Power module producers blaze new trails

Demands of applications like electric vehicles, renewable energy and rail transport have triggered a burst of innovation in IGBT modules and their packaging Fuji Electric, Hitachi, Infineon, Mitsubishi Electric and Semikron tell Power Dev'.

Many modern industries using IGBT modules want to smash their power, reliability, size and cost limits. Current chip designs, for wide bandgap devices as well as silicon IGBTs, promise to provide the capabilities they demand. But to capitalise on them, in electric and hybrid electric vehicles (EV/HEV) and renewable energy industries, among others, the packaging these chips are integrated into has a critical part to play. Thanks to this clamor, and perhaps the millions of EV/HEVs expected to be sold in coming years, more companies want to produce power modules, noted Yutaka Yoshida, chief expert, power semiconductors, at Fuji Electric headquarters in Tokyo, Japan. There have been a limited number of players in IGBT power module manufacturing because total sales are not so large, he said. "A few companies have enjoyed this niche market, however we speculate that the recent rapid growth of power electronics market is attracting new players."

Fuji Electric is among those already in the niche, Yoshida underlined. "Fuji has mainly been focusing on motor drives in industrial markets while we are expecting more sales in EV/HEV and renewable energy markets," he said. "In addition, we are launching products into the air conditioner market where energy saving designs with inverters are creating growing IGBT module demand. We are ready with newly developed intelligent power module (IPM) products for this application."

As well as attractive demand, newer markets can also bring their own challenges. In EV/HEV applications, they need compact packages with high power capability which require high current density and high thermal conductivity, Yoshida said. "We are now applying alternative interconnection technology and pin-fin heat sink with liquid coolant to evaluation samples to achieve such requirements."

Tatsuo Oomori, deputy general manager at Mitsubishi Electric Corporation’s Power Device Works, also in Tokyo, emphasised that EV/HEV innovations will soon help other power electronic industries. "The main drivers for our packaging innovation are automotive applications, which incorporate cutting-edge technologies in packaging," he told Power Dev’. "We generalize these technologies to achieve innovation in other products."

Mitsubishi Electric launched its most recent series of IGBT modules, the sixth generation Mega Power Dual (MPD) series, in May, targeted largely at renewable energy rather than EV/HEV. However, this market also needs many new features. "The MPD has
improved from 1000A/1700V to 1800A/1700V, a large capacity product that has a smaller size, lighter weight, lower inductance and higher density," Oomori said. "The technical background to this innovation was the change from a copper base plate to an insulated board with an integrated aluminum plate, as well as lower inductance due to laminated bus bars. This innovation also owes to the improvement in the way electrodes are connected, from soldering to ultrasonic bonding."

These applications where package innovations are occurring fall mainly in the medium and high voltage categories, highlights Neil Markham, product marketing manager in Hitachi Europe Limited’s Power Device Division. But performance needs in scenarios that are medium-voltage, like EV/HEV, and high voltage, like rail transport, are ‘diametrically opposed’ to lifetime improvement needs, he says. And that puts the responsibility squarely on module packaging.

"If a 25 year product lifetime is to be maintained, it is imperative to integrate mechanical packaging improvements as part of any progressive manufacturer’s product development road map," Markham said. "Alternative surface bonding structures must be researched, validated and adopted. Hitachi continues to research and implement new metal bonding structures, particularly for power terminal design, as well as other on-going efforts to reduce the overall number of solder layers. As part of every Hitachi new product development, each step change in electrical performance requires an equivalent ‘Eureka!’ packaging innovation to offset any negative influences on product cost, performance and especially lifetime."

**Original sintering**

Nuremburg, Germany, headquartered Semikron has developed an alternative interconnect technology called SKiN, explains Thomas Grasshoff, head of product management. Based around silver sintering attachments between die and copper foil, Semikron will use SKiN in IGBT-based products launched in years ahead. "We have sintered connections attaching IGBTs and freewheeling diodes to copper foil and to direct bonded copper (DBC) ceramic substrates, and sinter the DBCs to a heat sink," Grasshoff said. "Normally their different thermal expansion coefficients diminish lifetime as operating temperatures rise. Our sintered material’s porosity ‘breathes’ and takes up force the expansion produces, which is key for reliability."

That allows Semikron to increase power density, though it’s still deciding where this is most beneficial, Grasshoff said. "IGBTs can reach such high heat density that you have to consider how to transport heat out of the module," he explained. "With air-cooled systems most of the thermal resistance is in the heat sink, so the main benefit of SKiN technology comes in water cooled systems. The benefit’s a trade-off between performance and cost, and we have to find the balance that benefits the customer."

For fellow German power module producer Infineon Technologies die attach and improved joining techniques have been a focus for innovation in the company’s .XT technology. With attachment being a major location of failure, this helps modules withstand wider temperature ranges, said Claus Panzer, the company’s marketing director for industrial power modules. " .XT technology enables us to move the junction temperature towards 200°C, up from 150°C," Panzer said. " .XT improves power cycling capability substantially, and allows about 25 per cent higher output current."

To accommodate its high power density solutions, Infineon’s lead customers are currently qualifying its next generation IGBTs. Panzer said: "There is copper metallisation on the chip as part of the .XT technology," he explained. "It makes sense to bring this in only with the newest IGBT 5 technology, which has the copper on the chip and further loss reduction. One of the first products with .XT will be the PrimePACK power module. The PrimePACK is made using very robust new assembly technologies, like ultrasonic welding for the power and auxiliary terminals. With its low inductive design and high power density capability the PrimePACK has already become very successful in windmill applications, which is one of the applications driving the trend towards higher power density and longer lifetime."

Fuji Electric is also developing better ways to harness the latest transistors’ performance capabilities to meet new applications’ specifications, according to Yoshida. "Evolution of silicon die technology, including the new generation of IGBT die technology and realization of wide bandgap devices, have made energy density higher and enable higher junction temperature," he said. "These events have been urging us to proceed in development of smaller packages, heat sinks with higher thermal conductivity, and higher thermostability modules."

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*Original image and diagram text*
Such developments mean that Fuji’s power module strategy carefully considers exactly what the markets it serves need, and then what other companies are already producing. “Fuji decides if we should catch them up, go after with different methods, or stay away after consider important points including merits for customers, cost and sales influence, and synergistic effects on our own technologies,” Yoshida said. “Fuji’s modules include both Fuji’s original and competitor-compatible formats. We consider designing and manufacturing competitor-compatible modules if they have already built an attractive market for Fuji to follow them.”

Fast-paced development

By contrast Mitsubishi Electric’s internal customers play a large part in its module strategy. “We believe it is important for us to utilize our advantages and continue our efforts in the competition inside and outside Japan,” said Tatsuo Oomori. “One of our advantages is that we have customers and laboratories in-house, which enables us to develop products that match market demand in a timely, rapid fashion through extracting, matching and prioritizing the needs from the users and the ideas from the laboratories.”

Another advantage comes through Mitsubishi Electric’s Unterhaching, Germany, inverter and power conditioner subsidiary Vincotech, which it bought in November 2010. That combined Mitsubishi’s strong capabilities in middle- and high-power devices with Vincotech’s strengths in low-power devices, and now the companies are pooling their packaging know-how. “We are developing packaging technologies by creating synergies from the advantages of the two companies,” Oomori said. That expertise has helped to develop SiC modules that Mitsubishi started sampling in July. “Our first step is to utilize existing packaging, which we believe will relatively make it easier for customers to consider tests and replacements,” he said.

Beyond the various technical approaches in development, the remaining packaging differences between module producers come down to a matter of process parameters, Panzer noted. That benefits the most experienced manufacturers, like Infineon. “You can buy some equipment off the shelf, but if a company has, for example, solder voids or poor bonding while in production, then the products might fail after a while,” Panzer said.

That’s been important for Infineon, as it has meant the company has been successful in China, even as the country develops its own module producers. “The Chinese local competitors will definitely find a place in the market, but we are very much known for our quality and performance,” Panzer said. “This is one reason why we have a very big market share in China. This region is still growing throughout all the applications, and very rapidly in solar and wind.”

Hitachi’s Neil Markham agrees that track-record is a powerful weapon for established producers, though he sees both room and a need for more competition. “From a technological perspective, competition drives innovation,” he said. “However the landscape is likely to remain the same in the near term. One or two new names will enter the market, perhaps from the Asian territory, in the lower voltage classes for consumer and other mass market applications. For medium and high voltage, the competition that exists today ought to remain dominant. High reliability is often critical in these voltage sectors and experience is therefore priceless, affording at least some security in the medium term to established manufacturers.”

With market demand for power electronics to continue growth, manufacturers must therefore act as reputable first and second sources of interchangeable products, or deliver custom specifications. “From a client production perspective there is a need to ensure stable supplies and this requires second sourcing,” Markham noted. “Where standardization is not a fundamental application driver, the market may well see more partnerships between clients with specific suppliers able to meet specialist design and specification demands.”

Semikron sees standard interfaces across suppliers as a major trend, but is focused on mass-produced integrated modules, with customer-specific modules rare and only possible in high volumes. For example, Semikron’s Nuremberg subsidiary Vepoint provides integrated automotive inverters using the SKiN technology, though it awaits complete market entry. “We don’t know when this sector will take off,” Grasshoff said. “It does not depend on the inverter – it depends on other complex safety, technology and cost issues.”
Integration is a top priority for Semikron, through which it intends to reduce the cost of its systems. Grasshoff asserted that such packaging strategies differentiate module producers. "Everybody is working on new directions for the future," he said. "Some are going for cost reduction alone, and others are going for different assembly technologies. All are looking in different directions, so it’s very interesting to see where it will end. What will become the common approach? Sintering, diffusion soldering, copper wire bonding? What will win the race?"

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Thomas Grasshoff, Head of product management, Semikron.
Thomas Grasshoff studied Electrical Engineering. He joined Philips Communication Industries as development engineer in 1992. Since 1997 he has held several positions in the Product Management area of Mobile Base Stations for Lucent Technologies. In 2002 he joined Semikron International and took over international product management responsibility with a focus on new technology and business development.

Neil Markham, Product marketing manager in the Power Device Division, Hitachi Europe Limited.
Neil Markham received his degree in Electronic Engineering from De Montfort University, United Kingdom in 1995. In 2001 he joined Hitachi Europe Limited as Product Marketing Engineer to support MOSFETs and linear ICs, notably for Telecoms and Automotive applications. From 2003 he took the position of Marketing Manager to support the European territory, working specifically to expand the IGBT product portfolio and client base.

Claus Panzer, Senior director in the Industrial Power Control Division, Infineon Technologies AG.
Claus Panzer studied Electrical Engineering at RWTH University in Aachen, Germany, and worked at the Institute of Materials for Electrical Engineering at the RWTH University from 1994 to 1996. In 1996, he became key account manager for high-power IGBT modules and high-power bipolar devices at Eupec GmbH Co. KG in Warstein, Germany. In 2000 he joined Infineon Technologies AG as a marketing manager for industrial electronics in Singapore. Today, Panzer heads all marketing activities of the Industrial Power Control (IPC) division of Infineon and is global head of strategic marketing, marketing operations, business development and market intelligence at IPC.

Tatsuo Oomori, Deputy general manager, Power Device Works, Mitsubishi Electric Corporation.
Tatsuo Oomori joined the company in 1980 after studying electronic engineering at the University of Tokyo’s Graduate School of Engineering, and started his career as an R&D engineer at Central Research Laboratory, which later changed its name to the Advanced Technology R&D Center. He became manager of the Advanced Device Technology Department in 2003, then manager of the SiC Device Development Project Group in 2005. In 2009, he was promoted to general manager of SiC Device Development Center, and was assigned to Deputy General Manager of Power Device Works in 2010. He is currently responsible for business development of SiC devices.

Yutaka Yoshida, Chief expert, power semiconductors, Fuji Electric.
Yutaka Yoshida joined Fuji Electric in 1984 after received Master’s degree of Electrical Engineering at Nagoya University, and started his career as a R&D engineer for Analog & Digital ICs. He was dispatched to Georgia Institute of Technology by the company in 1989, and carried out his study for two years. He has held manager level positions in the Products Design, Marketing, and Business Development in Semiconductor area including Power Supply ICs, Power Discrete Devices and Power Modules.