New Intelligent Power Module Series

Continuous market growth of general purpose inverters and servo drives is boosting the demand of Intelligent Power Modules (IPM). The new IPM 'L1-Series' featuring high speed and low loss IGBT chips with full gate CSTBT and is mechanical compatible to the existing L-Series IPM. **Prasad Bhalerao and Robert Wiatr, Mitsubishi Electric Europe, Ratingen, Germany**

The popularity of IGBTs in a wide range of industrial power conversion applications is a direct result of the technological advances that have been made. The development over the last few years has made the IGBT a power switch with rugged switching characteristics, low losses and simple gate drive.

Advances in module design

The existing L-Series IPM family (50 to 600A/600V, 25 to 450A /1200V) uses well-proven 5th generation CSTBT IGBT chip and is designed for optimized switching and conduction losses for reduced EMI performance up to 20kHz. The series is equipped with newly developed protection and control IC making easy interface with supplier circuitry.

Using the advantage of existing L-Series package, L1-Series incorporates new full gate CSTBT IGBT chip for improved electrical performance. The new L1-Series IPM family includes 50 to 300A/600V and 25 to 150A/1200V compatible L-Series IPM package and also introduces new 7 in 1 small package (90mm x 50mm) for 50A/600V and 25A/1200V range. Table 1 shows the line up and package outline of new L1-Series IPM for 600 and 1200V. L1-Series is suitable for a wide range of applications such as servo drives, air conditioners and standard motor control.

Figure 1 shows the difference of CSTBT structures in L-Series and L1-Series IPM. The inactive plugging cell merge into active parallel gates in full gate CSTBT gives better trade-off performance ($V_{CE(sat)}$and $E_{(off)}$). Also $V_{CE(sat)}$of 1.9V of L-Series IPM is further reduced to 1.75V (@ T_j = 125°C) in L1-Series by keeping E_{off} almost at the same level. The total switching losses in L1-Series is reduced by 15%, as compared to L-Series at comparable conditions. Table 2 shows the comparison of characteristic data of L-Series and L1-Series IPM. It can be seen that power cycling is increased by almost 63% by new wire bond technology. Figure 2 shows a loss comparison of L-Series 75A/1200V and L1-Series (conditions: V_{cc} = 600V, V_D = 15V,

L1-Series Line up and Package

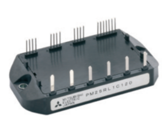
600V	50A	50, 75, 100, 150A	200, 300A
1200V	25A	25, 50, 75A	100, 150A
	Type S 7in1 	Type A(screw) / B(pin) (L-Series compatible) 	Type C (L-Series compatible) 
Package Size	90 x 50 (mm)	Type A: 131 x 66.75 (mm) Type B: 120 x 55 (mm)	135 x 110 (mm)

Table 1: **L1-Series IPM product line-up**

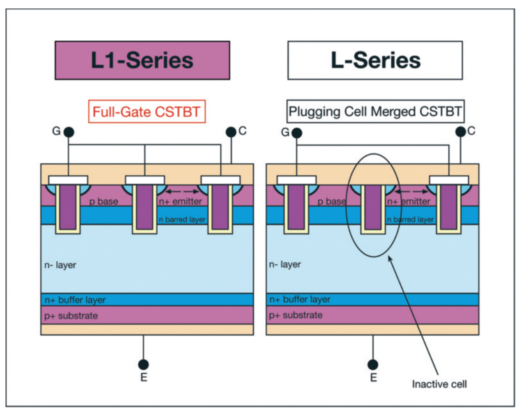


Figure 1: **New full gate CSTBT structure of L1-Series IPM**

	L-SERIES IPM	L1-SERIES IPM
$V_{ce(sat)}$ (V_D = 15V, I_L = 75A, T_j = 125°C)	1.9V	1.75V
E_{on} (V_D = 15V, V_{CC} = 600V, I_L = 75A, T_j = 25°C)	10.2mJ	10.5mJ
E_{off} (V_D = 15V, V_{CC} = 600V, I_L = 75A, T_j = 25°C)	6.5mJ	6.5mJ
$Rth_{(j-c)}$	0.21°C/W	0.21°C/W
Power cycle (Δ T_j of 1000 Million cycles)	29°C	46°C

Table 2: **Comparison of electrical data of L-Series and L1-Series IPM (75A/1200V)**

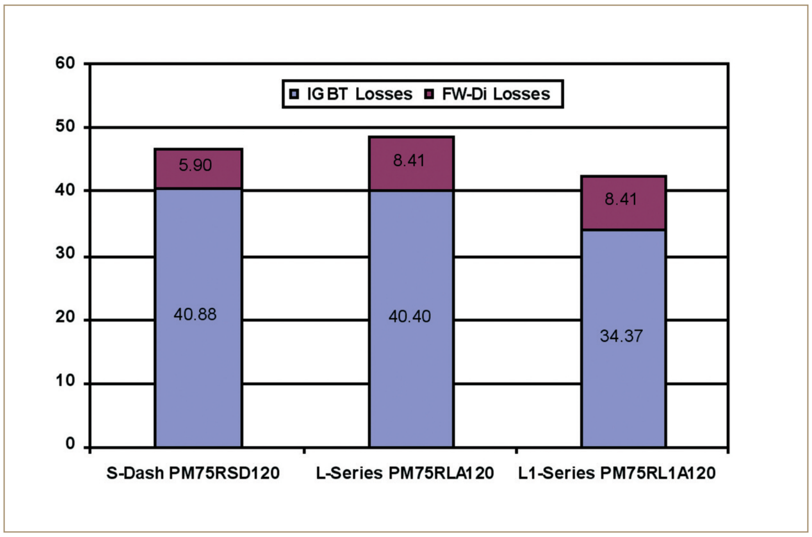


Figure 2: Loss comparison of L-Series 75A /1200V and L1-Series

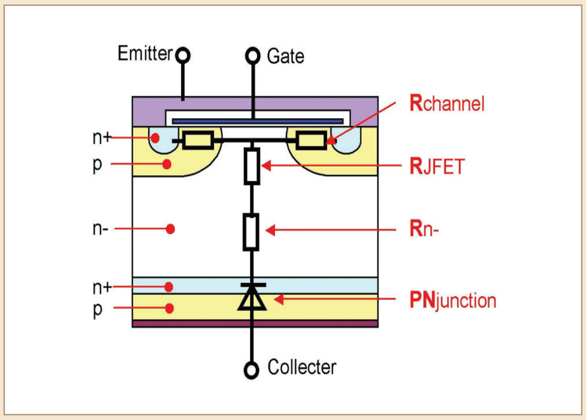
$I_L = 33A_{rms}$, $f_c = 5kHz$, p.f = 0.8, 3 phase PWM).

Conclusion

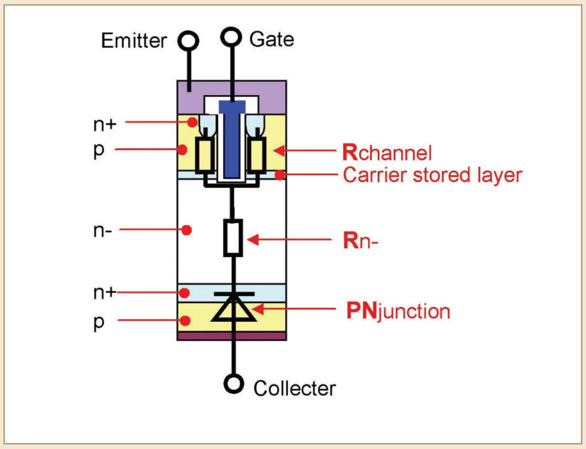
With the improved electrical performance at the same time keeping the high level of mechanical compatibility with existing L-Series IPM, new L1-Series IPMs offer a better product for servo, air-conditioning and standard motor control customers. Such improvement in IPM technology will get more attention and approval from the market in order to reduce the size, cost and time of the entire system.

Advances in power semiconductors

Improvements in the IGBT performance have generally been achieved by finer surface patterns and shallow diffusion technologies. But this conventional structure has four major resistance portions – MOS-channel, JFET, n-layer and PN-junction. The voltage drop of JFET and n- layer occupies more than 50% of the total saturation voltage $V_{ce(sat)}$. A significant performance gain was obtained by moving from planar IGBT structures to trench gate cell structures for the IGBT combined with a new carrier lifetime control process. Due to their high internal amplification, $\Delta V_{GE}/\Delta I_C$, trench gate IGBTs show increased natural short-circuit currents. In addition, the high cell density trench gate devices have an increased gate capacitance, resulting in higher power requirements for the gate driver. For heightened switching frequencies specially, this fact has to be considered for gate drive design.



Structure of planar IGBT



Structure of CSTBT

To surmount these drawbacks, still keeping the significant advantages of trench gate IGBTs, the Carrier Stored Trench Gate Bipolar Transistor (CSTBT) has been developed, which yields low on-state voltage compared with conventional IGBTs. Key technologies of this CSTBT are trench gate and carrier stored layer. Because the current through the narrow JFET area causes voltage drop of JFET portion, CSTBT is removing the JFET area completely by trench gate structure. The current can flow from the MOS-channel to the n- layer directly. As a result, CSTBT has no JFET voltage drop.

Secondly, the current through the resistance of n- layer causes voltage drop in n-layer. It is necessary to increase the carrier density in n- layer in order to decrease the resistance of n- layer. However, real carrier density in n- layer has some local distribution: at collector side the carrier density is rich, whereas at emitter side it is lean. Therefore, the main voltage drop in n- layer is caused by emitter side lean area. So it is very effective to increase the carrier density of emitter side area in order to decrease the voltage drop in n-layer. The carrier stored layer is employed nearby the emitter side n- layer. This carrier stored layer can intercept the escaping carriers like a 'water dam'. Thus, the carrier density at the emitter side of n- layer is increased, the total resistance of n- layer is decreased, and consequently the voltage drop in n- layer is reduced. Furthermore, increased carriers in n- layer by carrier-stored layer fasten the turn-on switching ability. So CSTBT can reduce not only static losses, but also switching losses.

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