EV/HEV are driving power module packaging innovations

OUTLINES:

- The power module market will reach US$6 billion by 2024, with a 2018 – 2024 CAGR of 6.6%. In 2024, the EV/HEV market value will be about US$2.5 billion.
- Major technical innovations are step by step transforming the power module packaging supply chain.
- Hitachi combined all key innovations in its new integrated 3rd generation double-side cooling power module for automotive applications and more.

“The power module is key in the development of power converters and inverters,” says Milan Rosina, PhD., Principal Analyst, Power Electronics & Batteries, Yole Développement (Yole). “At Yole, we expect this market to reach US$6 billion by 2024, with a 6.6% CAGR.”

“In the past, packaging needs were driven by industrial applications”, comments Amine Allouche, Junior Costing Analyst at System Plus Consulting. “But time has changed, and today’s market is increasingly driven by EV/HEV. By 2024, the EV/HEV market segment will surely become the biggest power module market.”

Both environmental regulations to reduce average CO₂ emissions and other automotive trends play in favor of stronger vehicle electrification and faster deployment of EV/HEVs. And Yole’s power electronics team expects that EV/HEV market in numbers of vehicles will reach 24 Million units by 2024.

Increasing battery energy capacity enables longer driving range of electric cars while powerful electric motors enable quick acceleration. High electric power requirement as well as need for inverter downsizing brings challenges on the power module level.

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1 Extracted from:
- Status of the Power Module Packaging Industry report, Yole Développement, 2019

2 CAGR: Compound Annual Growth Rate

3 EV/HEV: Electric Vehicles/ Hybrid Electric Vehicles
Power electronic innovations affect different solutions, such as power module (power card-like power module), baseplate structure (pin fin), and cooling technology (double-side cooling). The evolution of the technologies has been analyzed in-depth by Yole’s analysts in a dedicated report, Status of the Power Module Packaging. In this report, they reveal the latest innovations. “Major technology trends are related to substrates, die-attach, and interconnections,” asserts Shalu Agarwal, Technology & Market Analyst at Yole. “Although no major packaging technology breakthrough has been observed over the last several months, many technology trends from the past have been confirmed.”

“As one of the leaders of the automotive segment, Hitachi has, for example, defined a unique strategy combining technical innovations to follow this evolution. It includes double-side cooling, “direct” cooling using structured housing, use of dielectric insulation based on AlN4 and more…” adds Amine Allouche from System Plus Consulting.

EV/HEV applications are increasingly driving the technology trends in power module packaging, where high power density and highly reliable power module packages are needed. In parallel, the introduction of SiC5 technology is also pushing the development of new power packaging solutions, since SiC devices can work at higher junction temperatures and higher switching frequencies with smaller die sizes.

Without doubt, power module packaging solutions are moving toward high-performance materials together with a reduction of the number of layers, of size, and interfaces, while conserving electrical, thermal, and mechanical characteristics.

In terms of substrate, the most common choice for power module packaging is Al₂O₃ DBC⁶. As shown in Yole’s power module report, the industry is moving toward materials offering

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⁴ AlN: Aluminum Nitride
⁵ SiC: Silicon Carbide
⁶ DBC : Direct-Bonding Copper
better mechanical stability and higher thermal conductivity. So $\text{Si}_3\text{N}_4$, AMB\textsuperscript{7} ceramic substrate is increasingly used for high power silicon and for SiC power modules. On the other hand, IMS\textsuperscript{8} is an alternative to fragile ceramic substrate for low- and mid-power devices. In order to make the power module package more stable thermally, and to take advantage of SiC’s properties, reliable and robust die attach is required. Therefore, the use of silver sintering is increasing.

Additionally, the interconnection technology is a key factor influencing the power module’s strong performance. Even though aluminum wire bonding remains the mainstream, copper wire bonding will also be widespread. Wire-free modules using flexible interconnections or top leadframes will also see considerable growth, especially in the EV/HEV industry. Double-side cooling with two substrates / leadframes will have a strong impact on the choice of packaging materials – however, single-side cooled power modules with a pin-fin baseplate will also be preferred by many players…

To highlight the technology evolution, Hitachi is a good example. This leading company combined all these key innovations in its new integrated 3\textsuperscript{rd} generation double-side cooling power module. In its design, Hitachi implemented built-in silicon IGBTs\textsuperscript{9} and diodes. It is a compact module showing high performant heat dissipation. Hitachi’s solution is mainly dedicated to automotive applications.

“The use of Al heatsinks as well as the molded power card and the integrated insulating layer are part of the technology choices made by Hitachi”, comments Elena Barbarini, Head of Department Devices, System Plus Consulting. “The technical approach combined with specific design make Hitachi’s power module very attractive in term of performance, integration and cost”.

\textsuperscript{7} AMB : Active Metal Brazed  
\textsuperscript{8} IMS : Insulated Material Substrate  
\textsuperscript{9} IGBT : Insulated-Gate Bipolar Transistors
In an in-depth reverse engineering & costing analysis offered by System Plus Consulting, Hitachi Double-Side Cooling Power Module from Audi e-tron’s Inverter, analysts detail the structure of the Hitachi power module integrated in Audi e-tron’s inverter. Supported by a full teardown of the module’s components and housing, this report reveals Hitachi’s innovative assets, especially the assembly of its 3rd generation double-sided cooling package as well as the designs of its IGBT and diode. This report, of course, includes an estimated manufacturing cost of all the module’s components and an analysis of its selling price.

In addition, System Plus Consulting’s analysts investigated competitive technologies to offer a high added-value comparison between several double sided cooling automotive power modules developed by the leading companies, Toyota and Infineon Technologies. These comparisons clearly point out the technology choices made by each player, with a special focus on the packaging design, dies, and costs.

All year long, Yole Group of Companies publishes Power & Wireless reports including a collection on power electronics. Experts attend various key presentations throughout the year, including APEC (New Orleans, March 15-19, 2020). In addition, the Group offers a dedicated TechDay focused on power electronics for EV/IHEV applications. Taking place on February 18 in Stuttgart, this event will be a great opportunity to get a clear vision of current technical challenges and market evolution. Discover them on i-Micronews as well as the full 2020 program. Stay tuned!

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About our analysts

Shalu Agarwal, PhD. is Power Electronics and Materials Analyst at Yole Développement (Yole), within the Power & Wireless division. Based on Seoul, Shalu is engaged in the development of technology & market reports as well as the production of custom consulting studies.

Shalu Agarwal received her master’s and Ph.D. degree in Chemistry from the Indian institute of Technology (IIT) Roorkee (India).

Amine Allouche is part of System Plus Consulting’s Power Electronics and Compound Semiconductors team. Amine holds a Master’s degree focused on Micro and Nanotechnologies for integrated systems.

As Head of Department Devices, Elena Barbarini is in charge of costing analyses for MEMS, IC and Power Semiconductors. She has a deep knowledge of Electronics R&D and Manufacturing environment. Elena holds a Master in Nanotechnologies and a PhD in Power Electronics.

Véronique Le Troadec has joined System Plus Consulting as a laboratory engineer. Coming from Atmel Nantes, she has extensive knowledge in failure analysis of components and in deprocessing of integrated circuits.

Milan Rosina, PhD, is Principal Analyst, Power Electronics and Batteries, at Yole Développement (Yole), within the Power & Wireless division. He is engaged in the development of the market, technology and strategic analyses dedicated to innovative materials, devices and systems. His main areas of interest are EV/HEV, renewable energy, power electronic packaging and batteries.

About the reports

Hitachi Double-Side Cooling Power Module
Discover Hitachi’s power module and its innovative assembling technology of integrated double-side cooling structure. – Performed by System Plus Consulting.

Power Electronics for Electric & Hybrid Electric Vehicles
Stronger vehicle electrification means more power electronics content, resulting in a reshaping of the supply chain. – Performed by Yole Développement

Status of the Power Module Packaging Industry 2019
Major evolutions in substrate, interconnection, and die-attach technologies, driven by EV/HEV, are transforming the power module packaging supply chain. – Performed by Yole Développement

About System Plus Consulting

System Plus Consulting specializes in the cost analysis of electronics, from semiconductor devices to electronic systems. Created more than 20 years ago, System Plus Consulting has developed a complete range of services, costing tools and reports to deliver in-depth production cost studies and estimate the objective selling price of a product… More

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Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services and well as IP and patent analysis.

With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 80 collaborators worldwide… More

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