Cluster for Application and Technology Research in Europe on NanoElectronics

PROJECT RESULTS

CT315 | Using creative packaging of power-drive electronics in electric vehicles to reduce costs while increasing reliability and efficiency

[EmPower]

EmPower developed an innovative packaging concept for e-mobility and industrial applications, especially in automotive, resulting in a drastic improvement in heat dissipation and thermal impedance of embedded power modules, which can lead to other technical, business and financial benefits.

Packaging power-drive electronics – such as inverters, battery chargers and power controllers – in electric vehicle (EV) engines operating in harsh conditions, is based on costly direct copper-bonded (DCB) ceramics. However, deploying an embedded power-module offers an excellent way to reduce size and weight of power-drive electronics in EVs, while increasing switching performance and improving heat management.

Developing a total power-drive packaging concept

The EmPower project developed a total packaging concept for power-drive electronics in EV engines, based on embedding power-drive components as thinned chips into a built-up glass-fibre reinforced epoxy-resin layer. This creates large-area interconnections to form a conductor structure with the lowest possible thermal impedance needed to achieve optimal heat dissipation. In addition, it embeds the power semiconductors in a module which offers heat removal on both sides over the shortest possible heat-conduction paths.

This embedding technology also sets aside thick wire bonding of power devices on DCB substrates. Now, interconnections between these power devices and wire bonds are a primary source of parasitic inductances in today's power packages. This leads to significant switching losses and critical shortcomings (like limited lifetime and reliability issues due to high power-loss density). On the other hand, EmPower's packaging concept contains copper interconnections (with large cross-sections) between the power devices and the package pads by short copper-filled via and large copper cross-section. This technology enables the necessary copper connections and pads to be placed on both sides of the package in an arbitrary manner, thus satisfying the needs for both, high-electrical and high-thermal conductivities.

The entire development and manufacturing of such power cores takes place in a state-of-the-art PCB manufacturing environment. The full production capacity using large 18”x24” panels will achieve cost reduction by economy-of-scale manufacturing. In this context, the EmPower concept sets unusual demands on device metallisation, comparable to copper-electroplating processes, and the development of cost-effective thermal management solutions based on thick-copper interconnections and thermally conductive, electrically isolating materials.

The project also developed three demonstrators and ran simulations, with very promising results:

- A 50W demonstrator with a double-diode rectifier with the footprint of a D2PAK and a height of a tenth of this package. This ultra-thin power package passed all tests;
- A 500W demonstrator with a DC-AC converter for a pedelec application, formed by a B6 bridge with MOSFETs and a logic module. This module passed all major tests and showed excellent switching properties;
- 50kW demonstrator with a DC-AC inverter for EVs using IGBTs and diodes. It was able to demonstrate the interconnection concept and its reliability and thermal characterisation.

Supply-chain structure

Now, during the project set-up phase and initial analysis of target applications for the automotive industry, it became clear that expertise would be needed at the silicon-component level, as well as for embedding large and thin power components; in interconnection technology for building the power modules, and in modifying power applications to demonstrate the benefits of the newly developed power packages and power modules.

And the project consortium represented major stakeholders in the EV value-chain with financial interest in the production of compact, power-efficient embedded cores and modules which can improve the electric motor's autonomy thereby inducing energy savings; increased long-

PROJECT CONTRIBUTES TO

- Communication
- Automotive and transport
- Energy efficiency
- Digital lifestyle

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KEY PROJECT DATES

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term stability and reliability; and environmental friendliness. The project consortium was therefore organised as a supply chain to handle the technological gaps and challenges in developing embedded power-modules and power packages.

Technical, financial and ecological impact

Notably, EmPower generates technical, financial and ecological benefits. Two key project results – double-sided cooling and conductivity of semiconductor switches without the use of bond wires – enables a drive to be mounted directly on the motor to form a single unit with the motor housing. It will lead to lower power-resistivity and inductance of the power switch, and also provide a wider switching-frequency range and high power-efficiency. EmPower technology also promises to reduce the volume of the electrical control unit (ECU) of the drive inverter found in EVs and hybrid electrical vehicles (HEVs), thus lowering space requirements In such applications. This is critical because package density, weight and power-losses are the most design-critical boundary conditions, especially in the cooling system.

Of course, the general health of the automotive business, the main beneficiary of EmPower, is also crucial to the success of this project. Encouragingly, we see that automotive has the second-highest compounded annual growth rate (CAGR) at 14% in 2016. The innovative packaging of power-drive electronics of EV engines (and in some cases consumer applications) will result in lower costs and higher reliability, and therefore secure a competitive-edge in the European automotive industry. Analysis of the value-chain of existing power modules underscores future importance and ubiquity of the power module developed in the project, with roughly 25 % of the value-chain benefiting from the new power-module concept. Within automotive, EmPower's main potential market is EVs. Here, car registration is expected to rise from 500,000 in 2015 to over 1m in 2020. Importantly, power modules are not limited to only the electro-mobility sector: power semiconductors, excitation designs and mechatronic integration are also needed for industry and the consumer market.

And on the ecological side, a key success factor will be to develop power-efficient energy converters in order to maximise CO_2 reduction in the face of increased individual mobility. EmPower is doing its bit in this area. A European industrial consortium (which includes an EmPower project partner) is already involved in developing high-end green and efficient technologies based on this project's findings and deliverables. Certainly, a win in the sustainability battle.

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