC (High Voltage Integrated Circuit) technology has enabled the development of a complete line of modules for motors rated from about 100W to more than 15KW at line voltages of 100VAC to 480VAC. This paper will describe some of the key technologies utilized in the latest extension to this family of modules.

II. THE NEW LARGE DIP-IPM PACKAGE

In order to provide larger output power ratings cost effectively a new transfer molded package structure was developed. The cross sections of this new package compared to the previous large DIP-IPM is shown in fig.1. The DIP-IPMs are fabricated using a transfer molding process like a very large integrated circuit. First, bare power chips and the custom HVIC and LVIC die are assembled on a lead frame. Ultrasonic bonding of large diameter aluminum wires makes electrical connections between the power chips and lead frame. Small diameter gold wires are bonded to make the signal level connections between the IC die and lead frame. This part of the process is basically the same for both devices. Next, they are encapsulated. This is where the packages differ.

A cross section of the previous generation 3 Large DIP-IPM is shown in fig.1A. In
this device a heat spreader made of copper is attached to the lead frame and electrical insulation is provided by a thin layer of the molding compound at the mounting surface. The copper heat spreader gives relatively good thermal performance but the high thermal resistance of the molding compound limits this construction to devices with ratings of about 50A at elevated case temperatures.

The new generation 4 large DIP-IPM package cross section is shown in fig. 1B. This device uses a new low thermal impedance structure based on technology developed for the generation 4 super Mini DIP-IPM [1]. In this novel structure a partially cured insulating resin sheet is adhered to the rear surface of lead frame after chip bonding. The other surface of the resin sheet is attached to an aluminium heat spreader. The lead frame with the resin and aluminium heat spreader attached is then transfer-molded using epoxy resin. The transfer molding process causes the resin sheet to cure simultaneously with the epoxy resin. The result is a stable high reliability joint with low thermal impedance. The thin insulating resin sheet stays in a fixed form during the process so it does not need to have the fluidity of the epoxy resin over mold and thus it is possible to increase the amount of ceramic fill to improve the thermal conductivity. In addition, it is possible to achieve a thinner insulating layer because it is not constrained by the limitations of the molding process. The extremely thin layer of high thermal conductivity resin yields a substantial reduction in thermal impedance compared to previous DIP-IPM designs. A photograph of the new large DIP in its final form is shown in figure 2. The new module features a compact 31mm x 79mm footprint.

III. FEATURES OF THE NEW LARGE DIP-IPM

In addition to the six IGBTs and free wheeling diodes required for a three phase motor drive the new large DIP-IPM also contains HVIC and LVIC chips to provide gate drive and protection for the power devices. Figure 3 shows a complete functional diagram of the DIP-IPM. The integrated functions include the following:

A. High Voltage Level Shift

The DIP-IPM includes high voltage level shifting provided by integrated HVICs. The built-in level shift eliminates the need for relatively expensive opto-couplers or pulse transformers and allows direct connection of all six control inputs to the CPU/DSP.

B. Undervoltage Lockout

The DIP-IPM is protected from failure of the 15V control power supply by a built in under-voltage lock out circuit. If the voltage of the control supply falls below the UV level specified on the data sheet, the low side IGBTs are turned off and a
fault signal is asserted. In addition, the p-side HVIC gate drive circuits have independent under-voltage lock out circuits that turn off the IGBT to protect against failure if the voltage of the floating power supply becomes too low. This feature is particularly useful considering the sometimes complex dependence of boot-strap power supplies on the switching of the lower devices. If the high side under-voltage lockout protection is activated the respective IGBT will be turned off but a fault signal is not supplied.

C. Short-Circuit Protection

The new large DIP-IPM has an integrated short-circuit protection function. The LVIC monitors the voltage across an external current sensing resistor (R_{SHUNT}) to detect excessive current in the emitters of the low side IGBTs. In order to avoid large power dissipation in the shunt resistor the new DIP-IPM has been equipped with IGBT chips having a current mirror emitter that supplies a low level current that is approximately 1/10,000 of the main emitter current. This low level signal allows use of a small surface mount current sensing resistor. An RC filter (R_{SF}, C_{SF}) with a time constant of 1.5 to 2µs is normally inserted as shown in Fig. 3 to prevent erroneous fault detection due to di/dt induced noise on the shunt resistor and free-wheel diode recovery currents. When the voltage at the C_{IN} pin exceeds the V_{SC} reference level the lower arm IGBTs are turned off and a fault signal is asserted at the F_O output. When an overcurrent condition is detected the IGBTs remain off until the fault time (t_{FO}) has expired and the input signal has cycled to its off state. The duration of t_{FO} is set by an external timing capacitor C_{FO}.

D. Temperature Sensor

The LVIC in the new module includes a circuit that produces a voltage proportional to the modules temperature. This circuit eliminates the need for an external heatsink mounted thermistor to provide over temperature protection. In addition, unlike an external sensor, the integrated sensor is capable of detecting problems with the module to heatsink interface for improved manufacturing quality control. The circuit provides a buffered analog voltage feedback signal that is suitable for direct connection to the controller thereby eliminating the need for the associated buffering and amplifying components that would have been required with an external sensor. The temperature sensor characteristic is shown in figure 4. The module itself will not shutdown in the case of excessive temperature allowing the user to implement the most appropriate remedial action based on the measured temperature and operating conditions.

E. Interface Circuit

The new large DIP-IPM has eight microprocessor compatible input and output signals. The built in HVIC level shifters allow all signals to be referenced to the common ground of the 15V control power supply. The signals are compatible with 3.3V to 5V CMOS logic in order to permit direct connection to a PWM controller. Fig. 5 shows the equivalent internal circuit of the DIP-IPMs control signals and a simplified schematic of a typical external interface circuit. The components shown in dashed blue lines are optional noise filtering that may be required depending on the circuit layout and its proximity to

---

**Fig.4 Temperature Sensor Characteristic**

**Fig.5 New Large DIP IPM Interface Circuit**
noise sources. On and off operations for all six of the DIP-IPM’s IGBTs are controlled by the active high control inputs \( U_P, V_P, W_P, U_N, V_N, W_N \). These inputs are pulled low internally by a 3.3kΩ resistor. The controller commands the respective IGBT to turn on by pulling the input high. Approximately 1.8V of hysteresis is provided on all control inputs to help prevent oscillations and enhance noise immunity.

The fault signal output \( (F_O) \) is in an open collector configuration. Normally, the fault signal line is pulled high to the 5V logic supply with a 10kΩ resistor as shown in Fig.7. When an overcurrent, over temperature condition or improper control power supply voltage is detected the DIP-IPM turns on the internal open collector device and pulls the fault line low.

**IV. DIP-IPM SYSTEM ADVANTAGES**

Inverters for small AC motors used in appliance applications are required to meet stringent efficiency, reliability, size and cost constraints. Historically, many of these small inverters have utilized discrete IGBTs (Insulated Gate Bipolar Transistors) and free-wheel diodes in TO-247 or similar packages along with separately packaged HVICs (High Voltage Integrated Circuits). There are, however, several problems with this approach. One drawback is the high manufacturing cost associated with mounting and isolating multiple high voltage discrete components. Each of the discrete devices must be individually mounted using special hardware and insulating materials which typically results in a complex assembly and significant manufacturing time. In addition, relatively large and complex printed circuit designs are required to meet all of the spacing and layout requirements for the HVIC and discrete power device combination. Another equally perplexing problem is maintaining consistent performance and reliability when the characteristics of the HVIC drivers and IGBTs are not properly matched.

A much better approach, realized in the DIP-IPM described in this paper, is to assemble bare power chips and HVICs using a transfer molded lead frame design to maintain low cost and consistent, reliable performance. Clearly, there are significant manufacturing advantages to the DIP-IPM approach. With the fully isolated DIP-IPM mounting is accomplished with only two screws and no additional isolation material is required. The reduced manufacturing time and simplified assembly provided by the DIP-IPM will allow improvements in both cost and reliability of the finished system. Another advantage of the DIP-IPM is that the integrated HVIC and LVIC gate drive and protection functions are factory tested with the IGBTs as a subsystem. This eliminates uncertainty about the critical coordination of the electrical characteristics of these components. The end result is more consistent system performance and reliability.

**V. PRODUCT LINE-UP**

The new gen. 4 large DIP-IPM line-up is

<table>
<thead>
<tr>
<th>IGBT blocking voltage rating</th>
<th>Nominal / Peak Current Rating</th>
<th>Continuous Sinusoidal Inverter Output Current (ARMS)*</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IGBT and Free Wheeling Diode</td>
<td>Nominal Voltage (VCC=300V)</td>
<td>fsw=5KHz</td>
</tr>
<tr>
<td>600V 50A / 100A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS21A79</td>
</tr>
<tr>
<td>600V 75A / 150A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS21A7A</td>
</tr>
<tr>
<td>1200V 5A / 16A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS22A72</td>
</tr>
<tr>
<td>1200V 10A / 20A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS22A73</td>
</tr>
<tr>
<td>1200V 15A / 30A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS22A74</td>
</tr>
<tr>
<td>1200V 25A / 50A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS22A76</td>
</tr>
<tr>
<td>1200V 35A / 70A</td>
<td>TBD</td>
<td>TBD</td>
<td>PS22A78E</td>
</tr>
</tbody>
</table>

* \( T_j \leq 125C \) and \( I_{\text{PEAK}} \leq 1.7I_C \) are selected according to recommended design margins. The actual device limit is: \( T_j \leq 150C, I_{\text{PEAK}} \leq I_C \).
shown in Table 1. Modules are available with blocking voltage ratings of 600V and 1200V which are appropriate for 100VAC to 480VAC applications. Devices with nominal current ratings of 50A to 75A at 600V and 5A to 35A at 1200V are all available in the same compact package outline. The table also shows the usable sinusoidal RMS motor current per phase for some typical application conditions. These values are calculated using the loss simulation software available from the Powerex website.

In addition to the devices listed here Powerex offers devices in smaller transfer molded packages with nominal current ratings of 3A to 30A at 600V.

VI. CONCLUSION

A new large DIP-IPM has been presented. This device features a compact transfer molded package with significantly improved thermal performance compared to previous generation devices. In addition, the new DIP-IPM includes a temperature feedback signal for improved thermal management and assembly quality verification. Finally, in order eliminate the need for a high power current sensing resistor, IGBT chips with a current mirror output have been utilized for over current protection.

REFERENCES