Automakers And Industry Need Specific, Extremely Robust, Heterogeneously Integrated Chiplet Solutions

Comprehensive testing is needed to ensure that chiplet systems can withstand extreme conditions.

By Andy Heinig

Chiplets offer great potential for the automotive and industrial sectors, especially as these applications often have high performance requirements but are needed only in small quantities. The modular principle behind chiplets enables efficient design and production: individual components have to be produced only once and can then be flexibly combined to create tailored solutions. This offers major advantages when it comes to the cost-effective production of high-performance specialized chips.

However, using chiplets in these demanding sectors poses particular challenges. Systems destined for use in the automotive and industrial sectors need to be not only powerful but also particularly robust, as they are exposed to extreme environmental conditions. In particular, the challenges posed by thermal cycling and mechanical stresses such as vibrations and oscillations place high demands on the materials and technologies used. These robust requirements make it necessary to carefully examine the design variants used to date, as many of them may not be able to withstand the necessary loads. Here, more specialized solutions must be found that meet the requirements for long-term stability and reliability.

Ensuring that the chiplet systems can withstand the extreme conditions in automotive and industrial manufacturing calls for extended load tests and other comprehensive testing. This includes thermal cycling and vibration tests, which may not have been carried out to this extent in the past. Modeling must also be refined with a view to simulating such systems precisely in advance and identifying potential weaknesses at an early stage. Achieving this relies not only on further developing simulation methods, but also on creating new material databases to take into account the special properties of the materials used.

All this data and these new methodologies need to be integrated into an assembly design kit (ADK) and an assembly design flow (ADF) to simplify the development of chiplets and ensure efficient design. This guarantees that the systems meet the applications' requirements for both performance and robustness.

Another important consideration for using chiplets in these areas is the heterogeneity of the circuits used. Chiplets for automotive and industrial applications often call for different semiconductor technologies to meet different performance requirements. These can range from special CMOS variants that include high-voltage options to more advanced semiconductor materials such as gallium nitride (GaN), silicon carbide (SiC), or silicon-germanium (SiGe). These special semiconductor technologies offer higher efficiency in specific applications, but also present their own challenges. One of the greatest difficulties is that the threshold voltages for safe switching of the transistors in these special technologies are often significantly higher than in modern CMOS technologies. This poses a challenge for the electrical layer of the die-to-die interface, as the voltages in current standards such as UCIe (Universal Chiplet Interconnect Express) or BoW (Bunch of Wires) are in the 750 mV range. Since these voltages are too low to effectively switch the transistors in the specialized semiconductor technologies, there is a need to adapt the standards.

Moreover, these special semiconductor technologies often have a lower transistor density than advanced CMOS technologies, meaning a larger chip area is required for the same functionality – a particularly tough challenge for the protocol layer, which is required in addition to the purely electrical layer to ensure communication. Various protocols are currently under discussion, but these are often too complex or resource-intensive for specialized technologies with limited transistor density. That makes it necessary to develop greatly reduced protocols that are tailored to the requirements of these technologies and at the same time offer the required performance and efficiency.

Overall, the use of chiplets in the automotive and industrial sectors is a promising technology, but one that requires thorough further development of standards, test methods, and design processes in order to successfully overcome the challenges posed by the heterogeneity of the semiconductor technologies used and their extreme operating conditions.