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- MOSFET UIS Rating
- Serrated Heat Sinks
- PM Alternators

POWERSYSTEMS WORLD '97 CONFERENCE PROGRAM PAGE 49

Improved IGBT Structure Allows P.C. Board Mounted Modules

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By improving the IGBT process to obtain lower on-state voltage and reduce device power dissipation, high voltage, high power modules may be mounted on a p.c. board instead of resorting to screw terminals for interconnections.

Non-punch-through (NPT) IGBT structures have been a leader in the high voltage applications with comparable performance at the 1200V level. The NPT design also has the advantage of using a simpler lower cost silicon starting material and missing lifetime doping process. The inherent electrical ruggedness due to its low hole portion ratio of total current is yet another benefit.

Until now, punch-through IGBTs have shown advantages for the lower rated devices due to their low $V_{ce(sat)}$ levels. However, the vertical structure of the new NPT IGBTs has been improved by taking advantage of their capability of handling very thin silicon die. With the past limitation of chip thickness in the order of 220µm being broken, the V_{ce} saturation levels of the 1200V IGBTs have been reduced to 2.2V (*Figure 1*) using a chip thickness of 175µm. The new chip (DL series) reduces the $V_{ce(sat)}$ levels, and has not suffered in switching losses (*Figure 2*) with typical rise times of 60nsec and fall times of 85nsec, compared with 80nsec and 70nsec, respectively, for the past generation device that had maximum $V_{ce(sat)}$ levels 23% higher. The next step was to design a 600V NPT with a thickness of only 100µm (*Figure 3*). This device has a typical $V_{ce(sat)}$ level of 2.1V with switching times of 50nsec rise time and 35nsec fall time. The switching and conduction losses are now equal to or lower than older PT

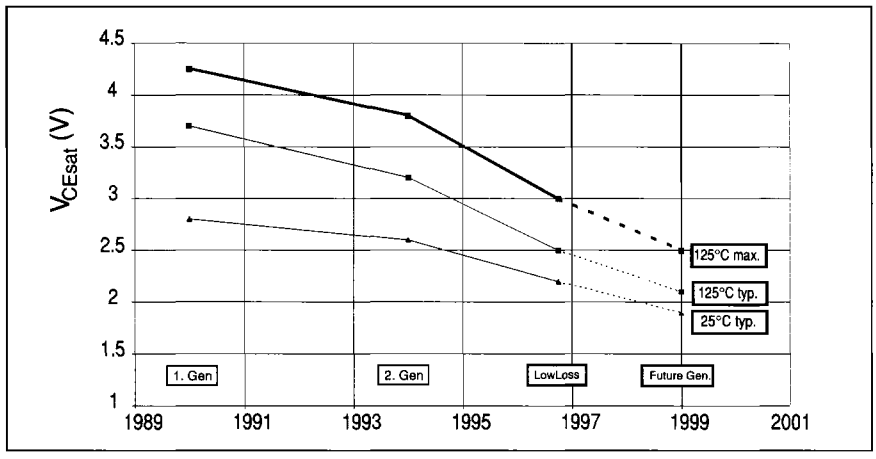

Figure 1. *On-State Voltage Trend of 1200V IGBTs.*

designs, while having the advantages of the NPT type.

Just as low power circuits have gone from through-hole designs to surface mount, the medium power designs are now going from screw terminal and bus bar designs to p.c. board mount IGBTs and diodes. A line of p.c. board solderable devices that include IGBTs rated up to 1200V and 600A total current (*Figure 4*) and three-phase diode rectifiers rated at 144A and 1600V. This allows the designer to control the overall circuit parameters without expensive bus bar structures or designs that require hours of labor to build or service.

Screw terminal designs that are so common among medium power circuit designs, usually offer many problems. Hours of labor are required per unit to assemble and torque all the power circuit connections. There may be as many as 38 individual screw connection points (*Figure 5*) on a 50 to 75 HP AC drive. These connections are potential service problems because inadequately factory-torqued terminals will loosen and heat up, eventually leading to failure. Corrosion on the mating surfaces or breaks in the plating due to the friction of the screws being tightened, lead to corrosion, which will eventually lead to a high resistance connection and failure. Poorly specified hardware that does not allow adequate thermal expansion of the connection will also lead to eventual failure. Although there are many reliable screw terminal designs in the present marketplace, the chance for failure due to a poor connection is great.

Hours of assembly time are required for most screw terminal designs. Torquing of screws, the hand labor of installing the screws, and the possibility of cross threaded screws all add to the time it takes to produce an inverter. Labor expenses can add many dollars to equipment costs. Also, due to the extensive hand labor required, the chances for wiring errors are increased, again adding to the final equipment costs.

In contrast with the screw terminal modules, Econopack IGBTs and diodes can be wave soldered. These modules form reliable consistent power connections that can be easily controlled by medium and high volume manufacturing process control procedures. Because the power connection for the parts is formed by a solder joint, the chance of a loose or corroded power connection is eliminated. Errors caused by improper torquing are also eliminated. The power connections can also be conformally coated to virtually eliminate any problems due to atmospheric contamination.

Assembly times as low as 15 minutes for the power stage can be achieved for p.c. board mount power circuits (*Figure 6*). Errors due to poor connections and misconnected wires will be eliminated. Also in-circuit test procedures and initial power circuit tests can be utilized for medium and high volume processes. No longer is the power circuit too large to be computer tested before final installation of the interface and control p.c. boards. Manufacturing processes for a 100 HP AC Drive power circuit can be similar to a 50W power supply.

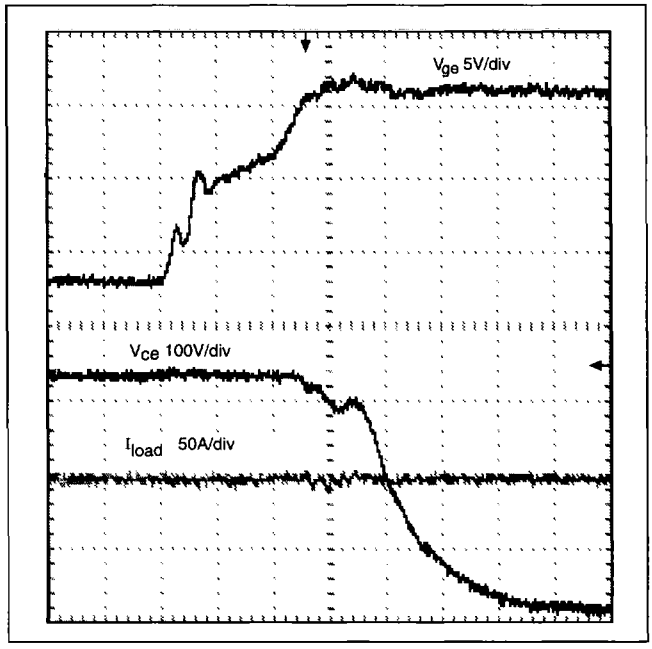

Figure 2(a). *Turn-On With Inductive Load, Tc=25°C.*

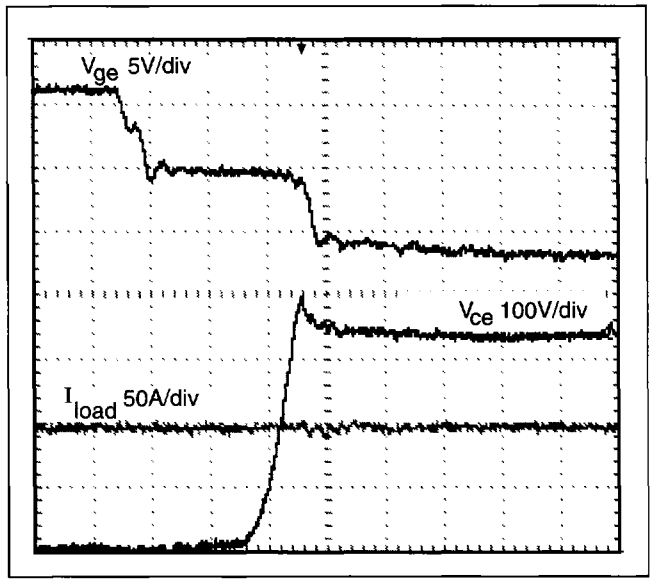

Figure 2(b). *Turn-Off With Inductive Load, Tc=25°C.*

Lower Inductance

Power circuit designers have been plagued with the difficulties of obtaining a low inductance design, a low cost design, a manufacturable design, and a design that is field service friendly. By the time the bus bars are installed with the high frequency bypass capacitors, snubber circuits and gate driver circuits the IGBTs are layers below the top surface or the design is larger than required. Design engineers try to keep the circuits coupled tightly, while service and manufacturing personnel want the circuits to be easily accessible. These goals have not been a common point until now.

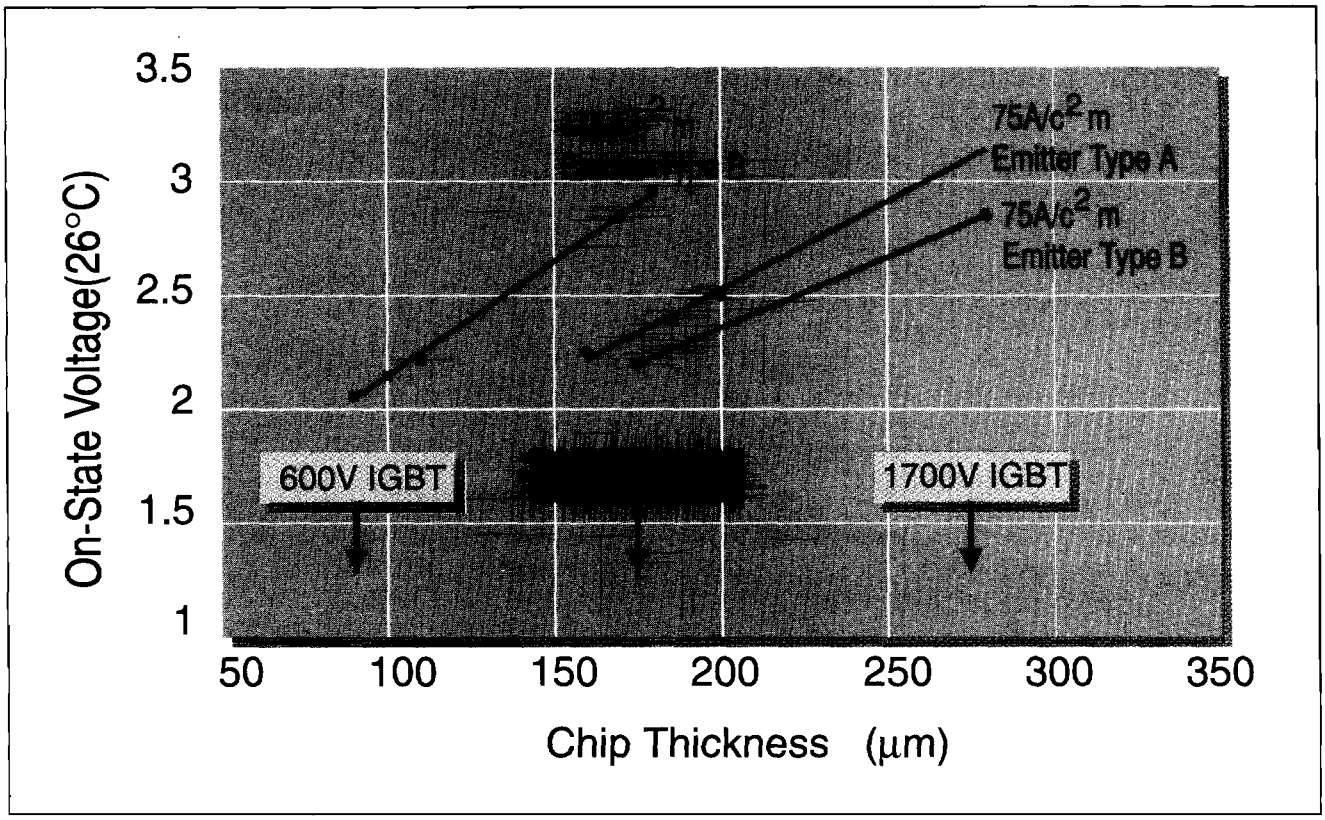

Figure 3. *On-State Voltage vs. Chip Thickness for Different NPT Emitter Types.*

Collector Emitter Voltage	Collector Current	Sixpack	Sixpack, Tripack
V_{CE} [V]	I_C [A]	EconoPACK 2	EconoPACK 3
1200	35	x	
1200	50	x	
1200	75		x
1200	100		x
1200	150		x
1200	200		x

Figure 4. *1200V, Low Loss EconoPACKs.*

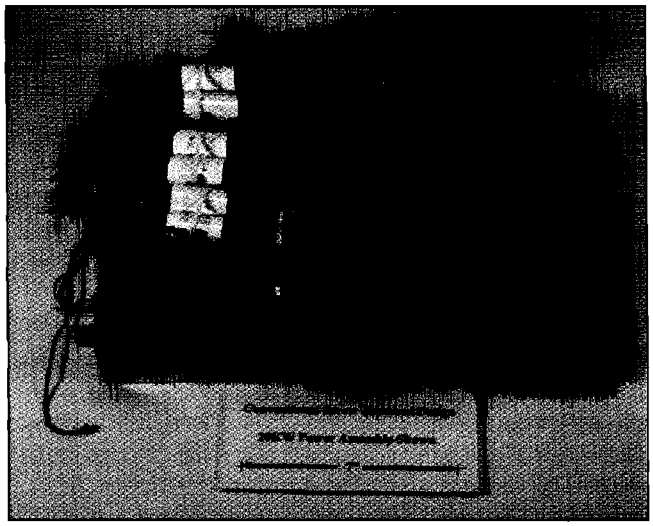

Figure 5. *Typical Screw Terminal Type Power Module.*

Taking advantage of the solderable Econopack modules enables the high frequency bypass and any snubbering circuits that are required to be wave soldered on the p.c. board. Because the Econopack modules have lower internal inductances than screw terminal designs, and the p.c. board layouts can be designed to have lower inductances than bus bar designs, the requirement for a snubber is either greatly reduced or eliminated. This will lower the overall size and cost of the circuit, while improving its reliability. Also for field service, the power circuit can now be replaced in a similar fashion as any other p.c. board. 100 HP power circuit boards can be designed small enough to be carried on an airplane, or shipped via UPS.

The new DL IGBT chips also help reduce the system costs by reducing the heat sink requirements. With smaller heat sinks and smaller power circuit sizes, overall package sizes are reduced. Smaller package sizes also lead to easier manufacturing handling processes due to reduced weight. Manufacturing processes capable of handling older style 50kW power converters can now handle units up to

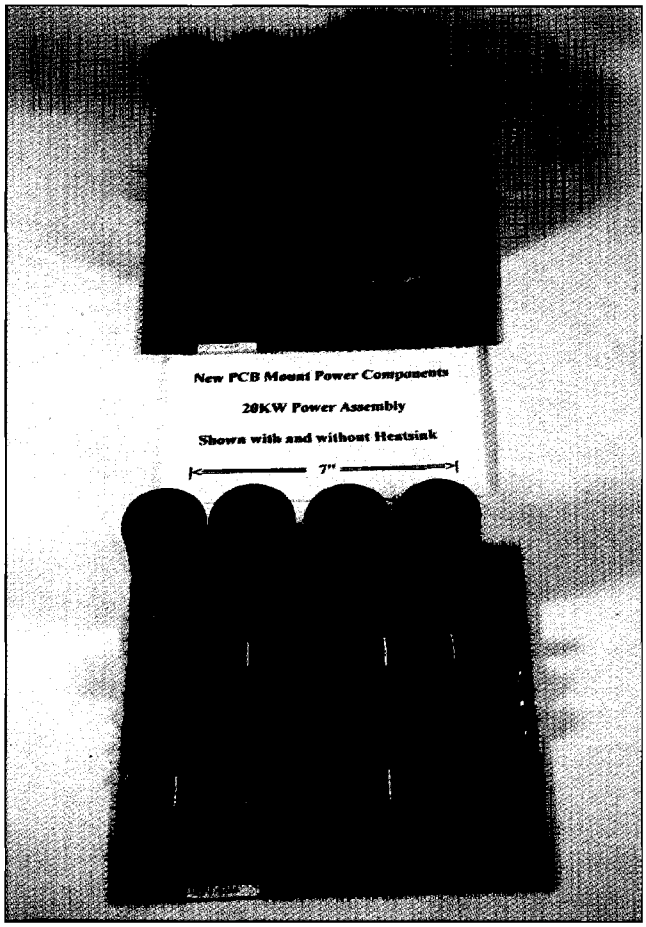

Figure 6. *EconoPACK Mounted on a P.C. Board.*

100kW without changing production processes and/or equipment. Power supplies with ratings of up to 250kW, 200 HP AC drives, 250kW UPS systems, and pulse generators capable of 500kW can be produced on a p.c. board. Manufacturers can develop p.c. board-based products in the 15 through 500kW range.

The lower IGBT cost per unit ampere can be viewed two ways: the conventional viewpoint of using a similar size heat sink and reducing the IGBT silicon costs, or the automotive and low voltage power supply manufacturing viewpoint of using the very low $R_{DS(on)}$ FETs to eliminate the need for a heat sink. Power circuit designers can use an IGBT with a current rating one or two sizes larger (the overall package size of the IGBT will still be smaller than a screw terminal design) and greatly reduce the heat sink requirements and improve the overall circuit reliability.

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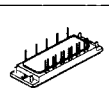
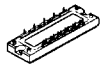
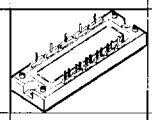
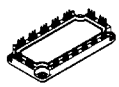
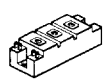
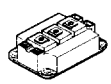
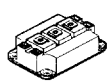
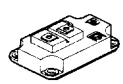
New IGBT Modules From eupec:

		Full Bridge	Full Bridge	Power Integrated	Full Bridge	Half Bridge	Half Bridge	Chopper	Single Switch
					Tri Pack				
		Econpack 1	Econopack 2	EconoPIM 2	Econopack 3	Half Bridge 34mm	Half Bridge 62mm	Half Bridge 62mm	Single Switch 62mm
600V	10A	BSM 10 GD 60 DL		BSM 10 GP 60 DL					
600V	15A	BSM 15 GD 60 DL		BSM 15 GP 60 DL					
600V	20A		BSM 20 GD 60 DL	BSM 20 GP 60 DL					
600V	30A		BSM 30 GD 60 DL	BSM 30 GP 60 DL					
600V	50A		BSM 50 GD 60 DL			BSM 50 GB 60 DL			
600V	75A		BSM 75 GD 60 DL			BSM 75 GB 60 DL			
600V	100A				BSM 100 GD 60 DL	BSM 100 GB 60 DL			
600V	150A				BSM 150 GD 60 DN2*	BSM 150 GB 60 DN2			
600V	200A				BSM 200 GT 60 DL*		BSM 200 GB 60 DN2		
600V	300A				BSM 300 GT 60 DN2*		BSM 300 GB 60 DN2		
600V	400A						BSM 400 GB 60 DN2		
1200V	10A			BSM 10 GP 120 DL					
1200V	15A			BSM 15 GP 120 DL					
1200V	25A			BSM 25 GP 120 DL					
	35A		BSM 35 GD 120 DL*			BSM 35 GB 120 DL*			
	50A		BSM 50 GD 120 DL*			BSM 50 GB 120 DL*			
1200V	75A				BSM 75 GD 120 DL	BSM 75 GB 120 DL*			
1200V	100A				BSM 100 GD 120 DL	BSM 100 GB 120 DL-K*	BSM 100 GB 120 DL*		
1200V	150A				BSM 150 GT 120 DL*		BSM 150 GB 120 DL	BSM 150 GAL 120 DL	
1200V	200A				BSM 200 GT 120 DL*		BSM 200 GB 120 DL	BSM 200 GAL 120 DL	BSM 200 GA 120 DL
1200V	300A						BSM 300 GB 120 DL*		BSM 300 GA 120 DL
1200V	400A								BSM 400 GA 120 DL
1700V	50A				BSM 50 GD 170 DL				
1700V	75A				BSM 75 GD 170 DL				
1700V	150A						BSM 150 GB 170 DL		
1700V	200A						BSM 200 GB 170 DL		
1700V	300A								BSM 300 GA 170 DL
1700V	400A								BSM 400 GA 170 DL

PT

NPT

LowLoss

LowLoss

* = on demand

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