Single Chip Inverter SOI IC in SMD Package

Drives covering an output power of less than 200W are currently realised mainly by discretes with DPAK packaged IGBTs or MOSFETs and surface mountable High Voltage Integrated Circuits (HVICs). Drives dedicated for high volume production, as required for white goods applications such as BLDC motors for dishwashing or compressors for refrigerators, are manufactured on highly automated production equipment preferring surface mounted components to optimise production cost. An ultra-compact and surface mountable IPM is addressing the needs for high reliability and compactness of state-of-the-art low power drives. **Kiyoto Watabe, Hatade Kazunari, Toru Araki and Marco Honsberg, Mitsubishi Electric Japan and Europe**

Transfer mold technology was introduced about 10 years ago and has been widely used to manufacture reliable power modules for power ranges starting from a few hundreds of Watts up to more than 4kW. This technology is well suited for large scale IGBT module and IPM production. Ever since, this technology has been improved particularly with regard to thermal resistance and the maximum achievable output power. New packages have been introduced to respond to further miniaturisation in power electronics.

Drives covering an output power of less than 200W are manufactured on highly automated production equipment preferring surface mounted components to optimise production cost. The surface mounted discrete approach however, comprises the drawback of complicated routing of a PCB respecting minimum clearance and creepage distances. Resulting from the complexity of the conventional approach and referring to the drawback of considerably higher PCB space requirement of a discrete solution a highly integrated, ultra-compact and surface mountable IPM is addressing the needs for high reliability and compactness of state-of-the-art low power drives. The new highly integrated surface mountable IPM allows a significant space reduction, and the employment of extended protection functions like short circuit (SC) and over temperature (OT) protection with a space requirement on a printed circuit board (PCB) of less than the equivalent of the six IGBTs only.

Innovative packaging technology

The outline of the 33pin counting package is shown in Figure 1. Certain pins of the lead frame have not been separated in order to improve the heat transfer from the lead frame to the PCB which acts as a heat sink to a certain extend. Moreover, the pin pitch is different for control and power part of the IPM reflecting the different creepage/clearance requirements of the high voltage and low voltage side.

The M81500FP is based on a leadframe construction and a single chip containing the control, drive and protection functions as well as the IGBTs, free-wheeling diodes and bootstrap diodes has been soldered on it. This chip is mounted upside down to optimise the thermal transfer from junction to the surface of the power semiconductors. The lead frame acts as heat spreader to enlarge the thermally active surface of the package, thus

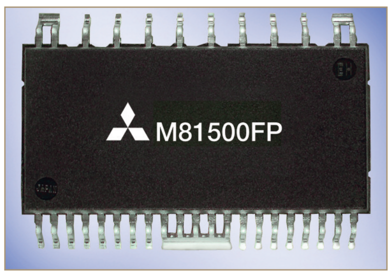


Figure 1: 33pin package of the new SOI single-chip inverter

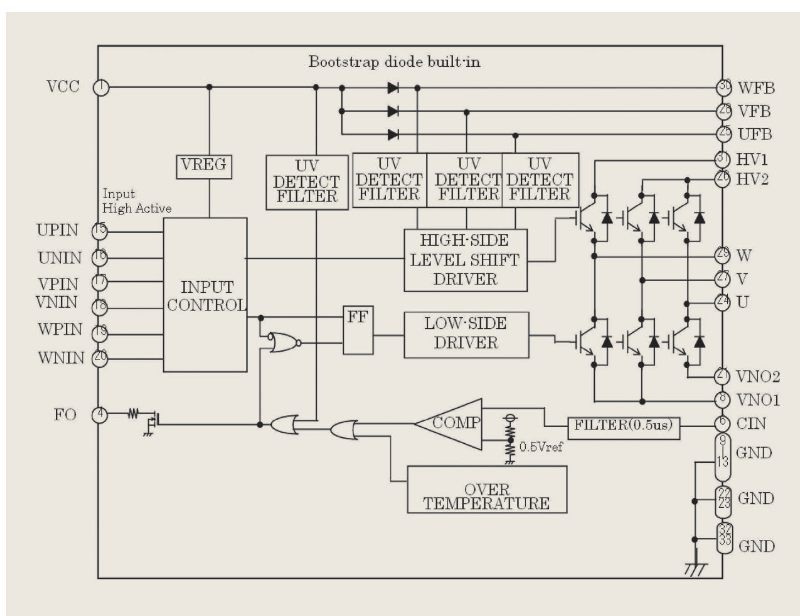


Figure 2: Block diagram of the M81500FP single-chip inverter

reducing the $R_{th(j-a)}$. Besides thermal interfacing to the PCB, this construction detail opens a second, electrically isolated and very efficient way of cooling the single chip inverter IC.

The total PCB surface required from this package is 11.93mm x 17.50mm = 208.78mm². Compared with a discrete solution utilising 3 pieces of SO-8 packaged HVIC half-bridge driver each having a surface demand of 5mm x 6.2mm = 31mm² and 6 pieces of DPAK packaged power semiconductors each having a surface demand of 6.5mm x 10mm = 65mm², the result of the totally occupied PCB area, ignoring the space for the more complicated routing of the discrete solution is: 3 x 31mm² + 6 x 65mm² = 483mm² for the discrete solution versus the 208.78mm² of the M81500FP.

The conservatively summarised advantage of the M81500FP is a PCB space requirement of only 45% of that of a competing discrete solution using DPAK transistors and SO-8 HVICs. By the clear interface separation of the power stage and the control part simple connections to the control system (MCU) and to the load can be realised even by routing only a single PCB layer.

Electrical and protection functions

The block diagram of the M81500FP is shown in Figure 2. A single voltage source of 15V is supplying the IPM at the Vcc terminal. All inputs UPIN...VPIN and UNIN...WNIN are compatible for 3 to 5V logic, thus can be directly controlled from DSPs or microcontrollers. Internal threshold voltages are derived from a stable internal reference voltage 'V_{REG}'. The logic input signals pass through the INPUT CONTROL which is preventing an arm shoot through at an erroneous simultaneous turn-on signal at the N-side and P-side input of one phase. From the Vcc supply pin the floating supply voltages for the P-side IGBTs are generated through the built-in bootstrap diodes every time the N-side path is conducting current. The N-side as well as the P-side are protected against an operation at low voltages by an under voltage (UV) detection circuit. In such a case the corresponding section of IGBTs is turned off and in case of a N-side under voltage situation, the fault output is activated to indicate this dangerous condition. The IGBTs of the M81500FP are efficiently protected against short circuit by a built-in high speed comparator circuit detecting a voltage of 0.5V to shut off the IGBTs. Such a voltage is derived from a shunt resistor connected between VNO1/2 and GND setting the current protection level to $I_{SCdetect} = 0.5V/R_{shunt}$.

In addition to these electrical protection functions the single chip inverter also contains a thermal shutdown which is acting at approximately 140°C and a hysteresis function of about 20°C. The thermal shutdown function blocks the IGBTs and issues a fault signal at the pin 'FO'.

An internal blanking first order low pass circuit having a time constant of 0.5µs connected between the 'CIN' terminal eliminates transient currents like leading edges of recovering free-wheeling diodes. This feature simplifies the operation of the M81500FP and, at the same time, it reduces the number of externally required components to operate the circuit. The minimum necessary passive components to operate the single chip inverter IC are 3 ceramic bootstrap capacitors, one 1206–class shunt resistor and a ceramic capacitor at the Vcc pin.

SOI chip technology

The silicon chip of the inverter is manufactured in Silicon On Insulator (SOI) technology. The power stage is formed by a N-channel lateral IGBT [3] having a cylindrical structure for high short circuit robustness and low $V_{ce(sat)}$ and HV-diodes. The control part is realised by a 24V CMOS technology, whereas the level shifters are using a HV-NMOS structure by a 1.3µm HVIC process [1]. For safe and rugged operation the isolation techniques - both for the surface and laterally - are essential. The sensitive high voltage isolation has been realised by a trench isolation and RESURF technique, while a Multiple Floating Field Plate (MFFP) [2] is stabilising the surface electrical field. These technologies control the electrical field strength during transient operation (switching) dynamically and, of course, for steady state operation. Both technologies have already been successfully applied to previously developed 600 and 1200V High Voltage ICs (HVIC) and have proven a reliable operation for many years.

The actual samples of the chip have been tested for their switching performance. A typical test waveform for the turn-on and the turn-off are shown in Figures 3 and 4 respectively. Figure 3 indicates the turn-on waveform of the IGBT. A softly declining waveform can be observed at 125°C and an IC = 0.5A. It should be noted that the maximum dV/dt is only 1.7kV/µs. The turn-off behaviour at a DC-link voltage of 300V shows a small voltage overshoot at a moderate dI/dt indicating that the IGBT/FwDi set-up is optimised for lower switching frequencies.

Short circuit (SC) withstand

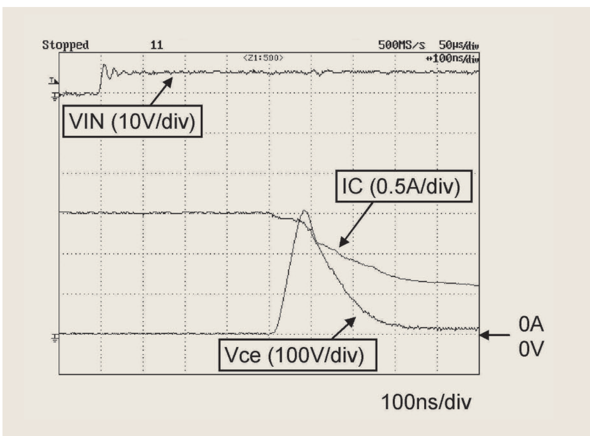


Figure 3: Turn-on at 125°C

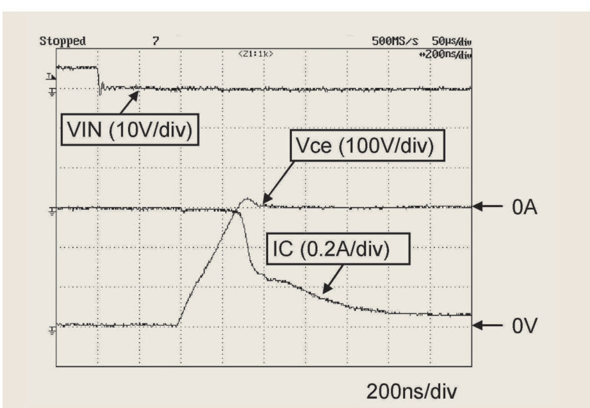
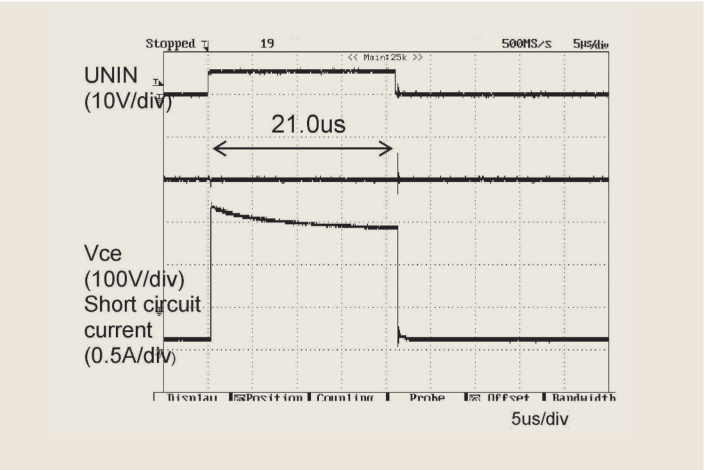


Figure 4: Turn-off at 125°C

capability is an important feature to ensure a highly reliable operation of the drive system. Hence, the IGBT must withstand the high stress during a short circuit until the built-in short circuit detection and protection function gets active and shuts down the IGBTs. In today's state-of-the-art transfer mold IPMs a typical SC withstand capability of about 4.5µs of the IGBT chip – 0.6µm planar technology or 1µm Carrier Stored Trench Bipolar Transistor (CSTBT) – itself was realised and the control IC was able to turn off the device within a microsecond. Thus, a reliable SC handling is realised. The actual capability of the lateral IGBT is indicated in Figure 5 for room temperature and in Figure 6 for 125°C.

Figure 5: **Turn-off at 25°C**



Evaluation board

A simple evaluation board dimensioned 59mm x 38mm also containing a microcontroller (NEC µPD78F0712) was developed (Figure 7). This board demonstrates the compactness of the core function of a small drive system realised by the M81500FP. A load evaluation was performed using this evaluation board PCB cooling of the FR4 PCB, and also with a combined cooling of PCB and the surface of the single chip inverter's housing. The load has been a real dishwasher BLDC pump undergoing pressure and flow rate variations. Various software approaches for sinusoidal and classical 120° BLDC control have been tested and the thermal performance has been verified.

Conclusion

A single chip inverter IPM has been manufactured using a SOI process. The IPM consists of lateral IGBTs, free-wheeling diodes, HVIC, control and protection functionality. The M81500FP is protected against under-voltage, short circuit and over-temperature. By PCB cooling and surface contact cooling, an output power of 100W can be achieved easily. An evaluation board for the M81500FP has been made and all functions were verified using this hardware platform.

Literature

[1] T. Araki et al., Proc. of PCIM2002, pp., (2002)
[2] T. Terashima et al., Proc. of ISPSD'93, pp.224-229, (1993)
[3] K. Watabe et al., Proc. of ISPSD'96, pp.151-154, (1996)

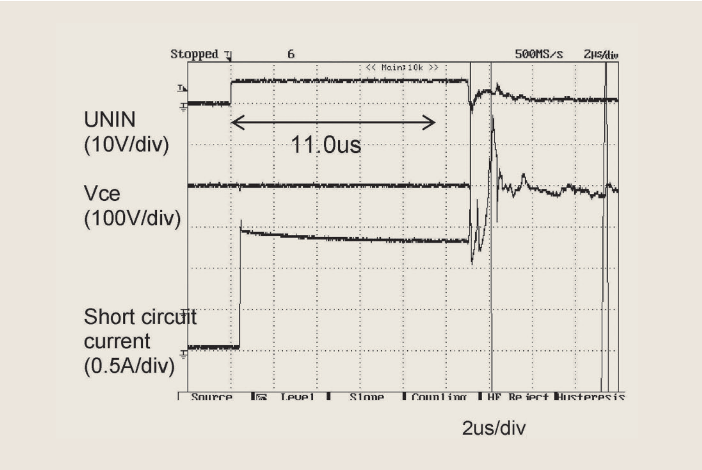


Figure 6: **SC Turn-off limit at 125°C**

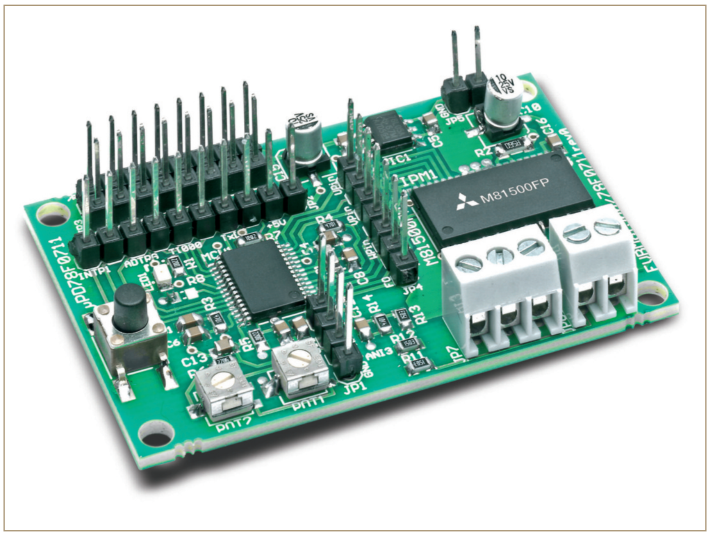


Figure 7: **Evaluation board dimensioned 59mm x 38mm containing the single-chip inverter and also a microcontroller**